IoT Technician (Smart Agriculture)

NSQF LEVEL - 4

1st Year (Volume II of II)

TRADE THEORY

SECTOR: IT & ITES

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL MEDIA INSTITUTE, CHENNAI

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21	Identify different IoT Applications with IoT architecture.	130. Identify various IoT Applications in smart agriculture viz. Precision Farming, Livestock Monitoring, Agricultural Drones etc.(07 hrs) 131. Recognise the functions of various Internets of Things (Smart Agriculture)(IoT) applications & their distinctive advantages. (08 hrs) 132. Identify and explore different functional building blocks of IOT enabled system / application. (08 hrs) 133. Test signal flow into IOT enabled system/application as per the IOT architecture. (07 hrs)	Introduction to Internet of Things applications in smart agriculture& their distinctive advantages - Precision Farming, Livestock Monitoring, Agricultural Drones etc. What is an IOT? What makes embedded system an IOT? Role and scope of IOT in present and future marketplace. Smart objects, Wired – Cables, hubs etc. Wireless – RFID, WiFi, Bluetooth etc. Different functional building blocks of IOT architecture.
22	Identify, test and interconnect components/parts of IoT system.	134. Connect and test Arduino board to computer and execute sample programs from the example list. (04 hrs) 135. Upload computer code to the physical board (Microcontroller) to blink a simple LED. (02 hrs) 136. Write and upload computer code to the physical Arduino board Micro controller to sound buzzer. (02 hrs) 137. Circuit and program to Interface light sensor – LDR with aarduino to switch ON/OFF LED based on light intensity. (03 hrs) 138. Set up & test circuit to interface potentiometer with Arduino board and map to digital values for eg. 0-1023. (03 hrs) 139. Interface Pushbuttons or switches, connect two points in a circuit while pressing them. This turns on the built-in LED on pin 13 in Arduino, while pressing the button. (03 hrs) 140. Rig up the Circuit and upload a program to Control a relay and switch on/off LED light using Arduino. (02 hrs) 141. Make Circuit and upload a program to Interface of LCD display with a microcontroller to display characters. (03 hrs)	Arduino development board, Pin diagram, Functional diagram, Hardware familiarization and operating instructions. Integrated development Environment, Running Programs on IDE, simple Programming concepts.(10 Hours)

		142. Rig up the circuit and upload a program to interface temperature sensor – LM35 with a controller to display temperature on the LCD. (02 hrs) 143. Set up Circuit and upload program to Interface DC motor (actuator) with microcontroller to control on /off /forward/reverse operations. (03 hrs) 144. Rig up Circuit and upload program micro-controller to switch on/off two lights using relay. (03 hrs)	
23-24	**Project Work / Industrial Visit (Optional)** **Broad Area: -** a) Full wave Voltage rectifier with indicator. b) Flashing LEDs. c) Visit to IoT Lab of different industries.		
25-26	**Revision**		
27-29	Identify and Select various types of sensors used in Smart Agriculture.	145. Identify various sensors used in Precision Farming viz. Location Sensors, Optical Sensors, Electrochemical Sensors, Mechanical Sensors, Airflow Sensors and Agricultural Weather Stations. (06 hrs) 146. Select appropriate sensor as per requirement. (06 hrs) 147. Determine clay, organic matter and moisture content of the soil by Optical Sensors. (06 hrs) 148. Measure pHby Electrochemical Sensor and soil nutrient. (06 hrs) 149. Apply Electrochemical Sensor to gather process and map soil chemical data. (06 hrs) 150. Measure soil compaction or “mechanical resistance” by Mechanical Sensors. (06 hrs) 151. Use of probe that penetrates the soil and records resistive forces through use of load cells	Basics of Location Sensors – Role, selection and characteristics, advantages and disadvantages. Use of signals from GPS satellites. Optical Sensors - Basic principle, salient features, operating range selection and characteristics. Electrochemical Sensors - Role, selection and characteristics, advantages and disadvantages. Mechanical Sensors –Operation Fundamentals, selection, advantages and disadvantages. Airflow Sensors – Basic principle, salient features, operating range, advantages and disadvantages. Agricultural Weather Stations – Fundamentals of self-contained units that are placed at various locations

		or strain gauges for Mechanical Sensors. (06 hrs) 152. Use Mechanical Sensors on large tractors to predict pulling requirements for ground engaging equipment. (08 hrs) 153. Detect the force used by the roots in water absorption that are very useful for irrigation interventions by Tensiometers. (10 hrs) 154. Measure soil air permeability by Airflow Sensors at singular locations or dynamically while in motion. (10 hrs) 155. Identify various types of soil properties including compaction, structure, soil type, and moisture level by Airflow Sensors. (10 hrs) 156. Measure and record Information such as air temperature, soil temperature at a various depths, rainfall, leaf wetness, chlorophyll, wind speed, dew point temperature, wind direction, relative humidity, solar radiation and atmospheric pressure at predetermined intervals by Agricultural Weather Stations.(10 hrs)	throughout growing fields. Knowledge of Stations, combination of sensors appropriate for the local crops and climate. Advantages - portability and decreasing prices for farms of all sizes.
30-31	Position the appropriate sensors and collect the information required in Smart Agriculture.	157. Study and interpret the result of sensors node block diagram and its components. (10 hrs) 158. Connection with sensors and send data wirelessly to a central data logger at program.(10 hrs) 159. Interface of wireless modules with IoT platform. (10 hrs) 160. Select and Install sensors like CO2, O2, VOC, air temperature, humidity, moisture, etc.(05 hrs) 161. Identify and select the data packet and sensor node configuration tool. (10 hrs)	Location Sensors - Determination of latitude, longitude and altitude, Concept of GPS integrated circuits. Optical Sensors - Measurement of different frequencies of light reflectance in near-infrared, mid-infrared, and polarized light spectrums, Placement on vehicles or aerial platforms. Determination of clay, organic matter and moisture content of the soil. Electrochemical Sensors - Collection of information like pH and soil nutrient levels, detection of specific ions in the

		162. Configure Sensor node using USB and Over the air programming. (05 hrs) 163. State the battery level and solar panel connects with sensor node. (05 hrs) 164. Control Variable rate controllers manually or automatically using an on-board computer guided by real GPS location. (05 hrs)	soil. Applications to gather, process, and map soil chemical data. Mechanical Sensors –Measurement of soil compaction or "mechanical resistance", Use of probe that penetrates the soil and records resistive forces through use of load cells or strain gauges. Detection of the force used by the roots in water absorption that are very useful for irrigation interventions. Airflow Sensors – Measurement of soil air permeability. Measurements at singular locations or dynamically while in motion. Knowledge of desired output - the pressure required to push a predetermined amount of air into the ground at a prescribed depth. Various types of soil properties, including compaction, structure, soil type and moisture level. Agricultural Weather Stations – Measurement and record Information such as air temperature, soil temperature at a various depths, rainfall, leaf wetness, chlorophyll, wind speed, dew point temperature, wind direction, relative humidity, solar radiation, and atmospheric pressure at predetermined intervals. Compilation and sending of data wirelessly to a central data logger at programmed intervals.
32-33	Identify, select different wireless communication modules and topology to generate and record the data.	165. Identify the interfacing of Zigbee module to create wireless sensor network. (02 hrs) 166. Check the M2M Wireless Sensor Network (WSN) in IoTZigbee router, end device and coordinator configuration. (04 hrs) 167. Identify the interfacing of Bluetooth module to create	Introduction to Zigbee. Block diagram of Zigbee based sensor network. Introduction to wireless personal area network system. Introduction to Zigbee networking system. Concept of interfacing of Bluetooth module to local sensor network, interfacing of GSM module to make node as a gateway. IoT Gateway using WiFi and Ethernet. Application of GPSsatellites in Location

		local sensor network. (03 hrs) 168. Identify the interfacing of GSM module to make node as a gateway. (03 hrs) 169. Apply IoT Gateway using WiFi and Ethernet. (04 hrs) 170. Check UART Communication, RS485 Communication,I2C Protocol device interfacing SPI Protocol device interfacing, Ethernet configuration, Zigbee interfacing, Wi-Fi AP and Router interfacing. (08 hrs) 171. Identify the Wi-Fi module and lua script for data communication. (04 hrs) 172. Check USB and Ethernet connectivity for data communication. (02 hrs) 173. Check RS485 interface for industrial agriculture sensors. (02 hrs) 174. Create a combine sensor appropriate for the local crops and for agricultural climate monitoring. (04 hrs) 175. Use portable Agricultural Weather Stations.(03 hrs) 176. Use signals from GPS satellites to determine latitude, longitude and altitude to within feet by Location Sensors for precise positioning. (03 hrs) 177. Measure yield and grain moisture in a field using crop yield measuring devices installed on harvesting equipment. (02 hrs) 178. Use Geographical information system(GIS) consisting of a computer software data base system used to input, store, retrieve, analyze and display in map like form, spatially referenced geographical information for more detailed analysis of fields.(04 hrs)	Sensors. RS485 interface for industrial agriculture sensors. Creation of a combine sensor appropriate for the local crops and for agricultural climate monitoring. Concept of portable Agricultural Weather Stations. Usage of signals from GPS satellites to determine latitude, longitude and altitude to within feet by Location Sensors for precise positioning. Use of Yield Monitors – measurement of yield and grain moisture in a field using crop yield measuring devices installed on harvesting equipment. Principle of operation & Application of Global Positioning System (GPS): satellites broadcasting signals that allow GPS receivers to calculate their position. Working principle & Use of Geographical information system(GIS) consisting of a computer software data base system used to input, store, retrieve, analyze, and display in map like form, spatially referenced geographical information for more detailed analysis of fields. Data Integration Through a Geographical Information System Use of Computer Hardware and Software to analyze the data collected by yield monitor and GPS and supply it to user in usable format – such as maps, graphs, charts or reports. Application of Precision irrigation through water management in precision agriculture. Identification of zones in the field that are irrigated with differing amounts and frequencies in precision irrigation.

		179. Analyze the data collected by yield monitor and GPS and supply it to user in usable format such as maps, graphs, charts or reports using suitable Computer Hardware and Software. (04 hrs) 180. Apply Precision irrigation through water management in precision agriculture. (04 hrs) 181. Identify zones in the field that are irrigated with differing amounts and frequencies in precision irrigation.(04 hrs)	
34	Identify and test Wired & Wireless communication medium such as RS232, RS485, Ethernet, Fiber Optic, Wi-Fi, GSM, GPRS, RF etc. and Communication protocol.	182. Identify Cable and its Pin Mapping. (04 hrs) 183. Crimp and Test RJ9 / RJ11 / RJ45 connectors. (04 hrs) 184. Understand Frequency Band, Gain, Antenna and Modulation for WiFi. (04 hrs) 185. Understand Frequency Band, Gain, Antenna and Modulation for GPRS. (04 hrs) 186. Understand Frequency Band, Gain, Antenna and Modulation for RF. (04 hrs) 187. Design and Test Local Area Networks over Ethernet & Wi-Fi. (03 hrs) 188. Design and Test Cellular Wide Area Networks over GSM & GPRS. (02 hrs) 189. Design and Test Personal Area Networks over RF. (05 hrs)	Basic blocks of networking, - Specifications, Standards and types of cables, - Concept of wired or wireless communication medium - Different types of networks - Design and establish networks
35-36	Identify Solar Panel Basics Testing, Characteristics, Charge Controller Circuit.	190. Identify, test and check series, parallel and series-parallel combination of Solar PV Modules. (12 hrs) 191. Measure VI Characteristics of Solar PV Module.(06 hrs) 192. Identify and test blocking diode and its working in Solar PV Module.(05 hrs) 193. Observe bypass diode and its working in Solar PV Module.(06 hrs) 194. Measure effect of inclination	Basics of solar Electricity, Working principle of PV panel, advantages of solar electricity and components of solar electricity, Various combinations, VI characteristics of solar PV module, effect of inclination angle on PV module, different battery charging techniques.

		angle of Solar PV Module.(06 hrs) 195. Identify and test different charging techniques.(05 hrs) 196. Test Buck &Boost converter.(06 hrs) 197. Check effect of change in solar radiation on Solar PV Module.(04 hrs) 198. Identify and test running different applications i.e. LEDs, Dusk to Dawn sensing. (05 hrs) 199. Check the use of P V Analyzer. (05 hrs)	
37-38	Perform installation, configuration and Check working of IoT devices, network, database, app and web services.	200. Install Linux Operating System porting. (05 hrs) 201. Configure Local cloud & server. (05 hrs) 202. Configure Over the air (OTA) node. (05 hrs) 203. Parameter configuration using GUI. (05 hrs) 204. Check IoT Gateway using WiFi and Ethernet. (05 hrs) 205. Work with the command line and the Shell. (05 hrs) 206. Manage directories and files. Manage user access and data security (Cyber security) by Cryptography.(03 hrs) 207. Set up a Linux file system. Perform system initialization.(05 hrs) 208. Install and Configure Linux. (05 hrs) 209. Create Shell Scripts, flow control in the Shell, Advanced Shell features.(04 hrs) 210. Apply Database management system.(03 hrs) 211. Configure Cloud and Server for IoT.(04 hrs) 212. Test Qt based GUI. (02 hrs) 213. Test Web and Application Development Tools for IoT. (03 hrs)	Installation of Linux Operating System porting. Configuration of Local cloud & server. Over the air (OTA) node configuration. GUI based parameter configuration, GUI based IoT application. IoT Gateway using WiFi and Ethernet. User access and data security management (Cyber security) by Cryptography. The command line and the Shell, directories and files. Linux file system, understanding system initialization. Connection of a system to the network. Installation and Configuration of Linux. Shell Scripts, flow control in the Shell, Advanced Shell features. Database management system. Cloud and Server Configuration for IoT. Qt based GUI, IoT Web and Application Development Tools for IoT.
39-41	Establish and troubleshoot IoT	214. Power up the Solar Inverter (similar device) as per the	- Basics of Industrial protocols ModbusRTU, ModbusTCP, DLMS

	connectivity of devices to cloud having multiple communication medium, protocols, device management and monitoring.	device manual. (03 hrs) 215. Integrate Solar Inverter(similar device) with serial protocol working on Modbus RTU. (04 hrs) 216. Communicate and Verify the parameters on Modbus Master Software (05 hrs) 217. Power up the DLMS device as per the device manual. (03 hrs) 218. Integrate device with serial protocol working DLMS protocol. (04 hrs) 219. Communicate and Verify the parameters on DLMS server software. (05 hrs) 220. Setup wired Local Area Network and wireless network. (04 hrs) 221. Setup environment for Modbus TCPIP server client testing. (04 hrs) 222. Communicate and Configure Modbus devices through GSM GPRS network (04 hrs) 223. Setup Serial to Ethernet protocol converter and verify. (05 hrs) 224. Setup Serial to WiFi protocol converter and verify. (04 hrs) 225. Setup Serial to GPRS protocol converter and verify. (04 hrs) 226. Setup Ethernet IoT Data Acquisition system, connect to cloud and verify (05 hrs) 227. Setup WiFi IoT Data Acquisition system, connect to cloud and verify. (06 hrs) 228. Setup Cellular (GSM / GPRS) IoT Data Acquisition system, connect to cloud and verify. (04 hrs) 229. Explore IoT Cloud Configuration utility. (03 hrs) 230. Create / modify organization, Connect devices over cloud. (06 hrs) 231. Configuration of parameters,	- Client server communication Basics of Protocol Converters. Basics of IoT Data Acquisition System. Device connectivity over cloud and troubleshooting. GUI based IoT Cloud Configuration utility. IoT device and its parameter configuration Cloud Device Management and troubleshooting.

		alarms, notifications on cloud platform. (04 hrs) 232. Explore user management roles and security. (04 hrs) 233. Observer Device Diagnostics for troubleshooting. (04 hrs) 234. Setup Environment for embedded SCADA testing. (05 hrs)	
42	Demonstrate and deploy responsive Web Application using APIs and generate reports using templates.	235. Explore Web API, required input parameters and output (04 hrs) 236. Map Web API to Widget / Control / Plugin (10 hrs) 237. Display and configure graphs, charts and other ready to use controls and widgets (07hrs) 238. To generate reports using readily available API, templates and to export it to excel, word pdf and other required formats (09hrs)	Usage of Web Services / Web API Development of Sample Web Application. Generation and export of Reports User access and rights management.
43	Identify and install the devices used in green house.	239. Select and Install Carbon dioxide sensors. (05 hrs) 240. Install Oxygen sensors. (05 hrs) 241. Carry out Selection and Installation of Volatile organic compound sensor. (05 hrs) 242. Execute Selection and Installation of Air temperature, Air humidity and atmospheric pressure sensor. (05 hrs) 243. Select and Install Soil Moisture and Soil Temperature sensor. (05 hrs) 244. Carry out Installation of Solar pump, motors and drip irrigation systems. (05 hrs)	Principle of selection and installation of Carbon dioxide sensor, Oxygen sensors &Volatile organic compound sensor. Selection and Installation of Air temperature, Air humidity and atmospheric pressure sensor. Selection and Installation of Soil Moisture and Soil Temperature sensor. Installation of Solar pump, motors and drip irrigation systems.
44-45	Monitor soil moisture, temperature etc. for controlling irrigation & record data.	245. Carry out Crop and soil observations logged in the form of snapped pictures, pinpoint locations, soil colours, water, plant leaves, and light properties. (05 hrs) 246. Measure leaf health, lighting brightness, chlorophyll amount, ripeness level, Leaf Area Index (LAI), soil organic	Process of carrying out Crop and soil observations logged in the form of snapped pictures, pinpoint locations, soil colours, water, plant leaves, and light properties. Measurement of leaf health, lighting brightness, chlorophyll amount, ripeness level, Leaf Area Index (LAI), soil organic and carbon makeup by using Smartphone Camera.

		and carbon makeup by using Smartphone Camera. (05 hrs) 247. Use Smartphone GPS for location for crop mapping, disease/pest location alerts, solar radiation predictions, and fertilizing. (05 hrs) 248. Perform predictive maintenance of machinery using Microphone. (05 hrs) 249. Determine Leaf Angle Index using Accelerometer. (05 hrs) 250. Apply Precision irrigation through water management in precision agriculture. (05 hrs) 251. Identify zones in the field that are irrigated with differing amounts and frequencies in precision irrigation.(05 hrs) 252. Apply Variable Rate Technology - Implement gathered information and decisions for site specific agriculture consisting of the machines and systems for applying a desired rate of crop production materials at a specific time and a specific location. (10 hrs) 253. Apply various Precision Agriculture tools: Soil Mapping, Yield Mapping, Remote Sensing, GIS Analysis, Nutrient Management, Variable Rate Technology, Integrated Pest & Weed Management, Water Management etc. for controlling irrigation & record data.(10 hrs) 254. Identify various benefits of application of Precision Agriculture in Smart Farming: Optimising Production Efficiency, Optimising Quality, Minimising Environmental Impact, Minimising Risk, Information To Act On. (05 hrs)	Usage of Smartphone GPS for location for crop mapping, disease/pest location alerts, solar radiation predictions, and fertilizing. Predictive maintenance of machinery using Microphone Determination of Leaf Angle Index using Accelerometer. Application of Precision irrigation through water management in precision agriculture. Identification of zones in the field that are irrigated with differing amounts and frequencies in precision irrigation. Application of Variable Rate Technology - Implement gathered information and decisions for site specific agriculture consisting of the machines and systems for applying a desired rate of crop production materials at a specific time and a specific location. Application of various Precision Agriculture tools: Soil Mapping, Yield Mapping, Remote Sensing, GIS Analysis, Nutrient Management, Variable Rate Technology, Integrated Pest & Weed Management, Water Management etc. for controlling irrigation & record data. Identification of various benefits of application of Precision Agriculture in Smart Farming: Optimising Production Efficiency, Optimising Quality, Minimising Environmental Impact, Minimising Risk, Information To Act On.
46	Select plant health	255. Test Non-contact surface	Non-contact surface temperature

	monitoring system and apply proper water, fertilizer and pesticides.	temperature measurement. (02 hrs) 256. Test Leaf and flower bud temperature. (02 hrs) 257. Check Soil oxygen level. (02 hrs) 258. Test Solar radiation (shortwave, PAR and UV). (02 hrs) 259. Measure Air temperature, humidity and pressure. (02 hrs) 260. Observe Conductivity, water content and soil temperature. (03 hrs) 261. Test Soil temperature and volumetric water content. (03 hrs) 262. Measure Soil water potentials. (03 hrs) 263. Test Vapor pressure, humidity, temperature, and atmospheric pressure in soil and air. (03 hrs) 264. Check Leaf wetness. (02 hrs) 265. Measure Stem, truck and fruit diameter. (02 hrs) 266. Test Wind speed and precipitations. (02 hrs) 267. Check Luminosity (Luxes Accuracy). (02 hrs)	measurement. Test of Leaf and flower bud temperature. Checking of Soil oxygen level. Test of Solar radiation (shortwave, PAR and UV). Measurement of Air temperature, humidity and pressure. Observation of Conductivity, water content and soil temperature. Test of Soil temperature and volumetric water content. Measurement of Soil water potentials. Test of Vapor pressure, humidity, temperature, and atmospheric pressure in soil and air. Checking of Leaf wetness. Measurement of Stem, truck and fruit diameter. Exploration and test of Wind and precipitations. Checking of Luminosity (Luxes Accuracy).
47	Identify and install the appropriate device for livestock monitoring.	268. Apply Wireless IoT in livestock monitoring - collect data regarding the location, well-being and health of cattle.(06 hrs) 269. Use Location Sensors, GPS &GPS integrated circuits.(06 hrs) 270. Apply Wearable Electronics to cattle.(06 hrs) 271. Use wireless retrofitted bolus in cow's stomach which can communicate via Bluetooth to an ear tag.(06 hrs) 272. Select wireless technology with enough battery power to list the lifespan of the animal. (06 hrs)	Application of Wireless IoT in livestock monitoring – collection of data regarding the location, well-being and health of cattle. Usage of Location Sensors, GPS &GPS integrated circuits. Application of Wearable Electronics to cattle. Usage of wireless retrofitted bolus in cow's stomach which can communicate via Bluetooth to an ear tag. Selection of wireless technology with enough battery power to list the lifespan of the animal.
48	Identify, select and	273. Identify different types of	Identification of different types of

	operate drone in various applications.	drones – ground based and aerial based drones & their functions. (10 hrs) 274. Select various components of drones equipped with appropriate cameras, sensors (Optical Sensors etc.)and integrating modules (Raspberry Pi 3 B module - Single-board computer with wireless LAN and Bluetooth connectivity). (20 hrs)	drones – ground based and aerial based drones & their functions. Selection of various components of drones equipped with appropriate cameras, sensors (Optical Sensors etc.)and integrating modules (Raspberry Pi 3 B module - Single-board computer with wireless LAN and Bluetooth connectivity).
49	Collect data using Drones.	275. Use ground-based and aerial based drones in agriculture for crop health assessment, irrigation, crop monitoring, crop spraying, planting and soil & field analysis.(04hrs) 276. Identify and apply thermal camera in smart farming. (02 hrs) 277. Carry out real-time data collection and processing, crop health imaging, integrated GIS mapping gathering valuable data via a series of sensors that are used for imaging, mapping, and surveying of agricultural land through drones/UAV. (04 hrs) 278. Select what field to survey altitude or ground resolution on the basis of farmer's information. (05 hrs) 279. Perform in-flight monitoring and observations. (05 hrs) 280. Collect multispectral, thermal and visual imagery during the flight of drones/UAV. (04 hrs) 281. Analyse Drone data for insights regarding plant health indices, plant counting and yield prediction, plant height measurement, canopy cover mapping, mapping, scouting reports, stockpile measurement, chlorophyll measurement, nitrogen	Usage of ground-based and aerial based drones in agriculture for crop health assessment, irrigation, crop monitoring, crop spraying, planting and soil & field analysis. Explore the use of thermal camera in smart farming. Process of Carrying out real-time data collection and processing, crop health imaging, integrated GIS mapping gathering valuable data via a series of sensors that are used for imaging, mapping, and surveying of agricultural land through drones/UAV. Selection of what field to survey altitude or ground resolution on the basis of farmer's information. Principle of in-flight monitoring and observations. Collection of multispectral, thermal and visual imagery during the flight of drones/UAV. Analysis of Drone data for insights regarding plant health indices, plant counting and yield prediction, plant height measurement, canopy cover mapping, mapping, scouting reports, stockpile measurement, chlorophyll measurement, nitrogen content in wheat, drainage mapping, weed pressure mapping and so on.

		content in wheat, drainage mapping, weed pressure mapping and so on.(06 hrs)	
50	**Project Work/Industrial Visit (Optional)** **Broad Area:-** a) Measurement of different soil moisture & temperature b) Measurement of solar radiation/oxygen for green house c) Construct wireless communication link between different nodes. d) Industrial visit for the applications of DRONE		
51-52	**Revision & Examination**		

Note: -

1. *Some of the sample project works (indicative only) are given at the mid and end of each year.*
2. *Instructor may design their own project and also inputs from local industry may be taken for designing such new project.*
3. *The project should broadly cover maximum skills in the particular trade and must involve some problem solving skill. Emphasis should be on Teamwork: Knowing the power of synergy/ collaboration, work to be assigned in a group (Group of at least 4 trainees). The group should demonstrate Planning, Execution, Contribution and Application of Learning. They need to submit Project report.*
4. *If the instructor feels that for execution of specific project more time is required then he may plan accordingly in appropriate time during the execution of normal trade practical.*

Introduction to IOT in smart agriculture & their distinctive advantages , What is an IOT? What makes embedded systems an IOT?

Objectives: At the end of this lesson you shall be able to
- **Understand what is IOT in Agriculture, its applications and its advantages.**
- **Comprehend the embedded systems and role of IOT in it.**

1. Introduction to IoT Agriculture

Internet of Things in Agriculture has come up as a second wave of green revolution. Smart farming is the application of modern computer technologies into agriculture. IoT based smart farming is a system built for monitoring the crop field with the help of sensors and automating the irrigation system. The sensors can be light, humidity, temperature and soil moisture.

Smart agriculture based on IoT technologies helps farmers to reduce waste and enhance productivity to increase efficiency of farming.

IoT based smart farming provides benefits like

- Efficient water usage.
- Decrease the cost and increase the yield.
- Farmers can monitor field conditions from anywhere.
- Reduce wastage and to increase productivity.

Fig 1

State of IoT and Agriculture

1.1 Precision farming

Precision farming is one of the most famous applications of IoT in agriculture. Precision farming enables farmers to have more control and accurate practices while raising crops. The goal of precision is to analyze the data generated via sensors, and to react based on data. Plant and soil monitoring are great uses for agriculture IoT.

Advantages:

- Sensing for soil moisture and nutrients.
- Controlling water usage for optimal plant growth.
- Determining custom fertilizer profiles based on soil chemistry.
- Determining the optimal time to plant and harvest.
- Reporting weather conditions.
- Helps to take quick decisions.

1.2 Agricultural Drones

Agriculture is one of the major industries to incorporate drones. Drones are used in agriculture in order to enhance agricultural practices. Ground based and aerial based drones are being used in agriculture for crop health assessment, irrigation, crop monitoring, crop spraying, planting and soil field analysis. Components such as controllers, Propulsion system, cameras, navigation system are used to grow production and improve crop field.

Fig 2

Drone in the field

Advantages

- The major benefits of using drones are
- Crop health imaging
- Integrated GIS mapping
- Ease of use
- Saves time
- Potential to increase yields

1.1 Live stock Monitoring

Livestock monitoring enables farm owners to collect data regarding the location, well being and health of the cattle. This helps to identify animals that are sick so they can be separated from the herd to prevent spreading of diseases.

Advantages

- Lowers labor costs
- Earlier identification of diseases of animals

1.2 Smart Green house

Greenhouse farming is a methodology helps in enhancing the yield of vegetables, fruits, crops. It monitors as well controls the climate eliminating the need for manual intervention. Different sensors that measure the environmental parameters according to the plant requirement are used. The IoT Sensors in green house provide information on light levels, pressure, humidity and temperature.

Advantage

- Eliminates need for constant manual monitoring

2. IoT and an Embedded System

Internet of Things is defined as a process in which objects are equipped with sensors, actuators and processors that involve hardware board design and development, software systems, web APIs, and protocols, which together create a connected environment of embedded systems.

Embedded systems will play an important role in Internet of Things (IoT) due to their unique characteristics and features such as real time computing, low power consumption, low maintenance and high availability are becoming the key enabler of IoT.

This connected environment allows technologies to get connected across multiple devices, platforms, and networks, creating a web of communication to interact digitally with the world. This connected embedded systems are changing interactions and behavior with the environment, communities, and homes, and even with our own bodies.

There are embedded systems in our day today life in the form of commercial systems like vending machines, smart kiosks, AC controller, connected cars, hotel bill printers, etc., which are capable of performing a unique variety of operations. Hence, when it comes to designing of these embedded IoT systems, they need to be designed for specific functions, possessing qualities of a good product design like low power consumption, secured architecture, reliable processor.

2.1 Market scope for Embedded systems and the Internet of Things

Embedded systems are part and parcel of every modern electronic component. These are low power consumption units that are used to run specific tasks for example remote controls, washing machines, microwave ovens, RFID tags , sensors, actuators and thermostats used in various applications, networking hardware such as switches, routers, modems, mobile phones, PDAs.

Usually embedded devices are a part of a larger device where they perform specific task of the device. For example embedded systems are used as networked thermostats in Heating, Ventilation and Air Conditioning (HVAC) systems, in Home Automation embedded systems are used as wired or wireless networking to automate and control lights, security, audio/visual systems, sense climate change, monitoring, etc.

Embedded systems will also be at the cornerstone for the deployment of many Internet of Things (IoT) solutions, especially within certain industry verticals and Industrial Internet of Things (IIoT) applications.

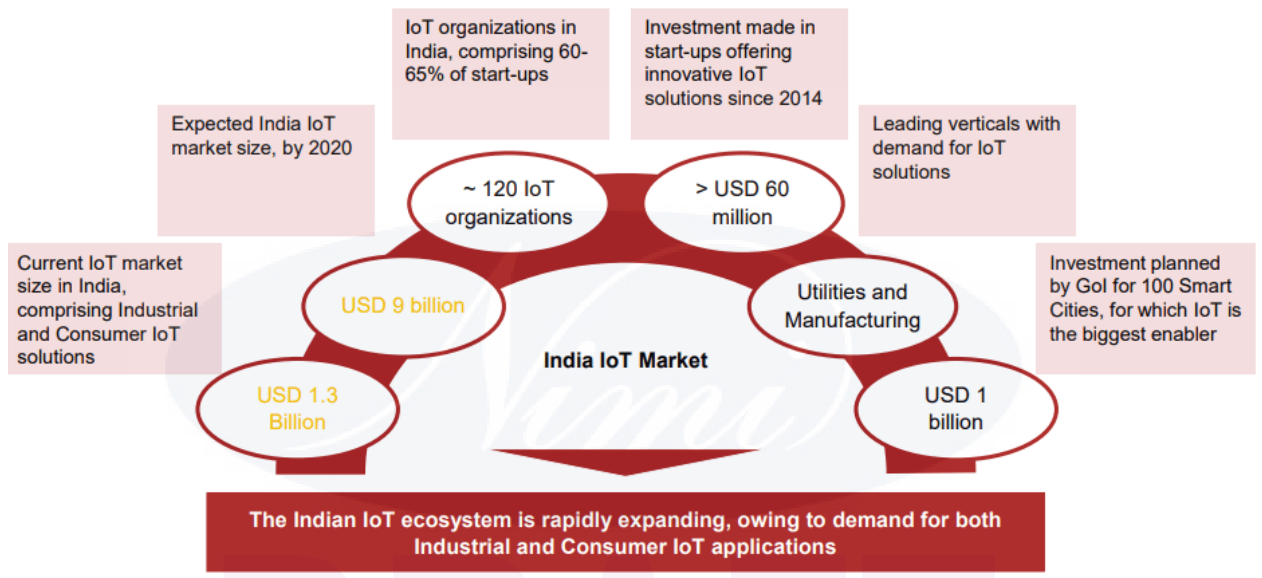
Role and Scope of IoT in present and future market place, Smart objects, wired and wirless technologies.

Objectives: At the end of this lesson you shall be able to
- **to understand the current market scenario of IoT.**
- **to comprehend the future market trends of IoT in India**
- **to realize the technologies which enable communication among IoT devices.**

1. Role and Scope of IoT in Present and Future market place

Internet of Things can connect devices embedded in various systems to the internet. When devices/objects can represent themselves digitally, they can be controlled from anywhere. The connectivity then helps us capture more data from more places, ensuring more ways of increasing efficiency and improving safety and IoT security.

Fig 1



Source: *Deloitte Analysis, GoI draft policy on IoT, NASSCOM*

According to the report published on by deloitte and Nasscom, The Internet of Things (IoT) market is expected to reach $ 9 billion by 2020. By the end of 2020 more than 1.9 billion devices are expected to be connected in India which leads to grow this market 31 times from the current market share of 5.6 this year.

1.1 IoT Market Trends in India

Indian IoT market has huge potential and expected to grow across industries in manufacturing, automotive, transportation and logistics. IoT is set to become a major differentiation in driving the next generation of services and products.

At present, there are approximately 7.6 billion people on the Earth. Nearly, 3.7 billion of these are connected to the Internet; roughly 50% of such connected population resides in Asia and 24% amongst them belongs to India.

A number of IoT startups In India (roughly 70%) have emerged a few years back only. Healthcare and manufacturing are popular verticals attracting a lot of investor interests. ThingsCloud, Doxper, SeeHow, Uncanny Vision, IOT Pot are some of the popular IoT startups. Market forces like cloud computing and analytics are the key drivers of IoT. There are several factors too that contribute to its growth like increased mobility, the evolution of smarter lifestyle, improved decision making, data analysis etc.

India has already more than 100 smart city initiatives planned. The focus is to enable seamless communication not only amongst humans but between machine to machine and machines to humans.

https://wire19.com/future-of-iot-in-india-current-market-trends-and-use-cases/

1.2 Future of IoT

Everyone wants a world which is connected to the internet and everything in it – from your smartphone to computers to watches and refrigerators can communicate in real-time. Internet of Things certainly makes it possible Future of IoT seems to be very bright as this is feeding and empowering Data Science and Artificial Intelligence in a big way. Data from IoT networks enables us to have better tracking, monitoring, prediction, management and control of various systems in different industries. Manufacturing, transportation, healthcare and utility sectors show more potential for IoT growth in the coming future.

1.2.1 Future of IoT in India

In India, the maximum push for IoT adoption is coming from the government, with initiatives like 'Digital India' and 'Make In India'. A special focus is on the development of Smart Cities – one that uses IoT devices to manage utilities, traffic, healthcare etc.

These projects are a good indication of the government's focus on IoT. But still, there are a number of obstacles that might stop the organizations from making maximum use of it. Lack of consistent internet connectivity, bandwidth issues, cost of IoT devices etc. are some of the prevalent challenges.

2 Components & Technologies of IoT

2.1 Smart Objects

The concept of smart in IoT is used for physical objects that are active, digital, networked, can operate to some extent autonomously, reconfigurable and has local control of the resources. The smart objects need energy, data storage, etc.

A smart object is an object that enhances the interaction with other smart objects as well as with people also. The world of IoT is the network of interconnected heterogeneous objects (such as smart devices, smart objects, sensors, actuators, RFID, embedded computers, etc.) uniquely addressable and based on standard communication protocols.

In a day to day life, people have a lot of object with internet or wireless or wired connection.

- Smartphone
- Tablets
- TV computer

These objects can be interconnected among them and facilitate our daily life (smart home, smart cities) no matter the situation, localization, accessibility to a sensor, size, scenario or the risk of danger.

Fig 2

Few smart objects

Smart objects are utilized widely to transform the physical environment around us to a digital world using the Internet of things (IoT) technologies. A smart object carries blocks of application logic that make sense for their local situation and interact with human users. A smart object sense, log, and interpret the occurrence within themselves and the environment, and intercommunicate with each other and exchange information with people.

2.2 Wired Components

IoT technology is deployed in many ways so no single network solution is right. It depends on the situation and where the devices are located.

2.2.1. Ethernet Cable

A wired network uses Ethernet cable to connect to the network. The Ethernet cable is in turn connected to a DSL or cable to the network gateway. The wired networks are mature technology and it is easy to get plugged into if phone lines, power lines, and coaxial cable lines are available.

Fig 3

Ethernet Cable

2.2.2 Hub

Hub is basically a multiport repeater. A hub connects multiple wires coming from different branches, for example, the connector in star topology which connects different stations. Hubs cannot filter data, so data packets are sent to all connected devices.

2.2.3 Bridge

A bridge is a repeater; with add on the functionality of filtering content by reading the MAC addresses of source and destination. Bridge is a Data link Layer Device. It is also used for interconnecting two LANs working on the same protocol. It has a single input and single output port, thus making it a 2 port device.

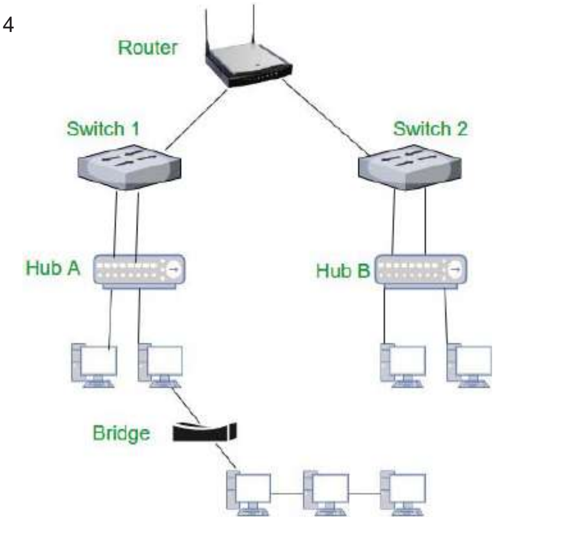
2.2.4 Switch

A switch is a multiport bridge with a buffer and a design that can boost its efficiency and performance. Switch is a Data link Layer Device. The switch can perform error checking before forwarding data that makes it very efficient as it does not forward packets that have errors and forward good packets selectively to correct port only.

2.2.5 Routers

A router is a device like a switch that routes data packets based on their IP addresses. Router is mainly a Network Layer device. Routers normally connect LANs and WANs together and have a dynamically updating routing table based on which they make decisions on routing the data packets.

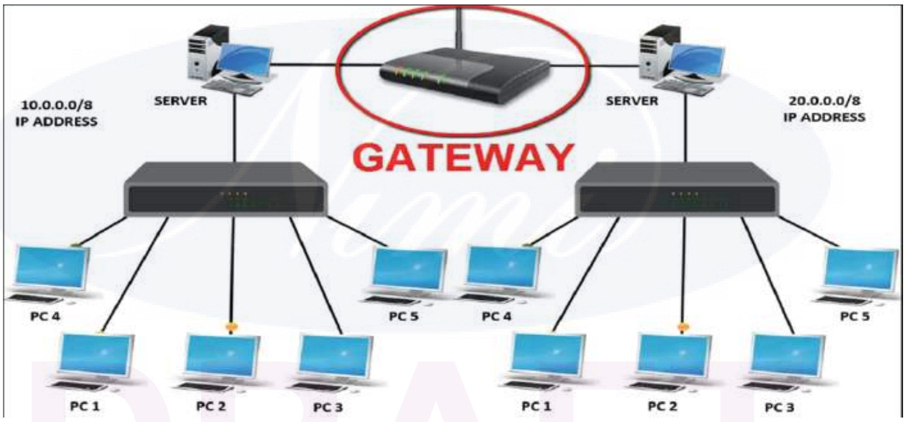
Fig 4



2.2.6 Gateway

A gateway, as the name suggests, is a passage to connect two networks together that may work upon different networking models. They basically work as the messenger agents that take data from one system, interpret it, and transfer it to another system. Gateways are also called protocol converters and can operate at any network layer. Gateways are generally more complex than switch or router.

Fig 5



Gateway Representation

2.3 Wireless Technologies

Setting up a wireless network is a simple process that involves configuring it to get it up and running in no time.

With the evolution of network technologies, a wide range of solutions like RFID, Bluetooth, WiFi as well as the less familiar ones like - ZigBee, Z-Wave or UWB (Wltra Wide-Band).

2.3.1 Bluetooth Low Energy, Bluetooth Smart

Bluetooth is a short-range communications technology, which has become important in computing and consumer products. It will be the key for wearable products connecting to Internet of Things via smartphones in most cases. For IoT applications it is Bluetooth Low-Energy or Bluetooth Smart, which is more important since its power consumption is lower than Bluetooth.

Unlike Bluetooth, Bluetooth Smart cannot be used for file transfers and its data packet size is smaller.

- Frequency: 2.4GHz
- Range: less than 150m
- Data Rates: 1Mbps

2.3.2 Zigbee

ZigBee and its various industrial profiles are based on IEEE802.15.4 protocol, which is an industry-standard wireless networking technology. It is meant for applications requiring limited data transfers at low transfer rates within 100m range, typically in a home or building. It has advantages in complex systems requiring low-power operation, high levels of security, high scalability, high node counts and can support wireless control and sensor networks in IoT applications.

- Frequency: 2.4GHz
- Range: less than 100m
- Data Rates: 250kbps

2.3.3 Z-Wave

Z-Wave is a low-power, low data rate, communication technology, designed for home automation. It supports full mesh networks and is scalable allowing control of up to 232 devices. Z-Wave uses a simpler protocol than others allowing faster development.

- Frequency: 900MHz
- Range: 30m
- Data Rates: less than 100kbps

2.3.4 LoRaWAN

LoRaWAN targets wide-area network applications with low power requirements including mobile communication in IoT, smart city and industrial applications. It is specifically optimised for low-power consumption and supports networks with thousands and millions of devices. The data transfer rate is very low at less than 50 kbps.

- Frequency: Various
- Range: 2-5km urban, 15km suburban
- Data Rates: less than 50 kbps

2.3.5 6LowPAN

6LowPAN stands for IPv6 Low-power wireless Personal Area Network. 6LowPAN is a networking protocol and can be used across Ethernet, Wi-Fi, 802.15.4 and sub-1GHz industrial, scientific and medical bands. A key attribute is the IPv6 stack, which has been important to enable IoT. IPv6 is the successor to IPv4 and enables any object in the world to connect to the Internet with its own unique IP address. It has been designed for home and building automation, and is a transport mechanism connecting complex control systems with devices through a low-power wireless network.

2.3.6 Thread

Thread is based on IPv6 networking protocol and is meant for automating the home environment. It uses existing wireless silicon from chip vendors and supports a mesh network using IEEE802.15.4. It is capable of handling up to 250 nodes with high levels of authentication and encryption. It is based on 6LowPAN and designed to complement WiFi. It recognises that while WiFi is good for many consumer devices it has limitations for use in a home automation setup. A software upgrade allows users to run thread on existing IEEE802.15.4-enabled devices.

- Frequency: 2.4GHz

2.3.7 WiFi

WiFi connectivity is an obvious choice for developers, especially within home environments and LANs. It provides fast data transfer and can handle high quantities of data. But its power consumption is likely to be too high for many IoT applications.

- Frequencies: 2.4GHz and 5GHz bands
- Range: Approximately 50m
- Data Rates: 150-200Mbps is typical, 600 Mbps maximum, latest 802.11-ac offers 500Mbps to 1Gbps

2.3.8 Cellular

Any IoT application that requires operations over long distances can take advantage of Cellular GSM, 3G, 4G. Cellular is suitable for high volumes of data, but the cost and power consumption for managing high volumes of data transfer are likely to be too high for most IoT applications. Cellular is suitable for sensor driven, low data projects, transferred over the Internet.

- Frequencies: 900, 1800, 1900, 2100MHz
- Range: 35km max for GSM, 200km max for HSPA
- Data Rates: less than 170kps GPRS, less than 384kbps EDGE, less than 2Mbps UMTS, less than 10Mbps HSP, 3-10Mbps LTE

Different functional building blocks of IoT architecture

Objectives: At the end of this lesson you shall be able to
- **to understand basic IoT architecture representation.**
- **to realize the working process of connected components.**
- **ability to develop an architecture functional blocks for the given application.**

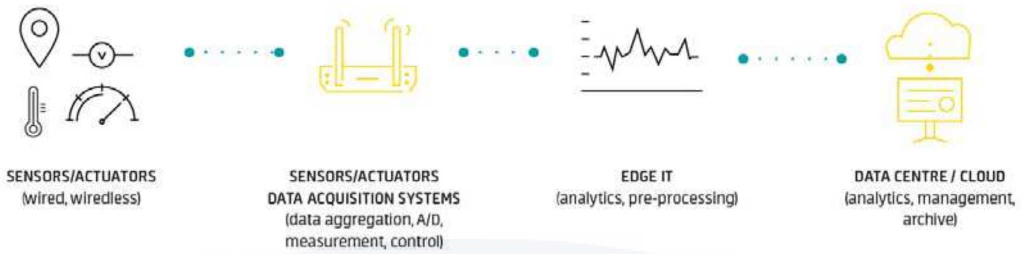
1 IoT Architecture

IoT architecture comprises a collection of physical objects, sensors, cloud services, developers, actuators, communication layers, users, business layers, and IoT protocols.

1.1 Basic Architecture

While every IoT system is different, the foundation of each Internet of Things architecture as well as its general data process flow is same. The below diagram shows the four layers

Fig 1



Four Layer of IoT Architecture

1.1.1 Layer 1

First layer consists of the Things, which are objects connected to the Internet which by means of their embedded sensors and actuators are able to sense the environment around them and gather information that is then passed on to IoT gateways. To pick up physical parameters in the outside world or within the object itself, they need sensors. These can be either embedded in the devices themselves or implemented as standalone objects to measure and collect telemetry data. For an example, think of agricultural sensors whose task is to measure parameters such as air and soil temperature and humidity, soil pH levels or crop exposure to sunlight.

Another indispensable element of this layer are the actuators. Being in close collaboration with the sensors, they can transform the data generated by smart objects into physical action.

Example

Let's assume a smart watering system with all the necessary sensors in place. Based on the input provided by the sensors, the system analyses the situation in real time and commands the actuators to open selected water valves located in places where soil humidity is below the set value. The valves are kept open until the sensors report that the values are restored to default. Obviously, all of this happens without a single human intervention.

1.1.2 Layer 2

The Second stage consists of IoT data acquisition systems and gateways that collect the great mass of unprocessed data, convert it into digital streams, filter and pre-process it so that it is ready for analysis. Gateway act as an intermediaries between the connected things and the cloud and analytics,.

Gateways provide a place for the local preprocessing of sensor data which is squeezed into useful bundles ready for further processing.

Another aspect that the gateways support is security. Because the gateways are responsible for managing the information flow in both directions, with the help of proper encryption and security tools they can prevent IoT cloud data leaks as well as reduce the risk of malicious outside attacks on IoT devices.

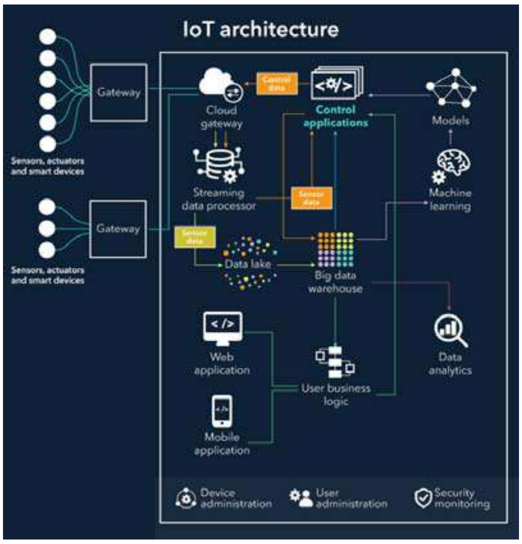
1.1.3 Layer 3

The third layer is represented by edge devices responsible for further processing and enhanced analysis of data. This layer is also where visualization and machine learning technologies are applied. Data is transferred to data centers which can be either cloud-based or installed locally, where the data is stored, managed and analyzed in depth for actionable insights.

1.2 IoT Architecture

Because of the wide domain of internet objects, there is no single consensus on IoT architecture, which is universally agreed

Fig 2



1.2.1 Architecture Components

Things. A "thing" is an object equipped with sensors that gather data which will be transferred over a network and actuators that allow things to act .

Gateways. Data goes from things to the cloud and vice versa through the gateways. A gateway provides connectivity between things and the cloud part of the IoT solution, enables data preprocessing and filtering before moving it to the cloud and transmits control commands going from the cloud to things.

Cloud gateway facilitates data compression and secure data transmission between field gateways and cloud IoT servers. It also ensures compatibility with various protocols and communicates with field gateways using different protocols depending on what protocol is supported by gateways.

Streaming data processor ensures effective transition of input data to a data lake and control applications. No data can be occasionally lost or corrupted.

Data lake. A data lake is used for storing the data generated by connected devices in its natural format. Big data comes in "batches" or in "streams". When the data is needed for meaningful insights it's extracted from a data lake and loaded to a big data warehouse.

Big data warehouse. Filtered and preprocessed data needed for meaningful insights is extracted from a data lake to a big data warehouse. A big data warehouse contains only cleaned, structured and matched data (compared to a data lake which contains all sorts of data generated by sensors). Also, data warehouse stores context information about things and sensors (for example, where sensors are installed) and the commands control applications send to things.

Data analytics. Data analysts can use data from the big data warehouse to find trends and gain actionable insights. For example, the performance of devices, help identify inefficiencies and work out the ways to improve an IoT system .

Machine learning and the models ML generates. With machine learning, there is an opportunity to create more precise and more efficient models for control applications.

Control applications send automatic commands and alerts to actuators, for example:

- Windows of a smart home can receive an automatic command to open or close depending on the forecasts taken from the weather service.
- When sensors show that the soil is dry, watering systems get an automatic command to water plants.
- Sensors help monitor the state of industrial equipment, and in case of a pre-failure situation, an IoT system generates and sends automatic notifications to field engineers.

Control applications can be either rule-based or machine-learning based. In the first case, control apps work according to the rules stated by specialists. In the second case, control apps are using models which are regularly updated (once in a week, once in a month depending on the specifics of an IoT system) with the historical data stored in a big data warehouse.

Although control apps ensure better automation of an IoT system, there should be always an option for users to influence the behavior of such applications (for example, in cases of emergency or when it turns out that an IoT system is badly tuned to perform certain actions).

User applications are a software component of an IoT system which enables the connection of users to an IoT system and gives the options to monitor and control their smart

1.2.2 Device management

To ensure sufficient functioning of IoT devices, there are some procedures required to manage the performance of connected devices (facilitate the interaction between devices, ensure secure data transmission and more):

- Device identification to establish the identity of the device to be sure that it's a genuine device with trusted software transmitting reliable data.
- Configuration and control to tune devices according to the purposes of an IoT system. Some parameters need to be written once a device is installed (for example, unique device ID). Other settings might need updates (for example, the time between sending messages with data).
- Monitoring and diagnostics to ensure smooth and secure performance of every device in a network and reduce the risk of breakdowns.
- Software updates and maintenance to add functionality, fix bugs, address security vulnerabilities.

1.2.3 User management

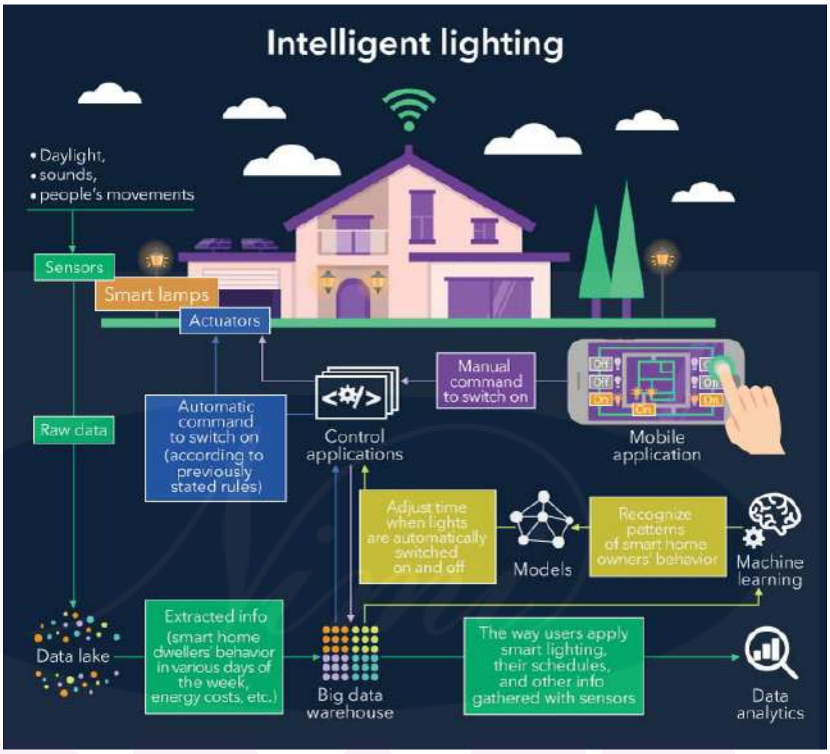
Along with device management, it's important to provide control over the users having access to an IoT system.

User management involves identifying users, their roles, access levels and ownership in a system. It includes such options as adding and removing users, managing user settings, controlling access of various users to certain information, as well as the permission to perform certain operations within a system, controlling and recording user activities and more.

1.2.4 Security monitoring

Security is one of the top concerns in the internet of things. Connected things produce huge volumes of data, which need to be securely transmitted and protected from cyber-criminals.

Fig 3



Example : Intelligent Lighting Functional Blocks

Arduino development board, Pin diagram, Functional diagram, Hardware familiarization and operating instructions.

Objectives: At the end of this lesson you shall be able to
- **to Understand the usage, pin layout of Arduino board.**
- **to familiarize with the bard components and its operational steps.**

1. Arduino

Arduino provides open-source electronics prototyping platforms based on flexible, easy-to-use hardware and software. Arduino prototyping platforms are intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments. Arduino's prototyping platforms can sense the environment by receiving input from a variety of sensors and can affect their surroundings by controlling lights, motors, and other actuators. Arduino projects can be stand-alone or they can communicate with software running on a computer. Arduino also simplifies the process of working with microcontrollers. and its advantages are :

- The Arduino boards are very easy to get started.
- The Arduino boards are used in the automatic room light control.
- On the Arduino, both software, hardware, and IDE are open source.
- The Arduino boards are used in the real-time application.

1.1 Types of Arduino Boards

1.1.1 Arduino UNO (R3):

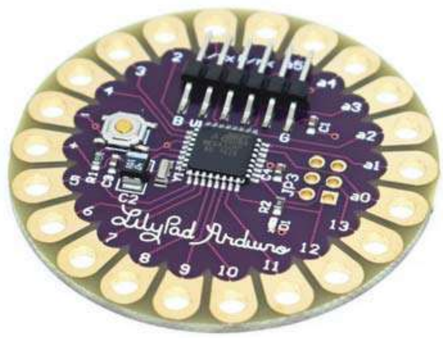
Arduino Uno allows faster transfer rate & more memory.

Fig 1

1.1.2. LilyPad Arduino

This is designed to integrate easily into an e-textiles & wearable projects. designed to have large connecting pads to allow them to be sewn into clothing. There is an available of various input, output, and sensor boards and they are washable.

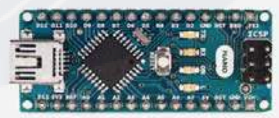
Fig 2



1.1.3. Arduino Nano development Board

Arduino Nano 3.0 is a small, complete, and breadboard-friendly surface mount embedded version of Arduino with integrated USB, which is based on the ATmega328.

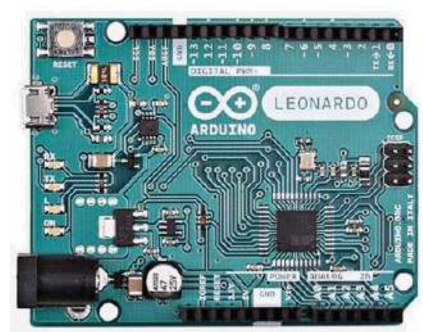
Fig 3



1.1.4. Arduino Leonardo

The Leonardo differs from all preceding boards in that the ATmega32u4 has built-in USB communication, eliminating the need for a secondary processor.

Fig 4



1.1.5. Arduino Red Board

The Arduino red board is programmed by using the USB cable of mini-B with the help of Arduino IDE software. Without any modifications in the security system there, it will work in Windows8 OS. The Arduino red board is more constant because USB and FTDI chips are used and they are flat on the back.

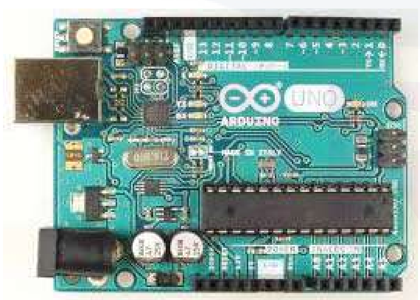
Among these boards Arduino Uno is commonly used and throughout this week Arduino Uno will be discussed in detail.

Fig 5

1.2 Arduino uno R3 development board

The Arduino UNO R3 is frequently used microcontroller board in the family of an Arduino. This is the latest third version of an Arduino board and released in the year 2011. The main features of this board mainly include, it is available in DIP (dual-inline-package), detachable and ATmega328 microcontroller. The programming of this board can easily be loaded by using an Arduino computer program.

Fig 6



Arduino Uno Board

1.2.1 Arduino Uno R3 Specifications

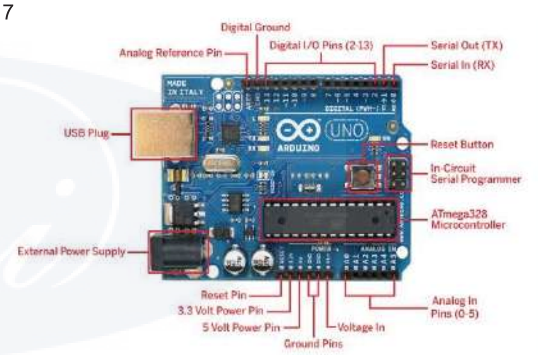
The Arduino Uno R3 board includes the following specifications.

- It is an ATmega328P based Microcontroller
- The Operating Voltage of the Arduino is 5V
- The recommended input voltage ranges from 7V to 12V
- The i/p voltage (limit) is 6V to 20V
- Digital input and output pins-14
- Digital input & output pins (PWM)-6
- Analog i/p pins are 6
- DC Current for each I/O Pin is 20 mA
- DC Current used for 3.3V Pin is 50 mA
- Flash Memory -32 KB, and 0.5 KB memory is used by the boot loader
- SRAM is 2 KB
- EEPROM is 1 KB
- The speed of the CLK is 16 MHz
- In Built LED
- Length and width of the Arduino are 68.6 mm X 53.4 mm
- The weight of the Arduino board is 25 g

1.3 Arduino Uno R3 Pin, Functional Diagram and Hardware Familiarization

The Arduino Uno R3 pin diagram comprises of 14-digit I/O pins. From these pins, 6-pins can be utilized like PWM(Pulse Width Modulation) outputs. This board includes 14 digital input/output pins, Analog inputs-6, a USB connection, quartz crystal-16 MHz, a power jack, resonator-16Mhz, a power jack, an ICSP header an RST button.

Fig 7



Arduino Uno Pin Diagram

1.3.1 Power Supply

The power supply of the Arduino can be done with the help of an exterior power supply otherwise USB connection. The exterior power supply (6 to 20 volts) mainly includes a battery or an AC to DC adapter. The connection of an adapter can be done by plugging a center-positive plug (2.1mm) into the power jack on the board. The battery terminals can be placed in the pins of Vin as well as GND. The power pins of an Arduino board include the following.

Vin: The input voltage or Vin to the Arduino while it is using an exterior power supply opposite to volts from the connection of USB or else RPS (regulated power supply). By using this pin, one can supply the voltage.

5Volts: The RPS can be used to give the power supply to the microcontroller as well as components which are used on the Arduino board. This can approach from the input voltage through a regulator.

3V3: A 3.3 supply voltage can be generated with the onboard regulator, and the highest draw current will be 50 mA.

GND: GND (ground) pins

1.3.2 Memory

The memory of an ATmega328 microcontroller includes 32 KB and 0.5 KB memory is utilized for the Boot loader), and also it includes SRAM-2 KB as well as EEPROM-1KB.

1.3.3 Input and Output

Uno R3 includes 14-digital pins which can be used as an input otherwise output by using the functions like pin Mode (), digital Read(), and digital Write(). These pins can operate with 5V, and every digital pin can give or receive 20mA, & includes a 20k to 50k ohm pull up resistor. The maximum current on any pin is 40mA which cannot surpass for avoiding the microcontroller from the damage. Additionally, some of the pins of an Arduino include specific functions.

Serial Pins

The serial pins of an Arduino board are TX (1) and RX (0) pins and these pins can be used to transfer the TTL serial data. The connection of these pins can be done with the equivalent pins of the ATmega8 U2 USB to TTL chip.

External Interrupt Pins

The external interrupt pins of the board are 2 & 3, and these pins can be arranged to activate an interrupt on a rising otherwise falling edge, a low-value otherwise a modify in value

PWM Pins

The PWM pins of an Arduino are 3, 5, 6, 9, 10, & 11, and gives an output of an 8-bit PWM with the function analog Write ().

SPI (Serial Peripheral Interface) Pins

The SPI pins are 10, 11, 12, 13 namely SS, MOSI, MISO, SCK, and these will maintain the SPI communication with the help of the SPI library.

LED Pin

An arguing board is inbuilt with a LED using digital pin-13. Whenever the digital pin is high, the LED will glow otherwise it will not glow.

TWI (2-Wire Interface) Pins

The TWI pins are SDA or A4, & SCL or A5, which can support the communication of TWI with the help of Wire library.

AREF (Analog Reference) Pin

An analog reference pin is the reference voltage to the inputs of an analog i/ps using the function like analog Reference().

Reset (RST) Pin

This pin brings a low line for resetting the microcontroller, and it is very useful for using an RST button toward shields which can block the one over the Arduino R3 board.

1.3.4 Communication

The communication protocols of an Arduino Uno include SPI, I2C, and UART serial communication.

UART

An Arduino Uno uses the two functions like the transmitter digital pin1 and the receiver digital pin0. These pins are mainly used in UART TTL serial communication.

I2C

An Arduino UNO board employs SDA pin otherwise A4 pin & A5 pin otherwise SCL pin is used for I2C communication with wire library. In this, both the SCL and SDA are CLK signal and data signal.

SPI Pins

The SPI communication includes MOSI, MISO, and SCK.

MOSI (Pin11)

This is the master out slave in the pin, used to transmit the data to the devices

MISO (Pin12)

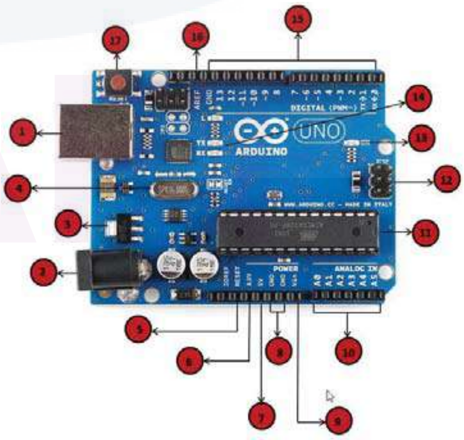
This pin is a serial CLK, and the CLK pulse will synchronize the transmission of which is produced by the master.

SCK (Pin13)

The CLK pulse synchronizes data transmission that is generated by the master. Equivalent pins with the SPI library is employed for the communication of SPI. ICSP (in-circuit serial programming) headers can be utilized for programming ATmega microcontroller directly with the boot loader.

1.4 Hardware Familiarization

Fig 8



1	**Power USB** Arduino board can be powered by using the USB cable from ther computer.Connect the USB cable to the USB connection (1).
2	Power (Barrel Jack)Arduino boards can be powered directly from the AC mains power supply by connecting it to the Barrel Jack (2).
3	Voltage RegulatorThe function of the voltage regulator is to control the voltage given to the Arduino board and stabilize the DC voltages used by the processor and other elements.
4	Crystal OscillatorThe crystal oscillator helps Arduino in dealing with time issues. Arduino calculate time using the crystal oscillator. The number printed on top of the Arduino crystal is 16.000H9H. It tells us that the frequency is 16,000,000 Hertz or 16 MHz.
5,17	Arduino ResetTo reset the Arduino board, i.e., start the program from the beginning. Resetting the UNO board in two ways. First, by using the reset button (17) on the board. Second, connect an external reset button to the Arduino pin labeled RESET (5).
6,7 8,9	Pins (3.3, 5, GND, Vin)· 3.3V (6) “ Supply 3.3 output volt· 5V (7) “ Supply 5 output volt· Most of the components used with Arduino board works fine with 3.3 volt and 5 volt.· GND (8)(Ground) “ There are several GND pins on the Arduino, any of which can be used to ground your circuit.· Vin (9) “ This pin also can be used to power the Arduino board from an external power source, like AC mains power supply.
10	Analog pinsThe Arduino UNO board has six analog input pins A0 through A5. These pins can read the signal from an analog sensor like the humidity sensor or temperature sensor and convert it into a digital value that can be read by the microprocessor.
11	Main microcontrollerEach Arduino board has its own microcontroller (11). It as the brain of your board. The main IC (integrated circuit) on the Arduino is slightly different from board to board. The microcontrollers are usually of the ATMEL Company.
12	ICSP pinMostly, ICSP (12) is an AVR, a tiny programming header for the Arduino consisting of MOSI, MISO, SCK, RESET, VCC, and GND. It is often referred to as an SPI (Serial Peripheral Interface), which could be considered as an “expansion” of the output. It is slaving the output device to the master of the SPI bus.
13	Power LED indicatorThis LED should light up when Arduino is plugged into a power source to indicate that your board is powered up correctly. If this light does not turn on, then there is something wrong with the connection.
14	TX and RX LEDsOn the board two labels: TX (transmit) and RX (receive) will be available. They appear in two places on the Arduino UNO board. First, at the digital pins 0 and 1, to indicate the pins responsible for serial communication. Second, the TX and RX led (13). The TX led flashes with different speed while sending the serial data. The speed of flashing depends on the baud rate used by the board. RX flashes during the receiving process.

15	Digital I/OThe Arduino UNO board has 14 digital I/O pins (15) (of which 6 provide PWM (Pulse Width Modulation) output. These pins can be configured to work as input digital pins to read logic values (0 or 1) or as digital output pins to drive different modules like LEDs, relays, etc. The pins labeled “~” can be used to generate PWM.
16	AREFAREF stands for Analog Reference. It is sometimes, used to set an external reference voltage (between 0 and 5 Volts) as the upper limit for the analog input pins.

1.4 Operating Instructions

To make Arduino into a Operating process, the need for the working system are:

- Arduino Uno board
- USB programming cable (A to B)
- 9V battery or external power supply (for stand-alone operation)
- Solderless breadboard for external circuits, and 22 g solid wire for connections
- Host PC running the Arduino development environment. Versions exist for Windows, Mac and Linux

Integrated development environment, Running Programs on IDE, Simple programming concepts.

Objectives: At the end of this lesson you shall be able to
- **understand Arduino IDE environment installation**
- **to be familiar with its functions, data types and simple coding.**

1. Integrated Development Environment

1.1 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop . In order to start with arduino the following steps has to be followed

1. Download & install the Arduino environment (IDE)
2. Connect the board to your computer via the USB cable
3. If needed, install the drivers
4. Launch the Arduino IDE
5. Select your board
6. Select your serial port

The arduino IDE can be downloaded from the below link

1.2 Running programs on IDE

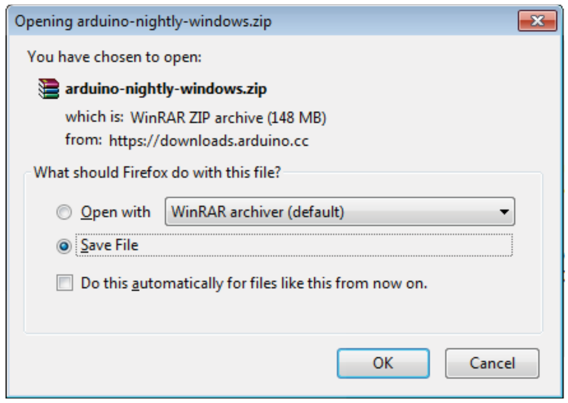
1.2.1 Steps to set up Arduino IDE on computer and prepare the board to receive the program via USB cable

Step 1 " First you must have your Arduino board and a USB cable. You will need a standard USB cable (A plug to B plug), the kind you would connect to a USB printer as shown in the following image.

Fig 1

Step 2 - Download Arduino IDE Software. Select your software, which is compatible with your operating system (Windows, IOS, or Linux). After your file download is complete, unzip the file.

Fig 2

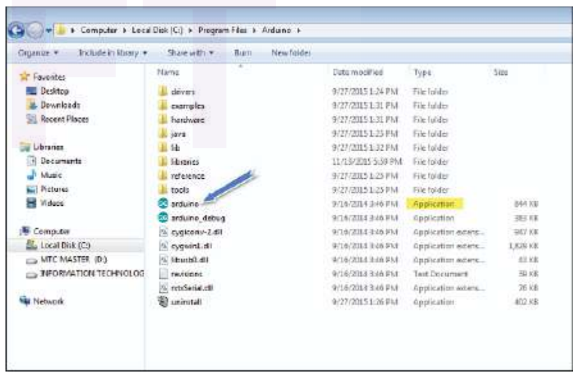


Step 3 - Power up your board. Connect the Arduino board to your computer using the USB cable. The green power LED (labeled PWR) should glow.

Step 4 " Launch Arduino IDE.

After your Arduino IDE software is downloaded, unzip the folder. Inside the folder, find the application icon with an infinity label (application.exe). Double-click the icon to start the IDE.

Fig 3



Step 5 " Open your first project

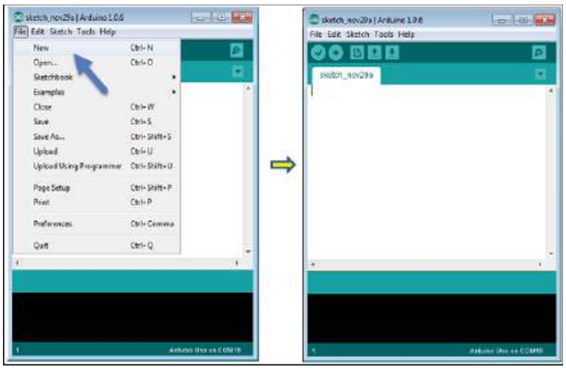
Once the software starts, you have two options "

· Create a new project.

· Open an existing project example.

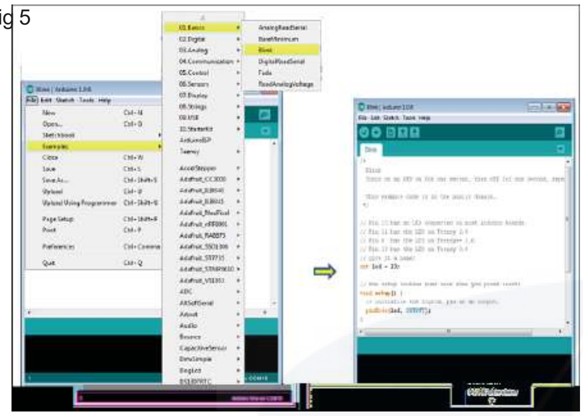
To create a new project, select File '! New.

Fig 4



To open an existing project example, select File '! Example '! Basics '! Blink.

Fig 5

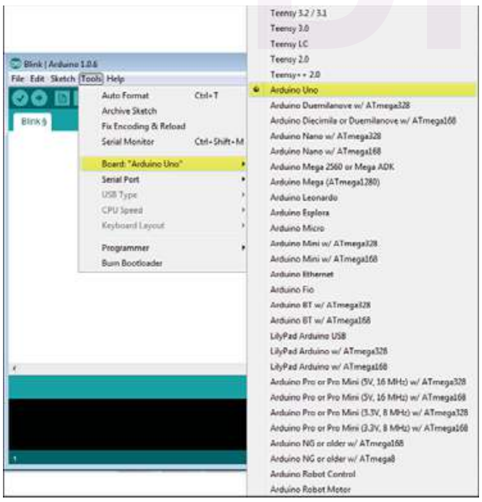


Step 6 “ Select your Arduino board.

To avoid any error while uploading the program to the board, select the correct Arduino board name, which matches with the board connected to your computer.

Go to Tools '! Board and select your board.

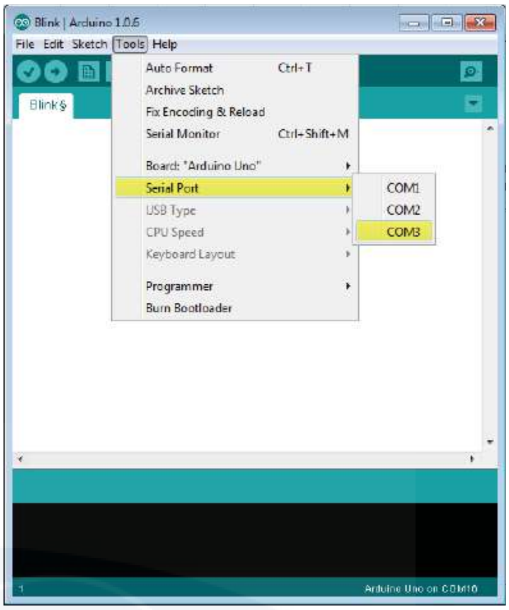
Fig 6



Step 7 “ Select your serial port.

Select the serial device of the Arduino board. Go to Tools '! Serial Port menu. This is likely to be COM3 or higher (COM1 and COM2 are usually reserved for hardware serial ports). To find out, you can disconnect your Arduino board and re-open the menu, the entry that disappears should be of the Arduino board. Reconnect the board and select that serial port.

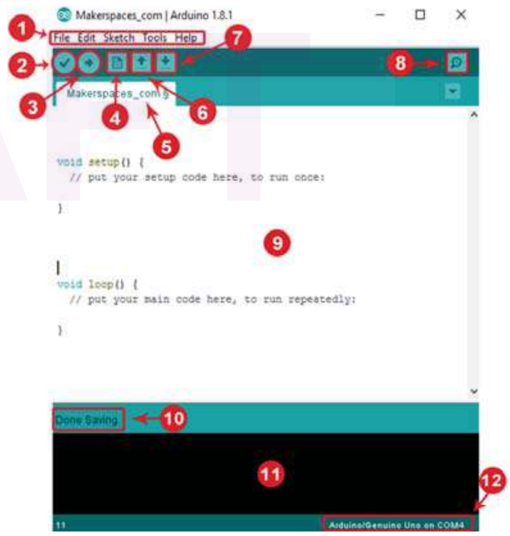
Fig 7



Step 8 “ Upload the program to your board.

Before uploading, the function of each symbol appearing in the Arduino IDE toolbar.

Fig 8



1. Menu Bar: Gives you access to the tools needed for creating and saving Arduino sketches.
2. Verify Button: Compiles your code and checks for errors in spelling or syntax.

3. Upload Button: Sends the code to the board that's connected such as Arduino Uno in this case. Lights on the board will blink rapidly when uploading.
4. New Sketch: Opens up a new window containing a blank sketch.
5. Sketch Name: When the sketch is saved, the name of the sketch is displayed here.
6. Open Existing Sketch: Allows you to open a saved sketch or one from the stored examples.
7. Save Sketch: This saves the sketch you currently have open.
8. Serial Monitor: When the board is connected, this will display the serial information of your Arduino
9. Code Area: This area is where you compose the code of the sketch that tells the board what to do.
10. Message Area: This area tells you the status on saving, code compiling, errors and more.
11. Text Console: Shows the details of an error messages, size of the program that was compiled and additional info.
12. Board and Serial Port: Tells you what board is being used and what serial port it's connected to.

Now simply click the "Upload" button in the environment. Wait for few seconds; the RX and TX LEDs on the board, flashing. If the upload is successful, the message "Done uploading" will appear in the status bar.

1.3 Simple Programming Concepts

Arduino programs are written in the Arduino Integrated Development Environment (IDE). Arduino IDE is a special software running on the system that allows to write sketches (Arduino language programming). The Arduino programming language is based on a very simple hardware programming language called processing, which is similar to the C language. After the sketch is written in the Arduino IDE, it should be uploaded on the Arduino board for execution.

1.3.1 Structure of Arduino program

Arduino programs have a minimum of 2 blocks, Preparation & Execution

A semicolon needs to follow every statement written in the Arduino programming language.

THE DOUBLE BACKSLASH FOR SINGLE LINE COMMENTS //

Each block has a set of statements enclosed in curly braces:

```
void setup( )
{
statements-1;
…..
…..
statement-n;
}
void loop ( )
{
statement-1;
…..
…..
statement-n;
}
```

Here setup ( ) is the preparation block and loop ( ) is an execution block.

The setup function is the first to execute when the program is executed, and this function is called only once. The setup function is used to initialize the pin modes and start serial communication. This function has to be included even if there are no statements to execute.

```
void setup ( )
{
pinMode (pin-number, OUTPUT); // set the 'pin-number' as output
pinMode (pin-number, INPUT); // set the 'pin-number' as output
}
```

After the setup ( ) function is executed, the execution block runs next. The execution block hosts statements like reading inputs, triggering outputs, checking conditions etc..

In the above example loop ( ) function is a part of execution block.The loop( ) function executes the set of statements (enclosed in curly braces) repeatedly.

```
Void loop ( )
{
digitalWrite (pin-number,HIGH); // turns ON the component connected to 'pin-number'
delay (1000); // wait for 1 sec
digitalWrite (pin-number, LOW); // turns OFF the component connected to 'pin-number'
delay (1000); //wait for 1sec
}
```

1.3.2 Data Types

The size and the type of value to be stored in a variable is known as Data type. Few commonly used arduino data types are

1. Int
2. Float
3. Char
4. Boolean

5. Long
6. Short
7. Byte
8. Word

1.3.3 Operators

An operator is a symbol that tells the compiler to perform specific mathematical or logical functions. C language is rich in built-in operators and provides the following types of operators "

- Arithmetic Operators
- Comparison Operators
- Boolean Operators

Arithmetic Operators

Assume variable A holds 10 and variable B holds 20 then"

Operator name	Operator simple	Description	Example
assignment operator	=	Stores the value to the right of the equal sign in the variable to the left of the equal sign.	A = B
Addition	+	Adds two operands	A + B will give 30
subtraction	-	Subtracts second operand from the first	A - B will give-10
multiplication	*	Multiply both operands	A * B will give 200
Division	/	Divide numerator by denominator	B / A will give 2
Modulo	%	Modulus Operator and remainder of after an integer division	B % A will give 0

Comparison Operators

Assume variable A holds 10 and variable B holds 20 then
"

Show Example

Operator name	Operator simple	Description	Example
equal to	==	Checks if the value of two operands is equal or not, if yes then condition becomes true.	(A == B) is not true
not equal to	!=	Checks if the value of two operands is equal or not, if values are not equal then condition becomes true.	(A != B) is true
less than	<	Checks if the value of left operand is less than the value of right operand, if yes then condition becomes true.	(A < B) is true
greater than	>	Checks if the value of left operand is greater than the value of right operand, if yes then condition becomes true.	(A > B) is not true
less than or equal to	<=	Checks if the value of left operand is less than or equal to the value of right operand, if yes then condition becomes true.	(A <= B) is true
greater than or equal to	>=	Checks if the value of left operand is greater than or equal to the value of right operand, if yes then condition becomes true.	(A >= B) is not true

Boolean Operators

Assume variable A holds 10 and variable B holds 20 then "

Show Example

Operator name	Operator simple	Description	Example
And	&&	Called Logical AND operator. If both the operands are non-zero then then condition becomes true.	(A && B) is true
Or	||	Called Logical OR Operator. If any of the two operands is non-zero then then condition becomes true.	(A || B) is true
Not	!	Called Logical NOT Operator. Use to reverses the logical state of its operand. If a condition is true then Logical NOT operator will make false.	!(A && B) is false

1.3.3 Branching Statements

Decision making structures require that the programmer specify one or more conditions to be evaluated or tested by the program. It should be along with a statement or statements to be executed if the condition is determined to be true, and optionally, other statements to be executed if the condition is determined to be false.

Following is the general form of a typical decision making structure found in most of the programming languages –

IF Statement

It takes an expression in parenthesis and a statement or block of statements. If the expression is true then the statement or block of statements gets executed otherwise these statements are skipped.

Different forms of if statement

Form 1

```
if (expression)
   statement;
```

You can use the if statement without braces { } if you have one statement.

Form 2

```
if (expression) {
   Block of statements;
}
```

Example

```
/* Global variable definition */
int A = 5 ;
int B = 9 ;
Void setup () {
}
Void loop () {
   /* check the boolean condition */
   if (A > B) /* if condition is true then execute the following statement*/
   A++;
   /* check the boolean condition */
   If ( ( A < B ) && ( B != 0 )) /* if condition is true then execute the following statement*/ {
      A += B;
      B—;
   }
}
```

An **if** statement can be followed by an optional else statement, which executes when the expression is false.

if … else Statement Syntax

```
if (expression) {
   Block of statements;
}
else {
   Block of statements;
}
```

Example

```
/* Global variable definition */
int A = 5 ;
int B = 9 ;

Void setup () {
```

```
}

Void loop () {
  /* check the boolean condition */
  if (A > B) /* if condition is true then execute the
following statement*/ {
     A++;
  }else {
     B =B - A;
  }
}
```

Introduction tovarious smart agricultural sensorswith their working principles, operation, advantages and disadvantages. What is the role involved in selection of sensors? And its uses.

Objectives: At the end of this lesson you shall be able to
- **understand what are the types of sensors involves in IoT based smart Agriculture and its applications**
- **understand how the sensors are selected for appropriate sensing parameter.**
- **differentiating types of sensors and its role.**
- **discussing about advantages and disadvantages in agriculture due to the use of sensors.**

1. Basics of location sensors

1.1 Location sensor:

It is a feature that communicates with the GPS of the corresponding location. It can be used in an application by a user to learn lot of things about current location. The GPS concept is based on time and the known position of GPS specialized satellites. The satellites carry very stable atomic clocks that are synchronized with one another and with the ground clocks. Any drift from time maintained on the ground is corrected daily. In the same manner, the satellite locations are known with great precision. GPS receivers have clocks as well, but they are less stable and less precise.

Each GPS satellite continuously transmits a radio signal containing the current time and data about its position. Since the speed of radio waves is constant and independent of the satellite speed, the time delay between when the satellite transmits a signal and the receiver receives it is proportional to the distance from the satellite to the receiver. A GPS receiver monitors multiple satellites and solves equations to determine the precise position of the receiver and its deviation from true time. At a minimum, four satellites must be in view of the receiver for it to compute four unknown quantities (three position coordinates and clock deviation from satellite time).

1.2 Characteristics of gps:

1. User-satellite geometry
2. Receiver in continuous operation
3. Non-navigation applications
4. Space segment
5. Control segment
6. User segment

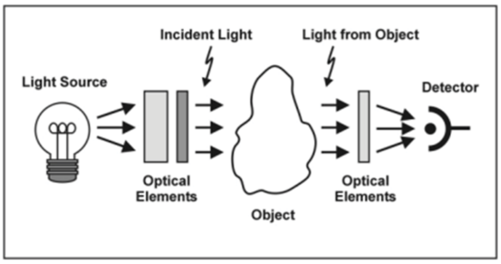
1.3 Satellite signals:

1. L1 carrier is modulated by both the C/A and P codes,
2. L2 carrier is only modulated by the P code.The P code can be encrypted as a so-called P(Y) code that is only available to military equipment with a proper decryption key. Both the C/A and P(Y) codes impart the precise time-of-day to the user.
3. L3 signal at a frequency of 1.38105 GHz is used to transmit data from the satellites to ground stations. This data is used by the United States Nuclear Detonation (NUDET) Detection System (USNDS) to detect, locate, and report nuclear detonations (NUDETs) in the Earth's atmosphere and near space.One usage is the enforcement of nuclear test ban treaties.
4. L4 band at 1.379913 GHz is being studied for additional ionospheric correction.
5. L5 frequency band at 1.17645 GHz was added in the process of GPS modernization. This frequency falls into an internationally protected range for aeronautical navigation, promising little or no interference under all circumstances.

Satellite signal frequency

Band	Frequency	Description
L1	1575.42 MHz	Coarse-acquisition (C/A) and encrypted precision (P(Y)) codes, plus the L1 civilian (L1C) and military (M) codes on future Block III satellites.
L2	1227.60 MHz	P(Y) code, plus the L2C and military codes on the Block IIR-M and newer satellites.
L3	1381.05 MHz	Used for nuclear detonation (NUDET) detection
L4	1379.913 MHz	Being studied for additional ionospheric correction.
L5	1176.45 MHz	Proposed for use as a civilian safety-of-life (SoL) signal.

Fig 1



2 Optical sensors

2.1 Basic principle:

The processes in which light incident onto a surface produces a current or a voltage are therefore processes around which photodetectors can be designed. The most important of these processes is the photoeffect upon which the working principles of different types of detectors are based as shown in fig it always consists of

- a light source,
- a photodetector, and
- a number of optical elements.

The object that the sensor points to is a part of the measurement process in the sense that it " processes " the incident light in such a way that the quantity to be measured can be extracted from the photodetector signal

2.2 Light source

The light source is the very heart of an optical sensor. It not only provides the "medium" through which information is transferred, but it may also become a component of the detection circuit itself, for example, by a modulation of the emitted light. A light source is characterized in terms of, for example, its emission spectrum, degree of coherence, radiant intensity, power consumption, lifetime, and all other parameters decisive for the respective application. Therefore, this chapter starts with a summary of these parameters before it reports on the most important light sources to date. Due to the physical nature of their light generation process, they can be divided up into thermal sources and line sources. Lasers,although line sources as well, will be treated in a separate section due to their very particular type of radiation.

2.3 Important Properties of Light Sources

One of the most important properties of a light source is its emission spectrum. This spectrum may be either wide and offer a great variety of wavelengths, or it may be narrow, monochromatic and, thus, only suited for very particular applications. In the visible part of the electromagnetic spectrum, the shape of the emission spectrum determines the light color perceived by the human eye

- Luminous flux: Light power perceived by the human eye.
- Luminous energy: Light energy perceived by the human eye.
- Luminance: Brightness of a light source. The smaller a light source, the brighter it is (at identical luminous intensities).
- Illuminance: Intensity of light incident on a surface.
- Luminous emittance: Intensity of light emitted from a surface.

Selection based on properties of light

Color	Wavelength range (nm)
Violet	380 – 450
Blue	450 – 500
Cyan	500 – 520
Green	520 – 565
Yellow	565 – 590
Orange	590 – 625
Red	625 – 740

2.4 Types of Optical Sensors

There are different kinds of optical sensors, the most common types are as given below.

- Photoconductive devices used to measure the resistance by converting a change of incident light into a change of resistance.
- The photovoltaic cell (solar cell) converts an amount of incident light into an output voltage.
- The Photodiodes convert an amount of incident light into an output current.

3.Electrochemical Sensors

3.1 Role

These sensors help in gathering chemical data of the soils by detecting specific ions in the soil. They provide information in the form of pH and soil nutrient levels.

3.2 Selection and characteristics

When soil samples are sent to a soil-testing laboratory, a set of standardized laboratory procedures is performed. These procedures involve sample preparation and measurement. Some measurements (especially determination of pH) are performed using an ion-selective electrode (with glass or polymer membrane or ion sensitive field effect transistor). These electrodes detect the activity of specific ions (nitrate, potassium, or hydrogen in case of pH). Several researchers are trying to adapt existing soil preparation and measurement procedures to essentially conduct a laboratory test on the go. The values obtained may not be as accurate as a laboratory test, but the high sampling density may increase the overall accuracy of the resulting soil nutrient or pH maps.

3.3 Advantages and Disadvantages

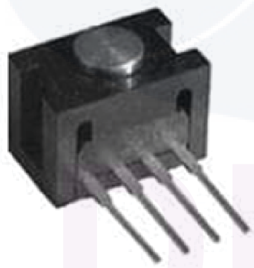
- Electrochemical sensors can rapidly respond to the target ions in minutes, suitable for in-field rapid detection.
- small-sized sensors require small volume of reagents and samples, which can also reduce the cost in soil testing.
- microsensors may be of automatic control and easily used even for non-trained users
- One main challenge faced is the reliability of sensor array, that is, to avoid or diminish the interferences from other ions while using a sensor array for simultaneous detection.

4.Mechanical Sensors

These sensors are used to measure soil compaction or mechanical resistance. It can be used to estimate soil mechanical resistance (often related to compaction).These sensors use a mechanism that penetrates or cuts through the soil and records the force measured by strain gauges or load cells.

The sensors use a probe that penetrates the soil and records resistive forces through use of load cells or strain gauges. A similar form of this technology is used on large tractors to predict pulling requirements for ground engaging equipment. Tensiometers, like HoneywellFSG15N1A, detect the force used by the roots in water absorption and are very useful for irrigation interventions.

Fig 2



Honeywell Force Sensors

Compacted soil, which can be caused by the heavy weight of field equipment or just the natural soil forming processes, can lead to soil degradation and affect crop production negatively.

5. Airflow Sensors

Airflow Sensors measure soil air permeability. Measurements can be made at singular locations or dynamically while in motion. The desired output is the pressure required to push a predetermined amount of air into the ground at a prescribed depth. Various types of soil properties, including compaction, structure, soil type, and moisture level, produce unique identifying signatures.

The pressure required to squeeze a given volume of air into the soil at fixed depth was compared to several soil properties. Experiments showed potential for distinguishing between various soil types, moisture levels, and soil structure/compaction.

6.Agricultural Weather Stations

6.1 Introduction

Agricultural weather stations are self-contained sensors that are located at different spots through the growing fields. These stations have a blend of sensors that are applicable for the local crop and climate. Information such as air temperature, soil temperature at various depths, rainfall, leaf wetness, chlorophyll, wind speed, dew point temperature, wind direction, relative humidity, solar radiation, and atmospheric pressure are determined and recorded at programmed intervals.

This data is amassed and transmitted wirelessly to a central data logger at programmed intervals. Because they are portable and reasonably priced, weather stations are appealing for farms of all sizes.

There could be a loss of time and production should a farm vehicle break down. Farmers now have the ability to remotely gather and manage information from their field equipment. Equipment telematics lets mechanical devices such as tractors to notify mechanics that a failure is likely to happen soon. Most of the agricultural equipment companies are building telematics systems.

6.2 Benefits or advantages of Agriculture Sensors

- They are invented to meet increasing demand of food by maximizing yields with minimum resources such as water, fertilizers and seeds.
- They fulfill this by conserving resources and mapping fields.
- They are simple to use and easy to install.
- They are cheaper.
- In addition to agricultural use, they can also be used for pollution and global warming.
- They are equipped with wireless chip so that they can be remotely controlled.

Drawbacks or disadvantages of Agriculture Sensors

- Smart farming and IoT technology require continuous internet connectivity.
- There is presumption in the market that consumers are not always ready to adopt latest IoT devices equipped with agriculture sensors.
- The basic infrastructure requirements such as smart grids, traffic systems and cellular towers are not available everywhere. This further hinders the growth of its use.

Location sensors , Optical sensors, Electrochemical Sensor, Mechanical sensors, Airflow sensors, Agricultural weather stations.

Objectives: At the end of this lesson you shall be able to
- **Understand what is IOT in Agriculture, its applications and its advantages.**
- **Comprehend the embedded systems and role of IOT in it.**

1. Location Sensors

1.1 Introduction

Location Sensors use signals from GPS satellites to determine latitude, longitude, and altitude to within feet. Three satellites minimum are required to triangulate a position. Precise positioning is the cornerstone of precision agriculture. GPS integrated circuits like the NJRNJG1157PCD-TE1are a good example of location sensors.

1.2 Global Positioning System

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS measurements can be taken to better than a centimeter. In a sense it's like giving every square meter on the planet a unique address.

GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. These days GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, even laptop computers.Soon GPS will become almost as basic as the telephone.

1.2.1 How GPS Work

The GPS receiver gets a signal from each GPS satellite. The satellites transmit the exact time the signals are sent. By subtracting the time the signal was transmitted from the time it was received, the GPS can tell how far it is from each satellite. The GPS receiver also knows the exact position in the sky of the satellites, at the moment they sent their signals. So given the travel time of the GPS signals from three satellites and their exact position in the sky, the GPS receiver can determine the position in three dimensions – east, north and altitude.

To calculate the time the GPS signals took to arrive, the GPS receiver needs to know the time very accurately. The GPS satellites have atomic clocks that keep very precise time, but it's not feasible to equip a GPS receiver with an atomic clock. However, if the GPS receiver uses the signal from a fourth satellite it can solve an equation that lets it determine the exact time, without needing an atomic clock.

If the GPS receiver is only able to get signals from 3 satellites, it can still get the position, but it will be less accurate. The GPS receiver needs 4 satellites to work out the position in 3-dimensions. If only 3 satellites are available, the GPS receiver can get an approximate position by making the assumption that are at mean sea level. A modern GPS receiver will typically track all of the available satellites simultaneously, but only a selection of them will be used to calculate the position.To determine the location of the GPS satellites two types of data are required by the GPS receiver: the almanac and the ephemeris. This data is continuously transmitted by the GPS satellites and the GPS receiver collects and stores this data.

1.2.2 How to use GPS module for Base Station Applications

The following things are required to use GPS for base station applications:

External Antenna

This antenna is mounted outside BTS box on the tower facing sky. This antenna is mounted on the BTS chassis using screws.

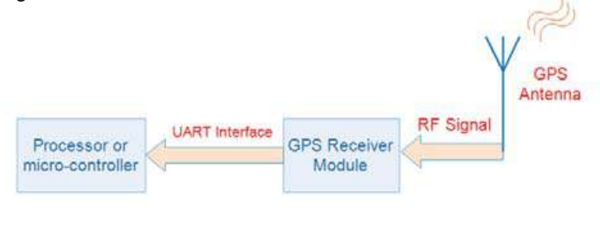
GPS module

Antenna is connected to the GPS module using RF cable. This GPS module is mounted inside BTS box.

Processor

BTS's processing unit i.e. FPGA, CPLD or other base band processor connected to the GPS module using UART (or SPI, I2C etc) interface. This processor send command to GPS module and receives desired response from it.

Fig 1



Thus using a GPS module and external antenna, one can get the most accurate 1 Hz clock and synchronize other clock circuitry

1.2.3 Parameters for selecting GPS module

GPS Pulse Accuracy

This is the accuracy of 1Hz pulse received from GPS module or chipset. (Typical ±25ns)

GPS Sensitivity

Minimum level of signal that allows GPS receiver to acquire or track the GPS signal.

Acquisition sensitivity: minimum level to successfully get GPS signal information while system powers up first time. (typically around -140 to -150 dBm)

Tracking sensitivity: minimum level to maintain location fix once it has been attained (typically -150 to -160 dBm)

Interface Type

When GPS chipset or GPS module is used, then over some interface, we need to get the GPS packet information. That interface could be UART, I2C, SPI etc.

Operating Supply Voltage

This is the voltage over which GPS module or chipset works. (Typically, +2.5V or +3.3V)

Operating Temperature Range

If using GPS module for outdoor applications, then minimum and maximum operating temperature range shall be checked. (Typically -40 to +85 degreeC)

1.2.4 Where does GPS is used ?

Location – determining a basic position

Navigation – getting from one location to another

Tracking – monitoring the movement of people and things

Mapping – creating maps of the world

Timing – bringing precise timing to the world

2.Optical Sensors

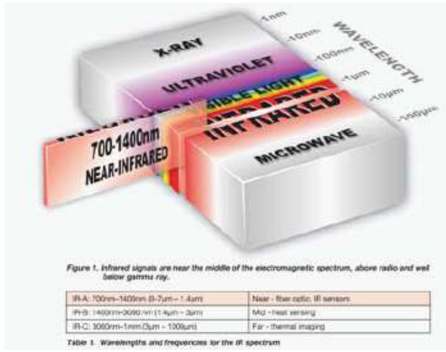
2.1 Introduction

Optical sensors are used for detecting light intensity. Typically, they respond only to particular wavelengths or spectral bands. One sensor may respond only to visible light in the blue-green region, while another sensor may have a peak sensitivity to near-infrared radiation.

2.2 Optical Sensor work process

To understand infrared technology, the best starting point is the electromagnetic spectrum. The frequency range and wavelengths of the entire spectrum are shown in below figure. The IR portion of the electromagnetic spectrum is usually divided into three regions: the near-, mid- and far-infrared. The wavelengths for these regions are shown in the below Table. Infrared wavelengths range from red to violet. The frequencies are higher than microwave but shorter than visible light. Focusing on near infrared devices

Fig 2



Optical wireless communication uses IR data transmission for short range applications such as computer peripherals and PDAs (personal digital assistants). For optical communication, a modulated IR light beam transmitted by an emitter LED is received by a silicon photodiode. Infrared Data Association (IrDA) standards provide the protocol for these types of communication. Since IR does not penetrate walls, it does not interfere with other signals in indoor environments. IR technology is the most commonly used technique for remotely controlling appliances.

2.3 Aerial Images

Drones can be used to capture multispectral imagery over fields. Some drones can cover tens of thousands of acres per day. Resolutions are sharp enough to count insects on a single leaf. Deep learning engines use math models and cloud-based computing trained by agronomists and millions of examples of crop health issues.

1.4 Moisture content of the soil

2.4.1 Introduction

Soil Organic Matter is composed mainly of carbon, hydrogen and oxygen, and has small amounts of other elements, such as nitrogen, phosphorous, sulfur, potassium, calcium and magnesium contained in organic residues. It is divided into 'living' and 'dead' components and can range from very recent inputs, such as stubble, to largely decayed materials that are thousands of years old. The moisture content of a soil sample is defined as the mass of water in thesample expressed as a percentage of the dry mass, usually heating at 1050C.

2.4.2 Estimating soil organic matter stock from soil organic carbon

Start with the measured total organic carbon %

If 58% of the mass of organic matter exists as carbon. We can estimate the percentage of SOM from the SOC% using the conversion factor 1.72 (derived from 100/58).Organic matter (%) = total organic carbon (%) x 1.72. This conversion factor can vary in different soils, but 1.72 provides a reasonable estimate of SOM for most purposes.

Convert % to weight for a given depth and area

SOC stock in tonnes of carbon per hectare (tC/ha) = (soil organic carbon %) x (mass of soil in a given volume)

For example, a soil with a SOC of 1.3% (0.013) and a bulk density of 1.2 grams per cubic centimetre (equivalent to 1.2 tonnes per cubic metre), would have SOC to a depth of 10cm (0.1m) per hectare (10 000m^2) of:

(0.013) x (1.2 x 0.1 x 10 000) = 15.6tC/ha.

Using the conversion factor of 1.72, the amount of SOM would be: 15.6 x 1.72 = 26.8 tonnes of organic matter.

2.4.3 Determination of organic matter content

The amount of organic matter in a soil can be determined either directly or

indirectly. In the direct methods the soil is treated with an agent, which can in some way remove the organic compounds, the residue after the treatment being weighed. The weight loss gives the organic content.

Direct method involves :

a. Extraction with Alkali

b. Hydrogen Peroxide method

c. Loss on ignition Method

d. Rathers Method

Indirect method involves:

a. Dry Combustion methods

b. Wet Cobustion methods

c. The Kjeldahl or Bangor Method

d. Rapid Titration Methods

e. The Tinsley iVlethocl

3. Electrochemical Sensors

3.1 Introduction

Electrochemical sensors are devices that give information about the composition of a system in real time by coupling a chemically selective layer (the recognition element) to an electrochemical transducer.

Electrochemical sensors could provide the most important type of information needed for precision agriculture — soil nutrient levels and pH. When soil samples are sent to a soil-testing laboratory, a set of standardized laboratory procedures is performed. These procedures involve sample preparation and measurement. Some measurements (especially determination of pH) are performed using an ion-selective electrode (with glass or polymer membrane or ion sensitive field effect transistor). These electrodes detect the activity of specific ions (nitrate, potassium, or hydrogen in case of pH). Several researchers are trying to adapt existing soil preparation and measurement procedures to essentially conduct a laboratory test on the go. The values obtained may not be as accurate as a laboratory test, but the high sampling density may increase the overall accuracy of the resulting soil nutrient or pH maps.

Fig 3

3.2 What do Electrochemical Sensors Do?

Electrochemical sensors are used for detecting oxygen and toxic gases. More specifically, they measure the concentration of a specific gas within an external circuit. This is done by method of oxidation or reduction reactions.These reactions generate the positive or negative current flow through said external circuit. An electrochemical sensor is made up of a "working" electrode, a "counter" electrode, and usually a "reference" electrode. All of these components sit inside of a sensor housing along with a liquid electrolyte. At the top of the housing, there is a mechanism made up of a membrane and a diffusion limiting outlet. This outlet allows the outside air to interact with the liquid electrolyte.

A few examples of electrochemical sensors are:

- Breathalyzer
- Blood Glucose sensor
- Respiratory Carbon Dioxide sensor
- (Electrochemical) Carbon Monoxide sensor
- (Electrochemical) Oxygen sensor

3.3 How do Electrochemical Sensors Work?

The sensor type works by means of gas diffusion. Gas finds its way into the outlet of the membrane on top of the sensor housing. Once the gas reaches the working electrode, an electrochemical reaction occurs. This reaction is either an oxidation or a reduction, depending on the type of gas. (For example, carbon monoxide gets oxidized into carbon dioxide, and oxygen gets reduced to water).

Oxidation causes the flow of electrons to move from the working electrode to the counter electrode through the external circuit. Reduction adversely causes the flow of electrons to move from the counter electrode to the working electrode. Either direction of electron flow creates an electric current proportional to the concentration of gas.

The electrons within the external circuit detect and amplify this current. It then scales the output accordingly with the calibration to give a reading in engineered units. The engineered units are read in PPM (parts per million) to give a percentage of the volume of gas.

Electrochemical sensors depend on chemical processes with proportional temperature rates. Since temperatures vary, some form of temperature compensation is encouraged for the most accurate readings.

4. Mechanical Sensors

4.1 Introduction

Mechanical sensors detect some form of mechanical deformation and translate the deformation into an electrical signal. Mechanical sensors are used to measure variables such as position, velocity, acceleration, force, pressure, levels (such as a liquid in a tank), and flow.

4.2 Uses

Mechanical sensors are used to assess soil compaction as related to the variable level of compaction. These sensors employ a mechanism that cuts through the soil and documents the force measured by strain gauges or load cells.When a sensor cuts through the soil, it records the resistance forces resulting from the cutting, breaking, and displacing of soil. Soil mechanical resistance is measured in a unit of pressure and represents the ratio of the force required to penetrate the soil medium to the frontal area of the tool engaged with the soil.

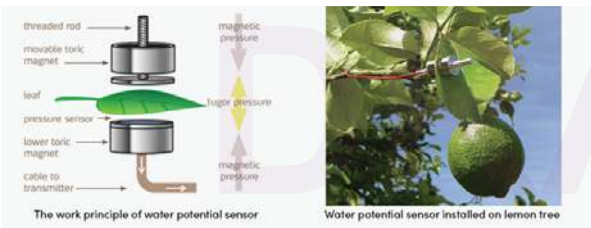
4.3 Classification

Mechanical Crop Sensor

Mechanical sensors operate based on a plant contact. According to the measured parameter, they can be classified into:

· Sensors which measure crop water potential, i.e. the relative changes in the leaf's turgor pressure. The leaf is placed between two magnets which measure the difference between plant turgor and magnetic pressure. Low plant turgor will increase magnetic pressure, thus indicating that the plant lacks sufficient water, making, irrigation necessary. Such sensors can measure changes in leaf turgor pressure in real time.

Fig 4

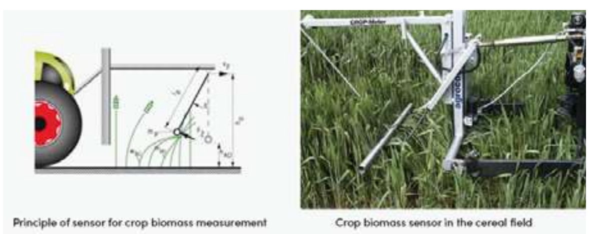


The work principle of water potential sensor

Water potential sensor installed on lemon tree

· Sensors for crop biomass density measuring; in which the sensor has a pendulum system which passes over the crop under a certain angle, thus detecting differences within the crop. In measuring the crop biomass, the sensor serves to be beneficial, as it regulates nitrogen applications over specific areas as well as ensures optimum plant protection.

Fig 5



Principle of sensor for crop biomass measurement

Crop biomass sensor in the cereal field

5. Air Flow Sensors

5.1 Uses

Airflow Sensors measure soil air permeability. Measurements can be made at singular locations or dynamically while on the go. The desired output is the pressure required to push a predetermined amount of air into the ground at a prescribed depth. Various types of soil properties, including compaction, structure, soil type, and moisture level, produce a unique identifying signature. Experiments have the potential for classifying various soil types, moisture levels, and soil structure/compaction.The pressure required to squeeze a given volume of air into the soil at fixed depth was compared to several soil properties.

5.2 Need for Airflow sensors

Airflow is crucial in indoor farming for several reasons. One, it forces air through the filtration systems that limit the number of microbes that enter the facility in the first place. Many believe that indoor facilities are immune to a lot of the challenges that face outdoor farm in terms of bacteria, pests, and mold or rot, but indoor facilities are just as much as risk for these types of crop-killers as field growing operations.

Airflow circulates CO2 through these indoor farming facilities, which both supplies the plants with the crucial gas for growth and reduces the level of humidity. Too much moisture gathering on the cops can create a quite hospitable environment for mold and mildew. The circulated air also reduces the build-up of heat, which can create the perfect environment for pests, pathogens, disease, and bacteria. In fact, without constant and substantial airflow through these indoor farms, significant growth would be downright impossible.

5.3 Applications

· Agriculture - irrigation and water use, green house heating, effluents

· Food Process - chemical flow monitoring, effluents, treated waste water

· Heating, Ventilation and Air Conditioning - for maintaining energy and utility efficiency

· Water Management - pump monitoring, system-flow balancing, monitor waste water recycling, sewage

· Power and Energy - Diesel and other oils, cooling water flow, water treatment plant

· Mining Industry - water use, fuel and lubricant use, sludge and slurry monitoring

5. Agricultural Weather Stations

6.1 Introduction

An agricultural weather station is an automatic device for specific monitoring of the agricultural environment.

6.2 Functions

Its main function is real-time monitoring of wind, temperature, humidity, pressure, rainfall, radiation, photosynthetic efficiency, soil temperature, soil moisture, soil pH, soil salinity, CO2.

6.2.1 Wind Measurement

Regulation of winds on the microclimate of farmland

(1) Wind will affect farmland turbulent exchange intensity;

(2) Increase the exchange of heat and moisture between the ground and the air

(3) Increase soil evaporation and crop transpiration, and also increase the exchange of CO2 and other components in the air.

Wind Measurement Parameter

Item	Content	Remark
Wind direction	Measuring range 0~360°Accuracy ± 3°	
Wind speed	Measuring range 0~60 m/sAccuracy ÿ± 0,3m/s or ±3%	In the greenhouse agro-meteorological research, ultra-low wind speed standards will be adopted
	Measuring range 0~1m/s or 0~2m/s Accuracy ÿ0.2…1m/s:±(0.05m/s (10ft/min) +2% of MV)0,2… 2m s:±(0.08m/s (16ft/min) +4% of MV)	

6.2.2 Temperature Measurement

The low temperature will effect

· Cool damage

- Cool damage means that during the growing season of crops, the temperature is 0°C.

Above, sometimes even crops at about 20°C Hazard.

Frost

Frost refers to the short-time low-temperature frost damage that occurs when the temperature of the soil surface or plant surface drops below the freezing point of the plant tissue in the warm season and freezes in the body tissue.

Freeze damage

Freezing damage refers to a kind of agrometeorological disaster caused by low temperature below 0°C or severe temperature change during overwintering of overwintering crops and fruit trees.

Parameter

Item	Content	Remark
Temperature	Measuring range -50-85°C Accuracy ±0.3°C	Monitoring atmospheric temperature and soil temperature

6.2.3 Water Measurement

Water affects the main aspects of crops

· Water is the raw material for photosynthesis of green plants.

· How much water affects the intensity of crop photosynthesis.

· Moisture as a medium also affects the process of crop photosynthesis.

· Water supply the need for crop transpiration, and transpiration is regulating the body temperature of the crop, or plant roots absorb moisture and nutrients from the soil one of the power.

· Moisture is one of the main factors of plant composition. According to the determination, the water content of the general plants is 75-90% of the fresh weight, and even the aquatic plants are as high as 98%.

Item	Content	Remark
Humidity	Measuring range 0-100%Accuracy ±2%	Air Humidity
Soil Moisture	0-50% ±2%50-100% ±3%	
Rainfall	Measuring range: 0-999.9mmResolution: 0.1mmAccuracy: 4%	
Water Level	Measuring Range: 0-30mResolution: 1mmAccuracy: ±2%	

6.2.4 Solar Radiation Measurement

Influence of Solar Radiation

- Photosynthetic effect
- Thermal effect
- Morphological effects of light

Light also affects the geographical distribution of plants to a considerable extent.Light mainly affects plants from three aspects:

- The length of the light, which is the length of the light.
- Light intensity, the intensity of light.
- Light quality, ie different spectral composition.

Parameter

Item	Content
Radiation	Measuring range: 0-2000w/m2Resolution: 1W/m2Accuracy: ±5%

6.2.5 Soil EC

Influence Of Soil EC

a. Make the soil more compact.

When the granule structure in the soil is reduced, the aeration and water permeability of the soil will be poor, and the soil will become sticky when it comes into contact with water.

After the drying, there will be a large number of cracks on the surface. Roots stretch very slowly in such soils, and impervious and impermeable soils are more likely to cause root injury.

b. Inhibition of vegetable root development.

Planting vegetables in salt-damaged soils generally shows short stature, poor development, and dense foliage.In severe cases, they start to dry or brown from the leaves, turning inwards or outwards, and the roots turn brown and die.

Parameter

Item	Content	Remark
Soil EC	Measuring range: 0.00-19.99ms/cm Resolution: 0.01ms/cm Accuracy: EC±2!	

7. Co2

Influence of CO2

Photosynthesis is the basis on which the biological community depends. Green plants and certain bacteria utilize chlorophyll, which converts carbon dioxide and water into organic matter, and releases the biochemical process of oxygen.For almost all living things in the biological community, this process is the key to their survival and the carbon and oxygen cycle on Earth, photosynthesis is essential.

Parameter

Item	Content
CO2	Measuring range: 0~5000ppmAccuracy: 3!

Introduction to Zigbee. Block diagram of Zigbee based sensor network. Introduction to wireless personal area network system. Introducing to Zigbee networking system.

Objectives: At the end of this lesson you shall be able to
- **understand the concept of Zigbee technology.**
- **analyzing the work process of Zigbee technology**
- **understanding the concept of wireless personal area network system.**

1.Zigbee Technology

1.1 Introduction

ZigBee is the most popular industry wireless mesh networking standard

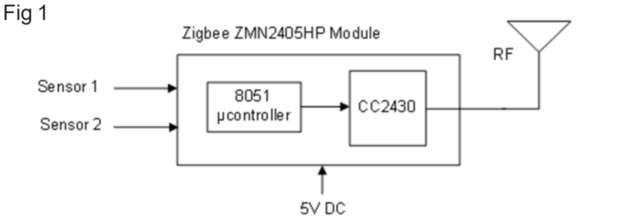
for connecting sensors, instrumentation and control systems. ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, such as for home automation, medical device data collection, and other low-power low-bandwidth needs, designed for small scale projects which need wireless connection. Hence, ZigBee is a low-power, low data rate, and close proximity (i.e., personal area) wireless ad hoc network.

1.2 Block Diagram

The wireless sensor nodes used are based on the Zigbee compliance product from Cirronet. The high power transmission type ZMN2405HP Zigbee module is using the CC2430 transceiver IC from Texas Instrument comply to the IEEE 802.15.4 standards with a maximum transmission power of 100 mW using the dipole antenna and 250 mW using the directional patch antenna. The transceiver IC is integrated with the 8051 microcontroller, low power but high performance, 64 kByte programmable flash microcontroller. The module alone requires a 5VDC power supply, multiple sensor inputs/outputs with ADC, operating at a frequency of 2.4 GHz with a configurable sleep mode to get the best of power consumption as low as 3uA. The main microcontroller in the module is reprogrammable whether

to function as an end device or as a router or coordinator nodes.

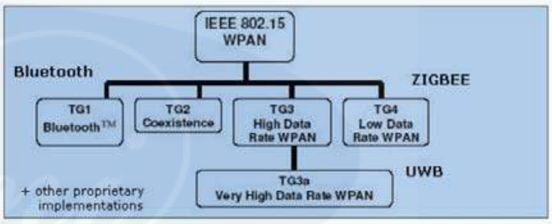
Fig 1



1.3 Wireless Personal Area Networks

A *wireless personal area network* (WPAN) is a personal, short distance area wireless network for interconnecting devices centered around an individual person's workspace. WPANs address wireless networking and mobile computing devices such as PCs, PDAs, peripherals, cell phones, pagers and consumer electronics. WPANs are also called *short wireless distance networks*.

Fig 2



Applications include

- Short-range (< 10 m) connectivity for multimedia applications.
- PDAs, cameras, voice (hands free devices)
- High QoS, high data rate (IEEE 802.15.3).

Industrial sensor applications includes

Low speed, low battery, low cost sensor networks (IEEE 802.15.4)

Common goals

Getting rid of cable connections

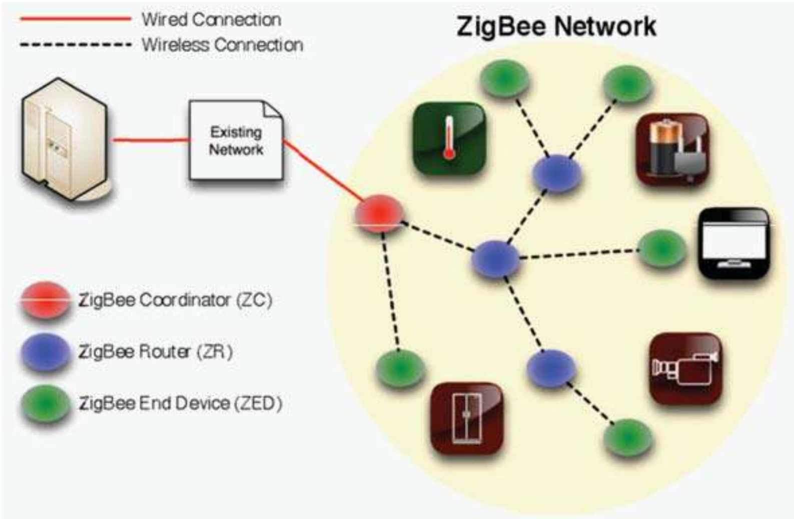
Little or no infrastructure

Device interoperability

1.4 Zigbee Networking systems

Zigbee system structure consists of three different types of devices such as Zigbee coordinator, Router and End device. Every Zigbee network must consist of at least one coordinator which acts as a root and bridge of the network. The coordinator is responsible for handling and storing the information while performing receiving and transmitting data operations. Zigbee routers act as intermediary devices that permit data to pass to and fro through them to other devices. End devices have limited functionality to communicate with the parent nodes such that the battery power is saved as shown in the figure. The number of routers, coordinators and end devices depends on the type of network such as star, tree and mesh networks.

Fig 3



Smart Agriculture Related Theory for Exercise 32 -33. 165 to 181

Identify different IOT Applications with IOT architecture Different functional building blocks of IoT architecture

Concept of interfacing of Bluetooth module to local sensor network, interfacing of GSM module to make a node as a gateway. IoT Gateway using WiFi and Ethernet. Application of GPS satellite in Location Sensors. RS485 interface for industrial agriculture sensors.

Objectives: At the end of this lesson you shall be able to
- **understand the concept of Bluetooth and GSM module**
- **to know various applications used through GPS satellite**
- **to understand the role of RS485 for agriculture sensors.**

1.Interfacing of Bluetooth module to local sensor network

Bluetooth module is a basic circuit set of chip which integrated Bluetooth functions and which can be used in wireless network transmission.

Fig 1

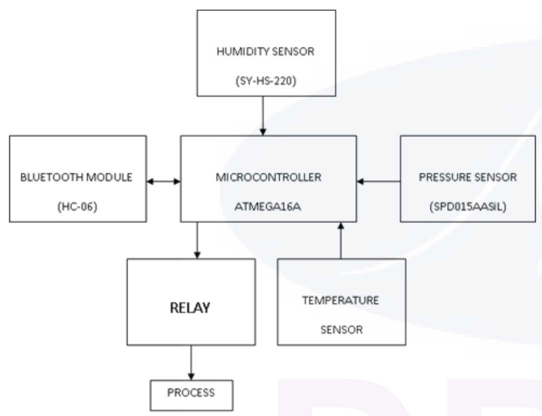
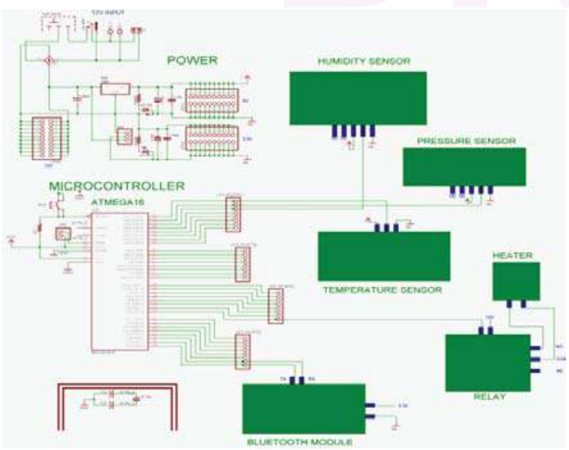


Fig 2



The circuit diagram consist of Power supply unit in which IC 7805 & IC 16 is used to obtain 5V & 3.3V for Microcontroller, Sensors & Bluetooth Module. After switching on the power supply unit we can see that the LED of Bluetooth module starts Blinking, once the Bluetooth enabled device establishes connection or pairing of devices is done then LED stops blinking which means that data communication can be established. Once communication between Bluetooth enabled device is established then the different sensors such as Temperature Pressure & Humidity can sense the data and send it to PORT A of microcontroller ATmega16 and since the data obtained from the sensors are in analog values, this data is given to Microcontroller ATmega16 that converts received analog data in to digital form with the help of in built ADC in Microcontroller ATmega16.After conversion the digital data is send to the Bluetooth Module which is connected at PORT D of microcontroller. TheBluetooth enabled laptop or smart phone can observe the different parameter such as Temperature, Pressure &Humidity.The temperature of a process is set to 100 degree Celsius if the temperature of process reaches above set point then relay is triggered to turn of the process & indicates on the display of the operator that the maximum temperature reached, once the temperature of the process is reached below or 100 degree Celsius then relay is triggered to turn on the process.

2.Interfacing of GSM module to make node as a gateway

2.1 Introduction

A GSM Module is basically a GSM Modem (like SIM 900) connected to a PCB with different types of output taken from the board – say TTL Output (for Arduino, 8051 and other microcontrollers) and RS232 Output to interface directly with a PC (personal computer). The board will also have pins or provisions to attach mic and speaker, to take out +5V or other values of power and ground connections.The below discussion is about connecting a gsm modem or module to arduino and hence send and receive sms using arduino – it is always good to choose an arduino compatible GSM Module – that is a GSM module with TTL Output provisions.

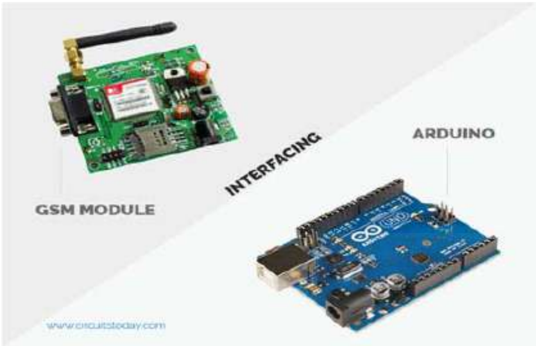
2.2 Steps:

SIM900 GSM Module – This means the module supports communication in 900MHz band.

Check the power requirements of GSM module – GSM modules are manufactured by different companies. They all have different input power supply specs. If gsm module requires a 12 volts input,feed it using a 12V,1A DC power supply. In a 5V module, power it directly from Arduino's 5V out.

Check for TTL Output Pins in the module – You can feed the data from gsm module directly to Arduino only if the module is enabled with TTL output pins. Otherwise you have to convert the RS232 data to TTL using MAX232 IC and feed it to Arduino. Most of the gsm modules in market are equipped with TTL output pins.

Fig 3



2.3 Booting the GSM Module

1. Insert the SIM card to GSM module and lock it.

2. Connect the adapter to GSM module and turn it ON!

3. Now wait for some time (say 1 minute) and see the blinking rate of 'status LED' or 'network LED' (GSM module will take some time to establish connection with mobile network)

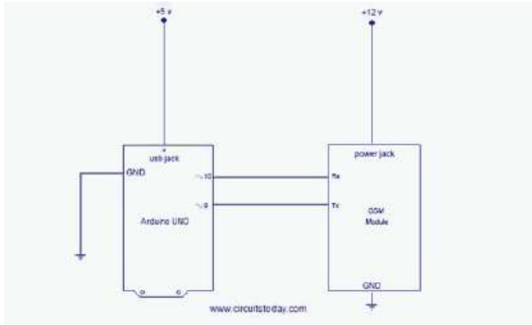
4. Once the connection is established successfully, the status/network LED will blink continuously every 3 seconds. You may try making a call to the mobile number of the sim card inside GSM module. If you hear a ring back, the gsm module has successfully established network connection.

2.4 Connecting GSM Module to Arduino

There are two ways of connecting GSM module to arduino. In any case, the communication between Arduino and GSM module is serial. Serial pins of Arduino (Rx and Tx) can be applied in this method, to connect the Tx pin of GSM module to Rx pin of Arduino and Rx pin of GSM module to Tx pin of Arduino. GSM Tx –> Arduino Rx and GSM Rx –> Arduino Tx. Connect the ground pin of arduino to ground pin of gsm module. Now different programs can be loaded to communicate with gsm module and make it work.

Note:- The problem with this connection is that, while programming Arduino uses serial ports to load program from the Arduino IDE. If these pins are used in wiring, the program will not be loaded successfully to Arduino. To disconnect wiring in Rx and Tx each time you burn the program to arduino. Once the program is loaded successfully, these pins can be connected to make the system working.

Fig 4



3.IoT gateway using WIFI and Ethernet

3.1 Introduction

An Internet of Things (IoT) gateway is a physical device or software program that serves as the connection point between the cloud and controllers, sensors and intelligent devices. All data moving to the cloud, or vice versa, goes through the gateway, which can be either a dedicated hardware appliance or software program. An IoT gateway may also be referred to as an intelligent gateway or a control tier.

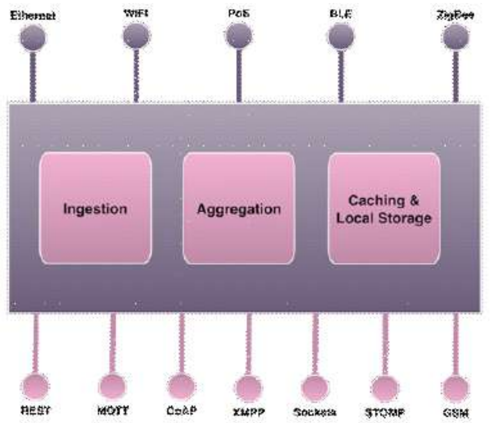
Some sensors generate tens of thousands of data points per second. A gateway provides a place to preprocess that data locally at the edge before sending it on to the cloud. When data is aggregated, summarized and tactically analyzed at the edge, it minimizes the volume of data that needs to be forwarded on to the cloud, which can have a big impact on response times and network transmission costs.An IoT gateway has multiple roles to play.

One of the first jobs of the gateway is to transform and normalize the data. The datasets generated by the sensor nodes will be in disparate formats. Some of the legacy nodes use proprietary protocols, while the contemporary ones may rely on JSON or CSV. The gateway acquires heterogenous datasets from multiple sensor nodes and converts them to a standard format that is understood by the next stage of the data processing pipeline.

The second role of an IoT gateway is protocol transformation. Since the sensor nodes cannot use power hungry Wi-Fi or ethernet, they use low-powered communication networks. A gateway supports multiple communication protocols for accepting the inbound data sent by the sensor nodes. It uses a variety of protocols for the outbound communication, which typically connects the gateway to a process running in the cloud. Some of the popular outbound protocols used in the context of IoT are REST, MQTT, CoAP, STOMP and even SMS. In some scenarios, the gateway may also process the data and raise alerts in real time. But this is best left to the powerful stream processing pipelines running in the cloud.

The diagram below represents the deployment architecture of an IoT gateway.

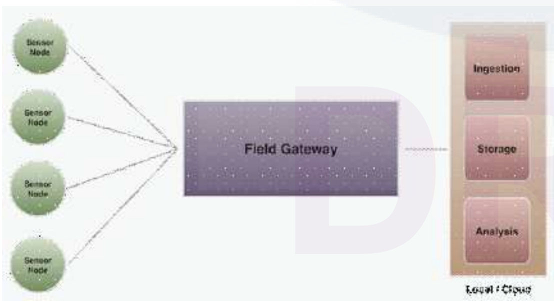
Fig 5



Gateways act as an edge device, obscuring the sensor nodes from the public internet. Though the sensor nodes can make outbound connections to the internet and cloud through the gateway, they cannot be accessed directly. Thus, gateways play the dual role of routers and firewall securing the sensor nodes and internal network.

Sensor nodes that are capable of connecting to the Internet still need a gateway for data aggregation and transformation. They connect to an appliance running in the cloud called a cloud gateway. The local edge device running on-premises is often referred to as a field gateway.

Fig 6



Arduino as a Sensor Node and Raspberry Pi as a Gateway

To build a working prototype, the sensor node configuration simple. An inexpensive DHT22 sensor that captures the ambient humidity and temperature and sends it to the gateway.

The following components can be applied:

Sensor Node

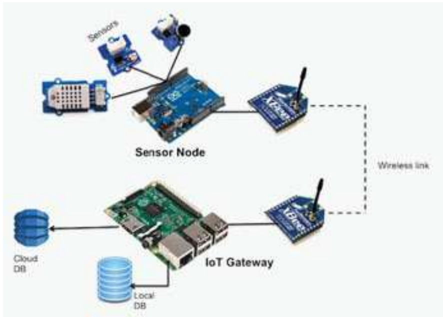
- Arduino Uno R3
- DHT 22 humidity / temperature sensor
- XBee breakout board
- XBee series 2

IoT Gateway

- Raspberry Pi 2
- XBee series 2
- Wi-Fi Dongle

To connect the Internet of Thing or device to the Internet, depends ultimately on what we actually want to do with the device. Shown below is a typical home network. This would normally consist of a router / firewall that connects to your ISP (Internet Service Provider). The connection to the ISP could by via ADSL or Ethernet using a fibre service.

Fig 7



4.Application of GPS satellite in Location Sensors

4.1 Introduction

Global Positioning System (GPS) is a satellite-based system that uses satellites and ground stations to measure and compute its position on Earth.GPS is also known as Navigation System with Time and Ranging (NAVSTAR) GPS.GPS receiver needs to receive data from at least 4 satellites for accuracy purpose. GPS receiver does not transmit any information to the satellites.This GPS receiver is used in many applications like smartphones, Cabs, Fleet management etc.

The LocationSensor is used to communicate with the global positioning satellite receiver (GPS) in your phone/ tablet. When the LocationSensor communicates with the built-in GPS receiver, the GPS determines the location of your device. The sensor can also work with network/wifi location services.

4.2 Applications

The United States government created the system, maintains it and makes it freely accessible to anyonewith a GPS receiver. The global positioning system provides critical capabilities to military, civilandcommercial users around the world.

A. ROAD TRAFFIC CONGESTION : A navigation device has a GPRS receiver for receiving real timeinformation about or slow average speed on a stretch of motorway, indicating congestion. The device calculates a new itinerary to avoid the congestion, based on historically record speeds on secondary roads weighed by the current average speed in the congestion area.

B. TECTONICS : GPS enables direct fault motion measurement of earthquake between earthquake GPS can be used to measure crustal motion and deformation to estimate seismic strain build up for creating seismic hazard maps.

C. GPS OF MINING : The use of RTK GPS has significantly improved several mining operations suchasdrilling, shovelling, vehicle tracking and surveying, RTK GPS provides centimetre-level positioning accuracy.

D. GPS AND TOURS : Location determines what content to display, for instance, information about anapproaching point of interest.

E. NAVIGATION : Navigators value digitally precise velocity and orientation measurements. With the help of GPS roads or paths available, traffic congestion and alternative routes, roads or paths that might be taken to get to the destination. If some roads are busy (now or historically) the best route to take, The location of food,banks, hotels, fuel, airports or other places of interests, the shortest route between the two locations, the different options to drive on highway or back roads.

F. DISASTER RELIEF : Depend upon GPS for location and timing capabilities of earthquake, flood wildfires.

G. FLEET TRACKING : The use of GPS technology to identify, locate and maintain contact reports with one or more fleet vehicles in real time.

5. RS485 interface for Industrial Agriculture Sensors

5.1 Introduction

RS-485 is the most versatile communication standard. The RS-485 standard defines the electrical characteristics of drivers and receivers for use in digital systems. RS-485 signals are used in a wide range of computer and automation systems and are used in programmable logic controllers and on factory floors. Since it is differential, it resists electromagnetic interference from motors and welding equipment. It may be used to control video surveillance systems or to interconnect security control panels and devices such as access control card readers. It does not specify or recommend any communications protocol. In the table the electrical characteristics of the standard are defined.

RS-485

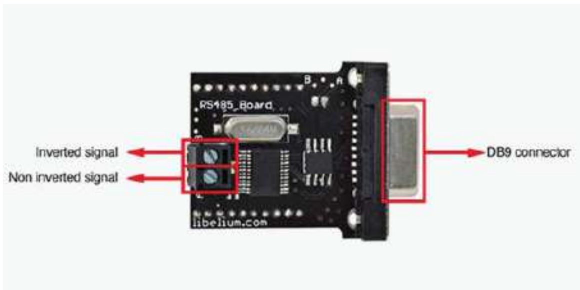
Standard EIA	RS-485
Physical media	Twisted pair
Network topology	Point-to-point, multi-dropped, multi-point
Maximum devices	32 drivers or receivers
Mode of operation	Differential signaling
Voltage levels	-7 V to +12 V
Mark (1)	Positive voltages (B-A > +200 mV)
Space (0)	Negative voltages (B-A < -200 mV)
Available signals	Tx+/Rx+, Tx-/Rx- (Half Duplex), Tx+, Tx-,Rx+,Rx- (Full Duplex)

This RS-485 Sensor Node module can be used in various applications such as intelligent agriculture, environment monitoring, home automation...etc. It is aInternet of things device. This RS-485 Sensor node provides 6 channel analog input and 1 SHT1x Humidity & Temperature digital input. The RS485 protocol supports up to 254 nodes at 1200m distance between each node. This allows a wide range cover for monitoring the environment. A screw free design allows easy connection of cables without sacrifice reliable & stable.

RS-485 standard is used effectively over long distances and in electrically noisy environments. Multiple receivers may be connected to such a network in a linear, multi-drop configuration. These characteristics make such networks useful in industrial environments and similar applications.RS-485 enables the configuration of inexpensive local networks and multidrop communications links. It offers data transmission speeds of 35 Mbit/s up to 10 m and 100 kbit/s at 1200 m.

RS-485 bus is the most popular communication method in industry. Compared with RS-232 bus, it is able to transfer information in further distance with lower cost. Establishing an "Internet of Things" by integrating RS-485 with Ethernet, which is the widely available in the world, in the hope that this method will coordinate all devices with low cost and high efficiency.

Fig 8



Creation of a combine sensor appropriate for the local crops and for agricultural climate monitoring. Concept of portable Agricultural weather stations. Usage of signals from GPS satellites to determine latitude, longitude and altitude to within feet by Location Sensor for precise positioning.

Objectives: At the end of this lesson you shall be able to
- **understanding the sensors used for environment conditions.**
- **understanding the concept of portable agricultural weather stations.**
- **understanding the usage of GPS satellite for precision farming.**

1. Sensors appropriate for local crops and for agricultural climate monitoring

Monitoring environmental conditions is very essential in research field like agriculture. Typical sensors used are

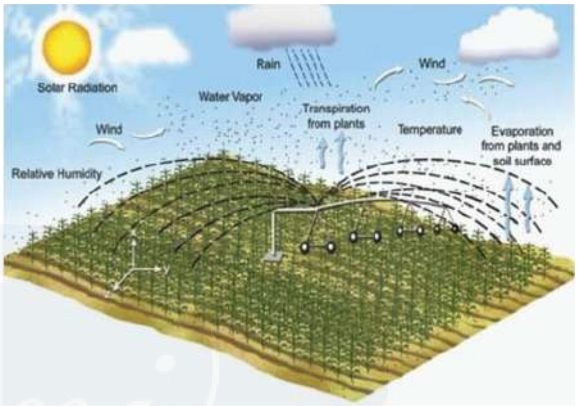
- Wind speed and direction
- Solar radiation
- Temperature (air, water, soil)
- Relative humidity
- Precipitation
- Snow depth
- Barometric pressure
- Soil moisture

2.Concept of Portable Agricultural Weather Stations

2.1 Introduction

An agricultural weather station is an automatic device for specific monitoring of the agricultural environment.Its main function is real-time monitoring of wind, temperature, humidity, pressure, rainfall, radiation, photosynthetic efficiency, soil temperature, soil moisture, soil pH, soil salinity, CO2.

Fig 1



2.2 Wind Measurement

Wind measurement gives advantages and adverse effects in the field. It gives wind measurement parameter values as shown in the table below

Item	Content	Remark
Wind direction	Measuring range 0~360° Accuracy ± 3°	
Wind speed	Measuring range 0~60 m/s Accuracy ÿ± 0,3m/s or ±3%	In the greenhouse agro-meteorological research, ultra-low wind speed standards will be adopted
	Measuring range 0~1m/s or 0~2m/sAccuracy ÿ0.2… 1m/s:±(0.05m/s (10ft/min) +2% of MV)0,2… 2m/s: ±(0.08m/s (16ft/min) +4% of MV)	

2.3 Temperature Measurement

Temperature measurement gives low temperature effect and high temperature hazards and gives parameters as shown in the below table

Item	Content	Remark
Temperature	Measuring range -50-85°CAccuracy ±0.3°C	Monitoring atmospheric temperature and soil temperature

2.4 Water Measurement

Water Measurement gives hypohydration hazards and excessive water hazards and gives parameter values as show in the below table

Item	Content	Remark
Humidity	Measuring range 0-100%Accuracy ±2%	Air Humidity
Soil Moisture	0-50% ±2%50-100% ±3%	
Rainfall	Measuring range: 0-999.9mmResolution: 0.1mmAccuracy: 4%	
Water Level	Measuring Range: 0-30mResolution: 1mmAccuracy: ±2%	

2.5 Solar Radiation Measurement

Solar radiation gives information like

- Photosynthetic effect
- Thermal effect
- Morphological effects of light

Light also affects the geographical distribution of plants to a considerable extent.

Light mainly affects plants from three aspects:

- The length of the light, which is the length of the light.
- Light intensity, the intensity of light.
- Light quality, ie different spectral composition.

Solar Measurement Parameter

Item	Content
Radiation	Measuring range: 0-2000w/ m2Resolution: 1W/m2Accuracy: ±5%

2.6 Soil EC

Soil EC gives parameter values like

Item	Content
Soil EC	Measuring range: 0.00-19.99ms/ cmResolution: 0.01ms/cm Accuracy: EC±2!

And gives influence of CO_2 with parameter value as shown below

Item	Content
CO_2	Measuring range: 0~5000ppm Accuracy: 3!

2.7 Other Information

IT gives information about power in, data communication and system support.

3.Usage of signals from GPS satellites for precision positioning

3.1 Introduction

GPS is a satellite-based navigation system that is able to determine the exact position of objects on the Earth, sky, or space. By increasing the velocity of a moving object, the accuracy of positioning decreases; meanwhile, the calculation of the exact position in the movement by high velocities like airplane movement or very high velocities like satellite movement is so important.

1.2 Process

Global positioning system (GPS) does the positioning with the help of a group of satellites that each travels in its orbit around the Earth. These satellites by sending L1 and L2 signals with frequency of 1575.42 MHz and 1227.6 MHz, respectively, identify their time and place toward the Earth. A GPS receiver by receiving these signals from at least four satellites organizes the navigation equations and by solving them shows the position of the user.

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth.

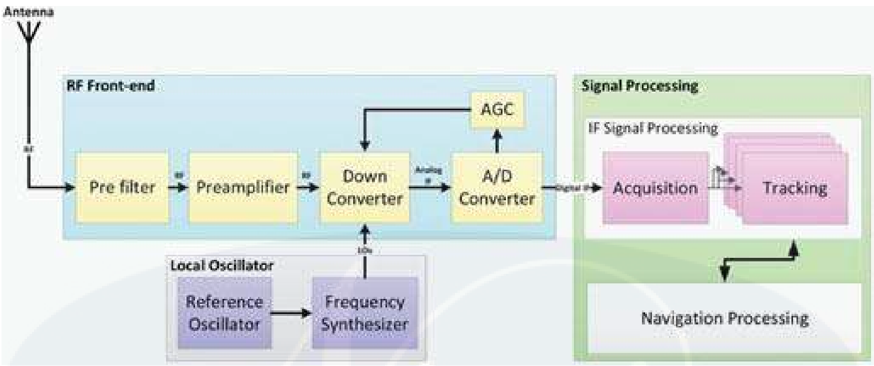
Each satellite continually transmits messages that include the time the message was transmitted and the satellite position at the time of message transmission.The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite using the velocity of light. This measured distance is called pseudorange.

3.3 Architecture

GPS receivers are made up of the antenna, RF front end, local oscillator, and navigation processor. The first element of the receiver architecture is the antenna, which must be able to receive right-hand circularly polarized (RHCP) signals because this is the type of signal transmitted by GPS satellites. Also important is the antenna gain pattern, which indicates how well the antenna performs at various center frequencies, polarizations, and elevation angles. The below diagram shows about GPS high level architecture.

The preamplifier is the first active component that comes after the antenna. It is often housed in the same enclosure as the antenna element. Because the antenna can receive multiple frequency bands, typically, there is one preamplifier per band; nonetheless, a single preamplifier may cover multiple bands. The main function of the preamplifier is to amplify the signal at the antenna's output. Preamplifiers generally have three components: (1) a pre selector filter that removes out-of-band interference and limits the noise bandwidth, (2) burnout protection that prevents possible high-power interference with the electronic components of the receiver, and (3) a low-noise amplifier (LNA). GPS signals are typically very weak, around "160 dBw or 10–6 W; thus, an LNA amplifies the signals by 20 to 35 dB to increase them to levels suitable for processing.

Fig 2

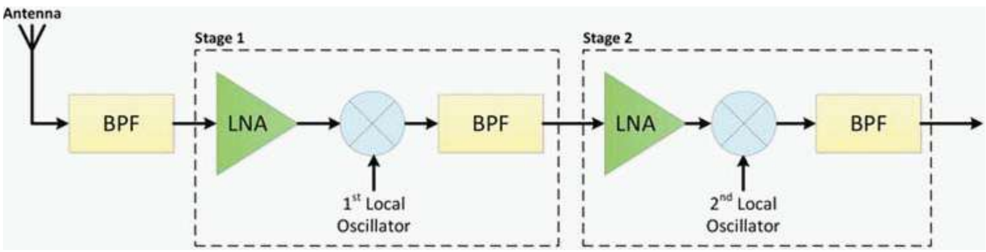


After the antenna and LNA comes the RF front end. This unit generates a clean sampled signal for the signal-processing block. Indeed, the front-end pre-filters amplify, down convert, and digitize the received signal.

Filtering is crucial for several reasons: it rejects out-of-band signals, reduces noise in the received signal, and lessens the impact of aliasing. Wide bandwidth signals can provide high-resolution measurements in the time domain but demand higher sampling rates, causing the receiver to consume much more power. A filter can mitigate this by allowing narrower band signals.

Down-conversion is the process performed by the front end to lower the RF signal frequency to either an intermediate frequency or directly to baseband. This is necessary to facilitate the sampling and filtering processes. The down-conversion is often done using a mixer which multiplies the received signal by a locally generated replica and, then, filters the output signal to remove double-frequency terms, as depicted in below figure. The filtering and down-conversion of the signal frequencies are typically achieved in multiple, consecutive, stages due to the difficulty in implementing a stable band-pass filter with a high central frequency. he last stage in the processing of the signal inside the RF front end is the conversion of the analogue signal to a digital signal. The band-pass sampling completes both discretization and down-conversion of the signal

Fig 3



Identify and select different wireless communication modules and topology to generate record the data

Use of yield monitors - measurement of yield and grain moisture in a field using crop yield measuring device installed on harvesting equipment. Principle of operation & apllication of global positioning system (GPS): satellites broadcasting signals that allow GPS receivers to calculate their position

Objectives: At the end of this lesson you shall be able to

- **to understand the use of yield monitors**
- **to understand of work process of GPS**
- **to analyze various applications using GPS.**

1. Use of Yield Monitors :

1.1 Introduction

Yield Monitoring is an aspect of precision agriculture that helps to provide farmers with adequate information to make educated decisions about their fields.A yield monitor is a recent development in precisionfarming that allows farmers to assess the yield variability in the field during harvesting of crop.

1.2 Materials and methods

Self propelled combine harvester was used to harvestthe rice crop. The yield monitor was developed andinstalled on the combine. The system consisted ofdifferent components like optical sensor, moisture sensor,global positioning system (GPS) receivers to determinecombine location and data acquisition system. The yield was determined as a product of thevarious parameters being sensed.

1.2.1 Grain Yield Sensor

Grain yield was measured by an optical sensor (noncontact type) installed near the top of the clean grainelevator as shown in below Figure 1.The transmitter and receivertogether with lens and lens holders were secured to ahinged mounting bracket which is riveted to the elevatorhousing. Sensor operation was indicated by a lightemitting diode (L.E.D.) on the end of each sensor. Aninfrared (non visible) light beam transmitted across theelevator paddles from one side to the other. A receiver detects the light beam broken or not broken.

Fig 1

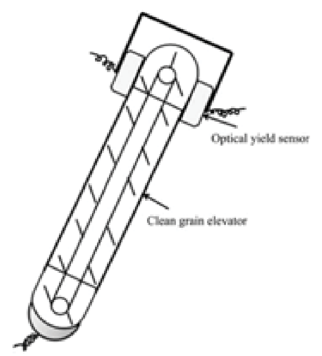


Figure Optical yield sensor mounted on the clean grain elevator

1.2.1Moisture sensor

To obtain an accurate yield, yield and moisture datawere required simultaneously. Moisture sensors wereoften located in the clean grain elevator. The moisturesensor was essentially a conductive shell or a series ofmetal plates with an electrically isolated internal metal fin.As grain rises in the clean grain elevator, a small amountenters the top of the moisture sensor and moves betweenthe metal plates. Moisture content was determined ondielectric property of harvested grain.

1.2.3 Global positioning system

In the sensor based yield monitoring system, GPSutilizes the signal received from different satellitesavailable and feedback control to measure the desiredlocation, and also uses this signal to display the combinespeed.

1.3 Evaluation of yield monitor

1.3.1 Calibration

Widthof cutter bar, offset position (front or behindand left or right from the center line of cutter bar) of GPSand height of GPS from above the ground were insertedfor the existing combine harvester. Baud rate (19200)was set for GPS in the port A of field computer. Thedesired display units were selected for the yield (kg ha-1),work rate (ha h-1), forward speed (km h-1), total area (ha),total weight (t), crop density (kg m-1), distance (m), andspeed of operation (m s-1) and then set in the fieldcomputer.

The tare setting was used to re-zero the yield sensorfor the percentage of time which the beam was broken byclean grain in the grain elevator. For tare setting,combine harvester was placed on level ground. Theclean grain elevator was operated empty, at threshingRPM and the tare value set. Combine was operated infield at maximum forward speed.

1.3.2 Field tests

Yield monitor was installed on the combine harvester,and rice crop was harvested. The combine cutter bar ofwidth of 4 m was put in the initial settings. The fieldtests were performed in fields to fine tune the system andmake sure it was working correctly. Real-time yield andmoisture of grain display in t ha-1 and % (wet basis) weredisplayed on the field computer. The rice yield wasautomatically measured and recorded in the hard drive(USB drive) and a map was created with the help ofsoftware. The performance of the software andhardware of yield monitor was assessed by surveying thethree fields of different sizes. The Arc GIS softwarewas used to process the yield data to estimate the yield atparticular location.

1.3.3 System check up

Before starting the operations, the yield sensor andGPS signal were properly checked. The yield sensorwas checked by operating the combine at normalharvesting RPM with the clean grain elevator empty.The diagnostics screen indicated a frequency for eachsensor currently connected to the system. This valueindicated the number of elevator paddles passing thesensor each second.Operation of the grain or yieldsensor may be verified by observing the LEDs on sensorbody. The green LED was the transmitter elementwhich was visible and the red LED was flashing. Thespeed sensor was checked by driving the machineforward. The forward speed displayed on the fieldcomputer screen corresponded to the actual combineforward speed. A voltage reading indicated that thesensor was functioning.

2.Principle of Operation & Application of GPS :

2.1 Introduction

Global Positioning System or GPS is a Global Navigation Satellite System (GNSS) that provides positioning, navigation, and timing system (PNT).in order to access the GPS services, the user has to be equipped with GPS Receivers like Stand – alone GPS Modules, Mobile Phones that are GPS enabled and dedicated GPS Consoles.With these GPS Receivers, civil users can know standard position, accurate time and speed while the military uses them for precise positioning, missile guidance, navigation, etc.

2.2 Working Principle of GPS

With the help of GPS Receivers, the position of an object can be calculated anywhere on Earth either in two – dimensional or three – dimensional space. For this, GPS receivers use a Mathematical method called Trilateration, a method using which the position of an object can be determined by measuring the distance between the object and few other object with already known positions.So, in case of GPS Receivers, in order to find out the location of the receiver, the receiver module has to know the following two things:

- Location of the Satellites in the space and
- Distance between the Satellites and the GPS Receiver

2.2.1 Determining the Location of the Satellites

In order to determine the location of the satellites, the GPS Receivers makes use of two types of data transmitted by the GPS Satellites: the Almanac Data and the Ephemeris Data.The GPS Satellites continuously transmit its approximate position. This data is called the Almanac data, which is periodically updated as the satellite moves in the orbit. This data is received by the GPS Receiver and stored in its memory. With the help of Almanac data, the GPS Receiver can be able to determine the orbits of the satellites and also where the satellites are supposed to be.

The conditions in the space cannot be predicted and there is a huge chance that the satellites might deviate from their actual path. The Master Control Station (MCS) along with the dedicated Monitor Stations (MS) track the path of the satellites along with other information like altitude, speed, orbit and location.

If there is any error in any of the parameters, the corrected data is sent to the satellites so that they stay in exact position. This orbital data sent by the MCS to satellite is called Ephemeris Data. The satellite, upon receiving this data, corrects its position and also sends this data to the GPS Receiver.

With the help of both the data i.e. Almanac and Ephemeris, the GPS Receiver can be able to know the exact position of the satellites, all the time.

2.2.2 Determining Distance between the Satellites and GPS Receiver

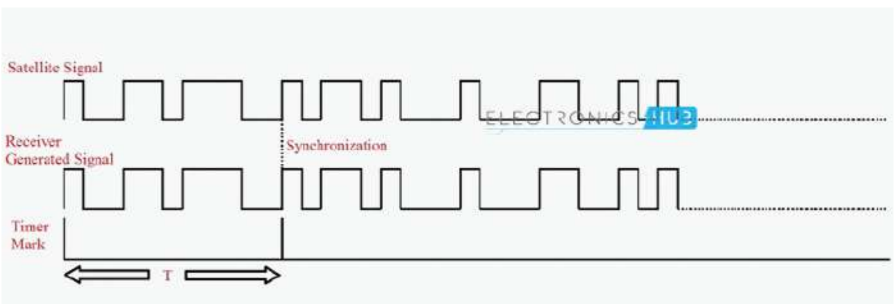
In order to measure the distance between the GPS Receiver and the Satellites, time place a major role. The formula for calculating the distance of the satellite from the GPS Receiver is given below:

Distance = Velocity of Light x Transit Time of the Satellite Signal

Here, the Transit Time is the Time taken by the Satellite Signal (Signal in the form of Radio Waves, sent by the Satellite to GPS Receiver) to reach the Receiver.

The velocity of the light is a constant value and is equal to C = 3 x 108 m/s. In order to calculate the time, first we need to understand the signal sent by the Satellite.

Fig 2



The Transcoded Signal transmitted by the Satellite is called Pseudo Random Noise (PRN). As the satellite generates this code and starts transmitting, the GPS Receiver also starts to generate the same code and tries to synchronize them.

The GPS Receiver then calculates the amount of time delay the Receiver generated code has to undergo before getting synchronised with the satellite transmitted code.

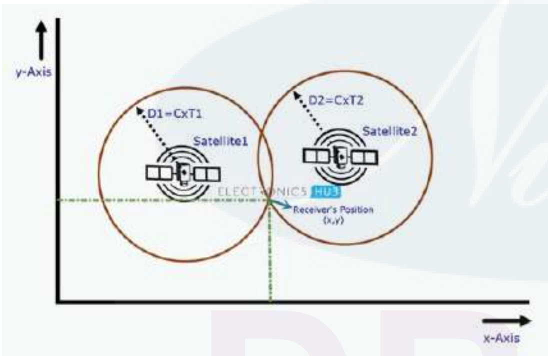
Once the location of the satellites and their distance from the GPS Receiver are known, then finding out the position of the GPS Receiver in either 2D Space or 3D Space can be done using the following method.

2.2.3 Position of Receiver in 2-D Plane

In order to find the position of the object or GPS Receiver in 2 – Dimensional space i.e. an X-Y Plane, all we need to find is the distance between the GPS receiver and two of the satellites. Let D1 and D2 be the distance of the Receiver from Satellite 1 and Satellite 2 respectively.

Now, with the satellites at the center and a radius of D1 and D2, draw two circles around them on an X-Y Plane. The pictorial representation of this case is shown in the following image.

Fig 3



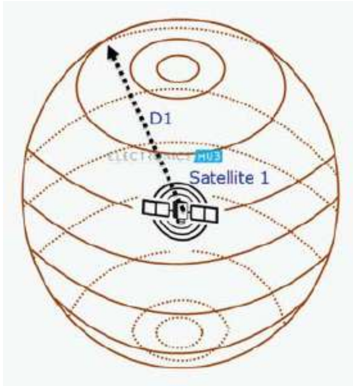
From the above image, it is clear that the GPS Receiver can be located at either of the two points where the two circles intersect. If the area above the satellites is excluded, we can pin point the position of the GPS Receiver at the point of intersection of the circles beneath the satellites.

The distance information from two satellites is sufficient in order to determine the position of the GPS Receiver in a 2-D or X-Y Plane. But the real world is a 3 – Dimensional Space and we need to determine the 3 – Dimensional position of the GPS Receiver i.e. its Latitude, Longitude and Altitude. We will see a step – by – step procedure to determine the 3 Dimensional location of the GPS Receiver.

2.2.4 Position of the Receiver in 3D Space

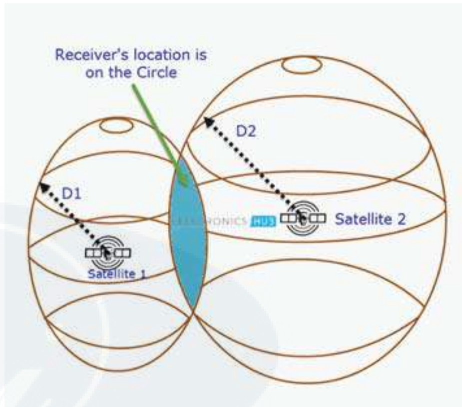
Let us assume that the locations of the satellites with respect to the GPS Receiver are already known. If Satellite 1 is at a distance of D1 from the Receiver, then it is clear that the position of the receiver can be anywhere of the surface of the sphere that is formed with satellite 1 as center and D1 as its radius.

Fig 4



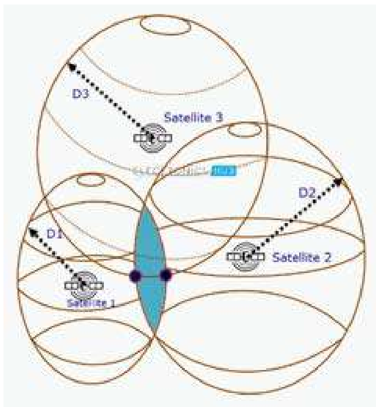
If the distance of a second satellite (Satellite 2) from the receiver is D2, then the position of the receiver can be limited to the circle formed by the intersection of two spheres with radii D1 and D2 with Satellites

Fig 5



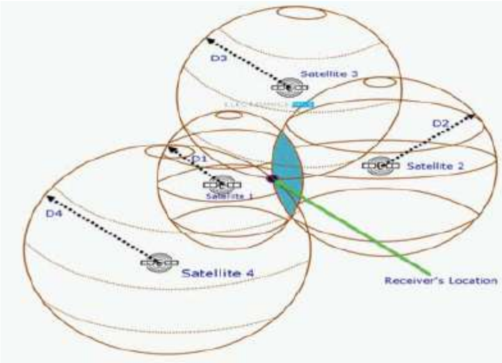
1 and 2 at the centres respectively. From this image, the position of the GPS Receiver can be narrowed down to a point on the circle of intersection. If we add a third satellite (Satellite 3) with a distance D3 from the GPS Receiver to the existing two satellites, then the location of the receiver is confined to the intersection of the three spheres i.e. either of the two points.

Fig 6



In real time situations, having the ambiguity of GPS Receiver located at one out of the two positions is not viable. This can be resolved by introducing a fourth satellite (Satellite 4) with a distance D4 from the receiver.

Fig 7



The fourth satellite will be able to pin point the location of the GPS Receiver from the possible two locations which were determined earlier with only three satellites. Hence, in real time, a minimum of 4 satellites are required to determine the exact location of the object.Practically, the GPS System works such that at least 6 satellites are always visible to an object (GPS Receiver) located anywhere on Earth.

2.3 Types of GPS Receivers

The GPS is utilized by both civilians and military. Hence, the types of GPS receiver can be classified in to Civilian GPS Receivers and Military GPS Receivers. But the standard way of classification is based on the type of code that the receiver can be able to detect.Basically, there are two types of codes that a GPS Satellite transmits: Coarse Acquisition Code (C/A Code) and P – Code. The consumer GPS Receiver units can detect only C/A Code. This code is not accurate and hence the civilian positioning system is called Standard Positioning Service (SPS).

The P – Code, on the other hand is used by the Military and is a highly accurate code. The positioning system used by the military is called Precise Positioning Service (PPS). The GPS Receivers can be classified based on the ability to decode these signals.

Another way to classify commercially available GPS receivers is based on the capability of receiving signals. Using this method, GPS Receivers can be divided into:

· Single – Frequency Code Receivers

· Single – Frequency Carrier – Smoothed Code Receivers

· Single – Frequency Code & Carrier Receivers

· Dual – Frequency Receivers

2.4 Applications of Global Positioning System (GPS)

GPS has become an essential part of the Global Infrastructure, similar to the Internet. GPS has been the key element in the development of a wide range of application spreading across different aspects of modern life. Increase of large scale manufacturing and miniaturisation of components has reduced the price of GPS Receivers. A small list of applications where GPS plays an important role is mentioned below.

· Modern agriculture has seen a boost in production with the help of GPS. Farmers are using GPS Technology along with modern electronic devices to get precise information about field area, average yield, fuel consumption, distance covered, etc.

· In the field of automobiles, automated guided vehicles are the most often used in the industrial or consumer applications. GPS enables these vehicles in navigation and positioning.

· Civilians use GPS Receivers for navigation purpose. The GPS receiver can be a dedicated module or an embedded module in mobile phones and wrist watches. They are very helpful in trekking, road trips, driving, etc. Additional features include accurate time and speed of the vehicle.

· Emergency services like fire and ambulance benefit from the accurate positioning of the disaster location by GPS and can be able to respond on time.

· Military uses high precision GPS receivers for navigation, target tracking, missile guidance systems, etc.

There are numerous other applications where GPS is being used or a huge scope of use in the future.

Working principle & use of GIS consisting of a computer software database system used to input, store, retrieve, analyze and display in map like form, spatially referenced geographical information for more detailed analysis of the fields. Data integration through a geographical information system.

Objectives: At the end of this lesson you shall be able to
- **understand the concept of GIS**
- **analyzing the data integration through a GIS.**

1.Geographical Information Systems

1.1 Introduction

Geography is the study of Earth's features and patterns of their variations in spatial location and time. Many questions of agricultural production are geographic in nature as the production depends on the environment and prevailing socio economic conditions, both of which vary spatially and in time. Examples are questions related to natural resources management, precision agriculture, agroecological classification for land use planning, regional trends and patterns in technology adaptation, agricultural productivity and income, non-point source pollution from agricultural lands, etc. Answering these questions requires access to large volumes of multidimensional geographical (spatial) information of weather, soils, topography, water resources, socio economic status, etc. Further, answers to even apparently simple questions require that the data from several sources be integrated in a consistent form. Geographical Information Systems or GIS enable representation and integration of such spatial information. The traditional method of presenting geographical information in two dimensions is in the form of maps. Maps are graphic representations of the earth's surface on a plane paper They shape the way we visualize, assess and analyze spatial information. A map consists of points, lines and area elements that are positioned with reference to a common coordinate system (usually latitude and longitude).. They are drawn to specified scales and projection. Map scales can vary and depend on the purpose for which the maps are created. Projection is a mathematical transformation used to represent the real 3-dimensional spherical surface of the earth in 2-dimensions on a plane sheet of paper. The map legend links the non-spatial attributes (name, symbols, colours, thematic data) to the spatial data. The map itself serves to store and present data to the user. Such, analogue maps (on paper) are cumbersome to produce and use, particularly when there are a large number of them to be used for analysis. Computer based GIS facilitates both creation of maps and using them for various complex analyses. It allows working with geographic data in a digital format to aid decision making in resources management GIS is a generic term implying the use of computers to create and display digital maps. The attribute data which describe the various features presented in maps may relate to physical, chemical, biological, environmental, social, economic or other earth surface properties. GIS allows mapping, modelling, querying, analyzing and displaying large quantities of such diverse data, all held together within a single database. Its power and appeal stem from its ability to integrate quantities of information about the environment and the wide repertoire of tools it provides to explore the diverse data. The history of development of GIS parallels the history of developments in digital computers and database management systems on one hand and those in cartography and automation of map production on the other. The development of GIS has also relied upon innovations made in several other disciplines – geography, photogrammetry, remote sensing, civil engineering, statistics, etc.

A GIS produces maps and reads maps. Its major advantage is that it permits identifying spatial relationships between specific different map features. It can create maps in different scales, projections and colours. But it is not just a map making tool. It is primarily an analytical tool that provides new ways of looking at, linking and analyzing data by projecting tabular data into maps and integrating data from different, diverse sources. This it does by allowing creation of a set of maps, each with a different theme (soils, rainfall, temperature, relief, water sources, etc.). From its early beginnings, GIS has been an integrating technology both from the point of view of its development as well as its use. This is because, once geographic information of any kind is translated into the digital form in a GIS, it becomes easy to copy, edit, analyze, manipulate and transmit it. This allows vital linkages to be made between apparently unrelated activities based on a common geographic location. This has led to fundamental changes in the way resource management decisions are made in a variety of situations - forest management, marketing management, utility management, transportation, as well as in agricultural, environmental and regional planning and management. Some potential agricultural applications where GIS can lead to better management decisions are: precision farming, land use planning, watershed management, pest and disease management, irrigation management, resources inventory and mapping, crop area assessment and yield forecasting, biodiversity assessment, genetic resources management, etc.

1.2 Definition of GIS :

A GIS is basically a computerized information system like any other database, but with an important difference: all information in GIS must be linked to a geographic (spatial)reference (latitude/longitude, or other spatial coordinates).

1.3 What A GIS Can Do

There are five basic questions which a complete GIS must answer. These are:

a.What exists at a particular location? Given a geographic reference (eglat,long) for a location, the GIS must describe the features of that location

b.Where can specific features be found? This is the converse of the first question. For example, where are the districts with rainfall greater than 500 mm and less than less than 750 mm?

c.Trends or What has changed over time? This involves answering both questions above. For example, at what locations are the crop yields showing declining trends?

d.What spatial patterns exist? if occurrence of a pest is associated with a hypothesized set of conditions of temperature, precipitation, humidity, where do those conditions exist?

e.Modelling or What if ...? This is a higher level application of GIS and answers questions like what would be the nitrate distribution in groundwater over the area if fertilizer use is doubled?

1.4 Geographic Referencing Concepts

A GIS is to be created from available maps of different thematic layers (soils, land use, temperature, etc). The maps are in two-dimensions whereas the earth's surface is a 3-dimensional ellipsoid. Every map has a projection and scale. To understand how maps are created by projecting the 3-d earth's surface into a 2-d plane of an analogue map, we need to understand the georeferencing concepts. Georefencing involves 2 stages: specifying the 3-dimensional coordinate system that is used for locating points on the earth's surface that is, the Geographic Coordinate System (GCS) and the Projected Coordinate System that is used for projecting into two dimensions for creating analogue maps.

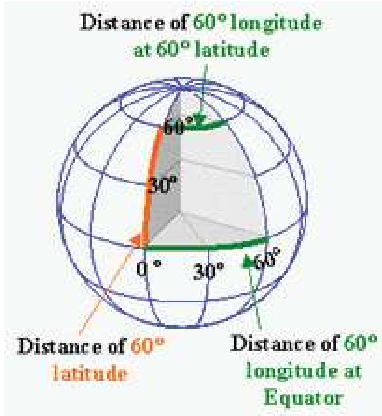
1.4.1 Geographic Coordinate System

The traditional way of representing locations on the surface of the earth is in the 3-dimensional coordinate system is by its latitude and longitude.

Source: ESRI

Note that the distance between two points on the 3-d earth's surface varies with latitude. The 3-d system therefore does not provide a consistent measure of distances and areas at all latitudes. The true surface of the Earth is not the smooth ellipsoid shown in the figure but is quiet uneven and rugged. The GCS which is the surface used for specifying the latitude and 5longitude of a point on the earth's surface is also an approximation and a 3-d model of the earth. Several standard models of the ellipsoid are available to define the GCS (WGS 84, Everest ellipsoid) etc. The different models vary in their critical parameters (semi major or equatorial axis and semi minor or polar axis of the ellipsoid and the point of origin). The ellipsoid model that is used to calculate latitude and longitude is called the datum. Changing the datum, therefore, changes the values of the latitude and longitude.

Fig 1



Specifying the Geographic Coordinate System therefore requires specifying the Datum. The datum is a fixed 3-d ellipsoid that is approximately the size and shape of the surface of the earth, based on which the geographic coordinates (latitude and longitude) of a point on the Earth's surface are calculated. In fact describing a place by its lat/long is not complete without specifying its datum. In India the Everest Ellipsoid is used as the Datum for the Survey of India maps.

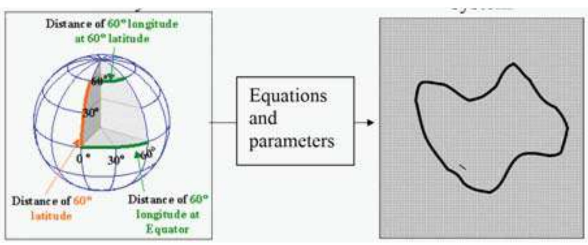
The ideal solution to would be a spheroidal model of the Earth that has both the correct equatorial and polar radii, and is centered at the actual center of the Earth. One would then have a spheroid, that when used as a datum, would accurately map the entire Earth. All lat/longs on all maps would agree. That spheroid, derived from satellite measurements of the Earth, is GRS80, and the WGS84. datum matches this spheroid.

1.4.2 Projected Coordinate System

The development of GIS starts with an available map on paper (an analogue map). This map therefore represents a projection of a 3-d GCS in 2-dimensional form.

Geographic coordinate System
Projected coordinated system

Fig 2

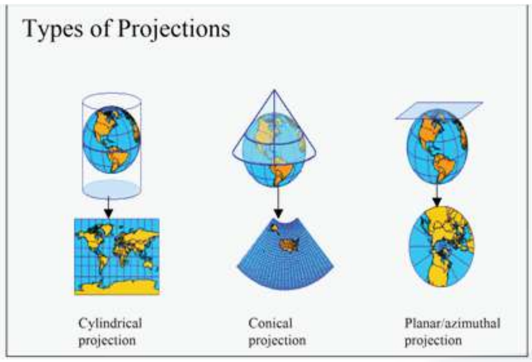


Projection is a mathematical transformation used to project the real 3-dimensional spherical surface of the earth in 2-dimensions on a plane sheet of paper. The projection causes distortions in one or more spatial properties (area, shape, distance, or direction).

There are many methods of map projections, since there are an infinite number of ways to project the 3-dimensional earth's surface on to a 2-dimensional planar surface. The 3-d to 2-d projections can be done to a plane or to the surface of a cone or cylinder leading to azimuthal, , conic or cylindrical projections respectively with many variations.

1.4.3 Types of Projections

Fig 3



Depending on the scale and the agreeable tradeoffs with respect to distortions, a specific projection form is chosen. Different countries have adopted different standard projections at different map scales. In India, the polyconic projection is commonly used by Survey of India (SOI). All SOI toposheets are in the polyconic projection.

1.4.2 Map Scale

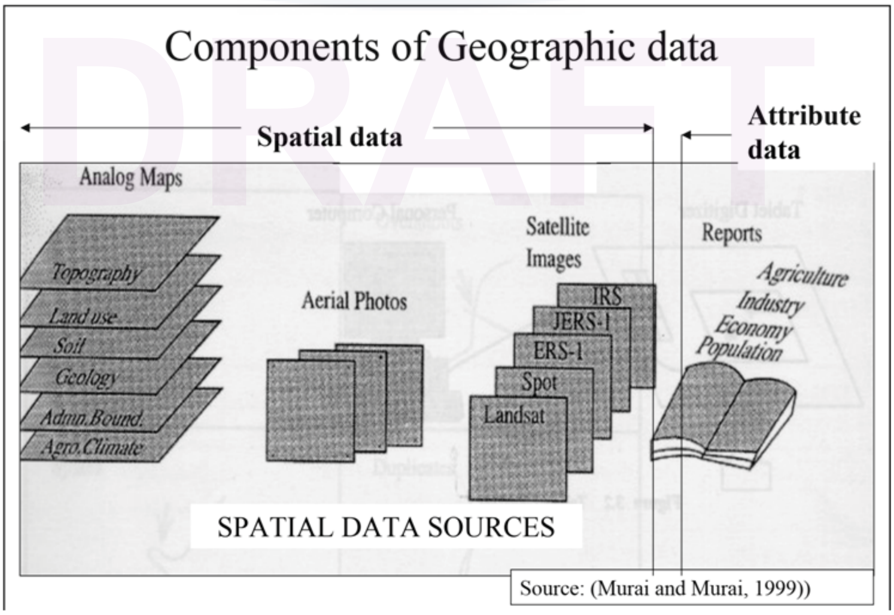
Map Scale is the ratio of distances on map to distances to on the surface of the earth. It is specified in verbal, numeric or graphical form on all standard maps. A graphical scale should be present on all maps that are used in GIS as it ensures that any changes in scale in photocopying, etc. are accounted for. The standard map scales are: 1:1000,000 Country level or State level 1: 250, 000 State or District level 1: 50,000 District level 1: 12,500 Micro level Survey of India maps are available at all the above levels except the micro-level. 8

1.5 Creating a GIS

Like for any other Information System , creating a GIS involves 4 stages: (i) Data input (ii) Data Storage (iii) Data Analysis and modelling, and (iv) Data Output and presentation The distinction from other Information Systems is that for a GIS the data inputs are of two types: (i) Spatial data (latitude/longitude for georeferencing,the features on a map, eg soil units, administrative districts), and (ii) Attribute data (descriptive data about the features, eg soil properties, population of districts, etc.)

Spatial data sources for creating a GIS are analogue maps (soil map, land use map, administrative districts, map, agroecological zone map, etc.) or aerial photographs and satellite imageries. Data input is the process of encoding analogue data in the form of maps, imageries or photographs into computer readable digitized form and writing data into the GIS database.

Fig 4



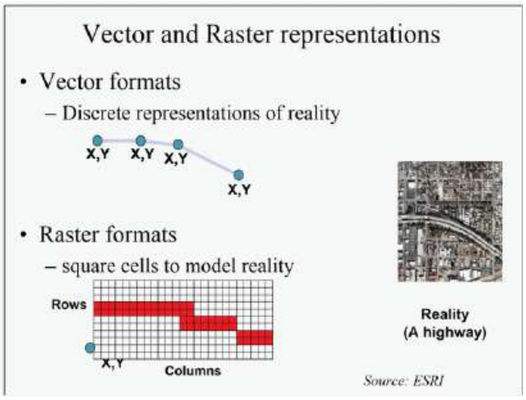
1.5.1 GIS Data Input :

Spatial Data (representing locations in a database) can be in two basic formats:

(i) Vector format (ii) Raster format

In the Vector format reality is represented as points lines and areas and in the raster format reality is represented as grid of cells/pixels. The Vector format is based on discrete objects view of reality (analogue maps) and the raster format is based on continuous fields view of reality (photographs, imageries, etc. In principle, any real world situation can be represented in digital form in both raster and vector formats. The choice is up to the user. Each format has its advantages and disadvantages

Fig 5



2. Data Integration through a Geographic Information System

2.1Introduction

The well-worn argument that geo-information is a pre-requisite for development. Most map makers absolve themselves from responsibility for the poor state of mapping with their territory. As the mapping will take several years to complete, it is clear that the National Survey and Mapping organization has to take initiatives to supply upto date geo- information for the users on their various requirements and expectations. The integration of satellite data into a Geographic Information System (GIS) is one of the great idea that focus on the rapid acceptance of GIS technology in to the geo-information oriented applications in operational environments. Institutionalizing of the GIS and Remote Sensing process into everyday decision making has greater efficiency to overcome the problems identified in mapping at a National Mapping agency.

2.2Integration of Remote Sensing with GIS

The volume of Remote Sensing is so large, its associated powerful image processing technology is used to manage geo-information with preprocessing analysis, accuracy assessment and information distribution.

GIS are more and more being used for the storage and analysis of geo- referenced data and also it handles the linkages between spatial entities and their discrete attributes. GIS system have become accepted as a standard way of handling geographic data and performing analysis on those data for a number of earth related disciplines.

With the availability of high resolution satellite data and its processing technologies. integration of digital image analyzing systems with advance GIS systems permit compositing data sources as well as promoting a partnership between man and machine. Furthermore. a GIS when combine with upto date remote sensing data could assist in the automated interpretation, change detection and map revision processes.

Technical Impediments to Integration Geographic phenomena do not occur with a specific data structure. Obviously certain types of objects are well represented in a raster data structure (eg.. elevation. soil type) while others more appropriately represented as vectors. However, the full potential of integrate GIS with remote sensing will not be realized unless we overcome the dichotomy of data structures for GIS and remote sensing (Ehlers, 1991) .Data accuracy and system communications are other major issues that discussed under problems related in integration.

2.3Data Structures

The major problem is caused by the different in the data structures used to acquire and store data.Remote Sensing detectors produce raster digital information directly then the raster processing of these data seems natural.GIS systems typically used the vector data structure. In a model of geo-information extraction from raster imagery, at lower level processed raster data can be used to extract and manipulate at “..””,,-, pattern recognition in middle level. At the highest level with the knowledge based information creates the models for the predictive description of the “imaged” object. Hence at the middle and the highest level the image information can be stored as vectors or objects than gray values.Additionallythe data structures that used for computer vision, quad trees and other tessellation are also possible data structures to manipulate remote sensing data. Presently, the common used approach dealing with this problem is data conversion eventhough the raster to vector conversion leads to a loss of accuracy of information.

2.4 Data Accuracy

The classification accuracy, mapping accuracy and spatial resolution are main data accuracy problem which have to considered when integrating Remote Sensing data with GIS. The problem of classification accuracy present a major difficulty in the integration. Researchers has been suggested to improve Remote Sensing image classification accuracy by referencing the information already available in GIS’s.

A data processing system must assess levels of data accuracy and associate the level with the data it provides. Based on the assessment a user can understand how reliable the data are and determine how being to use them. Different methods are used in Remote Sensing and GIS’s for data accuracy assessment. The method are incompatible with each other. Remote Sensing data analyzing mainly uses the error matrix method which provide global accuracy information while GIS operators use error model which provide more local accuracy information. But up to now no effective approach has been reported which facilitate the flow of accuracy information between Remote Sensing image analysis system and GIS’s.

2.5 System Communication

In the communication between Remote Sensing system and GIS, spatial and non spatial data must be transferred in an integration fashion. Facilitating the communication have been mainly made on query/reasoning languages and communication procedures. This method developed usually include the steps of language conversion, query optimization and data translation. Even so mismatch is unavoidable and the communication is still expensive.

Use of computer hardward and software to analyze the data collected by yield monitor and GPS and supply it by yield monitor and GPS and supply it to user in usable format - such as maps, graphs, charts or reports. Application of precision irrigation through watermanagement precision agriculture. Identification of zones in the field that are irrigated with differing amounts and frequencies in precision irrigation

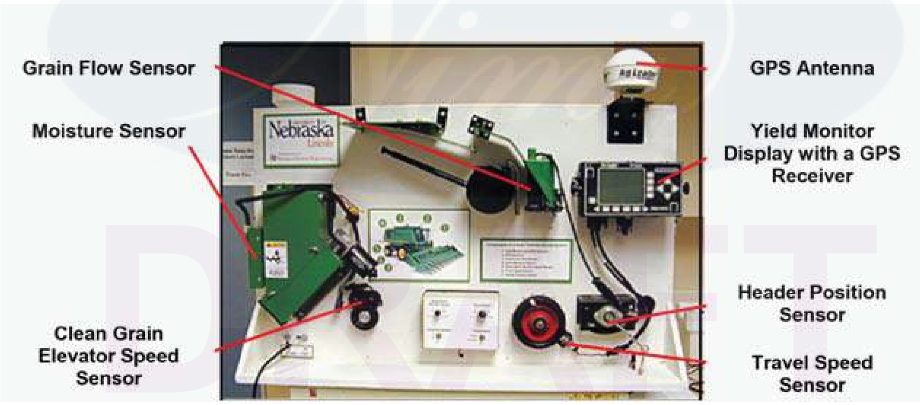
Objectives: At the end of this lesson you shall be able to
- **To represent the data extracted from yield monitor in graphical format.**
- **Analyzing the various applications through water management in precision agriculture**
- **To identify zones in precision irrigation.**

1. Analysing the data collected by yield monitor and GPS and Yield mapping

1.1 Introduction of Yield Mapping

Yield mapping refers to the process of collecting georeferenced data on crop yield and characteristics—such as moisture content—while the crop is being harvested. Various methods, using a range of sensors, have been developed for mapping the yield of a variety of crops from small grains to fruits and vegetables. Creating a yield map is one of the primarily tasks of precision agriculture., There are many GIS applications similar to yield mapping in which users enter measurements done throughout the area of investigation and color the markers for each measurement according to the value obtained. The basic components of a grain yield mapping system are shown here.

Fig 1



The amount of grain harvested by the combine in a unit of time is usually determined with a grainflow sensor mounted at the exit of the clean grain elevator.A moisture sensor is used to compensate for grain moisture variability.A yield monitor display and a Global Positioning System (GPS) receiver are used togeoreference and record data.A header position sensor is used to remove measurements logged during turns.A travel speed sensor determines the distance the combine travels during a certain logginginterval. (In most cases, travel speed is measured with a GPS receiver, or, less often, a radar orultrasonic sensor.)Finally, the speed of the clean grain elevator speed sensor is used by some yield mappingsystems to improve the accuracy of grain flow measurements.Each sensor has to be properly calibrated according to the operator's manual for best results.Calibration converts the sensor's signal to an actual readout. During harvest, a proprietary binarylog file is created, recording the output of all sensors as a function of time.To get ready for yield data analysis you convert the log files from proprietary binary code to anASCII text with columns corresponding to geographic latitude, longitude, yield and other relevantattributes.

1.2Yield Monitoring Data Analysis

Even though yield monitor manufacturers normally sell computer software to help analyze yielddata, growers may want to conduct their own analyses using commonly available data management software and geographic information system (GIS) software programs. Being able to export your data into useful files is important in analyzing yield data in data management software. Choose a yield monitor capable of exporting data in .txt (text) format because this format is compatible with most database spreadsheets and GIS software programs.A number of yield monitor data errors are associated with normal yield data collection. Here are some examples:

- The yield monitor may not shut off at the field end and will register "0" data until harvestable crop again moves into the combine.
- The combine grain-flow system may plug temporarily, especially if the crop has lodged or weeds interfere with continuous grain flow.
- A lag can occur between the time the crop is cut and the time its yield is measured in the grain flow.

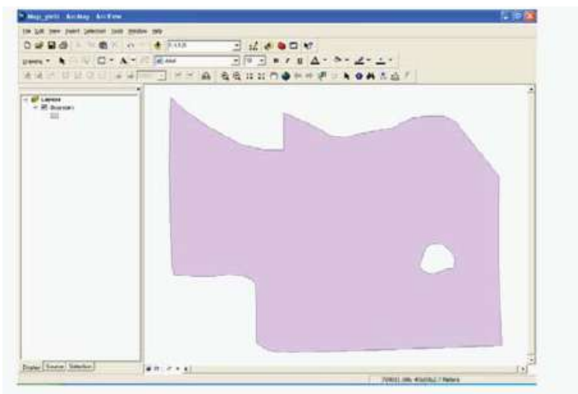
These anomalies must be deleted from the dataset if you want to construct meaningful maps that represent the true spatial yield values in the field. In some fields, a 0 yield is not possible, and the farmer would know this if grain was within all the borders of the field. However, in some years, high rainfall might result in 0 yield in depressions, and noting that to the yield monitor cleaner will be important. Also, high soil salt areas that have 0 areas are very common in North Dakota. Being able to map real 0 yield is important, but remember to delete those data that are errors.High yields also should be deleted. In a wheat harvest, for example, yield in a field averaging 80 bushels per acre might achieve 150 bushels per acre in a particularly perfect area of the field, but a yield of 250 bushels per acre is not real and should be deleted. Choosing a limit for allowable high yield is as important for realistic field mapping as deletion of false 0 yield.If a farmer only has to clean a few fields, using a spreadsheet such as Microsoft Excel is possible. Sort yields from low to high, and choose a low yield that is appropriate for the field and a high yield that is reasonably attainable, then delete all data outside of those high and low parameters.

1.3 Yield Mapping

Step 1 : 1. Start ArcMap and add Boundary.shp

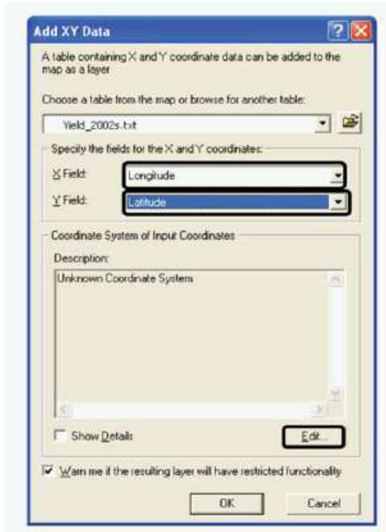
Fig 2

Fig 3



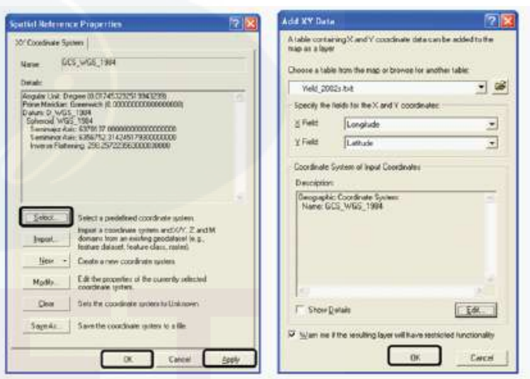
Step 2 : Now you need to add the yield data which is in txt format. Add the yield data into ArcMap using the Tool> Add XY data. X field should show the longitude and Y field should show the latitude.

Fig 4



Step 3 : Now click the Edit button as shown here, to specify a coordinate system for the yield data.

Fig 5

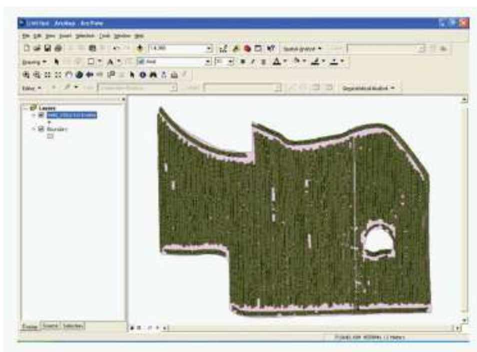


Choose Select as shown here and navigate to Geographic Coordinate system > World >

WGS84.prj. Click Apply and OK when done.

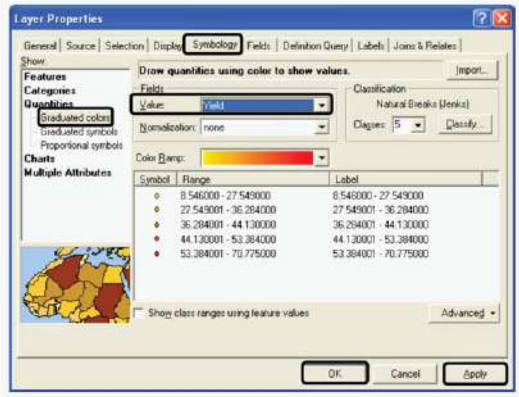
Step 4 : Click OK to the warning message. Your XY event data should look like this.

Fig 6



Step 5: Change the symbology of the yield events layer. Right click the yield_2002s.txt Events to get layer properties. Click the Symbology tab. Choose Quantities> Graduated Colors.

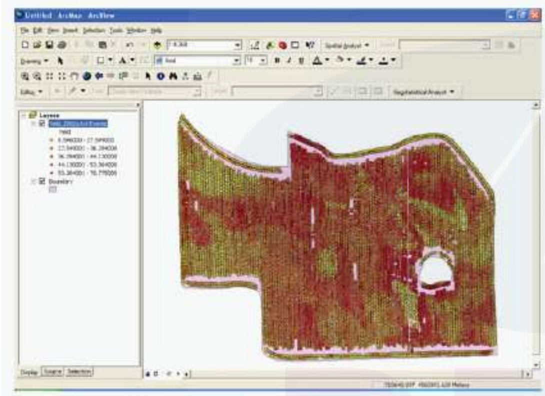
Fig 7



Select Yield as value field. Click Apply and OK.

Step 6 : Your map should look like this. Looking at the map, you'll see it's now easy to find the areas with maximum yield and minimum yield. Save your map.

Fig 8



2. Application of Water Management in precision agriculture

1.1 Introduction

Drip irrigation is an efficient method of providing irrigation water directly into soil at the root zone of plants and thus, minimizes conventional losses such as deep percolation, runoff and soil erosion. Unlike surface irrigation, drip irrigation is more suitable and economical if it is introduced in water scarce areas having undulated topography, shallow and sandy soils and for wide spaced high value crops. It also permits the utilization of fertilizers, pesticides and other water-soluble chemicals along with irrigation water resulting in higher yields and better quality produce.

1.2 Drip Irrigation Applications

Drip irrigation is a technology widely used in agriculture, landscape, greenhouses, and nurseries toapply water directly where it is needed. Drip irrigation minimizes the use of water and enables the injection of fertilizers through the drip irrigation system while at the same time growing healthier plants that have less disease.

Drip irrigation systems can be used on a wide variety of plants, including:

- Low-growing crops, such as: bell peppers, lettuce, beans, and squash;
- Grape vines, olive trees, and orchards on irregular landscapes;
- Fruits, including: blackberries, strawberries, and blueberries;
- Staple crops, such as cotton;
- Crops that grow just below the surface in the soil, such as: potatoes, onions, and carrots.

2. Zone identification in precision irrigation

3.1 Introduction

Precision irrigation is a farming management system based on the use of modern technologies at every stage of work. Usually, a field has heterogeneous zones, and technologies allow to identify such zones and manage this variability. As a result, farmers use seeds, fertilizers, and pesticides more efficiently; this also helps to increase harvest. Intuition and luck mean less and less as technology steps in and allows you to make decisions that are based on data.

3.2 Technologies applied to identify zones

Onboard computers and GPS-navigators for vehicles that help to avoid overlaps and underlaps when applying seeds, fertilizers, and pesticides. Digital maps of fields based on variable characteristics. Variable rate applications that calculate fertilizer dosage for each individual zone. Drones and satellites help to monitor the field remotely. Wireless weather sensors along with other sensors help to determine temperature, moisture, pressure, and dozens of other field indicators. Computers, smartphones, and applications help to analyze information, maintain documentation and manage the farm efficiently.

Basic blocks of networking: Specifications, standards and types of cables of wired and wireless communication media, different types of networks, design and establish networks

Objectives: At the end of this lesson you shall be able to
- **to understand networj cabe types and specifications**
- **to establish a network setup**
- **to setup a network using wired or wireless communication medium.**

1. Basic Blocks of Networking

A network connects computers, mobile phones, peripherals, and even IoT devices. Switches, routers, and wireless access points are the essential networking basics.

1.1 Network Cable Types and Specifications

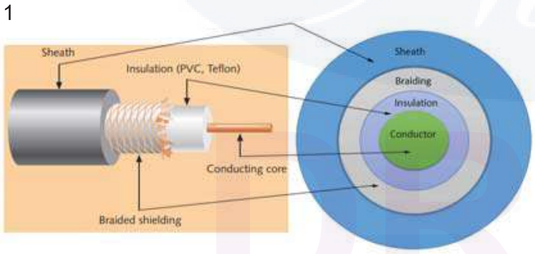
To connect two or more computers or networking devices in a network, network cables are used. There are three types of network cables; coaxial, twisted-pair, and fiber-optic.

1.1.1 Coaxial cable

This cable contains a conductor, insulator, braiding, and sheath. The sheath covers the braiding, braiding covers the insulation, and the insulation covers the conductor.

The following image shows these components.

Fig 1



Sheath

This is the outer layer of the coaxial cable. It protects the cable from physical damage.

Braided shield

This shield protects signals from external interference and noise. This shield is built from the same metal that is used to build the core.

Insulation

Insulation protects the core. It also keeps the core separate from the braided-shield. Since both the core and the braided-shield use the same metal, without this layer, they will touch each other and create a short-circuit in the wire.

Conductor

The conductor carries electromagnetic signals. Based on conductor a coaxial cable can be categorized into two types; single-core coaxial cable and multi-core coaxial cable.

A single-core coaxial cable uses a single central metal (usually copper) conductor, while a multi-core coaxial cable uses multiple thin strands of metal wires. The following image shows both types of cable.

Fig 2

The coaxial cables were not primarily developed for the computer network. These cables were developed for general purposes. They were in use even before computer networks came into existence. They are still used even their use in computer networks has been completely discontinued.

At the beginning of computer networking, when there were no dedicated media cables available for computer networks, network administrators began using coaxial cables to build computer networks.

Because of low-cost and long durability, coaxial cables were used in computer networking for nearly two decades (80s and 90s). Coaxial cables are no longer used to build any type of computer network.

Specifications of coaxial cables

Coaxial cables have been in use for the last four decades. During these years, based on several factors such as the thickness of the sheath, the metal of the conductor, and the material used in insulation, hundreds of specifications have been created to specify the characteristics of coaxial cables.

From these specifications, only a few were used in computer networks. The following table lists them.

Type	Ohms	AWG	Conductor	Description
RG-6	75	18	Solid copper	Used in cable network to provide cable Internet service and cable TV over long distances.
RG-8	50	10	Solid copper	Used in the earliest computer networks. This cable was used as the backbone-cable in the bus topology. In Ethernet standards, this cable is documented as the 10base5 Thicknet cable.
RG-58	50	24	Several thin strands of copper	This cable is thinner, easier to handle and install than the RG-8 cable. This cable was used to connect a system with the backbone-cable. In Ethernet standards, this cable is documented as the 10base2 Thinnet cable.
RG-59	75	20 - 22	Solid copper	Used in cable networks to provide short-distance service.

- Coaxial cable uses RG rating to measure the materials used in shielding and conducting cores.
- RG stands for the Radio Guide. Coaxial cable mainly uses radio frequencies in transmission.
- Impedance is the resistance that controls the signals. It is expressed in the ohms.
- AWG stands for American Wire Gauge. It is used to measure the size of the core. The larger the AWG size, the smaller the diameter of the core wire.

1.1.2 Twisted-pair cables

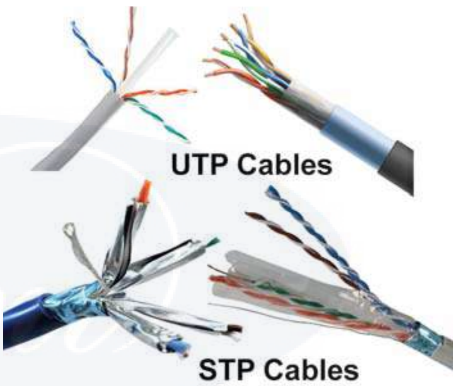
The twisted-pair cable was primarily developed for computer networks. This cable is also known as Ethernet cable. Almost all modern LAN computer networks use this cable. This cable consists of color-coded pairs of insulated copper wires. Every two wires are twisted around each other to form pair. Usually, there are four pairs. Each pair has one solid color and one stripped color wire. Solid colors are blue, brown, green and orange. In stripped color, the solid color is mixed with the white color.

Based on how pairs are stripped in the plastic sheath, there are two types of twisted-pair cable; UTP and STP.

In the UTP (*Unshielded twisted-pair*) cable, all pairs are wrapped in a single plastic sheath.

In the STP (*Shielded twisted-pair*) cable, each pair is wrapped with an additional metal shield, then all pairs are wrapped in a single outer plastic sheath

Fig 3



The TIA/EIA specifies standards for the twisted-pair cable. The TIA/EIA 568 divides the twisted-pair cable into several categories. The following table lists the most common and popular categories of the twisted-pair cable.

Category / name of the cable	Maximum supported speed	Bandwidth/support signals rate	Ethernet standard	Description
Cat 1	1Mbps	1MHz	Not used for data	This cable contains only two pairs (4 wires). This cable was used in the telephone network for voice transmission.
Cat 2	4Mbps	10MHz	Token Ring	This cable and all further cables have a minimum of 8 wires (4 pairs). This cable was used in the token-ring network.
Cat 3	10Mbps	16MHz	10BASE-T Ethernet	This is the first Ethernet cable that was used in LAN networks.
Cat 4	20Mbps	20MHz	Token Ring	This cable was used in advanced Token-ring networks.
Cat 5	100Mbps	100MHz	100BASE-T Ethernet	This cable was used in advanced (fast) LAN networks.

Cat 5e	1000Mbps	100MHz	1000BASE-T Ethernet	This cable/category is the minimum requirement for all modern LAN networks.
Cat 6	10Gbps	250MHz	10GBASE-T Ethernet	This cable uses a plastic core to prevent cross-talk between twisted-pair. It also uses a fire-resistant plastic sheath.
Cat 6a	10Gbps	500MHz	10GBASE-T Ethernet	This cable reduces attenuation and cross-talk. This cable also potentially removes the length limit. This is the recommended cable for all modern Ethernet LAN networks.
Cat 7	10Gbps	600MHz	Not drafted yet	This cable sets a base for further development. This cable uses multiple twisted-pairs and shields each pair by its own plastic sheath.

- Cat 1, 2, 3, 4, 5 are outdated and not used in any modern LAN network.
- Cat 7 is still a new technology and not commonly used.
- Cat 5e, 6, 6a are the commonly used twisted-pair cables.

1.1.3 Fiber optic cable

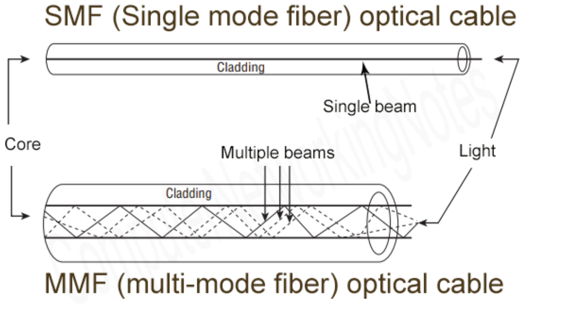
This cable consists of core, cladding, buffer, and jacket. The core is made from the thin strands of glass or plastic that can carry data over the long distance. The core is wrapped in the cladding; the cladding is wrapped in the buffer, and the buffer is wrapped in the jacket.

- Core carries the data signals in the form of the light.
- Cladding reflects light back to the core.
- Buffer protects the light from leaking.
- The jacket protects the cable from physical damage.

Fiber optic cable is completely immune to EMI and RFI. This cable can transmit data over a long distance at the highest speed. It can transmit data up to 40 kilometers at the speed of 100Gbps.

Fiber optic uses light to send data. It reflects light from one endpoint to another. Based on how many beams of light are transmitted at a given time, there are two types of fiber optical cable; SMF and MMF.

Fig 4



SMF (Single-mode fiber) optical cable

This cable carries only a single beam of light. This is more reliable and supports much higher bandwidth and longer distances than the MMF cable. This cable uses a laser as the light source and transmits 1300 or 1550 nano-meter wavelengths of light.

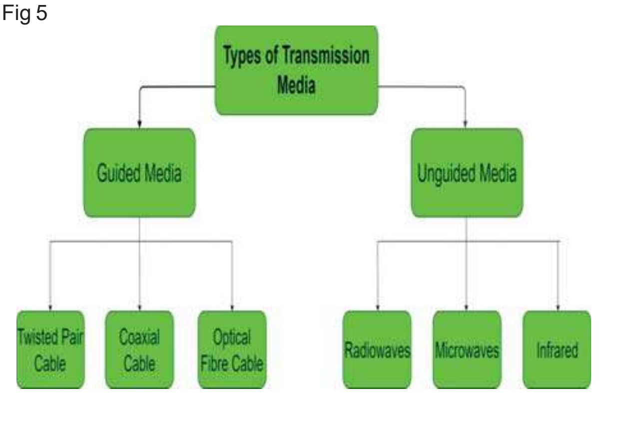
MMF (multi-mode fiber) optical cable

This cable carries multiple beams of light. Because of multiple beams, this cable carries much more data than the SMF cable. This cable is used in shorter distances. This cable uses an LED as the light source and transmits 850 or 1300 nano-meter wavelengths of light.

1.1 Communication Media

Communication media refers to the means of delivering and receiving data or information. In network communications, a transmission medium is a physical connection or an interface between the transmitter and the receiver. There are two major categories of transmission media, namely guided and wireless (or unguided).

Fig 5



1.2.1 Guided Media

It is also referred to as Wired or Bounded transmission media. Signals being transmitted are directed and confined in a narrow pathway by using physical links. Details about the guided media have been discussed in the previous section 34. 182.

1.2.2 Unguided Media

It is also referred to as Wireless or Unbounded transmission media. No physical medium is required for the transmission of electromagnetic signals.

Features:

- Signal is broadcasted through air
- Less Secure
- Used for larger distances

There are 3 major types of Unguided Media:

1.2.2.1 Radiowaves –

These are easy to generate and can penetrate through buildings. The sending and receiving antennas need not be aligned. Frequency Range:3KHz – 1GHz. AM and FM radios and cordless phones use Radiowaves for transmission.

Further Categorized as (i) Terrestrial and (ii) Satellite.

1.2.2.2 Microwaves –

It is a line of sight transmission i.e. the sending and receiving antennas need to be properly aligned with each other. The distance covered by the signal is directly proportional to the height of the antenna. Frequency Range:1GHz – 300GHz. These are majorly used for mobile phone communication and television distribution.

1.2.2.3 Infrared –

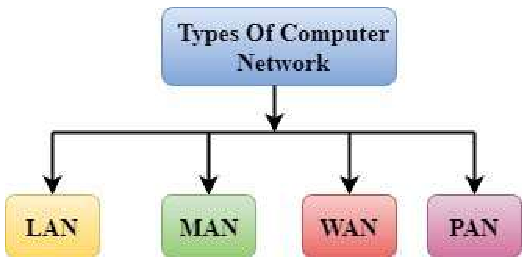
Infrared waves are used for very short distance communication. They cannot penetrate through obstacles. This prevents interference between systems. Frequency Range:300GHz – 400THz. It is used in TV remotes, wireless mouse, keyboard, printer, etc.

1.3 Different Types of Networks

A computer network is a group of computers linked to each other that enables the computer to communicate with another computer and share their resources, data, and applications.

A computer network can be categorized by their size. A computer network is mainly of four types:

Fig 6



1.3.1 LAN(Local Area Network)

- Local Area Network is a group of computers connected to each other in a small area such as building, office.
- LAN is used for connecting two or more personal computers through a communication medium such as twisted pair, coaxial cable, etc.
- It is less costly as it is built with inexpensive hardware such as hubs, network adapters, and ethernet cables.
- The data is transferred at an extremely faster rate in Local Area Network.
- Local Area Network provides higher security.

Fig 7

1.3.2 PAN (Personal Area Network)

- Personal Area Network is a network arranged within an individual person, typically within a range of 10 meters.
- Personal Area Network is used for connecting the computer devices of personal use is known as Personal Area Network.
- Personal Area Network covers an area of 30 feet.
- Personal computer devices that are used to develop the personal area network are the laptop, mobile phones, media player and play stations.

Fig 8

Wireless Personal Area Network: Wireless Personal Area Network is developed by simply using wireless technologies such as WiFi, Bluetooth. It is a low range network.

Wired Personal Area Network: Wired Personal Area Network is created by using the USB.

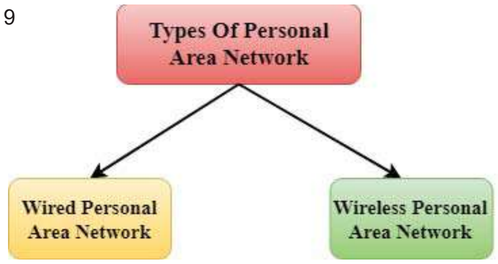


Fig 9

Examples Of Personal Area Network:

- Body Area Network: Body Area Network is a network that moves with a person. For example, a mobile network moves with a person. Suppose a person establishes a network connection and then creates a connection with another device to share the information.
- Offline Network: An offline network can be created inside the home, so it is also known as a home network. A home network is designed to integrate the devices such as printers, computer, television but they are not connected to the internet.
- Small Home Office: It is used to connect a variety of devices to the internet and to a corporate network using a VPN

1.3.3 MAN(Metropolitan Area Network)

- A metropolitan area network is a network that covers a larger geographic area by interconnecting a different LAN to form a larger network.
- Government agencies use MAN to connect to the citizens and private industries.
- In MAN, various LANs are connected to each other through a telephone exchange line.
- The most widely used protocols in MAN are RS-232, Frame Relay, ATM, ISDN, OC-3, ADSL, etc.
- It has a higher range than Local Area Network(LAN).

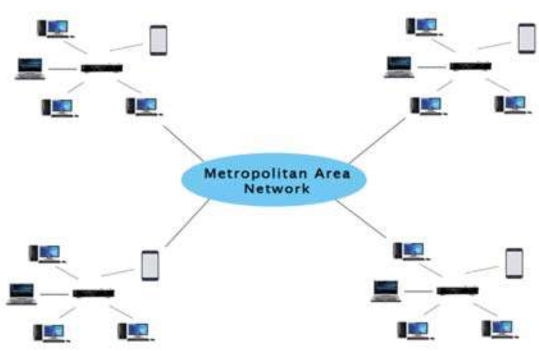


Fig 10

- Uses Of Metropolitan Area Network:
- MAN is used in communication between the banks in a city.
- It can be used in an Airline Reservation.
- It can be used in a college within a city.
- It can also be used for communication in the military.

1.3.4 WAN (Wide Area Network)

- A Wide Area Network is a network that extends over a large geographical area such as states or countries.
- A Wide Area Network is quite bigger network than the LAN.
- A Wide Area Network is not limited to a single location, but it spans over a large geographical area through a telephone line, fibre optic cable or satellite links.
- The internet is one of the biggest WAN in the world.
- A Wide Area Network is widely used in the field of Business, government, and education.

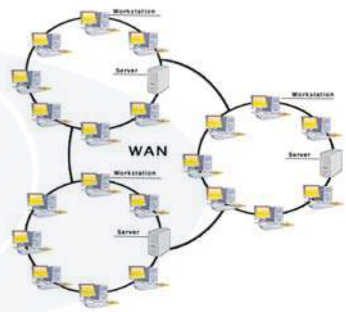


Fig 11

Examples of Wide Area Network:

- Mobile Broadband: A 4G network is widely used across a region or country.
- Last mile: A telecom company is used to provide the internet services to the customers in hundreds of cities by connecting their home with fiber.
- Private network: A bank provides a private network that connects the 44 offices. This network is made by using the telephone leased line provided by the telecom company.

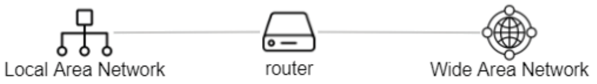
1.1 Network Components

The main types of network components: router, hub and switch. Other devices can also be used on a network such as a Wireless Access Point (WAP) and a Firewall.

1.3.1 Router

A router is needed to connect a LAN to a WAN (or to the Internet). A router scans data packets and redirects them towards the LAN or towards other routers depending on their origin and their destination.

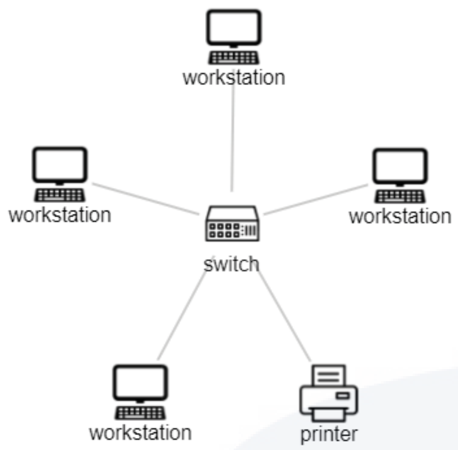
Fig 12



1.3.1 Switches and Hubs

A switch is a network component used to connect multiple devices together in a star topology. A switch would have a number of Ethernet ports (typically between 8 and 28 ports) to connect to other devices such as workstations and servers, WAPs, other hubs or switches or to a firewall or a router.

Fig 13

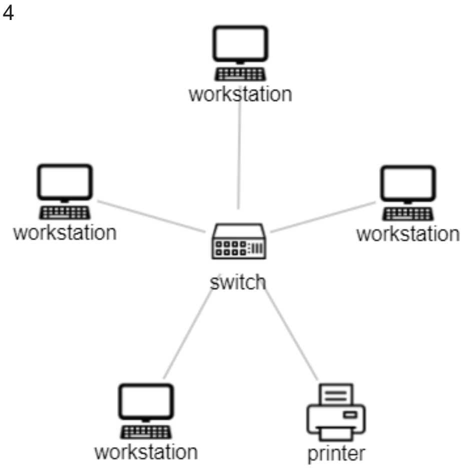


A switch is more efficient than a hub as it can redirect traffic towards the device it is aimed at. Switches can hence be used on larger networks where hubs would be inefficient. (e.g. school network, hospital network, etc).

1.3.3 Hub

A hub is a network component used to connect multiple devices together in a star topology. A hub would have a number of Ethernet ports (typically between 5 and 8 ports) to connect to other devices such as workstations and servers, WAPs, other hubs or switches or to a firewall or a router.

Fig 14

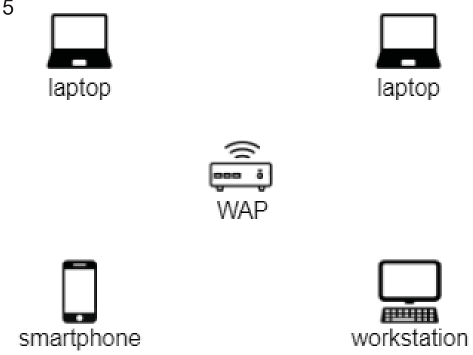


A hub is not as efficient as a switch and hence should only be used on a small network. (e.g. home network).

1.3.4 Wireless Access Point (WAP)

A Wireless Access Point (WAP) is a network component used to connect multiple devices together without using wires. A WAP could hence be described as being a wireless hub! It provides WiFi access to a network. Most WAPs have a fairly small coverage area (10 to 30 meters) hence several WAPs may be required to cover a large building.

Fig 15



Devices equipped with a wireless Network Interface Card (NIC) can connect to a WAP. Wireless data can easily be intercepted by potential hackers hence the need to encrypt wireless transmissions and to set a network key to restrict access to a wireless network (WiFi).

1.3.4 Firewall

A firewall is a network component that usually "sits" just after the main router. It scans all incoming traffic to identify/block and report potential security threats coming from "outside" (e.g. the Internet) before they can reach the rest of the Local Area Network. A firewall is a necessary precaution to minimise the risk of hackers illegally accessing a network.

Fig 16

1.3.5 NIC Cards

To connect a workstation to a LAN, the workstation needs to be equipped with a Network Interface Card (NIC). The NIC card will have a wired connection (e.g. Ethernet port) and/or a wireless connection to connect wirelessly to a WAP (Wireless Access Point).

1.4 Design Considerations For a Network

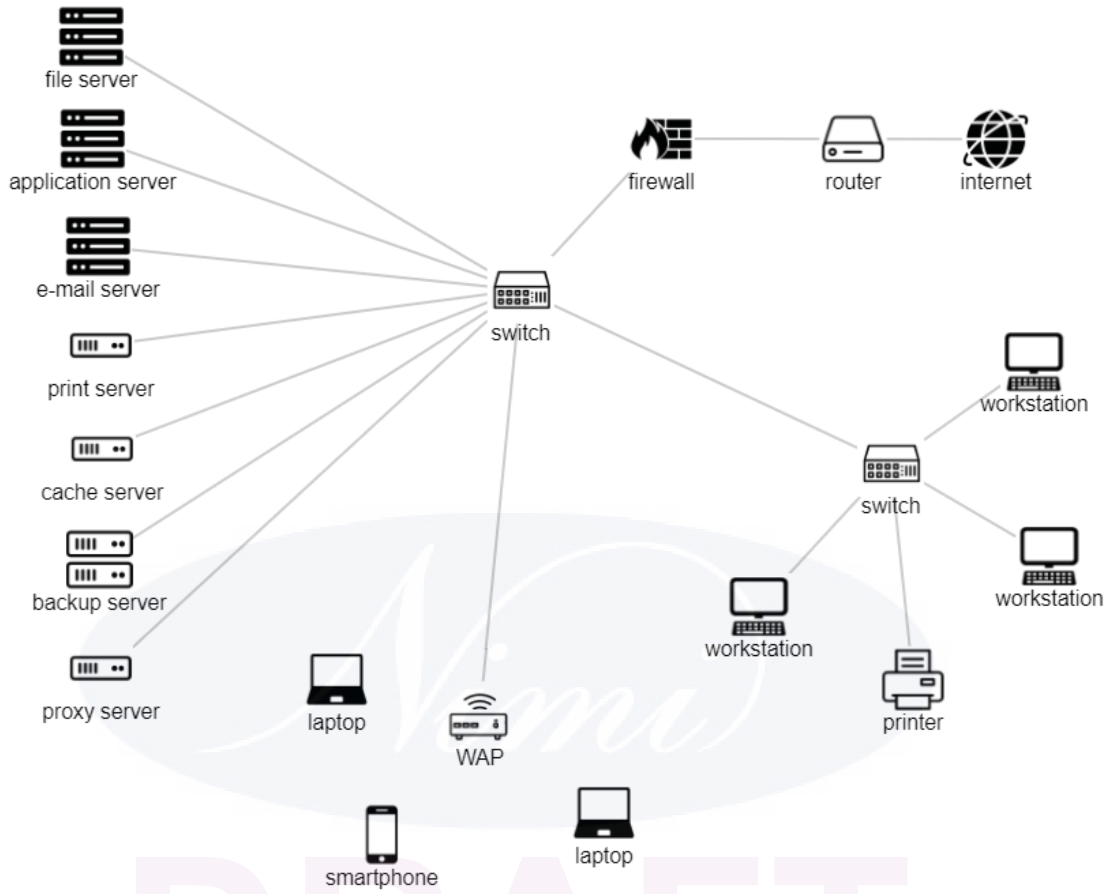
The main factors to be considered are

- The purpose of the network - exchange of information/ data between computers, applications/database hosting, voice/messaging services
- The size of the network - number of users, area of coverage, location of the users, hardware etc.

- The amount of data being transferred/exchanged
- Security of the data
- Other important factors to be considered - connectivity requirements (whether wired, wireless or combination), the type of cabling, the type of computers/equipment to be used and their location(s), the software and operating system(s) to be used.

The below diagram shows a sample network layout to design a simple lab in educational institution

Fig 17



1.4.1 Setting up a wireless network on Windows

Step 1: Click the Wi-Fi symbol as shown in Fig 1

Fig 18

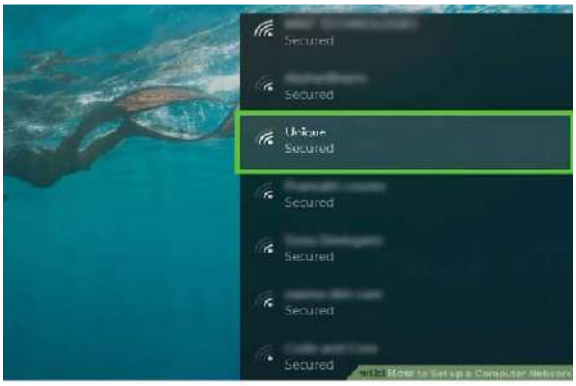
- It's in the lower-right corner of the screen. A pop-up window will appear.
- If Wi-Fi is currently disabled, click the Wi-Fi button in the lower-left side of the pop-up window before proceeding.
- In some cases, you'll need to click the ^ icon in the lower-right side of the screen to see the Wi-Fi icon.

Fig 19

Step 2: Select a network as show in Fig 2.

Click the network to which you want to connect each of your network computers.

Fig 20



Step 3: Click Connect as shown in Fig 3.

It's in the lower-right side of the network's name box.

Step 4: Enter the network's password as shown in Fig 4. Type in the network's password when prompted.

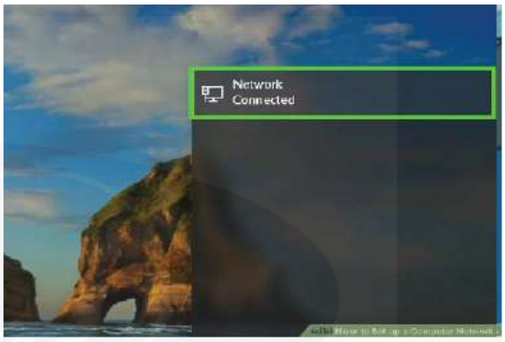
Fig 21

Step 5: Click Next as shown in Fig 5. It's below the network. As long as the password is correct, doing so will connect you to the network.

Fig 22

Step 6: Connect other computers in the network to the Internet as shown in Fig 6. For each computer that you want to use in your network, repeat the Wi-Fi connection process. Once each computer is connected to the Wi-Fi network, you can proceed with setting up file sharing.

Fig 23



Basics of solar electricity, working prnciple of PV panel, advantage of solar electricity and components of solar electricity, VI characteristics of solar PV module, effects of inclination angle on PV module, different battery charging techniques

Objectives: At the end of this lesson you shall be able to
- **to understand the concept of solar energy and PV working principle**
- **to comprehend the advantages, characteristics and effects of inclination angle**
- **to understand the various battery charging techiques.**

1. Solar Electricity

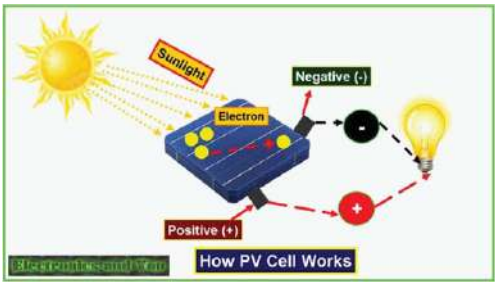
Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaics (PV), indirectly using concentrated solar power, or a combination. Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect.

Photovoltaics (PV) or solar cells as they are often called, are semiconductor devices that convert sunlight into direct current (DC) electricity. Groups of PV cells are electrically configured into modules and arrays, which can be used to charge batteries, operate motors, and to power any number of electrical loads. With the appropriate power conversion equipment, PV systems can produce alternating current (AC) compatible with any conventional appliances, and can operate in parallel with, and interconnected to, the utility grid.

2. Working Principle of PV panel

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load

Fig 1



Regardless of size, a typical silicon PV cell produces about 0.5 – 0.6 volt DC under open-circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions, a typical commercial PV cell with a surface area of 160 cm^2 (~25 in^2) will produce about 2 watts peak power. If the sunlight intensity were 40 percent of peak, this cell would produce about 0.8 watts.

1. Advantages & Components of Solar Electricity

3.1 Advantages

- Solar power is pollution free and causes no greenhouse gases to be emitted after installation
- Reduced dependence on foreign oil and fossil fuels
- Renewable clean power that is available every day of the year, even cloudy days produce some power
- Return on investment unlike paying for utility bills
- Virtually no maintenance as solar panels last over 30 years
- Creates jobs by employing solar panel manufacturers, solar installers, etc. and in turn helps the economy
- Excess power can be sold back to the power company if grid intertied
- Ability to live grid free if all power generated provides enough for the home / building
- Can be installed virtually anywhere; in a field to on a building
- Use batteries to store extra power for use at night
- Solar can be used to heat water, power homes and building, even power cars
- Safer than traditional electric current
- Efficiency is always improving so the same size solar that is available today will become more efficient tomorrow

- Aesthetics are improving making the solar more versatile compared to older models; i.e. printing, flexible, solar shingles, etc.
- Federal grants, tax incentives, and rebate programs are available to help with initial costs

3.2 Components

Any potential solar power system owner should take the time to understand what summarizes a photovoltaic array and how those components work to enable electrical generation for the energy needs. Each system is unique in its size and structure, therefore application of a photovoltaic array will differ from another.

Solar Energy System

A Solar Energy System is a renewable energy generating system that collects photovoltaic energy from the sun and converts it into usable electricity. Often found as roof-top PV arrays, these systems can range in size and are able to power different types of properties - such as residential, commercial, and utility-scale zones.

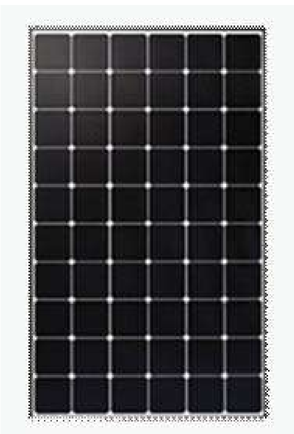
Photovoltaic systems can be used in multiple applications: standard arrays such as roof-top or ground mount serve to generate energy for a residence or building, while other non-traditional systems can be utilized to power other objects or function (such as space satellites, hand-held calculators or vehicles).

Standard residential or commercial solar power systems consist of a core set of components - (Solar Panels, Inverters, DC/AC Disconnects, Meters, Wiring, Racking and Mounting), these are usually grid-tied. Some systems require additional components added to the core set to function – (Charge Controllers, Batteries, Additional Balance of Systems items and more), these are usually off-grid.

Solar Panels

Solar Panels or PV modules are the most commonly known component in a photovoltaic array. Made up of mostly solar cells, framing, and glass; solar panels work by collecting and harnessing photovoltaic energy from the sun, and delivering that energy as 'direct current' (DC) power to an inverter or converter component (may be a charge controller in some instances).

Fig 2



The DC power generated by a solar module is an electric current that flows in a constant direction. This type of power is generally not readily useable for standard electric demands, and must be translated into 'alternating current' (AC) power before it can be used for standard electric devices inside a home or building. Solar Panels consist of two most well-known types of solar cells, Polycrystalline and Monocrystalline. The difference consists of how silicon crystals in the ingots or wafers are harvested, developed and formed, each creating a different look and color to their appearance. Both types of PV cells are known to be effective in their general ability to produce solar electricity.

Inverters

Inverters (or Converters) intake DC power generated by a solar panel and process that energy by converting it into AC power, the resulting power can then be sent to a breaker or balance of system component and is available for standard use. Inverters may be located after a charge controller and battery bank in certain off-grid energy systems.

nverters come in different types of sizes and use various technologies to enable efficiency in the function to produce AC power. The most common inverters are; String Inverters, Central Inverters, Microinverters, and Battery-based Inverters. Each will carry different mechanical and technicalcharacteristics.

String Inverters can be wired for a row of solar panels to connect to one of several strings inside the inverter to accommodate a series of modules, while Microinverters are generally mounted to the back of each panel or (every other panel), to convert energy per module into AC power. Each type of inverter is not necessarily better than another as each one has its benefits and drawbacks, and their technologies are specifically used for application purposes in certain circumstances.

Monitoring

Monitoring Equipment components are usually connected to a concurrent Inverter manufacturer, and they view and relay system energy information analytics to a in product console or web connected device through their proprietary software. Monitoring Equipment components may be integrated into an Inverter, or in some instances – be connected to another component of a photovoltaic array.

Monitoring technology is able to display information ranging from energy generated by the solar panels, to real-time data, to immediate fault detection and troubleshooting, to energy yield data over a set amount of time. A comprehensive Monitoring system can benefit the system operator to better understand the way the solar energy system is operating, (and measures that can be taken to better increase yields, productivity, maintenance and other variables) in real time or over the course of the systems lifespan.

Racking

Racking and Mounting components work to ensure a PV array is connected to either the ground or a roof and is made up of multiple key products that encompass an entire racking system.

Most racking systems will use a combination of: Rails, Flashings, Lugs, Mounting Brackets, Wire Clips, Splice Kits, Braces, End Caps, Attachments, Tilt Legs - and other components to complete a full racking and mounting system. Ground mount systems will require concrete and steel piping in addition to a complete racking kit to be placed onto land.

Racking and Mounting is an essential part of any solar energy system. Both roof-top and ground mount arrays need to be set atop a sound and reliable structure to ensure the system can maintain integrity and operate for an extended period of time.

Balance of Systems

Balance of System components work to combine other electrical products within the system, then combining and delivering a series of power control and distribution options for any PV array.

Commonly, most items that make up Balance of Systems products include: DC/AC Disconnects, Junction Boxes, Combiner Boxes, Circuit Breakers, Fuses, Load Centers, Rapid Shutdowns, Surge Devices, among other components that may vary from system to system. These components will differ per individual solar energy system, as some systems will need more or less power control and distribution depending on their application.

Every photovoltaic array needs a series of safeguards and power control options to be available at any time - whether it be for the safety or integrity of the system, or to enable emergency maintenance in case of a fire or other potential issue that may arise. Power Control is necessary in any electric generating system

Wiring

Wiring acts to ensure other solar energy components are interconnected, and can pass energy from one device onto another. PV Wire is commonly used to move energy from the Solar Modules to the Inverter(s), and then be transformed to be sent for another product within the photovoltaic array supply chain.

Wires will generally be made of aluminum or copper, be solid or standard, are insulated, and meant to either pass through DC current or AC current depending on where they are positioned and connected. Wires will also be color coded for safety and identification purposes by a system operator or inspector who needs to understand which wire controls a certain current, (Positive, Negative, Grounded, etc.)

Standard systems will utilize wires which can hold and pass through certain voltages and wire gauges depending on the PV array setup. These values are commonly dependent upon the voltage of the system and its concurring components used within the interconnected stream of items.

Charge Controllers

Charge Controllers work to regulate electrical charge and they limit the rate at which electric current is added to or withdrawn from the Batteries. They work to control voltage and watts from Solar Panels; thus, passing through more stable energy, preventing overcharging and protecting against overvoltage - which can hinder and reduce Battery performance or lifespan.

Charge Controllers come with various types of sizes and technologies that enable generally an off-grid (Battery Bank) system to function properly. These two types of technologies are MPPT (Maximum Power Point Tracking) and PWM (Pulse Width Modulation). Charge Controllers are often used within an off-grid or hybrid with battery back-up solar energy system.

A series of Charge Controllers are important for maintaining battery integrity with a system that utilizes them. Due to the sensitive nature of power storage components, it is vital to regulate their ongoing activity to derive the maximum lifespan possible, and helping to reduce future maintenance costs and upkeep.

Batteries enable the ability to store solar power for use at a later date. They are used within off-grid or hybrid solar electric arrays, which require power to be used in the case of lack of available sunlight (night time), unstable power distribution from a utility company, or lack of access to a utility supplier.

1.Various Combinations and VI characteristics of Solar PV module

Solar Cell IV Characteristic Curves show the current and voltage (IV) characteristics of a particular photovoltaic (PV) cell, module or array giving a detailed description of its solar energy conversion ability and efficiency. Knowing the electrical I-V characteristics (more importantly P_{max}) of a solar cell, or panel is critical in determining the device's output performance and solar efficiency.

Photovoltaic solar cells convert the suns radiant light directly into electricity. With increasing demand for a clean energy source and the sun's potential as a free energy source, has made solar energy conversion as part of a mixture of renewable energy sources increasingly important. As a result, the demand for efficient solar cells, which convert sunlight directly into electricity, is growing faster than ever before.

1.Photovoltaic Cell

Photovoltaic (PV) cells are made made almost entirely from silicon that has been processed into an extremely pure crystalline form that absorbs the photons from sunlight and then releases them as electrons, causing an electric current to flow when the photoconductive cell is connected to an external load. There are a variety of different measurements we can make to determine the solar cell's performance, such as its power output and its conversion efficiency.

The main electrical characteristics of a PV cell or module are summarized in the relationship between the current and voltage produced on a typical solar cell I-V characteristics curve. The intensity of the solar radiation (insolation) that hits the cell controls the current (I), while the increases in the temperature of the solar cell reduces its voltage (V).

Solar cells produce direct current (DC) electricity and current times voltage equals power, solar cell I-V curves are created representing the current versus the voltage for a photovoltaic device.

Solar Cell I-V Characteristics Curves are basically a graphical representation of the operation of a solar cell or module summarising the relationship between the current and voltage at the existing conditions of irradiance and temperature. I-V curves provide the information required to configure a solar system so that it can operate as close to its optimal peak power point (MPP) as possible.

5.Effect of Inclination angle on PV module

1. The tilt angle orientation of the PV panel affects its output power.
2. The maximum PV panel output power occurred when the tilt angle was optimum

   i.e. the sun rays were perpendicular to the PV panel.
3. The PV panel output power decreases significantly when the tilt angle becomes far off from its optimum value and the output continuously drops how far it away from the optimum angle.

2. Basic Charging Methods

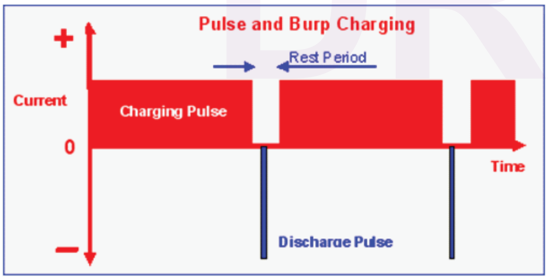
Constant Voltage A constant voltage charger is basically a DC power supply which in its simplest form may consist of a step down transformer from the mains with a rectifier to provide the DC voltage to charge the battery. Such simple designs are often found in cheap car battery chargers. The lead-acid cells used for cars and backup power systems typically use constant voltage chargers. In addition, lithium-ion cells often use constant voltage systems, although these usually are more complex with added circuitry to protect both the batteries and the user safety.

- Constant Current Constant current chargers vary the voltage they apply to the battery to maintain a constant current flow, switching off when the voltage reaches the level of a full charge. This design is usually used for nickel-cadmium and nickel-metal hydride cells or batteries.

- Taper Current This is charging from a crude unregulated constant voltage source. It is not a controlled charge as in V Taper above. The current diminishes as the cell voltage (back emf) builds up. There is a serious danger of damaging the cells through overcharging. To avoid this the charging rate and duration should be limited. Suitable for SLA batteries only.

- Pulsed charge Pulsed chargers feed the charge current to the battery in pulses. The charging rate (based on the average current) can be precisely controlled by varying the width of the pulses, typically about one second. During the charging process, short rest periods of 20 to 30 milliseconds, between pulses allow the chemical actions in the battery to stabilise by equalising the reaction throughout the bulk of the electrode before recommencing the charge. This enables the chemical reaction to keep pace with the rate of inputting the electrical energy. It is also claimed that this method can reduce unwanted chemical reactions at the electrode surface such as gas formation, crystal growth and passivation. (See also Pulsed Charger below). If required, it is also possible to sample the open circuit voltage of the battery during the rest period.

The optimum current profile depends on the cell chemistry and construction.



The optimum current profile depends on the cell chemistry and construction.

- Burp chargingalso called Reflex or Negative Pulse Chargingused in conjunction with pulse charging, it applies a very short discharge pulse, typically 2 to 3 times the charging current for 5 milliseconds, during the charging rest period to depolarise the cell. These pulses dislodge any gas bubbles which have built up on the electrodes during fast charging, speeding up the stabilisation process and hence the overall charging process. The release and diffusion of the gas bubbles is known as "burping". Controversial claims have been made for the improvements in both the charge rate and the battery lifetime as well as for the removal of dendrites made possible by this technique. The least that can be said is that "it does not damage the battery".

- IUI Charging This is a recently developed charging profile used for fast charging standard flooded lead acid batteries from particular manufacturers. It is not suitable for all lead acid batteries. Initially the battery is charged at a constant (I) rate until the cell voltage reaches a preset value - normally a voltage near to that at which gassing occurs. This first part of the charging cycle is known as the bulk charge phase. When the preset voltage has been reached, the charger switches into the constant voltage (U) phase and the current drawn by the battery will gradually drop until it reaches another preset level. This second part of the cycle completes the normal charging of the battery at a slowly diminishing rate. Finally the charger switches again into the constant current mode (I) and the voltage continues to rise up to a new higher preset limit when the charger is switched off. This last phase is used to equalise the charge on the individual cells in the battery to maximise battery life.

- Trickle charge Trickle charging is designed to compensate for the self discharge of the battery. Continuous charge. Long term constant current charging for standby use. The charge rate varies according to the frequency of discharge. Not suitable for some battery chemistries, e.g. NiMH and Lithium, which are susceptible to damage from overcharging. In some applications the charger is designed to switch to trickle charging when the battery is fully charged.

- Float charge. The battery and the load are permanently connected in parallel across the DC charging source and held at a constant voltage below the battery's upper voltage limit. Used for emergency power back up systems. Mainly used with lead acid batteries.

- Random charging All of the above applications involve controlled charge of the battery, however there are many applications where the energy to charge the battery is only available, or is delivered, in some random, uncontrolled way. This applies to automotive applications where the energy depends on the engine speed which is continuously changing. The problem is more acute in EV and HEV applications which use regenerative braking since this generates large power spikes during braking which the battery must absorb. More benign applications are in solar panel installations which can only be charged when the sun is shining. These all require special techniques to limit the charging current or voltage to levels which the battery can tolerate.

Installation of Linux operting system porting, configuration of cloud & srever. Over the air node configuration, GUI based parameter configuration, GUI based IOT application. IOT gateway using WIFI and Ethernet. User access and data security management by cryptography. The command line and the shell directories and files. Linux file system and understanding system intialization. Connection of system to the network. Installation and configuration of linux. Shell scripts, flow control in the shell advanced shell features. Database management system. Cloud and server configuration for IOT. QT based GUI, IOT web and application development tools for IOT.

Objectives: At the end of this lesson you shall be able to
- **to undrestand the concept of linux operating system installation, porting, parameter configuration**
- **to realize the shell commands, its features and database management system. the specification for soil oxygen level, air, temperature and humidity and pressure**
- **to understand the QT based GUI and application development tools.**

1.Linux Operating system porting

Porting means making something work on an environment it is not designed for. Porting differs from development. Usually, porting doesn't involve as much of coding as in development.

What Linux kernel porting involves

Linux kernel porting involves two things at a higher level: architecture porting and board porting. Architecture, in Linux terminology, refers to CPU. So, architecture porting means adapting the Linux kernel to the target CPU, which may be ARM, Power PC, MIPS, and so on. In addition to this, SOC porting can also be considered as part of architecture porting. However, you still need to port Linux for the board and this is where the major focus lies. Architecture porting entails porting of initial start-up code, interrupt service routines, dispatcher routine, timer routine, memory management, and so on. Whereas board porting involves writing custom drivers and initialisation code for devices specific to the board.

2.Configuration of local cloud & server

Ubuntu Server is more popular than ever, thanks to containers and the cloud. Ubuntu Server is a server operating system, developed by Canonical, that runs on all major architectures: x86, x86-64, ARM v7, ARM64, POWER8, and IBM System z mainframes via LinuxONE. Ubuntu is a server platform that anyone can use for the following and much more:

- Websites
- FTP
- Email server
- File and print server
- Development platform
- Container deployment
- Cloud services
- Database server

Ubuntu Server has these minimum requirements:

- RAM: 512MB
- CPU: 1 GHz
- Storage: 1 GB disk space (1.75 GB for all features to be installed)
- Image by :
- Opensource.com ownCloud is a self-hosted open source file sync and share server. ownCloud allows to synchronize everything (or part of it) between your devices and share files with others.

3.Over the air node configuration

Over the airprogramming(OTA) is a process which allows devices to upgrade their firmware or software wirelessly without any physical access. It uses wireless technology like Wi-Fi, Bluetooth, GPRS or 4G/3G rather than wired serial communication. OTA is used to reprogram the devices like microcontrollers, cellphones, computers, set-top box etc. OTA updates are generally sent for updating the software, resolving the bugs, adding some features etc. With the increasing use of IoT devices OTA is transferred using frequency bands having low data transmission rate (868 MHz, 900 MHz, 2400 MHz).

4. **Parameter Configuration using GUI**

Boot parameters are Linux kernel parameters which are generally used to make sure that peripherals are dealt with properly. For the most part, the kernel can auto-detect information about your peripherals. To configure the network client hosts with the command line by using commands to change your current settings or by editing number of system files. The basic requirement is the need of the editor, vi editor can be used. The other options to use are linking, gedit, nano and so on. In order to change or set the host name, it can be done directly

5. GUI based IoT application

The IoT promises to bring about a revolution in the way we interact with devices around us. While many IoT devices will be hidden away, from sensors that measure manufacturing tolerances in a factory to hubs that control lighting around the home, there are a class of devices that need to provide some sort of graphical output or display to the user. Some examples include digital signage, interactive kiosks, automotive in-car entertainment gateways, smart meters, and the plethora of display screens seen on everything from washing machines to smart thermostats. All of these examples need some way to output graphics to a screen display but in an embedded environment that is not always easy.

Linux is one of the most popular OS choices for manufacturers and solution providers to use in IoT devices and with it there are a few options available for graphical environments. From custom software to drive the display, through direct frame buffer access with toolkits such as QT, to a full X windowing server.

6.IoT Gateway using WIFI and Ethernet

6.1 Introduction

An IoT gateway device bridges the communication gap between IoT devices, sensors, equipment, systems and the cloud. By systematically connecting the field and the cloud, IoT gateway devices offer local processing and storage solutions, as well as the ability to autonomously control field devices based on data input by sensors.

6.2How Does an IoT Gateway Device Work?

As the abilities and needs of devices proliferate, it is often not possible to have them communicate directly with systems. Some sensors and controllers don't support energy-intensive protocols like Wi-Fi or Bluetooth. Some devices aggregate data so that it is overwhelming and invaluable in its raw form and they are all connecting to a variety of public and private networks.

An IoT gateway performs several critical functions from translating protocols to encrypting, processing, managing and filtering data. If you imagine an IoT ecosystem, a gateway sits between devices and sensors to communicate with the cloud.

6.3 An example device

ModBus RTU Ethernet/WiFi IOT Gateway is a device which can be used to collect data from modbus slave devices or network and forward the same to cloud / server. It is completely plug and play without any need for coding or programming. This device is remotely configurable from our device configuration portal for user desired slave settings (slave ID, baud rate, modbus register addresses, data format etc) and server settings (URL, data-to-cloud rate, protocol etc).

It comes with default cloud / IOT platform where user can visualize modbus data in widgets, graphs, etc and set SMS/email alerts etc.

7. User access & Data Security management

7.1 Introduction

User management is a critical part of maintaining a secure system. Ineffective user and privilege management often lead many systems into being compromised. Users are encouraged to make use of a tool by the name of sudo to carry out system administrative duties. Sudo allows an authorized user to temporarily elevate their privileges using their own password instead of having to know the password belonging to the root account. This simple yet effective methodology provides accountability for all user actions, and gives the administrator granular control over which actions a user can perform with said privileges.

The process for managing local users and groups is straightforward and differs very little from most other GNU/Linux operating systems. Ubuntu and other Debian based distributions encourage the use of the "adduser" package for account management.

When a new user is created, the adduser utility creates a brand new home directory named /home/username. The default profile is modelled after the contents found in the directory of /etc/skel, which includes all profile basics. If the server will be home to multiple users, should pay close attention to the user home directory permissions to ensure confidentiality. By default, user home directories in Ubuntu are created with world read/execute permissions. This means that all users can browse and access the contents of other users home directories. This may not be suitable for the environment.

7.2 Password Policy

A strong password policy is one of the most important aspects of your security posture. Many successful security breaches involve simple brute force and dictionary attacks against weak passwords. If you intend to offer any form of remote access involving your local password system, make sure you adequately address minimum password complexity requirements, maximum password lifetimes, and frequent audits of your authentication systems.

7.3 Security Considerations

Many applications use alternate authentication mechanisms that can be easily overlooked by even experienced system administrators. Therefore, it is important to understand and control how users authenticate and gain access to services and applications on your server.

7.3.1 SSH Access by Disabled Users

Simply disabling/locking a user account will not prevent a user from logging into the server remotely if they have previously set up RSA public key authentication. They will still be able to gain shell access to the server, without the need for any password. Remember to check the users home directory for files that will allow for this type of authenticated SSH access, e.g. /home/username/.ssh/authorized_keys.

Remove or rename the directory .ssh/ in the user's home folder to prevent further SSH authentication capabilities.

Be sure to check for any established SSH connections by the disabled user, as it is possible they may have existing inbound or outbound connections. Kill any that are found.

8. Command line , Shell directories

8.1 Introduction

The Linux command line is a text interface of the computer. Often referred to as the shell, terminal, console, prompt or various other names, it can give the appearance of being complex and confusing to use. Yet the ability to copy and paste commands from a website, combined with the power and flexibility the command line offers.

Few commands are

8.2File & Directory Commands

· The tilde (~) symbol stands for your home directory. If you are *user*, then the tilde (~) stands for /home/*user*

· pwd: The pwd command will allow to know in which directory you're located (pwd stands for "print working directory"). Example: "pwd" in the Desktop directory will show "~/Desktop".

· ls: The ls command will show the files in the current directory. Used with certain options, the sizes of files can be known, when files were made, and permissions of files. Example: "ls ~" will show the files that are in the home directory.

· cd: The cd command will allow to change directories. When a terminal is openedit will direct you to the home directory. To move around the file system cd command is used. Examples:

- To navigate into the root directory, use "cd /"
- To navigate to your home directory, use "cd" or "cd ~"
- To navigate up one directory level, use "cd .."
- To navigate to the previous directory (or back), use "cd -"
- To navigate through multiple levels of directory at once, specify the full directory path that you want to go to. For example, use, "cd /var/www" to go directly to the /www subdirectory of /var/. As another example, "cd ~/Desktop" will move you to the Desktop subdirectory inside your home directory.

· cp: The cp command will make a copy of a file for you. Example: "cp file foo" will make an exact copy of "file" and name it "foo", but the file "file" will still be there. If you are copying a directory, you must use "cp -r directory foo" (copy recursively).

· mv: The mv command will move a file to a different location or will rename a file. Examples are as follows: "mv file foo" will rename the file "file" to "foo". "mv foo ~/Desktop" will move the file "foo" to your Desktop directory, but it will not rename it. You must specify a new file name to rename a file.

o To save on typing, you can substitute '~' in place of the home directory.

o Note that if you are using mv with sudo you can use the ~ shortcut, because the terminal expands the ~ to your home directory. However, when you open a root shell with sudo -i or sudo -s, ~ will refer to the root account's home directory, not your own.

· rm: Use this command to remove or delete a file in your directory.

· rmdir: The rmdir command will delete an *empty* directory. To delete a directory and all of its contents recursively, use rm -r instead.

· mkdir: The mkdir command will allow you to create directories. Example: "mkdir music" will create a directory called "music".

9.Introduction to File systems

File systems are one of the things any newcomer to linux must become acquainted with. Linux however, being built on a world of open source and differing opinions, is not limited in this way and so the user should have an understanding of what a file system is, and how it affects the computer.

Table

Now below is a very brief comparison of the most common file systems in use with the Linux world.

File System	Max File Size	Max Partition Size	Journaling	Notes
Fat16	2 GiB	2 GiB	No	Legacy
Fat32	4 GiB	8 TiB	No	Legacy
NTFS	2 TiB	256 TiB	Yes	(For Windows Compatibility) NTFS-3g is installed by default in Ubuntu, allowing Read/ Write support
ext2	2 TiB	32 TiB	No	Legacy
ext3	2 TiB	32 TiB	Yes	Standard linux filesystem for many years. Best choice for super-standard installation.
ext4	16 TiB	1 EiB	Yes	Modern iteration of ext3. Best choice for new installations where super-standard isn't necessary.
reiserFS	8 TiB	16 TiB	Yes	No longer well-maintained.
JFS	4PiB	32PiB	Yes (metadata)	Created by IBM - Not well maintained.
XFS	8 EiB	8 EiB	Yes (metadata)	Created by SGI. Best choice for a mix of stability and advanced journaling.
GiB = Gibibyte (1024 MiB) :: TiB = Tebibyte (1024 GiB) :: PiB = Pebibyte (1024 TiB) :: EiB = Exbibyte (1024 PiB)				

It is not recommended to install Linux on any type of FAT file system, because FAT does not have any of the permissions of a true Unix FS.

Editing Files

Those used to a Windows file system (NTFS, FAT) know that it isn't normally possible to change files while they are open. This restriction does not exist in a Unix file system. This is because in Unix file systems, files are indexed by a number, called the inode, and each inode has several attributes associated with it, like permissions, name, etc. When you delete a file, what really happens is the inode is unlinked from the filename, but if some other program is using the file, it still has a link open to the OS, and will continue to be updated. A file is not really deleted until all links have been removed (even then, the data is still on the disk, but not indexed in anyway and thus very hard to recover). All of this means that you can delete executing programs while they're running without crashing and move files before they're finished downloading without corruption.

Fragmentation

Another common Windows practice that is not needed in Unix is defragmenting the hard drive. When NTFS and FAT write files to the hard drive, they don't always keep pieces (known as blocks) of files together. Therefore, to maintain the performance of the computer, the hard drive needs to be "defragged" every once in a while. This is unnecessary on Unix File systems due to the way it was designed. When ext3 was developed, it was coded so that it would keep blocks of files together or at least near each other. No true defragmenting tools exist for the ext3 file system, but tools for defragmenting will be included with the ext4 file system.

10. Connection of the system to the network

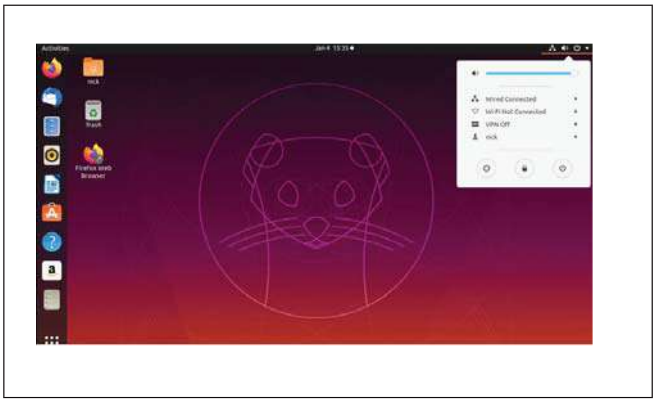
he Ubuntu open-source operating system is the most popular Linux distribution on personal desktop and laptop computers. Just like other operating systems, Ubuntu allows operators of wireless-enabled computers to connect to the internet wirelessly.

How to Connect to a Wireless Network With Ubuntu

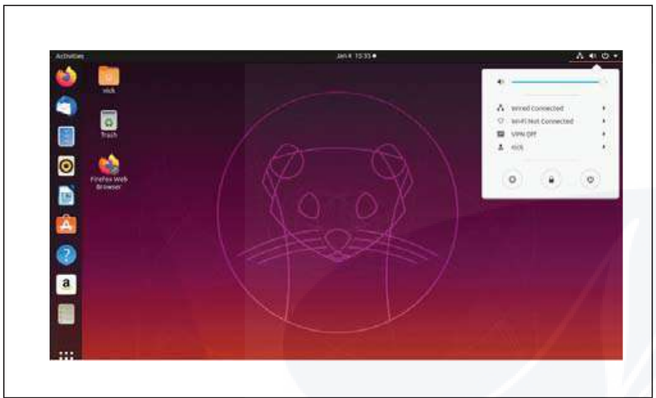
If you have a wireless-enabled computer running the Ubuntu operating system, you can connect to a nearby wireless network to get to the internet. To do this:

1. Open the System Menu on the right side of the top bar.
2. Select Wi-Fi Not Connected to expand the menu.

3. Choose Select Network.



4. Look through the names of the nearby networks. Select the required one and press Connect. If you don't see the name of the network , press More to see additional networks. If you still don't see the network that is required, it may be hidden or may be out of range.



1. Enter the password for the network, and press Connect.

11. System Intialization

11.1 Introduction

The sysVinit and systemdare service managers. OS distributions considered using upstart over init or a combination of upstart and init. It was started as an ambitious project as somewhat of a hybrid of SysVinit and Systemd. Upstart was originally developed for the Ubuntu distribution but is intended to be suitable for deployment in all Linux distributions as a replacement for the venerable System-V init. It was heavily adopted in Ubuntu and partially adopted in Centos 6 and RHEL 6.

11.2 What is upstart?

Like sysvinit and systemd upstart is a program that handles the system initialization process after the kernel is loaded. The system initialization is a critical part of operating system functionality; it controls the operation of every script and service. Upstart, like it's counterparts manages services not only during system boot or shutdown but constitutes management of existing services while the system is running and also the addition or removal of services or scripts from the system initialization process. Upstart is an event-based replacement for the /sbin/init daemon which handles starting of tasks and services during boot, stopping them during the shutdown and supervising them while the system is running.

11.3 Why use upstart over sysvinit?

The SysV boot process is strictly synchronous and serial in nature. This means that services get started or stopped one at a time, blocking future tasks until the current one has completed. If anything in the boot process takes a long time, everything else has to wait. Booting in a linear sequence also takes time, which is especially disadvantageous in a cloud-based environment where fast deployment is essential. Additionally, tasks only run when the init daemon changes state i.e. when the system transitions from one run level to another like a system shutdown or transitioning into single user mode.

Upstart is a new init daemon that allows services to be started in response to events rather than in bulk runlevels.With each job file in the /etc/init directory being responsible for launching a service or for a specific component of system initialization. There is no fixed sequence; instead, each job specifies the events to which it will react.

When an event occurs, Upstart starts all jobs that have been waiting for this event, in parallel.

Based on real-time events instead of a preset list of tasks in sequence, this replacement init daemon handles the starting and stopping of tasks and monitors these processes while the system is running. Upstart could support the most complex of systems and keep everything in check by using a structure of jobs.

The System V init daemon used changes in runlevels to determine when to start and stop processes. Ubuntu systems, which use the Upstart init daemon, have no concept of runlevels. To ease migration from a runlevel-based system to an event-based system, and to provide compatibility with software intended for other distributions, Ubuntu emulates runlevels using Upstart.

11.4Jobs

In the world of Upstart, jobs are working processes, split into task jobs (with a purpose) and service jobs (which can run in the background). A job is a series of instructions that init reads. The instructions typically include a program and the name of an event. The Upstart init daemon runs the program when the event is triggered. You can run and stop a job manually using the initctl start and stop commands, respectively. Jobs are divided into tasks and services. A task is a job that performs its work and returns to a waiting state when it is done. A service is a job that does not normally terminate by itself. The init daemon monitors each service, restarting the service if it fails and killing the service when it is stopped manually or by an event. There are also abstract jobs – processes that run forever until stopped by a user with administrative privileges.

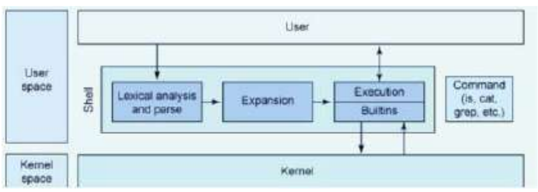
12. Shell Script

12.1 Definition of the Shell

Shell is an interactive environment which provides an interface to an Operating System. It gathers input from the user in a sequence to implement a specific use model.

12.2 Basic Architecture of the Shell

The fundamental architecture on which the hypothetical Shell is based isn't complex. The basic architecture is pretty similar to a pipeline, where input is analyzed and parsed, symbols are expanded. It uses a variety of methods such as brace, tilde, variable and parameter expansion and substitution, and filename generation. Then, commands are executed using shell built-in commands, or external commands.



12.3 Different Types of Shells in Linux

Each of these shells has its own flavour and is meant for people seeking solutions to different problems. You can see how similar or dissimilar these popular shells are from each other through their respective scripts which are written to perform the same task,i.e, ***finding all executable files***.

12.3.1 Bourne-Again Shell

Bash stands for **Bourne Again Shell** and it is the default shell on many Linux distributions today. It is also a sh-compatible shell and offers practical improvements over sh for programming and interactive use which includes:

Command line editing

- Job Control
- Unlimited size command history
- Shell Functions and Aliases
- Unlimited size Indexed arrays
- Integer arithmetic in any base from two to sixty-four
- Code Example

```
#!/bin/bash
#find all executables
count=0
#Test arguments
if [ $# ne 1 ] ; then
echo “Usage is $0 <dir>”
exit 1
fi
#Ensure argument is a directory
if [ ! d “$1” ] ; then
echo “$1 is not a directory.”
exit 1
fi
#Iterate the directory, emit executable files
for filename in “$1”/”
do
if [  x “$filename” ] ; then
echo $filename
count=$((count+1))
fi
done
echo
echo “$count executable files found.”
exit 0
```

Bash is a superset of the Bourne shell, and can run most Bourne scripts without changing them.

12.3.2. TENEX C Shell

Tcsh is enhanced **C** shell, it can be used as an interactive login shell and shell script command processor.

Tcsh has the following features:

- C like syntax
- Command-line editor
- Programmable word and filename completion
- Spelling correction
- Job control

Code Example

```
#!/bin/tcsh
#finding all executable files
set count=0
#Testing arguments
if ($#argv != 1) then
echo “Usage is $0 <dir>”
exit 1
endif
#Ensuring each argument is a directory
if (!  d $1) then
echo “$1 is not a directory.”
exit 1
endif
```

```
#Iterating the directory, printing executable files
foreach filename ($1/”)
if ( x $filename) then
echo $filename
@ count = $count + 1
endif
end

echo
echo “$count executable files found.”
exit 0
```

12.3.3 Korn Shell

Ksh stands for **Korn shell** and was designed and developed by **David G. Korn**. It is a complete, powerful, high-level programming language and also an interactive command language just like many other Unix/GNU Linux shells.

The Korn shell includes features from other shells and provides several more advanced features found in modern scripting languages such as;

- associative arrays
- floating point arithmetic
- job control
- command aliasing
- command history
- supports POSIX standards
- backward compatibility with bash

Code Example

```
#!/usr/bin/ksh
#finding all executable files
count=0
#Testing arguments
if [ $# ne 1 ] ; then
echo “Usage is $0 <dir>”
exit 1
fi
#Ensuring each argument is a directory
if [ ! d “$1” ] ; then
echo “$1 is not a directory.”
exit 1
fi
#Iterating the directory, printing executable files
for filename in “$1”/”
do
if [  x “$filename” ] ; then
echo $filename
count=$((count+1))
fi
done
echo
echo “$count executable files found.”
exit 0
```

12.3.4. Z Shell

Zsh is designed to be interactive and it incorporates many features of other Unix/GNU Linux shells such as bash, tcsh, and ksh.

It is also a powerful scripting language just like the other shells available. Though it has some unique features that include:

- Filename generation
- Startup files
- Login/Logout watching
- Closing comments
- Concept index
- Variable index
- Functions index
- Key index and many more that you can find out in man pages

Code Example

```
#!/bin/zsh
#finding all executable files
set count=0
#Testing arguments
if ($#argv != 1) then
echo “Usage is $0 <dir>”
exit 1
endif
#Ensuring each argument is a directory
if (!  d $1) then
echo “$1 is not a directory.”
exit 1
endif
#Iterating the directory, printing executable files
foreach filename ($1/”)
```

```
if ( x $filename) then
echo $filename
@ count = $count + 1
endif
end
echo
echo "$count executable files found."
exit 0
```

12.3.5. Scheme Shell

The *Scheme shell (scsh)* is an exotic shell that offers a scripting environment using *Scheme*, which is a derivative of the *Lisp language*. The *Pyshell* is an attempt to create a similar script that uses the *Python language*.

Code Example

```
#!/usr/bin/scsh  s
!#
(define argc
(length command line arguments))
(define (write ln x)
(display x)
)
(define (showfilesdir)
(for each write ln
(with cwddir
(filter file executable? (directory files "." #t)))))
(if (not (= argc 1))
(write ln "Usage is fae.scshdir")
(showfiles (argv 1)))
```

13. Database Management systems

MySQL is an open-source database management system, commonly installed as part of the popular LAMP (Linux, Apache, MySQL, PHP/Python/Perl) stack. It uses a relational database and SQL (Structured Query Language) to manage its data.

The short version of the installation is simple: update the package index, install the mysql-server package, and then run the included security and database initialization scripts.

- sudo apt-get update
- sudo apt-get install mysql-server
- sudomysql_secure_installation
- sudomysql_install_db

14. Cloud and Server Configuration for IoT

14.1 Internet of Things (IoT)

Internet of things widely known as IoT is a network of physical objects like devices, vehicles, buildings, etc. embedded with electronics, software, sensors, actuators, and network connectivity that allows the exchange of huge volume of data either through wired or wireless means. How this internet of things work is really simple, this is the concept of basically connecting devices to the Internet and let them communicate with other devices, users etc. This IoT structure basically involves sensors, a gateway device, and the cloud server over which the communication takes place. All the devices communicating in IoT network will talk to each other using the same Internet Protocol (IP).

Figure : communication between sensors, gateway and cloud server

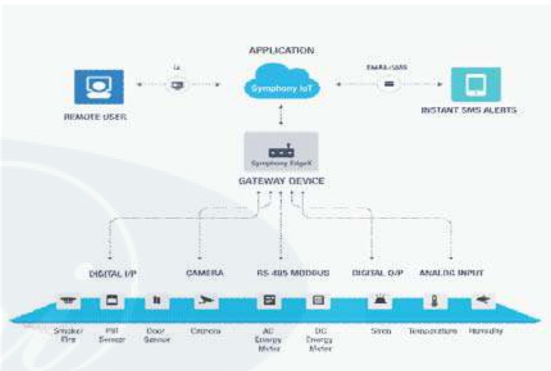


Figure : communication between sensors, gateway and cloud server

14.2 Sensor Deployment

Sensors are deployed at the remote location so that they can detect any changes in the environment and notify the user for the occurred changes. These changes are then captured and pushed to the cloud server. Multi-purpose EdgeX agent bridges the gap between the sensors installed at the remote location and the cloud server. The agent when pushed to the gateway device ensures that the communication establishes between the sensors and the cloud server. The user can then use the cloud server to get the periodical data from the sensors.

14.3 Communication between Sensor and Cloud Server

A sensor is fixed at the selected remote location and is connected to the gateway device. Communication establishes through the gateway device in either WAN mode or in the Ethernet mode. WAN mode helps the gateway device to interact directly with the internet whereas, Ethernet mode helps the gateway device to interact with the locally installed devices. Once the communication mode is set and the cloud server is configured, the communication initiates between the sensors and the cloud server. The established communication allows to monitor the data from any location at your ease.

With Cloud IoT Core, you can control a device by modifying its configuration. A device configuration is an arbitrary, user-defined blob of data. After a configuration has been applied to a device, the device can report its state to Cloud IoT Core.

Device configuration works differently in the MQTT and HTTP bridges.

15. QT based GUI

15.1 Introduction

QT is a free and open-sourcewidget toolkit for creating graphical user interfaces as well as cross-platformapplications that run on various software and hardware platforms such as Linux, Windows, macOS, Android or embedded systems with little or no change in the underlying codebase while still being a native application with native capabilities and speed.

15.2 Purpose

Qt is used for developing graphical user interfaces (GUIs) and multi-platform applications that run on all major desktop platforms and most mobile or embedded platforms. Most GUI programs created with Qt have a native-looking interface, in which case Qt is classified as a *widget toolkit*. Also non-GUI programs can be developed, such as command-line tools and consoles for servers. An example of such a non-GUI program using Qt is the Cutelystweb framework.

15.3 Modules

Qt has an impressive collection of modules, including

- QtCore, a base library that provides containers, thread management, event management, and much more
- QtGui and QtWidgets, a GUI toolkit for Desktop, that provides a lot of graphical components to design applications.
- QtNetwork, that provides a useful set of classes to deal with network communications
- QtWebkit, the webkit engine, that enable the use of web pages and web apps in a Qt application.
- QtSQL, a full featured SQL RDBM abstraction layer extensible with own drivers, support for ODBC, SQLITE, MySQL and PostgreSQL is available out of the box
- QtXML, support for simple XML parsing (SAX) and DOM
- QtXmlPatterns, support for XSLT, XPath, XQuery and Schema validation

16. Web and Application Development tools for IoT

16.1 Introduction

IoT platforms and tools are considered as the most significant component of the IoT ecosystem. Any IoT device permits to connect to other IoT devices and applications to pass on information using standard Internet protocols. IoT platforms fill the gap between the device sensors and data networks. IoT platforms connect the data to the sensor system and give insights using back-end applications to create a sense of the plenty of data developed by the many sensors.

16.2 IoT platforms and Tools

16.2.1 Zetta

Zetta is API based IoT platform based on Node.js. It is considered as a complete toolkit to make HTTP APIs for devices. Zetta combines REST APIs, WebSockets to make data-intensive and real-time applications. The following are some notable features.

- It can run on the cloud, or a PC, or even modest development boards.
- Easy interface and necessary programming to control sensors, actuators, and controllers.
- Allows developers to assemble smartphone apps, device apps, and cloud apps.
- It is developed for data-intensive and real-time applications.
- Turns any machine into an API.

16.2.2 Arduino

Arduino is a simple-to-use IoT platform. It operates through an array of hardware specifications that can be given to interactive electronics. The software of Arduino comes in the plan of the Arduino programming language and Integrated Development Environment (IDE).

16.2.3 Node- RED

Node-RED is a visual tool for lining the Internet of Things, i.e., wiring together hardware devices, APIs, and online services in new ways. Built on Node.js, Node-RED describes itself as “a visual means for wiring the Internet of Things.”

It provides developers to connect devices, services, and APIs using a browser-based flow editor. It can run on Raspberry Pi, and further 60,000 modules are accessible to increase its facilities.

16.2.4 Flutter

Flutter is a programmable processor core for electronics projects, designed for students, and engineers. Flutter’s take to glory is it’s long-range. This Arduino-based board includes a wireless transmitter that can show up to more than a half-mile. Plus, you don’t require a router; flutter boards can interact with each other quickly.

It consists of 256-bit AES encryption, and it's simple to use. Some of the other features are below.

- Fast Performance
- Expressive and Flexible UI
- Native Performance
- Visual finish and functionality of existing widgets.

16.2.5 M2MLabs Mainspring

M2MLabs Mainspring is an application framework for developing a machine to machines (M2M) applications such as remote control, fleet administration, or smart terminal. Its facilities include flexible design of devices, device structure, connection between machines and applications, validation and normalization of data, long-term data repository, and data retrieval functions.

It's based on Java and the Apache Cassandra NoSQL database. M2M applications can be modeled in hours rather than weeks and subsequently passed on to a high-performance execution environment made on top of a standard J2EE server and the highly-scalable Apache Cassandra database.

16.2.6 Things Board

ThingsBoard is for data collection, processing, visualization, and device management. It upholds all standard IoT protocols like CoAP, MQTT, and HTTP as quickly as cloud and on-premise deployments. It builds workflows based on design life cycle events, REST API events, RPC requests.

ThigsBoard features:

- A stable platform that is combining scalability, production, and fault-tolerance.
- Easy control of all connected devices in an exceptionally secure system
- Transforms and normalizes device inputs and facilitates alarms for generating alerts on all telemetry events, restores, and inactivity.
- Enables use-state specific features using customizable rule groups.
- Handles millions of devices at the same time.
- No single moment of failure, as every node in the bundle is exact.
- Multi-tenant installations out-of-the-wrap.
- Thirty highly customized dashboard widgets for successful user access.

12.2.7 Kinoma

Kinoma, a Marvell Semiconductor hardware prototyping platform, involves three different open source projects. Kimona Create is a DIY construction kit for prototyping electronic devices. Kimona Studio is the development environment that functions with Set up and the Kinoma Platform Runtime. Kimona Connect is a free iOS and Android app that links smartphones and stands with IoT devices.

12.2.8 Kaa IoT Platform

Kaa is a production-ready, flexible, multi-purpose middleware platform for establishing end-to-end IoT solutions, connected applications, and smart devices. It gives a comprehensive way of carrying out effective communication, deals with, and interoperation capabilities in connected and intelligent devices.

It mounts from tiny startups to a great enterprise and holds advanced deployment models for multi-cloud IoT solutions. It is primarily based on flexible microservices and readily conforms to virtually any need and application — some other features as below.

- Facilitates cross-device interoperability.
- Performs real-time device control, remote device provisioning, and structure.
- Create cloud services for smart products
- Consists of topic-based warning systems to provide end-users to deliver messages of any predefined format to subscribed endpoints.
- Perform real-time device monitoring
- Manage an infinite quantity of connected devices
- Collect and analyze sensor data

12.2.9 Sitewhere

SiteWhere platform offers the ingestion, repository, processing, and assimilation of device inputs. It runs on Apache Tomcat and provides highly tuned MongoDB and HBase implementations. You can deploy SiteWhere to cloud platforms like AWS, Azure, GCP, or on-premises. It also supports Kubernetes cluster provisioning.

The following are some of the other features.

- Run any estimate of IoT applications on a single SiteWhere instance
- Spring brings the root configuration framework
- Add widgets through self-registration, REST services, or in batches
- InfluxDB for event data storage
- Connect devices with MQTT, Stomp, AMQP and other protocols
- Integrates third-party integration frameworks
- Eclipse Californium for CoAP messaging
- HBase for the non-relational datastore
- Grafana to visualize SiteWhere data

12.2.10 DSA

Distributed Services Architecture (DSA) is for implementing inter-device communication, logic, and efforts at every turn of the IoT infrastructure. It allows cooperation between devices in a distributed manner and sets up a network engineer to share functionality between discrete computing systems.

Node attributes, permission, and links can be managed from DSLinks.

12.2.11 Thinger

Thinger.io provides a scalable cloud base for connecting devices. You can deal with them quickly by running the admin console or combine them into your project logic using their REST API. It supports all types of hackers boards such as Raspberry Pi, Intel Edison, ESP8266.

Thinger can be integrated with IFTT, and it provides real-time data on a beautiful dashboard.

Basic of industrial prtocols modbus RTU, Modbus TCP, DLMS- Client server communication

Objectives: At the end of this lesson you shall be able to
- **to understand the concept of industrial protocols**
- **to understand the working principle of modbus and DLMS communication.**

1.Industrial Protocols

1.1 Introduction

A protocol is a set of rules for communication among networked devices. Modbus communication protocol is a messaging structure developed by Modicon in 1979. It is used to establish a master-slave or client-server communication between intelligent devices. The intelligent devices can be a PLC, HMI, PC, Distributed Control Systems (DCS), Supervisory Control and Data Acquisition Systems (SCADA) etc. Modbus protocol is not industry specific and can be used in a wide variety of industries such as factory automation, building automation, process control, oil & gas, traffic & parking, agriculture & irrigation, water & wastewater, pharmaceutical and medical, material handling etc. Some common protocols used in the industrial arena include:

- Modbus RTU
- EtherNet/IP
- Ethernet TCP/IP
- Modbus TCP/IP
- Profinet

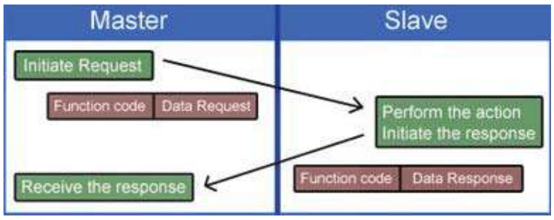
1.2 Modbus RTU

1.2.1 Introduction

Modbus RTU or Modbus over serial – This communication method or interface can be RS-485, RS-232, RS-422 and RS-423. Generally, in this interface, the Modbus devices would require the receive wire (RX), the transmit wire (TX) and the ground wire (GND) to exchange data between the Modbus devices. The interface can be either half duplex or full duplex. Typically, all intelligent devices can be configured for both half duplex and full duplex. Modbus RTU messages are a simple 16-bit structure with a CRC (Cyclic-Redundant Checksum). The simplicity of these messages is to ensure reliability. Due to this simplicity, the basic 16-bit Modbus RTU register structure can be used to pack in floating point, tables, ASCII text, queues, and other unrelated data.

1.2.2 Modbus Communication

The Modbus RTU protocol uses a Master/Slave technique to communicate between devices. Meaning, any application that utilizes the Modbus RTU protocol will have a Modbus Master and at least one Modbus Slave. A Modbus Master is typically a host supervisory computer running software that will communicate with one or more Modbus Slave devices.



Modbus enables Master/Slave communication between devices connected through buses or networks. On the OSI model, Modbus is positioned at level 7. Modbus is intended to be a request/reply protocol and delivers services specified by function codes. The function codes of Modbus are elements of Modbus' request/reply PDUs (Protocol Data Unit).

In order to build the Modbus application data unit, the client must initiate a Modbus transaction. It is the function which informs the server as to which type of action to perform. The format of a request initiated by a Master is established by the Modbus application protocol. The function code field is then coded into one byte. Only codes within the range of 1 through 255 are considered valid, with 128-255 being reserved for exception responses. When the Master sends a message to the Slave, it is the function code field which informs the server of what type of action to perform.

To define multiple actions, some functions will have sub-function codes added to them. For instance, the Master can read the ON/OFF states of a group of discreet outputs or inputs. It could also read/write the data contents of a group of MODBUS registers. When the Master receives the Slave response, the function code field is used by the Slave to indicate either an error-free response or an exception response. The Slave echoes to the request of the initial function code in the case of a normal response.

1.2.3 Modbus RTU Data Representation

The data representation in modbus is simple. The Bit of least importance is sent and received first. All devices within the network must interpret each transmitted byte analogously in this manner.

There are no methods for automated recognition of baud rates. The same baud rate must be utilized by the Slave(s) and Master connected to the bus. No specific baud rate is specified by the Modbus: typical baud rates are 9600 or 19200.

A transmitted Byte is coded as 8 Bit binary value, hexadecimal 0 – 9 and A – F. The least significant Bit is sent and received first.

There are only two data types in Modbus: coils and registers. Coils are simply single bits. The bits can be ON (1) or they can be OFF (0). Some coils represent inputs, meaning they contain the status of some physical discrete input. Or they represent outputs, meaning that they hold the state of some physical discrete output signal. Registers are simply 16-bit unsigned register data. Registers can have a value from 0 to 65535 (0 to FFFF hexadecimal). There is no representation for negative values, no representation for values greater than 65535, and no representation for real data like 200.125.

Registers are grouped into Input Registers and Holding Registers. Like Input Coils, Input Registers report the state of some external input as a value between 0 and 65535. The original intent of an Input Register was to reflect the value of some analog input. It is a digital representation of an analog signal like a voltage or a current. Most Modbus devices today are not I/O devices, and Input Registers simply function identically to Holding Registers.

Holding Registers were originally designed as temporary program storage for devices like Modbus controllers. Today, Holding Registers function as data storage for devices. Modbus RTU packets are only intended to send data; they do not have the capability to send parameters such as point name, resolution, units, etc. If the ability to send such parameters is needed, one should investigate a BACnet, EtherNet/IP, or other modern protocols.

1.2.4 Modbus RTU Address Requirements and Station Identification

Standard Modbus RTU node addresses are 1-255, with 0 being reserved for broadcast messages and write only. However, the 0 address is rarely used since there is no confirmation that the message was properly received at the slave node.RS-485 limits the number of nodes to 32, though some drivers will allow you to extend the amount.

Serial Modbus Slave devices are identified by a station number which precedes the general message structure. Generally, up to 32 stations are supported as that is the limit imposed by most RS485 serial drivers. There is no software limit to the number of stations that could be supported. Valid Slave addresses are assigned in the range of 1 to 255 with station number 0 reserved for broadcast messages, messages processed by all Slaves.

1.2.5 Modbus RTU Data Encoding

An encoding mechanism describes how bit patterns are formed from the control and data values that are encoded into the packet. Both the sender and the receiver must use the same encoding to correctly understand the contents of the data. There are two mechanisms for encoding Modbus messages: ASCII and RTU.

RTU encoding is the much more common encoding mechanism used on Modbus. RTU simply means that values are encoded as standard big-endian binary. That means that in the case of 16-bit values, the Most Significant Byte (MSB) is encoded prior to the Least Significant byte (LSB). An 8-bit value like decimal 41 (29 hex) is encoded simply as 0010 1001. Whereas a 16-bit value like decimal 300 (12C hex) is encoded as 0000 0001 0010 1100. The MSB of 01 is encoded and transmitted prior to the LSB of 2C.

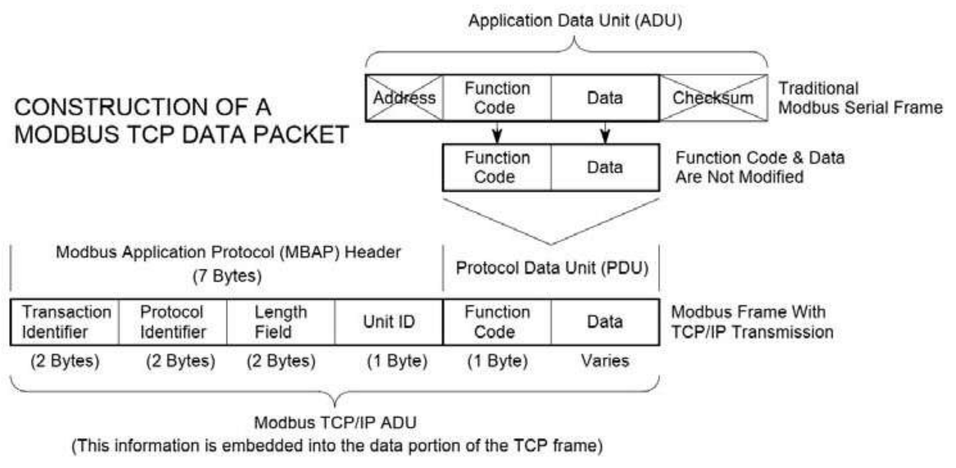
1.2.6 MODBUS RTU Memory Map

Modbus RTU Data Type	Common name	Starting address
Modbus Coils	Bits, binary values, flags	00001
Digital Inputs	Binary inputs	10001
Analog Inputs	Binary inputs	30001
Modbus Registers	Analog values, variables	40001

1.3 Modbus TCP

Modbus TCP/IP (also Modbus-TCP) is simply the Modbus RTU protocol with a TCP interface that runs on Ethernet. The Modbus messaging structure is the application protocol that defines the rules for organizing and interpreting the data independent of the data transmission medium. TCP/IP refers to the Transmission Control Protocol and Internet Protocol, which provides the transmission medium for Modbus TCP/IP messaging. Simply stated, TCP/IP allows blocks of binary data to be exchanged between computers. It is also a world-wide standard that serves as the foundation for the World Wide Web. The primary function of TCP is to ensure that all packets of data are received correctly, while IP makes sure that messages are correctly addressed and routed. Note that the TCP/IP combination is merely a transport protocol, and does not define what the data means or how the data is to be interpreted (this is the job of the application protocol, Modbus in this case). In practice, Modbus TCP embeds a standard Modbus data frame into a TCP frame, without the Modbus checksum, as shown in the following diagram.

The Modbus commands and user data are themselves encapsulated into the data container of a TCP/IP telegram without being modified in any way. However, the Modbus error checking field (checksum) is not used, as the standard Ethernet TCP/IP link layer checksum methods are instead used to guaranty data integrity. Further, the Modbus frame address field is supplanted by the unit identifier in Modbus TCP/IP, and becomes part of the Modbus Application Protocol (MBAP) header.



Modbus TCP frame format (primarily used on Ethernet networks)

Name	Length (bytes)	Function
Transaction identifier	2	For synchronization between messages of server and client
Protocol identifier	2	0 for Modbus/TCP
Length field	2	Number of remaining bytes in this frame
Unit identifier	1	Slave address (255 if not used)
Function code	1	Function codes as in other variants
Data bytes	n	Data as response or commands

Unit identifier is used with Modbus/TCP devices that are composites of several Modbus devices, e.g. on Modbus/TCP to Modbus RTU gateways. In such case, the unit identifier tells the Slave Address of the device behind the gateway. Natively Modbus/TCP-capable devices usually ignore the Unit Identifier. The complete Modbus TCP/IP Application Data Unit is embedded into the data field of a standard TCP frame and sent via TCP to well-known system port 502, which is specifically reserved for Modbus applications. Modbus TCP/IP clients and servers listen and receive Modbus data via port 502.

1.4 DLMS

1.4.1. Introduction

DLMS/COSEM (IEC 62056, EN13757-1) is the global standard for smart energy metering, control and management. It specifies an object-oriented data model, an application layer protocol and media-specific communication profiles.

DLMS/COSEM comprises three key components:

- COSEM - Companion Specification for Energy Metering - the object model capable of describing virtually any application;
- OBIS - Object Identification System, the naming system of the objects; and
- DLMS - Device Language Message Specification - the application layer protocol that turns the information held by the objects into messages.

DLMS/COSEM can be used for all utilities / energy kinds, all market segments, all applications and over virtually any communication media.

1.4.2 DLMS /COSEM application layer services

DLMS stands for Device Language Message Specification

The syntax of the language is specified by the DLMS services.

DLMS/COSEM uses a client-server paradigm where the end devices, typically meters are the servers and the Head End Systems or concentrators are the clients.

The DLMS/COSEM application layer provides:

- the ACSE services to connect the clients and the servers; and

- the xDLMS services to access the data held by the COSEM objects. The xDLMS services are the same for each object; this allows new objects to be added to the model without affecting the application layer.

The application layer also builds the messages (APDUs, Application Protocol Data Units), applies, check and removes cryptographic protection as needed and manages transferring long messages in blocks. The messages can be then transported over virtually any communication media. There are various built-in mechanisms available for optimizing the traffic to the characteristics of the media.

1.4.3 Transport

The application messages can be transported over virtually any communication media

The DLMS/COSEM communication profiles specify, for each communication the protocol stack and the binding of the lower protocol layers to the DLMS/COSEM application layer.

Communication profiles are available for:

- Local ports, PSTN/GSM: with HDLC data link layer RS232 / RS485;
- GPRS;
- IPv6, IPv4, TCP and UDP;
- S-FSK PLC;
- G3-PLC with UDP/ IPv6;
- Prime PLC without IP, with IPv6, IPv4, TCP and UDP;
- Wired and wireless M-Bus;
- Mesh networks with IPv6 and 6LowPAN;

Basic of protocol converters - basics of IOT data acquisition system - Device connectivity over cloud and troubleshooting.

Objectives: At the end of this lesson you shall be able to
- **to understand the concept of protocol converters**
- **to understand the IOT data acquistion system**
- **to set up a device connectivity over cloud and to troubleshoot it.**

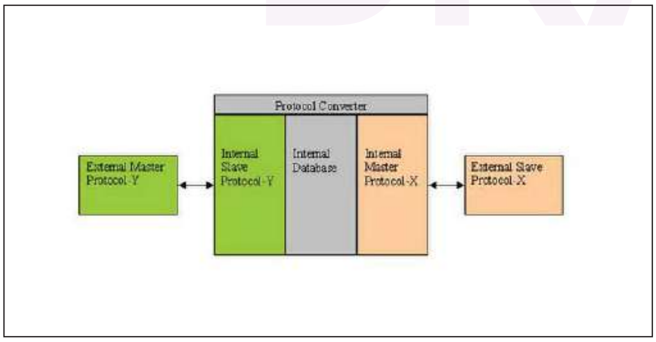
1. Protocol Converter

1.1 Introduction

A Protocol Converter is a device used to convert standard or proprietary protocol of one device to the protocol suitable for the other device or tools to achieve the interoperability. Protocols are software installed on the routers, which convert the data formats, data rate and protocols of one network into the protocols of the network in which data is navigating. There are varieties of protocols used in different fields like power generation, transmission and distribution, oil and gas, automation, utilities, and remote monitoring applications. The major protocol translation messages involve conversion of data messages, events, commands, and time synchronization.

1.2 General Architecture

The general architecture of a protocol converter includes an internal master protocol communicating to the external slave devices and the data collected is used to update the internal database of the converter. When the external master requests for data, the internal slave collects data from the database and send it to the external master. There will be different schemes for handling the spontaneous reporting of events and commands. There can be different physical medium for communication on protocol-X & Y, which include RS-232, RS-485, Ethernet, etc



1.1 Applications

Protocol Converter applications vary from industry to industry. The protocol converter can be a software converter, hardware converter, or an integrated converter depending on the protocols.

- Some of the key applications are:
- Substation Automation
- Building Automation
- Process Automation

2.IoT Data Acquisition System

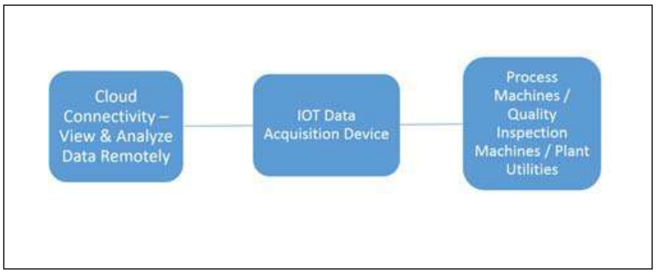
2.1 Introduction

Data acquisition is the sampling of continuous real world information to generate data that can be manipulated by a computer. Acquired data can be displayed, analyzed, and stored on a computer. A PC can be used to provide data acquisition of real world information such as voltage, current, temperature, pressure, or sound. The components of data acquisition systems include appropriate sensors, filters, signal conditioning, data acquisition devices, and application software. Ultimately data analysis can only be as good as the input data, so acquisition is responsible for providing high-quality data.

2.2 IOT – Data Acquisition Device

2.2.1 Overview

- IoT Data Acquisition Device helps to make your machines smarter by gathering and analyzing real time data
- Increased Efficiency & Productivity – Process Data provides valuable information to transform business practices and make real time decisions
- Quality Control & Assurance – Our device helps you to monitor & analyze critical product quality data



2.2.2. Product Features

- Portable & Compact Device – Easily configured & wired with a machine for data acquisition
- Cloud Connectivity – Upload data to amazon web service via wired / wireless internet connectivity
- Access & Analyse machine data remotely (Desktop, Mobile Applications)
- Frontend Client software for monitoring system parameters & real time plots
- Data Analysis Screens – Statistical Process Control Calculations (Cp, Cpk, IMR Chart, Bell Curve)
- Communication Ports – RS232 / RS485 / Ethernet for communication with machines & field instruments
- Analog Input Port for capturing data from process sensors
- Digital Input / Output Ports for discrete machine signals

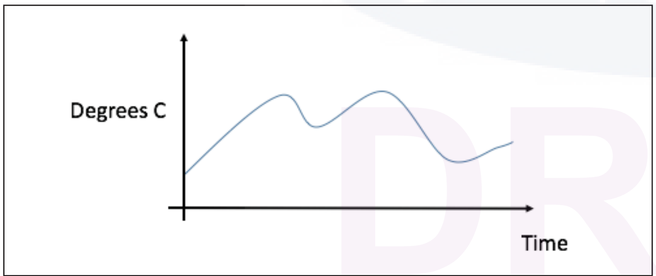
2.3 Data Acquisition Module

2.3.1. Introduction

The role of the Data Acquisition Module is to acquire physical signals from the real world and convert them into digital information that can be manipulated by a computer.

2.3.2 Analog Signal

An analog signal is defined as a continuous signal that varies its amplitude or frequency over time. These variations occur in response to a change of the physical phenomena they are measuring. For example, the image below shows temperature fluctuating over time.



2.3.3 Data Acquisition Process from Project Manager Perspective

The various components focused are:

- What real-world signal do you want to measure?
- Understanding sensors
- Signal conditioning
- Analog-to-Digital conversion work
- Interpretation of data

2.3.3.1 What real-world signal to measure?

The type of physical signals to be measured should be understood before planning for hardware. Examples of physical signals include:

- Temperature
- Sound
- Humidity
- Vibration
- Light
- Pressure

After determining the type of signals the additional parameters has to be considered before working to select the right sensors. Here are some key questions to be answered:

What is the exact signal type to measure?

It's not enough to say to measure "gas". Which type of gas? Oxygen? CO2? What information about the gas do you want to measure? Flow? Temperature? Particles per square inch? Be specific so your engineering team can choose the best sensor for the job.

How fast does the signal change?

Need to measure temperature. Depending on the application, the same physical phenomena (in this case temperature) can change very slowly (i.e. ambient temperature in a room), or can change very fast (i.e. temperature inside an engine).

Understanding how fast your signal changes (rate of change) will help your team select sensors and converters that can keep up with the signal you want to measure.

What is the range of the signal need to measure?

For example, if you are measuring room temperature, then having sensors with a range of 0-40 degrees Celsius should be enough. On the other hand, if you are measuring temperature inside a furnace, then you might needs sensors with a range in the thousands of degrees Celsius. Once again, the more specific you can be, the more you are empowering your engineering team to make the right decisions.

2.3.3.2 Understanding sensors

There are hundreds of sensors out there, which gives you great flexibility to choose the right sensor for the real-world signals to measure. But how do sensors work?

All analog sensors produce an electrical signal (voltage or current) that represents the variations of the real-world signal you want to measure. As the real-world signal varies over time, the sensor will produce an electrical signal that accurately represents those variations.

2.3.3.3. What is signal conditioning?

Each type of sensor produces a different level of voltage or current output. And oftentimes, the output of the sensor is not compatible with the input range required by the analog-to-digital converter (ADC). The device hardware is installed in a place with a lot of electromagnetic noise, and there is a need to clean the signal up before passing it to the ADC.

Signal conditioning refers to the process of manipulating the output of the sensor so it can be consumed by your ADC. The most common forms of signal conditioning are:

- DC offset
- Amplification
- Attenuation
- Filtering

2.3.3.4. Analog-to-digital conversion (ADC)

The device hardware needs to digitize the signal coming from the sensors before that data can be used by a computer. This process is call analog-to-digital conversion.

An analog-to-digital converter (ADC) is a piece of hardware (usually a chip) that digitizes a signal by constantly taking individual samples of that signal.

The key parameters to consider in an analog-to-digital converter are sample rate and resolution.

Sample rate

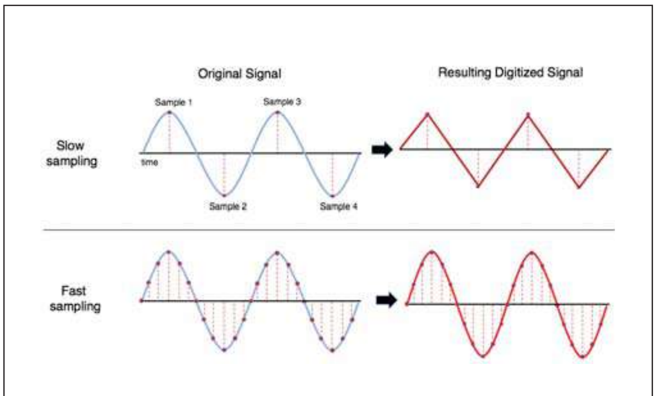
Sample rate refers to how often is the ADC taking samples of the analog signal. To accurately reproduce the frequency content of an analog signal, the ADC needs to sample at least twice as fast as the signal's highest frequency. This is based on the Nyquist frequency.

To reproduce not only the frequency content, but also the signal's shape and amplitude in the time domain, then the ADC needs to sample at a much higher rate. The engineering rule of thumb is to sample 10x the frequency of this original signal. That means that if the signal has a frequency of 100 Hz (100 cycles per second), then the converter needs to sample at 1,000 Hz.

The images below show the result of slow vs fast sampling of an analog signal.

Resolution

Resolution refers to how granular the accuracy to be. Resolution is specified by the number of bits the ADC uses to represent each sample. So for example, if you have a 2 bit ADC, 4 bit, 8 bit, 24 bit, etc. A 2 bit ADC could register 4 values (2^2 = 4). A 4 bit ADC can measure 16 values (2^4 = 16) and so on. The more bits per sample, the better your measurement's resolution will be.



2.3.5 Interpretation

Once the signal is digitized, the need to apply some transformation to make sense of that data. Remember that the output of a sensor is just a number that correlates to the changes of the physical phenomena they are measuring.

In temperature example, a thermocouple doesn't return values in degrees Celsius or Fahrenheit. It just returns a number that you need to convert to a unit that makes sense for humans to use. This process is called interpretation. Each sensor is different. The manufacturer of the sensor will provide you with a formula to convert the raw value into a usable unit. During the interpretation process, it is also common to attach metadata to your sensor measurement. Some metadata might include:

- Timestamp (added to each ADC sample to create a time series)
- Sensor ID
- Location ID
- Device ID

3.Device Connectivity over cloud and troubleshooting

3.1 Troubleshooting connection issues getting to Device Cloud from the WebUI:

3.1.1 Is your device configured to connect to a Device Cloud server?

To verify that you are configured for the Device Cloud server you intend to connect to:

1. Go to the WebUI under Configuration > Device Cloud > Device-Initiated Connection

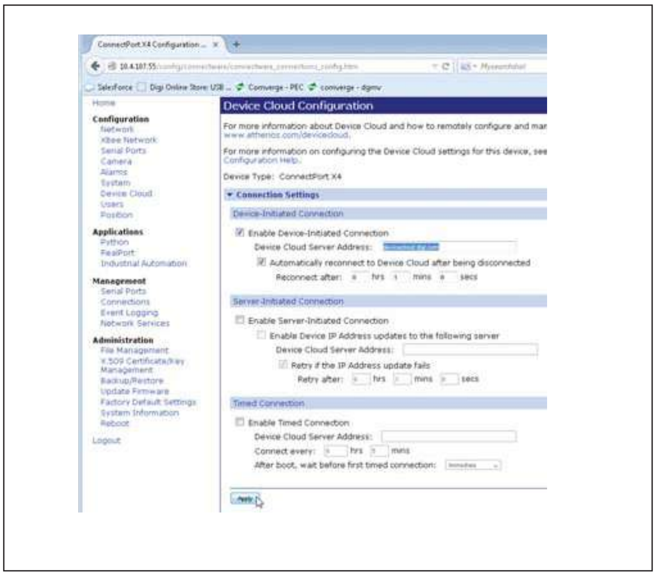
2. Check the Device Cloud Server Address and ensure the address configured is correct

(Example: devicecloud.digi.com or devicecloud-uk.digi.com).

3. Ensure the "Automatically reconnect" box is checked (use the device's default value, unless having need to change it).

4. If any changes in steps 2 or 3, use the Apply button to save the changes.

3.1.2 Device Cloud Configuration page example:



3.1.3 Is your device connected to the (correct) Device Cloud server?

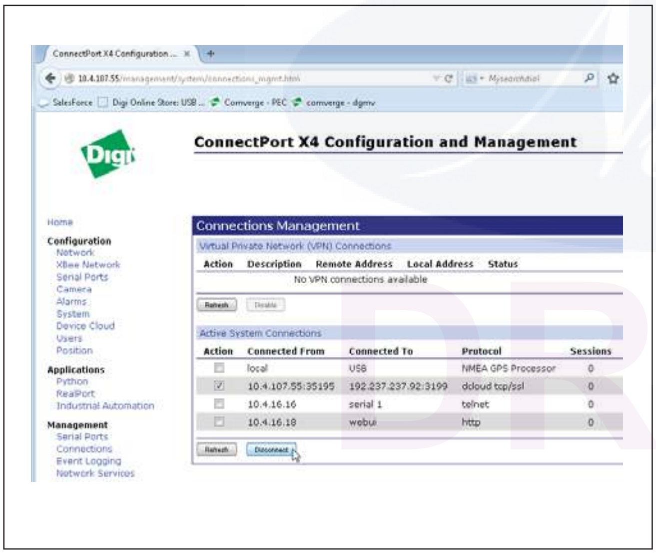
If Device Cloud Server Address configuration (step 2 above) is changed and the device was configured for a different Device Cloud Server Address previously, you will need to either disconnect the current Device Cloud connection to the previous server, or reboot your device.

3.1.4 To disconnect an active Device Cloud server connection:

1. Go to Management > Connections.
2. Under "Active System Connections", look for a connection with protocol listed as "dcloud tcp/ssl". This is the device's active connection to the Device Cloud server.
3. Check the action box next to that protocol, then click the "Disconnect" button.
4. Click the Refresh button occasionally, until you can verify that your device has established connection to the newly configured Device Cloud server.

(Not all Digi devices have a Management > Connections interface available from the WebUI. If this is true for your device, reboot or power-cycle the device to create a Device Cloud connection.)

3.1.5 Connections Management page example



If any of the settings is not changed on the Device Cloud Configuration page, the device is hopefully connected to Device Cloud right now. The Management > Connections is also useful to help diagnose whether a Device Cloud connection is being established at all. In the Connections Management page example shown above, an IP address:port number is listed for both Connected ends of the dcloud tcp/ssl entry under Active System Connections. Since the edp (easy device protocol) connection can only be established to a Device Cloud server, we know its a valid Device Cloud connection, even though we don't know which server its connected to yet (see the next section).

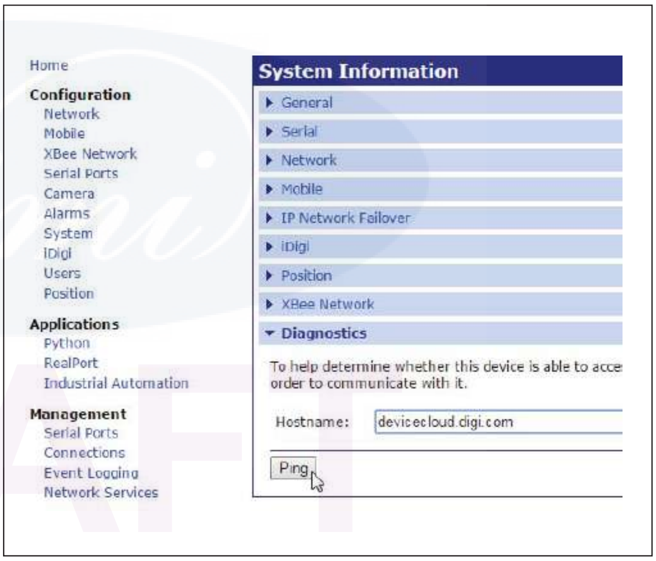
If the dcloud tcp/ssl entry shows waiting to connect, it means a Device Cloud connection hasn't been established. If you hit refresh a few times, notice the wait time shown will only increment as high as the time specified in the Reconnect after value specified under the Automatically reconnect box of the Device Cloud Configuration page. If the timer doesn't stop incrementing, verify the Automatically reconnect box was checked.

If the dcloud tcp/ssl entry changes to connecting server, it means the device is negotiating an edp socket connection with Device Cloud, and should show a valid Active System Connection soon. If the status returns to waiting to connect, something is getting in the way of the connection as its being established, and you'll need to continue troubleshooting.

3.1.6 Can you ping the server from your Digi device?

The Administration > System Information > Diagnostics section of the WebUI offers a basic PING capability. From this field, you'll want to verify that you can PING the host name of the Device Cloud server (i.e devicecloud.digi.com or devicecloud-uk.digi.com), as well as its IP address.

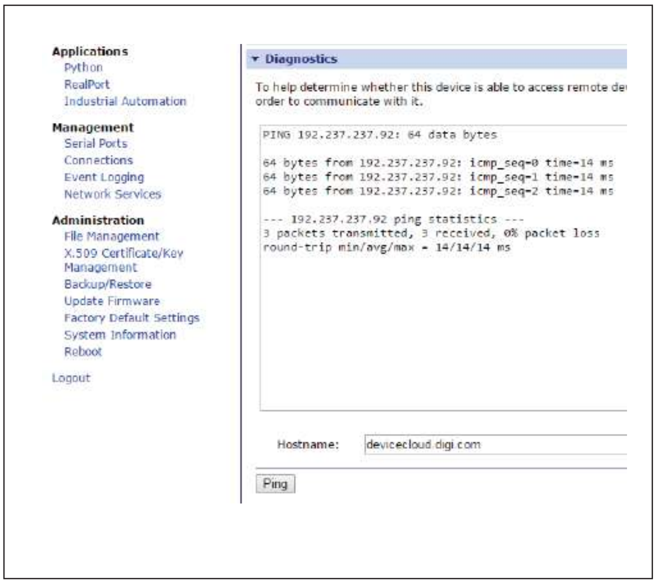
Diagnostics page:



3.1.7 Pinging Device Cloud hostname from the Diagnostics page:

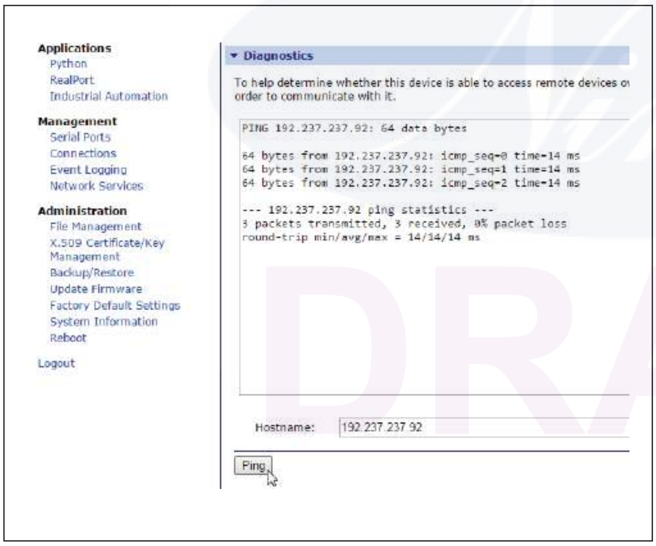
If the DNS name is pinged of the Device Cloud server successfully, all is set, as that indicates proper DNS name resolution.

If pinging the Device Cloud server name didn't work, the IP address of the Device Cloud server can be determined by doing an nslookup of the Device Cloud server name from any PC or server which supports the command.



3.1.8 Pinging the Device Cloud IP address from Diagnostic Page:

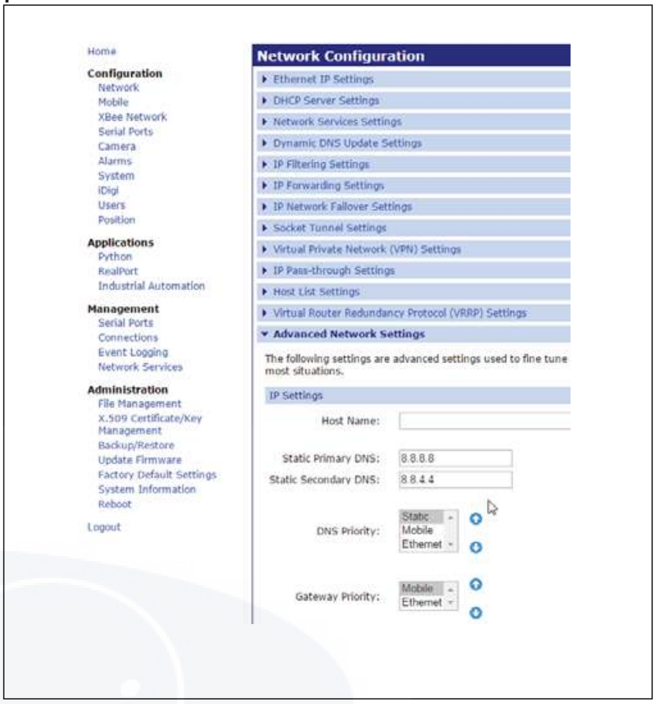
If the host name is not pinged, but can PING the IP address of the Device Cloud server, it indicates that IP routing is OK. Verify whether the device can resolve DNS at all by attempting to PING a known server, such as google.com. If pinging google.com also fails, but pinging IP addresses outside of your immediate LAN is working fine, it may mean that DNS name resolution isn't working properly.



One possibility is that to add a Static DNS address (such as 8.8.8.8 or 8.8.4.4) to your Digi Device. In the WebUI of the Digi go to Configuration> Network Configuration > Advanced Network Settings. Then add at least a static Primary DNS server address in "Static Primary DNS".

3.1.9 Statically Assigning a DNS Address:

If unable to PING the Device Cloud server name, google.com, or any IP address outside of your LAN (Local Area Network), try pinging the IP address of your LAN Router (typically the Default Gateway of your network). If you can successfully PING the LAN Router, it's likely that outbound connections are being blocked by a firewall, or your network settings aren't fully configured on your device .



GUI based IOT cloud configurationutility, IOT device and its parameter configuration, cloud device management and troubleshooting

Objectives: At the end of this lesson you shall be able to
- **to realize the uses of estabilishing IOT cloud**
- **to establish IOT device configuration in the cloud**
- **to handle trouble shooting and understanding device management.**

1. GUI based IoT cloud configuration utility

1.1 Introduction

IoT in cloud offers public cloud services can easily help the IoT area, by providing third party access to the infrastructure. Hence, the integration can help IoT data or computational components operating over IoT devices.

1.2 Benefits

Increased Scalability: IoT devices need a lot of storage to share information for valuable purposes.

Increased Performance: The large amounts of data produced by IoT devices need extreme performance to interact and connect with one another. IoT in cloud provides the connectivity which is necessary to share information between the devices and make meaning from it at a fast pace.

Pay-as-you-go: Internet Cloud Computing infrastructures help IoT to give meaning to the greater amount of data generated. Users have no worry of buying greater or less storage. They can easily scale the storage as the data generated increases and pay for the amount of storage they consume with Internet Cloud Computing.

2. IoT Device and its parameter configuration

2.1 Introduction

Google Cloud Internet of Things (IoT) Core is a fully managed service for securely connecting and managing IoT devices, from a few to millions. Ingest data from connected devices and build rich applications that integrate with the other big data services of Google Cloud Platform.

2.2 Configuring Devices

A device configuration is an arbitrary, user-defined blob of data. After a configuration has been applied to a device, the device can report its state to Cloud IoT Core. Device configuration works differently in the MQTT and HTTP bridges.

2.2.1MQTT

Devices using MQTT can subscribe to a special MQTT topic for configuration updates:

/devices/{device-id}/config

When a device subscribes to the configuration topic, the MQTT bridge responds with an MQTT SUBACK message, which contains the granted QoS for the config topic (0 or 1), or 128 if an error occurred.

After initially subscribing, the device receives the latest configuration in a message's payload, and will receive additional configuration updates as they are pushed to Cloud IoT Core.

The following samples illustrate how to retrieve configuration updates on a device over MQTT:

```
static MqttCallback mCallback;

/** Create a Cloud IoT Core JWT for the given project id, signed with the given RSA key. */

private static String createJwtRsa(String projectId, String privateKeyFile)

throws NoSuchAlgorithmException, IOException, InvalidKeySpecException {

DateTime now = new DateTime();

// Create a JWT to authenticate this device. The device will be disconnected after the token

// expires, and will have to reconnect with a new token. The audience field should always be set

// to the GCP project id.

JwtBuilder jwtBuilder =

Jwts.builder()

        .setIssuedAt(now.toDate())

        .setExpiration(now.plusMinutes(20).toDate())

        .setAudience(projectId);

byte[] keyBytes = Files.readAllBytes(Paths.get(privateKeyFile));

PKCS8EncodedKeySpec spec = new PKCS8EncodedKeySpec(keyBytes);

KeyFactory kf = KeyFactory.getInstance("RSA");

return jwtBuilder.signWith(SignatureAlgorithm.RS256, kf.generatePrivate(spec)).compact();

}
```

```
/** Create a Cloud IoT Core JWT for the given project id, signed with the given ES key. */
private static String createJwtEs(String projectId, String privateKeyFile)
    throws NoSuchAlgorithmException, IOException, InvalidKeySpecException {
  DateTime now = new DateTime();
  // Create a JWT to authenticate this device. The device will be disconnected after the token
  // expires, and will have to reconnect with a new token. The audience field should always be set
  // to the GCP project id.
  JwtBuilder jwtBuilder =
      Jwts.builder()
          .setIssuedAt(now.toDate())
          .setExpiration(now.plusMinutes(20).toDate())
          .setAudience(projectId);
byte[] keyBytes = Files.readAllBytes(Paths.get(privateKeyFile));
PKCS8EncodedKeySpec spec = new PKCS8EncodedKeySpec(keyBytes);
KeyFactory kf = KeyFactory.getInstance("EC");
return jwtBuilder.signWith(SignatureAlgorithm.ES256, kf.generatePrivate(spec)).compact();
}
/** Connects the gateway to the MQTT bridge. */
public static MqttClient startMqtt(
    String mqttBridgeHostname,
    int mqttBridgePort,
    String projectId,
    String cloudRegion,
    String registryId,
    String gatewayId,
    String privateKeyFile,
    String algorithm)
    throws NoSuchAlgorithmException, IOException, MqttException, InterruptedException,
        InvalidKeySpecException {
// Build the connection string for Google's Cloud IoT Core MQTT server. Only SSL
  // connections are accepted. For server authentication, the JVM's root certificates
  // are used.
  final String mqttServerAddress = String.format("ssl://%s:%s", mqttBridgeHostname, mqttBridgePort);

  // Create our MQTT client. The mqttClientId is a unique string that identifies this device. For
  // Google Cloud IoT Core, it must be in the format below.
  final String mqttClientId =
      String.format(
          "projects/%s/locations/%s/registries/%s/devices/%s",
          projectId, cloudRegion, registryId, gatewayId);
MqttConnectOptions connectOptions = new MqttConnectOptions();
  // Note that the Google Cloud IoT Core only supports MQTT 3.1.1, and Paho requires that we
  // explictly set this. If you don't set MQTT version, the server will immediately close its
  // connection to your device.
connectOptions.setMqttVersion(MqttConnectOptions.MQTT_VERSION_3_1_1);
Properties sslProps = new Properties();
 sslProps.setProperty("com.ibm.ssl.protocol", "TLSv1.2");
 connectOptions.setSSLProperties(sslProps);

  // With Google Cloud IoT Core, the username field is ignored, however it must be set for the
  // Paho client library to send the password field. The password field is used to transmit a JWT
  // to authorize the device.
 connectOptions.setUserName("unused");

 DateTime iat = new DateTime();
 if (algorithm.equals("RS256")) {
   connectOptions.setPassword(createJwtRsa(projectId, privateKeyFile).toCharArray());
 } else if (algorithm.equals("ES256")) {
   connectOptions.setPassword(createJwtEs(projectId, privateKeyFile).toCharArray());
 } else {
   throw new IllegalArgumentException(
       "Invalid algorithm " + algorithm + ". Should be one of 'RS256' or 'ES256'.");
 }

 System.out.println(String.format(mqttClientId));
```

```
// Create a client, and connect to the Google MQTT bridge.
MqttClient client = new MqttClient(mqttServerAddress, mqttClientId, new MemoryPersistence());


// Both connect and publish operations may fail. If they do, allow retries but with an
// exponential backoff time period.
long initialConnectIntervalMillis = 500L;
long maxConnectIntervalMillis = 6000L;
long maxConnectRetryTimeElapsedMillis = 900000L;
float intervalMultiplier = 1.5f;


long retryIntervalMs = initialConnectIntervalMillis;
long totalRetryTimeMs = 0;


while (!client.isConnected() && totalRetryTimeMs < maxConnectRetryTimeElapsedMillis) {
  try {
    client.connect(connectOptions);
  } catch (MqttException e) {
    int reason = e.getReasonCode();


    // If the connection is lost or if the server cannot be connected, allow retries, but with
    // exponential backoff.
    System.out.println("An error occurred: " + e.getMessage());
    if (reason == MqttException.REASON_CODE_CONNECTION_LOST
        || reason == MqttException.REASON_CODE_SERVER_CONNECT_ERROR) {
      System.out.println("Retrying in " + retryIntervalMs / 1000.0 + " seconds.");
      Thread.sleep(retryIntervalMs);
      totalRetryTimeMs += retryIntervalMs;
      retryIntervalMs *= intervalMultiplier;
      if (retryIntervalMs > maxConnectIntervalMillis) {
        retryIntervalMs = maxConnectIntervalMillis;
      }
    } else {
      throw e;
    }
  }
}
attachCallback(client, gatewayId);


// The topic gateways receive error updates on. QoS must be 0.
String errorTopic = String.format("/devices/%s/errors", gatewayId);
System.out.println(String.format("Listening on %s", errorTopic));


client.subscribe(errorTopic, 0);


return client;
}


public static void sendDataFromDevice(
  MqttClient client, String deviceId, String messageType, String data) throws MqttException {
  if (!messageType.equals("events") && !messageType.equals("state")) {
    System.err.println("Invalid message type, must ether be 'state' or events'");
    return;
  }
  final String dataTopic = String.format("/devices/%s/%s", deviceId, messageType);
  MqttMessage message = new MqttMessage(data.getBytes());
  message.setQos(1);
  client.publish(dataTopic, message);
  System.out.println("Data sent");
}


/** Sends data on behalf of a bound device using the Gateway. */
public static void sendDataFromBoundDevice(
  String mqttBridgeHostname,
  short mqttBridgePort,
  String projectId,
  String cloudRegion,
  String registryName,
  String gatewayId,
  String privateKeyFile,
  String algorithm,
  String deviceId,
```

```
    String messageType,
    String telemetryData)
        throws MqttException, IOException, InvalidKeySpecException, InterruptedException,
      NoSuchAlgorithmException {
  MqttClient client =
     startMqtt(
        mqttBridgeHostname,
        mqttBridgePort,
        projectId,
        cloudRegion,
        registryName,
        gatewayId,
        privateKeyFile,
        algorithm);
  attachDeviceToGateway(client, deviceId);
  sendDataFromDevice(client, deviceId, messageType, telemetryData);
  detachDeviceFromGateway(client, deviceId);
}

public static void listenForConfigMessages(
    String mqttBridgeHostname,
    short mqttBridgePort,
    String projectId,
    String cloudRegion,
    String registryName,
    String gatewayId,
    String privateKeyFile,
    String algorithm,
    String deviceId)
        throws MqttException, IOException, InvalidKeySpecException, InterruptedException,
      NoSuchAlgorithmException {
  // Connect the Gateway
  MqttClient client =
     startMqtt(
        mqttBridgeHostname,
        mqttBridgePort,
        projectId,
        cloudRegion,
        registryName,
        gatewayId,
        privateKeyFile,
        algorithm);
  // Connect the bound device and listen for configuration messages.
  attachDeviceToGateway(client, deviceId);
  attachCallback(client, deviceId);

  detachDeviceFromGateway(client, deviceId);
}

public static void attachDeviceToGateway(MqttClient client, String deviceId)
    throws MqttException {
  final String attachTopic = String.format("/devices/%s/attach", deviceId);
   System.out.println(String.format("Attaching: %s", attachTopic));
  String attachPayload = "{}";
      MqttMessage message = new MqttMessage(attachPayload.getBytes());
  message.setQos(1);
  client.publish(attachTopic, message);
}

/** Detaches a bound device from the Gateway. */
public static void detachDeviceFromGateway(MqttClient client, String deviceId)
```

```
throws MqttException {
final String detachTopic = String.format("/devices/%s/detach", deviceId);
System.out.println(String.format("Detaching: %s", detachTopic));
String attachPayload = "{}";
MqttMessage message = new MqttMessage(attachPayload.getBytes());
message.setQos(1);
client.publish(detachTopic, message);
}

public static void mqttDeviceDemo(MqttExampleOptions options)
throws NoSuchAlgorithmException, IOException, InvalidKeySpecException, MqttException,
InterruptedException {
// Build the connection string for Google's Cloud IoT Core MQTT server. Only SSL
// connections are accepted. For server authentication, the JVM's root certificates
// are used.
final String mqttServerAddress =
String.format("ssl://%s:%s", options.mqttBridgeHostname, options.mqttBridgePort);

// Create our MQTT client. The mqttClientId is a unique string that identifies this device. For
// Google Cloud IoT Core, it must be in the format below.
final String mqttClientId =
String.format(
"projects/%s/locations/%s/registries/%s/devices/%s",
options.projectId, options.cloudRegion, options.registryId, options.deviceId);

MqttConnectOptions connectOptions = new MqttConnectOptions();
// Note that the Google Cloud IoT Core only supports MQTT 3.1.1, and Paho requires that we
// explictly set this. If you don't set MQTT version, the server will immediately close its
// connection to your device.
connectOptions.setMqttVersion(MqttConnectOptions.MQTT_VERSION_3_1_1);

Properties sslProps = new Properties();
sslProps.setProperty("com.ibm.ssl.protocol", "TLSv1.2");
connectOptions.setSSLProperties(sslProps);

// With Google Cloud IoT Core, the username field is ignored, however it must be set for the
// Paho client library to send the password field. The password field is used to transmit a JWT
// to authorize the device.
connectOptions.setUserName("unused");

DateTime iat = new DateTime();
if (options.algorithm.equals("RS256")) {
connectOptions.setPassword(
createJwtRsa(options.projectId, options.privateKeyFile).toCharArray());
} else if (options.algorithm.equals("ES256")) {
connectOptions.setPassword(
createJwtEs(options.projectId, options.privateKeyFile).toCharArray());
} else {
throw new IllegalArgumentException(
"Invalid algorithm " + options.algorithm + ". Should be one of 'RS256' or 'ES256'.");
}

// Create a client, and connect to the Google MQTT bridge.
MqttClient client = new MqttClient(mqttServerAddress, mqttClientId, new MemoryPersistence());

// Both connect and publish operations may fail. If they do, allow retries but with an
// exponential backoff time period.
long initialConnectIntervalMillis = 500L;
long maxConnectIntervalMillis = 6000L;
long maxConnectRetryTimeElapsedMillis = 900000L;
float intervalMultiplier = 1.5f;
long retryIntervalMs = initialConnectIntervalMillis;
```

```
long totalRetryTimeMs = 0;

while (!client.isConnected() && totalRetryTimeMs < maxConnectRetryTimeElapsedMillis) {
  try {
    client.connect(connectOptions);
  } catch (MqttException e) {
    int reason = e.getReasonCode();

    // If the connection is lost or if the server cannot be connected, allow retries, but with
    // exponential backoff.
    System.out.println("An error occurred: " + e.getMessage());
    if (reason == MqttException.REASON_CODE_CONNECTION_LOST
        || reason == MqttException.REASON_CODE_SERVER_CONNECT_ERROR) {
      System.out.println("Retrying in " + retryIntervalMs / 1000.0 + " seconds.");
      Thread.sleep(retryIntervalMs);
      totalRetryTimeMs += retryIntervalMs;
      retryIntervalMs *= intervalMultiplier;
      if (retryIntervalMs > maxConnectIntervalMillis) {
        retryIntervalMs = maxConnectIntervalMillis;
      }
    } else {
      throw e;
    }
  }
}

attachCallback(client, options.deviceId);

// Publish to the events or state topic based on the flag.
String subTopic = options.messageType.equals("event") ? "events" : options.messageType;

// The MQTT topic that this device will publish telemetry data to. The MQTT topic name is
// required to be in the format below. Note that this is not the same as the device registry's
// Cloud Pub/Sub topic.
String mqttTopic = String.format("/devices/%s/%s", options.deviceId, subTopic);

// Publish numMessages messages to the MQTT bridge, at a rate of 1 per second.
for (int i = 1; i <= options.numMessages; ++i) {
  String payload = String.format("%s/%s-payload-%d", options.registryId, options.deviceId, i);
  System.out.format(
      "Publishing %s message %d/%d: '%s'\n",
      options.messageType, i, options.numMessages, payload);

  // Refresh the connection credentials before the JWT expires.
  long secsSinceRefresh = ((new DateTime()).getMillis() - iat.getMillis()) / 1000;
  if (secsSinceRefresh > (options.tokenExpMins * 60)) {
    System.out.format("\tRefreshing token after: %d seconds\n", secsSinceRefresh);
    iat = new DateTime();
    if (options.algorithm.equals("RS256")) {
      connectOptions.setPassword(
          createJwtRsa(options.projectId, options.privateKeyFile).toCharArray());
    } else if (options.algorithm.equals("ES256")) {
      connectOptions.setPassword(
          createJwtEs(options.projectId, options.privateKeyFile).toCharArray());
    } else {
      throw new IllegalArgumentException(
          "Invalid algorithm " + options.algorithm + ". Should be one of 'RS256' or 'ES256'.");
    }
    client.disconnect();
    client.connect();
    attachCallback(client, options.deviceId);
  }

  // Publish "payload" to the MQTT topic. qos=1 means at least once delivery. Cloud IoT Core
  // also supports qos=0 for at most once delivery.
  MqttMessage message = new MqttMessage(payload.getBytes());
  message.setQos(1);
```

```
client.publish(mqttTopic, message);

if (options.messageType.equals("event")) {
  // Send telemetry events every second
  Thread.sleep(1000);
 } else {
  // Note: Update Device state less frequently than with telemetry events
  Thread.sleep(5000);
 }
}

// Wait for commands to arrive for about two minutes.
for (int i = 1; i <= options.waitTime; ++i) {
  System.out.print(".");
 Thread.sleep(1000);
}
System.out.println("");

// Disconnect the client if still connected, and finish the run.
if (client.isConnected()) {
  client.disconnect();
}

 System.out.println("Finished loop successfully. Goodbye!");
client.close();
}

/** Attaches the callback used when configuration changes occur. */
public static void attachCallback(MqttClient client, String deviceId) throws MqttException {
 mCallback =
   new MqttCallback() {
    @Override
    public void connectionLost(Throwable cause) {
      // Do nothing...
     }

    @Override
    public void messageArrived(String topic, MqttMessage message) throws Exception {
     String payload = new String(message.getPayload());
      System.out.println("Payload : " + payload);
       // TODO: Insert your parsing / handling of the configuration message here.
     }

    @Override
     public void deliveryComplete(IMqttDeliveryToken token) {
       // Do nothing;
     }
   };

 String commandTopic = String.format("/devices/%s/commands/#", deviceId);
 System.out.println(String.format("Listening on %s", commandTopic));

 String configTopic = String.format("/devices/%s/config", deviceId);
 System.out.println(String.format("Listening on %s", configTopic));

 client.subscribe(configTopic, 1);
 client.subscribe(commandTopic, 1);
 client.setCallback(mCallback);
}
```

2.2.2 HTTP

If HTTP bridge is used, devices must explicitly request new configurations.

The following samples illustrate how to retrieve configuration updates on a device over HTTP:

```
/** Publish an event or state message using Cloud IoT Core via the HTTP API. */
public static void getConfig(String urlPath, String token, String projectId,
  String cloudRegion, String registryId, String deviceId, String version)
  throws UnsupportedEncodingException, IOException, JSONException, ProtocolException {
 // Build the resource path of the device that is going to be authenticated.
 String devicePath =
   String.format(
```

```
        "projects/%s/locations/%s/registries/%s/devices/%s",
        projectId, cloudRegion, registryId, deviceId);
  urlPath = urlPath + devicePath + "/config?local_version=" + version;


  HttpRequestFactory requestFactory =
       HTTP_TRANSPORT.createRequestFactory(new HttpRequestInitializer() {
       @Override
       public void initialize(HttpRequest request) {
                 request.setParser(new JsonObjectParser(JSON_FACTORY));
        }
      });


  final HttpRequest req = requestFactory.buildGetRequest(new GenericUrl(urlPath));
  HttpHeaders heads = new HttpHeaders();


  heads.setAuthorization(String.format("Bearer %s", token));
  heads.setContentType("application/json; charset=UTF-8");
  heads.setCacheControl("no-cache");


  req.setHeaders(heads);
  ExponentialBackOff backoff = new ExponentialBackOff.Builder()
     .setInitialIntervalMillis(500)
     .setMaxElapsedTimeMillis(900000)
     .setMaxIntervalMillis(6000)
      .setMultiplier(1.5)
     .setRandomizationFactor(0.5)
      .build();
  req.setUnsuccessfulResponseHandler(new HttpBackOffUnsuccessfulResponseHandler(backoff));
  HttpResponse res = req.execute();
  System.out.println(res.getStatusCode());
  System.out.println(res.getStatusMessage());
  InputStream in = res.getContent();


  System.out.println(CharStreams.toString(new InputStreamReader(in, Charsets.UTF_8)));
}
```

2.3 Updating and reverting device configuration

To update and revert device configuration using Cloud Platform Console, the Cloud IoT Core API, or gcloud.

To update the device configuration:

1. Go to the Registries page in Cloud Console.
2. Click the ID of the registry that contains the device.
3. In the registry menu on the left, click Devices.
4. Click the ID of the device whose configuration you want to update.
5. At the top of the page, click Update config.
6. Select a format for the configuration and paste the data in the Configuration box.
7. Click Send to device.

To revert the device configuration to a previous version:

1. Go to the Registries page in Cloud Console.
2. Click the ID of the registry that contains the device whose configuration you want to revert.
3. In the registry menu on the left, click Devices.
4. Click the ID of the device whose configuration you want to revert.
5. Click Configuration & state history. Use the checkboxes to display configuration history, state history, or both. By default, both are shown.
   - o A green checkmark indicates that the device has acknowledged the configuration (MQTT only).
   - o A yellow warning symbol indicates that the device has not yet acknowledged the configuration (MQTT only).
   - o Click a row to get the full configuration or state data in JSON, as well as the timestamp and version.
6. Click Compare to compare the configuration data with the state data. This view can help you debug configurations and, if you are using MQTT, make sure devices have acknowledged specific configuration versions. (The HTTP bridge does not support acknowledgment of configurations.)
7. Click the version you want to revert to.

   To see a text version of the configuration details, select Text in the Format list.
8. Click Revert, ensure you've selected the correct version, then click Revert.

2.4 Reviewing device configuration

You can review the last 10 versions of a device configuration using Cloud Platform Console, the API, or gcloud.

1. Go to the Registries page in Cloud Console.
2. Click the ID of the registry that contains the device whose configuration you want to update.

3. In the registry menu on the left, click Devices.

4. Click the ID of the device whose configuration you want to update.

5. Click Configuration & state history. Use the checkboxes to display configuration history, state history, or both. By default, both are shown.

o A green checkmark indicates that the device has acknowledged the configuration (MQTT only).

o A yellow warning symbol indicates that the device has not yet acknowledged the configuration (MQTT only).

o Click a row to get the full configuration or state data in JSON, as well as the timestamp and version.

6. Click Compare to compare the configuration data with the state data. This view can help you debug configurations and, if you are using MQTT, make sure devices have acknowledged specific configuration versions. (The HTTP bridge does not support acknowledgment of configurations.)

3.Cloud Device management and troubleshooting

3.1 Device management

Secure device connection and management

Cloud IoT Core is a fully managed service that allows you to easily and securely connect, manage, and ingest data from millions of globally dispersed devices. Cloud IoT Core, in combination with other services on Cloud IoT platform, provides a complete solution for collecting, processing, analyzing, and visualizing IoT data in real time to support improved operational efficiency.

3.2 Troubleshooting

This describes common issues encountered when using Cloud IoT Core.

· If the device has trouble establishing a TLS connection to the Cloud IoT Core MQTT bridge, your environment may need the root certificate. To install Google's root certificate from the Google Internet Authority site.

3.2.1 My device is unable to connect to the MQTT bridge

The device tries to connect to the MQTT bridge, but the connection is unsuccessful. Unfortunately, the MQTT protocol does not allow for robust error reporting, so these issues can be tricky to debug.

· Verify that you are able to connect via SSL to the MQTT bridge. Many corporate firewalls block port 8883. You can work with your internal IT team to allow access to port 8883, or you can use port 443 instead. Run one of the following commands (depending on the port you're using) to test the TLS connection to the MQTT bridge.

· openssl s_client -connect mqtt.googleapis.com:8883

openssl s_client -connect mqtt.googleapis.com:443

· If the connection to the MQTT endpoint is successful, this command prints certificate chain and server certificate information. It will stay connected and wait for input. This test confirms that you are able to establish a TLS connection to Cloud IoT Core.

Note: Make sure you're using TLS version 1.2 or higher. Cloud IoT Core does not support TLS 1.1 or other versions lower than 1.2.

· Verify that you have Google's root certificates installed. You can download them from the Google Internet Authority site.

· Use gcloud to check errors and verify that your devices and registries exist. Trying to connect with an invalid device ID will cause the connection to be closed immediately.

· gcloud iot registries describe *REGISTRY_ID* \

· —project=*PROJECT_ID* \

· —region=*REGION*

gcloud iot devices describe *DEVICE_ID* \

—project=*PROJECT_ID* \

—region=*REGION* \

—registry=*REGISTRY_ID*

· The devices describe command may show additional error messages that can be used to help debug.

· Verify that your device's credentials are not expired, using the devices describe command. If the credentials have no expiration set, they will never expire.

· Verify that your device's clock is accurate. Your device's clock determines when to connect to the MQTT client and publish sensor data, so all of the devices in the network must be synchronized with the MQTT server. Clients can use the Google Public NTP Server to synchronize device clocks with Coordinated Universal Time (UTC).

3.2.2 My device is disconnected from the MQTT bridge

The device is able to connect to the MQTT bridge, but is either disconnected immediately or disconnected unexpectedly. Note that very occasional disconnects are expected as servers are updated and load balanced.

· Check the most recent error status of the device. Use the gcloud command below to review the most recent error status and message for a device. Be sure to note the timestamp; this field is not cleared and may refer to an earlier error.

gcloud iot devices describe *DEVICE_ID* \

—project=*PROJECT_ID* \

—region=*REGION* \

—registry=*REGISTRY_ID*•

o The error code number refers to a Google RPC error code.

· Run the steps in the preceding section to ensure the device is able to connect.

· If the device disconnects immediately after connecting, verify that your MQTT client library is using MQTT 3.1.1. Many libraries default to MQTT 3.1, which is not supported by Cloud IoT Core and will cause the device to be disconnected immediately. The version is typically set in the MQTT library's client options when first connecting.

o For example, if you are using the Paho Java client, you will have to call connectOptions.setMqttVersion(MqttConnectOptions.MQTT_VERSION_3_1_1);

· Check the exp claim on the JWT that you use to authenticate your device. After your JWT expires, the device will be disconnected and will have to reconnect. This is expected behavior; your device should create a new JWT and reconnect.

· The MQTT bridge allows only a single connection for a given device ID. If a second device connects with the ID of a device that is already connected, the older device connection will be closed automatically.

· Verify that your device is heartbeating frequently enough. MQTT client libraries allow the user to specify a heartbeat_interval, and your device will be disconnected if the MQTT bridge does not receive a message from the device in 1.5x that amount of time. Many client libraries will automatically send an empty message if no other messages have been sent (an MQTT PINGREQ message); however, your client library may not do this automatically. In addition, you can try increasing the heartbeat_interval in the MQTT client config to ensure that your device is able to keep up.

3.2.3 I'm not receiving telemetry data on Cloud Pub/Sub

Your device is connected and publishing messages to the MQTT bridge; however, you are not receiving them in the Cloud Pub/Sub topic. This usually means Cloud Pub/Sub is misconfigured or out of quota.

· Use the preceding sections to verify that your device is able to connect and is not being disconnected. Client libraries provide connection and disconnection callbacks; use these to ensure that your device is successfully connecting.

· On the IAM page in Google Cloud Console, verify that the role Cloud IoT Core Service Agent appears in the Members list for the relevant project service account. (Look for the project service account that ends in @gcp-sa-cloudiot.iam.gserviceaccount.com.)

If the Cloud IoT Core Service Agent role does not appear in the Members list, use gcloud to add the cloudiot.serviceAgent role to the relevant project service account. This role includes permission to publish to Pub/Sub topics.

To find the *PROJECT_ID* and *PROJECT_NUMBER*, refer to this help article.

gcloud projects add-iam-policy-binding *PROJECT_ID* \

—member=serviceAccount:service-*PROJECT_NUMBER*@gcp-sa-cloudiot.iam.gserviceaccount.com \

—role=roles/cloudiot.serviceAgent

? Verify that the topics configured for your registry are correct:

gcloud iot registries describe *REGISTRY_ID* \

—project=*PROJECT_ID* \

—region=*REGION*

Verify that you have created a subscription for your topics for device telemetry. Cloud Pub/Sub will persist a message until all subscriptions have acknowledged it, but if there are no subscribers, your message will not be persisted.

To list subscriptions:

gcloud pubsub topics list-subscriptions \

projects/my-iot-project/topics/*TOPIC_NAME*

To create a subscription for a topic:

gcloud pubsub subscriptions create \

projects/my-iot-project/subscriptions/*SUBSCRIPTION_NAME* \

—topic *TOPIC_NAME*

Check whether you are able to pull messages from your subscription via gcloud. If you are able to pull them but are not receiving them in your Pub/Sub client software, your client software may be misconfigured.

gcloud pubsub subscriptions pull \

projects/my-iot-project/subscriptions/*SUBSCRIPTION_NAME*

· If you configured your device registry to have multiple Pub/Sub topics, verify that the following are true:

o The MQTT or HTTP subfolder to which you're publishing telemetry data has a matching Pub/Sub topic

o The device registry has a default Pub/Sub topic

The default Pub/Sub topic will be used for published telemetry events that don't have a subfolder or if the specified subfolder doesn't have a matching topic. If you don't select a default Pub/Sub topic, these telemetry events will be lost.

Add a default Pub/Sub topic when creating a device registry. To can add one using Cloud Console, the gcloud iot registries update command, or the DeviceRegistry patch method. To make the new Pub/Sub topic the default for the device registry, don't specify a subfolder when you add the topic.

3.2.4 I’m receiving old telemetry data from Cloud Pub/Sub

To receive telemetry events from Cloud Pub/Sub; however, your subscriber is receiving old events. This happens when Cloud Pub/Sub builds up a backlog. Cloud Pub/Sub guarantees that it will deliver each message at least once to each subscription for a topic, and if subscribers aren’t consuming messages or acknowledging them, they will be redelivered. This can happen if your subscriber is not running, or is processing messages too slowly.

· Verify that your Cloud Pub/Sub subscriber is acknowledging the messages it has processed.

· If your subscriber has fallen behind, you can clear the backlog by deleting the subscriber and re-creating it.

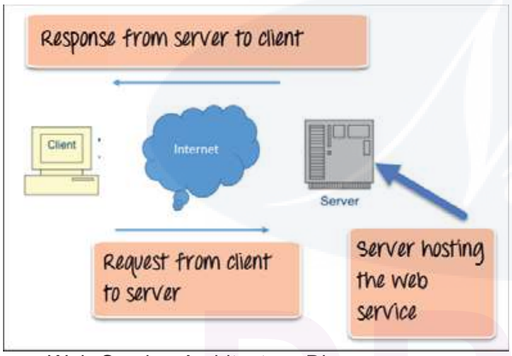
Usage of web services/ web API development of sample web application. Generate and export of reports user access and rights management

Objectives: At the end of this lesson you shall be able to
- **to understand the usage of web services**
- **to develop a sample web page**
- **to set access rights for the users.**

1. Usage of Web Services

Web service is a standardized medium to propagate communication between the client and server applications on the World Wide Web. A web service is a software module which is designed to perform a certain set of tasks.

- The web services can be searched for over the network and can also be invoked accordingly.
- When invoked the web service would be able to provide functionality to the client which invokes that web service.Web Service Architecture Diagram



Web Service Architecture Diagram

The above diagram shows a very simplistic view of how a web service would actually work. The client would invoke a series of web service calls via requests to a server which would host the actual web service. These requests are made through what is known as remote procedure calls. Remote Procedure Calls(RPC) are calls made to methods which are hosted by the relevant web service.

The main component of a web service is the data which is transferred between the client and the server, and that is XML. XML (Extensible markup language) is a counterpart to HTML and easy to understand the intermediate language that is understood by many programming languages. So when applications talk to each other, they actually talk in XML. This provides a common platform for application developed in various programming languages to talk to each other.

Web services use something known as SOAP (Simple Object Access Protocol) for sending the XML data between applications. The data is sent over normal HTTP. The data which is sent from the web service to the application is called a SOAP message. The SOAP message is nothing but an XML document. Since the document is written in XML, the client application calling the web service can be written in any programming language.

1. Web API Development of Sample Web Application

1.1 Introduction

Web API is an application programming interface (API) that is used to enable communication or interaction with software components with each other. ASP.NET Web API is a framework that makes it easy to build HTTP Service that reaches a broad range of clients, including browsers and mobile devices. Using ASP.NET, web API can enable communicating by different devices from the same database.

2.2 Uses of Web API

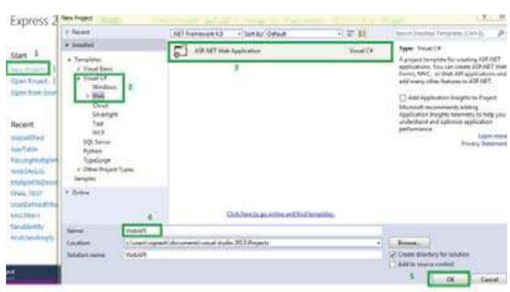
- It is used to access service data in web applications as well as many mobile apps and other external devices.
- It is used to create RESTful web services. REST stands for Representational State Transfer, which is an architectural style for networked hypermedia applications.
- It is primarily used to build Web Services that are lightweight, maintainable, and scalable, and support limited bandwidth.
- It is used to create a simple HTTP Web Service. It supports XML, JSON, and other data formats.

2.3 Creating Web API

To create a simple Web API using ASP.NET MVC, C#, and Visual Studio.

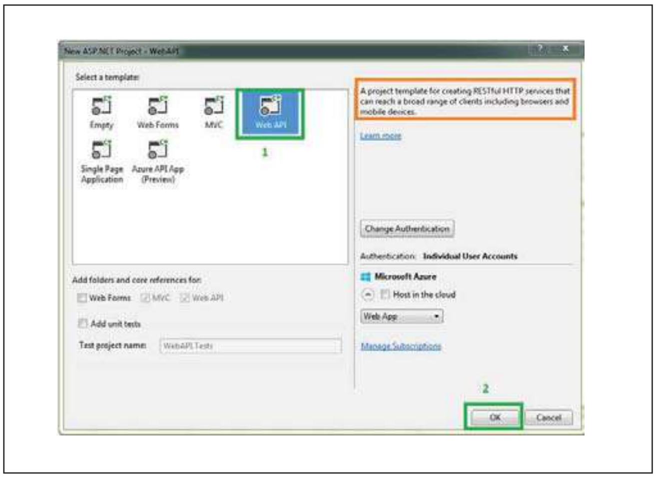
Step 1. Create ASP.NET Web Application in Visual Studio

Open Visual Studio and open a new project. Select Visual C# >> Web >> ASP.NET Web Application. After selecting all, give the project name and click OK.



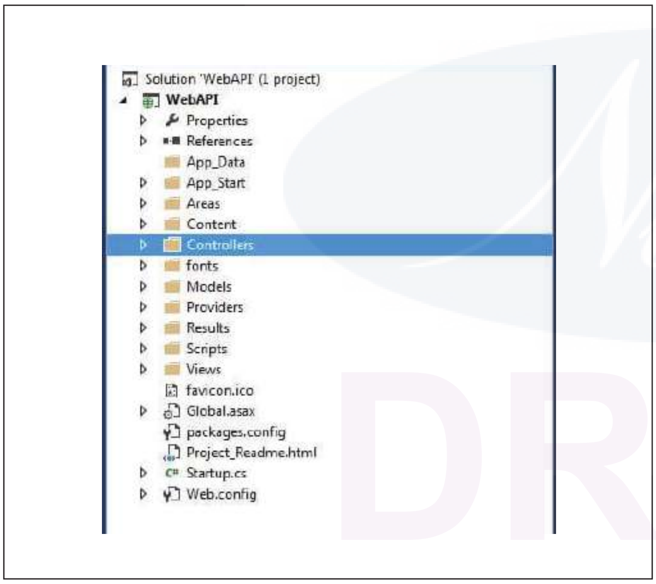
Step 2. Select Web API Template

Select Web API in the template window. After selecting Web API, we can see some messages on the right side in the template window. Now, click the OK button.



Step 3. Review Project Files

Now, in Visual Studio with project files listed under the project name. We can see in the Solution Explorer on the right side with all the important files and folders like MVC.

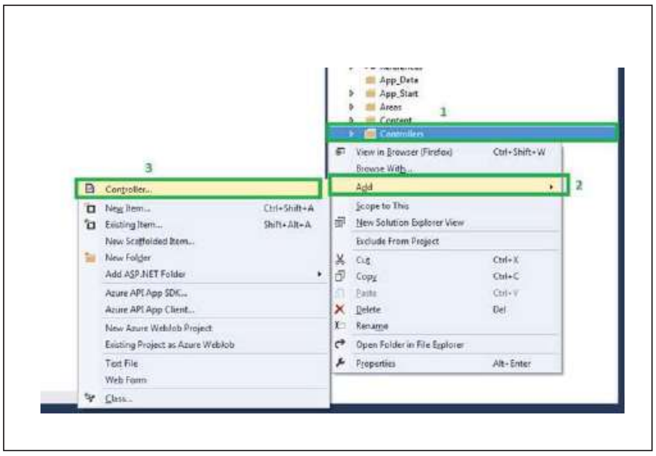


Step 4. Add a Controller

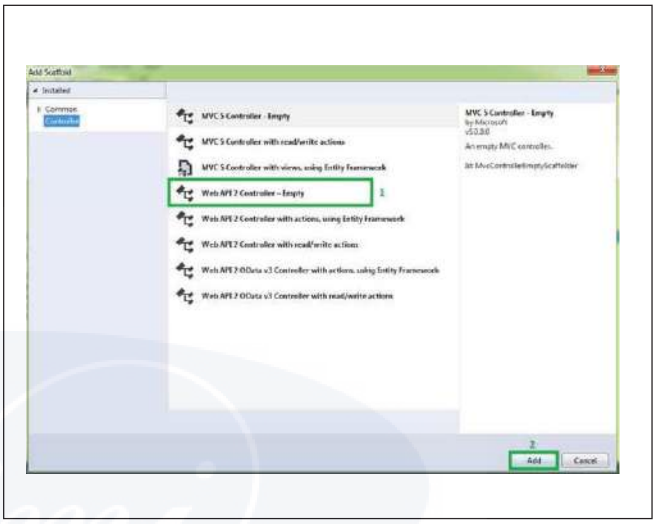
Now, go to Controller and expand the controller. Now, we can see "ValuesController.cs". It is the main class for Web API. This controller is created by default. If we need a new controller or one with a different name, we can create that in the following way.

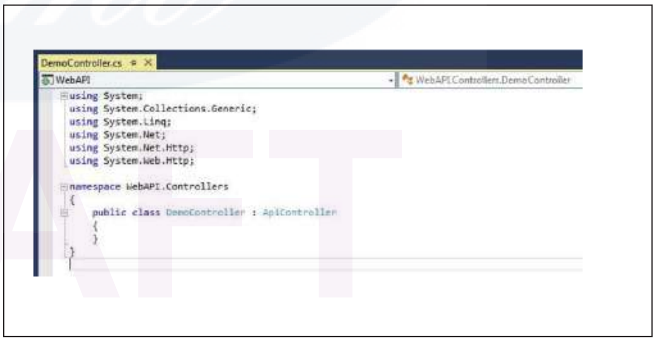
Select and right-click Controllers >>Add >> Controller, just like the below screen.

Select "Web API 2 Controller - Empty" and click the "Add" button from the "Add Scaffold" window.



Here is what the screen looks like.





In Web API, the Controller is inherited by the "ApiController" abstract class. It is very important and basic for Web APIs. The namespace for this class is "System.Web.Http".

Here is what the screen looks like.

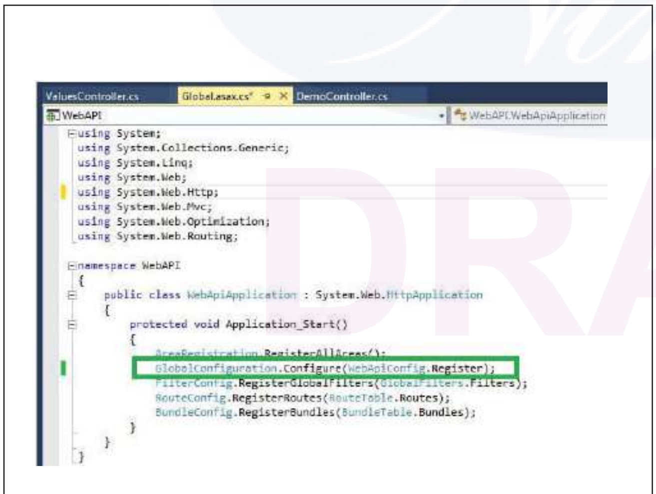
Step 5. Add Controller Method

Now, create a simple method in Controller, build the application, and run it finally. In web API, we use the method name as "Get ()". We can use any other method name. Let's write the below code in the Demo controller.

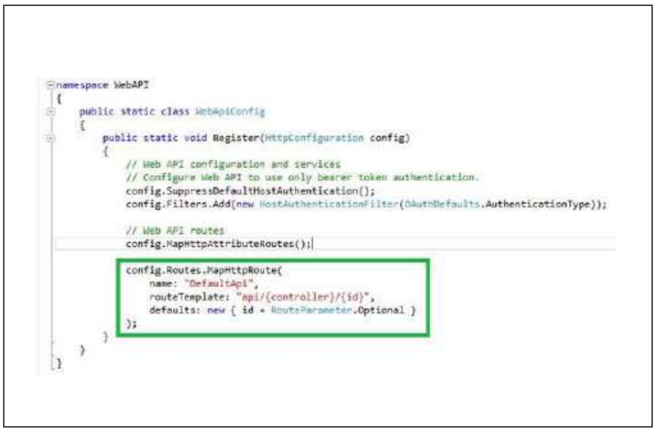
```
using System.Net;
using System.Net.Http;
using System.Web.Http;
namespace WebAPI.Controllers {
    public class DemoController: ApiController {
        public string Get() {
            return "Welcome To Web API";
        }
        public List < string > Get(int Id) {
            return new List < string > {
                "Data1",
                "Data2"
            };
        }
    }
}
```

URL Format to run Web API

To run the Web API "api/Controller_Name" URL format. For example, in MVC we define URL format using "RouteConfig" class and "RegisterRoutes" static methods. The same for Web API; "WebApiConfig" and "Register" static method are used. Go to the "Global.aspx" file we can see in detail.



Define the Web API URL format using "GlobalConfiguration" and "Configure" static method. We are passing the "Register" method from the "WebApiConfig" class as an argument into the "Configure" method. If we go to the "WebApiConfig" class, we can see Web API routes.



Step 6

Now, build the project and run the above-mentioned URL format. Our Controller name is "Demo", so will run the following

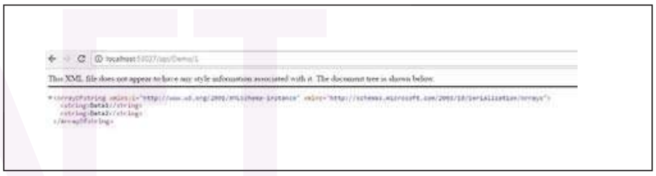
URL."http://localhost:53027/api/Demo".

Web API has returned a result in XML or JSON format. Our output looks like below.

run *http://localhost:53027/api/Demo,* it will call "Get ()". Since there is no parameter, the output looks like below.

Run *http://localhost:53027/api/Demo/1,* it will call "Get (int id)". When there is a parameter in the method, the output looks like below.

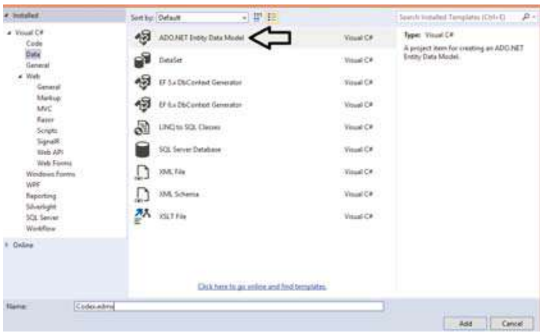
Outputs return as XML format.



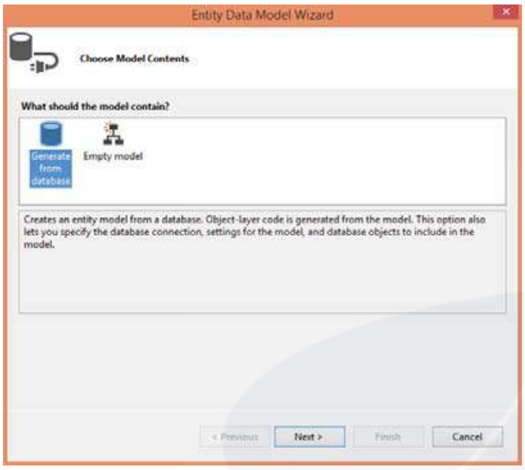
1.Generation and Export of Reports

To generate Crystal Report in a Web API call. The first step here is to create a new Web API project. After creating the project add a new controller as "DetailsController".

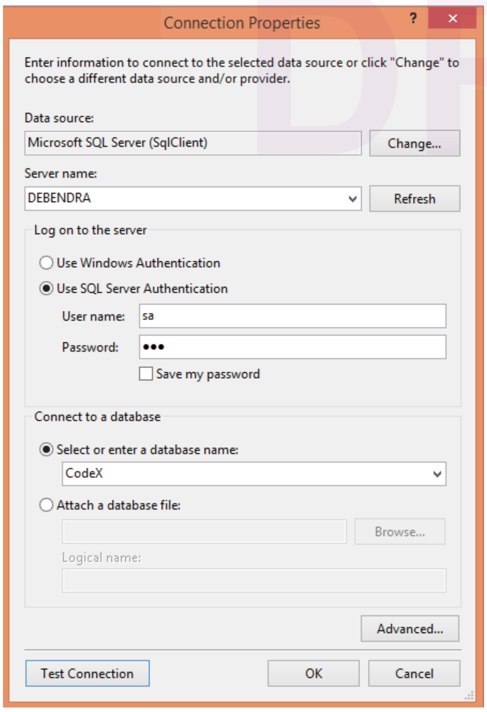
After adding this click on the Project, Add New Item, then ADO.NET Entity DataModel as in the following:



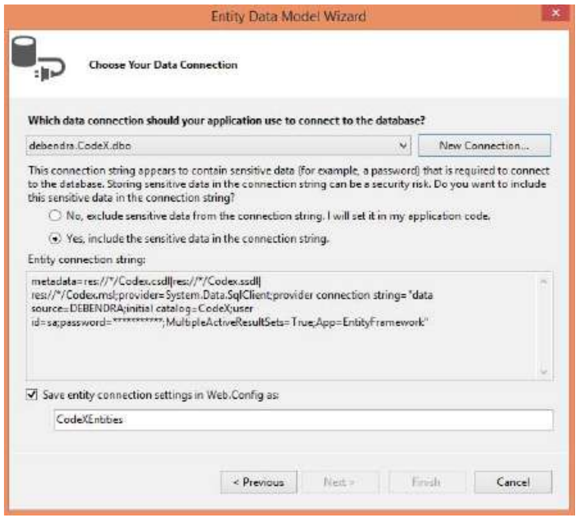
Now choose “Generate From database” and click Next.



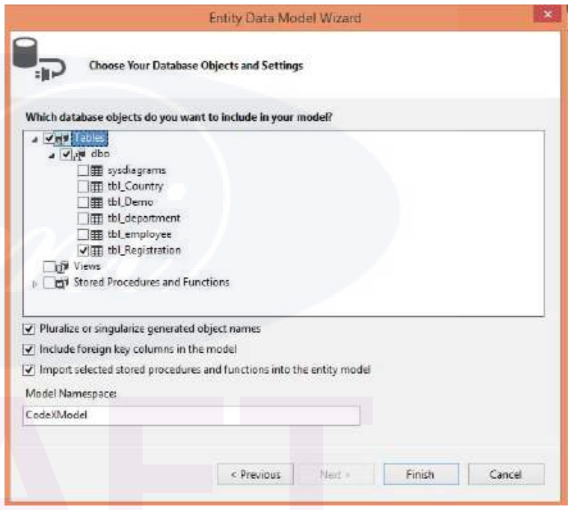
Provide all the Connection string details and test the connection.



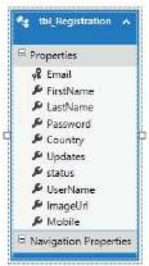
Choose Yes to include this connection string in Web.config.



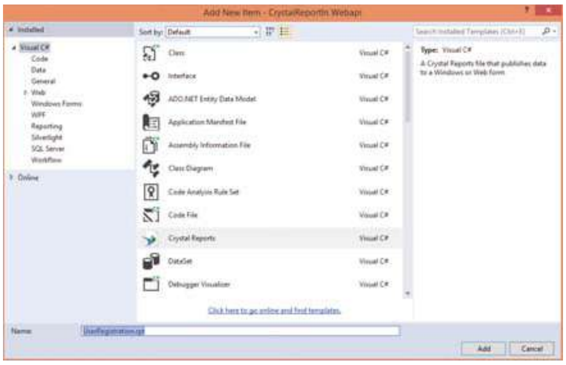
Choose the table on which you want to work.



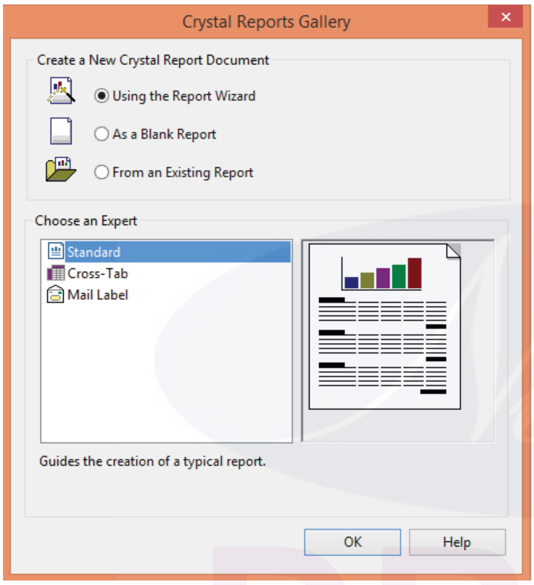
Click Finish and check your table



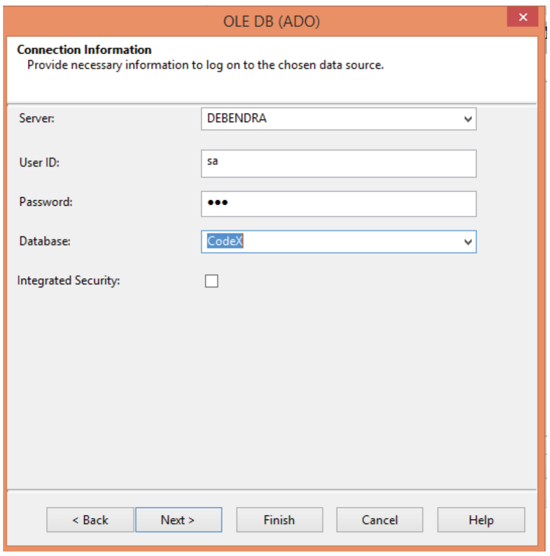
Now add the Crystal Reports as follows.



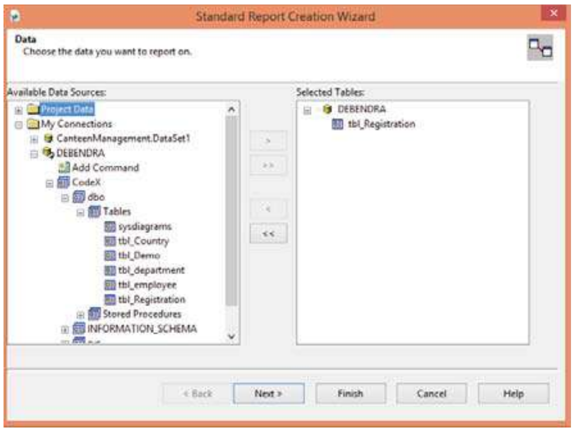
Choose the report as Standard,



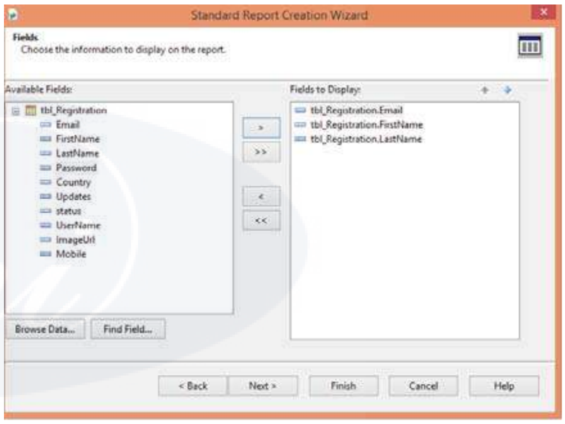
Click on OLEDB (ADO) and provide the credentials



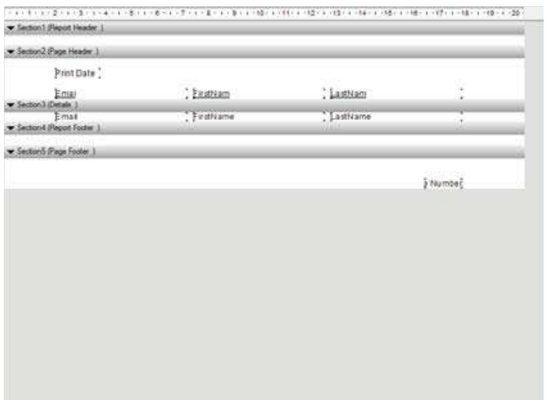
Select the table you want to show data in Crystal Report. Click Next to display all fields of that table.



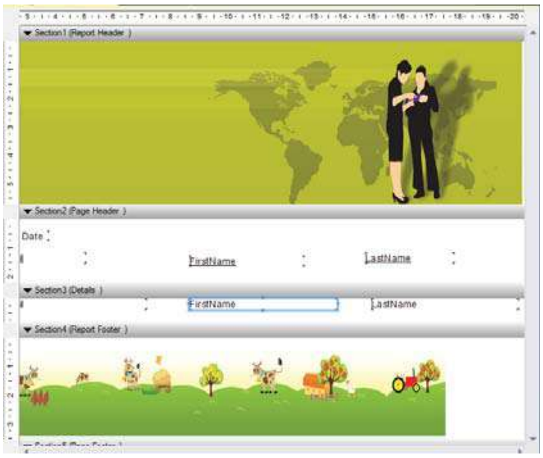
Now just select the field you want to display in the report.



After that Click "Finish" to complete the process and it will show the following report structure.



Designed the report by providing Header and Footer image as shown below.



Now Create a model as “Users” like this in Model Folder.

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Web;

namespace CrystalReportIn_Webapi.Models
{
    public class Users
    {
        public string FirstName { get; set; }
        public string LastName { get; set; }
        public string Email { get; set; }

    }
}
```

Now go to the “DetailsController”, create a method and write the following code.

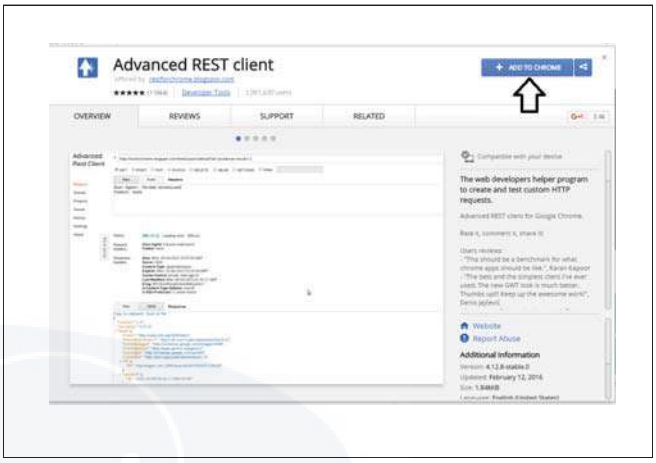
```
namespace CrystalReportIn_Webapi.Controllers
{
    [RoutePrefix(“api/Details”)]
    public class DetailsController : ApiController
    {
        CodeXEntities cX = new CodeXEntities();

        [AllowAnonymous]
        [Route(“Report/SendReport”)]
        [HttpPost]
        public HttpResponseMessage ExportReport(Users user)
        {
            string EmailTosend = WebUtility.UrlDecode(user.Email);
            List<Users> model = new List<Users>();
            var data = cX.tbl_Registration;
            var rd = new ReportDocument();

            foreach (var details in data)
            {
                Users obj = new Users();
                obj.Email = details.Email;
                obj.FirstName = details.FirstName;
                obj.LastName = details.LastName;
                model.Add(obj);

            }

            rd.Load(Path.Combine(System.Web.Hosting.HostingEnvironment.MapPath(“~/Reports”), ”UserRegistration.rpt”));
            ConnectionInfo connectInfo = new ConnectionInfo()
            {
                ServerName = ”Debendra”,
                DatabaseName = ”CodeX”,
                UserID = ”sa”,
                Password = ”123"
            };
            rd.SetDatabaseLogon(“sa”, ”123");
            foreach (Table tbl in rd.Database.Tables)
            {
```

```
                tbl.LogOnInfo.ConnectionInfo = connectInfo;
                tbl.ApplyLogOnInfo(tbl.LogOnInfo);
            }
            rd.SetDataSource(model);
    using(var stream = rd.ExportToStream(ExportFormatType.PortableDocFormat))
            {
                SmtpClient smtp = new SmtpClient
                {
                    Port = 587,
                    UseDefaultCredentials = true,
                    Host = "smtp.gmail.com",
                    EnableSsl = true
                };

                smtp.UseDefaultCredentials = false;
        smtp.Credentials = new NetworkCredential("de****@gmail.com", "*********");
    var message = new System.Net.Mail.MailMessage("[illegible]@gmail.com", Email.ToString(), "UsersRegistration Details", "[illegible]");
        message.Attachments.Add(new Attachment(stream, "UsersRegistration.pdf"));

                smtp.Send(message);
            }

        var Message = string.Format("Report Created and sended to your Mail.");
    HttpResponseMessage response1 = Request.CreateResponse(HttpStatusCode.OK, Message);
            return response1;
        }


    }
}
```

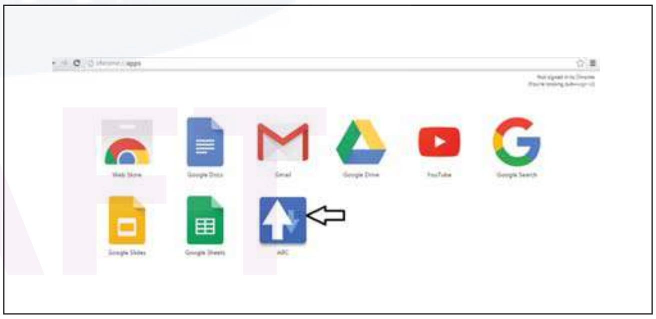
Code Explanation

- Here I have created a Web API method as "ExportReport". I am allowing all users to use AllowAnonymous attribute here. As it is a post method I have given post. This method needs a parameter as email which will come from my Users Model.
- I am getting all my data from my database using the following Query where cX is my entity object.
- 1. var data = cX.tbl_Registration;
- After that I create a report document object and bind its datasource as my model which is nothing but the data mapped with my users model.
- Now generate a report and send it to user as per the email entered.
- Sometime if it will ask for an invalid database so I have set the connection string detail here also.

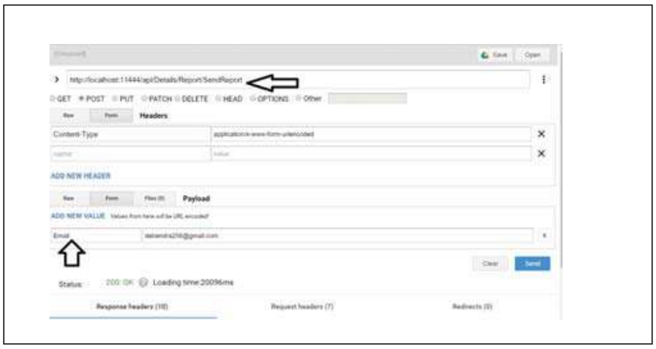
After that save all the things and put down as "Advance REST client" for Chrome to test the API call as follows.



Click ADD TO CHROME. It will added to the chrome. Now double click to open it.



After opening it provide the API url with the parameter as follows.



After that click on save. It will show you the response as 200 that means your request is successfully executed. Now go to the mail and check for the email.

Now click the mail to open it.

Click Open to open the pdf report as follows.

Thus Crystal Report using Web API call is generated.

1. User Access and Rights management

1.1 Set permissions on the Web API

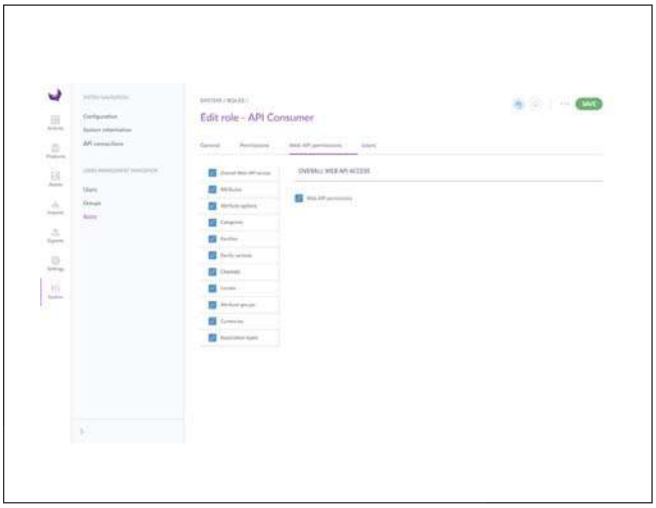
Permissions on the Web API are also granted according to the user's role(s).

To change Web API permissions for one user role:

1. Go to System and click on the Roles menu entry
2. Click on the role to edit

Click on the Web API

1. Check/uncheck the permissions you want
2. Click on the Save button to confirm your changes



1.1 Give the overall access

First, there is a permission that grants access to the overall Web API. It is called Overall Web API.

If it is turned on for a given role, it will give an overall access to the API to the users that have this role. Meaning these users would be able to call any endpoints in the API.

If it is turned off, the users that have this role won't be able to make calls to the API endpoints.

4.3Give access by endpoints

You can also be more precise in terms of endpoints you want your API users to call.

The following tables sum up the permissions you will find to restrict the access to the API, endpoint by endpoint.

Channel endpoints	
List channels	Gives permission to GET on the channel endpoint
Create and update channels	Gives permission to POST and PATCH on the channel endpoint
Locale endpoints	
List locales	Gives permission to GET on the locale endpoint
Currency endpoints	
List currencies	Gives permission to GET on the currency endpoint
Family endpoints	
List families	Gives permission to GET on the family endpoint
Create and update families	Gives permission to POST and PATCH on the family endpoint
Attribute endpoints	
List attributes	Gives permission to GET on the attribute endpoint
Create and update attributes	Gives permission to POST and PATCH on the attribute endpoint
Attribute option endpoints	
List attribute options	Gives permission to GET on the attribute options endpoint
Create and update attribute options endpoint	Gives permission to POST and PATCH on the attribute options
Attribute group endpoints	
List attribute groups	Gives permission to GET on the attribute groups endpoint
Create and update attribute groups endpoint	Gives permission to POST and PATCH on the attribute groups
Category endpoints	
List categories	Gives permission to GET on the category endpoint
Create and update categories	Gives permission to POST and PATCH on the category endpoint
Association type endpoints	
List association types	Gives permission to GET on the association type endpoint
Create and update association types endpoint	Gives permission to POST and PATCH on the association type

Principle of selection and installation of carbon dioxide sensor, oxygen sensors & volatile organic compound sensor. Selection and installation of air temperature, air humidity and atmosphere pressure sensor. Selection and installation of soil temperature sensor. Installation of solar pumps, motors and drip irrigation systems

Objectives: At the end of this lesson you shall be able to
- **to understand the selection and installation of carbondioxide sensor, oxygen sensors, air temperture, humidity, atmospheric sensor, soil moisture and temperature sensor**
- **to gain knowledge on installation of solar pump and drip irrigation system.**

1.Principle of selection and installation

1.1 Carbon dioxide sensor

1.1.1 Introduction

Carbon dioxide (CO_2) is an essential component of photosynthesis (also called carbon assimilation). Photosynthesis is a chemical process that uses light energy to convert CO_2 and water into sugars in green plants. These sugars are then used for growth within the plant, through respiration. A carbon dioxide sensor or CO_2 sensor is an instrument for the measurement of carbon dioxide gas. The most common principles for CO_2 sensors are infrared gas sensors (NDIR) and chemical gas sensors. Measuring carbon dioxide is important in monitoring indoor air quality, the function of the lungs in the form of a capnograph device, and many industrial processes.

1.1.2 Selection

In addition to temperatures conducive to growth, light , water, and nutrients, plants also require carbon dioxide (CO_2) for photosynthesis (carbon assimilation), which ultimately affects plant growth, vigor, and vegetable and cut flower yield. Carbon dioxide is an odorless and colorless trace gas.

For the majority of greenhouse crops, net photosynthesis increases as CO_2 levels increase from 340–1,000 ppm (parts per million). Most crops show that for any given level of photosynthetically active radiation (PAR), increasing the CO_2 level to 1,000 ppm will increase the photosynthesis by about 50% over ambient CO_2 levels. For some crops the economics may not warrant supplementing to 1,000 ppm CO_2 at low light levels. Today, ambient CO_2 levels outdoors comprise 0.04% of atmospheric volume, or around 400 ìmol’”mol”1 (or parts per million, ppm). Plants take up CO_2 by diffusion, through small pores called stomates that are primarily located on the underside of leaves. The opening and closing of stomates can be influenced by leaf and air temperatures, light levels, humidity, water stress, CO_2 concentration, and oxygen (O_2) in the air and leaf.

To provide a guideline for CO_2 addition, a theoretical calculation is given below for a glass house of 100 m^2, with a growing crop, on a day with average light intensity.

In this calculation, a level of 1,000 ppm CO_2 will be supplemented to maintain 1,300 ppm during the day. Normally CO_2 supplementation is not required at night as no photosynthesis occurs. Actually, the CO_2 concentration will tend to build up naturally as a result of plant respiration. Therefore, it is not uncommon to find elevated levels (500–600 ppm) early in the morning. Growers using high-pressure sodium lighting during the night should maintain at least 400 ppm of CO_2.

A typical greenhouse with a 2.4 m gutter has an approximate air volume of 400 m^3/100 m^2 floor area. To increase the level from 300–1,300 ppm requires the addition of 1,000 ppm or 0.1% CO_2. This requires 0.40 m^3 or 0.75 kg of CO_2 per 100 m^2 of greenhouse floor space. Add this amount before sunrise because photosynthetic activity is usually the greatest early in the day. After a level of 1,300 ppm is achieved, it must be maintained.

For the majority of greenhouse crops, net photosynthesis increases as CO2 levels increase from 340–1,000 ppm (parts per million)

1.1.3 Installation

To ensure the best performance from the equipment, it must be installed correctly.CO2 sensors should be treated as an electronic component and handled using the correct ESD handling precautions.

Electrical Connections

NOTE: Communication to and from the CO, sensor is via a serial connection. The recommended supply voltage is 3.3VDC; refer to the product datasheet for the minimum and maximum allowable range.

RS232 Setup(Serial Connection)

The Rx and Tx pins are normally high, suitable for direct connection to a UART. If the sensor is to be read by a true, RS232 device (e.g. a PC) it is necessary to pass through a level converter to step up/down the voltage and invert the signal. Sensors have different connector sizes.

NOTE: For all sensors, only GND, +3V3, Rx and Tx are required for bi-directions serial connection. All other pins should be left unconnected.

1.1.4 Working Principle

The carbon dioxide gas sensor measures gaseous carbon dioxide levels by detecting the quantity of IR radiation absorbed by carbon dioxide molecules. The sensor employs a hot metal filament that acts as an IR source to generate IR radiation. The IR source is located at one end of a sensor tube, and another end is provided with an IR sensor. The IR sensor measures the amount of radiation that passes through the sample without being absorbed by the carbon dioxide molecules.

The sensor measures the IR radiation absorbed in the narrow band at 4260 nm. The greater the absorbing gas concentration in the sampling tube, the lesser the amount of radiation from the source. As a result of this increase in temperature, a voltage is generated, amplified and read by an interface system. Meanwhile, the carbon dioxide gas diffuses via the sensor tube by the eight vent holes.

1.1.5. Applications

Some of the major applications of carbon dioxide sensors include the following:

- It can be used for HVAC applications to monitor the quality of air.
- It is used to monitor fermentation, aerobic respiration, photosynthesis and other carbon dioxide consuming or producing processes.

1.2 Oxygen Sensors

1.2.1 Introduction & Principle of selection

A good oxygen level in the substrate is important for the overall root quality and water and nutrient absorption of the roots. In addition, a good oxygen level contributes to healthier roots so that the plant can better defend itself against pathogenic fungi. The irrigation strategy influences these factors. With an oxygen sensor you can measure the amount of oxygen in the substrate and thus optimize the irrigation strategy.

Oxygen is a valuable output given by the plants, which can be measured with the help of oxygen sensors. Oxygen sensors can be connected to every plant and measure the amount of oxygen released by a plant per day.

1.2.2 Installation

The ICTO2 Soil Oxygen Sensor performs measurements based on a Galvanic cell principle. Therefore it is a passive sensor and does not require voltage input. The sensor has an automatic temperature compensation via an in-built thermocouple compensation circuit. The sensors are Teflon coated and made from long lasting plastics. Life expectancy in the field is five years.

ICT International can offer to assist with defining objectives of measurement programs, developing a plan for measurement and interpreting data.

Soil Oxygen Sensor Features

- Can be used for long term observation with easy set-up.
- Automatic temperature compensation as it has a built in thermocouple compensation circuit.
- Not influenced by the rain or water. TEFLON water protection.
- Easy span calibration. Users can calibrate at the usual atmosphere (20.9% Oxygen concentration).
- Zero calibration is not needed. 0% Oxygen = 0 mV output.

Specifications

Theory	Galvanic battery + porous membrane sheet
Shape	Diameter 35 mm, length 65mm(cable connector length 50mm)
Output	45~65 mV at 20.9% O_2(users must check the output of the air before set-up)
Accuracy	±0.5%
Weight	220 grams (includes 5m cable)
Cable Length	5 m (+ white, – black, shield cable)
Temperature effect	At R.H. 100% and O_2 20.9%. Sensor output is 20.8% at 5°C, 19.4% at 40°C. At R.H. 0% and O_2 20.9%. Sensor output is not Influenced by temperature.
Temperature	0~40°C when in use

1.2.3 Applications

Applications include:

- Measurement of O_2 in laboratory experiments
- Monitoring gaseous O_2 in indoor environments for climate control
- Monitoring of O_2 levels in compost piles and mine tailings
- Monitoring redox potential in soils
- Determination of respiration rates through measurement of O_2 consumption in sealed chambers
- Measurement of O_2 in soil/porous media

1.3 Volatile Organic Compound Sensor

1.3.1 Introduction

Volatile Organic Compounds, or "VOCs", are organic chemicals that have a high vapor pressure under normal atmospheric pressures and temperatures. As a result, they have a low boiling point and readily evaporate into the atmosphere, creating potentially toxic conditions for workers. A VOC Detector measures the presence of VOCs and displays a value proportional to the amount of VOC detected, usually measured in 'parts per million'.

VOCs occur naturally and exist in most all environments. VOCs include both naturally-occurring and man-made compounds. In industrial applications, VOC detectors are most often used to detect the presence of certain highly dangerous VOCs such as benzene, toluene, formaldehyde, and other gases

Plants emission of Volatile Organic Compounds (VOCs) is involved in a wide class of ecological functions, as VOCs play a crucial role in plants interactions with biotic and abiotic factors. Accordingly, they vary widely across species and underpin differences in ecological strategy.

1.3.2 VOC Sensor technology

The most commonly used method for detection of VOCs is a photoionization detector. VOC molecules are complex and easily broken down by high energy photons. VOC sensors use a bright ultraviolet light source to knock electrons out of the VOC molecule; the electrons are measured and their flow indicates that VOC molecules are present at the sensor. Each specific type of VOC molecule has an 'ionization potential' (IP) value that represents the amount of energy necessary to liberate an electron; this value is measured in 'electron volts', or eV. PID sensors have a specified level of energy, also measured in eV, and in general, any compound with an IP value less than the sensor's eV rating will be ionized and detected. For example, with a 10.6 eV VOC sensor, the presence of benzene (IP = 9.24 eV) will be detected, whereas molecules water vapor (IP = 12.6 eV) will not.

1.3.4 Applications

VOCs are commonly monitored as they are a key contributor in photochemical smog. Many are hazardous to human health, with several classified as carcinogenic. The key sources of VOCs are industrial processes (especially those involving solvents) vehicle emissions, evaporative loss from petrol storage and even natural sources like forest fires.

Indoor applications

- Indoor air quality
- Personal exposure studies
- Health and safety
- Checking indoor air pollution "hotspots"

Outdoor applications

- Urban air monitoring networks
- National air monitoring networks
- Roadside air monitoring
- Industrial perimeter monitoring
- Environmental impact assessments
- Research and consultancy projects
- Short term hot spot monitoring

2. Selection and installation

2.1 Air temperature & Humidity sensor

2.1.1 Introduction and Selection

Accurate greenhouse air measurement necessitates that the sensor be shielded from the sun and lights, and that a constant stream of air moves by the sensor. Therefore, the sensor should be in an aspirated box or tube that is reflective (for example, white in color). Ideally, this temperature chamber should be positioned away from heat pipes and walls and at the height of the crop canopy. If temperature is measured several feet above the crop, it's probably a few degrees warmer than at crop level.

Thermocouple is the most common device used to measure air temperature. A thermocouple consists of two different metals that are combined (usually by twisting them) to produce a voltage related to their temperature difference. There are several types of thermocouples that contain different metals, wire thicknesses, and thus have different costs and degrees of accuracy. Mercury thermometers are inadequate for most commercial production situations; they are hazardous if broken, don't allow automated measurements and lack precision.

A humidity sensor (or hygrometer) senses, measures and reports both moisture and air temperature. The ratio of moisture in the air to the highest amount of moisture at a particular air temperature is called relative humidity. Relative humidity becomes an important factor when looking for comfort.

To choose the humidity sensor, Some of the factors to consider are:

- Size, accuracy, and interchangeability
- Long-term stability needs
- Repeatability requirements
- Required resistances of the sensor to any chemicals or contaminants it will be exposed to

It is also important to understand the different types of humidity sensors available to choose from.

- Resistive humidity sensors measure an electrical change that can be caused by a conductive substance. These systems use electrodes and AC excitation voltage to produce a data value for relative humidity.
- Thermal conductivity humidity sensors measure absolute humidity. They do this by calculating the difference in the conductivity of dry air compared to air that contains water vapor. These sensors use thermistor elements to form a bridge circuit and measure the difference in resistance.

2.1.2 Installation

Air temperature and relative humidity probes typically consists of two separate sensors packaged in the same housing. Often relative humidity is measured with a capacitive RH sensor, while air temperature is measured by a PRT. The YDH-1 AWS Air Temperature and Relative Humidity Probes are recommended in humid areas or applications in which accurate measurements of RH (especially above the 90% RH level) are important. Solar radiation shield are required for the sensors if they were to be exposed to sunlight.

Air temperature

Range	-5° C to +60° C
Accuracy	± 0.1°C or better
Resolution	0.1°C
Sensor type	Resistance Type
Response time	60 seconds
Connecting cable	Cable length: as required
Output	DC analogue, RS 232
	Accessories
	All accessories (fixing units, etc.) as required

Relative Humidity

Range	0% to 100% RH
Accuracy	± 3% or better
Resolution	0.50%
Sensor type	Capacitive / solid state
Response time	60 seconds
Connecting cable	Cable length: as required
Accessories	All accessories (fixing units, etc.) as required

2.2 Atmospheric Pressure Sensor

2.2.1 Introduction

Barometric Pressure Sensor, also known as a newer form of barometer, is an Arduino compatible tool used for atmospheric pressure measurement in environments. Such measurements mainly allow for forecasting of short term changes in the weather.

With design changes over the years, barometric pressure sensors are now miniaturized for usages on smartphones and microcontroller boards such as Arduino, where one of the most common ones being BMP180, BMP280, BME280.

2.2.2 Choosing the right barometric pressure sensor

What to consider	Explanation
Pressure Precision	Higher pressure precision allow for better sensing accuracy and reliability. This results in a better, stable, and more accurate output.
Pressure and Temperature Range	Higher pressure and temperature range allow for a wider range of sensing If you require sensing at extreme temperatures/pressure, ensure that sensor you pick delivers the accuracy as well
Power consumption	No one likes a sensor that consumes a large chunk of power, hence do consider those that consume lesser powerEnsure the sensor chosen meet your power requirements of your project as well.
Size of sensor	Thankfully for most barometric pressure sensors, they are small in size, making it suitable for compact projects.
Price	If you're willing to splash the cash, there are high end barometric pressure sensors out there but may not provide the best bang for the buckSelecting one with the best cost-to-performance ratio is highly recommend for extra savings!

2.2.3 Installation

Hardware Configurations:

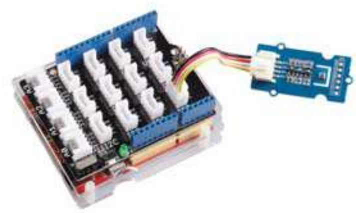
Step 1: Connect Grove-Barometer Sensor-BME280 to port I2C of Grove-Base Shield

You can opt to directly connect the BME280 to Seeeduino as well

Step 2: Plug Grove – Base Shield into Seeeduino

Step 3: Connect Seeeduino to PC via a USB cable

It should look something like this after the above steps:



Software configurations:

Step 1: Download the [Library and example code] from Github

Step 2: Refer [How to install library] to install library for Arduino

Step 3. Create a new Arduino sketch and paste the codes below to it or open the code directly by the path: File -> Example ->Barometer_Sensor->Barometer_Sensor

Here's the code:

```
9#include "Seeed_BME280.h"
#include <Wire.h>
BME280 bme280;
void setup()
{
 Serial.begin(9600);
 if(!bme280.init()){
  Serial.println("Device error!");
 }
}
void loop()
{
 float pressure;
//get and print temperatures
 Serial.print("Temp: ");
Serial.print(bme280.getTemperature());
Serial.println("C");//The unit for  Celsius because original arduino don't support speical symbols
//get and print atmospheric pressure data
Serial.print("Pressure: ");
Serial.print(pressure = bme280.getPressure());
 Serial.println("Pa");
//get and print altitude data
Serial.print("Altitude: ");
Serial.print(bme280.calcAltitude(pressure));
Serial.println("m");
//get and print humidity data
Serial.print("Humidity: ");
Serial.print(bme280.getHumidity());
Serial.println("%");
delay(1000);
}
```

Step 4: Upload the code.

Step 5: Open the serial monitor to receive the sensor's data including temperature, barometric pressure value, altitude, and humidity

2.2.3 Applications

A barometric pressure sensor can be used mainly in these applications:

Weather forecast and predictions

- Able to predict rain through seeing if there's a rapid increase in atmospheric pressure
  - Result in better planning of outdoor activities
  - Maintaining health and well-being as many believe weather correlates to human health

Smartphone applications

- Integrated pressure transducer sensors that detect pressure changes and converting it into an electric signal

Car Engines

- Engine management sensor found in many vehicles
- Located in the intake manifold towards the rear of the engine, it's responsible for pressure, density measurement
  - This affects how a vehicle runs as different air pressures affect engine oxygen and its fuel requirement

3. Selection and Installation

3.1 Soil Moisture Sensor

3.1.1 Introduction

The moisture of the soil plays an essential role in the irrigation field as well as in gardens for plants. As nutrients in the soil provide the food to the plants for their growth.

The soil moisture sensor is one kind of sensor used to gauge the volumetric content of water within the soil. As the straight gravimetric dimension of soil moisture needs eliminating, drying, as well as sample weighting. These sensors measure the volumetric water content not directly with the help of some other rules of soil like dielectric constant, electrical resistance, otherwise interaction with neutrons, and replacement of the moisture content.

3.1.2 Selection

Deciding how to measure soil moisture can be complicated, but METER's easy, plug and play soil sensors simplify the process. When choosing a METER soil moisture sensor, the first thing to know is that all METER soil sensors have the same research-grade accuracy with minimum sensitivity to salts (<10 dS/m bulk EC), temperature gradients, and soil texture. Among the thousands of peer-reviewed publications using METER soil sensors, no soil moisture sensor or water potential sensor emerges as the favorite. Thus sensor choice should be based on the needs and application.

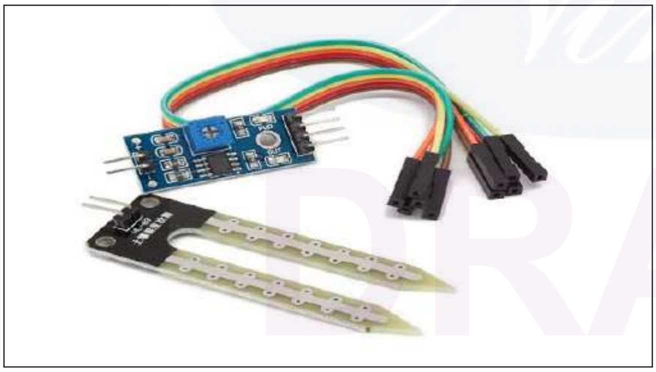
METER's soil moisture sensors have minimal sensitivity to temperature, but if the installation depth is shallow and the location is exposed, temperature effects need to be considered. The TEROS 11/12, 5TM, 5TE, and GS3 soil moisture sensors have an onboard thermistor that measures temperature along with soil moisture. This eliminates the need for extra temperature sensors at every measurement site.

Researchers who want to measure bulk electrical conductivity (EC) in addition to water content should choose the TEROS 12 soil moisture sensor, the 5TE soil moisture sensor, or the GS3 soil sensor. These sensors enable users to measure the bulk EC response to salts and fertilizers in the soil. EC measurements will require good contact between the stainless steel electrodes on the sensor and the soil.

For soil moisture measurements only, many scientists prefer the TEROS 10. It's easy to install, inexpensive, and reliable—perfect for big projects where sensors are needed in quantity. In difficult (hard or rocky) soils, potting soil, and soilless media, we recommend using TEROS series sensors to maintain good soil contact and compensate for air gaps in the soil or substrate.

All METER soil moisture sensors are plug and play with METER data loggers. They also integrate with third-party loggers using SDI-12 protocol. Use the ZL6 for easy data collection from remote sites, or you can manually download data.

3.1.3 Installation



The FC-28 soil moisture sensor includes 4-pins

- VCC pin is used for power
- A0 pin is an analog output
- D0 pin is a digital output
- GND pin is a Ground

This module also includes a potentiometer that will fix the threshold value, & the value can be evaluated by the comparator-LM393. The LED will turn on/off based on the threshold value.

This sensor mainly utilizes capacitance to gauge the water content of the soil (dielectric permittivity). The working of this sensor can be done by inserting this sensor into the earth and the status of the water content in the soil can be reported in the form of a percent.

This sensor makes it perfect to execute experiments within science courses like environmental science, agricultural science, biology, soil science, botany, and horticulture.

The specification of this sensor includes the following.

- The required voltage for working is 5V
- The required current for working is <20mA
- Type of interface is analog
- The required working temperature of this sensor is 10°C~30°C

3.1.4 Soil Moisture Sensor Applications

The applications of moisture sensor include the following.

- Agriculture
- Landscape irrigation
- Research
- Simple sensors for gardeners

3.2 Soil Temperature Sensor

3.2.1 Introduction & Selection

Soil temperature sensor is a high quality temperature sensor that is specifically designed for soil temperature measurement in extreme environments. Using top quality materials it is suitable for hostile conditions as encountered in outdoor installation (temperature, radiation, chemicals).

STP01 soil temperature profile sensor offers an accurate temperature difference measurement at five measurement locations at 0.02, 0.05, 0.1, 0.2 and 0.5 m below the soil surface. It also has a well specified and fixed distance between the measurement locations. STP01 contains 5 matched thermocouples, at locations A to E in figure 5, and one reference temperature sensor (Pt100 type) at location E at 0.5 m depth. By having the reference temperature measurement in the sensor and only measuring differential thermocouple voltages (relative to the reference at 0.5 m), the uncertainty of the temperature difference measurement is very low: ± 0.02 °C is attainable. Simple copper-conductor signal wire is used in STP01's cable. As an extra, a heating wire is incorporated in STP01. Analysis of the temperature change during the heating interval serves as a self-test. Soil temperature sensors are preferably left in the soil for as long as possible, so that the soil properties become representative of natural conditions. Using self-testing, the user no longer needs to take sensors to the laboratory to verify their stable performance. The result is a much improved accuracy & quality assurance of the measurement relative to measurements with conventional sensor types.

3.2.2 Installation

Measurand	temperature at 5 depths from 0 to 0.5 m
Measurement range	-30 to +70 °C
Temperature sensors	matched thermocouples type T

Uncertainty of temperature difference measurement

· 1.5 % of measured value plus measurement system uncertainty in x 10{ v V/40

Uncertainty of relative position	± 0.001 m
Rated operating environment	surrounded by soil
On-line functionality testing	self-test using the incorporated heater
Reference temperature sensor	Pt100, IEC 751:1983 class B
Sensor foil thickness	0.6 x 10{ ³ m, 2.5 x 10{ ³ m at Pt100
Measurement depths	0.02, 0.05, 0.1, 0.2 and 0.5 m
Standard cable length (2 cables)	5 m (see options)
IP protection class	IP67
Optional non-traceable measurand	thermal conductivity at 3 depths
Heater specifications	:
Heater rated power supply	9 to 15 VDC
Power consumption daily average	0.005 W
Interval between self-tests	24 h
Self-test duration	600 s

3.2.4 Soil Temperature Sensor Applications

- Measure air or soil temperature.
- Monitor germination temperature of seeds.
- Monitor greenhouse temperature.
- Get text messages and phone alerts from your plants.
- Protect plants from frost.
- Ice detection systems.
- Irrigation and sprinkler systems.

4. Solar Pump Drip Irrigation Systems

4.1 Introduction

In a solar power drip irrigation system, electricity is generated by solar Photovoltaic PV panels and used to operate pumps for abstraction , lifting and distribution of irrigation water. Drip irrigation pipe should still be produced efficiently and will need to operate with smart systems.

4.2 *How to install a drip irrigation system for your vegetable garden*

For the sake of simplicity a basic square vegetable garden as an example has been considered.

Step 1: Plan your drip irrigation design layout.

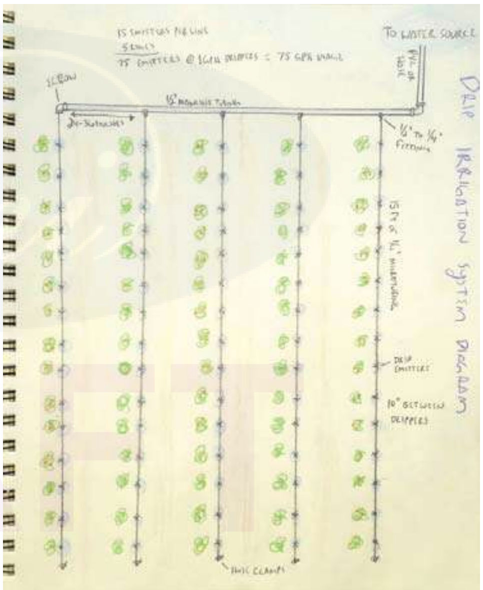
Proper planning prevents poor performance! Making a sketch of the garden will help you engineer the right layout and could help you see problem points that you wouldn't have otherwise noticed. Take note of dimensions and unmovable structures and objects.

Notes for designing the drip irrigation system

- Where the water source is located and if there are any obstacles along the way
- The distance is required to run your irrigation tubing
- Designing the system without crossing over walkways or burying the pipe under walkways
- Utilizing spaces along paths to grow vegetables and herbs (a permaculture philosophy)
- Laying out the system to use the least amount of pipe and tube for efficiency
- different gardening zones may require different amounts of water (a more complex form of drip irrigation)

Drip Irrigation System Diagram

With this knowledge, select the .50 inch tubing as the correct size mainline for our garden. We can run branches of tubing as shown on my diagram in the .25 inch size, you will need a 1/23 to 1/43 fitting.



Make sure not to surpass the maximum GPH of the tubing which will be listed on the manufacturer's instructions and do not overextend the tubing past its maximum run length.

Step 3: Gather drip irrigation components

Many components for drip irrigation systems are measured in the metric system. There are labeled conversions that are not entirely correct which can cause your system to fail. It is recommended that instead of trying to convert from metric to imperial (15mm and 16mm are both labeled as ½ inch!) stick to the metric system. Even a millimeter off can blow your entire system over time. Purchase a preassembled drip irrigation kit that will guarantee compatible components.

Option One: Buy a Drip Irrigation Kit

The nice thing about purchasing a drip irrigation kit is that all of the components match up. They are relatively cheap in price, but are not of the best quality in an effort to keep the cost down.

To build a larger setup and, then building a custom drip irrigation system piece by piece is the better option.

Koram 50 Foot Drip Irrigation Kit

There are a bunch of cheap knock-off drip irrigation kits on Amazon, but I found this one that has pretty good customer feedback and it comes with lots of parts and decently long tubing.

Grower's Solution 20x50ft Garden Drip Irrigation

For a small hobby farm, this kit is an upgraded version for the more serious gardening operation.

These are the basics for a simple drip irrigation system:

Drip tubing – this is a special tubing specifically designed for drip irrigation systems. It is a thin polyethylene tube that is much thinner than a standard hose. Drip tubing is meant for above ground use, do not bury the tubing underground, it will ruin it.

Drip irrigation emitters – these are the dripper devices that are installed along the tubing. Some tubes have them pre-installed, otherwise, these can be bought separately and installed onto the tubing. For manual install, a hole puncher is needed.

There are different varieties of drippers, the most common are standard drippers, bubblers, sprinklers, and sprayers. The spacing between the emitters will depend on the plant type you are growing and how your tubing is laid out. Anywhere from 6 to 24 inches between plants is typical.

Hole puncher – this is a must-have tool if your tubing does not have premade holes. This punches the holes into the tubing where you insert your dripper.

Irrigation backflow preventers – an essential piece to the setup, the backflow preventer keeps dirty garden water from flowing backward in the tubing. Backflow can contain contaminants that spread soil born disease. Do not skimp on this piece.

Pressure regulator – this reduces the pressure to a consistent PSI level to not overload the system. If your water pressure is above 40 PSI then you will need a regulator. If your pressure is between 25 to 35, then you do not need one.

Filter – Your water might already be filtered but the tiny emitters can get clogged easily. Take the extra precaution and purchase an additional filter for your drip system. It may feel redundant but is worth the peace of mind knowing that your emitters will not get clogged up.

Hose connect adapter – this connects your water source to the mainline of the irrigation system.

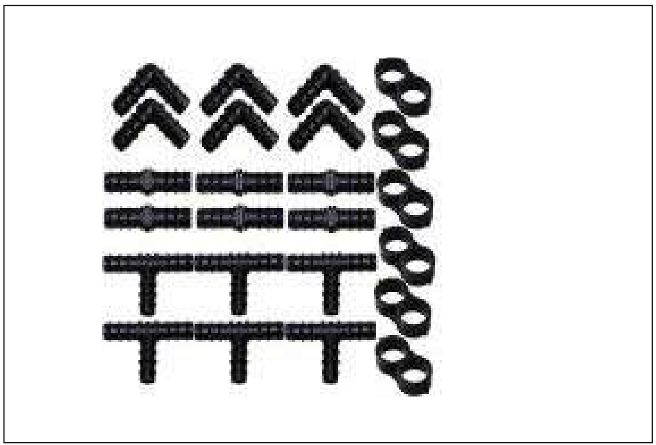
End cap or hose end clamps – the end piece to cap off or clamp the end of the tubing and mainline.

Tubing stakes – keeps the tube from rolling around – which it will – if not fixated onto the ground.

Additional materials for more complex system:

Timer – a timer will allow for a completely autonomous system. If you are connecting to a water spigot, you can get a timer for the hose. You will need a different timer if you are connecting it to the water pump, which I will cover in the next section.

Fittings – includes couplings, elbow fittings, barbed tees, barbed connectors, tee fittings. All these components add options for a more complex system such as running multiple drip tubing lines from the mainline, connecting .25 inch line to .5 inch main line, creating branch lines, etc.



Goof plugs – to plug up holes in your tubing that are no longer needed or placed by mistake.

Step 4: Installing your drip irrigation system

The time and planned out of all components and have measured everything correctly, a standard drip irrigation system shouldn't take too much effort to install.

1. Start installation at the water source

This step will vary depending on whether you are plumbed in or running off an off grid water pump.

Install components in this order: Valve or pump, backflow preventer, pressure regulator, filter, tubing adapter, mainline tubing.

2. Layout all of your tubing and fittings

Start by connecting your .5 inch mainline tubing and then position all of your tubing that branches out from the mainline and adjust as necessary. If the tubing is too stiff, let it sit in the sun to warm up, which makes it more pliable.

Start to connect all of the pieces starting from the source down to the very end.

Once you have everything laid out and connected, cut the hoses at the end but do not clamp off just yet.

3. Install drip emitters

To manually install emitters, simply punch a hole into the tubing with a hole puncher, then press the emitter into the hole. Make sure that you have calculated your spacing correctly before you start punching holes. Once you are done with the emitter installation, stake to the ground.

4. Flush the system thoroughly with water

Flush the system to remove any debris and then cap or clamp the tubing ends. Run the finalized system for about an hour to see if any adjustments need to be made.

4.3 Building a solar powered irrigation pump

There are many ways to get solar power to a pump; the goal is to make the system as simple and independent as possible.

How does a solar powered water pump work?

A solar powered water pump works by attaching a solar panel to the pump in order to give it power. The pump then draws from the water source and pushes it through the drip irrigation system.

The pump will run indefinitely while power is being delivered to it, which is why it's important to install a timer to the pump. It is also important to install a battery to the pump for days where the solar panel is not providing enough energy to keep the system going, usually during overcast and cold days.

Option 1: Purchase a solar powered water pump kit

There are some decent solar powered water pump kits out there, but there are very few that are specifically built for a drip irrigation system. Most are built for fountains which could be retrofitted for drip systems but it's probably not worth the hassle to do so. It's even harder to find a solar powered water pump kit with a battery backup included. Since the kits are cheaper than piecing together the components individually,

Option 2: Building a DIY solar powered irrigation pump

Building a diy solar powered water pump system will be superior to any kit that is available at this point in time. Another advantage of setting up your own solar powered water pump is that if a component does go out, you can easily replace each one.

4.4 Steps to Building a DIY Solar Powered Irrigation Pump

The key to success is to prepare all calculations and components before assembling and power up the system. Solar power systems are not all that complicated but need to make sure all of the components will be compatible or else they could damage the system.

Essential Components for a solar powered irrigation pump

Solar panel – harnesses energy from the sun to run the pump.

Stand for solar panel – so it's not just laying on the ground.

Solar charge controller – Keeps the connected battery powered and charged. It also makes sure that the battery doesn't get overfilled or run dry, prolonging the life of your battery. This is an essential component for your solar power setup. Don't worry, these are not that expensive.

To figure out what size controller you need, take the output watts of the solar panel and divide it by the volts of your battery. This will figure out the amps calculation for controller sizing.

100 watts / 12v = 8.33 amps

Being that we are only using one solar panel, we can get away with a super cheap charge controller.

Battery – keeps the system running in times of limited sunlight.

Cables – connects all the components together.

Water Pump Timer – Switches the pump on and off for an autonomous watering system. Make sure to match the correct voltage.

Water Pump – in this tutorial, I am using an above ground water pump, but this will also work for a submersible pump with some minor adjustments.

Step 1: Choosing the correct size water pump

First, figure out how much water is needed for the drip irrigation system and then purchase the correct size water pump. Too little water flow and we will not have enough water to run the system. Too much water flow and we could overload the system, causing damage. In the example, we need 75 gallons per hour flowing through our system. Most pumps measure in gallons per minute, so we divide 75 gallons by 60 minutes to get 1.25 gallons per minute.

Try to match up the flow rate of the pump as closely as you can to the GPH of the drip irrigation system. To find the exact pump for the calculation, but either err on the side of less GPM as opposed to higher GPM. You can also add a few more (or less) drippers to match up better to the flow of your pump.

This Shurflo pump runs at 3.5 GPM with 45 PSI and could be a good match for your system.

Step 2: Choosing the correct size solar panel

To figure out how many watts are needed to appropriately size the solar panel. If wattage is unknown, calculate it with a simple equation by using the voltage output and amps.

Volts times Amps = Power in Watts

For our example, we are using a 12 Volt DC 7.5 amp water pump. So our calculation is:

12 Volts x 7.5 Amps = 90 Watts per hour

For the pump, a 100-watt solar panel will provide enough electricity plus a little extra to keep the battery charged while the pump is running.

However, since the pump will not be running 24/7, we can downgrade the size of the solar panel and rely on the battery backup to run the pump for an hour or two, and then while the pump is off, the solar panel will charge the battery. In this case, we can choose the commonly sized 50-watt solar panel.

Note that our pump is a DC pump, so we do not need a power inverter to power the pump as the power supplied by solar panels is also DC.

Step 3: Choosing the correct size battery

To make sure that we select a battery with enough capacity to run the pump if the solar panel is operating at zero capacity.

Let's stick with the 100 watt solar panel for our example.

100 watts is the amount that the solar panel will produce per hour.

The average amount of power a solar panel can collect per day is typically 500 watts based on being in full sun for 5 hours.

While the battery is charging, there are some power losses of about 15%. So our 500 watts will probably be more along the lines of 425 watts.

Battery capacity is expressed in Amp hours (Ah).

Need a 12 volt battery for our pump.

Multiply our battery Amp hours (Ah) by the voltage:

Ah * Volts = Watts by the hour

So if a 35Ah 12V battery we simply multiply the two 35 * 12 = 420 Wh which will store most of the output of the solar panel.

Now, the pump will only be running for 2 hours out of the day. We need 90 watts per hour, so the system will only require 180 watts. Therefore, a 35Ah battery will give us a bit more than 2 days runtime without having to be charged.

Step 4: Connecting the solar power components in correct order

Before proceeding, make sure the solar panel is not in the sun. Place a piece of cardboard over the panel to ensure there is no electricity running through it.

The first step is to **hookup the charge controller to the battery** with stranded copper wire. Make sure not to cross-connect the + and -.

The second step is to **connect your timer to the battery**. I suggest using the negative cable as it's not hot. Splice in the timer on the negative cable. A battery-powered timer is ideal if you don't want to mess with wiring power to the timer.

The third step is to **connect the pump** to the timer and the battery.

The fourth and final step is to **hook up the solar panel** to the charge controller with the appropriate solar panel connector cables, which are usually included with the solar panel.

Make sure not to cross-connect the + and – MC4 connectors as this will damage your system.

Once all the components are connected, uncover the solar panel and the battery will start charging. The charge controller will inform you when it is full and regulate the battery to keep it in optimal charge.

Process of carrying out crop and soil observations logged in the form of snapped pictures, pin point locations, soil colours, water, plant leaves and light properties. Measurement of leaf and other parameter using smart phone camera. Usage of smartphone GPS predicitive maintenance for machinery. Determine leaf angle index. Applications of precision irrigation using water management identification of zones in precision irrigation. Application of variable rate technology. Application of various precision agricultural tools in smart farming.

Objectives: At the end of this lesson you shall be able to
- **to observe the soil using pictures and other properties**
- **to measure leaf properties and to determine leaf angle index**
- **to identify various applications of smart farming and irrigation through water management.**

1.Observation and Measurements

1.1 Introduction

Many farm managers are looking for new technologies to help them decide when and where to irrigate, fertilize, seed crops, and use herbicides. Using data collected by satellites combined with GIS environments, important agricultural factors like plant health, plant cover and soil moisture can be monitored from space, provide a much bigger picture of the land surface that can be combined with other technologies to help cut costs and increase crop yields. Smartphone sensors and apps, as well as small-scale machinery, allow smaller farms to take advantage of precision agriculture technologies.

1.2 Smartphone Tools

The smartphone alone has several tools that can be adapted to farming applications. For instance, crop and soil observations can be logged in the form of snapped pictures, pinpoint locations, soil colors, water, plant leaves, and light properties. The below table lists some in-phone tools that are useful for gathering data:

Table : Agricultural Uses of existing smart phone tools

Smartphone Tool	Smart Farming Applications
Camera	Provides pictures of leaf health, lighting brightness, chlorophyll measurement, and ripeness level. Also used for measuring Leaf Area Index (LAI) and measuring soil organic and carbon makeup.
GPS	Provides location for crop mapping, disease/pest location alerts, solar radiation predictions, and fertilizing.
Microphone	Helps with predictive maintenance of machinery.
Accelerometer	Helps determine Leaf Angle Index. Also used as an equipment rollover alarm.
Gyroscope	Detects equipment rollover.

1.3 Satellite Images

Many farm managers are looking for new technologies to help them decide when and where to irrigate, fertilize, seed crops, and use herbicides. Using data collected by satellites combined with GIS environments, important agricultural factors like plant health, plant cover and soil moisture can be monitored from space, provide a much bigger picture of the land surface that can be combined with other technologies to help cut costs and increase crop yields.

Precision farming is set to become even more precise with a new camera drawing on satellite imaging. "Hyperspectral imaging captures many very narrow wavelength bands in the visible and near-infrared instead of the more typical three or four broad spectral bands: red, green, blue and, sometimes, infrared." A camera that is more sensitive to subtle differences in colour allows to identify problems that you can't see with your naked eye or a normal camera until it's too late to do anything about it." Hyperspectral cameras produce huge amounts of data that have to be downloaded to VITO's cloud computing environment to be processed to produce the required information, including action maps to help the customer.

By using different types of visual resolutions (RGB composites, multitemporal NDVI indices), a farm operator can determine the issues affecting their crops and apply appropriate remedies to affected areas. If spectral resolution has identified areas within the crop-field as having too little or too much of a given nutrient for example, farmers can apply less or more fertiliser to those areas as needed, as opposed to treating the entire field with an evenly metered dose.

1.3.1 Different indexes

The below three indexes produces both Landsat and Sentinel:

NDWI (Normalised Difference Water Index). An index to quantify or relate the water content of soil and vegetation.

NDVI (Normalised Difference Vegetation Index). It practically relates the chlorophyll content of crops to their reflectance.

NDMI (Normalised Difference Moisture Index). As the name suggests, it correlated the moisture content of soil mainly with its spectral response.

Basic software analytical tools include:

1. Vegetation indices:

(a) NDVI – Normalized Difference Vegetation Index – estimates plant health with reflected NIR light

(b) ReCI – Red-edge Chlorophyll Index – detects chlorophyll and thus photosynthesis capability

(c) NDRE – Normalized Difference RedEdge Index – targets at chlorophyll as well but is intended to monitor crops in the middle and late seasons

(d) MSAVI – Modified Soil-Adjusted Vegetation Index – monitors early stages of plant development to monitor crop conditions

2. Predictive maintenance

2.1 Introduction

Predictive maintenance is a valuable tool utilized by many industries, where data and robust predictive and data analytics are leveraged to anticipate any issues or failures before they occur. As the name implies, these insights *predict* future behaviors and occurrences based on historical data and trends. Predictive maintenance is vital in both downtime prevention and overall cost savings. The objectives of predictive maintenance programs can be boiled down to one of two outcomes:

· Improving production efficiency.

· Improving maintenance efficiency.

2.2 Geographical Information Systems (GIS)

GIS has two different roles in precision farming vehicles. First, a combination of GIS and simulation models is highly relevant for precision farming. There are many simulation models for different purpose like the flow of water, crop growth, soil erosion, nutrient and pesticide leaching. GIS helps in integrating geographical data on various aspects such as soil, crop, weather and field history along with simulation models. Another aspect of GIS support to precision agriculture is the engineering component, in which the research findings are translated into operational systems for use at farm level. GIS can support this engineering activity by providing a good platform for storage of base data, simple modelling, presentation of results, development of a user interface, and, in combination with a GPS, controlling the navigation of farm. On the basis of GIS, a decision support system can be developed for operationalisation of precision farming at farm level.

Many farm information systems (FIS) are available, which use simple programmes to create a farm level database. One example of such FIS is LORIS (Figure 1). LORIS (Local Resources Information System) consists of several modules, which enable the data import; generation of raster files by different gridding methods; the storage of raster information in a database; the generation of digital agro-resource maps; the creation of operational maps etc. (Schroder et al., 1997)

3. Usage of GPS

3.1 Introduction

Precision agriculture is gaining in popularity largely due to the introduction of high technology tools into the agricultural community that are more accurate, cost effective, and user friendly. Many of the new innovations rely on the integration of on-board computers, data collection sensors, and GPS time and position reference systems.

Through the use of GPS, GIS, and remote sensing, information needed for improving land and water use can be collected. Farmers can achieve additional benefits by combining better utilization of fertilizers and other soil amendments, determining the economic threshold for treating pest and weed infestations, and protecting the natural resources for future use.

GPS equipment manufacturers have developed several tools to help farmers and agribusinesses become more productive and efficient in their precision farming activities. Today, many farmers use GPS-derived products to enhance operations in their farming businesses. Location information is collected by GPS receivers for mapping field boundaries, roads, irrigation systems, and problem areas in crops such as weeds or disease. The accuracy of GPS allows farmers to create farm maps with precise acreage for field areas, road locations and distances between points of interest. GPS allows farmers to accurately navigate to specific locations in the field, year after year, to collect soil samples or monitor crop conditions.

Crop advisors use rugged data collection devices with GPS for accurate positioning to map pest, insect, and weed infestations in the field. Pest problem areas in crops can be pinpointed and mapped for future management decisions and input recommendations. The same field data can also be used by aircraft sprayers, enabling accurate swathing of fields without use of human “flaggers” to guide them. Crop dusters equipped with GPS are able to fly accurate swaths over the field, applying chemicals only where needed, minimizing chemical drift, reducing the amount of chemicals needed, thereby benefiting the environment. GPS also allows pilots to provide farmers with accurate maps.

3.2 Use of GPS in Agriculture

Soil sampling: GPS provides the necessary data to accurately determine soil variability and to establish whether a given type of soil is ideal for the growth of a particular crop. Soil sampling also helps in profiling of soils to distinguish between soils that are viable and those that are not.

Weed location: Using linear sampling techniques, GPS can be used to single out weed patches in vast areas of lands. Weed usually hinders the effective growth of a crop and hampers the eventual yields over a given period of time.

Accurate planting: GPS also comes in handy when planning the planting of a given crop. Each seed has specific spacing and depth required depending on the soil type. Using GPS, it is easier to tell what spacing a given seed requires and to what depth the seed should be planted in order to return maximum yields.

Determination of planting ratios: GPS can also be used in the determination of planting ratios of seeds. Some seeds have specific spaces in between them while others may be planted together with other seeds. GPS helps in determining the ratio of this type of planting.

Creation of yield maps: GPS plays an important role in the creation of yield maps for specific types of crops. For instance, during harvests, GPS can be used to map out expected yields of a given crop from one piece of land based on the land characteristics and the seed characteristics.

Harvesting: GPS plays an important role in the determination of what area of a farm is ready to be harvested and how the harvesting will take place. The GPS will also give an estimate of the size of the area being harvested and the expected returns from the area.

Locating a yield map: GPS can also be used to locate a yield map by mounting a GPS receiver on a farm machinery and then collecting the data.

Environmental control: Applying herbicides or pesticides based on the capacity of each square meter reduces the application amount of the pesticide being used. This allows the soil to absorb all the pesticide hence reducing the chances of runoff.

Farm planning: GPS plays an important role in the planning of a farmland ready for planting. GPS will give the overall size of the area and help in determining what crop will be planted on what part of the farmland using various factors such as soil characteristics and crop characteristics.

Field mapping: GPS gives an exact estimate of the field that is being prepared for farming. Through this, experts can tell what part of the field will be used for farming activities and what area will be used for other non-farming related activities.

Soil sampling: Soil sampling is one of the most important uses of GPS in agriculture. It is important to know what type of soil is available on a given farmland as this will help in determining the type of crop to be planted on that farm.

Crop scouting: GPS gives an exact mapping of an area helping when scouting for crops that are grown in a particular area. Through this, experts are able to tell the nature and type of crops that thrive within a given locality and help in improving the quality of that crop.

Yield mapping: After a crop has been planted and is ready for harvesting, GPS can be used to make an estimation of the yield of a given farmland. This can be achieved through aerial mapping where experts can tell the quantity of a yield based on the area covered by the crop.

Correlation of production techniques with crop yields: GPS can be used to make a correlation of the production technique that was used over a given piece of land and the crop yields after a given period of time. This information can then be used to determine the viability of a given technique.

Soil property mapping: GPS plays an important role in determining the soil property of a given soil to establish its variability and suitability for a given crop. It also helps researchers identify which area of a farmland contains what type of soil and what area is suitable for a given crop.

Machinery location: It is easier to locate any farm machinery on a vast piece of land thanks to GPS. The farmer does not need to physically go out and locate farm equipment especially in cases where the number is high. GPS can pinpoint the exact location of these farm machineries.

Machinery direction: Technology has necessitated the use of autonomous farm machinery for use in farming. GPS is used to direct these machineries into deciding what direction the seeds will be placed and the spaces in between each seed.

Identification of areas suitable for cultivation: GPS plays an important role in deciding what areas in a given farmland are suitable for cultivation. This is done through aerial mapping of the area under cultivation and the analysis of the soil samples to determine the viability of the soil.

Classification of areas for cultivation based on various characteristics: GPS can be used to classify different areas for cultivation based on various characteristics such as soil types and the terrain maps. Areas that are not suitable for cultivation can be identified and alienated while those that are suitable can then be developed.

Assessment for the availability of water in an area: GPS has been used in the assessment of the availability of water or water sources within a given locality. Water sources such as rivers or canals can easily be singled out using GPS.

Identification of irrigated crops: GPS can also be used to identify areas where there are crops that have been irrigated and those that have not been irrigated. This helps in creating a profile between irrigated crops and non-irrigated crops to help in making comparisons.

Identification of swamps and other water logged areas: GPS can be used to identify swampy areas and waterlogged areas that may not be ideal for certain types of crops. This helps in determining the suitability of these types of lands for certain crops and their non-suitability for other types of crops.

Rivers mapping: GPS helps in creating a map of all rivers within a locality which builds a profile of the area with regards to the water flow. Farmers and researchers can be able to tell the presence of rivers and help in determining the crops that will be grown in that locality.

Land usage in the locality: GPS can also be used to monitor the land usage within a given locality. Through GPS, it is easier to tell what area of the land has been put under cultivation and what part of the land has been left bare.

Contour mapping: In cases where the land is irregular, GPS has been instrumental in determining the contours within the specific locality. This is because some crops may not do well in contoured lands while others may thrive in these lands.

Irrigation systems mapping such as dams or canals: In cases where the land needs to be irrigated, GPS can help locate some irrigations systems such as dams and canals. This will make it easy as it will avail the necessary water needed for irrigating the lands.

Meteorological mapping such as climatic patterns: GPS plays an important role in mapping out some climatic conditions which may determine the type of crop that can grow in a given region.

Personnel mapping: GPS may also play an important role in mapping out the number of personnel in a given farmland at specific times of the day. This is important if a farmer wants to measure the productivity of the personnel in a farm.

Plantation mapping: GPS can help in creating a map of a plantation and establishing the crop yields in a given plantation.

Water bodies mapping: GPS can also be used to map out the existing water bodies within a given area to assess the viability of crop growth and crop yields in a given area.

4.Predictive maintenance of machinery

4.1Problem

Seasonal resource shortages—especially during harvesting time—from two perspectives. Farmers' revenues are highly dependent on efficient and effective har-vesting, such that the breakdown of their machine is a worst-case scenario in that period. The breakdown of machines, maintenance strategies, and countermeasures are not exclusive to the agricultural sector but approaches that are discussed in different domains often lack applicability in this sector. While many approaches implemented in the industry rely on live-tracked sensor data, agriculture is subject to a lack of sensor data, divergent data-formats, and distributed data ownership.

4.2 Objective

The main objective implemented by IT artifact is to predict if a component will fail during harvesting times. Critical components are essential for a machine's operation and—if they fail—cause an entire machine to stop. Therefore, the prediction method of future defects is the core of a predictive maintenance service that can be provided on a web-based platform. If a critical component is predicted to fail during harvesting season, the farmer has to be notified by a mobile application. The service platform enables a farmer to make an ad hoc maintenance appointment for the replacement of defective components before the critical period starts and consequently to reduce harvesting losses due to machine failures. The prediction of defects also enables a service provider to plan a specific maintenance action and to order required spare parts proactively. Thus, the service provider can plan all resources in advance and increase the efficiency of the maintenance service.

4.2.1 Design & Development

Our method consists of two steps. Since the service records only contain information of a defect that already occurred and sensor data are not available, we cannot analyze the circumstances leading to a defect. Instead, we identify several features from the service records to predict, if a component has to be replaced during a maintenance appointment at the service station. Since this is no prediction for a future point in time but an existing service record, we need to create future service records containing the machine state during harvesting time and predict, if these generated service records will contain defect components. Therefore, in a first step, we implement a knowledge-based approach to identify the next period for harvesting and estimate the workload until and during the next harvesting period. This information is used to generate future service records since all varying information of the service records can be extracted from the expert system. In a second step, a data-driven approach is applied to predict the defects of critical components in the generated service records. If the defect of a critical component is predicted, it needs to be replaced before the harvest starts to prevent downtimes.

This method is an expert system based on the following rules:

1. Cultivated fields can be identified by clustering position data points that are nearby.
2. For each cultivated field, working hours can be analyzed to identify periods with a high workload.

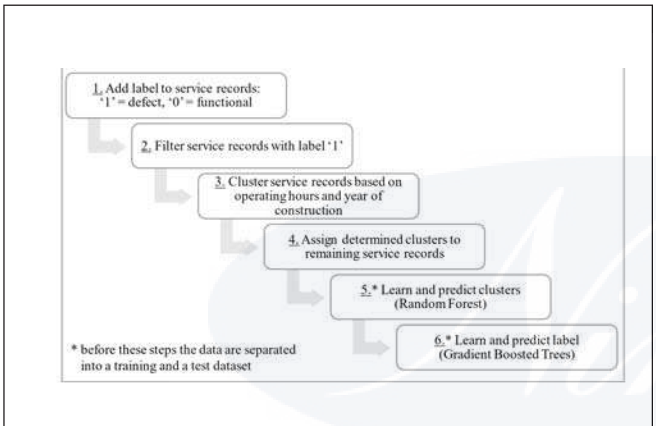
3. The harvesting period for each cultivated field can be estimated based on comparing periods with a high workload on a particular field to reference calendars for seeding and harvesting. The identified harvesting period is defined as prediction horizon.

4. The average workload of former harvesting periods is considered as the required workload for the prediction horizon. The required workload for the period between the last repair and the prediction horizon is estimated based on the average workload for cultivating the identified crops (rule 3).

5. If a farmer cultivates more than one field, the expected harvesting times for all fields are considered to determine the predicted time horizon.

6. If a defect of a critical component is predicted for the identified time horizon, a proactive exchange of the components is recommended to prevent downtimes.

The resulting prediction method consists of six steps as shown in the below figure



5.Determination of leaf angle index using accelerometer

5.1 Introduction

An accelerometer is an electromechanical device used to measure acceleration forces. Such forces may be static, like the continuous force of gravity or, as is the case with many mobile devices, dynamic to sense movement or vibrations.

5.2 Determining leaf angles using cell phones

The cell phone must be set in parallel to the leaf, the leaf lamina orientation matching the frontal side (i.e. the screen in the device faces the same orientation as leaf lamina) and the tip of the leaf placed at the upper part of the cell phone as shown in the below figure. Thus, the leaf angles match those read by the cell phone and can be recorded by pressing the selection key once. The instantaneous output of the accelerometer and magnetometer varies rapidly during operation of the software due to the high sensitivity of the sensors. The software application averages the last 100 values for the accelerometer and the last 25 values for the magnetometer in order to show a smooth display variation. The reliability of the measurement is visible by means of a green light displayed on the cell phone screen (when the device is held steady, values become stable in about 4 seconds). A characteristic beep sounds once a valid measurement is saved as text for further analysis. Data can be downloaded via Bluetooth, a flash memory card (microSD), USB or send via email.

Device set in parallel to a leaf. Device and leaf lamina facing East (â = 90°). Angles of interest are the same for the leaf and the device. á = á′, ã = ã′, é = é′ and â = â′. $n_é$: normal vector to the leaf lamina surface, n_d: normal vector to the device (parallel to each other), F_T: Top part of device's front side, F_B: Bottom part of device's front side, L: Leaf lamina. Insertion angles between leaf and petiole are parallel in this situation in which angle á is the same in leaf and petiole. Setting the device in parallel to a leaf with different insertion angle between petiole and leaf midrib will record á regarding leaf pitch and not petiole pitch.

6. Precision Irrigation

6.1 Introduction

Precision irrigation means how and when water to be applied or applying the right amount of irrigation water for the plants using new methods such as software models and sensors.

6.2 Variable Rate Technology

Variable rate application (VRA) in precision agriculture is an area of technology that focuses on the automated application of materials to a given landscape. The way in which the materials are applied is based on data that is collected by sensors, maps, and gps. These materials include things like fertilizers, chemicals, and seeds, and they all help optimize one's crop production. There are many forms of technology that are used in variable rate application for precision agriculture. They include everything from drones and satellites, to artificial intelligence (AI) and hyperspectral imaging.

6.3 Variable Rate Application Technology and Fertilization

Applying fertilizer is a common agricultural activity that can be completely automated with the correct implementation of variable rate application technology (VRT). Here is a step-by-step guide on how you would go about utilizing VRT for spraying fertilizer.

1. Zoning/Management Zones — Management zones are separate parts of a field where different materials should be applied. When using variable rate application for precision agriculture, it is important to dictate which zones the machines should apply specific materials to, otherwise you may be setting yourself up for a problem. Due to its importance, the first step when applying fertilizer with variable rate application technology is to set proper the management zones. It is also crucial to make sure this information is properly inputted into the VRA system itself.

2. Map-Based vs. Sensor-Based VRA — Variable rate application in precision agriculture can be map-based or sensor-based. The second step is to figure out which

form is more viable for the problem that you are facing. This can also be influenced by the limitations of the variable rate application technology that is being used. Map-based VRT is when a map is generated of the landscape and inputted into the system before the system goes about its activities. Sensor-based is when the variable rate application technology integrates sensors that can automatically detect the data that will help it decide which fertilizer should be applied. For example, it could sense the crop health and make a decision based on that.

3. What Data/Imagery Should Be Used — After selecting map-based or sensor-based, the next step is to determine what type of data the sensors should be collecting, or what sort of imagery should be used in the mapping. Many VRA technologies utilize drones or other imaging systems to detect information about the landscape. Others include sensors on the application hardware itself. The most popular machinery-based sensors are N-sensor from Yara, Isaria from Fritzmeier and GreenSeeker from Trimble. Some of the information that is relevant for applying fertilizer would be things like soil quality and materials, type of crop, climate information, and the speed at which the vehicle is traveling while applying the fertilizer. All of this information, and more, is made available through the variable rate application technologies that are being used.

6.4 Other Applications and Benefits

Variable rate application in precision agriculture focuses on many other areas than just fertilization. Some of the other uses of VRA technology are for the application of herbicides, lime, and other chemicals, seeding, and the detection of weeds and diseased crops. Overall, VRA technology is primarily used to both detect information about a given landscape and to have a system make decisions based on that information. The decisions that are made by the variable rate application technology systems determine which materials should be applied to the land.

The benefits of having a VRA system is that it can help automate this part of the agricultural process. The more automation and precision that a company introduces to their operations, the more money they can save through higher production and efficiency. Multiple sources present various economic benefits of VRA highlighted below:

1. Savings on fertilizers and chemicals. Based on a study at the University of Illinois, the farmers can save about 5 USD per acre due to a VRA technology for nitrogen fertilization.
2. Potential yield increase due to more efficient fertilization and spraying based on actual crop needs and variability of fields.
3. Environmental protection from excess fertilisation or spraying of chemicals.

7.Precision Agricultural Tools

7.1 Global positioning system

GPS is a set of satellites that identify the location of farm equipment within a meter of an actual site in the field. The value of knowing a precision location within inches is that:

- Location of soil samples and the laboratory results can be compared to a soil map.
- Fertilizer and pesticides can be prescribed to fit soil properties (clay and organic matter content) and soil conditions (relief and drainage)
- Tillage adjustments can be made as one finds various conditions across the field and
- One can monitor and record yield data as one goes across the field.

The GPS technology provides accurate positioning system necessary for field implementation of variable rate technology. The present internet makes possible the development of a mechanism for effective farm management using remote sensing.

7.2. Geographical information system (GIS)

A geographical information system (GIS) consists of a computer software data base system used to input, store, retrieve, analyse and display, in map like form, spatially referenced geographical information.

7.3. Grid sampling

Grid sampling is a method of breaking a field into blocks of about 0.5-5 ha. The sampling soils within those grids to determine appropriate application rates. Several samples are tkan from each grid, mixed and sent into the laboratory for analysis.

7.4. Variable rate technology

Variable rate technology (VRT) consists of farm field equipment with the ability to precisely control the rate of application of crop inputs that can be varied in their application commonly include tillage, fertilizer, weed control, insect control, plant population and irrigation.

7.5. Yield monitors

Yield monitors are crop yield measuring devices installed on harvesting equipment. The yield data from the monitor is recorded and stored at regular intervals alongwith positional data received from GPS unit. GIS software takes the yield data and produce yield maps.

7.6. Yield maps

Yield maps are produced by processing data from adopted combine harvester that is equipped with a GPS that is integrated with a yield recording system. Yield mapping involves the recording of the grain flow through the combine harvester, while recording the actual in the field at the same time.

7.7. Remote sensors

Remote sensors are generally categorized as aerial or satellite sensors. They can indicate variations in field colour that corresponds to changes in soil type, crop development, field boundaries, roads, water etc. Remote science in agricultural terms means viewing crop from overhead (from a satellite or low flying aircraft) without coming into contact, recording what is viewed and displaying the image and provide the map to pinpoint the field problems more earlier and more effectively. In remote sensing, information transfer is accomplished by use of electromagnetic radiation (EMR). EMR is a form of energy that reveals its presence by the observable effects it produces when it strikes the matter. Due to remote sensing we have been able to observe large regions suitable for agriculture, making use of sensors to measure energy at wavelengths which are beyond the range of human vision (ultraviolet infrared, etc.) and globally monitoring earth possible from nearly any site. Remote sensing technology can be used to provide valuable information on various agricultural resources which influences production. Some of the broad agricultural application areas are:

- Crop production forecasting: It includes the identification of crops, acreage estimation and yield forecasting.
- Soil mapping: Soil maps afford the information on the suitability and limitation of the soil for agricultural production, which are helpful in selection of proper cropping system and optimal land use planning.
- Wasteland mapping: Information on degraded and wasteland e.g. salt affected areas, acidic soils, eroded soils, water logged area, dryland etc.
- Water stress: The use of remote sensors to directly measure soil moisture has had very limited success. Synthetic Aperture Radar (SAR) sensors are sensitive to soil moisture. SAR data requires extensive use of processing to remove surface induced noise such as soil surface roughness, vegetation and topography.
- Insect detection: Aerial or satellite remote sensing has not been successfully used to identify and locate insects directly. Indirect detection of insects through the detection of plant stress has generally been used in annual crops. Te economic injury level for treatment is usually exceeded by the time plant stress is detected by remote sensing entomologists prefer to do direct in field scouting in order to detect insects in time for chemical treatments to be effective and economics.
- Nutrient stress: Plant nitrogen stress areas can be located in the field using high-resolution colour infrared aerial images. The reflectance of near infrared, visible red and visible green wavelengths have a high correlation to the amount of applied nitrogen in the field.

7.8. Auto-guidance systems

Auto-guidance system allows farmers to maintain straight rows during farm operations and to come back to the same rows the next season. They allow more precise input application with these systems.

7.9. Proximate sensors

Proximate sensors can be used to measure soil (N and pH) and crop properties as the tractor passes over the field. The soil sample is scooped, pressed against an electrode, stabilization period of about 10-15 seconds allowed, and the reading taken.

7.10. Computer hardware and software

In order to analyses the data collected by other precision agriculture technology components and to make it available in usable formats such as maps, graphs, charts or reports, computer support is needed.

8. Smart Farming

Smart Farming represents the application of modern Information and Communication Technologies (ICT) into agriculture, leading to what can be called a Third Green Revolution. Smart farming and precision agriculture involve the integration of advanced technologies into existing farming practices in order to increase production efficiency and the quality of agricultural products. As an added benefit, they also improve the quality of life for farm workers by reducing heavy labor and tedious tasks.

These technologies will take agriculture to next steps in aspects like :

8.1 Autonomous and Robotic Labour

Replacing human labor with automation is a growing trend across multiple industries, and agriculture is no exception. Most aspects of farming are exceptionally labor-intensive, with much of that labor comprised of repetitive and standardized tasks—an ideal niche for robotics and automation.

The agricultural robots—or AgBots—beginning to appear on farms and performing tasks ranging from planting and watering, to harvesting and sorting. Eventually, this new wave of smart equipment will make it possible to produce more and higher quality food with less manpower.

8.2 Driverless Tractors

The tractor is the heart of a farm, used for many different tasks depending on the type of farm and the configuration of its ancillary equipment. As autonomous driving technologies advance, tractors are expected to become some of the earliest machines to be converted.

In the early stages, human effort will still be required to set up field and boundary maps, program the best field paths using path planning software, and decide other operating conditions. Humans will also still be required for regular repair and maintenance.

Nevertheless, autonomous tractors will become more capable and self-sufficient over time, especially with the inclusion of additional cameras and machine vision systems, GPS for navigation, IoT connectivity to enable remote monitoring and operation and radar and LiDAR for object detection and avoidance. All of these technological advancements will significantly diminish the need for humans to actively control these machines.

According to CNH Industrial, a company that specializes in farm equipment and previewed a concept autonomous tractor in 2016, “In the future, these concept tractors will be able to use ‘big data’ such as real-time weather satellite information to automatically make the best use of ideal conditions, independent of human input, and regardless of the time of day.”

Seeding and Planting

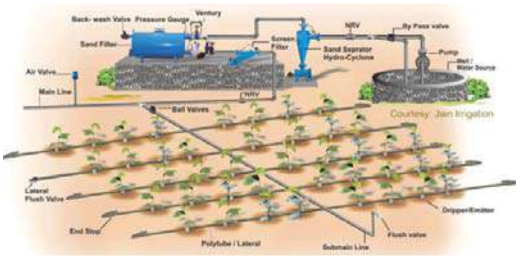
Sowing seeds was once a laborious manual process. Modern agriculture improved on that with seeding machines, which can cover more ground much faster than a human. However, these often use a scatter method that can be inaccurate and wasteful when seeds fall outside of the optimal location. Effective seeding requires control over two variables: planting seeds at the correct depth, and spacing plants at the appropriate distance apart to allow for optimal growth.

Precision seeding equipment is designed to maximize these variables every time. Combining geomapping and sensor data detailing soil quality, density, moisture and nutrient levels takes a lot of the guesswork out of the seeding process. Seeds have the best chance to sprout and grow and the overall crop will have a greater harvest.

As farming moves into the future, existing precision seeders will come together with autonomous tractors and IoT-enabled systems that feed information back to the farmer. An entire field could be planted this way, with only a single human monitoring the process over a video feed or digital control dashboard on a computer or tablet, while multiple machines roll across the field.

8.3 Automatic Watering and Irrigation

Subsurface Drip Irrigation (SDI) is already a prevalent irrigation method that allows farmers to control when and how much water their crops receive. By pairing these SDI systems with increasingly sophisticated IoT-enabled sensors to continuously monitor moisture levels and plant health, farmers will be able to intervene only when necessary, otherwise allowing the system to operate autonomously.



Example of an SDI system for agriculture. While current systems often require the farmer to manually check lines and monitor the pumps, filters and gauges, future farms can connect all this equipment to sensors that stream monitoring data directly to a computer or smartphone. (Image courtesy of Jain Irrigation.)

While SDI systems aren’t exactly robotic, they could operate completely autonomously in a smart farm context, relying on data from sensors deployed around the fields to perform irrigation as needed.

8.4 *Weeding and Crop Maintenance*

Weeding and pest control are both critical aspects of plant maintenance and tasks that are perfect for autonomous robots. A few prototypes are already being developed, including Bonirob from Deepfield Robotics, and an automated cultivator that is part of the UC Davis Smart Farm research initiative.

The Bonirob robot is about the size of a car and can navigate autonomously through a field of crops using video, LiDAR and satellite GPS. Its developers are using machine learning to teach the Bonirob to identify weeds before removing them. With advanced machine learning, or even artificial intelligence (AI) being integrated in the future, machines such as this could entirely replace the need for humans to manually weed or monitor crops.

The Bonirob farming robot. (Image courtesy of Deepfield Robotics.)

The UC Davis prototype operates a bit differently. Their cultivator is towed behind a tractor and is equipped with imaging systems that can identify a fluorescent dye that the seeds are coated with when planted, and which transfers to the young plants as they sprout and start to grow. The cultivator then cuts out the non-glowing weeds. While these examples are robots designed for weeding, the same base machine can be equipped with sensors, cameras and sprayers to identify pests and application of insecticides. These robots, and others like them, will not be operating in isolation on farms of the future. They will be connected to autonomous tractors and the IoT, enabling the whole operation to practically run itself.

8.5 *Harvesting from Field, Tree and Vine*

Harvesting depends on knowing when the crops are ready, working around the weather and completing the harvest in the limited window of time available. There are a wide variety of machines currently in use for crop harvesting, many of which would be suitable for automation in the future. Traditional combine, forage, and specialty harvesters could immediately benefit from autonomous tractor technology to traverse the fields. Add in more sophisticated tech with sensors and IoT connectivity, and the machines could automatically begin the harvest as soon as conditions are ideal, freeing the farmer for other tasks.

Developing technology capable of delicate harvest work, like picking fruit from trees or vegetables such as tomatoes, is where high-tech farms will really shine. Engineers are working to create the right robotic components for these sophisticated tasks, such as Panasonic's tomato-picking robot which incorporates sophisticated cameras and algorithms to identify a tomato's color, shape and location to determine its ripeness.

This robot picks tomatoes by the stem to avoid bruising, but other engineers are trying to design robotic end effectors that will be capable of gently griping fruit and vegetables tight enough to harvest, but not so hard that they cause damage. Another prototype for fruit picking is the vacuum-powered apple picking robot by Abundant Robotics, which uses computer vision to locate apples on the tree and determine if they are ready to harvest.

8.6 *Reducing Labor, Increasing Yield and Efficiency*

The core concept of incorporating autonomous robotics into agriculture remains the goal of reducing reliance on manual labour, while increasing efficiency, product yield and quality. Unlike their forebears, whose time was mostly taken up by heavy labor, the farmers of the future will spend their time performing tasks such as repairing machinery, debugging robot coding, analyzing data and planning farm operations. As noted with all of these agbots, having a robust backbone of sensors and IoT built into the farm's infrastructure is essential. The key to a truly "smart" farm relies on the ability of all the machines and sensors being able to communicate with each other and with the farmer, even as they operate autonomously.

8.7 Drones for Imaging, Planting and More

What farmer wouldn't want a bird's eye view of their fields? Where once this required hiring a helicopter or small aircraft pilot to fly over a property taking aerial photographs, drones equipped with cameras can now produce the same images at a fraction of the cost. In addition, advances in imaging technologies mean that you're no longer limited to visible light and still photography. Camera systems are available spanning everything from standard photographic imaging, to infrared, ultraviolet and even hyperspectral imaging. Many of these cameras can also record video. Image resolution across all these imaging methods has increased, as well, and the value of "high" in "high resolution" continues to rise.

All these different imaging types enable farmers to collect more detailed data than ever before, enhancing their capabilities for monitoring crop health, assessing soil quality and planning planting locations to optimize resources and land use. Being able to regularly perform these field surveys improves planning for seed planting patterns, irrigation and location mapping in both 2D and 3D. With all this data, farmers can optimize every aspect of their land and crop management.

But it isn't just cameras and imaging capabilities making a drone-assisted impact in the agricultural sphere—drones are also seeing use in planting and spraying.

8.8 *Planting from the Air*

Prototype drones are being built and tested for use in seeding and planting to replace the need for manual labor. For example, several companies and researchers are working on drones that can use compressed air to fire capsules containing seed pods with fertilizer and nutrients directly into the ground. DroneSeed and BioCarbon are two such companies, both of which are developing drones that can carry a module that fires tree seeds into the ground at optimal locations. While currently designed for reforestation projects, it's not hard to imagine that the modules could be reconfigured to suit various agricultural seeds. With IoT and software for autonomous operation, a fleet of drones could complete extremely precise planting into the ideal conditions for growth of each crop, increasing the changes for faster growth and a higher crop yield.

Example of a drone for tree planting. (Image courtesy of BioCarbon.)

8.9 Crop Spraying

There are also drones currently available and in development for crop spraying applications, offering the chance to automate yet another labor-intensive task. Using a combination of GPS, laser measurement and ultrasonic positioning, crop-spraying drones can adapt to altitude and location easily, adjusting for variables such as wind speed, topography and geography. This enables the drones to perform crop spraying tasks more efficiently, and with greater accuracy and less waste.

DJI Agras MG-1 crop spraying drone. (Image courtesy of DJI.)

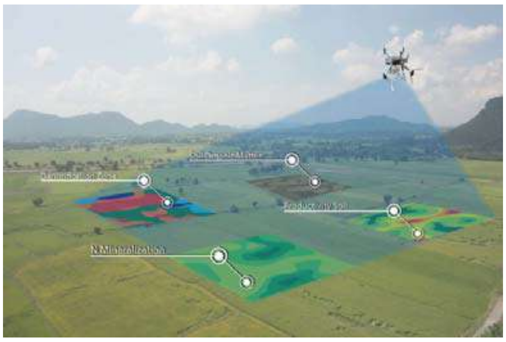
For example, DJI offers a drone called Agras MG-1 designed specifically for agricultural crop spraying, with a tank capacity of 2.6 gallons (10 liters) of liquid pesticide, herbicide or fertilizer, and a flight range of seven to ten acres per hour. Microwave radar enables this drone to maintain correct distance from the crops and ensure even coverage. According to DJI, it can operate automatically, semi-automatic or manual.

Working in conjunction with other agbots, crops identified as being in need of special attention could receive a personalized visit from the nearest drone at the first sign of trouble. Being able to provide individualized attention to any part of the field as soon as it's needed could help to stop many problems before they spread.

8.10 *Real-Time Monitoring and Analysis*

One of the most useful tasks drones can take on is remote monitoring and analysis of fields and crops. Imagine the benefits of using a small fleet of drones instead of a team of workers spending hours on their feet or in a vehicle travelling back and forth across the field to visually check crop conditions. This is where the connected farm is essential, as all this data needs to be seen to be useful. Farmers can review the data, and only make personal trips out into the fields when there is a specific issue that needs their attention, rather than wasting time and effort by tending to healthy plants.

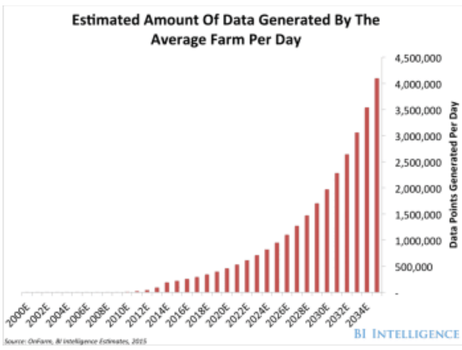
Given that drones for agricultural use are still early in their evolution, there are a few downsides. Ranges and flight times are not as robust as many farms would need—currently, even the longest running drones max out at around an hour of flight time before needing to return and recharge.

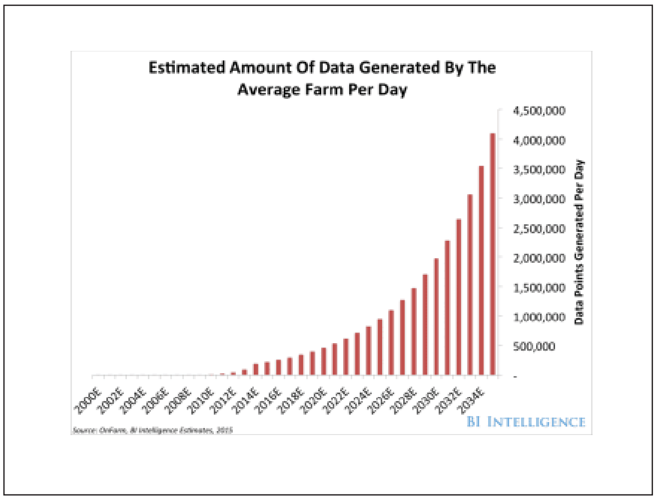


8.11The Connected Farm: Sensors and the IoT

Innovative, autonomous agbots and drones are useful, but what will really make the future farm a "smart farm" will be what brings all this tech together: the Internet of Things. The IoT has become a bit of a catch-all term for the idea of having computers, machines, equipment and devices of all types connected to each other, exchange data, and communicating in ways that enable them to operate as a so-called "smart" system. IoT technologies in use in many ways, such as smart home devices and digital assistants, smart factories and smart medical devices.

Smart farms will have sensors embedded throughout every stage of the farming process, and on every piece of equipment. Sensors set up across the fields will collect data on light levels, soil conditions, irrigation, air quality and weather. That data will go back to the farmer, or directly to AgBots in the field. Teams of robots will traverse the fields and work autonomously to respond to the needs of crops, and perform weeding, watering, pruning and harvesting functions guided by their own collection of sensors, navigation and crop data. Drones will tour the sky, getting the bird's eye view of plant health and soil conditions, or generating maps that will guide the robots, and help the human farmers to plan for the farm's next steps. All of this will help create higher crop production, and an increased availability and quality of food.





BI Intelligence shared their predictions that IoT devices installed in agriculture will increase from 30 million in 2015 up to 75 million by 2020. Under this trend, connected farms are expected to generate as many as 4.1 million data points each day in 2050—up from a mere 190,000 in 2014.

This mountain of data and other information generated by farming technology, and the connectivity enabling it to be shared, will be the backbone of the future smart farm. Farmers will be able to "see" all aspects of their operation—which plants are healthy or need attention, where a field needs water, what the harvesters are doing—and make informed decisions.

Non contact surface temperature measurement. Test of leaf and flower bud temperature. Checking of soil oxygen level. Test of solar radiation. Measurement of air temperure, humidity and pressure. Observation of conductivity, water content and soil temperature. Test of soil temperature and volumetric water content. Measurement of soilwater potentials. Test of vapour pressure, diameter. Exploration and test of wind and precipitations. Checking of lumiosity (Luxes accuracy).

Objectives: At the end of this lesson you shall be able to
- **to understand the concept of non contact surface measurment, leaf and flower bud temperature**
- **to understand the specification for soil oxygen level, air, temperature and humidity and pressure**
- **to understand the various applications of various sensor applied in plants.**

1. Non contact surface temperature measurement

1.1 Introduction

The Non-contact surface temperature measurement sensor probe is able to measure the electromagnetic radiation that every object with a temperature above absolute zero emits, which is used to calculate surface temperature from a distance.

Non contact surface temperature measurement sensor probe(Apogee S1-411)

1.1 Specifications

•Operating environment: -45 to 80 ºC •Operation humidity: 0 ~ 100% RH (non-condesing) •Calibration uncertainty (-20 to 65 ºC), when target and detector temperature are within 20 ºC: 0.2 ºC •Calibration uncertainty (-40 to 80 ºC), when target and detector temperature are different by more than 20 ºC: 0.5 ºC
•Measurement repeatability: less than 0.05 ºC
•Stability (Long-term drift): less than 2 % change in slope per year when germanium filter is maintained in a clean condition •Field of view: 22º half angle
•Spectral range: 8 to 14 ìm; atmospheric window
•Dimensions: 23 mm diameter; 60 mm length
•Mass: 190 g (with 5m of lead wire) •Cable: 5 m

1.3 Application examples

- Plant canopy temperature measurement for plant water status estimation
- Road surface temperature measurement for determination of icing conditions
- Terrestrial surface (soil, vegetation, water, snow) temperature measurement in energy balance studies

2. Test of Leaf and Flower Bud Temperature

2.1 Introduction

Frost events may happen in plants even though the ambient temperature is not 0 ºC or lower because the canopy temperature can be different than air temperature, this is called radiation frost. The Leaf and bud temperature sensor probe is designed to predict frost events. Radiation frost occurs when there is a lack of air mixing by the wind near the surface and a negative net long wave radiation balance at the surface.

Leaf and bud temperature sensor probe (Apogee SF 421)

2.2 Specifications

Operating temperature: -50 to 70 ºC •Operation humidity: 0 ~ 100% RH •Measurement range: -50 to 70 ºC •Measurement Uncertainty: -0.1 ºC (from 0 to 70 ºC) -0.2 ºC (from -25 to 0 ºC)-0.4 ºC (from -50 to -25 ºC)
•Measurement repeatability: less than 0.05 ºC
•Stability (Long-term drift): Less than 0.02 ºC per year

•Equilibration time: 10 s •Self-heating: Less than 0.01 ºC •Dimensions: 57 cm length, 2.1 cm pipe diameter, 7.0 cm disk diameter •Mass: 400 g •Cable: 5 m

2.3 Application examples

•Leaf and bud temperature estimates in cropped fields, orchards, and vineyards. •Detection of potential frost damage to crops.

3. Soil Oxygen Level

3.1 Introduction

Oxygen is the second major constituent of Earth's atmosphere and it is crucial for the development of life. There are sensors which measures oxygen in 2 states: dissolved in a solution and in a gaseous state. The Soil oxygen level sensor probe measures gaseous oxygen. The Soil oxygen level sensor probe consists of a galvanic cell type sensor and offers a measure of the percentage of the total number of molecules of oxygen in the air. This sensor is specially designed for use in soil or porous media

3.2 Specifications

•Operating environment: -20 to 60 ºC; 60 to 114 kPa •Operation humidity: 0 ~ 100% RH (non-condensing) •Measurement range: 0 to 100 % O2 •Measurement repeatability: Less than 0.1 % of mV output at 20.95 % O2 •Non-linearity: Less than 1 % •Long-term drift (Non-stability): 1.0 mV per year •Oxygen consumption rate: 2.2 ìmol O2 per day at 20.95 % O2 and 23 ºC •Response time: 60 s •Dimensions: 32 mm diameter, 68 mm length •Mass: 175 g •Cable: 5 m

3.3 Application examples

- Measurement of O2 in laboratory experiments.
- Monitoring gaseous O2 in indoor environments for climate control.
- Monitoring of O2 levels in compost piles and mine tailings
- Monitoring redox potential in soils
- Determination of respiration rates through measurement of O2 consumption in sealed chambers.
- Measurement of O2 gradients in soil/porous me

4. Solar Radiations

4.1 Shortwave

4.1.1 Introduction

The Shortwave radiation sensor probe (Apogee SP-510) measures incoming global shortwave radiation from the Sun. Shortwave radiation is radiant energy with wavelengths in the visible (VIS), near-ultraviolet (UV), and near-infrared (NIR) spectra. This sensor consists of a thermopile detector, acrylic diffuser, heater, and signal processing circuitry mounted in an anodized aluminum housing.

Shortwave radiation sensor probe(Apogee SP510)

4.1.2 Specifications

Operating temperature: -50 to 80 ºC •Operation humidity: 0 ~ 100% RH •Sensitivity (variable from sensor to sensor, typical values listed): 0.057 mV per W m-2 •Calibration factor (reciprocal of sensitivity): 17.5 W m-2 per mV •Calibration uncertainty: ± 5% •Calibrated output range: 0 to 114 mV •Measurement range: 0 to 2000 W m-2 (net shortwave radiation) •Measurement repeatability: less than 1% •Long-term drift (non-stability): less than 2% per year •Non-linearity: less than 1% •Detector response time: 0.5 s •Field of view: 180º •Spectral range (wavelengths where response is 50% of maximum): 385 to 2105 nm •Directional (cosine) response: less than 30 W m-2 up to solar zenith angles of 80º•Temperature response: less than 5% from -15 to 45 ºC •Cable length: 5 m

4.1.3 Application examples

- Incoming shortwave radiation measurement in agricultural, ecological, and hydrological weather networks
- Optimization of photo-voltaic systems

4.2 Photosynthetically active radiation (PAR)

4.2.1 Introduction

Photosynthetically active radiation (PAR) is the radiation that drives photosynthesis and is typically defined as total radiation across a range from 400 to 700 nm. PAR is often expressed as photosynthetic photon flux density (PPFD): photon flux in units of micromoles per square meter per second (ìmol‡m-2s-1).

4.2.2 Specifications

Operation temperature: -40 ~ 70 ºC

- Operation humidity: 0 ~ 100% RH

- Sensitivity: 0.2 mV / ìmol‡m-2s-1
- Calibration factor (Reciprocal of sensitivity): 5 ìmol‡m-2s-1 / mV
- Non-linearity: < 1% (up to 4000 ìmol‡m-2s-1 / mV)
- Non-stability (long-term drift): <2% per year
- Spectral range: 410 ~ 655 nm
- Repeatability: <0.5%
- Diameter: 2.4 cm
- Height: 2.8 cm
- Cable length: 5 m

4.2.3 Application examples

Photosynthetic photon flux density (PPFD) measures in:

- Plant canopies in outdoor environments
- Greenhouses and growth chambers
- Evapotranspiration analysis
- Aquatic environments, including salt water aquariums where corals are grown

4.3 Ultraviolet Radiations

4.3.1 Introduction

Ultraviolet (UV) radiation is typically defined as total radiation across a range from 100 to 400 nm and is subdivided into 3 wavelength ranges: UV-A (315 to 400 nm), UV-B (280 to 315 nm) and UV-C (100 to 280 nm).

Much of the UV-B and all of the UV-C wavelengths from the sun are absorbed by the Earth's atmosphere. The Ultraviolet radiation sensor probe for Smart Agriculture Xtreme (Apogee SU-100) detects UV radiation from 250 to 400 nm and is calibrated in photon flux units of micromoles per square meter per second (ìmol‡m-2s-1).

4.3.2 Specifications

- Operation temperature: -40 to 70 ºC
- Operation humidity: 0 to 100 %
- Sensitivity: 0.2 mV / ìmol‡m-2s-1
- Calibration factor (reciprocal of sensitivity): 5.0 ìmol‡m-m-2s-1 / mV
- Non-stability (long-term drift): <3% per year
- Non-linearity: <1% (up to 300 ìmol‡m-2s-1)
- Spectral range: 250 ~ 400 nm
- Repeatability: <1%
- Diameter: 2.4 cm
- Height: 2.8 cm
- Cable length: 5 m

4.3.3 Application examples

UV radiation measurement in:

- Outdoor environments
- Laboratory use with artificial light sources (e.g. germicidal lamps)
- Monitoring the filter ability and stability of different materials

5. Temperature, humidity and pressure sensor probe (Bosch BME280)

5.1 Introduction

The Bosch BME280 includes a humidity sensor that features an extremely fast response time which supports performance requirements for emerging applications such as context awareness, and high accuracy over a wide temperature range. The pressure sensor is an absolute barometric pressure sensor with features exceptionally high accuracy and resolution at very low noise. The integrated temperature sensor has been optimized for very low noise and high resolution. It is primarily used for temperature compensation of the pressure and humidity sensors, and can also be used for estimating ambient temperature.

5.2 Specifications

Temperature sensor

- Operational range: -40 ~ +85 ºC

- Full accuracy range: 0 ~ +65 ºC
- Accuracy: ±1 ºC (range 0 ºC ~ +65 ºC)
- Response time: 1.65 seconds (63% response from +30 to +125 °C).

Humidity sensor

- Measurement range: 0 ~ 100% of relative humidity (for temperatures < 0 °C and > 60 °C see figure below)

Accuracy: < ±3% RH (at 25 ºC, range 20 ~ 80%)

- Hysteresis: ±1% RH
- Operating temperature: -40 ~ +85 ºC
- Response time (63% of step 90% to 0% or 0% to 90%): 1 second

Pressure sensor

- Measurement range: 30 ~ 110 kPa
- Operational temperature range: -40 ~ +85 ºC
- Full accuracy temperature range: 0 ~ +65 ºC
- Absolute accuracy: ±0.1 kPa (0 ~ 65 ºC)

5.3 Application examples

- Weather observation and forecast
- Evapotranspiration analysis
- Control heating, ventilation or air conditioning in greenhouses
- Warning regarding dryness or high temperatures

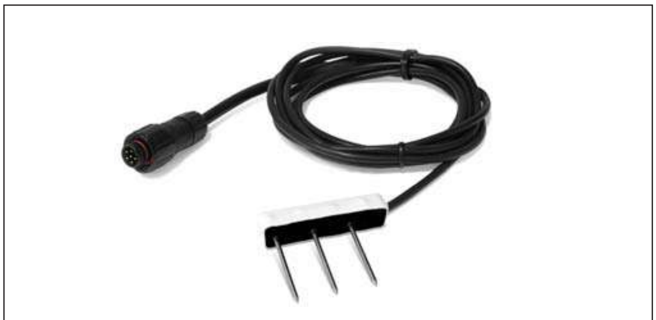
6. Conductivity, water content and soil temperature GS3 sensor probe (Decagon GS3)

6.1 Introduction

The Conductivity, water content and soil temperature sensor probe (Decagon GS3) can measure many types of growing media, specially in greenhouse applications where the probe can be inserted easily into different types of soilless substrates. The GS3 sensor determines volumetric water content (VWC) by measuring the dielectric constant (åa) of the medium using capacitance / frequency-domain technology, the temperature using a thermistor, and electrical conductivity using a stainless steel electrode array.

6.2 Specifications

Operating temperature:



-40 to 60 ºC•Dielectric measurement frequency: 70 MHz•Measurement time: 150 ms•Dimensions: 9.3 x 2.4 x 6.5 cm•Prong length: 5.5 cm•Cable length: 5 m

Volumetric water content

•Accuracy: åa: ±1 åa (unitless) from 1 to 40 (soil range), ±15% from 40 to 80•Resolution: -0.1 åa (unitless) from 1 to 20- < 0.75 åa (unitless) from 20 to 80-0.002 m3/ m3 (0.2% VWC) from 0 to 40% VWC-0.001 m3/ m3 (0.1% VWC) > 40% VWC•Range: Apparent dielectric permittivity (åa): 1 (air) to 80 (water)

Bulk electrical conductivity

•Accuracy: ± 5% from 0 to 5 dS/m, ±10% from 5 to 23 dS/ m•Resolution: 0.001 dS/m from 0 to 23 dS/m•Range: 0 to 25 dS/m (bulk)

Temperature•Accuracy: ±1 ºC•Resolution: 0.1 ºC•Range: -40 to 60 ºC

6.3 Application examples

•Maintain good soil contact and compensate for air gaps in the substrate of potting soil or soilless medias•Greenhouse substrate monitoring•Irrigation management•Salt management•Fertilizer movement•Modeling processes that are affected by temperature

7.Conductivity, water content and soil temperature 5TE sensor probe (Decagon 5TE)

7.1 Introduction

The Conductivity, water content and soil temperature sensor probe (Decagon 5TE) can measure volumetric water content, electrical conductivity, and temperature of soil. The sensor uses an oscillator running at 70 MHz to measure the dielectric permittivity of soil to determine the water content (VWC). A thermistor in thermal contact with the sensor prongs provides the soil temperature, while the screws on the surface of the sensor form a two-sensor electrical array to measure electrical conductivity.

7.2 Specifications

•Operating temperature: -40 to 60 ºC•Dielectric measurement frequency: 70 MHz•Measurement time: 150 ms•Dimensions: 10 cm x 3.2 cm x 0.7 cm•Prong length: 5.2 cm•Cable length: 5 m

Volumetric water content•Range: Apparent dielectric permittivity (åa): 1 (air) to 80 (water)•Resolution: -0.1 åa (unitless) from 1 to 20,-< 0.75 åa (unitless) from 20 to 80 -0.0008 m3/ m3 (0.08% VWC) from 0 to 50% VWC•Accuracy: åa : ±1 åa (unitless) from 1 to 40 (soil range), ±15% from 40 to 80 (VWC)

Bulk electrical conductivity•Range: 0 to 23 dS/m (bulk)•Resolution: 0.01 dS/m from 0 to 7 dS/m, 0.05 dS/ m from 7 to 23 dS/m•Accuracy: ±10% from 0 to 7 dS/m

Temperature•Range: "40 to 60 ºC•Resolution: 0.1 ºC Accuracy: ±1 ºC

7.3 Application examples

- Greenhouse substrate monitoring
- Irrigation management
- Salt management
- Fertilizer movement
- Modeling processes that are affected by temperature

8. Soil temperature and volumetric water content sen-sor probe (Decagon 5TM)

8.1 Introduction

The Soil temperature and volumetric water content sensor probe (Decagon 5TM) sensor can measure volumetric water content and temperature of soil. The sensor uses an oscillator running at 70 MHz to measure the dielectric permittivity of soil to determine the water content (VWC). A thermistor in thermal contact with the sensor prongs provides the soil temperature.

8.2 Specifications

General Specifications

•Operating temperature: -40 to 60 ºC •Dielectric measurement frequency: 70 MHz •Measurement time: 150 ms •Dimensions: 10 cm x 3.2 cm x 0.7 cm •Prong length: 5.2 cm •Cable length: 5 m

Volumetric water content

•Range: Apparent dielectric permittivity (åa): 1 (air) to 80 (water)•Resolution: -0.1 åa (unitless) from 1 to 20,-< 0.75 åa (unitless) from 20 to 80 -0.0008 m3/ m3 (0.08% VWC) from 0 to 50% VWC•Accuracy: åa : ±1 åa (unitless) from 1 to 40 (soil range), ±15% from 40 to 80 (VWC)

Temperature

•Range: "40 to 60 ºC•Resolution: 0.1 ºC Accuracy: ±1 ºC

8.3 Applications

- Soil water balance
- Irrigation management
- Modeling processes that are affected by temperature

9.Soil water potential sensor probe (Decagon MPS-6)

9.1 Introduction

There are 2 basic parameters that describe the state of water in soil: one is soil water content, or the amount of water per unit of soil, and the other is soil water potential, or the energy state of water in the soil. Although water content is useful when trying to describe the water balance of a soil, i.e. how much water is moving in, out, or being stored, water potential is often preferred over water content because it determines how water moves in a soil or from the soil to the plant. In addition, you can use water potential to determine plant availability of water, schedule irrigation, or determine the mechanical stress state of soil. The Soil water potential sensor probe (Decagon MPS-6) measures the water potential and temperature of a wide range of soil and other porous materials without user maintenance and factory calibration. Its extended range makes this sensor ideal for measuring the water potential in natural systems or other drier systems. The added temperature measurements can be used to determine approximate soil water potential in frozen soils

9.2 Specifications

General specifications

•Operating temperature: -40 to 60 ºC (no water potential measurement below 0 ºC) •Operation humidity: 0 ~ 100% RH •Dielectric measurement frequency: 70 MHz •Measurement time: 150 ms •Dimensions: 9.6 cm (L) x 3.5 cm (W) x 1.5 cm (D)•Sensor diameter: 3.2 cm •Cable length: 5 m

Water potential•Range: "9 to "100,000 kPa (pF 1.96 to pF 6.01)•Resolution: 0.1 kPa•Accuracy: ±(10% of reading + 2 kPa) from "9 to "100 kPa

Temperature•Range: "40 to 60 ºC•Resolution: 0.1 ºC•Accuracy: ±1 ºzC

9.3 Application examples

- Deficit irrigation monitoring and control
- Water potential monitoring in the vadose zone
- Crop stress
- Waste water drainage studies
- Plant water availability

10 Vapor pressure, temperature, barometric pressure and relative humidity sensor (Decagon VP-4)

10.1 Introduction

The VP-4 sensor probe is an accurate tool to measure air temperature, relative humidity (RH), vapor pressure, and barometric pressure in soil and in air. A microprocessor within the sensor calculates vapor pressure from the RH and temperature measurements. The sensor uses a sensor chip to measure both air temperature and RH and a secondary chip to measure barometric pressure.Despite this sensor can be installed in dry soils with a good performance, it is not recommended for saturated soils. The humidity measurements could saturate and could give a drift. Moreover, if the soil is completely saturated, it will not make sense to measure barometric pressure because there will not be air in the soil.

10.2 Specifications

General specifications

•Operating temperature: “40 to 80 ºC•Measurement time: 300 ms•Dimensions: 1.96 cm (dia) x 5.4 cm (h)•Cable length: 5 m

Vapor pressure•Range: 0 to 47 kPa•Resolution: 0.001 kPa

Temperature

•Range: “40 to 80 ºC•Resolution: 0.1 ºC•Equilibration time: < 400 s•Long term drift: < 0.04 ºC/year typical

Barometric pressure

•Range: 49 to 109 kPa•Resolution: 0.01 kPa•Accuracy: 0.4 kPa

Relative humidity

•Range: 0 to 100% RH•Resolution: 0.1% RH•Equilibration time: <40 s•Hysteresis: <1% RH typical•Long term drift: <0.5% RH/year typical

10.3 Application examples

- Greenhouse and canopy monitoring
- Reference evapotranspiration calculations
- Routine weather monitoring
- Building humidity monitoring
- Mold remediation
- Modeling processes that are affected by vapor pressure or humidity

11.Leaf wetness Phytos 31 sensor probe (Decagon Phytos 31)

11.1Introduction

The Leaf wetness Phytos 31 sensor probe (Decagon Phytos 31) measures leaf surface wetness by measuring the dielectric constant of the sensor’s upper surface. This sensor has very high resolution, which gives you the ability to detect very small amounts of water (or ice) on the sensor surface. Water on the sensor surface does not need to bridge electrical traces to be detected, as is common with resistance-based surface wetness sensors.

Leaf wetness Phytos 31 sensor probe (Decagon Phytos-31

11.1Specifications

•Operating temperature: -20 to 60 ºC •Measurement time: 10 ms •Probe dimensions: 11.2 cm x 5.8 cm x .075 cm•Cable length: 5 m

11.2 Application examples

- Decision of usage for crop fungicides
- Predict crop diseases or infections

12. Dendrometer sensor probes for Smart Agriculture Xtreme (Ecomatik DC3, DD-S and DF)

12.1 Introduction

Dendrometers are highly precise instruments for the continuous measurement of changes in plant diameter (i.e. growth dynamic, diurnal diameter changes). Dendrometer signals document the response of plants to their environment in high temporal resolution. This type of sensors do not measure the total diameter of the trunk or fruit, but the micro variations in diameter. That is a great tool to study how well the plant grows, absorbs and transpires water, its hydrological stress, possible diseases, etc.

Dendrometer sensor (Ecomatik DF)

12.2 Specifications

DC3 specifications (Trunk diameter)

•Operation temperature: -30 ~ 40 ºC •Operation humidity: 0 ~ 100% RH •Trunk/branch diameter: From 52 cm •Accuracy: ±3.3 ìm •Temperature coefficient: <1.4 ìm/K •Linearity: 0.7% •Output range: 0 ~ 20 kÙ

DD-S specifications (Stem diameter) •Operation temperature: -30 ~ 40 ºC •Operation humidity: 0 ~ 100% RH •Stem/branch diameter: 0 ~ 20 cm •Range of the sensor: 11 mm •Output range: 0 ~ 20 kÙ •Accuracy: ±2 ìm •Temperature coefficient: <0.1ìm/K •Cable length: 2 m

DF (Fruit diameter) •Operation temperature: -30 ~ 40 ºC •Operation humidity: 0 ~ 100% RH •Fruit diameter: 0 ~ 11 cm •Range of the sensor: 11 mm •Output range: 0 ~ 20 kÙ •Accuracy: ±2 ìm •Temperature coefficient: <0.1 ìm/K •Cable length: 2 m

12.3 Application examples

- Monitoring of growth processes of plants
- Examination of the influence of environmental factors on plant growth
- Precise dating of beginning and end of the growing season

13. Weather station sensor probes (Gill Instruments MaxiMet series)

13.1 Introduction

The Plug & Sense! Smart Agriculture Xtreme model offers the possibility of connecting any of the MaxiMet weather stations provided by Gill Instruments. The MaxiMet series offers a compact solution for weather forecast. The user can choose easily the best configuration thanks to the modularity that they offer, keeping the robustness, easy installation and low maintenance features. In other words, any of the different weather sensors can be combined in a custom model. Parameters related with wind, precipitation, solar radiation, dew point, air temperature, air humidity or atmospheric air pressure can be measured with these weather station probes

13.2 Specifications

General specifications

•Operating temperature: -40 to 70 ºC •Operation humidity: 0 ~ 100% RH •Weight (approximate, depends on models): 0.5 Kg •Dimensions (approximate, depends on models): 141 x 209.5 mm •Protection Class: IP66

Wind speed •Range: 0.01m/s to 60m/s •Accuracy: ±3% to 40m/s; ±5% above 40 and up to 60m/s •Resolution: 0.01 m/s •Threshold: 0.01 m/s

Wind direction •Range: 0-359º •Accuracy: ±3º to 40m/s; ±5º above 40 and up to 60m/s •Resolution: 1º •Starting threshold: 0.05 m/s

Compass •Range: 0-359º •Accuracy: ±3º •Resolution: 1º

Precipitation: optical method •Range: 0 to 300 mm/h •Precipitation resolution: 0.2mm•Repeatability: 3%

Precipitation: mechanical, tipping bucket method (Kalyx rain gauge) •Range: 0-1000 mm/hr •Precipitation resolution: 0.2 mm •Accuracy: 2%

Air temperature and dew point •Range: -40 °C to +70 °C •Resolution: 0.1 °C •Accuracy: ± 0.3 °C @ 20 °C

Air humidity •Range: 0 - 100% •Resolution: 1% •Accuracy: ± 2% @ 20 °C (10%-90% RH)

Atmospheric air pressure •Range: 300 to 1100 hPa •Resolution: 0.1 hPa •Accuracy: ± 0.5 hPa @ 25 °C

Global solar radiation •Wavelength sensitivity: 300 to 3000 nm •Range: 0 to 1600 W/m2 •Resolution: 1 W/m2 •DIN standard: ISO 9060 Second Class

13.2 Application examples

- Weather observation and forecast
- Evapotranspiration analysis•Forest fires development forecast

14 Luminosity sensor (AMS TSL2561)

14.1 Introduction

This is a light-to-digital converter that transforms light intensity into a digital signal output. This device combines one broadband photo-diode (visible plus infrared) and one infrared-responding photo-diode on a single CMOS integrated circuit capable of providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution). Two integrating ADCs convert the photo-diode currents to a digital output that represents the irradiance measured on each channel. This digital output in lux is derived using an empirical formula to approximate the human eye response.

Luminosity sensor probe (AMS TSL2561)

14.2 Specifications

Operating temperature: -30 ºC to +80 ºC •Dynamic range: 0.1 to 40000 Lux •Spectral range: 300 – 1100 nm •Usage: Indoors and outdoors

14.3 Applications

•Light presence detection for artificial lightning usage

Applications of wireless IOT inlivestock monitoring-collection of data regarding the location, well being and health of cattle. Usage of location sensors, GPS & GPS & GPS integrated circuits, application of wearable electronics to cattle, usage of wireless retrofitted bolus in cows stomach which can communicate via bluetooth to an eartag, selection of wireless technology with enough battery power to the list of life span of the animal.

Objectives: At the end of this lesson you shall be able to
- **to understand the applications of wireless IOT in livestock monitoring**
- **to understand the usage of GPS and its integrated circuits**
- **to make a selection of wireless technology and understand the applications of wearble electronics.**

1. Live Stock Monitoring

1.1 Introduction

IoT allows farmers to attach sensors to their animals that track location, well being, and even animal health. The farmer can then monitor their herd in real-time and receive alerts for important situations. Smart livestock implementations have been shown to:

- Lower labor costs.
- Increase herd health through methods like disease identification and estrous detection.
- Increase yield for meat and dairy through improved animal feeding and nutrition monitoring.

1.2 Applications

1.2.1 Cow Intelligence

Rumination is a proven direct indicator of cow wellbeing and health. As such, dairy producers, veterinarians, and nutritionists alike have long relied on cud chewing as a key indicator of dairy cow health. One of the primary purposes of rumination is to physically break down coarse material in food, in order to assist in its transfer from the rumen. An additional function is to increase the production of saliva, which acts as a buffer to the acids produced during the microbial degradation of carbohydrates. Dairy cows ruminate between 8-9 hours a day A drop in rumination time can be a result of low feed intake or a direct disruption of rumen function. Optimizing herd health, fertility, nutrition, and general management is the key to farm profitability – and in all these areas rumination can contribute useful information. Rumination monitoring can provide an early window for disease diagnosis, assessment of recovery and treatment effectiveness or diagnosis of feed related issues.

The advantages of rumination monitoring with SCR's management

systems on the individual cow, group, and herd level.

Early detection of disease:

Early detection and prompt treatment of sick cows can minimize the detrimental effects on their production, reproduction, and overall wellbeing. Research shows that using SCR's Health Report (that is based largely on rumination pattern analysis) enables the detection of disease days before it is apparent to the dairy farmer.

An example of a cow with mastitis is shown below. Rumination started to drop long before the farmer detected it in the milking parlor.

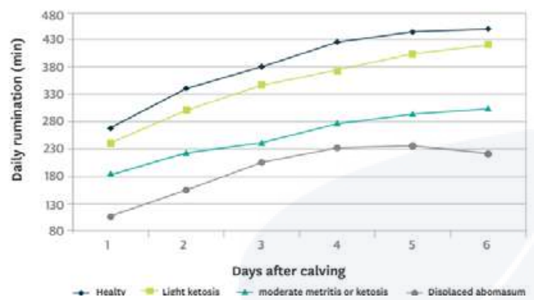
Easy recovery follow up

Rumination is essential for the cow. As such, her rumination will return to normal levels before her production level returns to normal. This means that rumination monitoring provide a more immediate way to evaluate the effectiveness of treatment.

An example of a cow with clinical mastitis is given below. After the cow was treated, rumination started rising.

Fresh cow monitoring:

The cow's wellbeing in the first days after calving dictates the fate of her health and productivity for the entire lactation. Cows with low feed intake in these critical days will suffer from various calving diseases (such as metritis and ketosis) later on, with a detrimental effect on future production and reproduction. The next graph shows the daily rumination time of healthy and sick cows in the first week after calving. Cowswith low rumination levels in this period appear on the SCR's Health Report, enabling the farmer to concentrate on these cows and properly respond before clinical diseases develop.



Real-time alerts in distress situations Cows ruminate in numerous sessions throughout the day. A pause in rumination of a few hours is a rare situation. If a cow stops ruminating for a long period of time, she is probably suffering from an acute situation that requires the farmer to react immediately, before fatal consequences occur. In order to protect the cow's wellbeing, SCR's system sends a distress alert to the farmer, as soon as distress occurs. The figure shows the rumination pattern of a cow suffering from milk fever after calving, and the relevant alerts noted by the system.

Heat detection:

The vast majority of cows in estrus will drop in their rumination level. SCR's Heat Index uses this rumination information in the calculation of the cows individual heat index, thus increasing the efficiency of heat detection based on activity levels alone. The next figure displays the typical relation between rumination and activity on the day of estrus.

Nutrition

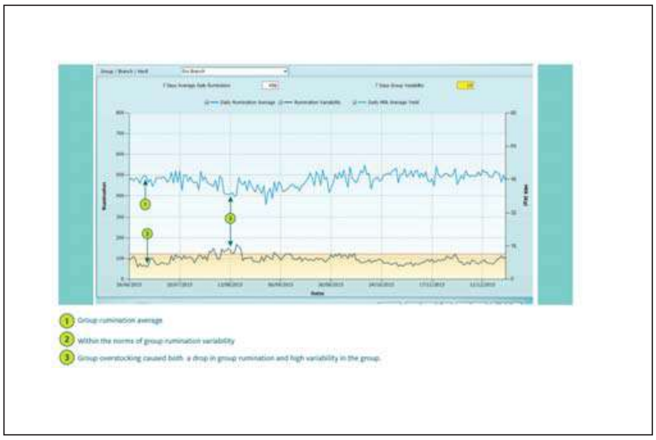
The trigger for the cow to start ruminating is rumen fill. The part of the feed that contributes to the rumination process is the long fibre part of the ration. During the rumination process the long fiber of the ration is broken down, enabling the rumen bacteria to digest the fiber. Rumination time is proportional to the amount of long finer that the cow has eaten. Cows will ruminate about 140 minutes per 1 kg of long fiber consumed. As such, changes in ration content and/or the

ration's physical characteristics will be reflected in rumination time changes.

In a typical dairy, feed and feeding management is usually very consistent. When a steady feeding schedule is maintained, one can expect a consistent rumination level on the group/herd level. Once a constant level of rumination is established, any expectations will indicate that there is a problem either with the ration itself, or with the feed management on the farm.

Daily rumination time of less than 400 minutes per day is considered low rumination, and is a major indicator/risk factor for rumen acidosis, due to less saliva production and insufficient rumen buffer. Rumen acidosis seriously impairs cow's health , welfare and farmer income.

In the graph below, the group rumination standard deviation (the lower line) reflects how variable the cows are in their daily rumination. Biological rumination standard deviation is deviation is typically between 50-80 minutes/day. Whenever one of the resources is less that optimal, some cows will not adequately eat, drink or lay down, causing the variability to increase substantially as seen below in the below diagram.



2.Usage of Location Sensors

2.1 Location Sensors use signals from GPS satellites to determine latitude, longitude, and altitude to within feet. Three satellites minimum are required to triangulate a position. Precise positioning is the cornerstone of precision agriculture. GPS integrated circuits like the NJR NJG1157PCD-TE1 are a good example of location sensors.

2.2 Global Positioning System

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS uses these “man-made stars” as reference points to calculate positions accurate to a matter of meters. In a sense it’s like giving every square meter on the planet a unique address.

GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. And that makes the technology accessible to virtually everyone. These days GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, even laptop computers.

2.2.1 How GPS Work

The GPS receiver gets a signal from each GPS satellite. The satellites transmit the exact time the signals are sent. By subtracting the time the signal was transmitted from the time it was received, the GPS can tell how far it is from each satellite. The GPS receiver also knows the exact position in the sky of the satellites, at the moment they sent their signals. So given the travel time of the GPS signals from three satellites and their exact position in the sky, the GPS receiver can determine your position in three dimensions – east, north and altitude.

There is a complication. To calculate the time the GPS signals took to arrive, the GPS receiver needs to know the time very accurately. The GPS satellites have atomic clocks that keep very precise time, but it’s not feasible to equip a GPS receiver with an atomic clock. However, if the GPS receiver uses the signal from a fourth satellite it can solve an equation that lets it determine the exact time, without needing an atomic clock

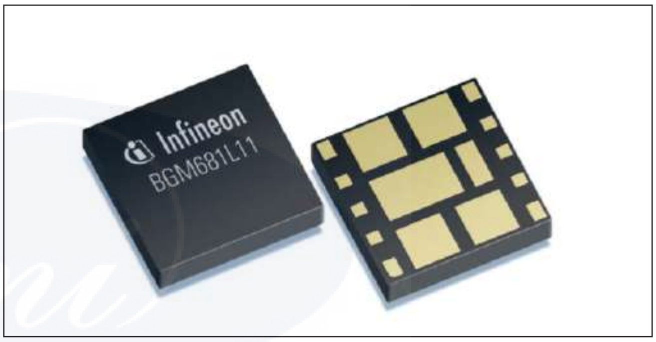
If the GPS receiver is only able to get signals from 3 satellites, you can still get your position, but it will be less accurate. As we noted above, the GPS receiver needs 4 satellites to work out your position in 3-dimensions. If only 3 satellites are available, the GPS receiver can get an approximate position by making the assumption that you are at mean sea level. If you really are at mean sea level, the position will be reasonably accurate. However if you are in the mountains, the 2-D fix could be hundreds of meters off.

A modern GPS receiver will typically track all of the available satellites simultaneously, but only a selection of them will be used to calculate your position.

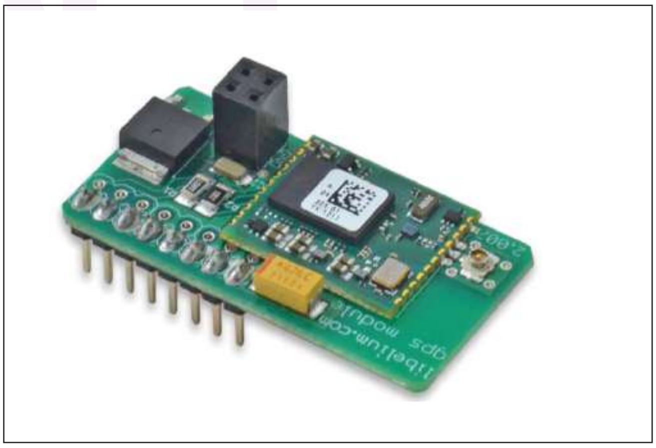
To determine the location of the GPS satellites two types of data are required by the GPS receiver: the almanac and the ephemeris. This data is continuously transmitted by the GPS satellites and your GPS receiver collects and stores this data.

2.2.2 GPS module vs GPS Chipset

GPS chipset is the main integrated circuit (IC), which receives the GPS signals, and decode it. It needs external peripherals to work such as external power supply, clock, antenna, low noise amplifier (for better sensitivity) etc.



On the other hand, GPS module comes in a complete package that requires no other external circuitry for GPS reception. It may or may not contains antenna on it. If someone has less knowledge or do not want to invest in GPS technology, but just want to use GPS system in his hardware, then GPS module is best solution there. You just have to plug and play.



2.2.3 How to use GPS module for Base Station Applications

The following things are required to use GPS for base station applications:

External Antenna

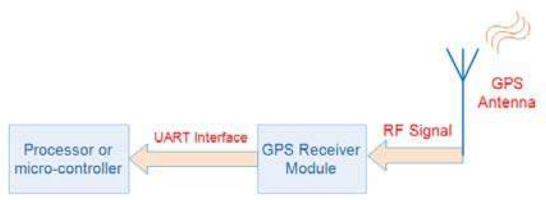
This antenna is mounted outside BTS box on the tower facing sky. This antenna is mounted on the BTS chassis using screws.

GPS module

Antenna is connected to the GPS module using RF cable. This GPS module is mounted inside BTS box.

Processor

BTS's processing unit i.e. FPGA, CPLD or other base band processor connected to the GPS module using UART (or SPI, I2C etc) interface. This processor send command to GPS module and receives desired response from it.



Thus using a GPS module and external antenna, one can get the most accurate 1 Hz clock and synchronize other clock circuitry

2.2.4 Parameters for selecting GPS module

GPS Pulse Accuracy

This is the accuracy of 1Hz pulse received from GPS module or chipset. (Typical ±25ns)

GPS Sensitivity

Minimum level of signal that allows GPS receiver to acquire or track the GPS signal.

Acquisition sensitivity: minimum level to successfully get GPS signal information while system powers up first time. (typically around -140 to -150 dBm)

Tracking sensitivity: minimum level to maintain location fix once it has been attained (typically -150 to -160 dBm)

Interface Type

When GPS chipset is used or GPS module, then over some interface, need to get the GPS packet information. That interface could be UART, I2C, SPI etc.

Operating Supply Voltage

This is the voltage over which GPS module or chipset works. (Typically, +2.5V or +3.3V)

Operating Temperature Range

If using GPS module for outdoor applications, then minimum and maximum operating temperature range shall be checked. (Typically -40 to +85 degreeC)

2.2.5 Where does GPS is used ?

Location – determining a basic position

Navigation – getting from one location to another

Tracking – monitoring the movement of people and things

Mapping – creating maps of the world

Timing – bringing precise timing to the world

3.Application of wearable electronics to cattle

3.1 Introduction

Wearable technology are smart electronic devices that are worn close to or on the surface of the skin, where they detect, analyse, and transmit information. Wearable devices such as activity trackers are an example of the Internet of Things, since "things" such as electronics, software, sensors, and connectivity are effectors that enable objects to exchange data through the internet with a manufacturer, operator, and/or other connected devices, without requiring human intervention.

3.2 Applications

The robotic milking system is capable of tracking a cows behaviour, temperature, and activity levels at their finger prints.

3.2.1 How It Works

The robotic milking system, is a collar tracking device worn by cows. The wearable technology, is capable of tracking a cow's internal and external behaviour, temperature, and activity levels, as well as incoming illnesses. In every collar device there is a pedometer inside which keeps track of a cow's activity and chewing. There is also a transponder- this part of the device helps by automatically adjusting the stall settings based on the cow that enters the stall. In other words, the stall is capable of "recognizing" the cow and then, adjusts the settings to match. The device is able to share those statistics and information with the farmer through an App on a smartphone.

3.2.2 Usage of Wireless Retrofitted Blous

Monitoring temperature in cattle is an effective way of preventing illness as early warning allows treatment before illness appears. The weight and size of the bolus prevent passage through the digestive tract. As developments in battery technology has occurred, it has made the bolus much more reliable across the lifespan of the animal. Remote means of detecting increased body temperature due to disease leads to more rapid and reliable detection, thereby decreasing severity of illness and minimising reductions in performance. A rumen bolus programmed to read and transmit core body temperature orally dosed to cattle is used with the age old saying “prevention is better than cure” in mind. The use of eartag/ probe temperature monitoring systems is best suited for short-term monitoring situations, as temperature probes must be frequently maintained. Ear temperatures are more variable than rectal temperatures, likely the result of decreased response time to both internal and environmental factors.

- Less stress to the animals
- Reduced feed bills
- Reduced medical bills

4. Selection of wireless technology

The world is becoming increasingly wireless as evidenced by the rapid emergence of the Internet of Things (IoT) and the development of low-power communications protocols such as ZigBee, Bluetooth, DASH7, INSTEON, and Z-Wave, EEE 802.15.4e, LoRA, WirelessHART, WiFi and cellular technologies. These energy-saving protocols, in conjunction with energy-saving chip design, permit certain wireless devices to operate maintenance-free for up to 40 years.

Identification of different types of drones, ground based and ariel based drones and their functions. Selection of various components of drones equipped with appropriate cameras, sensors and and integrating modules.

Objectives: At the end of this lesson you shall be able to
- **to identify different types of drones and their functions**
- **to understand about various components of drones with integrating modules.**

1.Drones

1.1 Introduction

Drones are known as unmanned aerial vehicles (UAVs) or unmanned aircraft systems (UASes). Essentially, a drone is a flying robot that can be remotely controlled or fly autonomously through software-controlled flight plans in their embedded systems, working in conjunction with onboard sensors and GPS.

1.2 Drones

1.2.1 Ground Based

An unmanned ground vehicle (UGV) is a vehicle that operates while in contact with the ground and without an onboard human presence. UGVs can be used for many applications where it may be inconvenient, dangerous, or impossible to have a human operator present. Generally, the vehicle will have a set of sensors to observe the environment, and will either autonomously make decisions about its behavior or pass the information to a human operator at a different location who will control the vehicle through teleoperation.

The UGV is the land-based counterpart to unmanned aerial vehicles and unmanned underwater vehicles. Unmanned robotics are being actively developed for both civilian and military use to perform a variety of dull, dirty, and dangerous activities.

1.2.2 Aerial Based

An unmanned aerial vehicle (UAV) commonly known as a drone is an aircraft without a human pilot on board and a type of unmanned vehicle. UAVs are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers.

1.2.3 How drones work

A typical unmanned aircraft is made of light composite materials to reduce weight and increase maneuverability. This composite material strength allows military drones to cruise at extremely high altitudes.

Drones are equipped with different state of the art technology such as infrared cameras, GPS and laser (consumer, commercial and military UAV). Drones are controlled by remote ground control systems (GSC) and also referred to as a ground cockpit.

An unmanned aerial vehicle system has two parts, the drone itself and the control system. The nose of the unmanned aerial vehicle is where all the sensors and navigational systems are present. The rest of the body is full of drone technology systems since there is no space required to accommodate humans.

The engineering materials used to build the drone are highly complex composites designed to absorb vibration, which decrease the sound produced. These materials are very light weight.

1.2.4 Types of Drones

Drones can be classified on a different basis – say based on *usage* like Drones for Photography, Drones for aerial Mapping, Drones for Surveillance etc. However, the best classification of 'Drones' can be made on the basis of aerial platforms. Based on the type of aerial platform used, there are 4 major types of drones.

1. Multi Rotor Drones
2. Fixed Wing Drones
3. Single Rotor Helicopter
4. Fixed Wing Hybrid VTOL

Multi Rotor Drones

Multi Rotor drones are the most common types of drones which are used by professionals and hobbyists alike. They are used for most common applications like aerial photography, aerial video surveillance etc.

Multi-rotor drones can be further classified based on the number of rotors on the platform. They are **Tricopter** (3 rotors), **Quadcopter** (4 rotors), **Hexacopter** (6 rotors) and **Octocopter** (8 rotors). Out of these, Quadcopters are the most popular and widely used variant.

Fixed Wing Drones

Fixed Wing drones are entirely different in design and build to multi-rotor type drones. They use a 'wing' like the normal airplanes out there. Unlike multi-rotor drones, fixed wing type models never utilize energy to stay afloat on air fighting gravity. Instead, they move forward on their set course or as set by the guide control (possibly a remote unit operated by a human) as long as their energy source permits.

Most fixed wing drones have an average flying time of a couple of hours. Gas engine powered drones can fly up to 16 hours or higher. Owing to their higher flying time and fuel efficiency, fixed wing drones are ideal for long distance operations (be it mapping or surveillance). But they cannot be used for aerial photography where the drone needs to be kept still on the air for a period of time.

Single Rotor Drones

Single rotor drones look very similar in design & structure to actual helicopters. Unlike a multi rotor drone, a single roter model has just one big sized rotor plus a small sized one on the tail of the drone to control its heading. Single rotor drones are much efficient than multi rotor versions. They have higher flying times and can even be powered by gas engines. In aerodynamics, the lower the count of rotors the lesser will be the spin of the object. And that's the big reason why quadcopters are more stable than octocopters. In that sense, single rotor drones are much efficient than multi-rotor drones.

However, these machines comes with much higher complexity and operational risks. Their costs are also on the higher side. The large sized rotor blades often pose a risk (fatal injuries have been recorded from rc copter accidents) if the drone is mishandled or involves in an accident. Multi-rotor drones, often owing to their small rotor blades have never been involved in fatal accidents (though a scar on human body is likely). They also demand special training to fly them on air properly (though they may not need a runway or a catapult launcher to put them on air).

Hybrid VTOL

These are hybrid versions combining the benefits of Fixed wing models (higher flying time) with that of rotor based models (hover). This concept has been tested from around 1960's without much success. However, with the advent of new generation sensors (gyros and accelerometers), this concept has got some new life and direction.

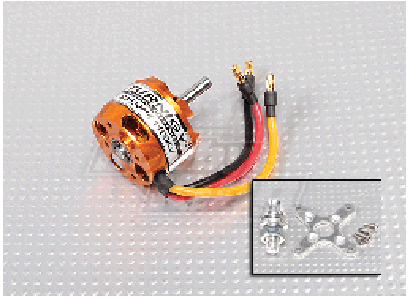
Hybrid VTOL's are a play of automation and manual gliding. A vertical lift is used to lift the drone up into the air from the ground. Gyros and accelerometers work in automated mode (autopilot concept) to keep the drone stabilized in the air. Remote based (or even programmed) manual control is used to guide the drone on the desired course.

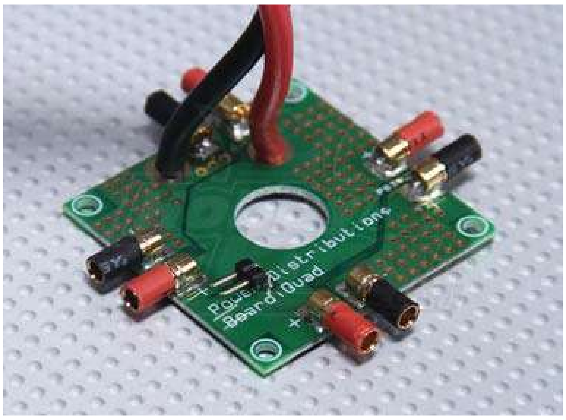
1.3 Selection of components of drones

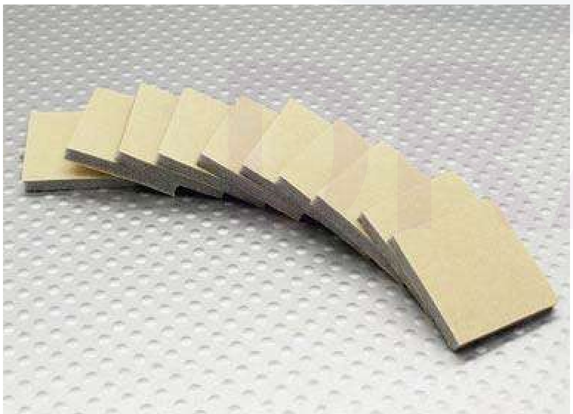
Depending upon the application the components varies. The following component discussion is for the quadcopter project powered by multiwii and controlled with Raspberry Pi 2 B. This quadcopter has a particularity because he's using 2 different controller and he could be pilot with 2 different devices : a remote control or a smartphone.

The Multiwii controller look after the 4 motors and distribute the power to supply them whereas the Raspberry Pi collect the information who came from the smartphone and relay them to the Multiwii. A Pi camera is placed on the front ground of the Drone Pi. It can record or just take a picture to a USB key.

The components used are A frame, 4 motors, 4 electronic speed controllers, battery, battery monitor, power distribution board, connectors 3.5mm,4.5mm, propellers, multiwii, mounting pad, Raspberry Pi 2 B, Pi camera, Wifi Key, USB key. The component images as follows:




Power Distributions
Board Quad




TURNIGY
nano-tech
3.3
3300mAh 25-50C DISCHARGE
HIGH DISCHARGE LI-PO BATTERY

Use of ground based and aerial based drones in agriculture for crop health assessment, irrigation, crop monitoring, crop spraying, planting and soil and field analysis. Explore the usage of thermal camera in smart farming. Process of carrying out real time data collection and processing, crop health imaging, integrated GIS mapping, gathering valuable data via series of sensors that are used

Objectives: At the end of this lesson you shall be able to
- **to understand the field and other parameter analysis using drones**
- **to explore the use of thermal camera in the field.**
- **to realize the usage of GIS mapping with real time data collection.**

1.Usage of Ground based and Aerial based Drones

Usage of ground-based and aerial based drones in agriculture for crop health assessment, irrigation, crop monitoring, crop spraying, planting and soil & field analysis.

High-tech drones allow farmers, and the drone pilots that operate them, to increase efficiency in certain aspects of the farming process. From crop monitoring to planting, livestock management, crop spraying, irrigation mapping, and more.

There are multiple uses for agricultural drones, including:

- Scouting land and crops
- Checking for weeds and spot treating plants
- Monitoring overall crop health
- Managing livestock and monitoring for health issues
- Soil & field analysis
- And more

Drones are equipped with technology like propulsion systems, infrared cameras, GPS and navigation systems, programmable controllers, and automated flight planning. Plus, with custom-made data processing software any collected information can instantly be put to use towards better management decisions.

2. Use of thermal camera in smart farming

Thermal imaging converts the invisible radiation pattern of an object into a visible image. In agriculture, thermal imaging has been successfully adopted for studying plant physiology, irrigation scheduling, and yield forecasting in agricultural fields. In addition, it evaluates growth maturity, detects bruises in fruits and vegetables, and spoilage made by microbial activities.

The thermal imaging monitors the visible and near infrared radiation that plants reflect, capturing the data needed in order to take action on time. This data can identify many problems which are caused by extreme climate changes, weeds, pests and diseases, over-planting, improper irrigation, inconsistent application of fertilizers, poor drainage and more.

Imaging systems that are carried by drones have distinct advantages over satellite-based monitoring systems or by manned aircrafts. Their views are less likely to be hindered by clouds, they are less influenced by atmospheric perturbations, and the images are captured continuously in a timely manner under the complete control of the user. And, the operational costs are much lower.

The concept of precision agriculture utilizes many tools and technologies to identify in-field variability, improve farming practices, and optimize agronomic inputs. For example, optimizing irrigation can be achieved by using thermal images to map the variability of water potential in the field. By applying water uniformly through traditional irrigation systems to a whole field, we do not take into account the variability in water uptake among plants.

Proper irrigation scheduling can reduce water stress and mitigate plant heat stress. Malfunctioning irrigation systems and non-uniform irrigation is a problem that may not be detected until viewed by aerial thermal imaging. The new technology can identify irrigation issues long before the symptoms are visually apparent or detect heat stress before the plant suffers permanent damage.

For example, in vineyards, the lack of uniformity among vines results in variability in grape quality and in the rate of ripening, which affects wine quality. One of the basic principles of the concept of precision agriculture is to fit resources to needs, according to temporal and spatial variability in the field. Irrigating according to the principle of precision agriculture will improve water distribution in the vineyard, help reach uniform maturity, and consequently, improve wine quality. Today drones enables us to supervise and monitor large fields, detecting problems long before they endanger plants, which is crucial in agriculture.

3.Real-time data collection and processing through drones/UAV

3.1 Introduction

Data collection is a crucial aspect of farm management and growth. In the past, farmers have employed weak data collection tools that led to poor decisions and huge losses. Even for large scale growers who engaged experts in the field in collecting accurate data, such data collection would take months to collect. By the time the data was ready for use, it had become irrelevant.

Since the early 80's when the first aerial unmanned drones were put into commercial use, there has been and increasing number of farmers using the drones in monitoring their crop production. Now, the unmanned aerial vehicle has become a data collection tool of choice in the agribusiness sector. In the ensuing discussion, we shall analyze the effectiveness of the use of the unmanned aerial vehicle to collect crop data.

3.2 Importance of UAVs In Crop Data Collection

The modern-day farmer faces various challenges in during the crop cycles. These include climate changes, resistant weeds and pests, and water scarcity. On the farm trials, yield measurements, forage quality evaluation, weed control effectiveness, and plant nutrient status are some of the popular data collection methods used to measure these risks. These methods rely on such gadgets as portable meters, test strips, manual stand counts, chlorophyll meters, seed sampling, and color charts for plant tissues. These gadgets have a limited accuracy, are cumbersome to operate, require an investment in the needed human expert to operate them and therefore subject to human error.

With the advent of agribusiness technology, these challenges are now addressed and precisely mitigated using high-tech data collection tools such as drones. Such tools utilize GPS and GNSS technologies in zoning and recording data on the large farms. This precise data collection ensures the use of accurate data in mitigating risks. This forms the basis of site-specific crop management.

3.3 Why Use Drones?

Drones have inbuilt sensors, navigation systems and recording devices that single out trouble spots in large farms at a bird's eye view. They can pick out anomalies that are difficult to see while on the ground. In turn, farmers map these farms according to such historical records as soil analysis, crop rotation and pest infestation. The data collected is of high resolution at an affordable cost. The UAV's are capable of translating the raw data using complex formulas and present practical statistics to the farmer.

The drones capabilities are not limited to just pinpointing problem areas. They are useful in monitoring ambitious growth plans undertaken by farmers. Such plans include data collection on the symbiotic relationship of keeping bees in a horticultural farm.

3.4 Real Time Crop Data Collection

The competitive advantage in the use of unmanned aerial vehicles to collect crop data lies in the drones' spontaneity. Farmers deploy unmanned aerial vehicles on demand. They stream real-time data directly to the decision making persons for quick action. Alternatively, the data is saved in a microchip inside the drone. These are inexpensive alternatives in precision farming.

3.5 Convenience of UAVs

These lightweight equipment weigh less than 20kgs. A farmer operates the drone using a wireless remote control. Alternatively, the farmer can program the drone to collect data on a particular route. They cover a large piece of land in a single flight. Little capital investment is needed to acquire the drones. Their price ranges from as low as $1,500 to more than $30,000 depending on the features. This expenditure can easily be paid back in one crop production cycle. They are convenient, safe, reliable and easy to use.

3.6 UAVs Application in Crop Data Collection

The following are some of the ways in with unmanned aerial vehicles are used in crop data collection: –

- The extent of pest and fungal infestation;
- Figures relating to plant anomalies, leaf coverage, flowering, the impact of insecticide application;
- Plant Growth Surveillance – Monitor the weather conditions;
- Irrigation – Drones are single out fields where water levels need to be increased or reduced. Upon the crop growth, the drones collect data relating to plant density, health and heat emission.

Sensors:

- Still image cameras
- Video
- Multispectral

- Identify nutrient deficiencies, pest damage, fertilizer needs and water quality.

Hyperspectral

- Used to analyze plant nutrients, plant diseases, water quality, and mineral and surface chemical composition.

Lidar

- Using lasers this sensor produces elevation data that can create 3D models of your farm

Thermal

- Track the surface temperature of land and plants

In combination these sensors can give a 3D GPS accurate model of your field and data that the human eye can not pickup on much less track easily over time.

Some terms you might hear are: Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge (NDRE). NDVI is basically a measure of plant health based on how a plant reflects light at specific frequencies. Healthy plants reflect large amounts of near-infrared light (NIR) where unhealthy plants absorb more.

Selection of what field to survey altitude or ground resolution on the basis of farmers information. Principle of inflight monitoring and observations. Collection of multispectral imagery during the flight of drones. Analysis of drone data.

Objectives: At the end of this lesson you shall be able to
- **to understand how information is gathered from farmers for field survey**
- **to understand process of inflight monitoring & multispectral imagining**
- **to analysis drone data for health monitoring of plants.**

1. Field Selection

Selection of what field to survey is know through informal surveys. Common features are

There is direct FSD worker-farmer interaction because the interviews are conducted by the FSD workers themselves, with FSD workers learning directly from farmers. Existing information and direct observation are also important sources of information in an informal survey. Special efforts are made to meet those (e.g., women, poorer people' more isolated people, etc.) who otherwise tend to be missed.

Interviews basically are unstructured and semi-directed. As a result, learning is rapid and progressive with a flexible use of methods to explore relevant issues as they arise with Improvisation, iteration, and probing. Questionnaires are not used, although FSD workers often use topic guidelines to make sure all relevant topics, on a given subject, are covered. Written notes sometimes are taken during the interviews, but the emphasis is on dialogue and questioning to obtain information.

The data collection process is dynamic and iterative, because FSD workers evaluate the data collected and reformulate data needs on a regular basis (i.e., often daily). More than one method or source of information often is used to cross check and confirm data and to improve approximations. Also, efforts are made not to find out more than is required and not to make, because of expense, inappropriately precise measurements.

The interviews often are conducted by an interdisciplinary team with each discipline contributing to the identification of problems and identifying and evaluating potential and actual solutions. These take into account factors influencing both the technical and human environment within which farmers operate.

Informal surveys don't permit statistical analysis, because they are undertaken without a formal sampling procedure, do not involve obtaining responses to a standard set of. questions, etc.

General characteristic of formal and informal surveys

CHARACTERISTIC	INFORMAL	FORMAL
Background information required	Minimal	Substantial
Time allocation by researchers:		
Preparation	Less	More
Implementation	More	Less
Analysis/writing	Less	More
Total time	Less	More
Hypotheses: Required beforehand	Not essential	Essential
Created during	Yes	No
Likely discipline interaction	More likely	Less likely
Implementation:		
Questionnaire used?	No	Yes
Interviewers	FSD worker(s)	Mainly enumerators
Potential for creativity/literation	Maximum	Minimal

Potential for learning/verification	Mainly learning	Mainly verification
Potential for representative sample	Le likely	More likely
Potential quality of information:		
Attitudinal	Better	Poorer
Qualitative	Better	Poorer
Quantitative	Poorer	Better
Probability of high: Sampling errors	Higher	Lower
Measurement errors	No difference	No difference
Value of statistical techniques in analysis	Little	Great

2. Principle of in-flight monitoring and observations

The use of drones in agriculture has massive benefits. In order to enhance various agricultural

practices, farmers and farming organizations use ground-based and aerial-based drones to

assess the crop conditions, irrigation, fertilizer spraying, soil analysis, planting, etc. Drones are important for integrated GIS mapping, crop health imaging, crop monitoring. They are easy to use and save a lot of time.

For example, PrecisionHawk is an organization that uses drones for gathering valuable data via

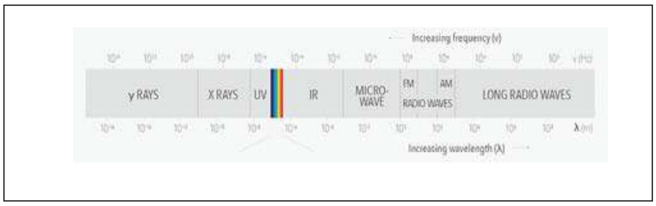
a series of sensors that are used for imaging, mapping, and surveying of agricultural land. These drones perform in-flight monitoring and observations. The farmers enter the details of what field to survey and select an altitude or ground resolution.

3.Collection of multispectral data

3.1 Multispectral Data

A standard visual sensor collects red, green and blue wavelengths of light. Multispectral sensors collect these visible wavelengths as well as wavelengths that fall outside the visible spectrum, including near-infrared radiation (NIR), short-wave infrared radiation (SWIR) and others.

Comprising of three-to-five spectral bands, multispectral sensors fall into two common categories: modified and multiband.

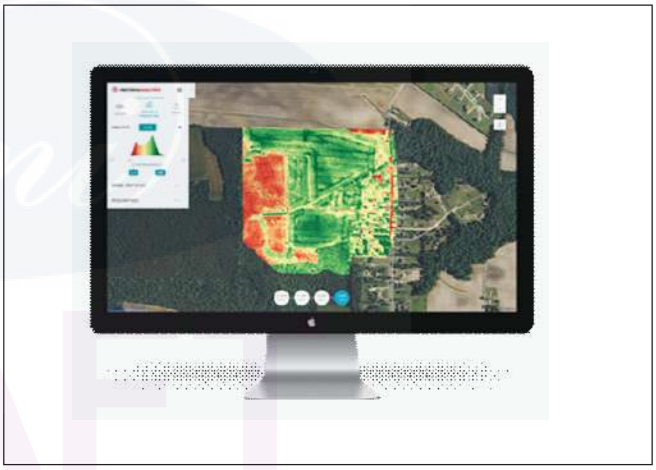


3.2 Modified Multispectral Sensors

Modified sensors are created by placing a filter on a standard visual sensor, which collects three bands of light at once through the same lens. Various filters allow for the capture of different combinations of spectral bands. The most common formats sacrifice one of the visual bands to record near-infrared information (NIR). For example, an R-G-NIR filter sacrifices blue for near-infrared energy (~700 - 800 nm).

3.3. Multiband Multispectral Sensors

A multiband multispectral sensor simultaneously collects several individual bands instead of a single combination of three bands, as with standard or modified visual sensors. To fly multiple drone flights with various modified sensors to capture all the multispectral data you need, you can collect everything in a single drone flight using a multiband sensor.



3.4 Choosing a Multispectral Sensor

So, choosing a multispectral sensor to deploy on the drone often comes down for desired analysis and the vegetation index it dictates is best suited to the use. In some cases, a simple visual sensor and NDVI output will do. But, when greater clarity is required, such as in the case of mid- and late-season crops or areas of interest that variable soil, a more sophisticated vegetation index will call for you to deploy a multiband multispectral sensor on your drone.

4. Analysis of Drone Data

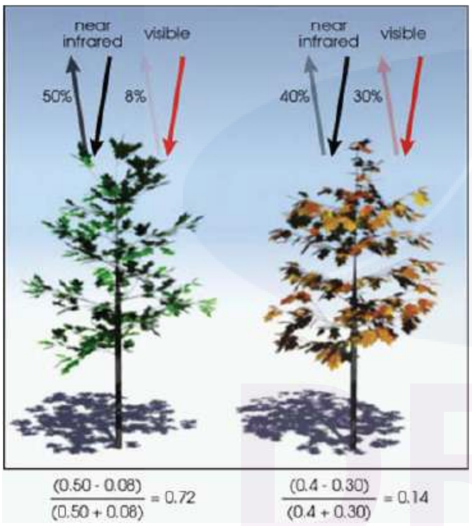
4.1 Introduction

Drones can be used to collect data related to crop yields, livestock health, soil quality, nutrient measurements, weather and rainfall results, and more. This data can then be used to get a more accurate map of any existing issues, as well as create solutions based upon extremely reliable data.

4.2 Processing Multispectral Sensor Data

By uploading multispectral sensor data into Precision analytics Agriculture, the mapping and data analytics platform, you can transform the various bands of multispectral data into indices that indicate vegetation health and stress. Indices require varying amounts of spectral data.

For example, a basic Normalized Difference Vegetation Index (NDVI) can be applied to basic red-green-blue (RGB) visual imagery captured by a regular camera. However, NDVI has its limitations. To gain a more accurate measure of crop health, multiband multispectral sensor can be deployed, that includes near-infrared and infrared wavelengths of light, enabling to run a Normalized Difference Red Edge (NDRE) vegetation index. This is better for mid- and late-season crops, which have greater accumulated levels of chlorophyll and multiple layers of vegetation.



4.3 Plant Health Algorithms Enable Growers and Agronomists to Identify Crop Variance

left (healthy) and right (unhealthy) with NDVI reflectance algorithm.

To measure plant health using drone imagery because healthy plants reflect light differently than unhealthy plants. Plants that are healthier tend to reflect more green light than red light, which is why they look green. Plants also reflect near-infrared light that is invisible to the naked eye, but can be detected with near-infrared sensors.

Plant health algorithms such as NDVI and VARI (more on this below) compare the proportions of light captured across different bands (red, green, blue and sometimes near-infrared) to compute numerical values for each pixel or area of a given drone map. Maps with plant health algorithms are then assigned colors based on those numerical values, which makes it easy to identify the variance between healthy and unhealthy areas.

4.4 Plant Health and Seeds Inspectorate (PHSI) role in APHA

Rapid detection of plant pathogens is critical in preventing widespread epidemics that can impact our environment, economy and social well-being. Early detection of new instances of plant pest and disease can make the response more manageable, reducing the impact of an outbreak. Early intervention can also reduce the cost of any containment or eradication activity.

The varied and complex nature of plant pests and disease means that visible symptoms can take time to develop after the initial infection resulting in plant pathogens being undetected for long periods of time. One of the ways that new technology can help us is by capturing and analysing aerial imagery to identify new disease outbreaks earlier, allowing for a swift, targeted response.

New technology

Farmers have started to use unmanned aerial systems (UAS) and aerial imagery to manage their land more effectively. An UAS describes the whole system that includes the drone or UAV, the ground-based ‘pilot’ and the system of communications between them both. This technology allows farmers to gain oversight of nutritional or protection requirements of crops, potentially saving them time and money by allowing for precision applications of chemicals, fertilisers or crop irrigation. Multispectral and hyperspectral imagery are often used to measure the responses of plants in the visible and near infrared parts of the electromagnetic spectrum to remotely detect plant stress.