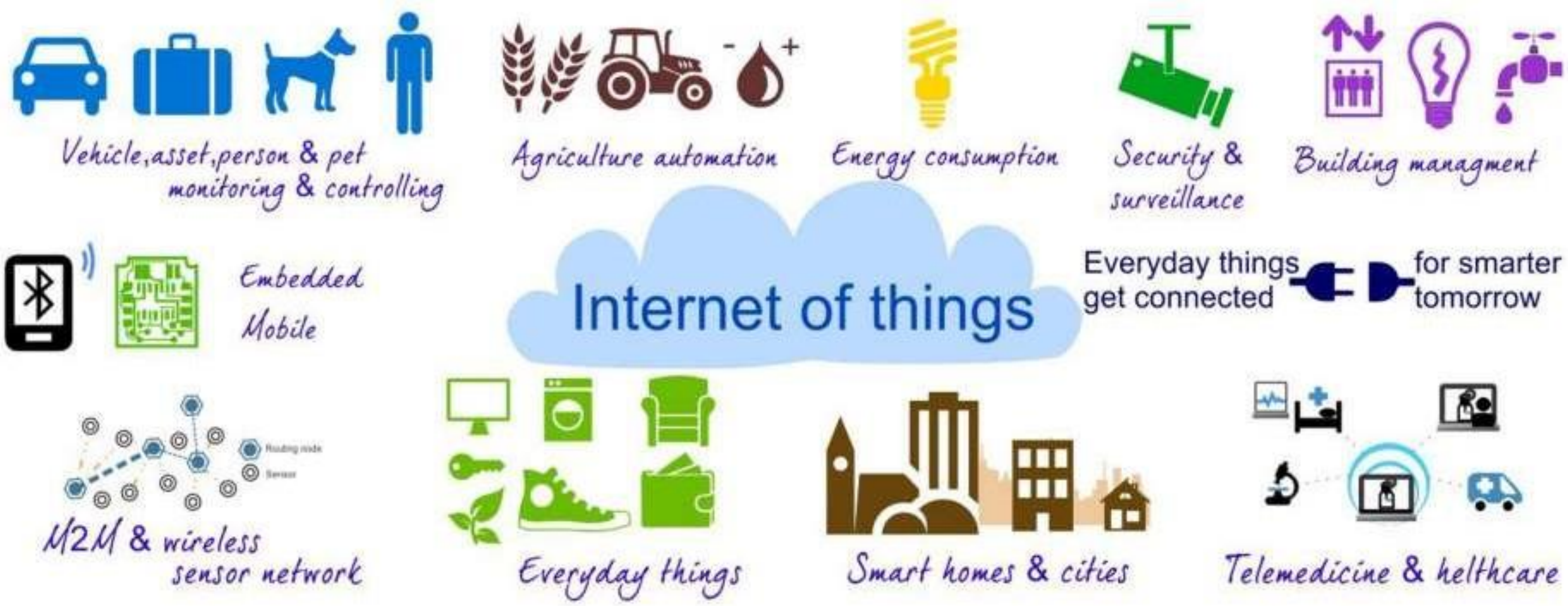
Domain Specific IoTs



Outline

IoT Applications for :

- Home
- Cities
- Environment
- Energy Systems
- Retail
- Logistics
- Industry
- Agriculture
- Health & Lifestyle

2.2 Home Automation

IoT applications for smart homes:

- *2.2.1 Smart Lighting*
- *2.2.2 Smart Appliances*
- *2.2.3 Intrusion Detection*
- *2.2.4 Smoke / Gas Detectors*

Home Automation

2.2.1 Smart Lighting

- Smart lighting achieve **energy savings** by sensing the human movements and their environments and controlling the lights accordingly.
- Key enabling technologies for smart lighting include :
  - ***Solid state lighting (such as LED lights)***
  - ***IP-enabled lights***
- Wireless-enabled and Internet connected lights can be controlled remotely from IoT applications such as a mobile or web application.
- Paper:
  - *Energy-aware wireless sensor network with ambient intelligence for smart LED lighting system control* [IECON, 2011] → presented controllable LED lighting system that is embedded with ambient intelligence gathered from a distributed smart WSN to optimize and control the lighting system to be more efficient and user-oriented.

Home Automation

2.2.2 Smart Appliances

- Smart appliances make the management easier and provide status information of appliances to the users remotely. ***E.g:*** smart washer/dryer that can be controlled remotely and notify when the washing/drying cycle is complete.
- ***OpenRemote*** is an open source automation platform for smart home and building that can control various appliances using mobile and web applications.
- It comprises of three components:
  - a Controller → manages scheduling and runtime integration between devices.
  - a Designer → allows to create both configuration for the controller and user interface designs.
  - Control Panel → allows to interact with devices and control them.
- Paper:
  - *An IoT-based Appliance Control System for Smart Home* [ICICIP, 2013] → implemented an IoT based appliance control system for smart homes that uses a smart-central controller to set up a wireless sensor and actuator network and control modules for appliances.

2.2.3 Intrusion Detection

- Home intrusion detection systems use *security cameras* and *sensors* to detect intrusions and raise alerts.
- The form of the alerts can be in form:
  - *SMS*
  - *Email*
  - *Image grab or a short video clip as an email attachment*
- Papers :
  - *Could controlled intrusion detection and burglary prevention stratagems in home automation systems* [BCFIC, 2012] → present a controlled intrusion detection system that uses location-aware services, where the geo-location of each node of a home automation system is independently detected and stored in the cloud
  - *An Intelligent Intrusion Detection System Based on UPnP Technology for Smart Living* [ISDA, 2008] → implement an intrusion detection system that uses image processing to recognize the intrusion and extract the intrusion subject and generate Universal-Plug-and-Play (UPnP-based) instant messaging for alerts.

2.2.4 Smoke / Gas Detectors

- Smoke detectors are installed in homes and buildings to detect smoke that is typically an early sign of fire.
- It uses optical detection, ionization or air sampling techniques to detect smoke
- The form of the alert can be in form :
  - *Signals that send to a fire alarm system*
- Gas detector can detect the presence of harmful gases such as carbon monoxide (CO), liquid petroleum gas (LPG), etc.
- Paper :
  - *Development of Multipurpose Gas Leakage and Fire Detector with Alarm System* [TIIEC, 2013] → designed a system that can detects gas leakage and smoke and gives visual level indication.

2.3 Cities

IoT applications for smart cities:

1. *Smart Parking*
2. *Smart Lighting for Road*
3. *Smart Road*
4. *Structural Health Monitoring*
5. *Surveillance*
6. *Emergency Response*

Cities

2.3.1 Smart Parking

- Finding the parking space in the crowded city can be time consuming and frustrating
- Smart parking makes the search for parking space easier and convenient for driver.
- It can detect the number of empty parking slots and send the information over the Internet to the smart parking applications which can be accessed by the drivers using their smartphones, tablets, and in car navigation systems.
- Sensors are used for each parking slot to detect whether the slot is empty or not, and this information is aggregated by local controller and then sent over the Internet to database.
- Paper :
  - *Design and implementation of a prototype Smart PARKing (SPARK) system using WSN* [International Conference on Advanced Information Networking and Applications Workshop, 2009] → designed and implemented a prototype smart parking system based on wireless sensor network technology with features like remote parking monitoring, automate guidance, and parking reservation mechanism.

Cities

2.3.2 Smart Lighting for Roads

- It can help in saving energy
- Smart lighting for roads allows lighting to be dynamically controlled and also adaptive to ambient conditions.
- Smart light connected to the Internet can be controlled remotely to configure lighting schedules and lighting intensity.
- Custom lighting configurations can be set for different situations such as a foggy day, a festival, etc.
- Paper :
  - *Smart Lighting solutions for Smart Cities* [International Conference on Advance Information Networking and Applications Workshop, 2013] → described the need for smart lighting system in smart cities, smart lighting features and how to develop interoperable smart lighting solutions.

Cities

2.3.3 Smart Roads

- Smart Roads provides information on driving conditions, travel time estimates and alerts in case of poor driving conditions, traffic congestions and accidents.
- Such information can help in making the roads safer and help in reducing traffic jams
- Information sensed from the roads can be communicated via internet to cloud-based applications and social media and disseminated to the drivers who subscribe to such applications.
- Paper:
  - *Sensor networks for smart roads* [PerCom Workshop, 2006] → proposed a distributed and autonomous system of sensor network nodes for improving driving safety on public roads, the system can provide the driver and passengers with a consistent view of the road situation a few hundred metes ahead of them or a few dozen miles away, so that they can react to potential dangers early enough.

Cities

2.3.4 Structural Health Monitoring

- It uses a network of sensors to monitor the vibration levels in the structures such as bridges and buildings.
- The data collected from these sensors is analyzed to assess the health of the structures.
- By analyzing the data it is possible to detect cracks and mechanical breakdowns, locate the damages to a structure and also calculate the remaining life of the structure.
- Using such systems, advance warnings can be given in the case of imminent failure of the structure.
- Paper:
  - *Environmental Effect Removal Based Structural Health Monitoring in the Internet of Things* [International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, 2013] → proposed an environmental effect removal based structural health monitoring scheme in an IoT environment.
  - *Energy harvesting technologies for structural health monitoring applications* [IEEE Conference on Technologies for Sustainability, 2013] → Explored energy harvesting technologies of harvesting ambient energy, such as mechanical vibrations, sunlight, and wind.

2.3.5 Surveillance

- Surveillance of infrastructure, public transport and events in cities is required to ensure safety and security.
- City wide surveillance infrastructure comprising of large number of distributed and Internet connected video surveillance cameras can be created.
- The video feeds from surveillance cameras can be aggregated in cloud-based scalable storage solutions.
- Cloud-based video analytics applications can be developed to search for patterns of specific events from the video feeds.

Cities

2.3.6 Emergency Response

- IoT systems can be used for monitoring the critical infrastructure cities such as buildings, gas, and water pipelines, public transport and power substations.
- IoT systems for critical infrastructure monitoring enable aggregation and sharing of information collected from lager number of sensors.
- Using cloud-based architectures, multi-modal information such as sensor data, audio, video feeds can be analyzed I near real-time to detect adverse events.
- The alert can be in the form :
  - Alerts sent to the public
  - Re-rerouting of traffic
  - Evacuations of the affected areas

2.4 Environment

IoT applications for smart environments:

1. Weather Monitoring

2. Air Pollution Monitoring

3. Noise Pollution Monitoring

4. Forest Fire Detection

5. River Flood Detection

Environment

2.4.1 Weather Monitoring

- It collects data from a number of sensor attached such as temperature, humidity, pressure, etc and send the data to cloud-based applications and store back-ends.
- The data collected in the cloud can then be analyzed and visualized by cloud-based applications.
- Weather alert can be sent to the subscribed users from such applications.
- AirPi is a weather and air quality monitoring kit capable of recording and uploading information about temperature, humidity, air pressure, light levels, UV levels, carbon monoxide, nitrogen dioxide and smoke level to the Internet.
- Paper:
  - PeWeMoS – Pervasive Weather Monitoring System [ICPCA, 2008] → Presented a pervasive weather monitoring system that is integrated with buses to measure weather variables like humidity, temperature, and air quality during the bus path

Environment

2.4.2 Air Pollution Monitoring

- IoT based air pollution monitoring system can monitor emission of harmful gases by factories and automobiles using gaseous and meteorological sensors.
- The collected data can be analyzed to make informed decisions on pollutions control approaches.
- Paper:
  - Wireless sensor network for real-time air pollution monitorings [ICCSPA, 2013] → Presented a real time air quality monitoring system that comprises of several distributed monitoring stations that communicate via wireless with a back-end server using machine-to machine communication.

Environment

2.4.3 Noise Pollution Monitoring

- Noise pollution monitoring can help in generating noise maps for cities.
- It can help the policy maker in making policies to control noise levels near residential areas, school and parks.
- It uses a number of noise monitoring stations that are deployed at different places in a city.
- The data on noise levels from the stations is collected on servers or in the cloud and then the collected data is aggregate to generate noise maps.
- Papers :
  - Noise mapping in urban environments : Applications at Suez city center [ICCIE, 2009]Presented a noise mapping study for a city which revealed that the city suffered from serious noise pollution.
  - SoundOfCity – Continuous noise monitoring for a health city [PerComW,2013] → Designed a smartphone application that allows the users to continuously measure noise levels and send to a central server here all generated information is aggregated and mapped to a meaningful noise visualization map.

Environment

2.4.4 Forest Fire Detection

- IoT based forest fire detection system use a number of monitoring nodes deployed at different location in a forest.
- Each monitoring node collects measurements on ambient condition including temperature, humidity, light levels, etc.
- Early detection of forest fires can help in minimizing the damage.
- Papers:
  - *A novel accurate forest fire detection system using wireless sensor networks* [International Conference on Mobile Ad-hoc and Sensor Networks, 2011] →Presented a forest fire detection system based on wireless sensor network. The system uses multi-criteria detection which is implemented by the artificial neural network. The ANN fuses sensing data corresponding to ,multiple attributes of a forest fire such as temperature, humidity, infrared and visible light to detect forest fires.

Environment

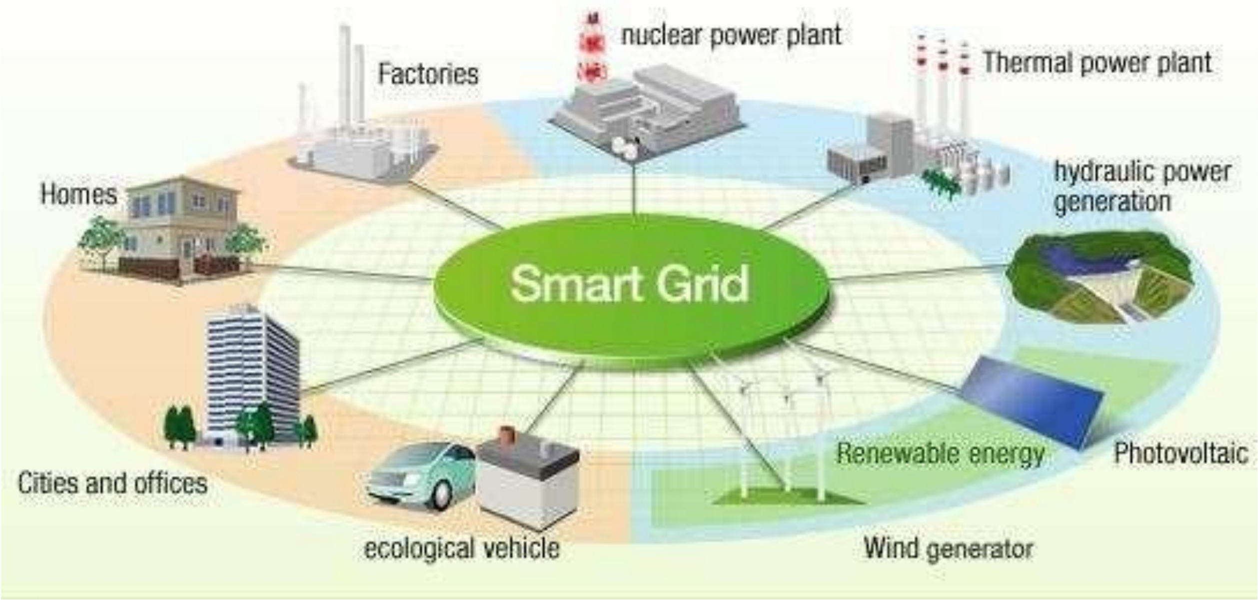
2.4.5 River Flood Detection

- IoT based river flood monitoring system uses a number of sensor nodes that monitor the water level using ultrasonic sensors and flow rate using velocity sensors.
- Data from these sensors is aggregated in a server or in the cloud, monitoring applications raise alerts when rapid increase in water level and flow rate is detected.
- Papers:
  - RFMS : Real time flood monitoring system with wireless sensor networks [MASS, 2008] → Described a river flood monitoring system that measures river and weather conditions through wireless sensor nodes equipped with different sensors
  - Urban Flash Flood Monitoring, Mapping and Forecasting via a Tailored Sensor Network System [ICNSC, 2006] → Described a motes-based sensor network for river flood monitoring that includes a water level monitoring module, network video recorder module, and data processing module that provides floods information n the form of raw data, predict data, and video feed.

2.5 Energy

IoT applications for smart energy systems:

1. *Smart Grid*
2. *Renewable Energy Systems*
3. *Prognostics*



Energy

2.5.1 Smart Grids

- Smart grid technology provides predictive information and recommendation s to utilize, their suppliers, and their customers on how best to manage power.
- Smart grid collect the data regarding :
  - Electricity generation
  - Electricity consumption
  - Storage
  - Distribution and equipment health data
- By analyzing the data on power generation, transmission and consumption of smart grids can improve efficiency throughout the electric system.
- Storage collection and analysis of smarts grids data in the cloud can help in dynamic optimization of system operations, maintenance, and planning.
- Cloud-based monitoring of smart grids data can improve energy usage usage levels via energy feedback to users coupled with real-time pricing information.
- Condition monitoring data collected from power generation and transmission systems can help in detecting faults and predicting outages.

Energy

2.5.2 Renewable Energy System

- Due to the variability in the output from renewable energy sources (such as solar and wind), integrating them into the grid can cause grid stability and reliability problems.
- IoT based systems integrated with the transformer at the point of interconnection measure the electrical variables and how much power is fed into the grid
- To ensure the grid stability, one solution is to simply cut off the overproductions.
- Paper:

  - *Communication systems for grid integration of renewable energy resources* [IEEE Network, 2011] → Provided the closed-loop controls for wind energy system that can be used to regulate the voltage at point of interconnection which coordinate wind turbine outputs and provides reactive power support.

Energy

2.5.3 Prognostics

- IoT based prognostic real-time health management systems can predict performance of machines of energy systems by analyzing the extent of deviation of a system from its normal operating profiles.
- In the system such as power grids, real time information is collected using specialized electrical sensors called Phasor Measurement Units (PMU)
- Analyzing massive amounts of maintenance data collected from sensors in energy systems and equipment can provide predictions for impending failures.
- OpenPDC is a set of applications for processing of streaming time-series data collected from Phasor Measurements Units (PMUs) in real-time.

2.6 Retail

IoT applications in smart retail systems:

1. *Inventory Management*
2. *Smart Payments*
3. *Smart Vending Machines*

Retail

2.6.1 Inventory Management

- IoT system using Radio Frequency Identification (RFID) tags can help inventory management and maintaining the right inventory levels.
- RFID tags attached to the products allow them to be tracked in the real-time so that the inventory levels can be determined accurately and products which are low on stock can be replenished.
- Tracking can be done using RFID readers attached to the retail store shelves or in the warehouse.
- Paper:
  - *RFID data-based inventory management of time-sensitive materials* [IECON, 2005] → described an RFID data-based inventory management system for time-sensitive materials

Retail

2.6.2 Smart Payments

- Smart payments solutions such as contact-less payments powered technologies such as Near field communication (NFC) and Bluetooth.
- NFC is a set of standards for smart-phones and other devices to communicate with each other by bringing them into proximity or by touching them
- Customer can store the credit card information in their NFC-enabled smart-phones and make payments by bringing the smart-phone near the point of sale terminals.
- NFC maybe used in combination with Bluetooth, where NFC initiates initial pairing of devices to establish a Bluetooth connection while the actual data transfer takes place over Bluetooth.

Retail

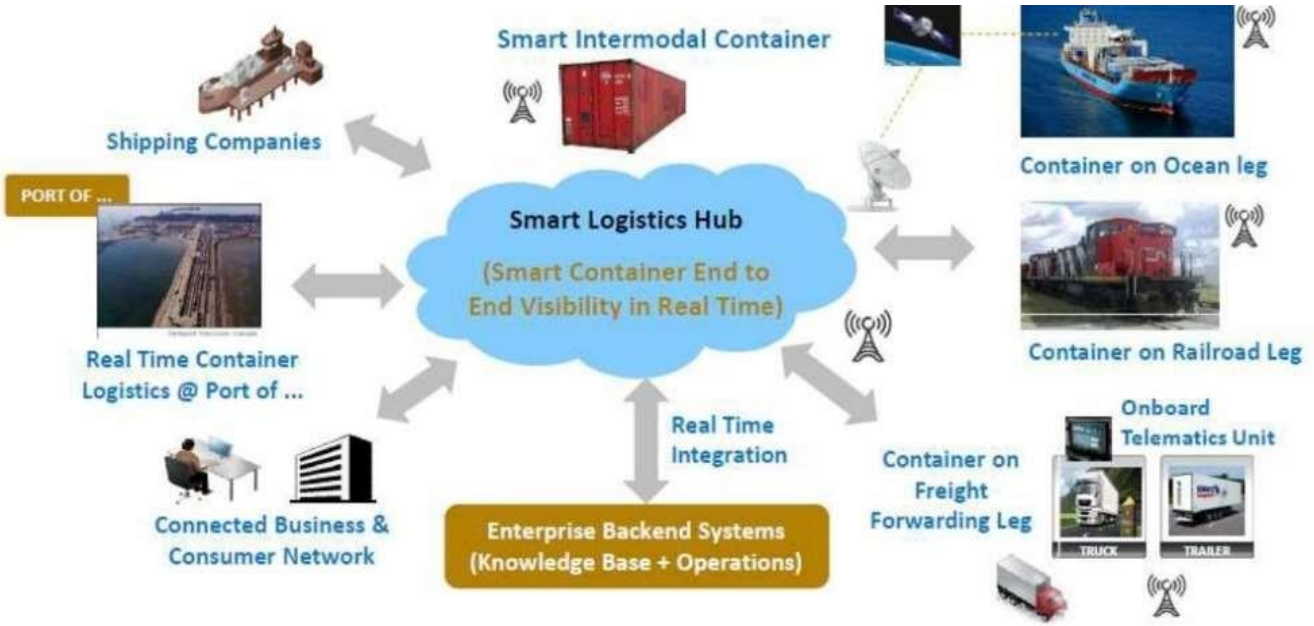
2.6.3 Smart Vending Machines

- Smart vending machines connected to the Internet allow remote monitoring of inventory levels, elastic pricing of products, promotions, and contact-less payments using NFC.
- Smart-phone applications that communicate with smart vending machines allow user preferences to be remembered and learned with time. E.g: when a user moves from one vending machine to the other and pair the smart-phone, the user preference and favorite product will be saved and then that data is used for predictive maintenance.
- Smart vending machines can communicated each others, so if a product out of stock in a machine, the user can be routed to nearest machine
- For perishable items, the smart vending machines can reduce the price as the expiry date nears.

2.7 Logistic

IoT applications for smart logistic systems:

1. *Fleet Tracking*
2. *Shipment Monitoring*
3. *Remote Vehicle Diagnostics*



Logistics

2.7.2 Fleet Tracking

- Vehicle fleet tracking systems use GPS technology to track the locations of the vehicles in the real-time.
- Cloud-based fleet tracking systems can be scaled up on demand to handle large number of vehicles,
- The vehicle locations and routers data can be aggregated and analyzed for detecting bottlenecks I the supply chain such as traffic congestions on routes, assignments and generation of alternative routes, and supply chain optimization
- Paper:
  - *A Fleet Monitoring System for Advanced Tracking of commercial Vehicles* [IEEE International Conference in Systems, Man and Cybernetics, 2006] → provided a system that can analyze messages sent from the vehicles to identify unexpected incidents and discrepancies between actual and planned data, so that remedial actions can be taken.

Logistics

2.7.3 Shipment Monitoring

- Shipment monitoring solutions for transportation systems allow monitoring the conditions inside containers.
- E.g : Containers carrying fresh food produce can be monitored to prevent spoilage of food. IoT based shipment monitoring systems use sensors such as temperature, pressure, humidity, for instance, to monitor the conditions inside the containers and send the data to the cloud, where it can be analyzed to detect food spoilage.
- Paper:
    - *On a Cloud-Based Information Technology Framework for Data Driven Intelligent Transportation System* [Journal of Transportation Technologies, 2013] → proposed a cloud based framework for real time fresh food supply tracking and monitoring
    - *Container Integrity and Condition Monitoring using RF Vibration Sensor Tags* [IEEE International Conference on Automation Science and Engineering, 2007] → Proposed a system that can monitor the vibrations patterns of a container and its contents to reveal information related to its operating environment and integrity during transport, handling, and storage.

2.7.4 Remote Vehicle Diagnostics

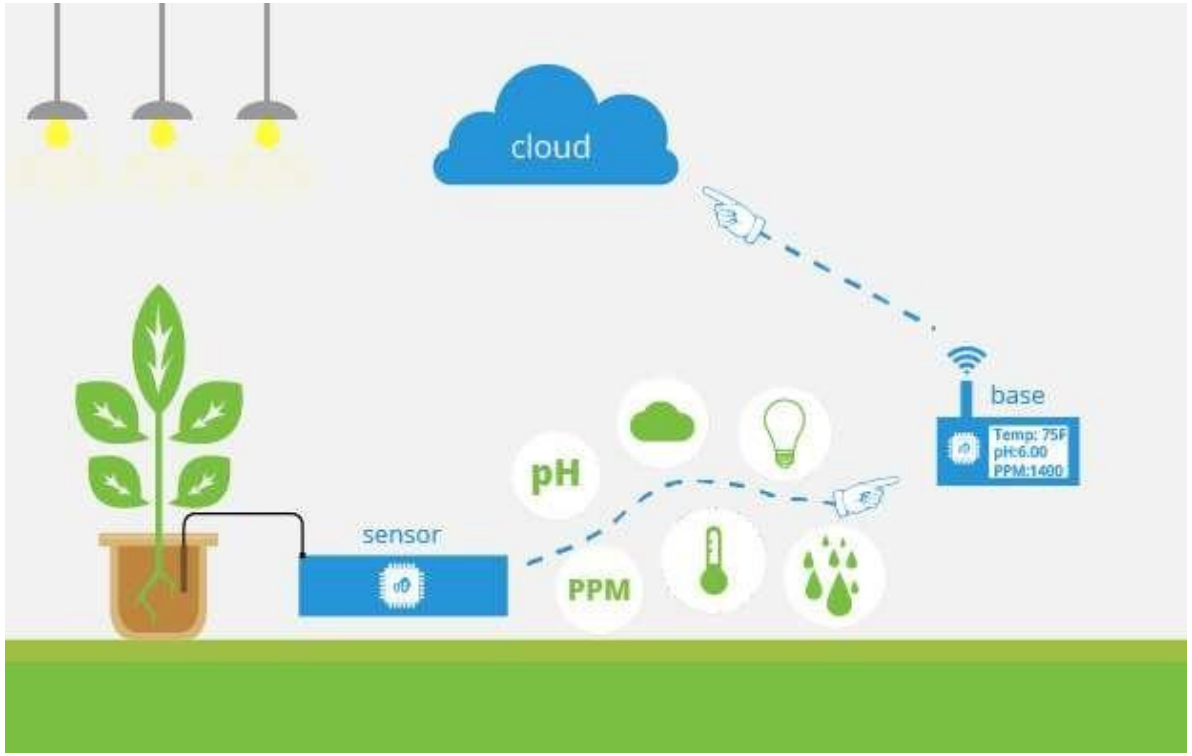
- It can detect faults in the vehicles or warn of impending faults.
- These diagnostic systems use on-board IoT devices for collecting data on vehicle operation such as speed, engine RPM, coolent temperature, fault code number and status of various vehicle sub-system.
- Modern commercial vehicles support on-board diagnostic (OBD) standard such as OBD-II
- OBD systems provide real-time data on the status of vehicle sub-systems and diagnostic trouble codes which allow rapidly identifying the faults in the vehicle.
- IoT based vehicle diagnostic systems can send the vehicle data to centralized servers or the cloud where it can be analyzed to generate alerts and suggest remedial actions.

2.8 Agriculture

IoT applications for smart agriculture:

1. Smart Irrigation

2. Green House Control



Agriculture

2.8.1 Smart Irrigation

- Smart irrigation system can improve crop yields while saving water.
- Smart irrigation systems use IoT devices with soil moisture sensors to determined the amount of moisture on the soil and release the flow of the water through the irrigation pipes only when the moisture levels go below a predefined threshold.
- It also collect moisture level measurements on the server on in the cloud where the collected data can be analyzed to plan watering schedules.
- *Cultivar's RainCould* is a device for smart irrigation that uses water valves, soil sensors, and a WiFi enabled programmable computer. [*http://ecultivar.com/rain-cloud-product-project/*]

Agriculture

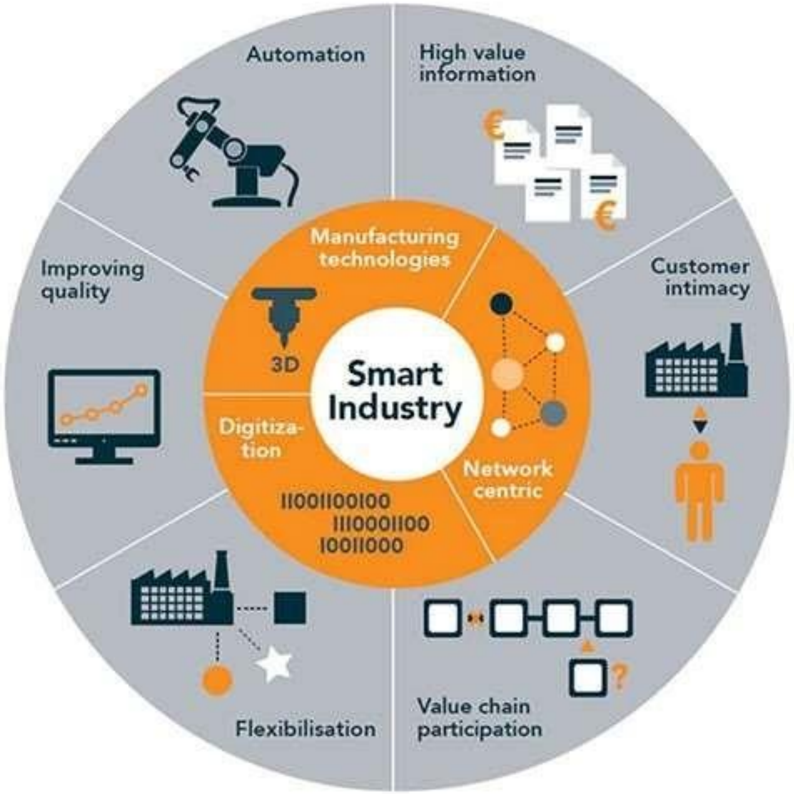
2.8.2 Green House Control

- It controls temperature, humidity, soil, moisture, light, and carbon dioxide level that are monitored by sensors and climatological conditions that are controlled automatically using actuation devices.
- IoT systems play an importance role in green house control and help in improving productivity.
- The data collected from various sensors is stored on centralized servers or in the cloud where analysis is performed to optimize the control strategies and also correlate the productivity with different control strategies.
- Paper:
    - *Wireless sensing and control for precision Green house management* [ICST, 2012] → Provided a system that uses wireless sensor network to monitor and control the agricultural parameters like temperature and humidity in the real time for better management and maintenance of agricultural production.

2.9 Industry

IoT applications in smart industry:

1. *Machine Diagnosis & Prognosis*
2. *Indoor Air Quality Monitoring*



Industry

2.9.1 Machine Diagnosis & Prognosis

- Machine prognosis refers to predicting the performance of machine by analyzing the data on the current operating conditions and how much deviations exist from the normal operating condition.
- Machine diagnosis refers to determining the cause of a machine fault.
- Sensors in machine can monitor the operating conditions such as temperature and vibration levels, sensor data measurements are done on timescales of few milliseconds to few seconds which leads to generation of massive amount of data.
- Case-based reasoning (CBR) is a commonly used method that finds solutions to new problems based on past experience.
- CBR is an effective technique for problem solving in the fields in which it is hard to establish a quantitative mathematical model, such as machine diagnosis and prognosis.

Industry

2.9.2 Indoor Air Quality Monitoring

- Harmful and toxic gases such as carbon monoxide (CO), nitrogen monoxide (NO), Nitrogen Dioxide, etc can cause serious health problem of the workers.
- IoT based gas monitoring systems can help in monitoring the indoor air quality using various gas sensors.
- The indoor air quality can be placed for different locations
- Wireless sensor networks based IoT devices can identify the hazardous zones, so that corrective measures can be taken to ensure proper ventilation.
- Papers:
  - *A hybrid sensor system for indoor air quality monitoring* [IEEE International Conference on Distributed Computing in Sensor System, 2013] → presented a hybrid sensor system for indoor air quality monitoring which contains both stationary sensor and mobile sensors.
  - *Indoor air quality monitoring using wireless sensor network* [International Conference on Sensing Technology, 2012] → provided a wireless solution for indoor air quality monitoring that measures the environmental parameters like temperature, humidity, gaseous pollutants , aerosol and particulate matter to determine the indoor air quality.

2.10 Health & Lifestyle

IoT applications in smart health & lifestyle:

1. Health & Fitness Monitoring

2. Wearable Electronics

Health & Lifestyle

2.10.1 Health & Fitness Monitoring

- Wearable IoT devices allow to continuous monitoring of physiological parameters such as blood pressure, heart rate, body temperature, etc than can help in continuous health and fitness monitoring.
- It can analyze the collected health-care data to determine any health conditions or anomalies.
- The wearable devices may can be in various form such as:
  - Belts
  - Wrist-bands
- Papers:
  - *Toward ubiquitous mobility solutions for body sensor network health care* [IEEE Communications Magazine, 2012] → Proposed an ubiquitous mobility approach for body sensor network in health-care
  - *A wireless sensor network compatible wearable u-healthcare monitoring system using integrated ECG, accelerometer and SpO2* [International Conference of the IEEE Engineering in Medicine and Biology Society, 2008] → Designed a wearable ubiquitous health-care monitoring system that uses integrated electrocardiogram (ECG), accelerometer and oxygen saturation (SpO2) sensors.

Health & Lifestyle

2.10.2 Wearable Electronics

- Wearable electronics such as wearable gadgets (smart watch, smart glasses, wristbands, etc) provide various functions and features to assist us in our daily activities and making us lead healthy lifestyles.
- Using the smart watch, the users can search the internet, play audio/video files, make calls, play games, etc.
- Smart glasses allows users to tae photos and record videos, get map directions, check flight status or search internet using voice commands
- Smart shoes can monitor the walking or running speeds and jumps with the help of embedded sensors and be paired with smart-phone to visualize the data.
- Smart wristbands can track the daily exercise and calories burnt.