MASTER IN ENTREPRENEURSHIP INNOVATION MANAGEMENT
IN COLLABORATION WITH MIT SLOAN

IN COLLABORATION WITH MIT MANAGEMENT SLOAN SCHOOL

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Introduction to IOT and its Applications

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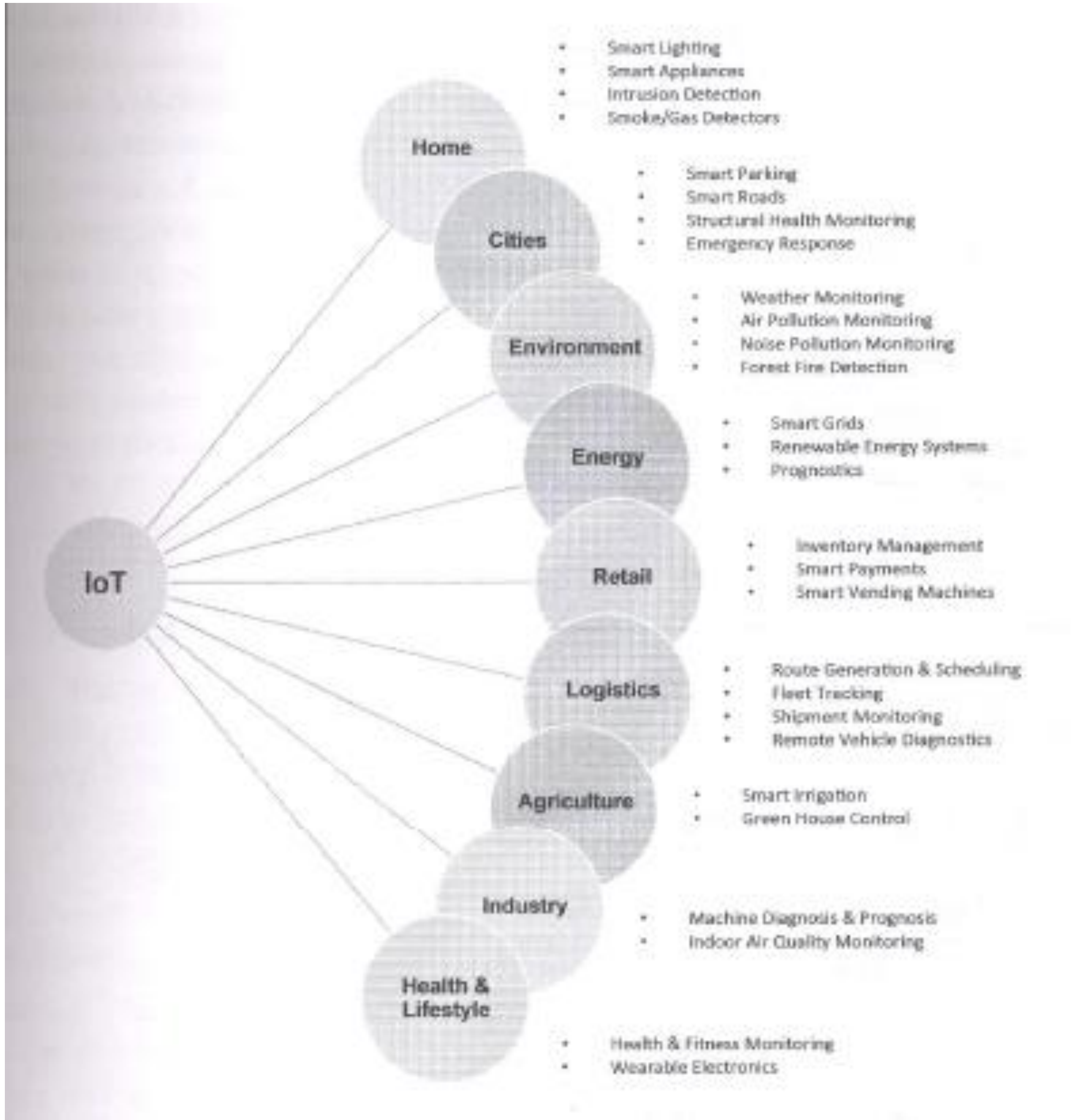
Overview

- Presentation of IoT
- Economic Perspectives of IoT
- IoT Applications

Internet of Things: Definition

- A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network, often communicate data associated with users and their environments.

IoT Applications



IoT Characteristics

- Dynamic & Self-Adapting
- Self-Configuring
- Interoperable Communication Protocols
- Unique Identity
- Integrated into Information Network

IoT: Dynamic and Self-Adapting

- IoT devices and systems may have the capability to dynamically adapt with the changing contexts and take actions based on their operating conditions, user's context, or sensed environment
  - Consider a surveillance system comprising a number of cameras. The cameras adapt their modes based on whether it is day or night. Hence, the surveillance system is adapting itself based on the context and changing conditions.

IoT: Self-Configuring

- IoT devices may have self-configuring capability, allowing a large number of devices to work together to provide certain funcionality. These devices have the ability configure themselves, setup the networking, and fetch latest software upgrades with minimal manual or user intervention.

IoT: Interoperable Communication Protocols

- IoT devices may support a number of interoperable communication protocols and can communicate with other devices and also with the infrastructure.

IoT: Unique Identity

- Each IoT device has only an identity and an identifier (e.g., IP Address). IoT systems may have intelligent interfaces which can adapt on the context, allow communicating with users an the environmental contexts. IoT device interface allows users to query the devices, monitor their status, and control them remotely, in association with the control, configuration and management infrastructure.

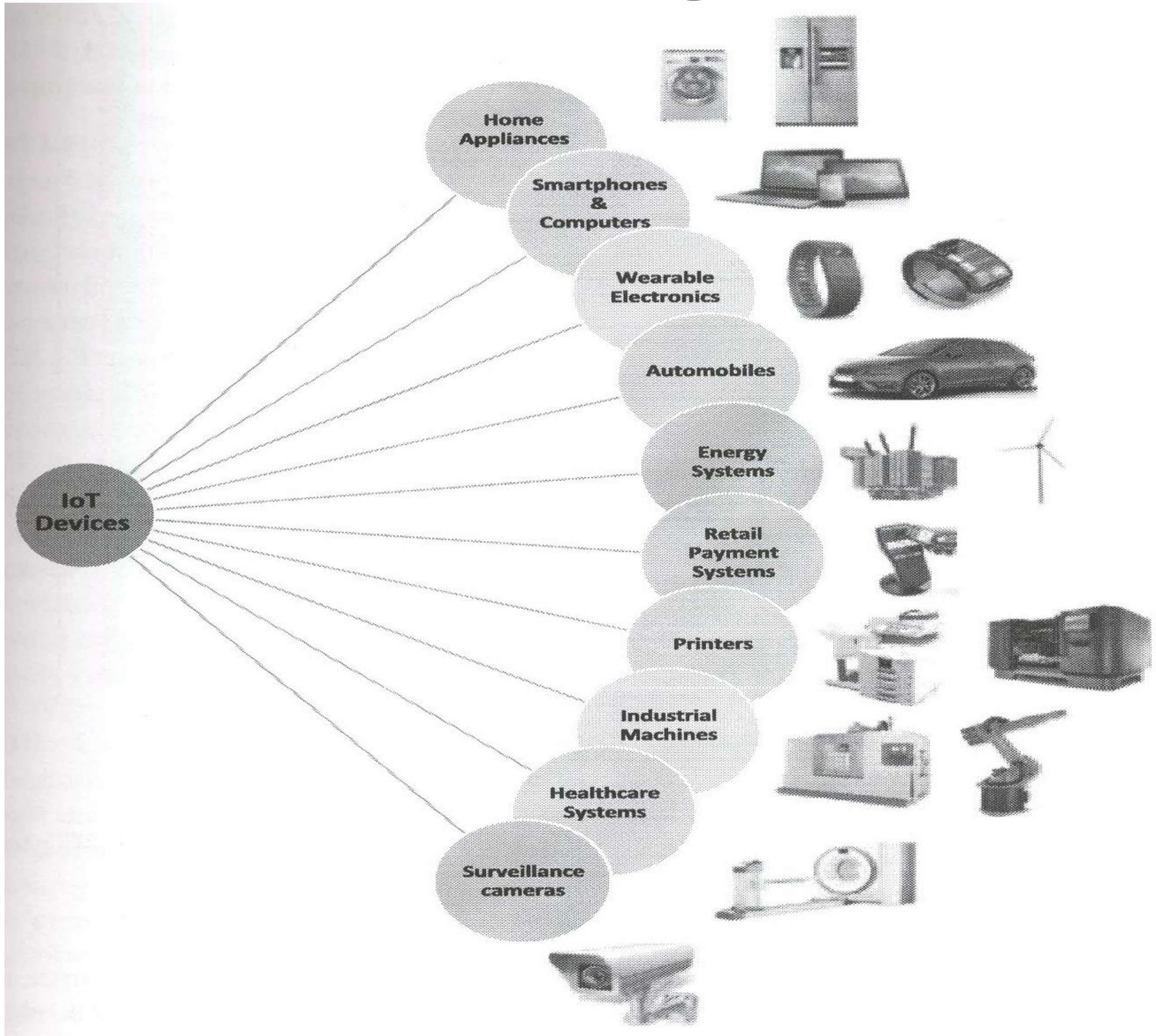
IoT: Integrated into Information Network

- IoT devices are usually integrated into the information network that allows them to communicate and exchange data with other devices and systems. IoT devices can be dynamically discovered in the network, by other devices and/or the network, and have the capability to describe themselves to other devices or user applications.
- Integration into the information network helps in making IoT system smarter due to the collective intelligence of the individual devices in collaboration with the infrastructure.

Things in IOT

- The ‘**Things**’ in IoT usually refers to IoT devices which have single identities and can perform remote sensing, actuating and monitoring capabilities.
- IoT devices can:
  - exchange data with other connected devices and applications
  - collect data from other devices and process the data locally
  - send the data to centralized servers or cloud-based application back-ends for processing the data, or perform some tasks locally and other tasks within the IoT infrastructure, based on temporal and space constraints.

IoT devices

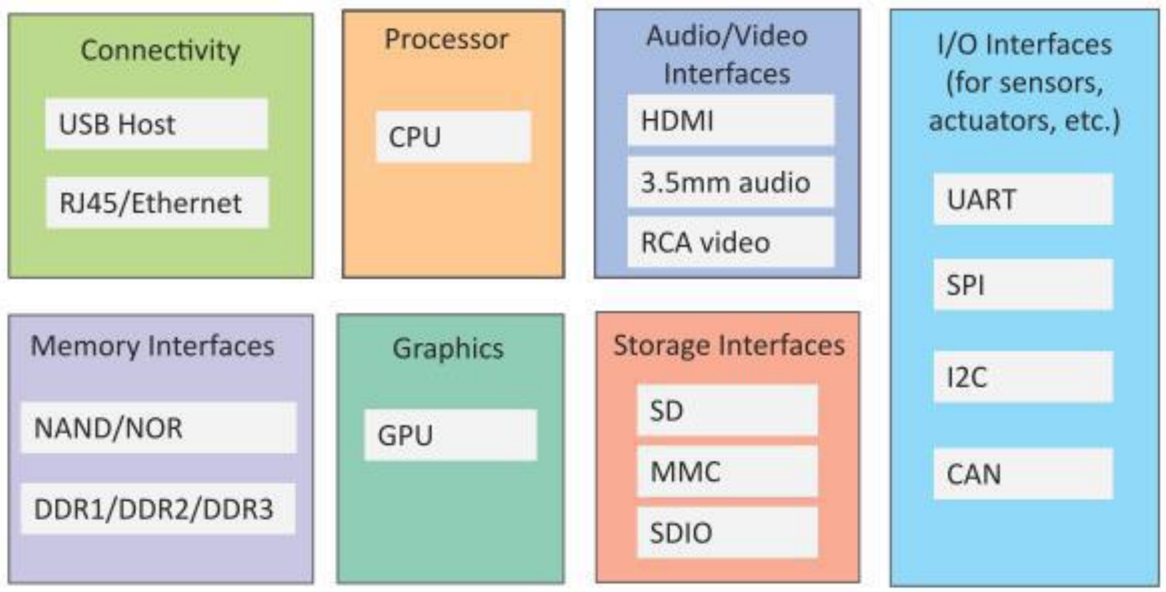

IoT Devices
Home Appliances
Smartphones & Computers
Wearable Electronics
Automobiles
Energy Systems
Retail Payment Systems
Printers
Industrial Machines
Healthcare Systems
Surveillance cameras

Types of IoT devices

- An IoT device can collect various type of data.
- IoT devices can also be of varied types:
  - wearable sensors
  - Smart watches
  - LED lights
  - Automobiles and industrial machines

Interfaces of IoT device

- An IoT device may consist of several interfaces for connections to other devices, both wired and wireless. These include:
  - I/O interfaces for sensors;
  - Interfaces for Internet connectivity
  - Memory an storage interfaces
  - Audio/video interfaces



Internet of Things Market in Italy

- According to Osservatorio of Internet of Things of School of Management of Politecnico di Milano:
- In Italy in 2022 the Italian Market of Internet of Things achieved the amount of **8.3 billions of euro**. The growth rate w.r.t. 2021 was **13%**. (although the growth found severe obstacle in the shortage of semiconductors)

IoT Application Domains: 1° Automotive

- The overall incomes of Smart Car domain was 1.4 billions of euro.
- The growth was 1.4 billions of euro, that corresponds to 17% of IoT overall market in Italy in 2022.

IoT Application Domains: 2° Utilities

- IoT applications in Utilities consist of **Smart Metering** and **Smart Asset Management**.
- The overall incomes of Utility domain was 1.37 billions of euro. The market is in growth but it is very close to be saturated. No growth is predicted for the future since in 2022
  - 1.1 smart gas meters achieving 82% of the overall amount of gas meters in Italy;
  - 1.7 smart electric meters of II generation achieving 64% of the overall amount of electric meters in Italy.

IoT Application Domains: 3° Smart Building

- The overall incomes of Smart Building domain was 1.3 billions of euro. The **growth of Smart Building domain w.r.t. 2021 is +19%** .

IoT Application Domains: 4° Smart City

- The overall incomes of Smart City   domain was 830 millions of euro.

IoT Application Domains: 5° Smart Factory

- The overall incomes of Smart Factory domain was 780 millions of euro.
- The **growth of Smart Factory domain w.r.t. 2021 is +22%** .

IoT Application Domains: 6° Smart Home

- The overall incomes of Smart Home domain was 770 millions of euro.

IoT Application Domains: 7° Smart Logistics

- The overall incomes of Smart Home domain was 715 millions of euro.

IoT Application Domains: 8° Smart Agriculture

- The overall incomes of Smart Agriculture domain was 540 millions of euro.
- This **domain has the highest growth (+32%) w.r.t. 2021** .

IoT in Italy

- The objects connected in Italy are about 124 millions, about 2.1 objects per person.
- There are:
  - about 39 millions of object with mobile connections. The growth rate w.r.t. 2021 is 11%.
  - about 85 millions of objects with not mobile connections . The average growth rate is about 15%, Among these technologies, LPWA (Low Power Wide Area) networks have the highest growth rate (20%), passing from 2.0 to 2.4 millions of connections.

IoT in Italian Companies

- The IoT Observatory made an inquiry on 153 large companies and 301 Italian SMEs.
- The amount of Italian SMEs that has knowledge of IoT solution is 87% (with a growth rate of 41% in the last year) whereas in the large companies the amount raises at 98%.
- The 77% of the large and the 58% of SMEs in Italy decided to start at least one IoT project.
- The highest obstacle to start IoT project is represented in (both large and SMEs) companies by the lack of IoT knowledge in company personnel.

Logical Design of IoT

- Logical design of an IoT system refers to **an abstract representation of the entities and processes without going into the low-level specifics of the implementation.**
- An IoT system comprises of a number of functional blocks that provide the system the capabilities for identification, sensing, actuation, communication, and management.

IoT Functional Blocks

IoT functional blocks are described as follows:

- Device
  - An IoT system comprises of devices that provide sensing, actuation, monitoring and control functions
- Communication
  - This block handles the communication for the IoT system
- Services
  - An IoT system uses various type of IoT services such as services for device monitoring, device control services, data publishing controls and services for device discovery

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- Management
  - Management functional block provides various functions to govern the oT system.
- Security
  - Security functional block secures the IoT system and by providing functions such as authentications, authorization, message and content integrity, and data security.
- Application
  - IoT applications provide an interface that the users can use to control and monitor various aspects of the IoT system. Application also allows user to view the system status and view or analyze the processed data.

IoT Enabling Technologies

- Wireless Sensor Networks (WSN)
- Cloud Computing
- Big Data Analytics

Wireless Sensor Networks

- A **Wireless Sensor Network** (**WSN**) comprises of distributed devices with sensors which are used to monitor the environmental and physical conditions.
- A WSN consist of a number of **end-nodes** and **routers** and a **coordinator**. End nodes have several sensors attached to them. Each node can act as routers.
- Routers are responsible for routing the data packets from end-nodes to the coordinator.
- The coordinator collects the data from all the nodes. Coordinator also acts as a gateway that connects the WSN to the internet

Examples of WSNs used in IOT systems

- Weather monitoring systems use WSNs in which the nodes collect temperature, humidity and other data, which is aggregated and analyzed.
- Indoor air quality monitoring systems use WSNs to collect data on the indoor air quality and concentration of various gases.
- Soil mosture monitoring systems use WSNs to monitor soil moisture at various locations.
- Surveillance systems use WSNs for collecting data.

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- Smart grids use WSNs for monitoring the grids at various points.
- Structural health monitoring systems use WSNs to monitor the health of structures by collecting vibration data from sensor deployed in the structure.

Cloud Computing

- Cloud computing is a computer paradigm that involves delivering applications and services over the Internet.
- Cloud computing paradigm that involves provisioning of computing networking and storage resources on demand and providing these resources as metered services to the users, in a ‘pay as you go’ model.
- Cloud computing resources can be provisioned on-demand by the users, without requiring interactions with the cloud services provider. The process of provisioning resources is automated.

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- Cloud computing resources can be accessed over the network using standard access mechanisms.
- The computing an storage resources provided by cloud service providers are pooled to serve multiple users using multi-tenancy.

Cloud Computing Services

Cloud Computing Services are offered in different forms.

- **Infrastructure-as-a-Services (IaaS)**
  - IaaS provides the users the ability to provision computing and storage resources. These resources are provided to the users as virtual machine instances and virtual storage. Users can start, stop, configure and manage the virtual machine instance and storage. Users can deploy operating systems and applications of their choice on the virtual resources provisioned in the cloud. The cloud service provider manages the underlying infrastructure. Virtual resources provisioned by the users are billed based on a pay-per-use paradigm.

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- **Platform-as-a-service** (**PaaS**)
  - Paas provides the users the ability to develop and deploy application in the cloud using the development tools, APIs, software libraries and services provided by the cloud service provider. The cloud service manages the underlying cloud infrastructure including servers, network, operating systems and storage. The users, themselves, are responsible for developing, deploying, configuring and managing applications on the cloud infrastructure

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- **Software-as-a-Service (SaaS)**
  - Saas provides the users a complete software application or the user interface to the application itself. The cloud service provider manages the underlying cloud infrastructure including servers, network, operating systems, storage and application software, and the user is unaware of the underlying architecture of the cloud.

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- Applications are provided to the user through a thin client interface (e.g., a browser). Saas applications are platform independent and can be accessed from various client devices such as workstations, laptop, tablets and smart-phones, running operating systems. Since the cloud manages both the application and data, the users are able to access the applications from anywhere.

Big Data Analytics

- Big Data is defined as **collections of data sets whose volume, velocity, variety is so large** that is difficult to store, manage, process and analyze the data using traditional databases and data processing tools.
- Examples of Big Data generated by IoT are:
  - Sensor data generated by weather monitoring stations;
  - Machine Sensor data collected by sensors in industrial and energy systems for monitoring their status and detecting failures;
  - Health and fitness data generated by IoT devices such as wearable fitness bands;

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- Data generated by IoT systems for location and tracking of vehicles;
- Data generated by retail inventory monitoring systems.

Big Data Analytics: Characteristics

- Volume
  - The volume of data generated by modern IT, industrial, and health-care systems is growing exponentially driven by the lowering costs of data storage and processing architectures and the need to extract valuable insights from the data to improve business process, efficiency and services to consumers.
- Velocity
  - Velocity of data refers to how fast the data is generated and how frequently it varies. Modern IT, industrial and other systems are generating data at increasingly higher speeds.

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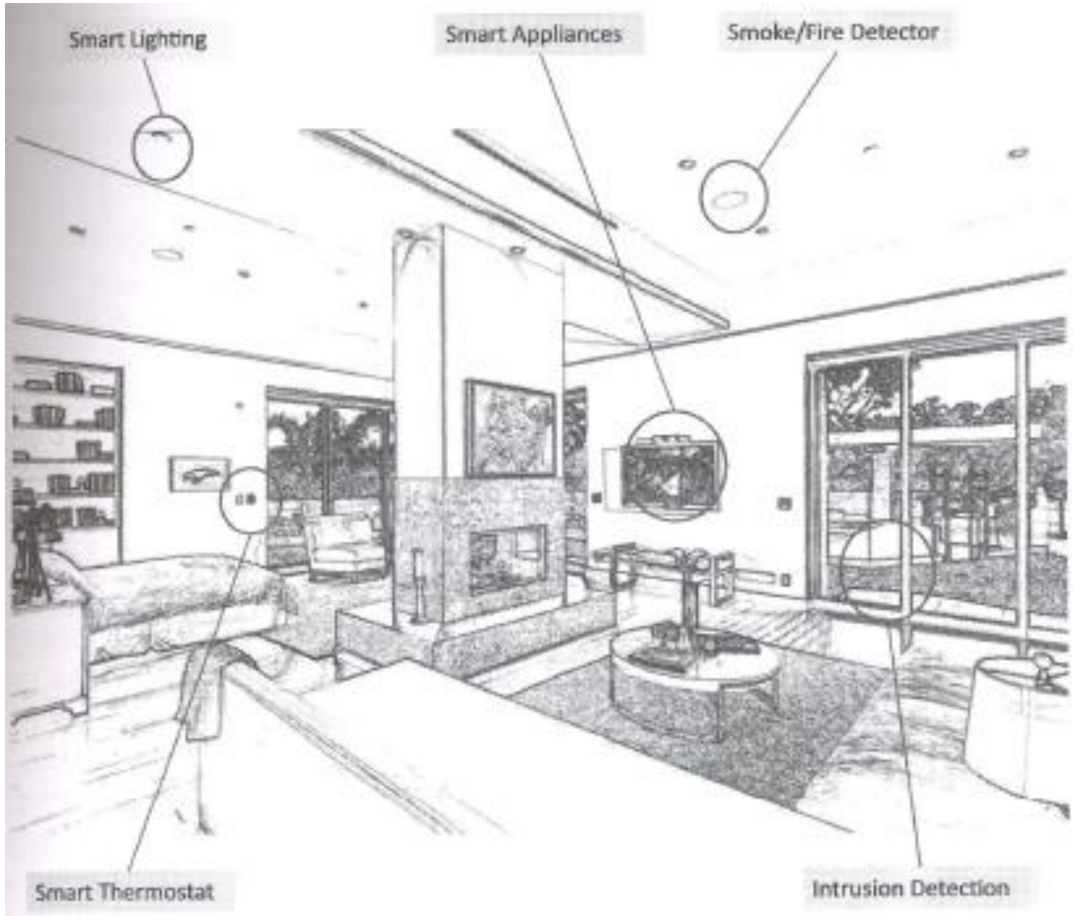
- Variety
  - Variety refers to the forms of data. Big Data comes in different forms, e.g., structured or unstructured data, including text data, image, audio, video and sensor data.

Domain Specific IoTs

- IoT applications span a wide range of domains including:
  - Home Automation
  - Cities
  - Environment
  - Energy Systems
  - Retail
  - Logistics
  - Industry
  - Agriculture
  - Health & LifeStyle

Home Automation

- Smart Lighting
- Smart Appliances
- Intrusion Detection
- Smoke/Gas Detectors



Smart Appliances

- Modern homes have a number of appliances such as TV, washers/dryers, refrigerators, music systems.
- Smart appliances make the management of these instrument easier and also provide status information to the user remotely.

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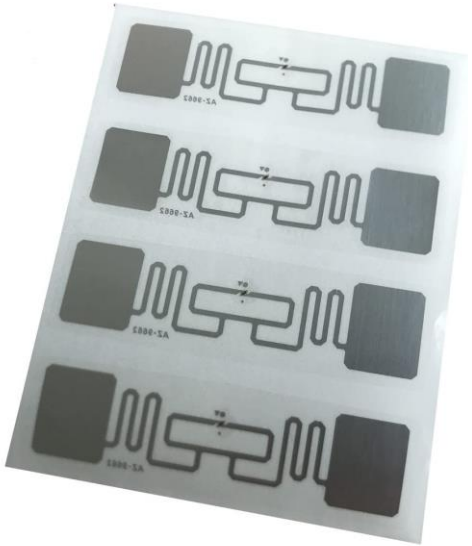
- Smart Washers can be controlled remotely and notify when the washing cycle is complete.
- Smart thermostats allow controlling the temperature remotely and can learn user preference.
- Smart Refrigerators can keep track of the item stored (using RFID tags) and segnalling to the users when an item is low on stock.
- Smart TV allows users to search videos or movies from Internet, and to fetch news, weather updates, and other contents.

RFID (Radio Frequence Identification) Tags

- https://www.amazon.it/Yarongtech-confezione-9662-etichetta-etichetta-adesiva/dp/B01DA0G67C/ref=sr_1_7?crid=3QMFO212W3LWY&keywords=rfid+label&qid=1684510275&sprefix=%2Caps%2C109&sr=8-7



RFID Reader

- https://www.amazon.it/Lettore-intelligente-identificare-HD-RD10-HDWR/dp/B0BV6VD15D/ref=sr_1_6?__mk_it_IT=%C3%85M%C3%85%C5%BD%C3%95%C3%91&crid=3GUQ4B4BVER9P&keywords=RFID+scanner&qid=1684510455&sprefix=rfid+scanner%2Caps%2C101&sr=8-6

Smoke and Gas Detectors

- Smoke detectors use optical detection, ionization or air sampling techniques to detect smoke. Alert raised by smoke detectors can be in the form of signals to a fire system.
- Gas detector can detect the presence of harmful gases such as carbon monoxide, liquid petroleum gas.

Cities

- Smart Parking
- Smart Lighting
- Smart Roads
- Structural Health Monitoring
- Surveillance
- Emergency Response

Smart Parking

- Smart Parking are powered by IoT systems that detect the number of empty parking slots and send the information over the Internet to smart parking application back-ends.
- These applications can be accessed by the drivers from smart-phones, tablets, and in-car navigation systems.
- In smart parking, sensors are used for each parking slot, to detect whether the slot is empty or occupied.
- This information is aggregated by a local controller and then sent over the Internet to the database.

Smart Lighting

- Smart Lighting allows lighting to be dynamically controlled remotely to configure lighting schedules and lighting intensity.
- Custom lighting configurations **can be set for different situation such as a foggy day, a festival**.
- Smart lights equipped with sensors can communicate with other lights and exchange information on the sensed ambient conditions to adapt the lighting.

Smart Roads

- Smart Roads equipped with sensors can provide information on driving conditions, travel time estimates and alerts in case of poor driving conditions, traffic congestions and accidents.
- 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.

Structural Health Monitoring

- Structural Health Monitoring system use 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 structure.
- By analyzing the data it can detect cracks and mechanical breakdowns, locate the damages of structure and also compute the remaining life of the structure.
- Using such systems, early warnings can be given in the case of imminent failure of the structure.

Surveillance

- 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 or specific event from video feeds.

Emergency Response

- IoT systems can be used for monitoring the critical infrastructure in cities such as buildings, gas and water pipelines , public transport and power substations. IoT systems for fire detection, gas and water leakage detection can help in generating alerts and minimizing their effects on the critical infrastructure.
- IoT system for critical infrastructure monitoring enable aggregation and sharing of information monitoring enable aggregation and sharing of information collected from large number of sensors. Using cloud-based architectures, multi-modal information such as sensor data, audio, video feeds can be analyzed in near real-time to detect adverse events.

Environment

- Weather Monitoring
- Air Pollution Monitoring
- Noise Pollution Monitoring
- Forest Fire Detection
- River Floods Detection

Weather Monitoring

- IoT-based weather monitoring systems can collect data from a number of sensor attached (e.g., temperature, humidity, pressure) and send the data to cloud-based applications and storage back-ends.
- The data collected in the cloud can then be analyzed and visualized by cloud-based applications.
- Weathers alerts can be sent to the subscribed users from such applications.

Air Pollution Monitoring

- IoT based weather systems can monitor emissions of harmful gases (CO_2, CO, NO_2,CO) by factories and cars using gaseous and meteorological sensors. The collected data can be analyzed to make informed decisions on pollutions control approaches.

Noise Pollution Monitoring

- Noise pollution monitoring can help in generating noise maps for cities. Urban noise maps can help the policy makers in urban planning and making policies to control noise levels near residential areas, schools and parks.
- IoT based noise pollution monitoring systems use 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.
- The collected data is aggregated to generate noise maps.

River Floods Detection

- IoT based river flood monitoring systems use a number of sensor nodes that monitors the water level (using ultrasonic sensors) and flow rate (using the flow velocity sensors). Data from a number of such sensor nodes is aggregated in a server or in the cloud. Monitoring applications raise alerts when rapid increase in water level and flow rate is detected.

Energy

- Smart Grids
- Renewable Energy Systems
- Prognostics

Smart Grids

- Smart Grid is **a data communications network integrated with the electrical grid that collects and analyzes data captured in near-real about power transmission, distribution, and consumption**. Smart Grid technology provides predictive information and recommendations to utilities, their supplies, and their customers on how best to manage power.
- Smart Grids collects data regarding electricity generation (centralized or distributed), consumption, storage, distribution and equipment health data.Smart grids use high-speed, fully integrated, two-way communication technologies for real-time information and power exchange.

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- By using IoT based sensing and measurement technologies, the health of equipment and the integrity of the grid can be evaluated.
- Smart Meter can capture almost real-time consumption, remotely control the consumption of electricity and remotely switch-off supply when required.
- Power Thefts can be prevented using smart metering. By analyzing the data on power generation, trasmission and consumption smart grids can improvee efficiency throughout the electric system. Storage collection and analysis of smart grids data in the cloud can help in dynamic optimization of system operation, maintenance and planning.

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- Cloud-based monitoring of smart grid data can improve energy usage levels by energy feedback to users coupled with real-time pricing information.
- Real-time demand response and management strategies can be used for lowering peak demand and overall load via appliance control an energy storage mechanisms. Condition monitoring data collected from power generation and trasmission system can help in detecting faults and predicting outages.

Renewable Energy Systems

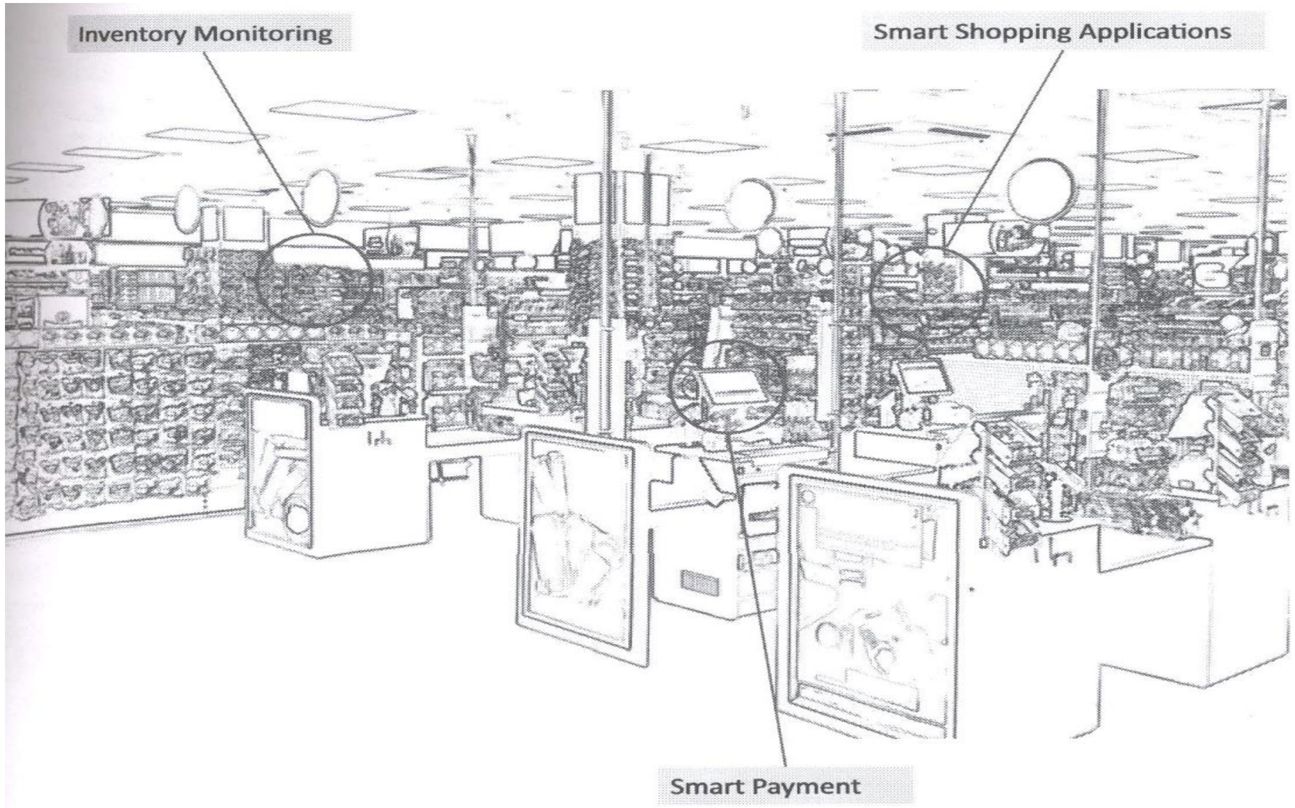
- When distributed renewable energy sources are integrated into the grid, they create power bidirectional power flows for which the grids were not originally designed.
- IoT based system integrated with the transformers at the point of interconnection measure the electrical variables and how much power is fed into the grid.
- To guarantee the grid stability, one solution is to simply to cut-off the overproduction.

Prognostics

- Energy systems have thousands of sensors, called Phasor Measurements units (PMU), that gather real-time maintenance data continuously for condition monitoring and failure prediction purposes.
- IoT based prognostic real-time health management systems can predict performance of machines or energy systems by analyzing the extent of deviation of a system from its normal operating profiles. Analyzing massive amounts of maintenance data collected from sensors in energy systems and equipment can provide predictions for the occurring failures so that their reliability and availability can be improved.

Retail

- Inventory Management
- Smart Payments
- Smart Vending Machines



Inventory Management

- **IoT systems using Radio Frequency Identification (RFID) tags** can help in **inventory management and mantaining the right inventory levels**.
- RFID tags attached to the products allow them to be tracked in real-time so that the inventory levels can be determined accurately and products that are low on stock can be replenished. Tracking can be done using RFID readers attached to the retail store shelves or in the warehouse.
- IoT systems enable remote monitoring of inventory using the data collected by the RFID readers.

Smart Vending Machines

- Smart vending machines connected to the Internet allow remote monitoring of inventory levels, elasting pricing of products, promotions, and contact-less payments using Bluetooth.
- Smart-phones applications that communicate with smart vending machines allow user preferences to be remembered and learned with time. When a user moves from one vending machine to the other, a user specific interface is presented where users can save their preferences and favorite products.
- Sensors in a smart vending machine monitor its operations and send the data to the cloud which can be used for predictive maintenance.

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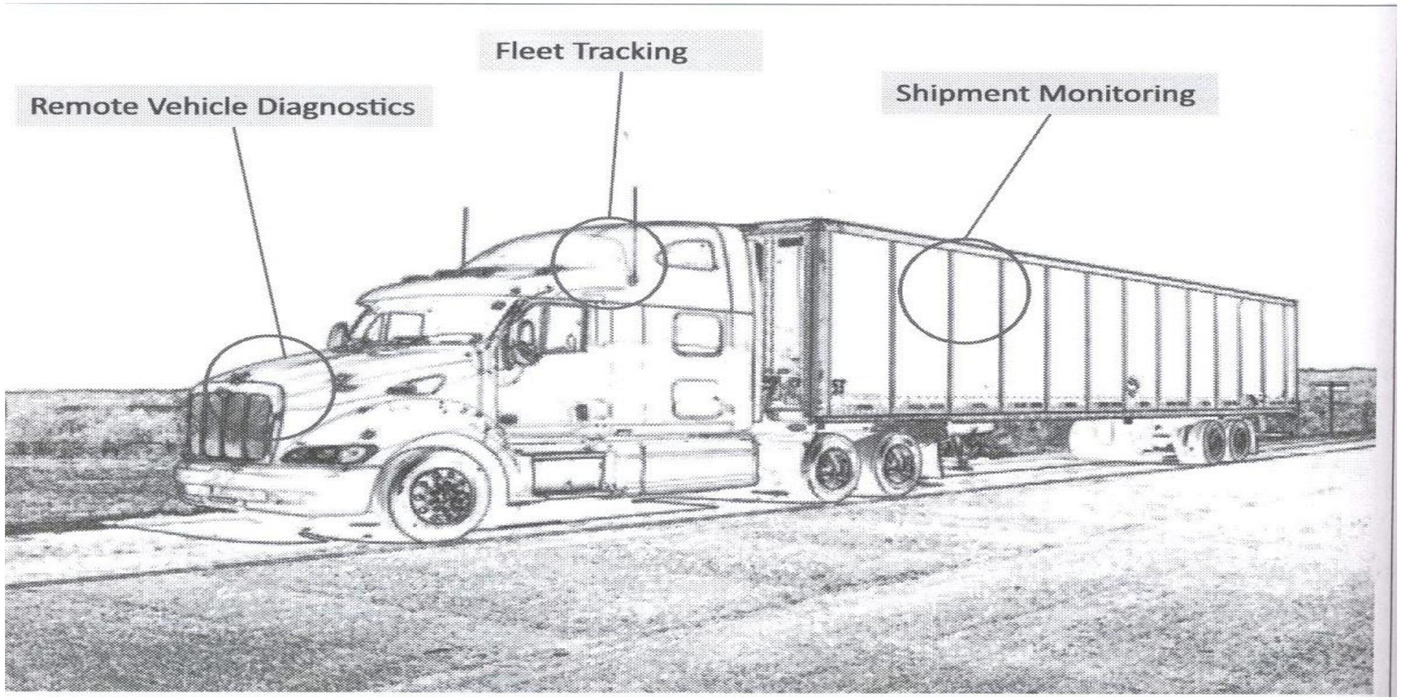
- Smart vending machines can communicate with other vending machines in their vicinity and share their inventory levels so that the customers can be routed to the closest machine in case a product goes out of stock in a machine.
- For perishable items, the smart vending machines can reduce the price as the expiry date nears. New products can be recommended to the customers based on the purchase history and preferences.

Logistics

- Route Generation & Scheduling
- Fleet Tracking
- Shipment Monitoring
- Remote Vehicle Diagnostics



Route Generation & Scheduling

- Modern transportation systems are driven by data collected from multiple sources which is processed to provide new services by stakeholders.
- Route generation and scheduling systems can generate end-to-end routes using combination of route patterns and transportation modes and feasible schedules based on the availability of vehicles. As the transportation network grows in size and complexity, the number of possible route combinations increases exponentially. IoT based systems backed by the cloud can provide fast response to the route generation queries and can be scaled up to serve a large transportation network.

Fleet Tracking

- Vehicle Fleet tracking systems use GPS technology to track the locations of the vehicles in real-time.
- Cloud-based fleet tracking systems can be scaled-up on demand to handle large number of vehicles. Alerts can be generated in case of deviations in planned routes. The vehicle locations and routes data can be aggregated and analyzed for detecting bottlenecks in the supply chain such as traffic congestions on routes, assignments and generation of alternative routes, and supply chain optimization.

Shipment Monitoring

- Shipment monitoring solutions for transportation systems allow monitoring the conditions inside containers.
- 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.
- The analysis and interpretation of data on the environmental conditions in the container and food truck positioning can enable more effective routing decisions in real time.

Remote Vehicle Diagnostics

- Remote vehicle diagnostic systems 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 and status of various vehicle sub-systems.
- Modern commercial vehicles **support on-board diagnostic (OBD) standard**. 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.

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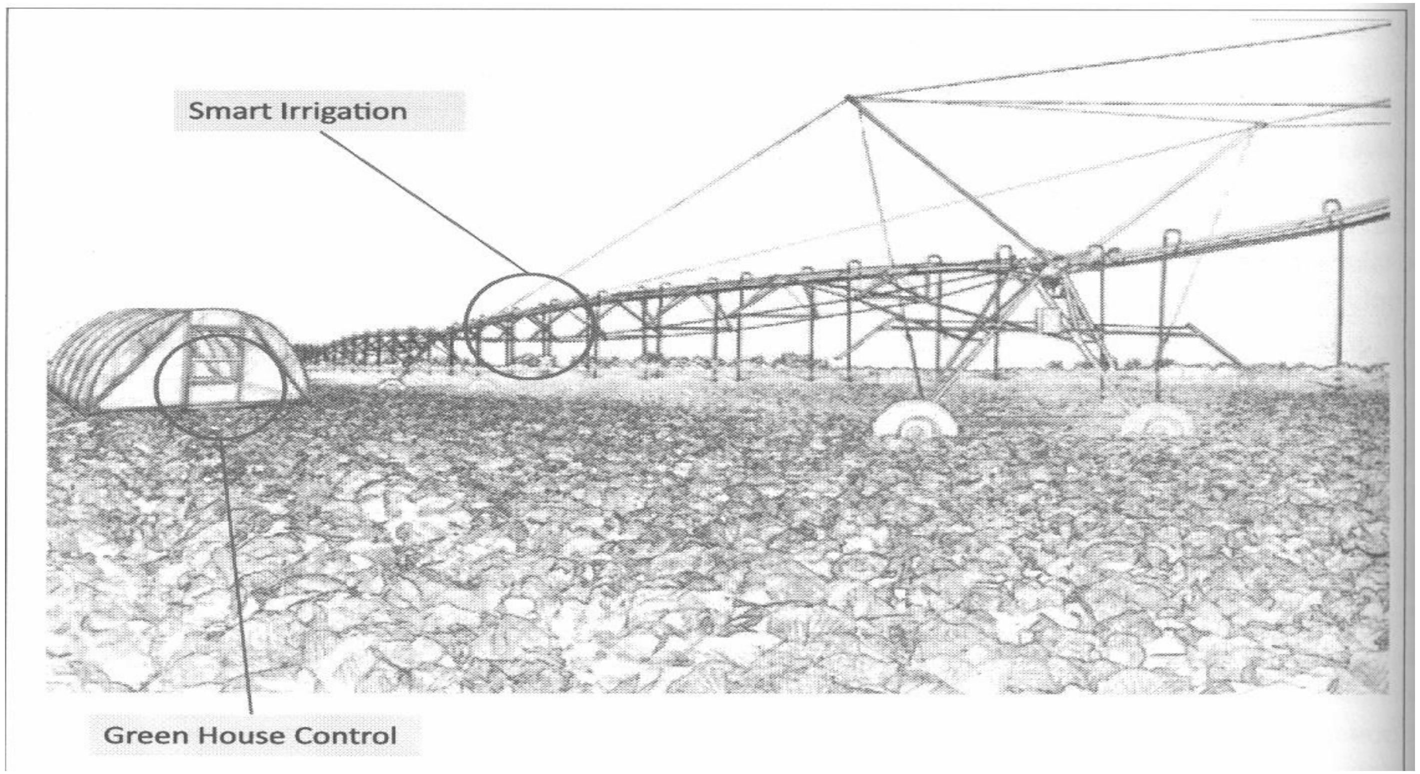
- IoT based vehicle diagnostic systems can send the vehicle data to centralized servers or the cloud where it can be analyzed to generate alerts and suggest remedial actions.

Agriculture

- Smart Irrigation
- Green House Control



Smart Irrigation

- Smart irrigation systems can improve crop yields while saving water.
- Smart irrigation systems use IoT devices with soil moisture sensors to determine the amount of moisture in the soil and release the flow of water through the irrigation pipes only when the moisture levels go below a predefined threshold. Smart irrigation systems also collect moisture level measurements on a server or in the cloud where the collected data can be analyzed to plan watering schedules.
- Cultivar's Rain Cloud is a device for smart irrigation that uses water valves, soil sensors and a WiFi enabled programmable computer.

Green House Control

- The climatological conditions inside a green house can be monitored and controlled to provide the best conditions for growth of plants. The temperature, humidity, soil mosture, light and carbon dioxide levels are monitored using sensors and the climatological conditions are controlled automatically using actuation devices (valves for releasing water or for controlling fans).
- IoT systems play an important role in green house control and help in improving productivity.

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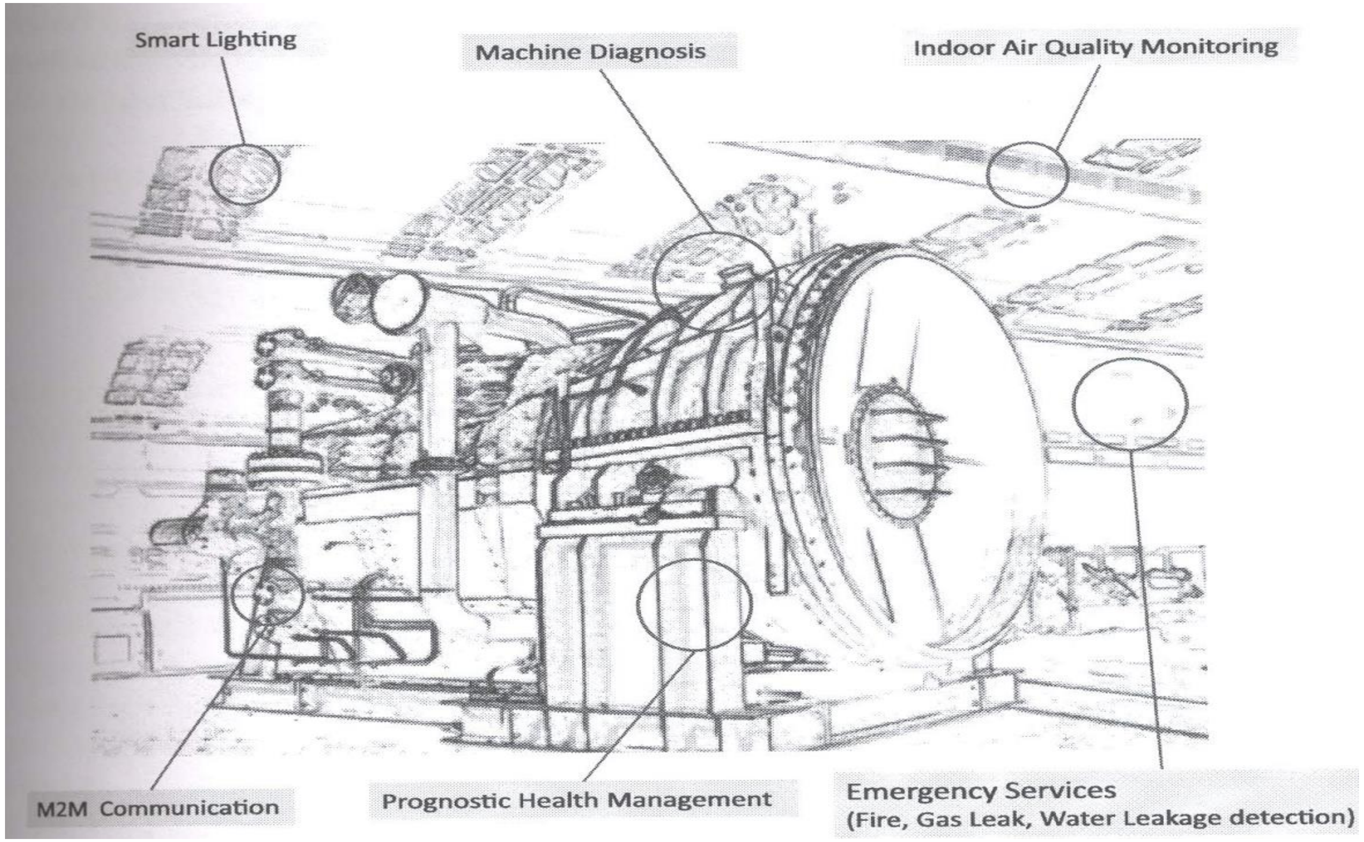
- The data collected from various sensors is stored on centralized servers or in the cloud where analysis is performed to optimize the control strategies and also correlate the productivity with different control strategies.

Industry

- Machine Diagnosis & Prognosis
- Indoor Air Quality Monitoring



Machine Diagnosis & Prognosis

- Machine prognosis refers to predicting the performance of a machine by analyzing the data on the current operating conditions and how much deviations exist from the normal conditions.
- Machine diagnosis refers to determining the cause of a machine fault.
- IoT plays a major role in both prognosis and diagnosis of industrial machines. Industrial machine have a large number of components that must function correctly for the machine to perform its operations. Sensors in machines can monitor the operating conditions (e.g., temperature, vibrations).

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- The sensor data measurements are done on timescales of few milliseconds to few seconds, which leads to generation of massive amount of data.
- IoT based systems integrated with cloud-based storage an analytics back-ends can help in storage collections and analysis of such massive scale machine sensor data.
- Artificial Intelligence-based methods have been proposed for reliability analysis and fault prediction in machines.

Indoor Air Quality Monitoring

- IoT based gas monitoring systems can help in monitoring systems can help in monitoring the indoor air quality using various gas sensors.
- The indoor air quality can vary 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.

Health & Lifestyle

- Health & Fitness Monitoring
- Wearable Electronics

Health & Fitness Monitoring

- Wearable IoT devices that allow non-invasive and continuous monitoring of physiological parameters can help in contonious health and fitness monitoring. These wearable devices form a type of wireless sensor networks called body area networks in which the measurements from a number of wearable devices are contonuous sent to a master node (e.g., a smartphone) which then sends the data to a server or a cloud-based back-end for analysis and archiving.
- Health-care providers can analyze the collected health-care data to determine any health conditions or anomalies.

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- Commonly uses body sensors include: body temperature, hearth rate, pulse oximeter oxygen saturation, blood pressure, electrocardiogram (ECG), movement (with accelerometers), and electroencephalogram (EEG).

Wearable Electronics

- Wearable electronics provide various functions and features to assist us in our daily activitues and making us lead healthy lifestyles.
- Smart watches allow the users to search the Internet, play audio/video files, make calls, play games and use various kinds of mobile applications.
- Smart glasses allow users to take photos and record videos, get map directions, check flight status, and search the Internet by using voice commands.

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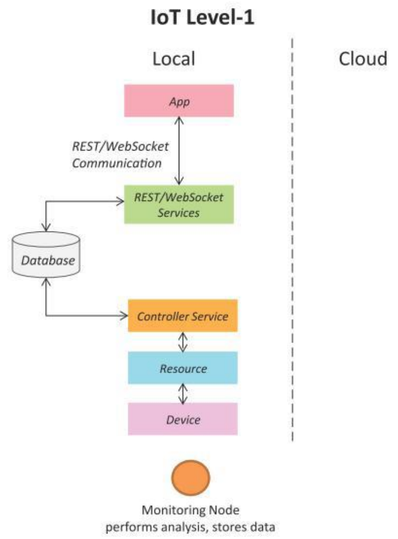
- Smart shoes monitor the walking or running speeds and jumps with the help of embedded sensors and be paired with smartphones to visualize the data.
- Smart wristbands can track the daily exercise and calories burnt.

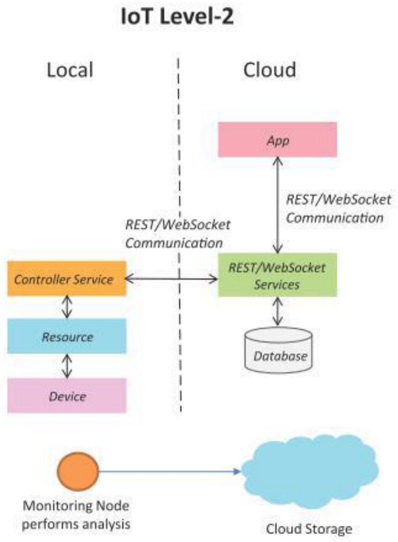
IoT Level-1

- A level-1 IoT system has a single node/device that performs sensing and/or actuation, stores data, performs analysis and hosts the application. Level-1 IoT systems are **suitable for modeling lowcost** and **low-complexity** solutions where **data involved is not big** and the **analysis requirements are not computationally intensive**.



IoT Level-2

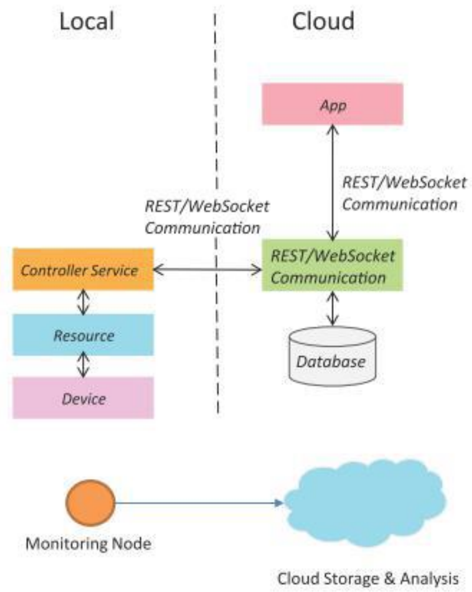
- A level-2 IoT system has a single node that performs sensing and/or actuation and local analysis. Data is stored in the cloud and application is usually cloud-based. Level-2 IoT systems are suitable for solutions where **the data involved is big, however, the primary analysis requirement is not computationally intensive and can be done locally itself**.



IoT Level-3

- A level-3 IoT system has a single node. Data is stored and analyzed in the cloud and application is cloud-based.Level-3 IoT systems are suitable for solutions where **data involved is big and the analysis requirements are computationally intensive**.

IoT Level-3

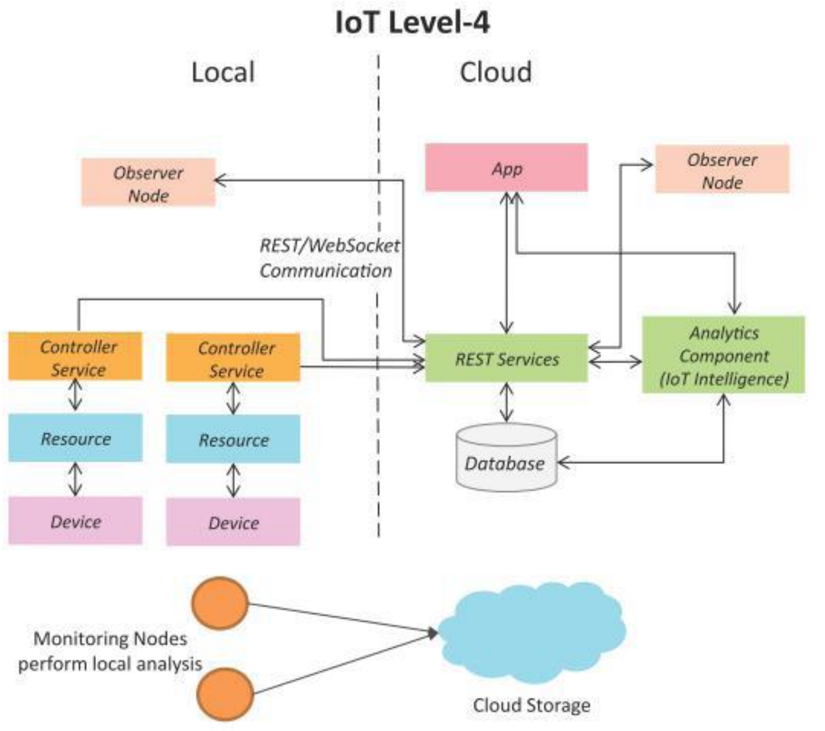


IoT Level-4

- A level-4 IoT system has multiple nodes that perform local analysis. Data is stored in the cloud and application is cloud-based.
- Level-4 contains local and cloud-based observer nodes which can subscribe to and receive information collected in the cloud from IoT devices.
- Level-4 IoT systems are suitable for solutions where multiple nodes are required, the data involved is big and the analysis requirements are computationally intensive.

IoT-Level 4

- Level-4 IoT systems are suitable for solutions **where multiple nodes are required, the data involved is big and the analysis requirements are computationally intensive**.

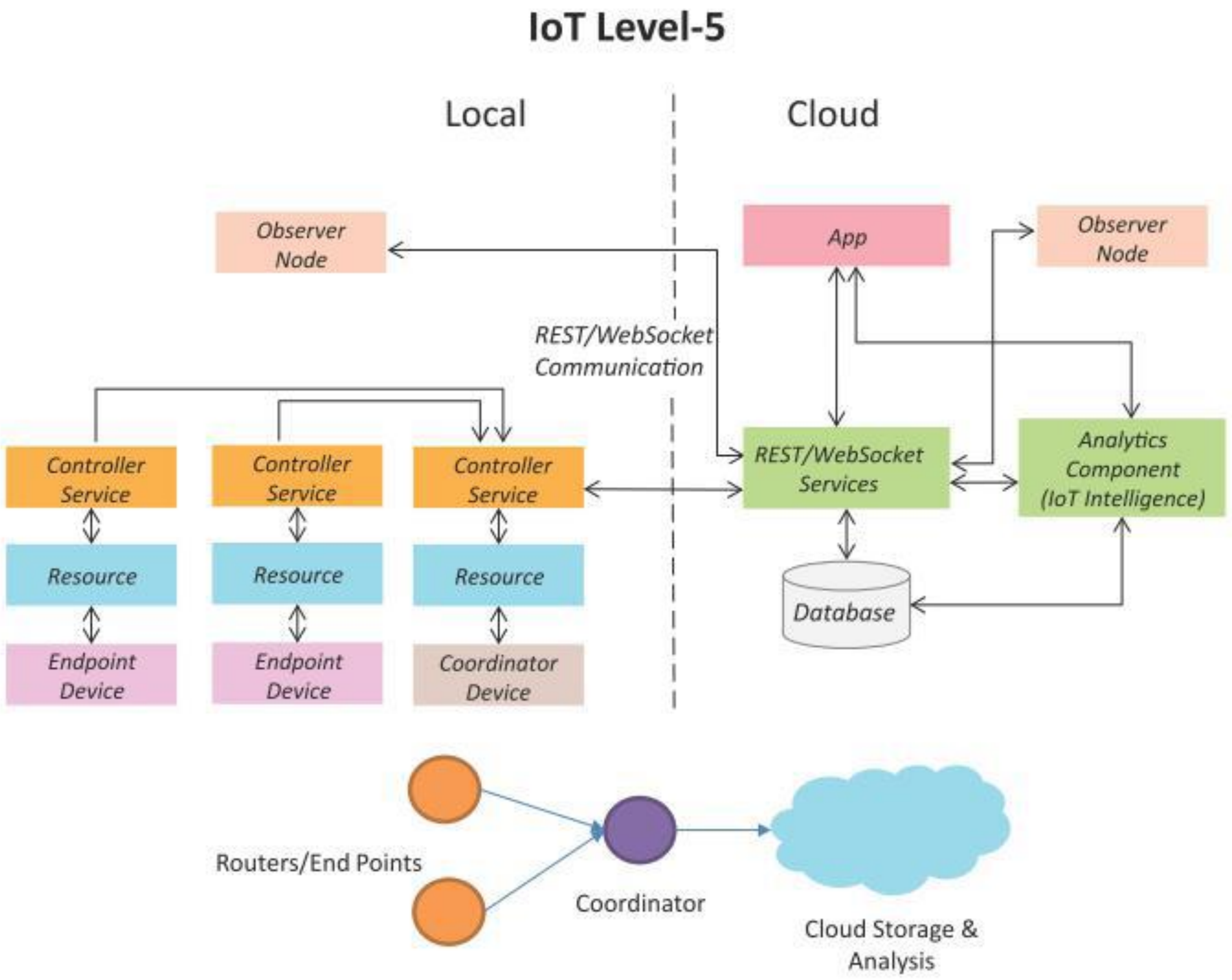


(cont.)

- Level-4 IoT systems are suitable for **solutions based on wireless sensor networks, in which the data involved is big and the analysis requirements are computationally intensive**.

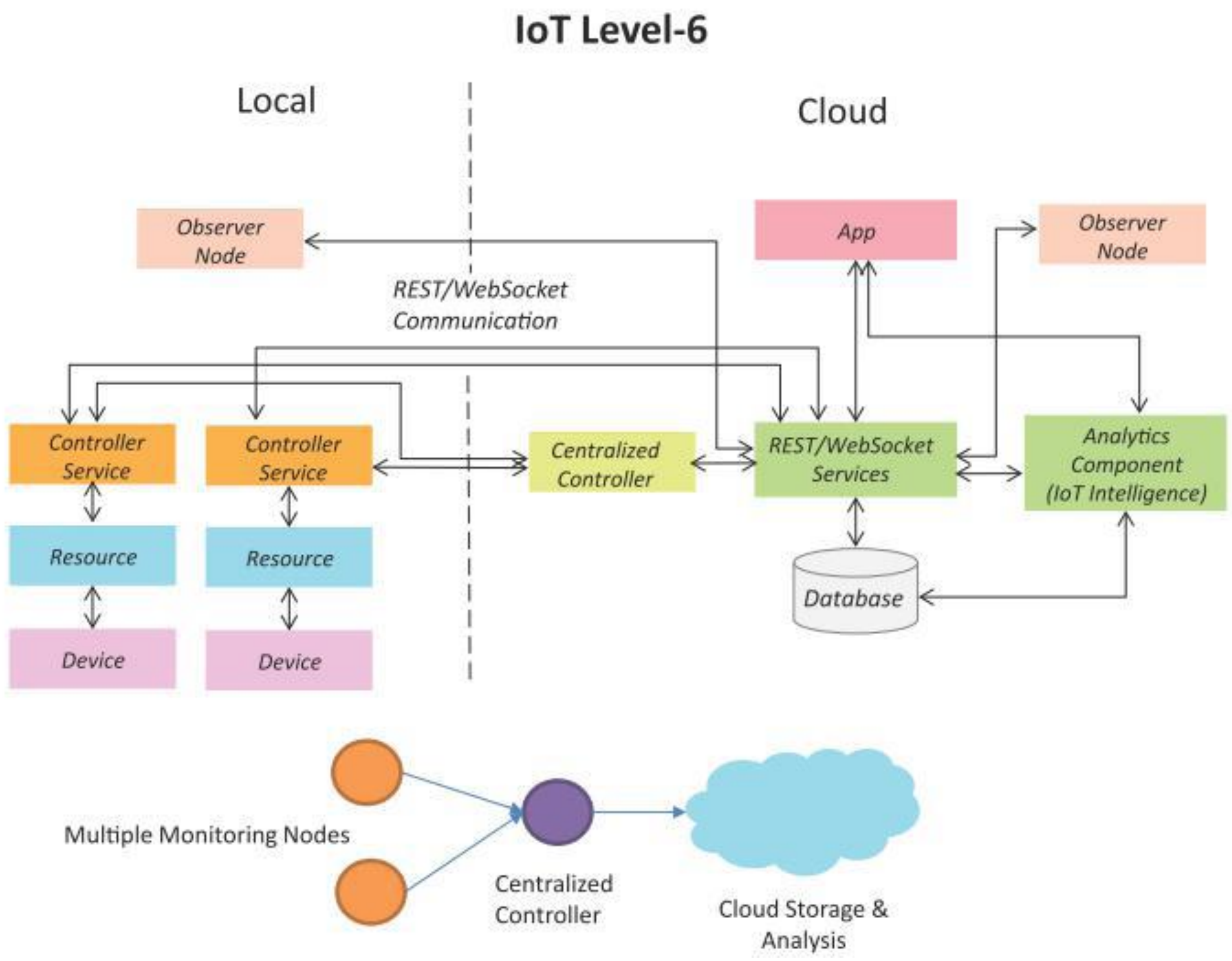
IoT Level-5

- A level-5 IoT system has multiple end nodes and one coordinator node.
- The end nodes that perform sensing and/or actuation.
- Coordinator node collects data from the end nodes and sends to the cloud.
- Data is stored and analyzed in the cloud and application is cloud-based.



IoT Level-6

- A level-6 IoT system has multiple independent end nodes that perform sensing and/or actuation and send data to the cloud.
- Data is stored in the cloud and application is cloud-based.
- The analytics component analyzes the data and stores the results in the cloud database.



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- The results are visualized with the cloud-based application.
- The centralized controller is aware of the status of all the end nodes and sends control commands to the nodes.