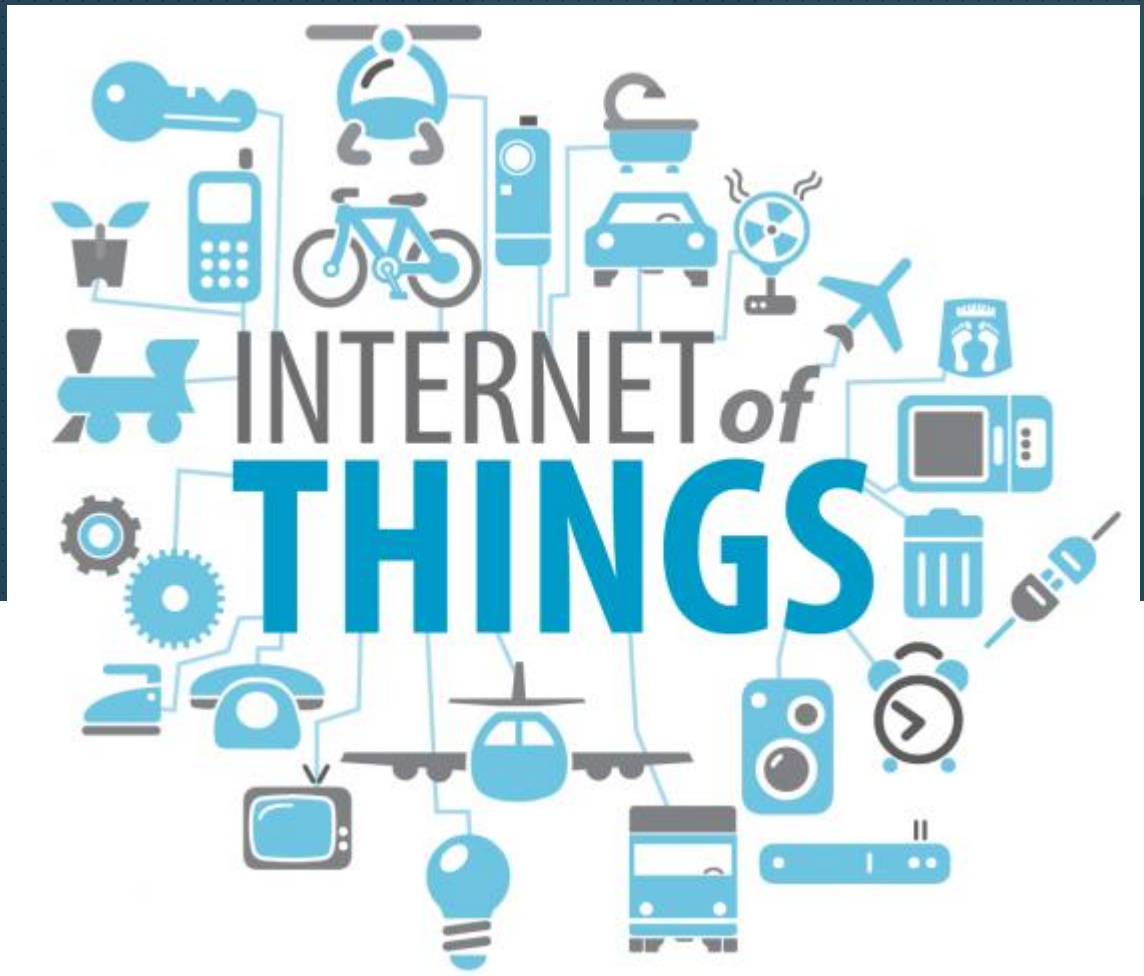
Introduction to IoT



What is IoT

Network of Physical Objects

- Internet of Things (IoT) comprises things that have unique identities and are connected to the Internet
- The focus on IoT is in the configuration, control and networking via the Internet of devices or “Things” that are traditionally not associated with the internet
  - Eg: pump, utility meter, car engine
- IoT is a new revolution in the capabilities of the endpoints that are connected to the internet

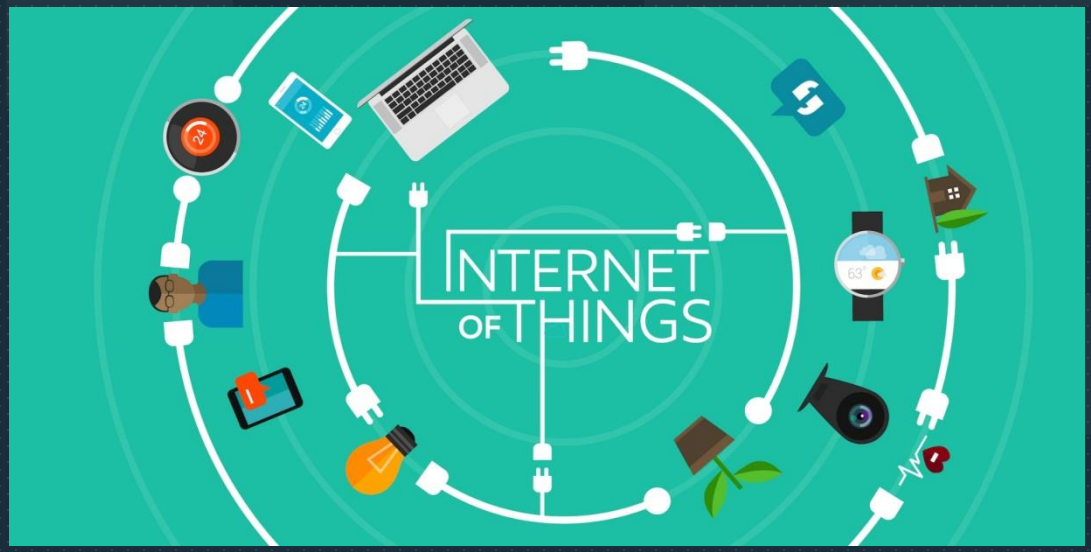
What is IoT

Network of Physical Objects

- The Scope of IoT is not limited to just connecting things (device, appliances, machines) to the Internet
- IoT allows these things to communicate and exchange data (control& information)
- Processing on these data will provide us various applications towards a common user or machine goal

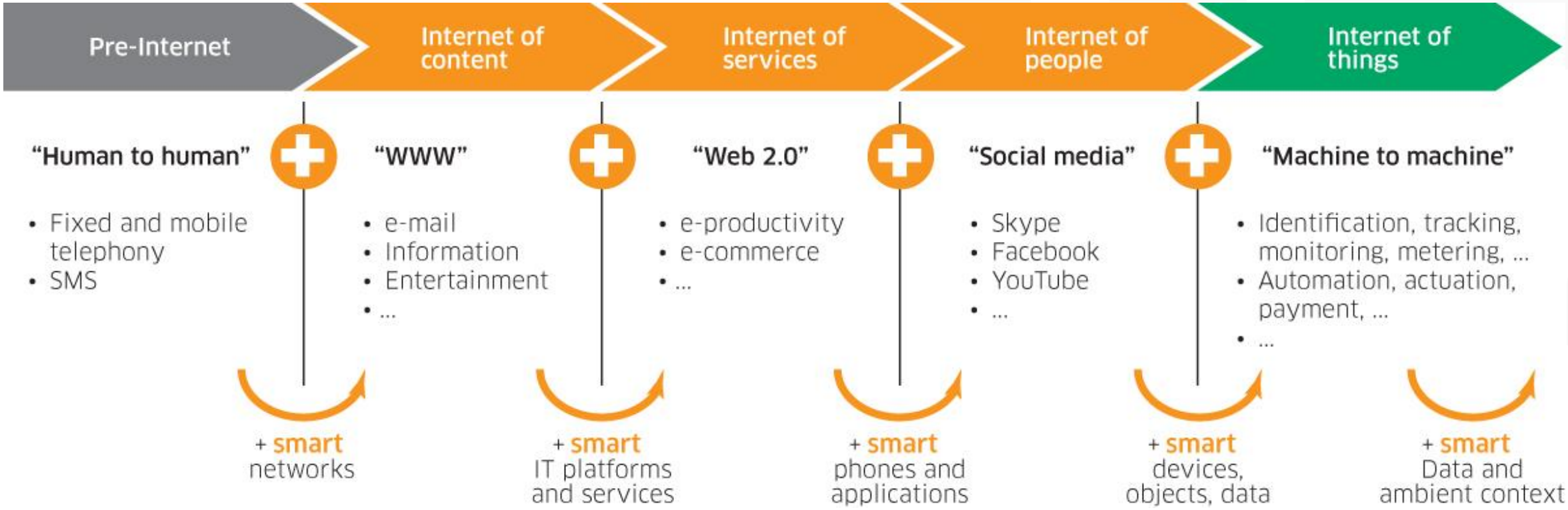
Idea: Move from Internet of People → Internet of Things

- Internet appears everywhere in the world
- It is primarily connection between people



- Internet of Things is a plan to connect things also using the same medium

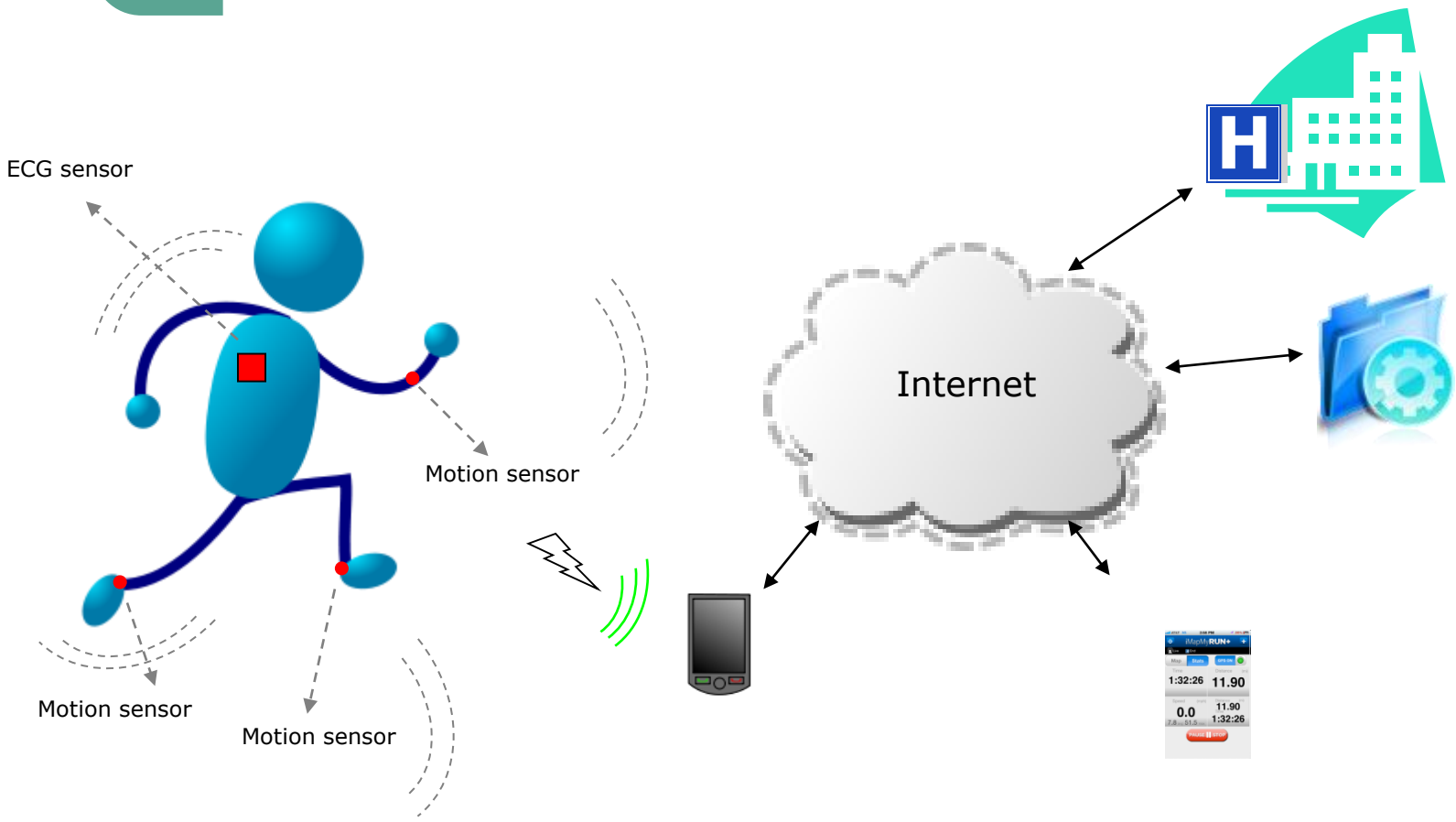
Internet of Things - Evolution



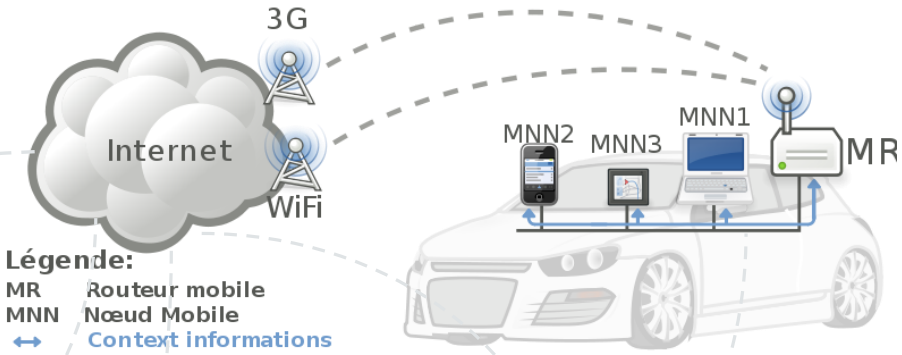
Difference between M2M and IoT

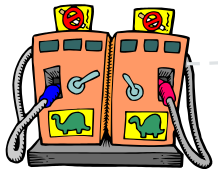
M2M	IoT
Point-to-point communication usually embedded within hardware at the customer site	Devices communicate using IP Networks, incorporating with varying communication protocols
Many devices use cellular or wired networks	Data delivery is relayed through a middle layer hosted in the cloud
Devices do not necessarily rely on an Internet connection	In the majority of cases, devices require an active Internet connection
Limited integration options, as devices must have corresponding communication standards	Unlimited integration options, but requires a solution that can manage all of the communications

IOT: People connecting with Things



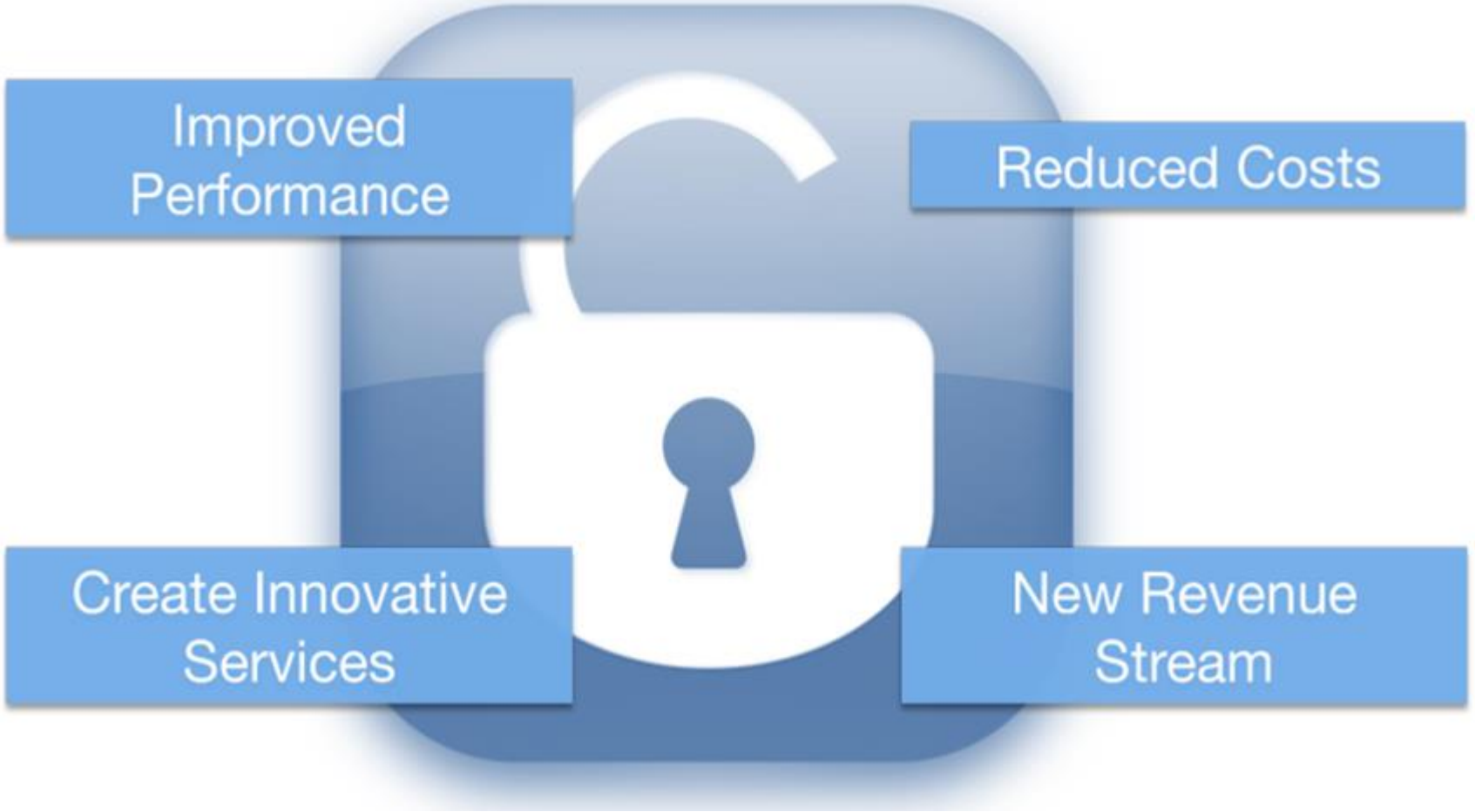
IoT: Things connecting with Things





- Complex and heterogeneous resources and networks

Unlocking the Massive potential of IoT



Looming Opportunity

Consumer
- Smart home control (lighting, security, comfort)
- Optimized energy use
- Maintenance

Retail
- Product tracking
- Inventory control
- Focused marketing

Medical
- Wearable devices
- Implanted devices
- Telehealth services

Military
- Resource allocation
- Threat analysis
- Troop monitoring

Industrial
- SmartMeters
- Wear-out sensing
- Manufacturing control
- Climate control

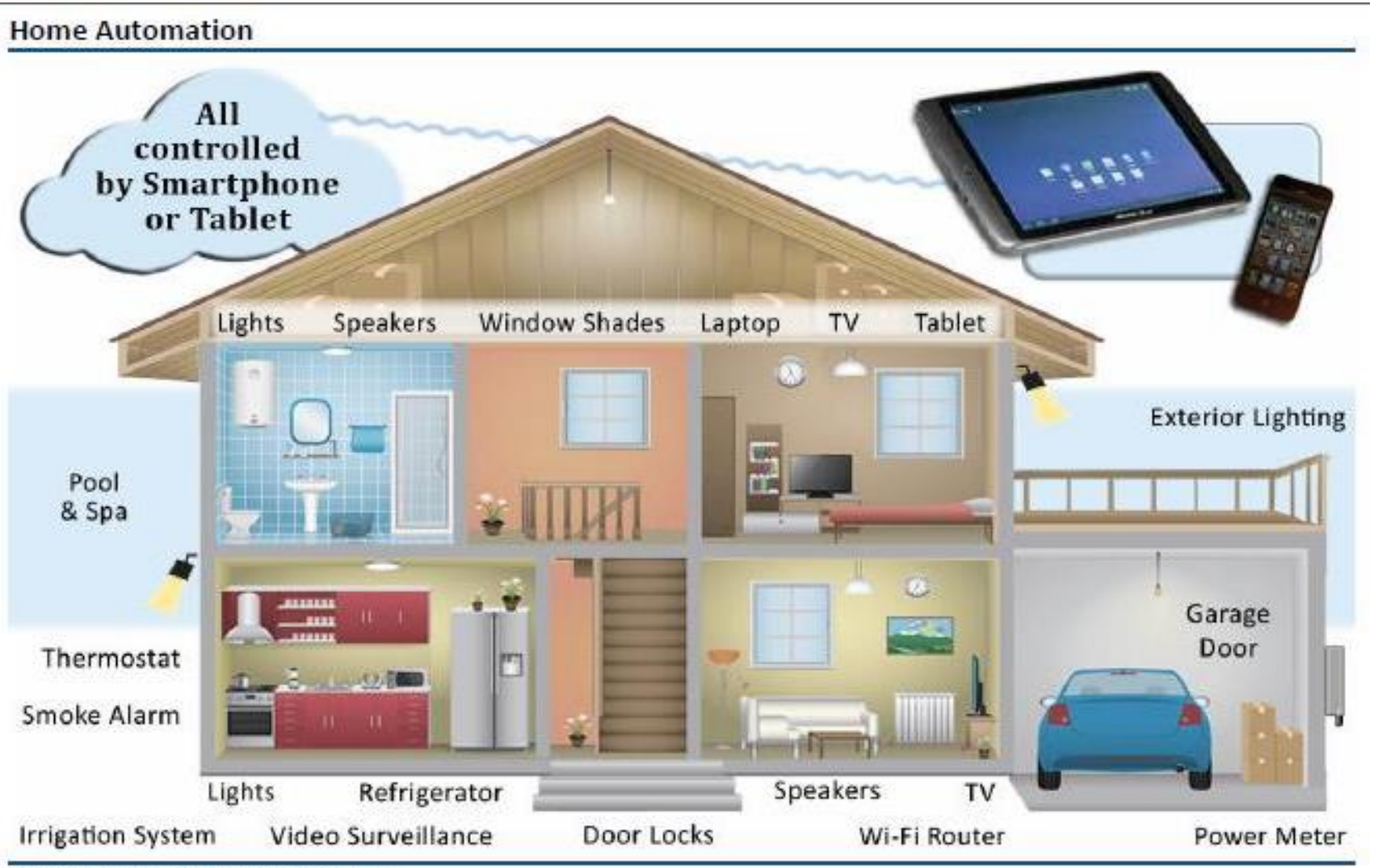
Automotive
- Parking
- Traffic flow
- Anti-theft location

Environmental
- Species tracking
- Weather prediction
- Resource management

Agriculture
- Crop management
- Soil analysis

Applications of IoT

IoT Applications : Intelligent Home



Source: Raymond James research.

Smart Egg Tray

Egg Minder syncs with your smartphone to tell you how many eggs you've got at home (up to 14 eggs) and when they're going bad.

http://www.quirky.com/shop/619

Smart Washing Machine

Smart Aqualtis is the first Indesit Company washing machine designed to be integrated in 'Smart' ecosystems, covering a wide range of use cases.

http://zigbee.org/Products/ByStandard/AllStandards.aspx

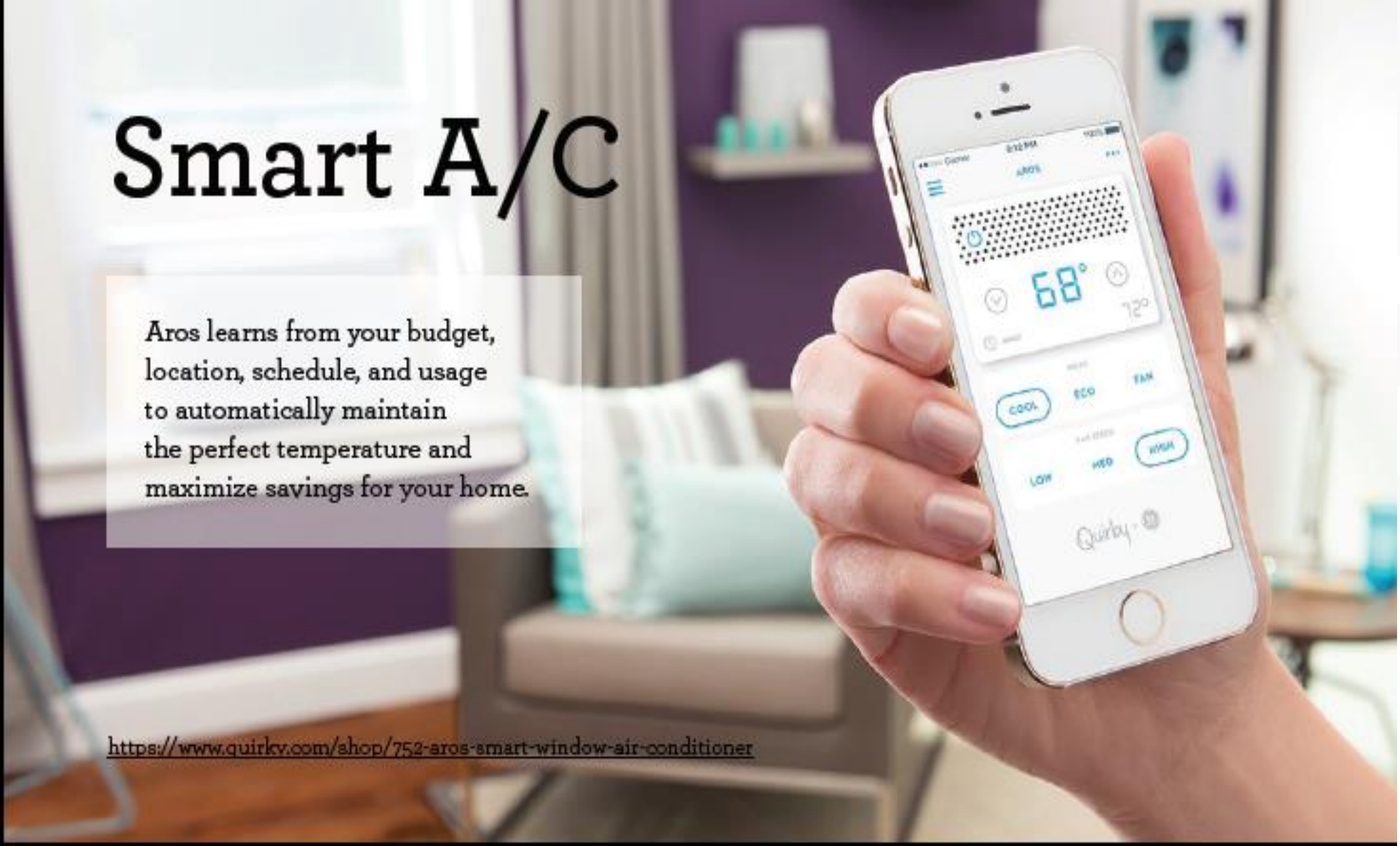
Smart Lighting

Control your bulbs one at a time or altogether. Find just the right shade of white. Pick that perfect tone to match the moment. Or recreate any color from a photo.

http://meethue.com/

Smart A/C

Aros learns from your budget, location, schedule, and usage to automatically maintain the perfect temperature and maximize savings for your home.



https://www.quirky.com/shop/752-aros-smart-window-air-conditioner

Smart Sleep System

Visualize your sleep cycles, understand what wakes you up, and compare nights. From the palm of your hand you can control your personalized wake-up, and fall-asleep programs.

http://www.withings.com/us/withings-aura.html

Smart Weather Station

The Netatmo Weather Station allows you to use indoor temperature, relative humidity and CO2 readings to live in a healthier home.

http://www.netatmo.com/en-US/product/weather-station/

Smart Slow Cooker

Enjoy remote access to all your slow cooker's functions, no matter where you are.

http://www.belkin.com/us/Products/home-automation/c/wemo-home-automation/

Smart Garbage Cans

BigBelly alerts when it needs to be emptied so smarter collection decisions can be made.

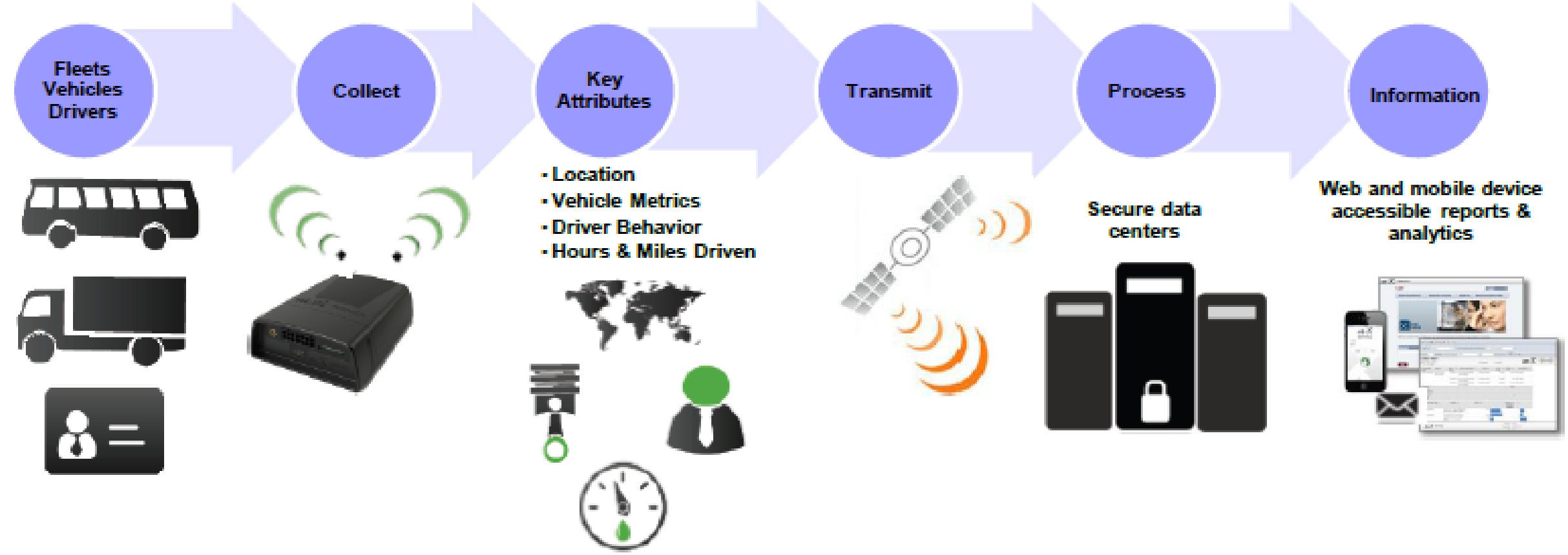
http://www.bigbelly.com/solutions/stations/smartbelly/

Smart Gardening

Bitponics gives data on plants and conditions surrounding them for better gardening.

http://www.bitponics.com/

IoT Applications : Transportation



Source: Raymond James research.

Supply Chain Management

- Logistic
- Product Design
- Warehouse
- Manufacturing

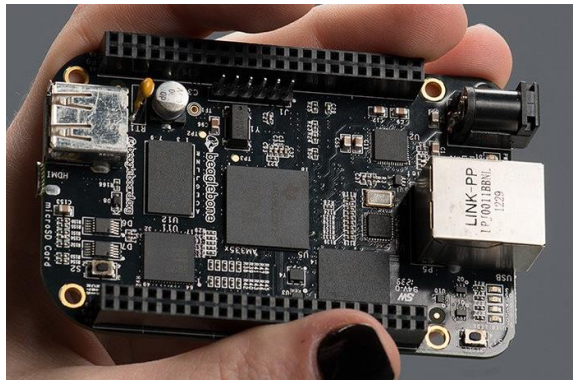
IoT Architecture

IoT Technologies

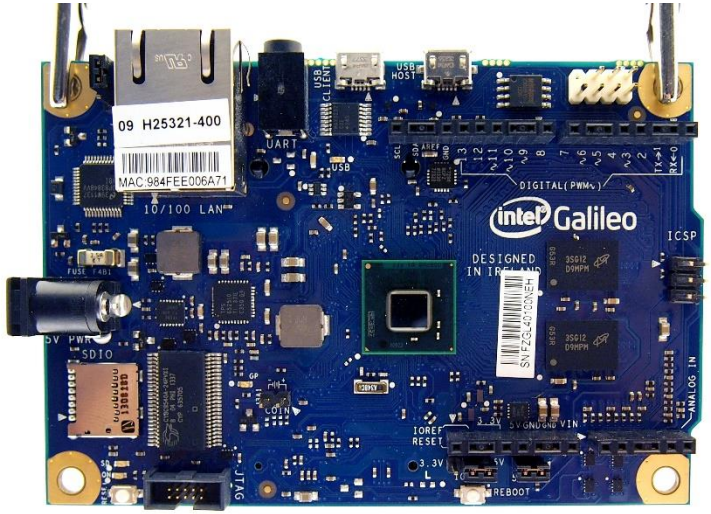
IoT Technologies

- Hardware (Device)
- Communication Technology
- Protocols for IoT
- Software (IDE)
- Cloud Platforms

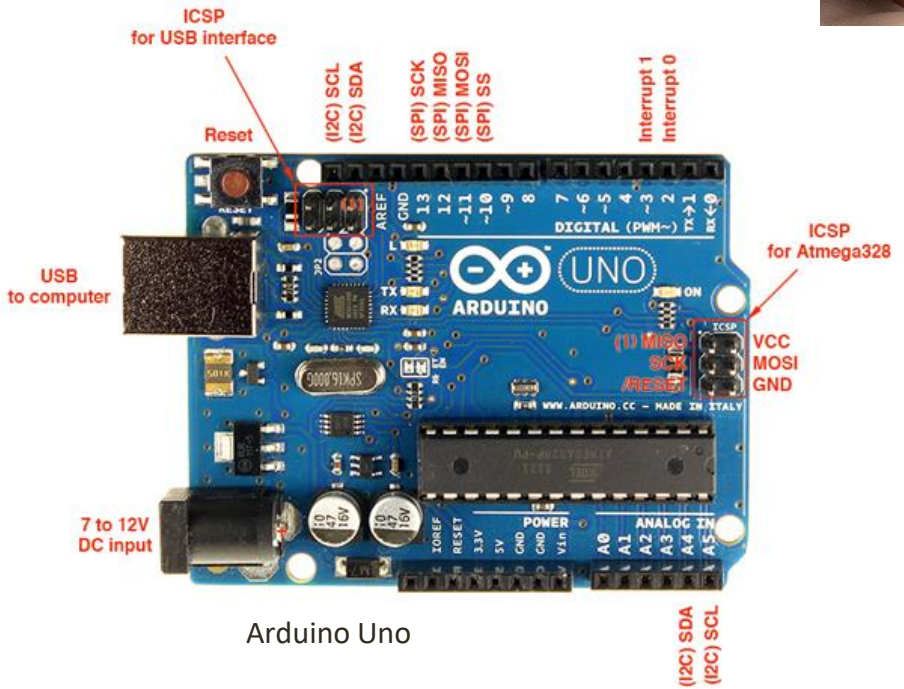
Implementing Smart Objects



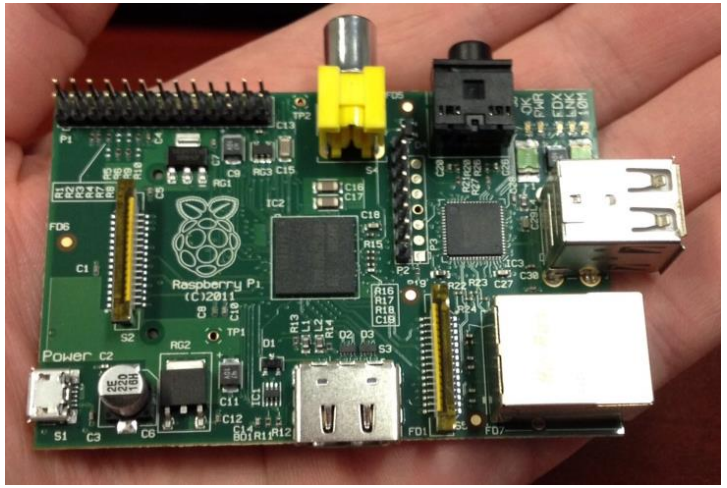
Beaglebone black



Intel Galileo

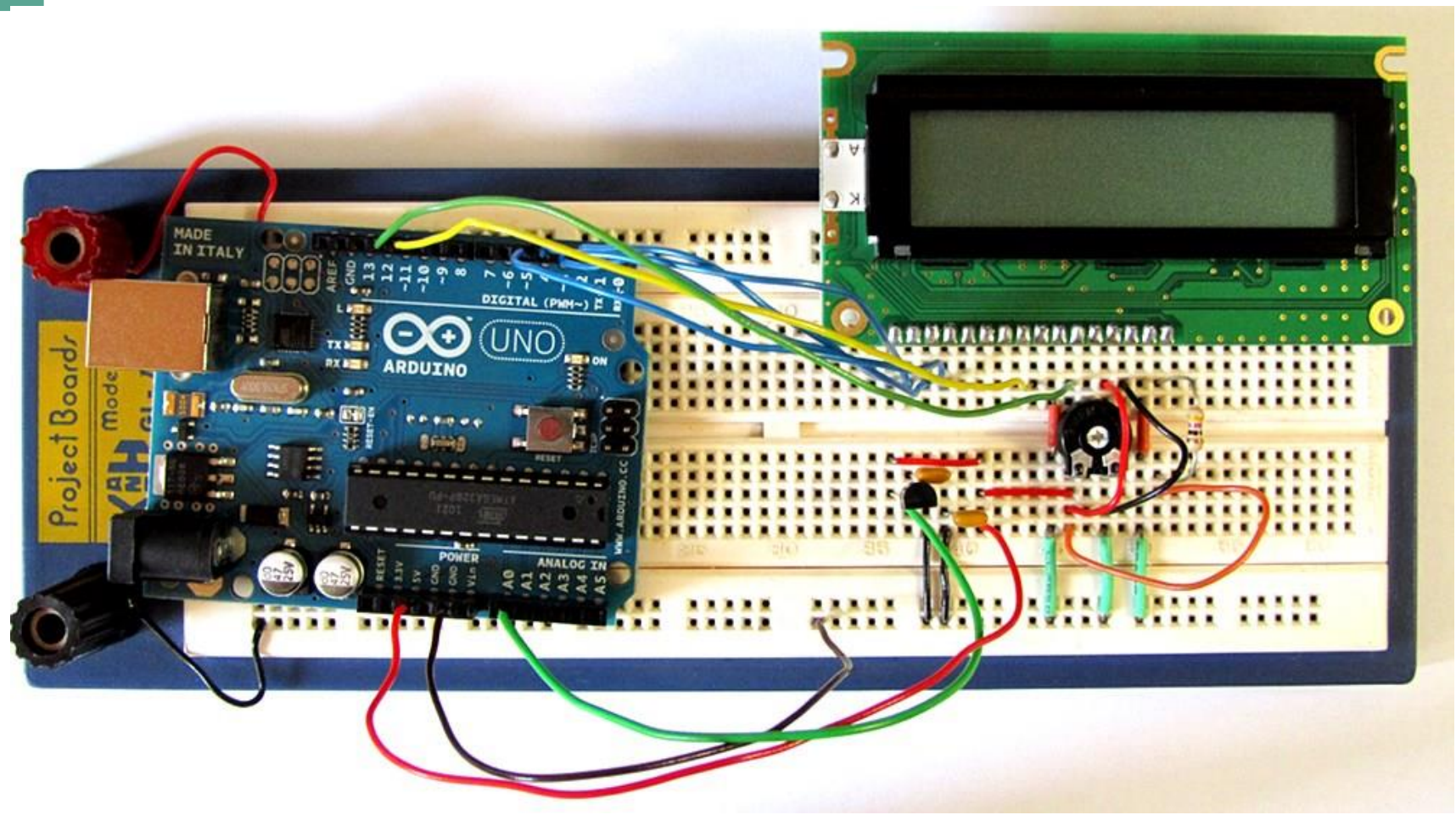


Arduino Uno

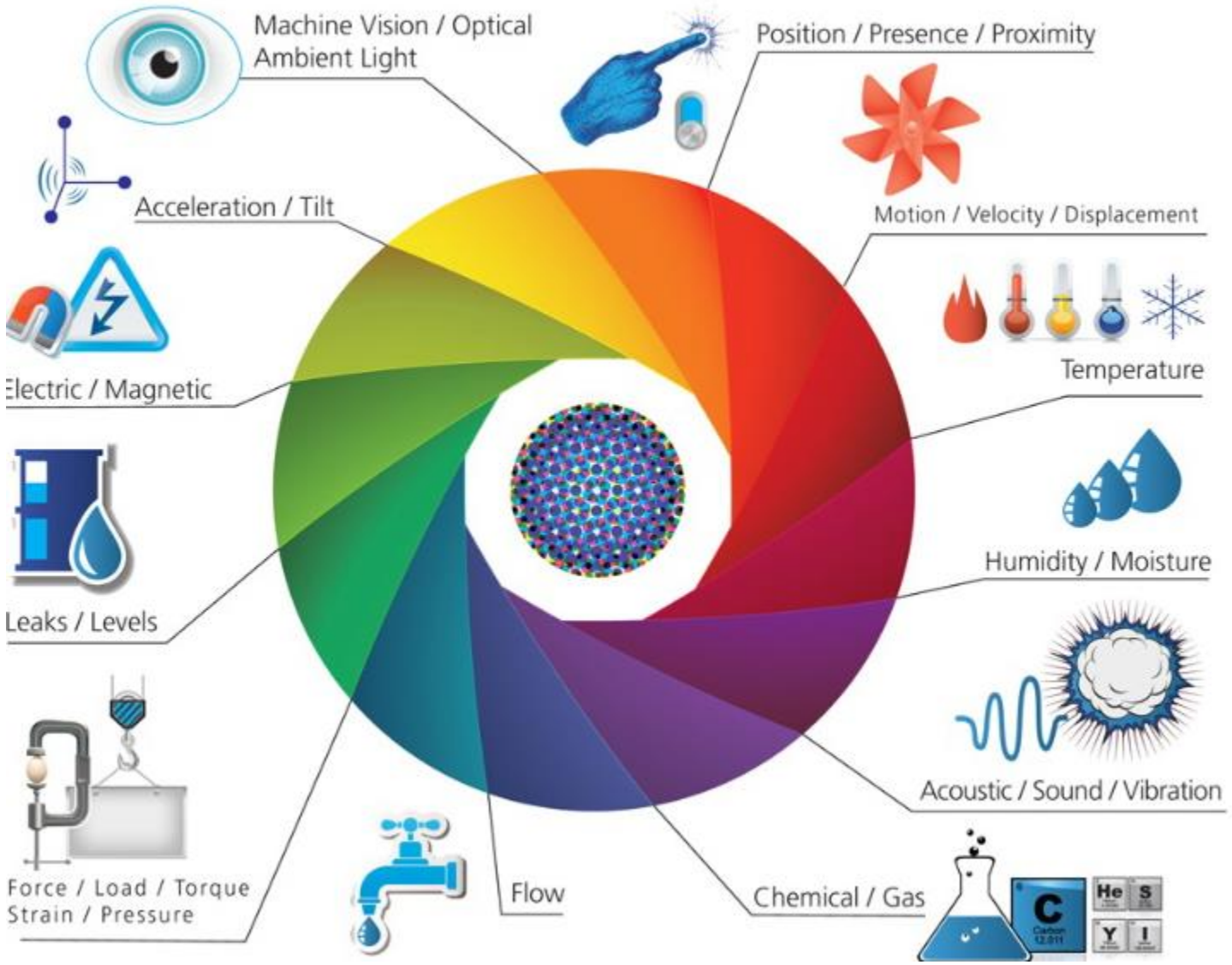


Raspberry Pi

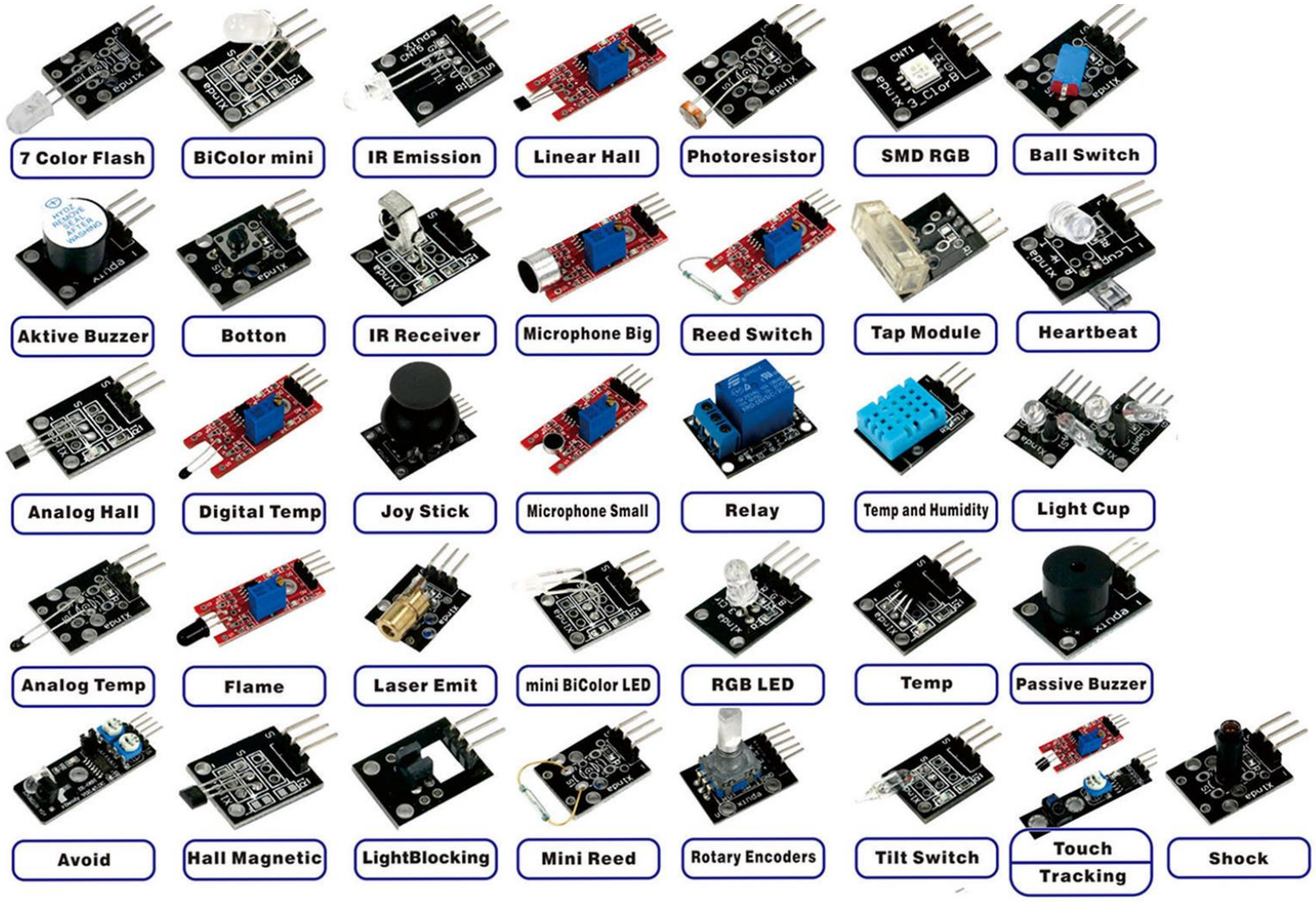
Board Connection



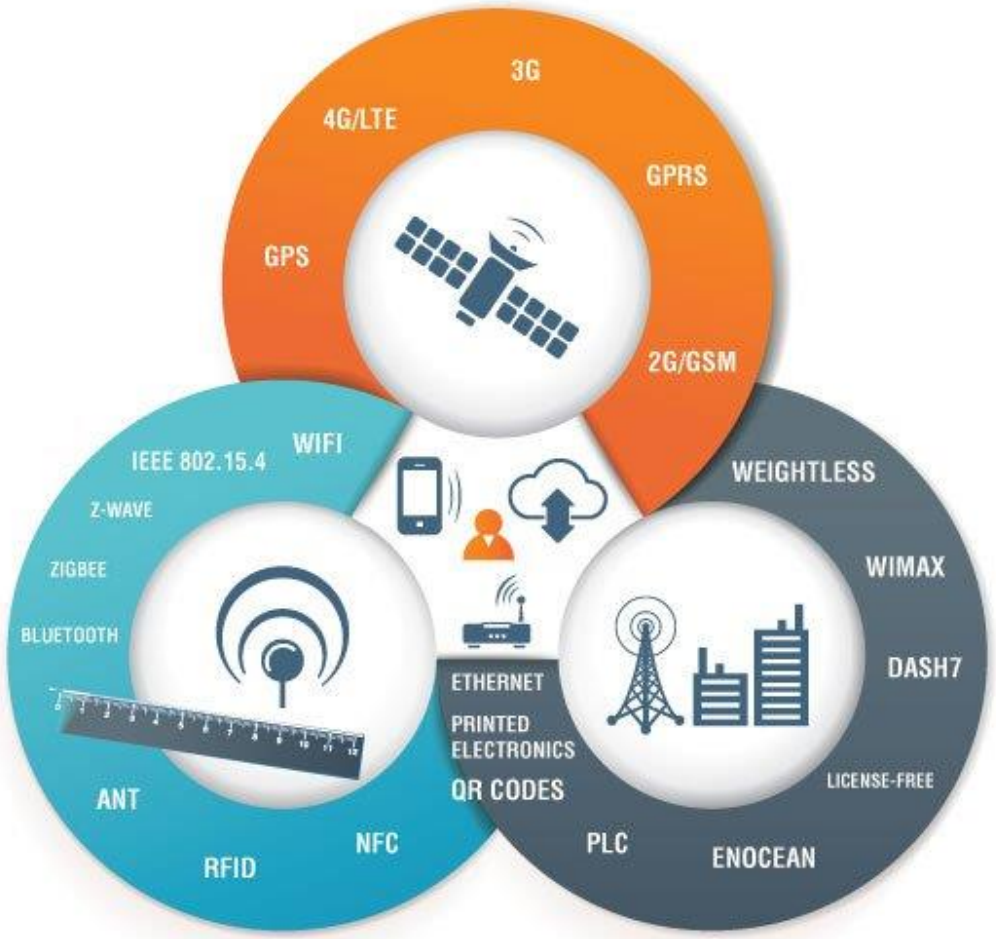
Sensors and Actuators



Sensors available in Market



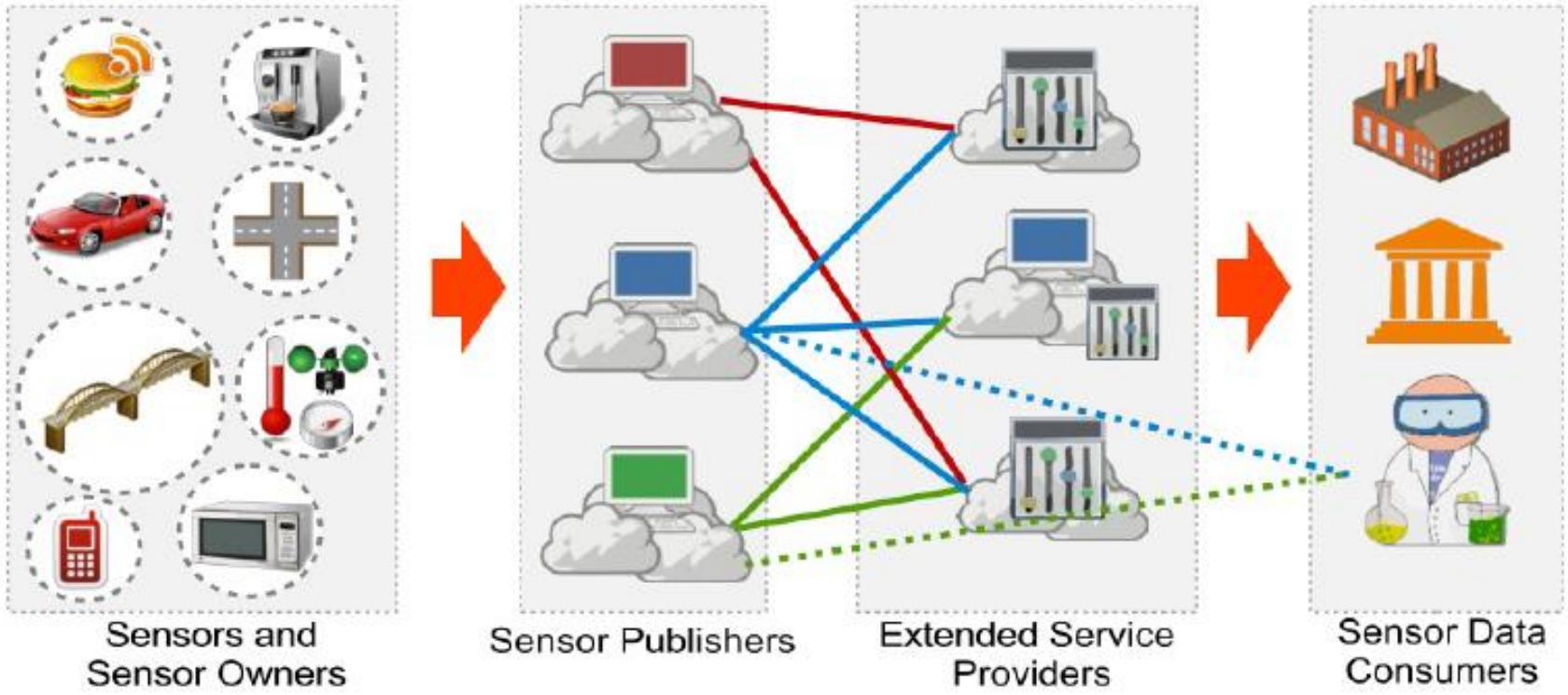
IoT Technologies : Communication Technology



IoT Technologies : Protocols

- CoAP (Constrained Application Protocol)
- MQTT (Message Queue Telemetry Transport)
- XMPP (Extensible Messaging and Presence Protocol)
- 6LoWPAN (Low power Wireless Personal Area Networks)

IoT Technologies : Cloud (Sensing as-a-service Model)



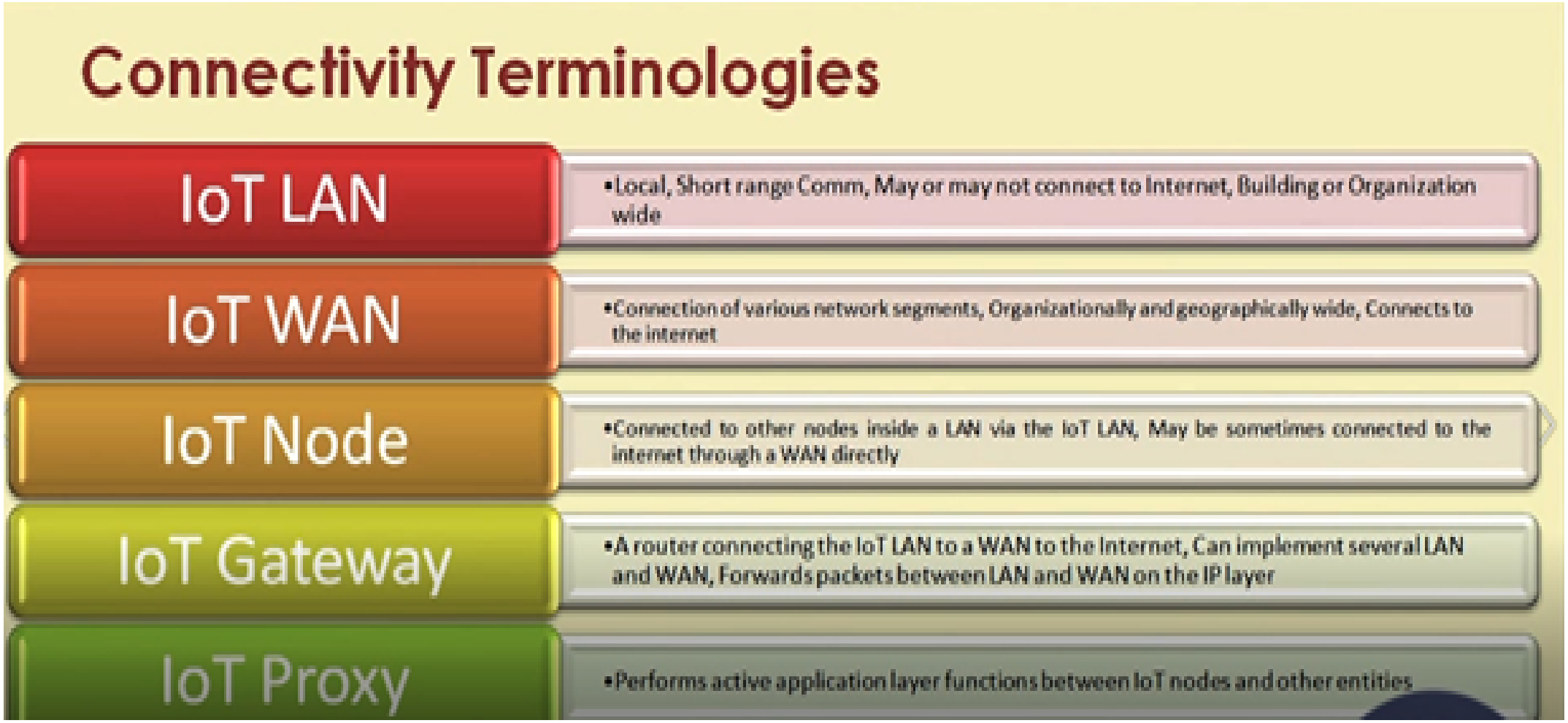
Challenges of IoT

- Connectivity
- Power Management
- Security
- Rapid Evolution

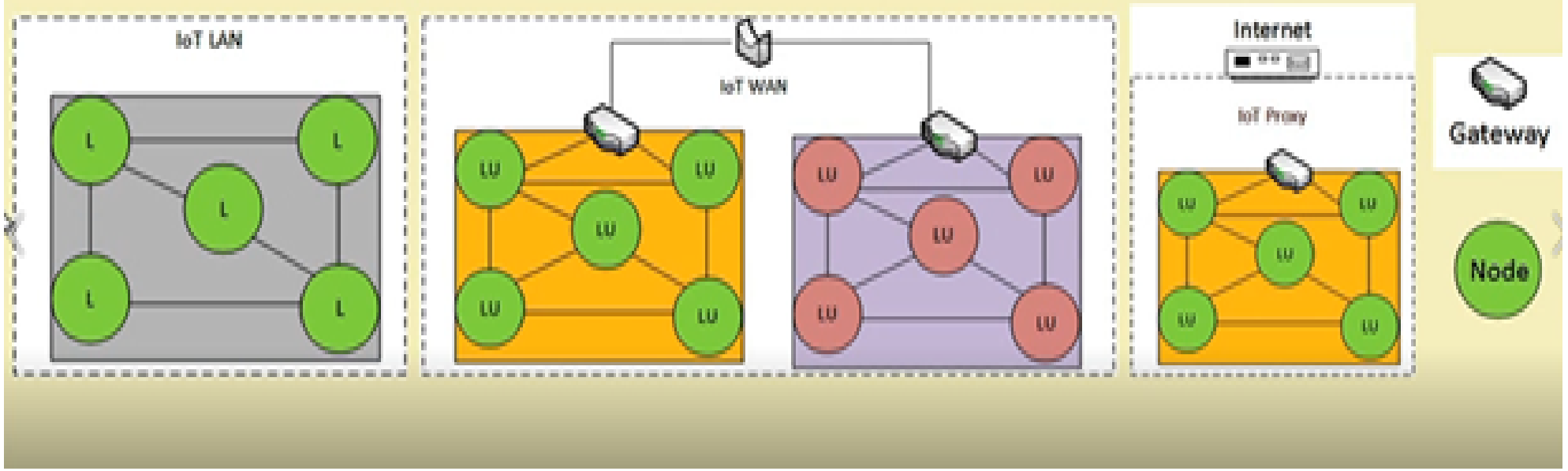
Introduction to IoT-II

- IoT resulting in Address Crunch
- Connectivity Terminologies
- IoT network Configuration
- Gateway Prefix Allotment
- Impact of mobility on addressing
- Gateways
- Multihoming
- IPV4 Vs IPV6
- Essential Building blocks of IoT
- Sensors Vs Transducers
- Types of Sensors
- Errors

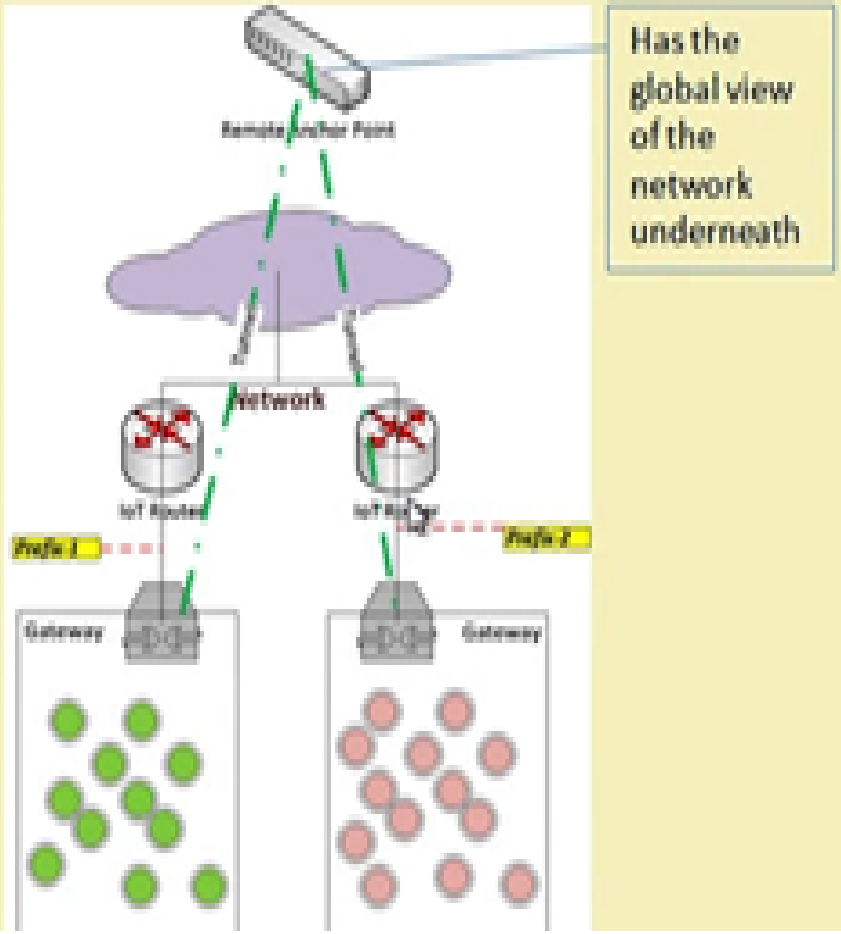
Connectivity Terminologies



IoT Network Configurations



Impact of Mobility on Addressing



- ✓ The network prefix changes from 1 to 2 due to movement, making the IoT LAN safe from changes due to movements.
- ✓ IoT gateway WAN address changes without change in LAN address. This is achieved using ULA.

Gateways:

Gateways are responsible mainly for:

- Internet Connectivity
- IoT LAN intra-connectivity

Multi Homing:

- A node/network connected to multiple networks for improved reliability.
- Two Approaches:

1. Proxy based
2. Gateway based

IPV4 Vs IPV6

IPv4 versus IPv6

	IPv4	IPv6
Developed	IETF 1974	IEF 1998
Length (bits)	32	128
No. of Addresses	2^32	2^128
Notation	Dotted Decimal	Hexadecimal
Dynamic Allocation of addresses	DHCP	SLAAC/ DHCPv6
IPSec	Optional	Compulsory

Essential building blocks of IoT

- Sensor
- Actuator

Sensors:

Sensing the physical phenomena that are occurring around them.

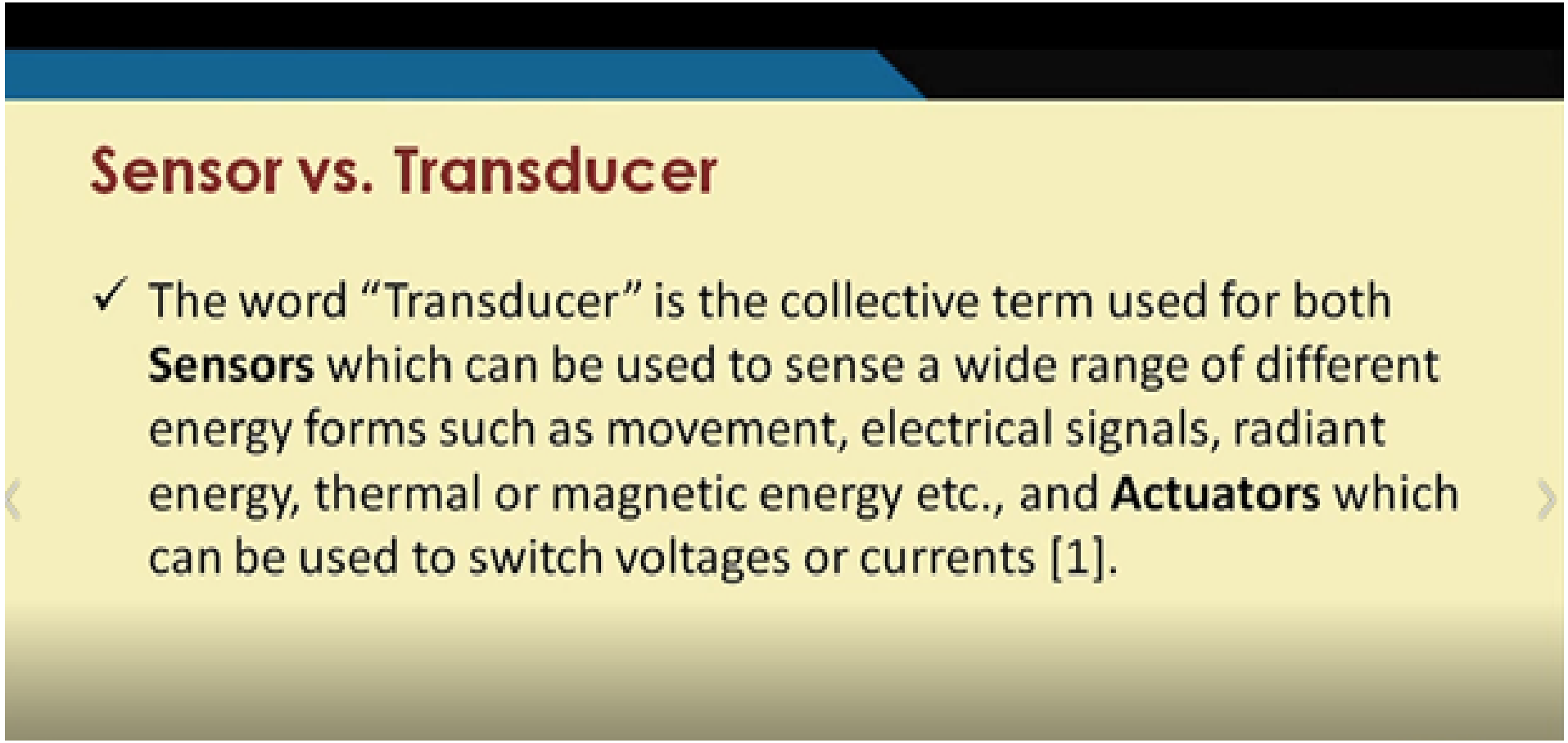
Transducers:

Transducers convert or transduce energy of one kind to another.

Sensor Resolution:

Smallest change it can detect.

Sensor Vs Transducer:



Sensors Classes

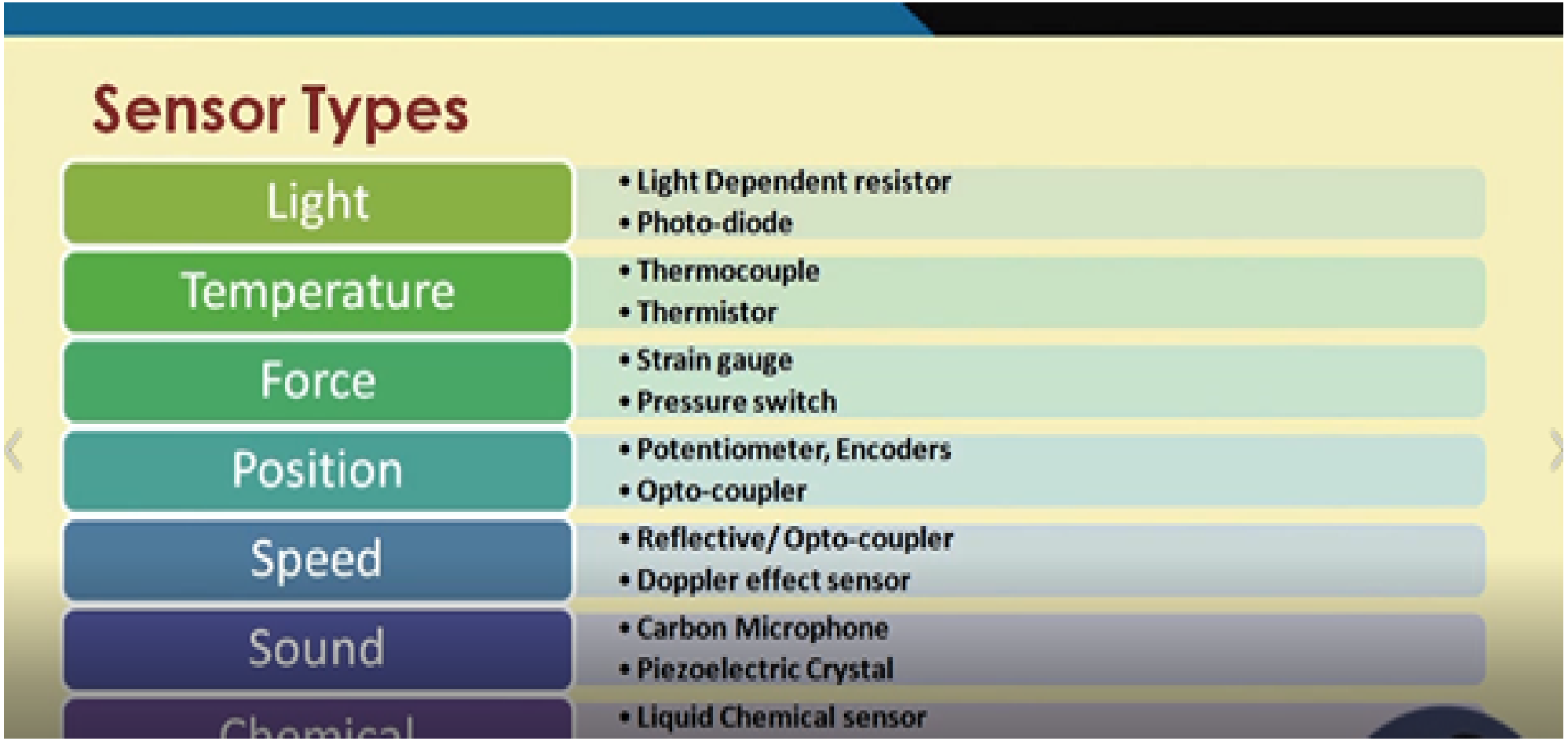
Based on output:

- Analog sensor
- Digital sensor

Based on data type:

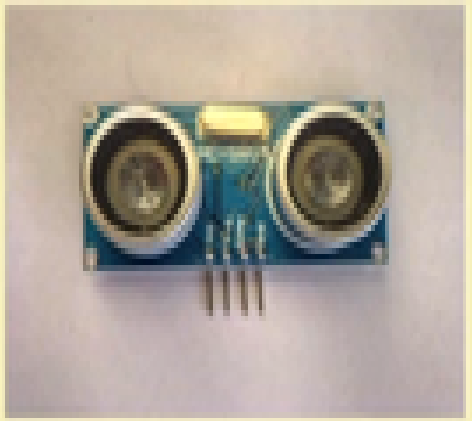
- Scalar Sensors
- Vector/Multimedia sensors

Types of Sensors



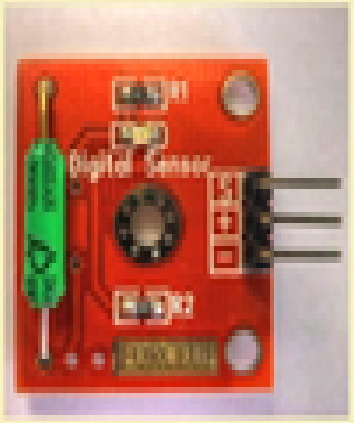
Pressure Sensor

Source: Wikimedia Commons



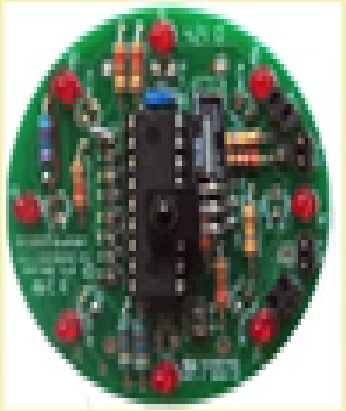
Ultrasonic Distance Sensor

Source: Wikimedia Commons



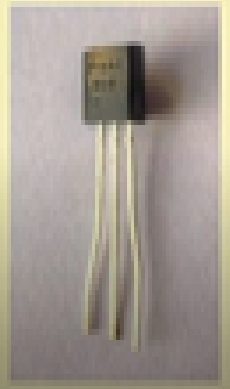
Tilt Sensor

Source: Wikimedia Commons

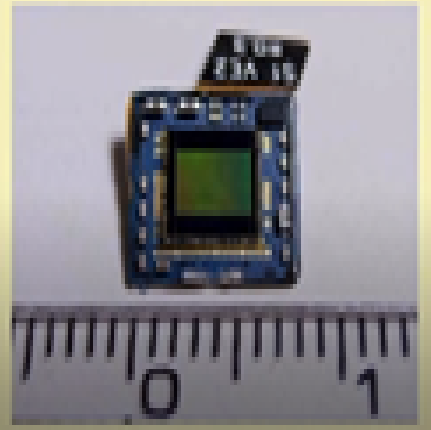


Infrared Motion Sensor

Source: Wikimedia Commons



Analog Temperature Sensor



Camera Sensor

Errors

- Sensorial deviations
- Non linearity
- Hysteresis error
- Quantization error
- Aliasing error

Topics to be covered

- Actuator
- Types of Actuator
- Convergence of Domains
- IoT Components
- IoT Interdependencies
- IoT Categories
- IoT Gateways
- IoT and associated technologies
- IoT Challenges
- Complexity of Network

Actuator:

Actuator is the mechanism by which a control system acts upon an environment.

Types of Actuator:

- Hydraulic
- Pneumatic
- Electrical
- Thermal/ Magnetic
- Mechanical
- Soft

Hydraulic Actuator

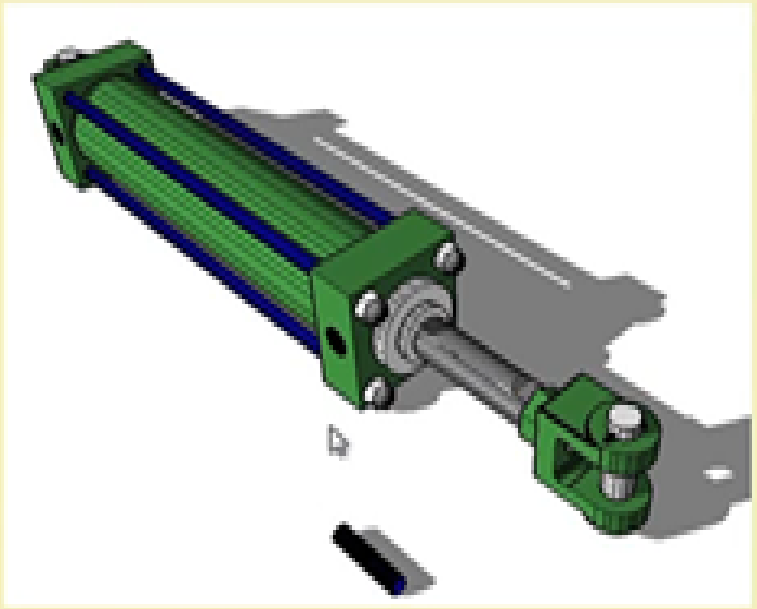


Fig: An oil based hydraulic actuator

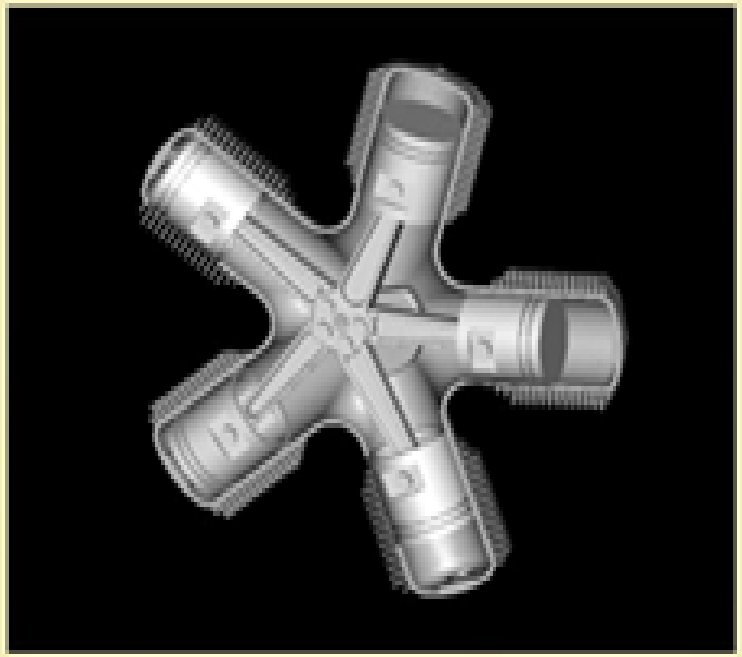


Fig: A radial engine acts as a hydraulic actuator

Pneumatic Actuator:

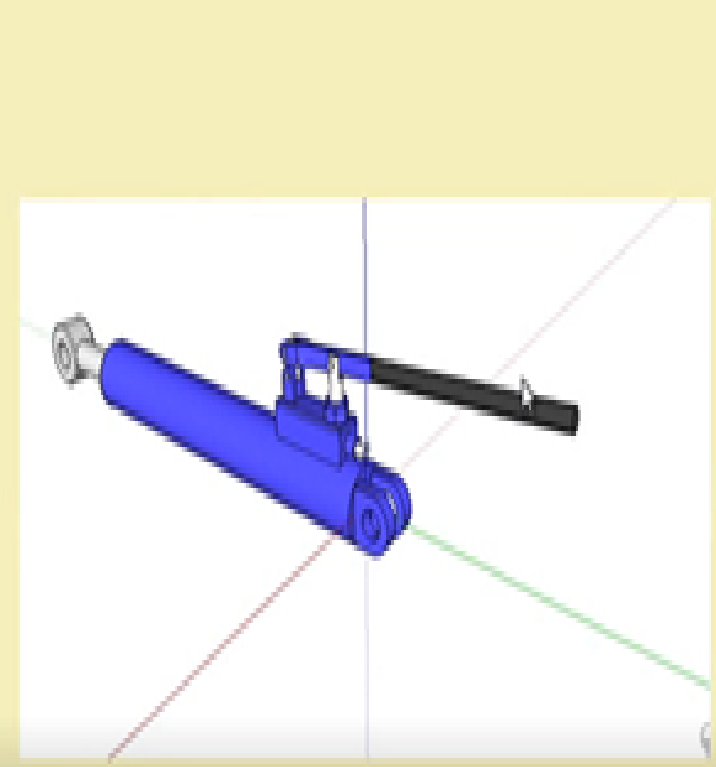


Fig: A manual linear pneumatic actuator

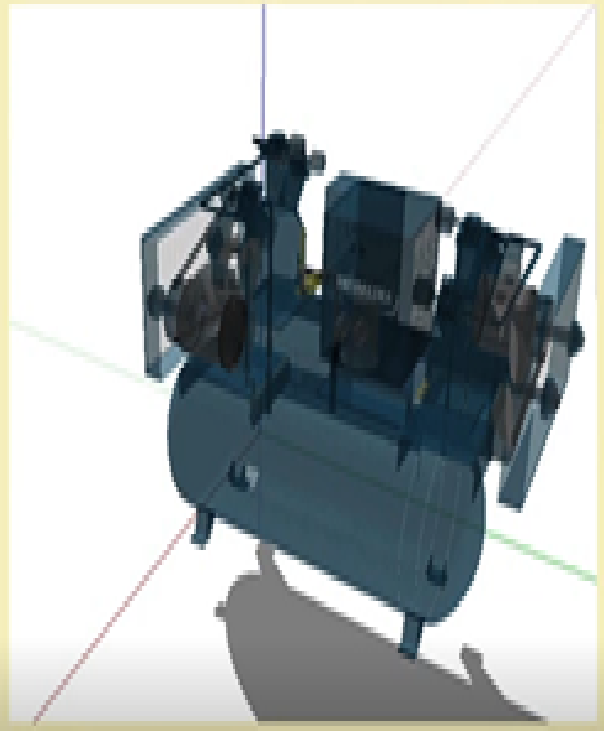


Fig: An air pump acts as a pneumatic actuator

Electrical Actuator:

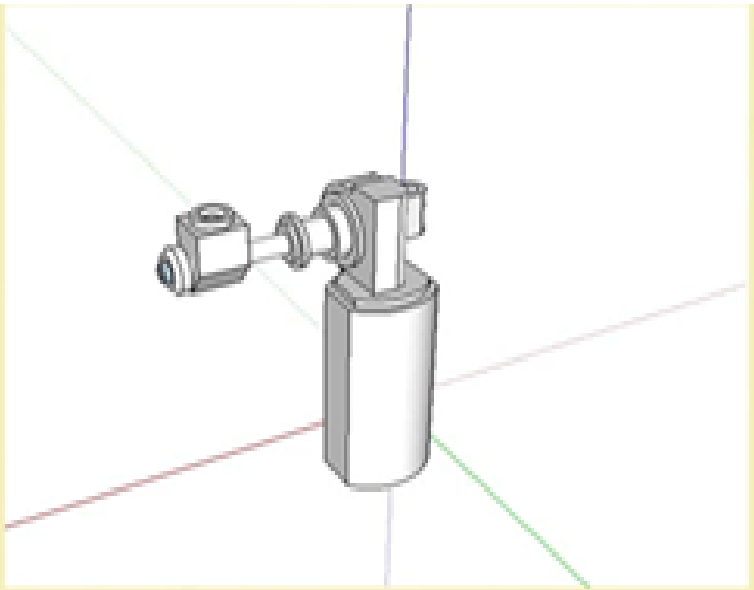


Fig: A motor drive-based rotary actuator

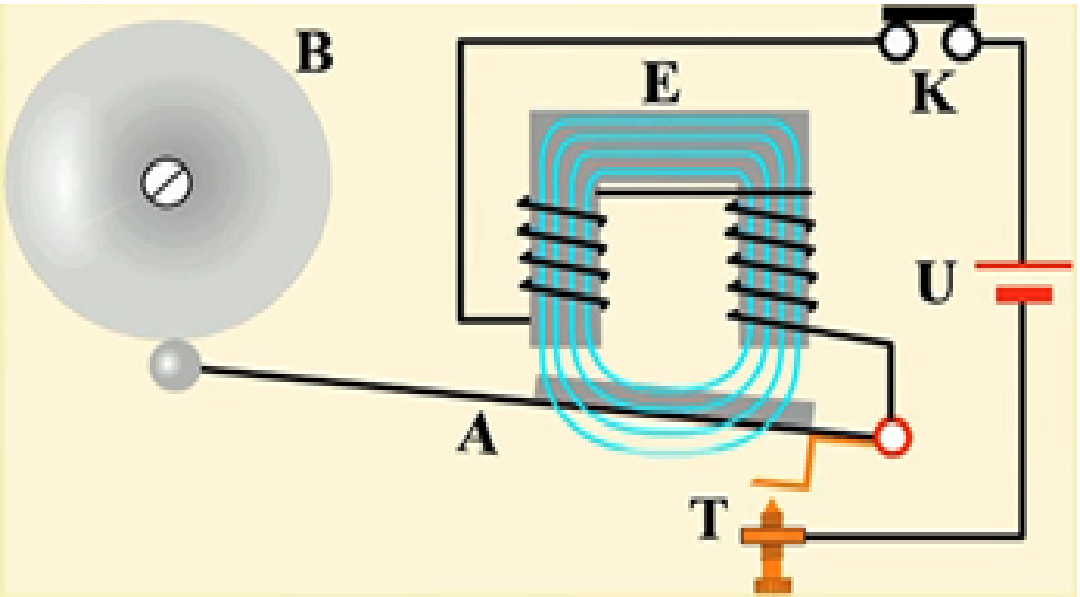


Fig: A solenoid based electric bell ringing mechanism

Thermal Actuator:

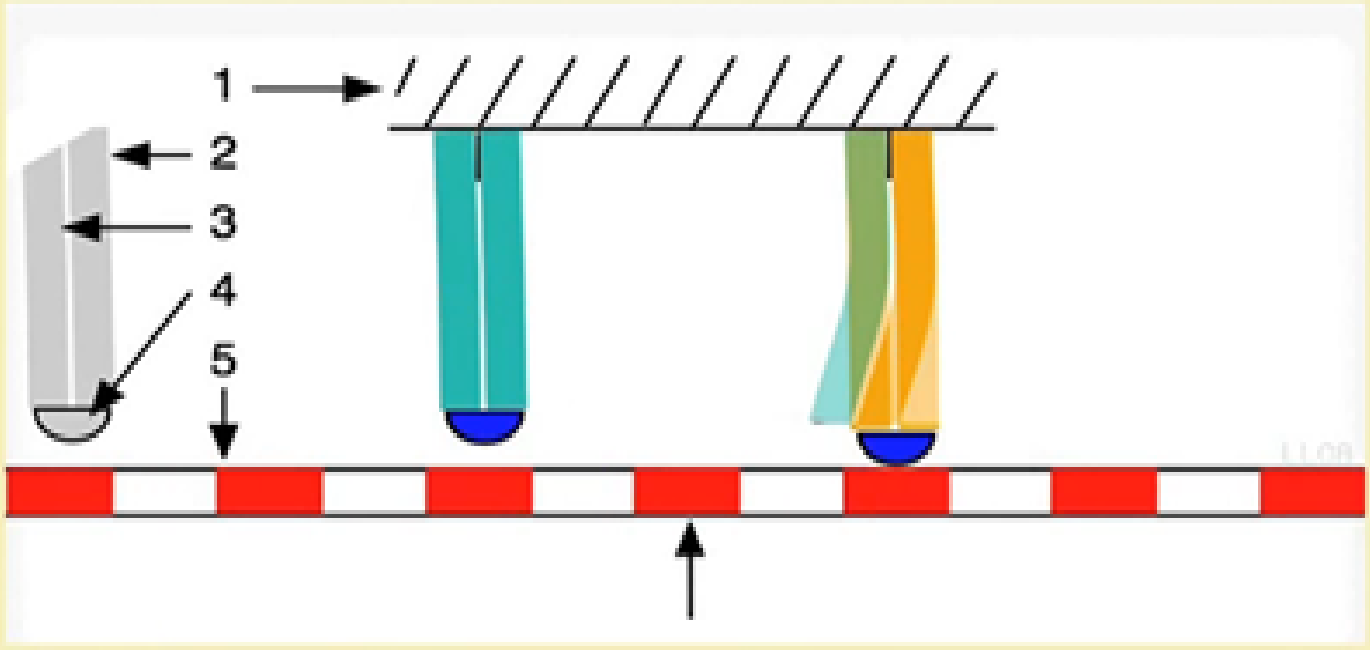


Fig: A piezo motor using SMA

Magnetic Actuator:

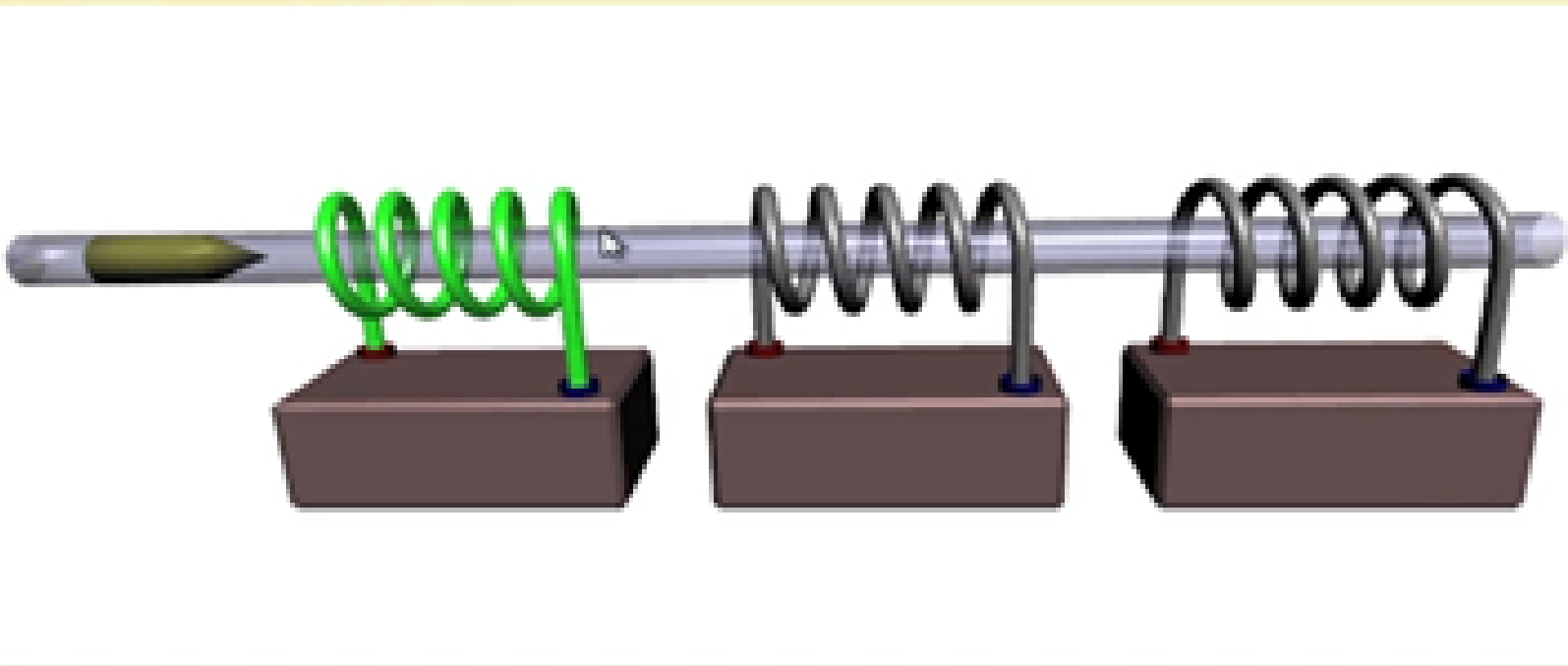


Fig: A coil gun works on the principle of magnetic actuation

Mechanical Actuator:

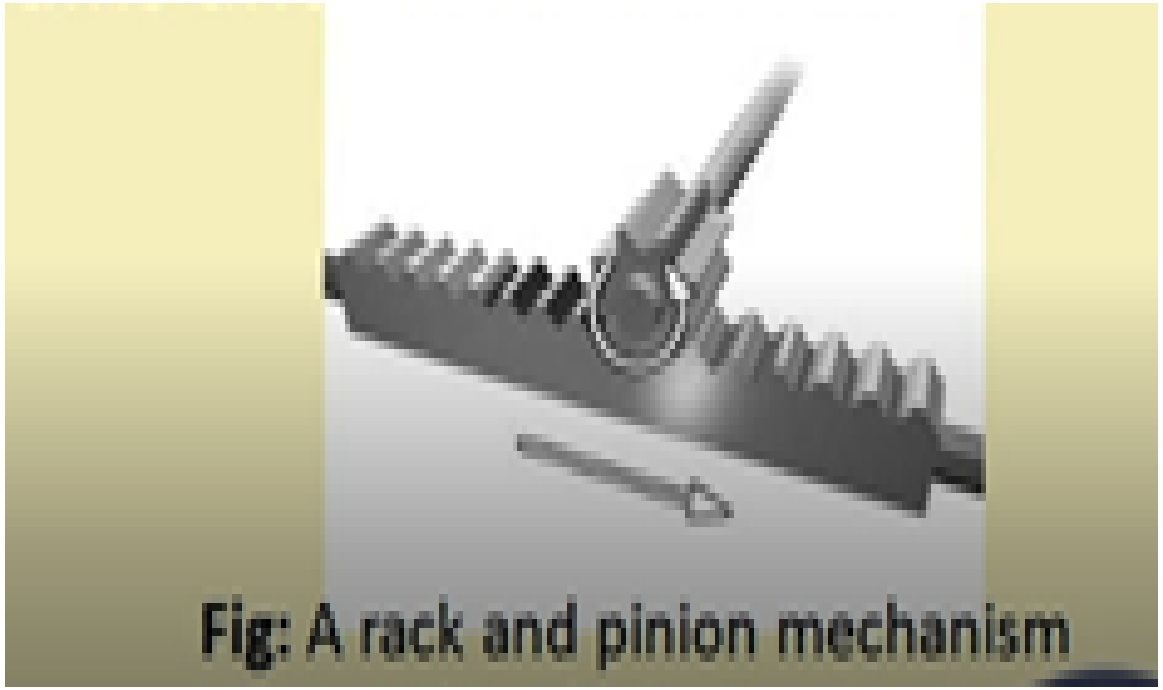


Fig: A rack and pinion mechanism

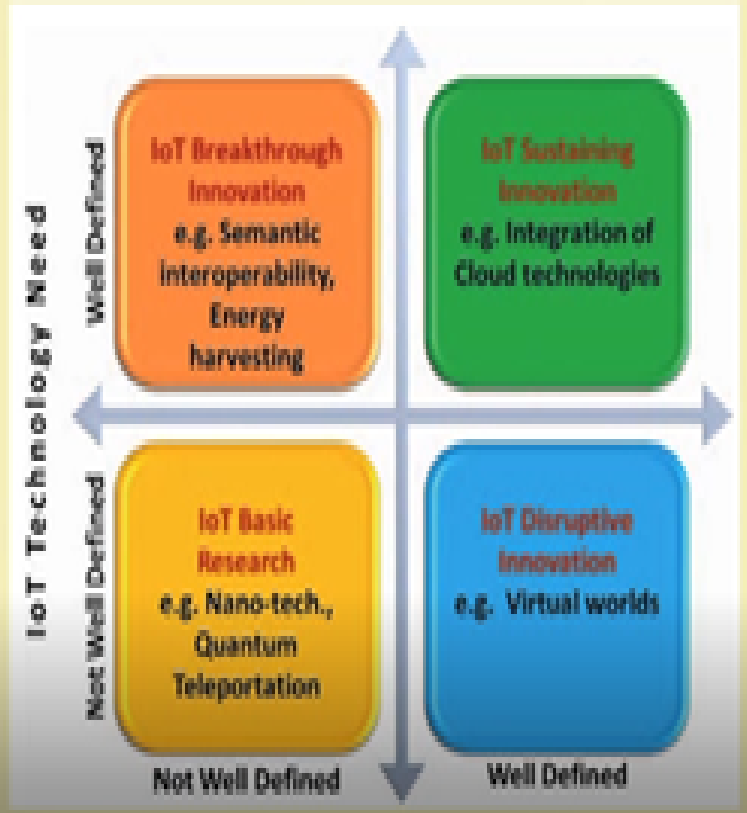
Soft Actuator:

Soft Actuator are designed to handle fragile object like fruit harvesting in agriculture or manipulating the internal organs in biomedicine.

- Shape memory polymer
- Light activated polymer

Basics of IoT Networking

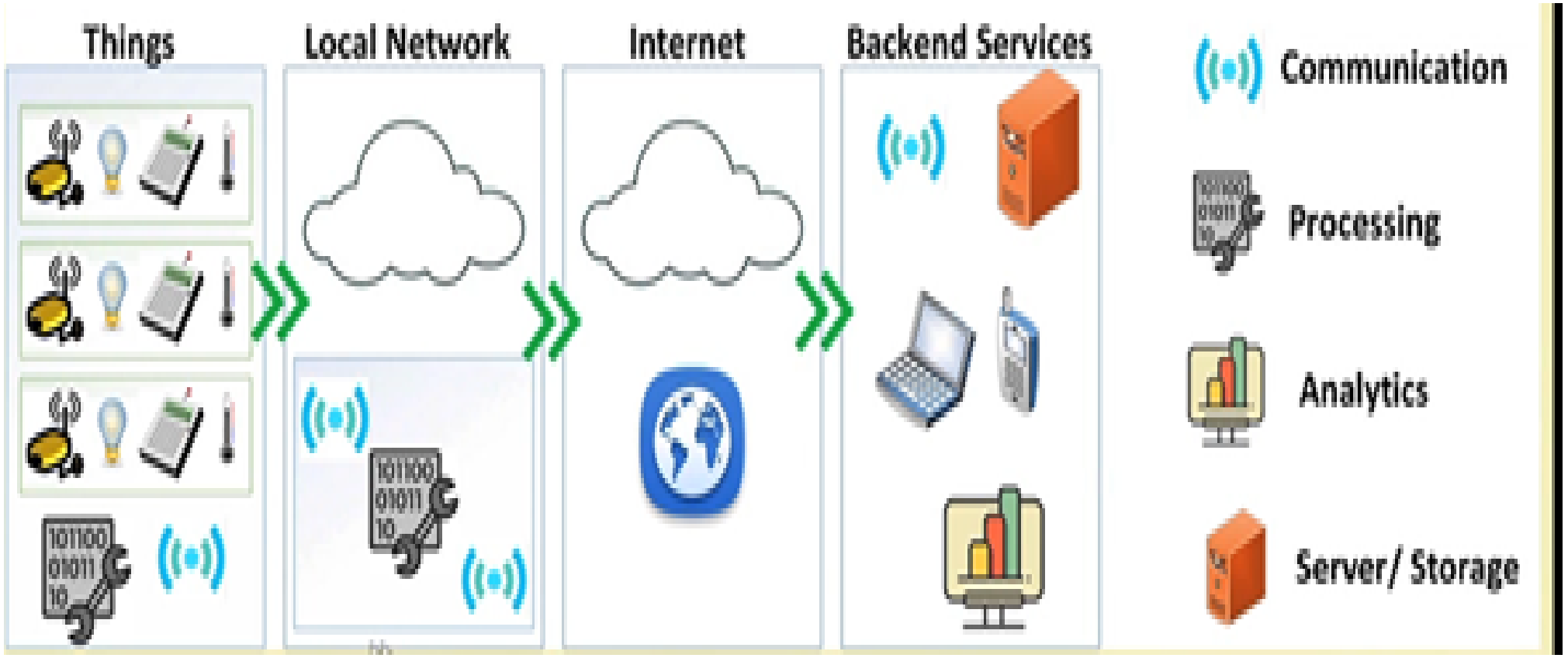
Convergence of Domains

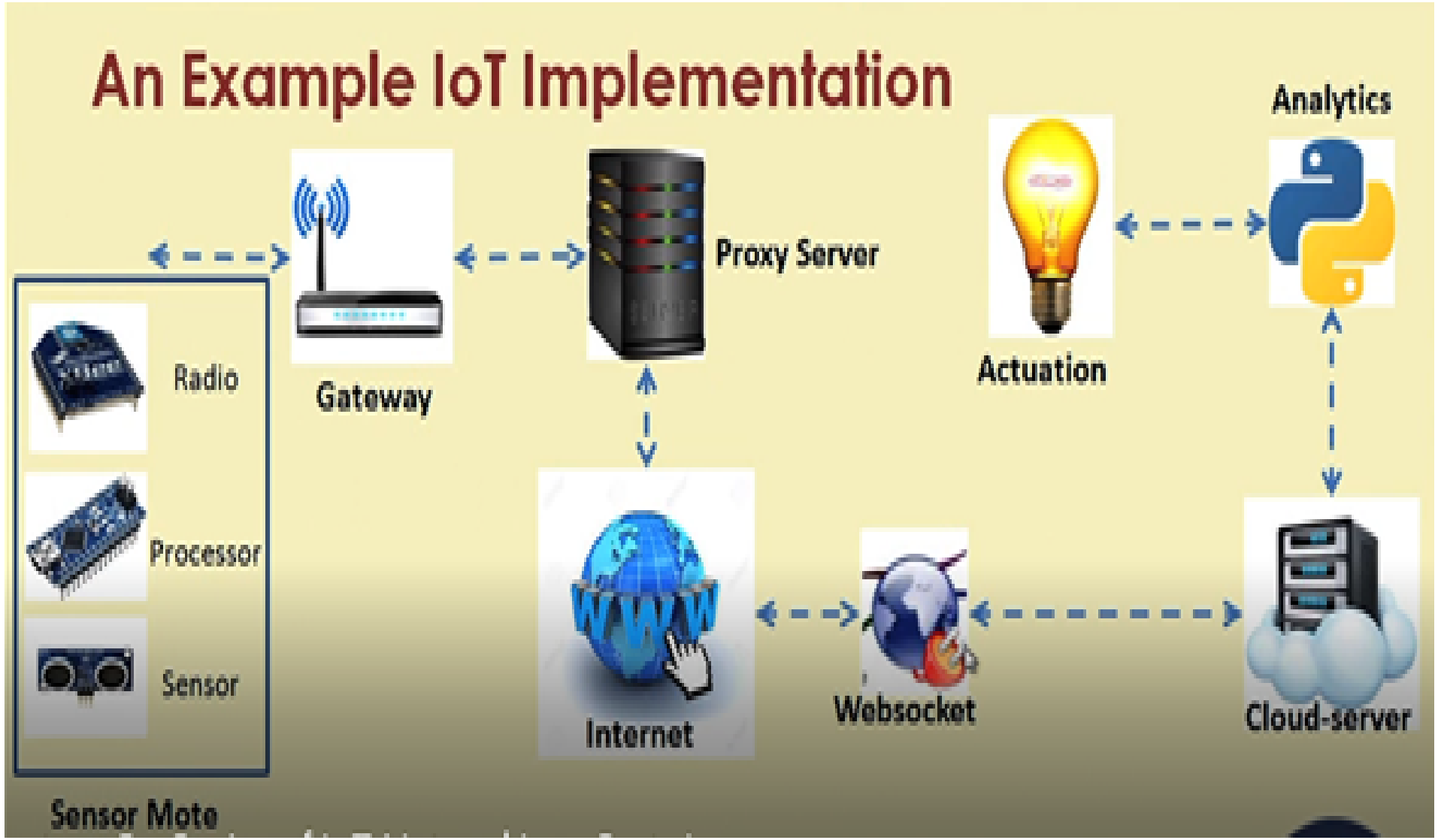


Source: O. Vermesan, P. Friess, "Internet of Things – Converging Technologies for Smart Environments and Integrated Ecosystems", River

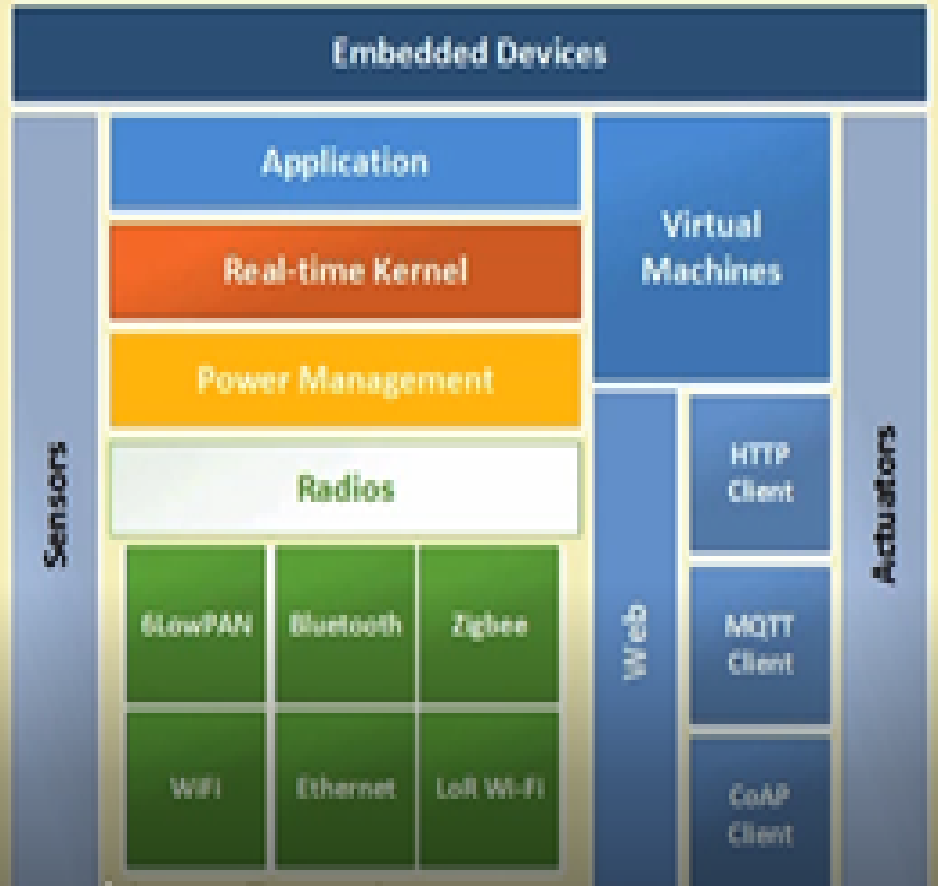
IoT Components:

- Device(the thing)
- Local Network
- Internet
- Backend Services
- Applications

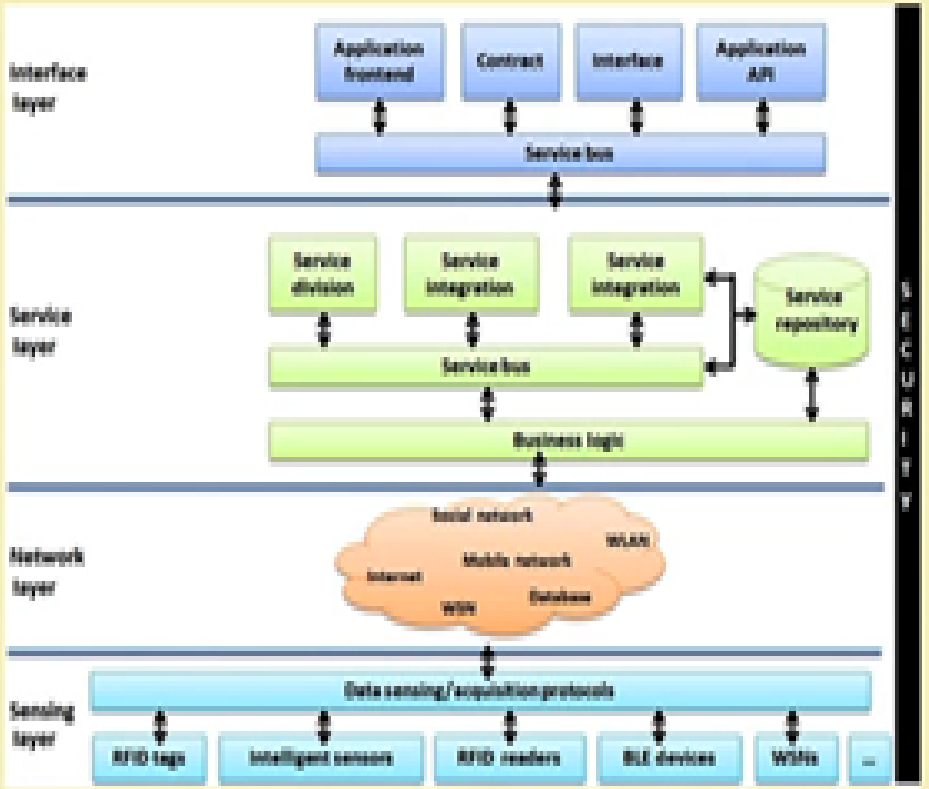

Things
Local Network
Internet
Backend Services
Communication
Processing
Analytics
Server/ Storage


An Example IoT Implementation
Analytics
Proxy Server
Actuation
Radio
Gateway
Processor
Sensor
Internet
Websocket
Cloud-server
Sensor Mote

IoT Interdependencies



IoT Service Oriented Architecture

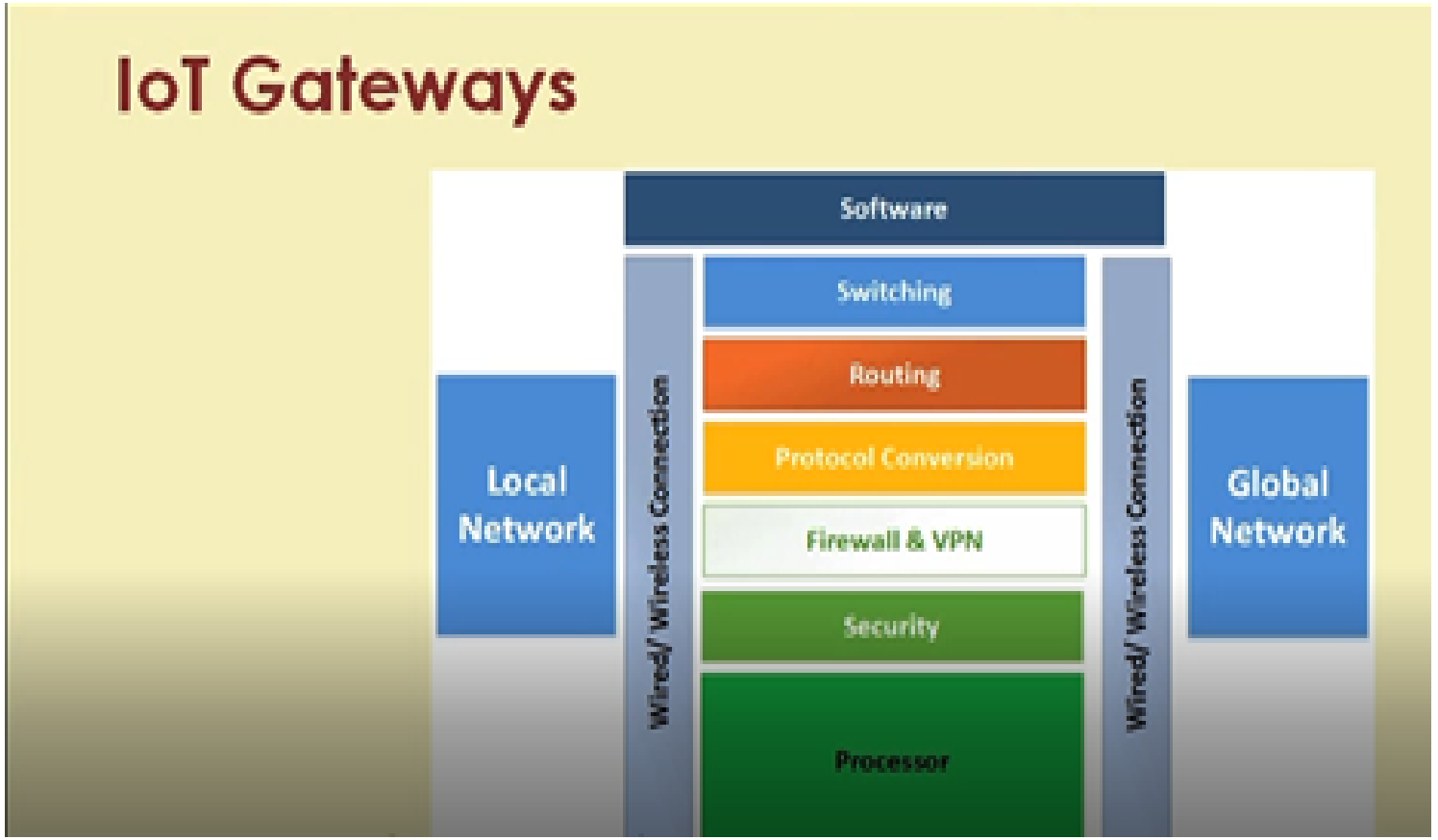


Source: Li Da Xu, Wu He, and Shancang Li, "Internet of Things in Industries: A Survey ", IEEE Transactions on Industrial Informatics, Vol. 10, No. 4, Nov. 2014.

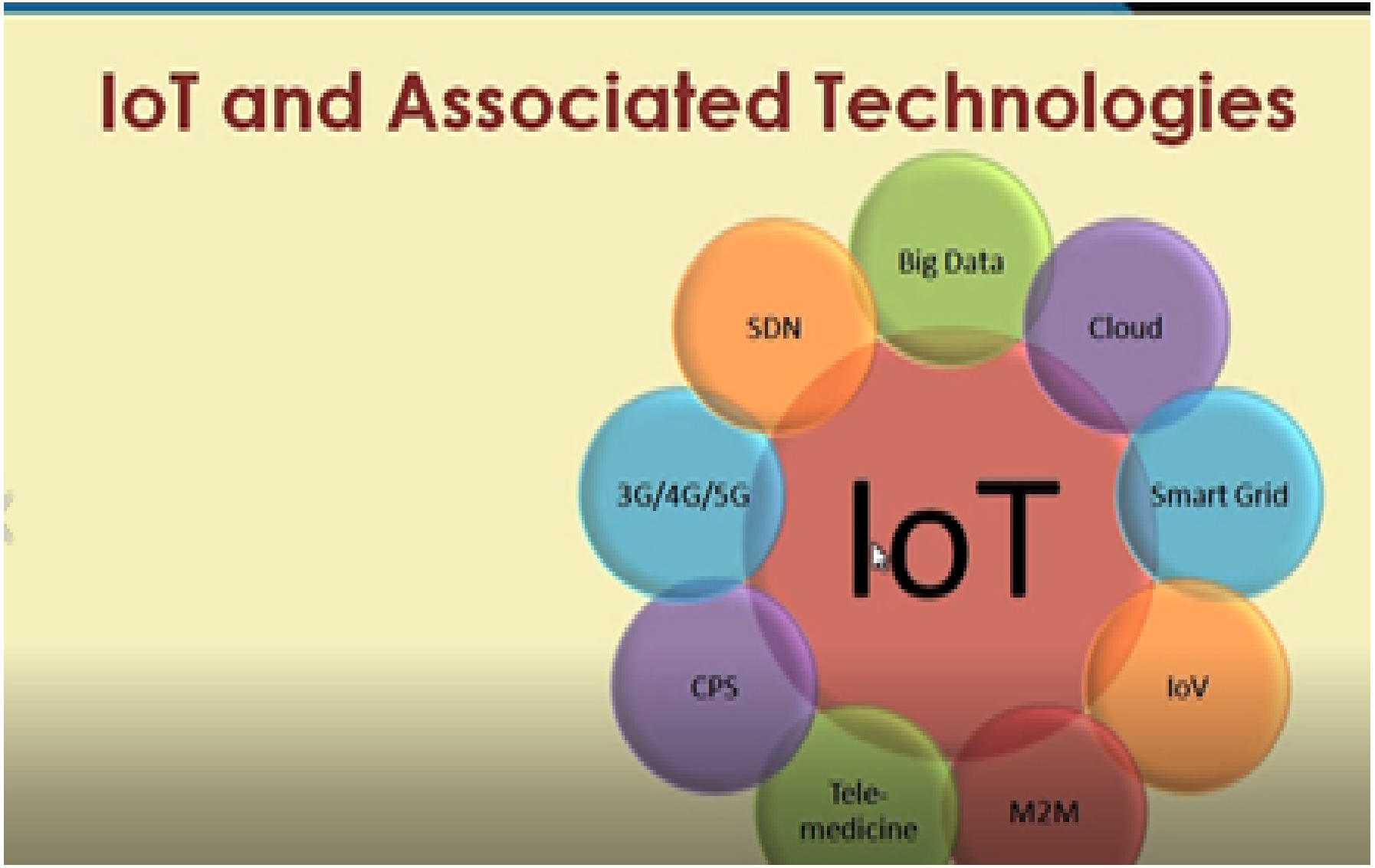
IoT Categories:

- Industrial IoT
- Consumer IoT

An **IoT Gateway** is a solution for enabling **IoT** communication, usually device -to-device communications or device-to-cloud communications. The **gateway** is typically a hardware device housing application software that performs essential tasks.



IoT and Associated Technologies



IoT Challenges:

- Security
- Scalability
- Energy Efficiency
- Modeling and Analysis
- Data Storage
- Data Analytics
- Complexity Management

Complexity of the network:

- Growth of Networks
- Interference among devices
- Network management
- Heterogeneity in Network

Topics to be covered

- Functionality based IoT Protocol Organization
- MQTT
- SMQTT
- CoAP
- REST
- XMPP
- Asset Management
- Telemetry

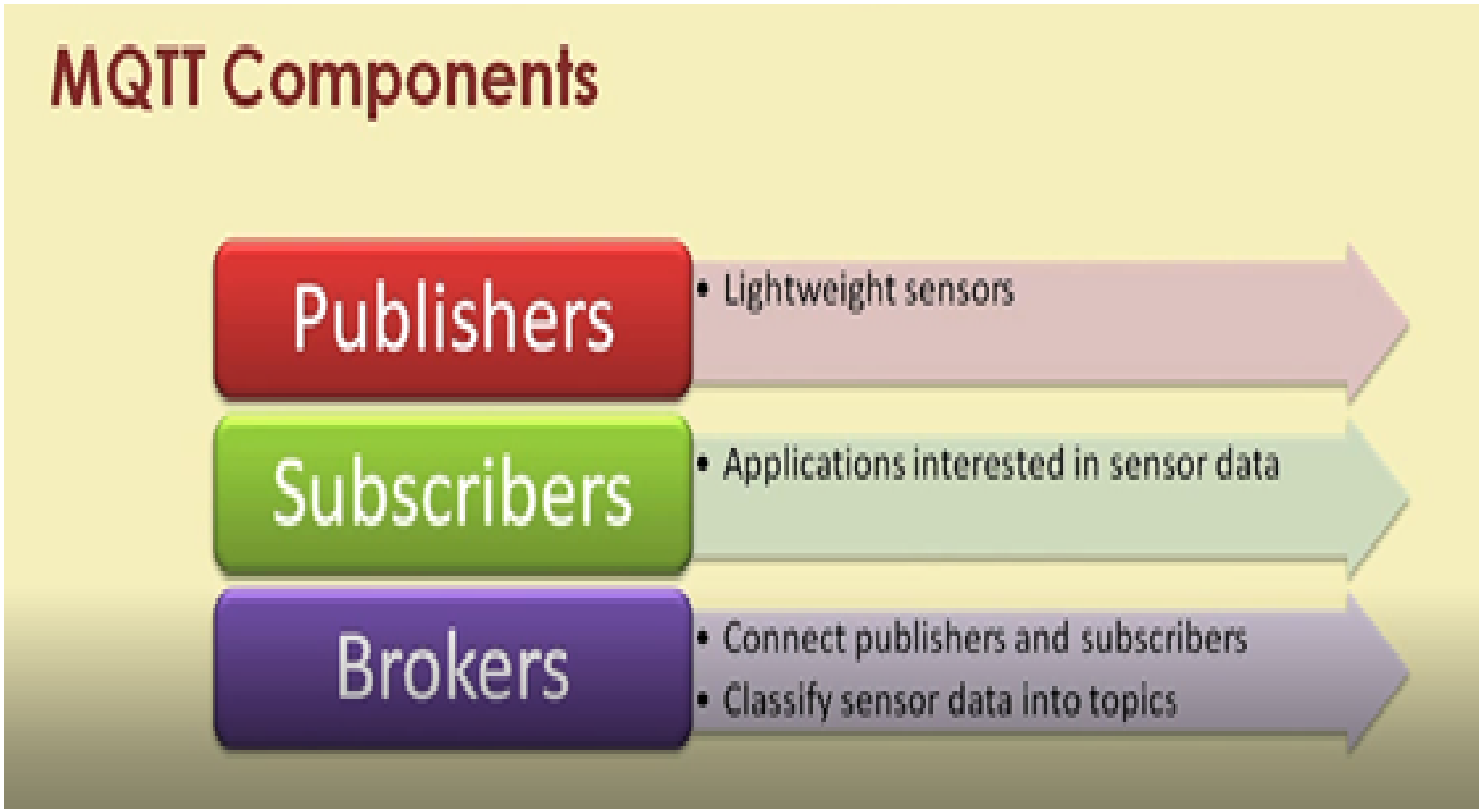
Functionality-based IoT Protocol Organization

- ✓ **Connectivity** (6LowPAN, RPL)
- ✓ **Identification** (EPC, uCode, IPv6, URIs)
- ✓ **Communication / Transport** (WiFi, Bluetooth, LPWAN)
- ✓ **Discovery** (Physical Web, mDNS, DNS-SD)
- ✓ **Data Protocols** (MQTT, CoAP, AMQP, Websocket, Node)
- ✓ **Device Management** (TR-069, OMA-DM)
- ✓ **Semantic** (JSON-LD, Web Thing Model)
- ✓ **Multi-layer Frameworks** (Alljoyn, IoTivity, Weave, Homekit)

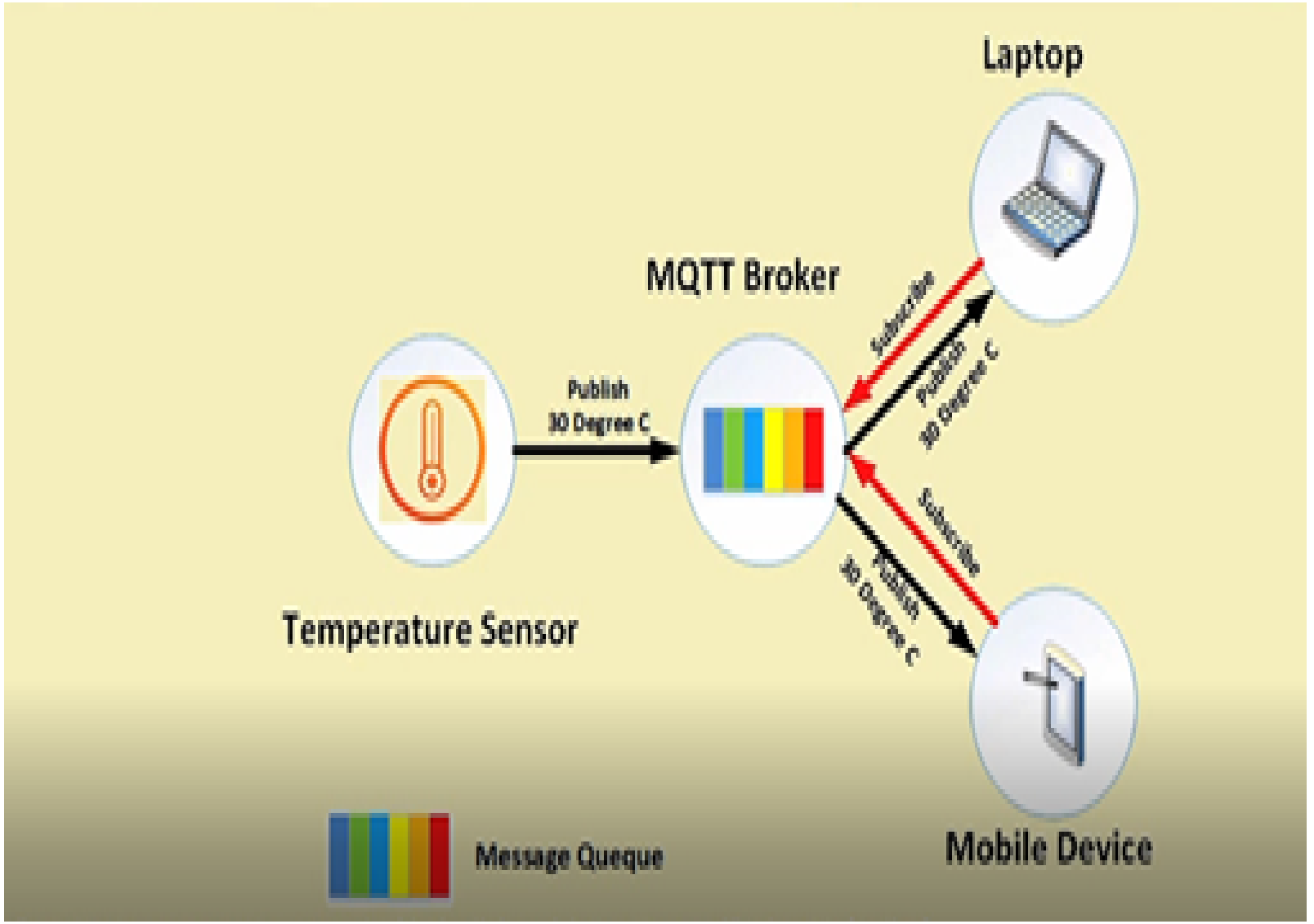
MQTT:

- ✓ **Message Queue Telemetry Transport.**
- ✓ ISO standard (ISO/IEC PRF 20922).
- ✓ It is a publish-subscribe-based lightweight messaging protocol for use in conjunction with the TCP/IP protocol.
- ✓ MQTT was introduced by IBM in 1999 and standardized by OASIS in 2013.
- ✓ Designed to provide connectivity (mostly embedded) between applications and middle-wares on one side and networks and communications on the other side.

- ✓ A message broker controls the publish-subscribe messaging pattern.
- ✓ A topic to which a client is subscribed is updated in the form of messages and distributed by the message broker.
- ✓ Designed for:
  - Remote connections
  - Limited bandwidth
  - Small-code footprint


MQTT Components
Publishers
• Lightweight sensors
Subscribers
• Applications interested in sensor data
Brokers
• Connect publishers and subscribers
• Classify sensor data into topics


MQTT Methods
Connect
Disconnect
Subscribe
Unsubscribe
Publish


Laptop
MQTT Broker
Publish
30 Degree C
Temperature Sensor
Mobile Device
Message Queque

Communication

- ✓ The protocol uses a **publish/subscribe** architecture (HTTP uses a request/response paradigm).
- ✓ Publish/subscribe is **event-driven** and enables messages to be pushed to clients.
- ✓ The central **communication point is the MQTT broker**, which is in charge of dispatching all messages between the senders and the rightful receivers.
- ✓ Each client that publishes a message to the broker, includes a **topic** into the message. The **topic is the routing information for the broker.**

- ✓ Each client that wants to receive messages subscribes to a certain topic and the broker delivers all messages with the matching topic to the client.
- ✓ Therefore the clients don’t have to know each other. They only communicate over the topic.
- ✓ This architecture enables highly scalable solutions without dependencies between the data producers and the data consumers.

MQTT Topics

- ✓ A topic is a **simple string** that can have more hierarchy levels, which are separated by a slash.
- ✓ A sample topic for sending temperature data of the living room could be *house/living-room/temperature*.
- ✓ On one hand the client (e.g. mobile device) can subscribe to the exact topic or on the other hand, it can use a **wildcard**.

- ✓ The subscription to *house/+/temperature* would result in all messages sent to the previously mentioned topic *house/living-room/temperature,* as well as any topic with an arbitrary value in the place of living room, such as *house/kitchen/temperature*.
- ✓ The plus sign is a **single level wild card** and only allows arbitrary values for one hierarchy.
- ✓ If more than one level needs to be subscribed, such as, the entire sub-tree, there is also a **multilevel wildcard** (#).
- ✓ It allows to subscribe to all underlying hierarchy levels.
- ✓ For example *house/#* is subscribing to all topics beginning with *house*.

Applications

- ✓ **Facebook Messenger** uses MQTT for online chat.
- ✓ **Amazon Web Services** use Amazon IoT with MQTT.
- ✓ **Microsoft Azure** IoT Hub uses MQTT as its main protocol for telemetry messages.
- ✓ The **EVRYTHNG IoT platform** uses MQTT as an M2M protocol for millions of connected products.
- ✓ **Adafruit** launched a free MQTT cloud service for IoT experimenters called Adafruit IO.

SMQTT

- ✓ **Secure MQTT** is an extension of MQTT which uses encryption based on lightweight attribute based encryption.
- ✓ The main advantage of using such encryption is the broadcast encryption feature, in which one message is encrypted and delivered to multiple other nodes, which is quite common in IoT applications.
- ✓ In general, the algorithm consists of four main stages: setup, encryption, publish and decryption.

- ✓ In the setup phase, the subscribers and publishers register themselves to the broker and get a master secret key according to their developer's choice of key generation algorithm.
- ✓ When the data is published, it is encrypted and published by the broker which sends it to the subscribers, which is finally decrypted at the subscriber end having the same master secret key.
- ✓ The key generation and encryption algorithms are not standardized.
- ✓ SMQTT is proposed only to enhance MQTT security features.

CoAP:

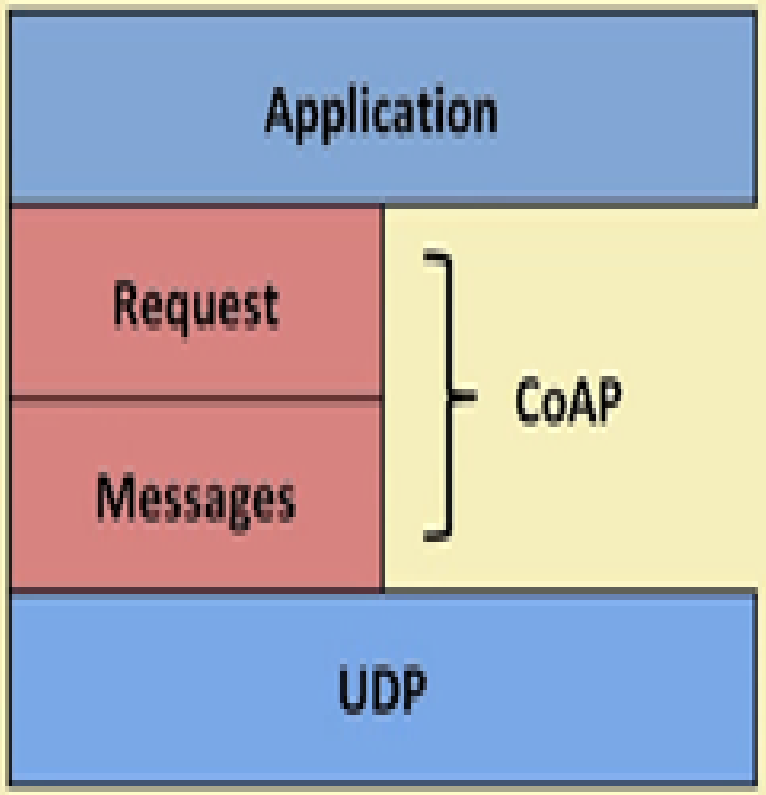
Introduction

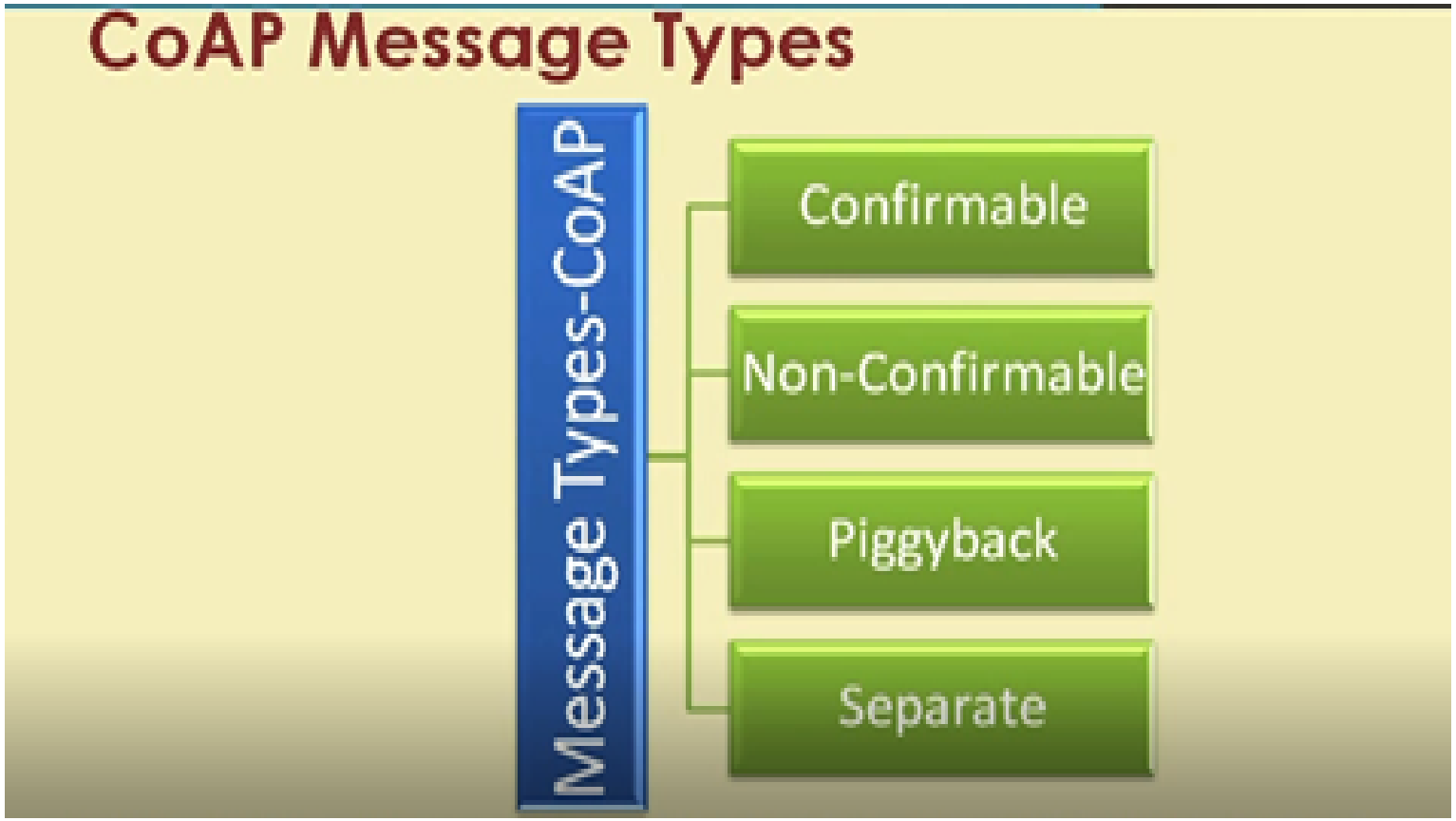
- ✓ CoAP – **Constrained Application Protocol**.
- ✓ **Web transfer protocol** for use with constrained nodes and networks.
- ✓ **Designed for Machine to Machine** (M2M) applications such as smart energy and building automation.
- ✓ Based on **Request-Response model** between end-points
- ✓ Client-Server interaction is **asynchronous over a datagram oriented transport protocol** such as UDP

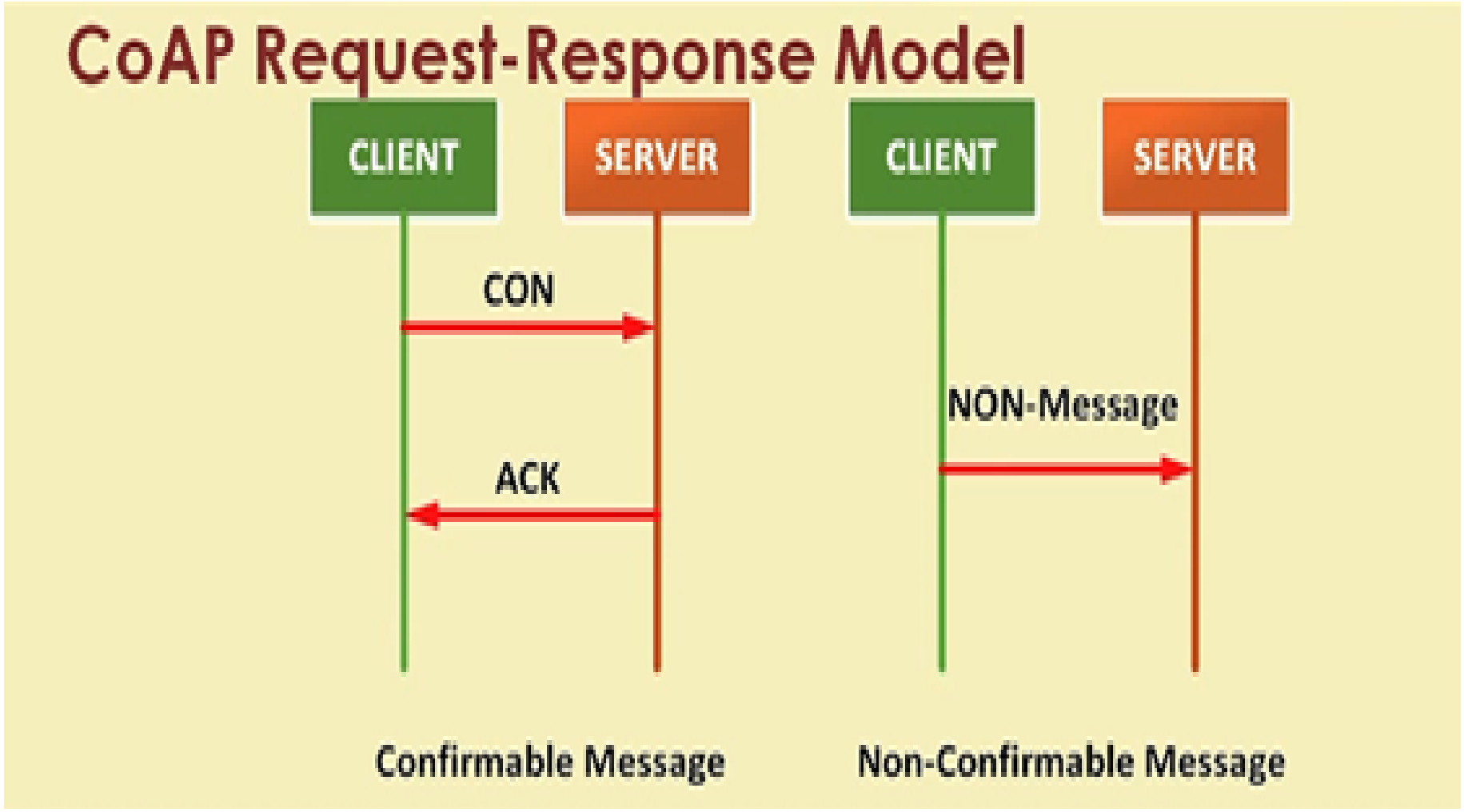
- ✓ The Constrained Application Protocol (CoAP) is a session layer protocol designed by IETF Constrained RESTful Environment (CoRE) working group to provide lightweight RESTful (HTTP) interface.
- ✓ Representational State Transfer (REST) is the standard interface between HTTP client and servers.
- ✓ Lightweight applications such as those in IoT, could result in significant overhead and power consumption by REST.
- ✓ CoAP is designed to enable low-power sensors to use RESTful services while meeting their power constraints.

- ✓ Built over UDP, instead of TCP (which is commonly used with HTTP) and has a light mechanism to provide reliability.
- ✓ CoAP architecture is divided into two main sub-layers:
  - Messaging
  - Request/response.
- ✓ The messaging sub-layer is responsible for reliability and duplication of messages, while the request/response sub-layer is responsible for communication.
- ✓ CoAP has four messaging modes:
  - Confirmable
  - Non-confirmable
  - Piggyback
  - Separate

CoAP Position

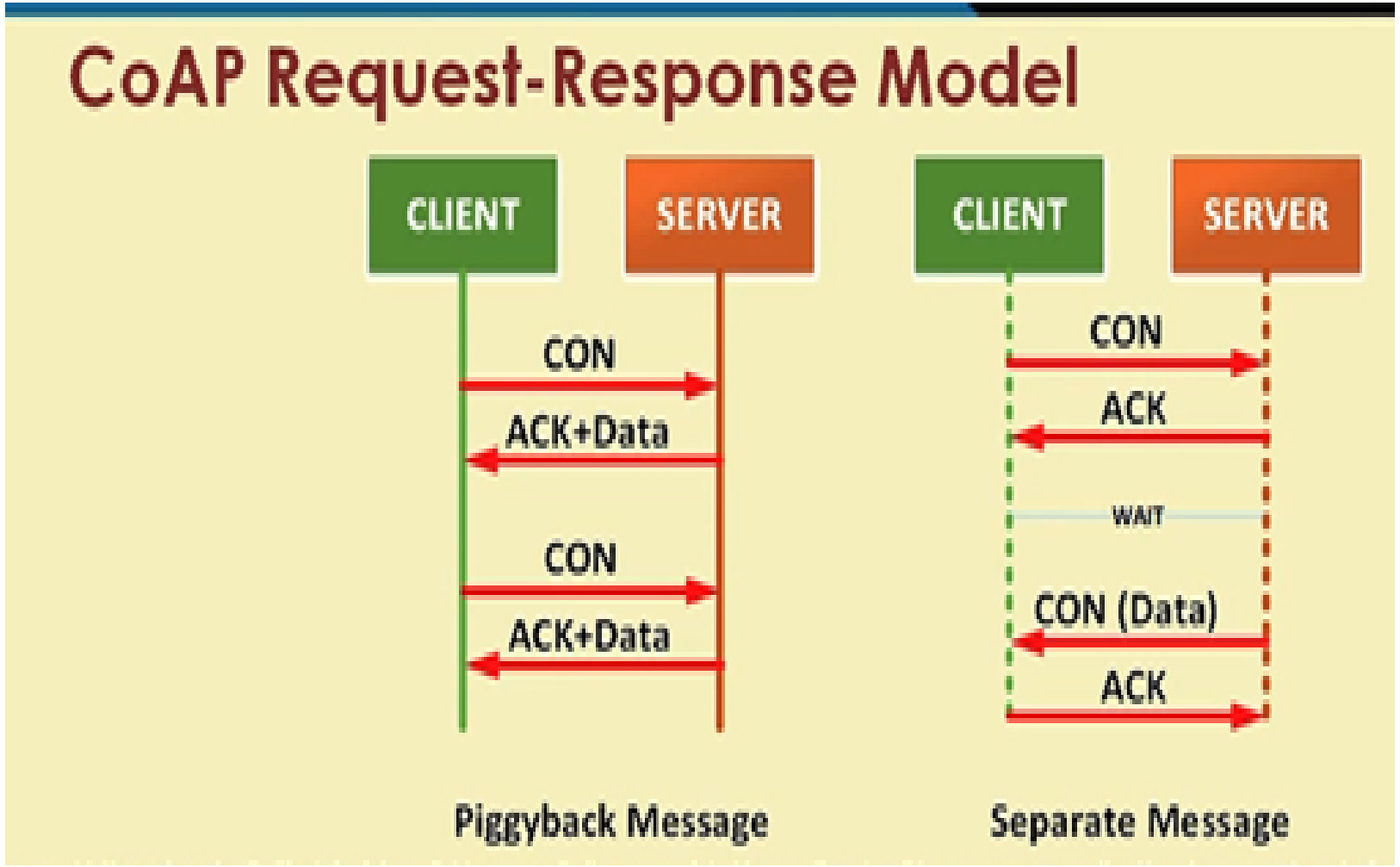



CoAP Message Types
Message Types-CoAP
Confirmable
Non-Confirmable
Piggyback
Separate


CoAP Request-Response Model
CLIENT
SERVER
CON
ACK
Confirmable Message
CLIENT
SERVER
NON-Message
Non-Confirmable Message

- ✓ Confirmable and non-confirmable modes represent the reliable and unreliable transmissions, respectively, while the other modes are used for request/response.
- ✓ Piggyback is used for client/server direct communication where the server sends its response directly after receiving the message, i.e., within the acknowledgment message.
- ✓ On the other hand, the separate mode is used when the server response comes in a message separate from the acknowledgment, and may take some time to be sent by the server.
- ✓ Similar to HTTP, CoAP utilizes GET, PUT, PUSH, DELETE messages requests to retrieve, create, update, and delete, respectively

CoAP Request-Response Model



Features

- ✓ Reduced overheads and parsing complexity.
- ✓ URL and content-type support.
- ✓ Support for the discovery of resources provided by known CoAP services.
- ✓ Simple subscription for a resource, and resulting push notifications.
- ✓ Simple caching based on maximum message age.

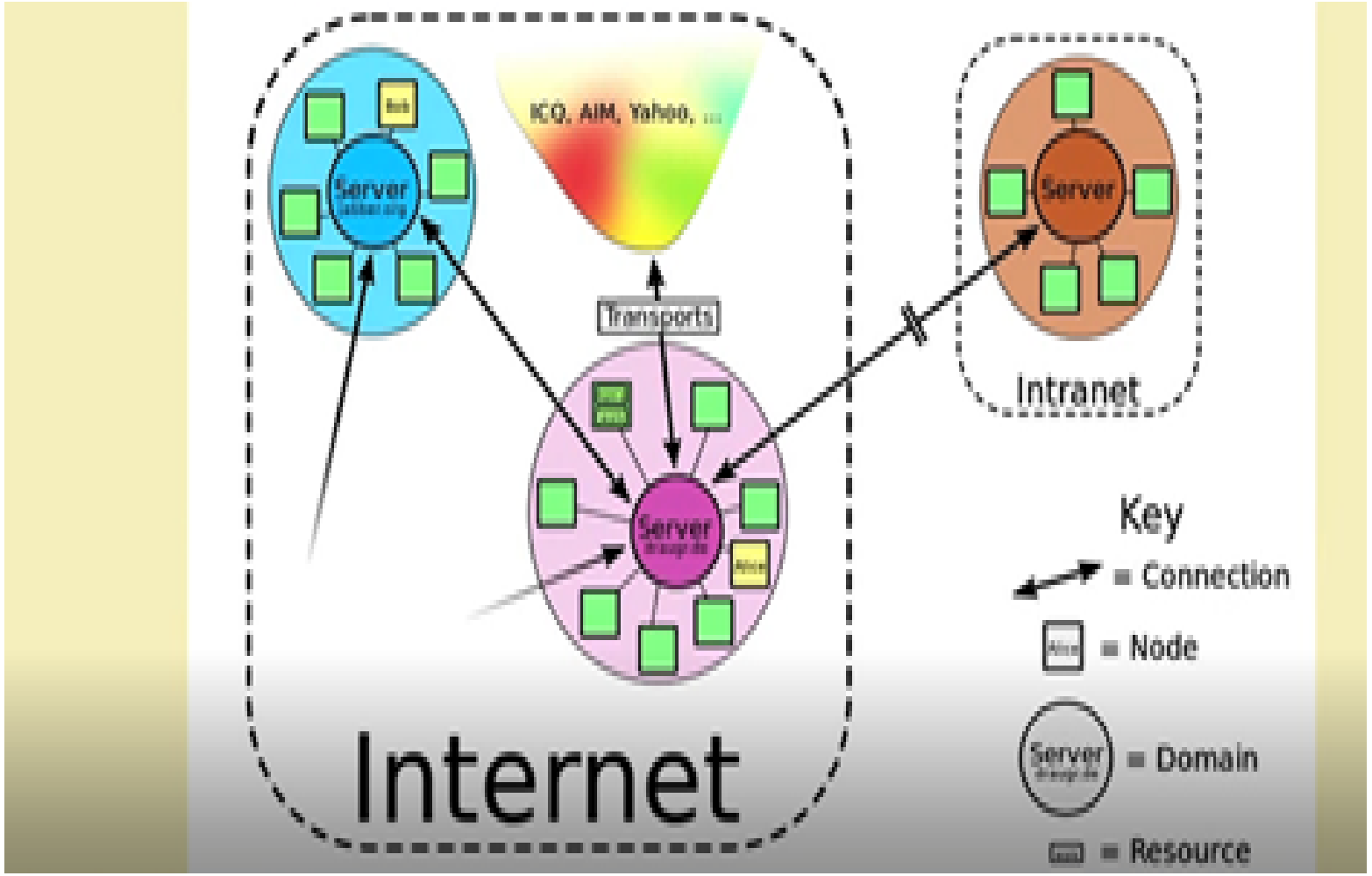
Introduction

- ✓ **XMPP – Extensible Messaging and Presence Protocol.**
- ✓ A communication protocol for **message-oriented middleware** based on XML (Extensible Markup Language).
- ✓ Real-time exchange of structured data.
- ✓ It is an open standard protocol.

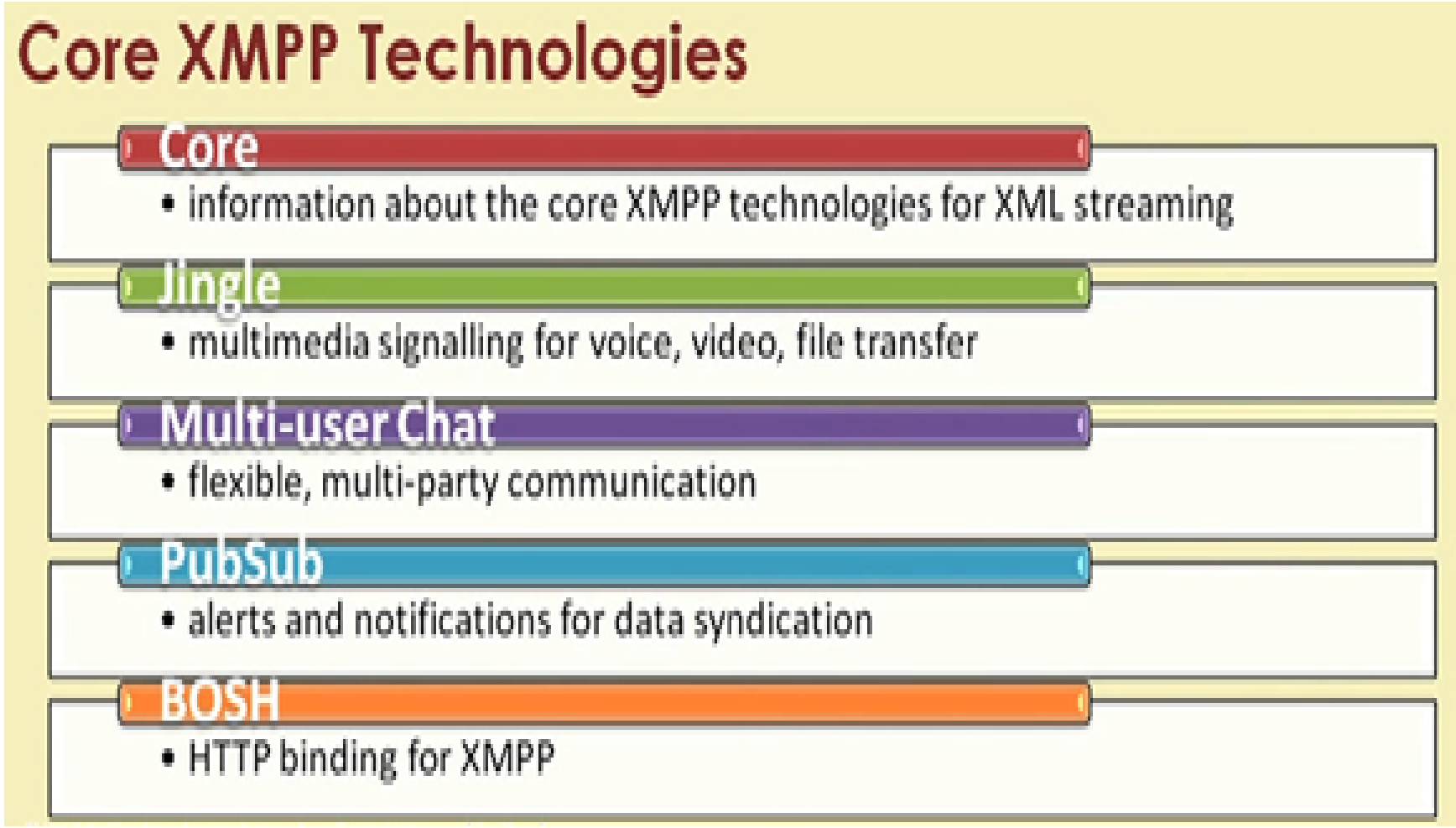
- ✓ XMPP uses a **client-server architecture**.
- ✓ As the model is **decentralized**, no central server is required.
- ✓ XMPP provides for the **discovery of services** residing locally or across a network, and the **availability information** of these services.
- ✓ Well-suited for cloud computing where virtual machines, networks, and firewalls would otherwise present obstacles to alternative service discovery and presence-based solutions.
- ✓ Open means to support machine-to-machine or peer-to-peer communications across a diverse set of networks.

Highlights

- ✓ Decentralization – No central server; anyone can run their own XMPP server.
- ✓ Open standards – No royalties or granted permissions are required to implement these specifications
- ✓ Security – Authentication, encryption, etc.
- ✓ Flexibility – Supports interoperability


ICQ, AIM, Yahoo, ...
Server
Transports
Server
Intranet
Server
Internet
Key
= Connection
= Node
Server
= Domain
= Resource

Core XMPP Technologies



Weaknesses

- ✓ Does not support QoS.
- ✓ Text based communications induces higher network overheads.
- ✓ Binary data must be first encoded to base64 before transmission.

Asset Management

- Real Time information
- Decrease Human Involvement
- Asset Optimization
- Asset & Cost Tracking
- Enhanced Monitoring Maintenance
- Security

IoT Telemetry:

- Monitoring data from space crafts
- Animal Tracking devices
- Heart Monitors
- Wearables

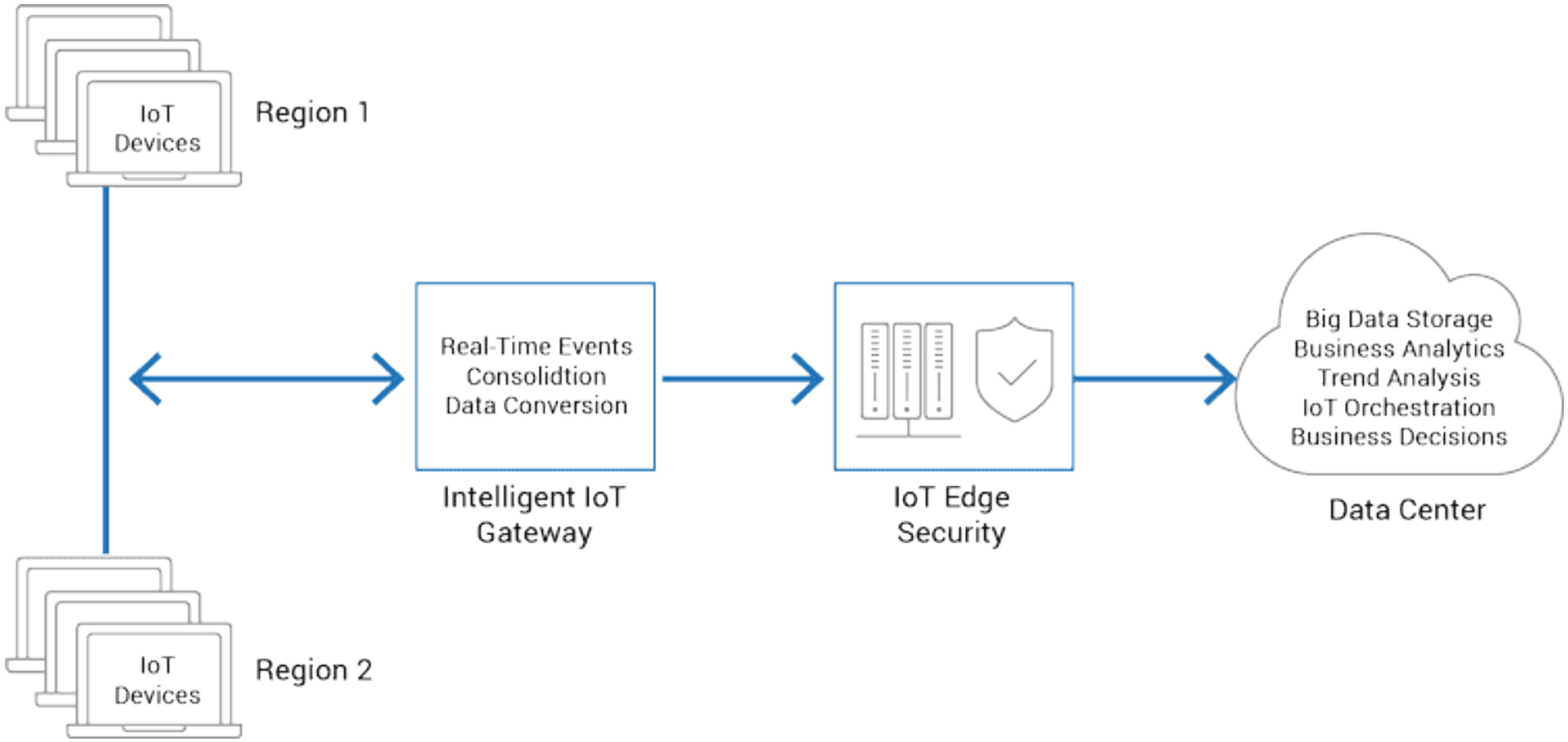
Topics to be covered

- Telemetry
- IoT Telemetry Protocols
- Logistics
- Cellular IoT
- IoT Verticals

Telemetry

Data collected by the device is called *telemetry*. This is the eyes-and-ears data that IoT devices provide to applications. Telemetry is read-only data about the environment, usually collected through sensors.

IoT Telemetry Architecture:



IoT Telemetry Protocols

- MQTT
- SMQTT
- CoAP

Logistics

- Goals for IoT technology for the Logistics Industry
- How the IoT is improving the transportation industry
- IoT logistics use cases

Goals for IoT technology for the Logistics Industry:

1. Improved Security & Theft Detection
2. Higher Employee Safety
3. End-to-end product tracking
4. Providing Business managers with advance analytics
5. Improving Delivery

How the IoT is improving the transportation industry:

1.Reliable Vehicle Tracking

2.Reducing shipping cost

3.Improve Supply chain planning

4.Employee Monitoring

5.Preventing product theft and monitoring transportation conditions

IoT logistics Applications:

1.Inventory Tracking System

2.Predictive Analytics System

3.Location Management Tools

4.Drone Based Delivery

5.Automated vehicles

Cellular IoT:

Cellular IoT is a way of connecting physical things (like sensors) to the internet by having them piggyback on the same mobile networks as smartphones.

Two key form of Cellular IoT:

- LTE-M
- NB-IoT

IoT Verticals:

- Smart Systems
- Smart Buildings
- Industrial IoT
- Transportation & Logistics
- Smart Agriculture
- Smart Home
- Smart Cities
- Connected Healthcare

1. Smart System

- Integrate
- Automate
- Communicate
- Mobile first

2. Smart Building

- Energy Efficiency
- Environmental Friendly
- Operational Efficiency
- Improved Security

3. Industrial IoT

- Minimize Human Error
- Ease of Adoption
- Lower Production Costs
- Make Better Decisions
- Optimize Performance
- Reporting

4. Transportation & Logistics

- End to end visibility
- Data from different sources
- Planning
- Reporting
- Cost Optimization
- Service improvement
- Real time traceability

5. Smart Agriculture

- Complete Visualizations of Operations
- Make Better Decisions
- Find Correlations
- Reporting
- Events & Notifications
- Lower Cost

6. Smart Homes

- Increase Security
- Energy Conservation
- Automation
- Home Assistance
- E-Health
- Remote Monitoring

7. Smart Cities

- Remote Monitoring
- Optimize Urban Development
- Engage Citizen
- Smart Living
- Smart Citizen integration

8. Connected Healthcare

- Aggregate data from disparate source & systems
- Enable real time insights into patient critical care metrics for doctors
- Full system transparency

Topics to be covered

- IoT Application Development
- IoT Connectivity
- IoT Software Providers

IoT Application Development

IoT application development is the process of building IoT apps or software which combine sensor data with machine learning technologies and predictive analytics to create smart and proactive user experiences.

Sub Topics:

- **Five main principles that must be taken into account by IoT developers before creating an application.**
- **Developing an Internet of Things-based application: 4 consecutive stages**
- **The top 5 tools to build an Internet of Things application**
- **The Five fastest-growing areas for Internet of Things applications**

Five main principles that must be taken into account by IoT developers before creating an application:

1. Ensure the safe collection of data.
2. Organize high-performance data streaming.
3. Create an Internet of Things platform.
4. Develop an Internet of Things solution in the cloud.
5. Provide for effective data management.

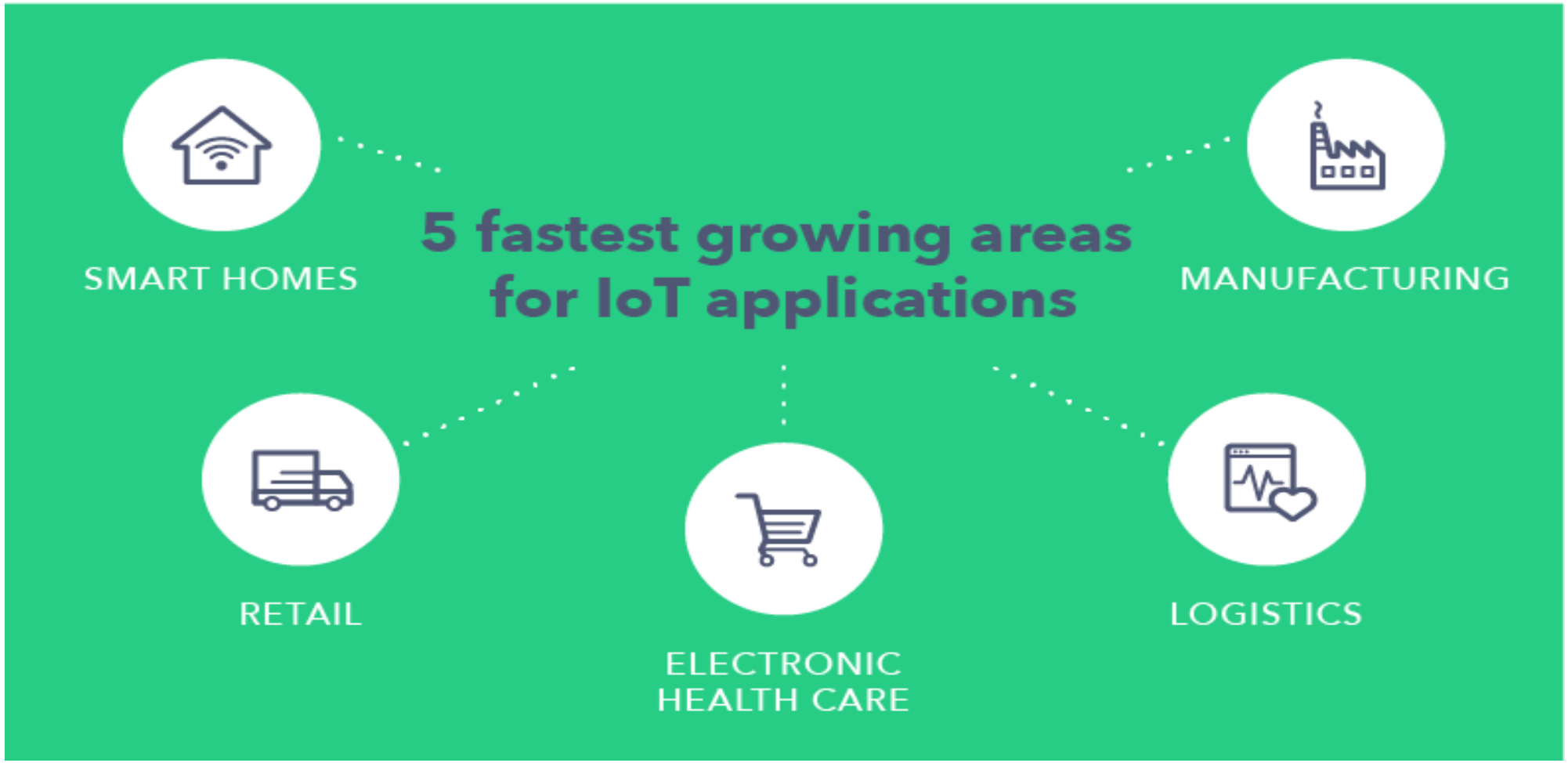
Developing an Internet of Things-based application: 4 consecutive stages

- Select centralized data storage
- Develop the server-side of data-handling algorithms
- Create a front-end.
- Development from scratch

The top 5 tools to build an Internet of Things application

- Azure IoT Suite: Azure IoT Hub, Azure stream analytics, Azure storage, Azure CosMos DB, Azure Web Apps.
- Amazon Web Services
- IBM Watson
- Oracle IoT
- KAA IoT

The Five fastest-growing areas for Internet of Things applications:



IoT Connectivity

IoT connectivity is a term defining connection between all the points in the IoT ecosystem, such as sensors, gateways, routers, applications, platforms and other systems. It usually refers to different types of network solutions based on their power consumption, range and bandwidth consumption. IoT projects vary in their requirements and many of them use different connectivity options depending on their needs.

IoT Connectivity :

- **Why is the selection of the right IoT connectivity option so important?**
- **Which communication option is the best for your IoT project?**

IoT Connectivity:

- Cellular IoT
- Satellite
- WiFi
- Bluetooth
- Ethernet
- LPWAN

IoT Software Providers:

- Vates: Famous due to Prototype.
- Science Soft: Provides IoT consulting, IoT development & Integration, IoT analytics, IoT managed services, IoT application Support.
- Oxagile: Provides a full range of services including IoT consulting, Software development, Hardware prototyping, Integration, and Continuous enhancement.
- R-Style Lab: provide services for Mobile Applications, Web front-end reporting & analytics, Middleware & Low-level, and backend infrastructure & integration.
- HQ Software
- PTC: Provides products for CAD, Industrial IoT etc.
- CISCO: Provides the solutions of IoT Networking, IoT Gateways, IoT Operations Management, IoT Data Management, and IoT Security.

IoT Software Providers:

- ARM: Provides a Device-to-Data Platform for connectivity management, device management, and data management.
- Huawei: Provides smart water solutions, Smart Meter Reading, Smoke Detection Smart Building, Smart Factory, Elevators, Smart Parking, Smart Gas, etc.
- GE Digital: Provides its products and services to industries like food and beverage, automotive, chemicals, steel manufacturing, semiconductor, pulp & paper manufacturing, water or wastewater, etc.
- BOSCH IoT Sensor Company: Provides the IoT Suite for connecting and managing devices, sensors, and gateways
- SAP
- Seimens IoT Analytics Company: Provides an intelligent gateway
- IBM: Provides the IoT solutions of IoT Platform, Watson IoT, Enterprise Asset Management, Facilities Management, and Systems Engineering

UNIT-IV

PART-I
Topics to be covered

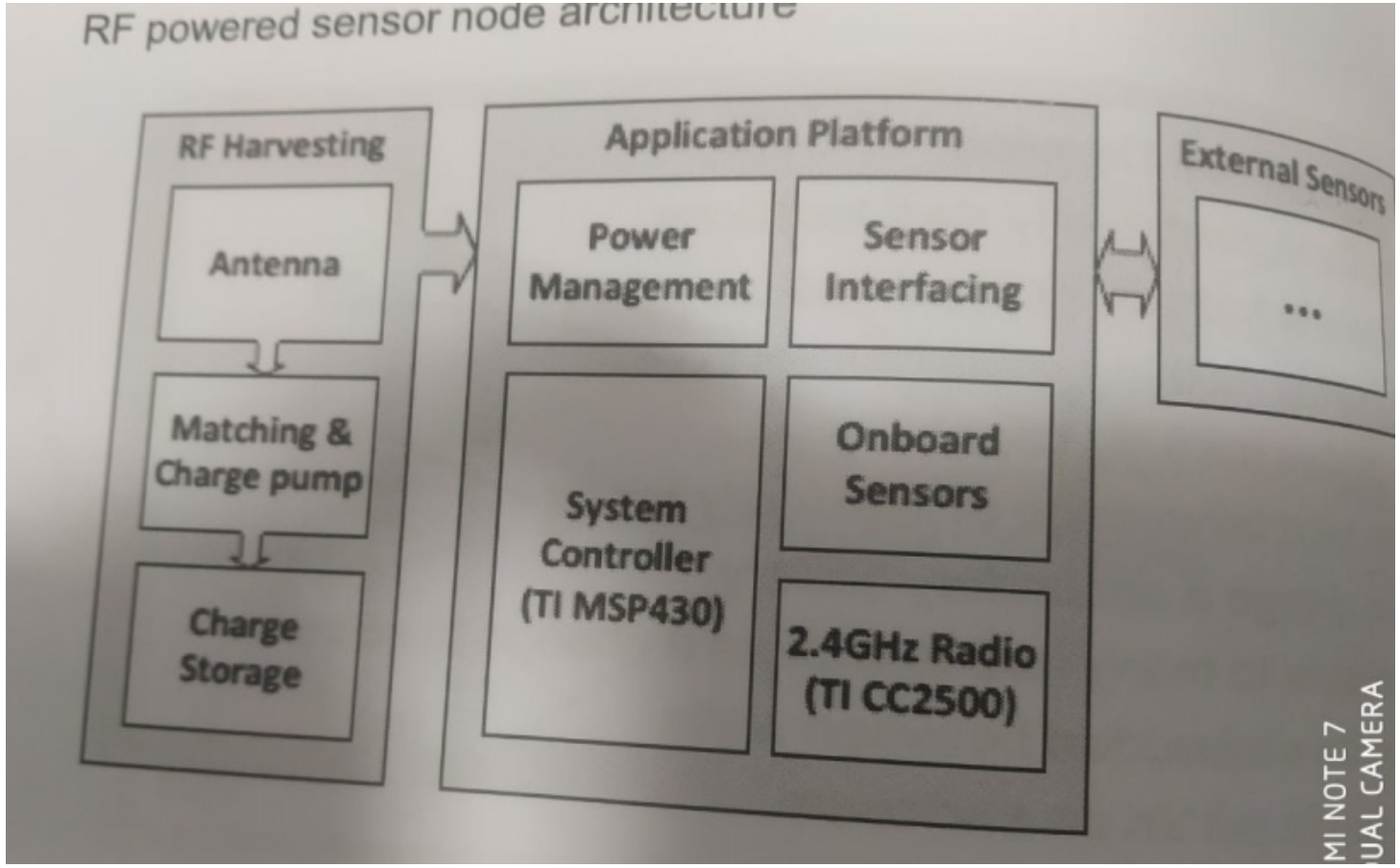
- Study of RF Wireless Sensors
- Wireless Network

Study of RF wireless sensors

- Available On Demand
- Works in perpetually dark locations
- Works in hazardous locations
- Provides Mobility
- Provides Tracking capability
- Can charge a secondary battery

Study of RF wireless sensors cont..

RF powered sensor node architecture



Study of RF wireless sensors cont..

Different type of Sensors:

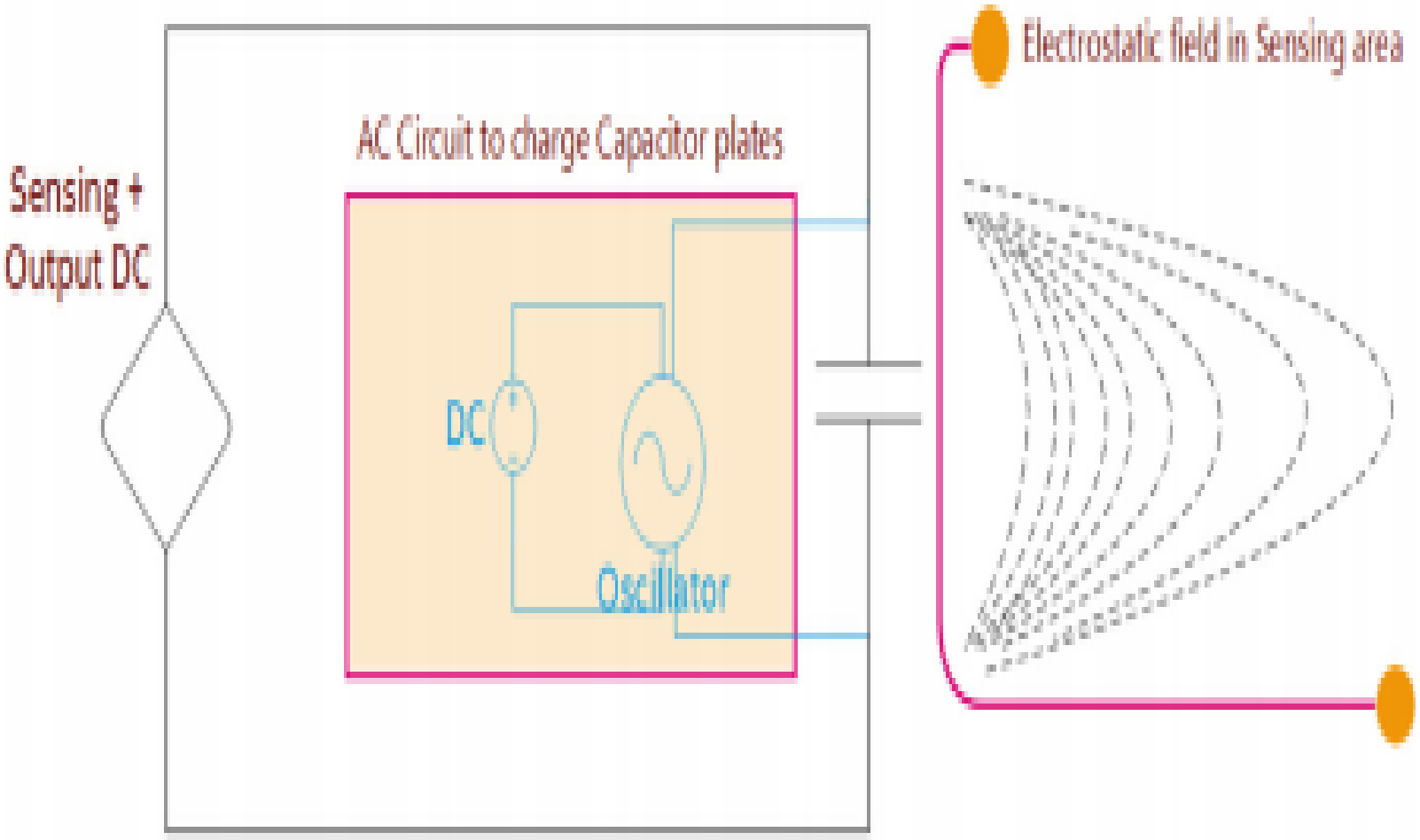
- Capacitive Sensors
- Current Sensors
- Gas & Chemical Sensors
- Hall Effect Sensors
- Humidity Sensors
- Inductive Sensors
- Optical Sensors
- Pressure Based Sensors
- Temperature Sensors
- Ultrasonic based sensors

Capacitive Sensors:

Capacitive proximity sensors are non-contact devices that can detect the presence or absence of virtually any object regardless of material. They utilize the electrical property of capacitance and the change of capacitance based on a change in the electrical field around the active face of the sensor.

Capacitive sensing technology is often used in other sensing technologies such as:

- Flow
- Pressure
- liquid level
- Spacing
- Thickness
- ice detection
- accelerometers


Sensing +
Output DC
AC Circuit to charge Capacitor plates
DC
Oscillator
Electrostatic field in Sensing area

Capacitive Sensors cont..

Capacitive sensor dimensional measurement requires three basic components:

- a probe
- driver electronics
- a device

Capacitive Sensors cont..

- Focusing the electric field
- Guarding
- Optimizing the Sensor
    a. Effects of target size
    b. Range of Measurement
    c. Multiple channel sensing
    d. Effects of target material

Capacitive Sensors cont..

Capacitive sensors can be very effective in measuring

- density,
- thickness, and
- location of nonconductors as well.

Capacitive Sensors Applications:

- Position Sensing
- Dynamic Motion
- Thickness Measurement

Basic Components of Capacitance Sensing Technology

- Driver-IC
- The Sensor
- Software

Current Sensor:

Current is fed to computers in which sensors convert it to proportional voltage.

- Direct Sensing
- Indirect Sensing

Current Sensor cont..

The current sensing resistor should have following attributes:

- Low value in order to minimize power losses
- Low inductance
- Tight tolerance
- Low temperature coefficient for accuracy
- High peak power rating to handle short duration high current pulses.

Gas and Chemical Sensors

Gas sensors (also known as **gas detectors**) are electronic devices that detect and identify different types of gasses. They are commonly used to detect toxic or explosive gasses and measure **gas** concentration.

Chemical sensors are measurement devices that convert a **chemical** or physical property of a specific analyte into a measurable signal, whose magnitude is normally proportional to the concentration of the analyte.

Hall Effect Sensors

A Hall-effect sensor is a device to measure the magnitude of a magnetic field. Its output voltage is directly proportional to the magnetic field strength through it. Hall-effect sensors are used for proximity sensing, positioning, speed detection, and current sensing applications.

Humidity Sensors

A **humidity sensor** is a device that detects and measures water vapor. ... Based on our robust capacitive technology, these **humidity sensors** provide accurate measurement of dew point and absolute **humidity** by combining relative **humidity** (RH) and temperature (T) measurements.

Inductive Sensors

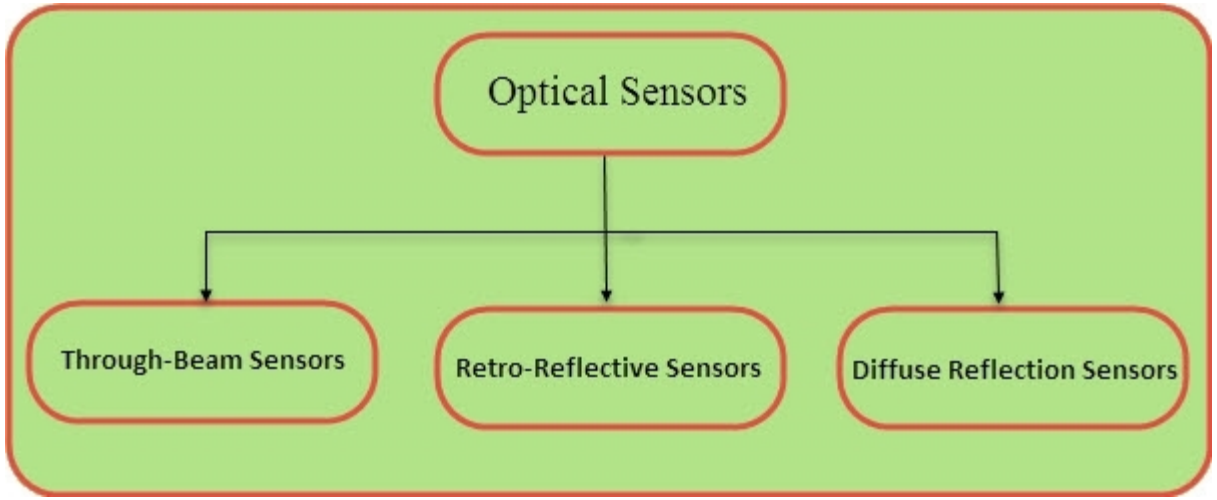
An **inductive sensor** is a device that uses the principle of electromagnetic **induction** to detect or measure objects. An inductor develops a magnetic field when a current flows through it; alternatively, a current will flow through a circuit containing an inductor when the magnetic field through it changes.

Shielded and Un-shielded Sensors

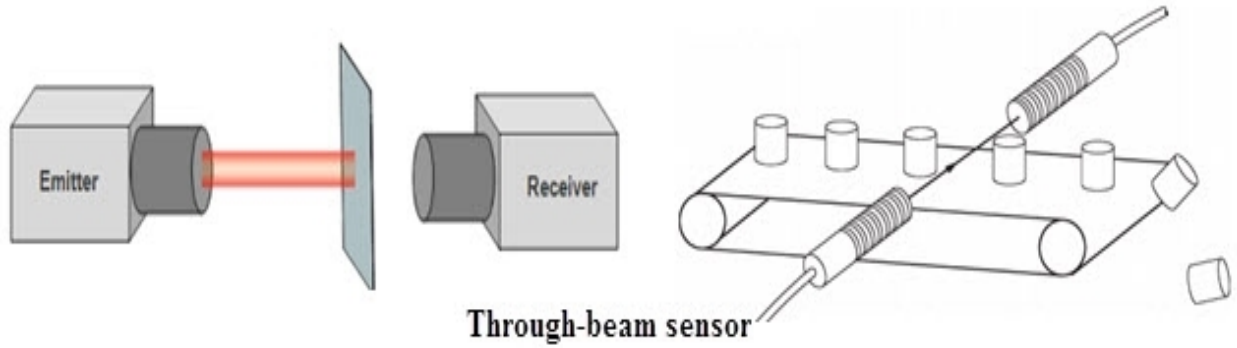
Optical Sensors

An **optical sensor** converts light rays into electronic signals. It measures the physical quantity of light and then translates it into a form that is readable by an instrument. An **optical sensor** is generally part of a larger system that integrates a source of light, a measuring device and the **optical sensor**.

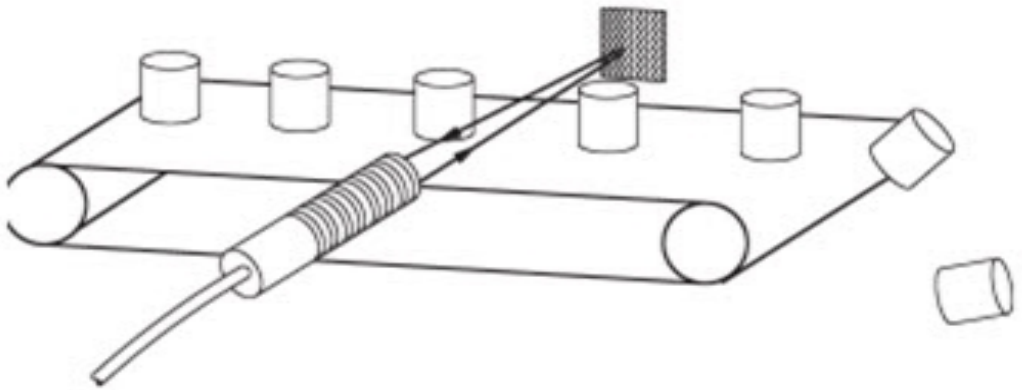
Types of Optical Sensors:



Optical Sensors

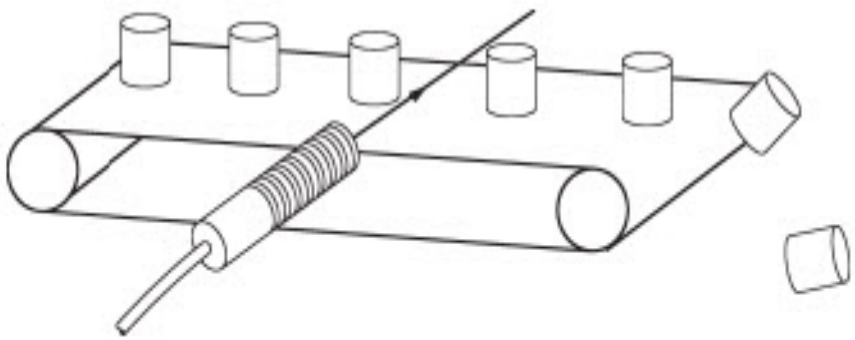


Through-beam sensor

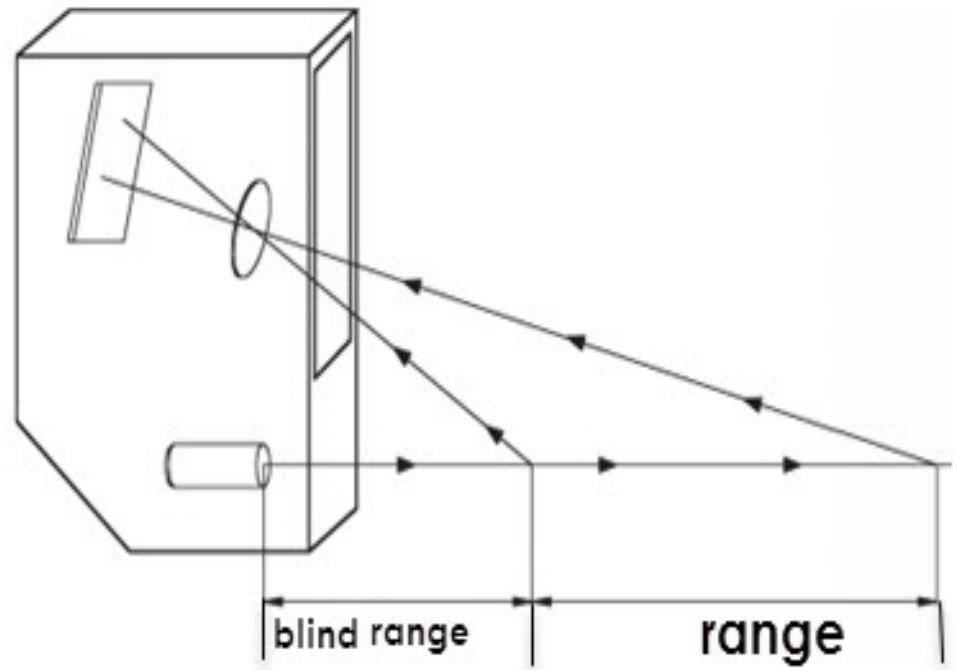


Retro-Reflective Sensors

Optical Sensors



Diffuse Reflection Sensor



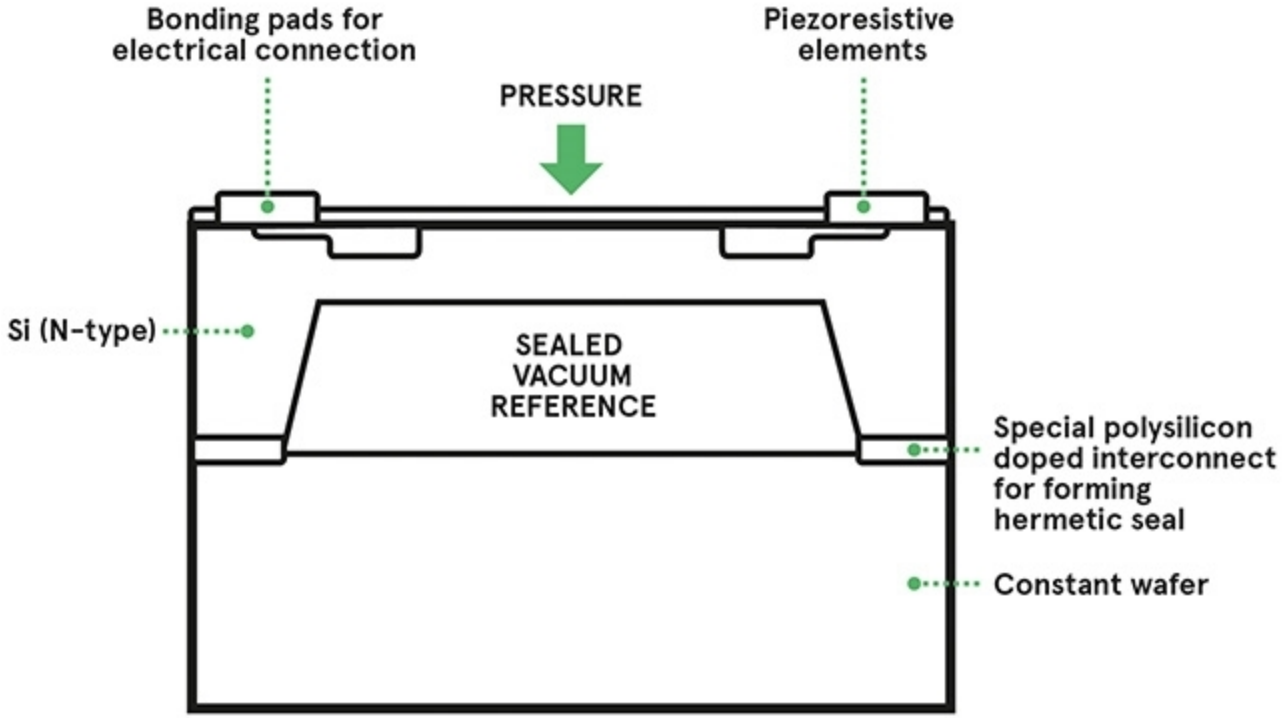
Pressure Sensors

A pressure sensor is a device for pressure measurement of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed.

Type of Pressure Measurement

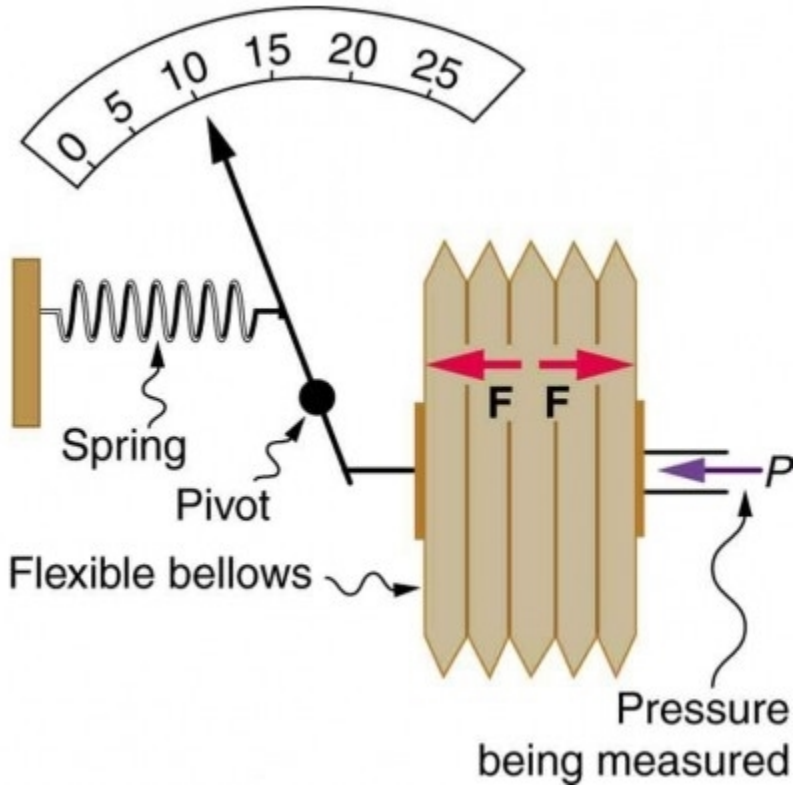
- Absolute
- Gauge
- Differential

Pressure Sensors



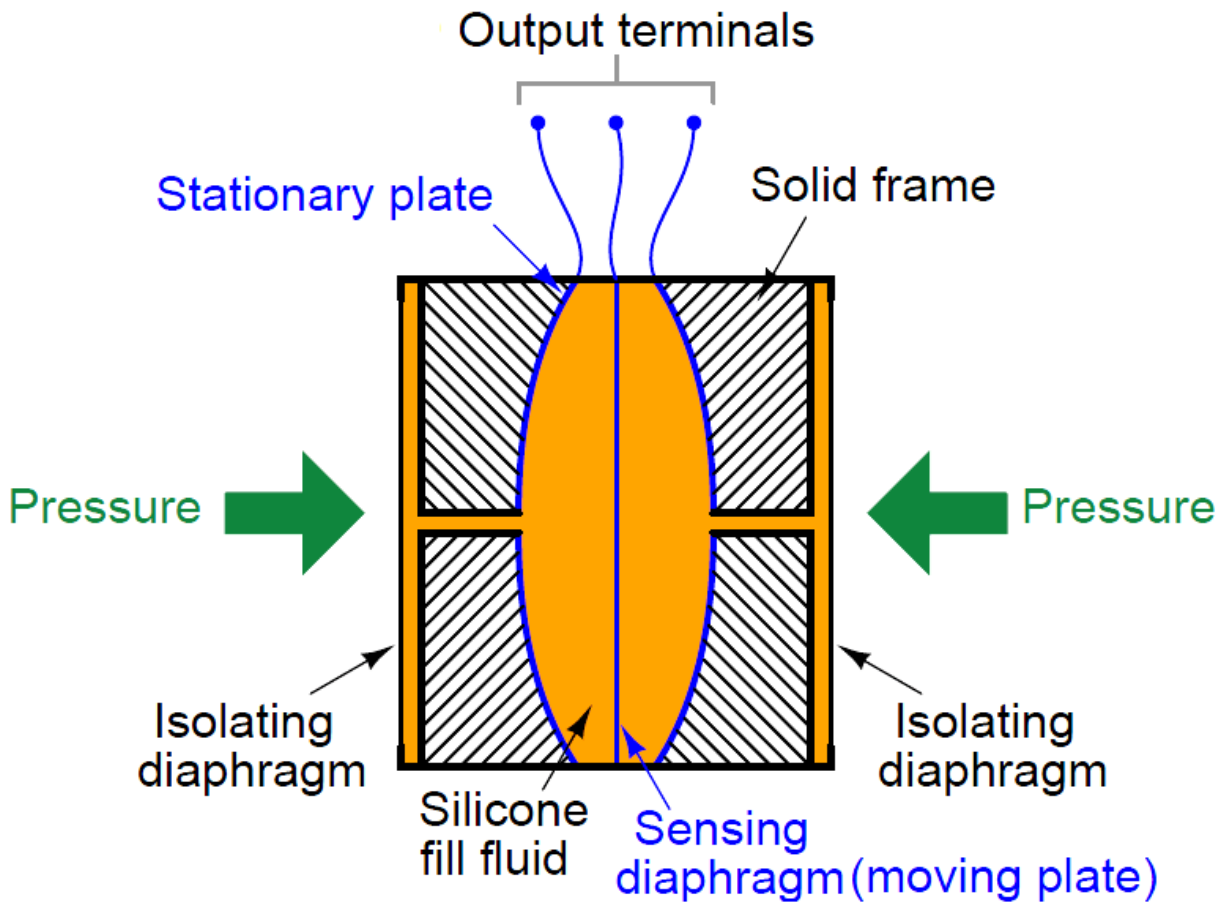
Absolute

Pressure Sensors



Gauge

Pressure Sensors



Differential

Temperature Sensors

A **temperature sensor** is an electronic device that measures the **temperature** of its environment and converts the input data into electronic data to record, monitor, or signal **temperature** changes. There are many different types of **temperature sensors**.

Ultrasonic Sensors

An **ultrasonic sensor** is an electronic device that measures the distance of a target object by emitting **ultrasonic** sound waves, and converts the reflected sound into an electrical signal. **Ultrasonic** waves travel faster than the speed of audible sound (i.e. the sound that humans can hear).

Wireless Networks and its types:

Computer **networks** that are not connected by cables are called **wireless networks**. They generally use radio waves for communication between the **network** nodes. They allow devices to be connected to the **network** while roaming around within the **network** coverage.

Types:

1. Bluetooth and BLE
2. Zigbee Protocols
3. Wi-Fi
4. Satellite Communication
5. RFID

1. Bluetooth and BLE

Attacks In Bluetooth enable devices:

- BLUEJACKING
- BLUEBUG Attack
- Car Whisperer
- SNARF Attack
- BACKDOOR Attack

2. Zigbee Protocols

Zigbee specifications:

- Zigbee PRO
- Zigbee RF4CE
- Zigbee IP

3. Wi-Fi

- Wired Equivalent Privacy (WEP)
- Wi-Fi Protected Access (WPA)
- Wi-Fi Protected Access version 2 (WPA2)

4. **Satellite Communication**

- **LEO, GEO, and ATG Satellites**

5. RFID

Radio Frequency Identification (RFID) uses radio waves to transmit small amounts of data from an RFID tag to a reader within a very short distance.

Computer Connect to Internet

- **Network Devices**
- **Hubs**
- **Switches**
- **Routers**
- **Gateways**
- **Firewalls**

- **Device Configuration and Management Hubs**
  - M2M device management
- **Exchange Information without Human Intervention Routers**
  - Quicker Processing and More accurate Delivery

UNIT-V

PART-I
Topics to be covered

- IoT Requirement
- Hardware and software Design
- Tagging and Tracking
- SIM and USIM CARD

IoT Requirement

- General Requirement and control Access Requirement
- Security Requirements
- Architecture Requirements
- IoT Functional Requirements

General Requirement and control Access Requirement

1. IoT Application communication principles
2. Message Delivery for sleeping devices
3. Delivery Modes
4. Message Transmission scheduling
5. Message Communication path selection
6. Communication with devices behind an IoT gateway
7. Communication Failure notification
8. Scalability

Security Requirements

- IoT service capabilities discovery and registration
- IoT trusted application
- Mobility
- Communications integrity
- Device/Gateway integrity check
- Continuous connectivity
- Confirm
- Priority
- Logging

Architecture Requirement:

- Anonymity
- Time Stamp
- Device/Gateway Failure robustness
- Radio transmission activity indication and control
- Operator telco capabilities exposure
- Location reporting support
- Support of multiple IoT applications

IoT Functional Requirements:

- Data Collection and Reporting
- Remote control of IoT devices
- Group Mechanisms
- Quality of Services
- IoT devices/gateway types variety
- Information reception
- Reachability
- Asymmetric Flows
- Path diversity
- Heterogeneous IoT area network
- Information collection and delivery to a multiple applications
- Management of multiple IoT devices

Hardware and Software Design

- Power Source
- Embedded Processor
- Sensors
- Enclosure

Tagging and Tracking

RFID

- Main components of RFID System

❑Antenna

❑Tags

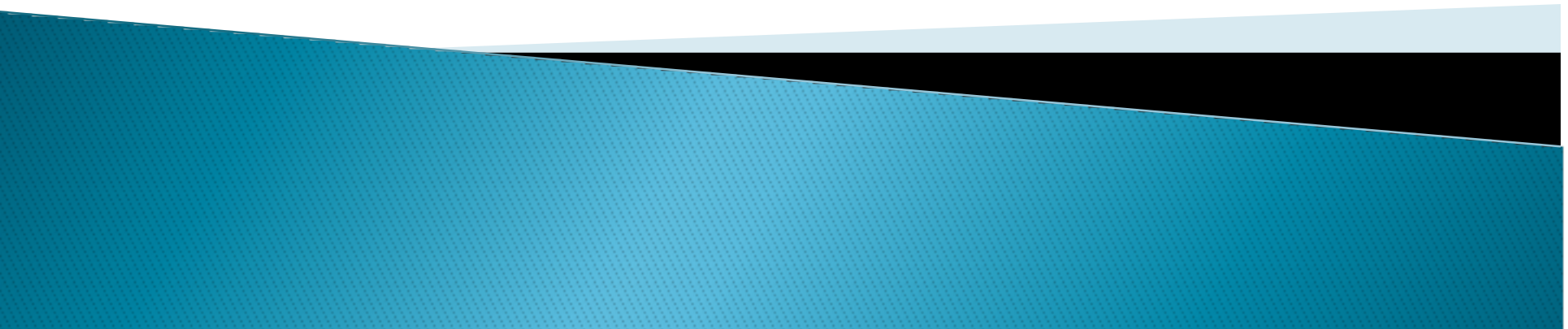
❑Form Factor

❑Frequencies

SIM and USIM CARD

- IoT connectivity & Management
- IoT Security and IoT Communication

Unit–VI



- WSN
- Cellular M2M
- Software for IoT Applications
- Hardware

Sensing and Sensors

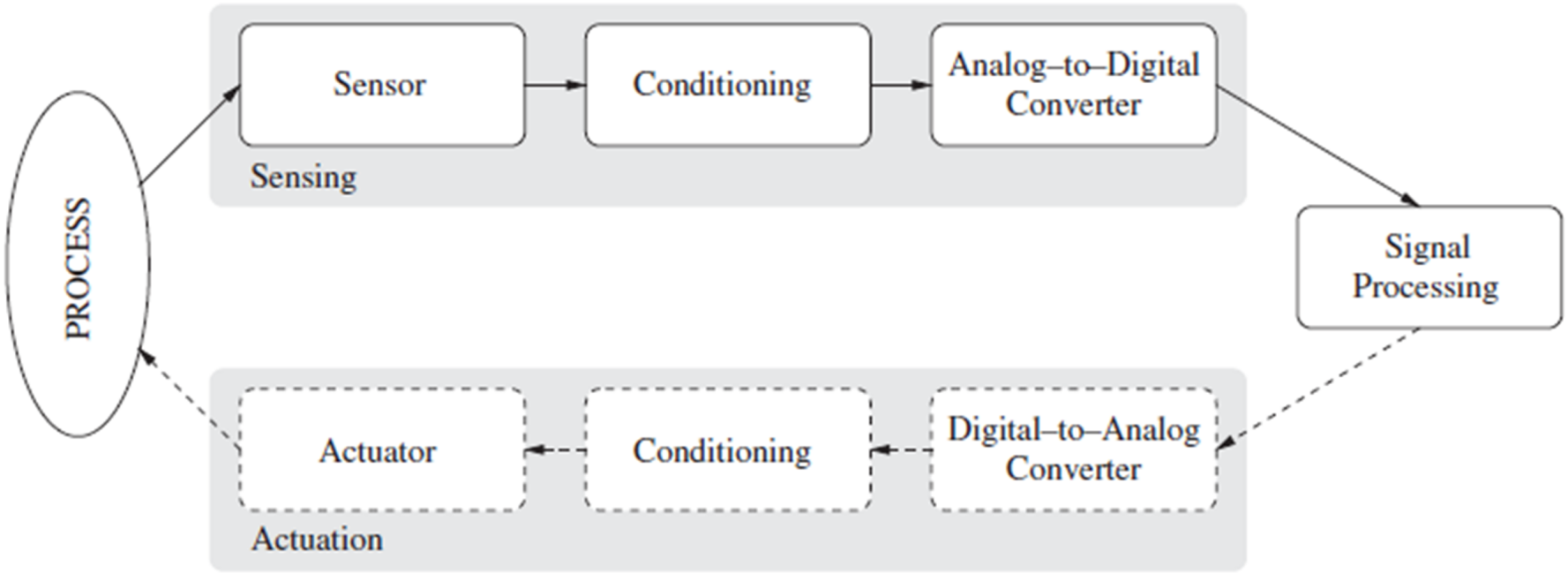
- *Sensing* is a technique used to gather information about a physical object or process, including the occurrence of events
- An object performing such a sensing task is called a *sensor*
- A sensor, then, is a type of transducer that converts energy in the physical world into electrical energy that can be passed to a computing system or controller.

Sensing and Sensors

An example of the steps performed in a sensing (or data acquisition) task

- Phenomena in the physical world are observed by a sensor device
- The resulting electrical signals are passed through a signal conditioning stage (tasks like amplification/attenuation/noise removal)
- Analog signal is transformed into a digital signal using an analog-to-digital converter (ADC)
- Signal is ready for further processing/ visualization/ storage
- Many wireless sensor networks also include actuators which allow them to directly control the physical world

Sensing and Sensors



Data Acquisition and actuation

Sensing and Sensors

- Sensor types
  - If the sensors require external power, they are referred to as ***active* sensors**. That is, they must emit some kind of energy (e.g., microwaves, light, sound) to trigger a response or to detect a change in the energy of the transmitted signal.
  - ***passive* sensors** detect energy in the environment and derive their power from this energy input – for example, passive infrared (PIR) sensors measure infrared light radiating from objects in the proximity

Sensing and Sensors

- Sensor types

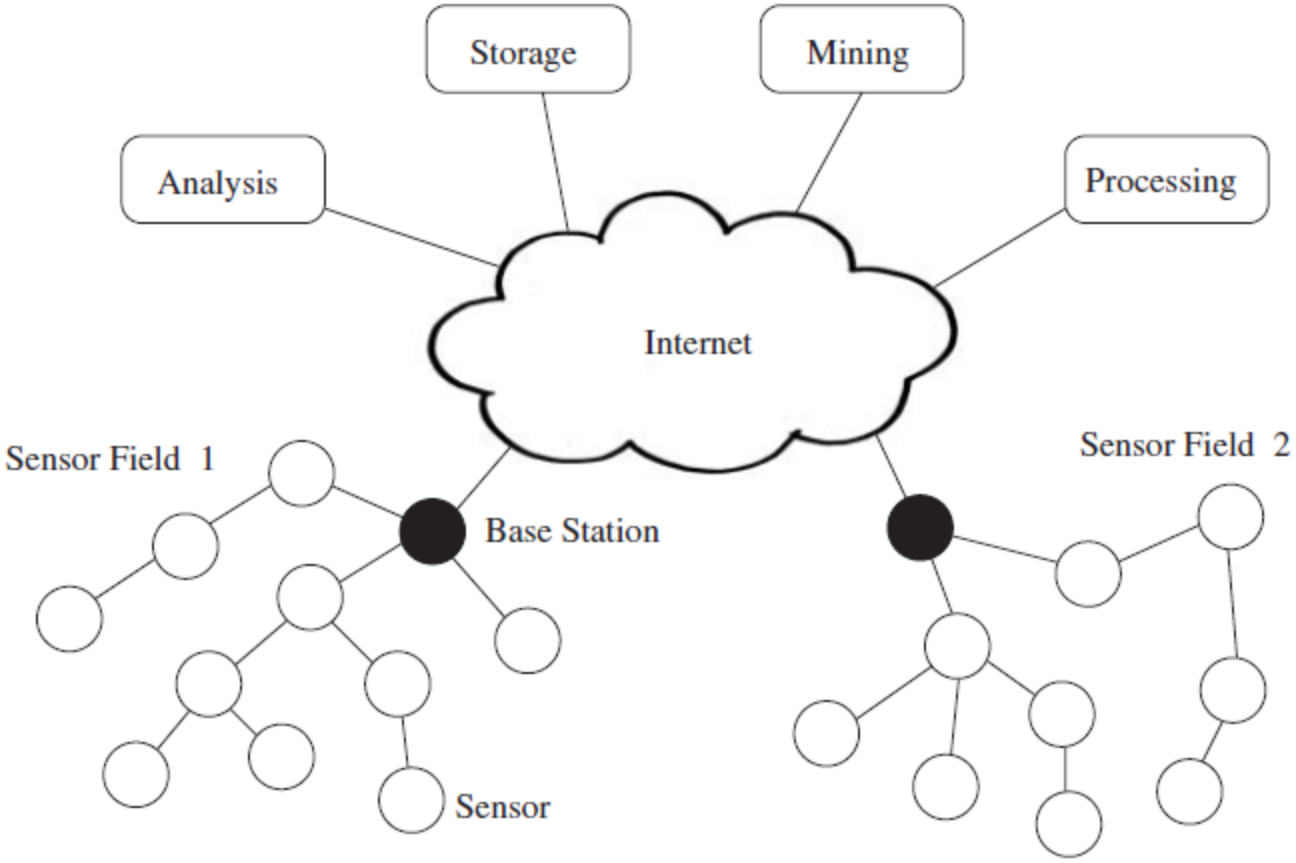
Type	Examples
Temperature	Thermistors, thermocouples
Pressure	Pressure gauges, barometers, ionization gauges
Optical	Photodiodes, phototransistors, infrared sensors, CCD sensors
Acoustic	Piezoelectric resonators, microphones
Mechanical	Strain gauges, tactile sensors, capacitive diaphragms, piezoresistive cells
Motion, vibration	Accelerometers, gyroscopes, photo sensors
Flow	Anemometers, mass air flow sensors
Position	GPS, ultrasound-based sensors, infrared-based sensors, inclinometers
Electromagnetic	Hall-effect sensors, magnetometers
Chemical	pH sensors, electrochemical sensors, infrared gas sensors
Humidity	Capacitive and resistive sensors, hygrometers, MEMS-based humidity sensors
Radiation	Ionization detectors, Geiger–Mueller counters

Wireless Sensor Networks

- When many sensors cooperatively monitor large physical environments, they form a *wireless sensor network* (WSN)

- Sensor nodes communicate not only with each other but also with a *base station* (BS) using their wireless radios, allowing them to disseminate their sensor data to remote processing, visualization, analysis, and storage systems

Wireless Sensor Networks

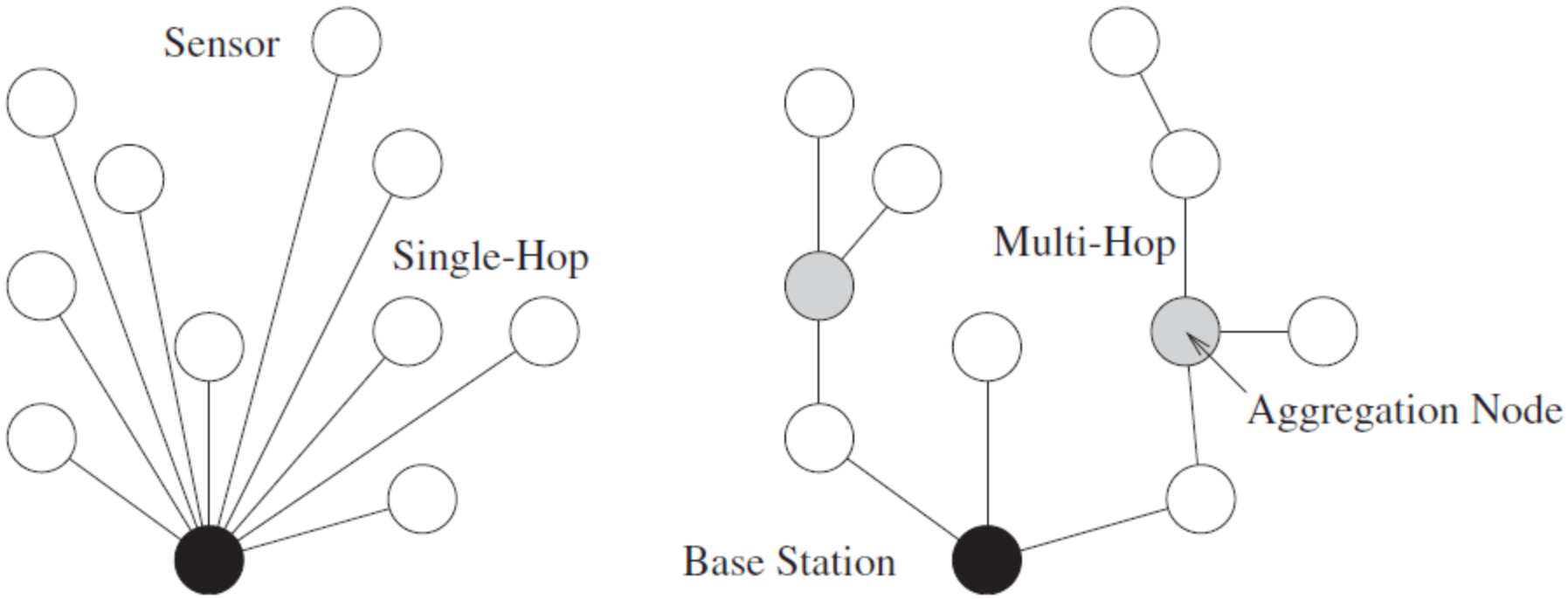


An example WSN with two sensor fields and their respective base stations

Wireless Sensor Networks

- IEEE 802.15.4 is the protocol specifically designed for low power consumption wireless networks and is supported by most of the commercial sensor nodes.
- When each node is within the range of the base station, it directly communicates with the base and forms a **single-hop star topology.**
- In case of large geographical coverage, communication is done via intermediate nodes forming **multi-hop mesh topology**
- In multi-hop topology, nodes must be capable of propagating sensor data towards base station.

Wireless Sensor Networks



Single-hop vs Multi-hop WSN

Challenges & Constraints

1. Energy

- Contention-based MAC strategies result in higher power consumption as the nodes may try multiple times to get access of the medium and may need to listen to the medium continuously
- Therefore Contention-free MAC strategies are preferred as they allow strictly regulated medium access and allow nodes to turn off their radios when no communication is expected

Challenges & Constraints

2. Wireless Networking

- a radio frequency (RF) signal fades

$$P_r \propto \frac{P_t}{d^2}$$

- Multi-hop networks
- Duty cycles further increases the problem

Challenges & Constraints

3. Self Management

- Ad-hoc deployment
  - ⓧ Deployment in predetermined locations is always not possible. Nodes have to determine their locations, search for available communicating nodes and work
- Unattended operation
  - ⓧ configuration, adaptation, maintenance, and repair must be performed in an autonomous fashion without human intervention

Challenges & Constraints

4. **Decentralized Management**
   - Due to large scale and energy constraints topology and routing management by base station is not feasible. Nodes have to collaborate with neighboring nodes and work through a non-optimal algorithms
5. **Design Constraints**
   - Cheaper
   - Small in size
   - Energy efficient
   - Wireless connectivity
6. **Security**
   - Unattended and wireless communication makes then susceptible to many security attacks i.e. Denial-of-service attacks

WSN Applications

- WSNs have many advantages over traditional networking techniques.

- They have an ever-increasing number of applications, such as infrastructure protection and security, surveillance, health-care, environment monitoring, intelligent transportation, and smart energy

WSN Applications

- The applications can be divided in three categories:
  1. Monitoring of objects.
  2. Monitoring of an area.
  3. Monitoring of both area and objects.

WSN Applications

- Monitoring Area
  - Environmental and Monitoring
  - Precision Agriculture
  - Indoor Climate Control
  - Military Surveillance
  - Intelligent Alarms

WSN Applications

- Example: Precision Agriculture
  - Precision agriculture aims at making agricultural operations more efficient, while reducing environmental impact and cost.
  - The information collected from sensors is used to evaluate optimum sowing density, estimate fertilizers and other inputs needs, and to more accurately predict crop yields.

WSN Applications

- Monitoring Objects
  - Structural Monitoring
  - Condition-based Maintenance
  - Medical Diagnostics
  - Urban terrain mapping

WSN Applications

- Monitoring Interactions between Objects and Space
  - Wildlife Habitats (Collar mounted sensors)
  - Disaster Management
  - Emergency Response
  - Asset Tracking
  - Health Care

WSN Applications

Example: Structural Health Monitoring

- Global and local inspection of structures
- Factors making WSN suitable for global inspection:
  - ⓧ can be placed in areas that are inaccessible
  - ⓧ By deploying a large number of nodes, it is possible to establish correlation between different measurements
  - ⓧ does not require disruption of the normal operation of the structure

WSN Applications

Example: Structural Health Monitoring

- Sensing seismic events
  - Challenges:
    - restrictions regarding the characteristics of the excitations
    - measurement noise
    - environmental constraints

WSN Applications

- Biomedical / Medical
  - Health Monitors
    - ⓧBlood pressure
    - ⓧOxygen saturation
    - ⓧHeart rate
  - Hospital Sensors
    - ⓧMonitor vital signs
    - ⓧRecord anomalies
    - ⓧMonitor patient movements

WSN Applications

- Numerous industrial and commercial applications:
  - Agricultural Crop Conditions
  - Inventory Tracking
  - In-Process Parts Tracking
  - Automated Problem Reporting
  - Theft Deterrent
  - Plant Equipment Maintenance Monitoring

WSN Applications

Example: Traffic Control

- These systems gather information about the density, sizes, and speed of vehicles on roads; detect congestions; and suggest to drivers some alternative routes and emergency exits
- Common methods used:
  - Video
  - sonar
  - Radar
  - Piezoelectric cables

WSN Applications

- Military
  - Enemy tracking, battlefield surveillance
  - Target detection
  - Monitoring, tracking and surveillance of borders
  - Nuclear, biological and chemical attack detection

WSN Applications

- Mobile Group Movement
  - Future military: attacking by sensor nodes
  - It needs coordination between nodes
  - Combination between AI (artificial intelligence), sensor technology and wireless communications
  - There is a goal for the nodes

Cellular M2M Application Networks

- Monitoring Sensing
- Communication Network
- Monitoring Software

Software for IoT applications

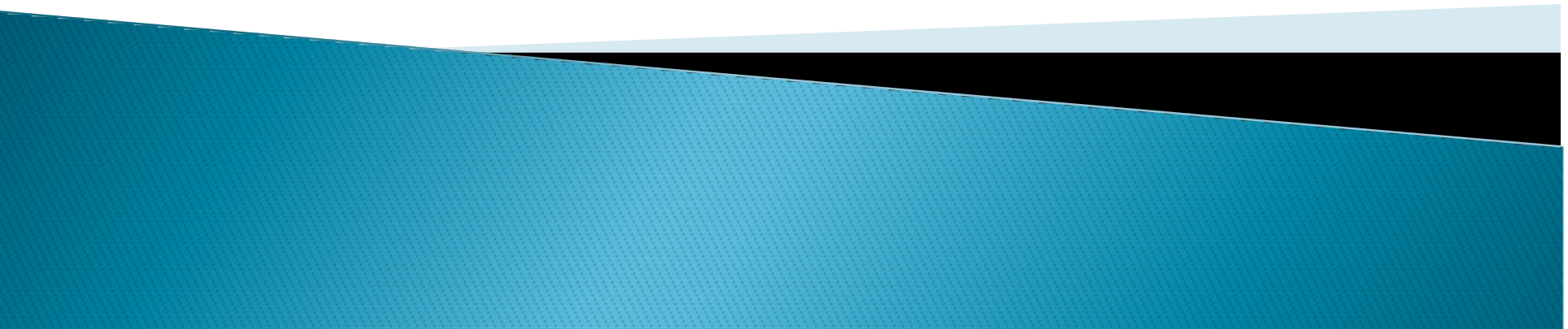
- Standardized End-to-end (E2E) Solution

1. Scalable Service Platform
2. Service Oriented Architecture
3. RESTful Architecture and so on.

Hardware

- Main Hard devices used in the M2M Network are
- Sensors
- Memory Processors
- Actuators
- RFID
- ADC/DAC
- Power Module
- Communication Module

Unit–VII



- Discuss Security & Trust IoT Communication
- Secure Communication
- IoT security framework

Discuss Security & Trust IoT Communication

All these below mentioned applications, have some common security requirements

- Traffic Cameras(WLAN)
- Metering
- Vending Machines(Stock level)
- Asset or Cargo Tracking

Discuss Security & Trust IoT Communication

Security threats for IoT

- Physical Attacks
- Compromise of Credentials(Brute Force Attack)
- Configuration Attacks
- Protocols attack on the device(Man-in-Middle)
- Attacks on the core networks(Threat to mobile n/w operator)
- User Data and Identity Privacy Attacks(eavesdropping)

Discuss Security & Trust IoT Communication

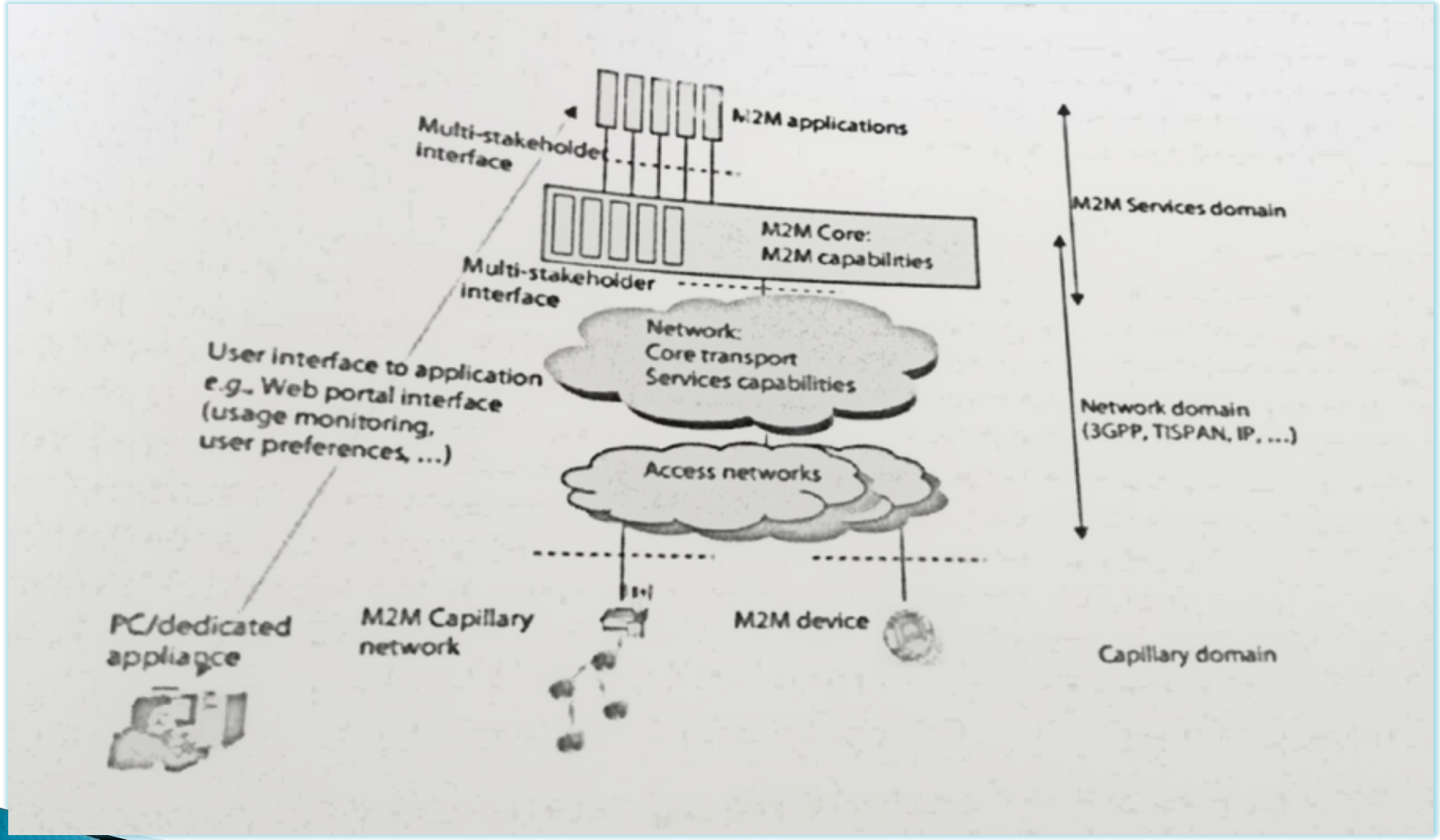
The Trusted Environment

- Introduction to trusted Environment(TRE)(Extension-Verification)
- Requirements, Functionalities and Interfaces
  - symmetric/Asymmetric encryption and decryption
  - Hash value calculation and verification(large to fix)
  - Random Number generation(Generate Cryptographic keys)
  - Digital Signature generation and verification
- Verification of Trustworthiness of M2M
- Validation
- Autonomous Validation(local)
- Remote Validation(Passive local)
- Semi Autonomous Validation

Secure Communication

- Authentication: provides the communicating parties with a way to verify their identity.
- Availability: ensures that the system remains operational even in the presence of malicious or faulty nodes.
- Confidentiality: Guarantees that communicated data is accessible only to the intended recipients.
- Integrity: enables the recipient of a message to verify that a message was not altered while in the network

IoT Security Framework



IoT Service Domain - IoT Core +IoT Applications

IoT Security Framework

- Communication and Sensors Devices: end point of IoT applications.
- Routers and gateways: end point of the operator's network where sensors and IoT devices do not connect directly to the network.
- Machine to Machine Applications: based of infrastructural assets.
- Operator Platform(Service delivery platform)

Discuss Security & Trust M2M Communications; Secure Communications;	CO3
M2M Security Framework; Securing Data Input / Output and internet communication	CO3

Discuss Wireless Sensor Networking (WSN);
Cellular Machine-to-Machine (M2M) application networks; Software for M2M Applications, Hardware
IP Based Cellular Networks & 3G, 4G.

Discuss IOT Requirements; Hardware & Software
Study of IOT Sensors, Tagging and Tracking
Embedded Products
IOT Design, (U) SIM Card Technology
IOT Connectivity and Management

Study of RF Wireless Sensors; Wireless Networks

Computer connected to Internet; Network Devices; Device Configuration and Management

Exchange information in real time without human intervention

IOT Verticals; IOT Hosted Services;

IOT Application development; IOT Connectivity

IOT Software providers.

Automation, asset management, telemetry
transportation, telematics
Telemetry and Telemetric; Report location
logistics, tracking and remote assistance
Next generation kiosks, self-service technology
Cellular IOT connectivity services

IOT Concepts, Introduction to IOT Communications, Telemetry vs IOT

Applications of IOT Communications, People, Processes and Devices