Unit III

Pillars of Embedded IoT and Physical Devices

Outline

- Horizontal and Vertical Applications of IoT
- Four Pillars of IoT
- M2M : Internet of Devices
- RFID : Internet of Objects
- WSN : Internet of transducer
- SCADA : Internet of Controllers
- DCM :
  - Device : Things that talk
  - Connect : Pervasive Network
  - Manage : Create Business Values

Outline

- IoT Pysical Devices and Endpoints
  - Basic building blocks of IoT device
- Exemplary device: Raspberry Pi
- Raspberry Pi interfaces
- Programming Raspberry Pi with Python
- Beagle board and other IoT Devices

Horizontal Applications

- Provide solution to common problems
- These are not business specific
- Can be Used monitored and controlled by multiple companies
- Allows multiple providers to work together on a single platform

Advantages

- Robust
- Developed fast and less costly

Vertical Applications

- These are business specific
- Can be Used monitored and controlled by only single company
- Does not allow multiple providers to work together on a single platform

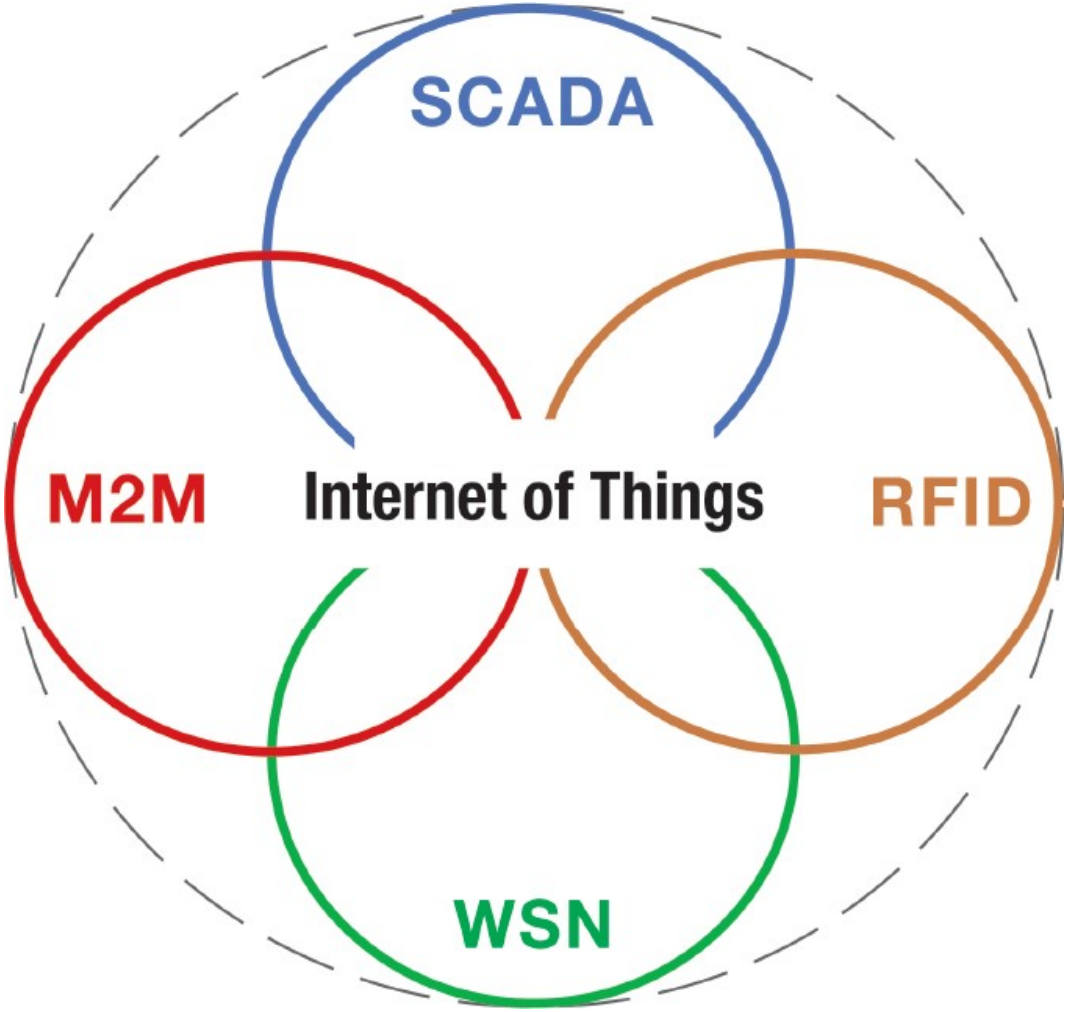
Advantages

- No compatibility issue as no other companies are involved

Disadvantages

- Depended entirely on a single vendor for modifications or upgrades

Four Pillars of IoT



M2M

- Machine to Machine
- Enables **flow of data between machines** which **monitors data by** means of **sensors** and at other end **extracts the information on gathered data and processes it.**
- Subset of IoT
- It uses WAN , GPRS, Cellular and Fixed N/w's

M2M Architecture

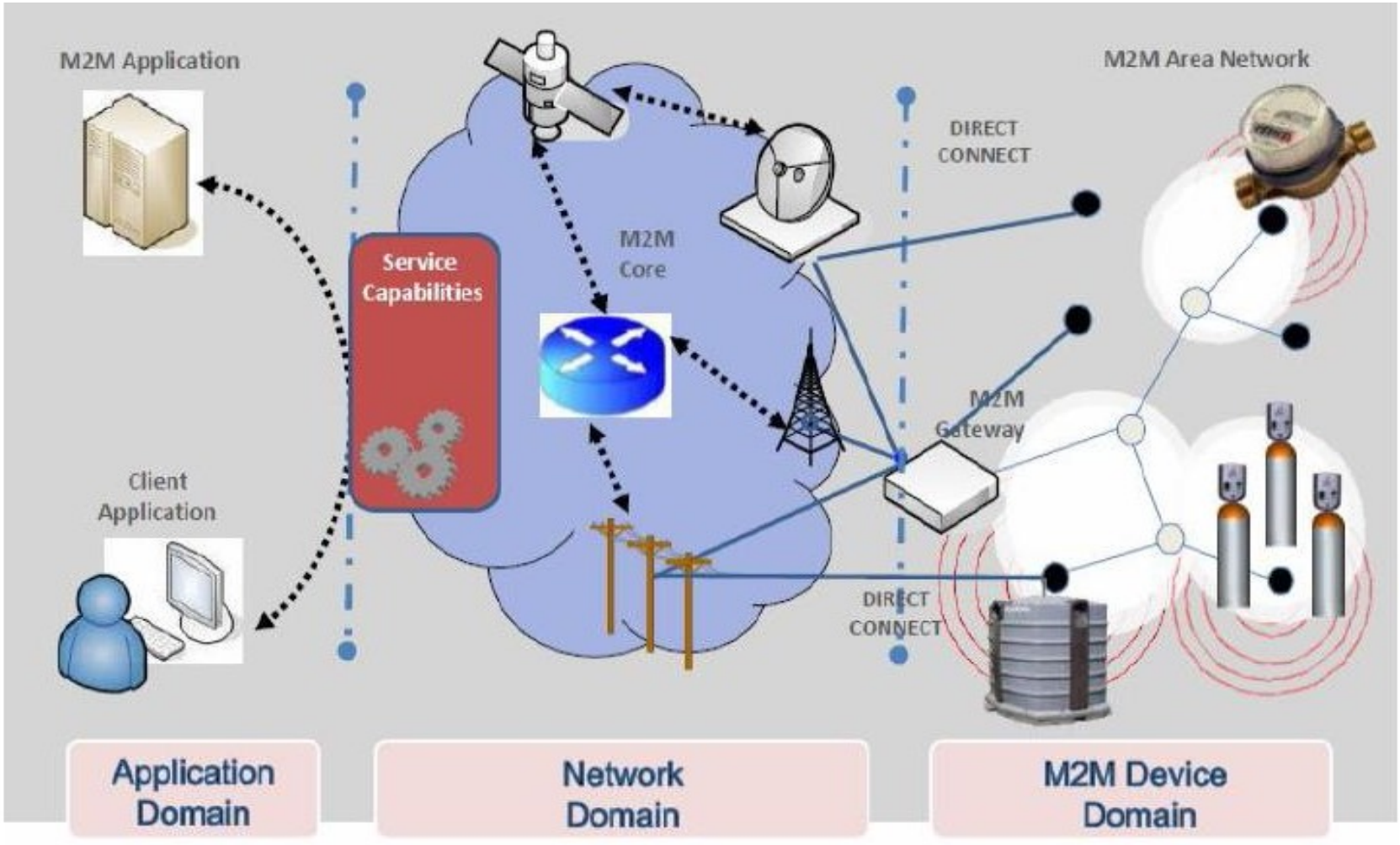


Figure 1: Architecture of M2M system

M2M Architecture

Components of M2M architecture are :

1) M2M Devices
2) **M2M Area Network i.e Device Domain**
3) M2M Gateway
4) **M2M Communcation N/w's : Network Domain**
5) **M2M Applications i.e Application Domain**

M2M Devices

- Device that are capable of replying to request for data contained within those devices or capable of transmitting data autonomously are M2M Devices.
- **Sensors and communication devices** are the endpoints of M2M applications.

M2M Area Network

- Provide connectivity between M2M Devices and M2M Gateways.
- **E.g. Personal Area Network**

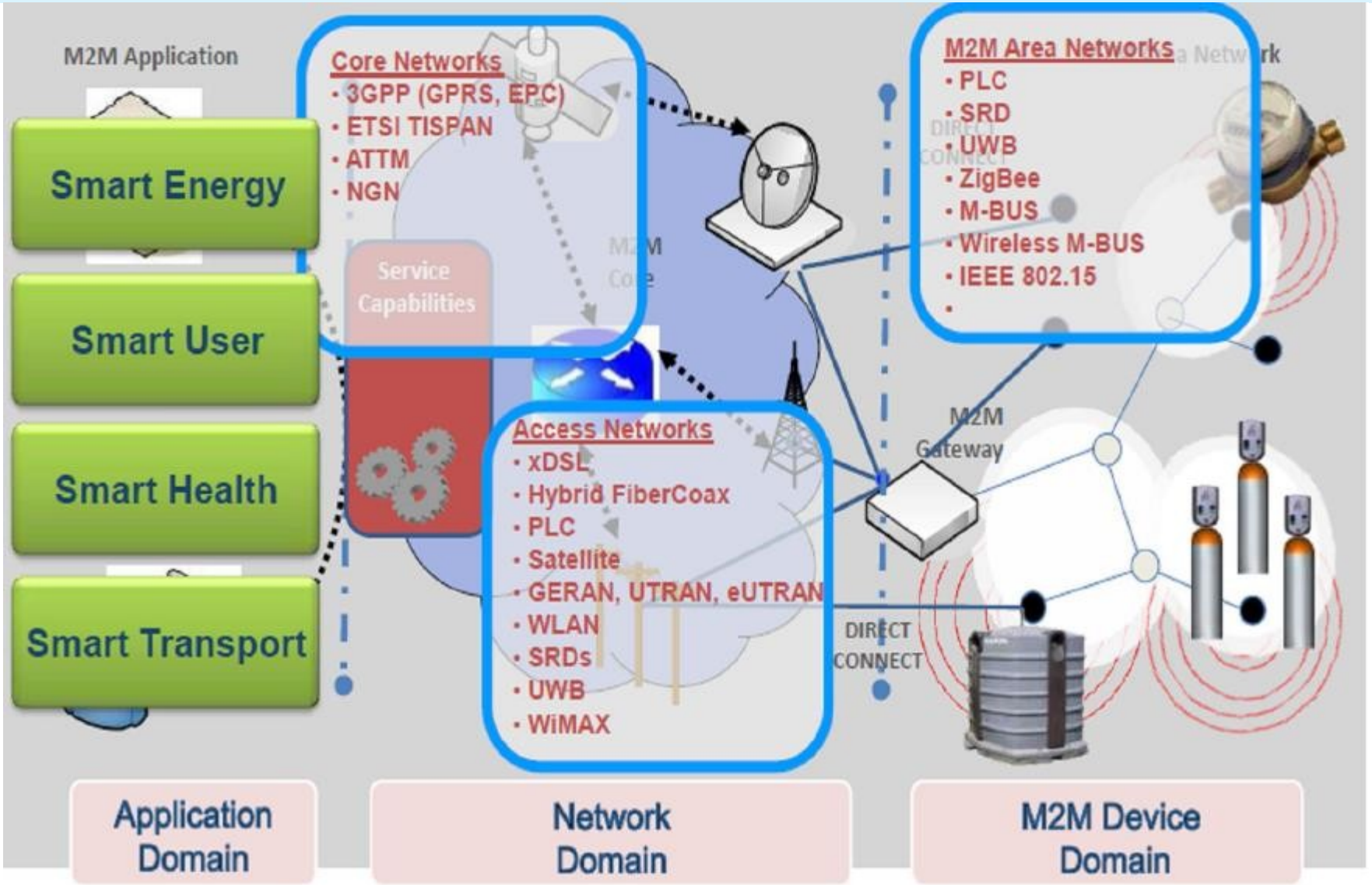
M2M Network Domain

- Communication between M2M Gateways and M2M Applications.
- **E.g. WiMax, WLAN, LTE**

M2M Application Domain

- It contains the middleware layer where data goes through various application services and is used by the specific business-processing engines.

Examples of M2M Components



RFID

- **Radio Frequency Identification**

- A tag can be read from up to several feet away and does not need to be within direct line-of-sight of the reader to be tracked.
- Uses NFC (Next Field Communication protocol), IC (Integrated Circuit) Cards, Radio Waves

RFID

What is RFID

Application of RFID

What is inside in RFID

How RFID Works? (Operating Principle)

What is RFID?

RFID

Objects can be books in library

RFID

Objects can be items in shopping mall

RFID

Objects can be inventory in the warehouse

RFID

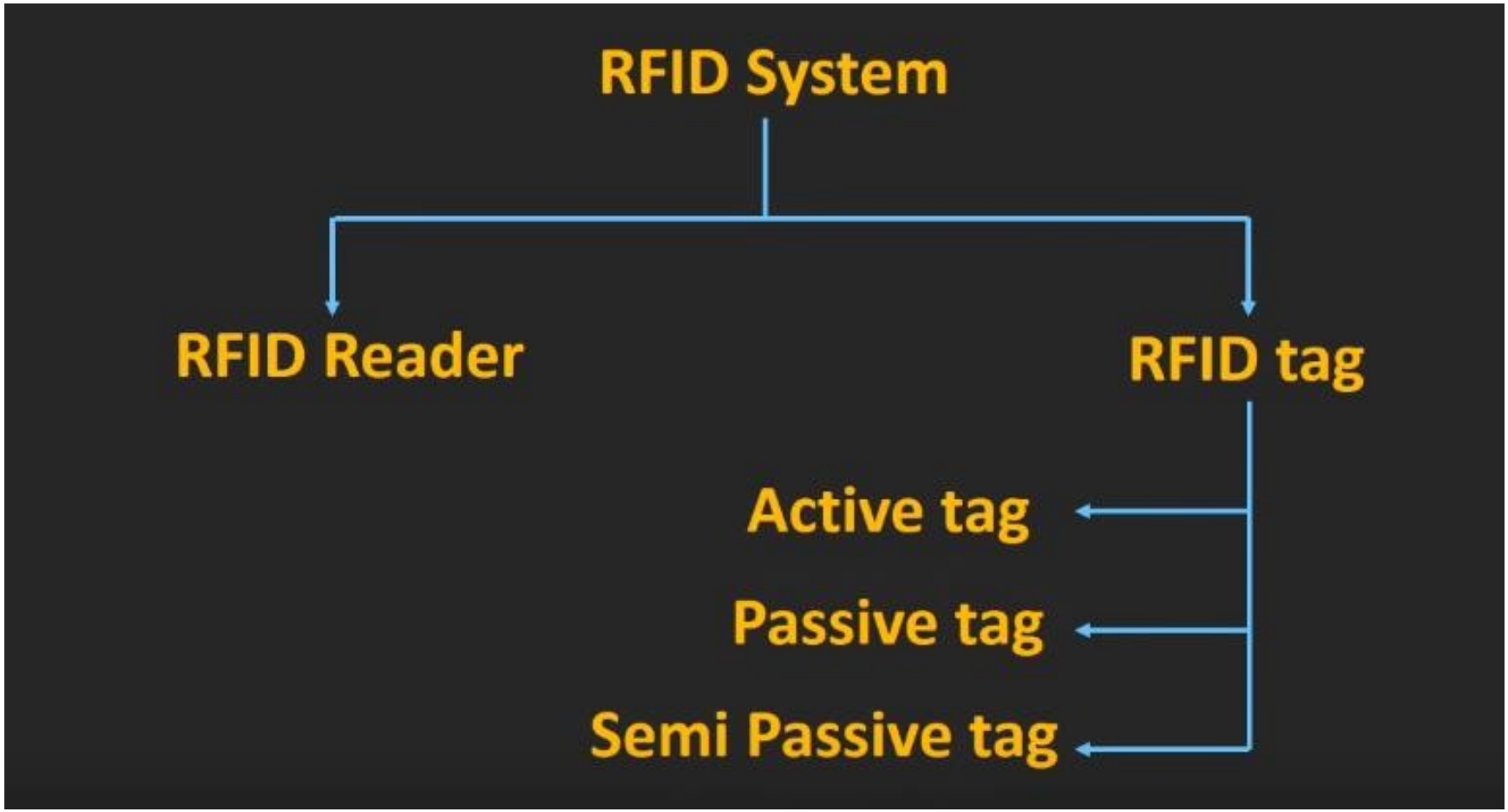
Objects can be a car

RFID Vs Bar Code

- In Bar code the scanner must be in line of sight…and this is not mandatory in RFID
- RFID can track multiple objects while Bar Code cannot

RFID Vs Bar Code Vs QR Code

RFID System

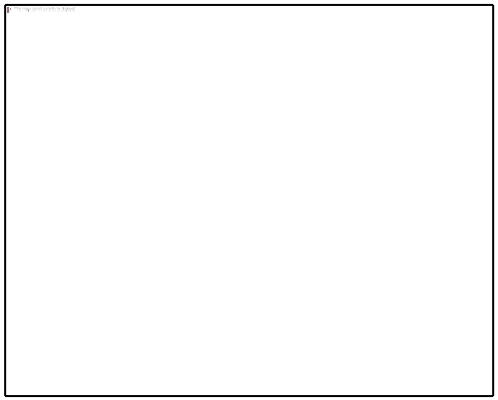

RFID System
RFID Reader
RFID tag
Active tag
Passive tag
Semi Passive tag

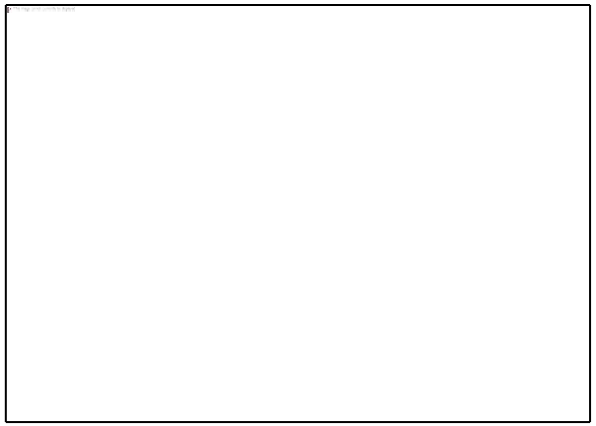
RFID Tags

- Passive Tags do not have their own power supply, hence rely on radiowaves for source of energy
- SemiPassive Tag have their own power supply, but for transmitting back they rely on signals coming from RFID Reader
- Active Tag uses their own power supply for both transmitting and receiving
- Range of Passive Tags is less than that of Semi and Active Tags

RFID Passive Tags

- Passive Tags are cheaper
- Passive tags donot use any power source hence are compact



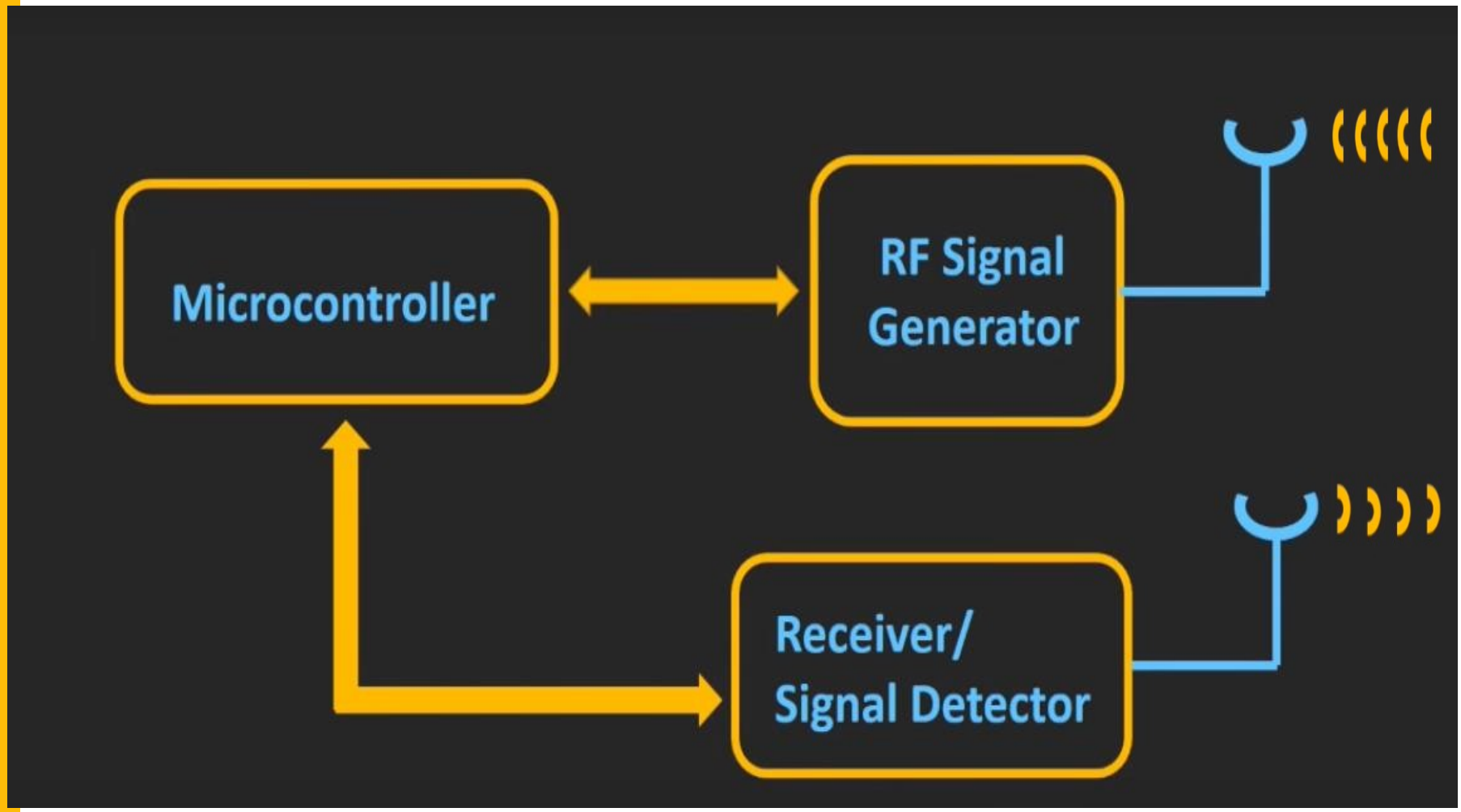


RFID Reader

- Come in many size and shapes

HandHeld Reader

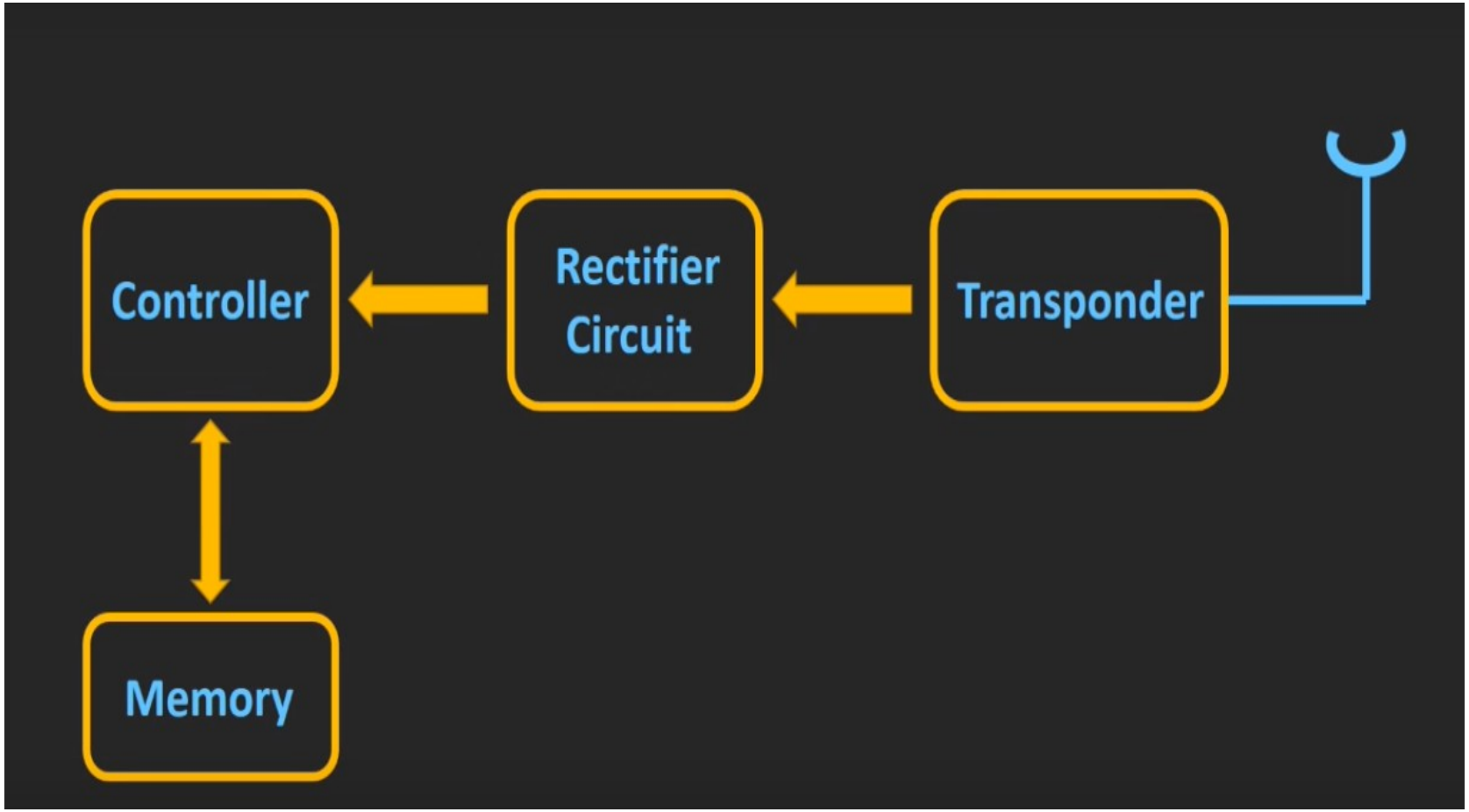
RFID Reader


Microcontroller
RF Signal Generator
Receiver/ Signal Detector

RFID Reader

- RF Signal Generator Generates radio waves which are transmitted through the antenna
- Receiver or signal detector receives the signals coming from the object
- And to process these signals microcontroller is used

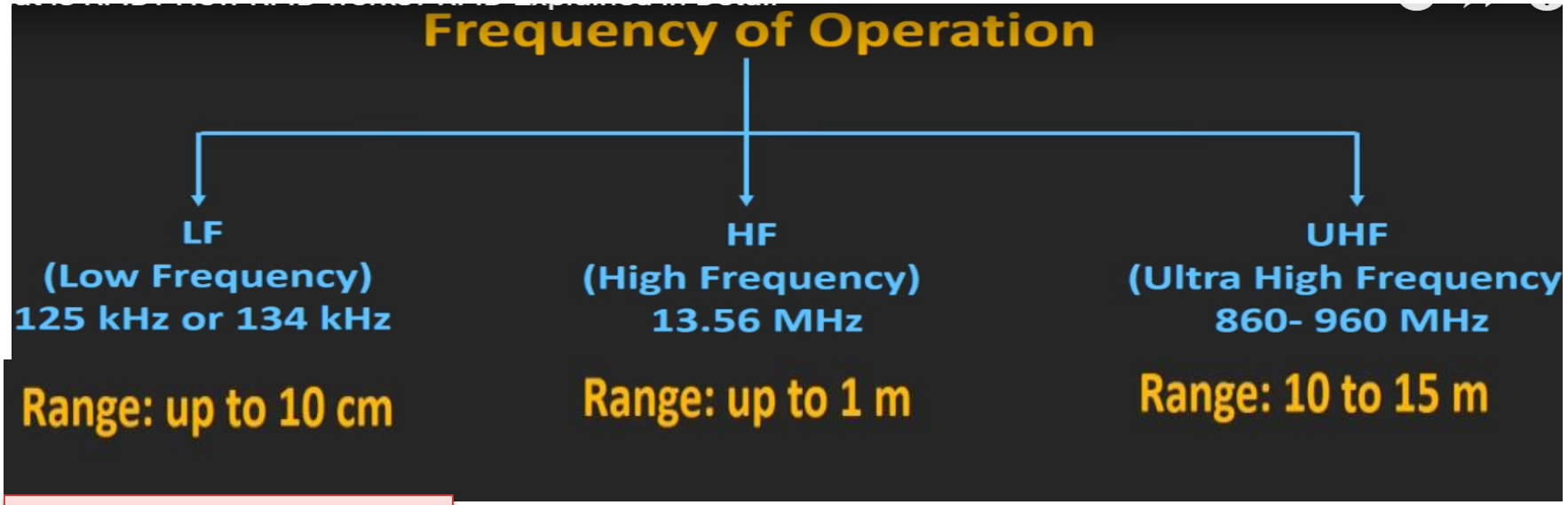
RFID Tag



RFID Tags

- Transponder receives signals from reader and sends back feedback to the reader
- The Passive Tags use the rectifier circuit to store the energy coming from the radio waves.
- This energy is used as the supply for the controller and the memory element

RFID Frequency Operation



Person Identification

Clothes at Shopping Mall

Vehicle Identification at Toll Plaza

RFID Frequency Operation

- Frequency Operation varies from country to country, but major countries

RFID Working Principle

LF and HF RFID Tags: Inductive Coupling (Near Field Coupling)

UHF RFID Tags: Electromagnetic Coupling (Far Field Coupling)

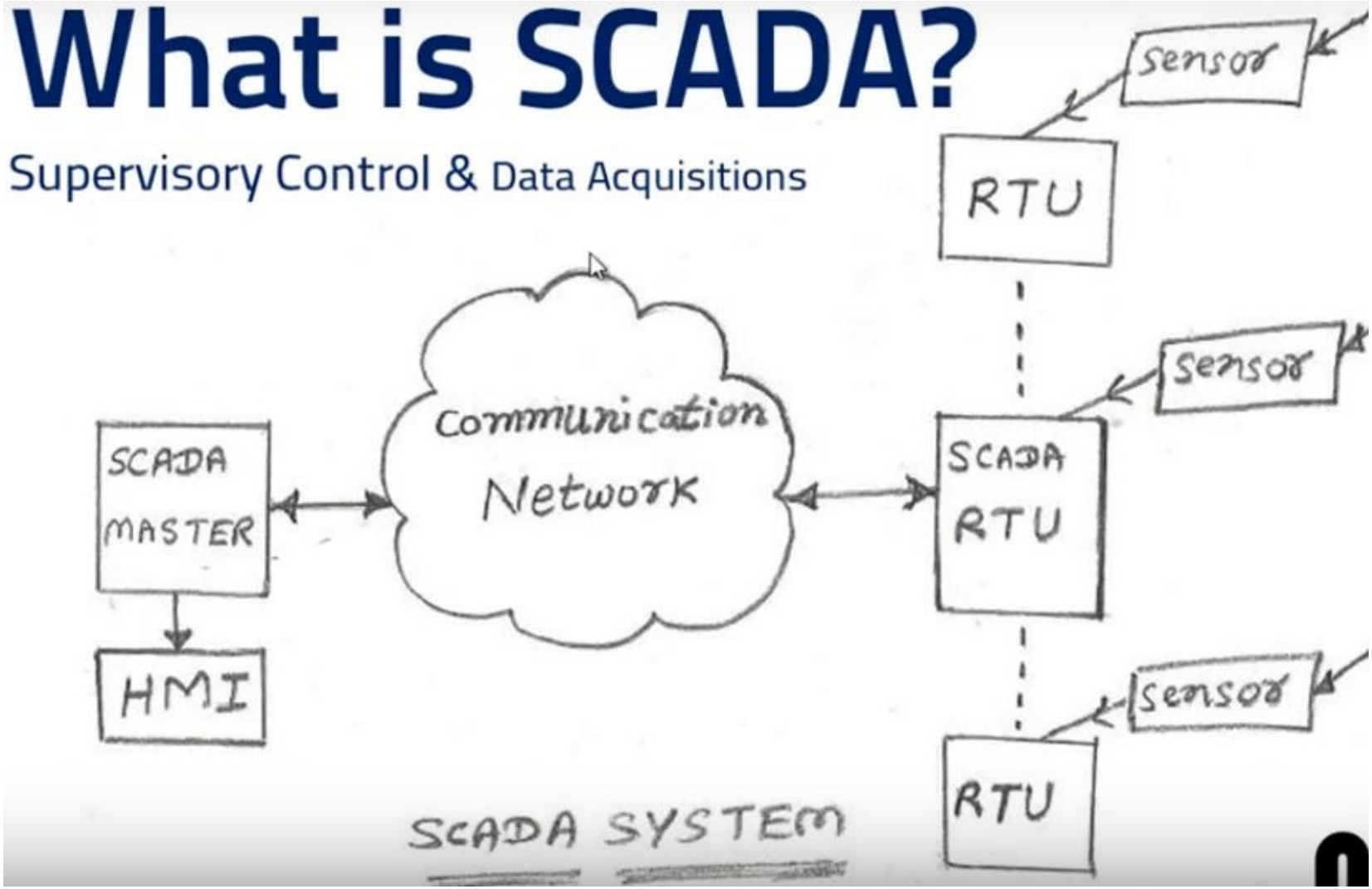
SCADA

- **Supervisory Control and Data Acquisition**
- These connect , monitor and control equipment's **using short range n/w inside a building or an industrial plant**
- Uses **BacNet** (communication protocol) , **CanBus** (Controller Area N/w) and **Wired FieldBuses**(Industrial Computer Network Protocols)

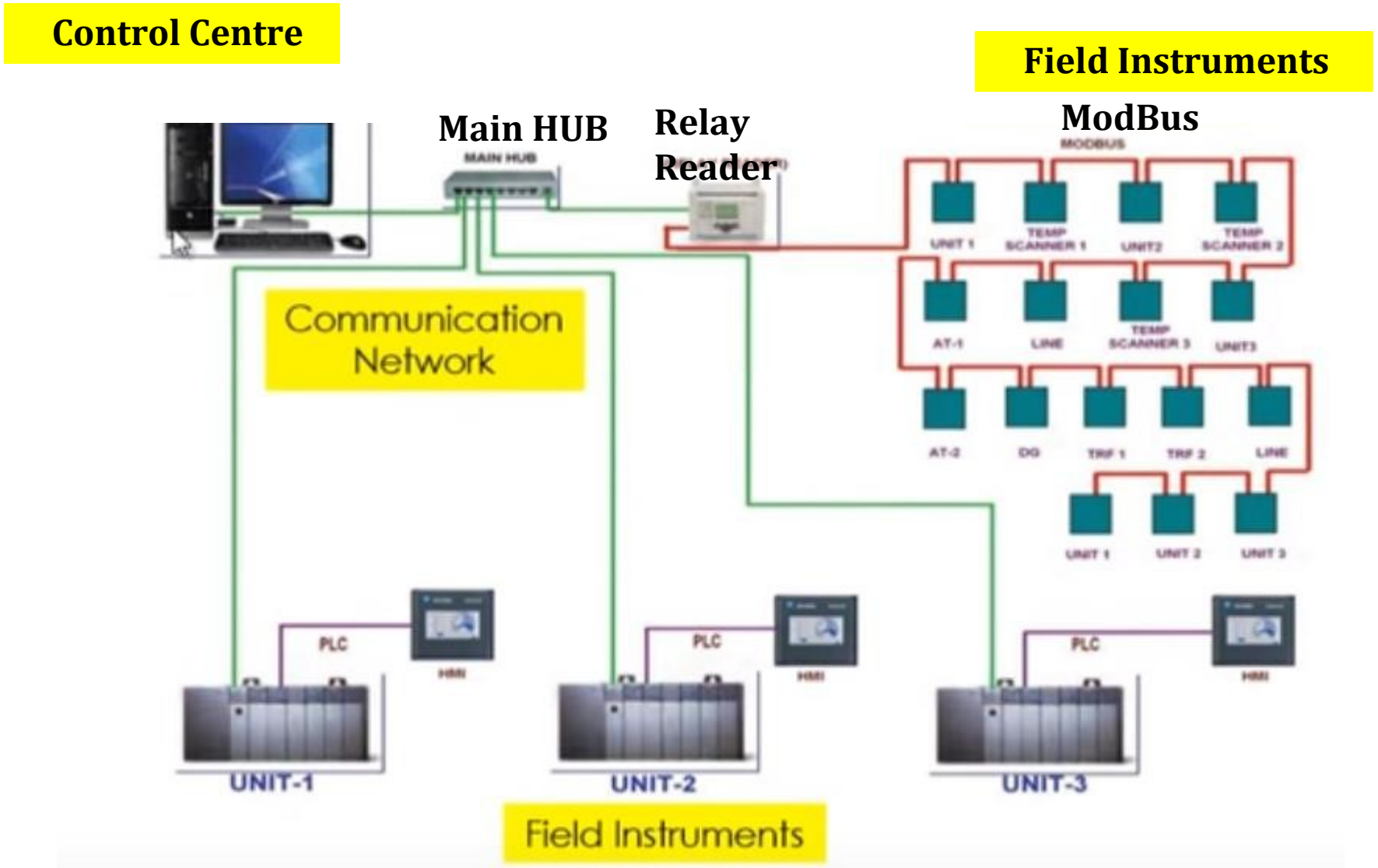
SCADA

- **Supervisory** means top level
- **Control** means controlling things
- **Data Acquisition** means acquiring the data / reading the data
- **SCADA is a s/w** used to **control** the **hardware** i.e PLC, drives , servers , sensors and also **acquire the data** which is **stored on** the **personal computer** or **Human Machine Interface(HMI)**

SCADA


What is SCADA?
Supervisory Control & Data Acquisitions
Sensor
RTU
Sensor
Communication
Network
SCADA
MASTER
SCADA
RTU
HMI
Sensor
RTU
SCADA SYSTEM

SCADA Architecture



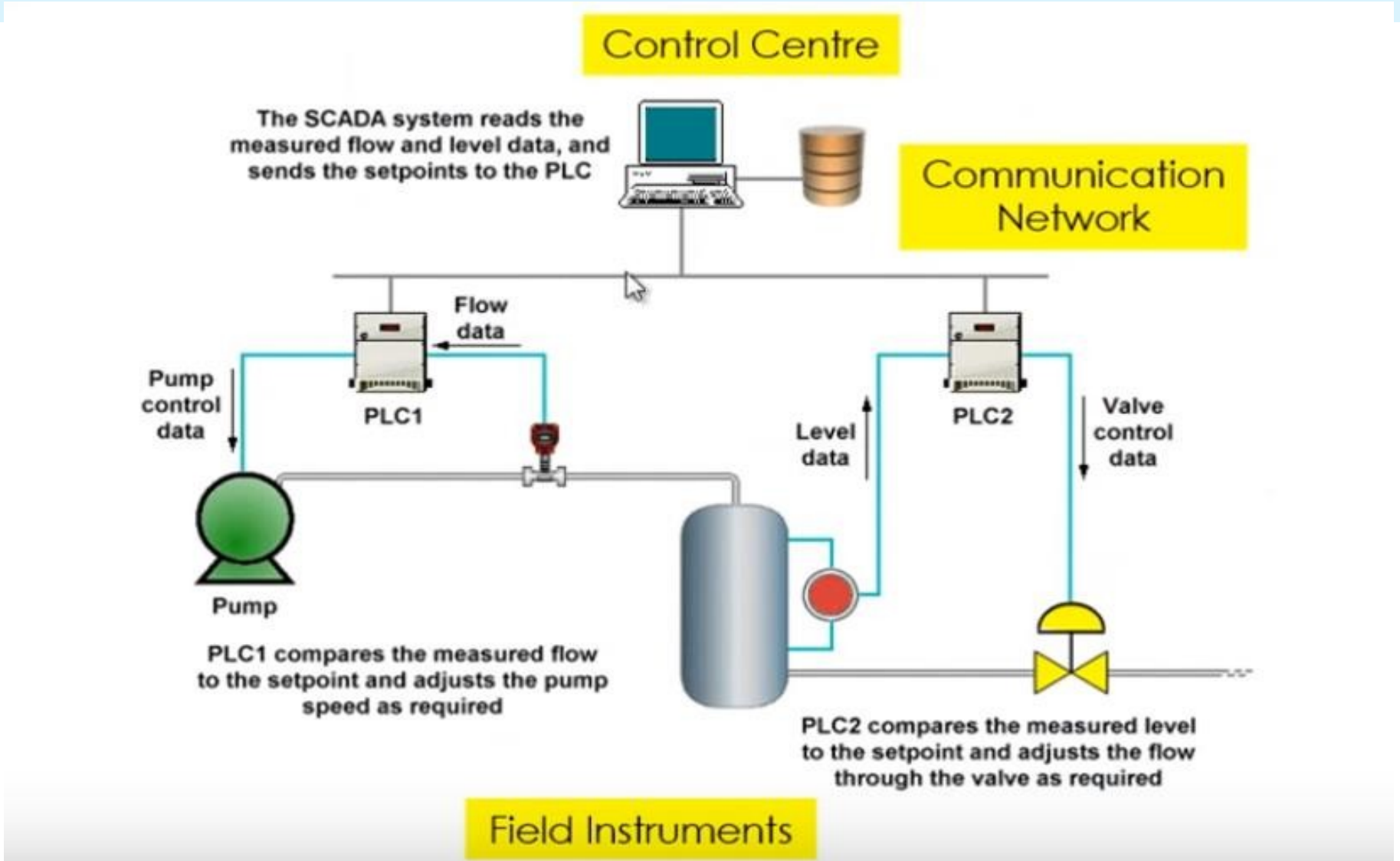
SCADA Architecture

- SCADA Architecture has a **control centre** connected to the main hub(i.e the ethernet port)
- **The PLC**(Relay Reader is **connected to** the **ethernet board** which is overall **connected to the CPU.**
- **PLC** on other hand is **connected to various field instruments** which can be the temperature sensors or actuators that can be analog or digital

SCADA Architecture

- The PC has a **SCADA s/w** which can **interact with** the **field instruments**
- PC is also connected to various other PLC's Unit I , Unit II, as shown in Diagram.
- There is an Human Machine Interface(**HMI**) which is **individually connected to the PLC**
- The **HMI** individually **monitors and controls** the **PLC**
- TO read information from all the units we need a SCADA system.
- **PLC (Programmable Logic Unit) monitor and control the data**
- **RTU(Remote Terminal Units)** receive data from sensors and convert this data to digital data and send to SCADA system

Example of SCADA Architecture



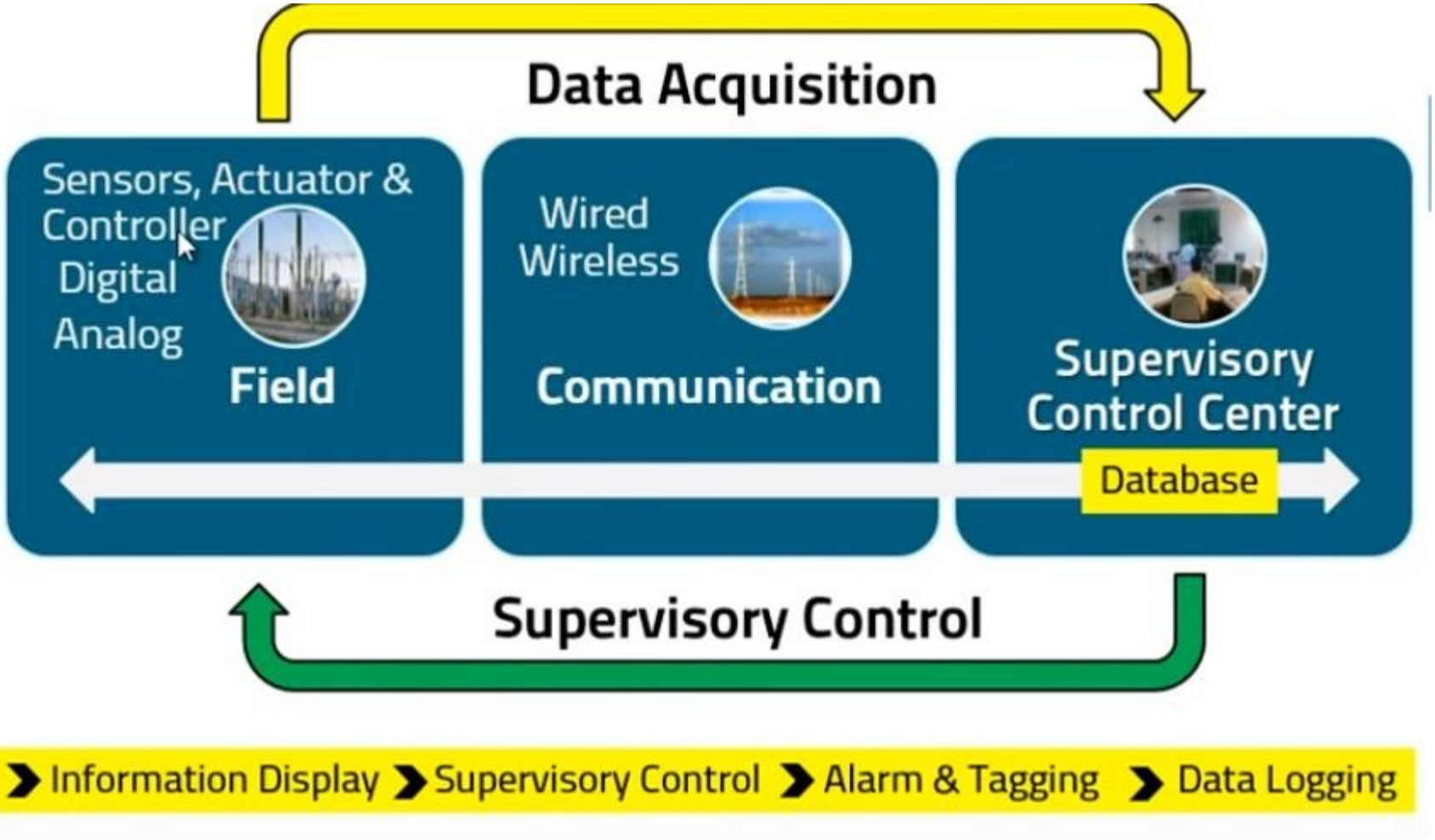
Example of SCADA Architecture

- As shown in the figure the Pump is controlled by the PLC1, which **controls speed of the pump.**
- There is a **water level sensor** that senses the level of water in water tank and gives the information to PLC2 that monitors the level of the water.
- The PLC1 and PLC2 are connected to the SCADA system.

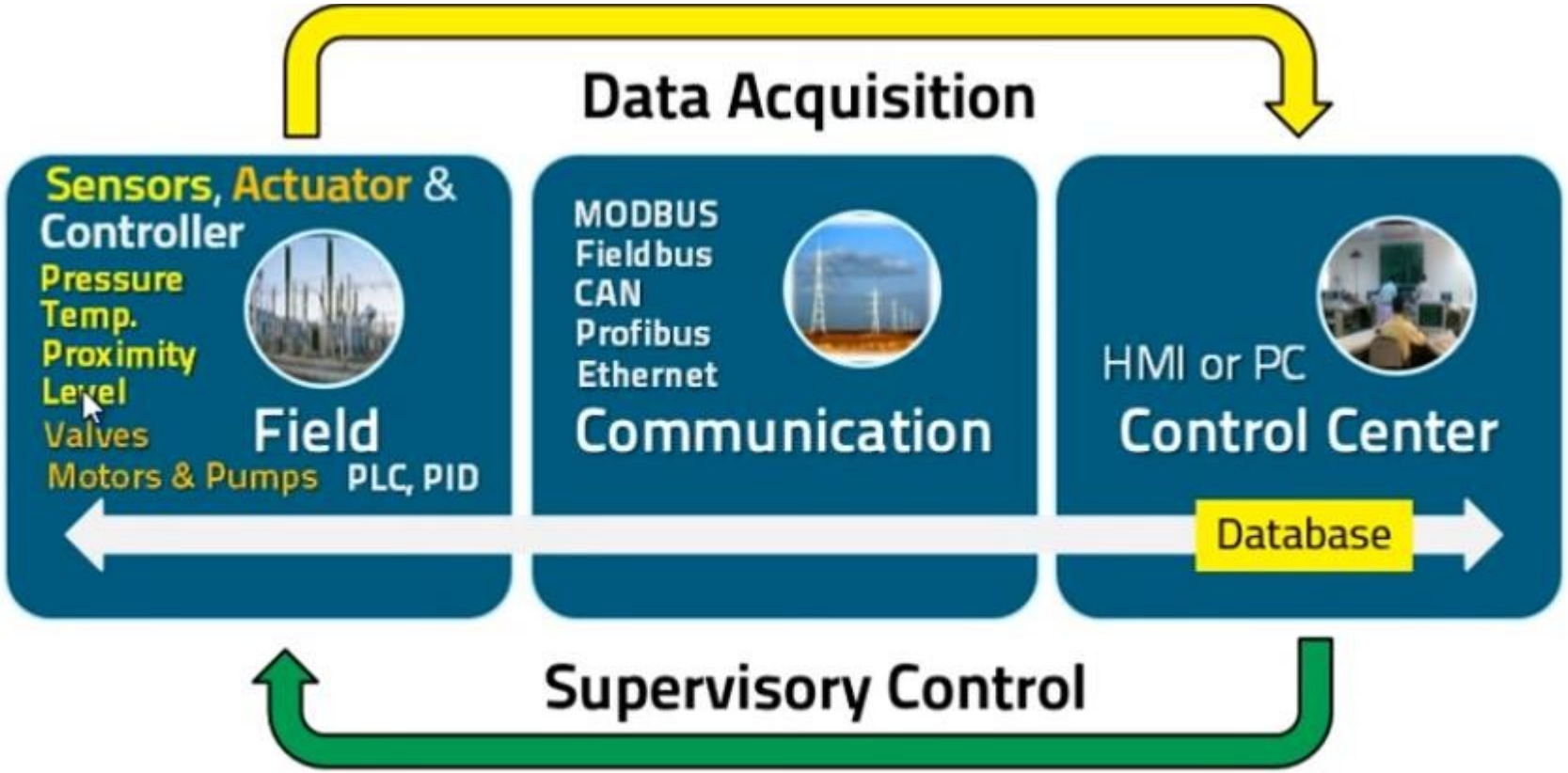
Example of SCADA Architecture

- The system contains the database which can store the data of **speed of the pump** and **water level.**

SCADA Architecture

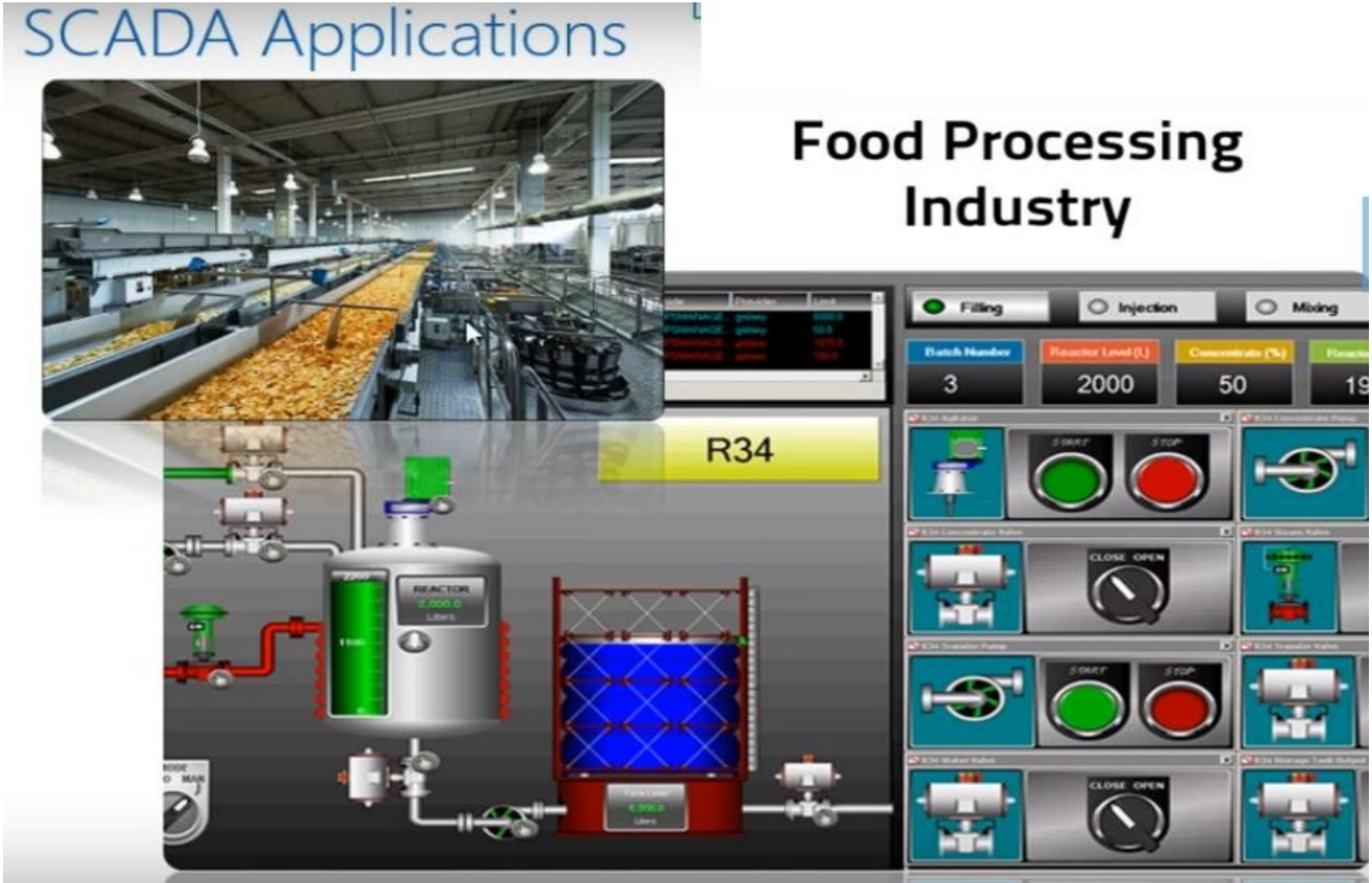


SCADA Architecture

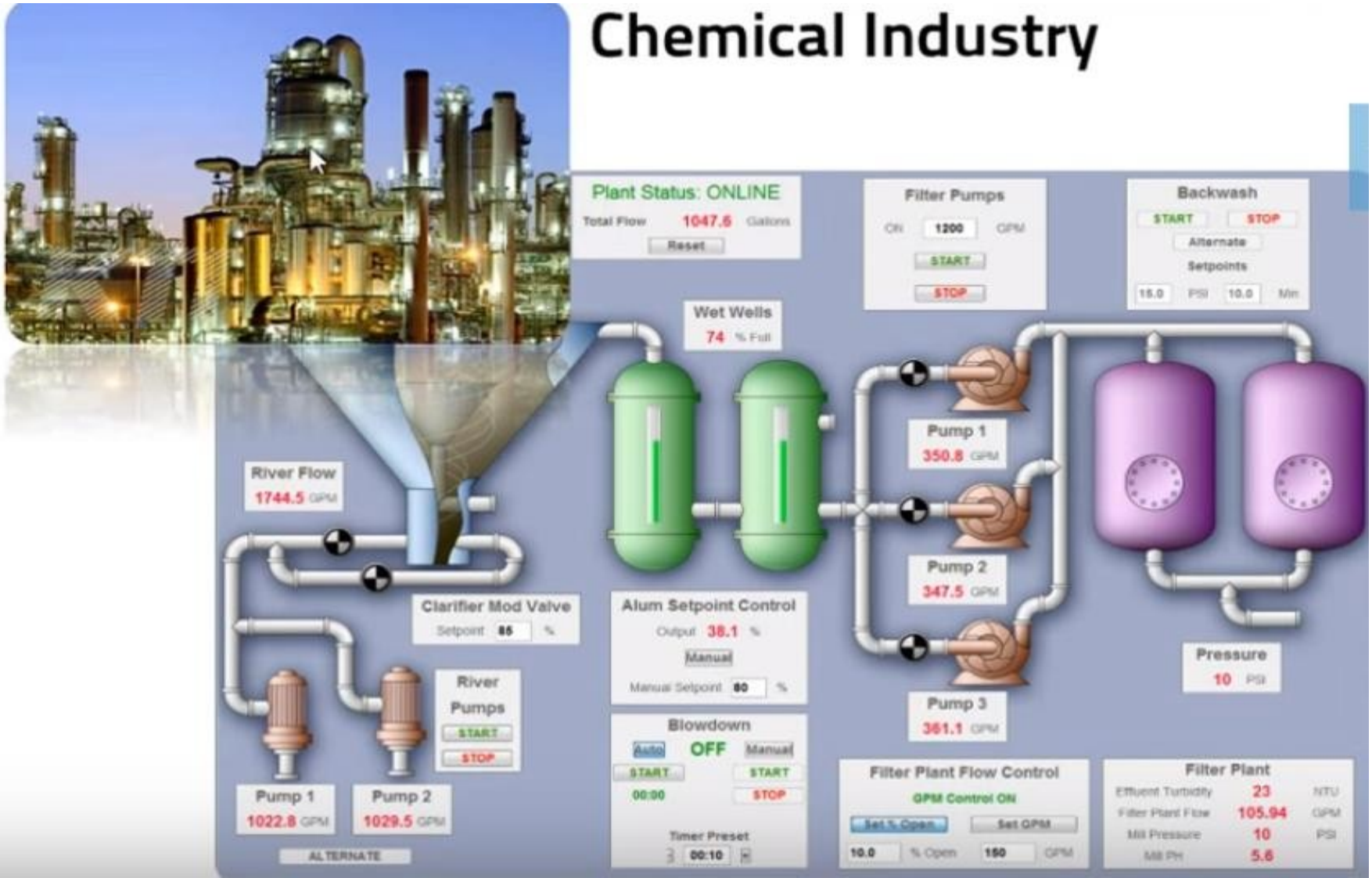


Information Display › Supervisory Control › Alarm & Tagging › Data Logging

SCADA Applications

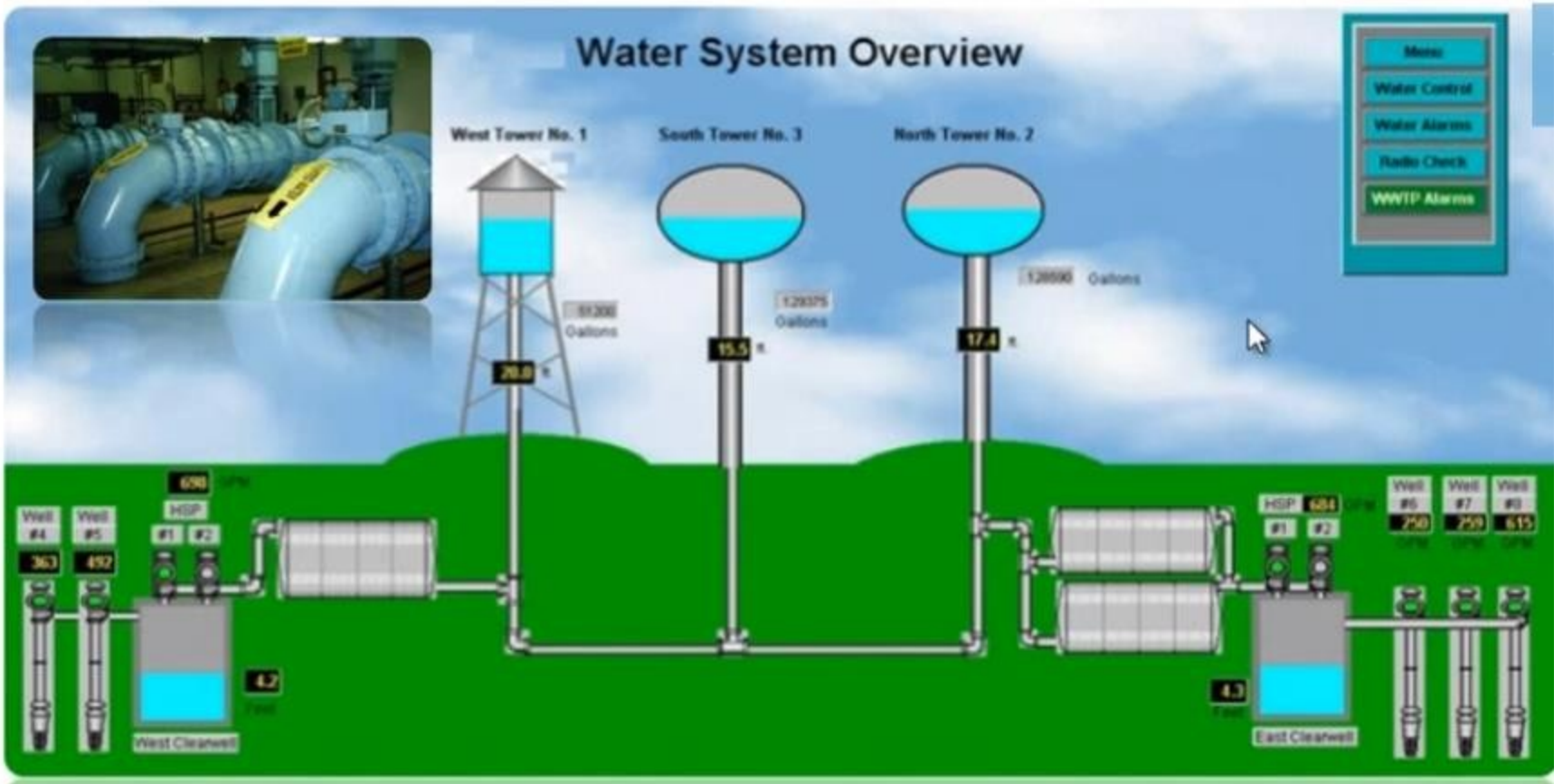


SCADA Applications



SCADA Applications

Water Treatment Plant



WSN

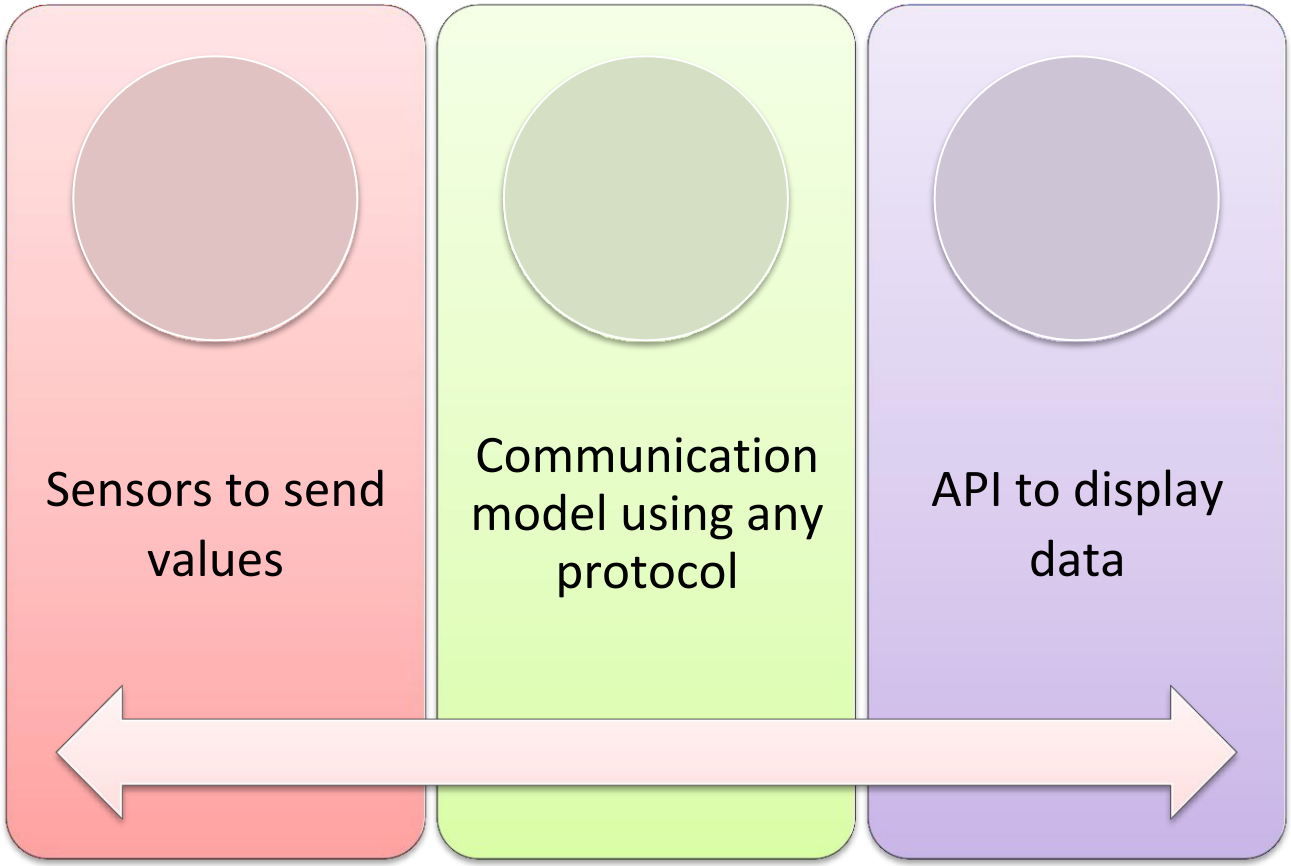
- **Wireless Sensor N/w**
- It senses and gathers data using sensors which are spatially distributed
- It collects this data into a centralized location with the help of wired / wireless connection

WSN

*It is a deployment of several devices equipped with sensors that perform a collaborative measurement process

WSN

- **Consists of three basic things**



WSN

Send any value...

+60 sensors

...using any protocol

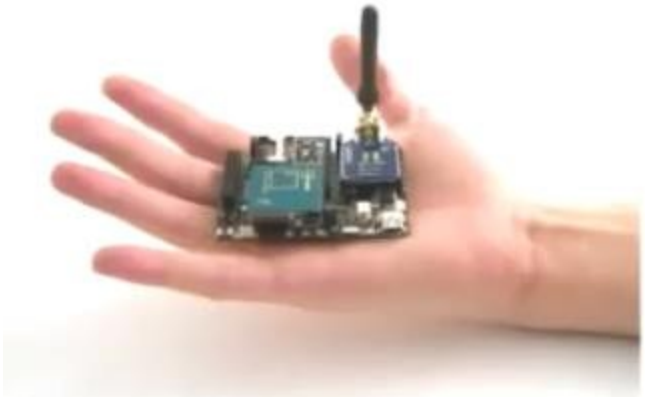
Wireless communication modules

...to any system

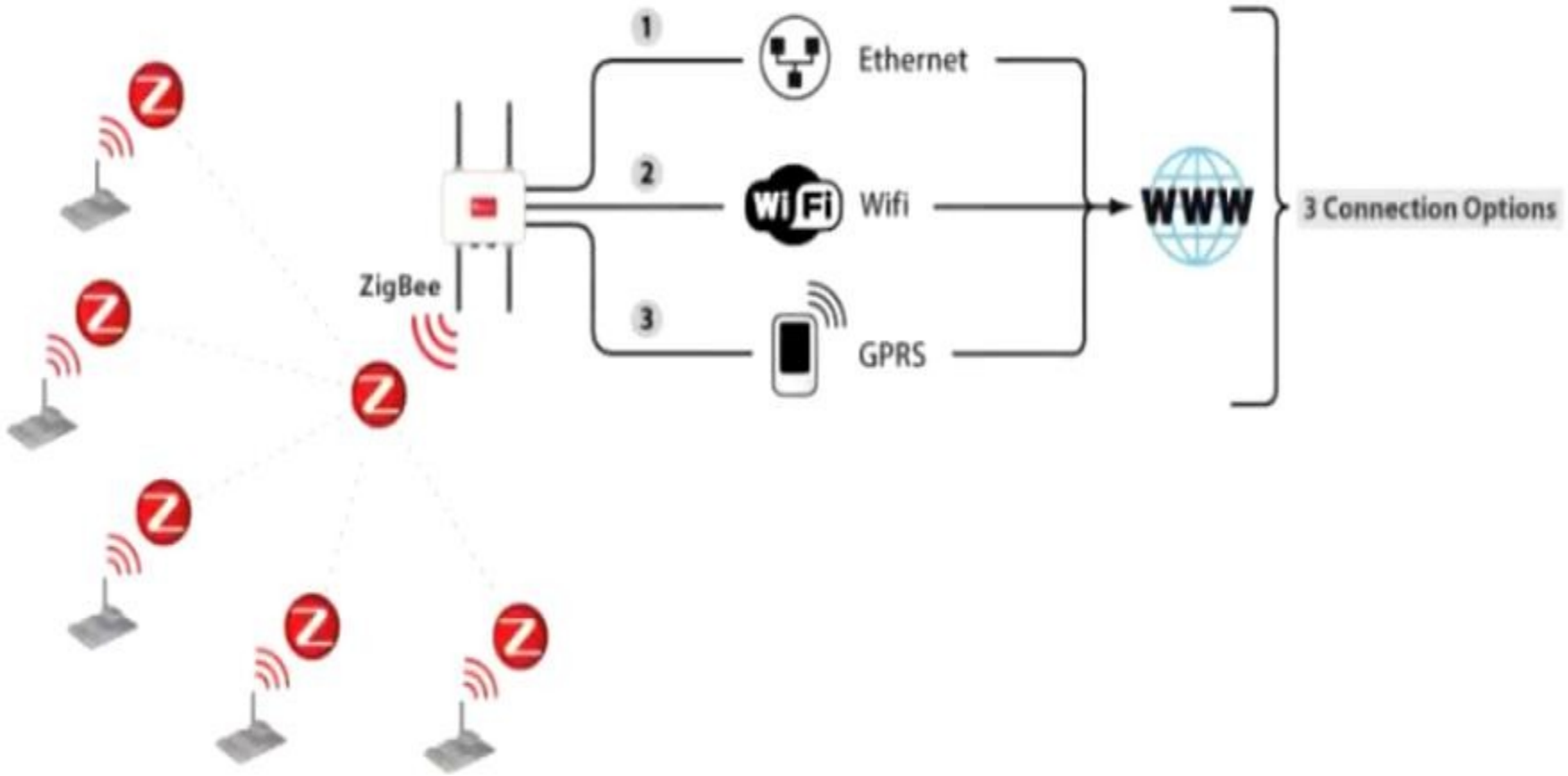
Open Source API

WSN Elements

* **Node**: Autonomous sensor-equipped device
* **Data gatherer**: Data capturer and gateway to external systems
* **External systems**: Data storing and managing centres



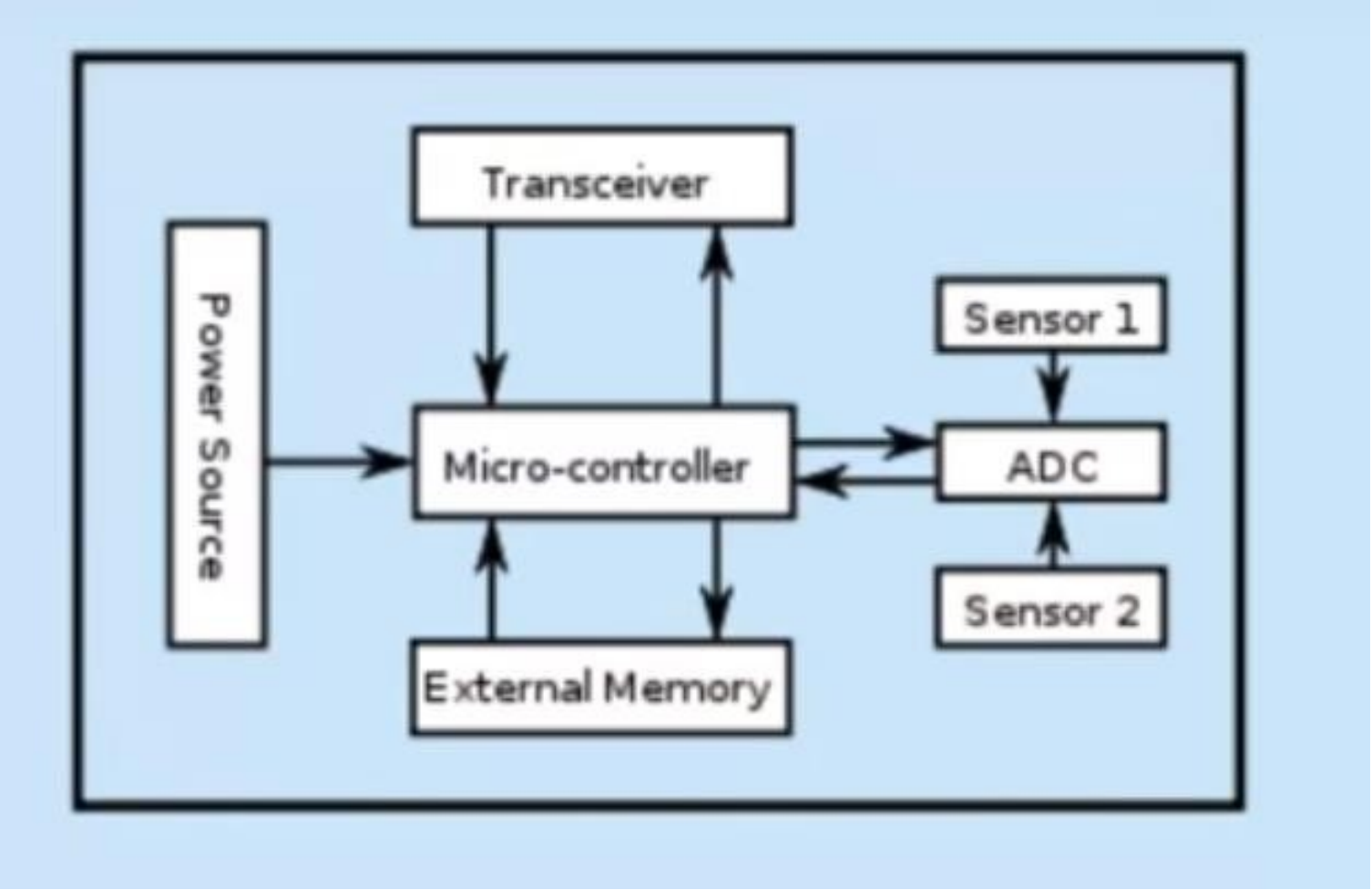
Working of WSN



Working of WSN

- In the above diagram we can see the **sensors (nodes)** are **sensing** the **device values**
- These **transmit** the **information to** the **measuring device (data gatherer)** which **transmits** the **values to external systems using Ethernet, Wifi, or GPRS**.

Parts of WSN


Transceiver
Power Source
Sensor 1
Micro-controller
ADC
Sensor 2
External Memory

Difference between four Pillars of IoT in terms of communication

Communication	Wired		Wireless	
Pillars	Short Range	Long Range	Short Range	Long Range
M2M	No	Some	Some	Yes
RFID	No	Some	Yes	Some
WSN	No	Some	Yes	Some
SCADA	Yes	Yes	Some	Some

So…..

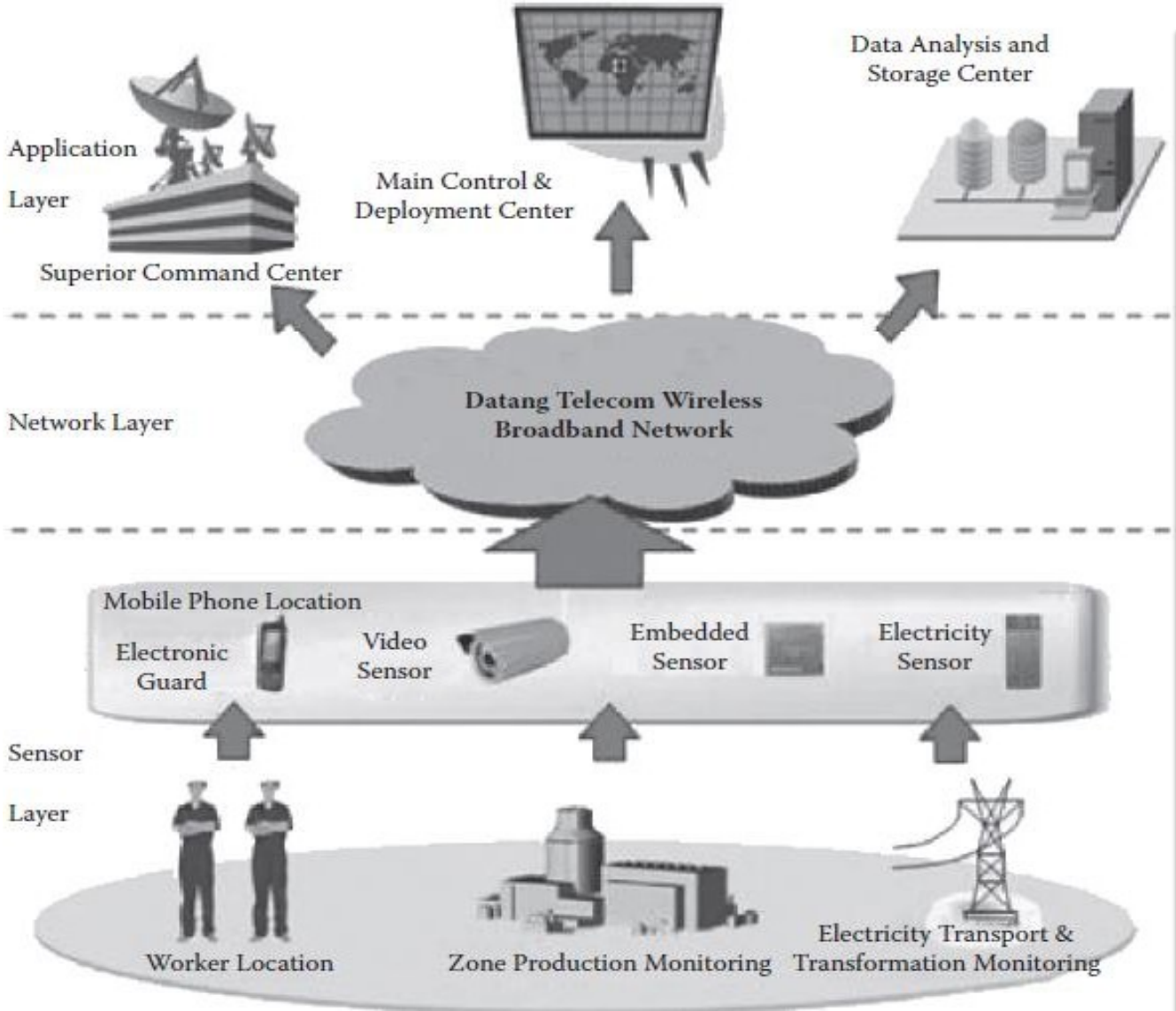
Internet of devices

Internet of Objects

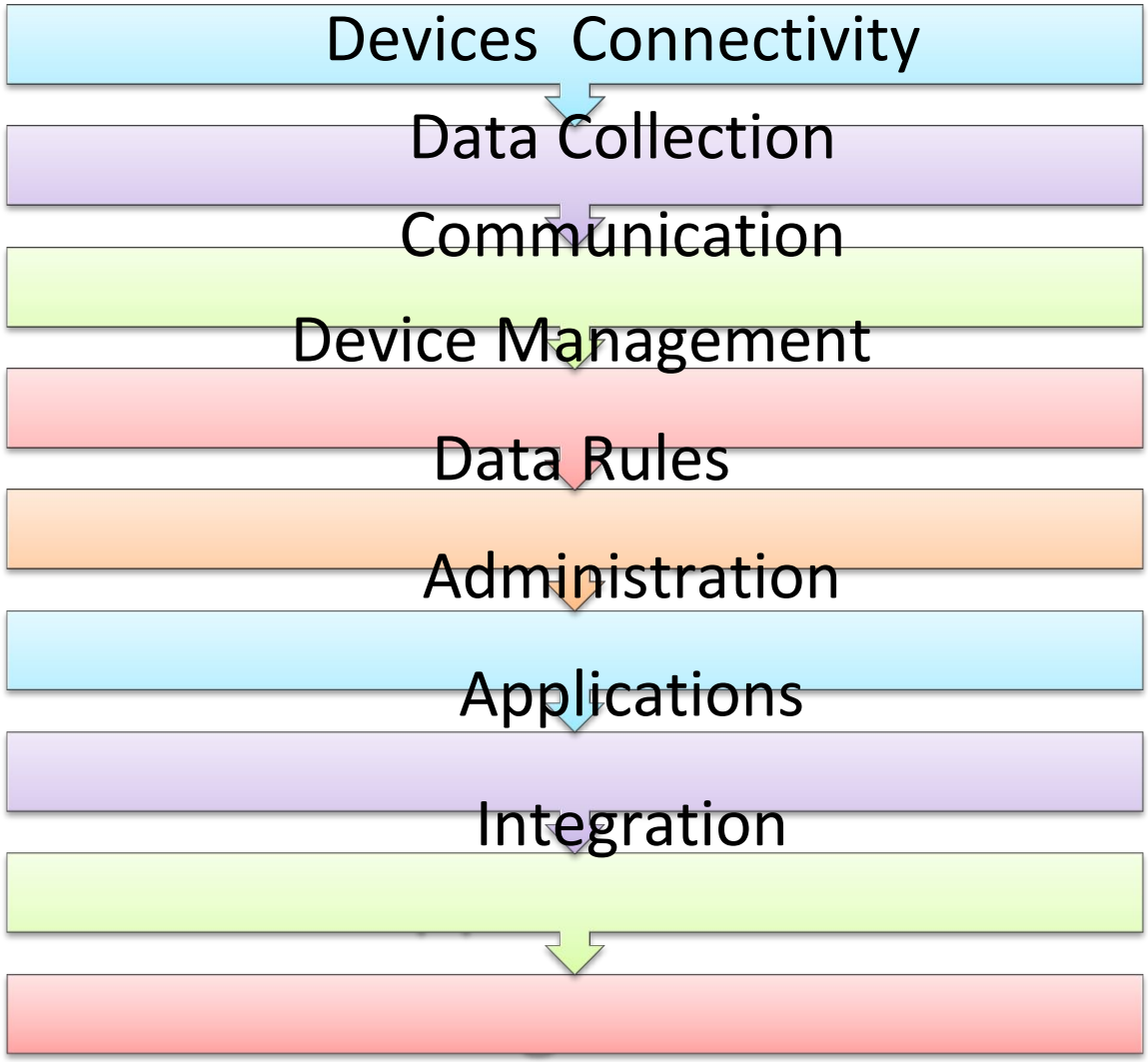
Internet of Transducer (Transmitter and

Internet of controllers

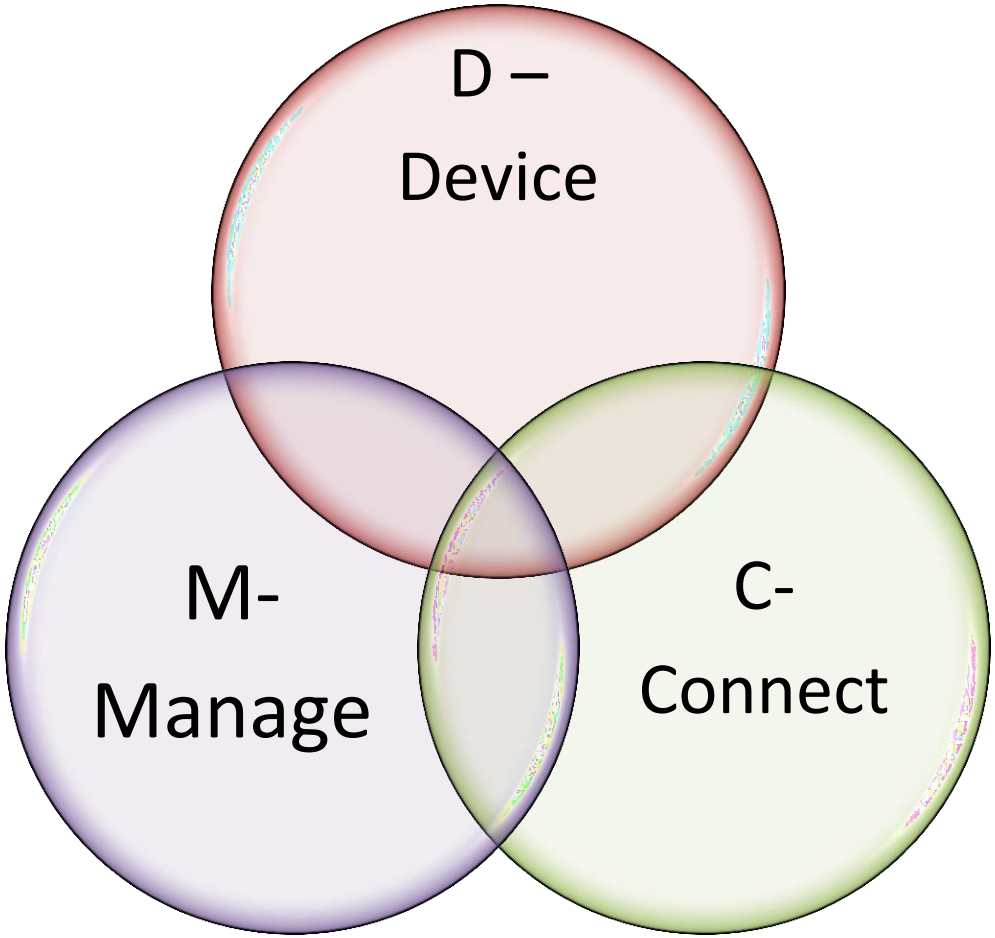
Three Layer architecture of IoT



Nine Layer architecture of IoT



DCM



Devices : Things that Talk

Inherent Intelligent

- Means Inbuilt Intelligent
- Eg. Washing Machines, ventilation, and air- conditioning, (HVAC) controllers

Enabled Intelligent

- Means need to be made intelligent
- RFID tagged devices

Devices : Things that Talk

Sensors

- Perform **Input function**
- Device that **responds to a physical stimulus**, **measures** the physical stimulus quantity, and **converts it into** a signal, usually **electrical,** which can be read by an observer or by an instrument Also called **detector**
- A sensor is basically an **electrical device**. It could be an **M2M terminal**, an **RFID reader**, or a **SCADA meter**.
- A sensor can be very small and itself can be a trackable device

Devices : Things that Talk

Sensors

- Perform Input function
- Device that responds to a physical stimulus, measures the physical stimulus quantity, and converts it into a signal, usually electrical, which can be observer or read by an by an instrument

Actuators

- Performs Output function
- RFID tagged devices

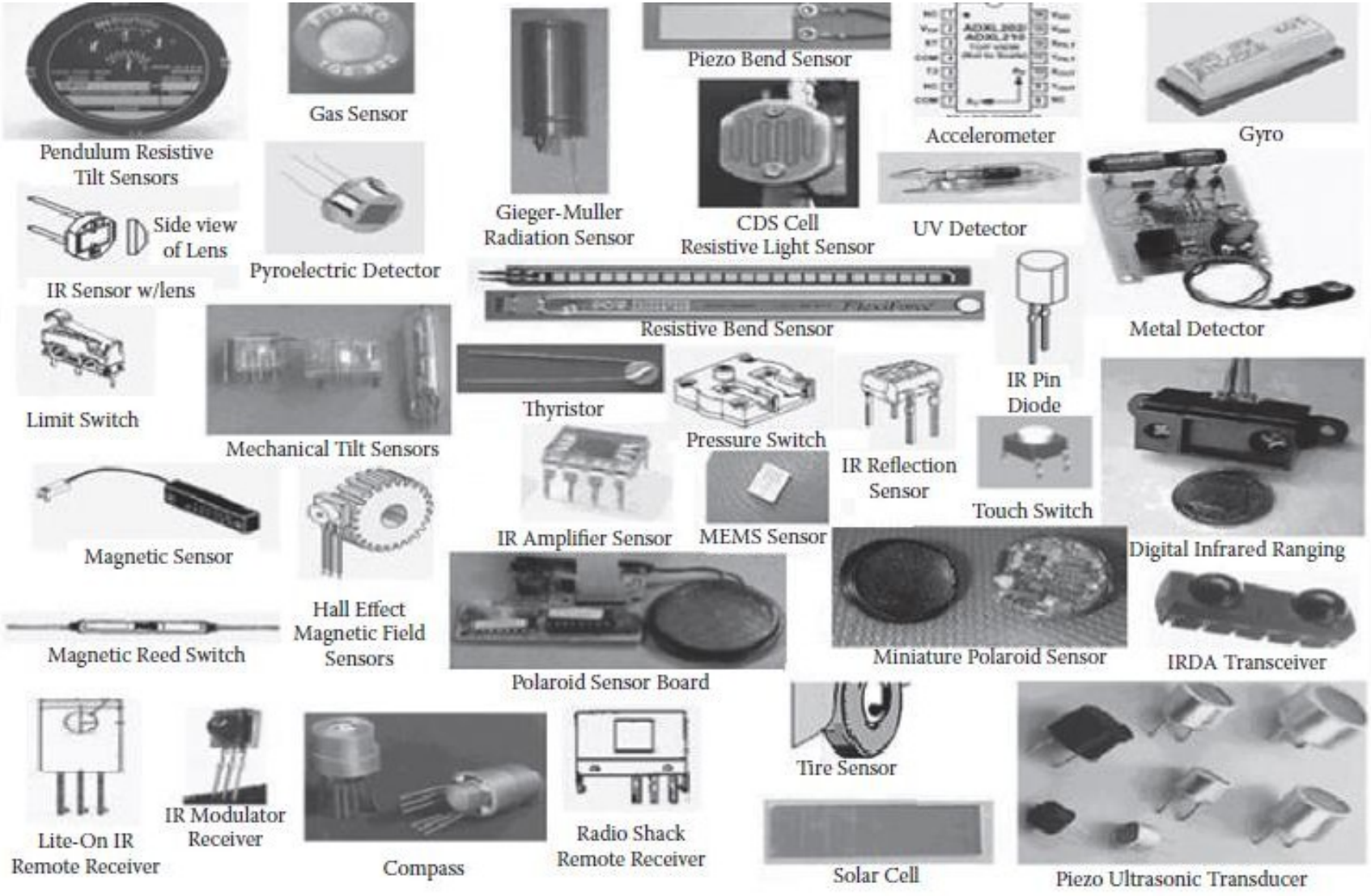


Figure 4.3 Examples of sensors.

Sensor Type and Example

Sensor Type	Example
Position, angle, displacement, distance, speed, acceleration	position sensor, Accelerometer, capacitive displacement sensor ….
Pressure	barometer, boost gauge, pressure sensor
Acoustic, sound, vibration	Geophone, hydrophone, lace sensor, microphone
Automotive, transportation	Air-fuel ratio meter, engine coolant temperature (ECT) sensor, parking sensors, ……..

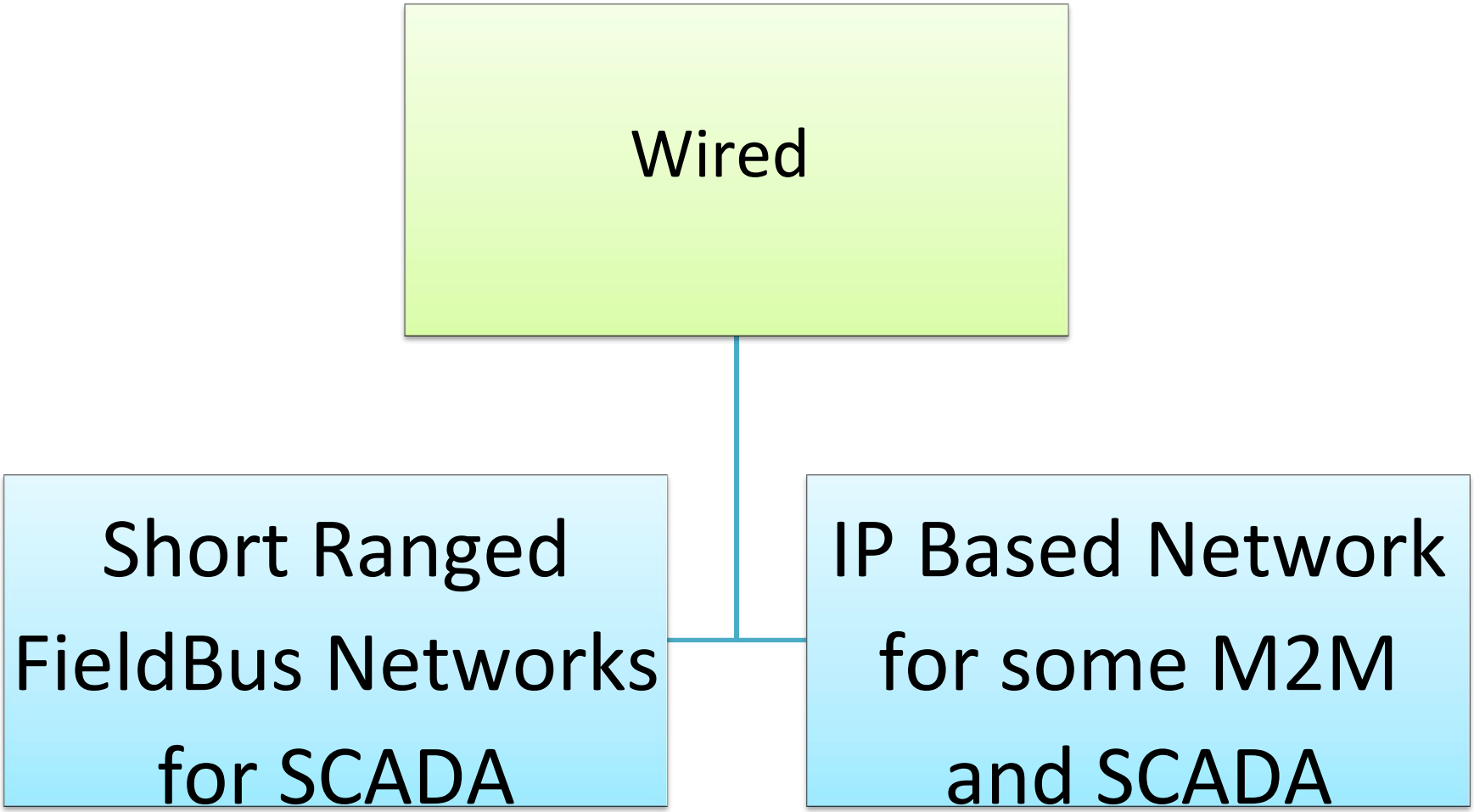
Sensor Type and Example

Sensor Type	Example
Environment, weather, moisture, Humidity	leaf sensor, rain sensor, soil moisture sensor
Flow, fluid velocity	Gas meter, water meter
Optical, light, imaging, photon	Contact image sensor, infra-red sensor……..

Connect : Pervasive Network

- The communications layer is the foundational infrastructure of IoT.
- There are two major communication technologies: **wireless and wired** (or wireline).
- When talking about **IoT, wireless communications** is the topic most of the times, because three (M2M, RFID, and WSN) of the four IoT pillars are based on wireless

Wired Communication



Wired Communication : FieldBus

- Field bus is the name of a family of **industrial computer network protocols** used **for real- time distributed** control of nodes.
- Standardized as **IEC 61158**
- **Field** refers to **geographical area** or contextual area in industry where IOT devices are distributed
- **Bus** refers to the **electrical medium** that carries **data** through it.

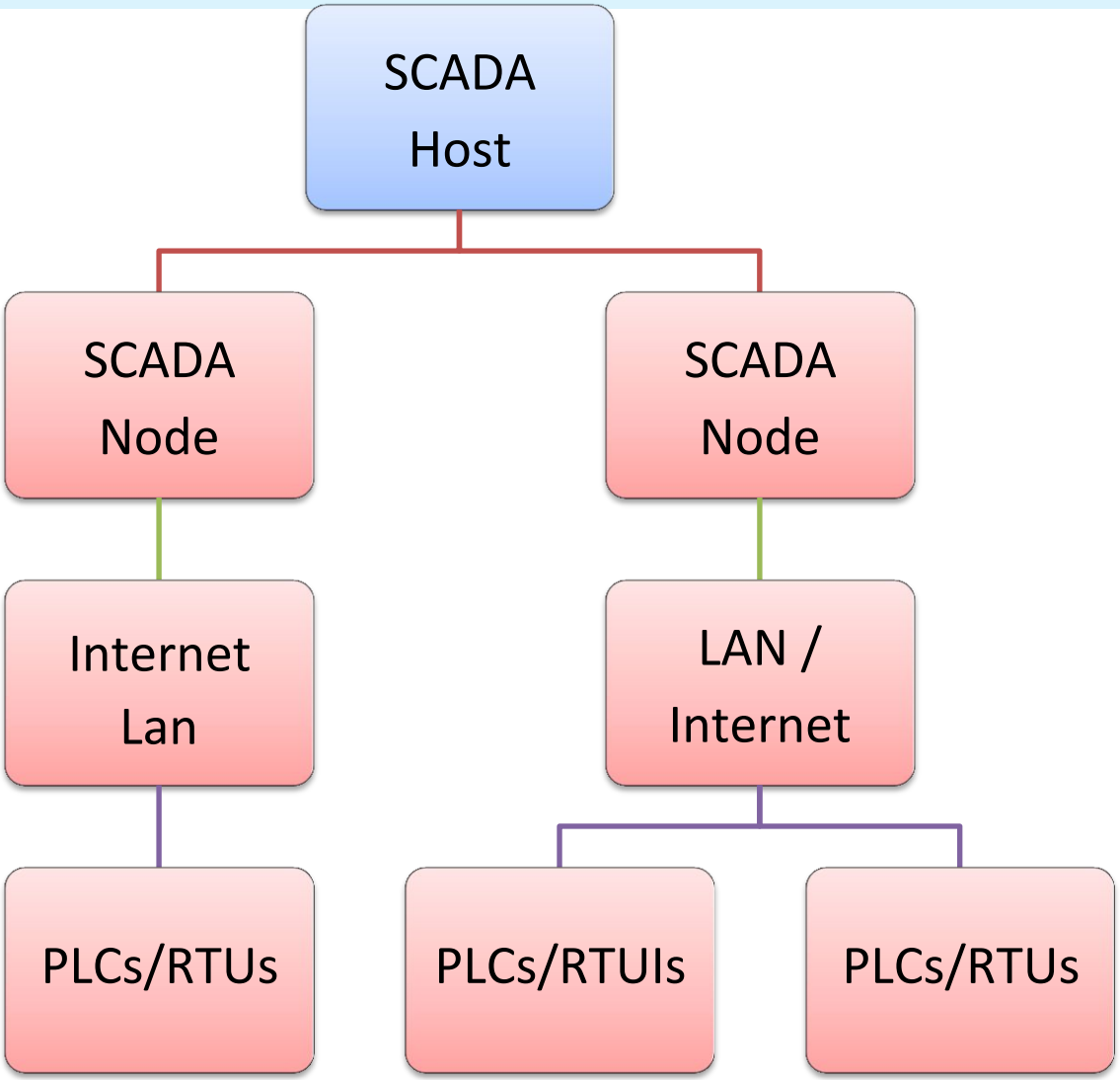
Wired Communication : FieldBus

- **Field bus has Eight different protocol sets**
  - **Type 1:** Foundation field bus H1
  - **Type 2** ControlNet
  - **Type 3** PROFIBUS
  - **Type 4** P-Net
  - **Type 5** FOUNDATION field bus HSE (high-speed Ethernet)
  - **Type 6** SwiftNet (a protocol developed for Boeing, since withdrawn)
  - **Type 7** WorldFIP
  - **Type 8** Interbus

Wired Communication : FieldBus

- Most use **Twisted pair or optical fiber** as a physical communication medium
- **Uses bidirectional communication** between the field instruments and HMI..
- Mainly **used for SCADA Based Applications**

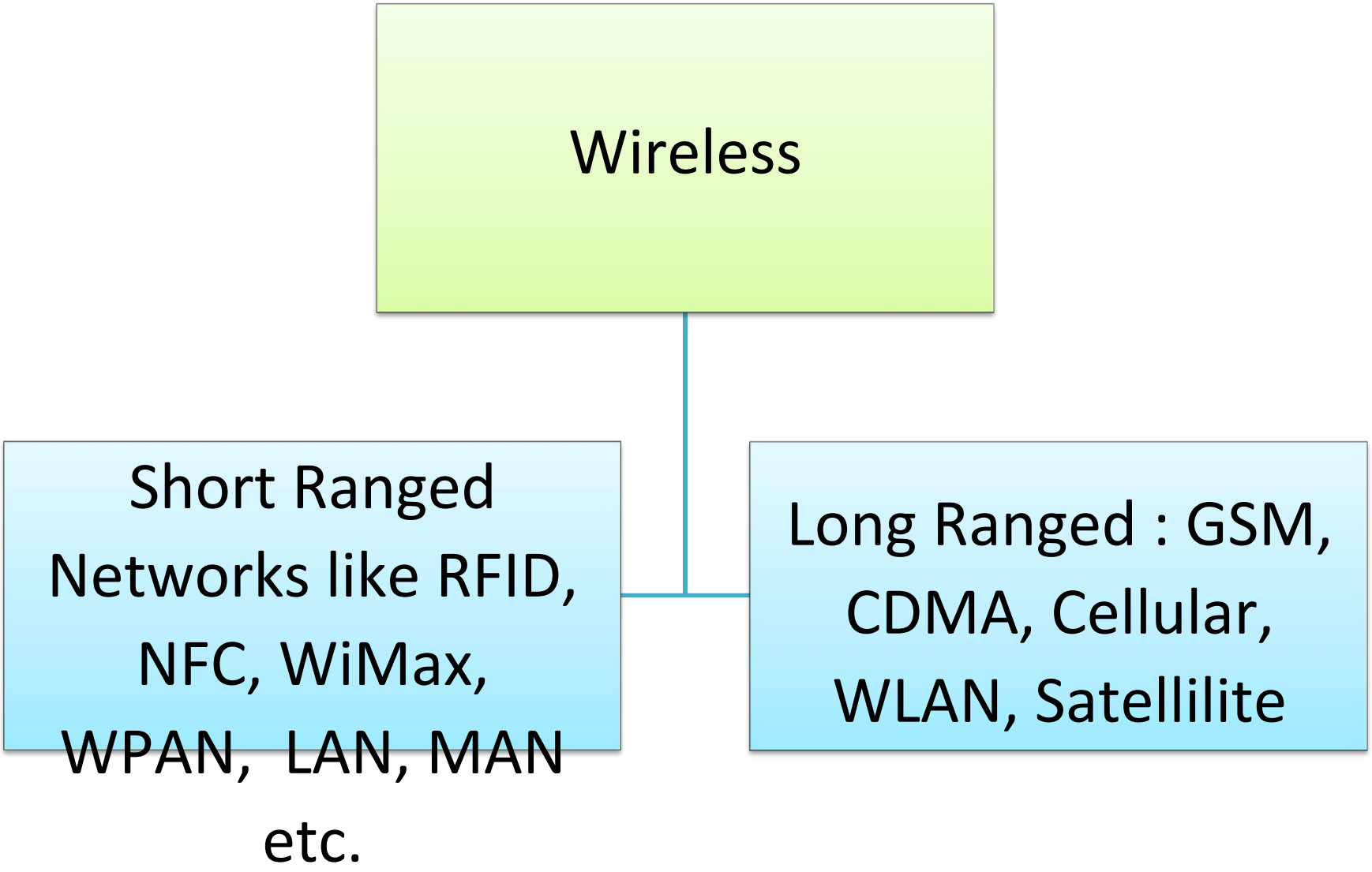
Wired Communication : FieldBus Communication



Examples for FieldBus

- **Automatic meter Reading :** ModBus
- **Home Automation :** Bacnet
- **Power Automation :** Profibus

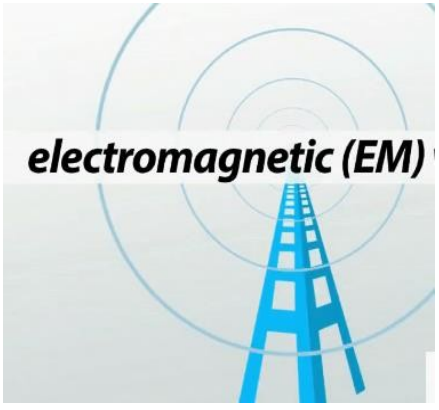
Wireless Communication

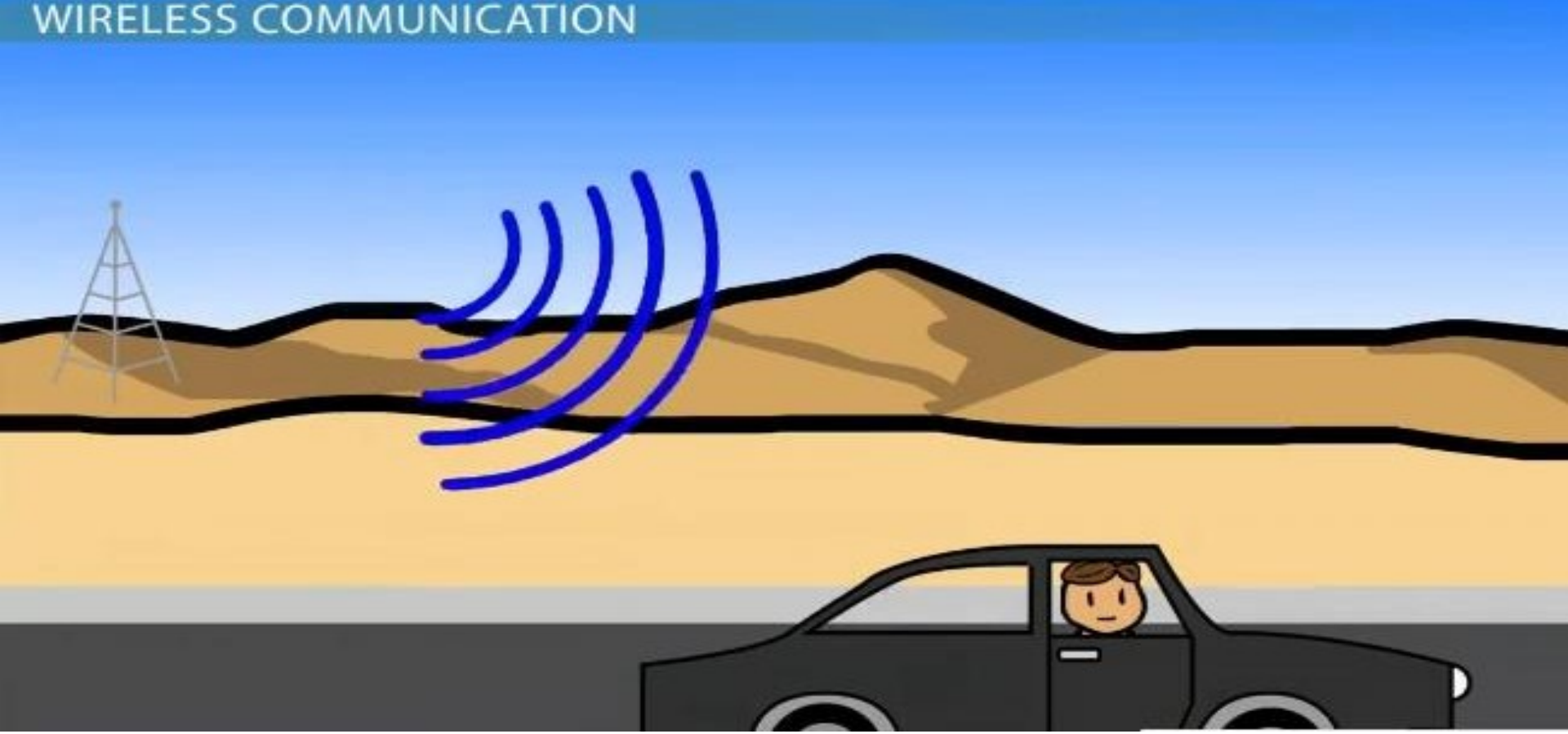


Wireless Network

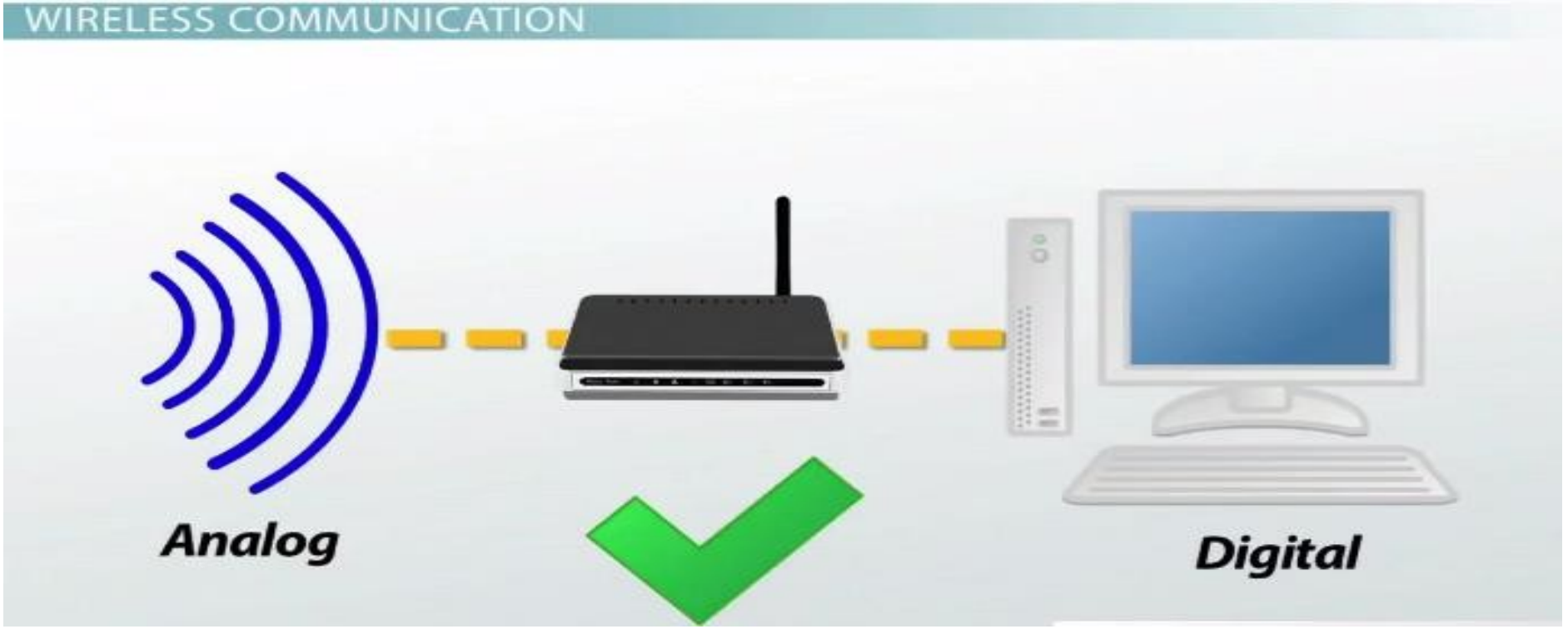
any type of network that establishes connections without cables

- Wireless Communication **use electromagnetic waves** that travel through the air
- Simplest example of this is : **Radio**





- When we listen radio in a moving car we are actually receiving radio waves which is one type of electromagnetic wave.

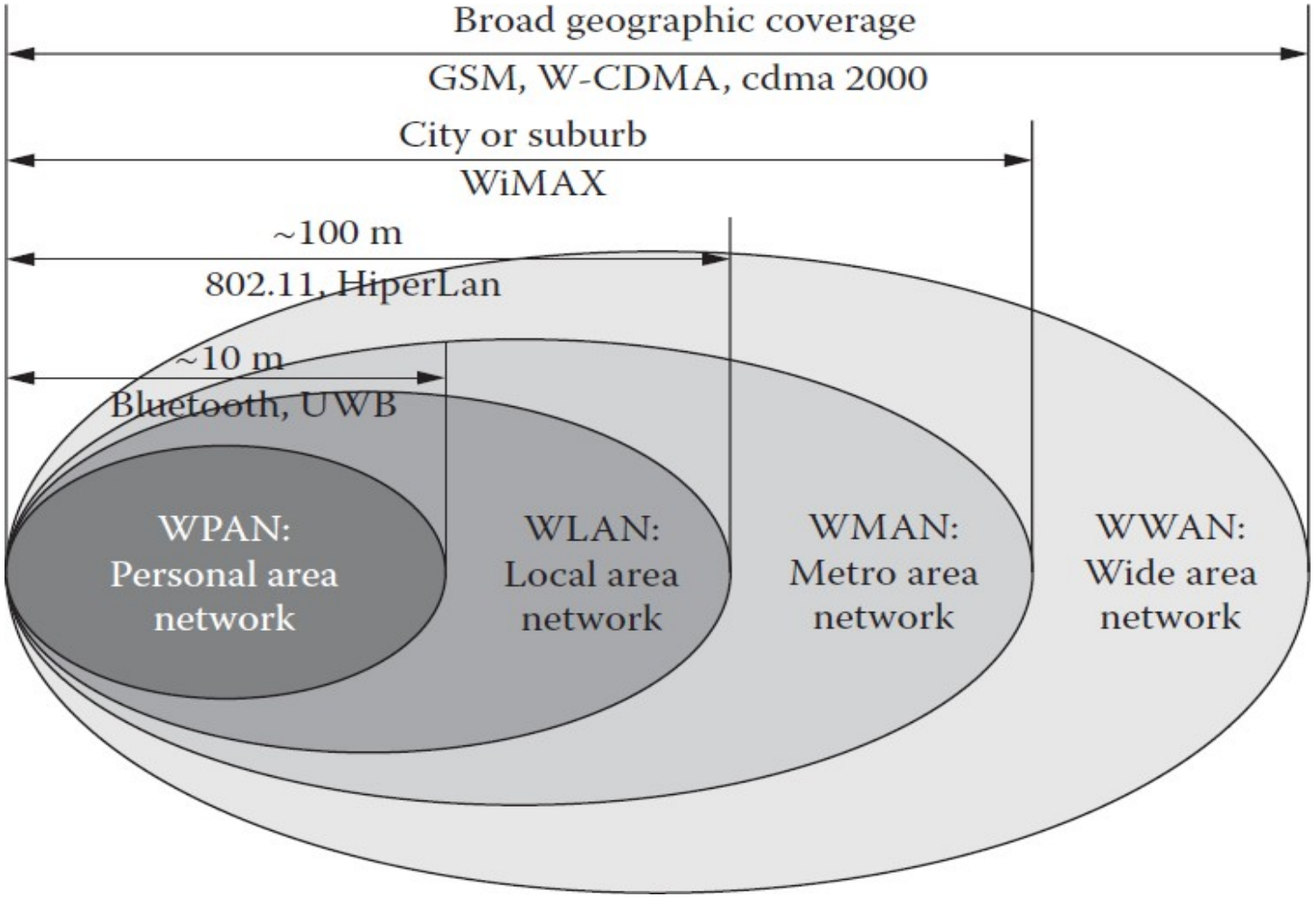


- Electromagnetic waves are analog whereas

information in computer is digital; **wireless systems therefore need adapter for analog to digital conversion.**

Categories of Wireless Communication

Short and long range wireless n/w's



Standards of Wireless n/w

- **RFID** and **NFC** are parts of WPAN.
- **6LowPAN** (IPv6 over low power wireless personal area networks)
- **BSN** (Body Sensor n/w)
- **HomeIR**: wireless IR home networking
- **HomeRF**: wireless RF home networking

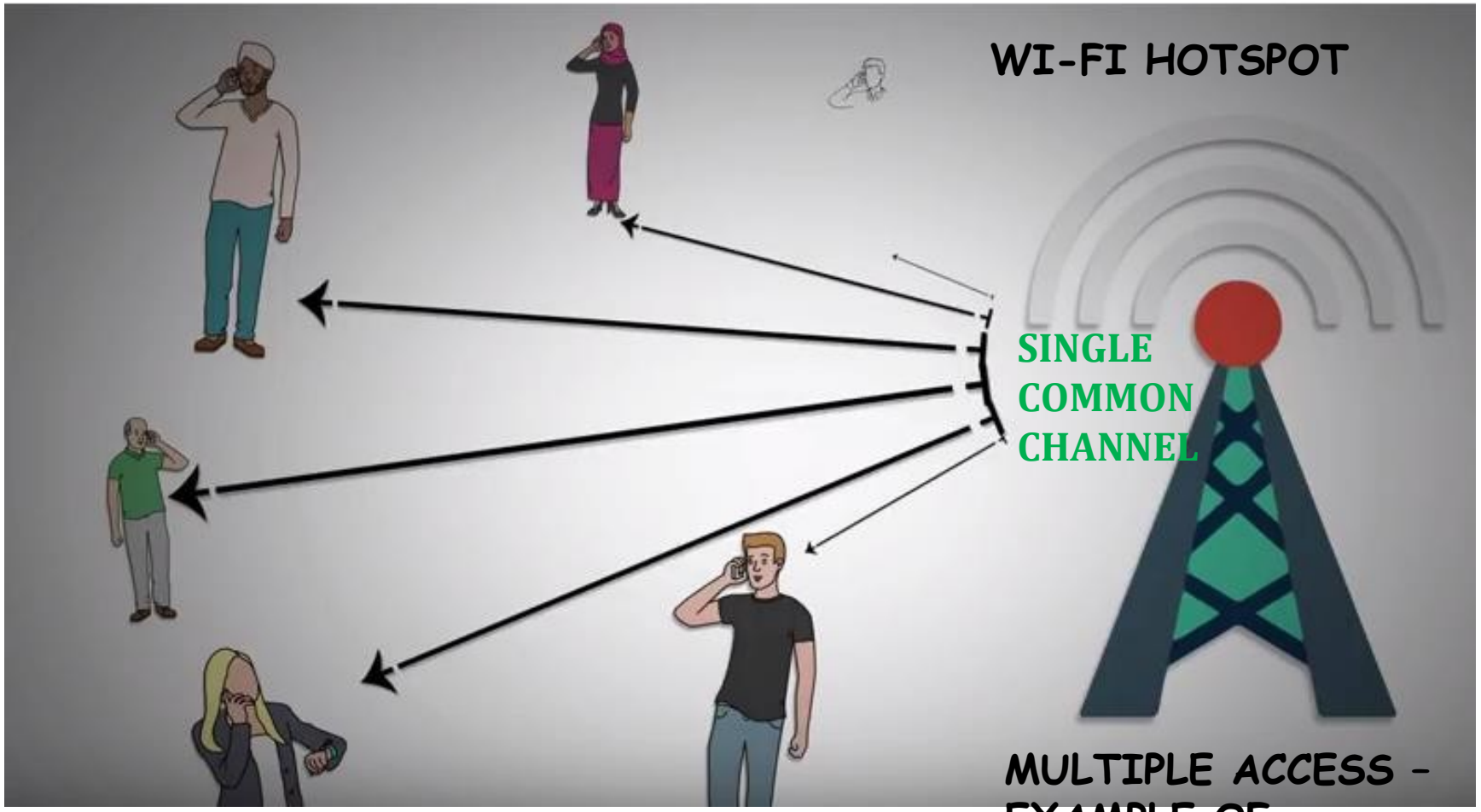
Communication Mechanisms of Wireless n/w

- Orthogonal frequency division multiplexing (**OFDM**) and orthogonal frequency division multiple access(**OFDMA**)
- Ad hoc sensor network
- Software defined radio (**SDR**)
- Cognitive radio (**CR**)

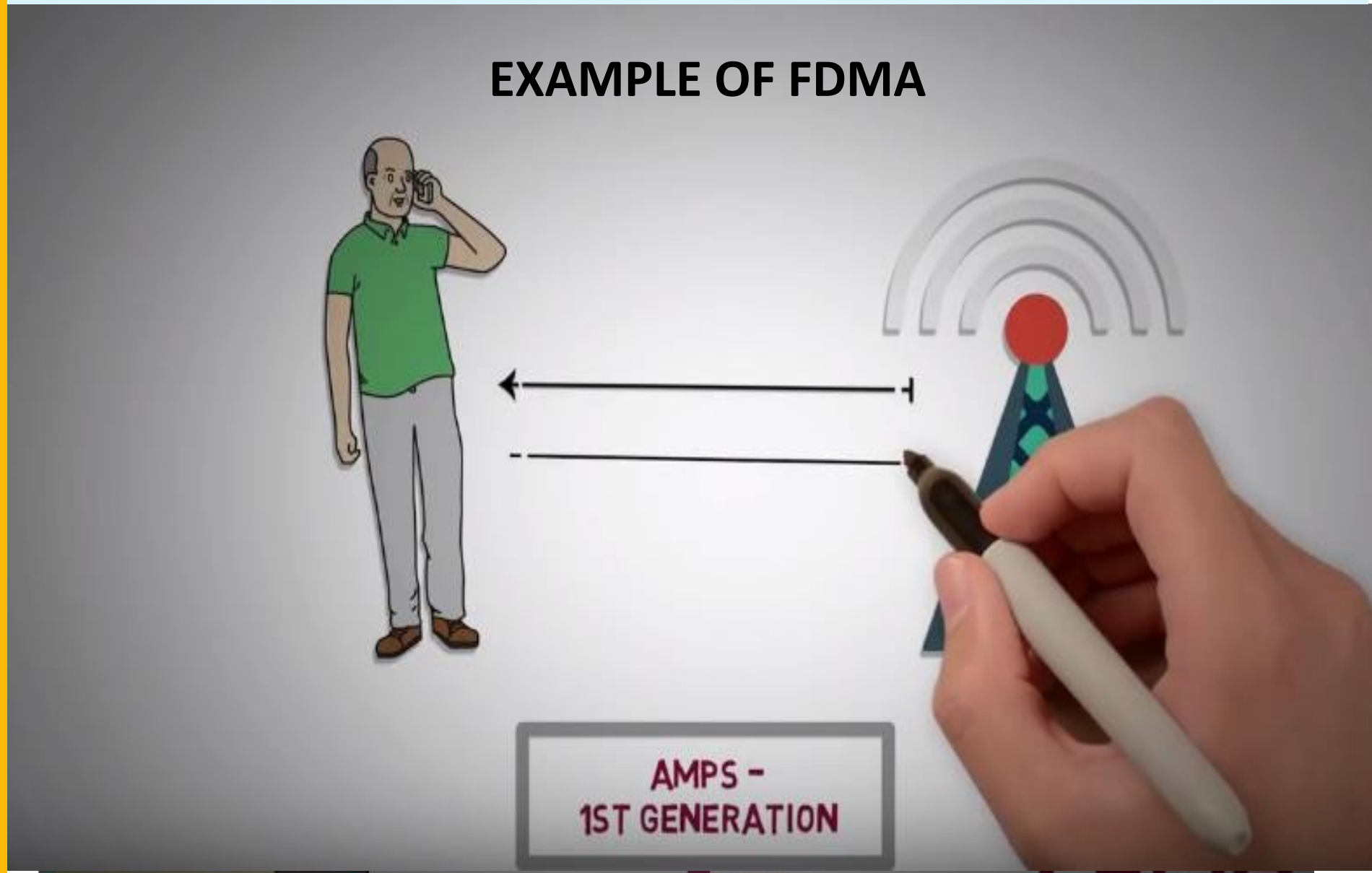
OFDM/OFDMA

- These are two different variants of the same **broadband wireless air interface**.
- **Long-Term Evolution (*LTE*)** the standard for **high- speed wireless communication** used for mobile devices and data terminal is an **OFDMA-based** technology **standardized in** *3rd Generation Partnership Project* (**3GPP**).
- Typically occupy roaming, fixed, and one-way transmission standards, ranging from TV transmission to Wi-Fi as well as fixed WiMAX and newer multicast wireless systems

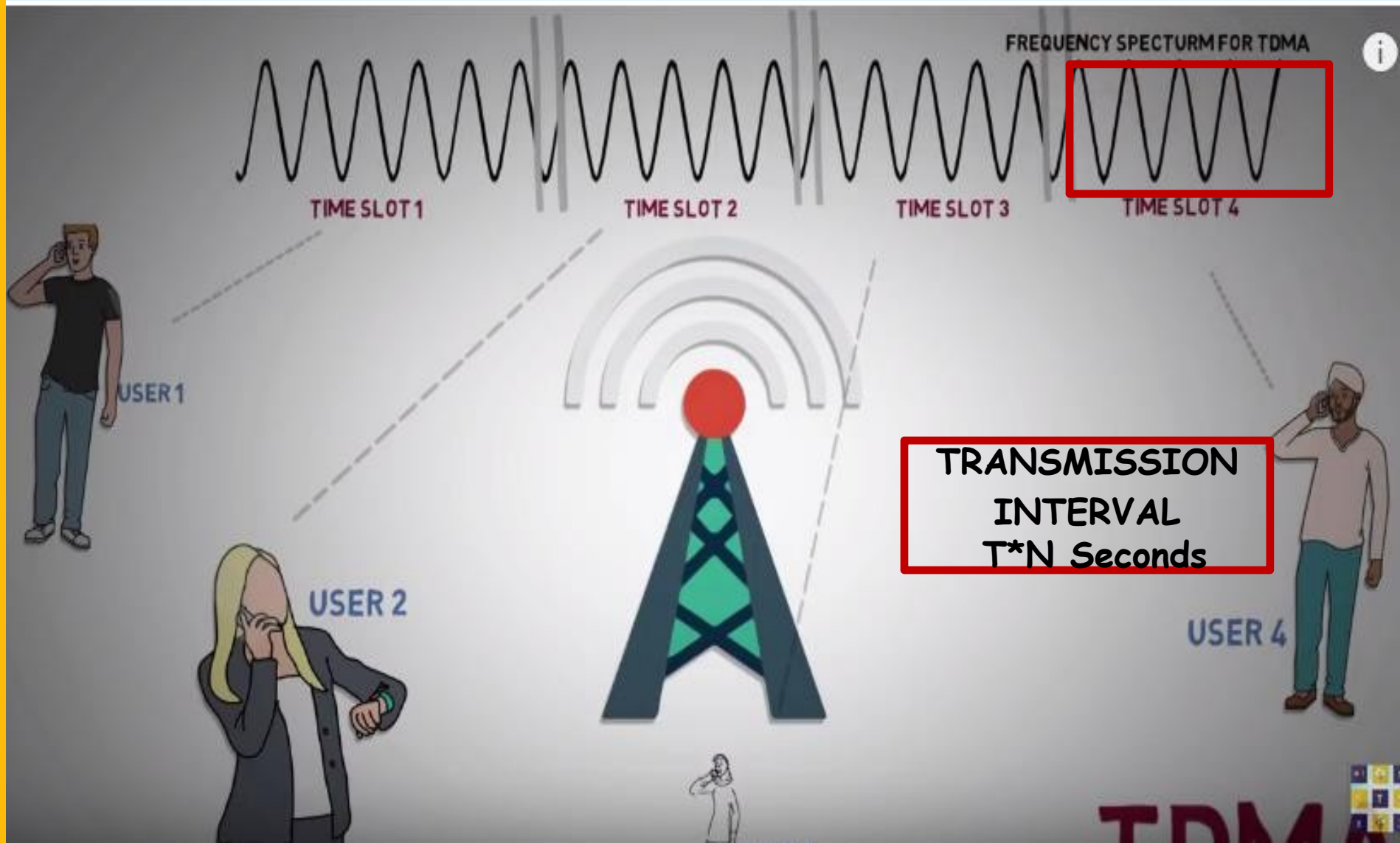
Multiple Access



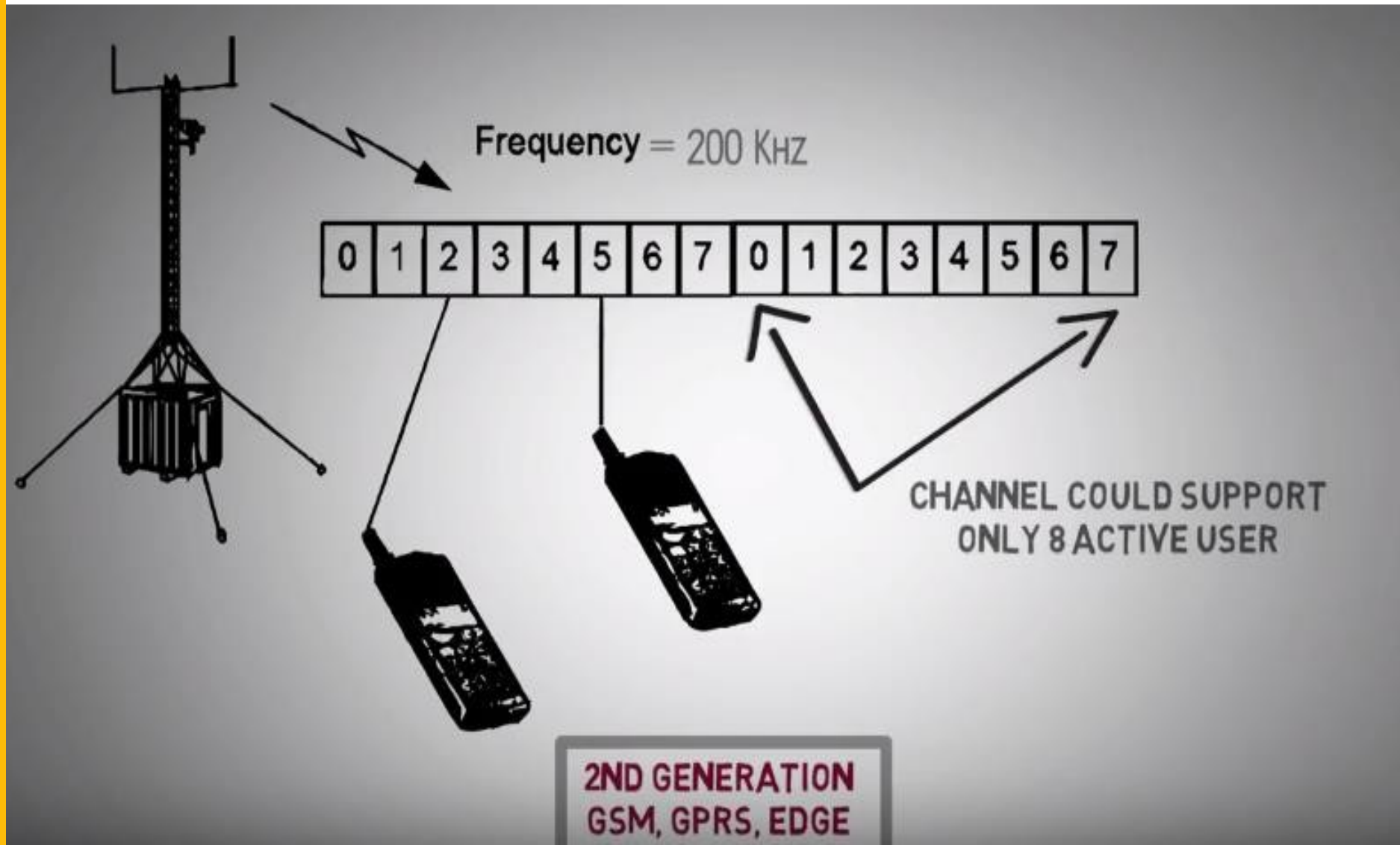
FDMA



TDMA


FREQUENCY SPECTURM FOR TDMA
TIME SLOT 1
TIME SLOT 2
TIME SLOT 3
TIME SLOT 4
USER 1
USER 2
USER 4
TRANSMISSION
INTERVAL
T*N Seconds

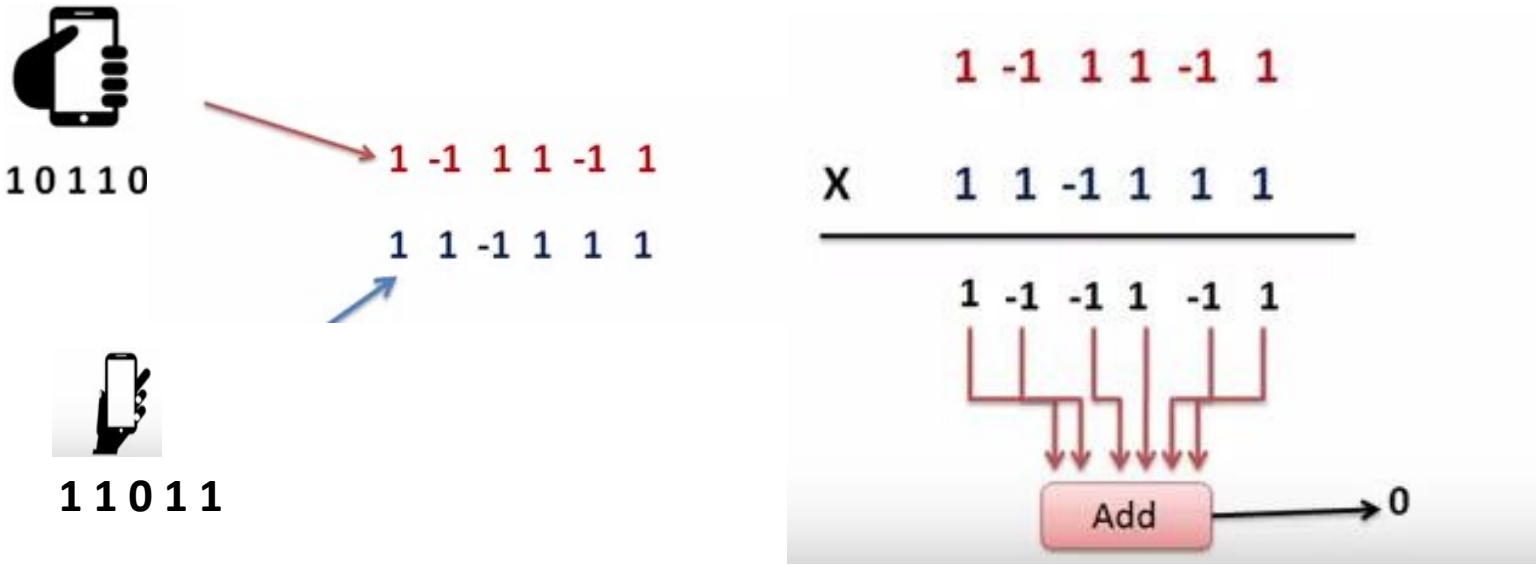
EXAMPLE OF TDMA



CDMA

Every User in CDMA get a unique code which is known as chipping sequence.

These codes are orthogonal which means if these codes are multiplied together , it will give zero. (consider 0 as -1)



CDMA ..>Encoding

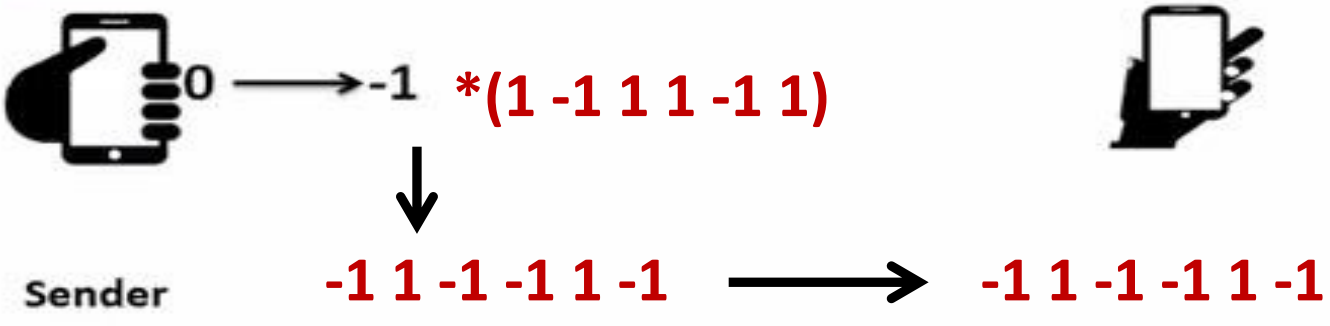
Encoding of Data : Data is encoded using chipping sequence.
In chipping sequence and data, consider 0 as -1

Chipping Sequence :1 0 1 1 0 1

chipping sequence :1 -1 1 1 -1 1

Saved Sequence : 1 0 1 1 0 1

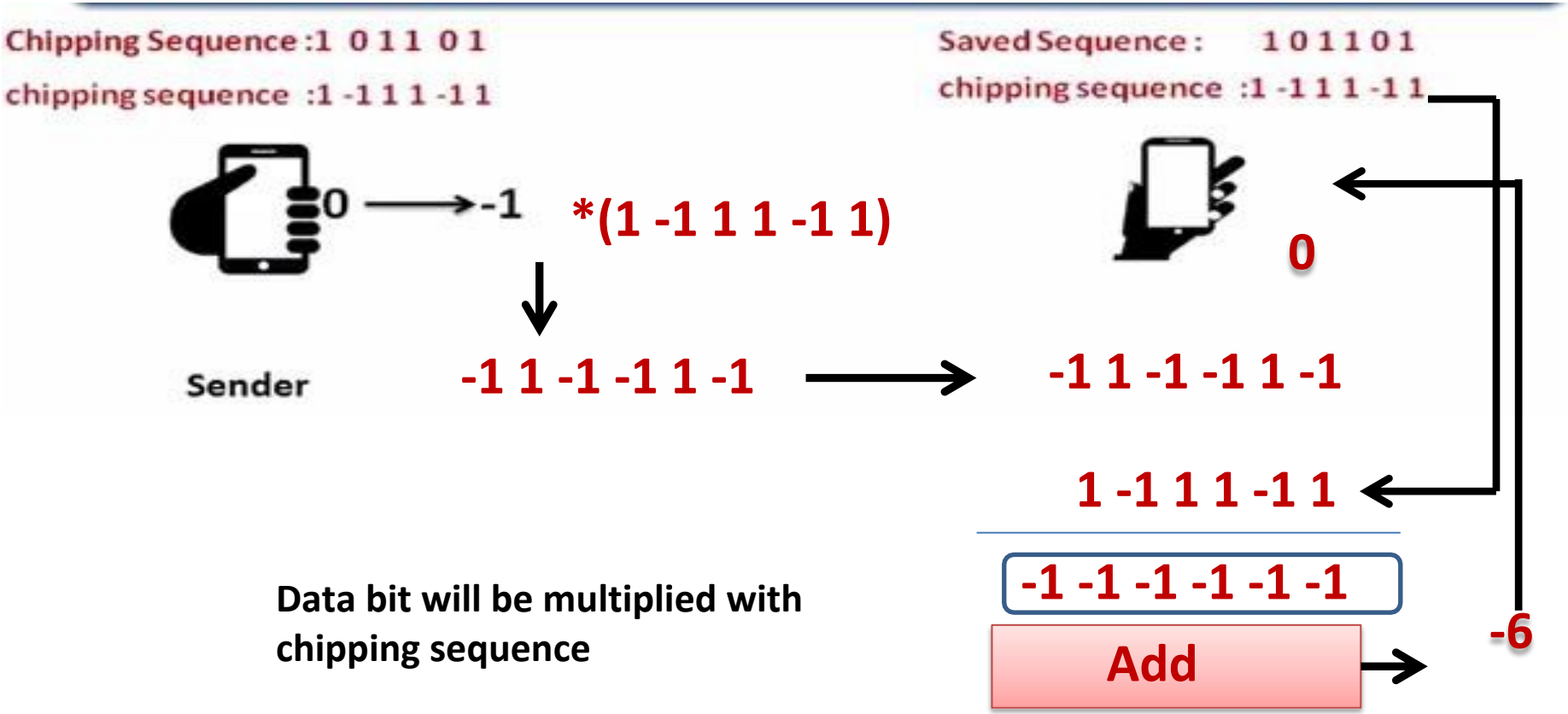
chipping sequence :1 -1 1 1 -1 1



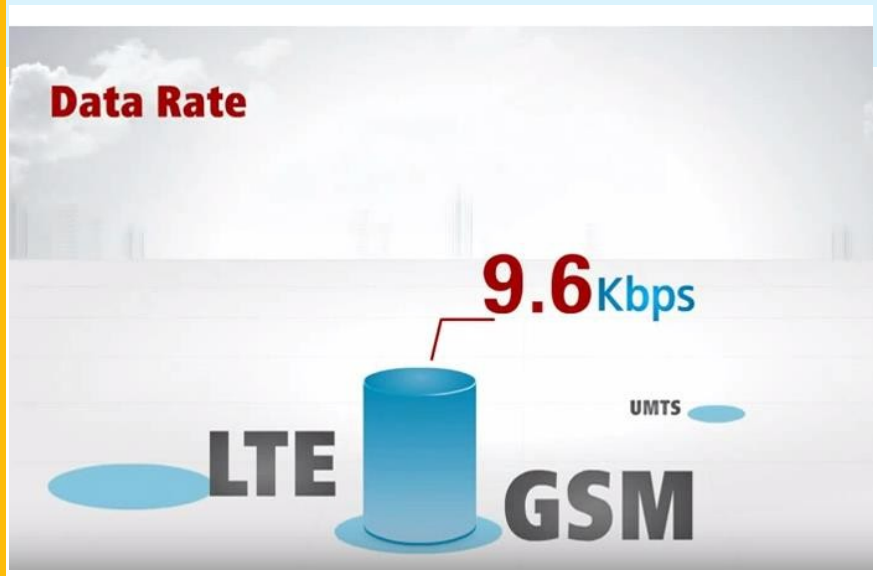
Data bit will be multiplied with every bit of chipping sequence

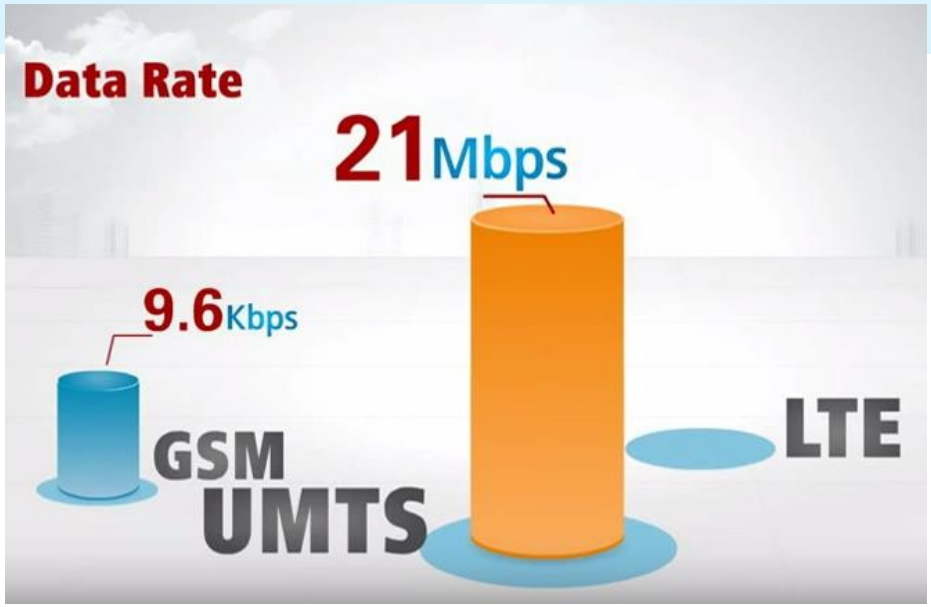
CDMA…>Decoding

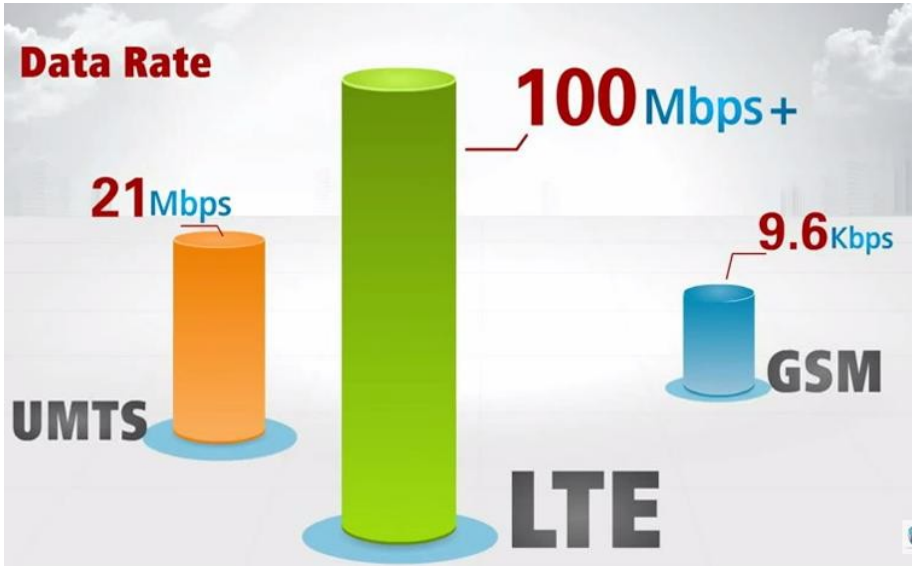
Decoding of Data : Decoding of data done by multiplying received signal with chipping sequence.

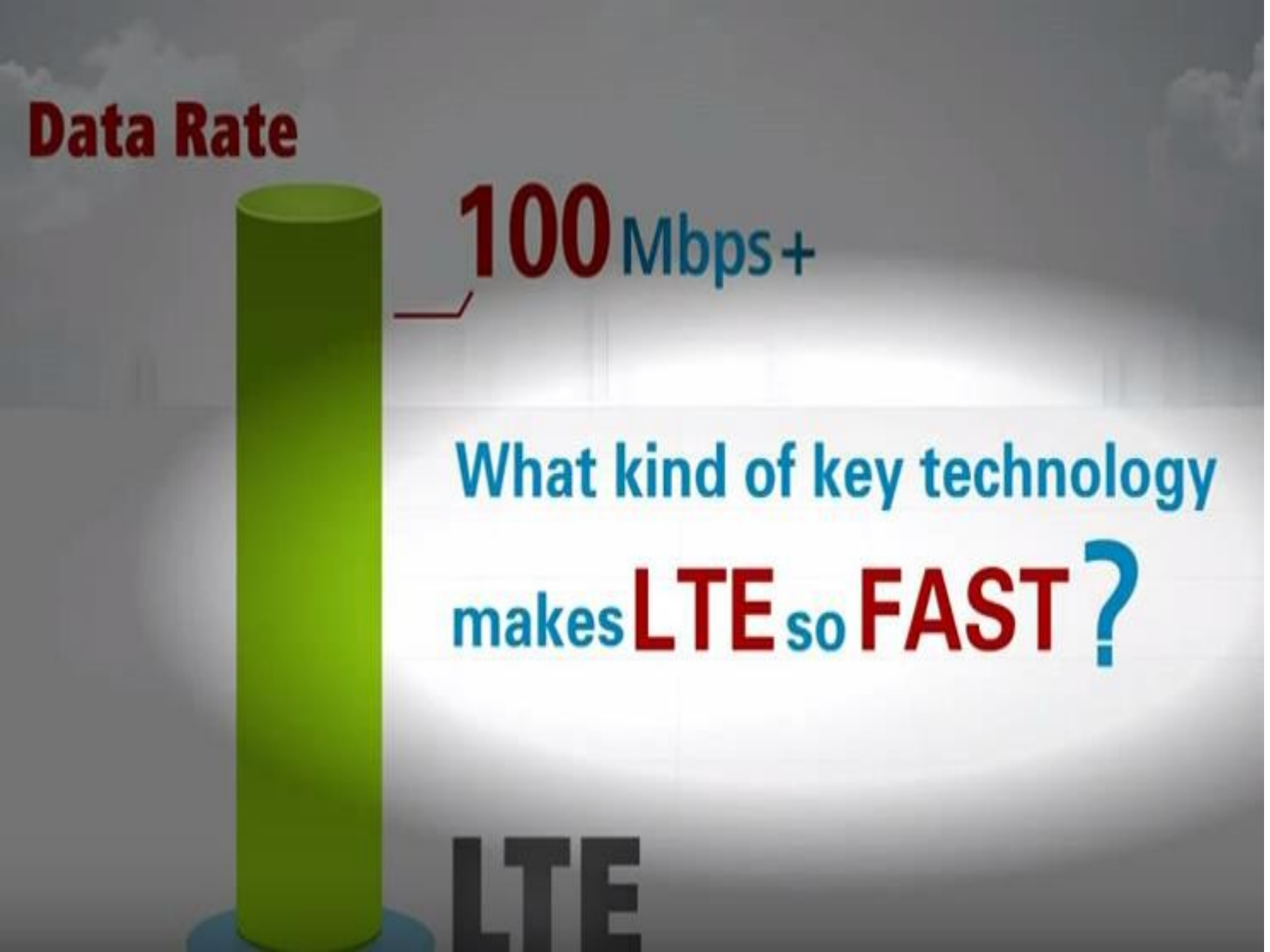


OFDM


Data Rate
9.6Kbps
LTE
UMTS
GSM


Data Rate
21Mbps
9.6Kbps
GSM
UMTS
LTE


Data Rate
100Mbps+
21Mbps
9.6Kbps
UMTS
GSM
LTE


Data Rate
100 Mbps +
What kind of key technology
makes LTE so FAST ?
LTE

OFDM

Orthogonal Frequency Division Multiplexing

FDM

- FDM Divides the bandwidth into many subcarriers
- And hence allows multiple users to access the system simultaneously

FDM

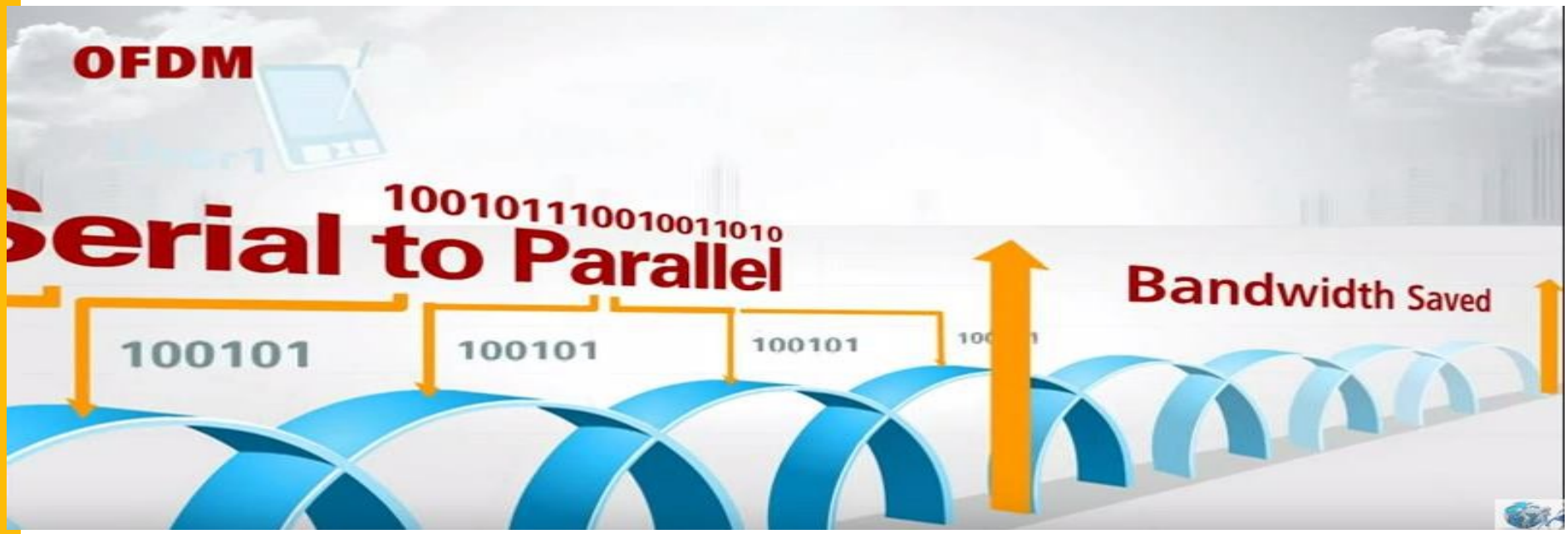
- Different users data gets transmits at different subcarriers
- Between Subcarriers there exists a **guard band** to avoid inteference

Multicarrier FDM

- In multicarrier FDM the data of a single user can be splitted into multiple sub streams and send them in parallel to make the data rate higher.

OFDM

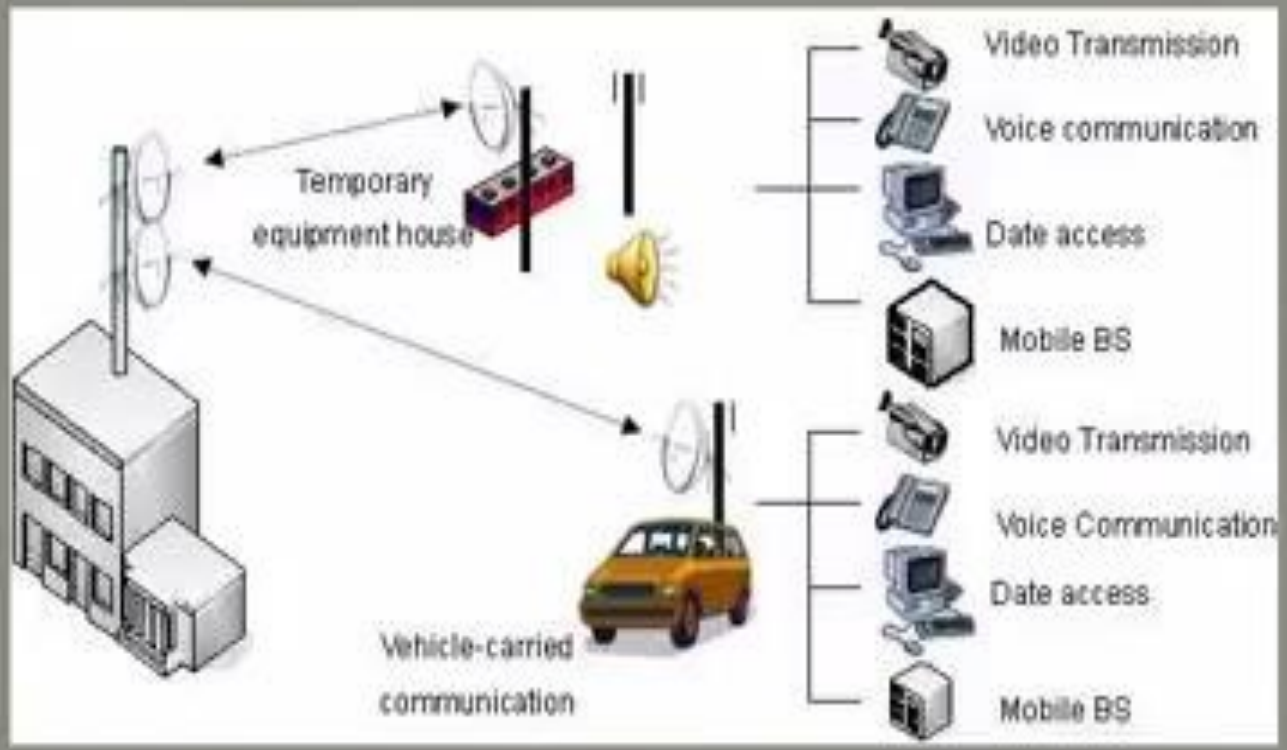
- In OFDM Subcarriers are orthogonal which allows subcarriers to overlap and hence save the bandwidth and achieving higher data rate.



Adhoc Sensor n/w

- **a short-lived network** of two or more mobile devices connected to each other without the help of intervening infrastructure
- an ad hoc network can be deployed in **remote geographical locations** and **requires minimal setup and administration costs.**
- **Said to be emergency and temporary network**

Adhoc Sensor n/w

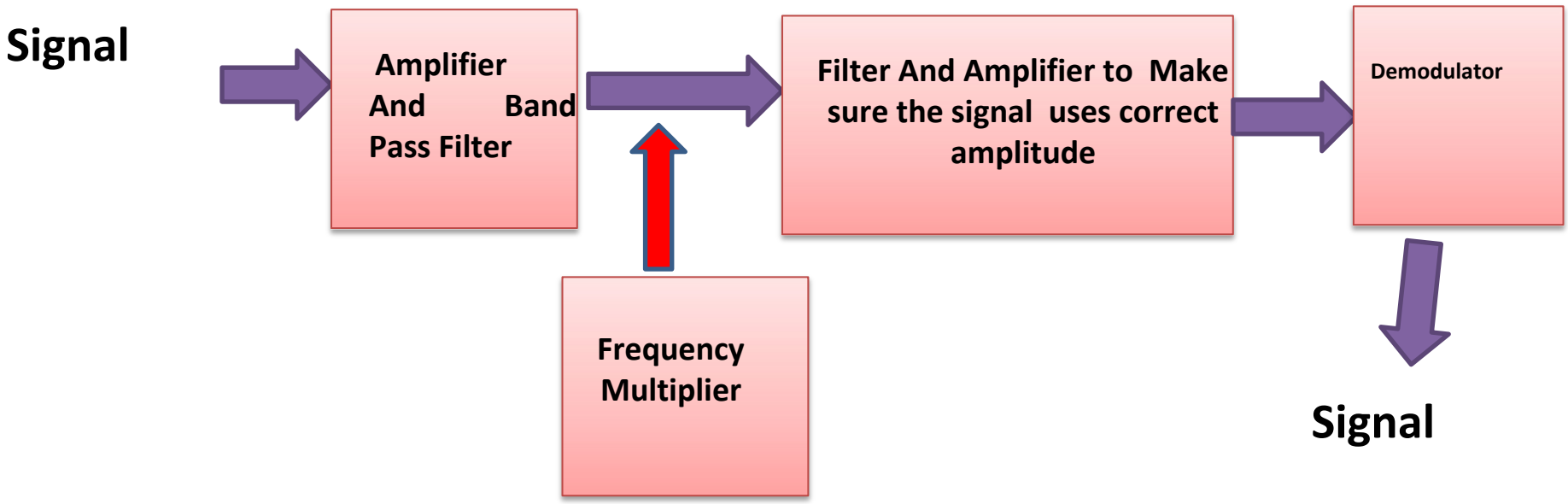


Software Defined Radio

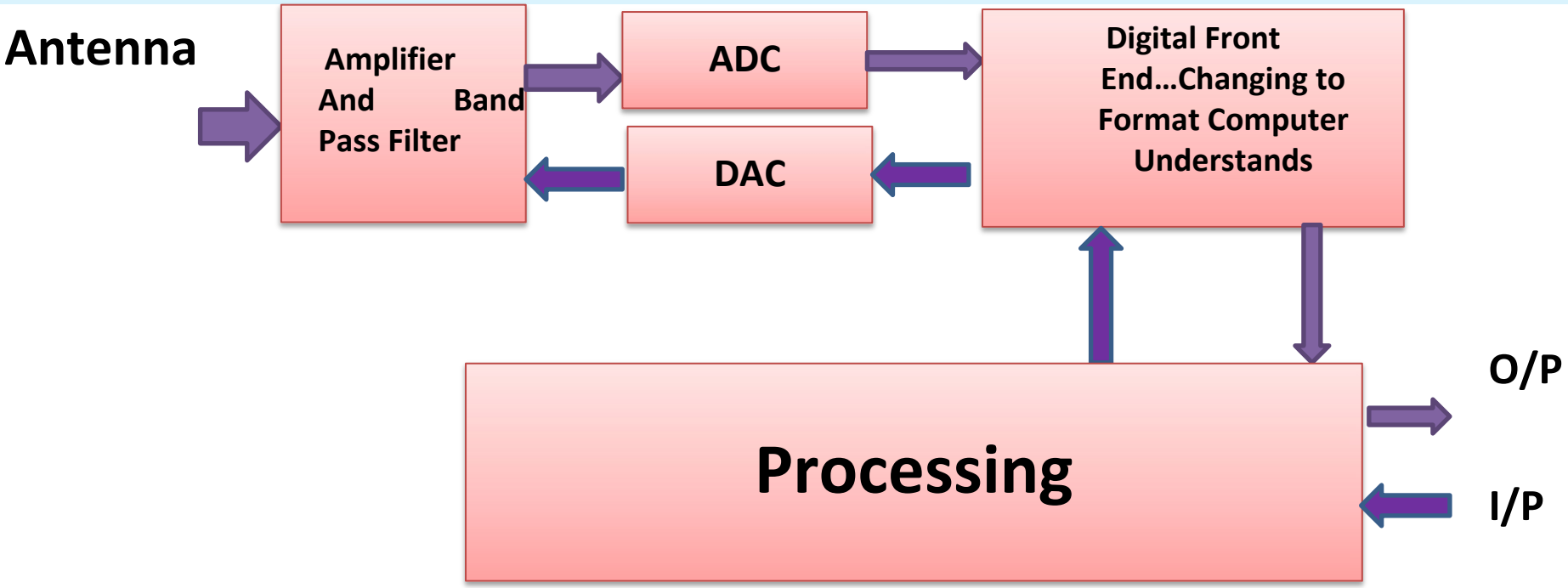
- Using Software to replace Hardware to modulate the signals.
- **Hardware is Still needed for RF** front end and **ADC** (Analog to Digital Converter)/ DAC (Digital to Analog Converter)

- Advantage : We can receive many signals with single piece of hardware

H/w Radio Receiver



Software Defined Radio



Software Defined Radio

- SDR is the result of an evolutionary process from purely hardware-based equipment to fully software- based equipment.
- **All functions, modes, and applications, such as transmit frequencies, modulation type, and other RF parameters, can be configured and reconfigured by software**
- Software-defined refers to the use of software processing within the radio system or device to implement operating (but not control) functions

Cognitive Radio

- **CR is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones.**
- This optimizes the use of available RF spectrum while minimizing interference to other users SDR is a required basic platform on which to build a CR.
- **Cognitive radios are radios that are aware of their environment and internal state and can make decisions about their radio operating behavior based on that information and predefined objective.**

Satellite IoT

- https://www.youtube.com/watch?v=hXa3bTcI GPU

Manage : TO Create Business Values

The business value of IoT comes from knowing how, when, and where to use the data in value-adding ways.

With IoT and analytics it is possible to make **business predictable : E.g : predict when machinery would need maintenance**

Manage : TO Create Business Values

Video analytics for **b2c environment**

- Installed equipment that use video cameras for detecting customers' features like age, gender and customer's mood. Based on the analysis the software determines which ad to display to each customer.
- These insights can be used to boost sales, help the customer find what they are looking for quicker and to test the attractiveness of different products, services and marketing messages.

Manage : TO Create Business Values

SnapSkan

- a service that detects tire tread depth when a customer drives into a parking hall.
- The depth of the tire tread is automatically scanned at the entrance and connected to the car's register plate number (only when customer makes query), ready to be presented to the customer when he makes the request via text message.

Manage : TO Create Business Values

Two Categories of IoT Business Value

- Increase Revenue
- Reduce Cost

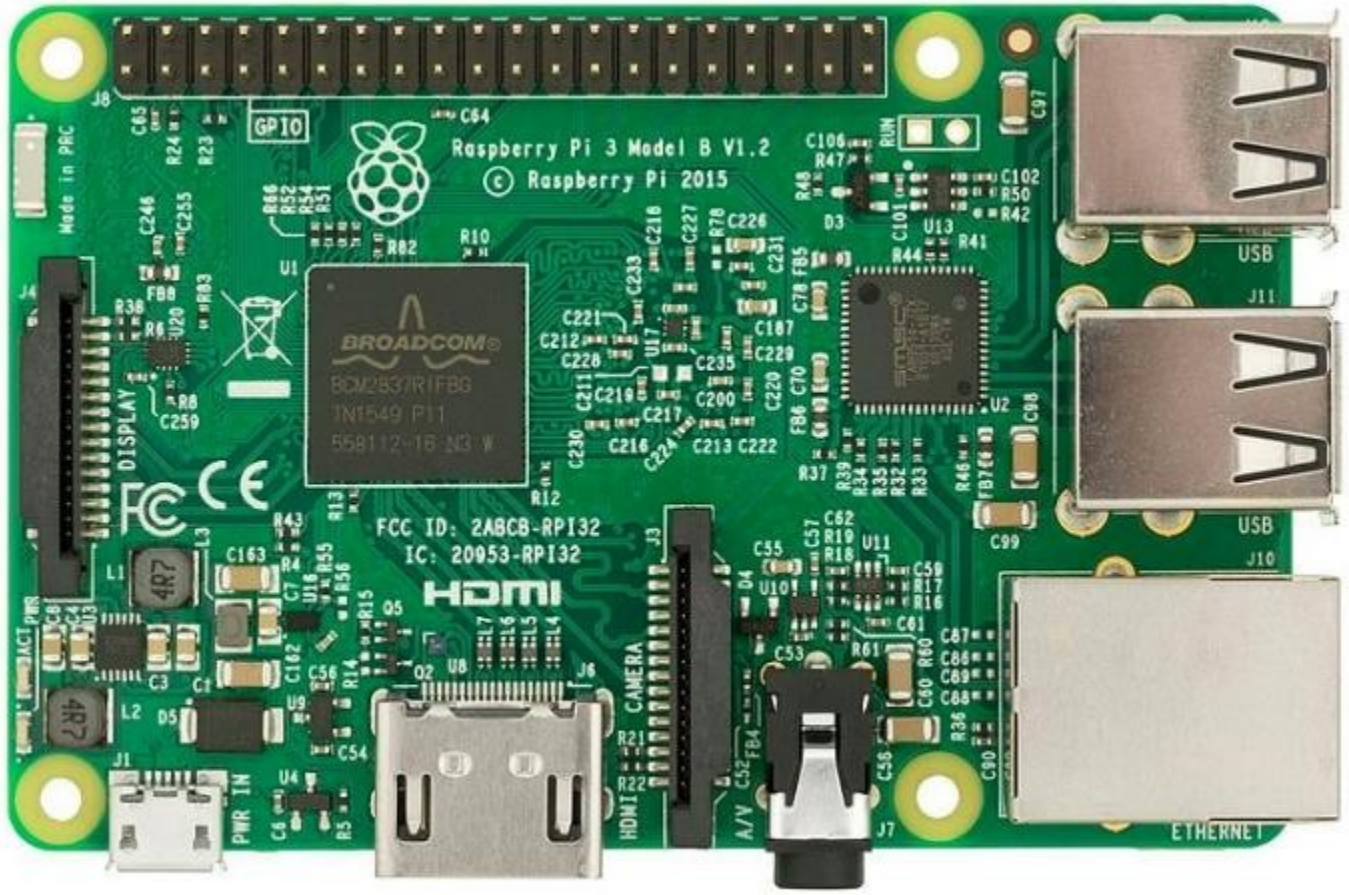
Manage : TO Create Business Values

- https:/www.youtube.com/watch?v=DfkGr8FurO

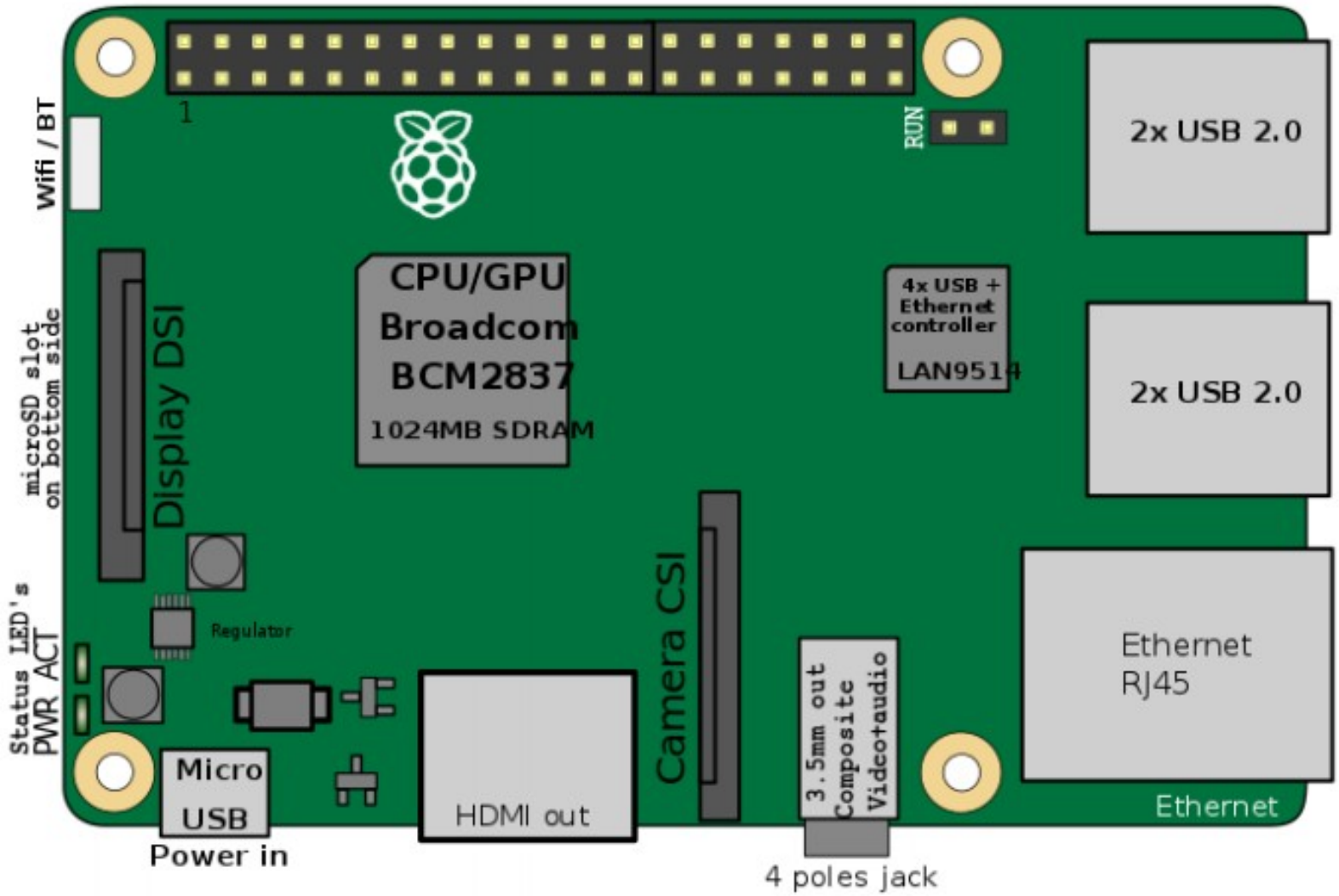
Raspberry Pi

- The Raspberry Pi is a **series of small single-board computers** developed in the **United Kingdom** by the **Raspberry Pi Foundation** to promote the teaching of basic computer science in schools and in developing countries.

Raspberry Pi 3 Model B



Raspberry Pi 3 Model B



Raspberry Pi …TimeLine

- The first generation (Raspberry Pi 1 Model B) was released in February 2012.
- It was followed by a simpler and inexpensive model Model A.
- In 2014, the foundation released a board with an improved design in Raspberry Pi 1 Model B+. These boards are approximately credit-card sized and represent the standard mainline form-factor.
- Improved A+ and B+ models were released a year later. A "compute module" was released in April 2014 for embedded applications, and a Raspberry Pi Zero with smaller size and reduced input/output (I/O) and general- purpose input/output (GPIO) capabilities was released in November 2015 for US$5.

Raspberry Pi …TimeLine

- The Raspberry Pi 2 which added more RAM was released in February 2015.
- Raspberry Pi 3 Model B released in February 2016, is bundled with on-board WiFi, Bluetooth and USB boot capabilities.
- As of January 2017, Raspberry Pi 3 Model B is the newest mainline Raspberry Pi. Raspberry Pi boards are priced between US$5–35.
- As of 28 February 2017, the Raspberry Pi Zero W was launched, which is identical to the Raspberry Pi Zero, but has the Wi-Fi and Bluetooth functionality of the Raspberry Pi 3 for US$10.

Raspberry Pi …Features

- Features a Broadcom **system on a chip** which includes an **ARM compatible** central processing unit (**CPU**) and an on-chip graphics processing unit (**GPU**).
- CPU speed ranges from **700 MHz to 1.2 GHz** for the Pi 3 and on board memory range from **256 MB to 1 GB RAM**.
- **Secure Digital (SD) cards are used to store the operating system** and program memory in either the SDHC or MicroSDHC sizes.

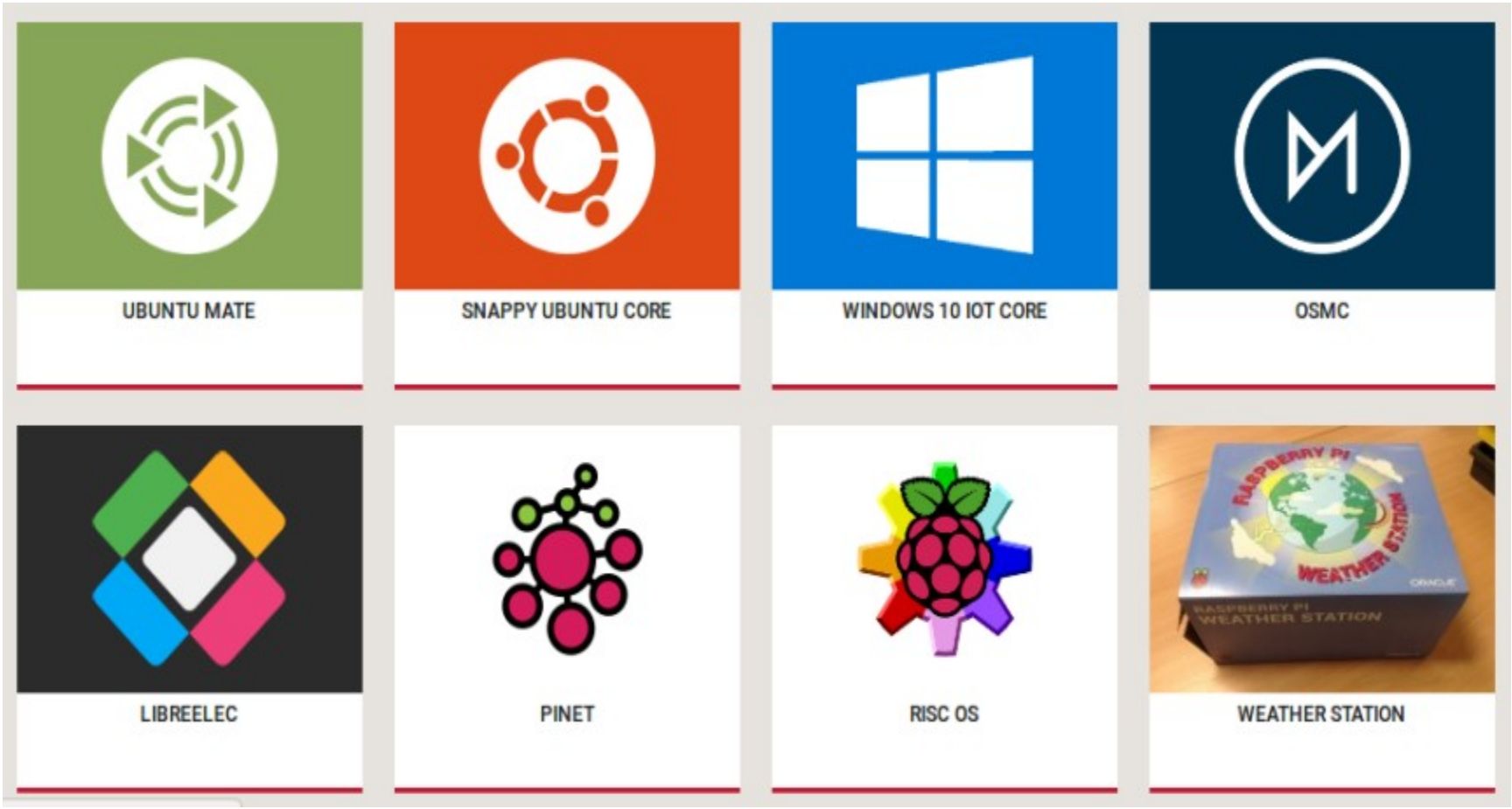
Raspberry Pi …Features

- Most boards have between **one and four USB** slots, **HDMI and composite video output**, and a **3.5 mm phono jack for audio**.
- **Lower level output** is provided by a number of **GPIO pins** which support common protocols like I^2C.
- The B-models have an 8P8C **Ethernet port** and the Pi 3 and Pi Zero W have **on board Wi-Fi 802.11n and Bluetooth.**

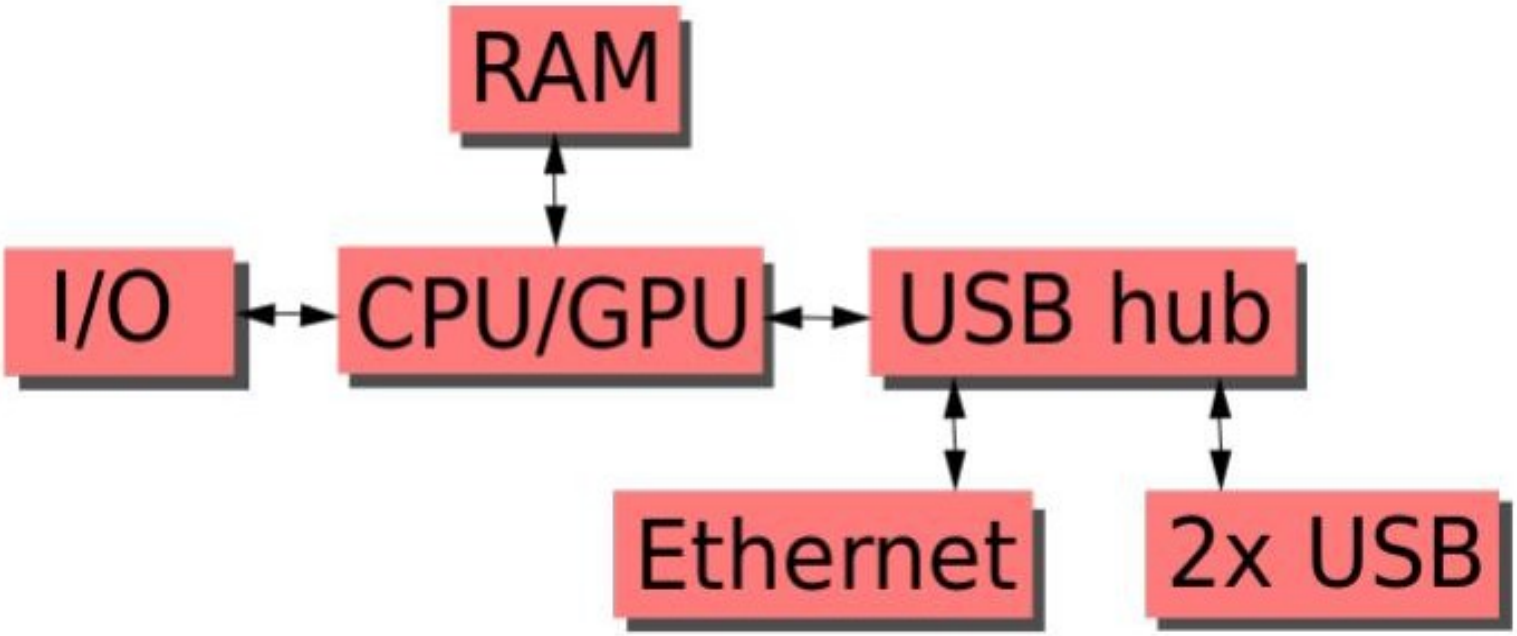
Raspberry Pi …Operating System

- The Foundation provides **Raspbian**, a Debian- based Linux distribution for download, as well as third party **Ubuntu, Windows 10 IOT Core, RISC OS,** and specialised media center distributions.
- It promotes **Python and Scratch** as the main programming language, with support for many other languages.
- The default firmware is closed source, while an **unofficial open source is available**.

Raspberry Pi …Operating System



Raspberry Pi …Hardware



Raspberry Pi …Hardware

	Raspberry Pi 1 Model A	Raspberry Pi 1 Model A+	Raspberry Pi 1 Model B	Raspberry Pi 1 Model B+	Raspberry Pi 2 Model B	Raspberry Pi 3 Model B	Raspberry Pi Zero
USB 2.0 Ports	1	1	2	4	4	4	1 (Micro-USB)
Ethernet	None	None	10/100 Mbit/s	10/100 Mbit/s	10/100 Mbit/s	10/100 Mbit/s	None
Bluetooth	None	None	None	None	None	4.1	None
WiFi	None	None	None	None	None	802.11n	None
Audio In	I²S	I²S	I²S	I²S	I²S	I²S	I²S
Audio Out	I²S, analog (3.5mm jack), digital (HDMI)	I²S, analog (3.5mm jack), digital (HDMI)	I²S, analog (3.5mm jack), digital (HDMI)	I²S, analog (3.5mm jack), digital (HDMI)	I²S, analog (3.5mm jack), digital (HDMI)	I²S, analog (3.5mm jack), digital (HDMI)	Digital (mini-HDMI), analog GPIO PWM
Video In	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	CSI Camera Connector	None
Video Out	HDMI, Composite (RCA)	HDMI, Composite (TRRS)	HDMI, Composite (RCA)	HDMI, Composite (TRRS)	HDMI, Composite (TRRS)	HDMI, Composite (TRRS)	Mini-HDMI, GPIO Composite
External Storage	SD	MicroSD	SD	MicroSD	MicroSD	MicroSD	MicroSD

Other Boards

- BeagleBone
- Banana Pi
- Orange Pi
- Ordroid

Other Boards

Parameter	Rpi	Orange Pi	Banana Pi	Odroid	Beaglebone
SOC Vendor	BroadCom	AllWinner	AllWinner	Amlogic	OMAP
CPU	Cortex A53	Cortex A7	Cortex A7	Cortex A53	CortexA8
CPU Freq	1.2 GHz	1.2-1.6GHz	1.8GHz	2GHz	1GHz
Memory	1GB	2GB	2GB	2GB	512MB
USB 2.0	400MHz	4+1 OTG	2+1OTG	4+1OTG	4+1
Ethernet	100Mb	1GB	1GB	1Gb	100Mb
Wireless	802.11n	802.11n	802.11n	None	None
Bluetooth	4.1	None	4.0	None	None
HDMI	1200P60	4KP30	1200P60	4K60	16b
Android	No	Yes	Yes	Yes	No

Mar 2020

- Q. 5 a) What is SCADA? What are the different blocks of SCADA [5]
- b) Justify 'the three-layer DCM classification is more about the IoT value chain than its system architecture at runtime'. [5]
- Q. 6 a) List and explain various features of Raspberry pi board (Model B Revision 2). [5]
- b) Define and explain Horizontal, vertical application and 5A and 3I.

Mar 2019

- Q. 5 a) Q.5 a) Draw and explain the four pillars of IoT paradigms. [4M]
- Q.5 b) Justify the three layer DCM Classification is more about the IoT value chain than its system architecture at run-time? [4M]
- Q.5 c) Explain the concept of horizontal and verticals in IoT. [2M]
- Q.6 a) List and explain interfaces available with Raspberry Pi board?[3M]
- Q.6 b List and explain various features of Raspberry pi board(Model B Revision2).[4]
- Q.6 b Explain SCADA(Internet of controllers) pillar of IoT ? [3]