

### UNIT-III

**SENSORS AND ACTUATORS:** Introduction, Sensor, Types of Sensors, Actuators, classification of Actuators.

**TECHNOLOGIES USED IN IoT:** Bluetooth, Bluetooth Low Energy (BLE), WiFi, LiFi, Cellular Networks, Z-Wave, X-10, Sig fox, ZigBee, LoRaWAN, 6LowPAN, 5-G, LPWAN, RFID and NFC, WSN.

**COMMUNICATION PROTOCOLS:** CoAP, MQTT, XMPP, DDS, AMQP, REST, HTTP

Text book: Yashavant Kanetkar, Shrirang Korde, 21 IOT Experiments, 1st Edition, BPB Publications, 2018

## Bluetooth:

- Bluetooth is a **wireless personal area network(WPAN)** protocol designed by the Bluetooth special interest group(SIG).
- **Applications:** used in cellphones-providing wireless connection to a head set  
automobile's audio system- for hand free operation
- It operates in the frequency band of 2.45GHz
- Data transfer rate is 2.1Mbps

### Features:

- Short range communication
- Supports point to point or multi point applications
- Standard iot protocol for wireless data transmission
- Secure and perfect for short range, low power, low cost, and wireless transmission between electronic devices.



**Advantages:**

- Low power consumption
- It has a range better than Infrared communication
- Creates adhoc connection immediately without any wires
- Low cost

**Disadvantages:**

- Bandwidth is lower compared to WiFi
- Battery usage is more compare to the condition when Bluetooth is powered OFF.

## Bluetooth low energy(BLE):

- The BLE also known as Bluetooth 4.0 and marketed as Bluetooth smart.
- It builds personal area network to exchange the data over short distances.
- Due to improved energy consumption, it is suited for sensors and other devices that require low power.
- Data transfer rate is 1Mbps
- It is not suitable for sending data in real-time.

**Applications:** smart building, smart transportation, smart phones, fitness trackers and wearables.

### **Features:**

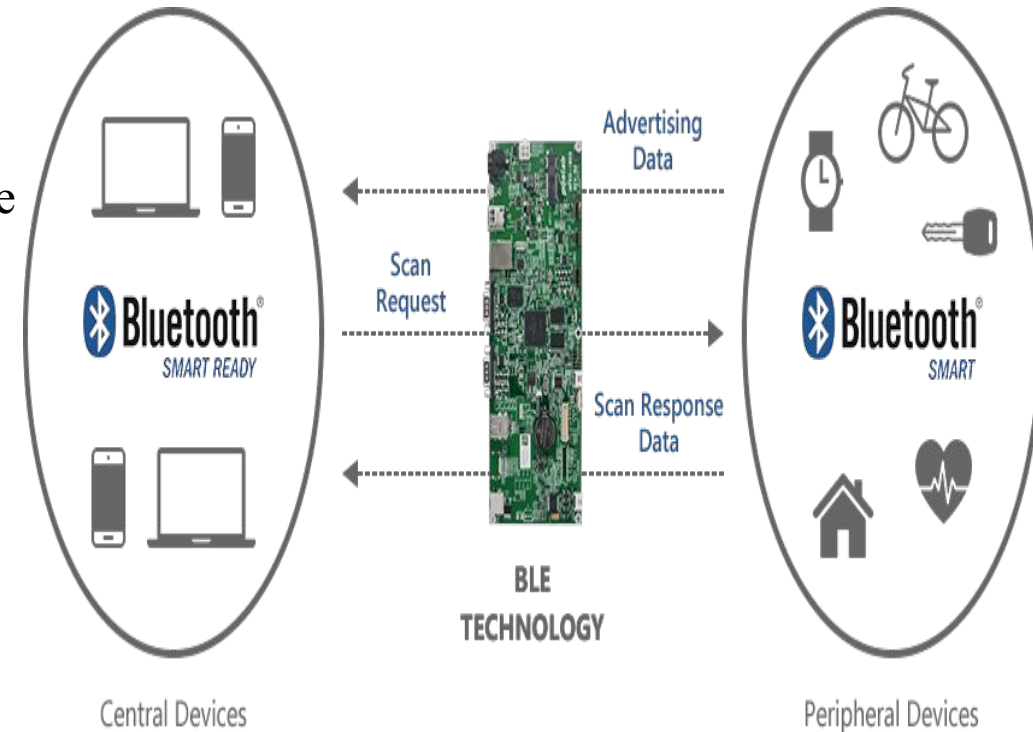
- Reduced power consumption, cost.
- Unlike classic Bluetooth, BLE remains in sleep mode constantly except for when a connection is initiated.
- Used in battery powered devices developed for industries.
- ✕ Compatibility with a large installed base of mobile phones, tablets and computers.

## Advantages:

- It offers very low power consumption, thus battery life is very long
- Inexpensive
- Offers reliability and enables digital life
- Devices from different manufacturers are compatible with the others.

## Disadvantages:

- It supports low data rates like 1Mbps or 2Mbps
- Cannot be used for long distance communication
- It is open to interception and attack due to wireless transmission/reception.



## WiFi (Wireless Fidelity):

WiFi is a **wireless technology** that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network, including high speed internet connections.

### Features:

- WiFi technology enables IoT wireless connectivity over a LAN using IEEE 802.11 standards.
- There are different WiFi transmission standards, IEEE 802.11a, b, and g. currently, the most common WiFi standard used in homes and many businesses is 802.11n, ~~which offers serious throughput in the range of hundreds of megabit per second~~, which is fine for file transfers, but may be too power consuming for many IoT applications.
- In car radios and TV sets, broadcasts are on different channels to avoid interference. 802.11b and g have only 3 non overlapping channels. To avoid interference, the radio power, and therefore transmission distances are short.
- The frequency ranges are referred to as 2.4GHz and 5 GHz.
- IEEE 802.11n has been agreed upon and standard products are expected. Speeds will be around 300Mbps and distances increased.



## Advantages:

- Wireless connection – can merge multiple devices together.
- ~~WiFi allows managing or communicating network~~. It can reduce the cost of cables and laying charges.
- It is easy to setup and add new clients
- Send and receive any amount of data in the air; its completely safe and it will not interfere with any network.
- Wifi networks are widely used to connect a variety of devices, not only between themselves but also to the internet.

## Disadvantages:

- Wifi has a limited radius of action and it is suitable for home networking, which is more dependent on the environment.  
Eg: home router- 45m to 450m
- At high density wifi points operating in the same or adjacent channels, they can interface with each other. This affects the quality of the connection. This problem is common in apartment buildings.
- Wifi technology is not perfect and has many flaws that limit its use.
- WiFi network implementation is more costly than wired network. There are some limit to transfer the data rate, it can't send the huge data compared to wired technology.
- Wifi will generates some radiation which effects on human health.
- Consumes high power.



## Low power WiFi(WiFi-HaLow):

- The original WiFi standards are not suitable for IoT applications due to their frame overhead and high power consumption.
- IEEE 802.11ah <sup>h/a</sup> supports low overhead, power friendly communication suitable for sensors and motors.
- This standard is far more IoT centric than many other WiFi counterparts.

### Advantages:

- It consumes lower power than a traditional WiFi device
- The range is doubled
- Designed specifically for low data rate, long range sensors and controllers

### Disadvantages:


- Because of the relatively lower frequency, the range is longer since higher frequency waves suffers from higher attenuation.

# Wi-Fi CERTIFIED HaLow™ for IoT

## Features

 Sub-1 GHz spectrum operation


 Narrow band OFDM channels

 Several device power saving modes

 Native IP support


 Latest Wi-Fi® security

## Benefits

 Long range: approximately 1 km

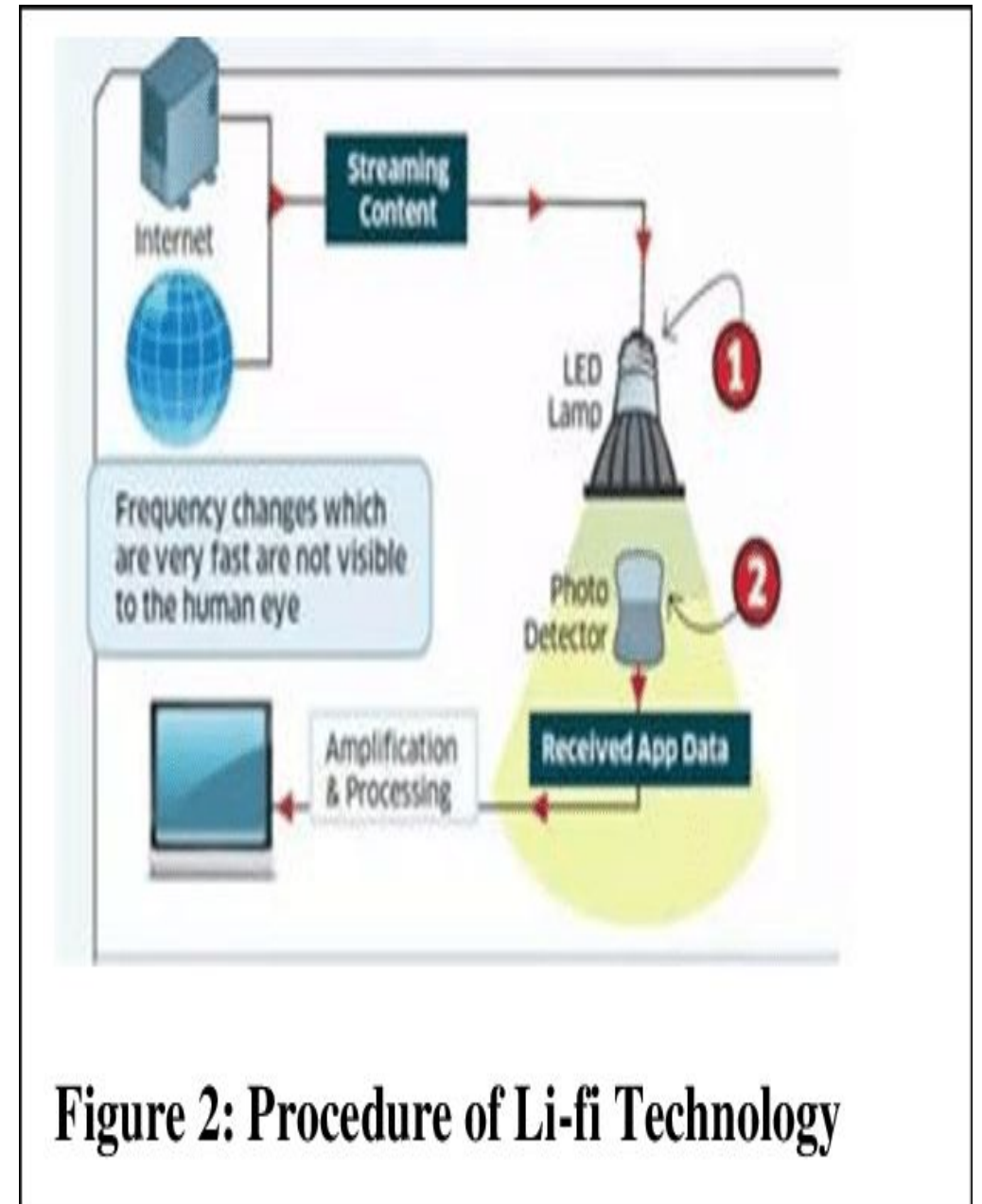
 Penetration through walls and other obstacles

 Supports coin cell battery devices for months or years

 No need for proprietary hubs or gateways

## LiFi(Light Fidelity):

- It is a new **wireless technology** that offers high speed data transmission based on visible light communication(VLC) principle.
- It uses 2 main components: LiFi Controller or coordinator
- LiFi Dongles
- The technology uses LED lamps on source side and photo detector based LiFi dongles on destination side.
- LiFi can also utilize energy efficient LED lights to reduce energy costs.
- It is limited to the line of sight and is subject to interference or failure due to objects blocking the light signals.
- The LiFi devices consume low power for operation and hence used in IoT applications like street lights, sign boards, Internet etc.



**Figure 2: Procedure of Li-fi Technology**

**Advantages:**

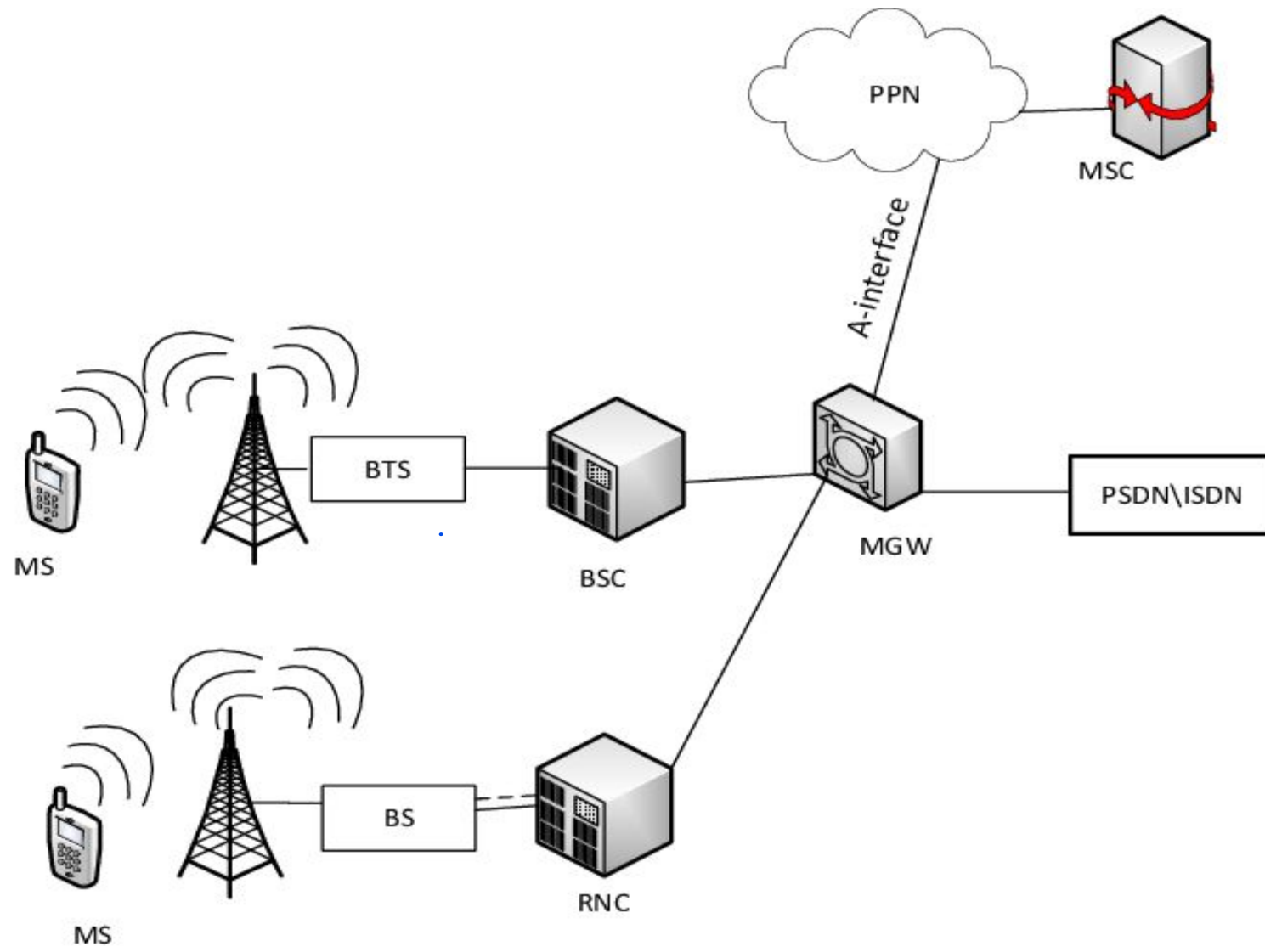
- Uses light as medium for data communication. In LiFi, light does not pass through the walls and hence will provide a much secure data transfer.
- It transfers data very rapidly and securely through LOS operation of optical signals
- The speed of data provided by these LEDs is 100 times faster than the WiFi speed
- It is very efficient in terms of cost and energy

**Disadvantages:**

- Internet cant be used without a light source
- A new infrastructure for lifi is required to be constructed.

## Cellular network:


- A cellular network is a radio network distributed over land through cells where each includes a <sup>tower</sup> fixed location transceiver known as base station.
- Cellular technology is the basis of mobile phone networks. These networks exist in various generations such as 3G and 4G of cellular network standards that are often employed in smartphones but are also suitable for IoT due to their high mobility and speed.
- Any IoT application that requires operation over longer distances can take advantage of GSM/3G/4G/5G cellular communication capabilities
- However Narrowband -IoT (NB-IoT) along with LTE-M (long term evolution cat-M1) are newer standards that were developed especially for running IoT systems using existing cellular networks.
- LTE-M is a subset of the LTE cellular technology that is optimized for low data rate devices running from small batteries.



## **Advantages:**

- It is used areas where cables can not be laid out due to its wireless nature.
- It provides voice/data services even while roaming
- It connects both fixed and wireless telephone users

## **Disadvantages:**

- The technology is able to transfer high quantities of data, but the power consumption and expenses are high
  - The wireless communication is influenced by physical obstructions, climatic conditions and interference from other wireless devices
  - It offers less data rate compare to wired networks such as fiber optics, DSL etc. the data rate varies based on wireless standards such as GSM, CDMA, LTE etc.
  - It requires higher cost in order to setup cellular network infrastructure.
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## Z-Wave:

- Z- Wave is a **wireless network standard** that consumes very low power and it is widely used for connecting smart devices in the IoT like home automation, lighting controls, security systems, energy saving etc.
- Z-Wave devices can be attached to home appliances, which enable them to be controlled over the internet.
- Z-Wave is a complete communications solution, which consists of everything from the physical layer to the applications layer.

### Advantages:

- Easy to install the system
- Easy to add or remove devices.
- Interoperable with other devices.
- Uses low energy radio waves to communicate
- Uses a simpler protocol than some others, which can enable faster and simpler development.



### Disadvantages:

- Cannot be deployed over a wide area as the range is less.
- Applicable for less data speed and small data size applications.



## X-10 :

- X-10 is a **protocol for communication** among IoT devices, mainly in the home automation sector. It is called as the father of modern home automation.
- The existing household wiring, which powers the house acts as the physical layer to transmit and receive data.
- ✓ X-10 devices are connected to the plugs in the wall like a normal electrical appliances.
- A remote interface(touch screen) could be provided so that lights and other appliances can be turned on and off.

### Advantages:

- The infrastructure for the medium of communication exists and thus needs less effort to set-up. And the equipment is also inexpensive.
- No new or specialized wiring is required.

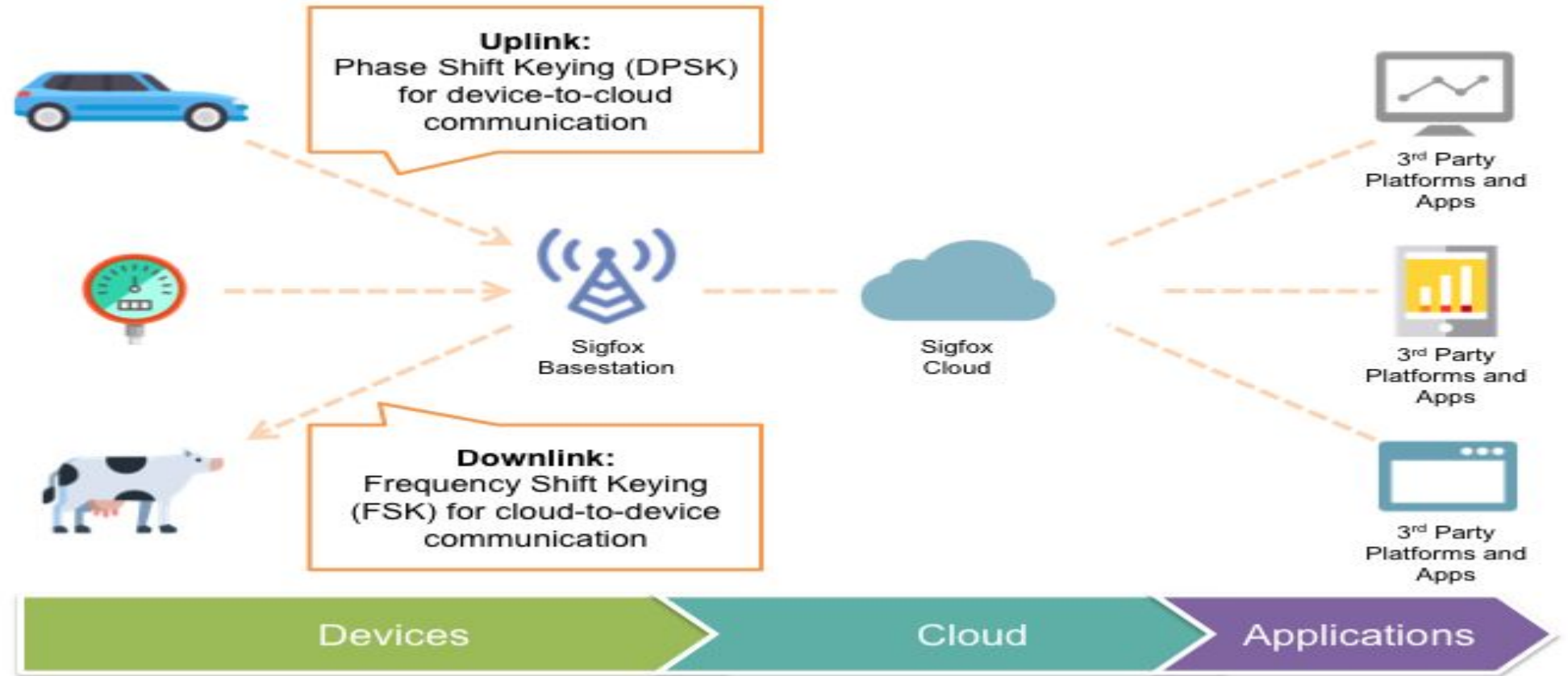
## Disadvantages:

- Low data rate 20bps- only for turning on and off devices only
- Other electrical devices in the house can create interference on the power lines, which may prevent X10 signals being received by modules.
- It is not suitable as a safety device.
- There is a time delay in sending signals-up to one second



## Sigfox:

- Sigfox is a cellular style system that enables remote devices to connect using ultra-narrow band(UNB), to provide low power low data rate, and low cost communications for remote connected devices.
- It a subscription based service that offers connectivity solutions over dedicated LPWAN networks.
- low data transfer speeds of 10 to 1000 bps.
- The concept behind sigfox is to provide an effective connectivity solution for low power M2M applications requiring low levels of data transfer for which the WiFi range is too short, and cellular range is too expensive.
- IoT applications: alarm systems, smart meters, smart street lighting, patient monitors etc.



## Advantages:

- Sigfox offers significant cost and battery life
- The sigfox network provides very long-range wireless connectivity for the IoT.
- It is lightweight protocol which handles smaller messages efficiently.
- Due to less overhead, more space will be available for the user data to be transported.

## Disadvantages:

- Sigfox supports one way communication without acknowledgement. This necessitates multiple transmissions if server doesnot receive data without errors. Due to this power consumption will increase which depends on number of re-transmissions.
- Due to low data rate support, it cannot be used for high data rate applications.
- Sigfox system works well in fixed location. There are issues such as interference and frequency inaccuracies in the mobility environments.

## Zigbee:

- Zigbee is a low powered, low cost standard on a wireless mesh network designed for battery powered devices and cheaper alternative to Bluetooth.
- It is based on the IEEE 802.15.4 communication protocol standard and is used for personal area networks or PANs.
- The range is 10-100mts – within small buildings
- Zigbee devices often transmit data over longer distances by passing data through intermediate devices to reach remote ones, creating a mesh network.
- They can be used in applications that require a low data rate, long battery life, and secure networking.

**Applications:** street lighting , electric meters, security systems, smart homes, remote controls, road map products-tracking and health-care systems.

### Advantages:

- Low- power consumption, powerful and direct communication.
- ✓ It supports a large number of nodes and these nodes are capable of multi-year battery lives.
- Zigbee has a flexible network structure.
- It is less complex than Bluetooth.

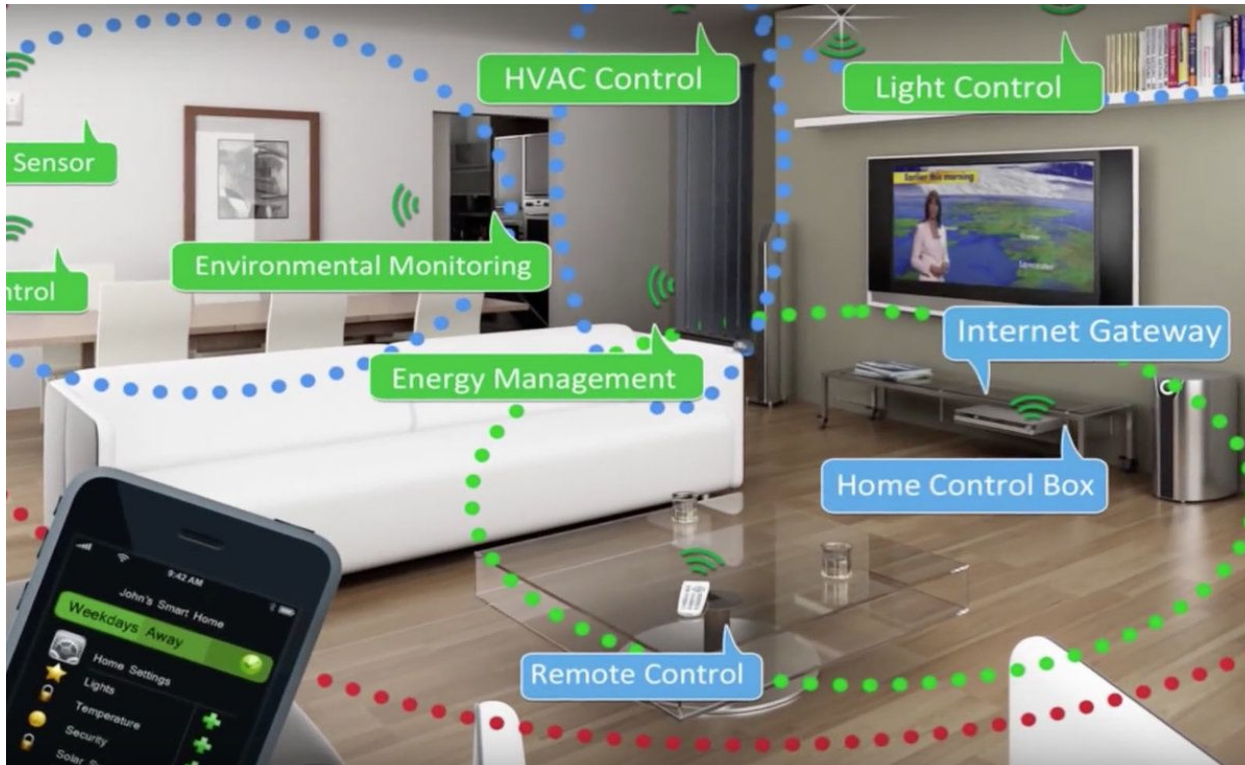




## Disadvantages:

- Working on small distance with low speed.
- Its high maintenance cost.
- Low transmission, as well as low network stability.
- Zigbee is not secure like WiFi based secured system.

What?





## Low range wide area network (LoRaWAN):

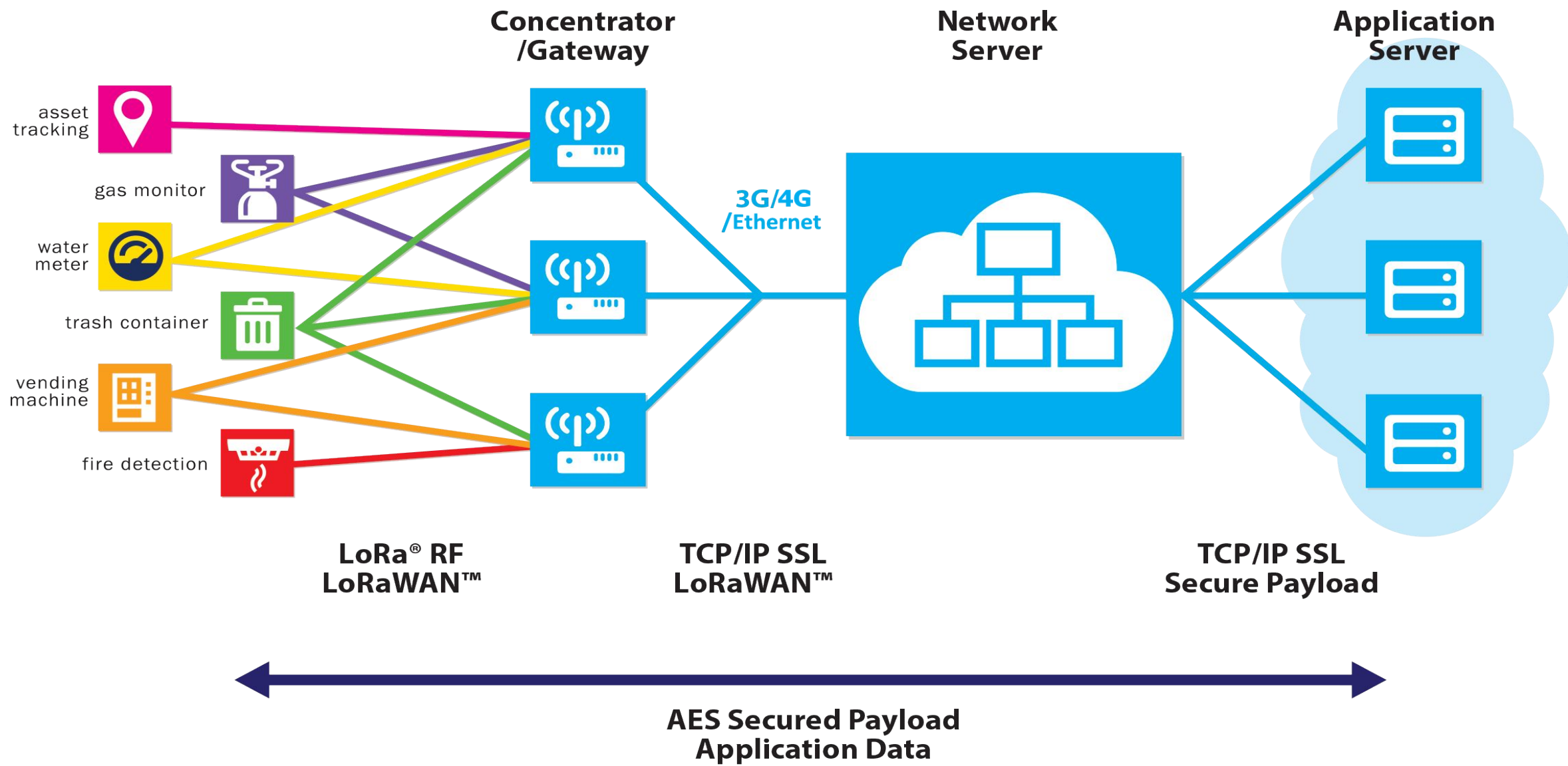
- LoRaWAN is a newly developed long range wide area network technology designed for IoT applications.
- LoRaWAN defines the communication protocol and system architecture for the network in the MAC alayer protocol.
- It is ideal for smart cities and industrial applications.

### Advantages:

- low cost, mobile and secure and bidirectional communication
- Low power consumption and supports large networks with millions of nodes
- Battery life for the attached node is normally very long
- It is easy to deploy due to its simple architecture

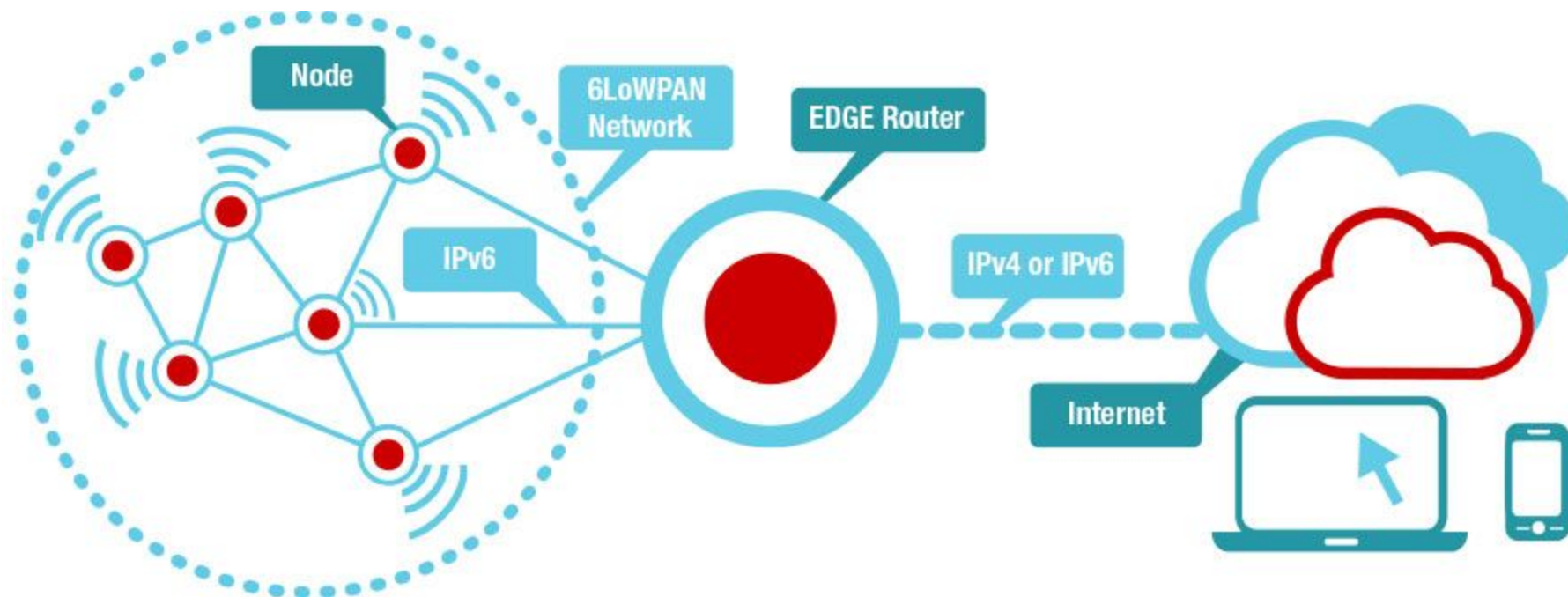
### Disadvantages:

- It is not ideal to be used for real time applications
- It can be used for applications requiring low data rate i.e upto about 27Kbps.




## 6Lowpan:

- 6Lowpan is an acronym of IPv6 over low power wireless personal area networks.
- It is a protocol that is primarily intended for long range wireless battery operated IoT devices in regional, national, or global networks.
- It is specially known for its ability to communicate in long range with the least power consumption and detects the signals below the noise level.
- Mainly used in smart cities, where there is a large network with millions and millions of devices connected to each other that function with less power, memory, low cost mobile secure communication in IoT devices and a wide range of industrial applications.
- The 6Lowpan group has defined encapsulation and header compression mechanisms that allow IPv6 packets to be sent to and received from over IEEE 802.15.4 based networks.



## Advantages:

- The 6Lowpan standard enables any low power radio to communicate to the internet, including 802.15.4, BLE, Z-Wave for home automation appliances.
- 6Lowpan uses reduced transmission time and thus saves energy
- 6Lowpan is a mesh network that is robust, scalable and self healing
- It offers one to many and many to one routing 

## Disadvantages:

- 6Lowpan offers a secure and non secure mode but the overall security in 6Lowpan is still in progress. In comparison, Zigbee has more robust and tested security protocol.
- It require extensive training as it is complicated to work with and require extensive knowledge of IPv6 protocol.

## 5G:

- G- generation of mobile technology installed in phones and on cellular networks.
- 5G is medium range communication that offers many improvement over 4G, such as increased speed and better coverage.
- It enable a larger number of nodes to be connected with extra mobility.

### Advantages:

- Provides high data transfer rates
- More effective and efficient
- Easily manageable with the previous generations
- Possible to provide uniform, uninterrupted, and consistent connectivity across the world

4G - 5G

### Disadvantages

- Technology is still under process and research on its viability is going on
- Developing infrastructure needs high cost
- ✓ Many of the old devices would not be component of 5G, hence all of them need to be replaced with new one.

## Low power wide area networks(LPWAN):

- Used for low power IoT and M2M applications.
- It defines LPWAN standard to enable IoT and can transmit data over long distances while having low power consumption.
- Mainly its aim is to guarantee interoperability between various operators in one open global standard.

### Advantages:

- Long range- 5km to 30km
- Consumes Low power – longer life time
- Offers simple network installation and easy network management due to smart architecture
- Offers secured data communication between nodes and gateways dueto use of encryption algorithms

### Disadvantages:

- Low data rate
- High latency between end to end nodes.

## Near field communication(NFC): *Nice*

- NFC is a **set of the communication based protocol** used for communication between 2 devices in the range of approximately 10cm.
- All types of data can be transferred between 2 NFC enabled devices in seconds by bringing them close to each other.
- In this 2 way, short range communication one of the devices must be portable for the purpose of finding a suitable location.
- NFC make it possible to use our phone as readers. you can extract information from certain objects just by tapping it or bringing our device close to it.

*phone camera capturing statue*

*qrcode scanner etc*

### Advantages:

- Offers low speed connection with extremely simple setup.
- Short range and supports encryption
- Very easy to used

### Disadvantages:

- Short range
- Low data transfer rate
- Expensive technology.



## Wireless sensor network(WSN):

- A WSN is the networks that are wireless In nature which comprises of distributed devices with sensors which are used to sense or monitor the environmental and physical conditions like temperature, gyroscope, pressure etc., and make the embedded processing using these devices.
- They collect data about the environment and communicate it to gateway devices that relay the information to the cloud over the internet.  
through multihop
- These devices are connected through different devices such as GPS, WiFi, RFID etc. over the networks.

Examples: wealth monitoring system, soil moisture monitoring system, surveillance system, healthcare monitoring, indoor air quality monitoring system etc.

### advantages:

- Flexible network and it can adapt to the changes.
- Used in very hard and poor environments where wired cannot be deployed.
- Save a lot of wiring cost

cheaper

sensor nodes can be configured and re configured easily into various topologies like mesh ,star,etc.

•sensor nodes can be added and removed from wireless network easily

### Disadvantages:

- Not fully secure
- Communication speed is very poor
- Distracted by other wireless devices like bluetooth