UNIT 2

Infrastructure and Service Discovery Protocols for the IoT system

Low power wide area networking Technologies

- Low power wide area networking (LPWAN) technologies are wireless communication protocols that are designed to provide

  Low power

  Long-range connectivity for devices that require long battery life and low bandwidth.

LPWAN technologies are used in a variety of applications

- Industrial IoT
- Smart cities
- Environmental monitoring

Key features of LPWAN

- **Long-range communication**:

  Ability to support nodes that are greater than or equal to 10 km distance from the gateway.

  The correct distance is based on the LPWAN technology that is used.

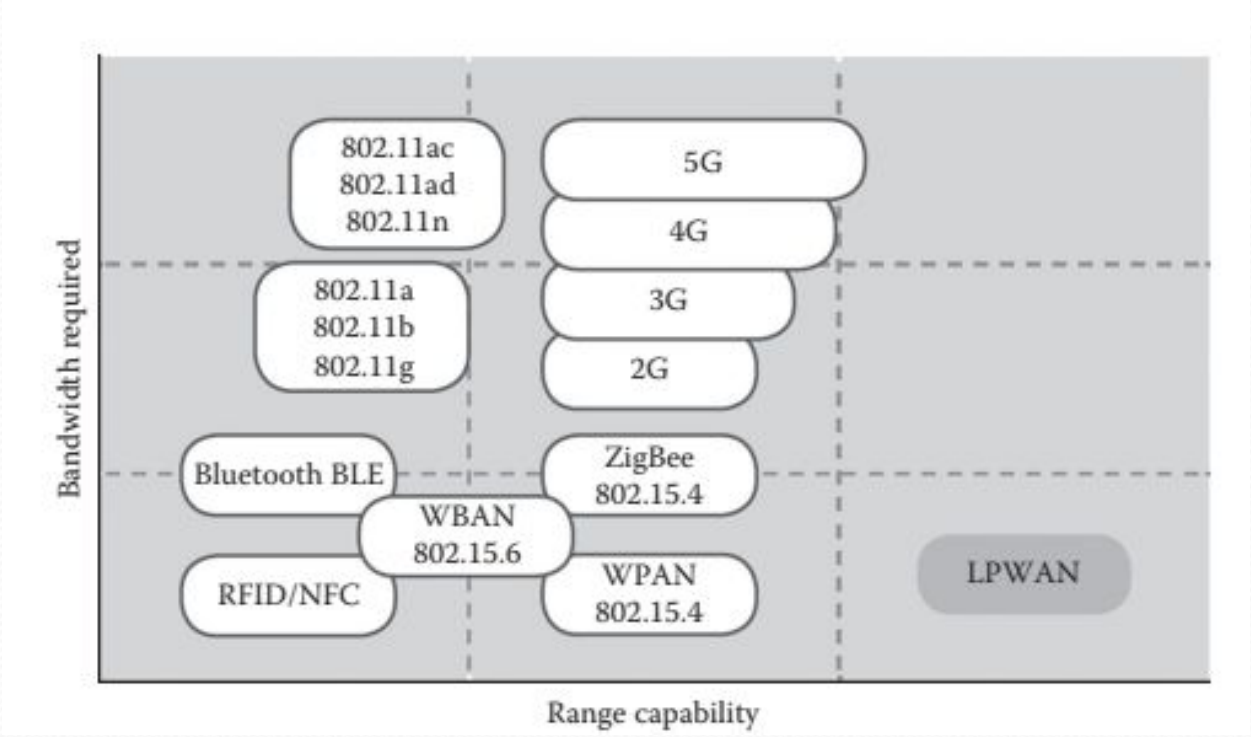
- **Low transmission data rate:**

  Less than 5000 bits of data are sent per second. Often only 20–256 bytes per message sent several times a day.

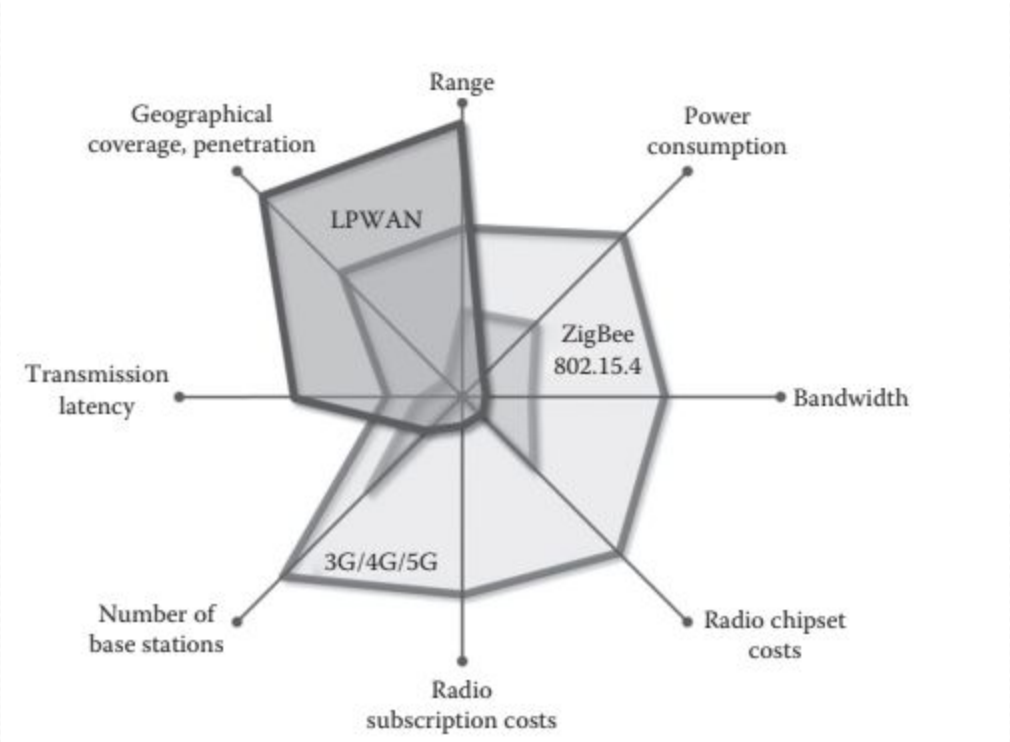
- **Low-power consumption:** This provides very long battery life for the devices. Many times, the battery life may last up to 10 years.

- LPWAN technology is ideally suited for the following two types of applications:
  - **Fixed, medium-to-high density connections**
  - **Long life, battery powered applications**

The bandwidth and the range requirements of various wireless networking technologies



The needs of IoT and M2M applications have given rise to some **specific requirements** on LPWAN technologies as compared with other wireless technologies.



- For LPWAN technology, a **star-topology** network is preferred instead of a mesh-topology network
- The endpoints of star networks are connected directly to access points
- Repeaters can be used to fill in gaps in coverage areas so that there is no drop in transmission power.
- LPWAN technologies operate with 140–160 decibels that can provide several miles of range
- In order to accomplish high miles, highly sensitive receivers are employed in LPWAN technologies

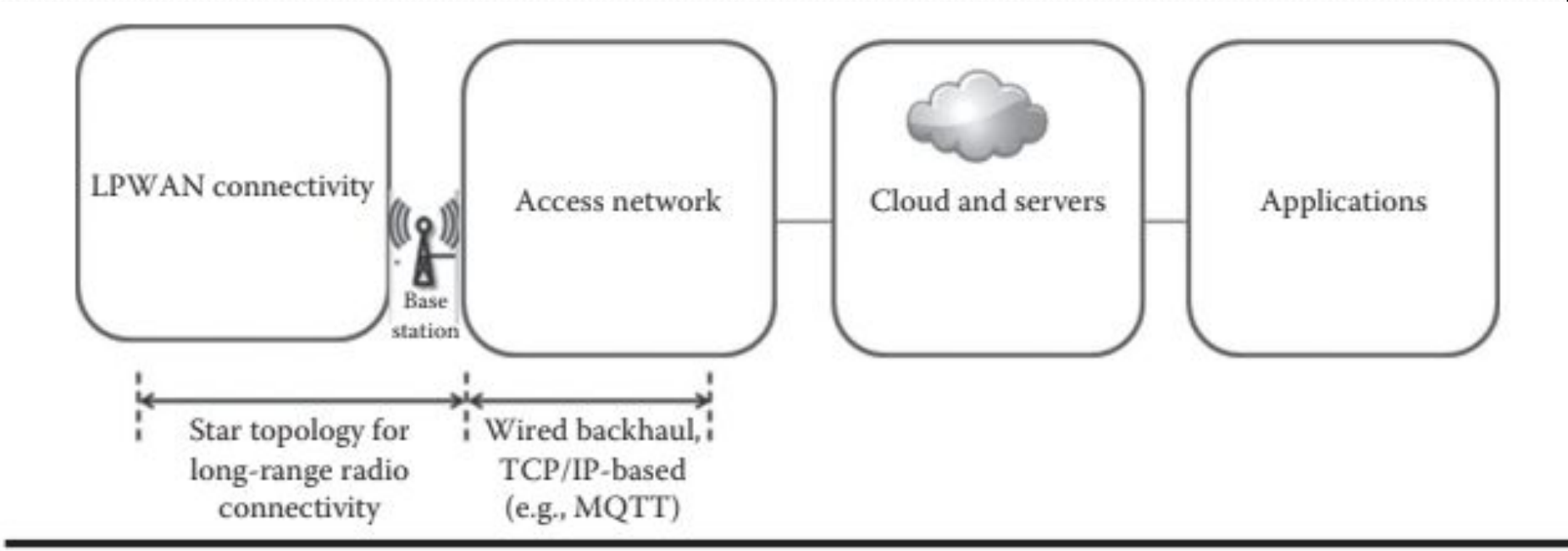
- The following are the most important parameters to be considered while choosing a LPWAN technology:

- ▪ Capacity
- ▪ Quality of service
- ▪ Range
- ▪ Reliability
- ▪ Battery life
- ▪ Security
- ▪ Cost
- ▪ Proprietary versus standard

LPWAN Network Topologies

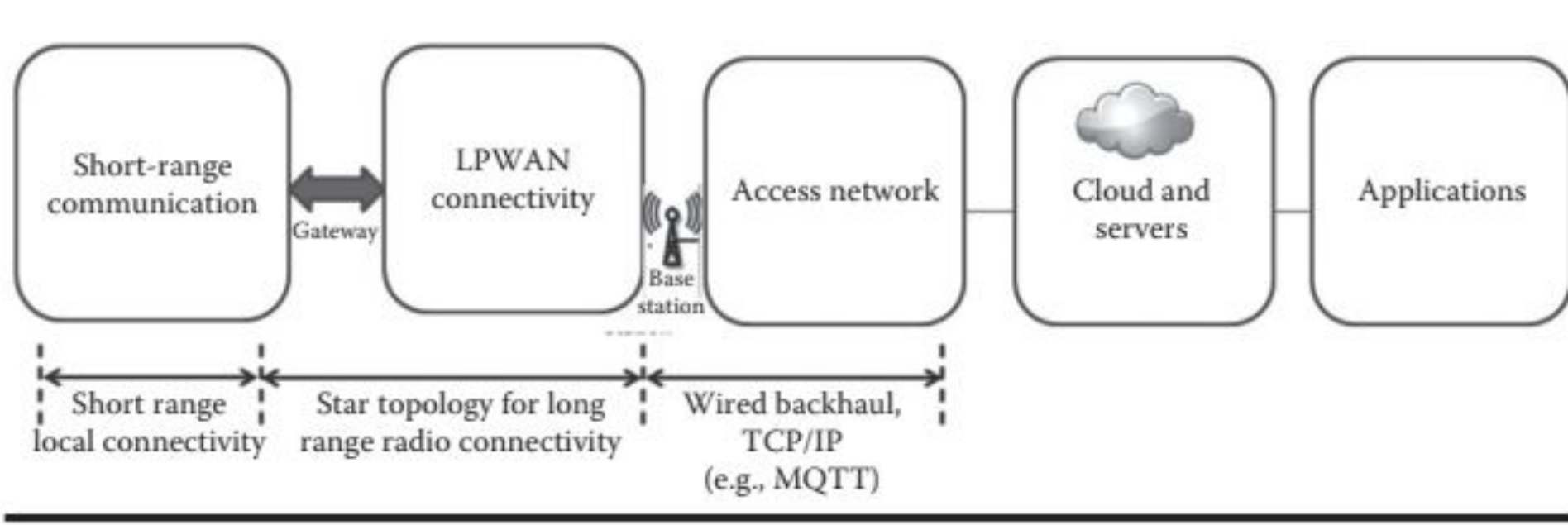
- LPWAN has two network topologies:
- Direct device connectivity (base station)
- Indirect device connectivity through an LPWAN gateway

Direct Device Connectivity Topology of LPWAN



- The **base station** that is present in the network provides connectivity to a large number of devices.
- The traffic is sent to servers (cloud) through TCP or IP-based networks (Internet).
- The base station is responsible for **translation of protocol from IoT protocols** such as MQTT or CoAP to specific device application protocols.

Indirect Device Connectivity through an LPWAN Gateway



- In certain networks where it is not possible to connect devices directly to LPWAN, **a local gateway** is used to bridge LPWAN connectivity to some short-range radio (SRD) technology like ZigBee or BLE
- This gateway generally runs on mains power as it has to support a large number of devices.
- The **gateway** should also have the capability to perform protocol conversion from **SRD radio technologies to LPWAN technology**.
- Gateways also provide more security to IoT ecosystem as they offer options to implement powerful security algorithms.

LoRaWAN

- LoRaWAN (Long Range Wide Area Network) is a popular LPWAN technology that uses **chirp spread spectrum modulation** to achieve long-range communication.
- It can transmit data over distances of several kilometers, even in urban environments.
- LoRaWAN is designed to be low power, with devices that can last for years on a single battery.

Sigfox

- Sigfox is a proprietary LPWAN technology that uses **ultra-narrowband modulation** to achieve long-range communication.
- It operates in the unlicensed spectrum and can transmit small amounts of data over long distances.
- Sigfox is designed to be low power, with devices that can last for years on a single battery.

NB-IoT

- NB-IoT (Narrowband IoT) is a cellular LPWAN technology that operates in licensed spectrum.
- It uses narrowband modulation to achieve long-range communication and is designed to be low power, with devices that can last for years on a single battery.
- NB-IoT can transmit small amounts of data over long distances and is ideal for applications that require low bandwidth.

LTE-M

- LTE-M (Long-Term Evolution for Machines) is another cellular LPWAN technology that operates in licensed spectrum.
- It uses LTE technology to achieve long-range communication and is designed to be low power, with devices that can last for years on a single battery.
- LTE-M can transmit larger amounts of data than NB-IoT and is ideal for applications that require higher bandwidth.

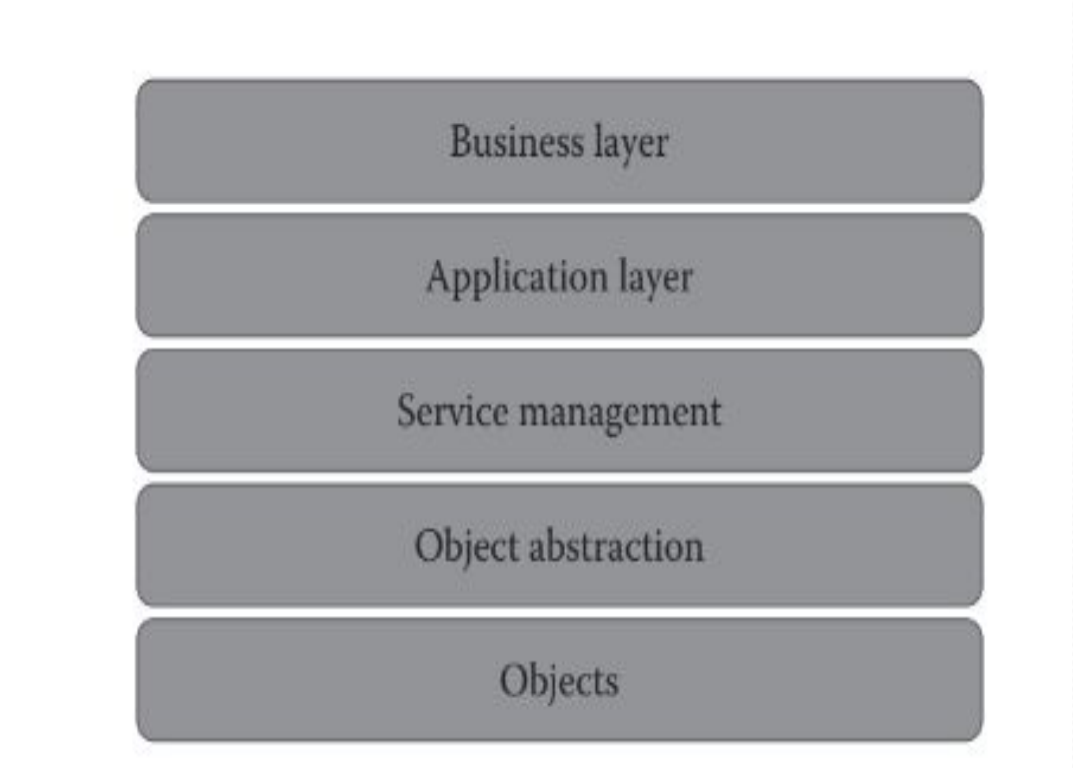
- Overall, LPWAN technologies offer a range of options for low power, long-range communication that can be tailored to specific use cases and application requirements.

Layered Architecture for IoT

- IoT should have the capability to connect and transfer data among billions and trillions of devices.
- For this to happen seamlessly, it is critical to have a layered architecture in place.

The different layers are as follows:

- Objects layer
- Object abstraction layer
- Service management layer
- Application layer
- Business layer


Business layer
Application layer
Service management
Object abstraction
Objects

Objects Layer

- Objects layer, also known as **devices layer.**
- It comprises the physical devices that are used to collect and process information from the IoT ecosystem.
- Sensors could be optical sensors, light sensors, gesture and proximity sensors, touch and finger-print sensors, pressure sensors, and more.
- The device data that are collected at this layer are transferred to the object abstraction layer using secure channels.

Object Abstraction Layer

- This layer transfers data that are collected from objects to service management layer using secure transmission channels.

Data transmission can happen using any of the following technologies:

- RFID
- 3G
- GSM
- UMTS
- Wi-Fi
- Bluetooth low energy
- Infrared
- ZigBee

Service Management Layer

- This layer acts as **middleware** for the IoT ecosystem.
- This layer pairs specific services to its requester based on addresses and names.
- This layer provides flexibility to the IoT programmers to work on different types of heterogeneous objects irrespective of their platforms.
- After data processing, **necessary decisions** are taken about the delivery of required services,

Application layer

- This layer provides the **diverse kinds of services** requested by the customer.
- The type of service requested by the customer depends on the specific use case that is adopted by the customer.

- For example,

  if smart home is the use case under consideration, then the customer may request for specific parameters such as heating, ventilation, and air conditioning (HVAC) measurements or temperature and humidity values.

Business Layer

- This layer performs the **overall management of all IoT activities and services**.
- This layer uses the data that are received from the network layer to build various components such as business models, graphs, and flowcharts.
- This layer also has the responsibility to design, analyze, implement, evaluate, and monitor the requirements of the IoT system.

PROTOCOL ARCHITECTURE OF IOT

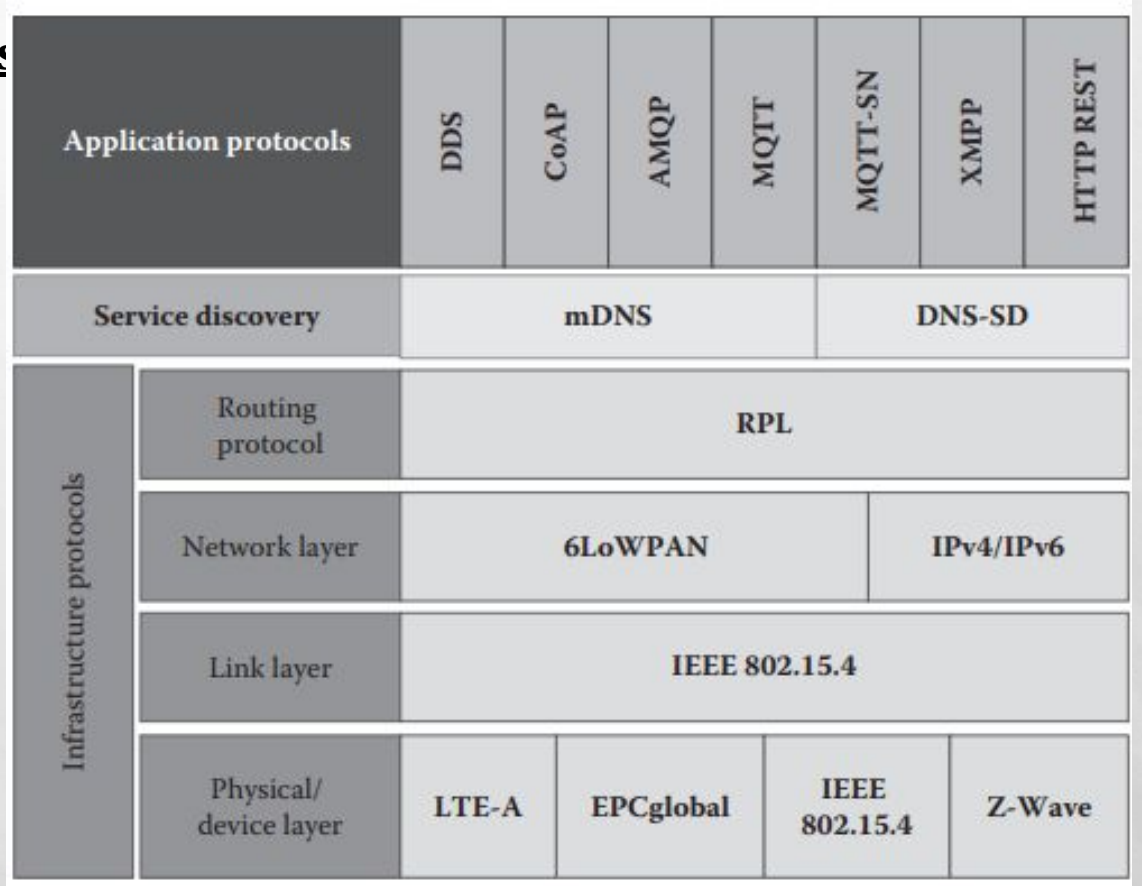
20CST62 IOT & CLOUD: UNIT 2

BY,
DR.M.GEETHA,
AP(SLG)/CSE,
KONGU ENGINEERING COLLEGE, ERODE

PROTOCOL ARCHITECTURE

Protocols used for communication in the various the IoT ecosystem:

- Infrastructure Protocols
  - Routing Protocols
  - Network Layer Protocols
  - Link Layer Protocols
  - Physical/Device Layer Protocols
- Protocols for Service Discovery



PROTOCOL ARCHITECTURE-
INFRASTRUCTURE PROTOCOLS

Routing Protocols - RPL

- Routing protocol for low power and lossy networks
- IPv6 protocol
- Low-power lossy networks:
  - wireless personal area networks (WPANs)
  - low-power line communication (PLC) networks
  - wireless sensor networks (WSNs).
- Characteristics of Low-power lossy networks:
  - Capability to optimize and save energy
  - Capability to support traffic patterns other than unicast communication
  - Capability to run routing protocols over link layers with restricted frame sizes

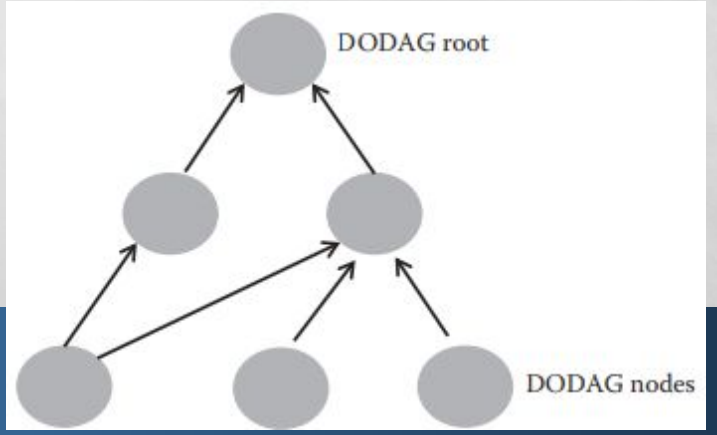
PROTOCOL ARCHITECTURE-
INFRASTRUCTURE PROTOCOLS

Routing Protocols - RPL

- A **Distance Vector Routing Protocol** that creates a tree-like routing topology called the Destination Oriented Directed Acyclic Graph (DODAG)
- support **minimal routing needs** by building a highly robust topology over lossy networks
- support **various types of traffic models:**
  - multipoint-to-point, point-to-multipoint, and point-to-point
- Devices are connected to each other in such a way that **no cycles are present in the connection**
  - Done using a node called **destination oriented directed acyclic graph (DODAG)**, which is routed at a single destination

Defines two modes for each node:

- **Storing mode: All nodes contain the entire routing table** of the RPL domain. Every node knows how to reach every other node directly.
- **Non-Storing mode: Only the border router(s) of the RPL domain contain(s) the full routing table**. All other nodes in the domain maintain their list of parents only



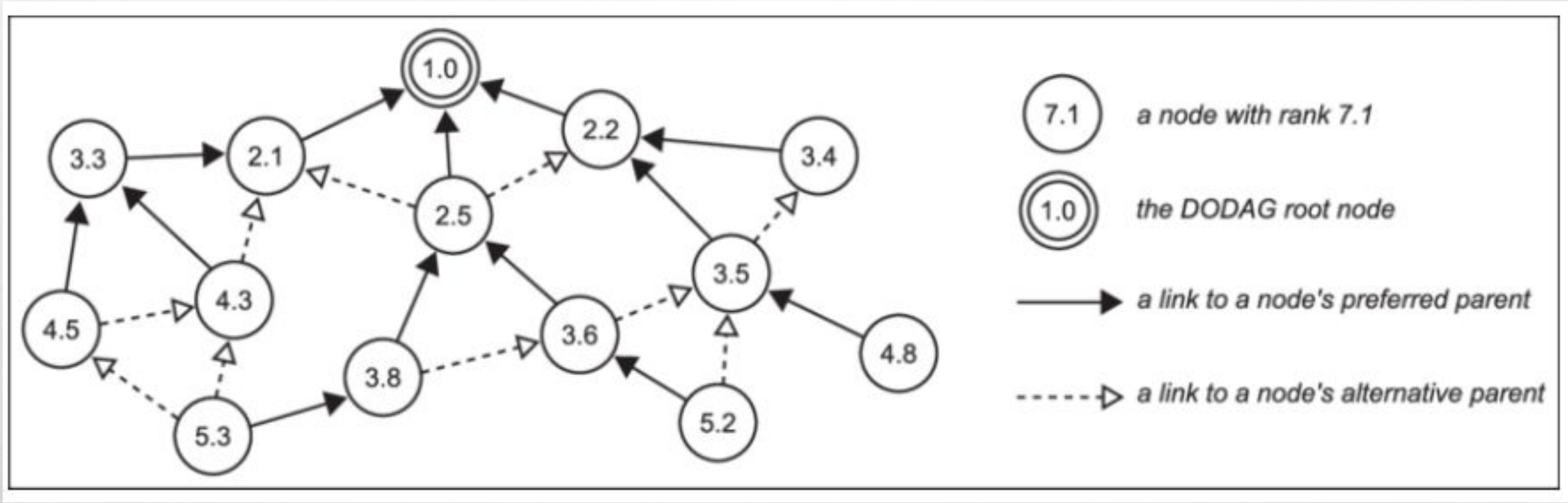
PROTOCOL ARCHITECTURE-

INFRASTRUCTURE PROTOCOLS

RPL: DODAG

- Used by RPL to maintain routing topology and update routing information.
- A parent node can have multiple child nodes
- A child node can have multiple parent nodes
- Each node knows its parent node but does not have any information about its child nodes
- Maintains at least a single path from each node to the root and the preferred parent

Serial Number	*Name of the Message*	*Description*
1	DODAG information object (DIO)	This message is used to keep the current rank (level) of the node, determine the distance of each node to the root based on some specific metrics, and choose the preferred parent path.
2	Destination advertisement object (DAO)	This message is used to unicast destination information toward selected parents of a node. This control message helps RPL to maintain upward and downward traffic.
3	DODAG information solicitation (DIS)	This message is used by a specific node in order to acquire DIO messages from another reachable adjacent node.
4	DAO acknowledgment (DAO-ACk)	This message is used as a response to a DAO message and is sent by a DAO recipient node like a DAO parent or DODAG root.


1.0
3.3
2.1
2.2
3.4
2.5
3.5
4.3
4.5
3.6
4.8
3.8
5.3
5.2
7.1
a node with rank 7.1
1.0
the DODAG root node
a link to a node's preferred parent
a link to a node's alternative parent

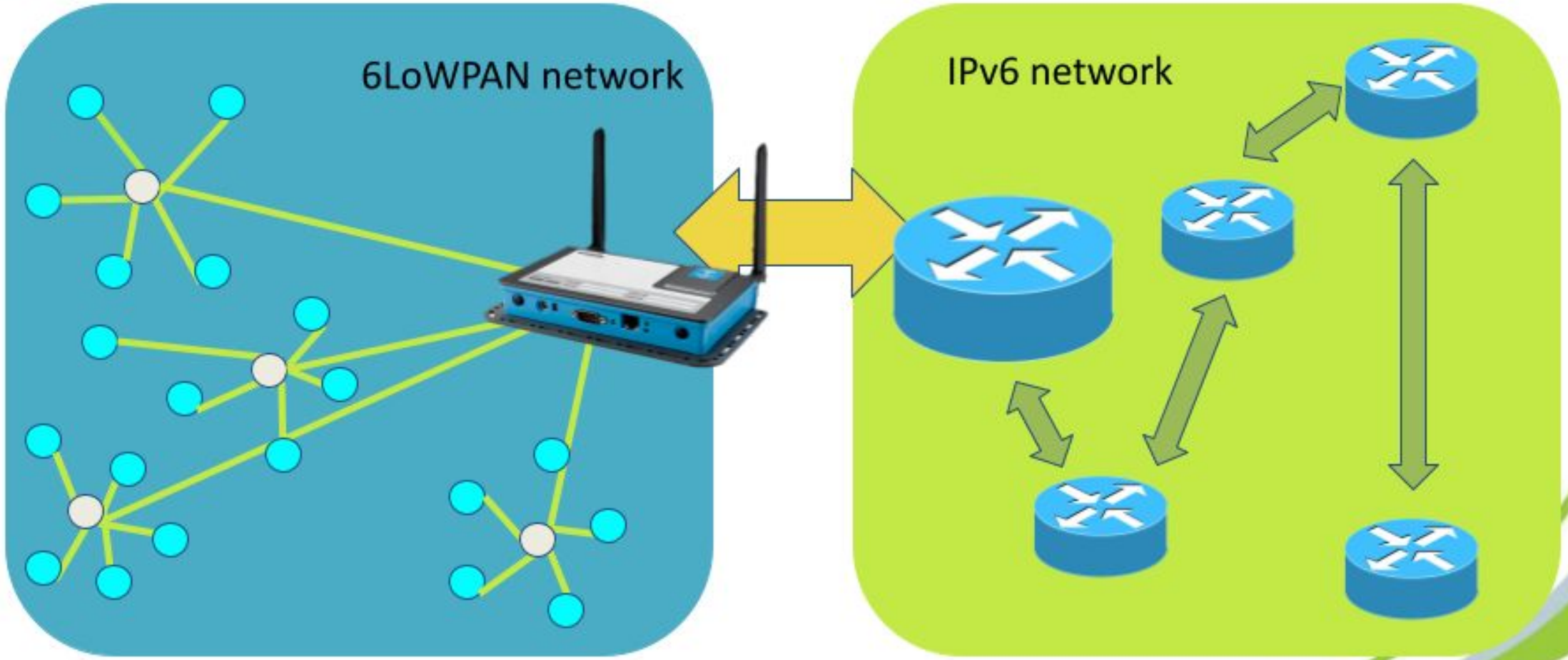
PROTOCOL ARCHITECTURE-

INFRASTRUCTURE PROTOCOLS

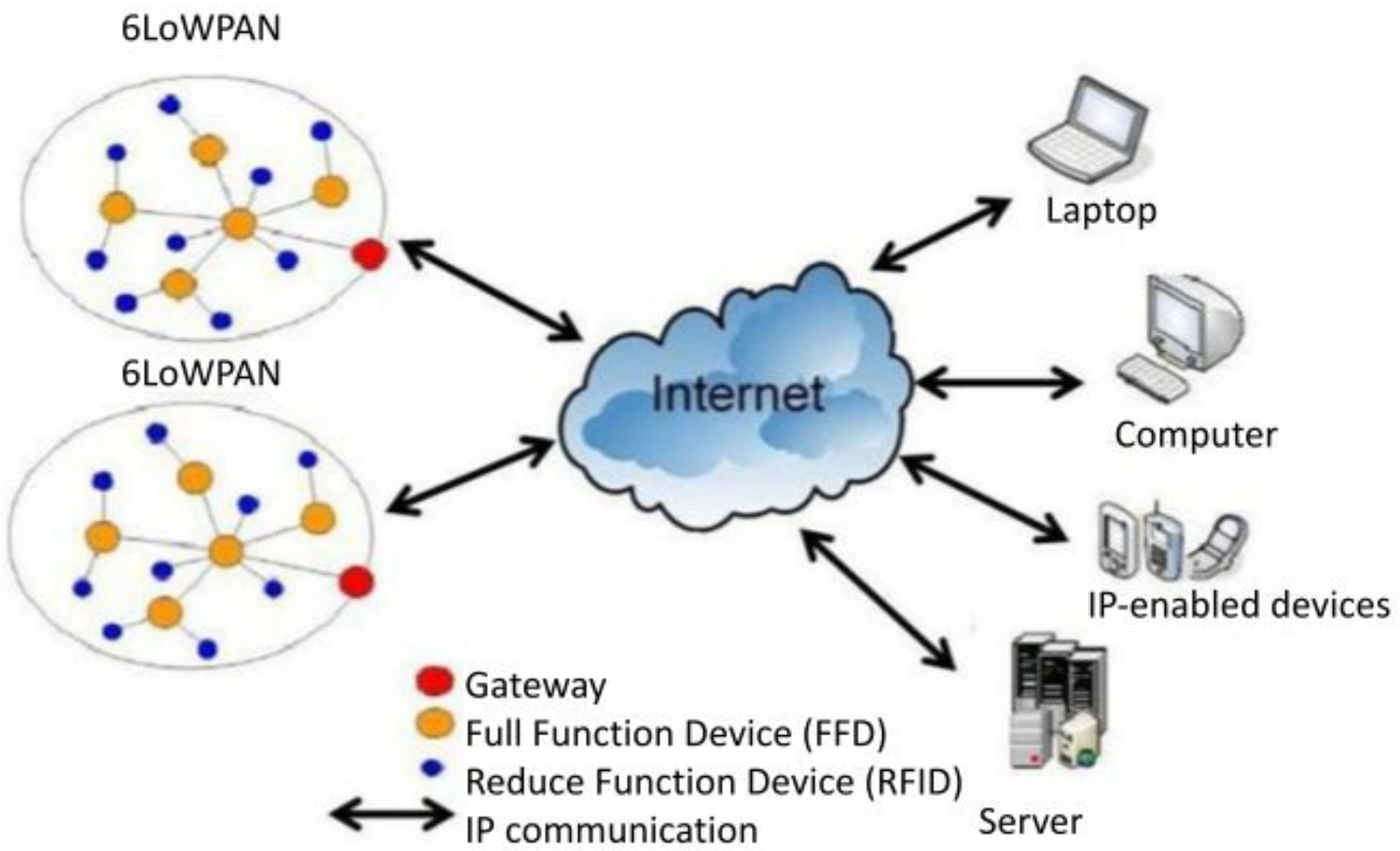
RPL: DODAG – Tree Construction

- Root **advertises a DIO message** to all nodes
- A node upon receiving the DIO, performs the following:
  - **Computes its rank**
  - **Identifies its set of parents**
  - **Chooses a preferred parent**
- Root node **register the parent path and participation paths** for each node
- **Parent (min distance to reach root) obtained by the router is set as a default path toward the root**

6LoWPAN network model

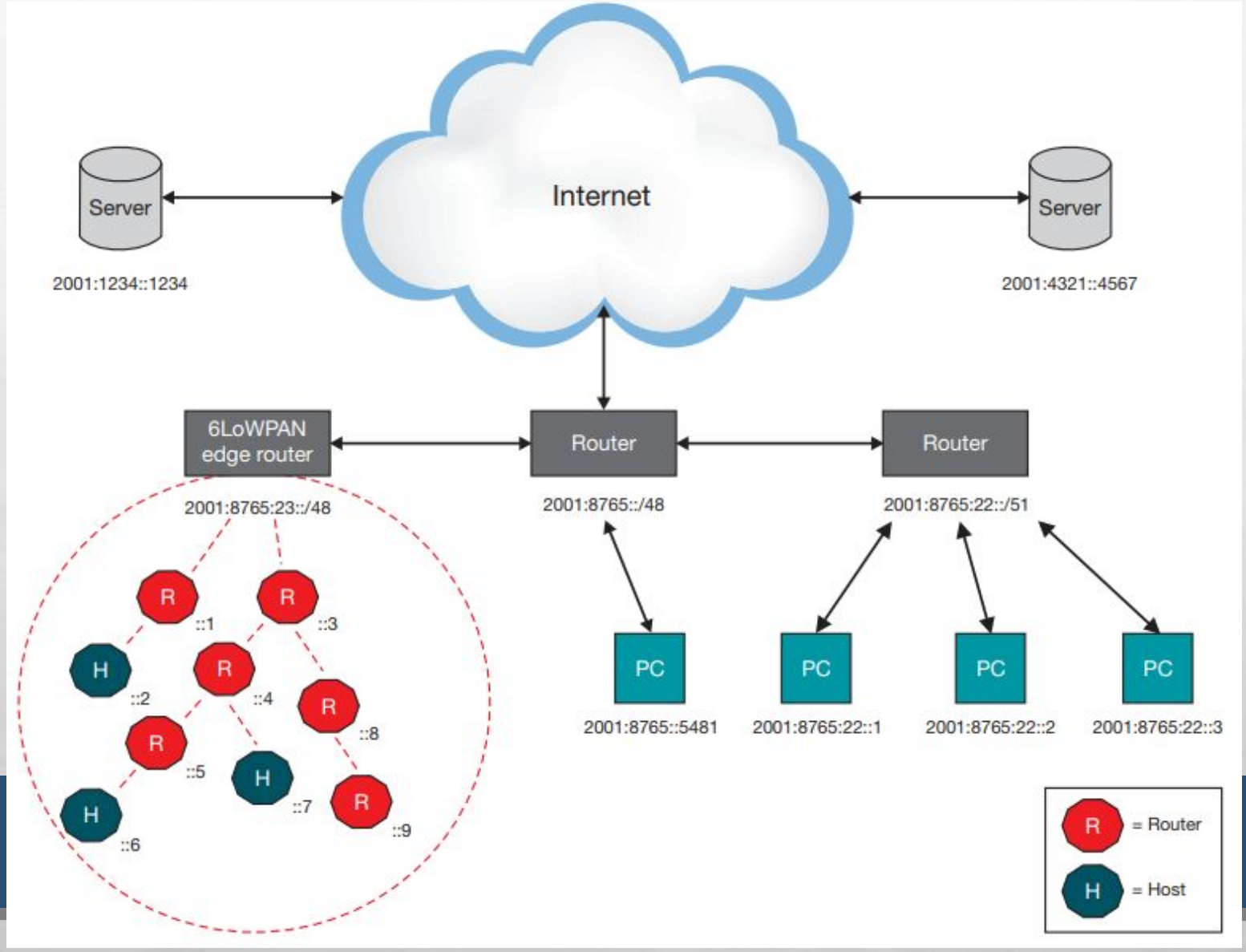


6LoWPAN Architecture



INFRASTRUCTURE PROTOCOLS-

6LOWPAN…



INFRASTRUCTURE PROTOCOLS-
6LOWPAN…

Network Architecture of 6LoWPAN

- Uplink to the Internet is provided by the access point (AP), which is an IPv6 router.
- Different types of devices such as PCs and servers could be connected to the AP
- The components of the 6LoWPAN network are connected to the IPv6 network using a 6LoWPAN edge router

INFRASTRUCTURE PROTOCOLS-
6LOWPAN…

Network Architecture of 6LoWPAN

- Functions performed by the edge router:
  - exchange of data between 6LoWPAN devices and the Internet (or other IPv6 network)
  - exchange of data among devices that are part of 6LoWPAN network
  - generate and maintain the 6LoWPAN network
  - Forward IP datagrams between different communication media that are used in IP networks.
    - The media used in IP network could be Ethernet, Wi-Fi, 3G, or 4G
  - Do not maintain the state of application layer. This reduces the workload on the edge router in terms of processing power

INFRASTRUCTURE PROTOCOLS-
6LOWPAN…

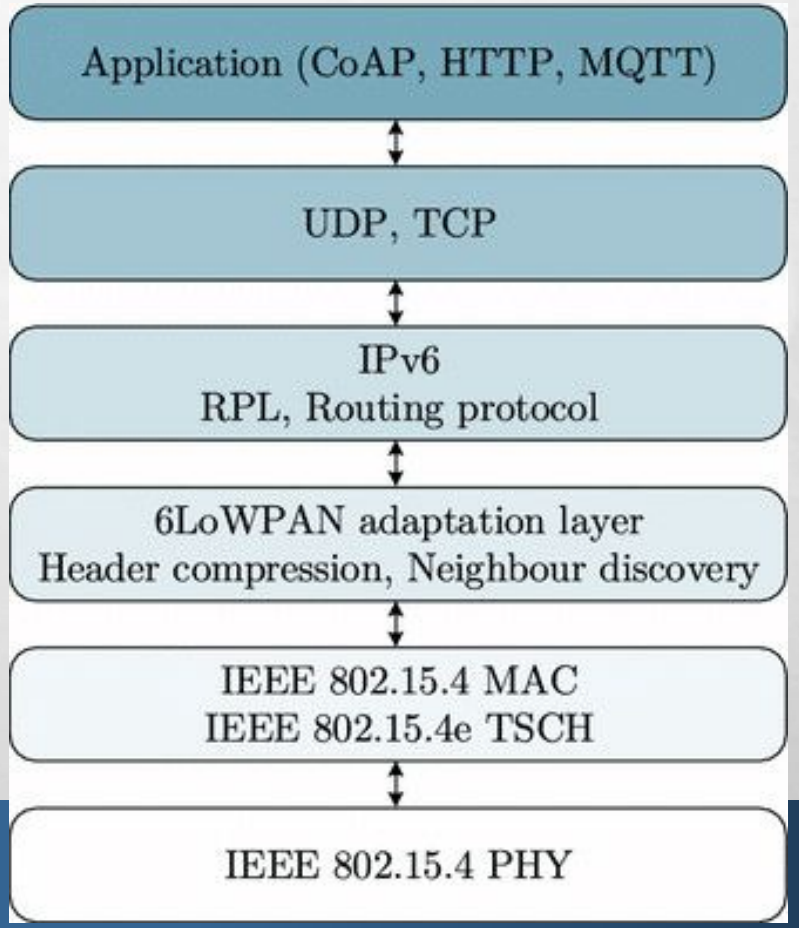
Network Architecture of 6LoWPAN…

- Two categories of devices are present:
  - Routers - route data to other nodes
  - Hosts - check the routers at regular intervals for data

INFRASTRUCTURE PROTOCOLS-
6LOWPAN…

Protocol Stack of 6LoWPAN…

- **Physical layer:**
  - Converts data bits into signal that can be transmitted through air.
  - IEEE 802.15.4 is used as physical layer
- **Data link layer:**
  - ensures that a reliable connection or link is established between two nodes
  - IEEE 802.15.4 is the MAC layer
  - Includes Adaptation layer also



INFRASTRUCTURE PROTOCOLS-
6LOWPAN…

Protocol Stack of 6LoWPAN…

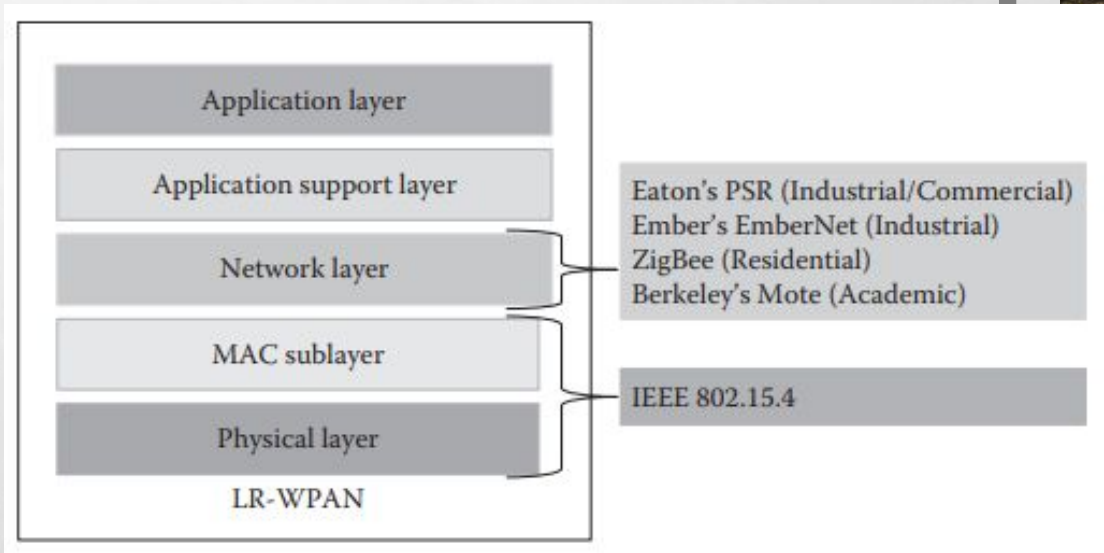
- **Network layer:**
  - Routes data in the network
  - ensures that data from a source device is delivered to the correct destination device
  - devices are identified using their IP address
  - IPv6, or RPL, is used
- **Transport layer:**
  - ensures that a reliable connection or link is established between two nodes
  - IEEE 802.15.4 is the MAC layer
  - Adaptation layer is also present
- **Application layer:**
  - Does data formatting
  - COAP and MQTT are used in 6LoWPAN systems

INFRASTRUCTURE PROTOCOLS-
IEEE 802.15.4

- specifies a sub-layer for the medium access control (MAC) and physical layer primarily **for low-rate wireless private area networks**

- **Benefits:**
  - Low power consumption, low data rate, and low-cost and high-message throughput
  - Reliable communication
  - Capable of handling a huge number of nodes (approximately about 65K nodes)
  - Provides high levels of security, encryption, and authentication services

- **Does not provide any quality of service (QoS) guarantees**



INFRASTRUCTURE PROTOCOLS-
IEEE 802.15.4

- Supports **transmission at three frequency bands** using a direct sequence spread spectrum (DSSS) method
  - 250 kbps at 2.4 GHz
  - 40 kbps at 915 MHz
  - 20 kbps at 868 MHz
- Supports **two types of network nodes:**
  - Full function devices (FFD)
  - Reduced function devices (RFD)

INFRASTRUCTURE PROTOCOLS- IEEE 802.15.4

Full function devices (FFD)

- Act as personal area network (PAN) **coordinator or as just a normal node**
- Coordinator has the capability **to create, control, and maintain the network**.
- **Store routing table** within their memory and can **implement a MAC**
- Can **also communicate with other devices** using one of the following topologies:
  - Star
  - Peer-to-peer
  - Cluster Tree

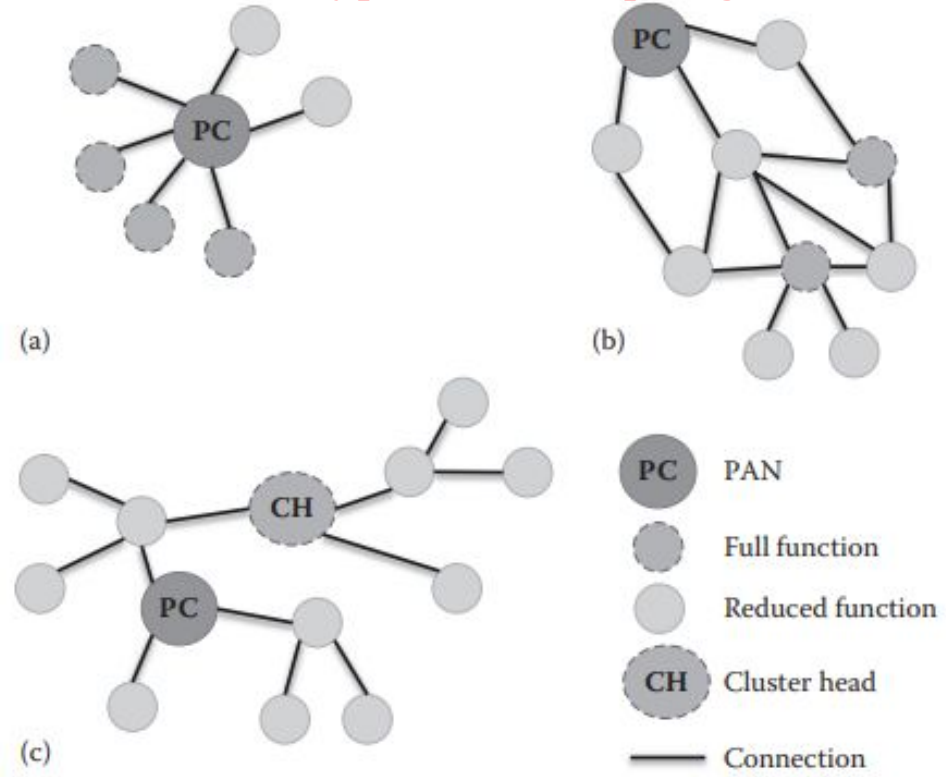
Reduced function devices (RFD)

- Very simple nodes, and they have **constrained resources**.
- Can **only communicate with a coordinator node using only the star topology**.

INFRASTRUCTURE PROTOCOLS-
IEEE 802.15.4

- **Star topology:**
  - Contains at least one FFD and a few other RFDs
  - PAN coordinator should be located at the center of the network.
  - Coordinator manages and controls all other nodes that are a part of the network
- **Peer-to-peer topology:**
  - Contains a PAN coordinator
  - Other nodes communicate with each other in the same network or through intermediate nodes to other networks
- **Cluster-tree topology:**
  - Special kind of the peer-to-peer topology
  - Consists of a PAN coordinator, a cluster head, and normal nodes.

Different types of star topologies



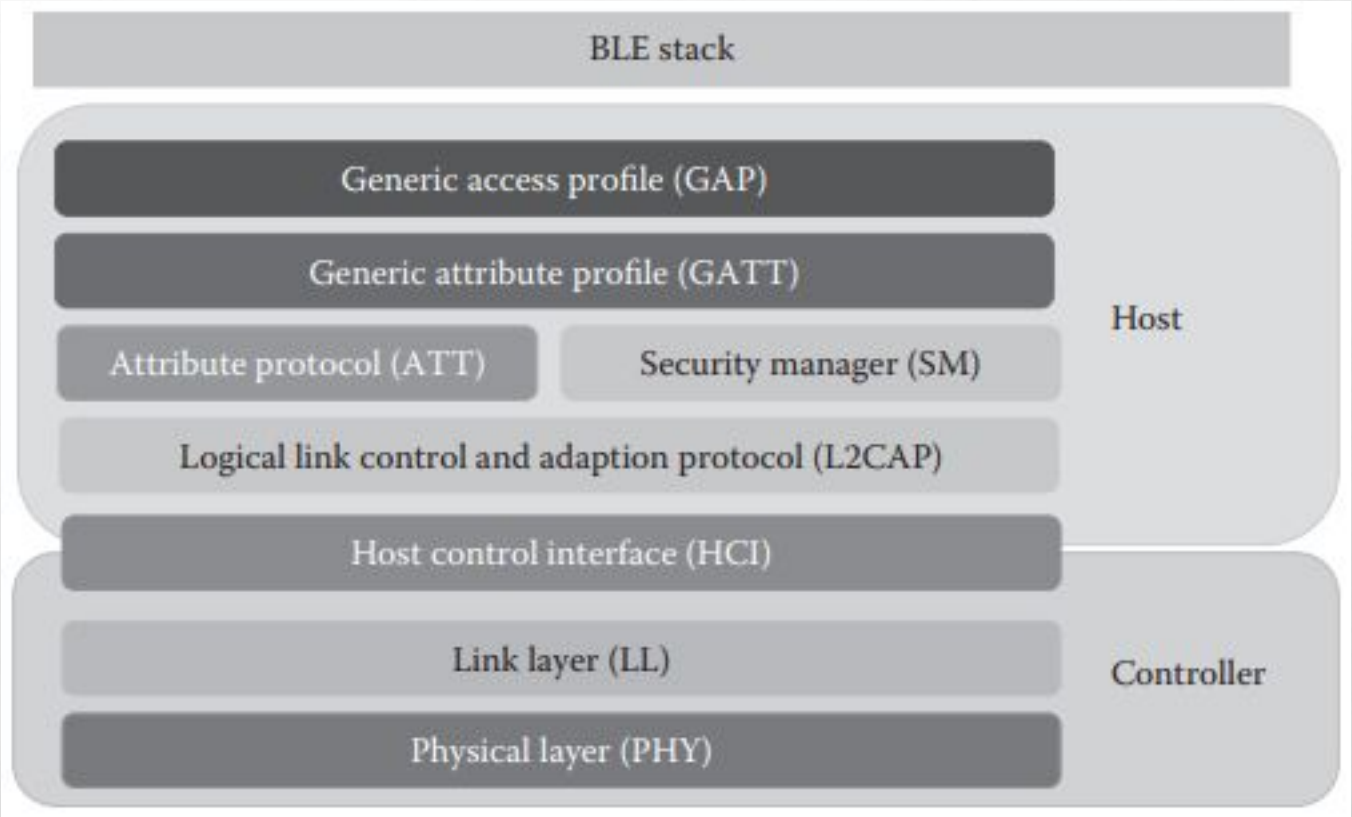
INFRASTRUCTURE PROTOCOLS-
BLUETOOTH LOW ENERGY

- Part of the Bluetooth 4.0 core specification
- Uses short-range radio with minimum power and operates for a long time
- Range coverage is about 100 meters, which is roughly about 10 times more than conventional Bluetooth.
- Latency of BLE is 15 times lesser than that of conventional Bluetooth.
- Operates using a power between 0.01 mW and 10 mW

INFRASTRUCTURE PROTOCOLS-
BLUETOOTH LOW ENERGY

Protocol Stack

- **Physical layer:**
  - This layer receives and transmits data bits
- **Link layer:**
  - Media access control
  - Error control
  - Connection establishment
  - Flow control



INFRASTRUCTURE PROTOCOLS-
BLUETOOTH LOW ENERGY

Protocol Stack

- Host control interface (HCI):
  - The HCI layer provides a command, event, and data interface that allows link layer to access the data from upper layers such as GAP, L2CAP, and SMP.
- Logical link control adaptation protocol (L2CAP):
  - Performs multiplexing of data channels.
  - Also does fragmentation and reassembly of larger packets.
- Generic access profile (GAP):
  - Defines processes related to the discovery of Bluetooth devices
  - Also lays down link management aspects while establishing connection between Bluetooth devices
  - Different types of roles defined by GAP when operating over low-energy (LE) physical channel:

INFRASTRUCTURE PROTOCOLS-
BLUETOOTH LOW ENERGY

Protocol Stack

- **Different types of roles defined by GAP** when operating over low-energy (LE) physical channel:
  - **Broadcaster role:** The device **sends advertising events**. The broadcaster **has a transmitter and may have a receiver**
  - **Observer role:** The device **receives advertising events.** The observer has a receiver, and it may have a transmitter as well
  - **Peripheral role:** The device **accepts the establishment of an LE physical connection.**
    - The device will be in a **slave role** in the link layer connection state.
    - It is called a peripheral device
    - A peripheral device has both a transmitter and a receiver.
  - **Central role:**
    - The **device initiates establishment of a physical connection.**
    - It will be in a **master role** in the link layer connection.
    - Has both a transmitter and a receiver

INFRASTRUCTURE PROTOCOLS-
BLUETOOTH LOW ENERGY

Protocol Stack - Generic attribute profile (GATT)

- **Specifies a framework** using the attribute protocol (ATT) layer
  - defines the structure in which data is exchanged between two devices and how ATT attributes are grouped into sets to form services
- Defines **services and their characteristics -** Services define functions the BLE device supports
- Frames the service procedures, characteristics, and various aspects that pertain to the broadcast of service characteristics
- Two roles that are specified by GATT profiles:
  - **GATT Client** - Any device that wants data
  - **GATT Server** - Any device that has the data and can accept incoming requests from the GATT client
- BLE stack can **support both the roles** simultaneously

INFRASTRUCTURE PROTOCOLS-
BLUETOOTH LOW ENERGY

Protocol Stack

- **Attribute Protocol (ATT)**
  - ATT layer **defines a client or server architecture** above the BLE logical transport channel
  - **Allows a GATT server to communicate with a GATT client** by exposing a set of attributes and interfaces
- **Security Manager Protocol (SMP)**
  - **specifies the procedures and behavior to ensure security** by managing pairing, authentication, and encryption between the devices

INFRASTRUCTURE PROTOCOLS-
EPCGLOBAL

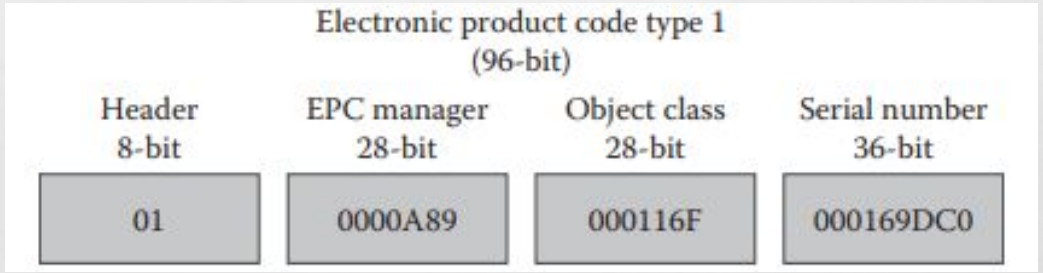
- Developed **industry-driven standards for the Electronic Product Code (EPC)** to support the use of Radio Frequency Identification (RFID) and allow global visibility of items (EPCIS)
- **EPC is a unique identifier stored in an RFID tag** that helps to identify and track items in a supply chain management scenario
- **RFID** devices are wireless microchips used for **tagging objects for automated identification**
- RFID can be used as a key technology for IoT devices for the following reasons:
  - Openness, Scalability, Reliability, Support for object IDs and service discovery

INFRASTRUCTURE PROTOCOLS-
EPCGLOBAL

EPC	*Description*	*Tag Type*	*Functionality*
0	Read only	Passive	Write once and read many times
1	Write once and read only	Passive	Write once and read many times
2	Read or write	Passive	Read or write many times
3	Read or write	Semipassive	Attached within sensor
4	Read or write	Active	Attached within sensor While providing a radio wave field to communicate with the reader

INFRASTRUCTURE PROTOCOLS- EPCGLOBAL

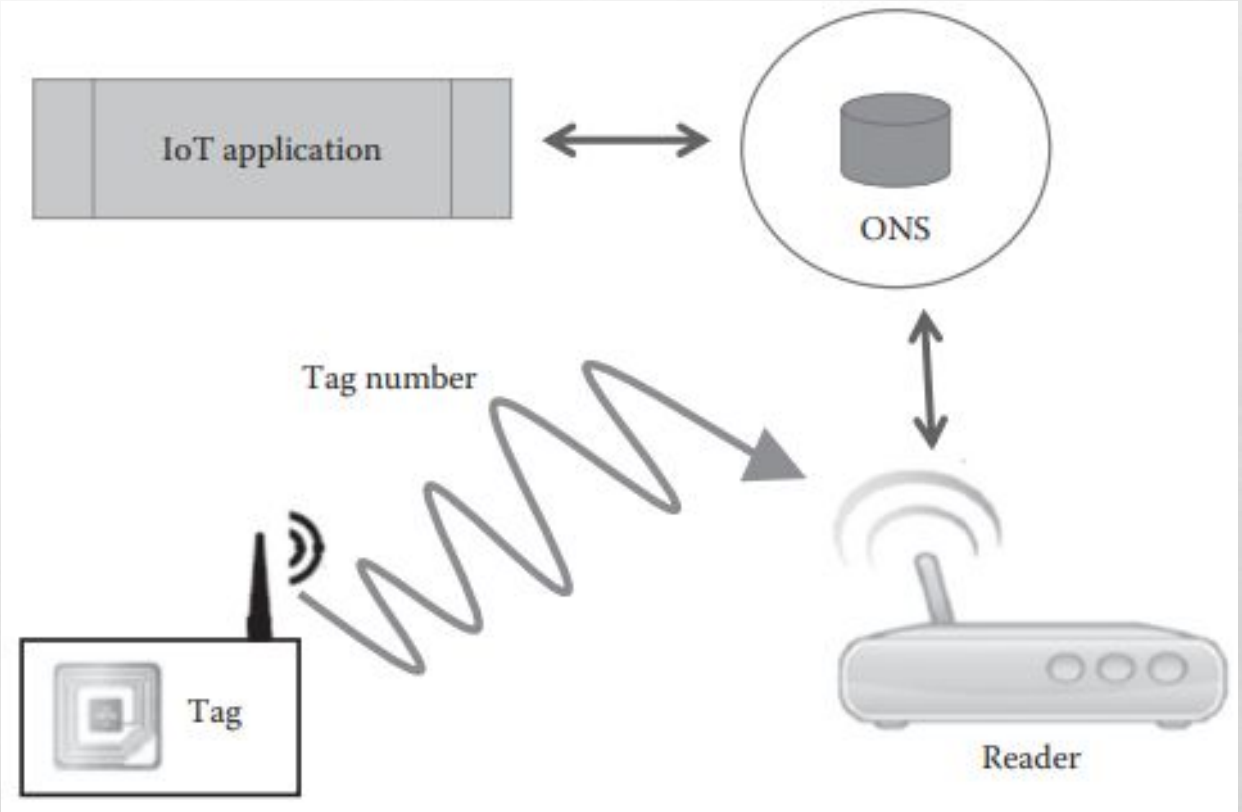
- The key components **of EPCs are classified into four types**:
  - 96-bit
    - supports about 268 million companies with unique identities and cover 16 million types of products and 68 million serial numbers for each type



  - 64-bit (I)
  - 64-bit (II)
  - 64-bit (III)
    - supports about 16,000 companies with unique identities and cover 1–9 million types of products and 33 million serial numbers for each type

INFRASTRUCTURE PROTOCOLS- EPCGLOBAL

- **Two main components of an RFID Tag:**
  - an electronic chip to store the identity of the object
  - an antenna that allows the chip to communicate with the tag-reader system
- **Communication** between the tag and tag reader happens with the help of **radio waves**
- **Two main components of an RFID system:**
  - Radio signal transponder
  - Tag reader
- EPC id system connects the EPC identities to a centralized database using an EPC reader



INFRASTRUCTURE PROTOCOLS-
LONG TERM EVOLUTION-ADVANCED (LTE)

- Referred to as 4G LTE is a **standard for wireless mobile network**
- Provides **high speed data transfer rates** for wireless networks
- Several key use cases of LTE exists for IoT **due of its service cost, scalability, and performance**

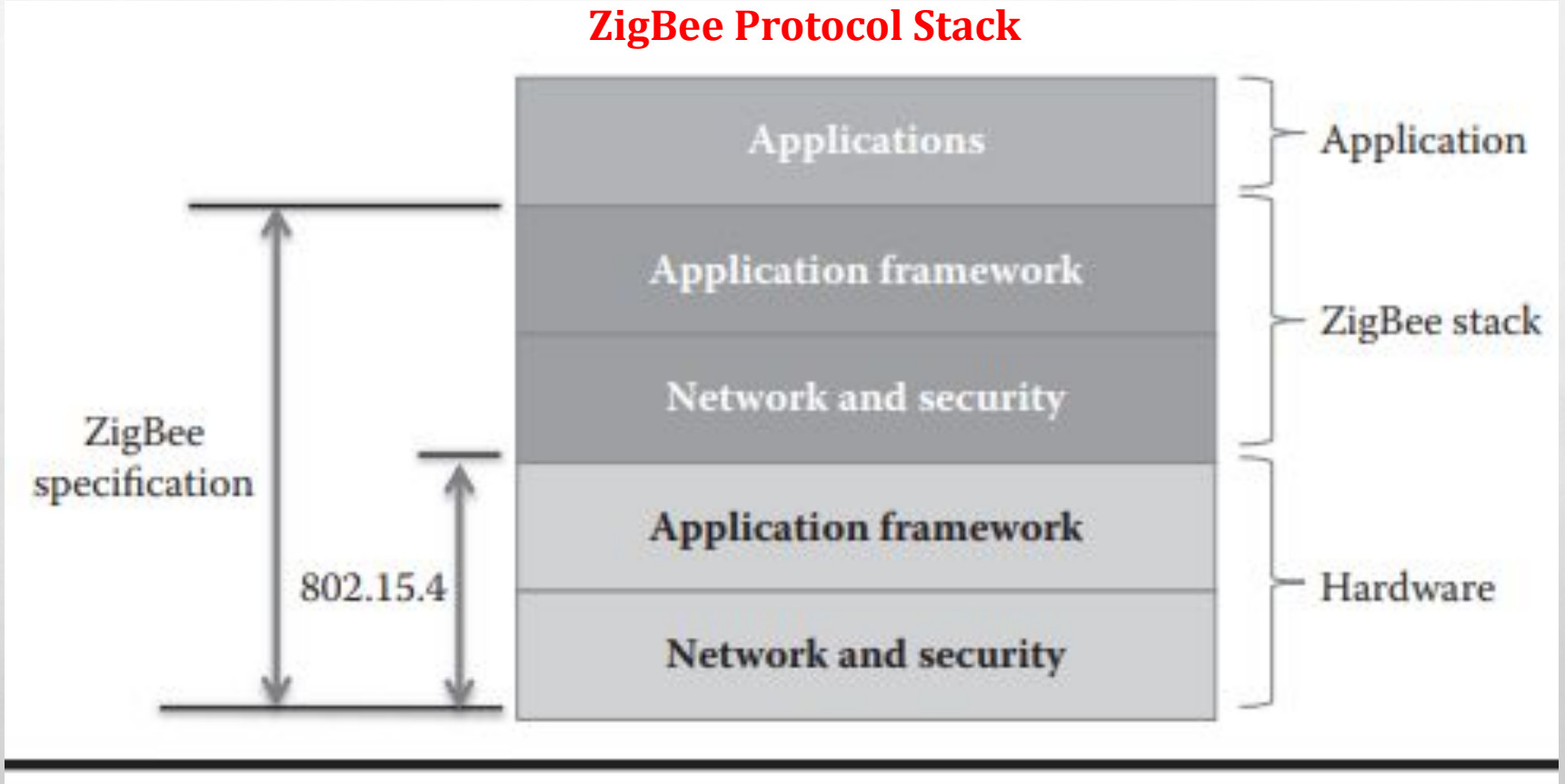
INFRASTRUCTURE PROTOCOLS-
LONG TERM EVOLUTION-ADVANCED (LTE)

LTE Service Offering	*Usage for Intelligent Cities*
Live event streaming	Live coverage of key events happening in a city such as sports, concerts, award ceremonies, elections, and so on.
Real-time TV streaming	Real-time delivery of important sports events, news channels, and other popular TV shows. This will enable entertainment amid work that will in turn go a long way in boosting the productivity. In contrast to a situation where an employee may be prompted to take a leave of absence or abstain from work in order to watch some key TV event.
News, stock market reports, weather, and sports updates	Provides news, stock market reports, weather, and sports updates several times during the course of a day with on-device caching features.

INFRASTRUCTURE PROTOCOLS- ZIGBEE

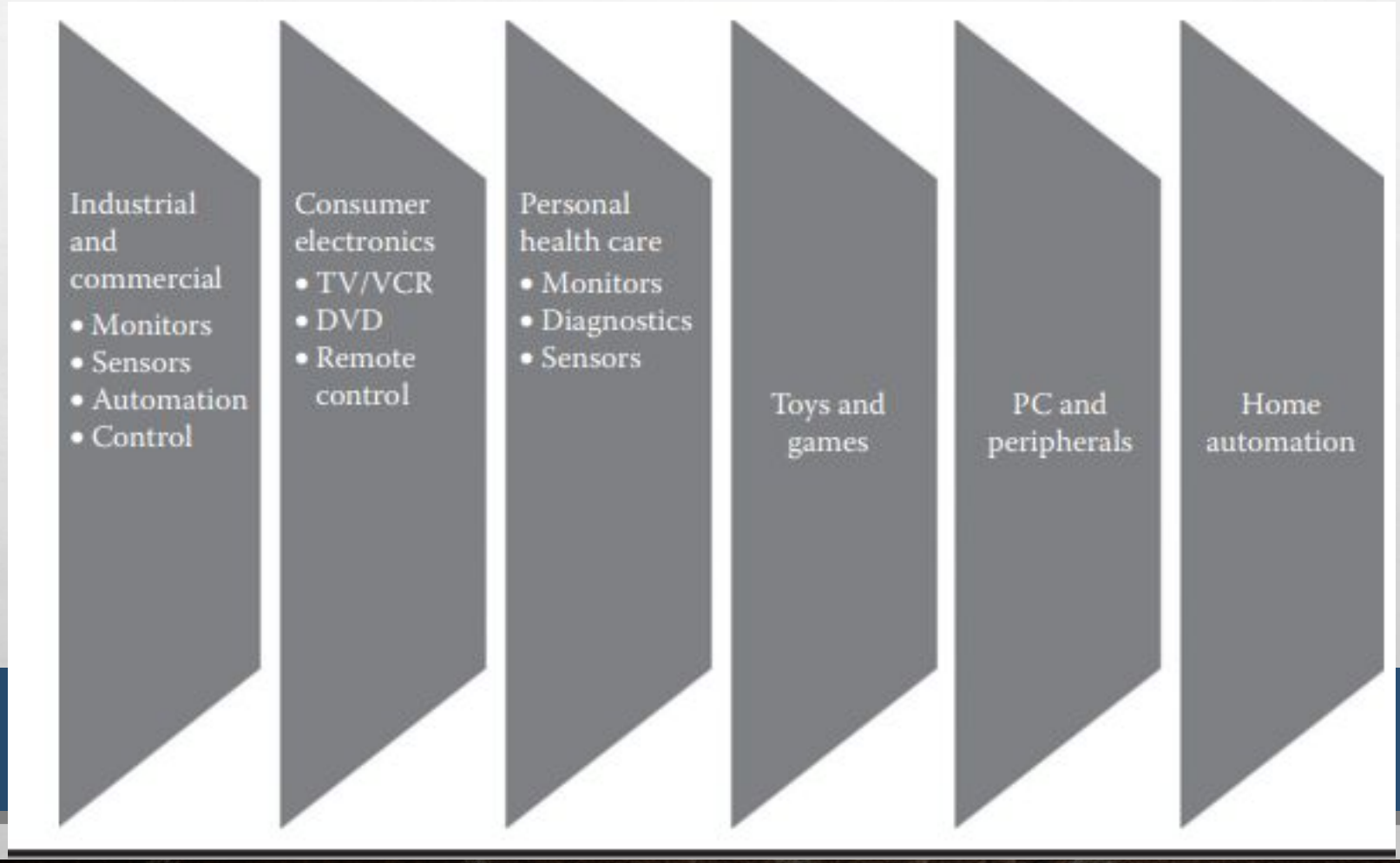
- Framed by the ZigBee alliance
- Following features make it very suitable for IoT applications:
  - Low power consumption
  - Low cost
  - Support for large number of network nodes **(<=65K nodes)**
- Has a **decentralized network topology**
- Allows nodes to **find new routes** if one route fails in the network
- **Frequency:** 2.4GHz
- **Coverage Range:** 50 – 100 feet

INFRASTRUCTURE PROTOCOLS-
ZIGBEE



INFRASTRUCTURE PROTOCOLS-
ZIGBEE

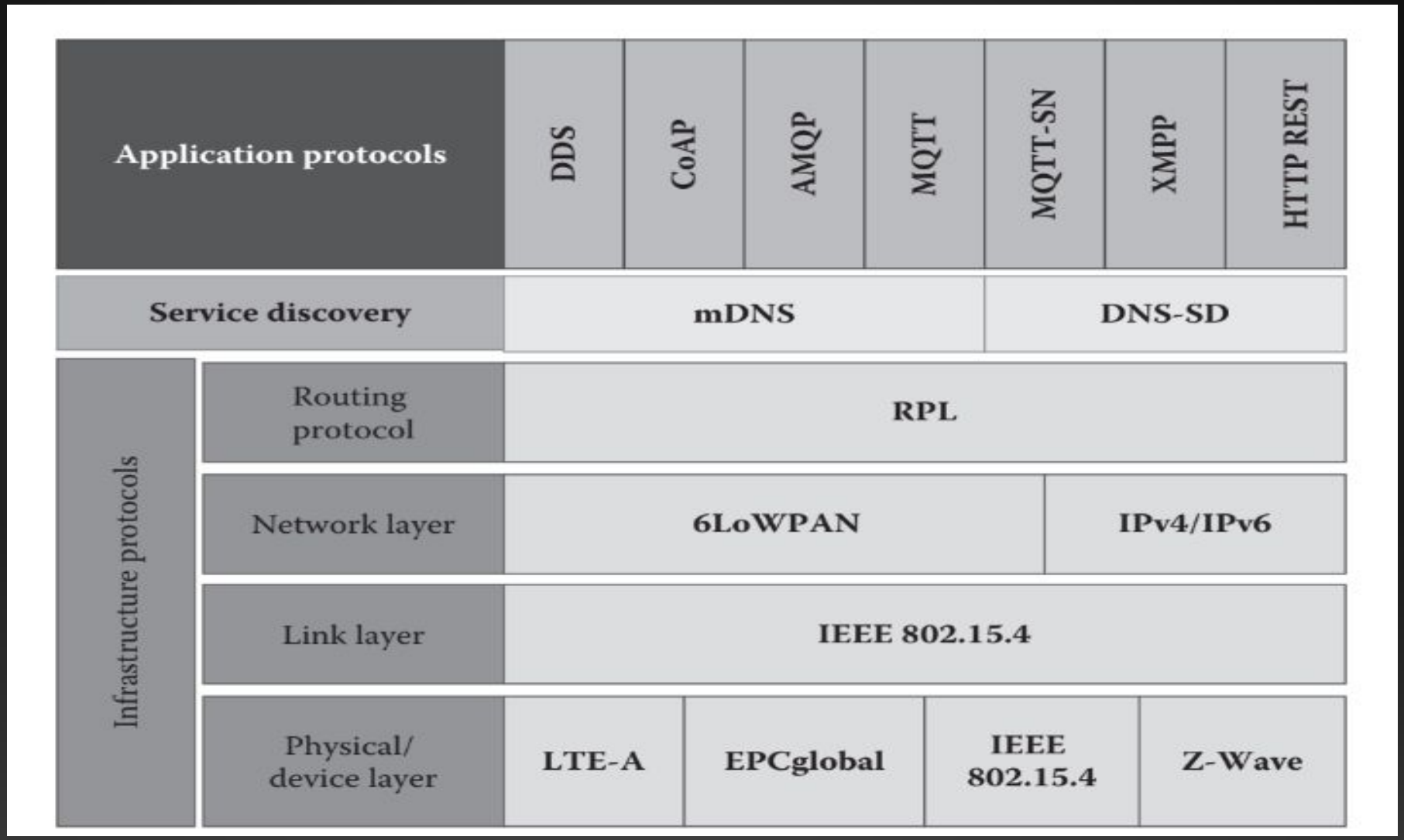
Main application areas of ZigBee



- https://youtu.be/Tz9pFn5zZTw (DODAG)
- https://www.e-spincorp.com/6lowpan-network-architecture/

Categorization of IoT protocols.

- K N PADHMASHREE(20CSR144)


Application protocols
DDS
CoAP
AMQP
MQTT
MQTT-SN
XMPP
HTTP REST
Service discovery
mDNS
DNS-SD
Infrastructure protocols
Routing protocol
RPL
Network layer
6LoWPAN
IPv4/IPv6
Link layer
IEEE 802.15.4
Physical/ device layer
LTE-A
EPCglobal
IEEE 802.15.4
Z-Wave

IEEE 802.15.4

- This protocol was created in order to specify a sublayer for the medium access control (MAC) and physical layer primarily for low-rate wireless private area networks

BENEFITS OFFERED :

- low power consumption
- low-data rate
- low-cost and high-message throughput(suitable for iot systems as communication protocol)
- This protocol also provides reliable communication
- This protocol is ideal for secured communication as it provides high levels of security, encryption, and authentication services.

CONS:

- This protocol does not provide any quality of service (QoS) guarantees.

IEEE 802:15.4 supports transmission at three frequency bands using a direct sequence spread spectrum (DSSS) method.

- On the basis of frequency channel, data transmission happens at three data rates :
  - 250 kbps at 2.4 GHz
  - 40 kbps at 915 MHz
  - 20 kbps at 868 MHz

This protocol supports two types of network nodes:

- Full function devices (FFD)
- Reduced function devices (RFD)

FULL FUNCTION DEVICES (FFD):

- It act as personal area network (PAN) coordinator or as just a normal node. The coordinator has the capability to create, control, and maintain the network.

- FFDs can store routing table within their memory and can implement a MAC.

- They can also communicate with other devices using one of the following topologies:

  - Star
  - Peer-to-peer
  - Cluster-tree

Reduced function devices (RFD):

- RFDs are very simple nodes, and they have constrained resources. They can only communicate with a coordinator node using only the star topology.

STAR TOPOLOGY:

- This contains at least one FFD and a few other RFDs.
- The FFD that is designated to work as a PAN coordinator should be located at the center of the network.
- It has the responsibility of managing and controlling all other nodes that are a part of the network

Peer-to-peer topology:

- This contains a PAN coordinator and other nodes communicate with each other in the same network or through intermediate nodes to other networks.

Cluster-tree topology:

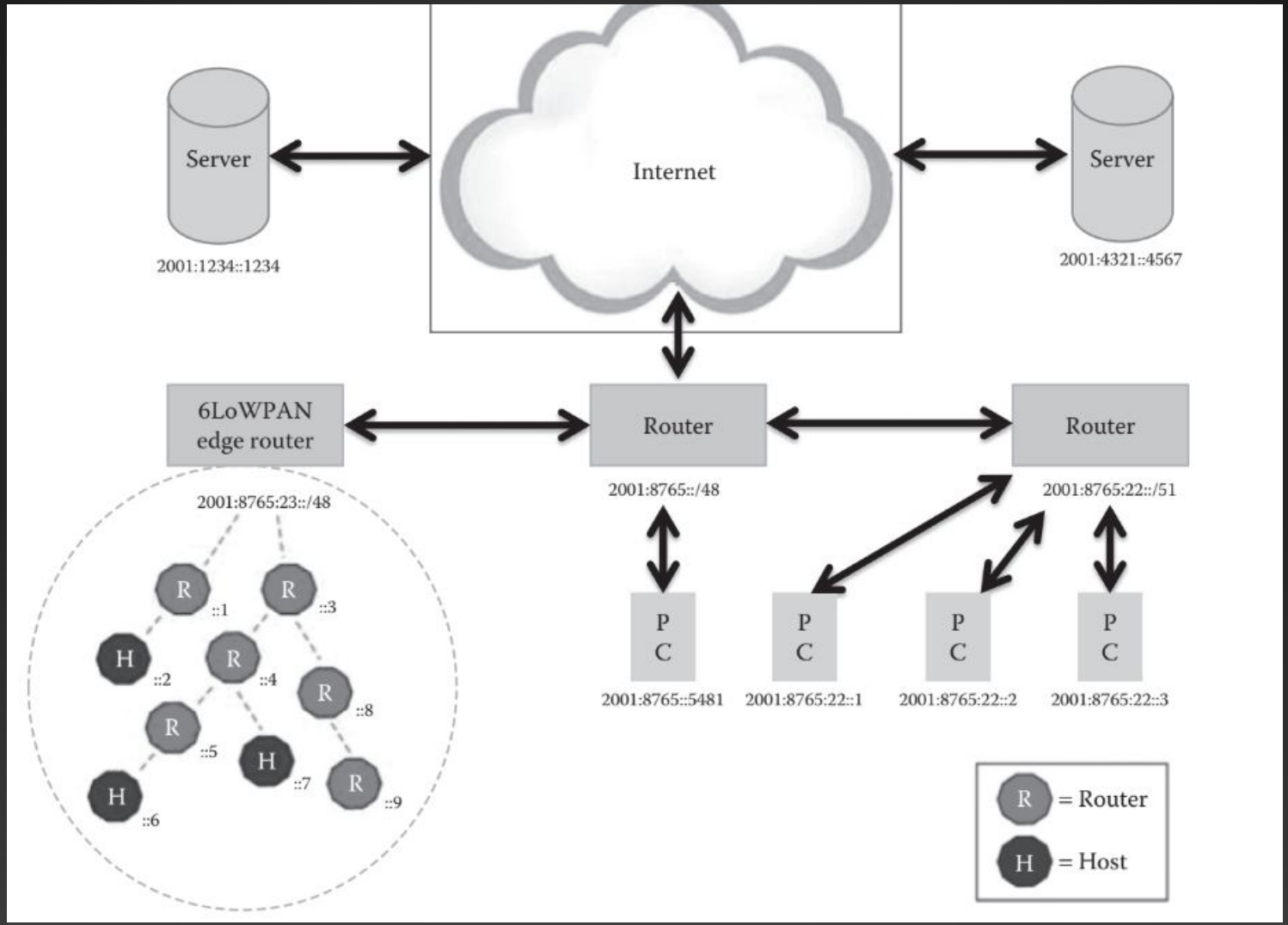
- This is a special kind of the peer-to-peer topology. It consists of a PAN coordinator, a cluster head, and normal nodes.

6LoWPAN :

IPv6 Low Power Personal Area Network

- it uses a lightweight IP-based communication to travel over low data rate networks.
- It has limited processing ability to transfer information wirelessly using an internet protocol.
- So, it is mainly used for home and building automation.
- The 6LoWPAN protocol operates only within the 2.4 GHz frequency range with 250 kbps transfer rate. It has a maximum length of 128-bit header packets.

Network Architecture of 6LoWPAN



functions performed by the edge router:

- It enables exchange of data between 6LoWPAN devices and the Internet (or other IPv6 network).
- It enables exchange of data among devices that are part of 6LoWPAN network.
- It helps to generate and maintain the 6LoWPAN network

The devices that are present in a 6LoWPAN network can be classified into two categories:

- Routers
- Hosts

- Routers are devices that route data to other nodes in the 6LoWPAN network.
- Hosts are also known as end point devices, and they do not have the capability to route data to other devices in the network.
- Host could also be a sleepy device that could check the routers at regular intervals for data.

In short, 6LoWPAN is very promising for use in the IoT market because of the following reasons:

- Support for IP communication
- Support for large mesh network topology
- Very low power consumption
- Robust communication capabilities

BLUETOOTH LOW ENERGY

- Bluetooth Low Energy or more popular as BLE or Bluetooth LE was introduced in the Bluetooth 4.0 specification and was a low power consumption protocol, especially for IoT-based implementations.

- Typically one hears about BLE beacons which are BLE devices that send out Bluetooth signals to electronic devices in the vicinity.

BLUETOOTH

- wireless technologies standards
- Regularly works with large chunks of data but consumes a large amount of battery
- it used in consumer electronic devices where there is a need to exchange data in a continuous stream

BLE(BLUETOOTH LOW ENERGY)

- wireless technologies standards
- It is a lesser amount of data but consumes less energy
- It used where there is less amount of data transfer needed between devices and this data transfer happens in an intermittent manner.

EPC GLOBAL:

- Electronic product code (EPC) is a unique identifier stored in an RFID tag
- RFID (radio frequency identification) devices are wireless microchips used for tagging objects for automated identification that helps to identify and track items in a supply chain management scenario.
- EPCglobal is the organization that developed EPC, and EPC global also prepares and maintains standards that are related to RFID and EPC.
- RFID can be used as a key technology for IoT devices for the following reasons:
  - Openness
  - Scalability
  - Reliability
  - Support for object IDs and service discovery

- The key components of EPCs are classified into four types:
  - 96-bit
  - 64-bit (I)
  - 64-bit (II)
  - 64-bit (III)

- An RFID tag has two main components: an electronic chip to store the identity of the object and an antenna that allows the chip to communicate with the tag-reader system. The communication between the tag and tag reader happens with the help of radio waves. The two main components of an RFID system are:
  - Radio signal transponder
  - Tag reader
- The tag reader generates a radio field that can identify objects using reflected radio waves of the RFID tag.

Protocols for IoT Service Discovery

The commonly used protocols for IoT Service Discovery are

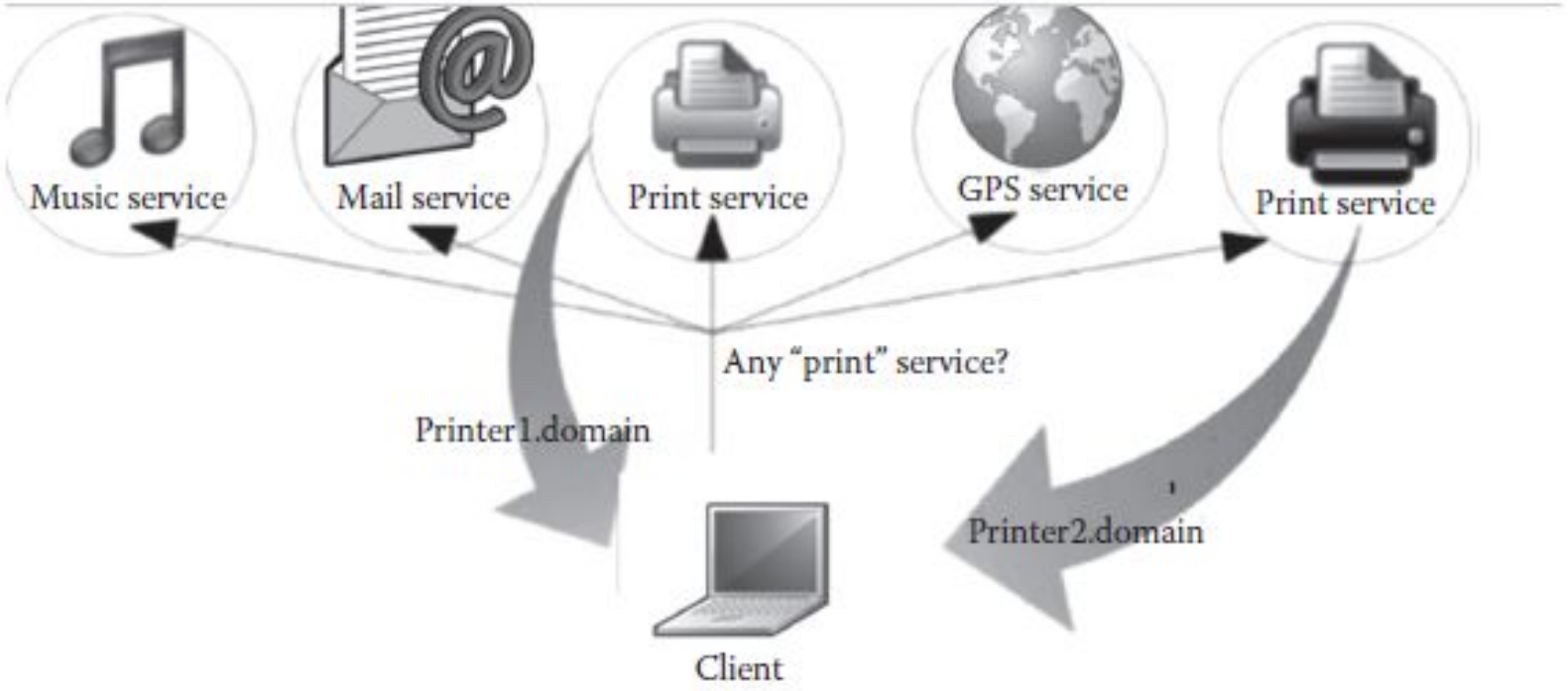
- DNS service discovery (DNS-SD)
- multicast domain name system (mDNS)
- Simple service discovery protocol (part of UPnP)

DNS service discovery (DNS-SD)

- This protocol helps the clients to **discover a set of desired services** that are present in a network with the help of standard DNS messages

- This protocol also helps to connect devices **without any external administration or configuration**

- DNS service discovery (DNS-SD) typically uses mDNS to send DNS packets to specific multicast destinations using UDP
- Service discovery is a two-step process:
    1. Finding host names of required services
    2. Pairing IP addresses with their host names using mDNS


Music service
Mail service
Print service
GPS service
Print service
Any "print" service?
Printer1.domain
Printer2.domain
Client

- **IP addresses may change**, whereas host names will not change (critical to find host names of devices)

- The pairing function multicasts network related details like **IP address and port number** to each related host in the same network

- With the help of DNS-SD, the **host names of the devices in the network can be kept constant** so that the same host name can be used later on without decrease of trust and reliability

multicast Domain Name System (mDNS)

- Multicast Domain Name System (mDNS) is a service that can work like a **unicast DNS server**
- DNS namespace can be used locally with-out any additional configuration (flexible)
- mDNS is an apt choice for embedded Internet-based devices because of the following reasons:
- No manual configuration or administration is required to manage devices.
- It is possible to run this **without any additional infrastructure**
- The capability to function even if infrastructure failure happens (High level of fault tolerance)

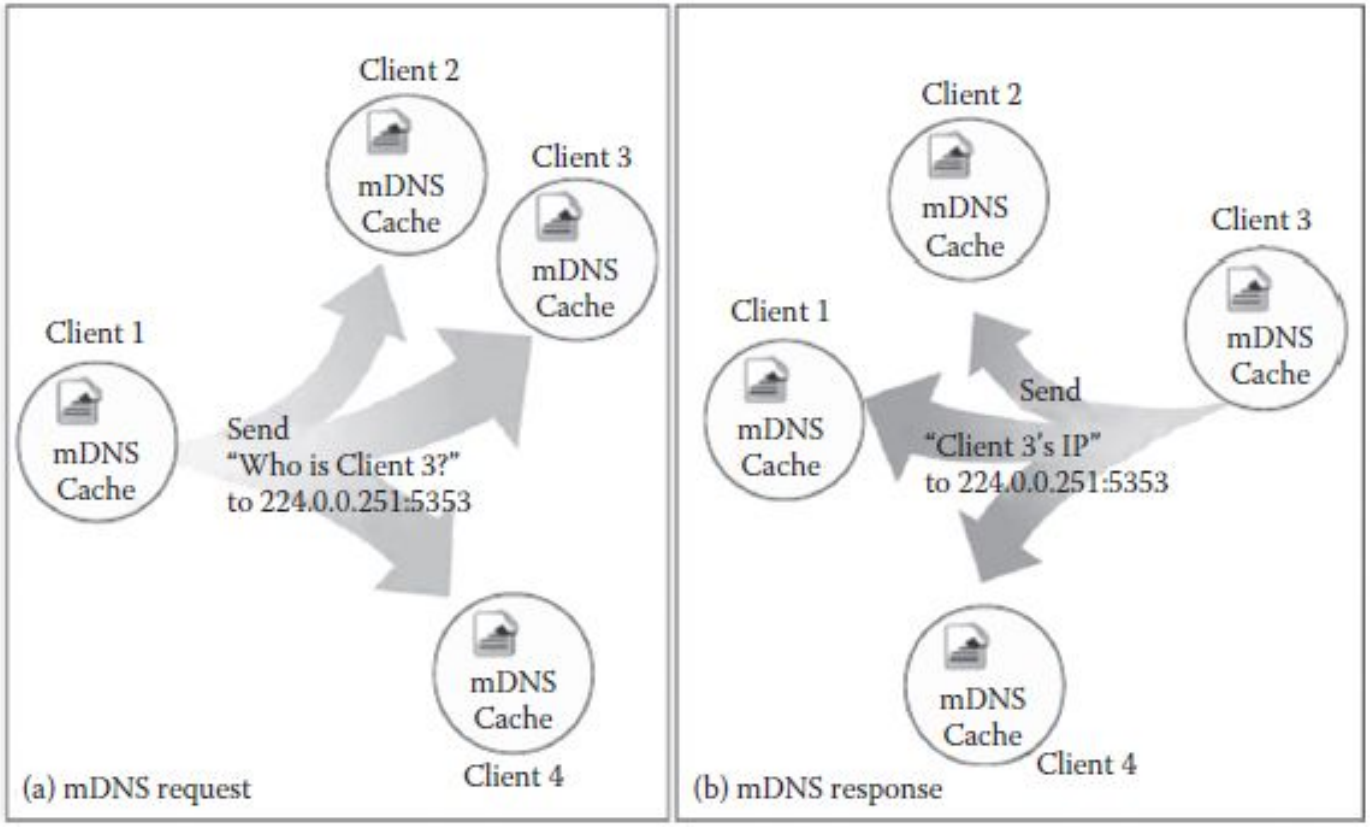
Working of mDNS

- A service of IoT that wants to use service discovery using mDNS first **inquires names** by sending an **IP multicast message to all the nodes** that are present in the local domain

- This message is a query, using which the client asks the devices with a specific name to respond back

- When the target device receives a message, which contains its **name**, it sends a **multicast response message** that contains its IP address

- All devices that are a part of the network update their local cache with the **target device's name and corresponding IP address** that can be used for service request at a later point in time


Client 2
mDNS Cache
Client 3
mDNS Cache
Client 1
mDNS Cache
Send
"Who is Client 3?"
to 224.0.0.251:5353
mDNS Cache
Client 4
(a) mDNS request
Client 2
mDNS Cache
Client 3
mDNS Cache
Client 1
mDNS Cache
Send
"Client 3's IP"
to 224.0.0.251:5353
mDNS Cache
Client 4
(b) mDNS response

Universal Plug and Play

- The main features of UPnP that makes it suitable for service discovery of IoT devices are the following:

  - Capability of a UPnP device to join a network dynamically (automatically) and obtain IP addresses of other devices and at the same time convey its capabilities to other devices
  - Zero configuration and administration

- The **three basic components** of a UPnP network are the following:
  - Devices
  - Services
  - Control points

- **Device:**

  - It is a container for services and other nested devices, which are part of the network

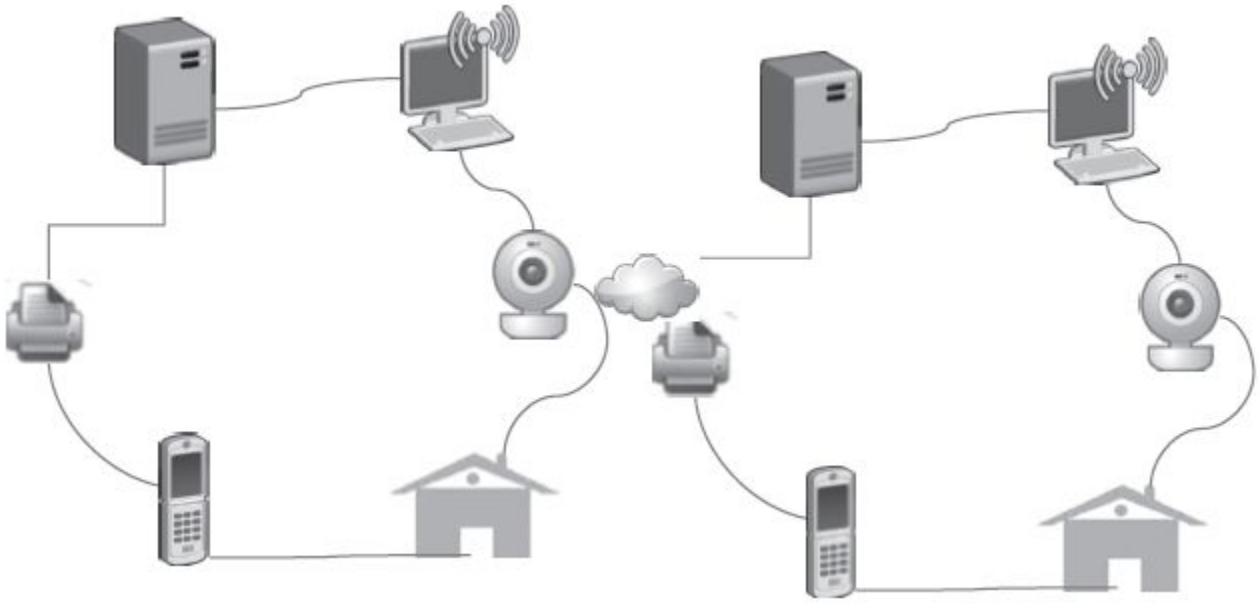
  - A service basically is the most granular unit of control that offers a set of actions

- **Control points:**

  - This provides the feature of device discovery and control by receiving device and service descriptions and by invoking service actions.

- **Services:**

  - The set of services that are offered by UPnP devices.



- The protocol that offers service discovery feature for a UPnP network is the **simple service discovery protocol** (SSDP)
- SSDP is based on **multicast-based discovery of devices** that form a part of the network
- The SSDP lets a control point look for devices and services, and it also allows a device to announce its availability
- A UPnP control point sends an SSDP search request in order to discover devices and services that are available on a specific network
- A UPnP device in turn listens to the multicast port.
- Remote access feature of UPnP networks enables a remote UPnP device or UPnP control point to connect home or any other small business network to interact with a UPnP device or control point that is present in another home or small business network
- This remote access support and flexible connectivity options offered by the UPnP make it very suitable for service discover and interconnection of multiple IoT networks

20CST62 – IoT and Cloud

Unit 2

Low Power Wide Area Networking Technologies

By,
Dr.M.Geetha,
ASP(CSE),
Kongu Engineering College, Erode

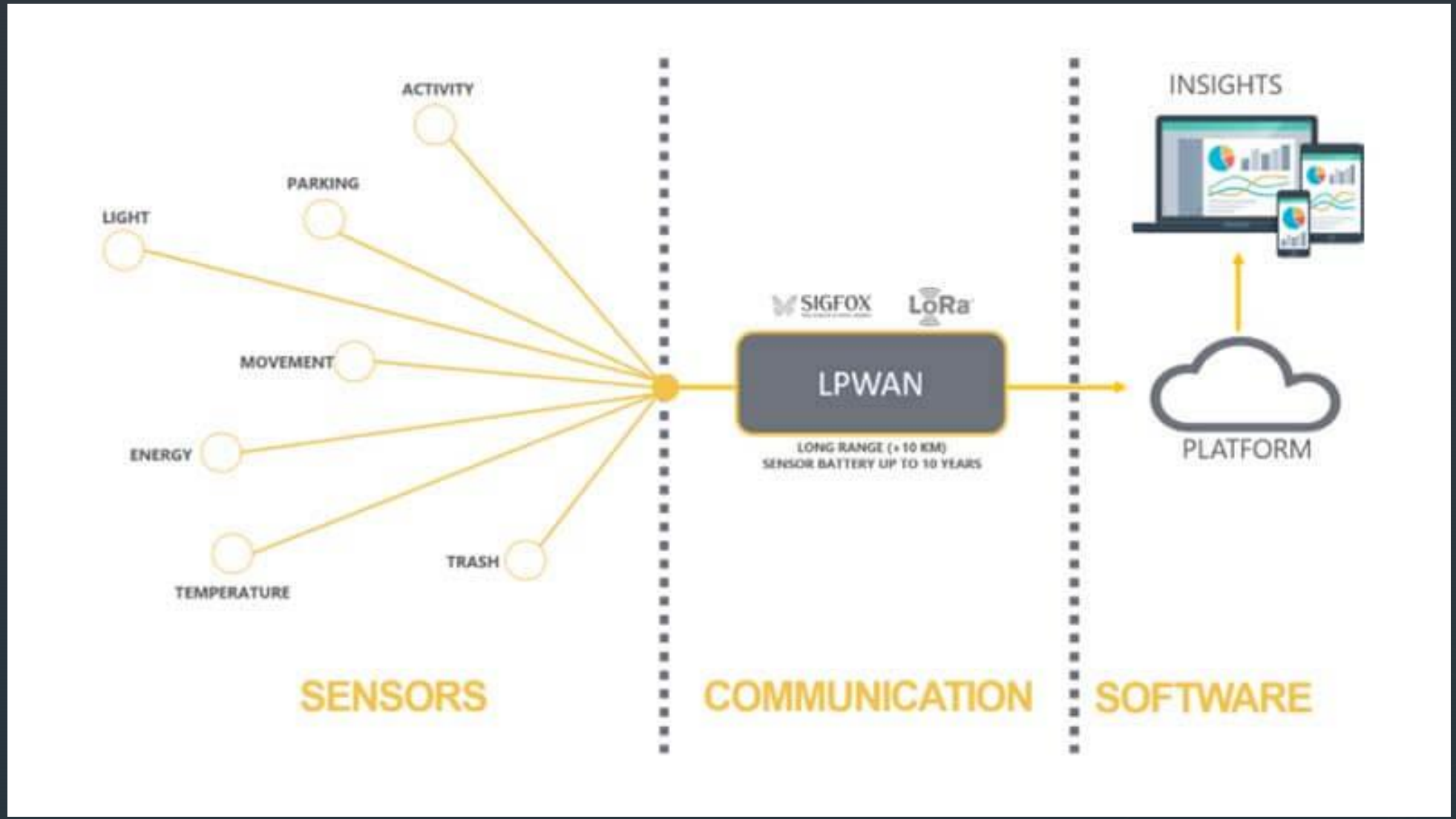
Introduction

- Used extensively for communication in the IoT ecosystem
- Perfectly suits for connecting devices that send small amounts of data over a long range with battery efficiency
  - example of devices that fall under this category are sensors, which are used for transmitting data within smart homes, buildings, parking systems, etc
- Optimize battery life by decreasing power consumption
- Networking standards ensure reliable connections at low speeds to support low levels of data use
- Two categories of LPWANs:
  - Cellular (e.g. NB-IoT and LTE Category M1) WANs using licensed spectrum.
  - Wireless WANs operating in unlicensed frequency bands(e.g. LoRaWan and Sigfox)

Introduction…

- For LPWAN technology, a star-topology network is preferred
- The endpoints of star networks are connected directly to access points.
- To avoid drop in transmission power, Repeaters can be used
- LPWAN technologies operate with 140–160 decibels that can provide several miles of range.
- High sensitive receivers are used to achieve high miles
- Accommodate packet sizes from 10 to 1,000 bytes at uplink speeds up to 200 Kbps
- LPWAN's long range varies from 2 km to 1,000 km, depending on the technology

Introduction…



Key Features of LPWAN

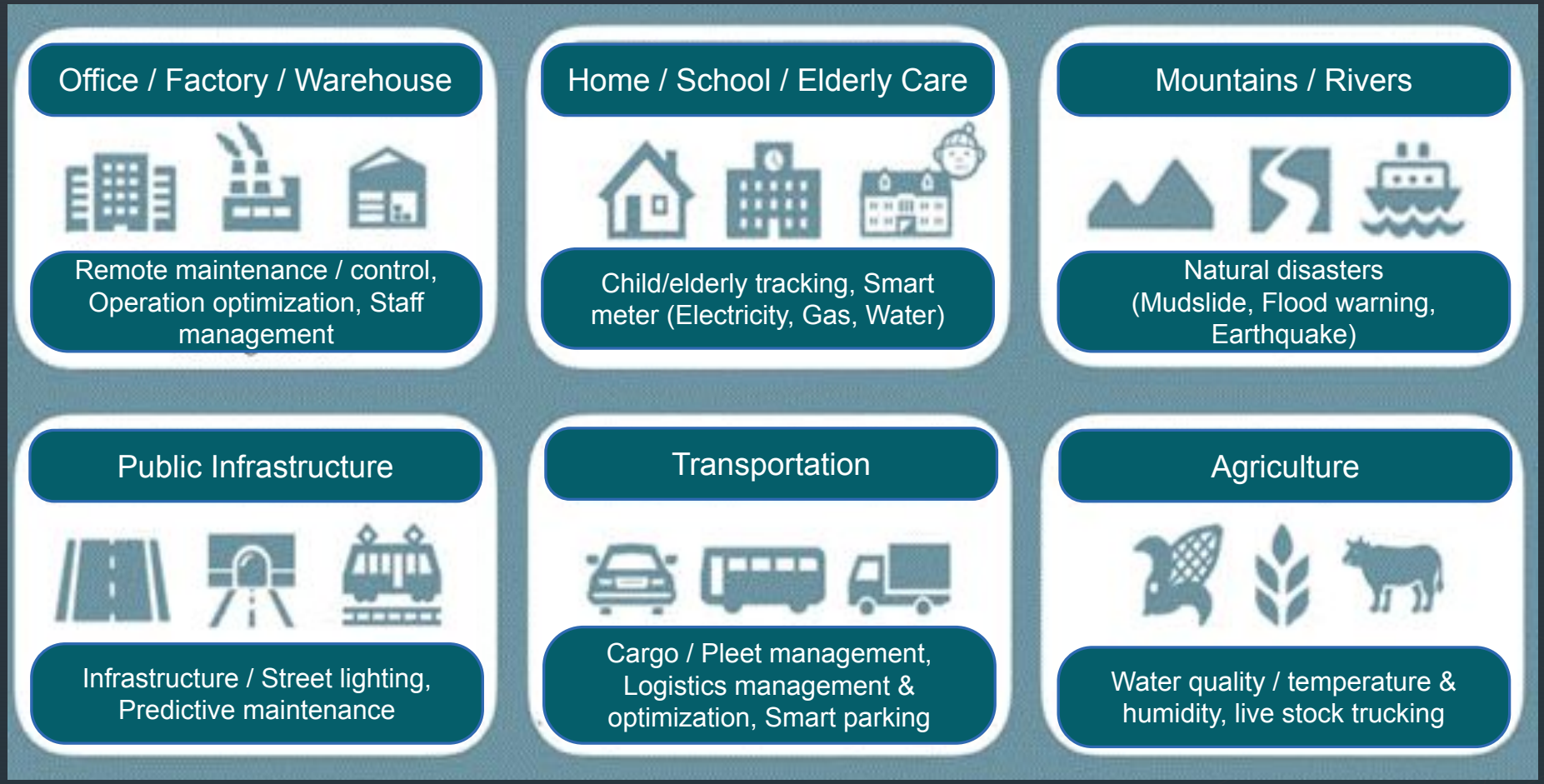
Key features of LPWAN that make it suitable for IoT ecosystem

- Long-range communication: Support nodes that are greater than or equal to 10 km distance from the gateway
- Low transmission data rate: Less than 5000 bits of data sent per second
  - Only 20–256 bytes per message sent several times a day.
- Low-power consumption: Provides very long battery life for the devices.
  - Battery life may last up to 10 years

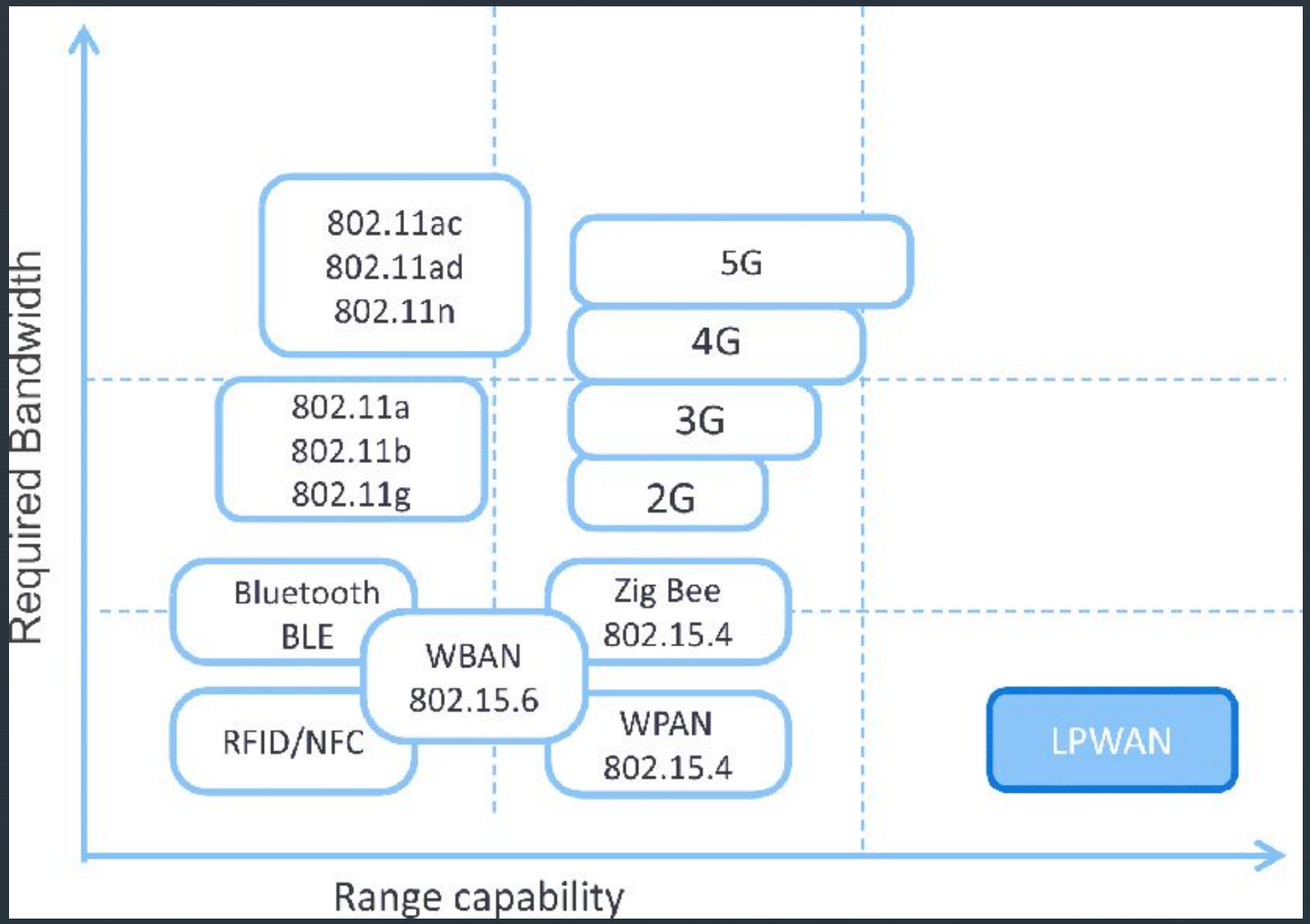
Types of Applications

- Fixed, medium-to-high density connections
  - Examples: smart grids, GPS-based asset tracking systems, and smart lighting systems
- Long life, battery powered applications
  - Examples: water meters, gas detectors, smart agriculture systems

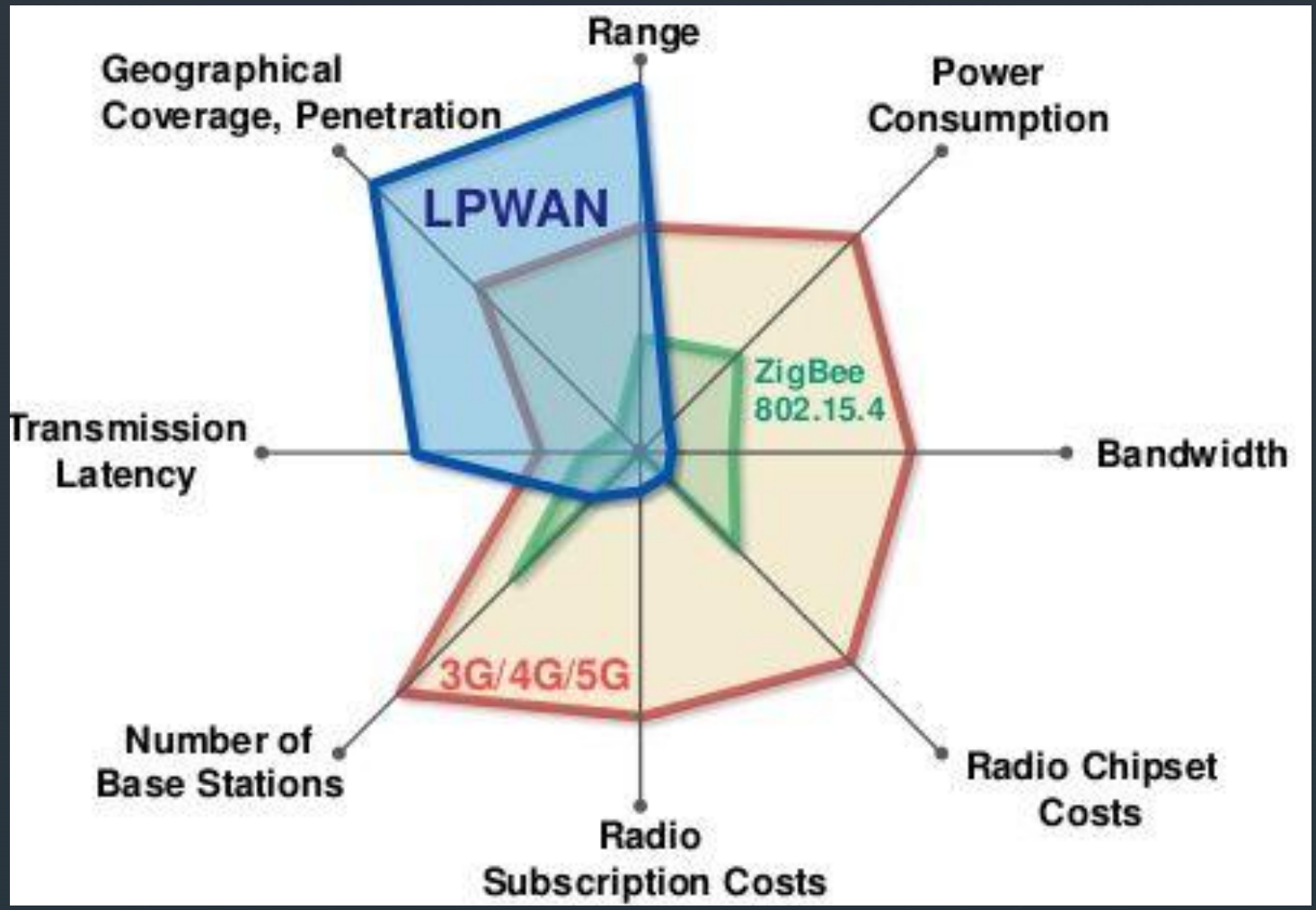
LPWAN Use Cases



LPWAN - Bandwidth Requirements



Specific Requirements on LPWAN Technologies



Important Parameters

Important parameters to be considered while choosing a LPWAN technology:

- Capacity
- Quality of service
- Range
- Reliability
- Battery life
- Security
- Cost
- Proprietary versus standard

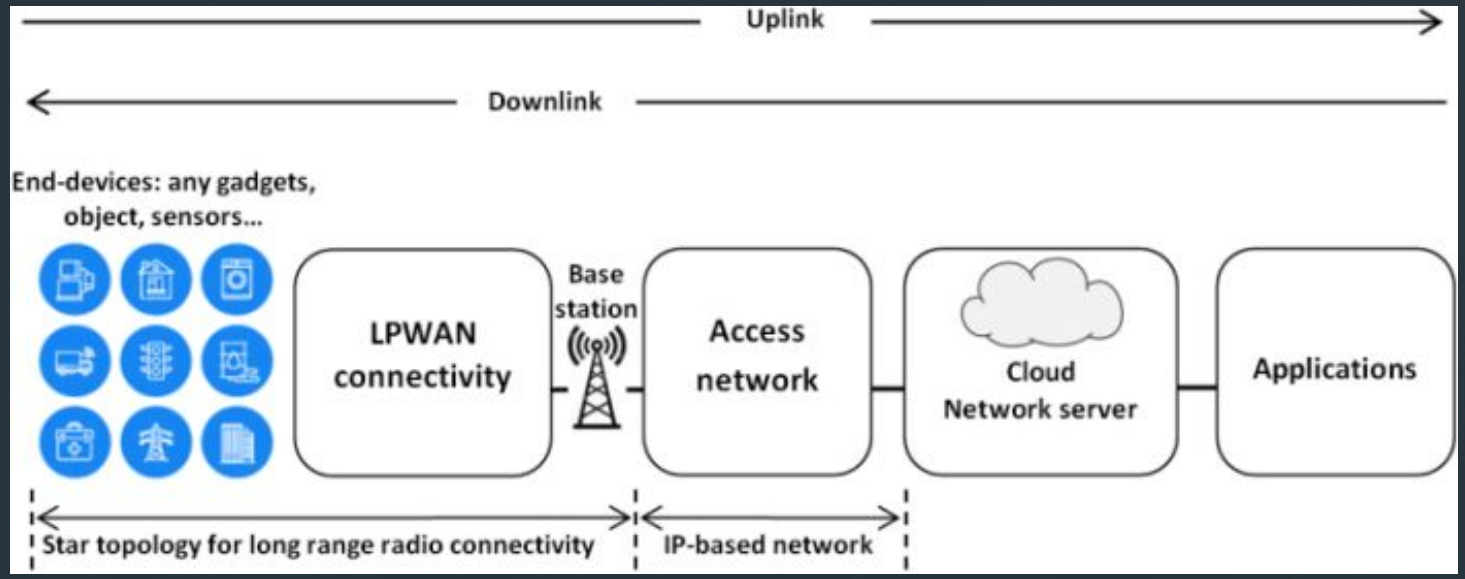
LPWAN Network Topologies

Two network topologies:

- Direct device connectivity (base station)
- Indirect device connectivity through an LPWAN gateway

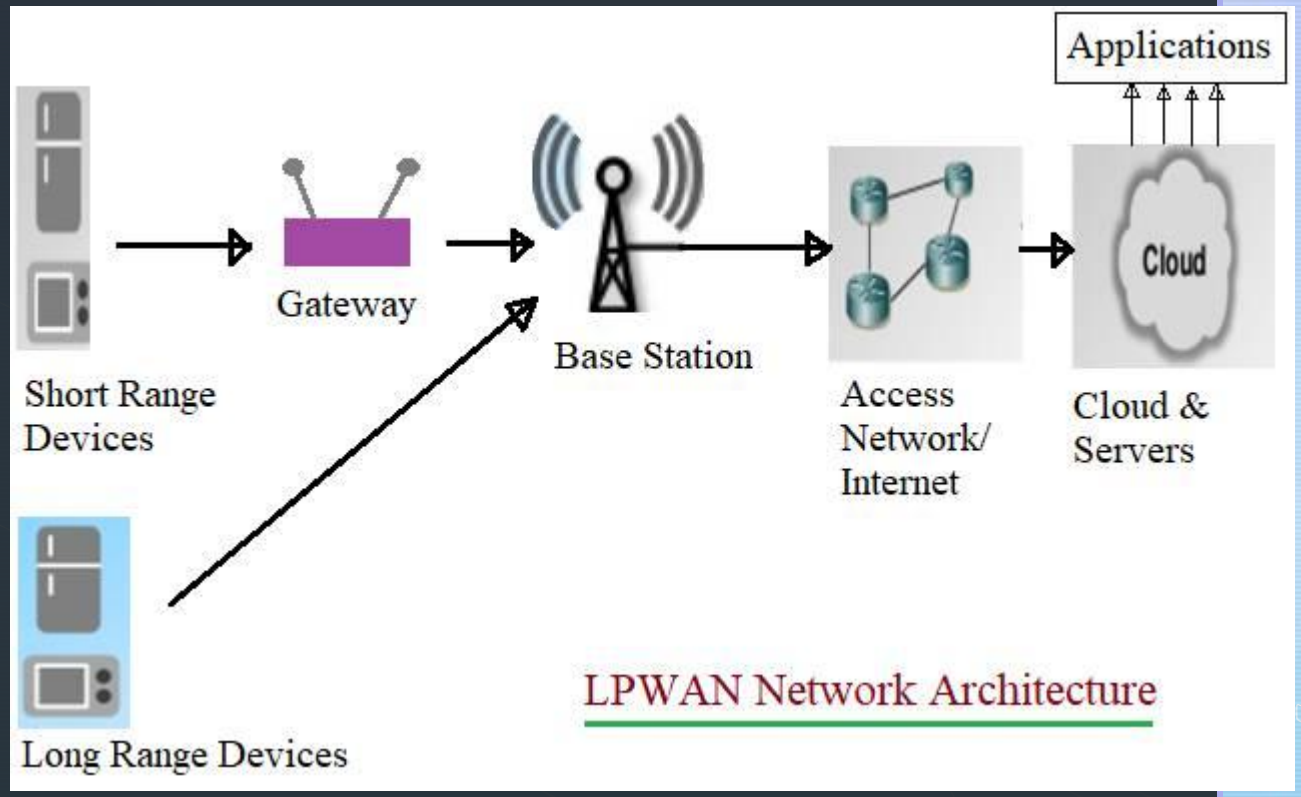
Direct Device Connectivity Topology

- The base station that is present in the network provides connectivity to a large number of devices.
- The base station is responsible for translation of protocol from IoT protocols such as MQTT or CoAP to specific device application protocols
- The traffic is sent to servers (cloud) through TCP or IP-based networks (Internet).



Indirect Device Connectivity Topology

- Used in networks where it is not possible to connect devices directly to LPWAN
- A local gateway is used to bridge LPWAN connectivity to some short-range radio (SRD) technology like ZigBee or BLE
  - Runs on main power as it has to support a large number of devices
  - Should have the capability to convert SRD radio technologies to LPWAN technology
  - Provides more security to IoT ecosystem



LPWAN Technologies

- Sigfox
- Weightless
- Nwave
- Ingenu
- LoRa

LPWAN Technologies - Sigfox

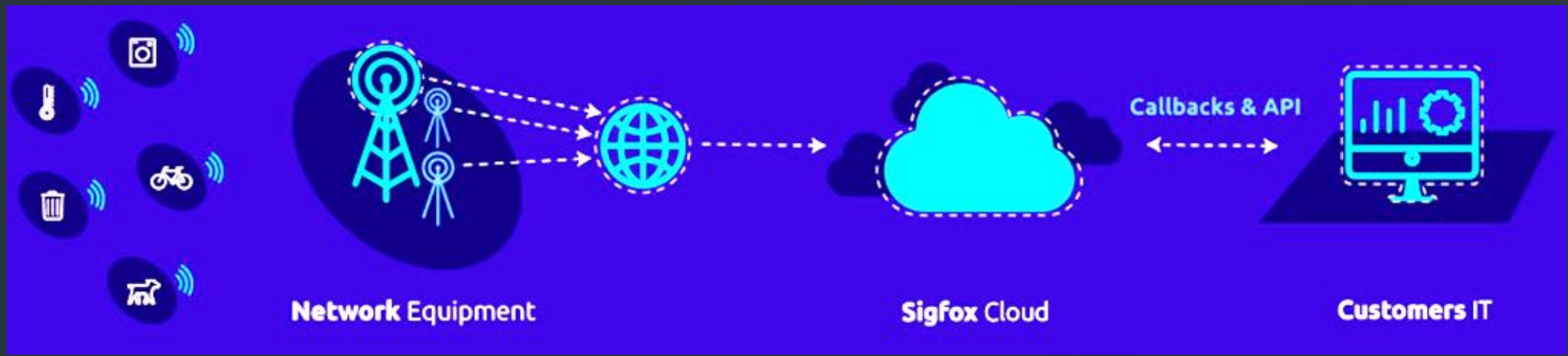
- Has partnership with vendors in the radio space such as Texas Instruments, Silicon Labs, and Axom.
- Offers support for uplink only sensor applications
- Transfers only 15 bytes of traffic at a time with an average of only 10 messages per day. Hence, used only for very simple devices
  - 12 bytes uplink and 8 bytes downlink
  - 120 messages/day at present
- Uses antennas set up on towers in order to receive data from devices such as parking sensors and water sensors
- Data transmissions happen in 868 or 915 MHz frequency bands using a technology called binary phase shift keying (BPSK)
  - widely used for data transmission using RFIDs, wireless LANs, and Bluetooth.
- Application domains: alarm systems, location monitoring systems, and simple metering systems
- Disadvantage: shorter battery life for battery powered applications

LPWAN Technologies – Sigfox…

Life cycle of a Sigfox message:

1. A device wakes up and emits a message using its radio antenna
2. Multiple Sigfox base stations in the area receive the message
3. Base stations send the message to the Sigfox Cloud
4. The Sigfox Cloud sends the message to a customer's backend platform

Sigfox Network



LPWAN Technologies – Weightless

- Open LPWAN standard which operates in sub-1 GHz unlicensed spectrum
- Has three open standards:
  - Weightless-P
  - Weightless-N
  - Weightless-W

LPWAN Technologies – Weightless…

- Weightless-P
  - Offers bidirectional communication using narrow band modulation scheme
  - Advantages: offer the committed performance rate, network reliability, and security parameters, low cost, less power consumption (<100uW) in idle state
- Weightless-W

LPWAN Technologies – Weightless…

Weightless-N

- offers one-way communication
- very low power consumption, and hence, long battery life of about 10 years
- low network cost
- Covers a range of several kilometers even in urban areas
- uses differential binary phase shift keying (DBPSK) digital modulation scheme to transmit using narrow frequency bands
- provides support for encryption and implicit authentication using 128 bit AES algorithm
- automatically route terminal messages to the correct destination

LPWAN Technologies – Weightless…

Weightless-W

- most extensively used option as it runs in the unused TV spectrum
- Data rates: 1 Kbit/s - 10 Mbit/s
- size of data packets starting from 10 bytes
- Supports both acknowledged and unacknowledged message transmission modes
- Supports multicast and interrupt features
- provides an ultra secure 128-bit encryption and authentication model
- facilitates low-cost implementation using minimal memory and processor power
- Supports scheduling to plan data transmission ahead
- Maximize throughput through frequency hopping and intelligent frequency planning
- The range is about 5 km in indoor terminals

LPWAN Technologies – NWave

- Basis for the Weightless-N protocol
- Use a star networking topology allowing direct communication with base stations
- coexist with other radio technologies using advance demodulation techniques

LPWAN Technologies – Ingenu

- Makes use of Random phase multiple access (RPMA) technology designed exclusively for wireless M2M communication
- supports large coverage area due to the high sensitivity levels of its receivers
- support hundreds and thousands of endpoint devices with various data rates
- operates in 2.4 GHz band that provides greater transmission power
- endpoints send signals that fall inside predefined frame sizes

LPWAN Technologies – LoRa

- Developed by Semtech, IBM research, and Activity
- primarily for uplink-only applications
  - data from sensors/devices to a gateway—with many endpoints
- main features of LoRaWAN:
  - three open standards that provide various types of options for end users
  - lot of software and vendors are available in the market
  - network server software should be run in the cloud
  - underlying chip to implement a full LoRaWAN stack is only available with Semtech

References

- Pethuru Raj and Anupama C. Raman, “The Internet of Things Enabling Technologies, Platforms, and Use Cases”, Taylor & Francis, CRC Press, 2017.
- https://behrtech.com/lpwan-technology/
- https://www.techtarget.com/iotagenda/definition/LPWAN-low-power-wide-area-network