Network Configuration in IoT

What is network configuration?

- Network configuration is **the process of assigning network settings, policies, flows, and controls**.

- In a virtual network, it's easier to make network configuration changes because physical network devices appliances are replaced by software, removing the need for extensive manual configuration.

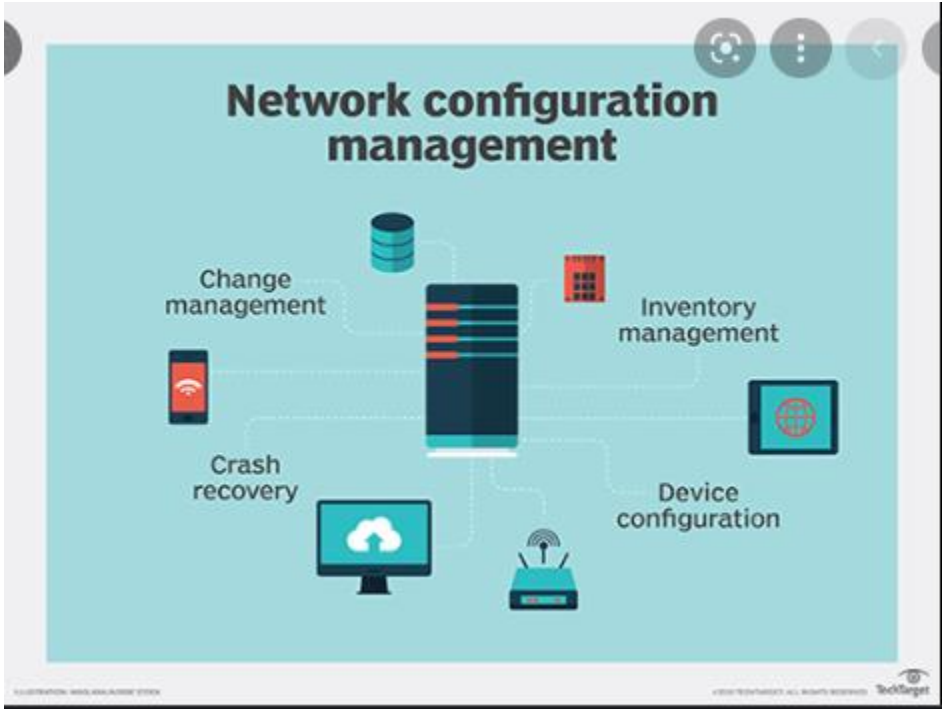
How do you configure a network?

A step-by-step guide to setting up a home network

- Connect your router. The router is the gateway between the Internet and your home network.
- Access the router's interface and lock it down.
- Configure security and IP addressing.
- Set up sharing and control.
- Set up user accounts.

What are the benefits of network configurations

- Streamline the processes of maintenance, repair, expansion and upgrading.
- Minimize configuration errors as part of change management.
- Optimize network security.
- Ensure that changes made to a device or system do not adversely affect other devices or systems.



What are the types of network configuration?

- Personal Area Network (PAN)
- Local Area Network (LAN)
- Wireless Local Area Network (WLAN)
- Campus Area Network (CAN)
- Metropolitan Area Network (MAN)
- Wide Area Network (WAN)
- Storage-Area Network (SAN)

PAN

- A personal area network is a computer network for interconnecting electronic devices within an individual person's workspace.

- A PAN provides data transmission among devices such as computers, smartphones, tablets and personal digital assistants.

LAN

- A local area network is a computer network that interconnects computers within a limited area such as a residence, school, laboratory, university campus or office building.

- The computers in a LAN connect to each other via TCP/IP ethernet or Wi-Fi.

Wireless LAN

- A wireless LAN is a wireless computer network that links two or more devices using wireless communication to form a local area network within a limited area such as a home, school, computer laboratory, campus, or office building.

Vishwakarma Institute of Technology

CAN

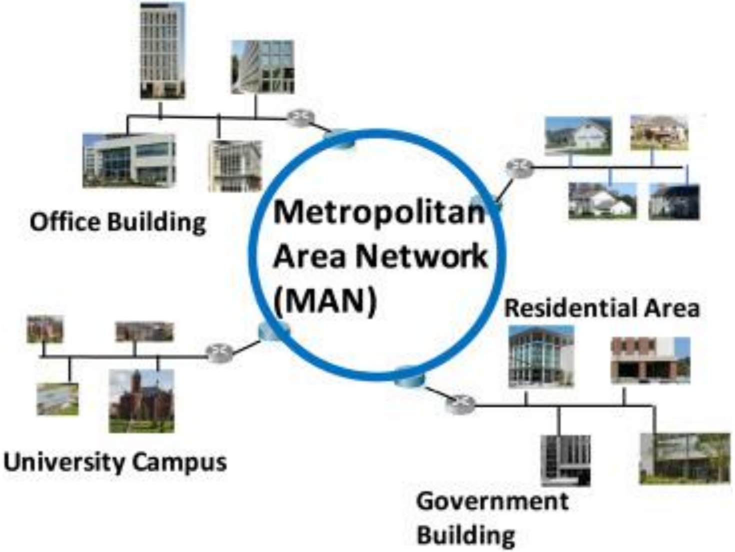
- A campus network, campus area network, corporate area network or CAN is a computer network made up of an interconnection of local area networks within a limited geographical area.

- Examples include elementary schools, university campuses, and corporate buildings

MAN

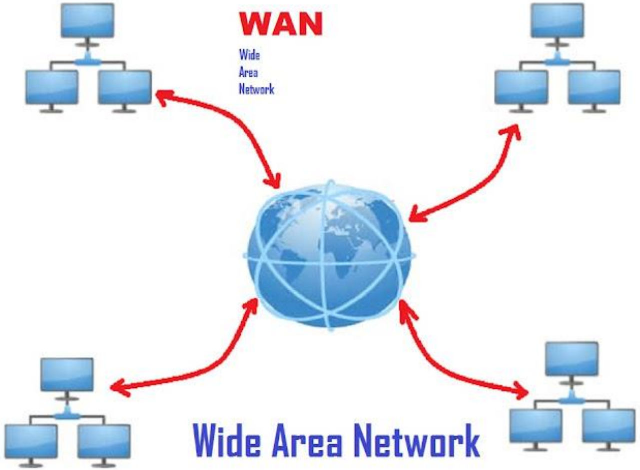
- A metropolitan area network is a computer network that interconnects users with computer resources in a geographic region of the size of a metropolitan area. Size: **5 kilometers to 50 km**

- Most widely used technologies to develop a MAN (Metropolitan Area Network) network are **FDDI (fiber distribution data interface), ATM (Asynchronous Transfer Mode) and SMDS (switched multi megabit data service)**.



WAN

- A wide area network is a telecommunications network that extends over a large geographic area. Wide area networks are often established with leased telecommunication circuits.
- The best example of a Wide Area Network is **Internet itself**.
- Other smaller examples of WANs are: A network of bank cash dispensers; A Company network with several branch offices geographically distant.



SAN

- A storage area network or storage network is a computer network which provides access to consolidated, block-level data storage. SANs are primarily used to access data storage devices, such as disk arrays and tape libraries from servers
- Fiber Channel Protocol (FCP)FCP is the most commonly used SAN protocol.

What are network topologies?

- Different types of network configuration in computer networks are commonly referred to as *network topologies*.
- A network topology describes how the nodes or devices (physical or virtual) in a network are arranged and how they communicate with each other.
- Network topology can be physical (referring to where physical devices are placed in relation to each other) or logical (referring to how data is transmitted through the network, including any virtual or cloud resources).
- When choosing a network topology, an organization must consider the size of its network, its performance requirements and the flow of its traffic.

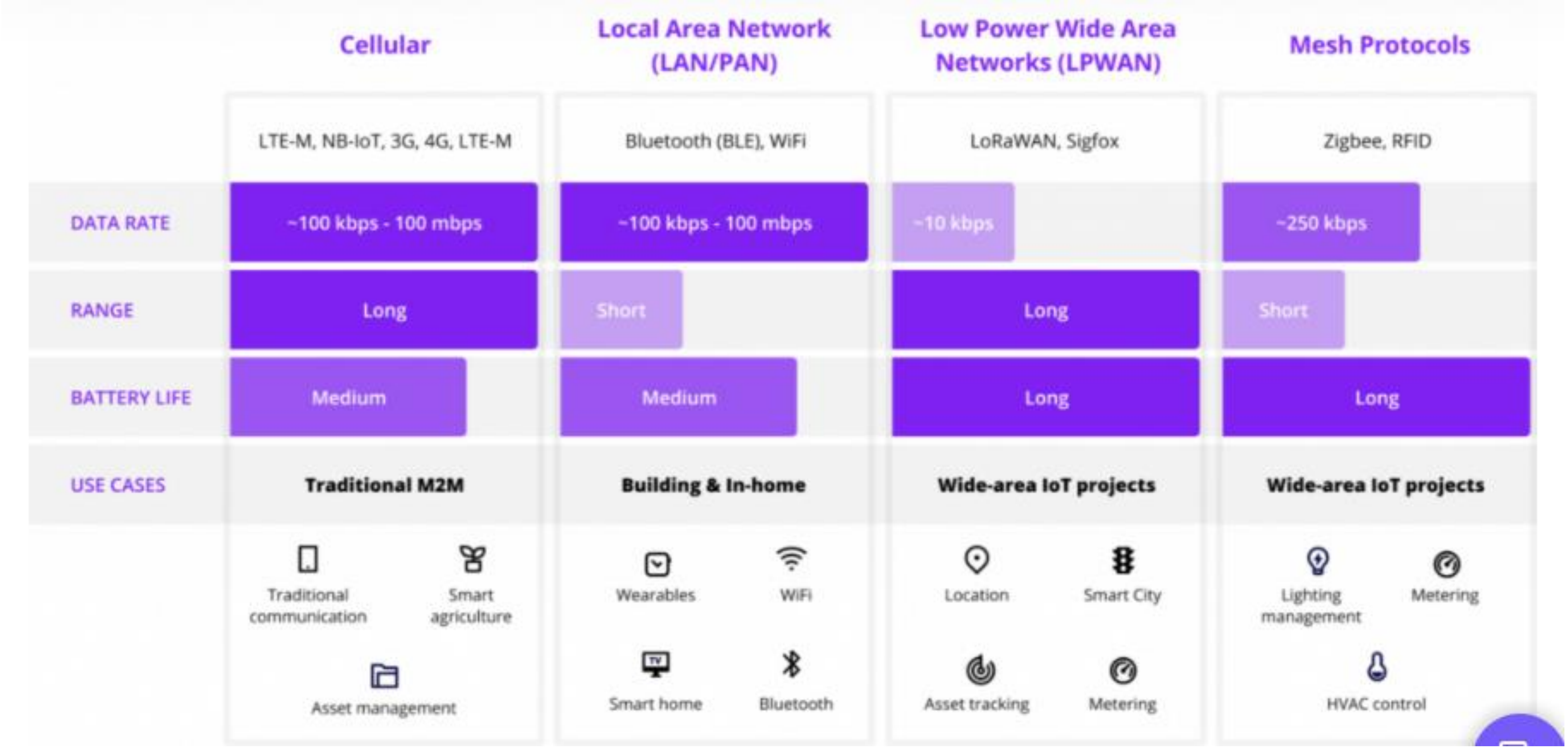
Common Network Topologies

- **Bus:** Every node in the network is connected along a linear path. This simple topology is used most often for small networks.
- **Ring:** Nodes are connected in a loop, and traffic may flow in one direction or in both directions. Ring networks tend to be cost-effective, but not as scalable or stable as other network topologies.
- **Star:** A central node connects to all other nodes in the network. This is a common and stable topology that's often used for local area networks (LANs).
- **Mesh:** Nodes are linked in such a way that multiple paths between nodes are possible. This type of network topology increases the resiliency of the network, but also increases cost. A network may be fully meshed (all nodes connecting to all other nodes) or partially meshed (only some nodes having multiple connections to other nodes).
- **Spine-Leaf (Tree):** Multiple star topologies are connected together in a larger star configuration.
- **Hybrid:** A combination of other topologies are used together within one network.

What is an IoT network?

IoT network is the network with physical interconnected objects embedded with sensors, smart devices that connect and exchange data with other devices and systems without human intervention.

4 Types of IOT Networks



	Cellular	Local Area Network (LAN/PAN)	Low Power Wide Area Networks (LPWAN)	Mesh Protocols
	LTE-M, NB-IoT, 3G, 4G, LTE-M	Bluetooth (BLE), WiFi	LoRaWAN, Sigfox	Zigbee, RFID
DATA RATE	~100 kbps - 100 mbps	~100 kbps - 100 mbps	~10 kbps	~250 kbps
RANGE	Long	Short	Long	Short
BATTERY LIFE	Medium	Medium	Long	Long
USE CASES	**Traditional M2M**	**Building & In-home**	**Wide-area IoT projects**	**Wide-area IoT projects**
	Traditional communication Smart agriculture Asset management	Wearables WiFi Smart home Bluetooth	Location Smart City Asset tracking Metering	Lighting management Metering HVAC control

How to select the most suitable IoT network?

- **The important criteria which should be considered are-**
- **Power Consumption**. If you’re looking for longevity and a solution without the need to supply a device with power, Bluetooth and LPWAN are the networks suitable for this case. Technologies with a high-power consumption like Wi-Fi is not recommended.
- **Coverage Area**. The size of the area that needs to be covered defines the type of protocol to be applied for your IoT project. Whereas LoRA is limited to national boundaries, the Sigfox network is available in 60 countries.
- **Data amount**. If you need to transmit small data quantities, there are solutions like BLE over a short distance or LPWAN for long-range data transfers. For big data amounts, we recommend Wi-Fi and GSM networks.
- **Devices’ density**. The selection of proper IoT protocol depends here on the need for geographical proximity whether on the need to be spread out. If the objects need to be connected closely to each other, WiFi will be a good option; in the case of proximity, LPWAN and GSM networks are recommended.

IEEE 802.15.4

Introduction

- Until recently, the main concern in wireless communication was on high throughput
- Some applications need a different set of requirements

  -Low cost communication network

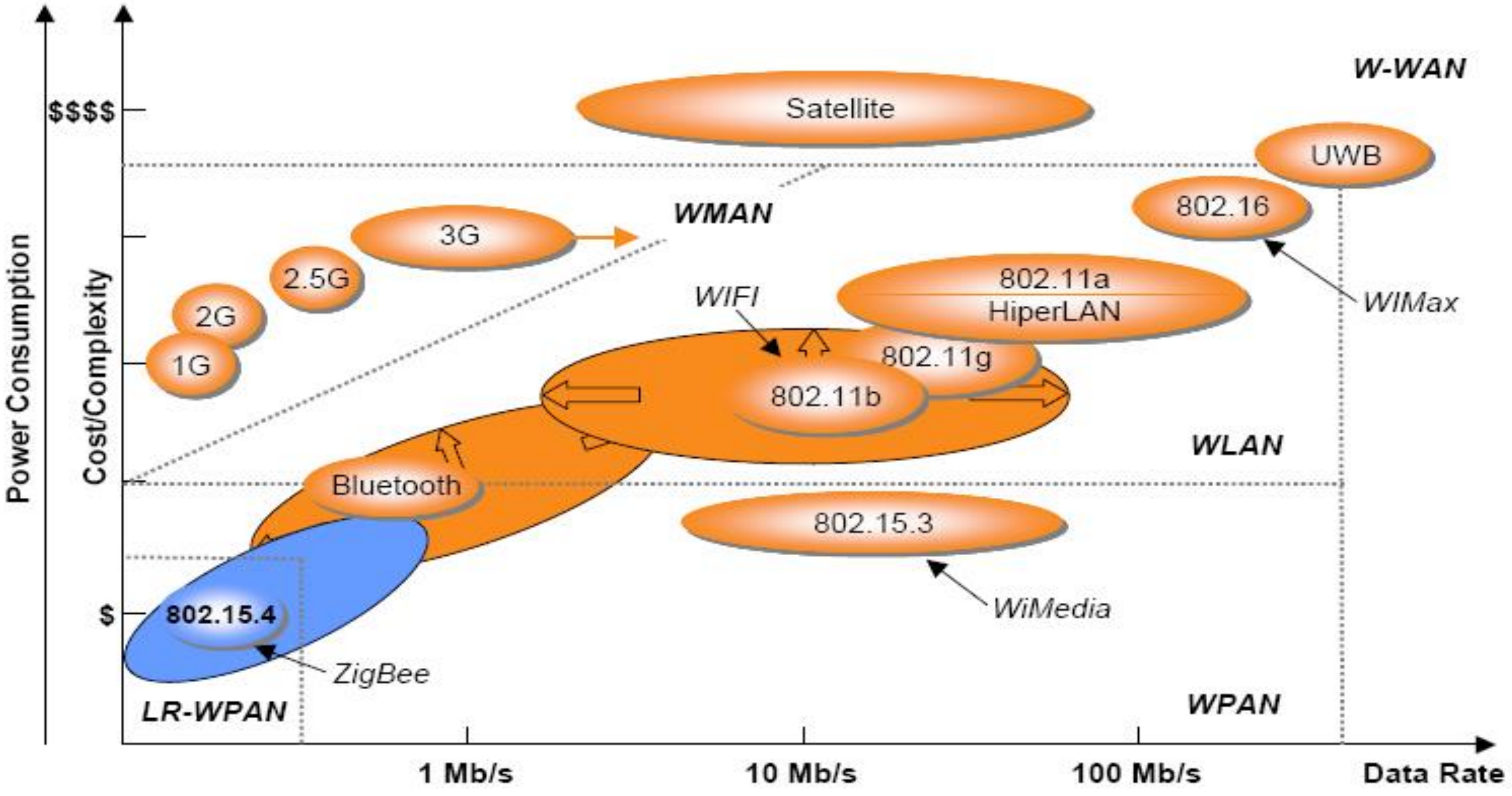
  -Limited power

  -Low throughput
- Require: reasonable battery life, extremely low cost, short range operation, reliable data transfer
- Technology: LR-WPAN (Low Rate Wireless Personal Area Network) applications

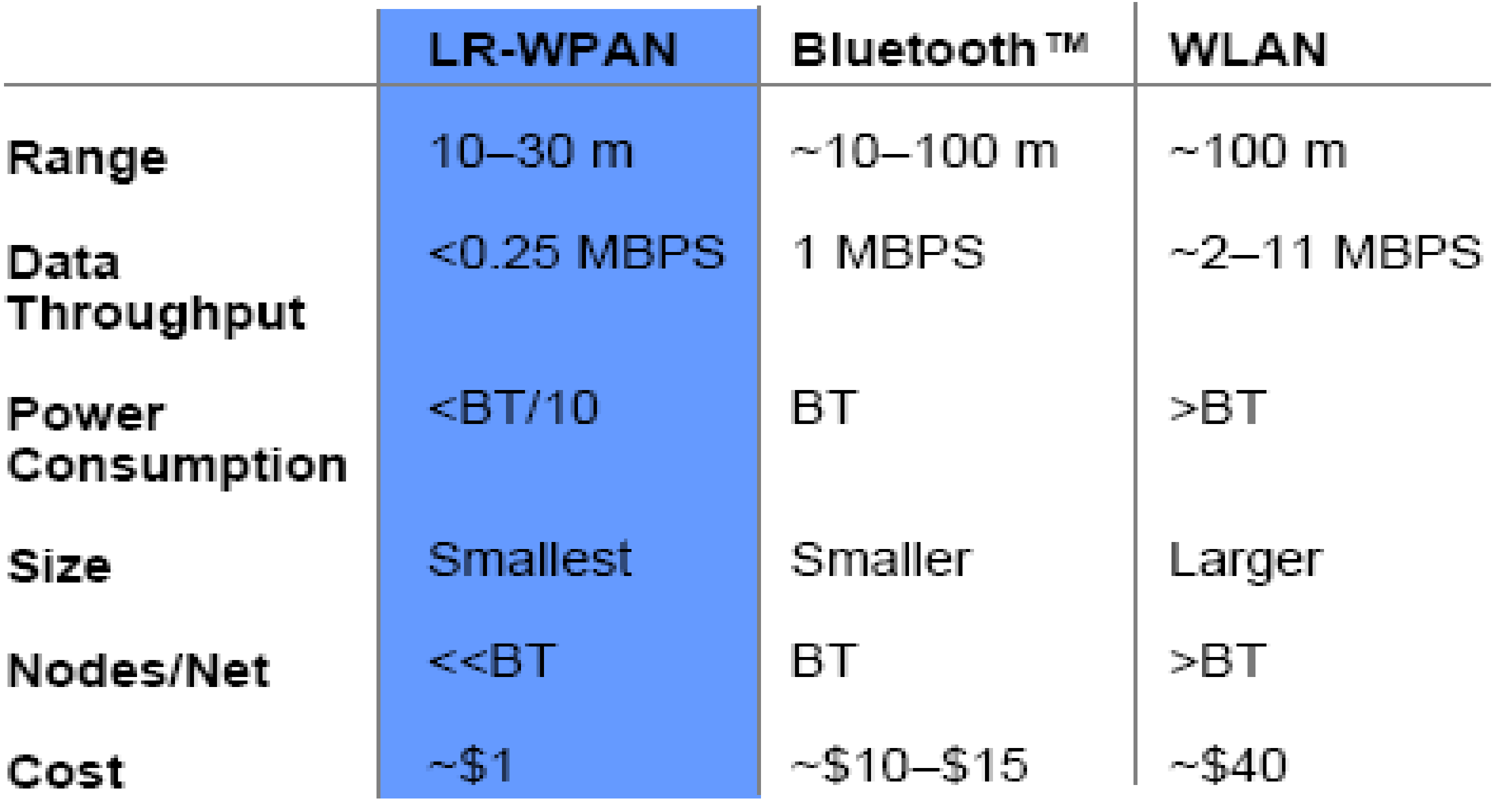
LR-WPAN Applications

Home Automation	Heating, ventilation, air conditioning, security, lighting, control of objects.
Industrial	Detecting emergency situations, monitoring machines.
Automotive	Automotive sensing such as time pressure monitoring.
Agriculture	Sensing of soil moisture, pesticide, herbicide, PH levels.
Others	Controlling consumer electronics, PC peripherals, etc.

Wireless Protocol Comparison



Comparison



	LR-WPAN	Bluetooth™	WLAN
Range	10–30 m	~10–100 m	~100 m
Data Throughput	<0.25 MBPS	1 MBPS	~2–11 MBPS
Power Consumption	<BT/10	BT	>BT
Size	Smallest	Smaller	Larger
Nodes/Net	<<BT	BT	>BT
Cost	~$1	~$10–$15	~$40

LR-WPAN IEEE 802.15.4

- LR-WPAN needs a simple, flexible protocol
- IEEE 802.15.4 defines protocol via RF for PAN.
- Provides a standard with ultra-low complexity, cost, and power for low-data-rate wireless connectivity among inexpensive fixed, portable, and moving devices.

Properties of 802.15.4

- Raw Data Rate: 868 MHz, 20 kbps; 915 MHz, 40 kbps; 2.4 GHz, 250 kbps
- Range: 10-30 mtr
- Latency: Down to 15 ms
- Channels: 868 MHz, 1 Channel; 915 MHz, 10 Channels; 2.4 GHz, 16 Channels
- Frequency Band: Two PHYs: 868 MHz / 915 MHz & 2.4 GHz
- Addressing: Short 16-bit or 64-bit IEEE
- Channel Access: CSMA-CA & Slotted CSMA-CA
- Temperature: Industrial temperature range -40 °C to +85 °C

Device Types

- Full function device (FFD)
  - Any topology
  - PAN coordinator capable
  - Talks to any other device
  - Implements complete protocol set
- Reduced function device (RFD)
  - Limited to star topology or end-device in a peer-to-peer network.
  - Cannot become a PAN coordinator
  - Very simple implementation
  - Reduced protocol set

Modes of Operation of a Device

- *Network Device:*

  An RFD or FFD implementation containing an IEEE 802.15.4 medium access control and **physical interface** to the wireless medium.

- *Coordinator:*

  An FFD with network device functionality that **provides coordination** and other services to the network.

- *PAN Coordinator:*

  A coordinator that is the **principal controller** of the PAN. A network has exactly one PAN coordinator.

Network Topologies

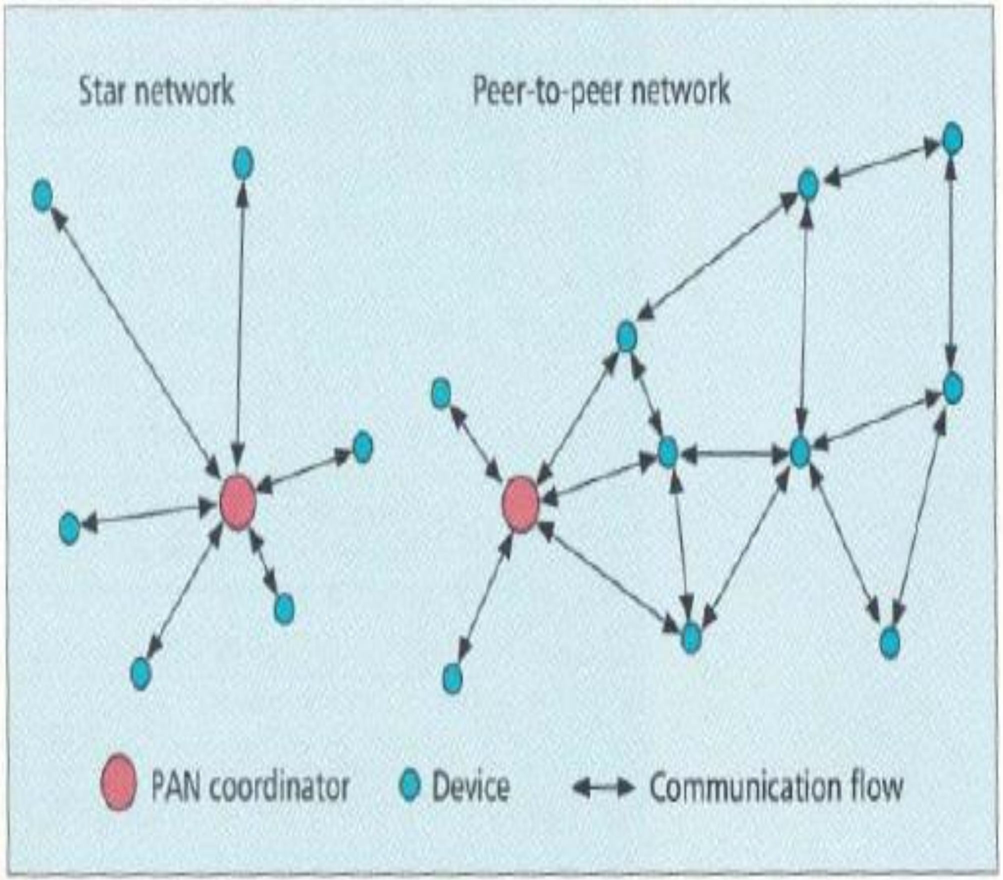
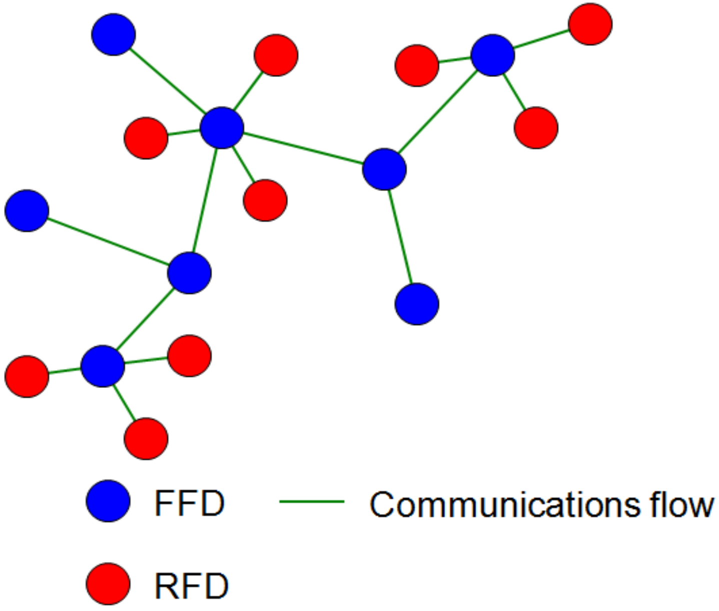


Figure 1. *Star and peer-to-peer networks.*

Combined Topology



Ex: Hotel where cluster nodes exist between the rooms of a hotel and each room has a star network for control.

Star Network Formation

Step 1: An FFD is activated

Step 2: It establishes its own network and become the PAN coordinator

Step 3: The FFD device chooses a PAN Identifier different from surrounding networks (within RF sphere of influence)

Step 4: The PAN coordinator allows other devices, potentially both FFDs and RFDs, to join its network.

Peer-to-peer Network Formation

Step 1: One Device is nominated as the PAN coordinator

Step 2: It forms the first cluster by choosing an unused PAN identifier and broadcasting beacon frames to neighboring devices.

Step 3: A candidate device receiving a beacon frame may request to join the network at the PAN coordinator.

Step 4: If the PAN coordinator permits the device to join, it adds the new device as a child device in its neighbor list.

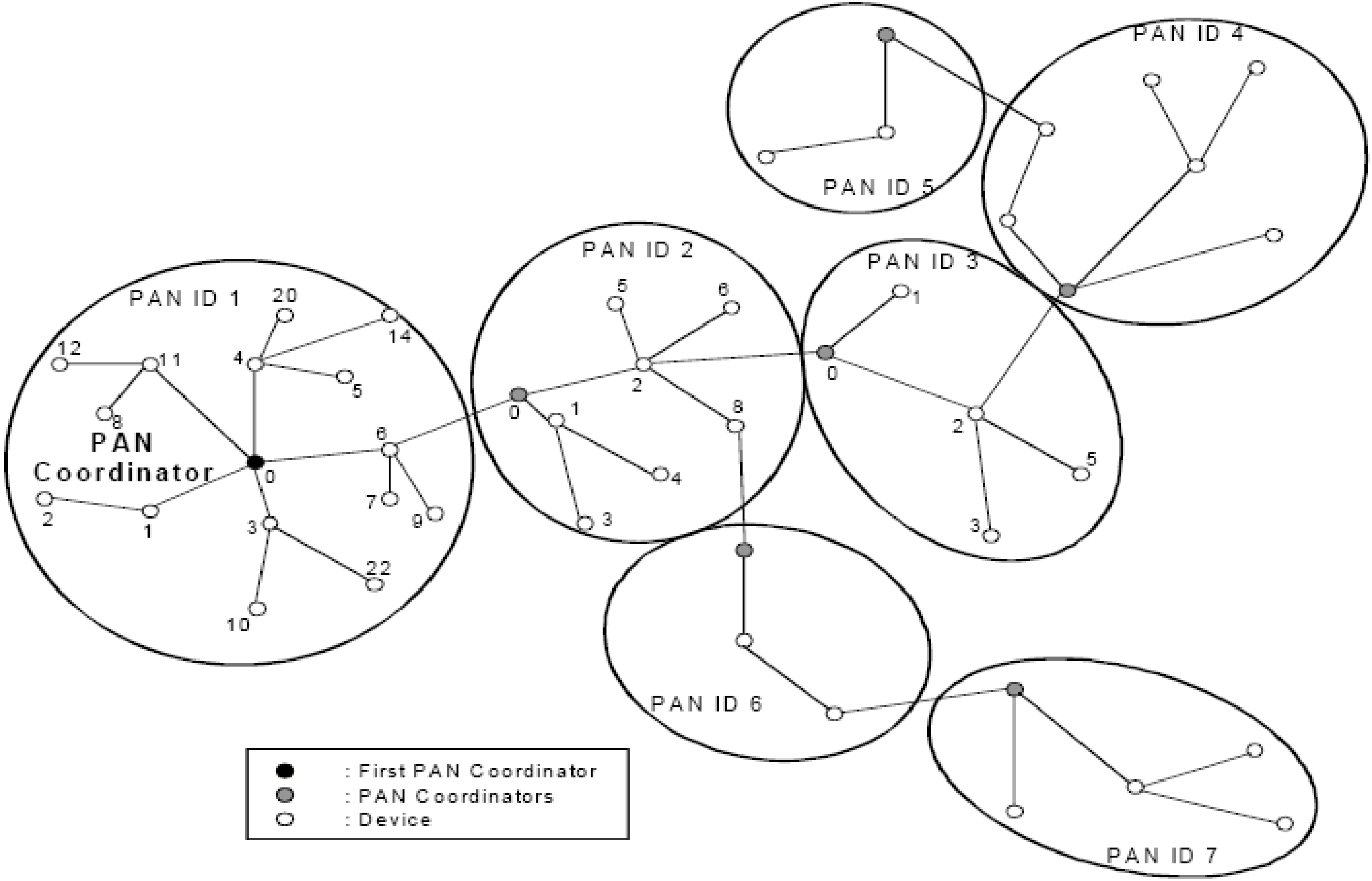
Step 5: Newly joined device adds the PAN coordinator as its parent in its neighbor list and begins transmitting periodic beacons

Step 6: Other candidate devices may then join the network at that device.

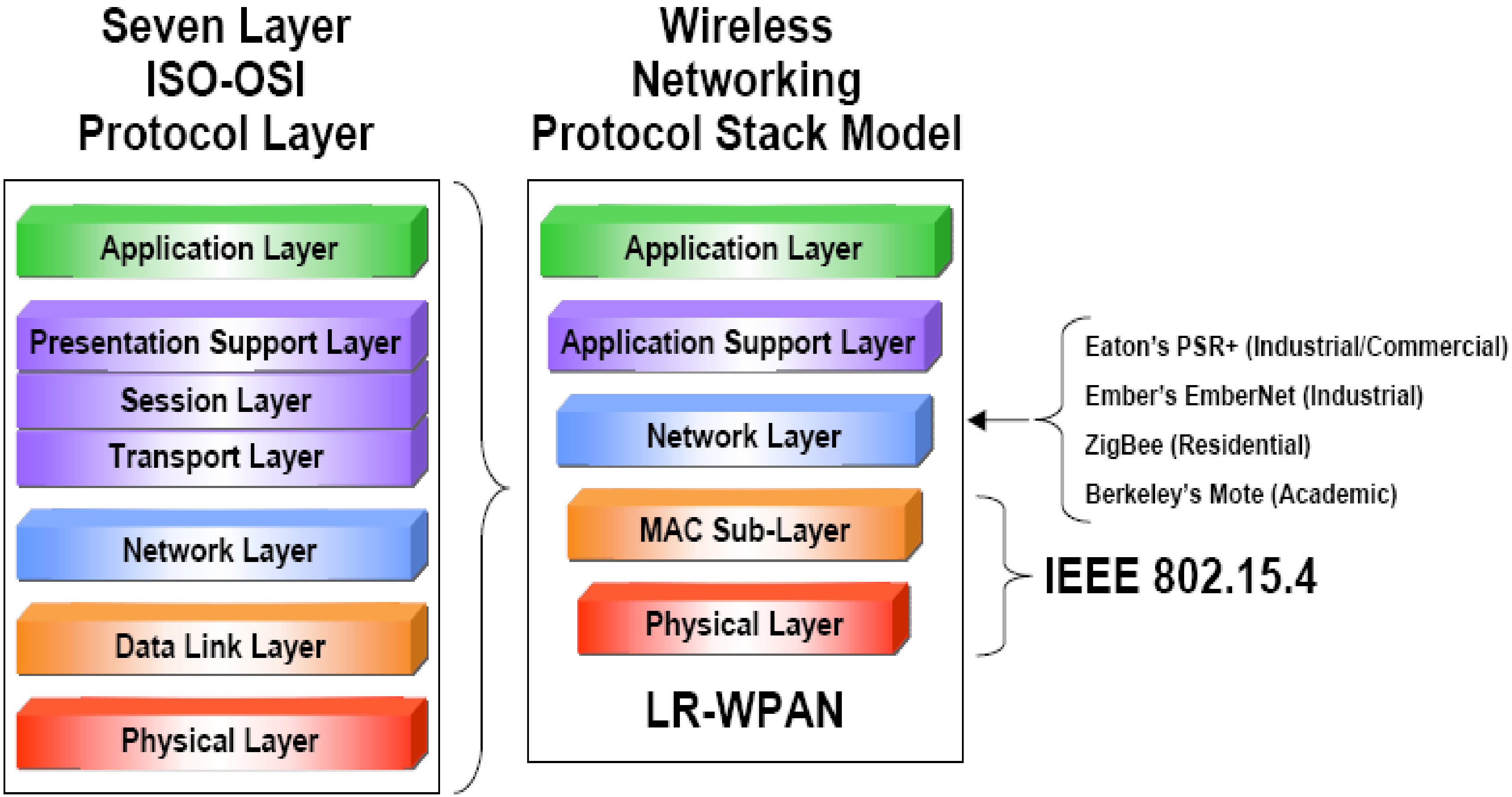
Step 7: Once predetermined application or network requirements are met, the first PAN coordinator may instruct a device to become the PAN coordinator of a new cluster adjacent to the first one.

Step 8: Other devices gradually connect and form a multi-cluster network structure

Cluster Tree Network



Architecture- 802.15.4



Data Transfer

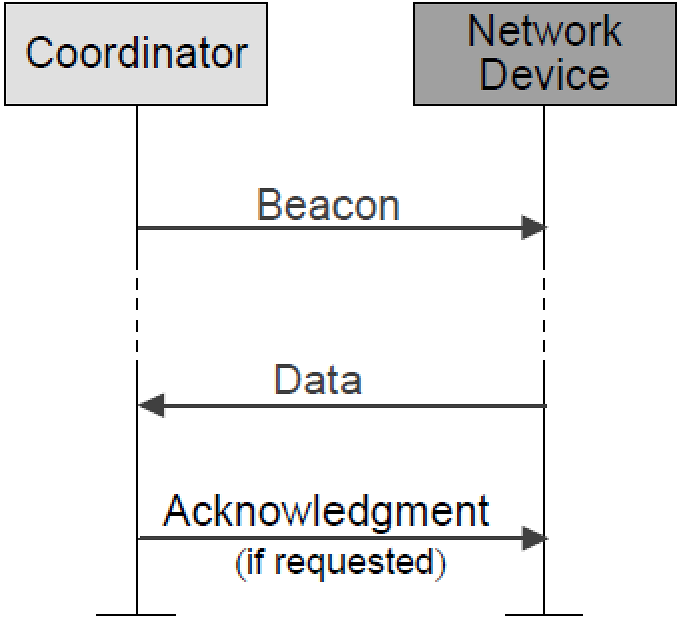
- Three types of data transfer:

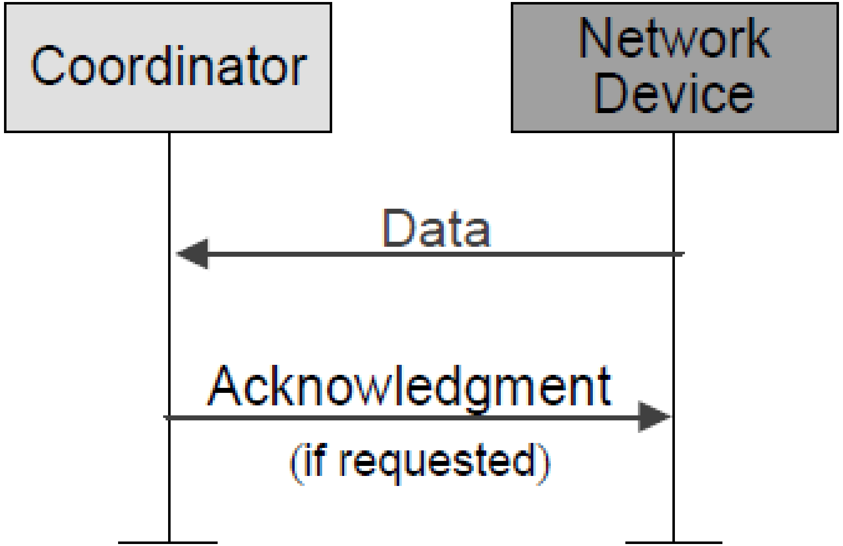
1. -Data transfer to a coordinator in which a device transmits the data
2. -Data transfer from a coordinator in which the device receives the data
3. -Data transfer between two peer devices

*In star topology only first two are used

*The mechanisms for each transfer type depend on whether the network supports the transmission of beacons

Data Transfer to a Coordinator

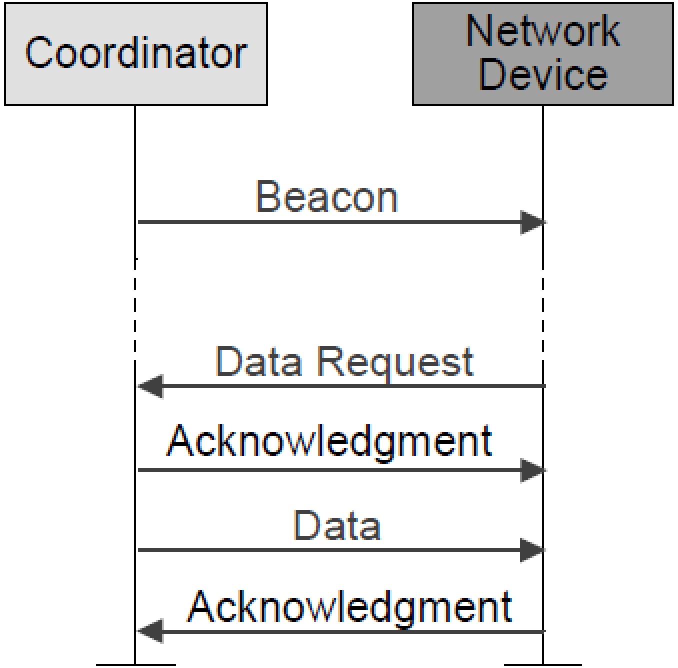


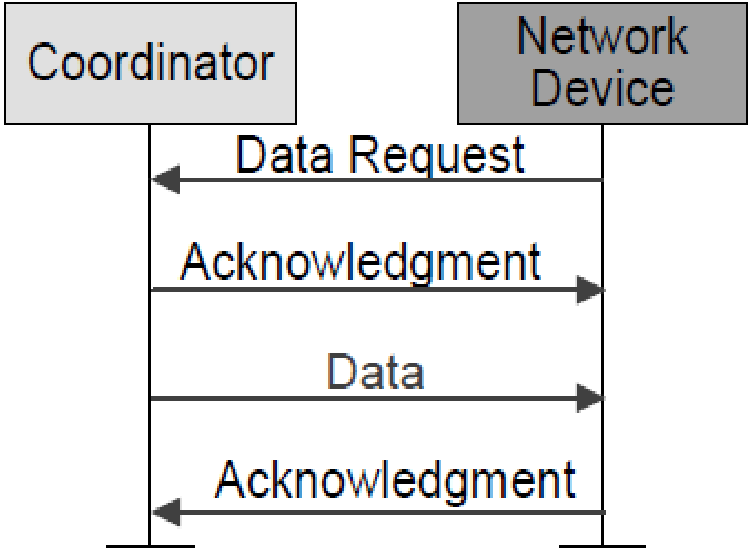


Beacon –enabled PAN
Slotted CSMA-CA

Non-Beacon PAN
Unslotted CSMA-CS

Data Transfer from a Coordinator





PAN indicates message is pending in the beacon frame

Device requests data at application-defined rate

Zigbee

Introduction

- Zigbee is a standards-based wireless technology developed to enable low-cost, low-power wireless machine-to-machine (M2M) and internet of things (IoT) networks.

- Zigbee is for low-data rate, low-power applications and is an open standard.

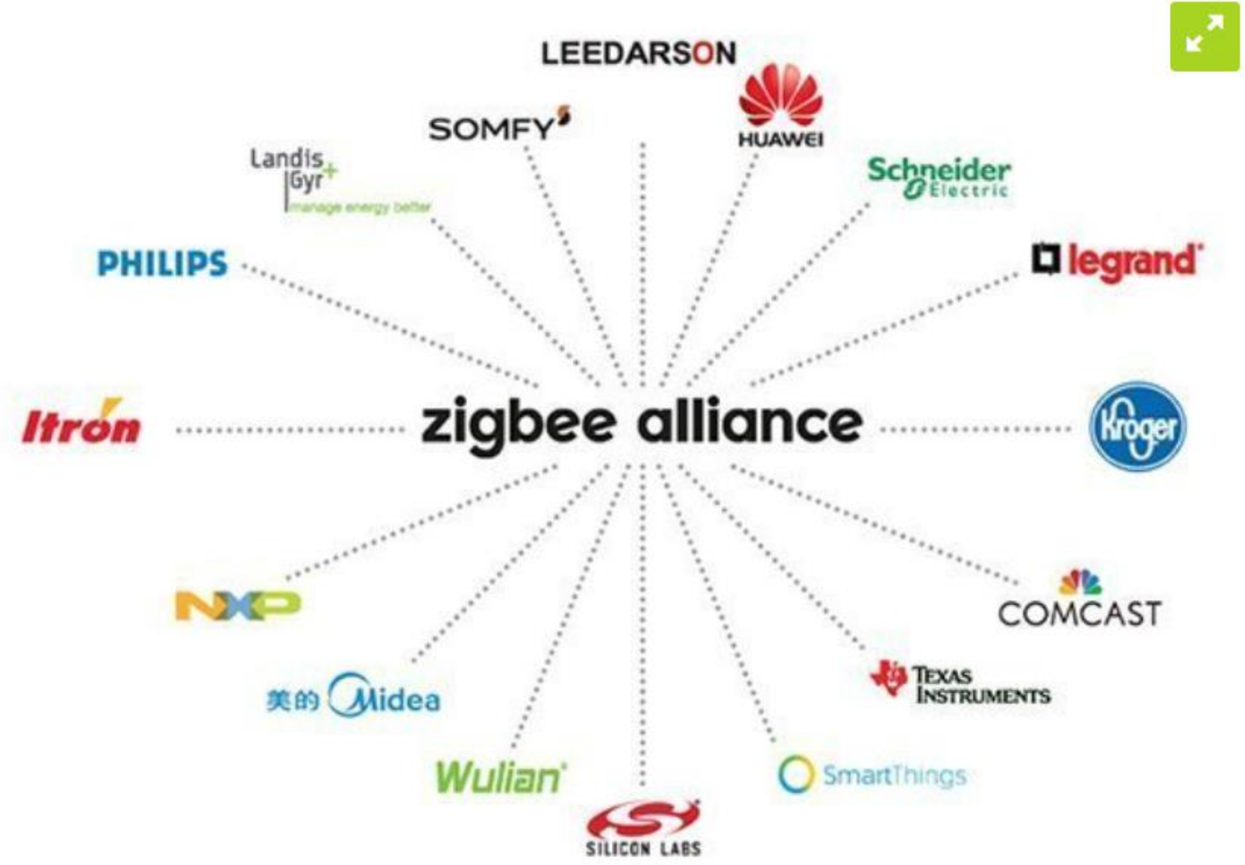
- Zigbee is primarily developed to focus on home and building automation and controls, consumer electronics, PC peripherals, medical monitoring, and toys

- Primary drivers in Zigbee popularity are simplicity, long battery life, networking capabilities, reliability, and cost.

- Zigbee Alliance provides interoperability and certification testing

ZigBee Alliance

Zigbee Alliance



Zigbee Features

Based on the IEEE 802.15

Used for control and sensor networks for WPANs

Operate on 2.4 GHz, 900 MHz and 868 MHz frequencies.

Manufacturers can create their own specific variations and extensions.

Zigbee Features

- As of today, there are three Zigbee specifications:
  - Zigbee PRO
  - Zigbee RF4CE
  - Zigbee IP

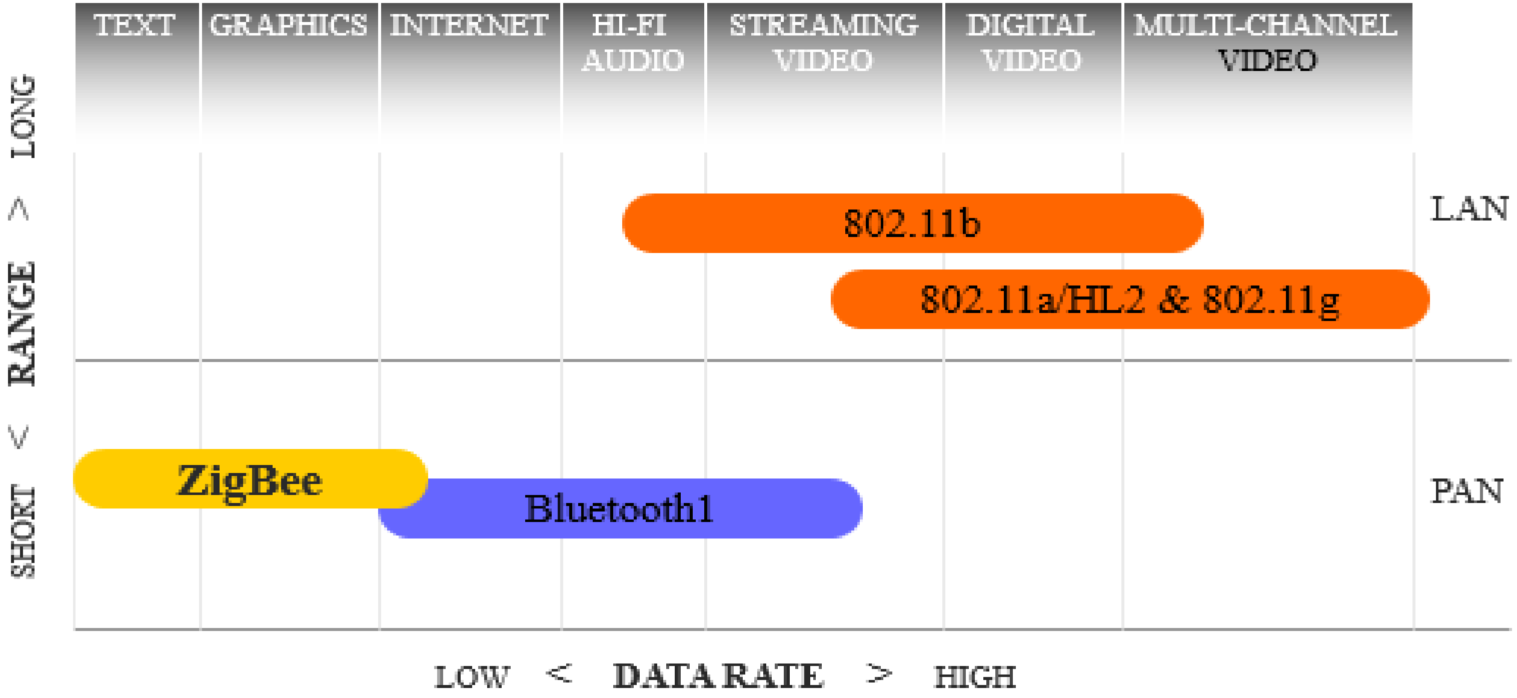
Zigbee Features

- Zigbee PRO aims to provide the foundation for IoT with features to support low-cost, highly reliable networks for device-to-device communication. It also offers Green Power, a new feature that supports energy harvesting or self-powered devices that don't require batteries or AC power supply.

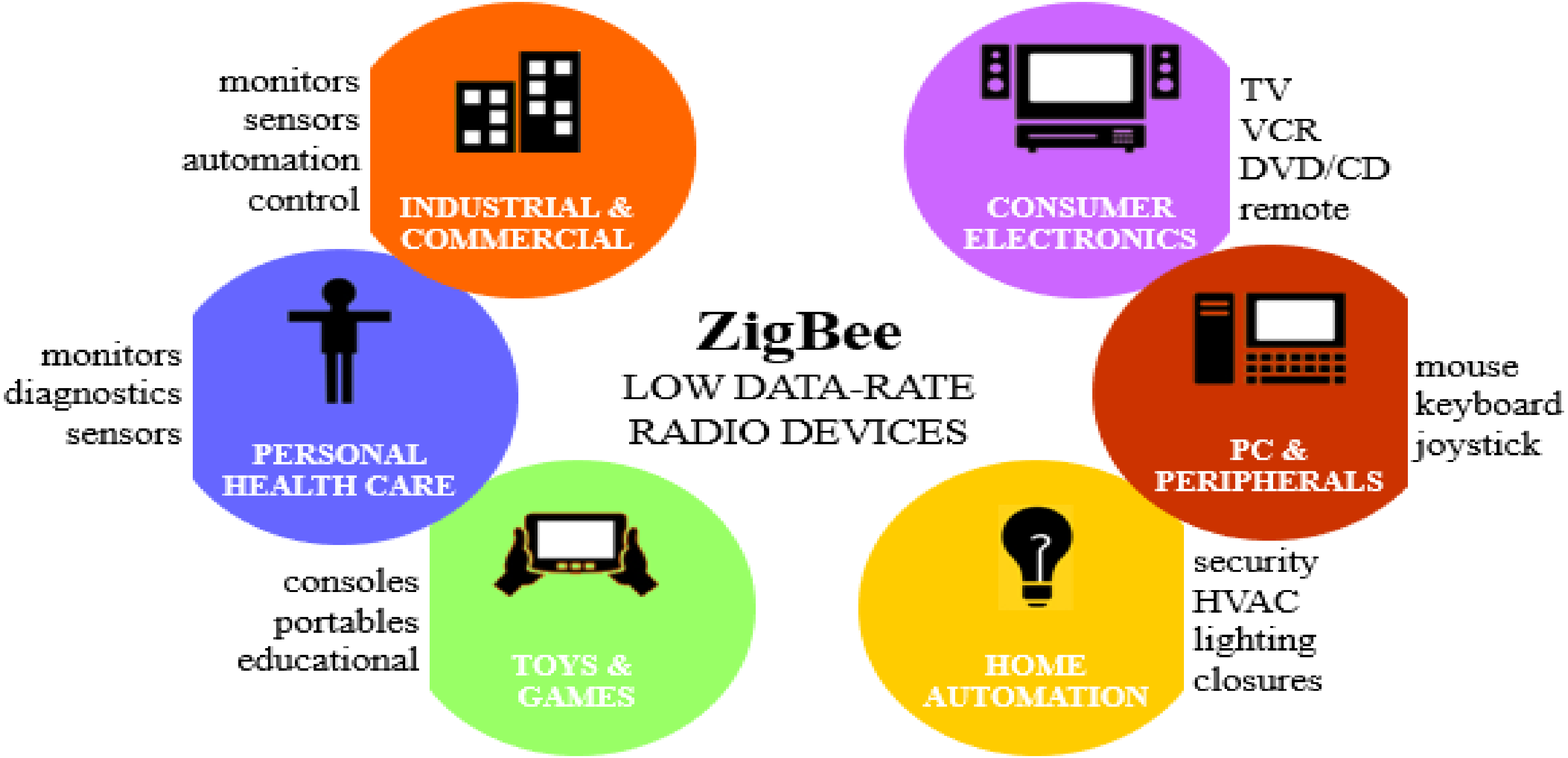
- Zigbee RF4CE is designed for simple, two-way device-to-device control applications that don't need the full-featured mesh networking functionalities offered by the Zigbee specification.

- Zigbee IP optimizes the standard for IPv6-based full wireless mesh networks, offering internet connections to control low-power, low-cost devices.

The Wireless Market



Applications



ZigBee

LOW DATA-RATE RADIO DEVICES

INDUSTRIAL & COMMERCIAL
monitors
sensors
automation
control

CONSUMER ELECTRONICS
TV
VCR
DVD/CD
remote

PERSONAL HEALTH CARE
monitors
diagnostics
sensors

PC & PERIPHERALS
mouse
keyboard
joystick

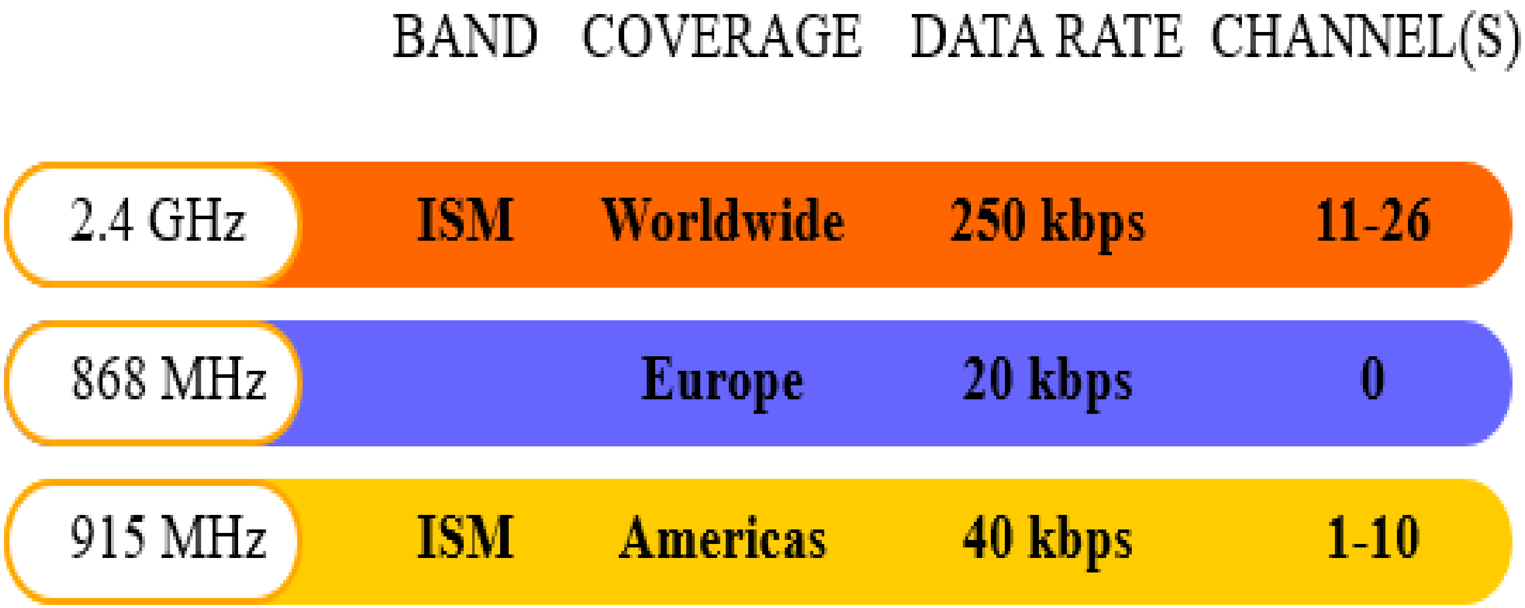
TOYS & GAMES
consoles
portables
educational

HOME AUTOMATION
security
HVAC
lighting
closures

Zigbee Features

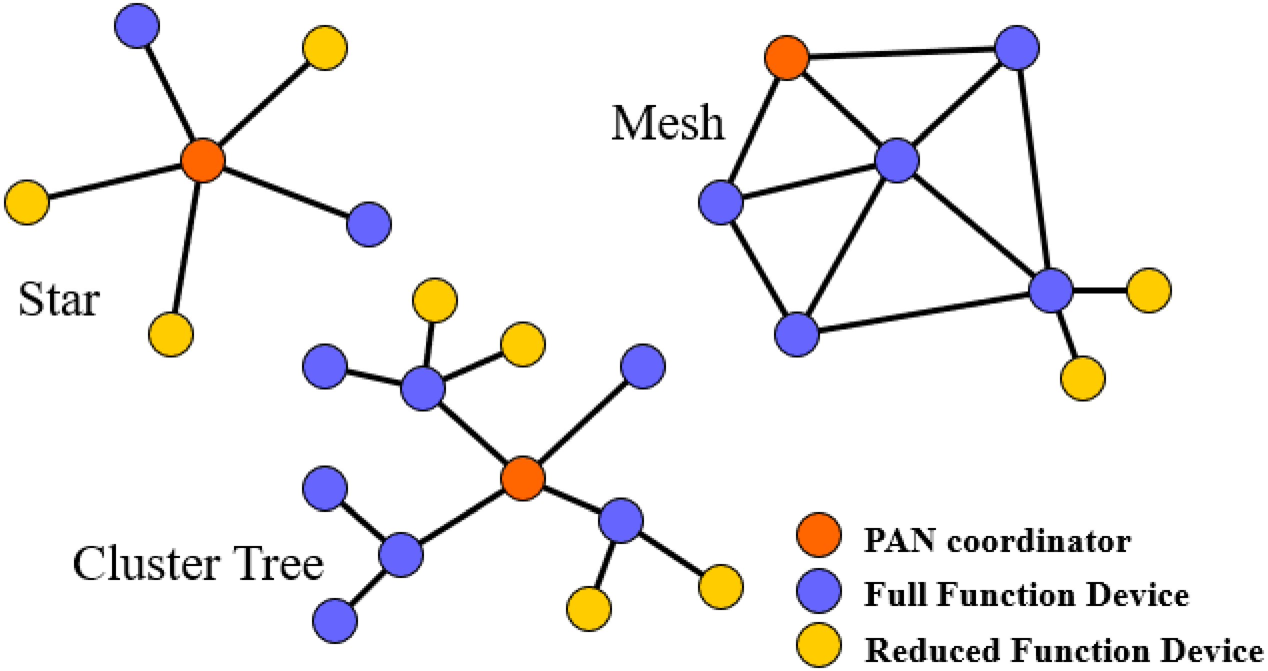
- Global, license free ISM band operation
- Unrestricted geographic use
- RF penetration through walls & ceilings
- Automatic/semi-automatic installation
- Ability to add or remove devices
- Cost advantageous
- 10k-115.2kbps data throughput
- 10-75m coverage range
- Up to 65k slave nodes per network
- Up to 100 co-located networks
- Up to 2 years of battery life on standard Alkaline batteries

Frequencies and Data Rates



	BAND	COVERAGE	DATA RATE	CHANNEL(S)
2.4 GHz	ISM	Worldwide	250 kbps	11-26
868 MHz		Europe	20 kbps	0
915 MHz	ISM	Americas	40 kbps	1-10

Topology Models



Zigbee Disadvantages

It needs the system information to control Zigbee based devices for the owner.

As compared with WiFi, it is not secure.

The high replacement cost once any issue happens within Zigbee based home appliances

The transmission rate of the Zigbee is less

It does not include several end devices.

It is so highly risky to be used for official private information.

It is not used as an outdoor wireless communication system because it has less coverage limit.

Similar to other types of wireless systems, this ZigBee communication system is prone to bother from unauthorized people.

What Devices use ZigBee?

The following list of devices supports the ZigBee protocol.

- Belkin WeMo
- Samsung SmartThings
- Yale smart locks
- Philips Hue
- Thermostats from Honeywell
- Ikea Tradfri
- Security Systems from Bosch
- Comcast Xfinity Box from Samsung
- Hive Active Heating & accessories
- Amazon Echo Plus
- Amazon Echo Show

Bluetooth

Why do we need Bluetooth and Zigbee

Bluetooth wireless technology

- Well focused towards voice applications and higher data rate applications (cell phones, headsets, etc.)

ZigBee technology

- Best suited for control and monitoring applications

A VIDEO ON BLUETOOTH

Bluetooth Overview

Applications

- Automatic synchronization between mobile and stationary devices
- Example:
  - Walk into office and have your PDA synch with your laptop on your desk without even taking your PDA out of your briefcase
- Connecting mobile users to the internet using bluetooth-enabled wire-bound connection ports
- Dynamic creation of private networks

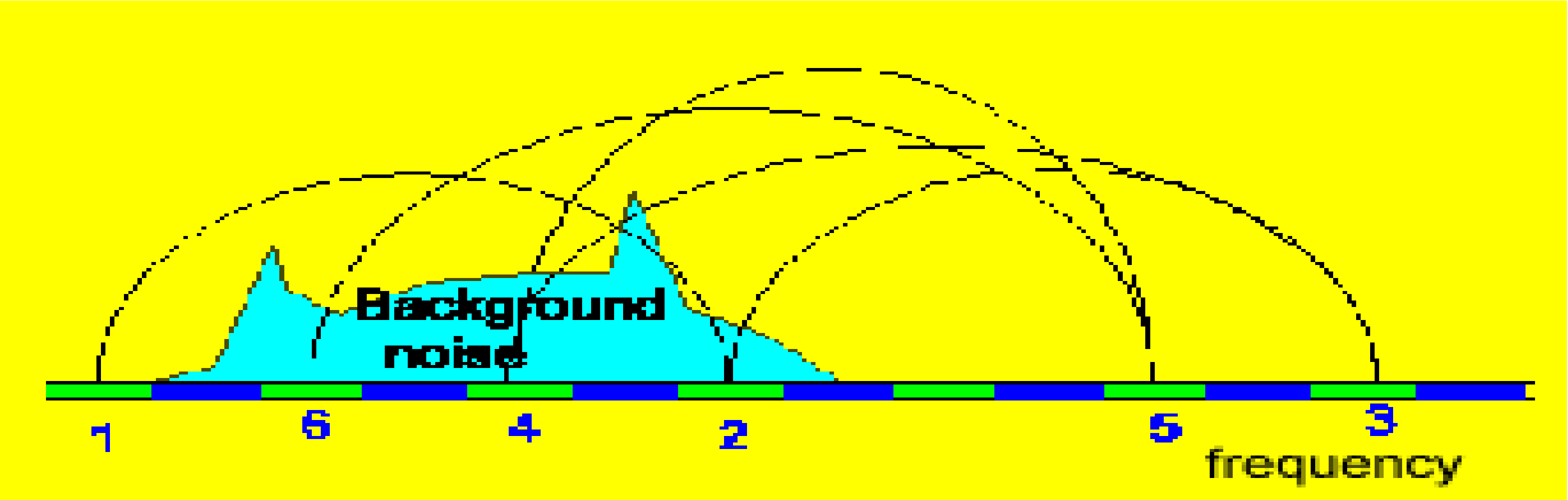
Bluetooth Protocol Stack

Bluetooth Radio

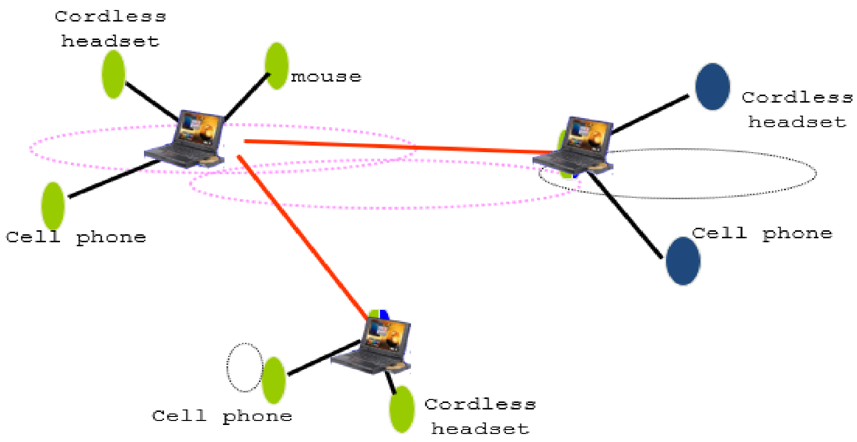
- Uses 2.4 GHz ISM band spread spectrum radio (2400 – 2483.5 MHz)
- Advantages -Free, Open to everyone worldwide
- Disadvantages-Can be noisy (microwaves, cordless phones, garage door openers)

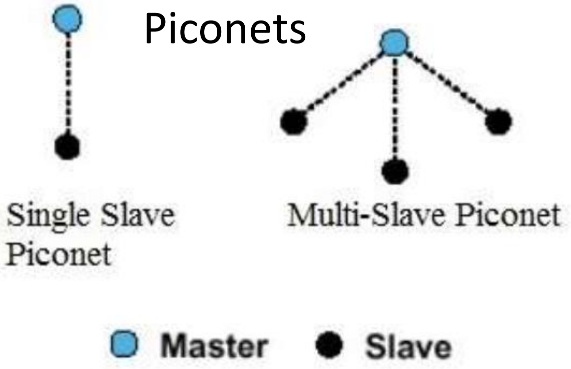
Frequency Hopping

- In order to mitigate interference, Bluetooth implements frequency hopping
- 1600 hops per second through 79 channels, 1 MHz each.
- Spreads Bluetooth traffic over the entire ISM band
- All slaves in piconet follow the master for frequency hop sequence

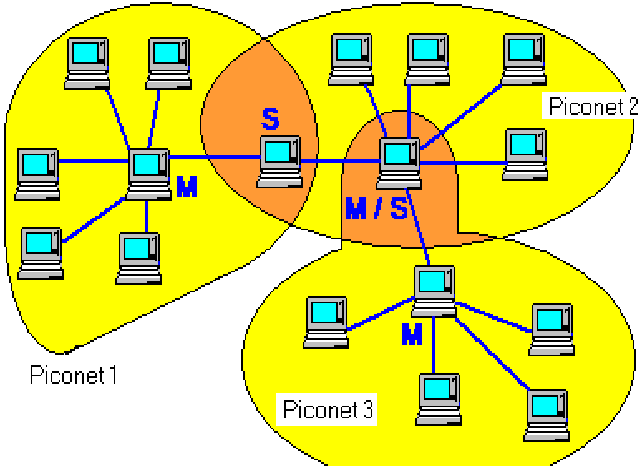


Piconets and Scatternets



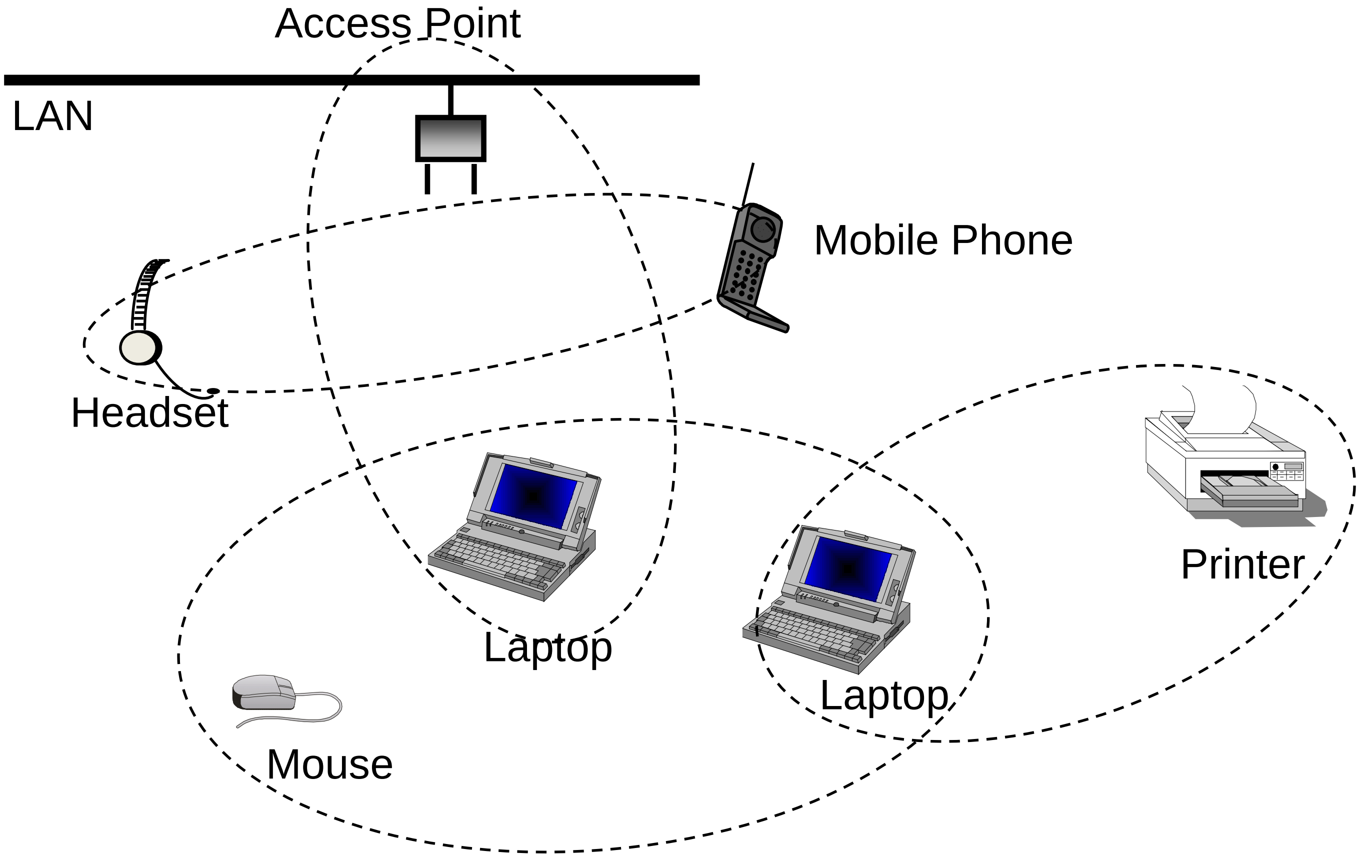


- Piconet-Basic unit of **bluetooth** networking.
- Devices function as master and slave in piconet.
- Scatternet-Formed by two or more Piconets
- Master of one piconet can participate as a slave in another connected piconet

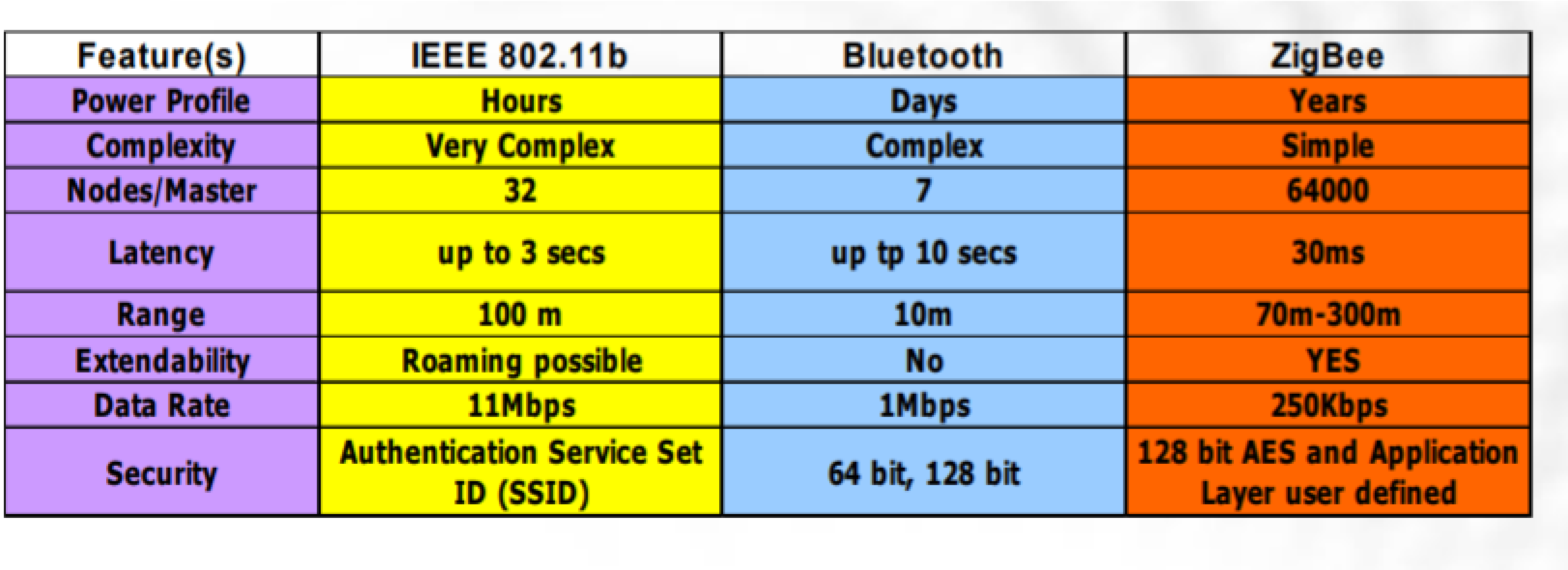


Scatternet

Interconnected Piconets- Scatternets



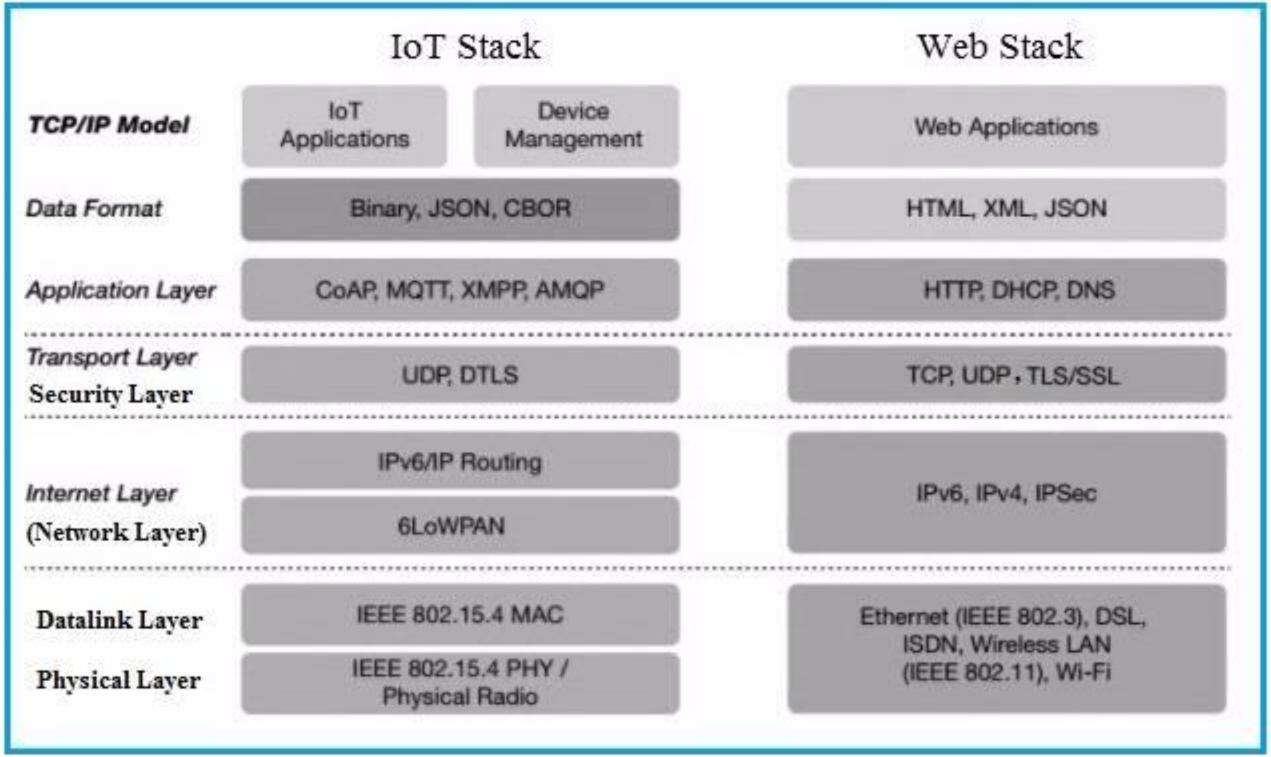
Comparison



Feature(s)	IEEE 802.11b	Bluetooth	ZigBee
Power Profile	Hours	Days	Years
Complexity	Very Complex	Complex	Simple
Nodes/Master	32	7	64000
Latency	up to 3 secs	up tp 10 secs	30ms
Range	100 m	10m	70m-300m
Extendability	Roaming possible	No	YES
Data Rate	11Mbps	1Mbps	250Kbps
Security	Authentication Service Set ID (SSID)	64 bit, 128 bit	128 bit AES and Application Layer user defined

IoT stack and Web stack

IoT Stack VS Web Stack



	IoT Stack	Web Stack
TCP/IP Model	IoT Applications Device Management	Web Applications
Data Format	Binary, JSON, CBOR	HTML, XML, JSON
Application Layer	CoAP, MQTT, XMPP, AMQP	HTTP, DHCP, DNS
Transport Layer Security Layer	UDP, DTLS	TCP, UDP , TLS/SSL
Internet Layer (Network Layer)	IPv6/IP Routing 6LoWPAN	IPv6, IPv4, IPSec
Datalink Layer	IEEE 802.15.4 MAC	Ethernet (IEEE 802.3), DSL, ISDN, Wireless LAN (IEEE 802.11), Wi-Fi
Physical Layer	IEEE 802.15.4 PHY / Physical Radio	

MQTT

Message Queuing Telemetry Transport

MQTT – Message Queuing Telemetry Transport

1. What is MQTT?

❑ **MQTT is a lightweight message queueing and transport protocol.**

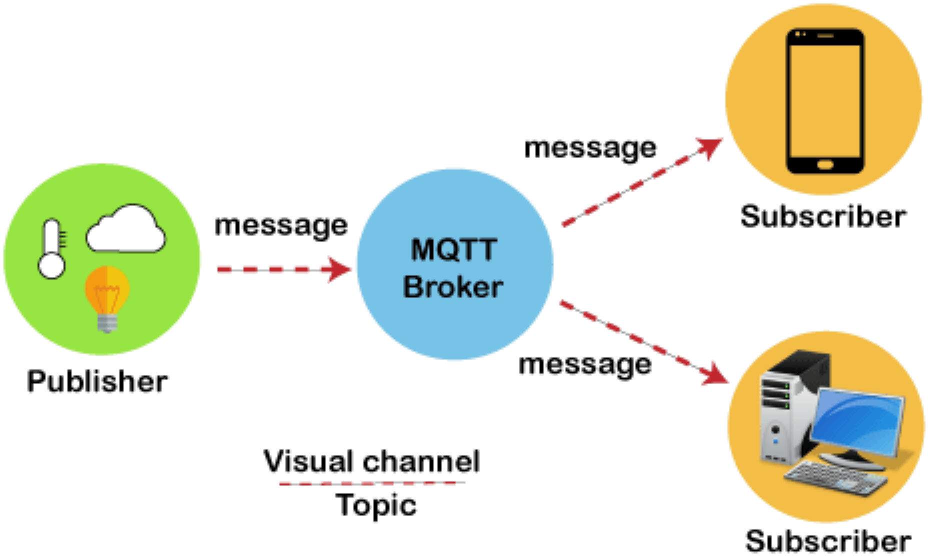
❑ **MQTT, as its name implies, is suited for the transport of telemetry data (sensor and actor data).**

❑ **MQTT is very lightweight and thus suited for M2M (Mobile to Mobile), WSN (Wireless Sensor Networks) and ultimately IoT (Internet of Things) scenarios where sensor and actor nodes communicate with applications through the MQTT message broker.**

MQTT model

The core elements of MQTT are clients, servers (=brokers), sessions, subscriptions and topics.

MQTT Architecture



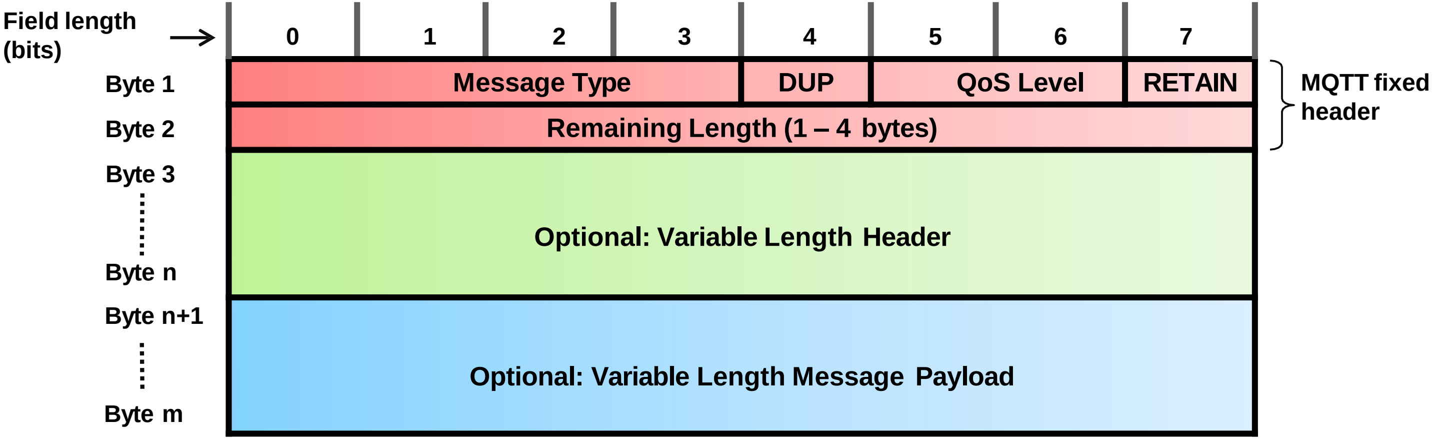
MQTT message format

Message format:

MQTT messages contain a mandatory fixed-length header (2 bytes) and an optional message-specific variable length header and message payload.

Optional fields usually complicate protocol processing.
However, MQTT is optimized for bandwidth constrained and unreliable networks (typically wireless networks), so optional fields are used to reduce data transmissions as much as possible.

MQTT uses network byte and bit ordering.



Field length (bits) →	0	1	2	3	4	5	6	7
Byte 1	Message Type				DUP	QoS Level		RETAIN
Byte 2	Remaining Length (1 – 4 bytes)							
Byte 3 ⋮ Byte n	Optional: Variable Length Header							
Byte n+1 ⋮ Byte m	Optional: Variable Length Message Payload							

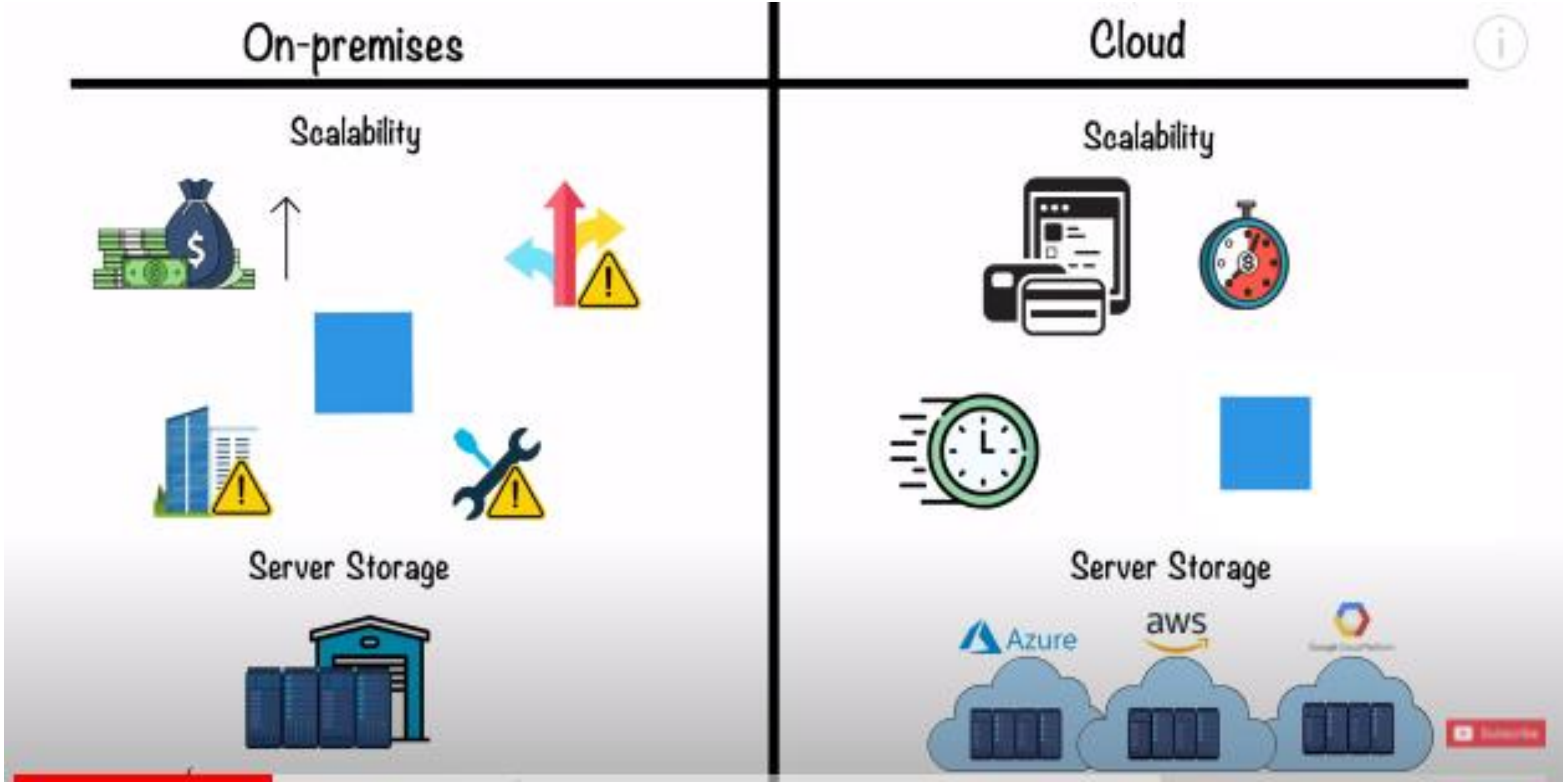
MQTT message format

Overview of fixed header fields:

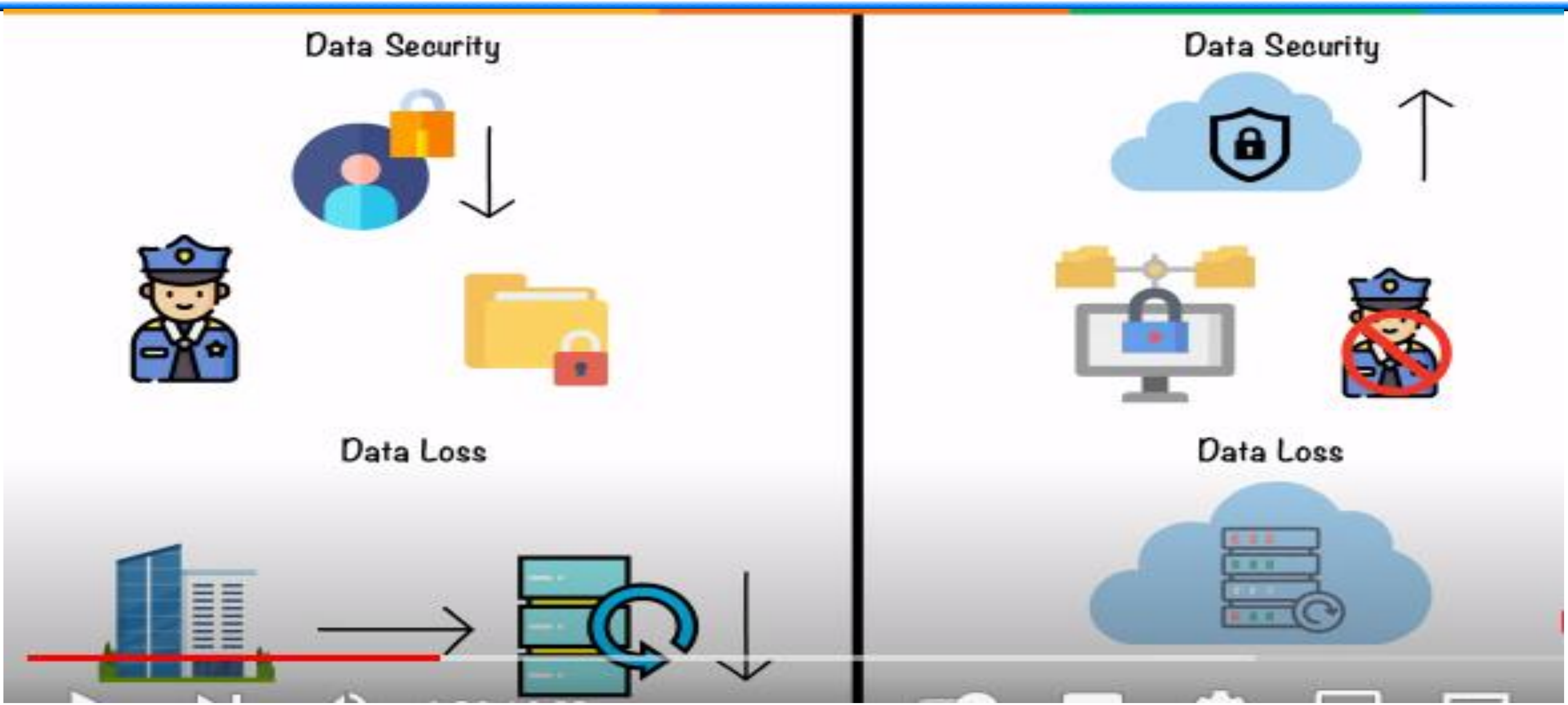
Message fixed header field	Description / Values	
Message Type	0: Reserved	8: SUBSCRIBE
	1: CONNECT	9: SUBACK
	2: CONNACK	10: UNSUBSCRIBE
	3: PUBLISH	11: UNSUBACK
	4: PUBACK	12: PINGREQ
	5: PUBREC	13: PINGRESP
	6: PUBREL	14: DISCONNECT
	7: PUBCOMP	15: Reserved
DUP	Duplicate message flag. Indicates to the receiver that this message may have already been received. 1: Client or server (broker) re-delivers a PUBLISH, PUBREL, SUBSCRIBE or UNSUBSCRIBE message (duplicate message).	
QoS Level	Indicates the level of delivery assurance of a PUBLISH message. 0: At-most-once delivery, no guarantees, «Fire and Forget». 1: At-least-once delivery, acknowledged delivery. 2: Exactly-once delivery. Further details see MQTT QoS.	
RETAIN	1: Instructs the server to retain the last received PUBLISH message and deliver it as a first message to new subscriptions. Further details see RETAIN (keep last message).	
Remaining Length	Indicates the number of remaining bytes in the message, i.e. the length of the (optional) variable length header and (optional) payload. Further details see Remaining length (RL).	

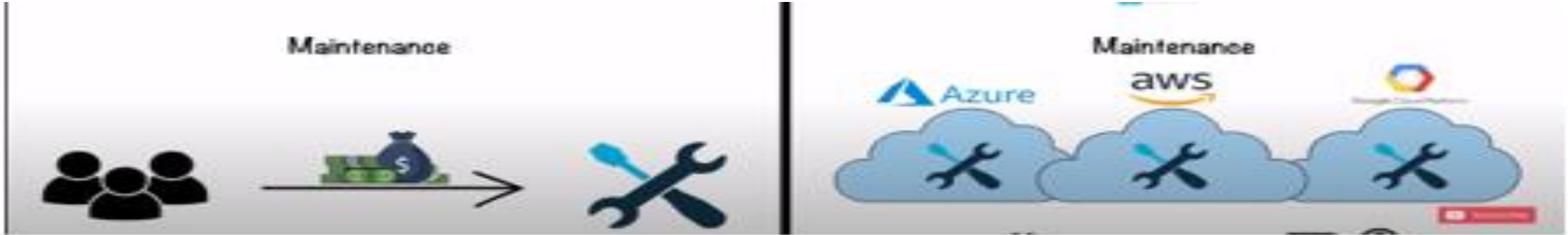
Cloud Architecture

Differences



Cont...

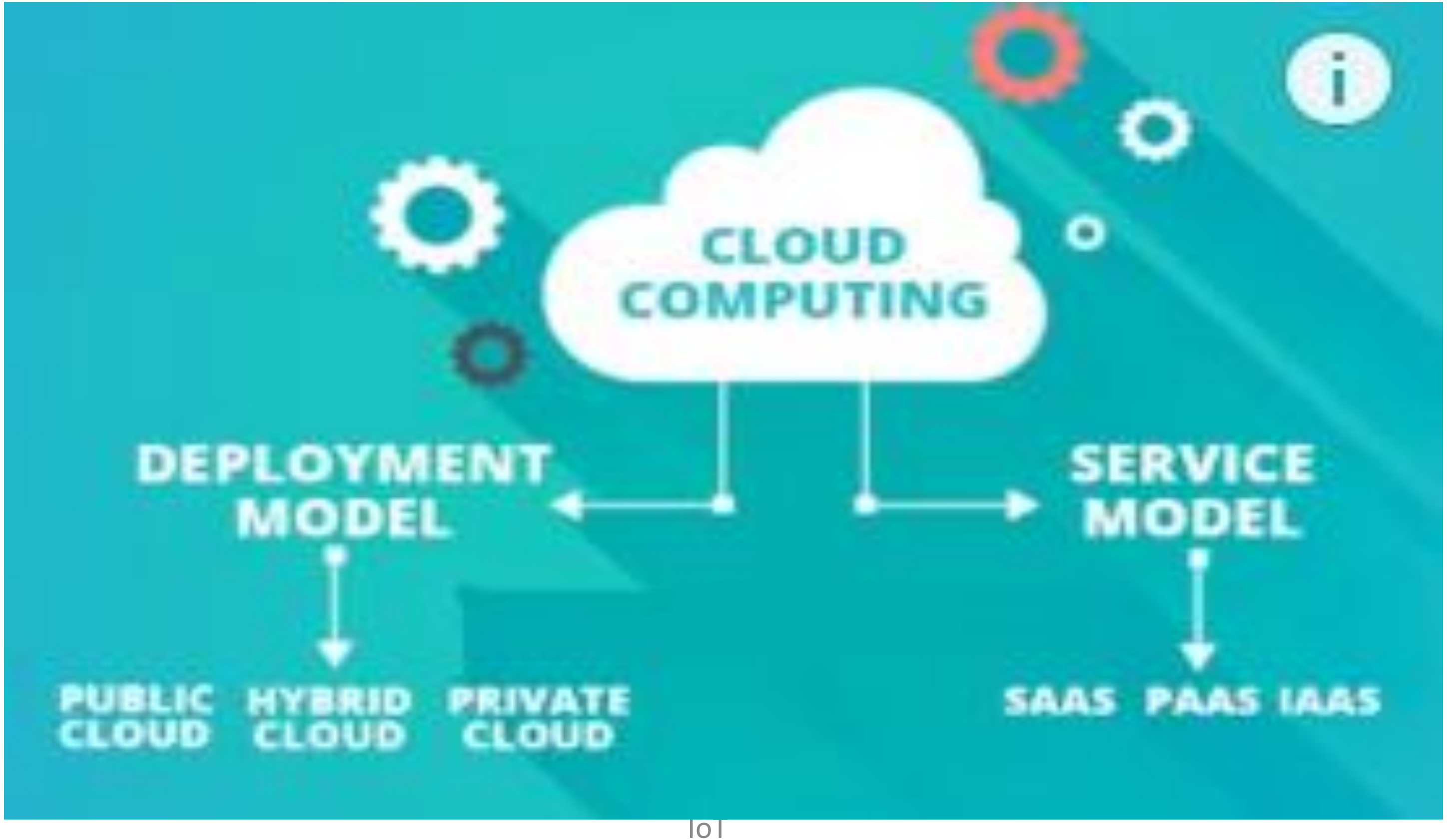

Data Security
Data Loss
Data Security
Data Loss


Maintenance
Maintenance
Azure
aws

What is cloud computing?

- Cloud Computing is the delivery of On-Demand resources (such as server, database, software , etc.) over the internet.
- It also gives the ability to build, design and manage applications on the cloud platform
- Cloud Computing service providers are the vendors to manage applications through a global network
- Ex. Amazon Web Services, Microsoft Azure, GCP etc.

Types of Cloud Computing and Cloud Services



Cloud Computing- Types

There are 4 main types of cloud computing:

- Public clouds,
- Private clouds,
- Hybrid clouds,
- Multiclouds

Public Clouds

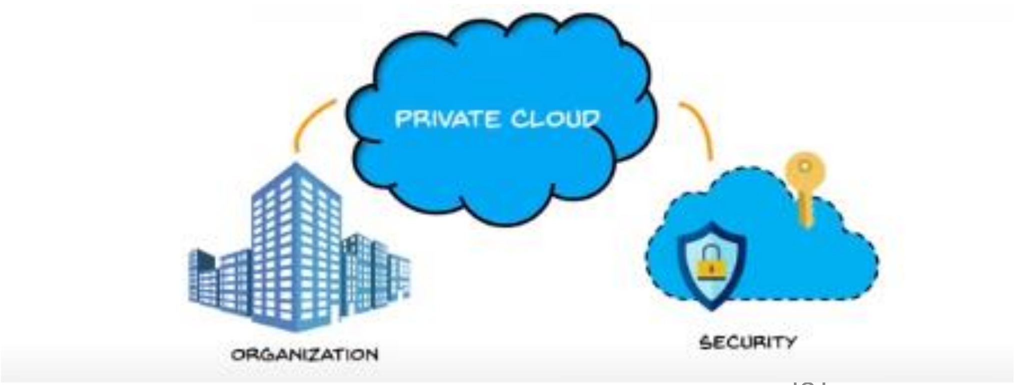
- The cloud infrastructure is made available to the general public over the internet and is owned by a cloud provider.

- Public clouds are cloud environments typically created from IT infrastructure not owned by the end user.

- Some of the largest public cloud providers include Alibaba Cloud, Amazon Web Services (AWS), Google Cloud, IBM Cloud, and Microsoft Azure.

Private Clouds

- Private clouds are loosely defined as cloud environments solely dedicated to a single end user or group, where the environment usually runs behind that user or group's firewall. All clouds become private clouds when the underlying IT infrastructure is dedicated to a single customer with completely isolated access.
- But private clouds no longer have to be sourced from on-prem IT infrastructure. Organizations are now building private clouds on rented, vendor-owned data centers located off-premises, which makes any location and ownership rules obsolete. This has also led to a number of private cloud subtypes, including:



The cloud infrastructure is exclusively operated by a single organisation. It can be managed by the organisation or a third party and may exist on or off premise. Ex. AWS, VMware

Hybrid Clouds

- A hybrid cloud is a seemingly single IT environment created from multiple environments connected through local area networks (LANs), wide area networks (WANs), virtual private networks (VPNs), and/or APIs.

- The characteristics of hybrid clouds are complex and the requirements can differ, depending on whom you ask. For example, a hybrid cloud may need to include:

  - At least 1 private cloud and at least 1 public cloud
  - 2 or more private clouds
  - 2 or more public clouds

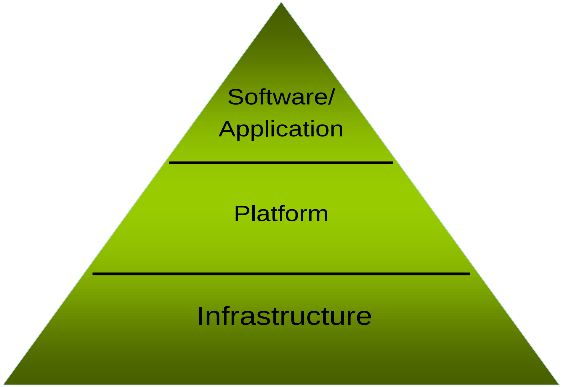
Multiclouds

- Multiclouds are a cloud approach made up of more than 1 cloud service, from more than 1 cloud vendor—public or private.
- All hybrid clouds are multiclouds, but not all multiclouds are hybrid clouds.
- Multiclouds become hybrid clouds when multiple clouds are connected by some form of integration or orchestration.
- A multicloud environment might exist on purpose (to better control sensitive data or as redundant storage space for improved disaster recovery) or by accident (usually the result of shadow IT). Either way, having multiple clouds is becoming more common across enterprises that seek to improve security and performance through an expanded portfolio of environments.

Service Models

There are 3 main types of cloud computing services:

- Infrastructure-as-a-Service (IaaS),
- Platforms-as-a-Service (PaaS),
- Software-as-a-Service (SaaS).

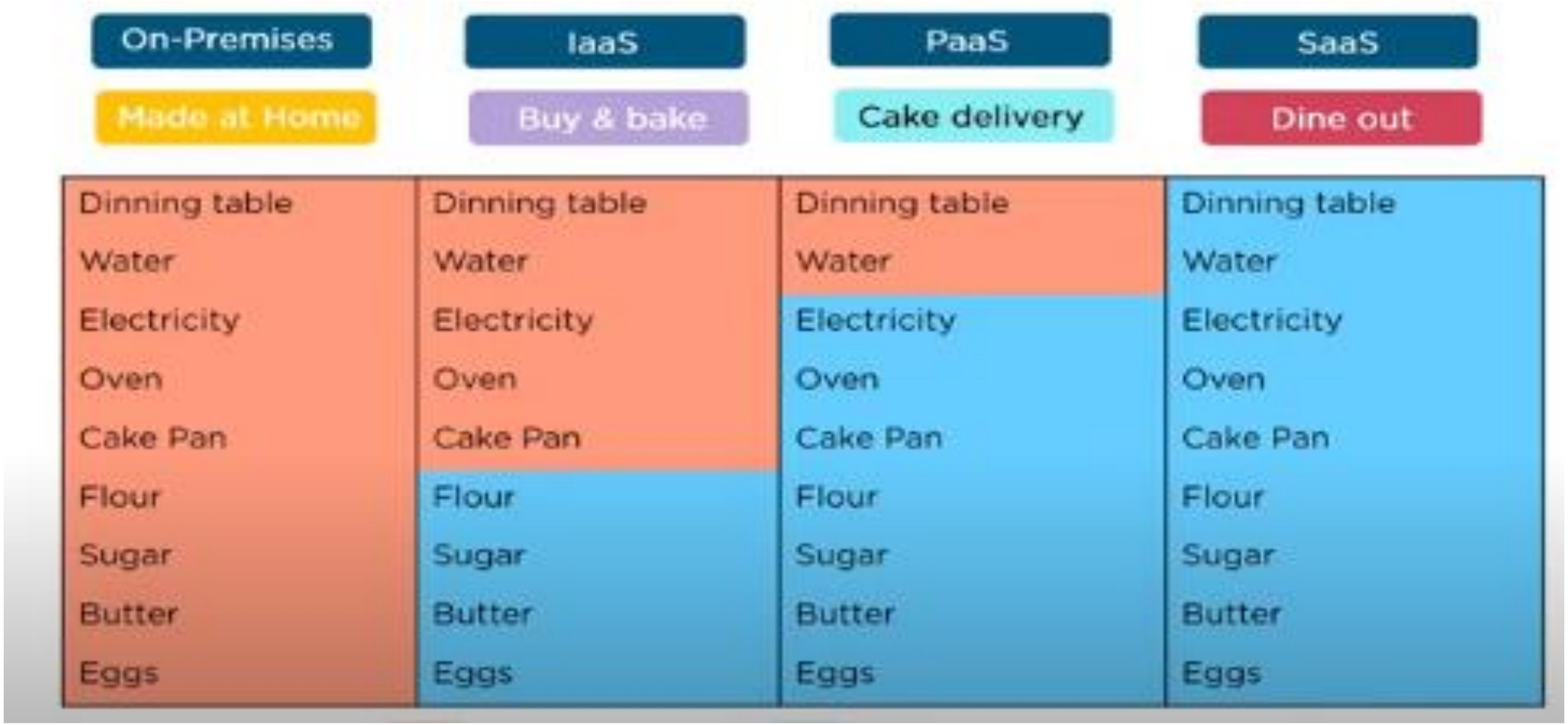


Which cloud service is suitable for you?

- **IAAS-** If your business needs a virtual machine , opt for infrastructure as a service. Amazon Web, Microsoft Azure and Google compute Engine.
- **PAAS-** If your company requires a platform for building software products, pick platform as a service. E.g. windows Azure
- **SAAS-** If your business doesn’t want to maintain any IT equipment, then choose software as a service. E.g. Gmail, Microsoft Office 365

Differences between Iaas,PaaS and SaaS

- Consider a task where you are planning to bake a cake-



On-Premises	IaaS	PaaS	SaaS
Made at Home	Buy & bake	Cake delivery	Dine out
Dinning table	Dinning table	Dinning table	Dinning table
Water	Water	Water	Water
Electricity	Electricity	Electricity	Electricity
Oven	Oven	Oven	Oven
Cake Pan	Cake Pan	Cake Pan	Cake Pan
Flour	Flour	Flour	Flour
Sugar	Sugar	Sugar	Sugar
Butter	Butter	Butter	Butter
Eggs	Eggs	Eggs	Eggs

Thank You!