Selected Topics in Computer Architecture, Computer Networks, and Distributed Systems
(Internet of Things)
(IN3450)

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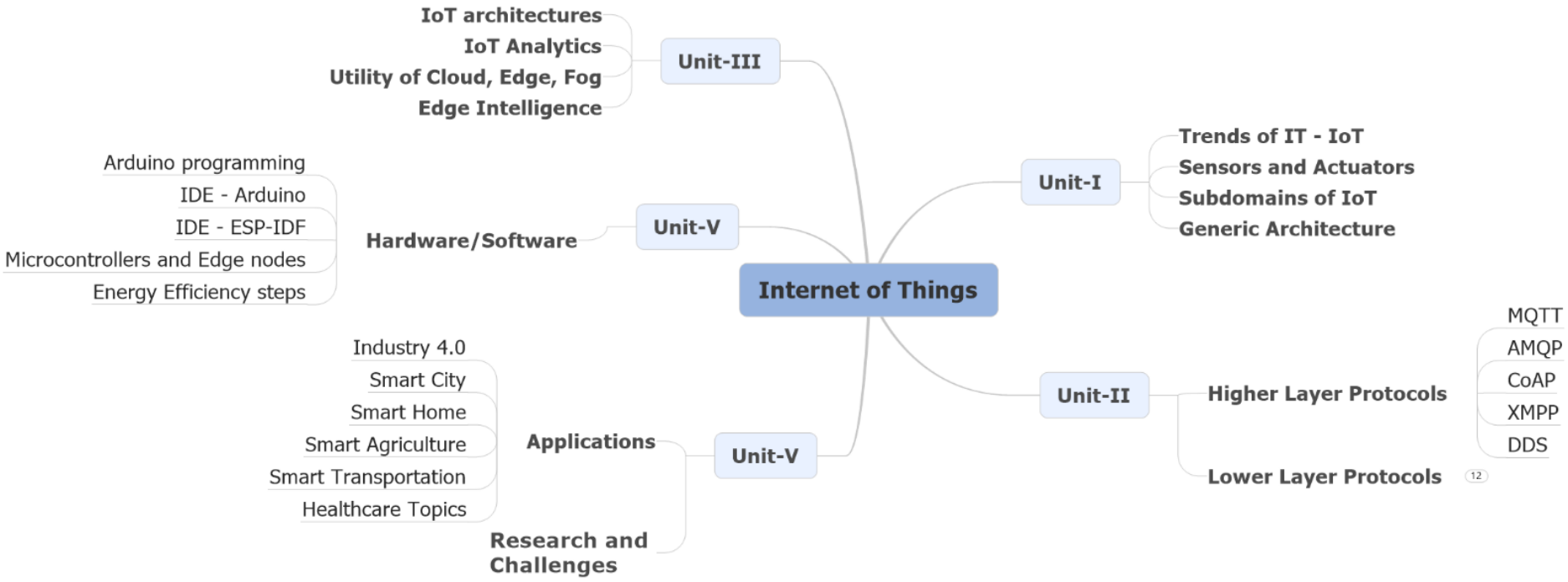
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Protocols

- IEEE 802.15.4
- Zigbee
- 6LoWPAN
- Wireless HART
- Bluetooth
- RFID
- NFC
- WiFi 5/6
- Zwave
- LoRaWAN
- 5G
- Bluetooth

Standard

Range

Power

Data rate

Topology

Frames

Layers

Routing

Devices/

Architecture

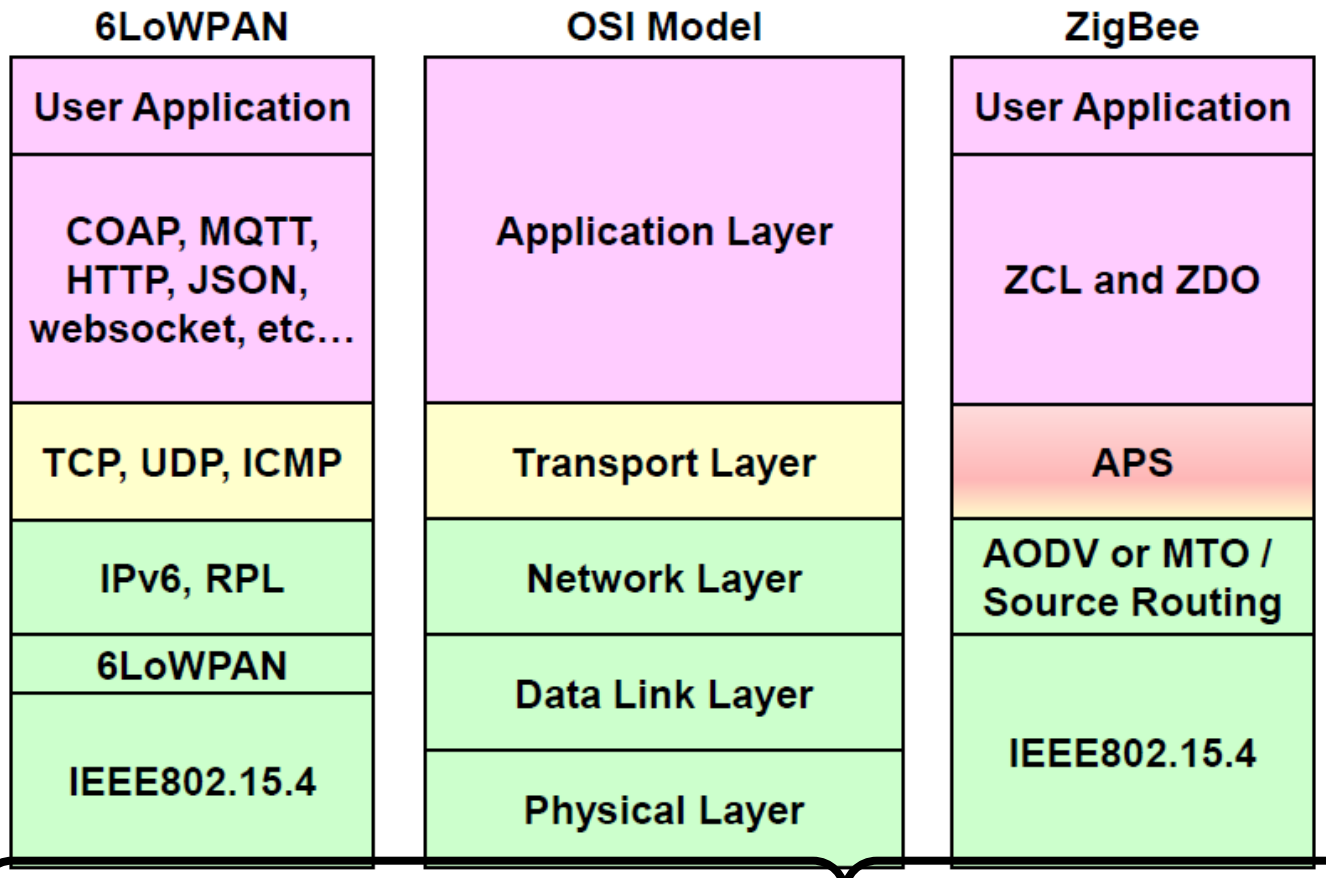
6LoWPAN

- 6LoWPAN
  - IPv6 over Low Power Wireless PAN.
- It is used for connecting IoT devices over internet.
  - Intended for IEEE802.15.4 devices.
- It runs over IPv6 – mostly, wireless devices
  - Hence, the name is 6LowPAN
- It allows the low power devices to connect to the internet.
- It allows IEEE802.15.4 radios to carry 128-bit addresses of IPv6.
- It adds header compression and address translation techniques to support internet.
  - i.e., IPv6 are compressed to support the low power IEEE802.15.4 radios.

6LoWPAN vs. ZigBee

- Essentially, 6LoWPAN products have reached the competition level of ZigBee's market.
- As 6LoWPAN can utilize 802.15.4,
  - Low power and low data rate are ensured.
- 6LoWPANs have seamless integration with other IP-based systems.

6LoWPAN vs. ZigBee



MTO – Multi-cast based Traffic Optimization

APS – Application Support Sublayer

ZCL – Zigbee Coordinator Layer

ZDO – Zigbee Device Object

6LoWPAN - 2 types of MAC addresses

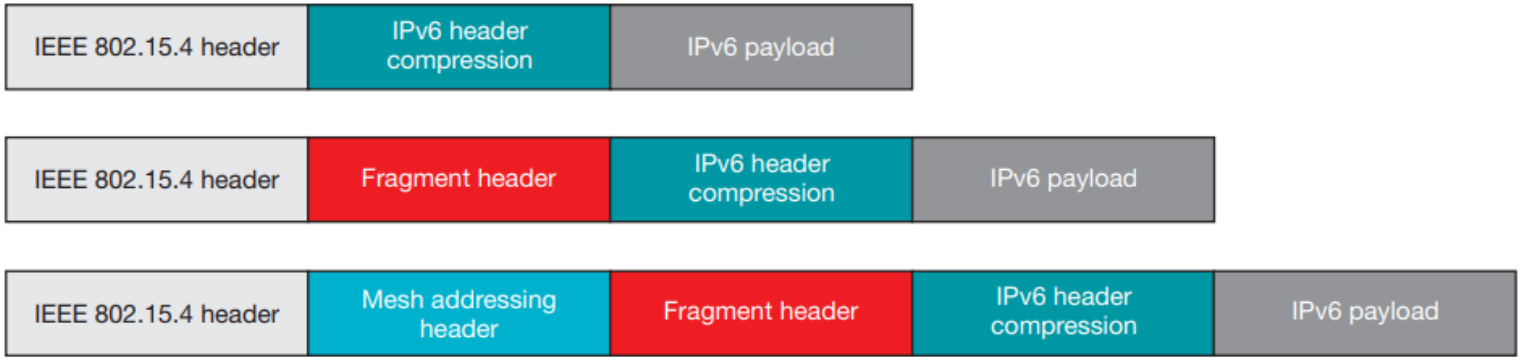
- 64-bit extended
  - It is used for global unique addressing or global unique connectivity.
- 16-bit short addresses
  - It is PAN specific.
  - The 16-bit short addresses are assigned by the PAN coordinator.

6LoWPAN format

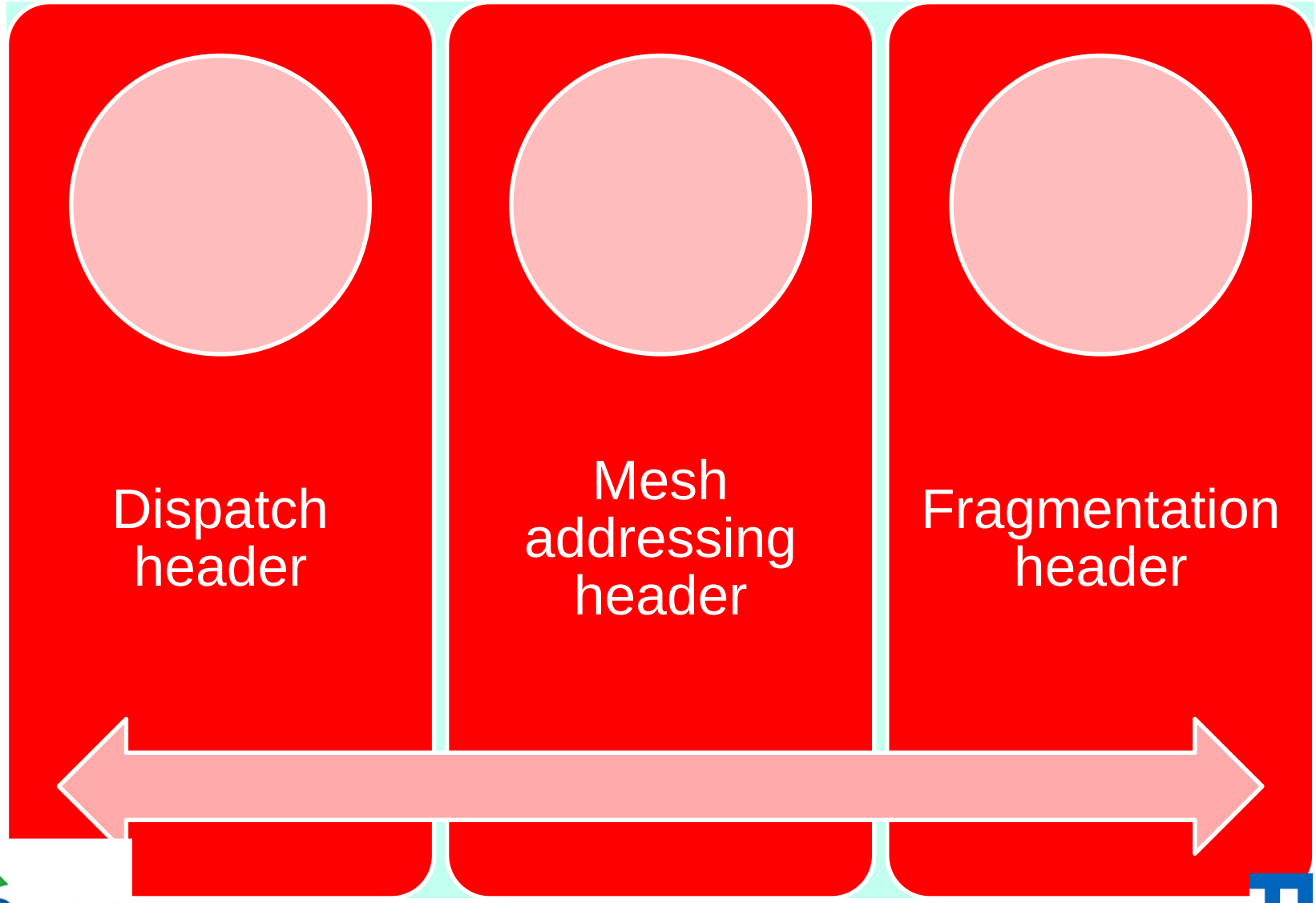
- It uses stacked headers (or, termed as extension headers)
- i.e., it has information about IEEE802.15.4 and IPv6 together for the internet.
- Note that IPv6 and IEEE802.15.4 are together combined with a header.

6LoWPAN format

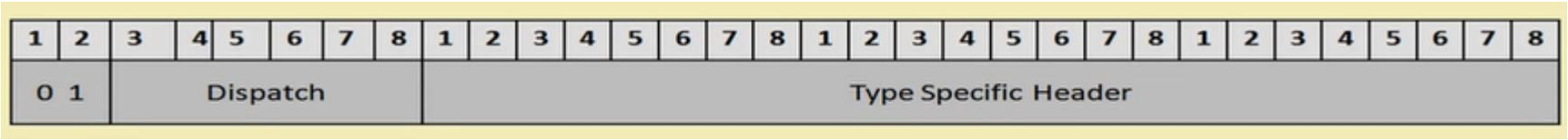
- It utilizes header compression techniques
  - Due to this feature, the header size could be reduced
  - to 2 bytes to 20 bytes when compared to 40 bytes in IPv6.



Types of headers



Dispatch Header



- Dispatch header is used for initiating the communication.
- First two bits indicate the dispatch packet.
- Dispatch information has 6-bits
- Dispatch bits identify the next header type.
- Type specific header (24 bits) – for e.g., mentioning a specific routing process.
  - i.e., it represents the current LowPAN functionality.

http://www.ti.com/lit/wp/swry013/swry013.pdf

Dispatch Header

Pattern	Header Type	
00 xxxxxx	NALP	- Not a LoWPAN frame
01 000001	IPv6	- Uncompressed IPv6 Addresses
01 000010	LOWPAN_HC1	- LOWPAN_HC1 compressed IPv6
01 000011	reserved	- Reserved for future use
...	reserved	- Reserved for future use
01 001111	reserved	- Reserved for future use
01 010000	LOWPAN_BC0	- LOWPAN_BC0 broadcast
01 010001	reserved	- Reserved for future use
...	reserved	- Reserved for future use
01 111110	reserved	- Reserved for future use
01 111111	ESC	- Additional Dispatch byte follows

Sample Dispatch Headers

Mesh Addressing Header

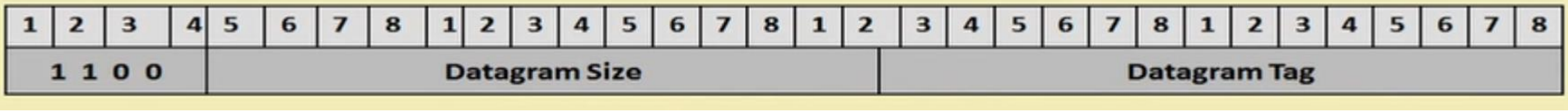
- 1-0 defines the packet as Mesh Addressing Header.
- V → 0 if source is 64-bit extended address
- V → 1 if source is 16-bit address.
- F → 0 if destination is 64 bit address
- F → 1 if destination is 16 bit address
- Hops left
  - Consists of 3 bits
  - Represents the hops
  - Decremented by each node before sending it to next hop.

Fragmentation

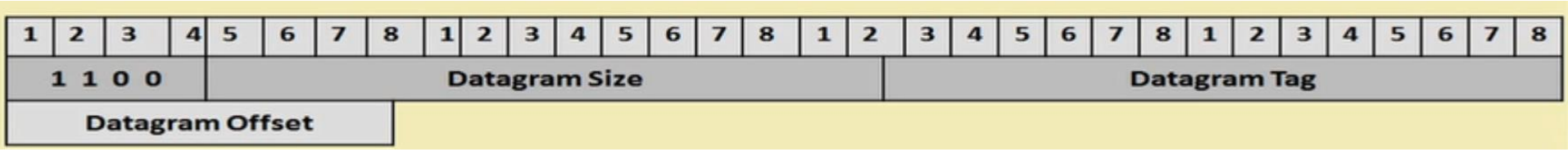
- In general, IPv6 requires the connected links to support at least 1280 bytes of transmissions.
- IEEE 802.15.4 allows only 80-100 bytes of payload (per frame), in most cases…

- Hence, fragmenting packets is a mandatory step.
- NOTE: Fragmentation should accompany compressions of payloads… (If not the performance will be poor).

Fragmentation Header



- First fragment has 1100, Datagram size and the tag.

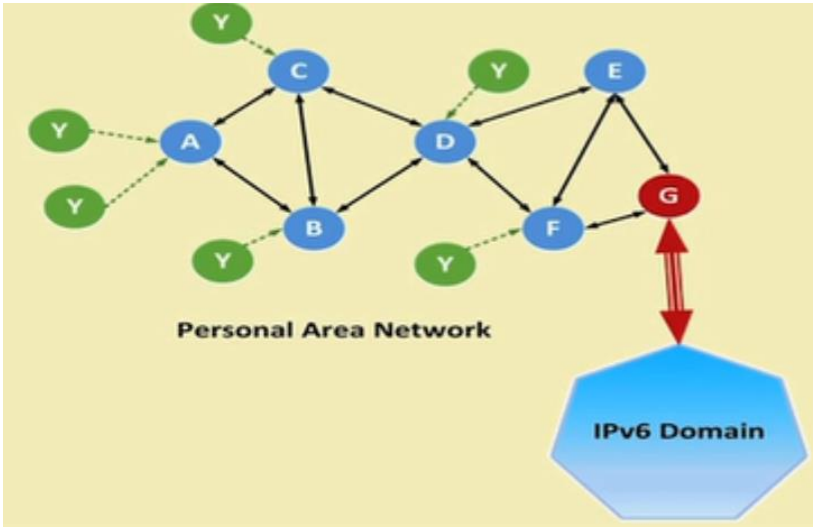


- Subsequent fragments have 1100, datagram size, tag and the datagram offset.

- Datagram size – specifies the unfragmented payload size.

6LoWPAN Routing

- Mesh based routing
- It is applied in PAN domain.
- Two commonly used routing protocols are
  - LOADng – a lightweight version of AODV routing protocol.
    - Ie. RREQs, RREPs, and RERR messages. (Reactive Type)
  - RPL – Routing Protocol for Lossy and Low Power networks.
    - Based on DVR; Maintains routing topology using low rate beaconing. (Active Type)
- As seen, PAN networks are connected to IP domains using gateway.
- Both routing protocols aims at
  - Optimizations such as
    - Minimizing energy
    - Minimizing latency
    - Node power
    - Bandwidth and so forth



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Architecture

RFID

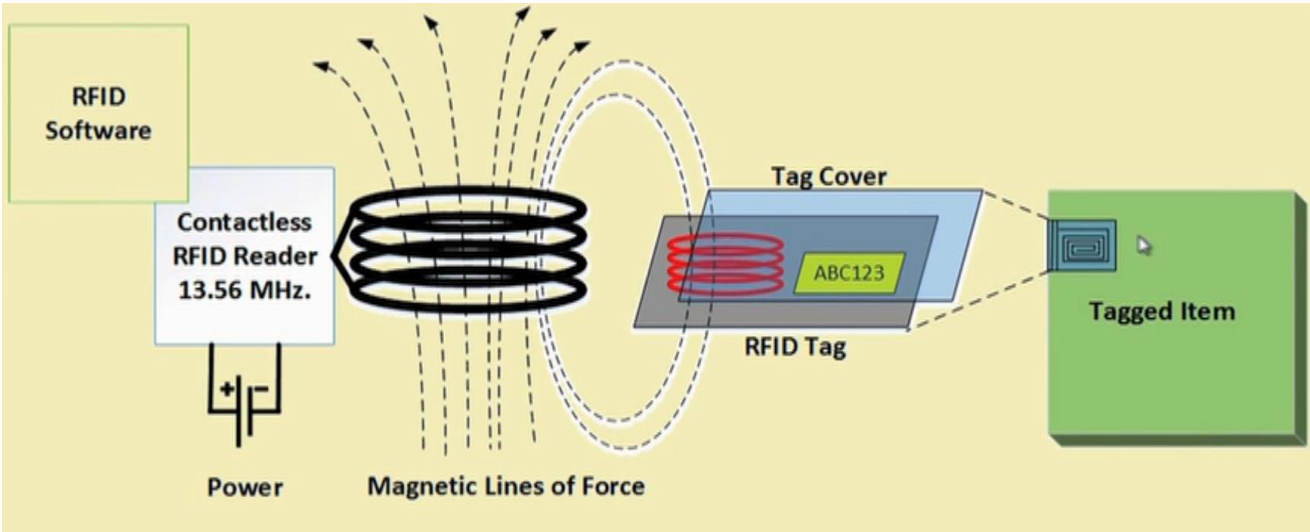
- Radio Frequency Identification.
- It is commonly used in various places including shopping malls, wallets, Idcards, books, and so forth.
- Data are digitally encoded in RFID tags.
- Data available in the RFID tags are scanned in the RFID readers.
- Similar to barcodes and QRcodes – which are read by the appropriate readers.
- RFID performs one-way communication.

RFID tags

- Inside each tag there is an integrated circuit embedded into it. It also includes an antenna.
- Data such as employee details are stored in this tag.
- Antennas are used to radiate the signals to the other readers.
- The circuit is protected using an shield (mostly water resistant and interference resistant).
- Tags are of two types:
  - Passive tags
    - Most widely used.
    - Passive tags have to be powered by a reader inductively before they can transmit information.
  - Active tags
    - These tags have their own power supply to send data to the readers.

RFID working principle

- RFID is adopted from the previous technology named as AIDC (Automatic Identification and Data capture).
- AIDC performs object identification, data collection, and so forth with little or no manual intervention. (BUT, AIDC was developed for WIRED systems).
- RFID does the same; but, for wireless devices.
- The main components of RFID include
  - RFID tag
  - RFID reader
  - Antenna



RFID applications

- Inventory management
- Personal tracking
- Asset tracking
- ID badging
- Supply chain management

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NFC – Near Field Communications

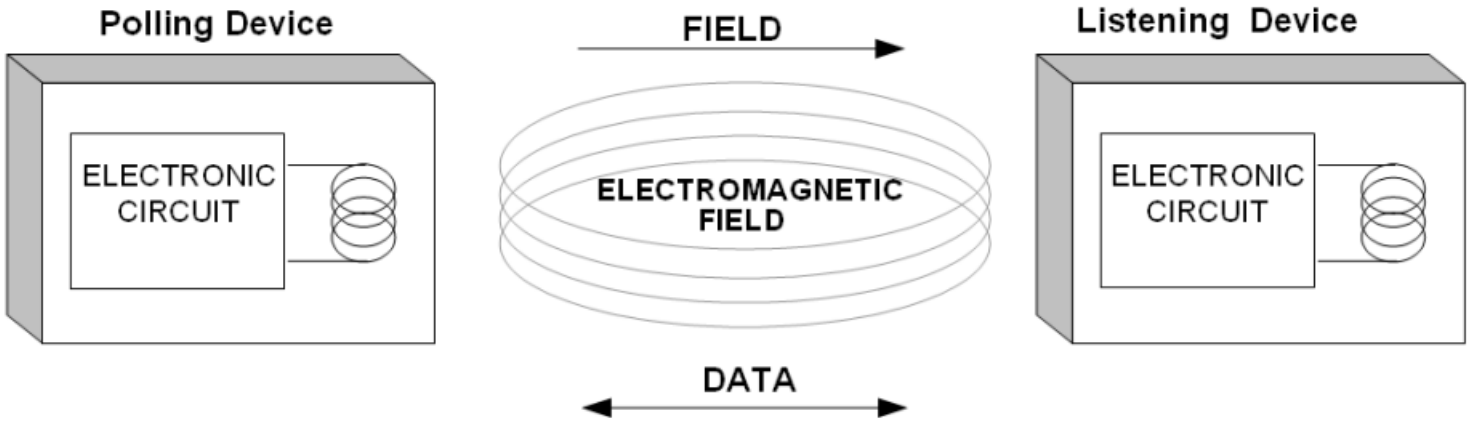
- NFC is a short-range wireless connectivity protocol.
- NFC enables users to perform contactless transactions.
- NFC is a subset of RFID.
- In contrary to RFID, NFC performs two-way communication.
- It is designed to exchange various types of information such as telephone numbers, MP3 files, or to perform digital authorizations between two NFC-enabled mobile phone or devices.
- It operates in 13.56 MHz.
- It offers a data transmission of upto 424 kbps.
- It covers the distance of approx. 10 centimeters.

NFC use-cases

- Mobile payments
- Store authentication access controls.
- Data transfer between two or more NFC-enabled devices.
- Access to digital information (e.g., vehicle keys)
- Event tickets on mobile phones.
- COVID-19 protection units

NFC Working principles

- NFC works as similar to RFIDs. (i.e, it uses the induction principle)



- NFC has active and passive type of communications.
  - Active – Tags are powered to send messages.
  - Passive – Tags are not powered with sources.
- NFC for healthcare applications
  - https://ieeexplore.ieee.org/abstract/document/4571079

NFC Working Modes

- P2P working mode
  - Both devices could exchange data.
- Read/Write working mode
  - One-way communication (Not commonly utilized).
  - E.g., smartphones are utilized to collect information from some tags (named as NFC advertisement tags).
- Card Emulation working mode
  - NFC device functions as contactless credit card.
  - Some additional computations are performed in these devices.

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WiFi Communication Protocol

- WiFi is termed as Wireless Fidelity.
- Fidelity means compatibility between wireless equipment manufacturers.
- It attempts to provide in-building broadband coverage.
- It is based on IEEE 802.11 family of standards.
- WiFi Alliance does the compatibility testing and modifications (https://www.wi-fi.org/)

WIFI variants

IEEE 802.11 VARIANT	FREQUENCY BANDS USED
802.11a	5GHz
802.11b	2.4GHz
802.11g	2.4GHz
802.11n	2.4 & 5 GHz
802.11ac	Below 6GHz
802.11ad	Up to 60 GHz
802.11af	TV white space (below 1 GHz)
802.11ah	700 MHz, 860MHz, 902 MHz, etc. ISM bands dependent upon country and allocations
802.11ax	

WiFi - LANs

- It is popularly known as wireless LANs.
- Initial – IEEE 802.11
  - Operated at 1 and 2 Mbps
- Extended standards – IEEE 802.11b, 11.g
- WiFi-6 and 6E are recent standards
  - (targeted power efficiency and high speed)

- It supports base station-based and adhoc connections.

WiFi 6

- It falls under IEEE 802.11ax standard.
- It is released in 2019 (latest one).
- It is the successor to WiFi 5.
- It is faster than WiFi 5 (IEEE 802.11ac).
- The main goal of WiFi 6 is to increase the performance of WiFi network even if many devices were connected to the network.

- Normally, if many devices are connected to WiFi network, it could slowdown the network. (> 8 devices)
- WiFi6 endeavors to override the slowdown of the network.
- But, the device has to be a WiFi6 capable device.

WiFi 5 vs. WiFi 6 (5th and 6th Generation)

	WiFi 5	WiFi 6
Speed	3.6 Gbps	9.6 Gbps
Connection to internet	Each device gets internet one at a time.	Each device gets internet at all time (due to Orthogonal Freq Division Multiple access technique)
Users/Devices	Single User – Multiple input, Multiple output SU-MIMO	Multiple User – Multiple input, Multiple output MU-MIMO
Signals	No Beam forming	Beam forming is followed.
Battery utilization NOTE: They are not 5G (it is WirelessLANs)	No special features (little sleep time)	It follows Target Wake Time… i.e., the WiFi router or access points schedule a wake time with WiFi devices.

2 Known problems in Wireless LANs

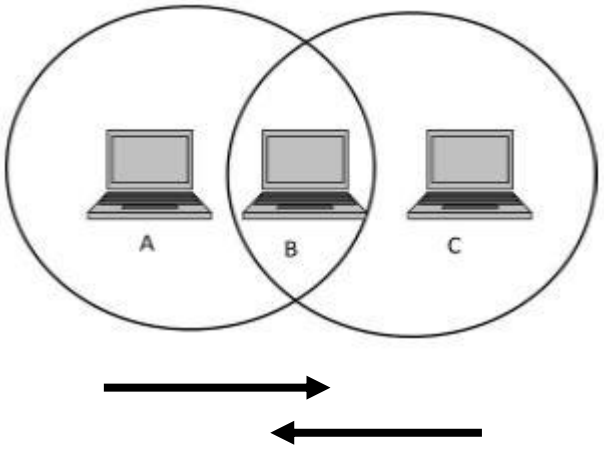
- A fully connected topology between the WLAN nodes cannot be assumed.

- Two well known problems are possible in wireless communications.
- They are…

Hidden terminal problem

Exposed terminal problem

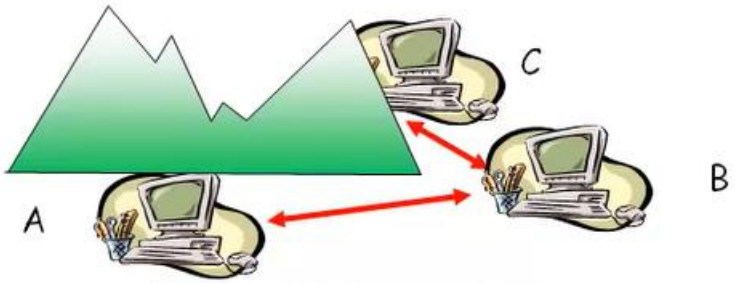
Hidden terminal problem



For instance, the transmission range of A reaches B but not C. Similarly, the range of C reaches B but not A. Also the range of B reaches both A and C.

A to B; Simultaneously, C to B
Collisions occur…!
Please note that the CSMA/CA will not notice it…

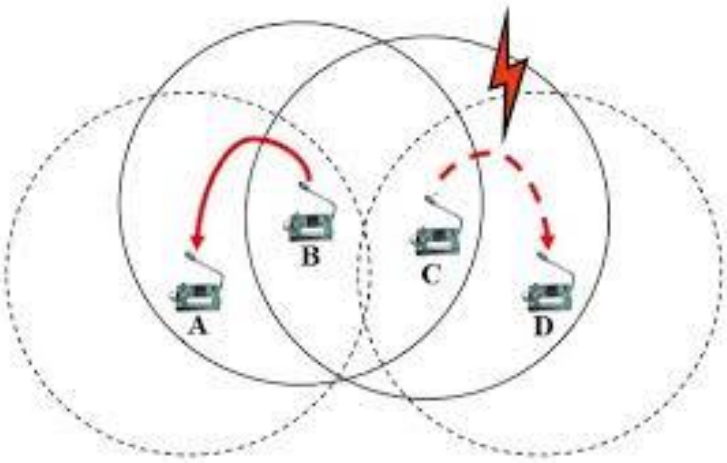
Solution: RTS/CTS handshake approach…(Ready to Send; Clear to Send)



Step 1: RTS packet from A to B;
Step 2: CTS packet is broadcasted from B To A and C
Step 3: C understands that A and B are communicating now!

NOTE: B alerts both A and C to avoid the problem.

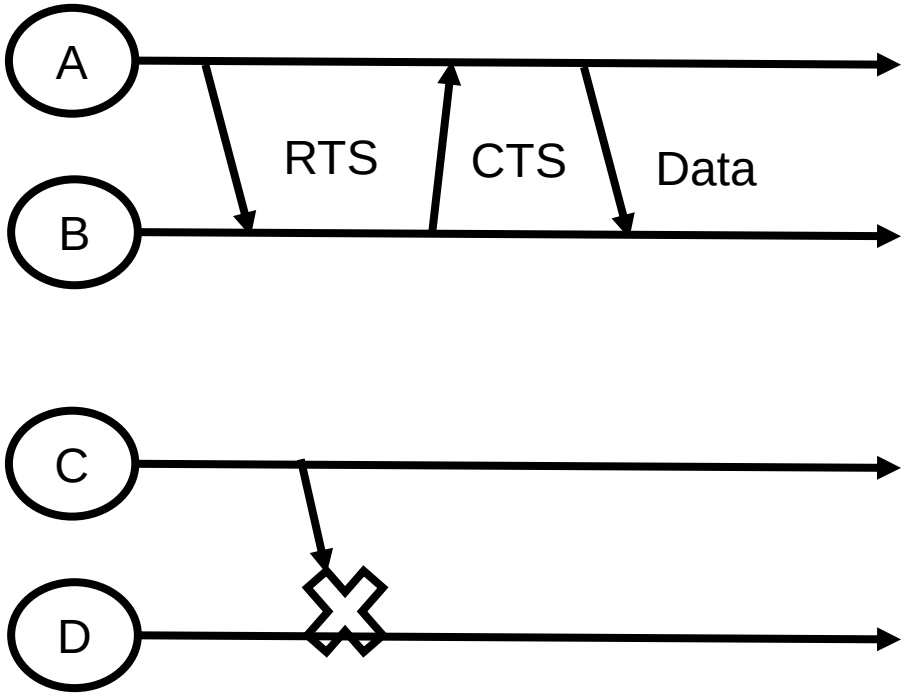
Exposed terminal problem



•Imagine a situation wherein the B node is currently sending some data to node A.

•Now the other node C wants to send data to some node D (which is outside the range of A and B).
•Now before starting transmission it senses the carrier and realizes that the carrier is busy (due to interference of B's signal).
•Hence, the C node postpones the transmission to D until it detects the medium to be idle.
•(unnecessary wait time)….

Solution to Exposed terminal problem -- RTS/CTS



It includes an
unique identifier for RTS
….

Hence, collisions are avoided.

Protocols

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- NFC
- WiFi 5/6
- Zwave
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Z-wave

- Z-wave was developed by Zensys, a Danish company in 1999.
- They developed over 2100 certified products.
- It is a low power RF communication technology designed for home automation.
- Eg. Lamp controllers based on SoC.
- Z-wave attempts to effectively communicate between home devices (sensors/actuators).

https://www.z-wave.com/

Z-wave

- Z-Wave, enables smart home products like locks, lights and thermostats to talk to each other.
- It provides ONE APP to control and configure all z-wave products.
- Nodes that are within range communicate directly with one another.
- If there is no range, the devices can link with other nodes and start communications.

Z-wave

- Low latency communication of small datapackets with data rates upto 100Kbit/s (Throughput: 40Kbps)
- It operates in 1GHz and therefore avoids the WiFi or the other wireless interferences (2.4GHz).
- Distance ranges from 30 to 40 meters.

Frequency in MHz	Used in
865.2	India
869	Russia
868.4	China, Singapore, South Africa
868.40, 868.42, 869.85	CEPT Countries (Europe and other countries in region), French Guiana
908.40, 908.42, 916	USA, Canada, Argentina, Guatemala, The Bahamas, Jamaica, Barbados, Mexico, Bermuda, Nicaragua, Bolivia, Panama, British Virgin Islands, Suriname, Cayman Islands, Trinidad & Tobago, Colombia, Turks & Caicos, Ecuador, Uruguay
916	Israel
919.8	Hong Kong
919.8, 921.4	Australia, New Zealand, Malaysia, Brazil, Chile, El Salvador, Peru
919–923	South Korea
920–923	Thailand
920–925	Taiwan

Z-wave

- It applies source-routed mesh networks for higher availability of devices.
- It forms adhoc-type of network connectivity.

Z-Wave Smart Home Automation Hubs And Controllers

Z-Wave Smart Lighting Products

Z-Wave Sensors and Actuators

Z-Wave Plus Smart Home Security Systems

Z-Wave Energy Management Monitors

ZIY – Popular Trend

- ZIY – Z-Wave it Yourself
- 3 Simple Approaches
  - Build http://ziy.io/
    - Build your device using the Arduino Platform.
    - Using some Arduino tutorials
  - Connect
    - Push the include button on the ZIY board to join your Z-Wave Network.
  - Use
    - Interact with your device using your phone, tablet or computer.
    - Schedule your device to turn on or off.
    - Schedule your device to read sensor values or talk to other devices on your home automation network.

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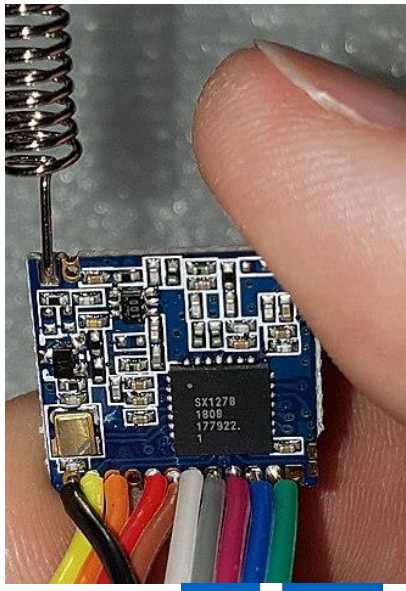
LoRaWAN Technology

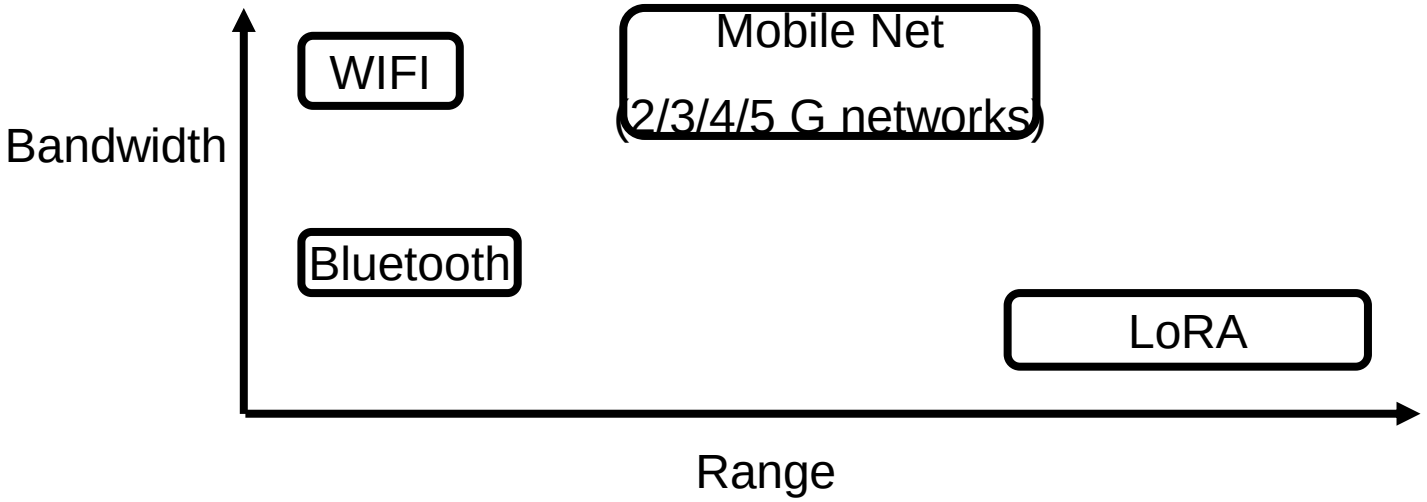
- Long Range Technology
- Low power, Long Range, -- for IoT
- Supports WAN
- It was developed by Cycleo of Grenoble, France and acquired by Semtech the founding member of the LoRa Alliance.
- Long Range -- > 10 KM in rural areas
  with low power consumption



LoRaWAN Technology

- LPWAN = Low Power Wide Area Network
- Low Power Wide Area Network (NAMING…)
- Network:
  - All sensors need to be connected…
  - May be millions of devices need to be connected.
- Wide Area
  - If WIFI is utilized, only LAN is possible (low range).
  - Wide Area, means, long distance via. n/w layers.
  - More than 10 kilometers…in rural; More than 500 m to 700 m in urban areas.
- Low Power
  - AM/FM Radio offers long range (BUT, high power – KiloWatts)
  - LoRaWAN works with batteries.
    - How? Reduce the bandwidth (i.e., less number of characters)

LoRaWAN Technology



- More the range, lesser the bandwidth (if power becomes a bottleneck)
- Data rate = 250bps (bits per second) to 50kbps (VERY SMALL)

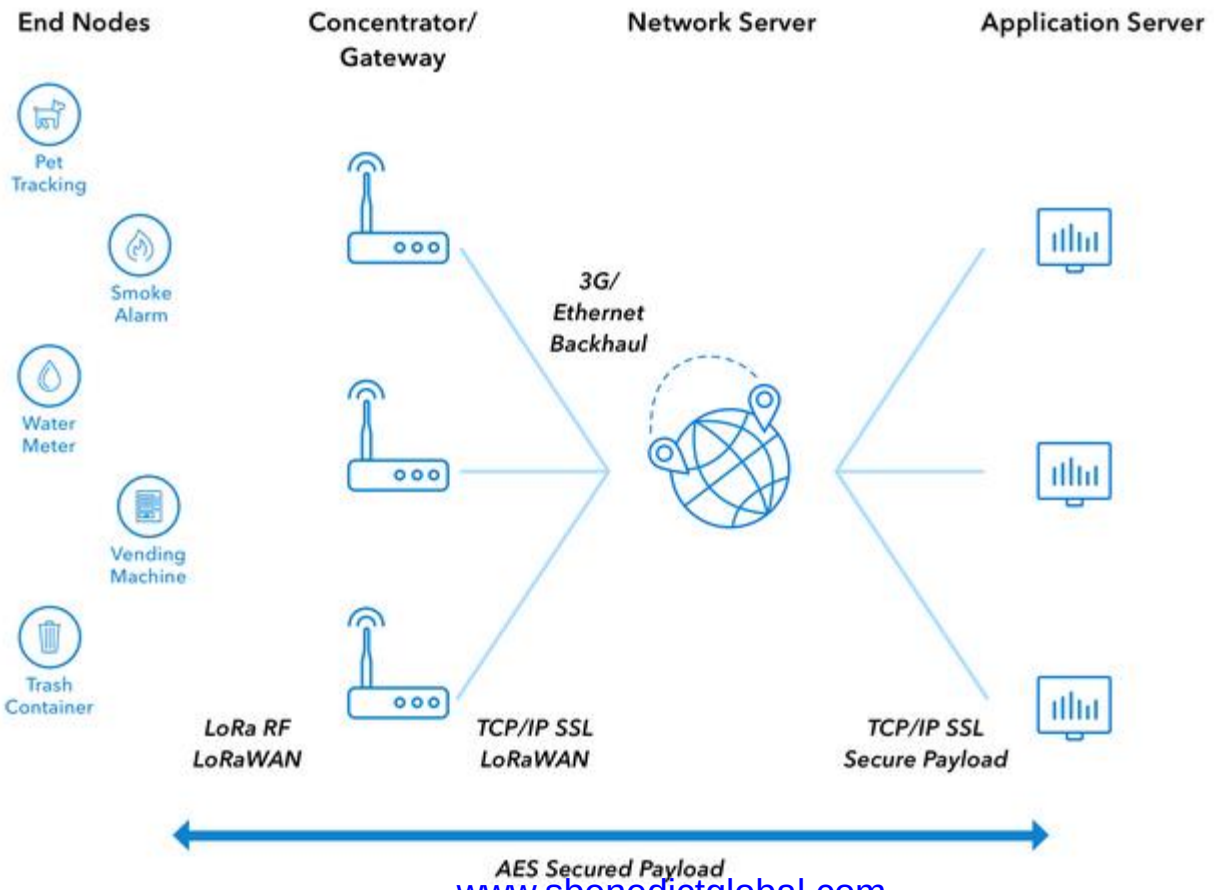
LoRaWAN Technology

- It is not comparable to WIFI or similar technologies.
- LoRaWAN Technology becomes unique.
- Hence, it fits only to a few applications (especially, long range and limited bandwidth).

- LoRa uses different frequencies for different regions
  - 868MHz for Europe
  - 915MHz for North America
  - 433MHz for Asia

LoRaWAN Architecture

- ThingsNetwork – built a community approach of connecting LoRA gateways.



LoRaWAN Architecture

- End Device, Node, Mote - an object with an embedded low-power communication device.
- Gateway - antennas that receive broadcasts from End Devices and send data back to End Devices.
- Network Server - servers that route messages from End Devices to the right Application, and back.
- Application - a piece of software, running on a server.

https://www.thethingsnetwork.org/docs/lorawan/architecture.html

LoRaWAN

- LoRaWAN uses ALOHA protocol
- What is ALOHA?
  - ALOHA, meaning hello, is a multiple access protocol for transmission of data via. Shared network.
- 2 versions of ALOHA
  - Pure ALOHA
    - In pure ALOHA, each node or station transmits a frame without trying to detect whether the transmission channel is idle or busy.
    - If two nodes transmit simultaneously, collisions are possible.
  - Slotted ALOHA
    - In slotted ALOHA, each node starts sending frames during their assigned slots.
    - The no.of collisions are reduced here.

Thingsnetwork Gateway

- Indoor vs. Outdoor gateways

LoRaWAN

- Can LoRaWAN send images?
  - No. due to low data rate.
  - Mostly, only text messages (short messages are communicated).
- Security
  - Is poor.
  - However, efforts are on progress

Use-cases


Utilities
Smart Metering
Smart Grid Management
Logistics
Fleet Management
Asses Tracking
LoRaWAN
Use Cases
Smart Cities
Parking Sensors, Waste
Management, Smart Lighting
Environmental Monitoring
Flood monitoring/alerts
(water,air, noise) etc.
Industrial IoT
Process Control and Monitoring
Predictive Maintenance
Wearables
Kids/Elderly Tracker
Medical Monitoring

Map of LoRa Gateways

- Gateways in Glassgov.

- Applications can utilize such gateways for transferring messages at free of cost…

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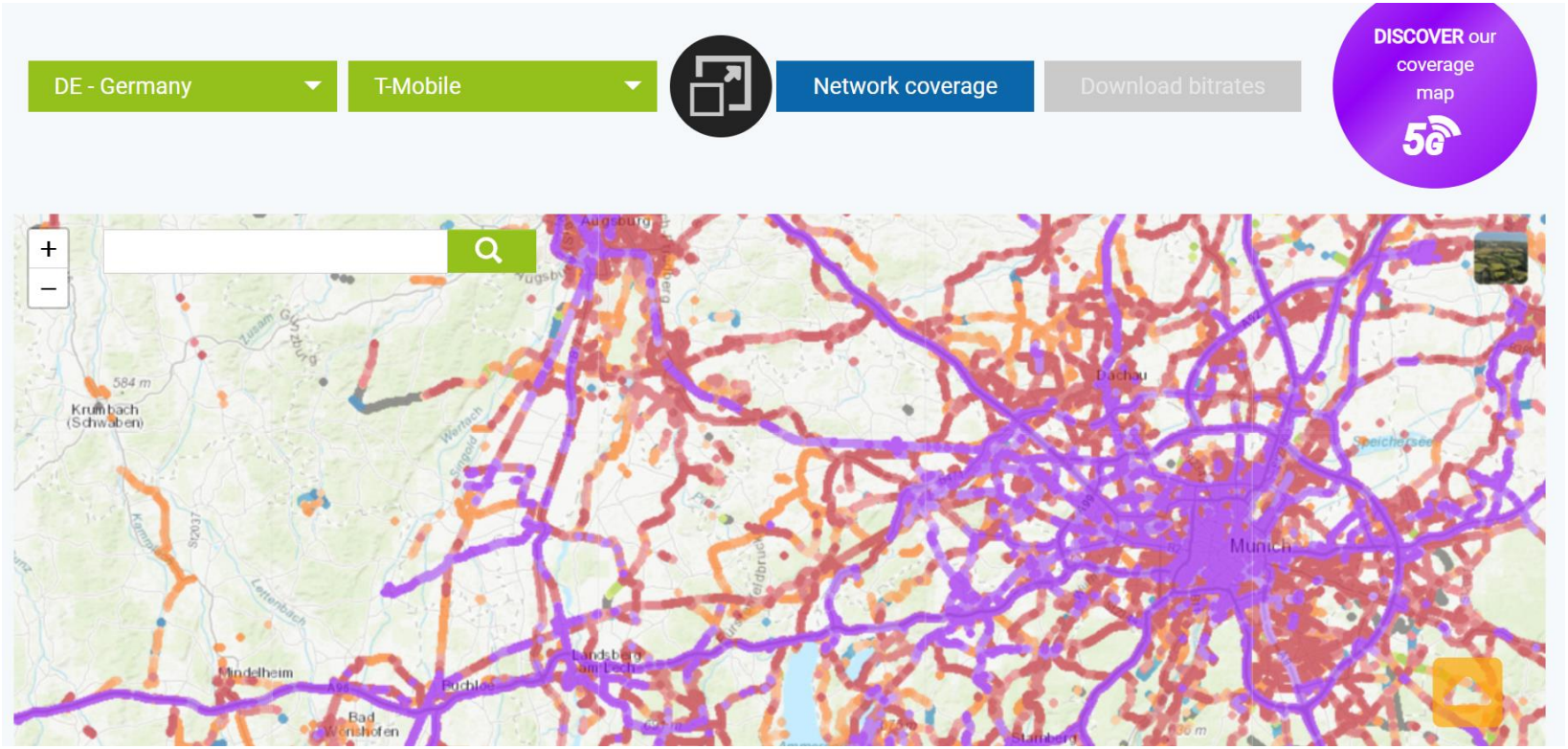
5G Technology

- 5G is the 5th Generation wireless communication technology for cellular networks – A broadband network connection.
- On 23 February 2018, Bharti Airtel and Chinese multinational telecom gear Huawei have successfully conducted India's first 5G network trial under a test setup at the former's network experience centre in Manesar, Gurugram (source: Wikipedia).
  - Although 5G is tested in India, it is not yet utilized for commercial purposes.
  - Munich has started its operation.
- Select cities have started 5G services in the other countries.

5G Technology – Coverage Map



https://www.nperf.com/en/map/DE/

5G Technology

- It offers exceptionally higher speed (uploads and downloads)
- It might replace 4G quickly.

Mobile	Speed
2G	64Kbps
3G	8Mbps
4G	50Mbps
5G	10Gbps

- 5G is operated in three bands of wavelength spectrum
  - High band → Mmwave
  - Mid band
  - Low band → Sub-6

Types of 5G bands

- Sub-6 GHz band
  - Low band and Mid band
- Sub-6 GHz band – Low Band
  - Operates in freq range from 600MHz to 2.4GHz.
  - The speed will be slightly better than the existing 4G technology (50Mbps).
  - Deep indoor penetration is possible.
  - Reaches sufficient distances.
- Sub-6 GHz band – Mid Band
  - Operates in freq. range from 3GHz to 6GHz.
  - Speed – 200 to 900Mbps.
  - Penetration is up to some limited buildings.

Types of 5G bands

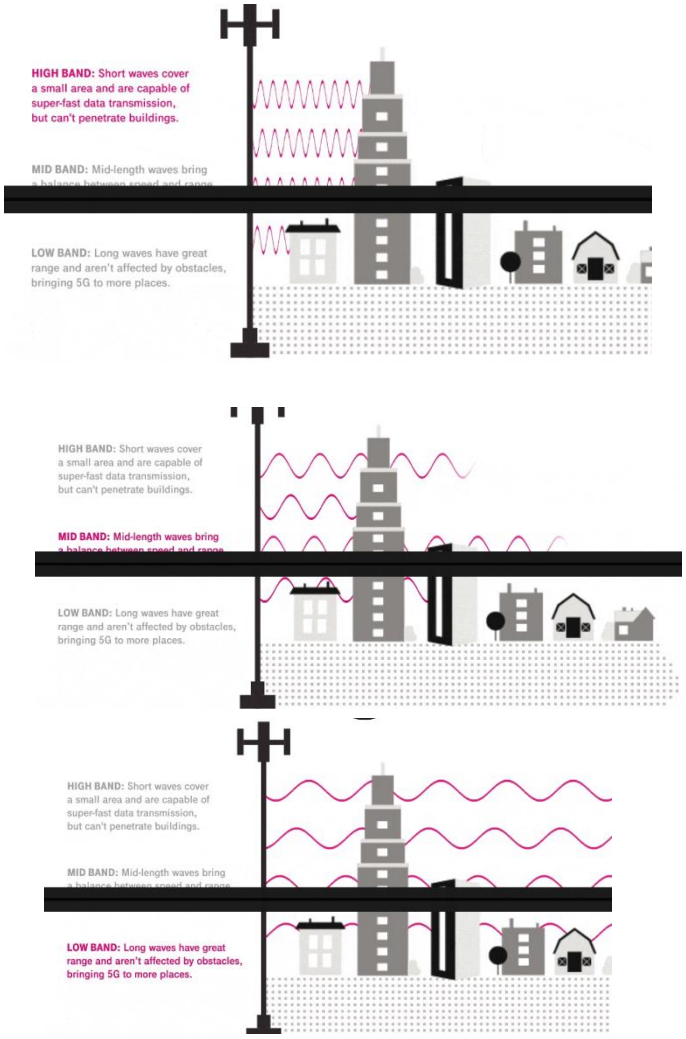
- mmWave Frequency spectrum
- It is considered as an elite spectrum.
- It can reach upto 10Gbps.
- Since it is having short wavelengths, the attenuation will be very high.
- Accordingly, the signals will be stopped by the atmosphere or buildings.

5G – High Band

High Band

Mid Band

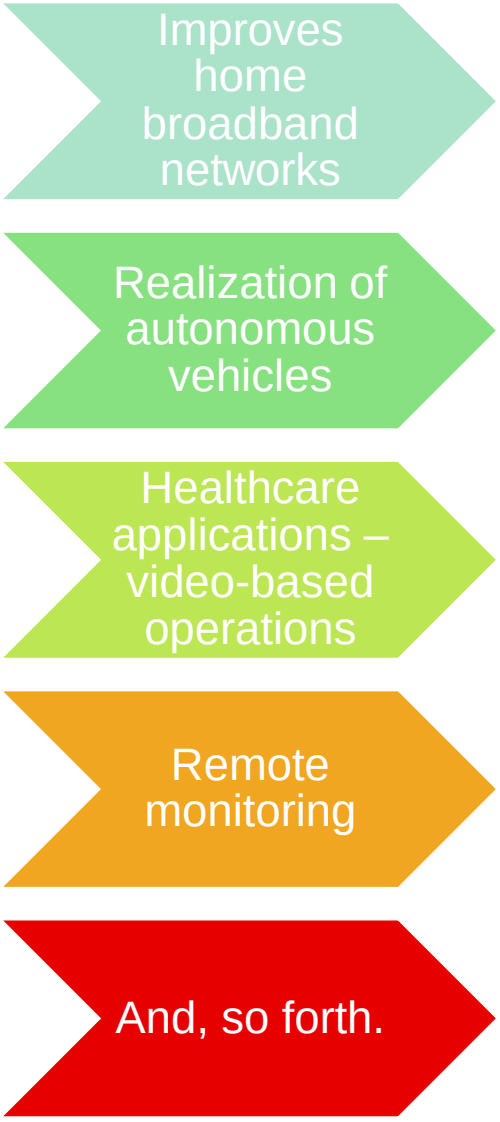
Low Band



Some Companies

- Verizon 5G network
- AT&T
- T-Mobile
- Reliance Jio?
- BSNL?

Benefits of 5G

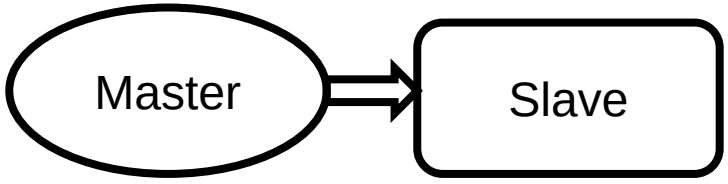


Bluetooth

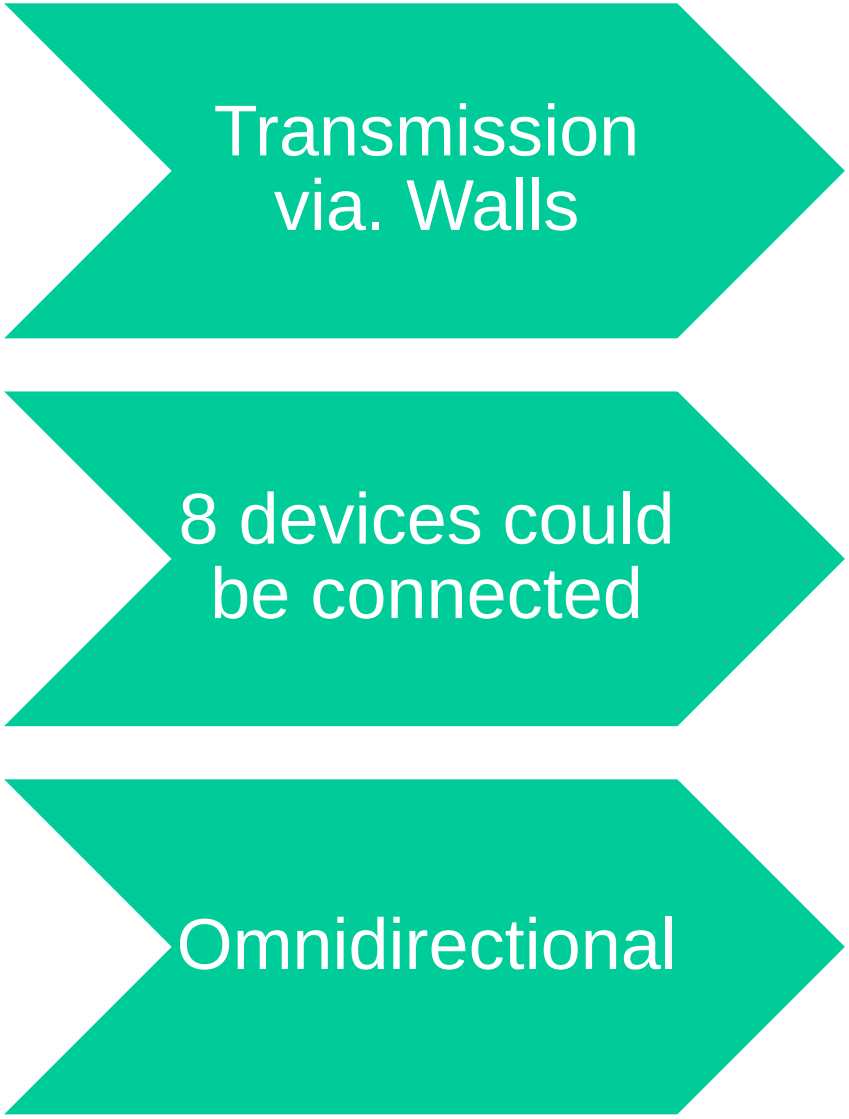
- Bluetooth was initially developed by Dr Jaap Haartsen and Sven Mattison at Ericsson in 1994.
- Released in 1999 by consortium led by Ericsson, Nokia, and Intel.
- Bluetooth is based on IEEE 802.15.1 standard.
- Bluetooth 1.0 was initially designed to replace cables to connect devices such as cell phones, laptops, headsets, and so forth.
  - It offers low datarate – 1 Mbps
  - It supports short range – 50m range
  - It has around100 meters range (theoretical)
- Bluetooth 4.0 was released in 2010.
  - It offers 2.4Mbps datarate
  - It includes a low energy extension – called Bluetooth/LE

Bluetooth protocol

- As informed, it is mainly utilized to pair wireless headphones to devices.
- Working methodology:
  - Bluetooth protocol supports Bluetooth network (also termed as piconets).
  - Piconets use pt-to-pt or pt-to-link communication.
  - They are typically serial communication approaches which follow master-slave communication pattern.



Bluetooth characteristics



Notable projects with Bluetooth

- Bluetooth enabled door lock.
  - https://www.youtube.com/watch?v=I3ntgKPkFPY
- Smartphone controlled Arduino robot car
- Gesture controlled Arduino robot arm
- Bluetooth controlled car
- Interactive LED table
- Over 179 projects
  - https://create.arduino.cc/projecthub/projects/tags/bluetooth