Advanced Communication Networks

Muhammad Taha Jilani

Lecture - 8

Before Midterm

- Recap
  - WWAN
    - WiFi
    - WiMAX

HSDPA : High Speed Downlink Packet Access

- Improves System Capacity and User Data Rates in the Downlink Direction to 10Mbps in a 5MHz Channel
- Adaptive Modulation and Coding (AMC)
  - Replaces Fast Power Control :
    User farer from Base Station utilizes a coding and modulation that requires lower Bit Energy to Interference Ratio, leading to a lower throughput
  - Replaces Variable Spreading Factor :
    Use of more robust coding and fast Hybrid Automatic Repeat Request (HARQ, retransmit occurs only between MS and BS)
- Fast Retransmission with Soft Combining and Incremental Redundancy
  - Soft Combining : Identical Retransmissions
  - Incremental Redundancy : Retransmits Parity Bits only
- Fast Scheduling Function
  - which is Controlled in the Base Station rather than by the RNC

HSDPA is max. **14.4 Mbps**,
HSUPA max. data rate of **5.74 Mbps**

Beyond 3G or 3.75G

Long-term Evolution (LTE)

- The ITU-R set standards for 4G connectivity in 2008, as follows:
  - For mobile use, including smartphones and tablets, connection speeds need to have a peak of at least 100 Mbps
  - For more stationary uses such as mobile hotspots, at least 1 Gbps
- Long Term Evolution, and isn't as much a technology as it is the path followed to achieve 4G speeds.
- Proposed in Release 8, main

Long-term Evolution (LTE)

Motivation for LTE

- Proposed in Release 8, with main motives are
  - Need to ensure the continuity of competitiveness of the 3G system for the future
  - User demand for higher data rates and QoS
  - All IP network & Packet Switch optimised system
  - Continued demand for cost reduction
  - Low complexity

Long-term Evolution (LTE)

LTE in Pakistan

- In Pakistan, since 2014, three telcos are providing 4G services to their subscribers.
- A detailed report released by Open Signal on 4G LTE speeds and coverage around the world, revealed that Pakistan has an average LTE speed of just 4 Mbps; which is slightly above the average for speeds of 3G (3.5 Mbps).
- South Korea and Singapore have set themselves apart by providing the best coverage (97% & 83%) and the best speed, respectively. Singapore provides its citizens the fastest average LTE speed of 37 Mbps
- While, in the World average speed is 13mbps.

Long-term Evolution (LTE)

- Changes at PHY Layer
  - The LTE physical layer is based on Orthogonal Frequency Division Multiplexing scheme OFDM to meet the targets of high data rate and improved spectral efficiency.
  - The spectral resources are allocated/used as a combination of both time (aka slot) and frequency units (aka subcarrier).
  - MIMO options with 2 or 4 Antennas is supported.
  - The modulation schemes supported in the downlink and uplink are QPSK, 16QAM and 64QAM.

Long-term Evolution (LTE)

- Changes at RLC & MAC Layer
  - At Radio Link Control (RLC) Sub Layer, the new functions that are added:
    - Acknowledged, Unacknowledged and Transparent Mode Operation
    - Concatenation, Segmentation and Reassembly of RLC SDUs (AM and UM)
    - Transfer of Upper Layer PDUs to MAC
    - Duplicate detection (UM and AM)
    - RLC re-establishment

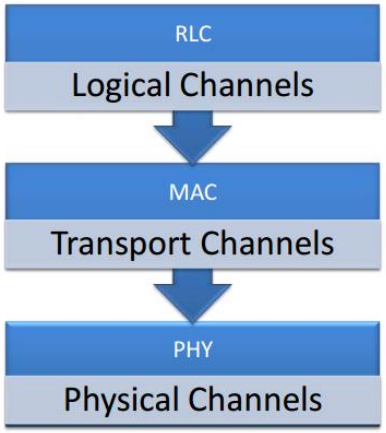
Acknowledged Mode
- SAR & RLC headers
- Reliable in sequence delivery
- Suitable for carrying TCP traffic

Unacknowledged Mode
- SAR & RLC headers
- No delivery guarantees
- Suitable for streaming traffic

Transparent Mode
- No SAR & RLC headers
- No delivery guarantees
- Suitable for carrying voice

Long-term Evolution (LTE)

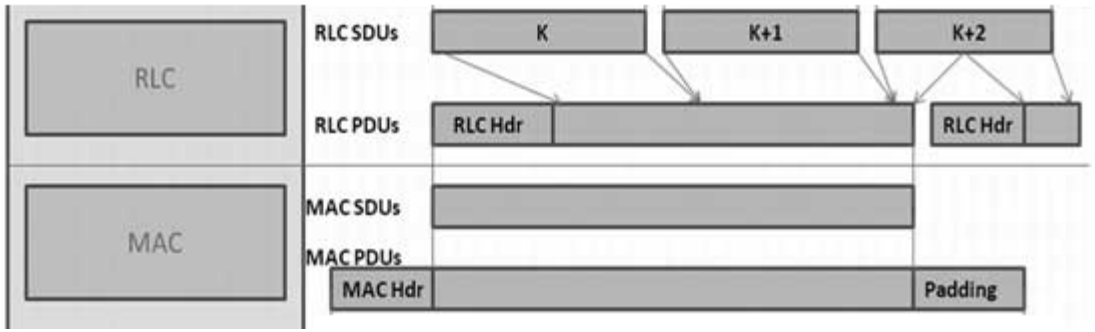
- Changes at RLC & MAC Layer
  - MAC functions are:
    - Mapping between Transparent and Logical Channels
    - Error Correction Through Hybrid ARQ
    - Priority Handling with Dynamic Scheduling
    - Logical Channel Prioritization



1. RLC layer passes data (PDUs) to the MAC layer as logical channels.
2. The MAC layer formats and sends the logical channel data as transport channel.
3. The physical layer encodes the transport channel data to physical channels.

Long-term Evolution (LTE)

- Changes at RLC & MAC Layer
  - MAC functions are:
    - Mapping between Transparent and Logical Channels
    - Error Correction Through Hybrid ARQ
    - Priority Handling with Dynamic Scheduling
    - Logical Channel Prioritization

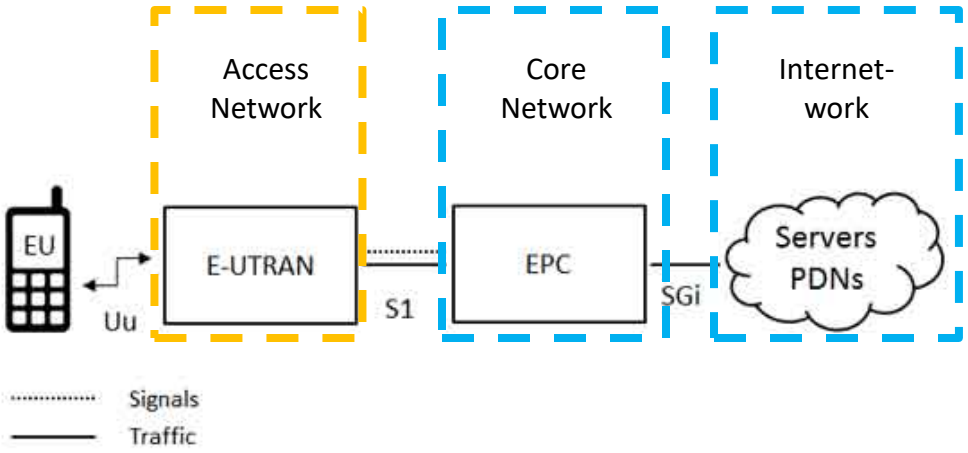


Long-term Evolution (LTE)

- Changes at RLC & MAC Layer
  - The Hybrid-ARQ is suggested at the MAC layer in addition to the ARQ at the RLC layer.
    - Automatic Repeat Query, is used for data error-control that uses acknowledgements and timeouts (specified periods of time allowed to elapse before an acknowledgment is to be received) to achieve reliable data transmission over an unreliable service. Also CRC bits are added to detect error in data.
    - Hybrid ARQ, use the original data that is encoded with a forward error correction (FEC) code, and the parity bits are either immediately sent along with the message or only transmitted upon request when a receiver detects an erroneous message. hybrid ARQ performs better than ARQ in poor signal conditions

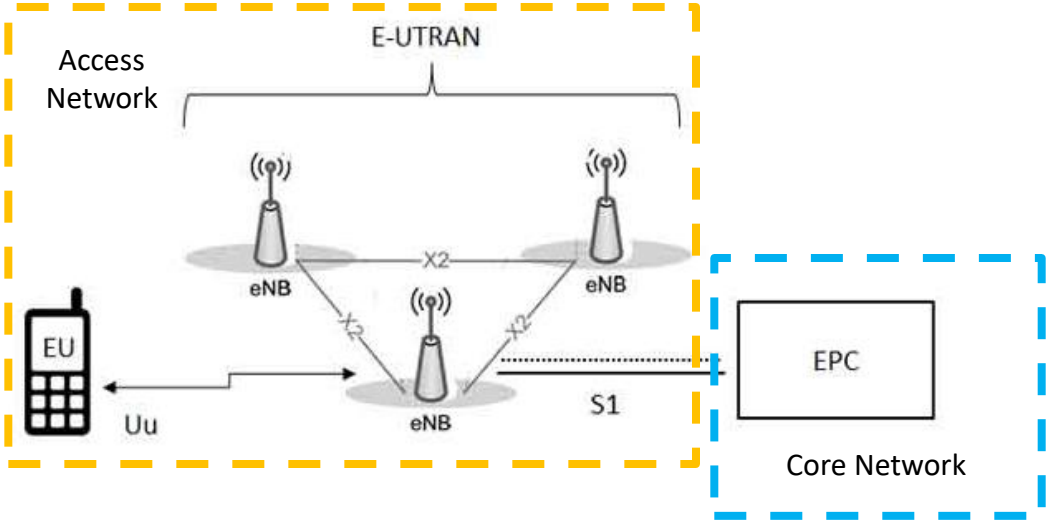
Long-term Evolution (LTE)

- Simple Network Architecture



Long-term Evolution (LTE)

- E-UTRAN - The Access Network Architecture



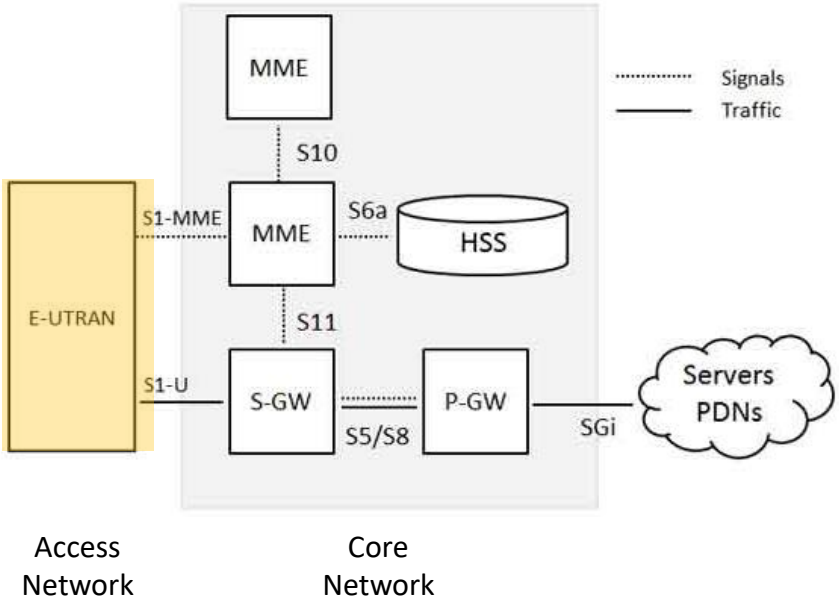
e-NodeB sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.

The eNB controls the low-level operation of all its mobiles, by sending them signaling messages such as handover commands.

eNBs communicate each other at X2 interface that is based on GTP-U over UDP or IP.

Long-term Evolution (LTE)

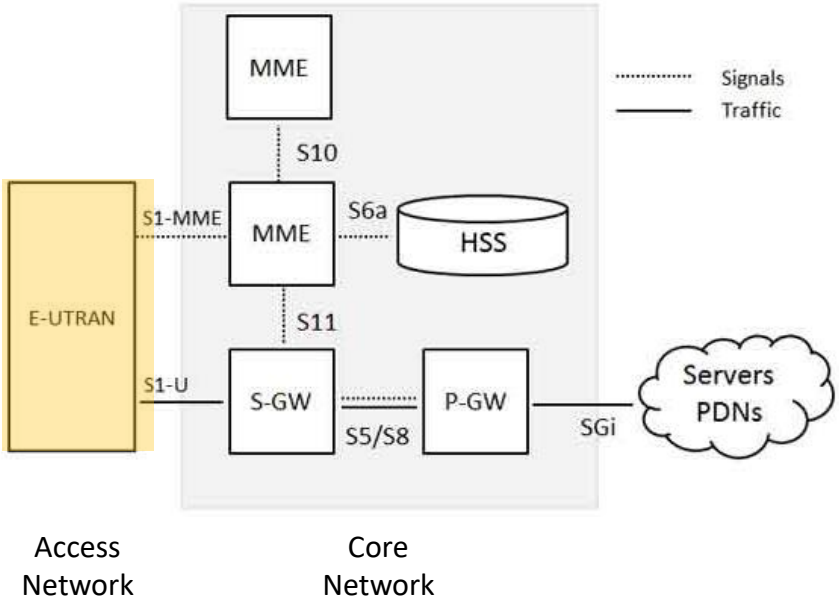
- Evolved Packet Core (EPC) - The core network



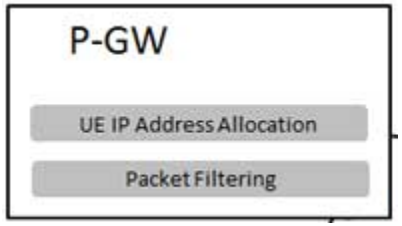
Serving Gateway (S-GW) acts as a router, and forwards data between the base station and the PDN gateway.

Long-term Evolution (LTE)

- Evolved Packet Core (EPC) - The core network

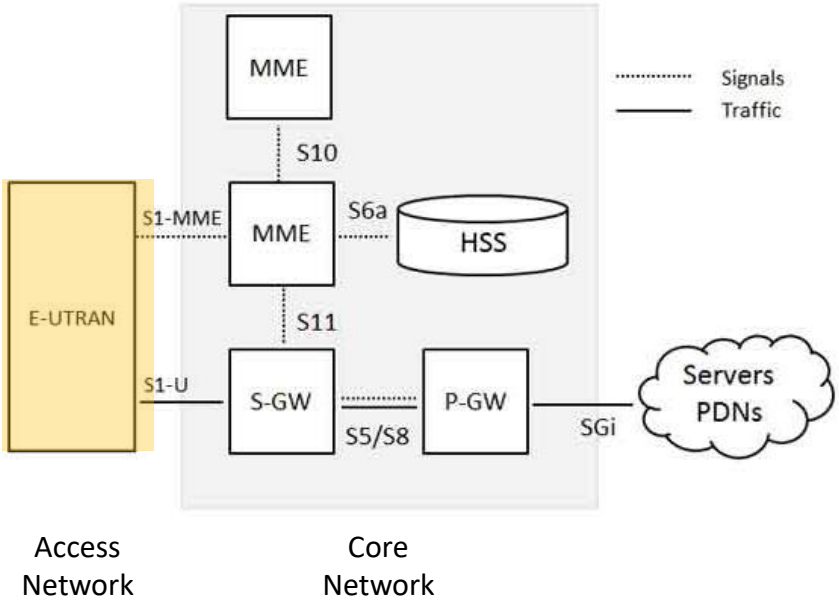


Packet Data Network (PDN) Gateway (P-GW) communicates with the outside world ie. packet data networks PDN. Each packet data network is identified by an access point name (APN). The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN) with UMTS and GSM.

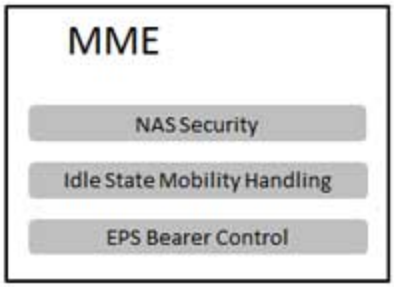


Long-term Evolution (LTE)

- Evolved Packet Core (EPC) - The core network



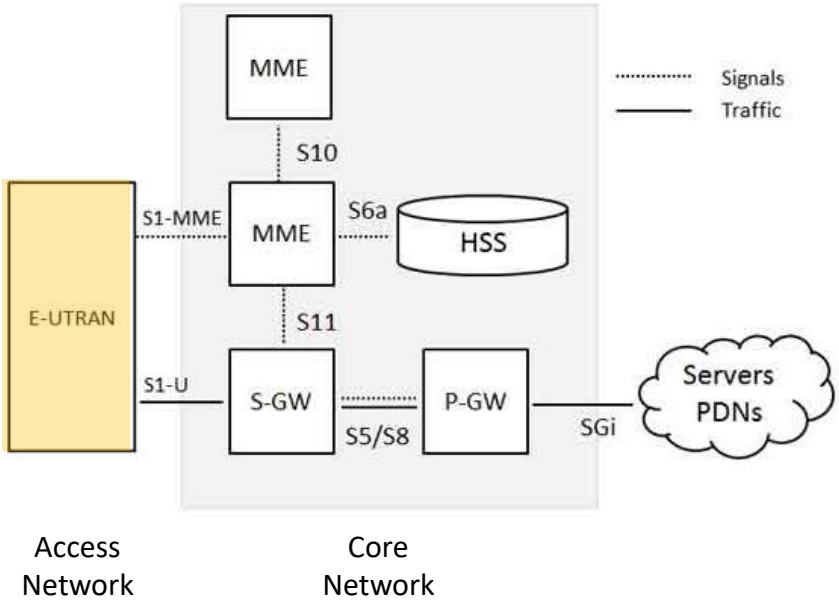
Mobility Management Entity (MME) controls the high-level operation of the mobile by means of signaling messages and Home Subscriber Server (HSS). MME is similar to VLR in GSM



MME connected to E-UTRAN through Stream Control Transmission Protocol (SCTP) over IP a *transport layer protocol*

Long-term Evolution (LTE)

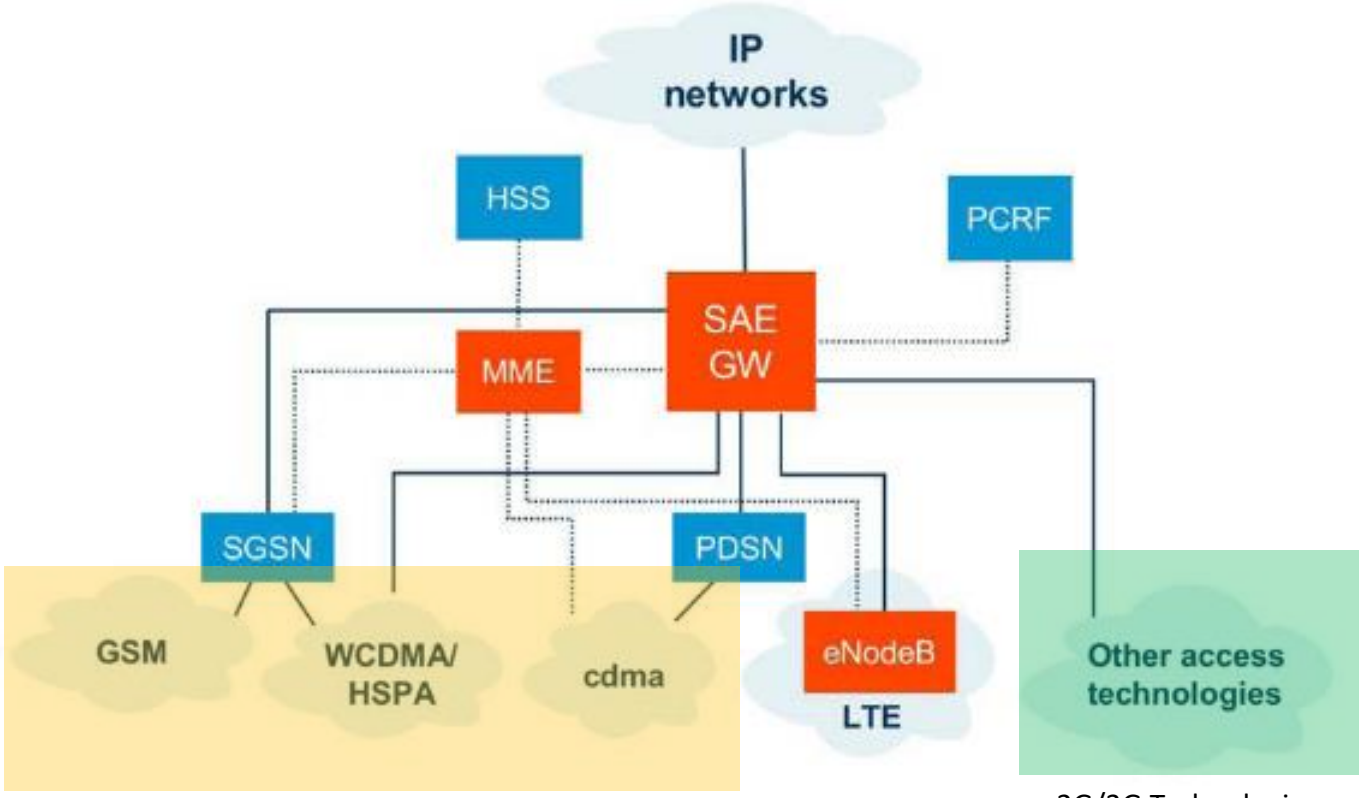
- Evolved Packet Core (EPC) - The core network



Home Subscriber Server (HSS)
Similar to UMTS and GSM, it is a central database that contains information about all the network operator's subscribers. HSS is similar to HLR in GSM

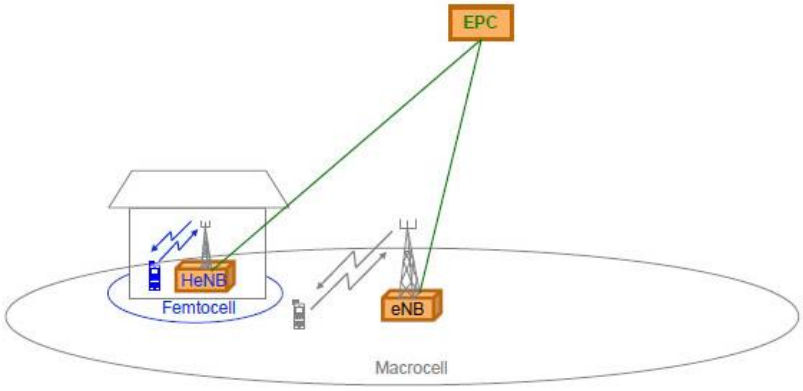
Long-term Evolution (LTE)

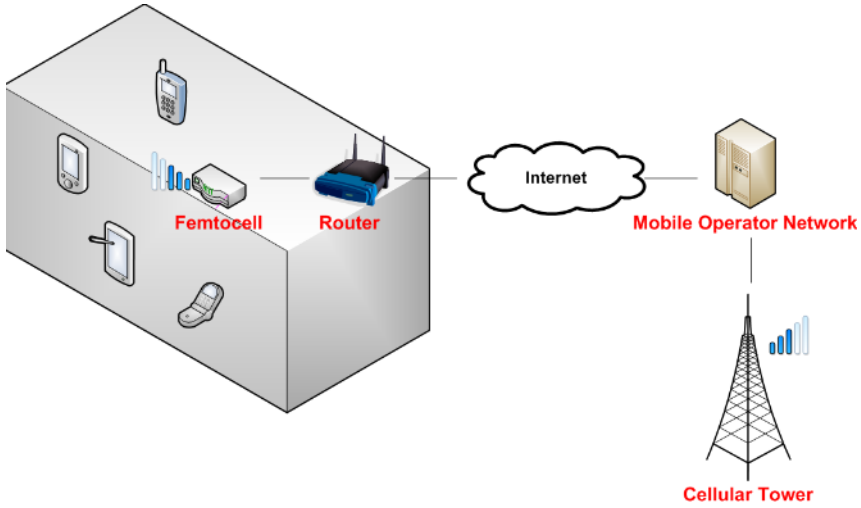
LTE Compatibility to Existing Networks



Long-term Evolution (LTE)

- Femtocell in LTE network

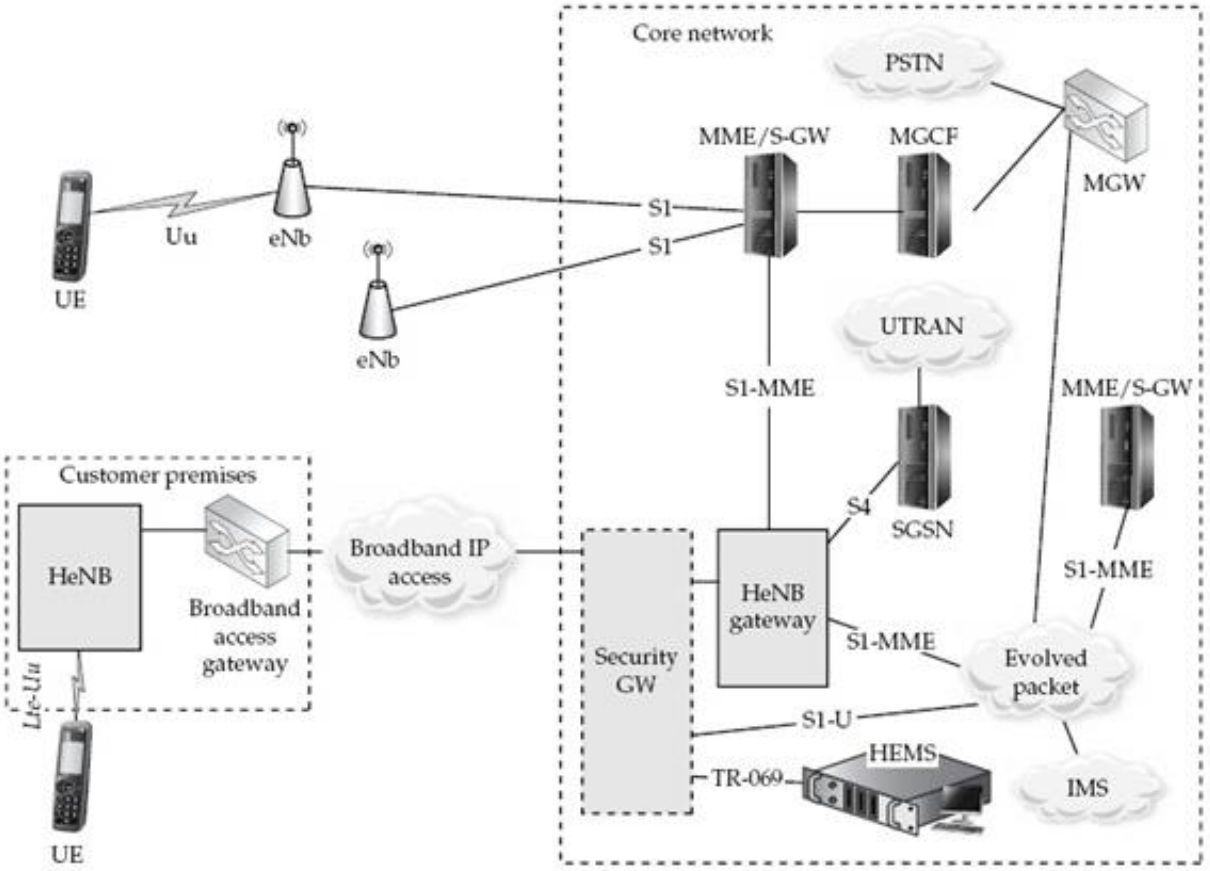




Home e-NodeB is a base station that has been purchased by a user to provide femto-cell coverage within the enterprise or home (in the order of 10 meters). A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belongs to the closed subscriber group.

Long-term Evolution (LTE)

- Femtocell in LTE network

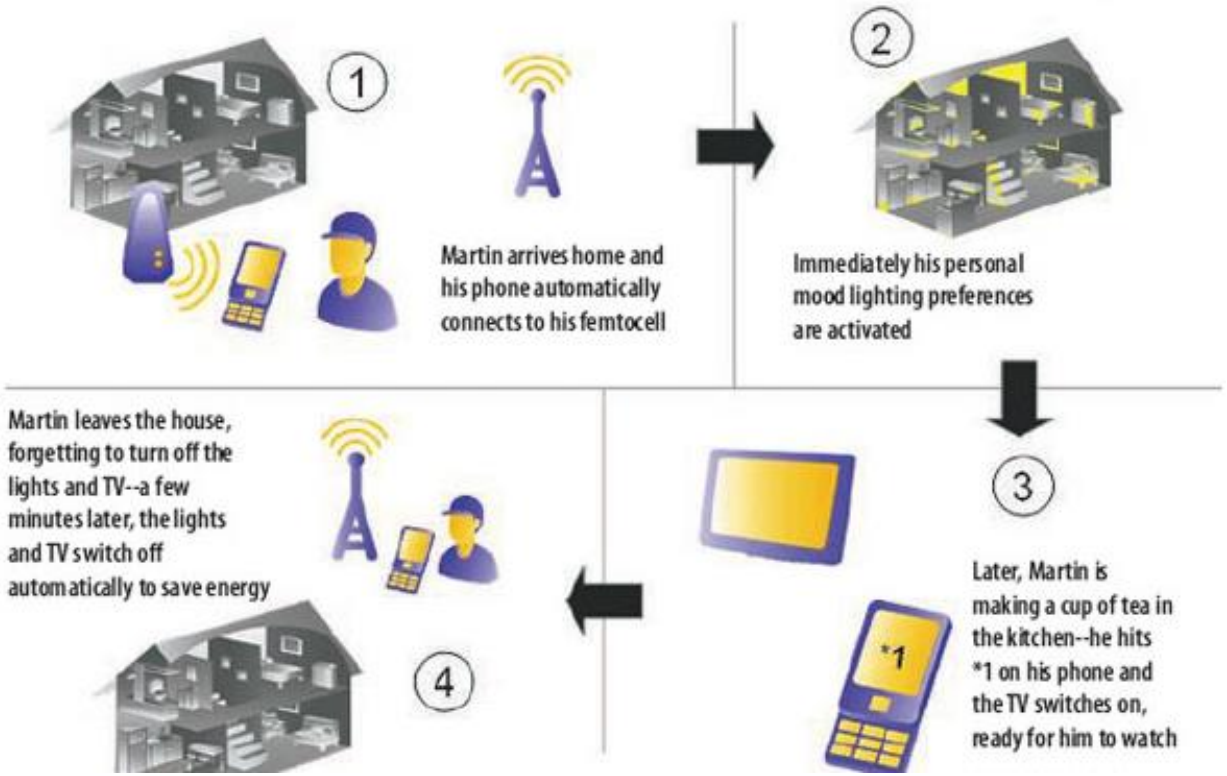


Long-term Evolution (LTE)

- Femtocell Connectivity

Long-term Evolution (LTE)

- Femtocell Application – *enables IoT*



Advanced Communication Networks

Muhammad Taha Jilani

Lecture - 9

Last Lecture

- Recap
  - WWAN
    - High Speed Packet Access (HSUPA/HSDPA)
    - Long-term Evolution (LTE)
  - Today : WPAN

WIRELESS PERSONAL AREA NETWORKS (WPAN)

Wireless Personal Area Networks (WPAN)

- Wireless personal area networks (WPANs) are used to convey information over short distances among a private, intimate group of participant devices.
- Unlike a wireless local area network (WLAN), a connection made through a WPAN involves little or no infrastructure or direct connectivity to the outside network.
  - This allows small, power-efficient, inexpensive solutions to be implemented for a wide range of devices.
- Original goal was to achieve a level of interoperability that could allow the transfer of data between a WPAN device and an IEEE 802.11 WLAN.

Wireless Personal Area Networks (WPAN)

- When considering communications options, parameters to be taken into account are:
  - Range
  - Battery consumption
  - Multi-hop capabilities
  - Security
  - Cost (device & service)
  - Availability
  - Regulation

Wireless Personal Area Networks (WPAN)

- WPAN is specified in IEEE 802.15 standard in 2005.
- It defines PHY and MAC layer specifications for wireless connectivity with fixed, portable, and moving devices within a personal operating space (POS).
  - POS is the space about a person or object that typically extends up to 10 m in all directions, whether stationary or in motion.
- Different technologies that are defined within WPAN umbrella are the:
  - 802.15.1 is Bluetooth,
  - 802.15.3 is a high data rate category for ultrawideband (UWB)
  - IEEE 802.15.4
    - ZigBee (often called Low-rate WPAN (LR WPAN)
    - 6LoWPAN
  - 802.15.6 is for body area networks (BAN)
  - 802.15.7 is for Visible Light Communication

Bluetooth - IEEE 802.15.1

- Origins in the BodyLAN project that is initiated in the 1990s for military networking, to connect “personal” devices around a solider
- Goal was to develop smart technology that self configures, recognizes other units within range and provides on the fly communications
- Provide low power communication over shorter distances
- Commercial launch by Ericsson in 1994

Bluetooth - IEEE 802.15.1

- Today, range of devices available with Bluetooth functionality, including:
  - keyboards,
  - pointing devices,
  - audio head sets,
  - printers may connect to personal digital assistants (PDAs),
  - cell phones

Bluetooth - IEEE 802.15.1

Standardization

- Bluetooth Special Interest Group (SIG) defines all standards
- Unlicensed ISM band at 2.400 to 2.485 GHz frequency range
- Physical Parameters
  - Modulation scheme: Gaussian FSK
  - Medium Access method : FHSS-TDMA
- Typical range is under 10m, it can be further extended upto 100m with amplifiers

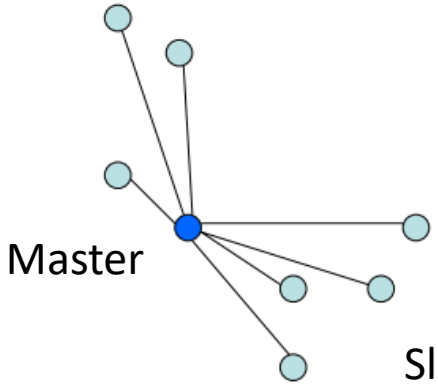
Bluetooth - IEEE 802.15.1

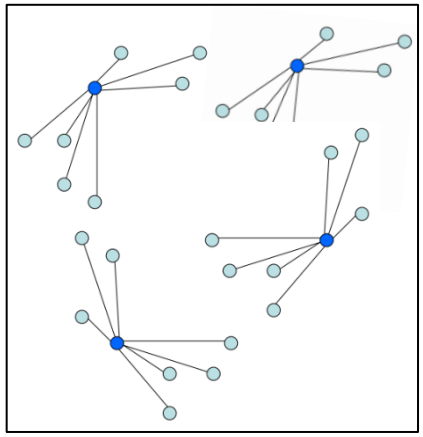
Standardization

- Versions proposed by Bluetooth SIG
  - Bluetooth v. 1.2 in 2002 : 1 Mbit/s – practically 721 kbit/s (Classic)
  - Bluetooth v. 2.0 in 2004 : 3 Mbit/s – practically 2.1 Mbit/s (Enhanced Data Rate EDR)
  - Bluetooth v. 3.0 in 2009 : 24 Mbit/s – (High speed and Alternative MAC/PHY) - addition of 802.11 as a high speed transport co-located link
  - Bluetooth v. 4.0 in 2010 : 24 Mbit/s – (Bluetooth Low energy BTLE or Bluetooth Smart: Power consumption = 0.01 to 0.5 W)
  - Bluetooth v. 5.0 in 2016 : Still to be announced (focused on Internet of Things , IoT) capable for low-energy and high speed communication

Bluetooth – Network Architecture

- Bluetooth enabled electronic devices connect and communicate wirelessly through short-range, **ad-hoc** networks known as *Piconets*
- Piconets are established dynamically and automatically as Bluetooth enabled devices enter and leave radio proximity.



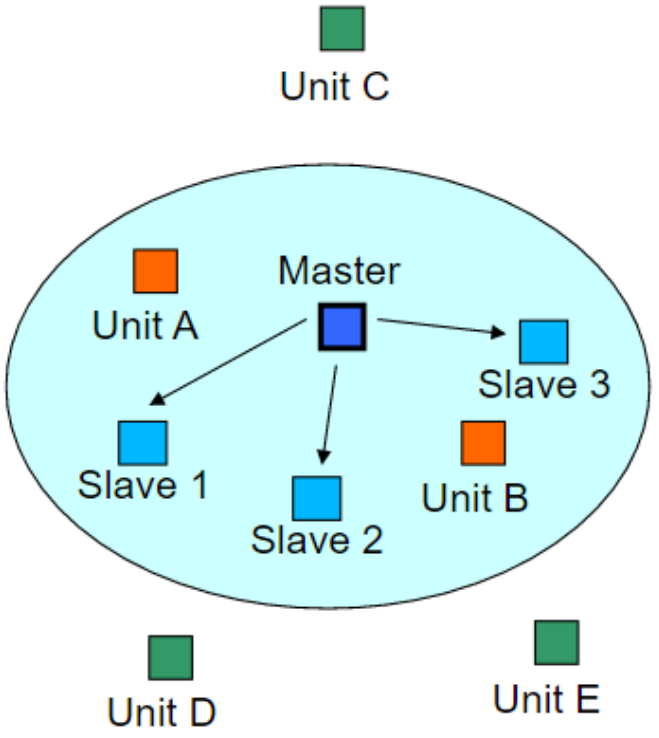


Up to 8 devices in one Piconet (1 master and 7 slave devices).
Beyond that?

Collection of Piconets froms
Scatternets

Bluetooth - Communication

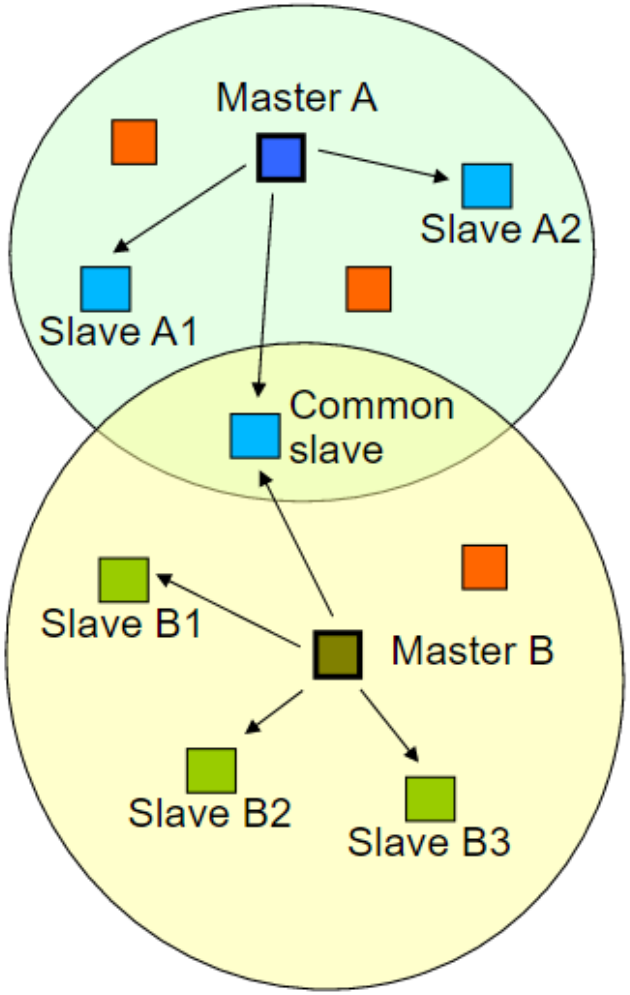
- Collection of devices connected in an *ad hoc* fashion
- One unit will act as **master**
  - Sets clock and frequency hopping pattern
  - Can connect to 7 **active** or 255 inactive (**parked**) **slaves**
  - Determines bit rate allocated to each slave
- Unique frequency hopping pattern/ID
- All devices participating in the **piconet** are synchronized to a common clock and hopping sequence.
- Slaves can communicate only with the master and not with other slaves.



Bluetooth - Communication

- A device may participate concurrently in two or more piconets on time-division multiplexing (TDM) basis.
- A device can be both master and slave.
- A device can never be a master of more than one piconet.

- Two or more piconets that include one or more devices participating in more than one piconet form a **scatternet** .



Communication between two piconet that forms scatternet, does not support relaying of data through common slave in the basic bluetooth protocol

Bluetooth - Connection States

The Units connected in bluetooth network are divided into diffrent states. These are

- **Active Connection**
  - Normal piconet operation
  - Max. 7 active slaves
- **Sniff**
  - the duty cycle of the slave's listen activity is reduced.
  - periodic sleep period
- **Hold**
  - the unit does not need to send data for relatively long time
  - one time sleep period,
- **Park**
  - the unit will have very little activity consuming very low power
  - slaves, that are associated to a piconet, but not active (rarely used)

Bluetooth - Communication

- To communicate between devices, different types of logical links are available to support different application data transport requirements. Each logical link is associated with a logical transport, which has a number of characteristics.
- These characteristics include flow control, acknowledgement, repeat mechanisms, sequence numbering, and scheduling behavior.
- Between master and slave(s), different types of logical transports may be established. These logical links are established and communicate over a shared physical channel (using TDM).
- Two types of Link delivery services can be established between the Piconet master and one or more slaves:
  - ***Synchronous connection-oriented (SCO)*** link allocates a fixed bandwidth for a point-to-point connection involving the Piconet master and a slave. Up to three simultaneous SCO links are supported in a Piconet.
  - ***Asynchronous connectionless or connection-oriented (ACL***) link is a point-to-multipoint link between the master and all the slaves in the Piconet. Only a single ACL link can exist in the Piconet.

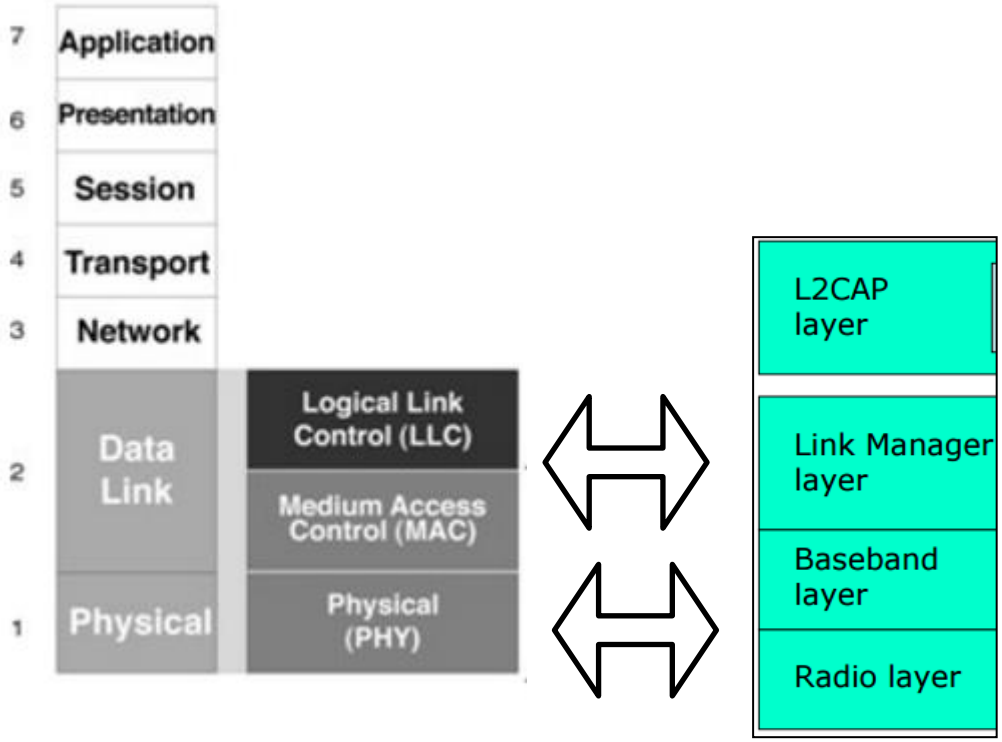
Bluetooth - IEEE 802.15.1

- SCO links are used primarily for carrying real-time data (speech, audio) where large delays are not allowed (so that retransmission cannot be used) and occasional data loss is acceptable.
- The guaranteed data rate is achieved through reservation of slots.
- The master maintains the SCO link by using reserved slots at regular intervals.
- The basic unit of reservation is two consecuive slots - one in each transmission direction. An ACL link must be established (for signalling) before an SCO link can be used.

Bluetooth - Network Architecture

- The ACL link offers packet-switched data transmission. No bandwidth reservation is possible and delivery may be guaranteed through error detection and retransmission.
- A slave is permitted to send an ACL packet in a slave-to-master slot only if it has been adressed in the preceeding master-to-slave slot.
- For ACL links, 1-, 3-, and 5-slot packets have been defined.
- Data can be sent either unprotected (although ARQ can be used at a higher layer) or protected with a 2/3 rate forward error correction (FEC) code.

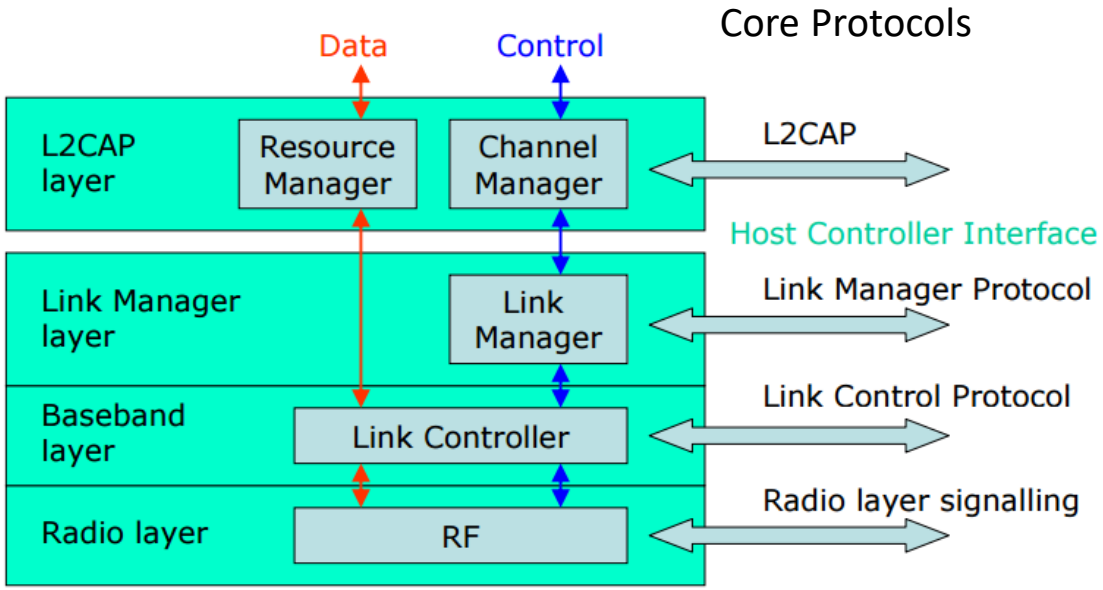
Bluetooth – OSI Perspective



IEEE 802.15.1 standard specifies the core system architecture and operation (i.e. Only physical layer and medium access control (MAC) layer)

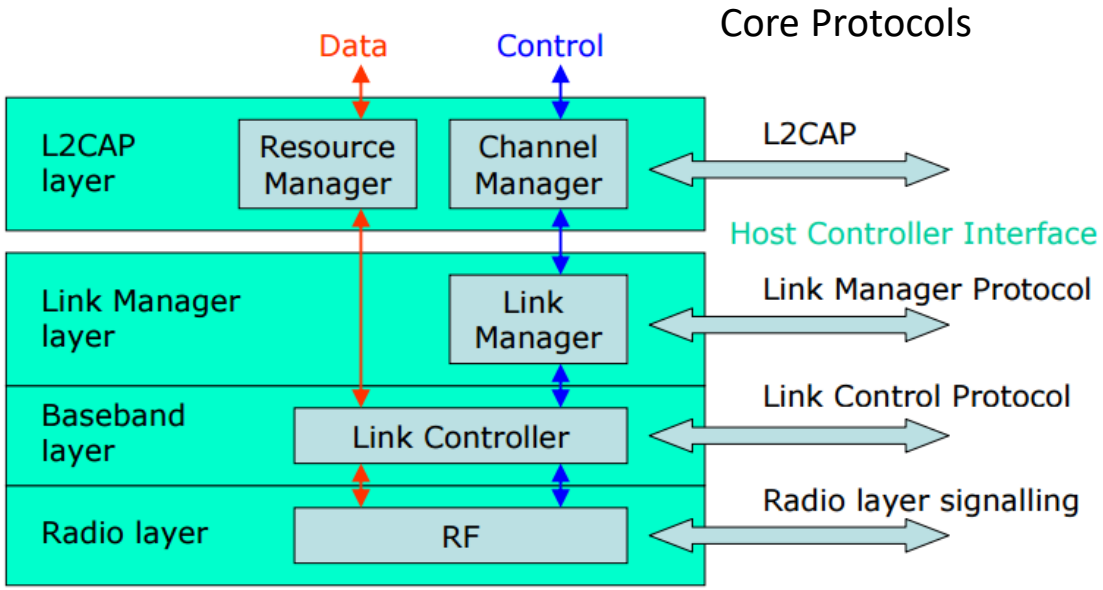
Higher protocol layers and applications are defined by Bluetooth Special Interest Group (SIG)

Bluetooth – Protocols



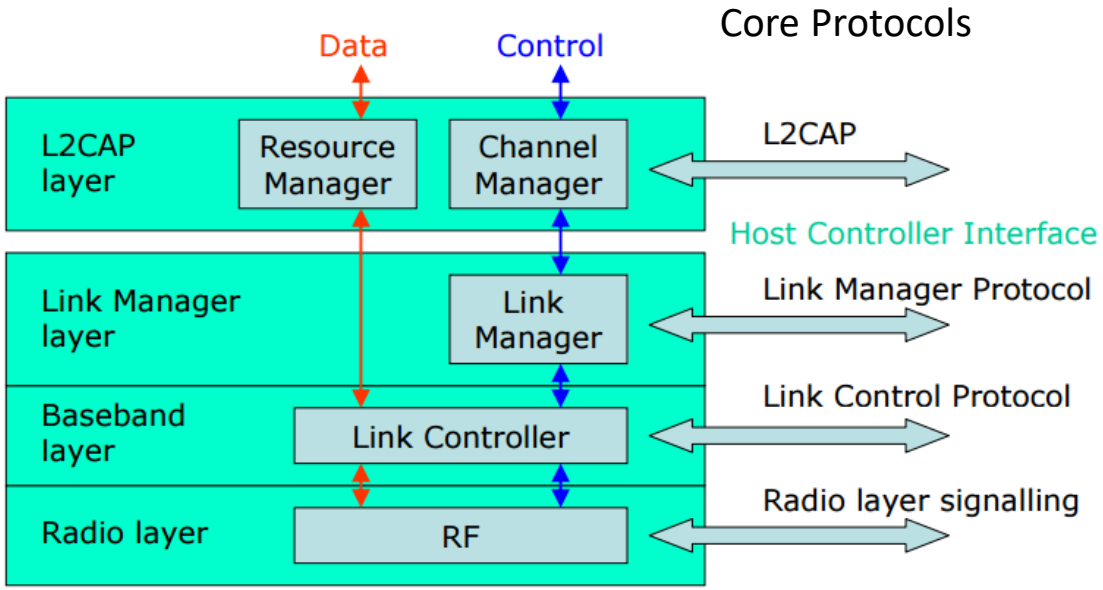
Radio Layer Signaling :
This protocol specification defines air interface, frequency bands, frequency hopping specifications, modulation technique used and transmit power classes.

Bluetooth – Protocols



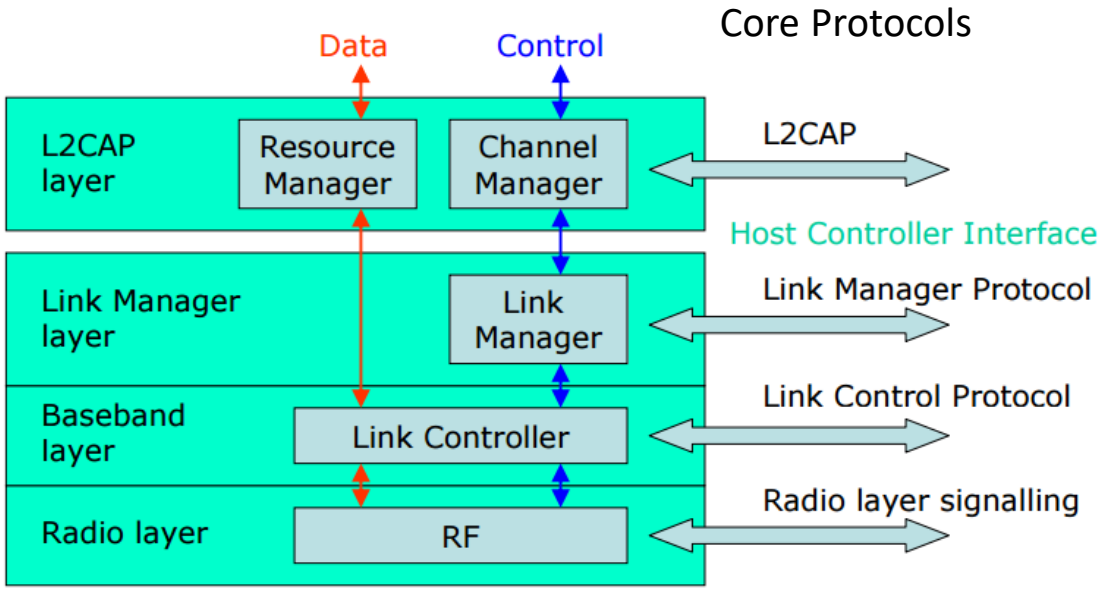
Baseband Layer Link Control Protocol:
Addressing scheme, packet frame format , timing and power control algorithms required for establishing connection between bluetooth devices within Piconet defined in this part of protocol specification.

Bluetooth – Protocols



Link Manager protocol:
It is responsible to establish link between bluetooth devices and to maintain the link between them. This protocol also includes authentication and encyption specifications. Negotiation of packet sizes between devices can be taken care by this.

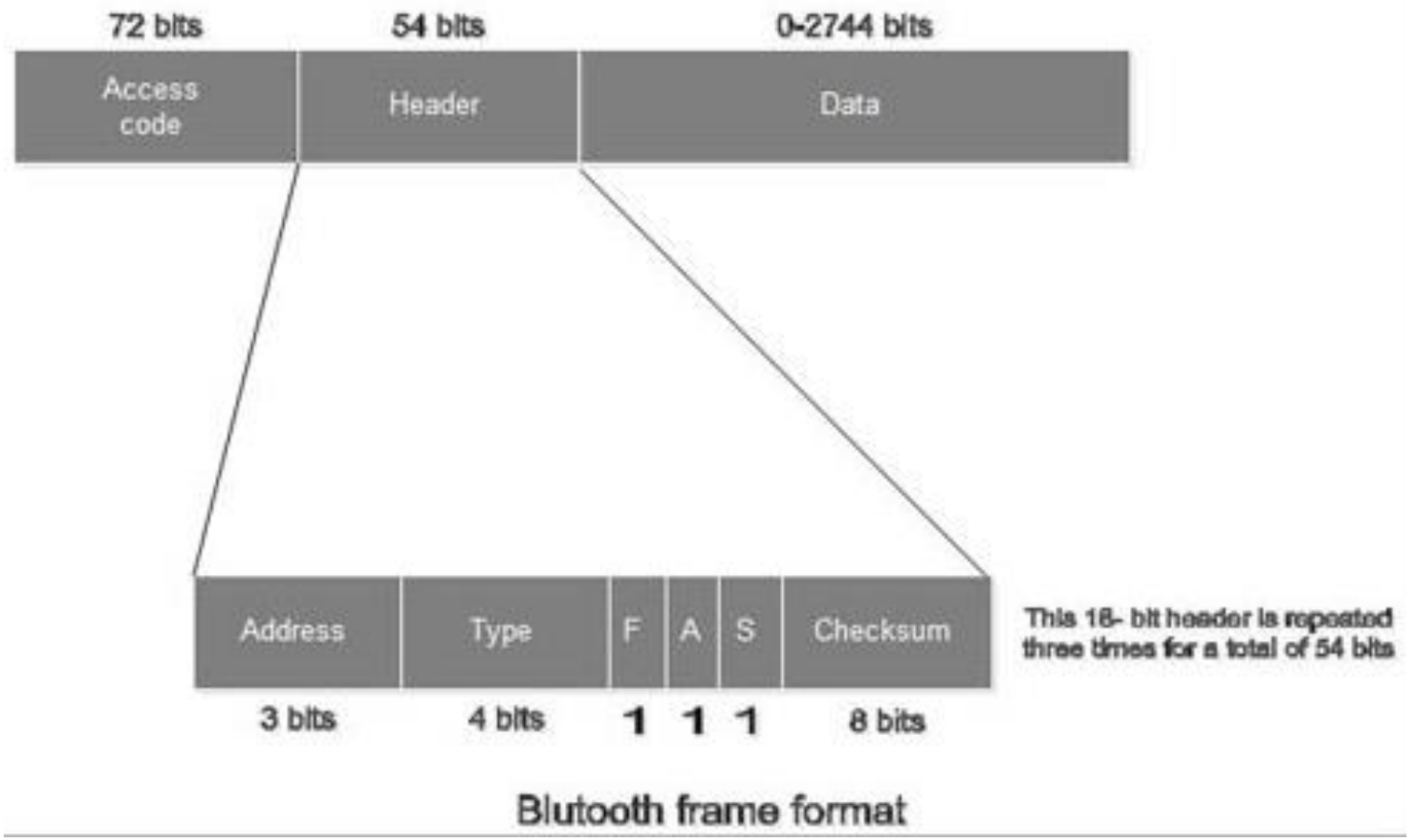
Bluetooth – Protocols



Logical link control and adaptation protocol (L2CAP) :

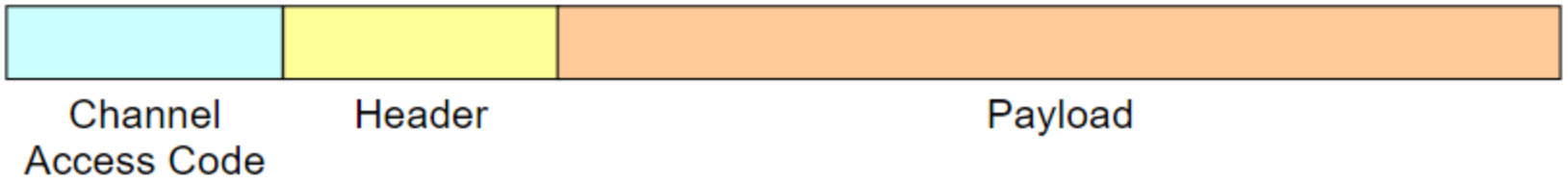
This L2CAP protocol adapts upper layer frame to baseband layer frame format and vice versa. L2CAP take care of both connection oriented and connectionless services.

Bluetooth – Frame



Blutooth frame format

Bluetooth – Frame



- All packets include the channel access code (CAC). This is used to identify communications on a particular physical channel and to exclude or ignore packets on a different physical channel that happens to be using the same RF carrier in physical proximity.

- Packet Types
  - High-quality Voice packets: HV1, HV2, HV3
  - Mixed data/voice packet: DV
  - Data–medium rate packets: DM1, DM3, DM5
  - Data–high rate packets: DH1, DH3, DH5, AUX1
  - Baseband control packets: NULL, POLL, ID, FHS

Bluetooth – Frame

Packet type	FEC	Symmetric max. rate (kbit/s)	Asymmetric max. rate (kbit/s)	
DM1	2/3	108.8	108.8	108.8
DH1	No	172.8	172.8	172.8
DM3	2/3	258.1	387.2	54.4
DH3	No	390.4	585.6	86.4
DM5	2/3	286.7	477.8	36.3
DH5	No	433.9	723.2	57.6
AUX1	No	185.6	185.6	185.6

Bluetooth – Error Protection

To protect Data from error, three different mechanism are use

- Forward Error Correction (FEC)
  - 1/3 FEC: Repeat each bit 3 times
  - 2/3 FEC: (15,10) shortened Hamming code
- Automatic Repeat Request (ARQ)
- Cyclic Redundancy Check (CRC)
  - Header Error Check (HEC)
  - Payload CRC

Bluetooth – For IoT

- Bluetooth was originally designed for continuous, streaming data applications.
  - Continuous exchange a lot of data at a close range.
- That's why Bluetooth is such a good fit for consumer products.
  - People like to receive data and talk at the same time, and exchange videos from one device from another.
- In other hand, Bluetooth-Low energy (BLE) remains in sleep mode constantly except for when a connection is initiated.
  - The actual connection times are only a few mS, unlike Bluetooth which would take ~100mS.

Bluetooth – IoT Application

- Smart Wireless Lighting
  - The number of smart LED bulbs using Bluetooth is rapidly growing and products based on Bluetooth Smart Mesh is an emerging trend.
  - By the end of 2019, Bluetooth will become the second largest smart lighting technology up from 7% of residential unit sales in 2014.

IEEE 802.15.4

- Due to continuous development in low-scale data communication, there is a need for **more simpler** and **less expensive** communication for **small & low-power devices**.
  - Comparing with WiFi & Bluetooth technologies
- IEEE established a working group to specify the standards for physical layer and media access control for **low-rate wireless personal area networks (LR-WPANs**).
  - Eventually, release LR-WPANs in IEEE 802.15.4 standard

ZigBee - IEEE 802.15.4

- On the basis of IEEE 802.15.4 standard, in 2003 the ZigBee Alliance specified the standards for ZigBee.
- The motive was design a protocol as “assemble and forget”,
  - meaning once you set it up, it can last for months.
- Operating standards
  - Frequency allocation (ISM band) and Data rates

	868 MHz	902-928 MHz	2.450 GHz
Data Rate	20 kbps	40 kbps	250kbps
# channels	1	10	16

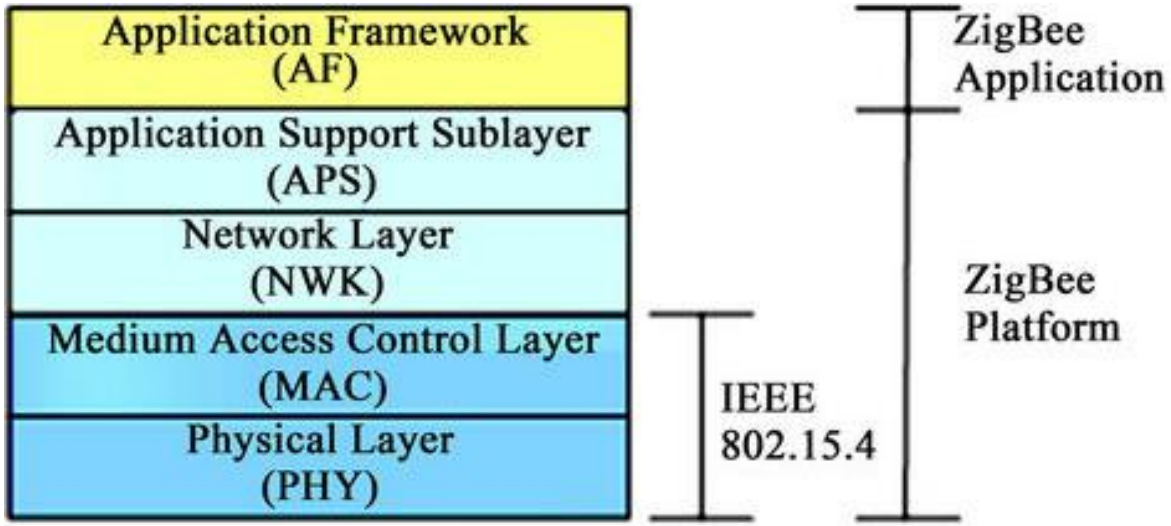
  - Modulation / signal spreading method
    - Offset-QPSK / DSSS

ZigBee - IEEE 802.15.4

- Its low power consumption limits transmission distances to 10–100 meters
  - depending on power output and environmental characteristics.
- Data can be transmit over long distances through a
  - mesh network of intermediate devices to reach more distant ones
- ZigBee is typically used in applications that requires
  - low data rate
  - long battery life
  - secure networking (128 bit AES encryption key)

ZigBee - IEEE 802.15.4

- In Layers Perspective



ZigBee - IEEE 802.15.4

MAC Layer Functions

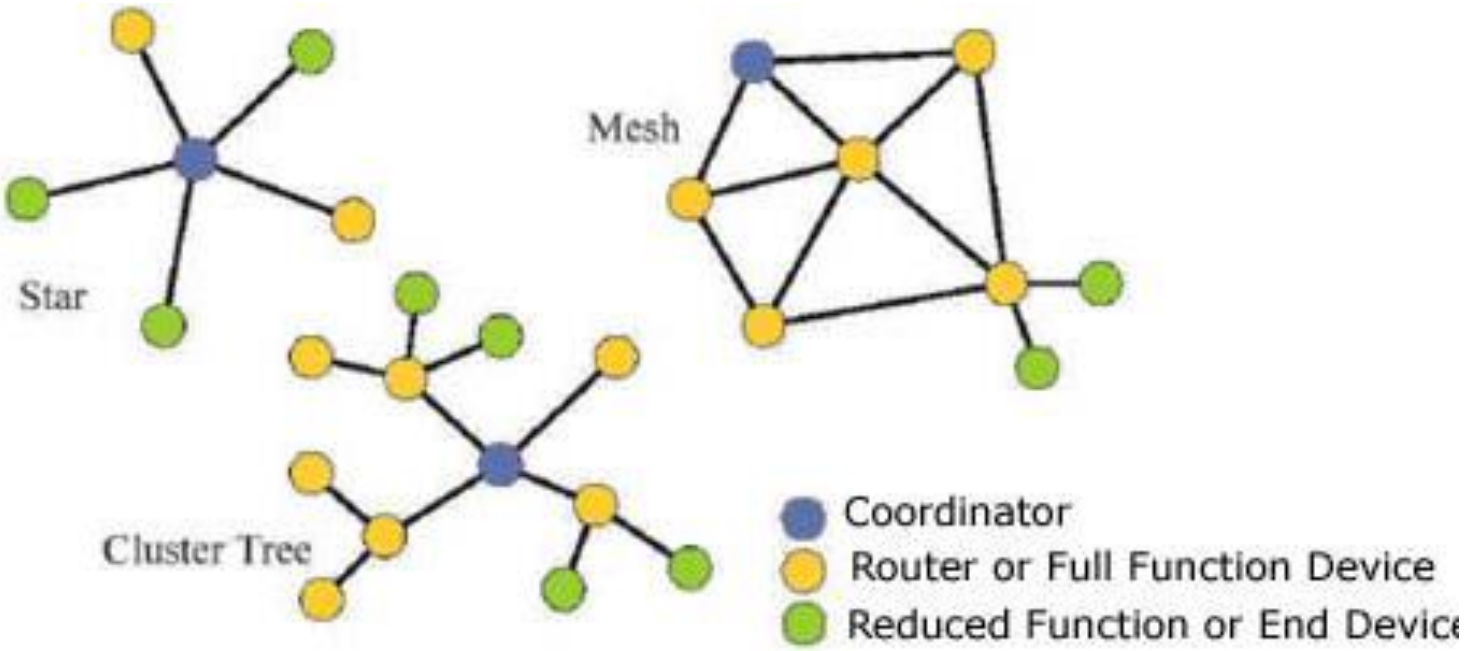
- The MAC frames are divided into following four major categories, which is used by zigbee devices to establish connection to the PAN by exchanging system information.
  1. Beacon
  2. Data
  3. Acknowledgement
  4. MAC command

ZigBee - IEEE 802.15.4

MAC Layer Functions

- The *data frame* provides frame numbered to ensure that all packets are tracked. A frame-check sequence ensures that packets are received without error. This frame structure improves reliability in difficult conditions.
- Another important structure for 802.15.4 is the *acknowledgment (ACK) frame*. It provides feedback from the receiver to the sender confirming that the packet was received without error.
- A *MAC command frame* provides the mechanism for remote control and configuration of client nodes. A centralized network manager uses MAC to configure individual clients' command frames no matter how large the network.
- Finally, the *beacon frame* wakes up client devices, which listen for their address and go back to sleep if they don't receive it. Beacons are important for mesh and cluster-tree networks to keep all the nodes synchronized without requiring those nodes to consume precious battery energy by listening for long periods of time.

ZigBee - Network Topologies



ZigBee - Network

ZigBee Network is comprised of

Coordinator (C):

- Always first coordinator need to be installed for establishing zigbee network service, it starts a new PAN (Personal Area Network), once started other zigbee components i.e. router(R) and End devices(E) can join the network(PAN).
- It is responsible for selecting the channel and PAN ID (a 16 bit number)
- It can assist in routing the data through the mesh network and allows join request from R and E.
- It is mains powered (AC) and it will not go to sleep mode.

ZigBee - Network

Router (R):

- First router needs to join the network then it can allow other R & E to join the PAN.
- It is also mains powered and can not go to sleep mode.

End Devices (E):

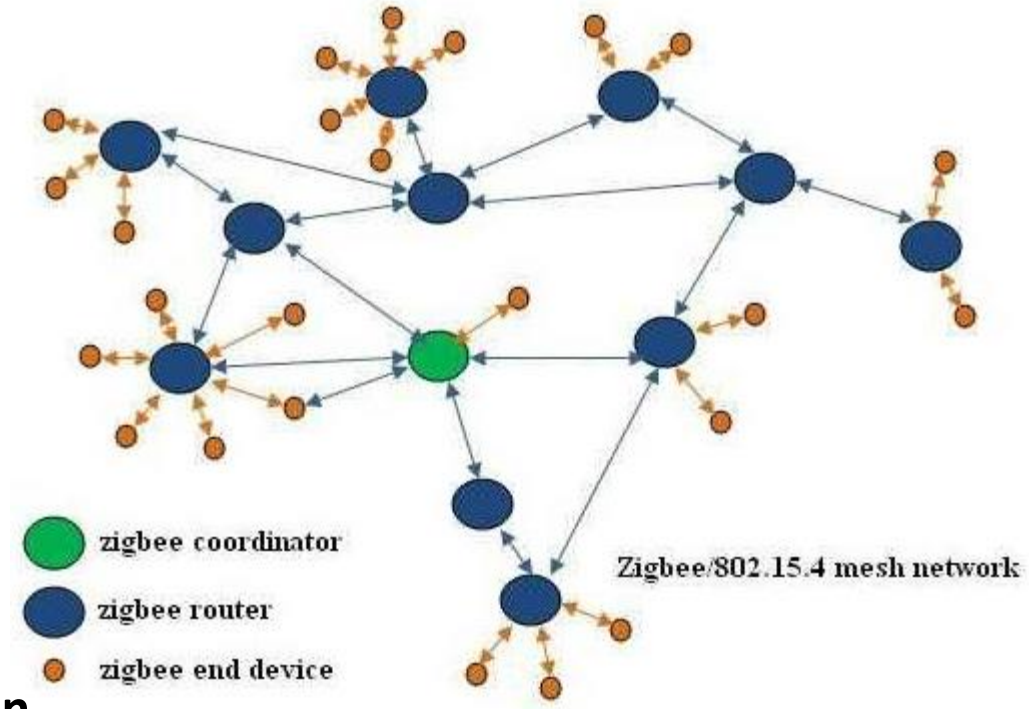
- It cannot allow other devices to join the PAN nor can it assist in routing the data through the network.
- It is battery powered and it may sleep hence battery consumption can be minimized to great extent.

ZigBee - Communication

Two channel-access mechanisms are implemented in 802.15.4.

- For a **non-beacon network**, a standard ALOHA CSMA-CA (carrier-sense medium-access with collision avoidance) communicates with positive acknowledgement for successfully received packets.
- In a **beacon-enabled network**, a superframe structure is used to control channel access. The superframe is set up by the network coordinator to transmit beacons at predetermined intervals (multiples of 15.38ms, up to 252s) and provides 16 equal-width time slots between beacons for contention-free channel access in each time slot. The structure guarantees dedicated bandwidth and low latency.

ZigBee - Communication

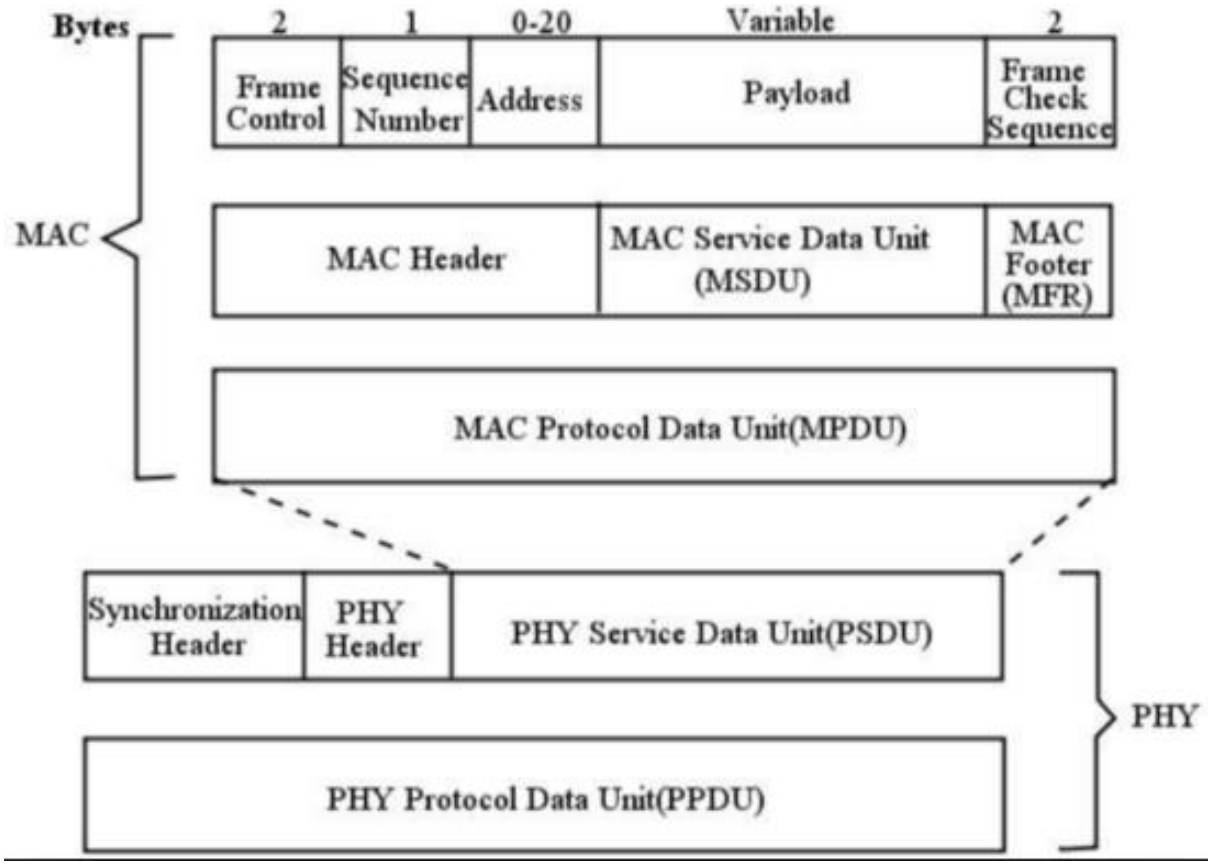


Communication

- There are two main steps in completing Zigbee Network
  - Forming the network by Coordinator and joining the network by Routers and End devices.
- PAN ID is used to communicate between zigbee devices, and when they join PAN they are assigned PAN ID by coordinator.
- Data is transmitted through Mesh routing by a Coordinator and Routers

ZigBee - Frame Format

Frame structure is based on 802.15.4



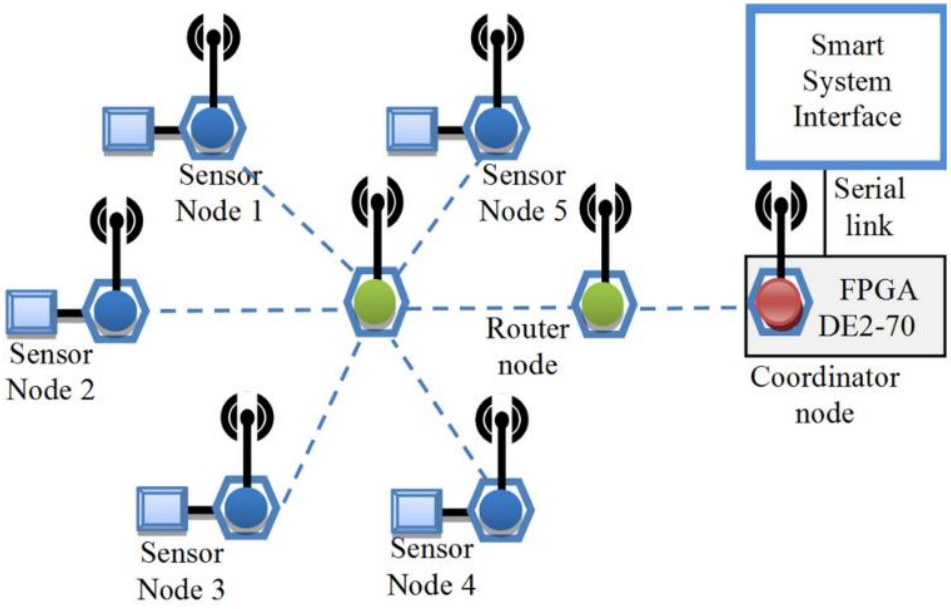
0-102 - Variable

Payload 0-127 Variable

ZigBee - Application

IoT Application

- An Intelligent Wireless Sensor Network Temperature Acquisition System with an FPGA



ZigBee based wireless system that monitors and visualizes periodically the environment temperature.

ZigBee - with IoT

IoT Application

ZigBee - Advantages

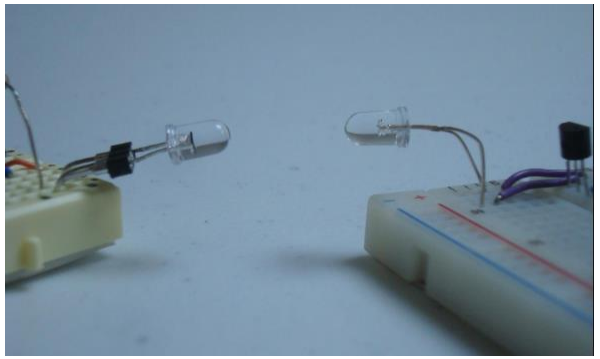
- ZigBee's battery life is a major plus over WiFi, the networks generally consume 25% of the power of WiFi networks.
- Comparing with Bluetooth, although it provide a low data rate, however, it can communicate over a longer distance
  - Considering, same parameters
    - BLE = 77m
    - ZigBee = 219 m

IEEE 802.15.7 Visible Light Communication

- The VLC is standardize to support the Free-space optical communication (FSO), that demands:
  - high-speed : +10 Gbit/s
  - long range : 3–5 km
- Several attempts made to achieve, like, 10 Gbit/s at distance of 2 km and 30 Gbit/s under "laboratory conditions"
- But due to several atmospheric factors such as rain, fog, dust and heat, eventually, able to communicate in
  - 10 Mbit/s
  - small ranges 400 to 500 meters

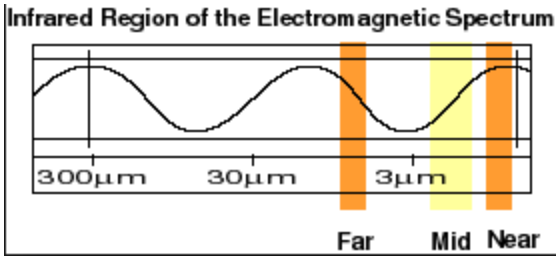
IEEE 802.15.7 : Visible Light Communication

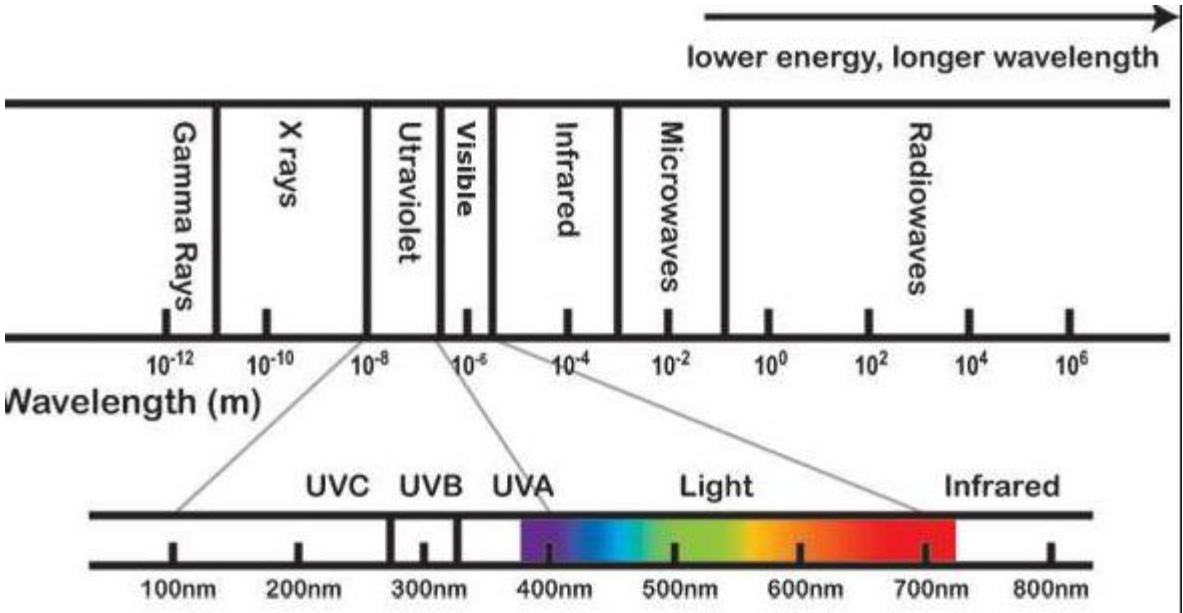
- In FSO, the one of the popular standard is Infrared (IR) communication.
- In 1993, Infrared Data Association (IrDA), specified complete protocol set for IR communication.
- IR has ability to provide a
  - faster,
  - less-prone to error,
  - high-bit rate
  - simple communication



IEEE 802.15.7 : Visible Light Communication

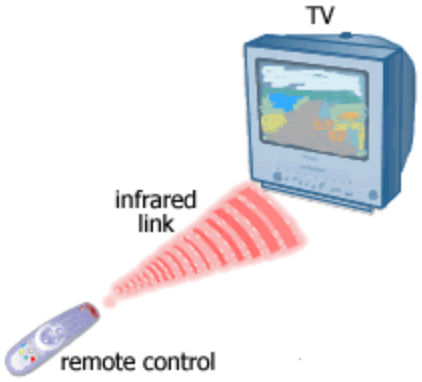
- Non-visible radiation, below Visible light wavelengths
  - Red color has longest wavelength
  - wavelength is around 870 nm and 930–950 nm
- Latin *infra* means “below” therefore, infra+Red is actually defines the portion of frequencies within EM spectrum.





IrDa

- Low rate technology, commonly refer by IrDA, it has
  - line-of-sight (LOS) communication
  - very low bit error rate (BER)
- Most common application in,
  - TV Remote
  - printers,
  - keyboards,
  - other serial data interfaces
  - medical instruments



IrDa – Protocols

- IrDA protocols are roughly divided into two main sets:
  - IrDA Control
  - IrDA Data
- These protocols are deal with interaction with other devices for the exchange of data. The protocols are not inter-operable.
  - IrDA Control protocols deal mainly with Human interface type peripherals such as keyboards, joysticks, mice etc.
  - IrDA Data uses a more complex protocol stack as it needs to allow for different types of application such as point-to-point communications, file transfer and LAN access.

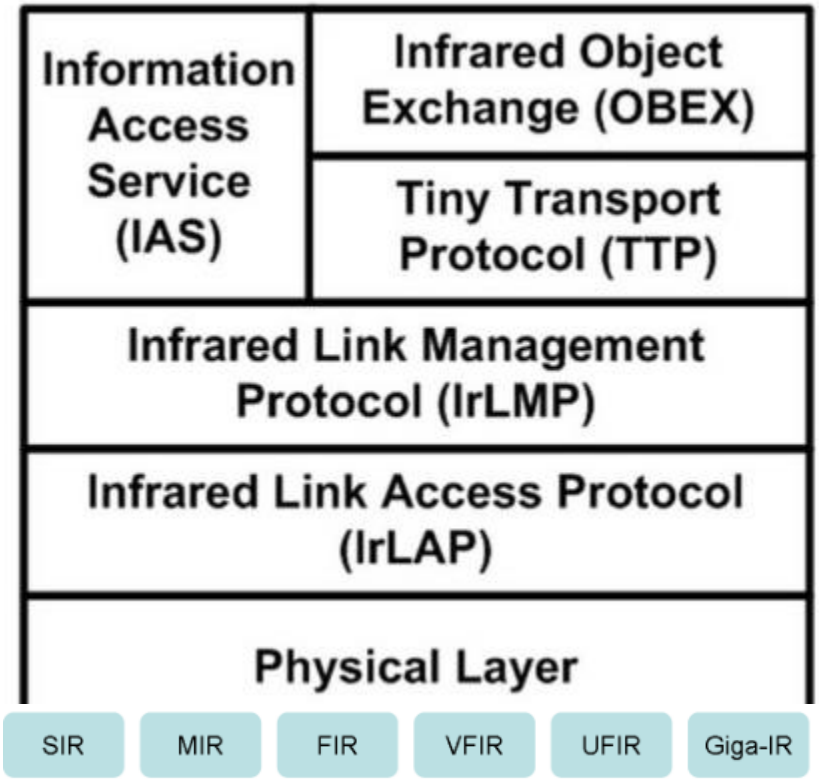
IrDa – Protocols

- **Main differences between IrDA Data and IrDA Control**

Parameters	IrDA Data	IrDA Control (IrDA-C)
Transfer Speed	Based on different Optical Modulations **SIR** - Asynchronous, 9600 -115200 bps **FIR** - Synchronous, up to 4Mb/s **VFIR**- Synchronous, up to 16Mb/s	75 kbps / number of devices.
Properties	Bi-directional communications at various speeds, including error correction and automatic discovery of devices in range.	Enables a host device to communicate with multiple peripheral devices (1:n) and up to 8 peripherals simultaneously. Ensures fast response time and low latency.
Associated Protocol Layers	**PHY**, **IrLAP**, **IrLMP**, **TinyTP**, **IrCOMM**, **IrOBEX**,**IrTran-P**, **IrMC**, **IrLAN**	**PHY**, **MAC**, **LLC**
Applications	PC, laptops, cell phones, personal assistants, cameras, toys,	Aimed at HID (human interface device) class devices: Keyboards, mice, joysticks whether communicating with PCs or TV top devices.

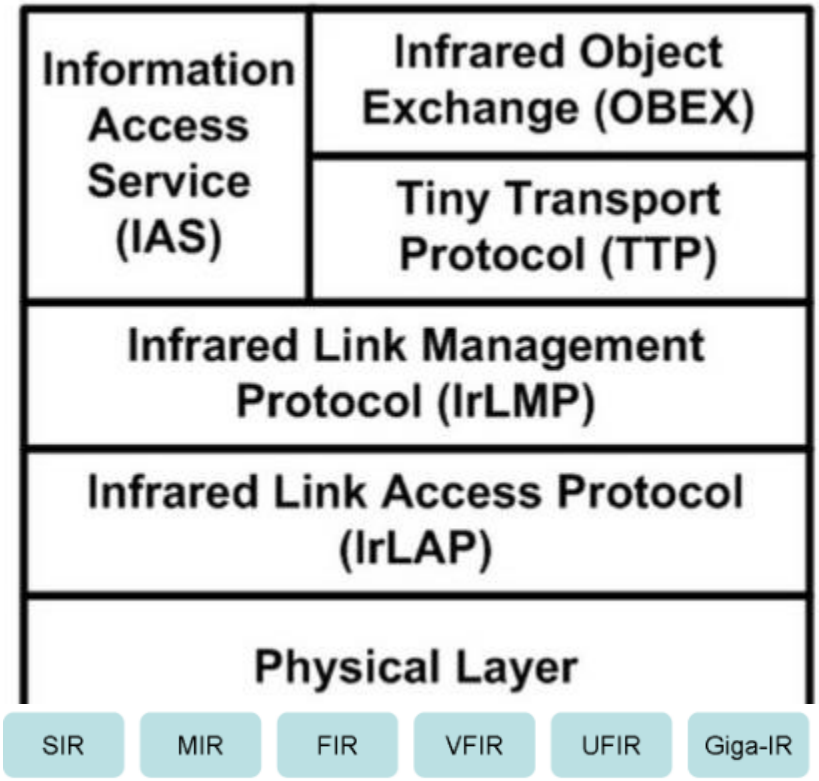
IrDa – Protocol Stack

- IrDA Data protocols in OSI Perspective



IrDa – Protocol Stack

- In OSI Perspective

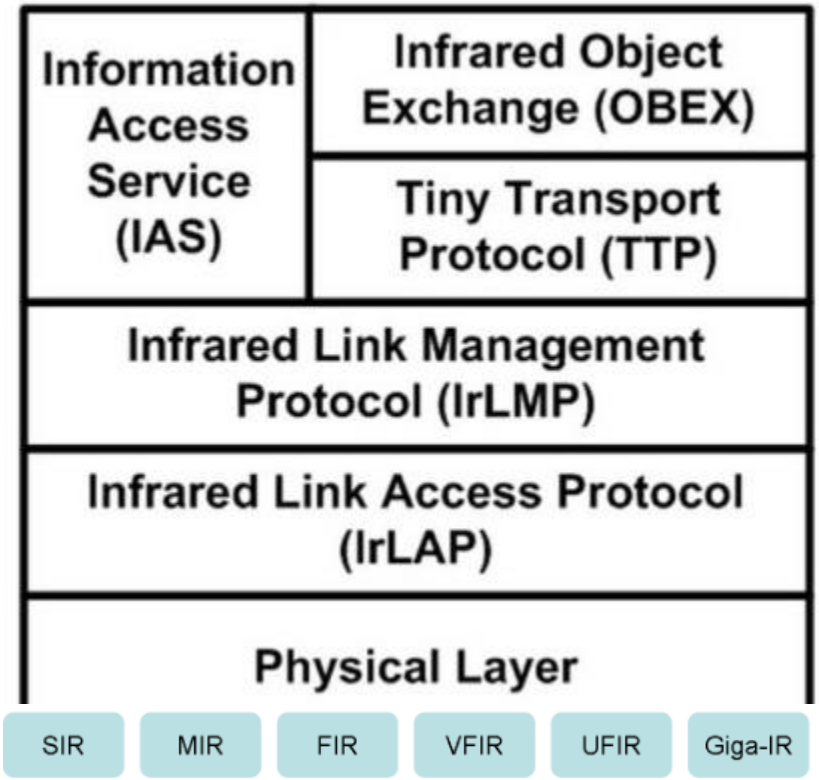


PHY: Mandatory protocol in IrDa specs. Different data rates (2.4 kbit/s to 1 Gbit/s) use different modulation/coding schemes:

- SIR: 9.6–115.2 kbit/s, RZ
- MIR: 0.576–1.152 Mbit/s, RZ
- FIR: 4 Mbit/s, 4PPM
- VFIR: 16 Mbit/s, NRZ,
- UFIR: 96 Mbit/s, NRZI,
- GigaIR: 512 Mbit/s – 1 Gbit/s, NRZI, 2-ASK

IrDa – Protocol Stack

- In OSI Perspective



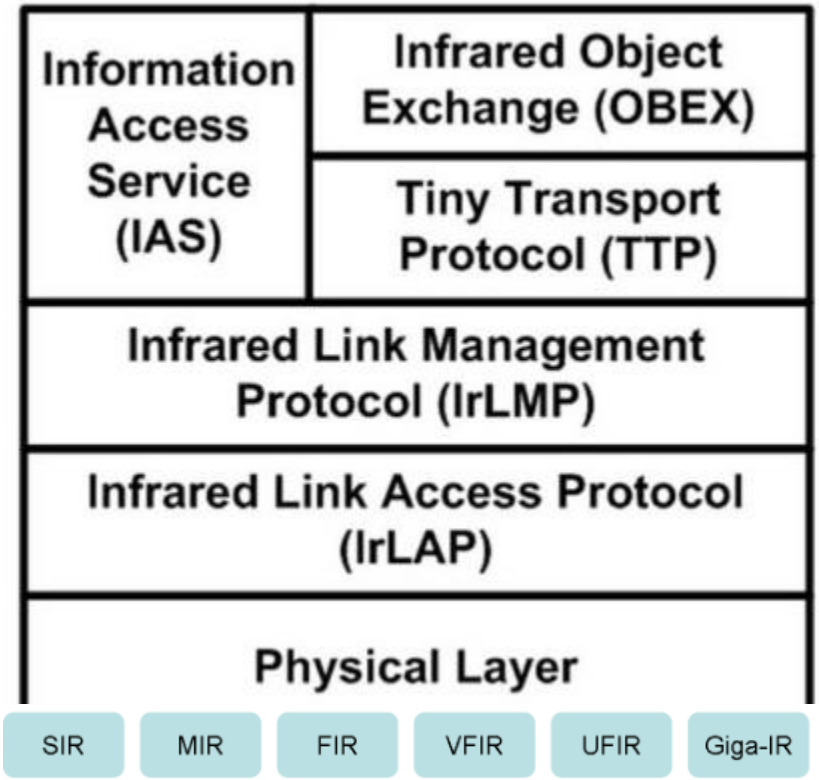
IrLAP (Infrared Link Access Protocol) is the second layer of the IrDA specifications. It lies on top of the IrPHY layer and below the IrLMP layer. It represents the data link layer of the OSI model. Mandatory protocol in IrDa specs:

The most important specifications are:

- Access control
- Discovery of potential communication partners
- Establishing of a reliable bidirectional connection
- Distribution of the primary/secondary device roles
- Negotiation of QoS parameters

IrDa – Protocol Stack

- In OSI Perspective



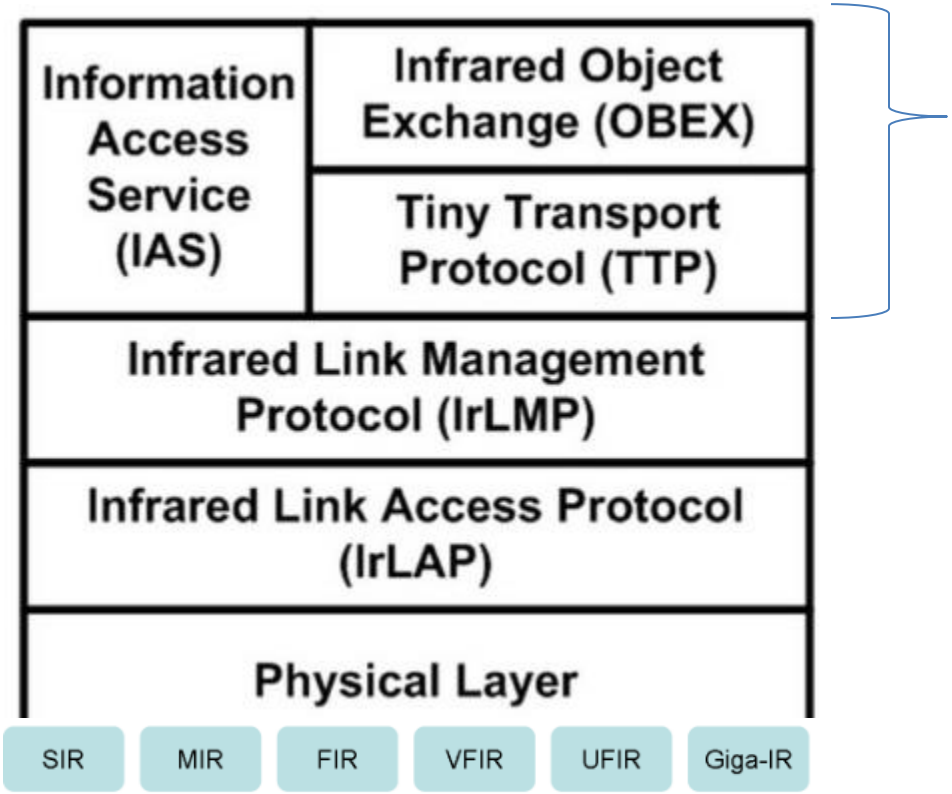
The mandatory IrLMP (Infrared Link Management Protocol) is the third layer of the IrDA specifications, which lies on top of the IrLAP layer.

Its most important achievements are:

- Provides multiple logical channels
- Allows change of primary/secondary devices

IrDa – Protocol Stack

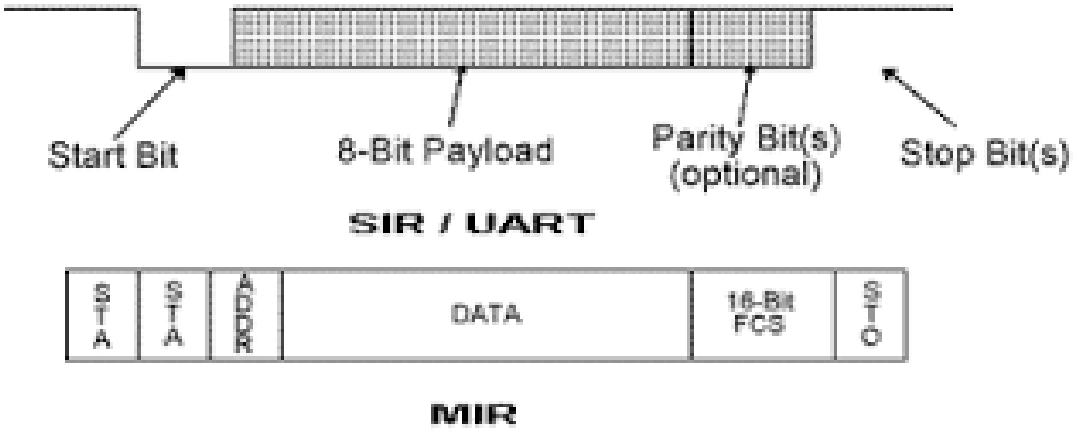
- In OSI Perspective



These layers are part of Protocol Stack but not Mandatory, they are optional

IrDa – Protocol Stack

- Frame Format

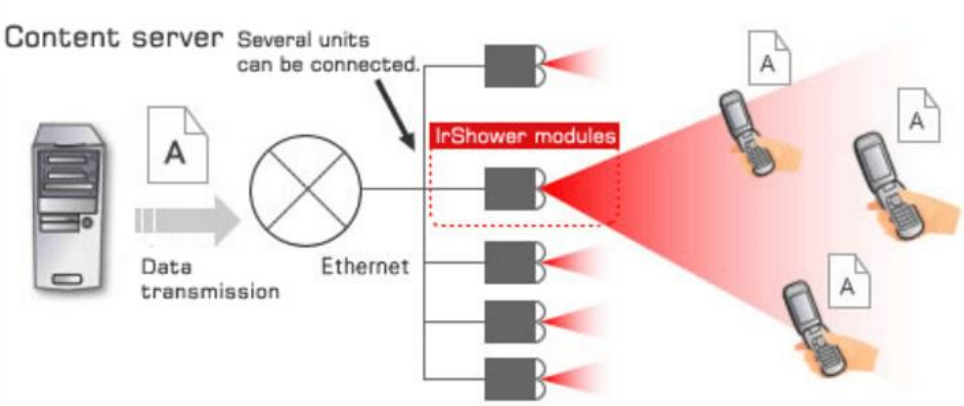


IrDa – Products

- Application
  - IrShower®

IrDa – Products

- Application
  - IrShower®



- Product ads, Critical announcements, Maps, Floor guides will be sent without using data/internet .
- Information can be sent to mobile phones and IR enable devices.
- Information can be received by several devices simultaneously.
- Data is sent directly without using radio waves (and can be received underground and in places not reached by radio waves.)
- High-speed communication is conducted at a speed of 4 Mbps, which is optimal for high-capacity data.

IrDa vs Bluetooth

- Network connection Latency—3 s for Bluetooth and a few ms for IrDA
- Bit rate—1 Mbps for Bluetooth and 1.152 Mbps to 4 Mbps for IrDA
- Code Size—50% down to 2% as compared to a Bluetooth device

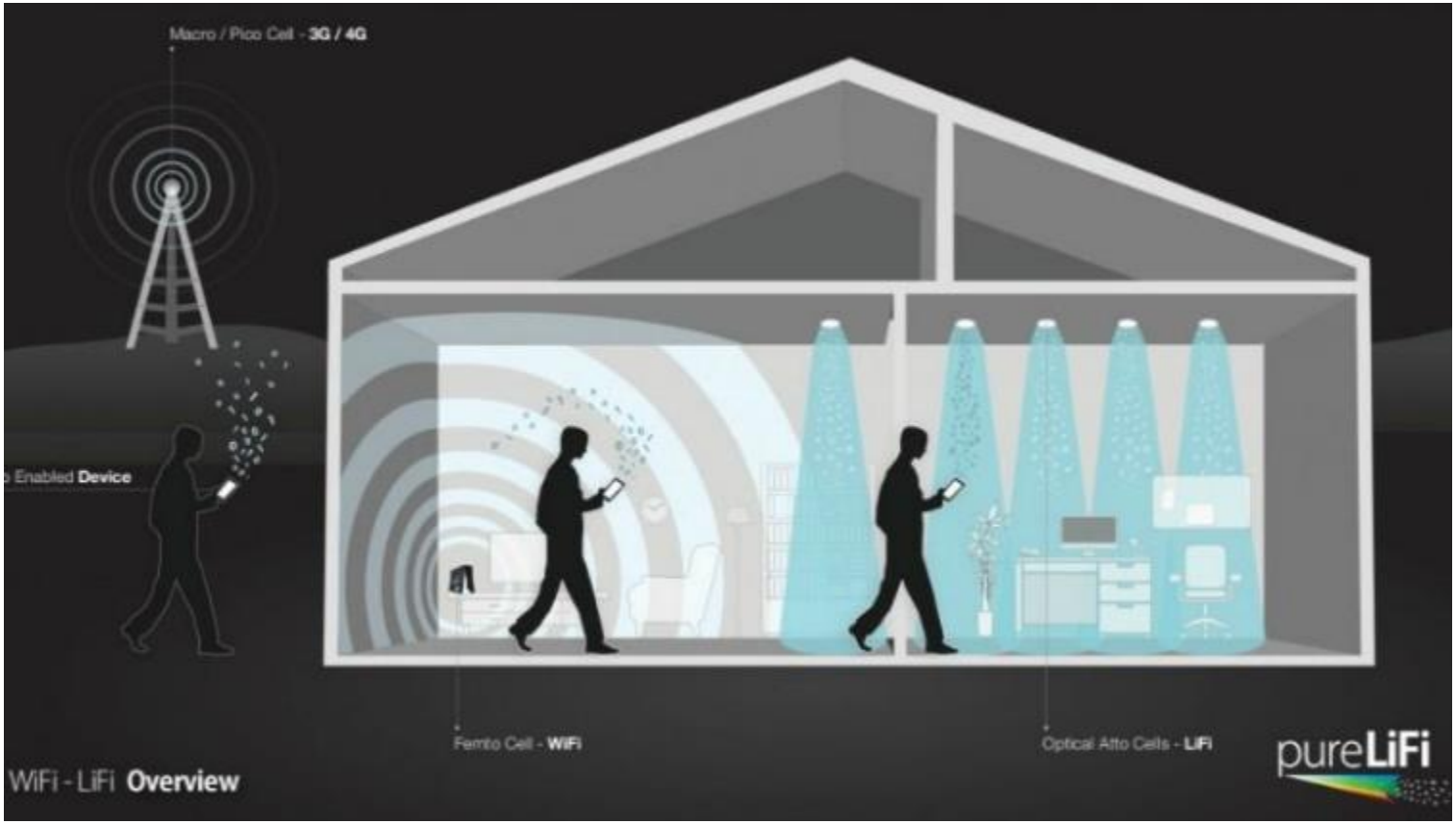
Li-Fi Technology

- In VLC, one emerging technology is Li-Fi
- **Li-Fi** technology was originated in 2011 by Professor Harald Haas of the University of Edinburgh, who demonstrated at **TED talk** that a flickering light from a single LED, he could transmit more data than a cellular tower.
  - technology has been trialed by airlines for in-flight connectivity

Li-Fi Technology

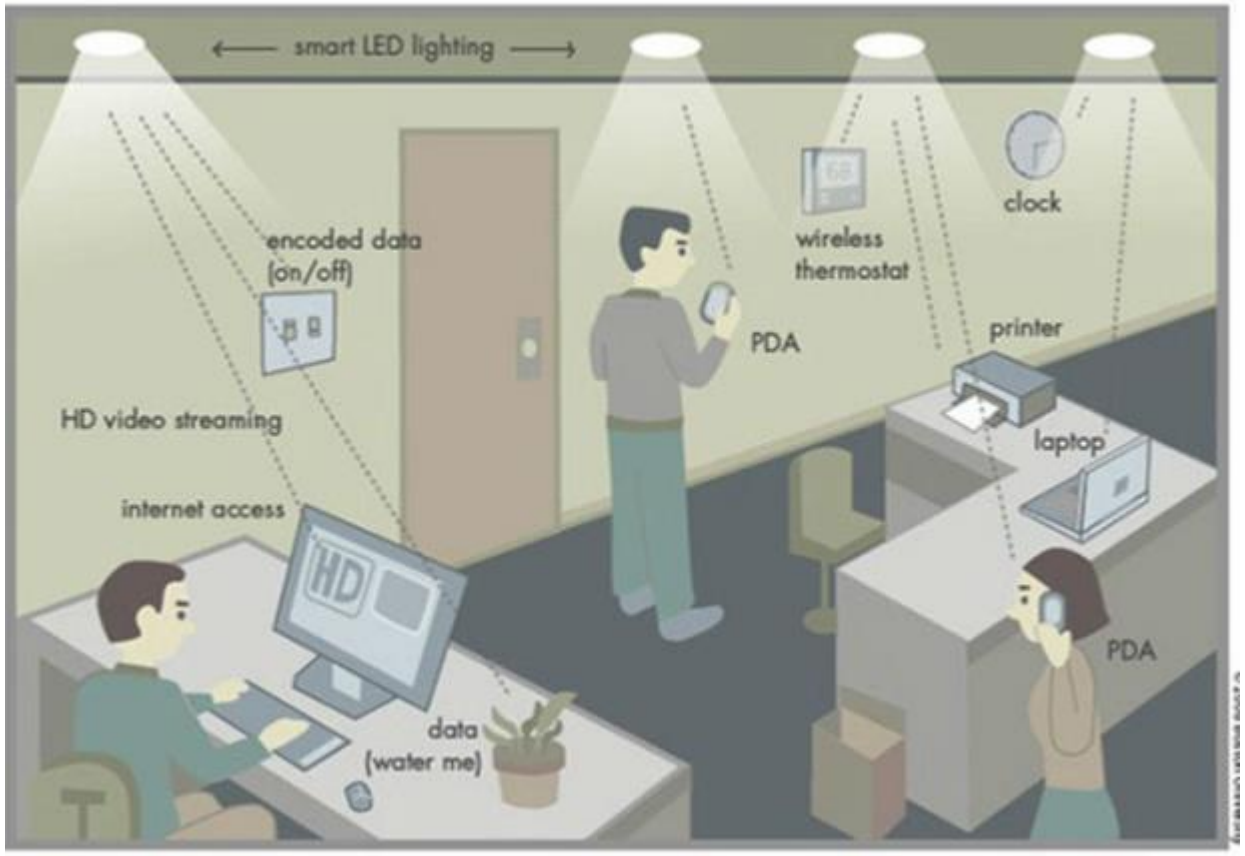
- Gallium nitride (GaN) LEDs, the speed of the systems is paramount and test LiFi waves so far have been mostly ‘only’ 150 Mbps (megabits per second) at least twice that of the everyday 802.11n WiFi in many homes and offices.
- More recently already able to reach 3.5 Gbps (gigabits per second) across red, green and blue visible light frequencies in parallel - this means that over 10 Gbps is possible.
- It uses visible light communication (instead of radio frequency waves), which has 10,000 times wider bandwidth than RF

Li-Fi Technology



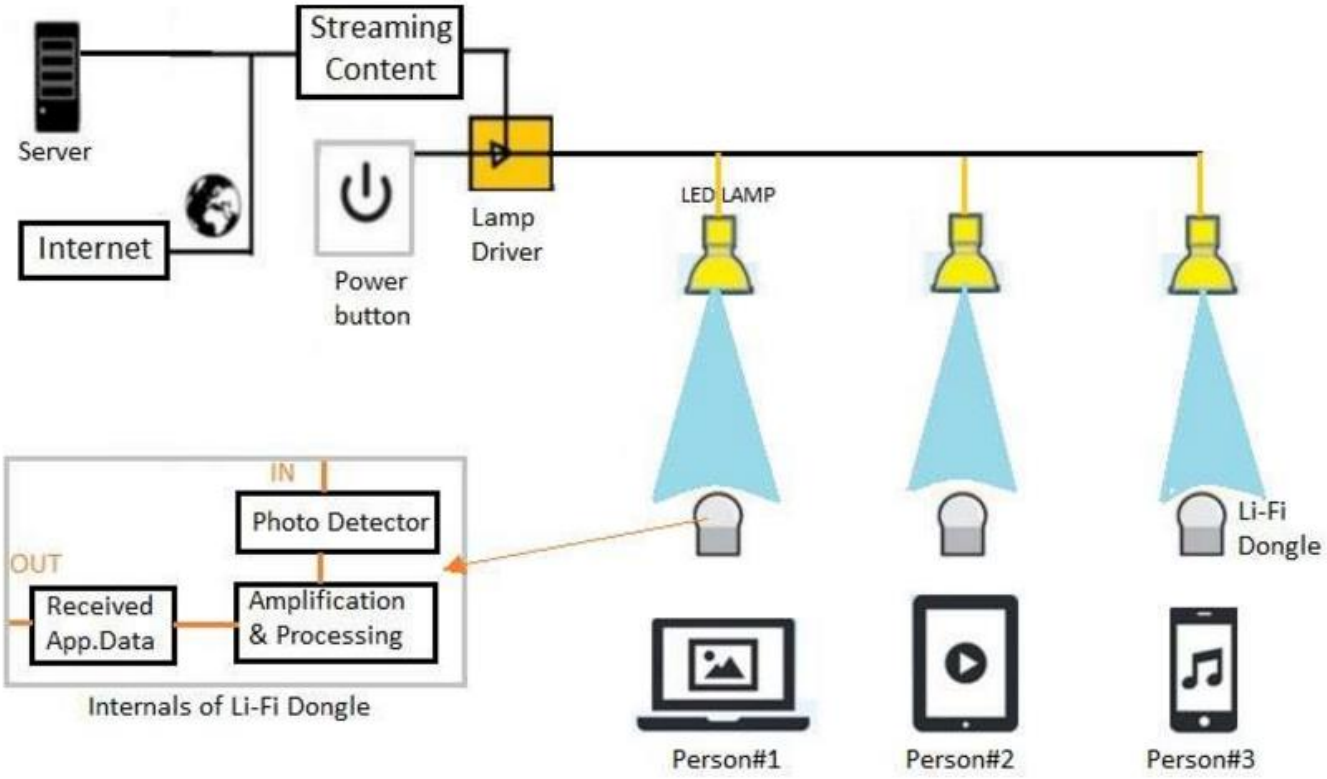
Cellular **WiFi** **LiFi**

Li-Fi Technology



Li-Fi Technology

Network Architecture



Li-Fi vs WiFi

Feature	LiFi	WiFi
Operation	LiFi transmits data using light with the help of LED bulbs.	WiFi transmits data using radio waves with the help of WiFi router.
Technology	Present IrDA compliant devices	WLAN 802.11a/b/g/n/ac/ad standard compliant devices
Applications	Used in airlines, undersea explorations, operation theaters in the hospitals, office and home premises for data transfer and internet browsing	Used for internet browsing with the help of wifi kiosks or wifi hotspots
Merits/Demertis	Interference is less, can pass through salty sea water, works in dense region Low power requirement Restricted to particular area	Interference is more, can not pass through sea water, works in less dense region High power requirement Expand into a large area

Li-Fi vs WiFi

Feature	LiFi	WiFi
Privacy	In LiFi, light is blocked by the walls and hence will provide more secure data transfer	In WiFi, RF signal can not be blocked by the walls and hence need to employ techniques to achieve secure data transfer.
Data transfer speed	About 1 Gbps and above	WLAN-11n offers 150Mbps, About 1-2 Gbps can be achieved using WiGig/Giga-IR
Coverage distance	About 10 meters	About 32 meters (WLAN 802.11b/11g), vary based on transmit power and antenna type
System components	Lamp driver, LED bulb(lamp) and photo detector will make up complete LiFi system.	requires routers to be installed, subscriber devices(laptops,PDAs,desktops) are referred as stations