Communication Technologies for IoT

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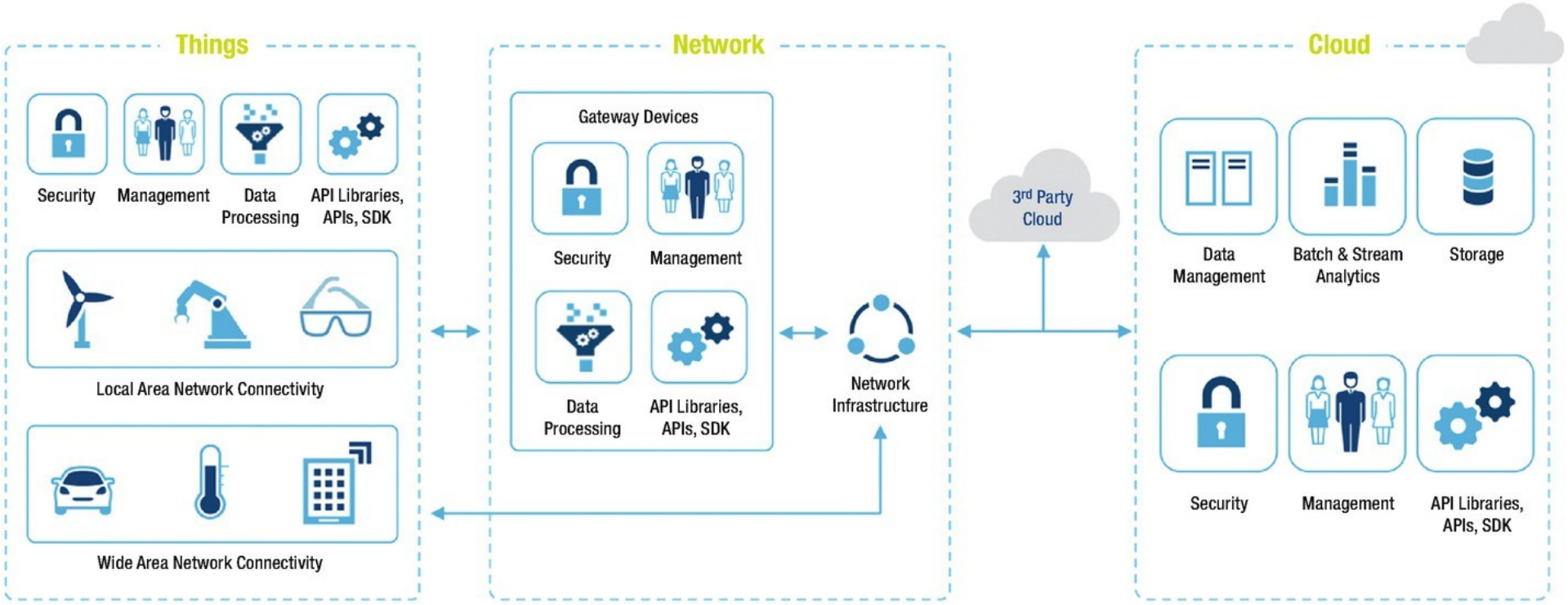
Connectivity Considerations

- **Connectivity between IoT devices and outside world dictates network architecture**
- **Choice of communication technology dictates IoT device hardware requirement and costs**
- **Due to presence of numerous applications of IoT enabled devices, a single networking paradigm not sufficient to all needs of the consumer or IoT device**
- **Complexity of networks - interference among devices, network management, heterogeneity in networks, protocol standardization within networks**

Network Configuration in IoT



Cheruvu S., Kumar A., Smith N., Wheeler D.M. (2020) Connectivity Technologies for IoT. In: Demystifying Internet of Things Security. Apress, Berkeley, CA. https://doi.org/10.1007/978-1-4842-2896-8_5

Some Network Terminologies

LAN : Local short range communication, may or may not connect to Internet

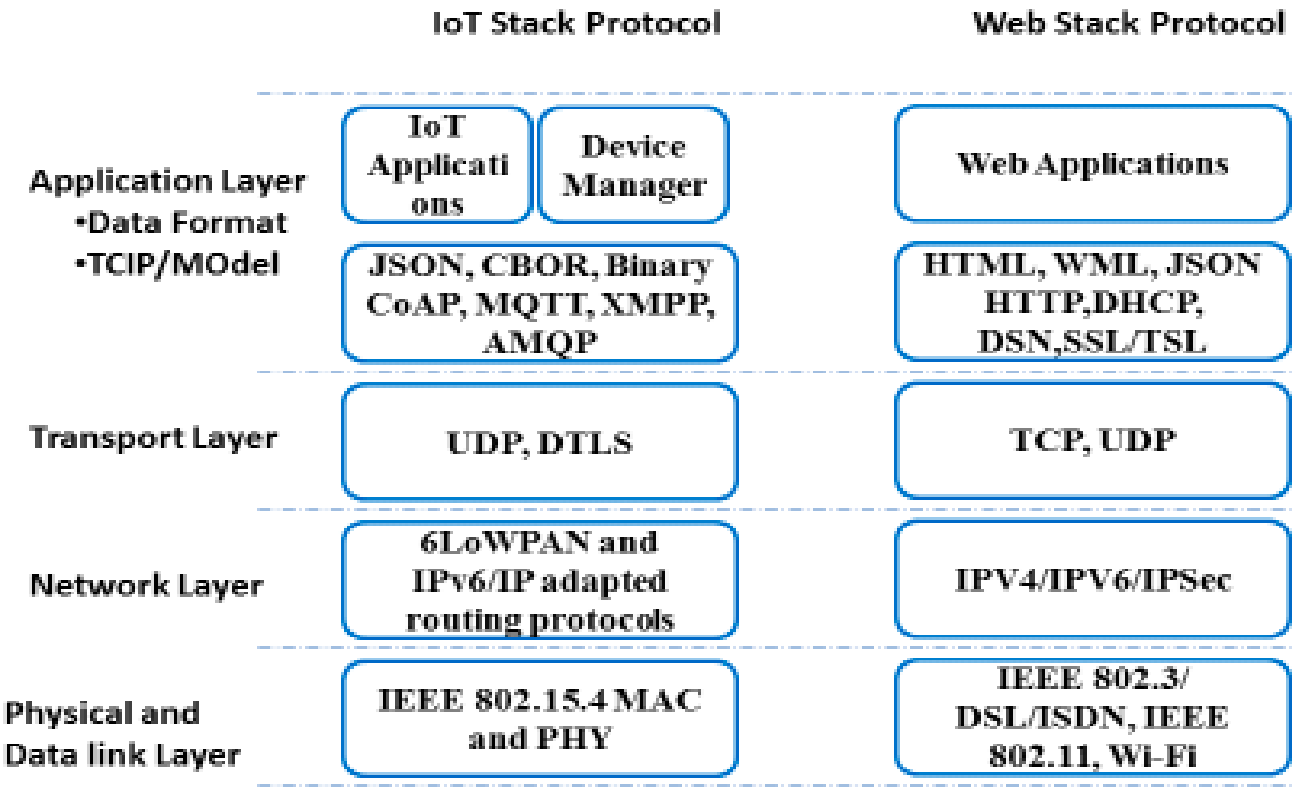
WAN : Connection of various network segments, connects to internet

Node : connects to other nodes via LAN, maybe connected to other nodes via WAN directly

Gateway : A router connecting LAN to WAN and Internet, can implement several LAN and WAN, forwards packets between LAN and WAN

Proxy : Performs active application layer functions between nodes and other entities

IoT Stack Versus Web Stack



- •Efficient Devices
- •Efficient web services applications
- •Optimized IP Access
- •Packets of Tens of bytes

- •Huge overhead
- •Requres lots of internet devices
- •Sometimes inefficient, content encoding
- •Packets of hundred and thousands of bytes

Functionality Based IoT Protocol To be Discussed

Connectivity – 6LowPAN

Identification - IPv6, URI

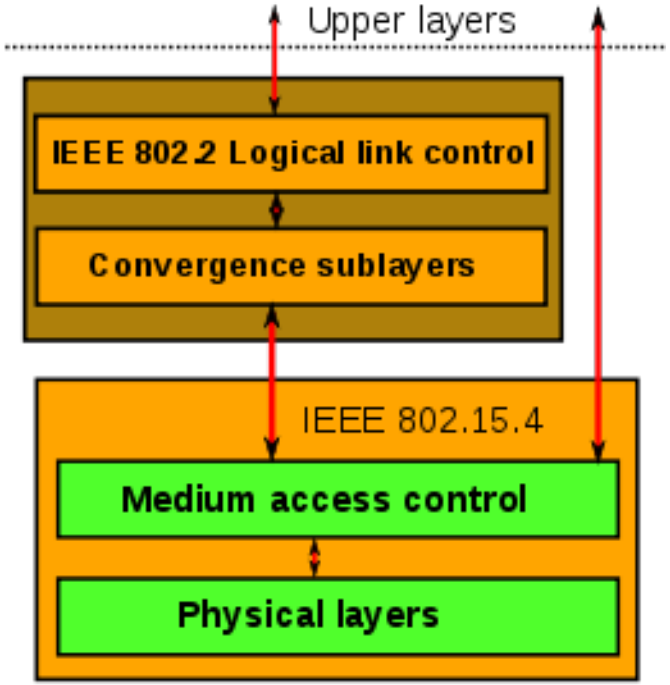
Communication / Transport - Wifi, Bluetooth, LPWAN

Data Protocols - MQTT, CoAP, AMQP, Web-socket

Discovery - Physical Web

Semantic – WebThing Model

IEEE 802.15.4



- **IEEE 802.15.4 specifies Physical and Media Access Control for low rate wireless personal area network (LR-WPANs)**
- **It is maintained by IEEE 802.15 working group**
- **It is the basis for Zigbee, WirelessHART protocols which extend the standard by developing upper layers not defined in IEEE 802.15.4**

IEEE 802.15.4 Features

- Allows low cost, low speed ubiquitous computing
- Low data rate Wireless Personal Area Network
- Power consumption is minimized due to infrequently occurring very short packet transmission with low duty cycle
- Highly tolerant of noise and interference and offers link reliability
- Uses carrier sense multiple access with collision avoidance (CSMA-CA) for channel access
- Multiplexing allows multiple users or nodes interference free access to same channel at different times
- Transmission for most cases is Line of Sight
- Best case transmission range achieved outdoors is 1000m
- Networking topologies defined : Star and Mesh

IEEE 802.15 Features – Physical Layer

- The physical layer provides the data transmission service.
- It also, provides an interface to the physical layer management entity, which offers access to every physical layer management function and maintains a database of information on related personal area networks.
- The PHY manages the physical radio transceiver, performs channel selection along with energy and signal management functions.

IEEE 802.15 Features – Media Access Layer

- The medium access control (MAC) enables the transmission of MAC frames through the use of the physical channel.
- It offers a management interface and itself manages access to the physical channel and network beaconing.
- It also controls frame validation, guarantees time slots and handles node associations.
- Facilitates secure services.

IEEE 802.15.4 Variants

A/B - base version

maximum data rates - 868/915 MHz bands, four physical layers Three of them preserve the DSSS approach - 868/915 MHz bands; one uses PSSS

C – China; 779–787 MHz bands

D – Japan ; 950–956 MHz band

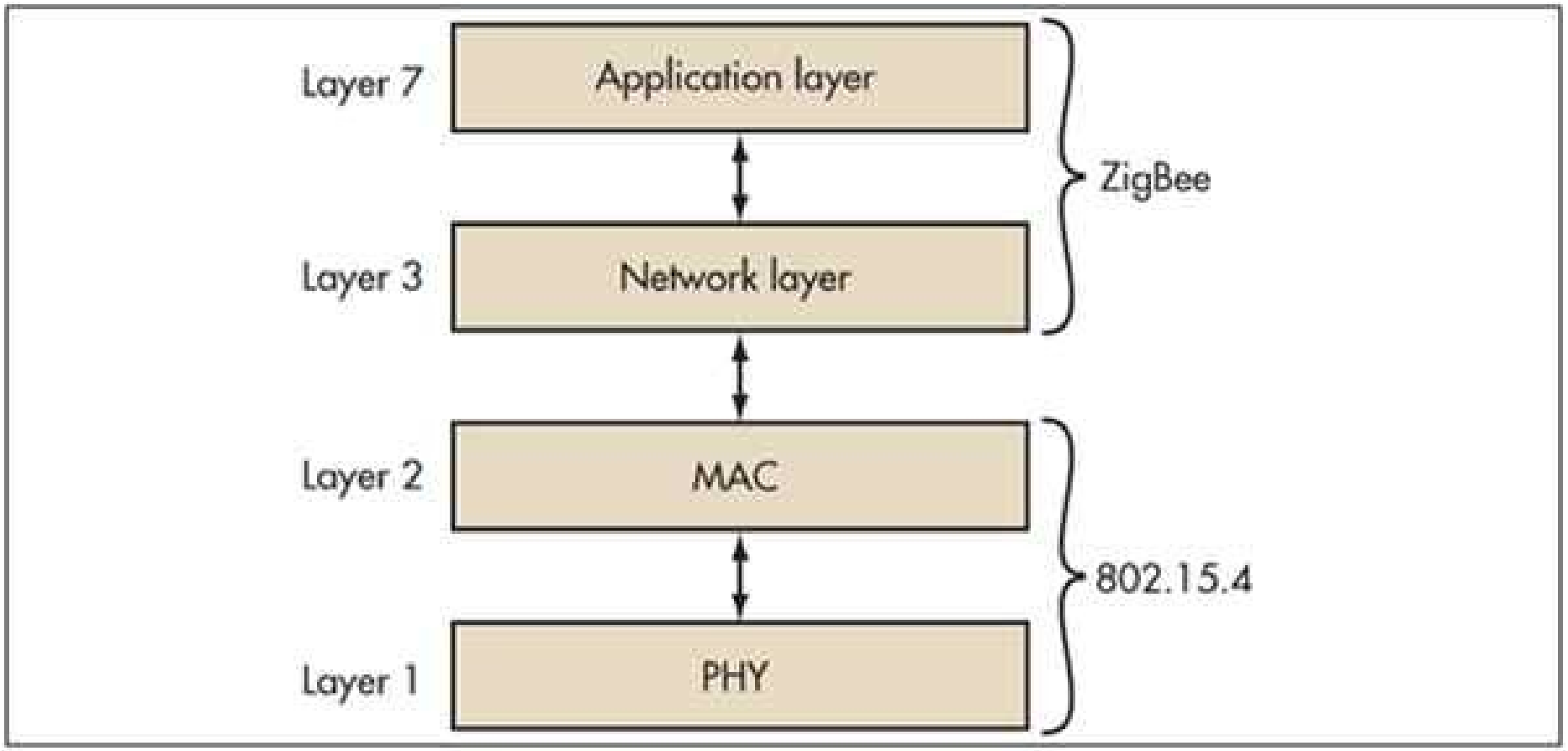
E – Industrial Applications

MAC amendment to the existing standard 802.15.4 adopting channel hopping to improve industrial markets

F – Active RFID users

G - Smart utility networks

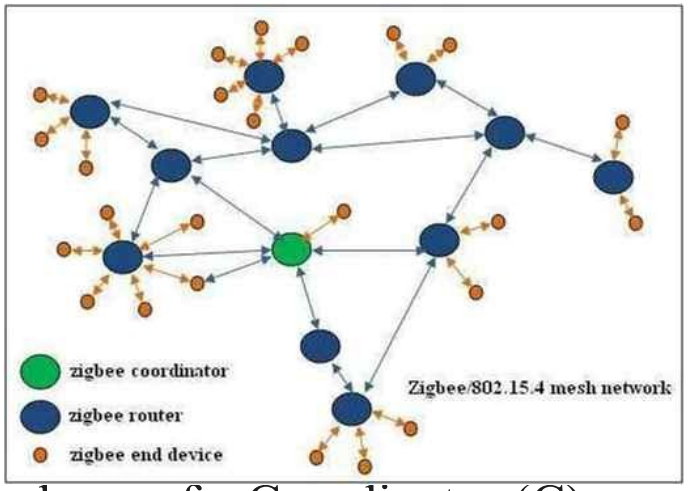
IEEE 802.15.4 Standard



ZigBee

- The ZigBee protocol uses the **802.15.4** standard and
- operates in two bands : **868/915MHz** and **2.4 GHz**
- Data rate of **868/915 band : 20/40 Kb/s**
- **Data rate of 2.4GHz band : 250 Kb/s.**
- The maximum number of nodes in the network is 1024 with a range up to 200 meter.
- ZigBee can use 128 bit AES encryption.
- end devices can go to sleep mode which saves battery consumption
-

Zigbee Network



- A Zigbee network is made up of a Coordinator (C) , router (R) and End Device (E) that are the IoT devices connected to the network.
- C – need to be installed first ; it starts a new PAN (Personal Area Network), once started other zigbee components PAN; selects channel and PAN id
- Router needs to join the network then it can allow other R & E to join the PAN
- Zigbee 3. 0 : enables different application areas to communicate and form a homogenous network
- Supports connectivity with IP networks such as LAN and WAN, products from different manufacturers can communicate asa single networking devices

Infrastructure based IoT Protocols : IPv6

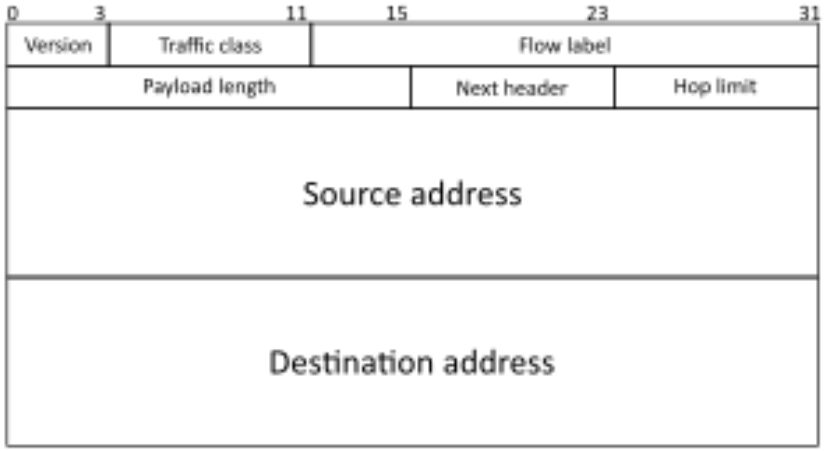
Internet protocol that provides identification and location system of devices and routes traffic across the internet

IPv6 is used to deal with problem of IPv4 address exhaustion (protocols are not interoperable)

IPv6 uses a 128-bit address, theoretically allowing 2128, or approximately 3.4×10^{38} addresses

IPv6 address are represented as eight groups of four hex digits

Ex : 2001:0db8:0000:0000:0000:8a2e:0370:7334



Infrastructure based IoT Protocols : 6LoWPAN

- Supports IPv6 packets over IEEE 802.15.4 WPANs.
- Low power design included - Good for battery-operated IoT devices.
- Supports applications that need wireless internet connectivity at lower data rates for devices with very limited form factor.
- Example usage : automation and entertainment applications in home, office and factory environments
- Challenges : management of addresses for devices that communicate across the two dissimilar domains of IPv6 and IEEE 802.15.4 is cumbersome
- IEEE 802.15.4 devices are intentionally constrained in form factor to reduce costs (allowing for large-scale network of many devices), reduce power consumption (allowing battery powered devices) and allow flexibility of installation (e.g. small devices for body-worn networks). On the other hand, wired nodes in the IP domain are not constrained in this way; they can be larger and make use of mains power supplies.

Communication/ Transport based IoT Protocols

Technology	Frequency	Data Rate	Range	Power Usage	Cost
2G/3G	Cellular Bands	10 Mbps	Several Miles	High	High
Bluetooth/BLE	2.4Ghz	1, 2, 3 Mbps	~300 feet	Low	Low
802.15.4	subGhz, 2.4GHz	40, 250 kbps	> 100 square miles	Low	Low
LoRa	subGhz	< 50 kbps	1-3 miles	Low	Medium
LTE Cat 0/1	Cellular Bands	1-10 Mbps	Several Miles	Medium	High
NB-IoT	Cellular Bands	0.1-1 Mbps	Several Miles	Medium	High
SigFox	subGhz	< 1 kbps	Several Miles	Low	Medium
Weightless	subGhz	0.1-24 Mbps	Several Miles	Low	Low
Wi-Fi	subGhz, 2.4Ghz, 5Ghz	0.1-54 Mbps	< 300 feet	Medium	Low
WirelessHART	2.4Ghz	250 kbps	~300 feet	Medium	Medium
ZigBee	2.4Ghz	250 kbps	~300 feet	Low	Medium
Z-Wave	subGhz	40 kbps	~100 feet	Low	Medium

Communication based IoT Protocols : WiFi

- **Wi-Fi is a Wireless Local Area Network (WLAN) technology based on the IEEE 802.11 standards.**

- **Wi-Fi Devices - Smartphones, Smart Devices, Laptop Computers, PC, etc. Applications Areas - Home, School, Computer Laboratory, Office Building**

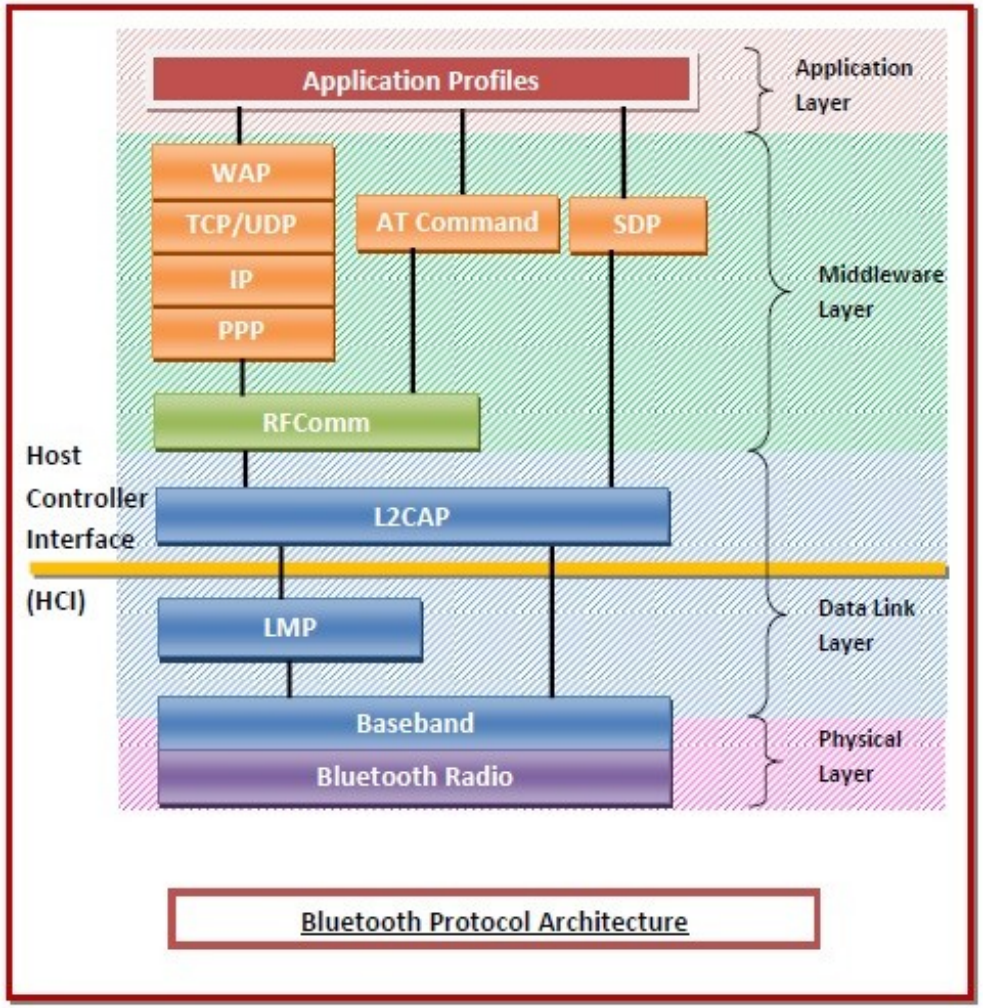
- **Wi-Fi devices and Access Points (APs) have a wireless communication range of about 30 meters indoors.**

- **Wi-Fi data rate is based on its protocol type :**
  - IEEE 802.11a can achieve up to 54 Mbps
  - IEEE 802.11b can achieve up to 11 Mbps
  - IEEE 802.11g can achieve up to 54 Mbps
  - IEEE 802.11n can achieve up to 150 Mbps
  - IEEE 802.11ac can achieve up to 866.7 Mbps
  - IEEE 802.11ad can achieve up to 7 Gbps

Communication based IoT Protocols : Bluetooth

- network technology connects mobile devices wirelessly over a short-range to form a personal area network (PAN).
- The Bluetooth architecture has its own independent model with a stack of protocols, instead of following the standard OSI model or TCP/IP model.
- Bluetooth works in the 2.4 GHz ISM band and uses frequency hopping. With a data rate up to 3 Mbps and maximum range of 100m.
- Each application type which can use Bluetooth has its own profile.

Communication based IoT protocols : Bluetooth



Communication based IoT protocols : Bluetooth

Physical Layer :

Radio : defines frequency band, modulation techniques

Baseband : addressing scheme, packet format, timing, power control

Data Link Layer :

Link Manager Protocol(LMP) : establishes logical link between bluetooth devices, authentication, message encryption

Logical Link Control and Adaptation Layer : adaption between upper layer frame and baseband layer frame format

Middleware Layer :

RFComm : provides a serial interface with WAP.

Adopted : protocols adopted from standard models (PPP, UDP, TCP)

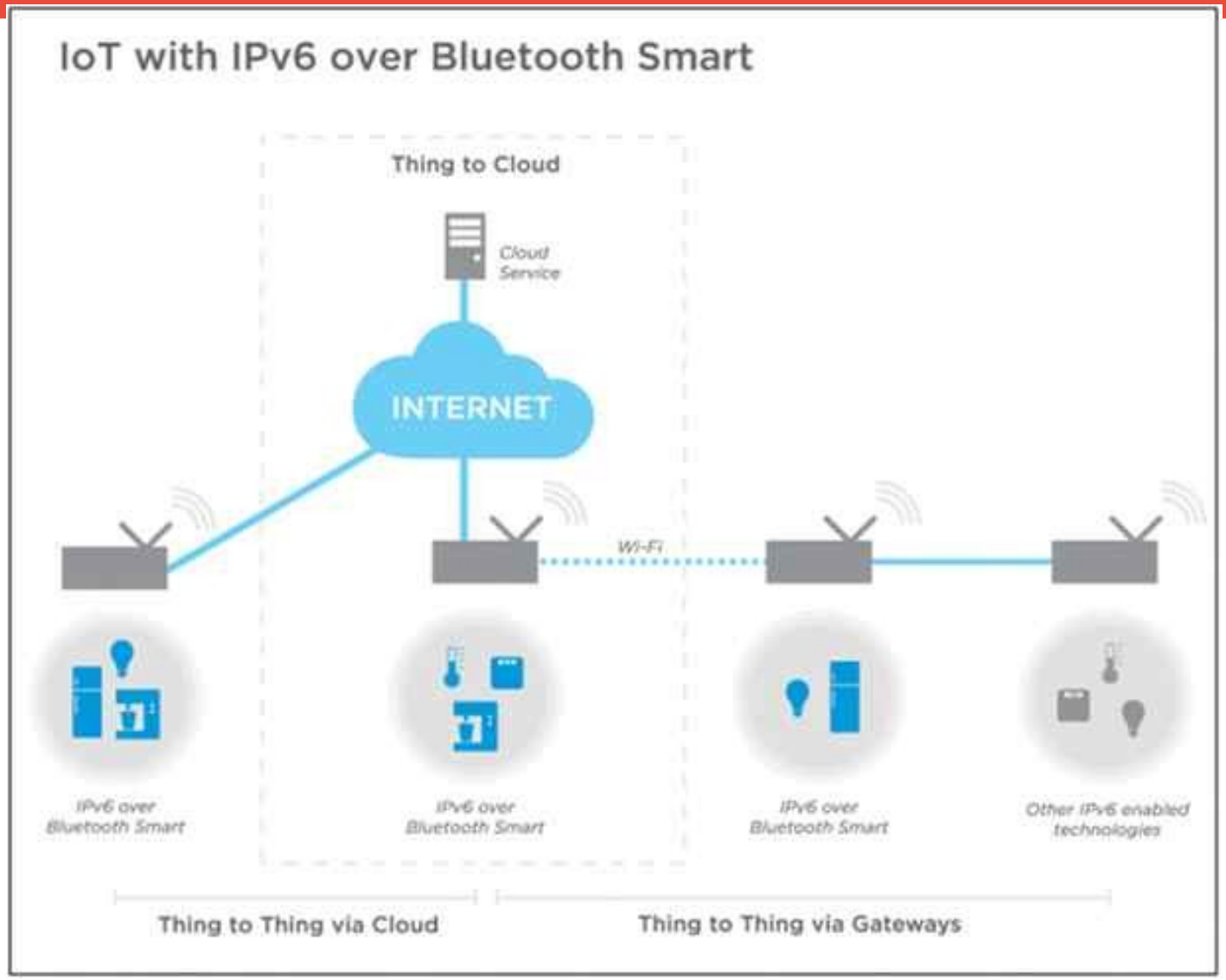
Service Discovery : takes care of service-related queries like device information so as to establish a connection between contending Bluetooth devices.

AT command set

Application Layer :

includes the application profiles that allow the user to interact with the Bluetooth applications

Bluetooth


IoT with IPv6 over Bluetooth Smart
Thing to Cloud
Cloud Service
INTERNET
Wi-Fi
IPv6 over Bluetooth Smart
IPv6 over Bluetooth Smart
IPv6 over Bluetooth Smart
Other IPv6 enabled technologies
Thing to Thing via Cloud
Thing to Thing via Gateways