Characteristics of Connectivity Technologies

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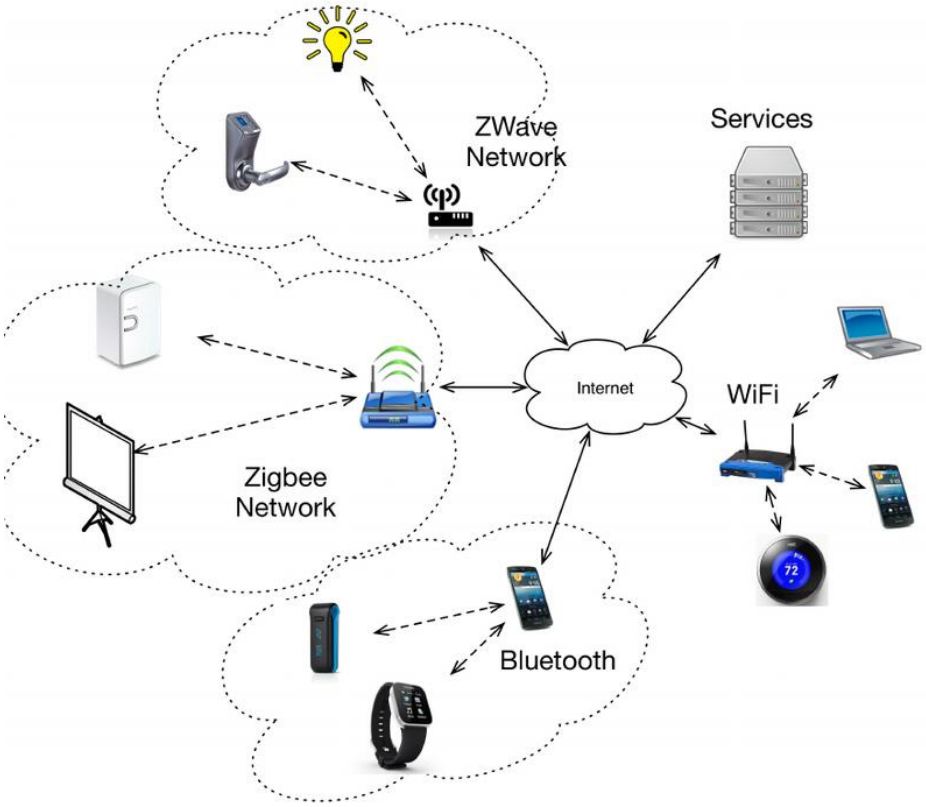
IoT Network Access Technologies

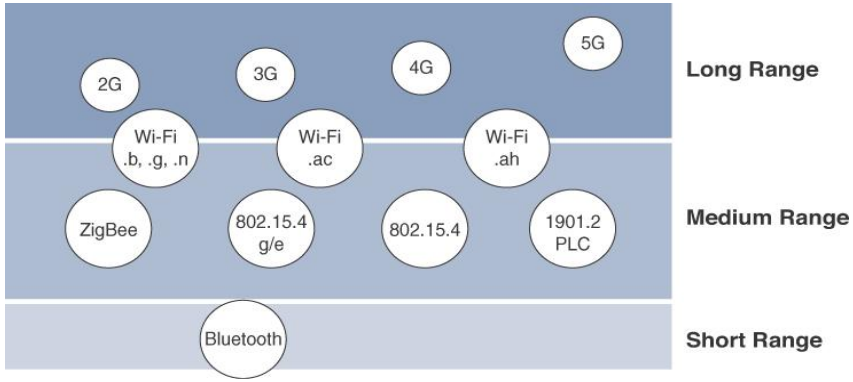
- There are many IoT access technologies in the market today

Criteria for Access Technologies

- Different criteria to describe the characteristics and attributes of IoT access technologies
- IoT access technologies could be wired or wireless
- Wireless communication is prevalent for smart object connectivity
  - ease of deployment
  - allows smart objects to be mobile
  - moving without losing connectivity
- Few basic criteria:
  - Range
  - Frequency bands
  - Power consumptions
  - Topology
  - Constrained devices
  - Constrained-node networks



Communication Range



- **Short range**:
  - **tens of meters** of maximum distance between two devices
  - often considered as an alternative to serial cable
  - Example:
    - IEEE 802.15.1 Bluetooth,
    - IEEE 802.15.7 Visible Light Communications (VLC)

- **Medium range**
  - **tens to hundreds of meters** between two devices
  - **Wireless** :
    - IEEE 802.11 WiFi,
    - IEEE 802.15.4 Low Rate WPAN,
    - IEEE 802.15.4g Smart Utility Networks (SUN)
  - **Wired** :
    - IEEE 802.3 Ethernet,
    - IEEE 1901.2 Narrowband Power Line Communications (PLC)

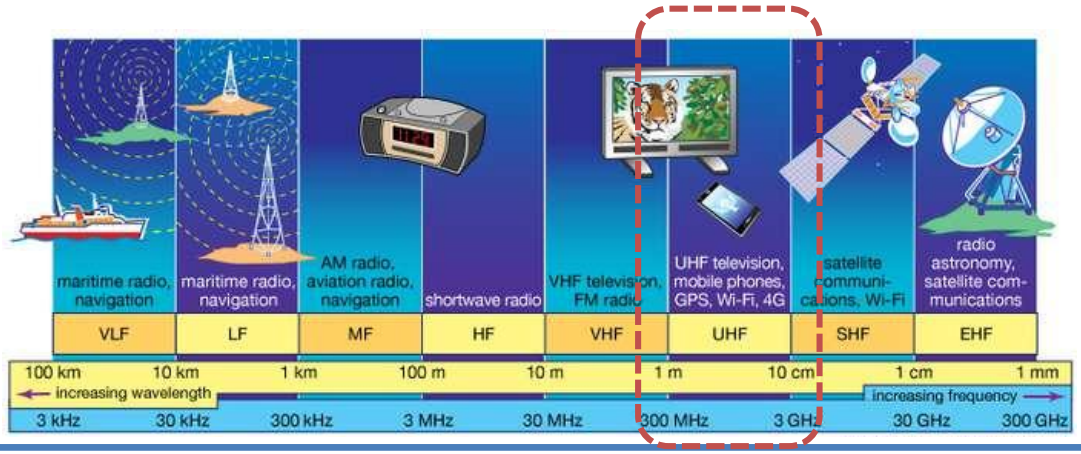
- **Long range**
  - **greater than 1 mile (1.6 km)** between two devices
  - **Wireless** :
    - 2G, 3G, 4G,
    - IEEE 802.11ah,
    - Low-Power Wide-Area (LPWA) communications
  - **Wired** :
    - IEEE 802.3 ethernet over optical fiber,
    - IEEE 1901.2 Broadband PLC

Frequency Bands

- Radio spectrum is regulated by countries and/or organizations
  - e.g. International Telecommunication Union (ITU), Federal Communications Commission (FCC), Telecom Regulatory Authority of India (TRAI)
- Frequency bands leveraged by wireless communications are split between:

1. **Licensed**
   - applicable to long-range access technologies
   - users must subscribe to services
   - common licensed spectrum for IoT :
     - Cellular (900-2100 MHz),
     - NB-IoT (700-900 MHz)

2. **Unlicensed**
   - *Unlicensed* means that no guarantees or interference protections are offered
   - industrial, scientific, and medical (ISM) portions of the radio bands
   - well-known ISM bands for IoT :
     - 2.4 GHz, 5 GHz, 915 MHz for WiFi, BLE, ZigBee;
     - 868 MHz for LoRa



ISM Bands in India

ISM Bands - Industrial, Scientific and Medical

900MHz
vs.
2.4GHz
vs.
5GHz

900MHz

Advantages:
- More robust, less prone to interference
- Lower attenuation, travels further through more obstacles

Disadvantages:
- Low bandwidth prevents large data transfer, speed
- Components are larger at lower frequencies

2.4GHz

Advantages:
- Higher bandwidth allows large data transfer, speed
- Components are smaller, cheaper

Disadvantages:
- Congested band due to abundance of Wi-Fi, Bluetooth, microwaves, cordless phones
- Attenuates much more quickly, will not pass through metal

5GHz

Advantages:
- Higher bandwidth allows large data transfer, speed
- Less congested, few RF devices in this band

Disadvantages:
- Low transmit power limitations
- High attenuation in cables, requires very high gain antennas

- **India** also allow 865-867 MHz ISM band

Power Consumption

- Grid-powered node
  - node has a direct connection to a grid power source
  - communications are not limited by power consumption criteria
  - ease of deployment is limited by the availability of a power source
  - makes mobility more complex
- Battery-powered nodes
  - bring more flexibility to IoT devices
  - batteries are small in size
  - batteries can be changed or recharged

- IoT Nodes
  - Nodes are battery powered
  - It's wireless access technologies must address
    - the needs of low power consumption
    - connectivity for battery-powered nodes

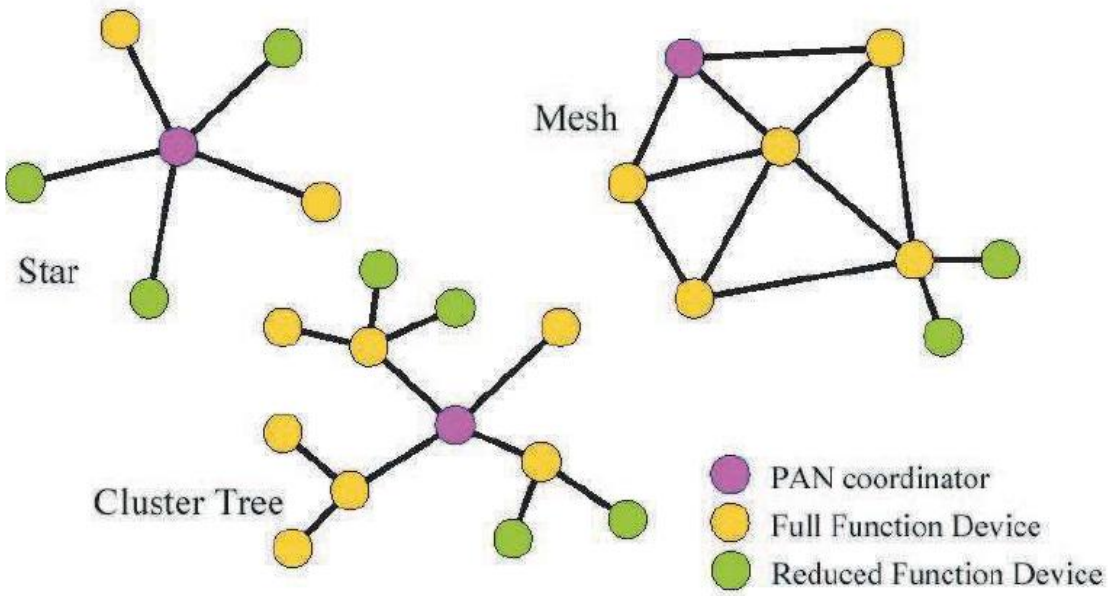
Power Consumption

	Bluetooth	ZigBee	WiFi	LoRaWAN	NB-IoT
Standard	IEEE 802.15.1	IEEE 802.15.4	IEEE 802.11b	LoRaWAN	3GPP NB-IoT
Sleeping	9 µA	12 µA	30 µA	0.1 µA	3 µA
Awake/Idle	35 mA	50 mA	245 mA	1.4 mA	6 mA
Transmitting	39 mA	52 mA	251 mA	44 mA	220 mA
Receiving	37 mA	54 mA	248 mA	12 mA	46 mA
Power Supply	3.3 V	3.3 V	5 V*	3.3 V	3.6 V

* The ESP8266 module powered by 3.3 V could be used as WiFi module.

Topology for Different Range

- Three main topology schemes are dominant:
  - star, mesh, and peer-to-peer (cluster tree)
- For long-range and short-range technologies:
  - star topology is prevalent
- For medium-range technologies:
  - star, peer-to-peer, or mesh topology is common



- IEEE 802.15.4, 802.15.4g, and wired IEEE 1901.2a PLC are generally deployed as a mesh topology.
- Indoor Wi-Fi deployments are mostly star topologies

FFD: A node that implements the full network functions

RFD: The device can implement a subset of protocol functions to perform just a specialized part (communication with the coordinator).

Constrained Devices

- Constrained nodes have limited resources that impact their networking feature set and capabilities.
- RFC 7228 defines three classes for constrained nodes: Class 0, 1, 2

	RAM	Flash Storage	IP stack	Security Scheme	Example
Class 0	< 10 KB	< 100 KB	Not present	No	Push button
Class 1	> 10 KB	> 100 KB	Optimized IP stack	Light	Sensors
Class 2	> 50 KB	> 250 KB	Full IP stack	Yes	Smart meter

Constrained Networks

- Constrained-node networks are often referred to as low-power and lossy networks (LLNs)

- Layer 1 and Layer 2 protocols must be evaluated using the following characteristics:
  - data rate and throughput
  - latency and determinism
  - overhead and payload.

- Data rate & throughput:
  - data rates available from 100 bps to tens of Mbps
  - actual throughput is less, sometimes much less, than the data rate
- Latency & determinism:
  - When latency is a strong concern, emergent access technologies such as Time-Slotted Channel Hopping (TSCH) mode of IEEE 802.15.4e should be considered.
- Overhead & Payload
  - The minimum IPv6 MTU size is expected to be **1280 bytes**.
  - MTU size for IEEE 802.15.4 is **127 bytes**; payload in LoRaWAN may **be from 19 to 250 bytes**
  - So, the fragmentation of the IPv6 payload has to be performed by the link layer

Lessons Learned

- Different Attributes of Access Technologies in IoT
  - ✓ Communication Criteria
  - ✓ Communication Range
  - ✓ Frequency Band
  - ✓ Power consumption
  - ✓ Topology
- Classifications of Constrained Nodes
- Characteristics of Constrained Networks

Thanks!

Figures and slide materials are taken from the following sources:

1. David Hanes *et al.*, “IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things”, 1st Edition, 2018, Pearson India.