

The background features a light teal color with a network diagram of white circles connected by lines. Various white icons are scattered throughout, including gears, a database cylinder, speech bubbles, a microwave, a house, a camera, a Wi-Fi router, a smartphone, a bar chart, a folder, a magnifying glass, a play button, a water drop, and a car. A central blue circle contains the text 'IoT'.

# Advanced Internet of Things Technologies

Designed by: Thuat NGUYEN-KHANH

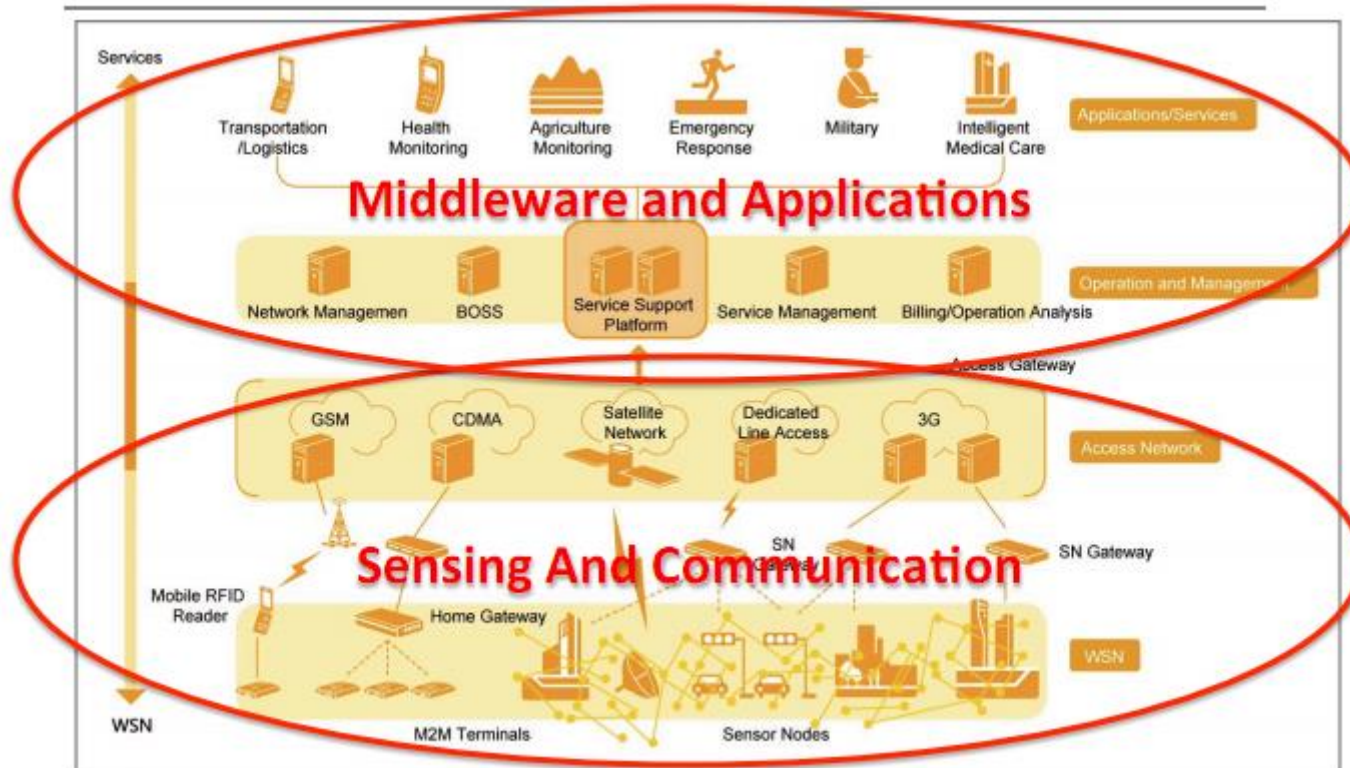
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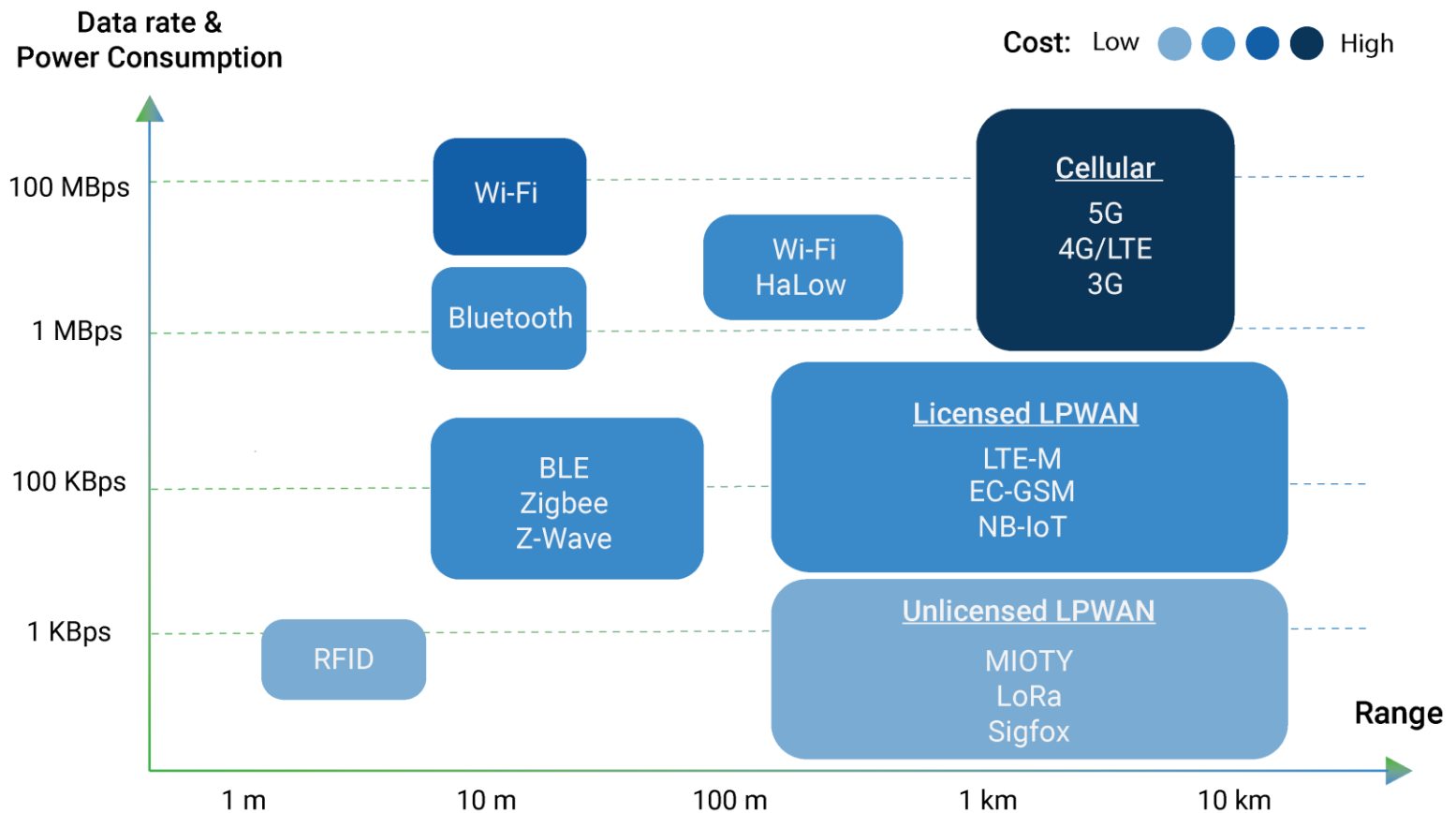
# Chapter 3: IoT Wireless Technologies

- Overview
- Wireless technology Characteristics
- IEEE 802.11 standard
- WPAN Characteristics
- Bluetooth
- Summary

# IoT Layered Architecture



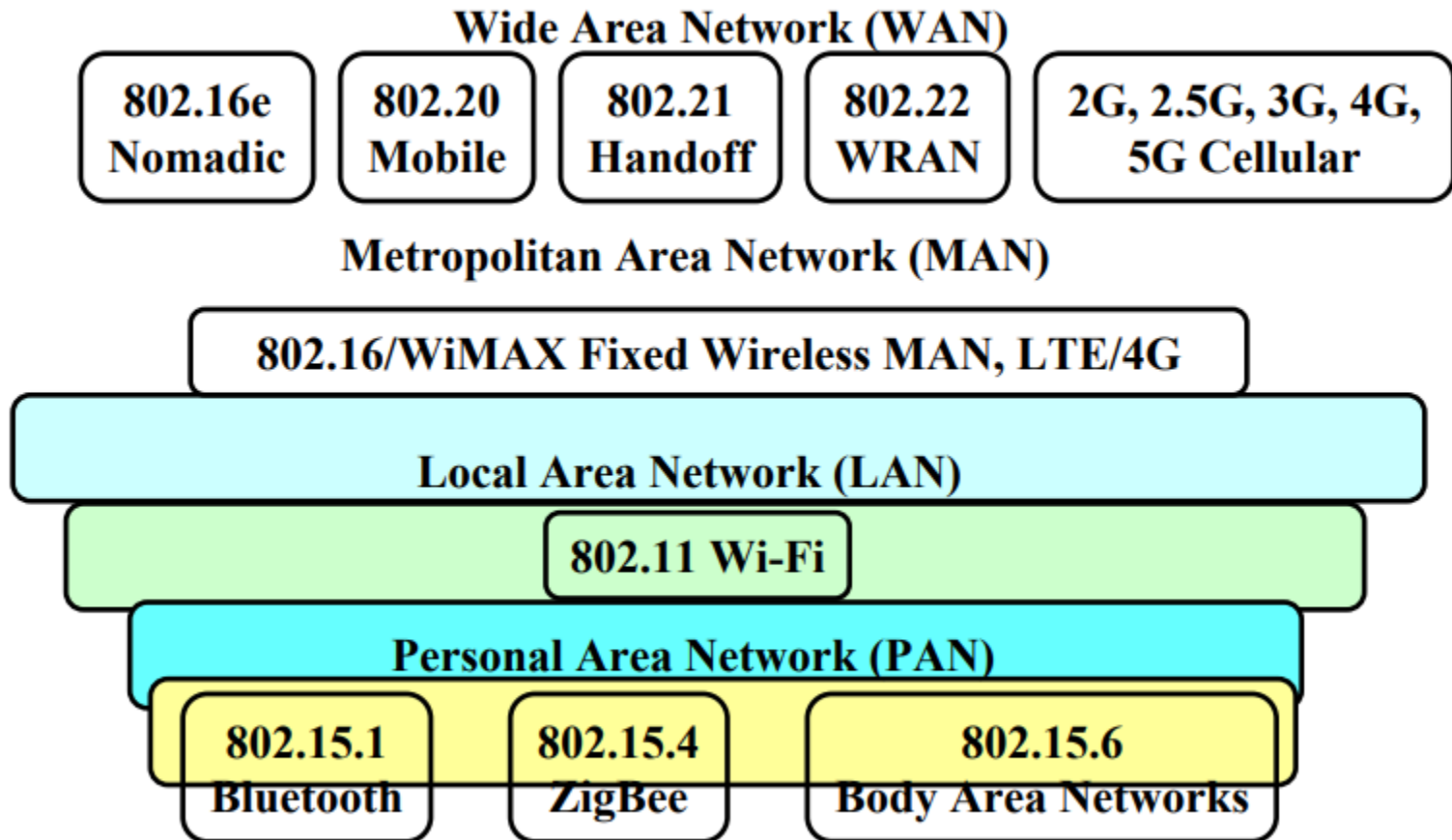
- Source: ZTE



# Wireless technology

## Characteristics

- Data rate of the devices
- Range or distance to the gateway
- The environment
- Need for encryption or authentication
- Power consumption
- Capacity
- Quality of service and reliability
- Network topology
- Simplex or duplex
- Suitable and available spectrum
- Available equipment
- Cost
- Development platform
- Internet access
- License



# IEEE 802.11 standard

- IEEE 802.11 vs. Wi-Fi
  - IEEE 802.11 is a standard
  - Wi-Fi = “Wireless Fidelity” is a trademark
- 802.11 has many options and it is possible for two equipment based on 802.11 to be incompatible.
- All equipment with “Wi-Fi” logo have selected options such that they will interoperate.

# IEEE 802.11 standard

- ISM Bands
  - The 2.4 GHz band is divided into 14 channels spaced 5 MHz apart, 3 non-overlapping channels
  - 5 GHz Band: 12 non-overlapping channels
- Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)

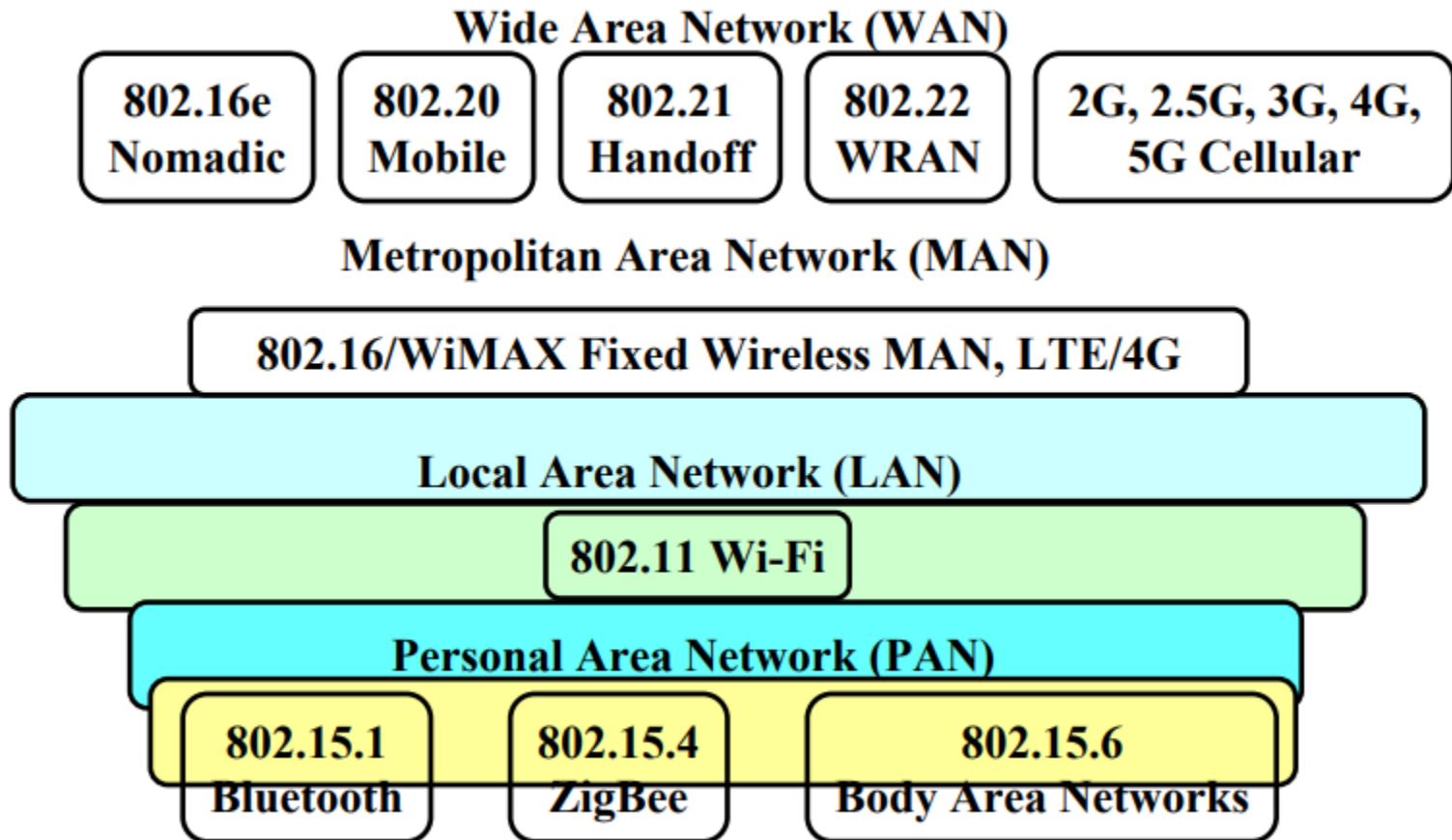


# IEEE 802.11 standard

- IEEE 802.11 Amendments
  - 802.11a-1999: Higher Speed PHY Extension in the 5 GHz Band
  - 802.11b-1999: Higher Speed PHY Extension in the 2.5 GHz Band
  - 802.11g-2003: Higher data rate extension in 2.4GHz band
  - 802.11n-2009: Enhancements for higher throughput (100+ Mbps)

# IEEE 802.11 standard

- IEEE 802.11 Amendments
  - 802.11ac-2013: Very High Throughput <6GHz
  - 802.11ad-2012: Very High Throughput 60 GHz
  - 802.11ah-2017: Sub 1 GHz for IoT, Transmission range up to 1 km, Data rates > 100 kb/s.
  - 802.11ax: High Efficiency WLAN. Extension of 802.11ac. Expected Dec 2019.
  - 802.11ay: Next Generation 60 GHz. Extension of 802.11ad. Expected Dec 2019.



# WPAN Characteristics

- Battery powered:  
Maximize battery life. A few hours to a few years on a coin cell.
- Dynamic topologies: Short duration connections and then device is turned off or goes to sleep
- No infrastructure
- Avoid Interference due to larger powered LAN devices
- Simple and Extreme Interoperability: Billions of devices. More variety than LAN or MAN
- Low-cost: A few dollars

# IEEE 802.15.4

- Used by several “Internet of Things” protocols: ZigBee, 6LoWPAN, Wireless HART, MiWi, and ISA 100.11a

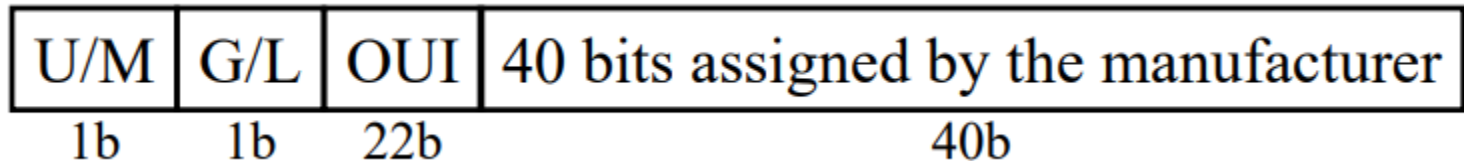
Application					
Network	ZigBee	6LoWPAN	Wireless HART	MiWi	ISA 100.11a
MAC	802.15.4	802.15.4	802.15.4	802.15.4	802.15.4
PHY	802.15.4	802.15.4	802.15.4	802.15.4	802.15.4

# IEEE 802.15.4 Overview

- Low Rate Wireless Personal Area Network (LR-WPAN)
- 2.4 GHz (most common). 16 5-MHz channels
- 250 kbps PHY => 50 kbps application data rate
- Similar to 802.11: Direct Sequence Spread Spectrum, CSMA/CA, Backoff, Beacon, Coordinator (similar to Access point)

# IEEE 802.15.4 Overview

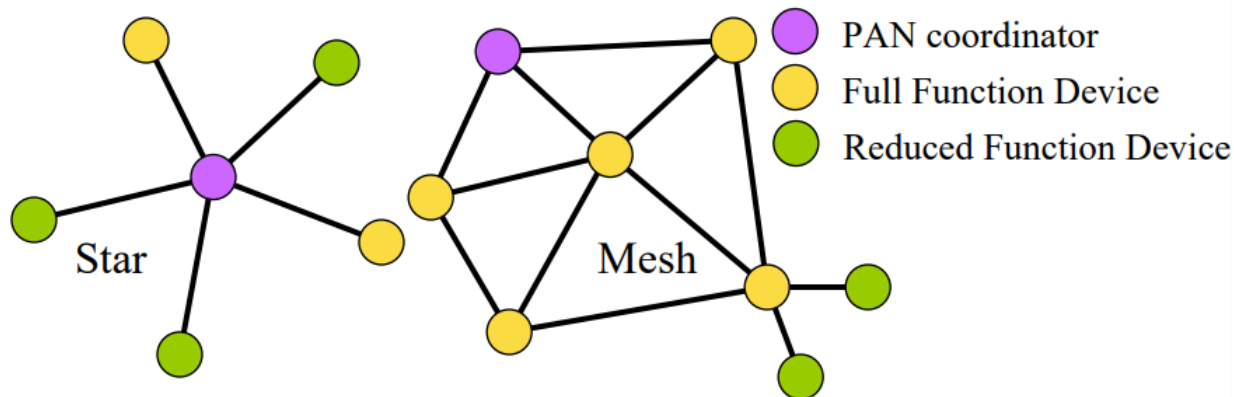
- Lower rate, short distance => Lower power => Low energy
- Each node has a 64-bit Extended Unique ID (EUI-64):



- No segmentation/reassembly. Max MAC frame size is 127 bytes with a payload of 77+ bytes.

# IEEE 802.15.4 Topologies

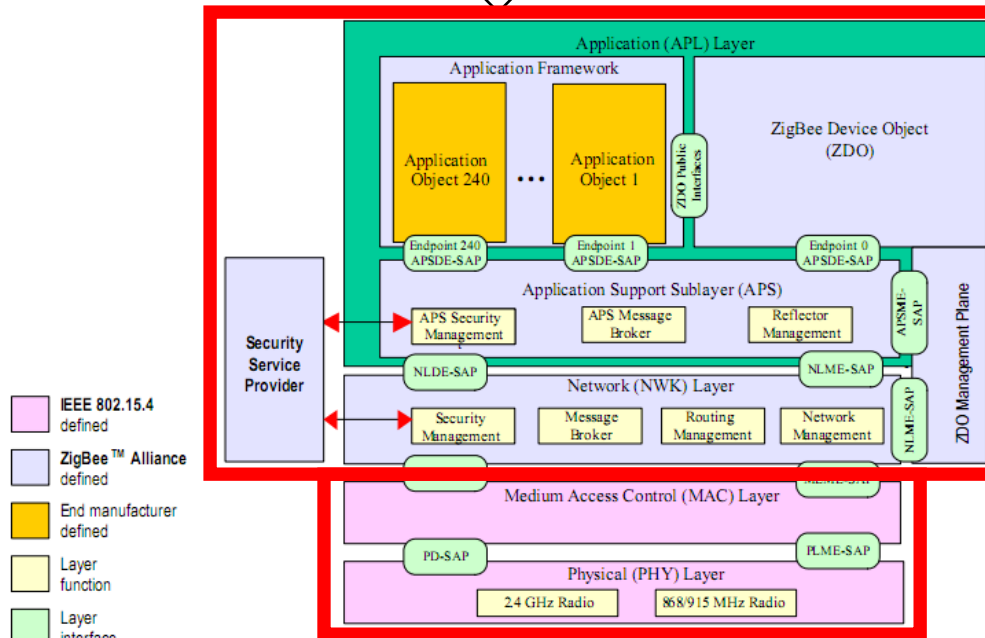
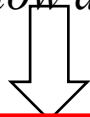
- Star and peer-to-peer
- Two types of devices: Full Function device (FFD), Reduced Function device (RFD)





# IEEE 802.15.4/ZigBee

*“low cost, low power, low data rate wireless networking”*



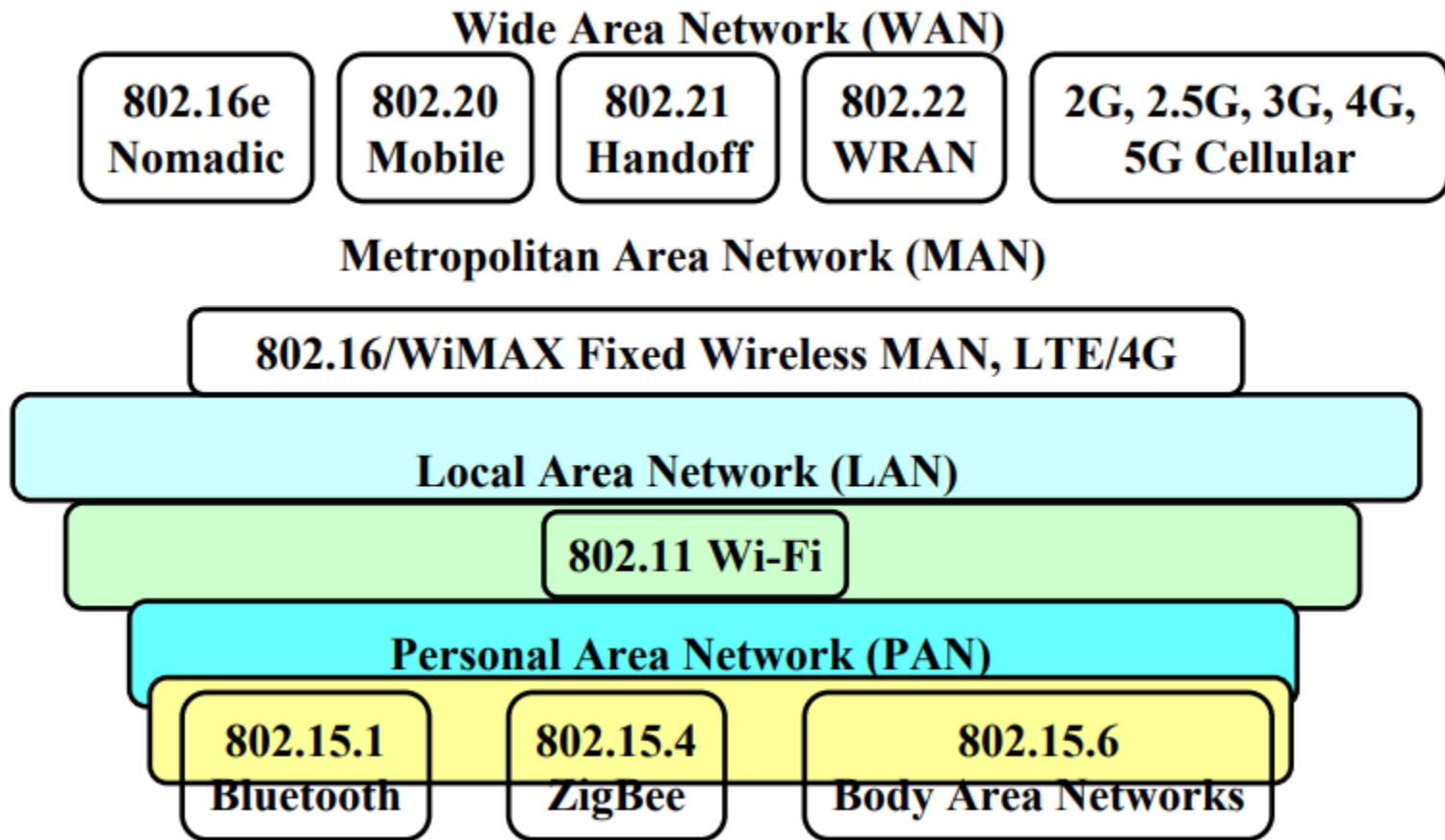
Source: ZigBee Specification Document



- “The Software”
- Network, Security & Application Layers

## IEEE 802.15.4

- “The Hardware”
- Physical & Medium Access Control Layers



# Bluetooth

- Started with Ericsson's Bluetooth Project in 1994 for radiocommunication between cell phones over short distances
- Named after Danish king Herald Blatand (AD 940-981) who was fond of blueberries
- Intel, IBM, Nokia, Toshiba, and Ericsson formed Bluetooth SIG in May 1998

# Bluetooth

- Key Features:
  - Lower Power: 10 mA in standby, 50 mA while transmitting
  - Cheap: \$5 per device
  - Small: 9 mm<sup>2</sup> single chips

# Bluetooth Versions

- Bluetooth 1.1: IEEE 802.15.1-2002
- Bluetooth 1.2: IEEE 802.15.1-2005, Higher variable rate retransmission, Adaptive frequency hopping
- Bluetooth 2.0: Enhanced Data Rate for video applications, reduced power due to reduced duty cycle

# Bluetooth Versions

- Bluetooth 2.1 (July 2007): Enhanced Data Rate, Secure Simple Pairing to speed up pairing
- Bluetooth 3.0 (April 2009): High Speed
- Bluetooth 4.0 (June 2010): Low energy, Smaller devices requiring longer battery life (several years). New incompatible PHY. Bluetooth Smart or BLE

# Bluetooth Versions

- Bluetooth 4.1: 4.0 + Core Specification Amendments (CSA) 1, 2, 3, 4
- Bluetooth 4.2 (Dec 2014): Larger packets, security/privacy, IPv6 profile

# Bluetooth Versions

- Bluetooth 5
  - 2X Data rate using a new modulation
  - 4X range using a special coding
  - 8X broadcast capacity by changing the advertising procedure
  - +20 dBm transmit power available



# Bluetooth: Details

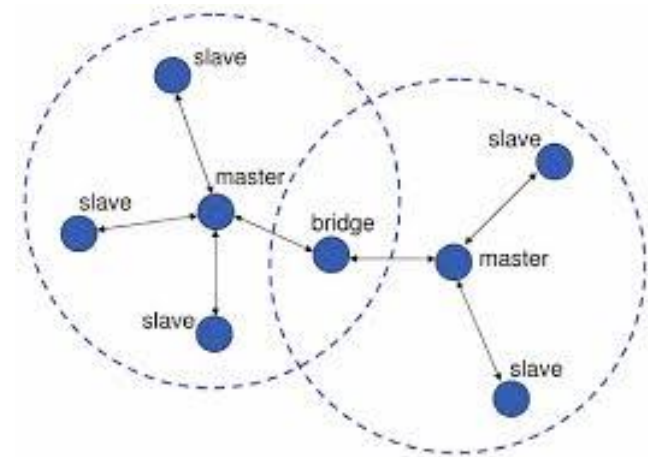
- Frequency Range: 2402 - 2480 MHz (total 79 MHz band) 23 MHz in some countries, e.g., Spain
- Data Rate: 1 Mbps using 1 MHz (Nominal) 720 kbps (User)
- Radio Frequency hopping: 1600 times/s => 625 ms/hop

# Bluetooth: Details

- Security: Challenge/Response Authentication. 128b Encryption
- TX Output Power:
  - Class 1: 20 dBm Max. (0.1 W) – 100m
  - Class 2: 4 dBm (2.5 mW)
  - Class 3: 0 dBm (1mW) – 10m

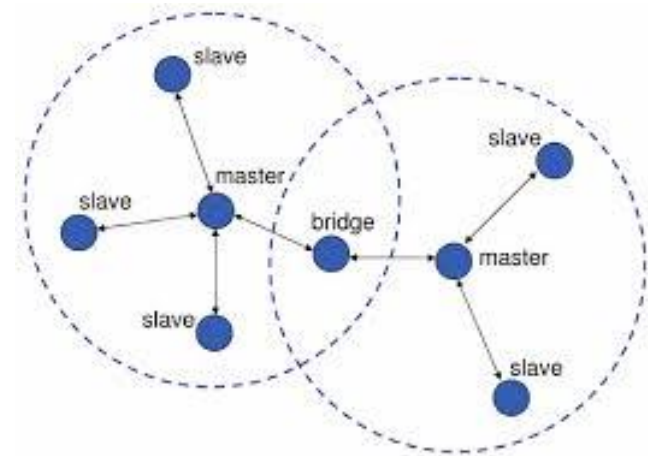
# Bluetooth: Piconet

- Piconet is formed by a master and many slaves
  - Up to 7 active slaves. Slaves can only transmit when requested by master
  - Up to 255 Parked slaves



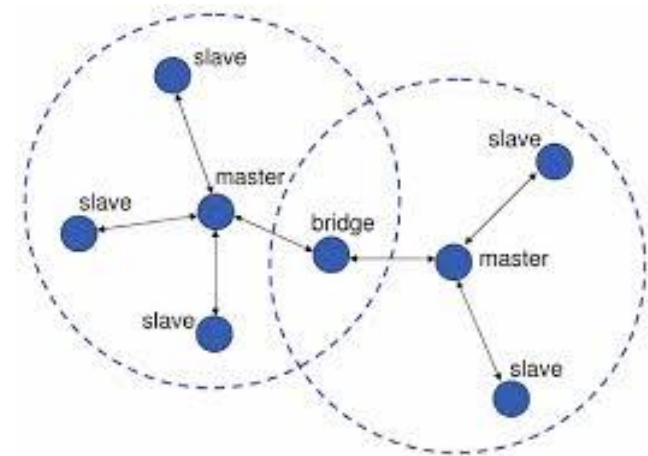
# Bluetooth: Piconet

- Piconet:
  - Active slaves are polled by master for transmission
  - Each station gets a 8-bit parked address => 255 parked slaves/piconet



# Bluetooth: Scatter net

- Scatter net: A device can participate in multiple Pico nets => Timeshare and must synchronize to the master of the current piconet. Routing protocol not defined.



# Bluetooth Smart

- Low Energy: 1% to 50% of Bluetooth classic
- For short broadcast: body temperature, Heart rate, Wearables, sensors, automotive, industrial. Not for voice/video, file transfers, ...
- Small messages: 1Mbps data rate but throughput not critical.

# Bluetooth Smart

- Battery life: In years from coin cells
- Simple: Star topology. No scatter nets, mesh, ...
- Lower cost than Bluetooth classic

# Bluetooth Smart

- New protocol design based on Nokia's WiBree technology Shares the same 2.4GHz radio as Bluetooth =>Dual mode chips
- All new smart phones (iPhone, Android, ...) have dual-mode chips



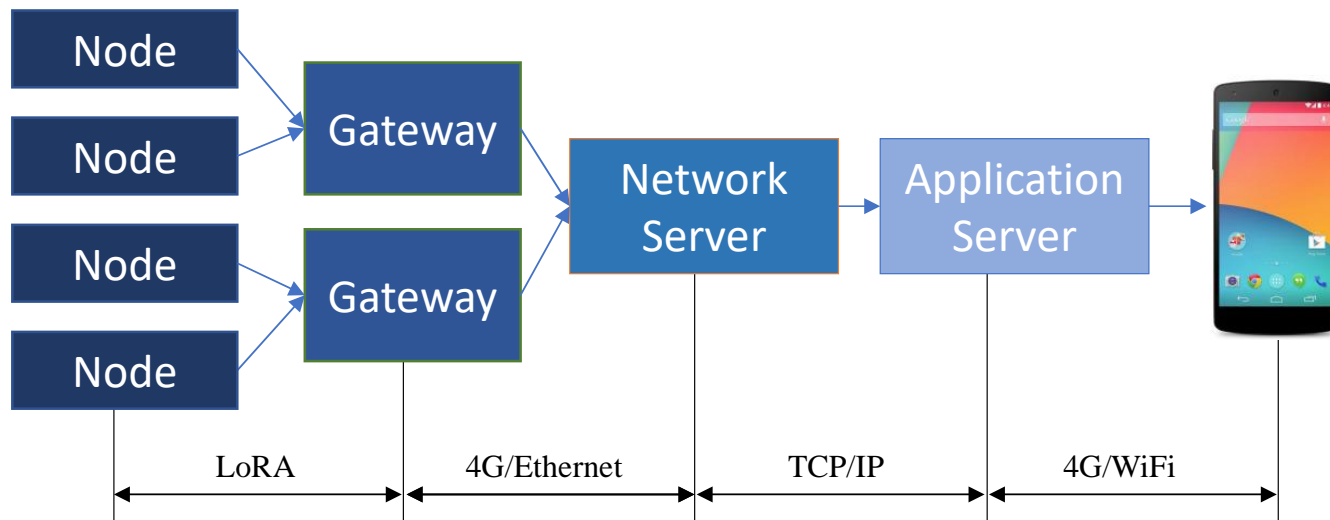
# Low Power Wide Area Network

- LPWAN is becoming popular day-by-day
- Long Range
- Low Power
- Low Data Rate

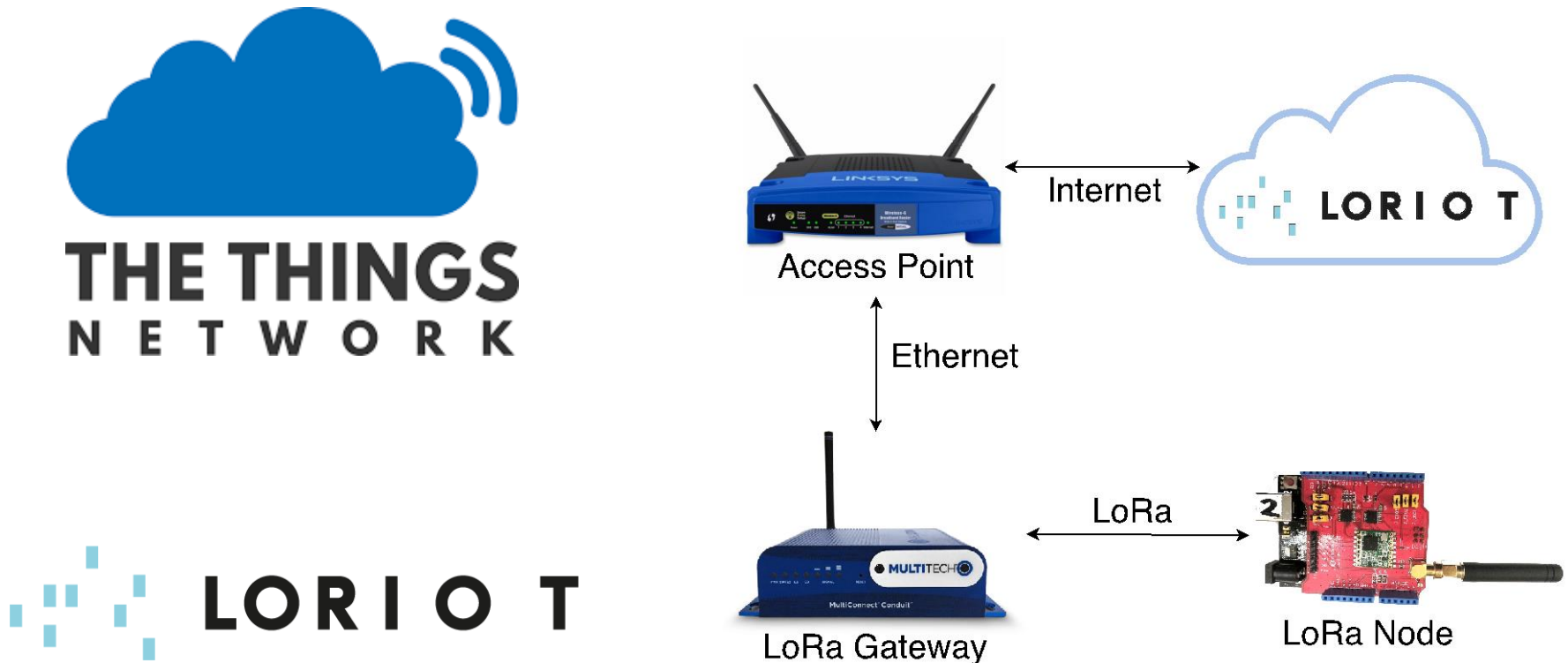


# Overview of LoRa

- Long Range: *9 miles*
- Low Power: *10 years*
- Low Data Rate: *50 kbps*



# Implementation (Application Server)



# Summary

- Wireless Technologies in IoT
- Wireless Technology Characteristics
- 802.11 or Wifi
- Wireless Personal Area Networks (WPAN)
- Bluetooth Technology
- LPWAN/LoRa

