

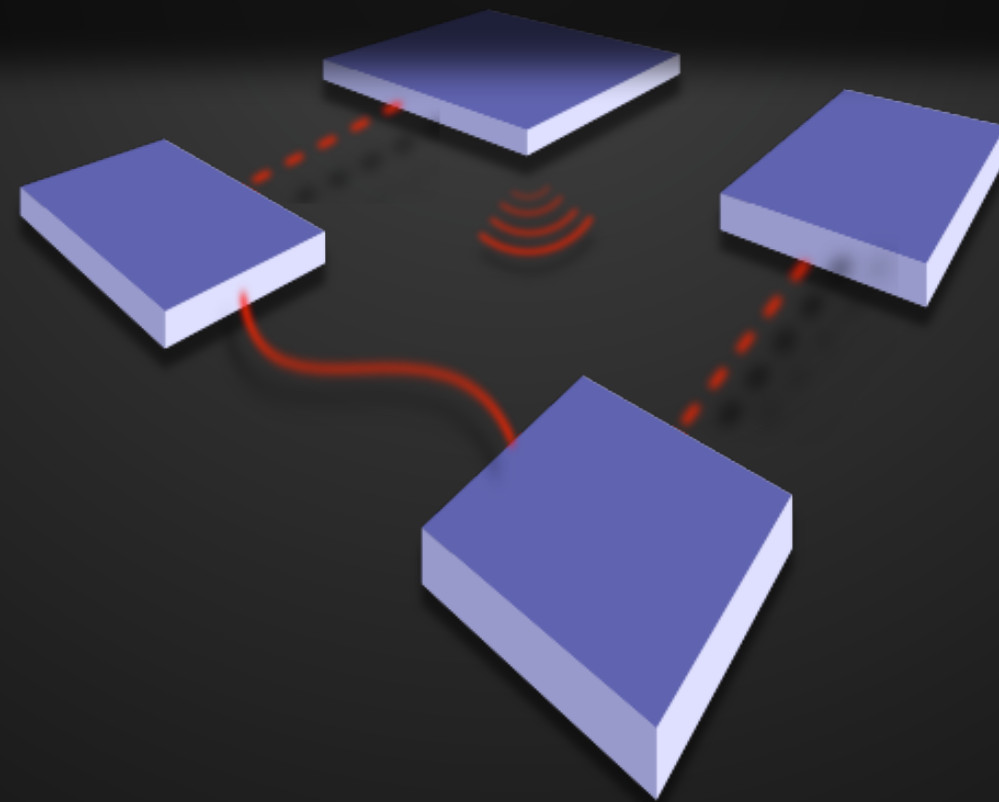
CS-435

spring semester 2025

Network Technology & Programming Laboratory

University of Crete
Computer Science Department

Stefanos Papadakis



CS-435

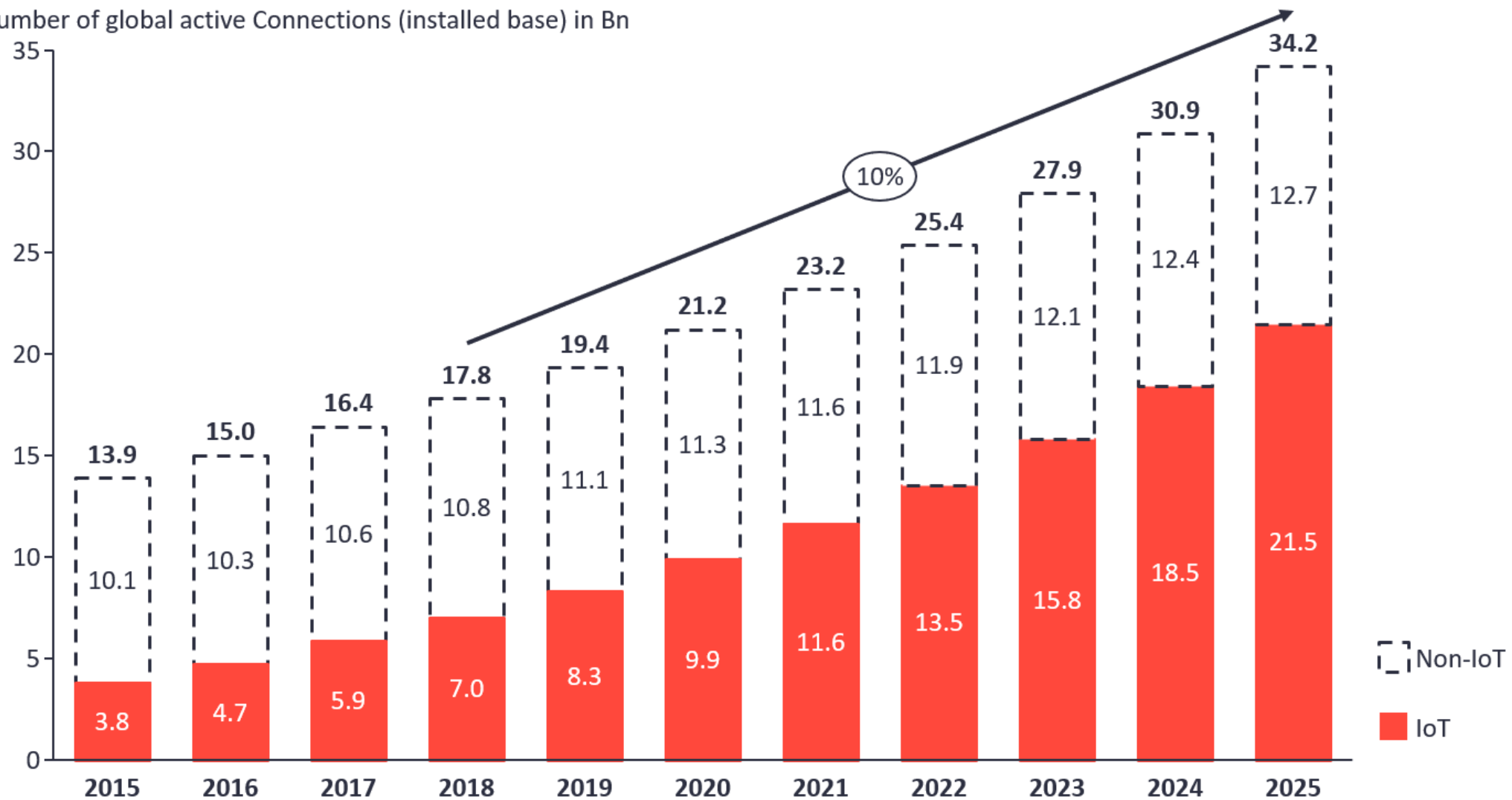
Lecture #14 preview:

- IoT
- PAN

Internet of Things

Total number of active device connections worldwide

Number of global active Connections (installed base) in Bn

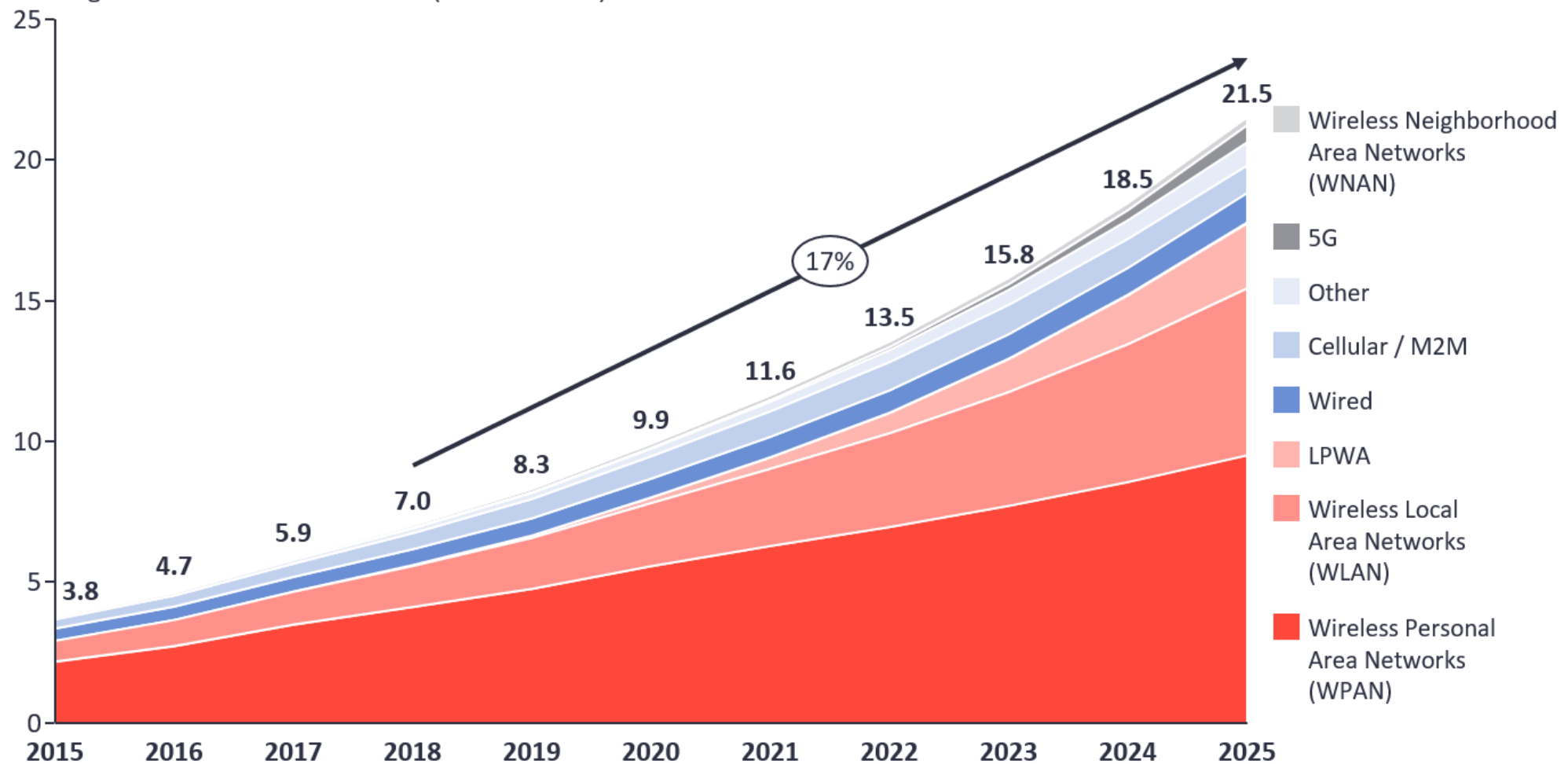


Note: Non-IoT includes all mobile phones, tablets, PCs, laptops, and fixed line phones. IoT includes all consumer and B2B devices connected – see IoT break-down for further details
Source: IoT Analytics Research 2018

Internet of Things

Global Number of Connected IoT Devices

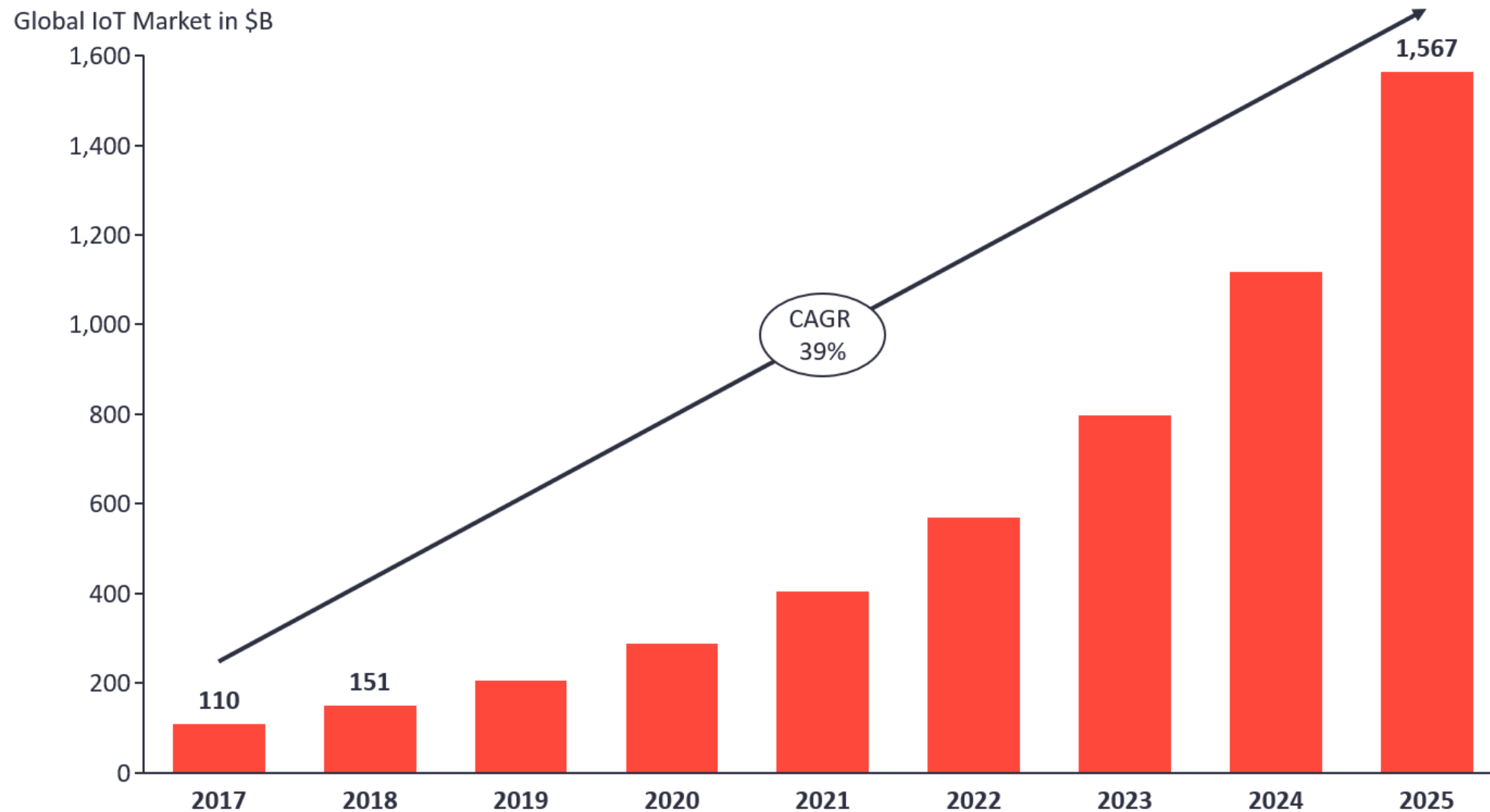
Number of global active IoT Connections (installed base) in Bn



Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes Ethernet and Fieldbuses (e.g., connected industrial PLCs or I/O modules); Cellular includes 2G, 3G, 4G; LPWAN includes unlicensed and licensed low-power networks; WPAN includes Bluetooth, Zigbee, Z-Wave or similar; WLAN includes Wi-fi and related protocols; WNAN includes non-short range mesh; Other includes satellite and unclassified proprietary networks with any range.
Source: IoT Analytics Research 2018

Internet of Things

Global IoT Market Forecast



Note: Market defined as total spend of end-users on IoT solutions
Source: IoT Analytics Research 2018

Internet of Things

- Smart Home/Building/City/everything
- V2X (vehicle to everything)
 - V2V (vehicle to vehicle)
 - V2I (vehicle to infrastructure)
- IIoT (Industrial IoT)
- IoMT (Internet of Medical Things) / Smart Healthcare
- IoMT (Internet of Military Things)

Smart Home Example

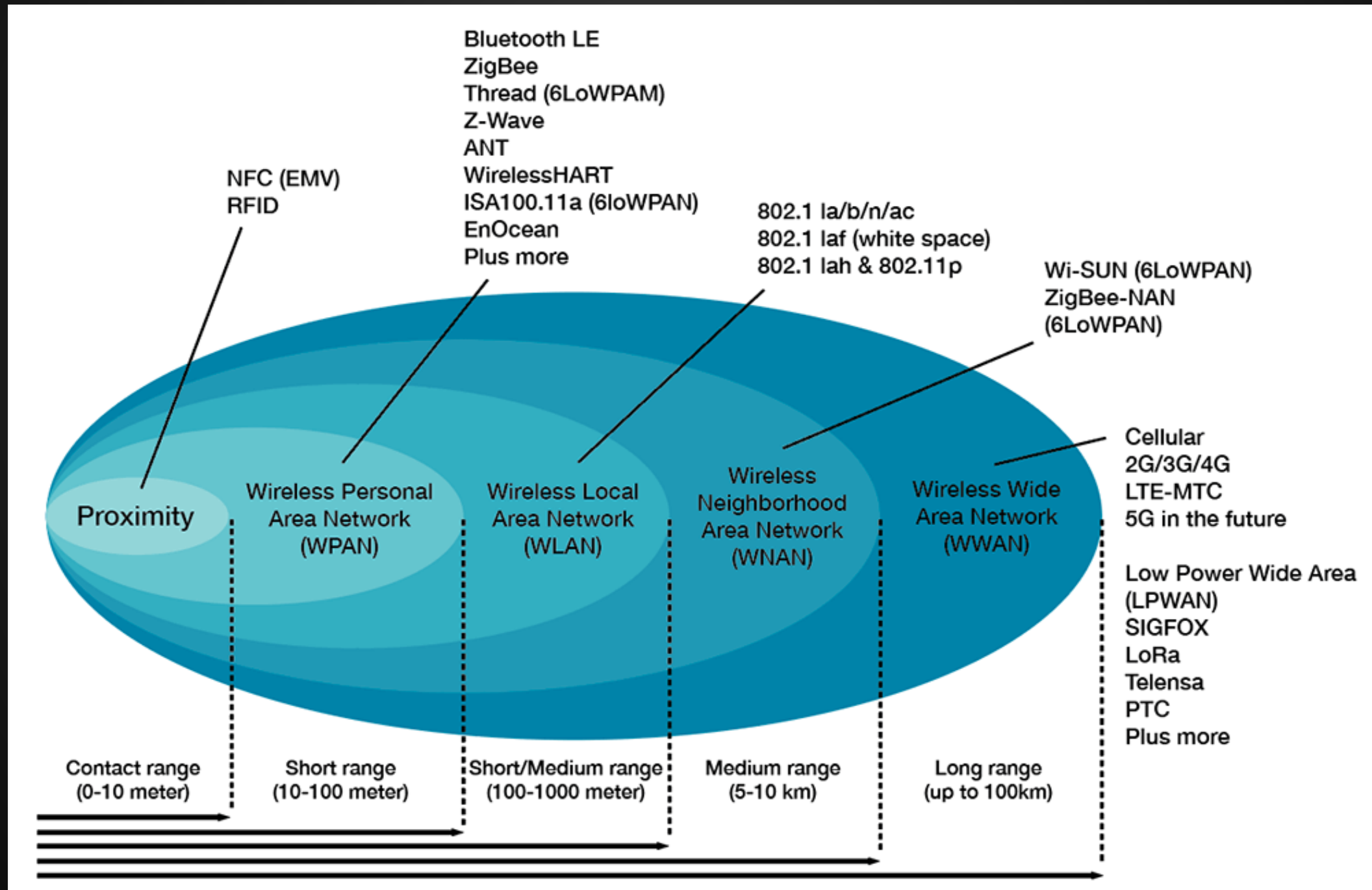


Internet of Things

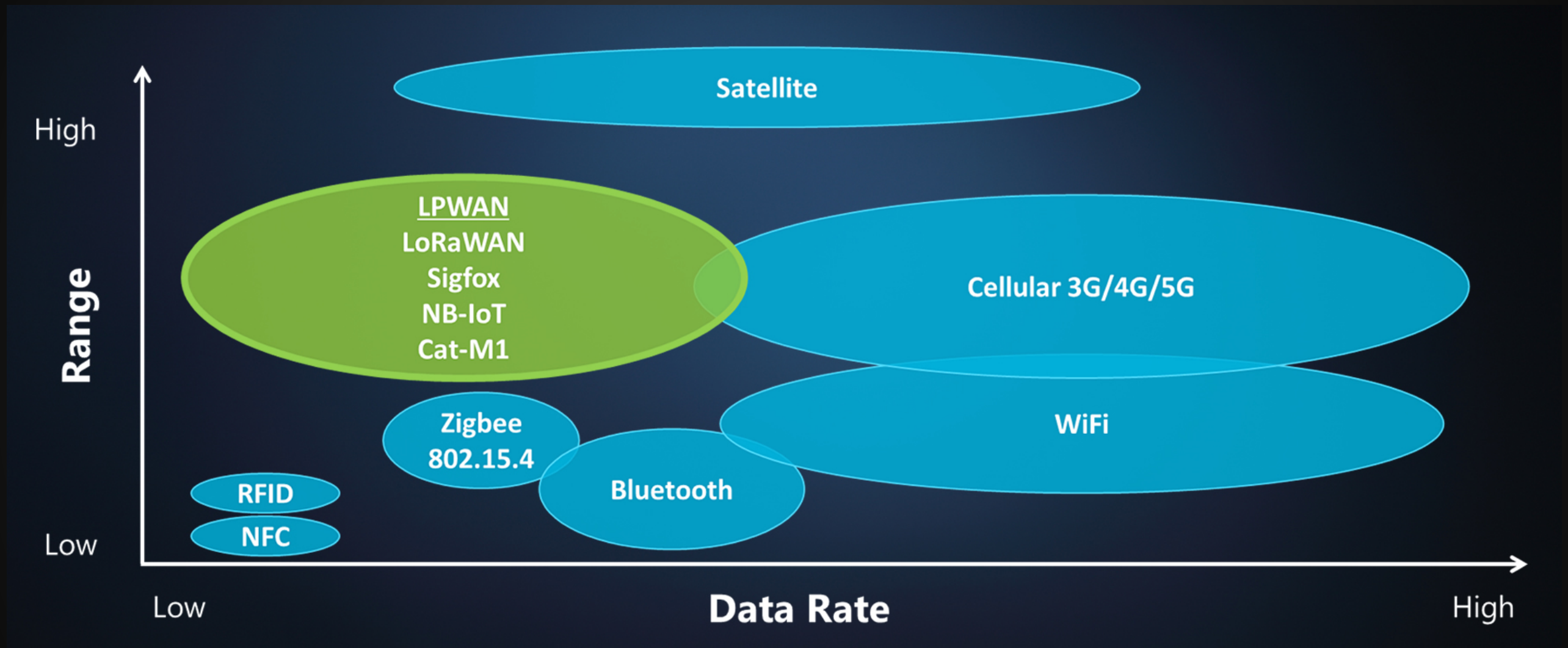
- Wi-Fi [IEEE 802.11]
- BLE
- Zigbee - 6LoWPAN - Thread [IEEE 802.15.4]
- LoRaWAN
- SigFOX
- Z-Wave
- 5G...

Types of Networks

Area Taxonomy



Comparison



Comparison

	2017	2018	2019	2020	2021
Sigfox	8424	14538	27951	52281	85042
LoRa	32316	57298	98162	161561	247724
IEEE 802.15.4	290000	320000	450000	600000	750000
LTE Cat-M1	1978	8571	20284	28801	52288
NB - IoT	16166	34062	84885	161628	222902
Other	4022	6201	8714	7069	8402

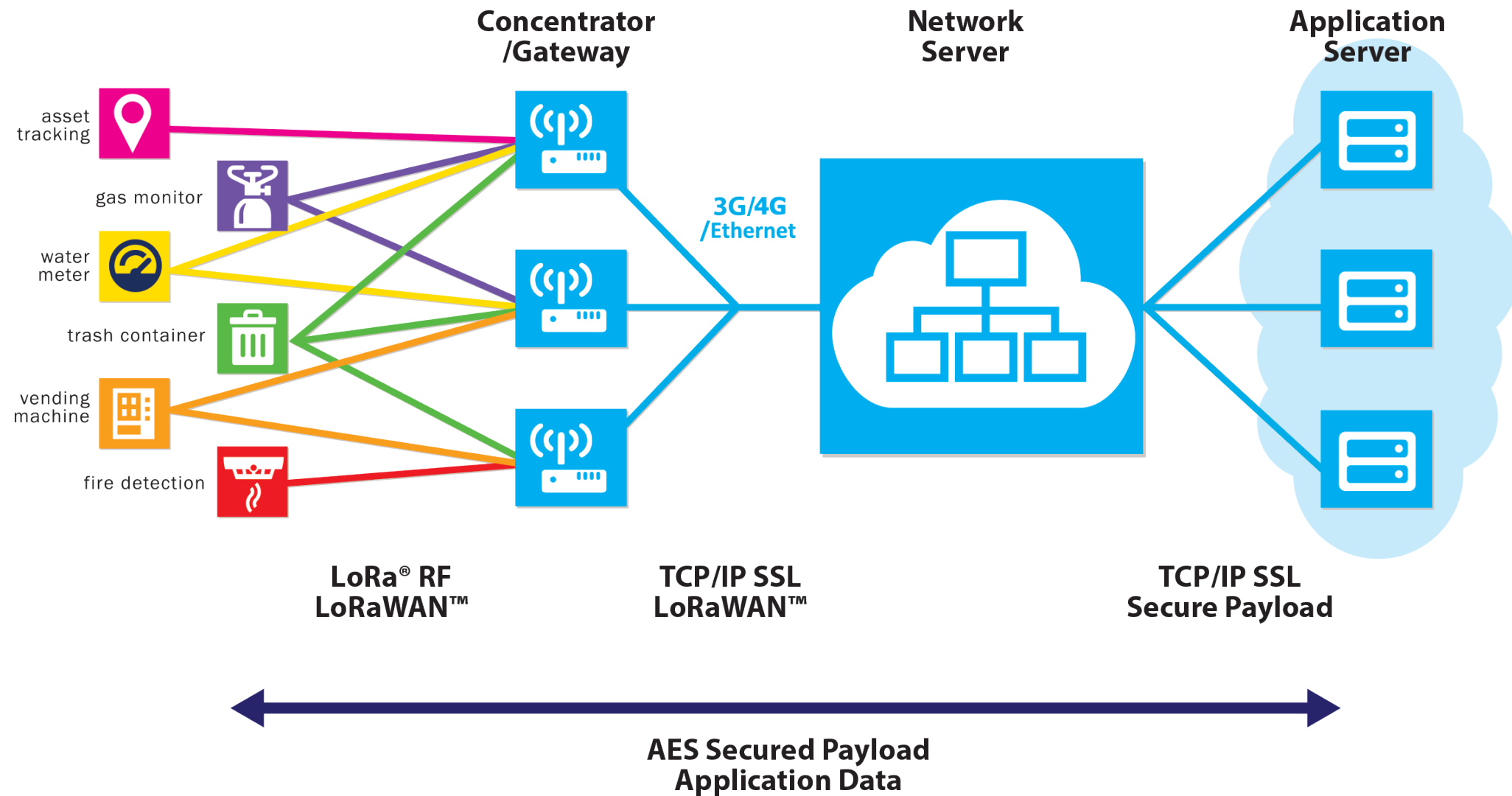
Table 1.1: Global Annoual Unit Shipment of LPWAN Modules in thousands

Comparison

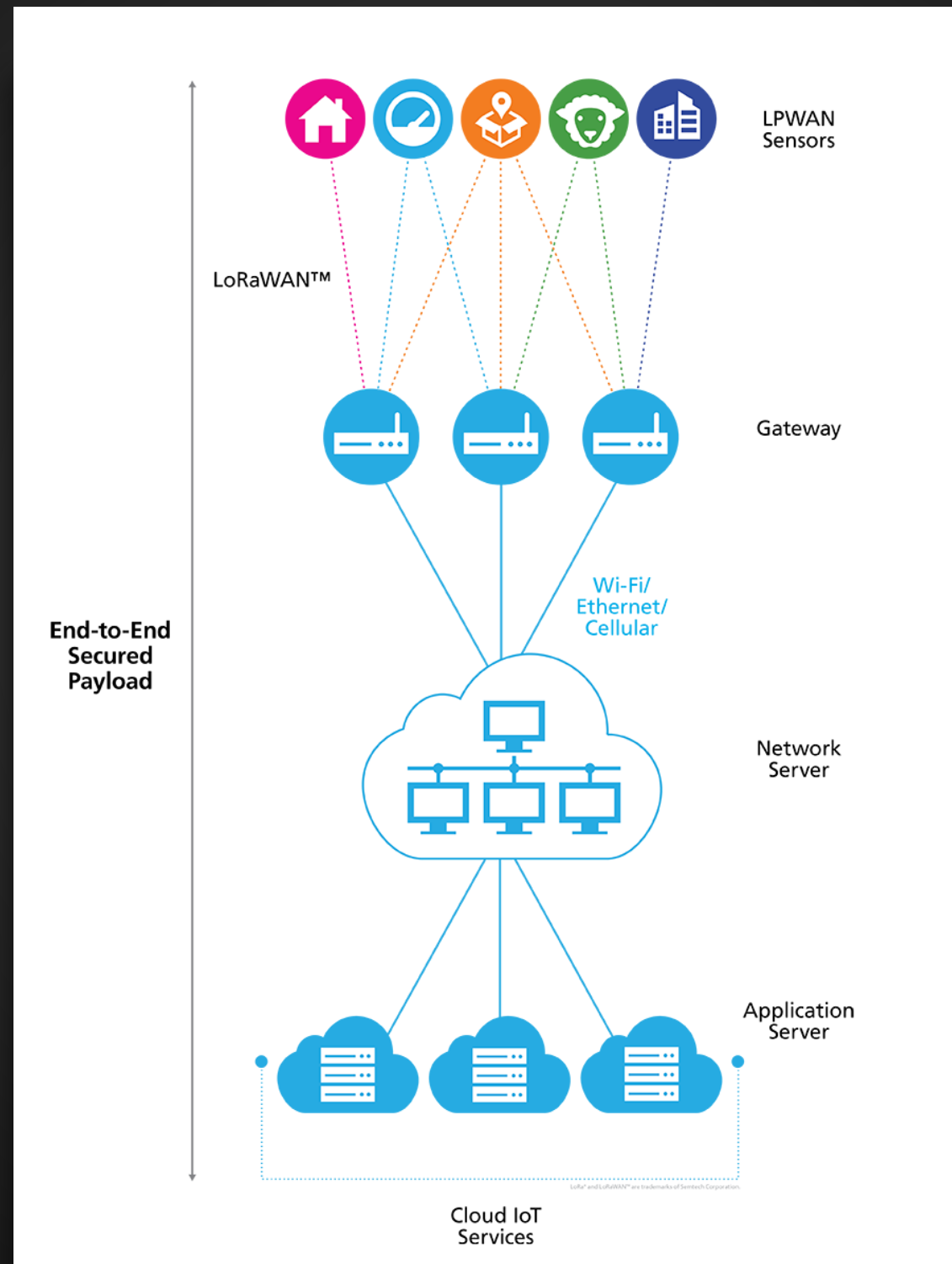
	LoRa	Sigfox	NWave	On-Ramp	Telensa	IEEE 802.15.4g
Range (km)	3-8 urban 15-20 suburban 15-45 flat	3-10 urban 30-50 suburban	10	4	Up to 8	Up to 1
Frequency Band	Sub-GHz	Sub-GHz	Sub-GHz	2.4 GHz	Sub-GHz	Sub-GHz
Modulation	Spread Spectrum	Ultra NarrowBand	Ultra NarrowBand	Spread Spectrum	Ultra NarrowBand	FSK
Data rate (Kbps)	0.3-22	0.1-0.6	0.1	19 per MHz	up to 0.5	50-200
OTA upgrades	Yes	No	Yes	Yes	Yes	Yes

Table 2.1: Popular LPWAN protocols and their characteristics

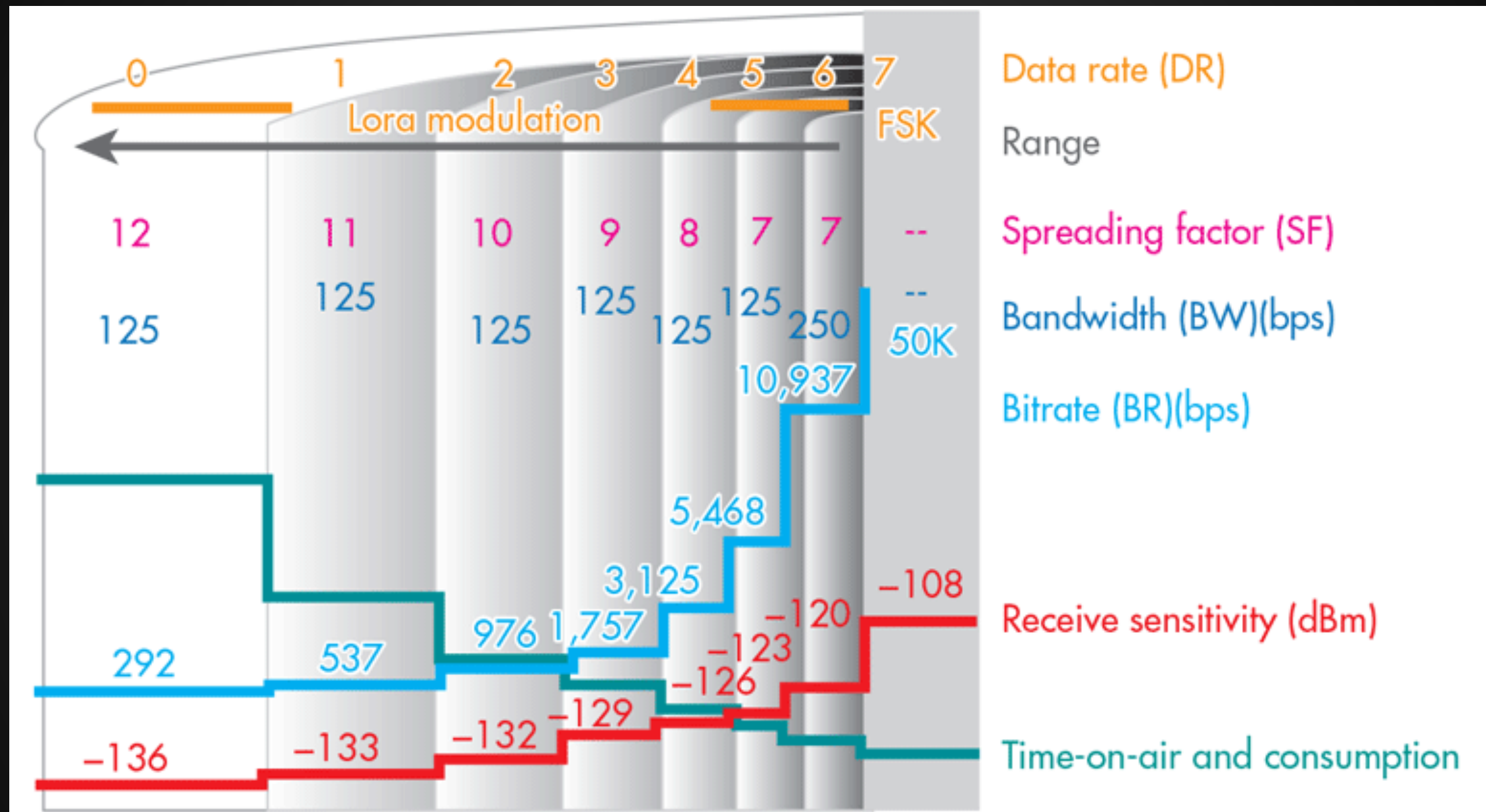
LoRaWAN



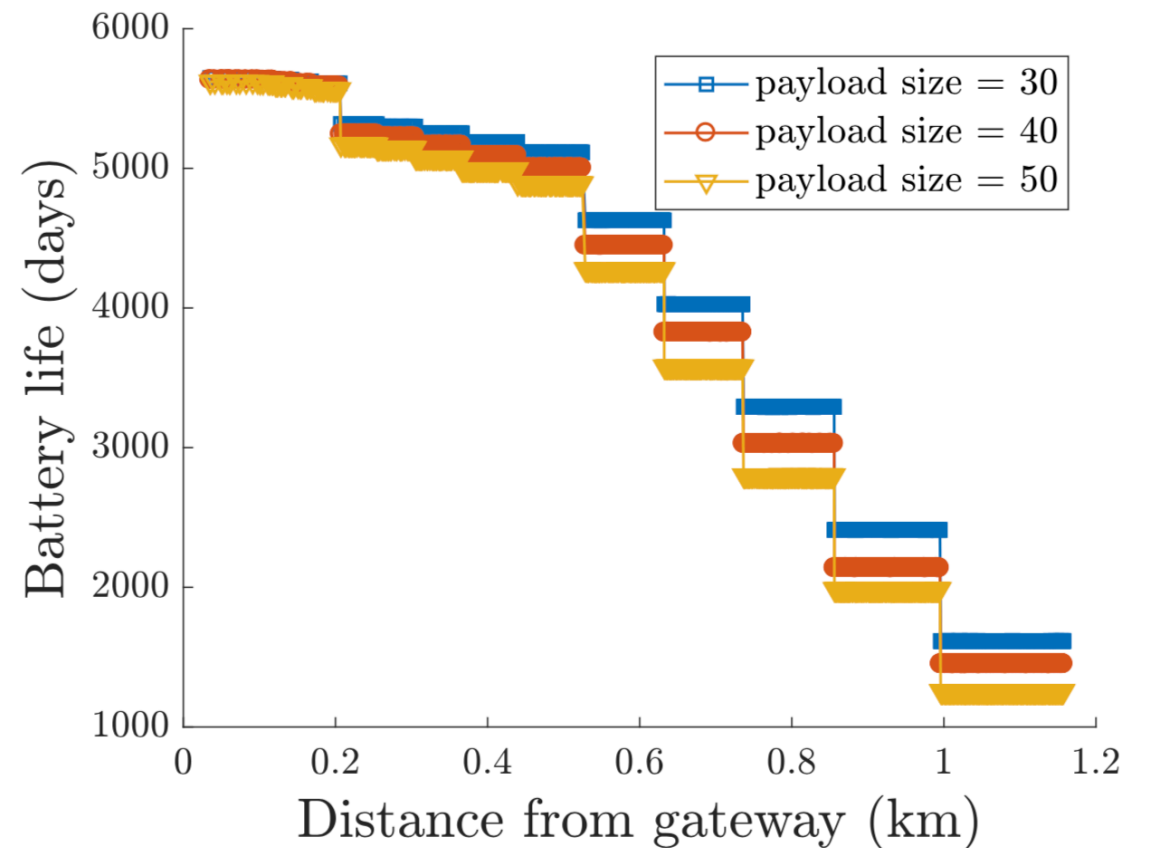
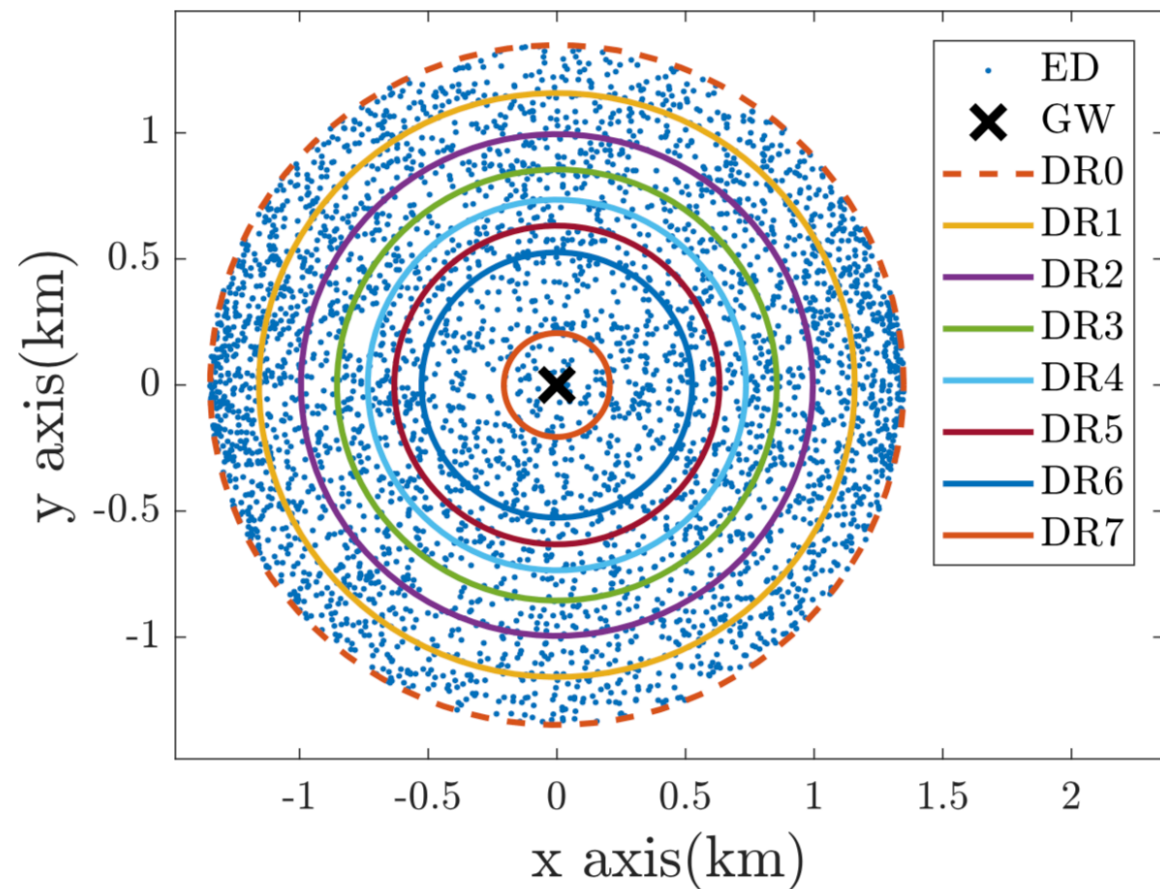
LoRaWAN



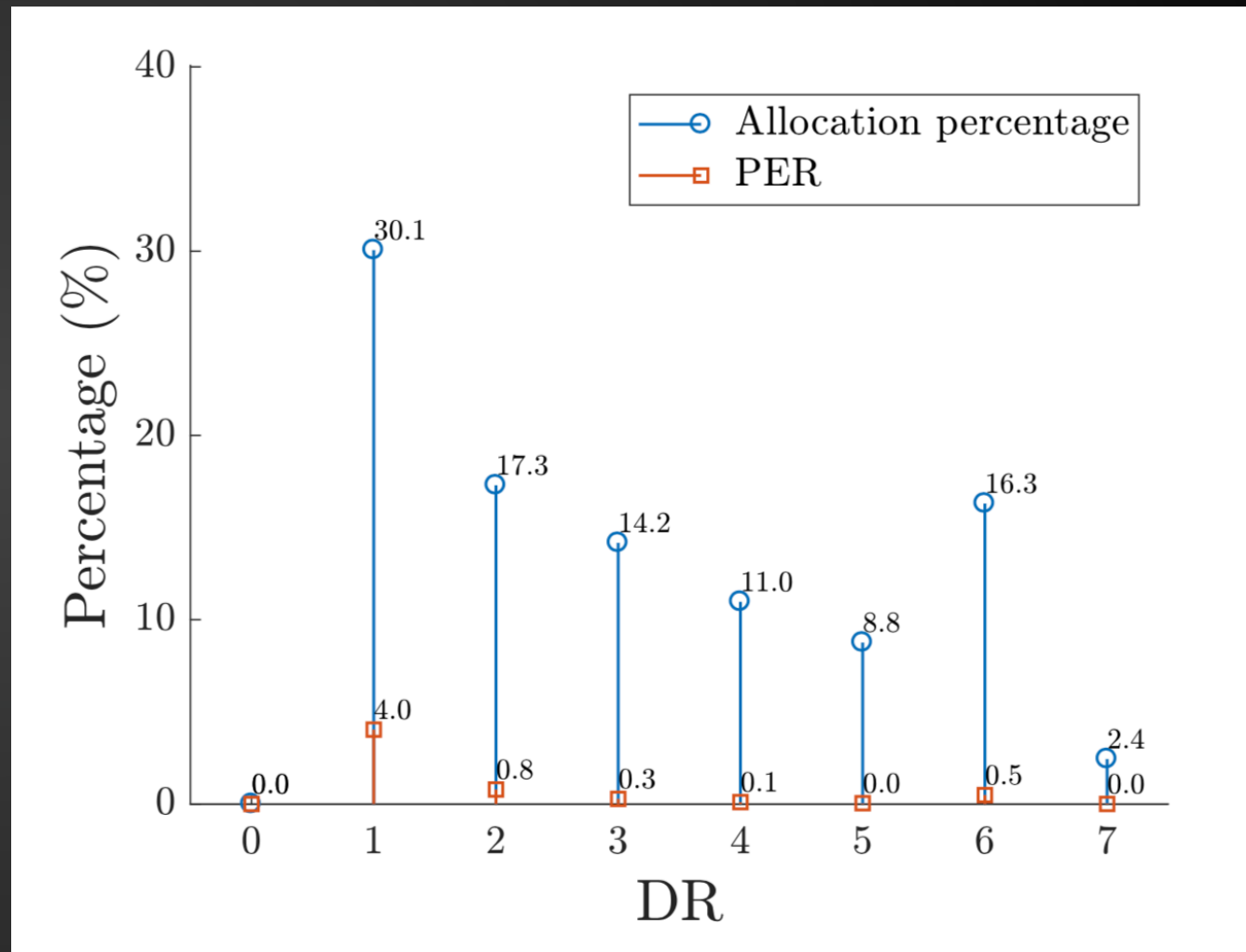
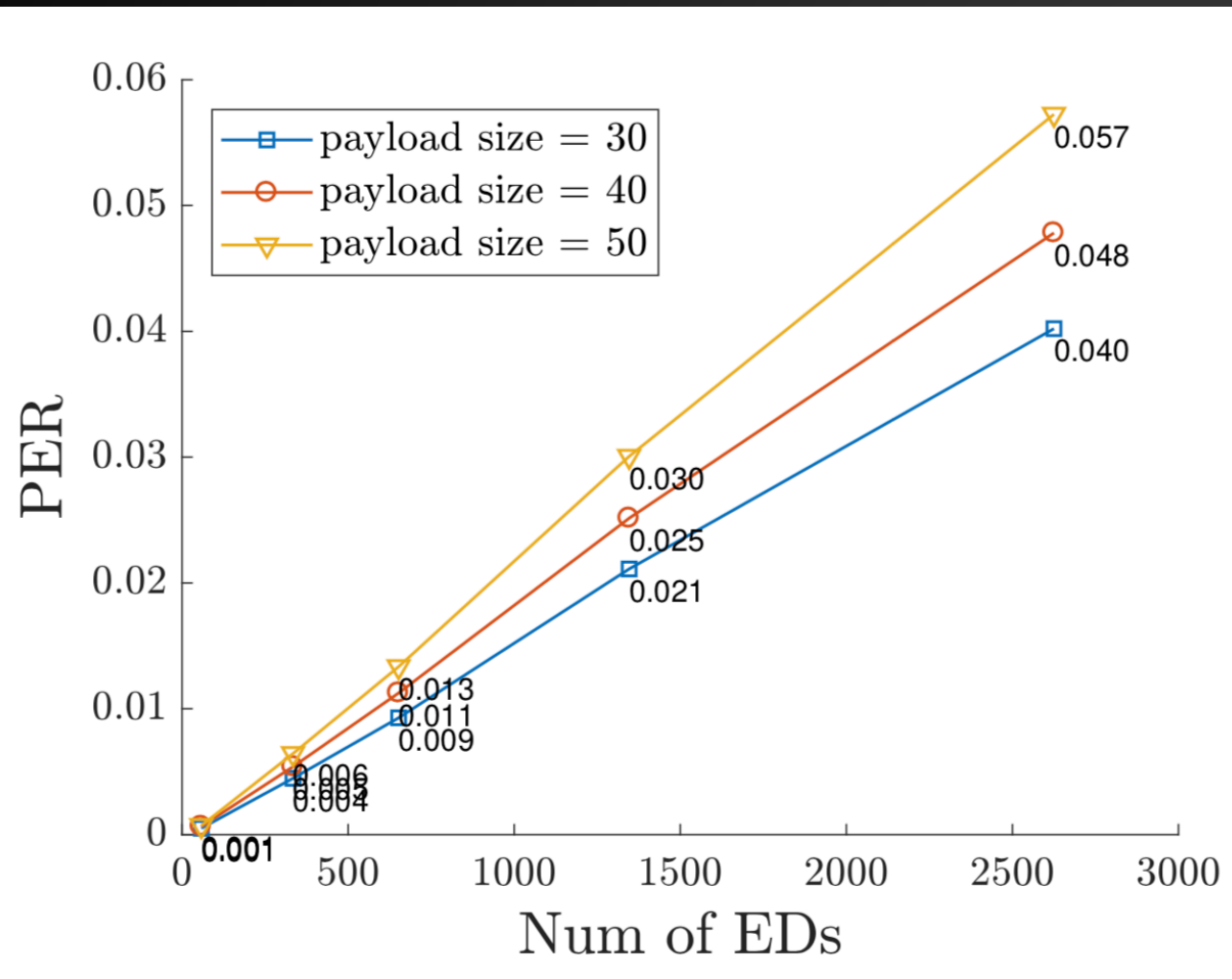
LoRaWAN



LoRaWAN



LoRaWAN

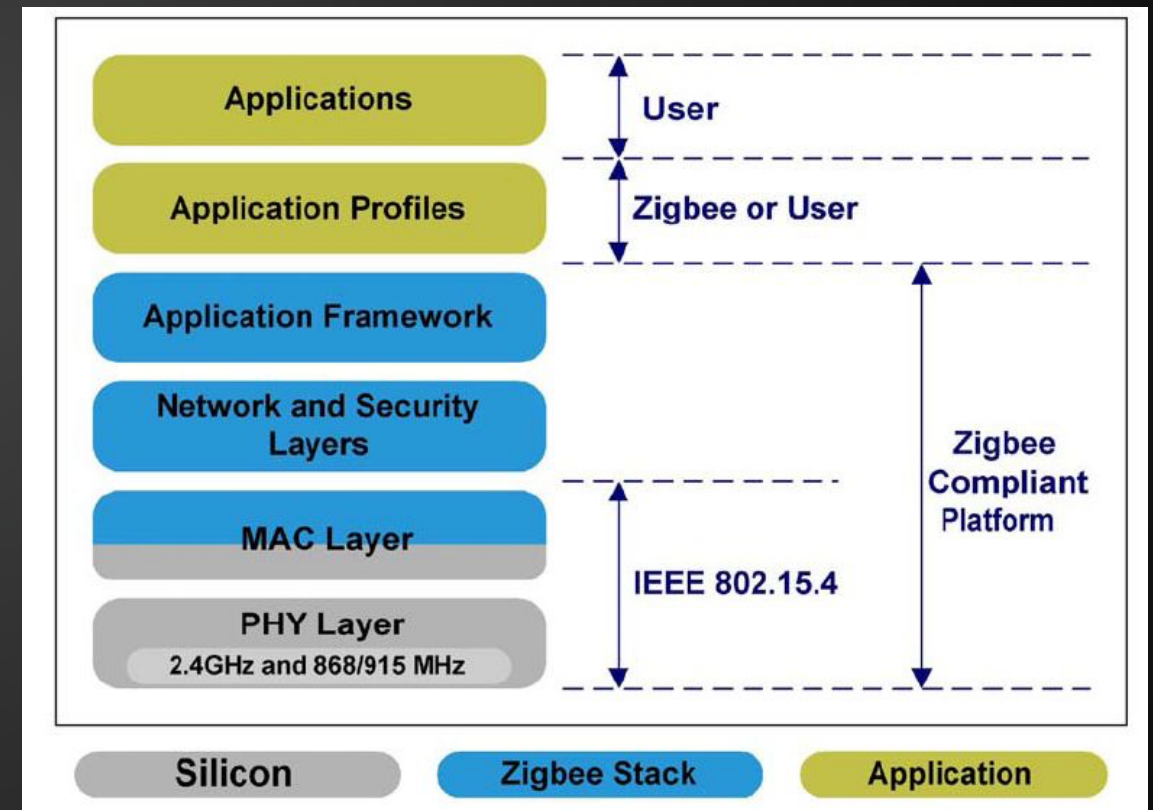
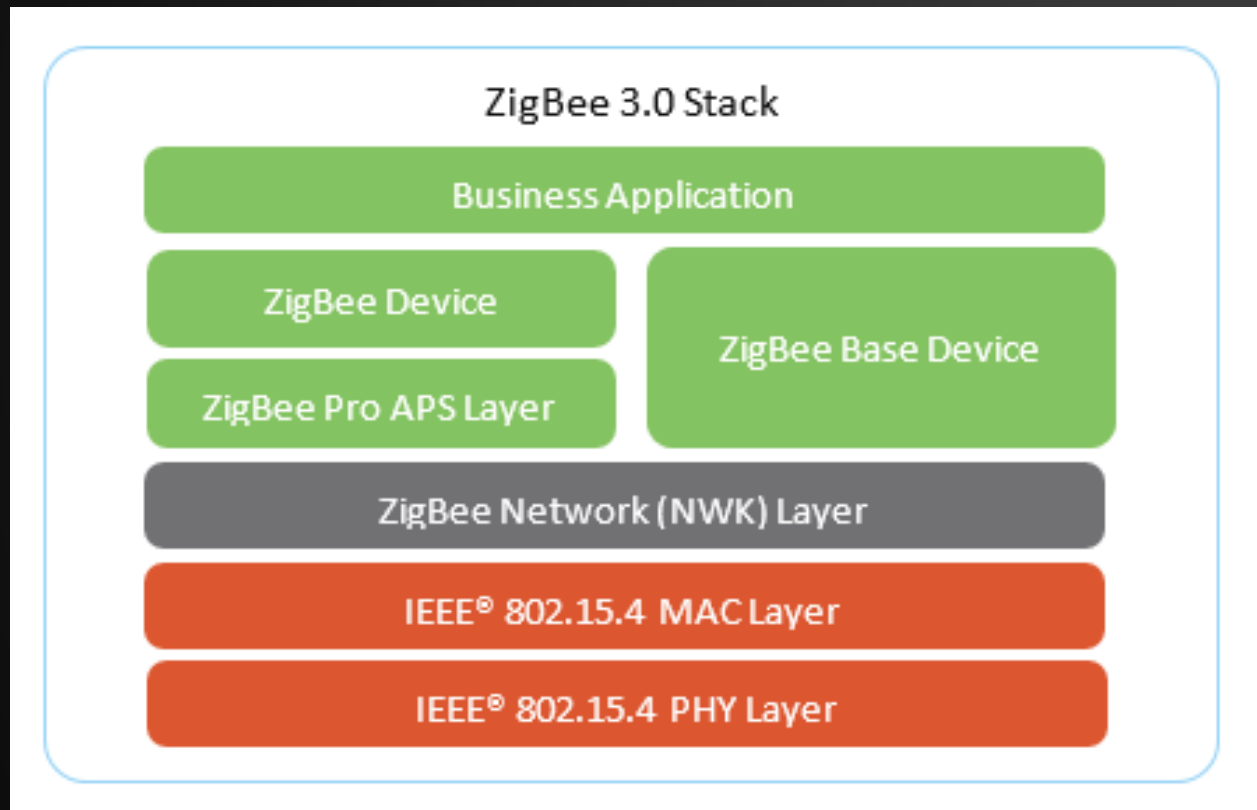


LoRaWAN

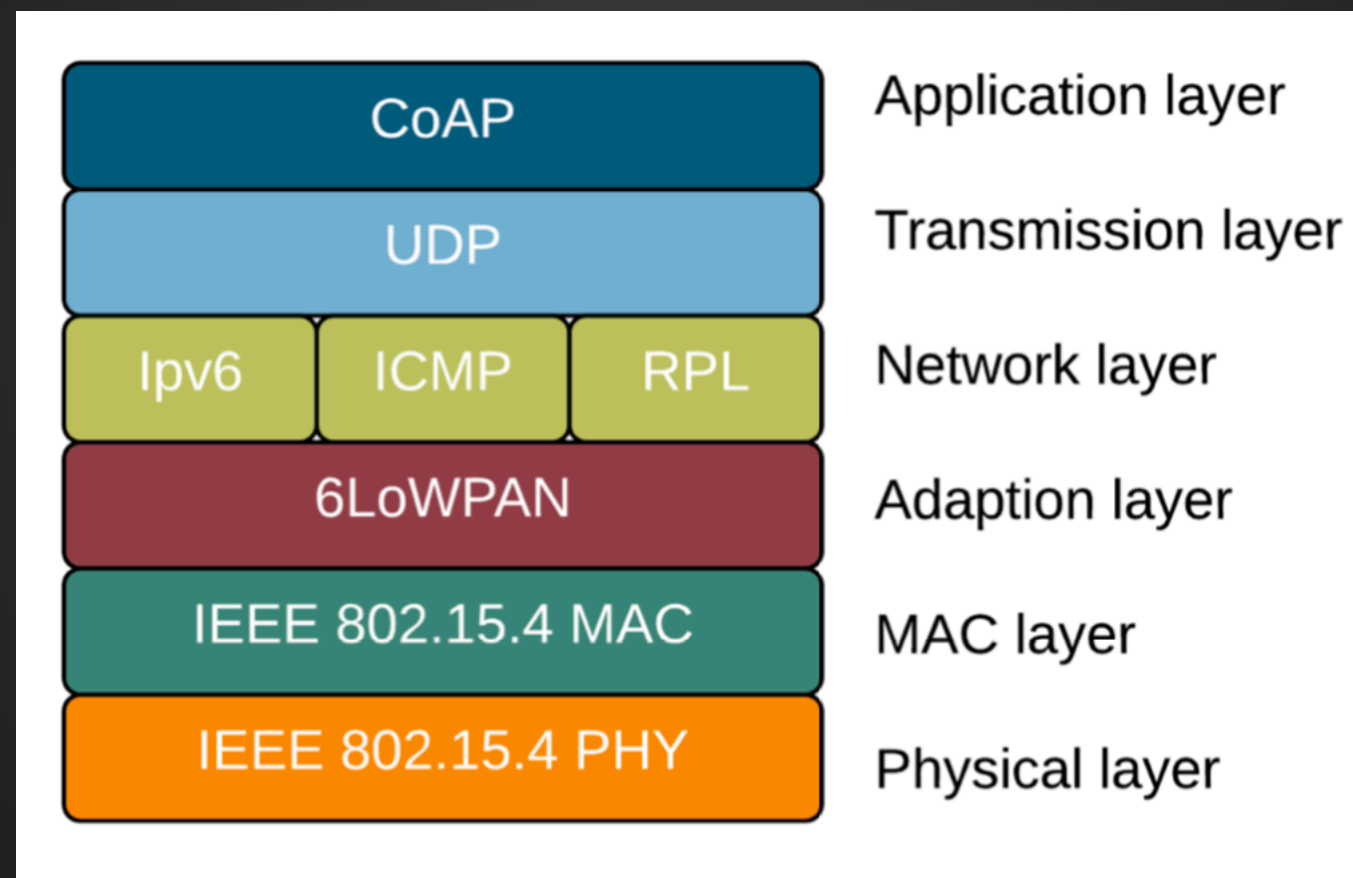
Spreading Factor	SNR (dB)
7	-7.5
8	-10
9	-12.5
10	-15
11	-17.5
12	-20

Table 3.2: SNR values for success demodulation of different SF

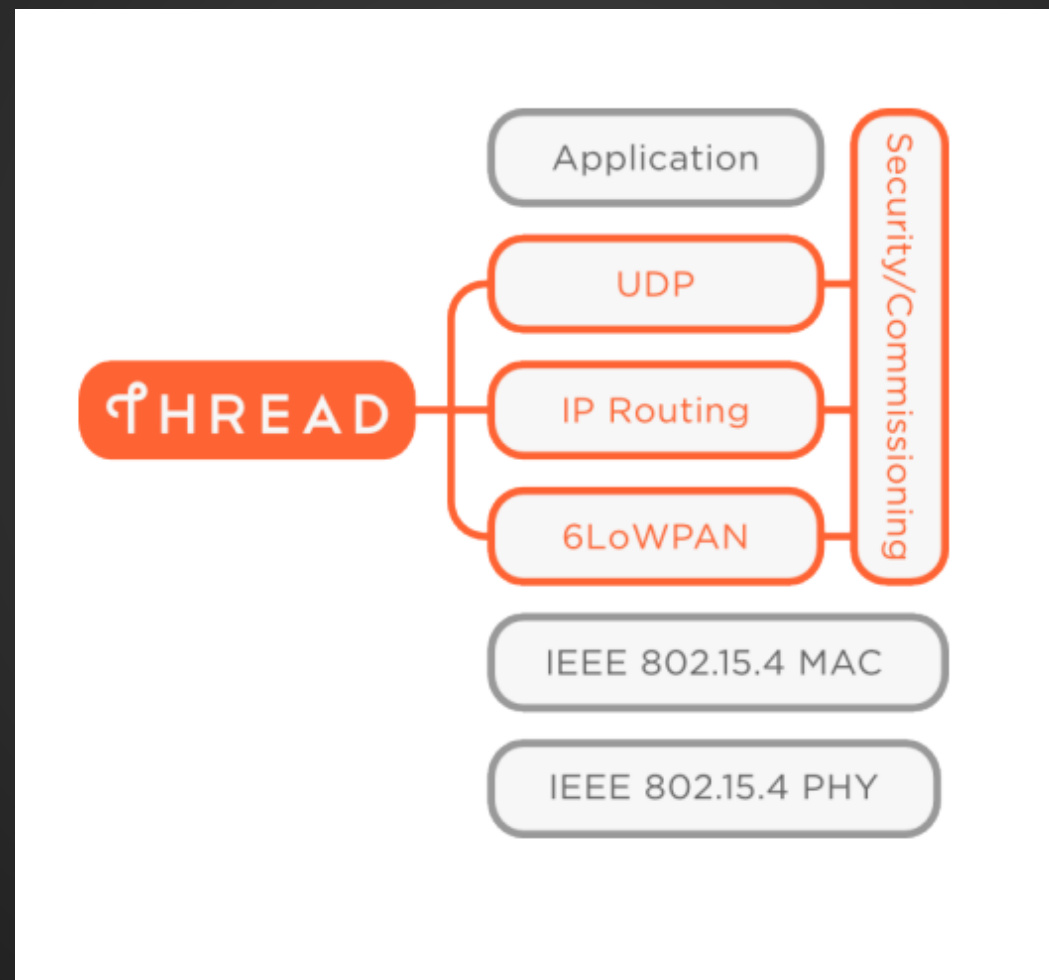
Zigbee stack



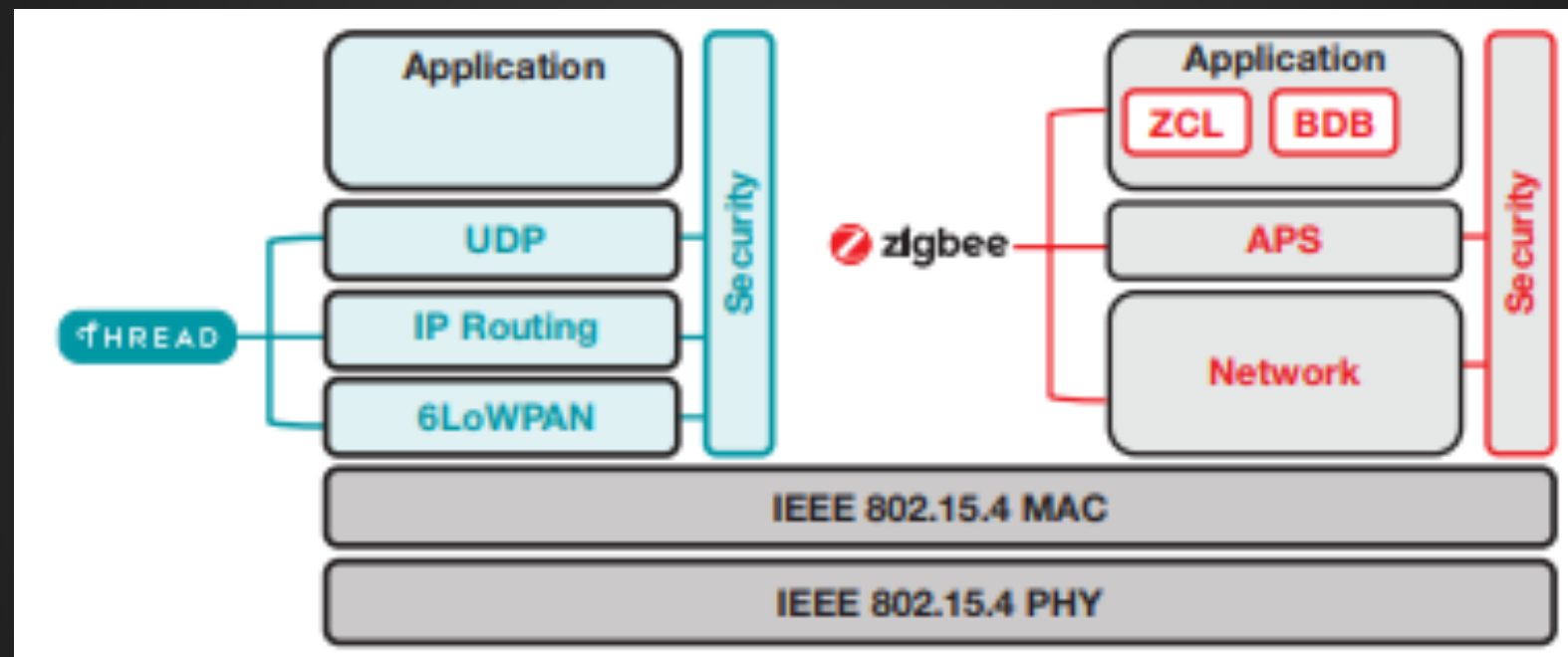
6LoWPAN stack



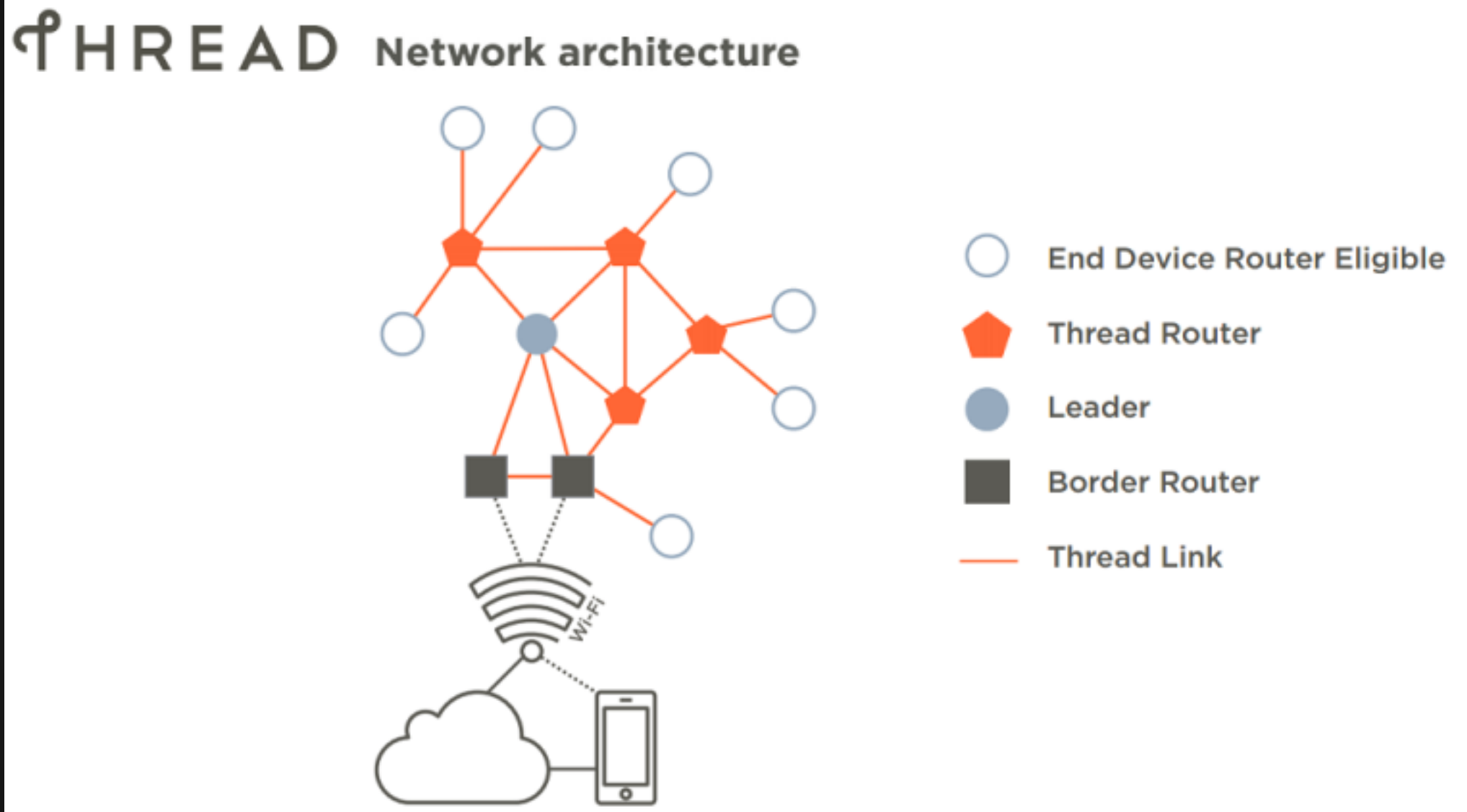
Thread stack



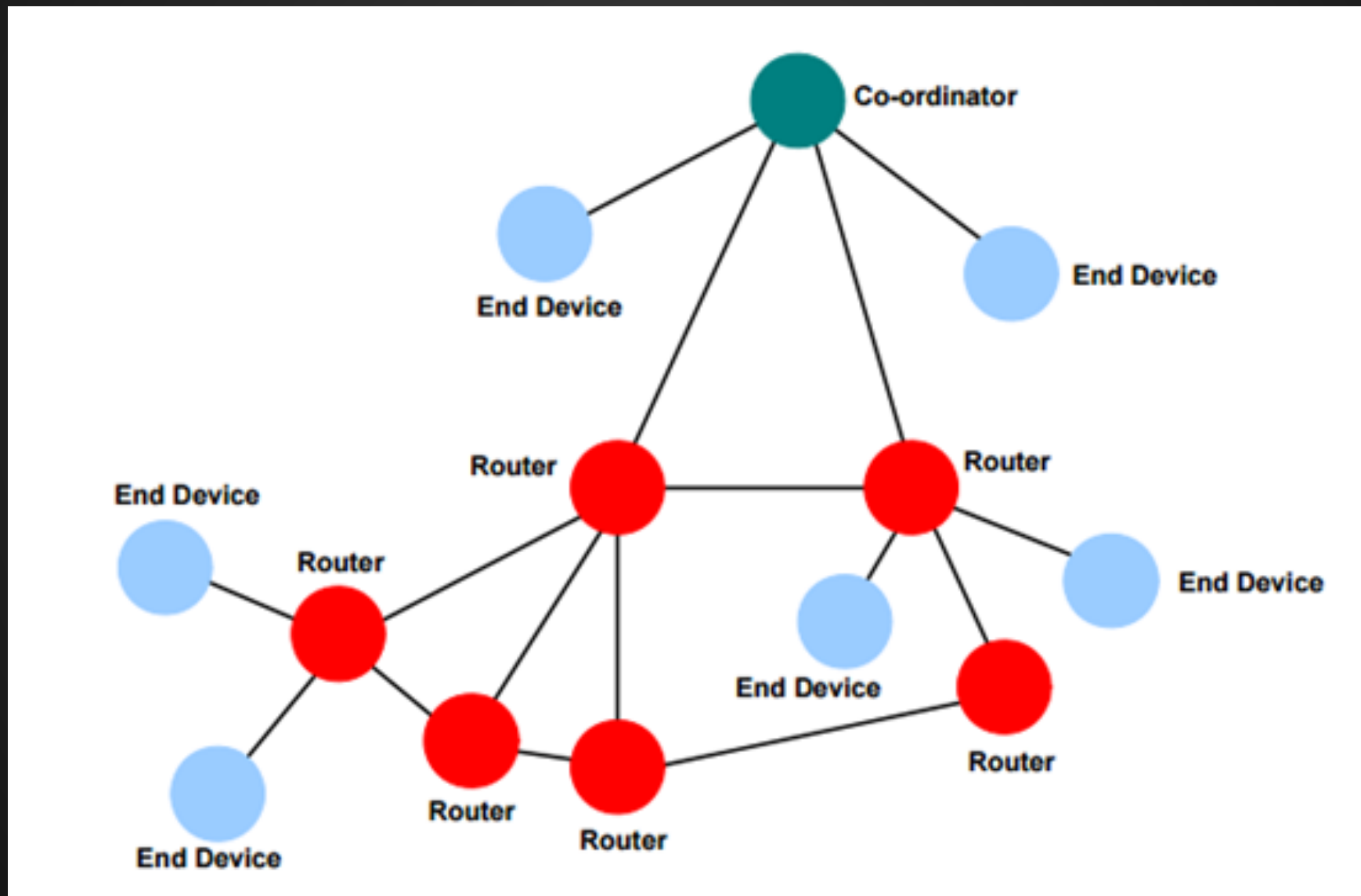
Thread vs Zigbee



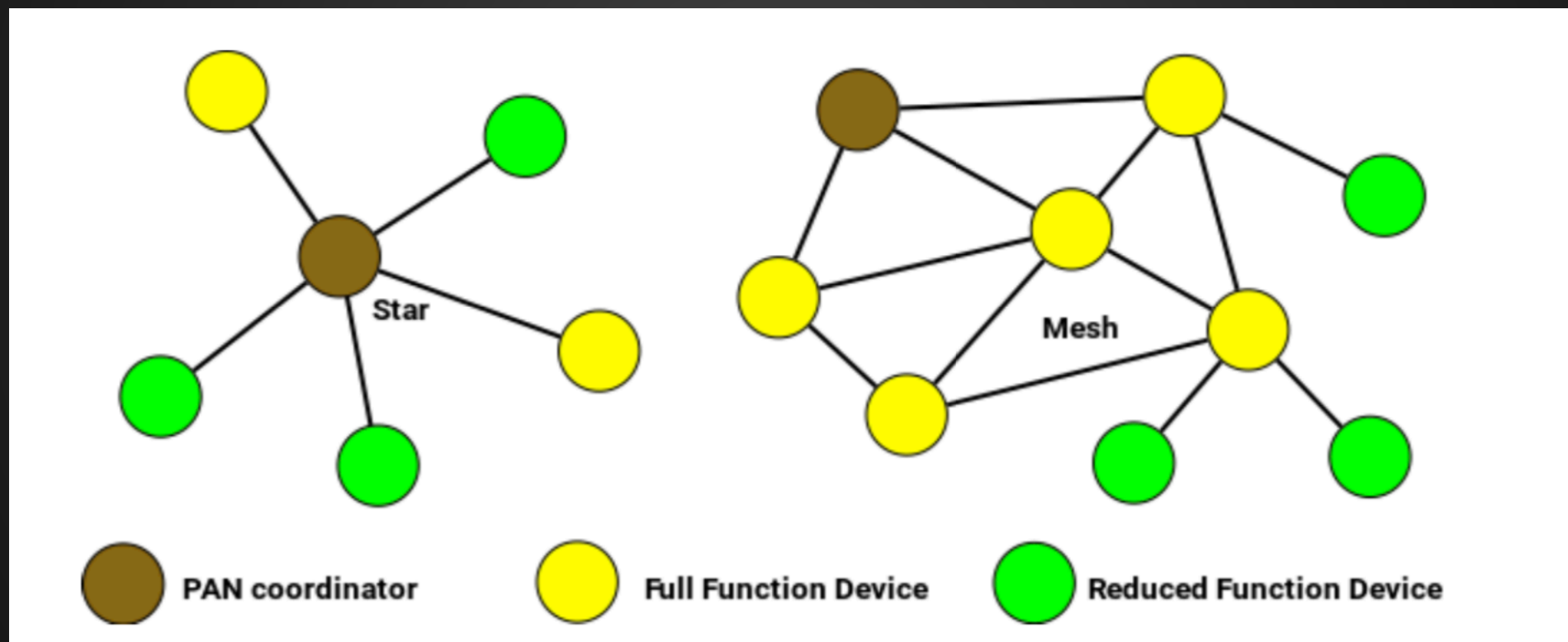
Thread architecture



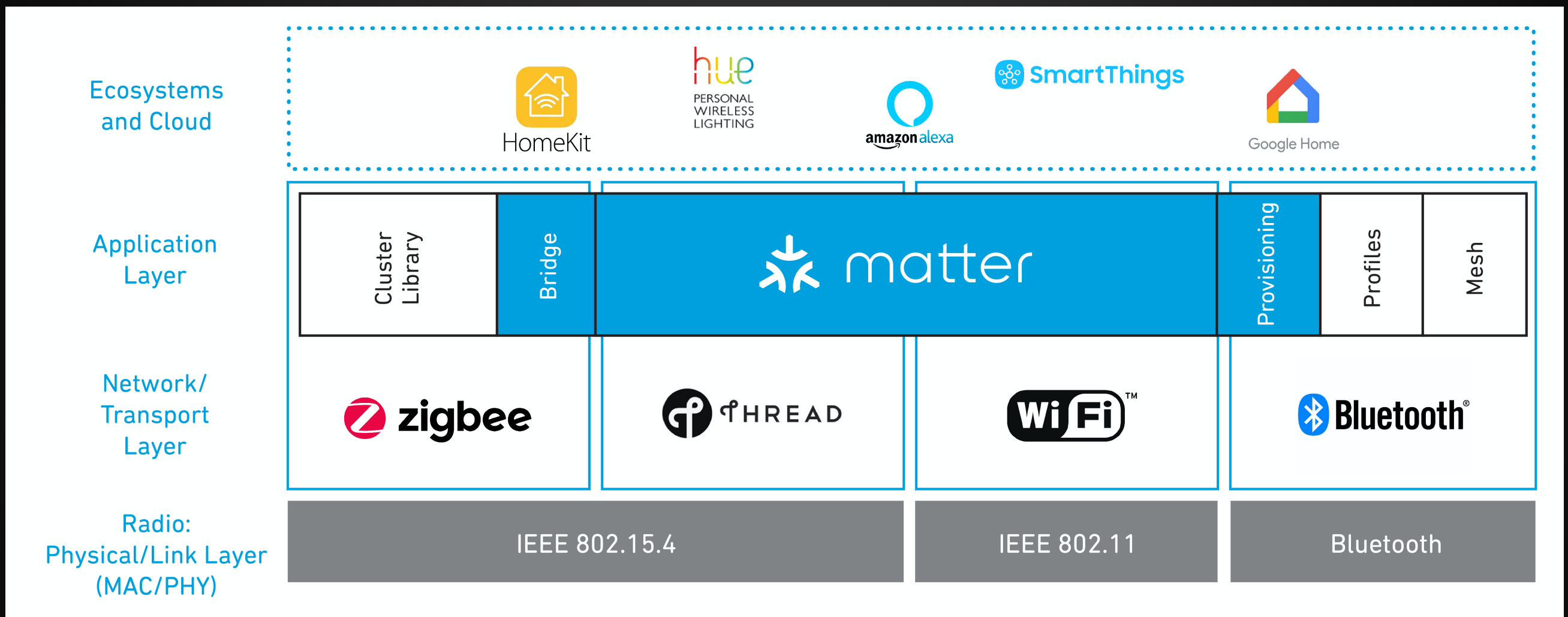
Zigbee architecture



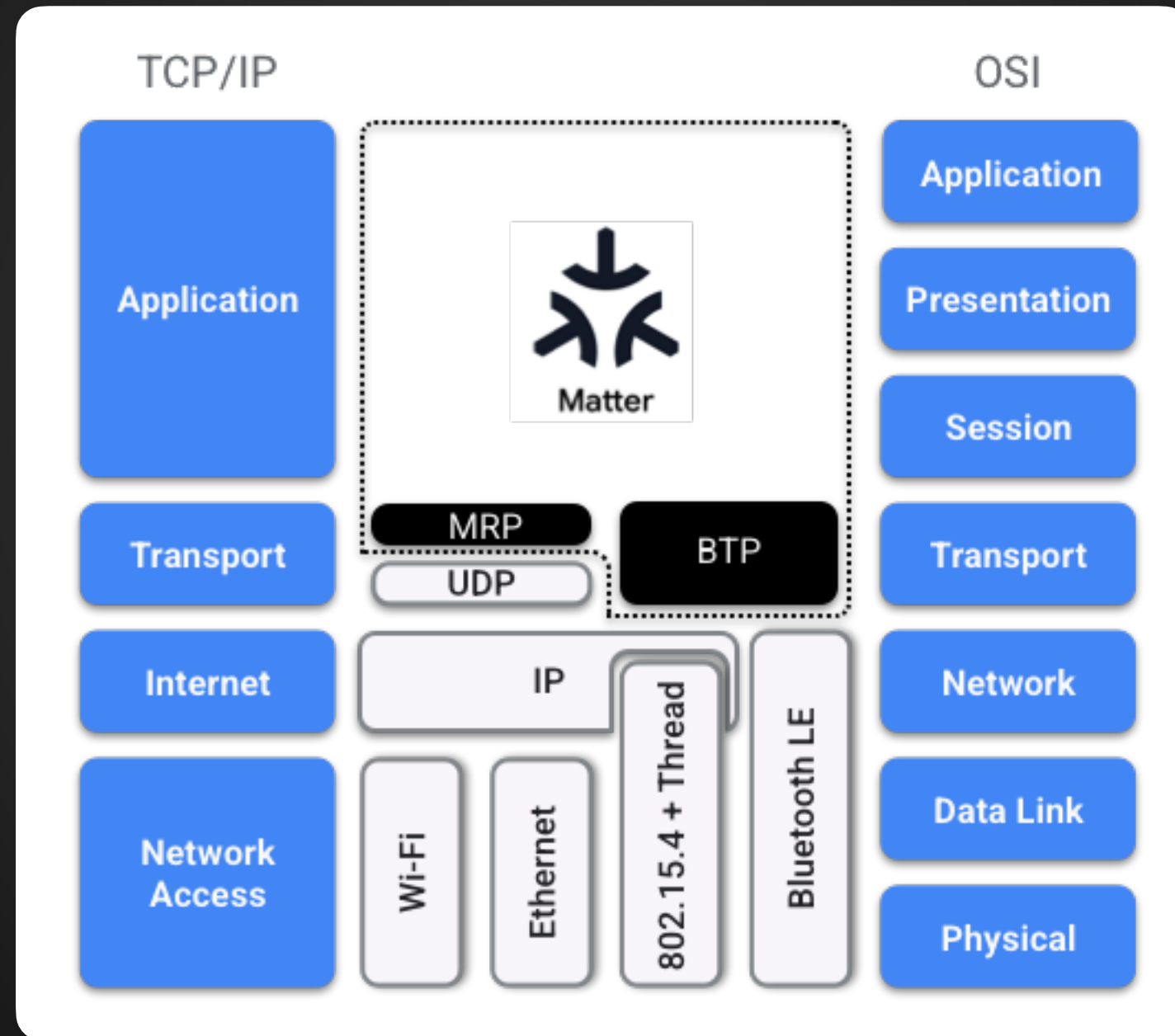
802.15.4 architecture



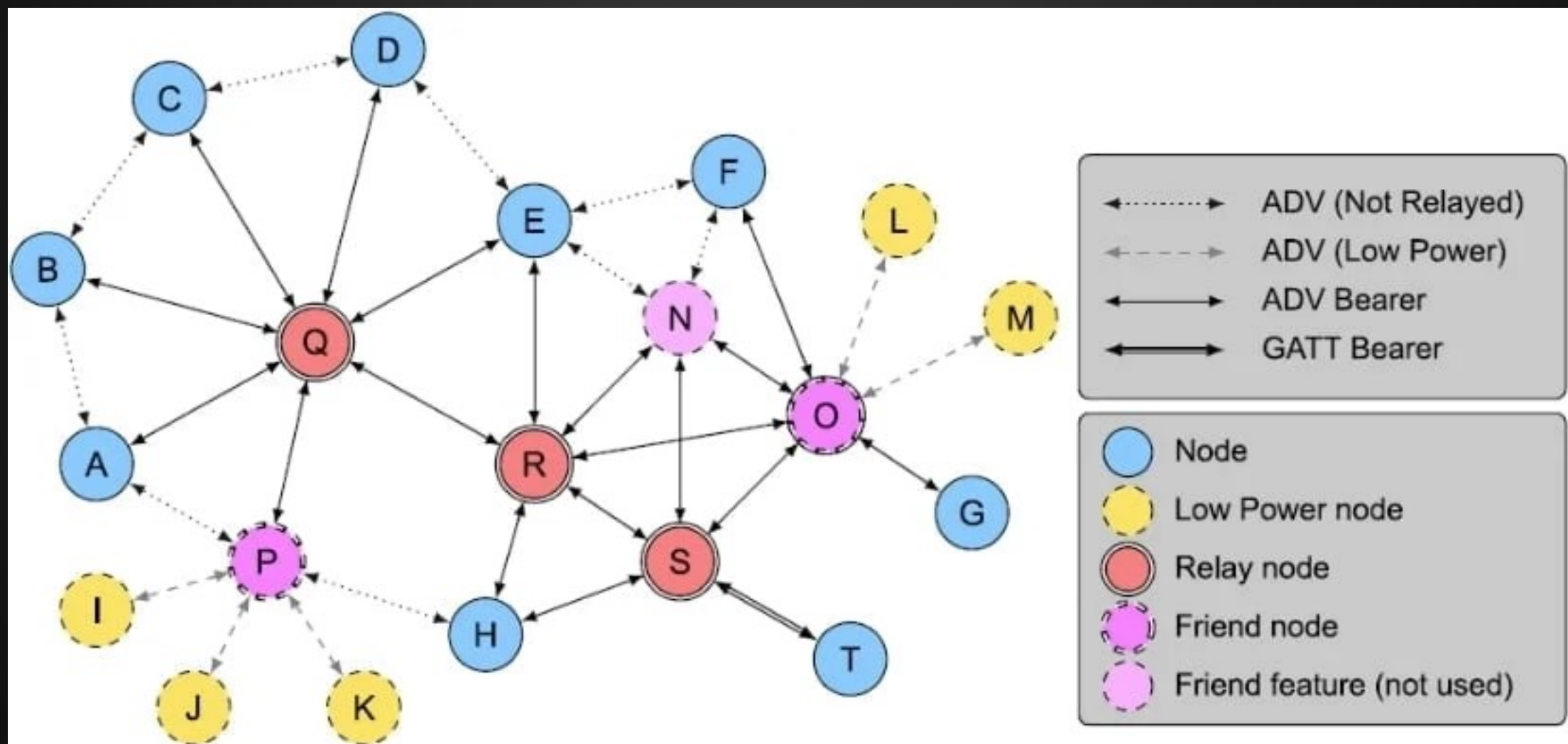
what is the matter?



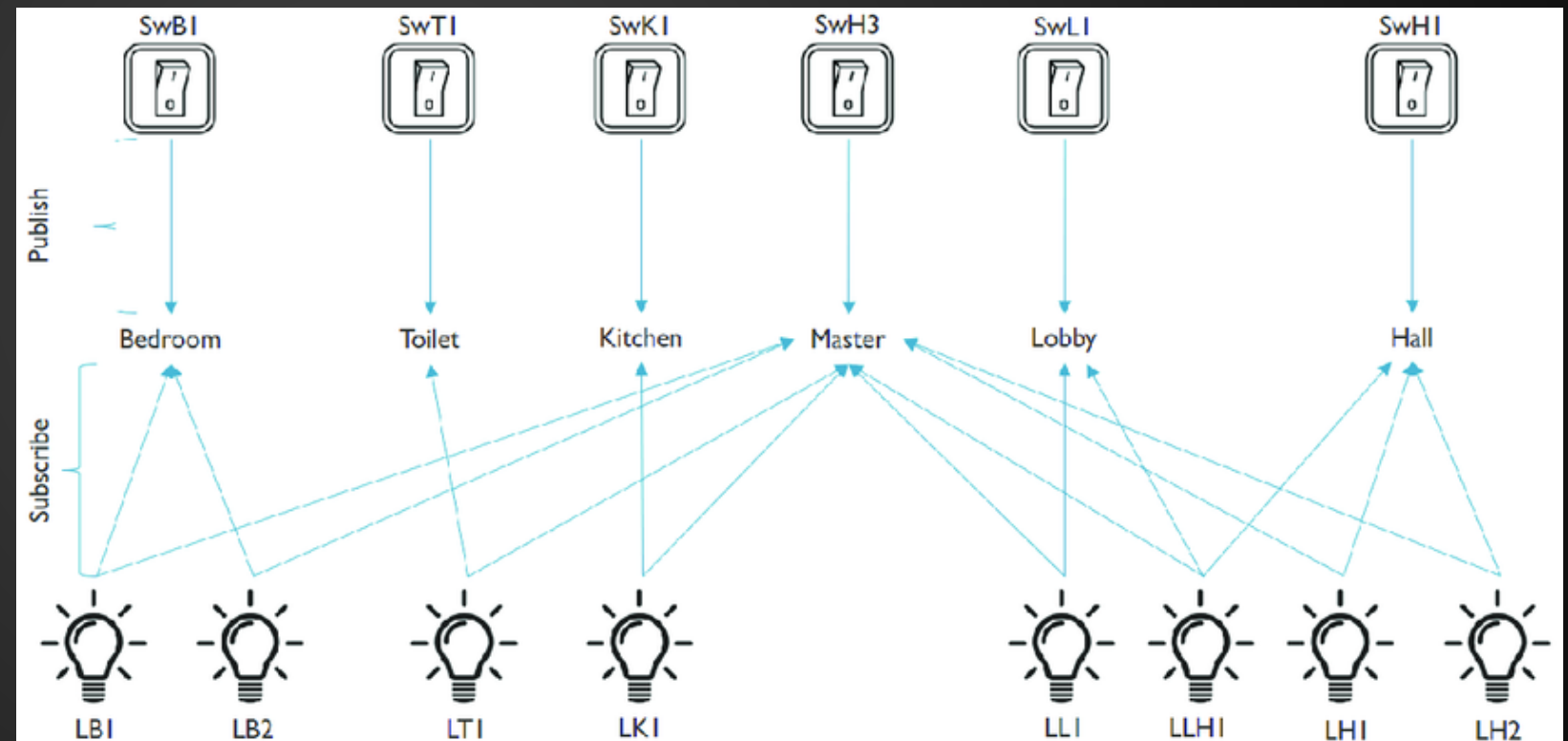
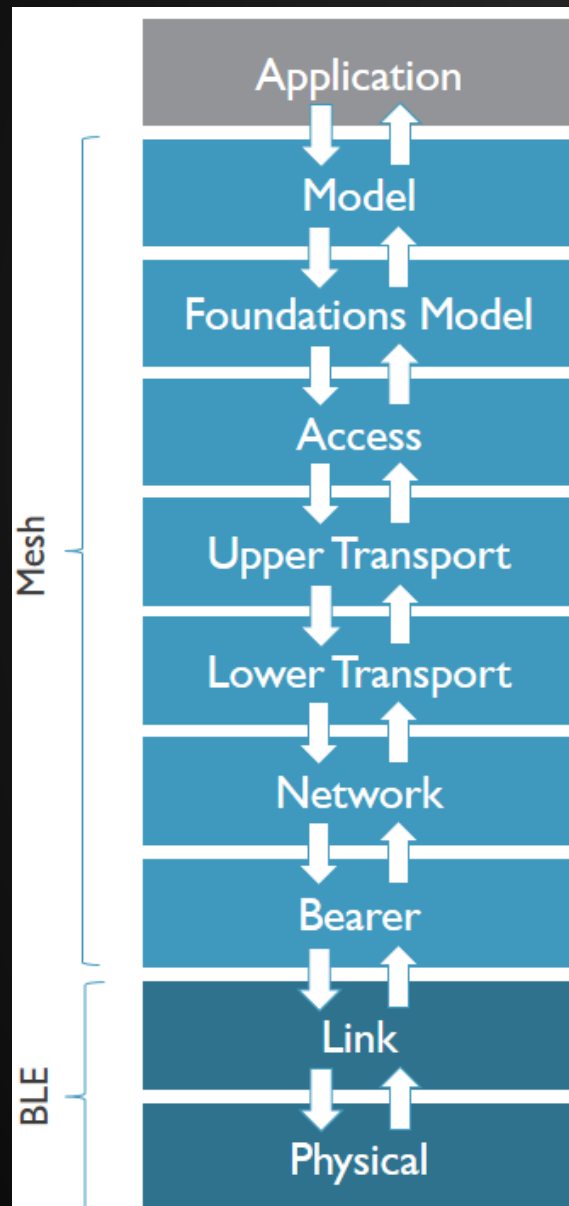
what is the matter?



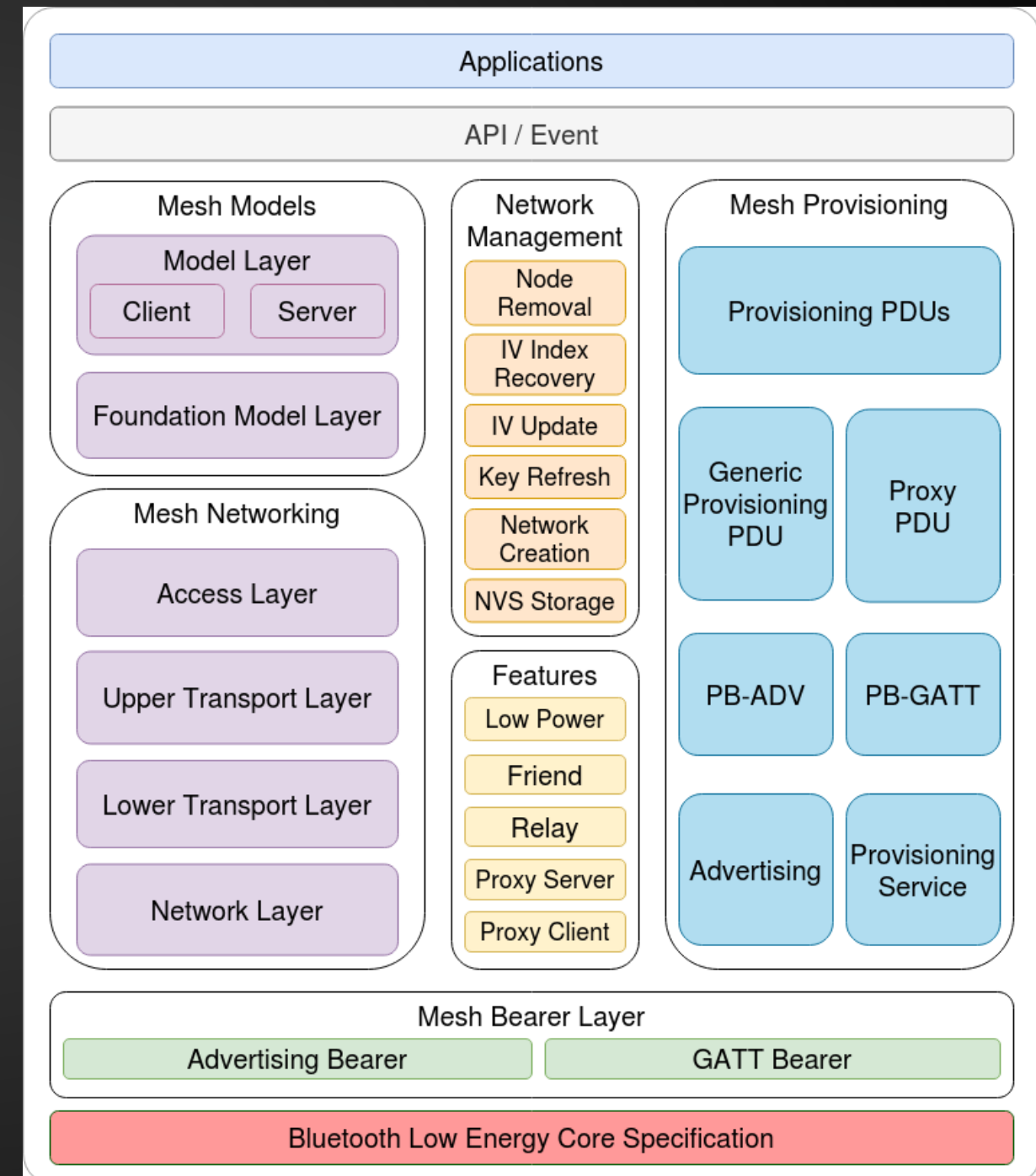
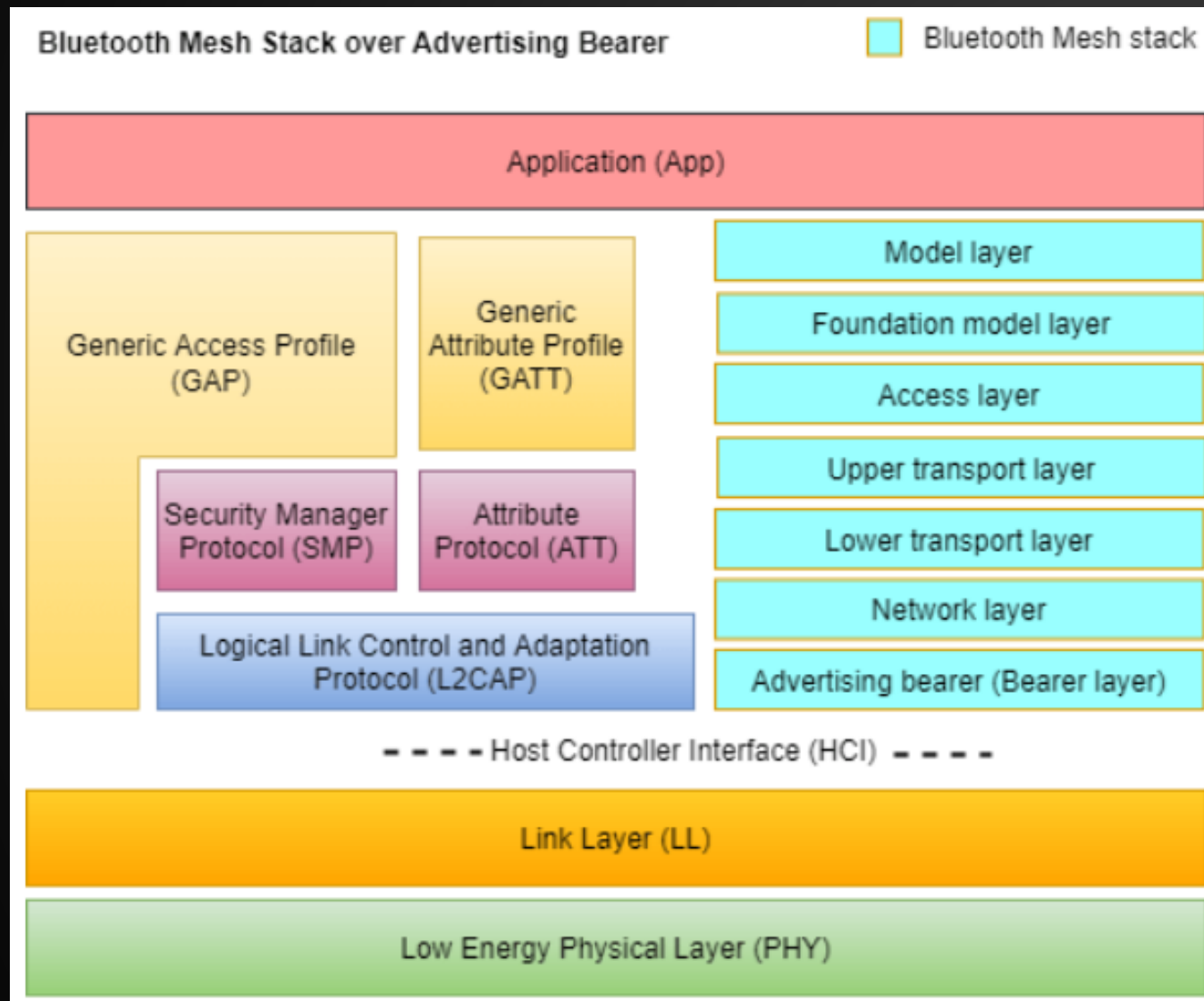
to BLE or not to BLE? it's a mesh...



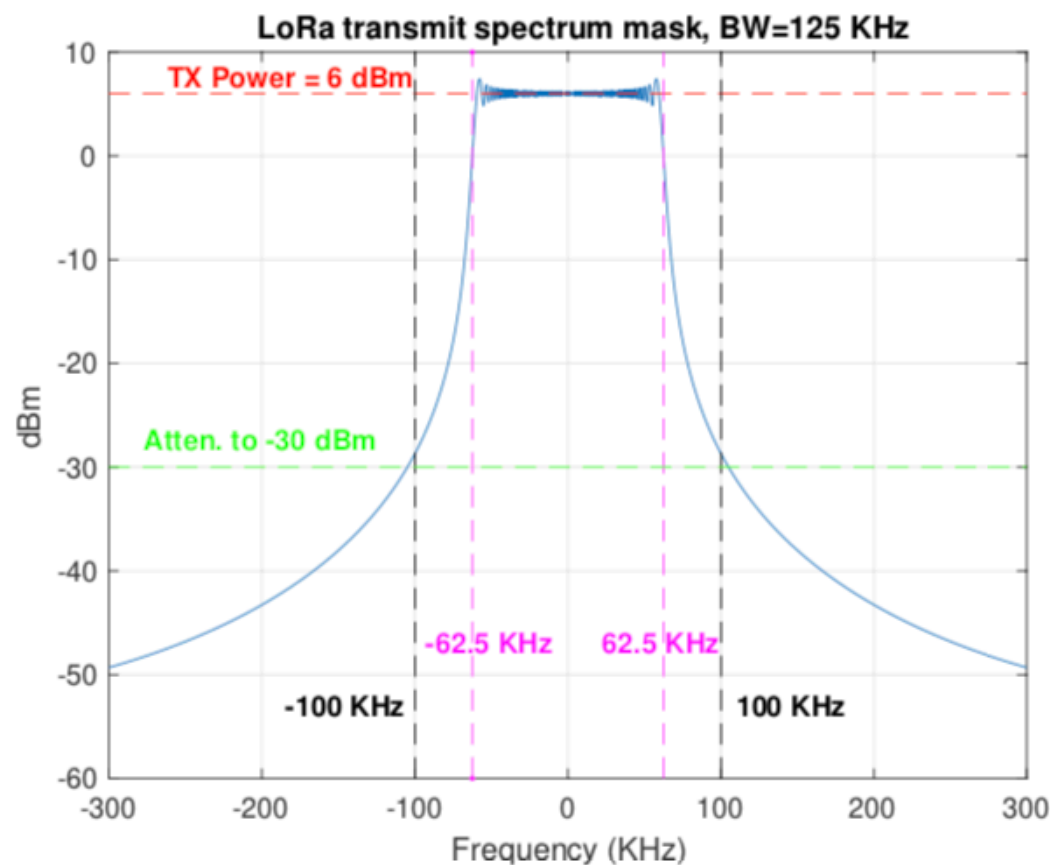
to BLE or not to BLE? it's a mesh...



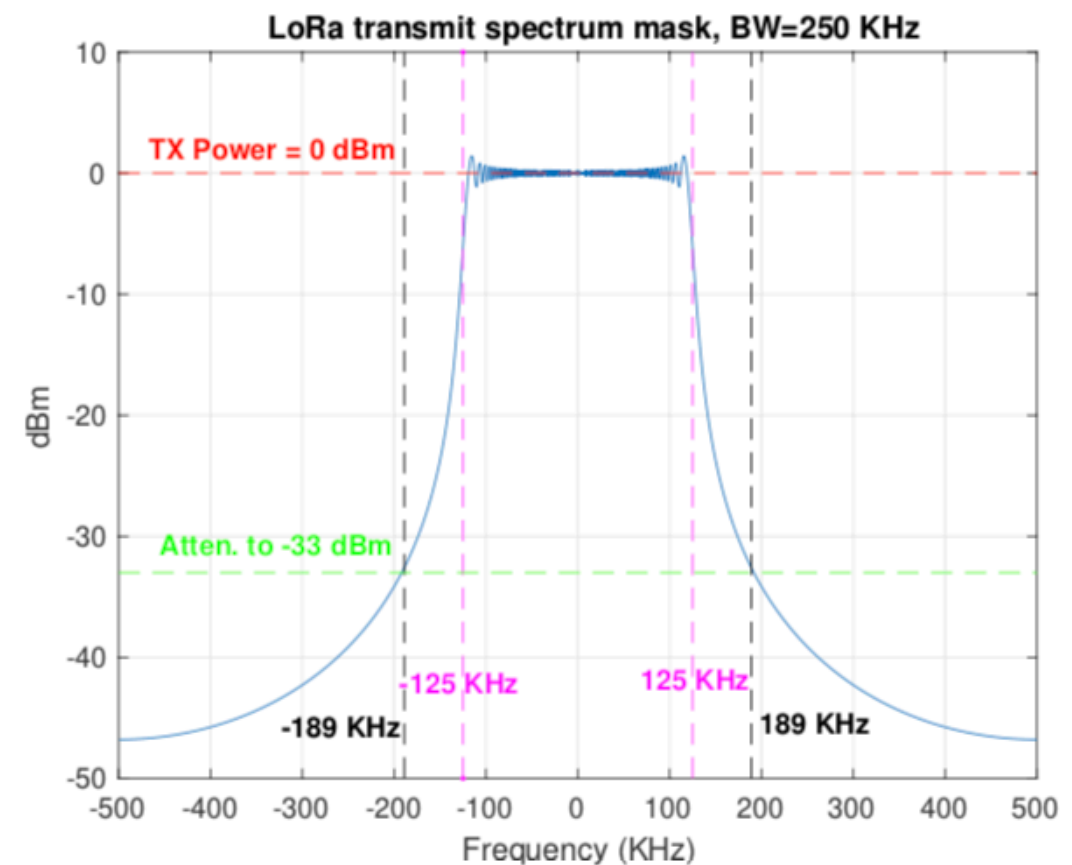
to BLE or not to BLE? it's a mesh...



Physical Layer LoRa

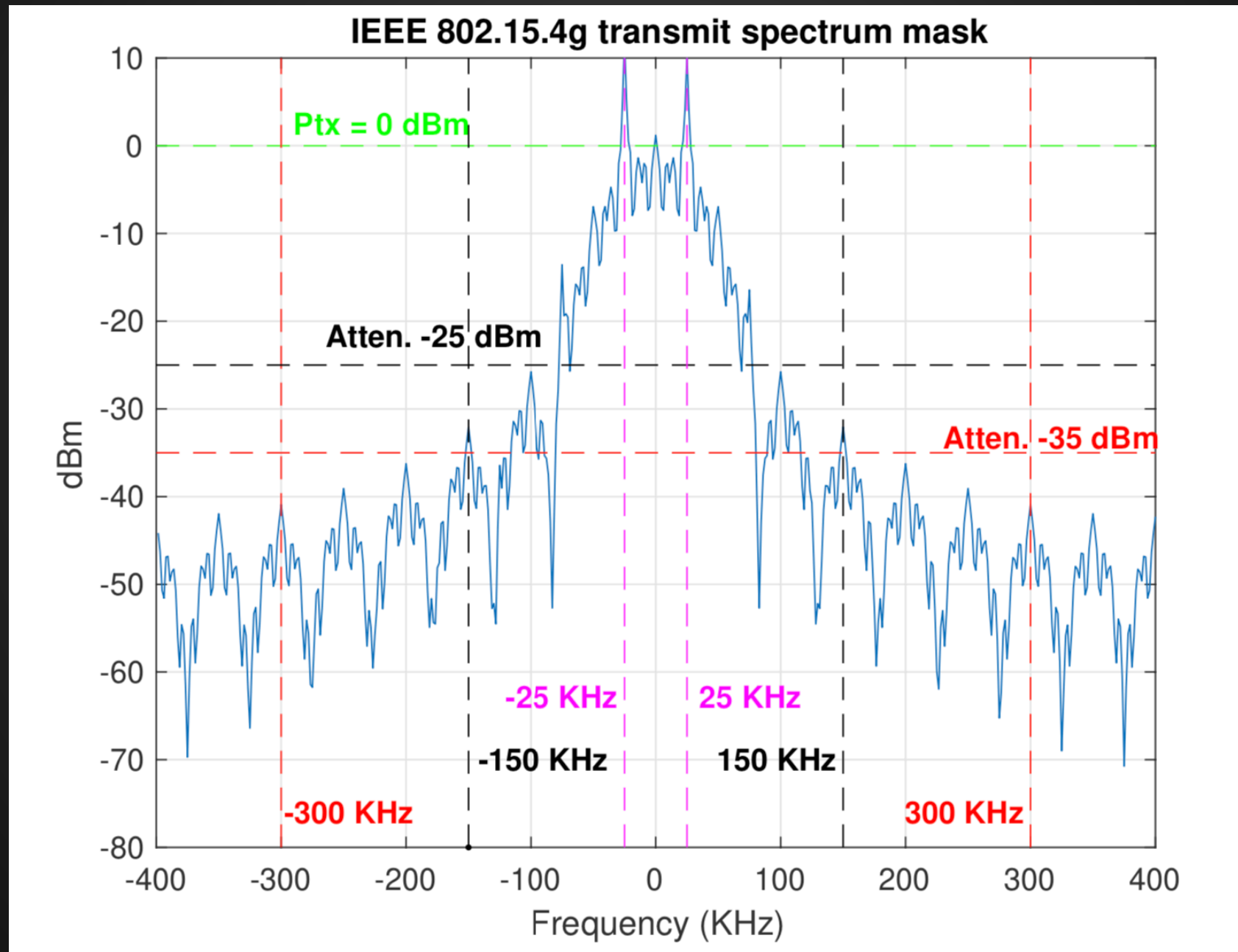


(a) Spectrum mask for $BW = 125$ KHz



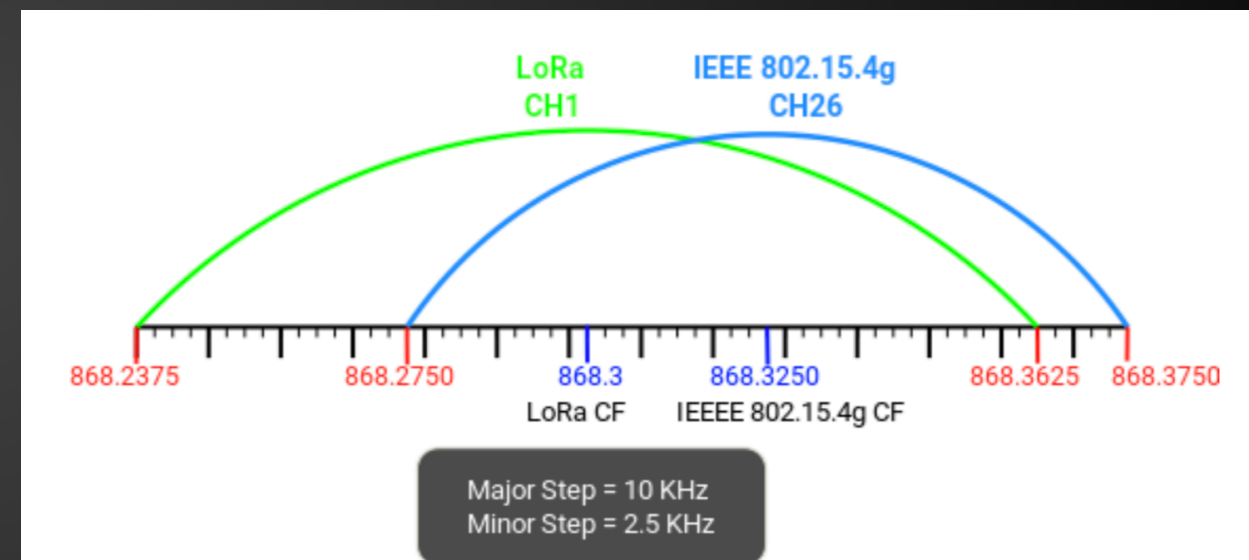
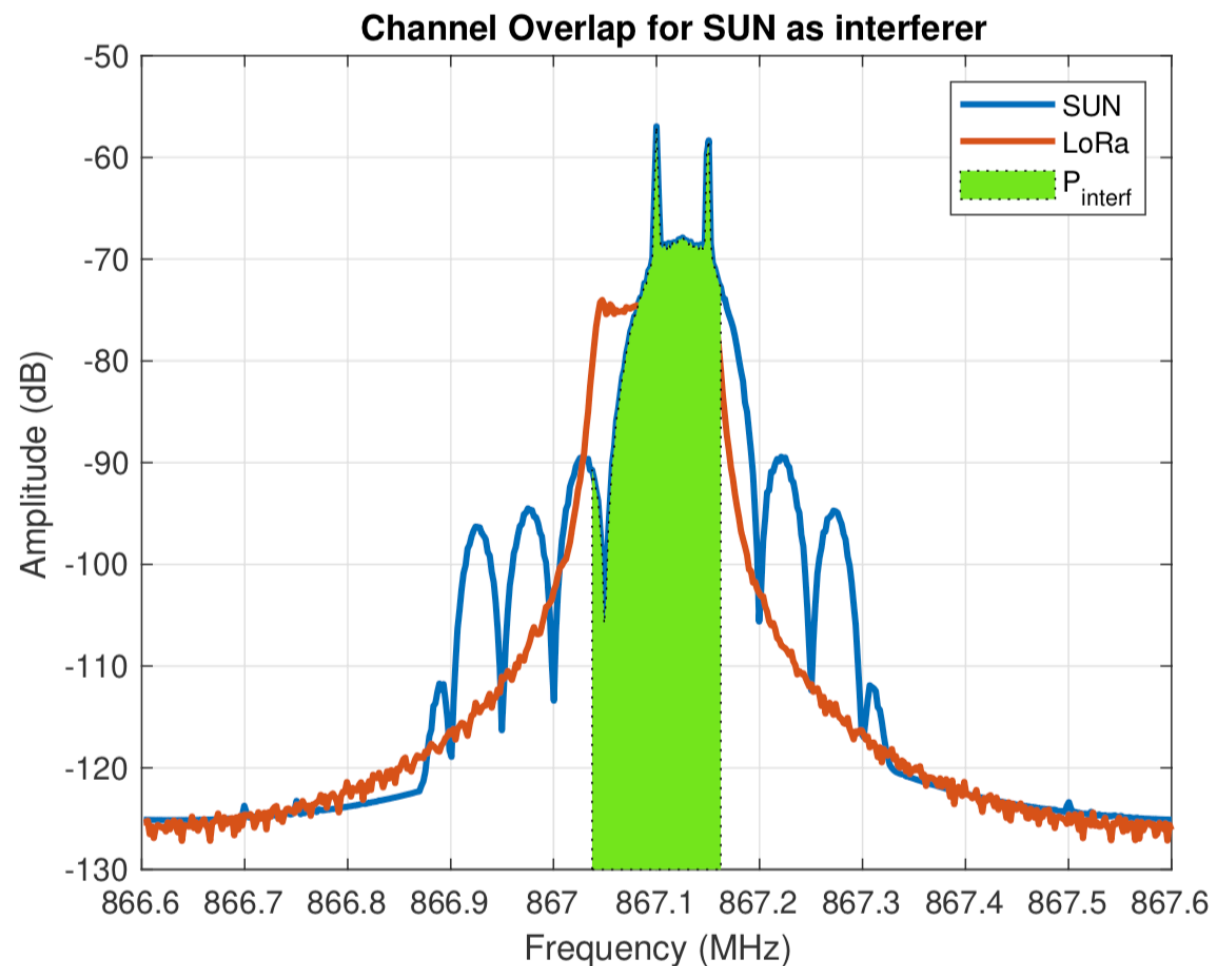
(b) Spectrum mask for $BW = 250$ KHz

Physical Layer 802.15.4g



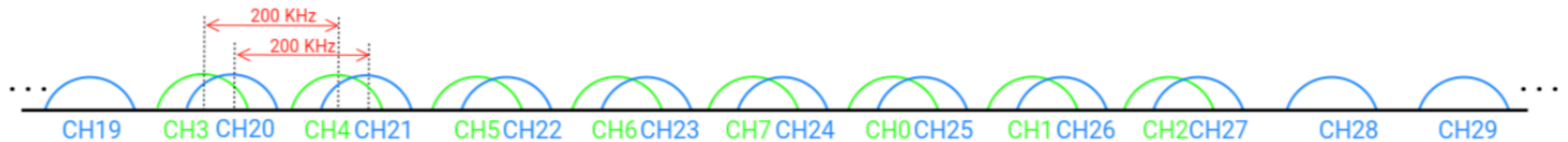
Spectrum Overlap 868 MHz

LoRa - 802.15.4g



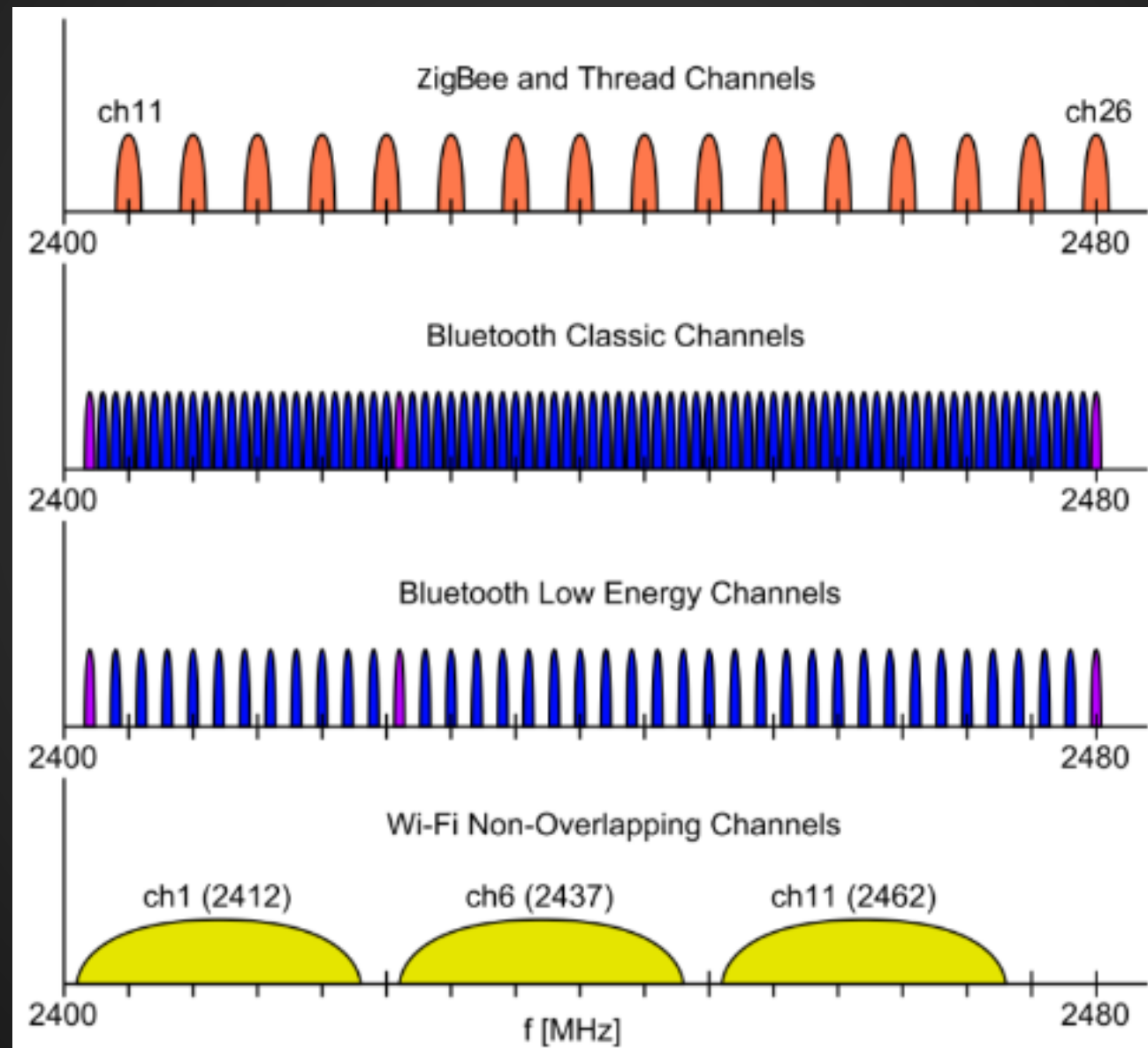
Channels Overlap 868 MHz

LoRa - 802.15.4g



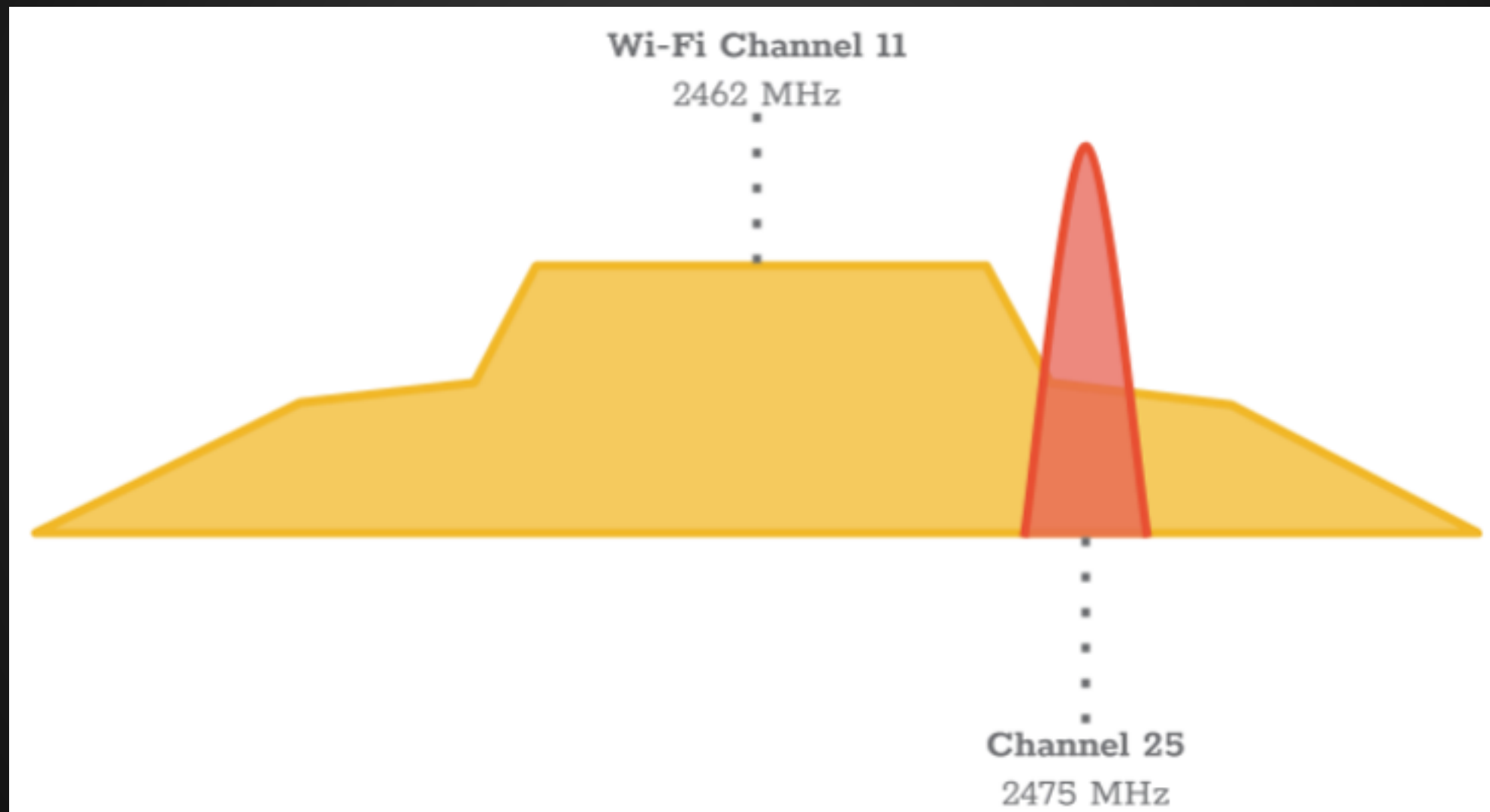
Channels Overlap 2.4 GHz

802.11 - 802.15.4 - BLE



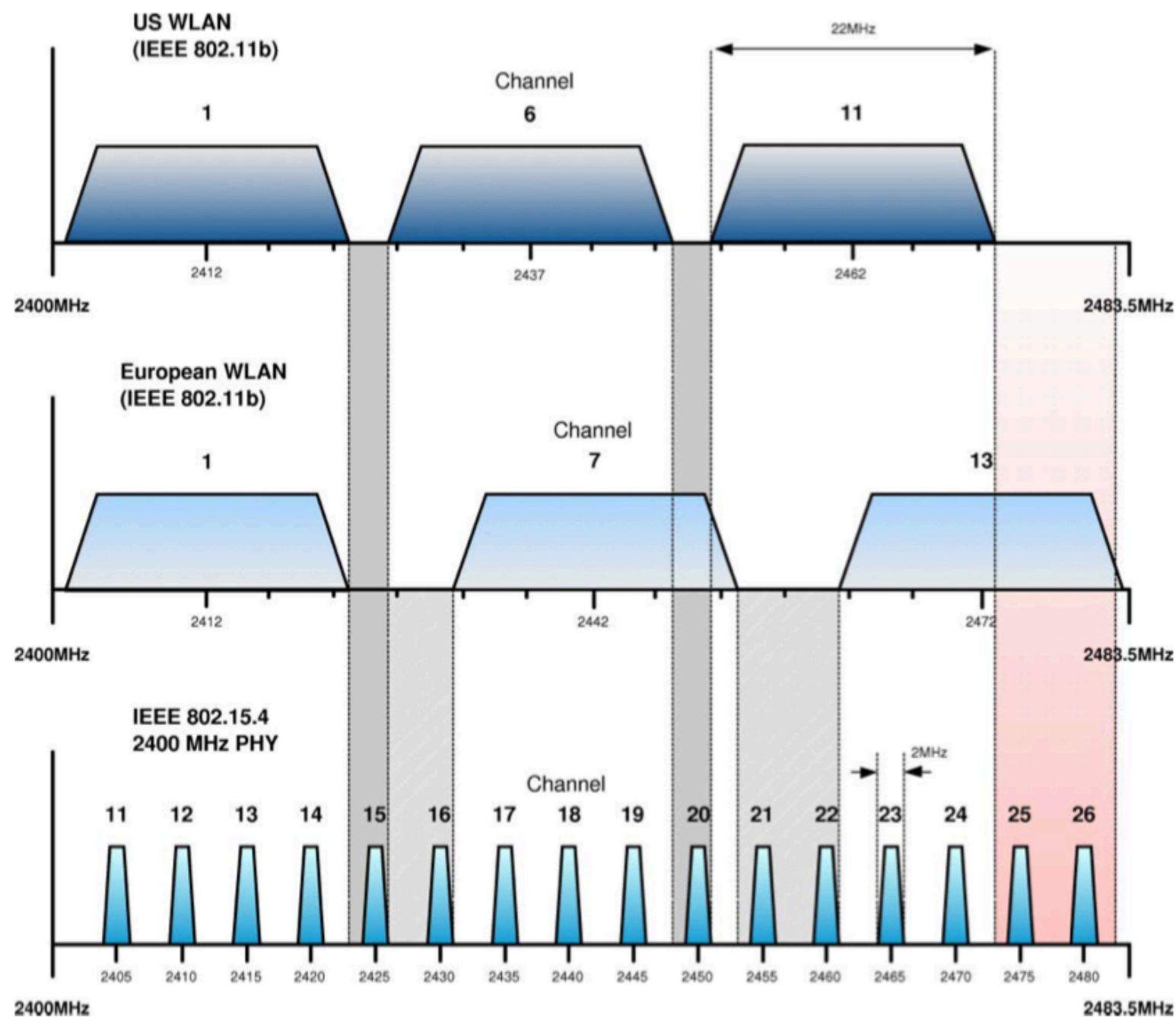
Channels Overlap

802.11 - 802.15.4



Channels Overlap

802.11 - 802.15.4



BLE channels

