Advanced Communication Technologies (CCE534)

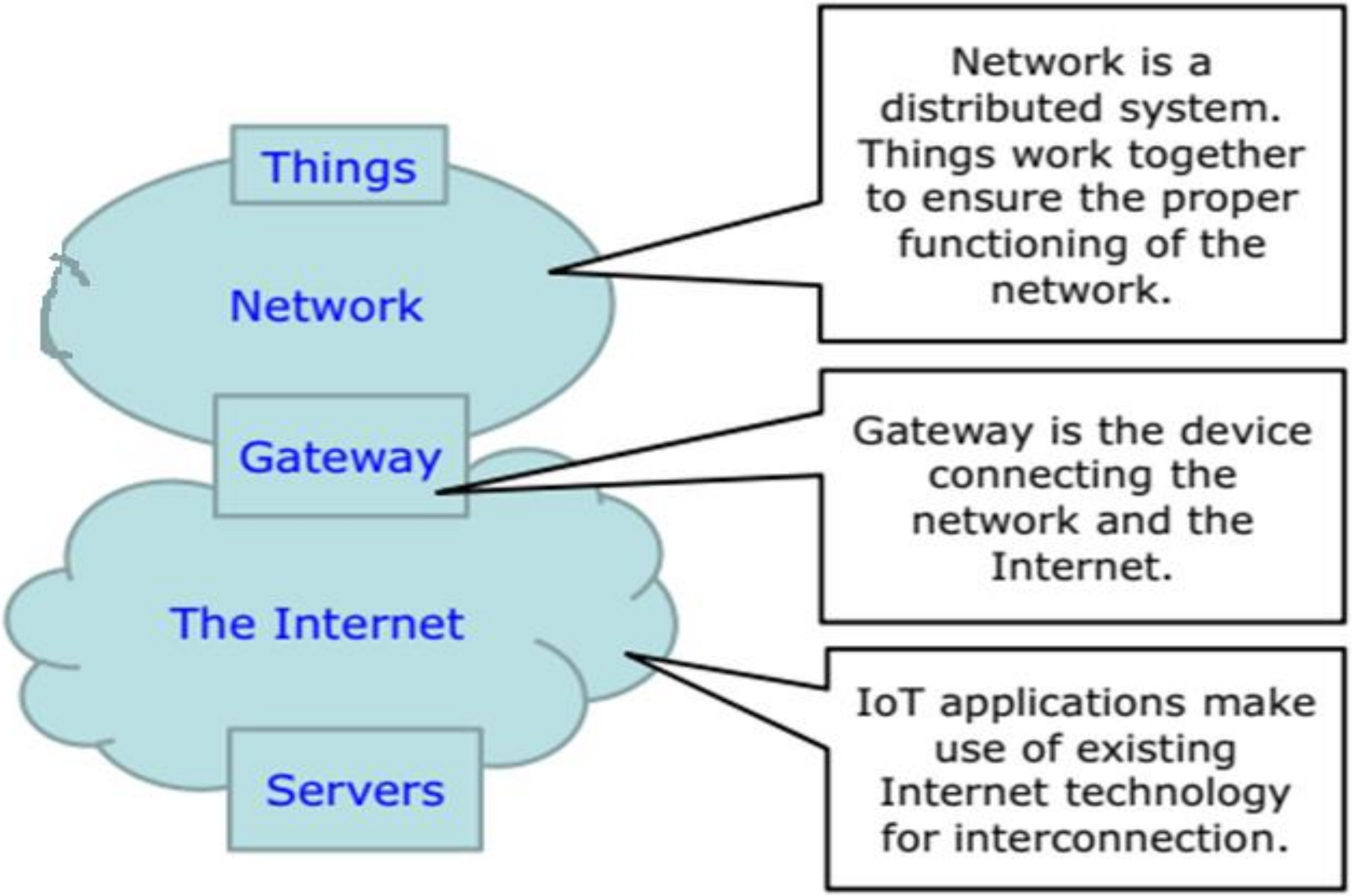
Lecture 4

IoT Architecture and Core IoT Modules

(Part 3: IoT Networking and LoRaWAN)

Assoc. Prof. Basem M. ElHalawany
Faculty of Engineering at Shoubra
Benha university, Egypt

IoT Networking



Considerations of IoT Networking:

- Communication between the IoT devices and the outside world dictates the network architecture.
- Choice of communication technology dictates the IoT device hardware requirements and costs.
- Due to the presence of numerous applications of IoT enabled devices, a single networking paradigm not sufficient to address all the needs of the consumer or the IoT device

Wireless communication for IoT Networking:

- **Wireless communication technologies are attractive for IoT ecosystem because of the significant reduction and simplification in wiring involved.**

- **Various wireless standards have been established, which generally can be grouped into two main categories, depending on the transmission range:**

    1. ***Short-range communication***
    2. **Long-range communication**

IoT Networking

***Short-range communication*:**

- **These types of communication bridge the sensors to a local network but not necessarily the internet.**
- **Several standards exists that use the instrumentation, scientific and medical (ISM) radio bands.**
- **Each standard has different data rate constraints**
- **This includes:**

  1) **Wireless LAN (Wi-Fi), namely IEEE 802.11**
  2) **Wireless PAN, such as:**
     a) **Bluetooth, namely IEEE 802.15.1 and Bluetooth Low Energy**
     b) **ZigBee, namely IEEE 802.15.4**
     c) **6LoWPAN (IPv6 over Low-power Wireless Personal Area Networks (LoWPAN).**

***Long-range communication*:**

- **This category includes low-power technologies and standards that cover the various WAN connectivity (known as LPWAN):**
  1) **Long-Range (LoRa/LoRaWAN), proprietary of SemTech: sub-gigahertz IoT communication technologies**
  2) **Sigfox, , proprietary of Sigfox**
  3) **Narrow-Band IoT (NB-IoT): Standardized by 3GPP (Rel 13) to enable IoT communication over existing cellular infrastructure**

3GPP : Third Generation Partnership Project is the group of seven telecom organizations that manage and govern cellular technology

Bandwidth vs Range

1. LoRa-Based Networks:

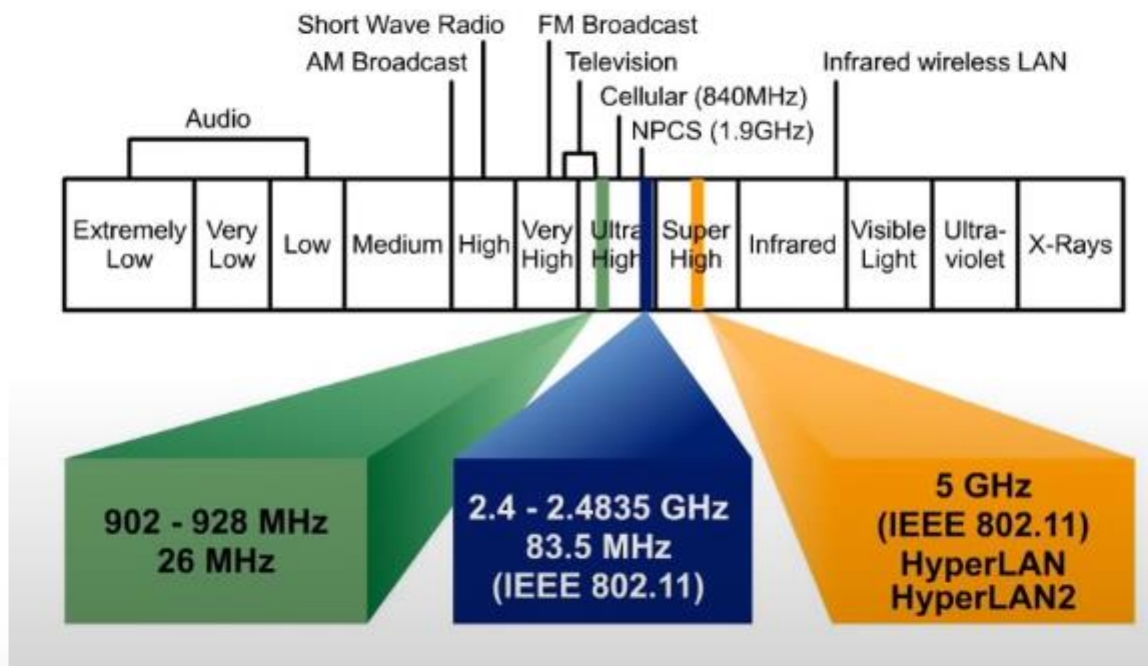
- **LoRa is a physical layer for a long-range and low-power IoT protocol while LoRaWAN represents the MAC layer.**
- **The PHY layer is a proprietary of (SemTech)**
- **Operates in license-free ISM bands**

WiFi

- 2.4 GHz
- 5 GHz

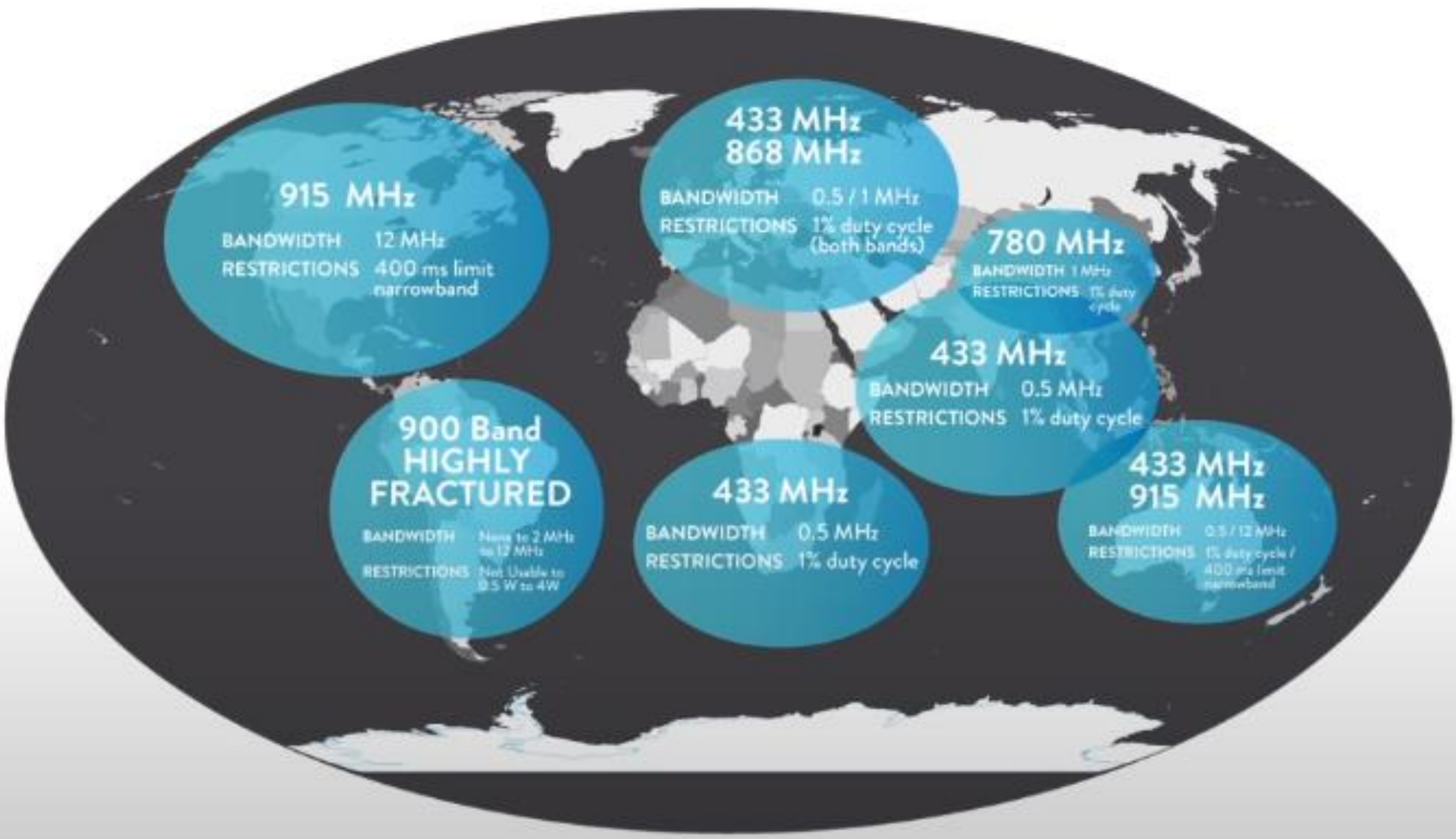
LoRA

- 415 MHz
- 868 MHz
- 915 MHz



1. LoRa-Based Networks:

- **LoRa ISM bands in different areas**



1. LoRa-Based Networks:

- LoRaWAN is One of the main contenders for LPWAN domain
- LoRaWAN has gained traction in Europe (network deployments by KPN, Proximus, Orange, Bouygues, Senet, Tata, and Swisscom).
- Since LoRa is the bottom of the stack, it has been adopted in competing architectures to LoRaWAN such as:

  - ✓ Symphony Link: for example, is LPWAN solution based on the LoRa PHY, using an eight-channel, sub-GHz base station for industrial and municipal IoT deployments.
  - ✓ DASH7: is a full network stack on the LoRa PHY (not just the MAC layer).

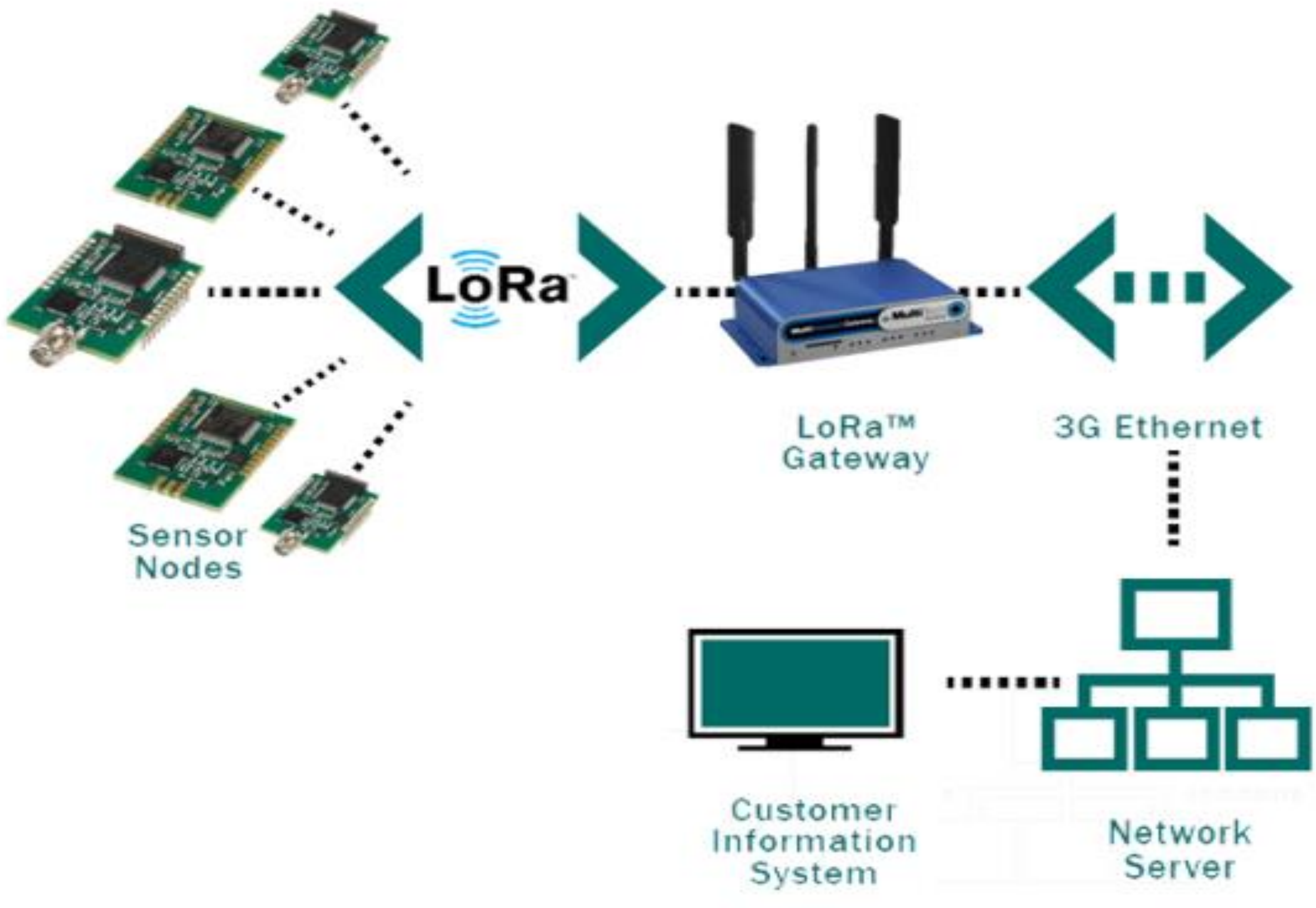
[1] Perry lea, “Internet of Things for Architects”, **Chapter 7**, Packt Publishing Ltd, 2018

1. LoRa-Based Networks:

- **The reasons for the wide-spread of LoRaWAN are:**
  - ✓ **Use unlicensed spectrum**
  - ✓ **A single LoRaWAN gateway has the potential to cover a significant amount of area. Belgium, with a land area of 30,500 km^2, is completely covered by seven LoRaWAN gateways.**
  - ✓ **Typical range is 2 to 5 km in urban areas and 15 km in suburban areas.**
  - ✓ **This reduction in infrastructure cost is very different than 4G-LTE with much smaller cells.**

[1] Perry lea, “Internet of Things for Architects”, **Chapter 7**, Packt Publishing Ltd, 2018

LoRaWAN Network Architecture



LoRaWAN Network Terminologies

NODES

Small devices

- Sensors
- Peripherals

Slave devices

GATEWAYS

Powerful devices

Router

- LoRa
- IP Network (Ethernet/WiFi etc)

LoRaWAN Nodes on the Market (Sample)

LoPy
868/915 MHz
ESP32
WiFi/BLE
4 MB Flash
Python

LORA GPS Hat
868/433/915 MHz
LoRa
GPS
SPI
Raspberry Pi 2/3

RN2483
868/433 MHz
Microchip

Waspmote
Libelium
868/915 MHz
C/C++

- **ESP32, Microchip: are microcontroller chips**
- **LORA GPS Hat: can be connected to the Raspberry Pi to work either a node or a gateway. It is only a transponder without processing power**

LoRaWAN Gateways on the Market (Sample)

IMST IC880A-SPI (Lora Lite)

LoRa -> IP
- Packet forwarder

8 channels at a time

Decodes multiple SF

Kerlink IoT

LoRa -> IP
- Packet forwarder

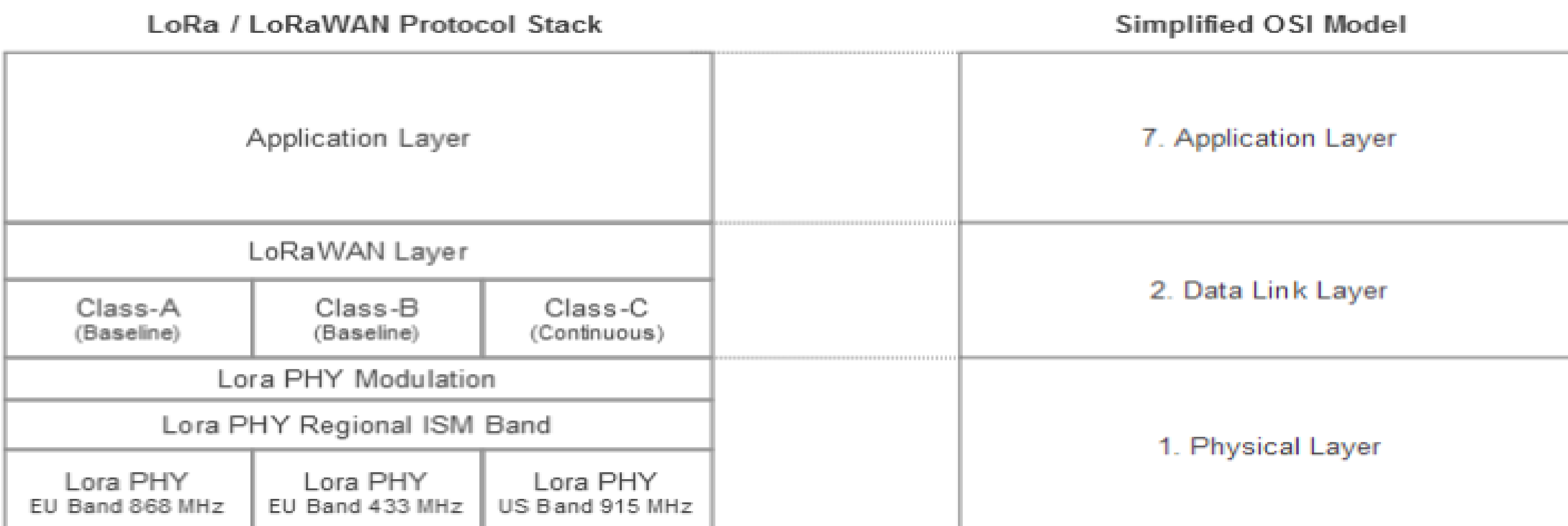
8 channels at a time

Decodes multiple SF

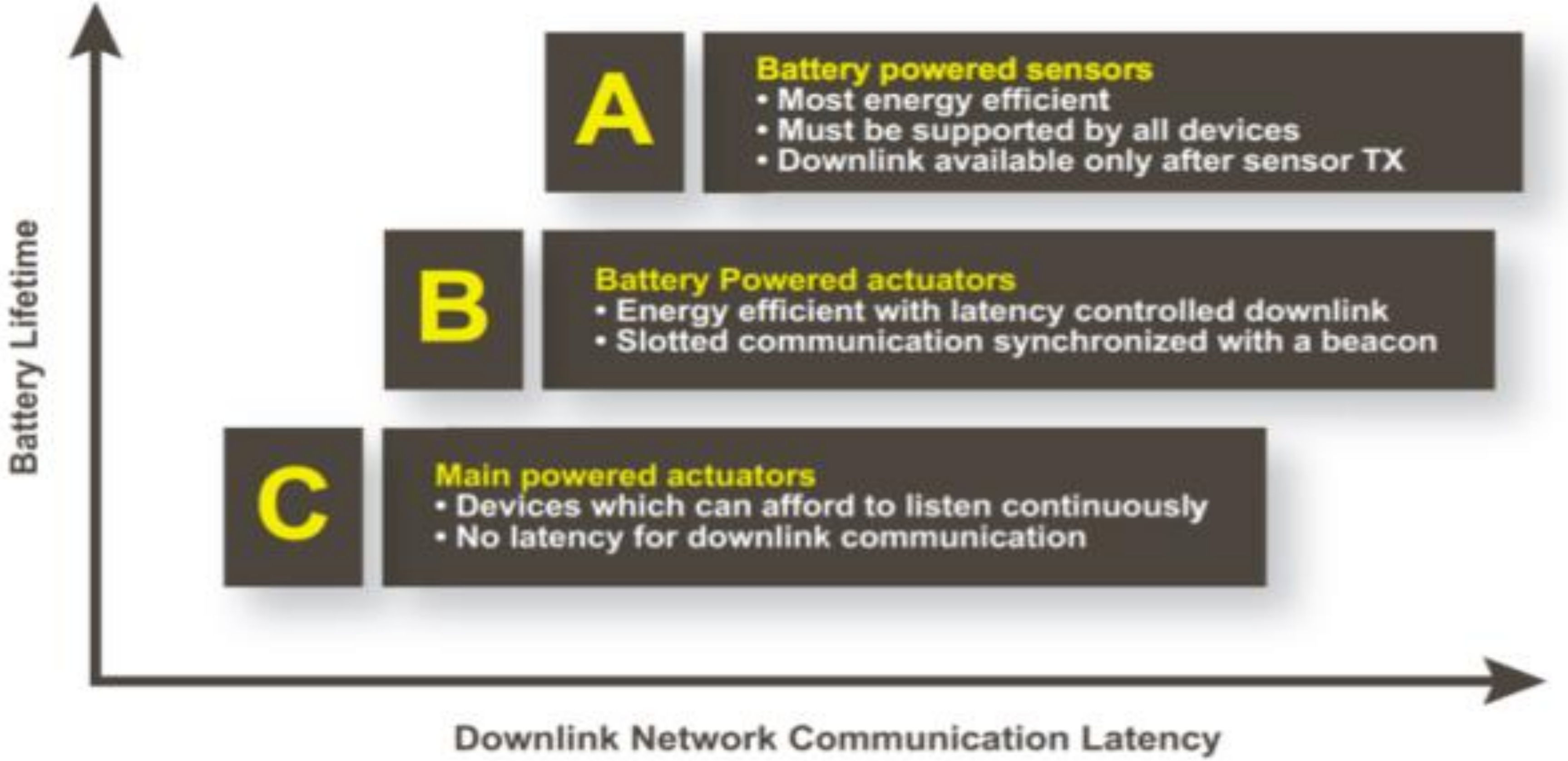
- **IMST can be connected to Raspberry Pi**

LoRa and LoRaWAN protocol Stack

- ✓ **LoRa represents the physical layer of a LoRaWAN network.**
- ✓ **LoRaWAN is another layer (MAC/ Data link layer) on top of LoRa which added by the LoRa Alliance.**
- ✓ **This means a set of rules and software that specifies how the payload looks, energy efficiency, and latency**
- ✓ **There are three MAC protocols that are part of the data link layer, which balance latency with energy usage**

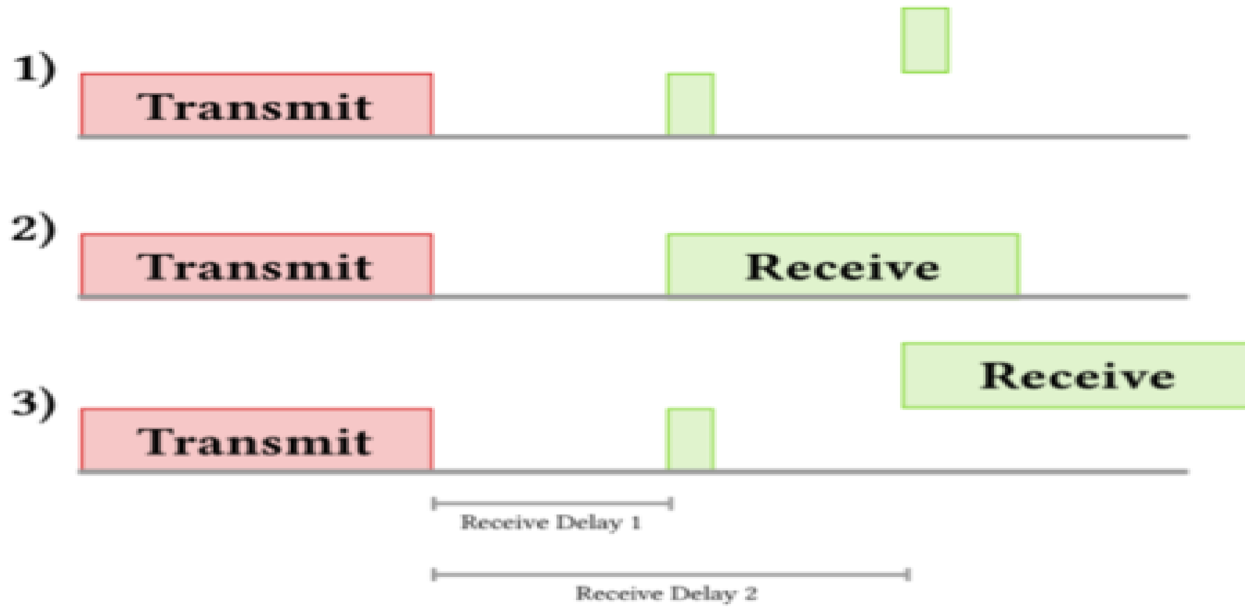


LoRaWAN Devices' Classes



- ✓ **Class A sleeps most of the time, Class C is always on, while Class B is a mix (where Gateway can tell the device not to sleep)**
- ✓ **The Gateway must know when the Class A device is on for downlink transmission**

Receive (Downlink) Window of Class A Device:



- ✓ Class A transmits, then go to sleep and wait a time "Receive Delay 1" and try to receive data, otherwise go to sleep again
- ✓ Then wait for a second sleep period and try to receive, otherwise go to sleep.
- ✓ The gateway can send data to the node only at those times after it receives transmission from the node
- ✓ This is a problem because the class A may go to sleep for hours and the Gateway must wait even if it has messages, so it is not suitable for actuator nodes

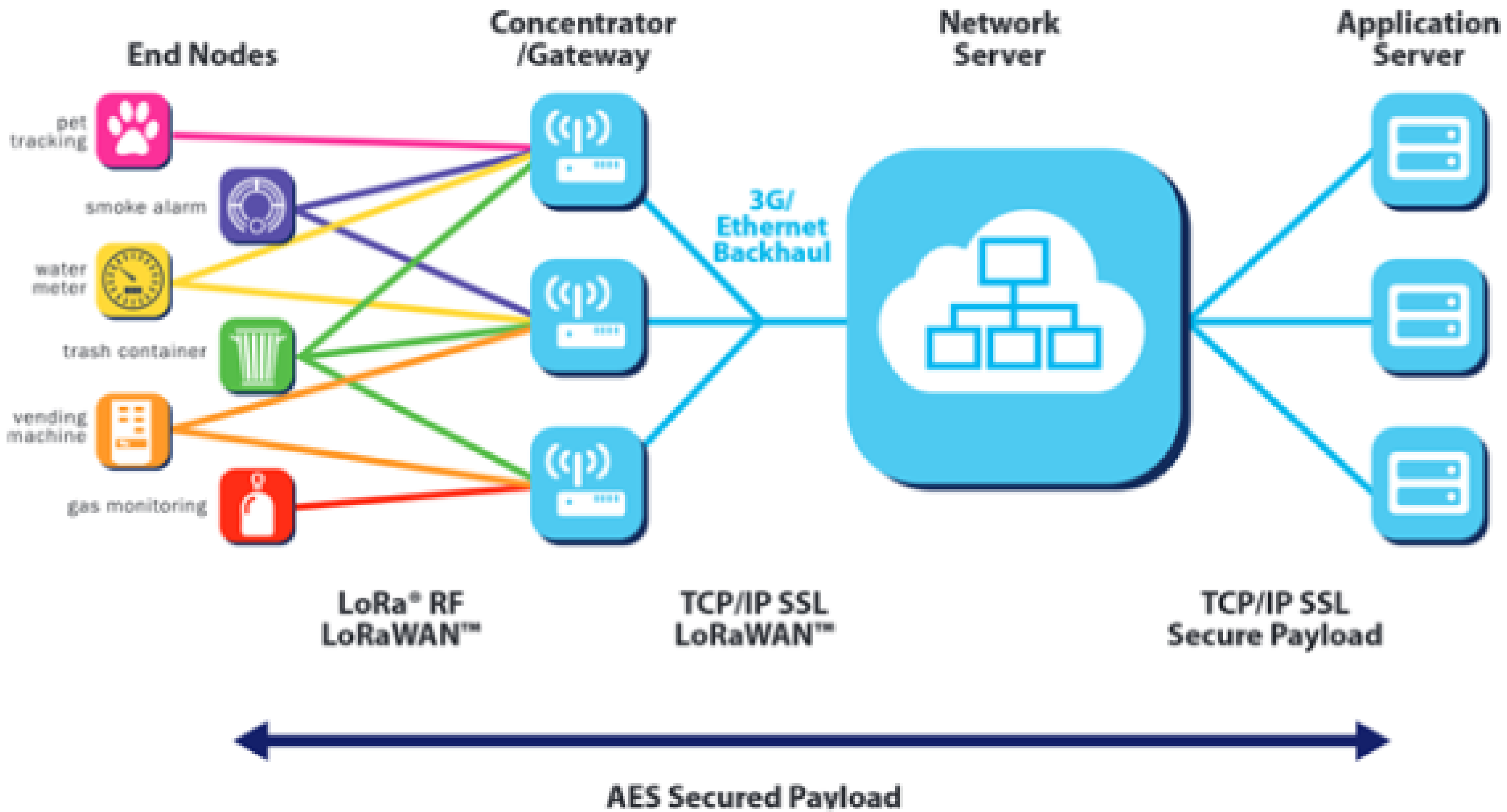
LoRaWAN Devices' Classes

- ✓ Class-A is the best for energy consumption but have the highest latency.
- ✓ Class-B is between Class-A and Class-C.
- ✓ Class-C has minimum latency but the highest energy usage.

- ✓ All endpoints that join a LoRaWAN network are first associated as Class-A with the option of changing class during operation.
- ✓ Class-A optimizes power by setting various Receive Delays during transmission.

- ✓ Class-B devices balance power and latency.
- ✓ It relies on a synchronization beacon being broadcasted by the gateway at regular intervals to the network.
- ✓ When a device receives a beacon, it creates a short ping slot (reception window), while it sleeps on other times.
- ✓ Essentially this is a gateway-initiated session and based on a slotted communication method

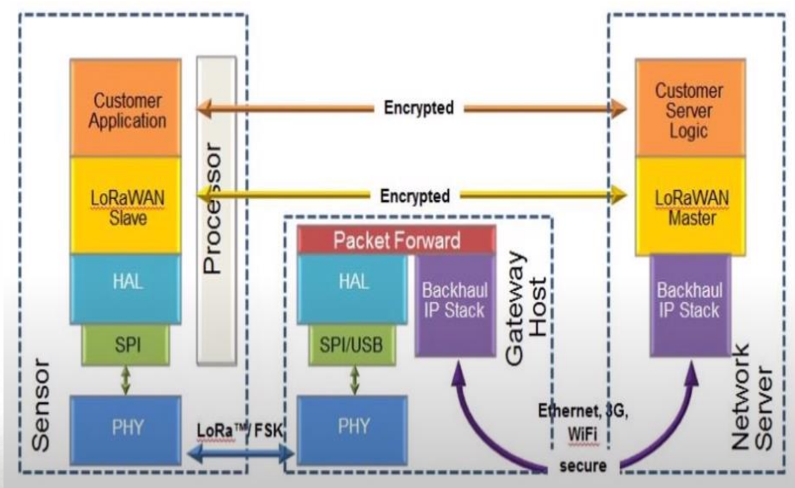
LoRaWAN Network Security



LoRaWAN Network Security

- ✓ **LoRaWAN security encrypts data using the AES128 model.**
- ✓ **One difference in its security from other networks is LoRaWAN separates authentication and encryption.**
- ✓ **Authentication uses one key (NwkSKey), and user data uses a separate key (AppSKey).**

- ✓ **Network Security Key (NwkSkey) : authenticates nodes in the network**
- ✓ **Application Security Key (AppSkey) : ensures network operator cannot inspect the data, but only service provider can**



- ✓ **Notice that the gateways can not decrypt the payloads of different nodes but only the specific application server can do**

LoRaWAN Network Security

- ✓ Two types of activations are available:

Over-the-Air-Activation (OTAA)

- ✓ To join any LoRaWAN network, devices will send a JOIN request.
- ✓ Security keys can be updated on a per session basis, which enables roaming
- ✓ App server has to answer to join requests each time a device (re)starts, generating more downlink traffic
- ✓ The application and network session keys will be derived during the JOIN procedure.

Activation by Personalization (ABP)

- ✓ A LoRaWAN operator pre-allocates 32-bit network and session keys and a client will purchase a connectivity plan and appropriate set of keys.
- ✓ The end-device pre-registered on the network, where keys are stored in end-device and NS.
- ✓ Simpler from application server point of view
- ✓ Node tied to a particular network;

LoRa physical layer:

- ✓ It manages the modulation, power, receiving range
- ✓ LoRa modulation is based on Chirp spread- spectrum (CSS) technology, which makes it work well with channel noise, multipath fading and the Doppler effect, even at low power.
- ✓ The data rate depends on the used bandwidth and spreading factor (SF).
- ✓ LoRaWAN can use channels with a bandwidth of either 125 kHz, 250 kHz or 500 kHz, depending on the region.
- ✓ The spreading factor is chosen by the end-device and influences the time it takes to transmit a frame.

LoRa Parameters:

Parameter	Value Range	Explenation
frequency	863 - 870 Mhz / 902 – 928 MHz …	The frequency used to transmit data
tx power	2 - 14 dBm / 5 – 20 dBm	Power used to transmit
bandwidth	125 / 250 / 500 KHz	Data bandwidth
spreading factor	7 - 12	Frequency spreading factor
coding rate	4/5, 4/6, 4/7, 4/8	Error correction data are (how many error correction bits)

- **Notice that both transmission frequency and power are country specific and are subject to laws**
- **The higher the tx power, the longer the range but the shorter the battery life (tradeoff)**
- **The bandwidth that are used around the used frequency to transmit your data**
- **The higher the BW, the more possible interference, the shorter the range, the lower the battery life**
- **In Europe, they can use only 125 and 20 KHz bandwidth**

Assignment

✓ **Prepare a report on Chirp spread Spectrum (CSS) Modulation containing at least answers to the following questions, but not limited to:**

1. **Explain How CSS works?**
2. **How CSS Modulation and Demodulation is done?**
3. **What is the difference between chirps and chips?**
4. **How symbols are encoded in CSS?**
5. **Why CSS is resilient to interference?**
6. **What is the spreading factor (SF) and how it affects on the LoRaWAN network scalability and range?**
7. **What is the relation between SF, data rate, and range**

Watching Assignment

https://www.youtube.com/watch?v=T3dGLqZrjIQ
https://www.youtube.com/watch?v=dxYY097QNs0
https://www.youtube.com/watch?v=8Oxcp9wQQnk

References

- Simone Cirani, etal , “Internet of Things: Architectures, Protocols and Standards”, Wiley, 2019
- Perry lea, “Internet of Things for Architects”, Packt Publishing Ltd, 2018
- https://www.thethingsnetwork.org/getting-started#

Thank You