Department of Computer Science

FLORIDA TECH
FLORIDA'S STEM UNIVERSITY™

CSE 4820: Wireless and Mobile Security

18. LoRaWAN

Dr. Abdullah Aydeger
Location: Harris Inst #310
Email: aaydeger@fit.edu

Outline

LoRaWAN

- As a Wireless Standard
- History
- Characteristics
- Network Architecture

LoRaWAN

- Long Range (LoRa) Wide Area Network (WAN)
  - "A Low Power, Wide Area (LPWA) networking protocol designed to wirelessly connect battery operated 'things' to the internet in regional, national or global networks,
  - And support targets key Internet of Things (IoT) requirements such as bi-directional communication, end-to-end security, mobility and localization services"

LoRaWAN Protocol

- The LoRaWAN specification is open so anyone can set up and operate a LoRa network
  - Wireless audio frequency technology that operates in a license-free radio frequency spectrum
- It uses a narrow band waveform with a central frequency to send data
  - Makes it robust to interference

LoRaWAN Protocol

- LoRa is a physical layer protocol that uses spread spectrum modulation and supports long-range communication at the cost of a narrow bandwidth
  - Modulation technique derived from Chirp Spread Spectrum (CSS) technology
  - It encodes information on radio waves using chirp pulses;
    - Similar to the way dolphins and bats communicate!

LoRaWAN as Wireless Standard

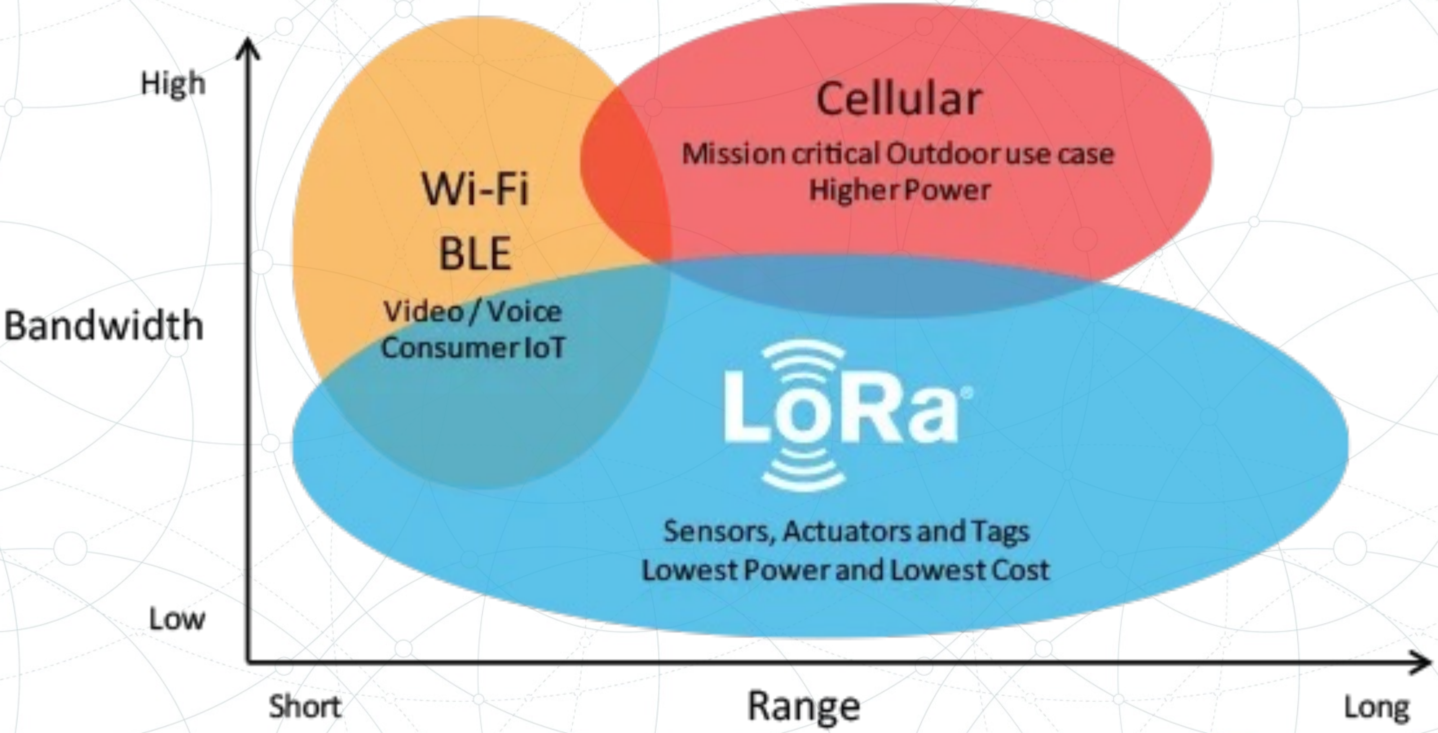
- LoRa is ideal for applications that transmit small chunks of data with low bit rates
- Data can be transmitted at a longer range compared to technologies like WiFi, Bluetooth or ZigBee
- These features make LoRa well suited for sensors and actuators that operate in low power mode

LoRaWAN as Wireless Standard

- LoRa can be operated on the license free sub-gigahertz bands, for example, 915 MHz, 868 MHz, and 433 MHz
- It also can be operated on 2.4 GHz to achieve higher data rates compared to sub-gigahertz bands, at the cost of range
- These frequencies fall into ISM bands that are reserved internationally for industrial, scientific, and medical purposes

LoRaWAN as Wireless Standard

- Suitable for transmitting small size payloads (like sensor data) over long distances
  - <u>Greater communication range with low bandwidths</u> than other competing wireless data transmission technologies



Why LoRaWAN?

- Ultra low power;
  - LoRaWAN end devices are optimized to operate in low power mode and can last up to 10 years on a single coin cell battery
- Long range;
  - LoRaWAN gateways can transmit and receive signals over a distance of over 10 kilometers in rural areas and up to 3 kilometers in dense urban areas
- Deep indoor penetration;
  - LoRaWAN networks can provide deep indoor coverage, and easily cover multi floor buildings

Why LoRaWAN?

- License free spectrum;
  - You don't have to pay expensive frequency spectrum license fees to deploy a LoRaWAN network
- Geolocation;
  - A LoRaWAN network can determine the location of end devices using triangulation without the need for GPS
  - A LoRa end device can be located if at least three gateways pick up its signal
- High capacity;
  - LoRaWAN Network Servers handle millions of messages from thousands of gateways

Why LoRaWAN?

- Public and private deployments;
  - It is easy to deploy public and private LoRaWAN networks using the same hardware (gateways, end devices, antennas) and software (UDP packet forwarders, Basic Station software, LoRaWAN stacks for end devices)
- End-to-end security;
  - LoRaWAN ensures secure communication between the end device and the application server using AES-128 encryption

Why LoRaWAN?

- Firmware updates over the air;
  - You can remotely update firmware (applications and the LoRaWAN stack) for a single end device or group of end devices
- Roaming;
  - LoRaWAN end devices can perform seamless handovers from one network to another
- Low cost;
  - Minimal infrastructure, low-cost end nodes and open source software

Why LoRaWAN?

- Certification program;
  - The LoRa Alliance certification program <u>certifies end devices</u> and provides end-users with confidence that the devices are reliable and compliant with the LoRaWAN specification
- Ecosystem;
  - LoRaWAN has a very <u>large ecosystem of device makers</u>, gateway makers, antenna makers, network service providers, and application developers

LoRaWAN Use Cases

- Vaccine cold chain monitoring;
  - LoRaWAN sensors are used to ensure vaccines are kept at appropriate temperatures in transit
- Animal conservation;
  - Tracking sensors manage endangered species such as Black Rhinos and Amur Leopards
- Dementia patients;
  - Wristband sensors provide fall detection and medication tracking

LoRaWAN History

- The LoRaWAN protocol is developed and maintained by the LoRa Alliance
- The first LoRaWAN specification was released in January 2015

Version	Release date
1.0	January 2015
1.0.1	February 2016
1.0.2	July 2016
1.1	October 2017
1.0.3	July 2018
1.0.4	October 2020

Characteristics of LoRaWAN

- LoRaWAN is a Media Access Control (MAC) layer protocol built on top of LoRa modulation
  - A software layer which defines how devices use the LoRa hardware, for example when they transmit, and the format of messages
- Long range communication up to 10 miles in line of sight
- Long battery duration of up to 10 years
  - For enhanced battery life, you can operate your devices in class A or class B mode, which requires increased downlink latency

Characteristics of LoRaWAN

- Low cost for devices and maintenance
- License-free radio spectrum but region-specific regulations apply
- Has a limited payload size of 51 bytes to 241 bytes depending on the data rate
  - The data rate can be 0,3 Kbit/s – 27 Kbit/s

LoRaWAN Network Overview

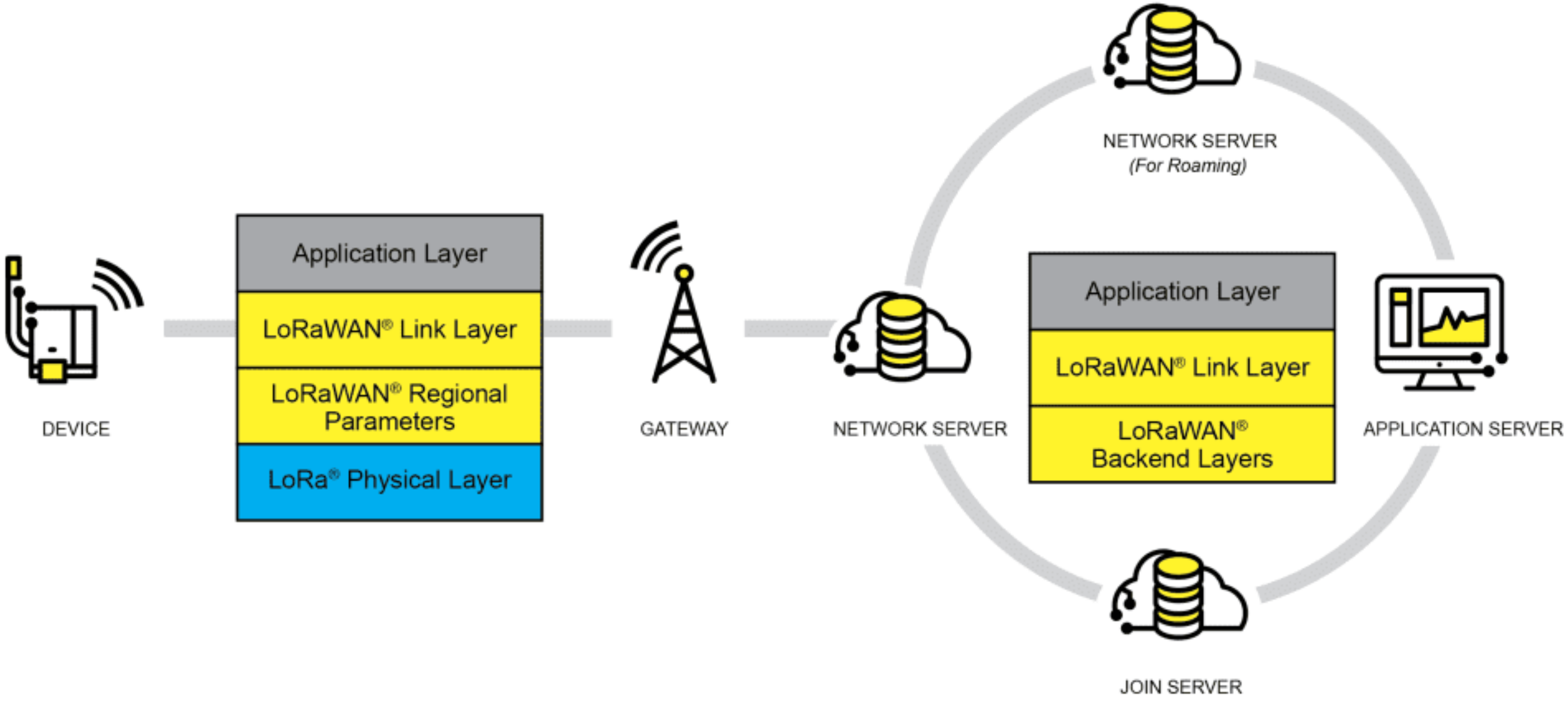
- LoRaWAN® network architecture is deployed in a star-of-stars topology in which gateways relay messages between end-devices and a central network server
- The gateways are connected to the network server via standard IP connections and act as a transparent bridge, simply converting RF packets to IP packets and vice versa

LoRaWAN Network Overview

- The wireless communication takes advantage of the Long Range characteristics of the LoRa physical layer, allowing a single-hop link between the end-device and one or many gateways
- All modes are capable of bi-directional communication,
  - And there is support for multicast addressing groups to make efficient use of spectrum during tasks such as Firmware Over-The-Air (FOTA) upgrades or other mass distribution messages

LoRaWAN Network Overview

- The specification defines the device-to-infrastructure (LoRa®) physical layer parameters & (LoRaWAN®) protocol and so provides seamless interoperability between manufacturers



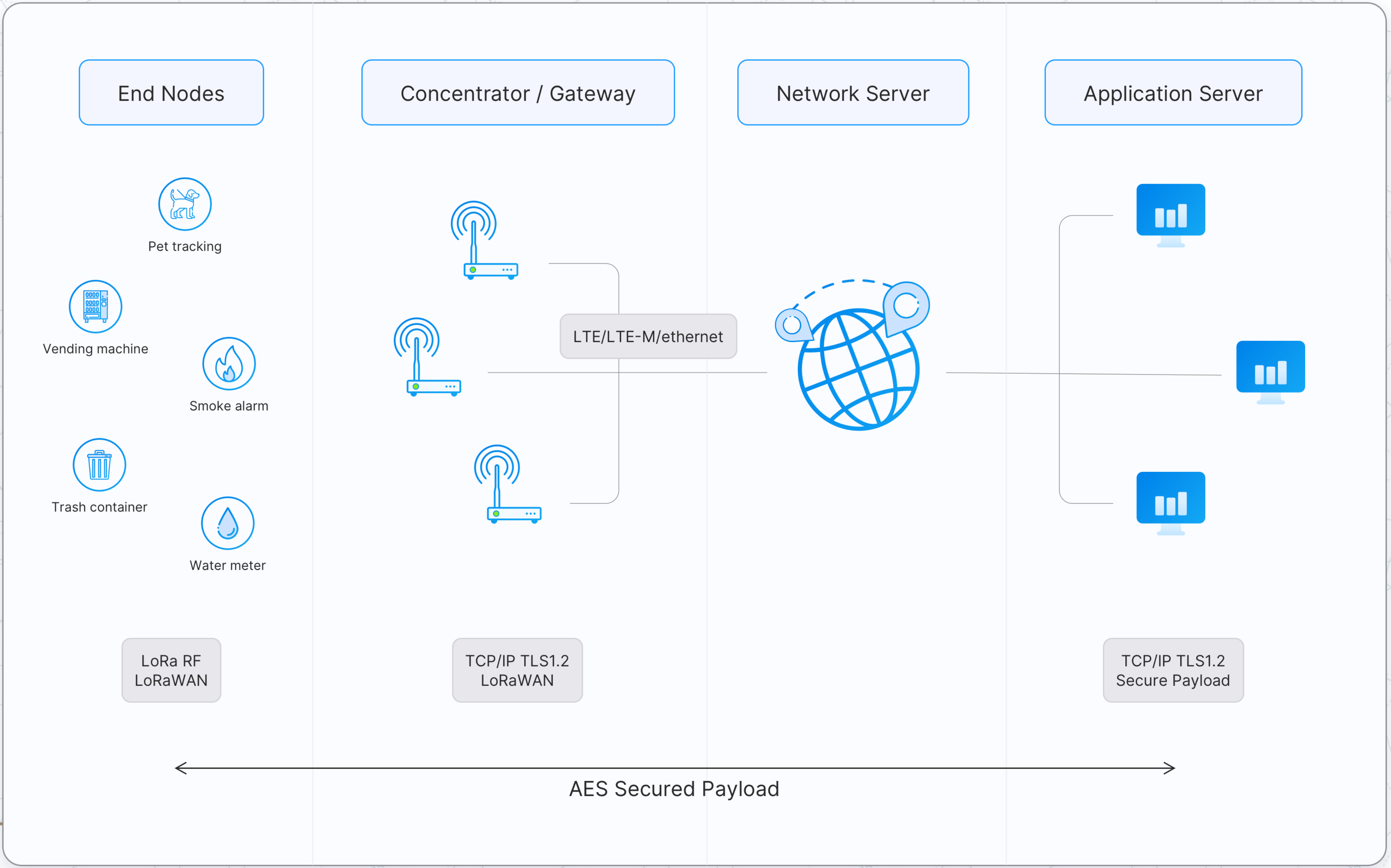
LoRaWAN Network Architecture

- While the specification defines the technical implementation, it <u>does not define any commercial model</u> or type of deployment (public, shared, private, enterprise) and so offers the industry the freedom to innovate and differentiate how it is used
- The LoRaWAN® specification is developed and maintained by the LoRa Alliance®: an open association

LoRaWAN Network Devices

- LoRaWAN Device Types:
  - End Devices
  - Gateways
  - Network Server
  - Application servers
  - Join Server

LoRaWAN Architecture



LoRaWAN: End Device

- A LoRaWAN end device can be a sensor, an actuator, or both
- They are often battery operated
- These end devices are wirelessly connected to the LoRaWAN network through gateways using LoRa RF modulation
- *LoRaWAN end device - The Things Industries Generic Node Sensor Edition*:
  - An end device that consists of sensors like temperature, humidity, and fall detection

LoRaWAN Device Classes

- LoRaWAN has three different classes of end-point devices to address the different needs reflected in the wide range of applications:
  - Class A – Lowest power, bi-directional end-devices
  - Class B – Bi-directional end-devices with deterministic downlink latency
  - Class C – Lowest latency, bi-directional end-devices

LoRaWAN Device Class A

- The default class which must be supported by all LoRaWAN end-devices, class A communication is always initiated by the end-device and is fully asynchronous
- Each uplink transmission can be sent at any time and is followed by two short downlink windows, giving the opportunity for bi-directional communication, or network control commands if needed

LoRaWAN Device Class A

- This is an ALOHA type of protocol
  - Multiple access protocol for transmission of data via a shared network channel
- The end-device is able to enter low-power sleep mode for as long as defined by its own application:
  - There is no network requirement for periodic wake-ups

LoRaWAN Device Class A

- This makes class A the lowest power operating mode, while still allowing uplink communication at any time
- Because downlink communication must always follow an uplink transmission with a schedule defined by the end-device application, <u>downlink communication must be buffered at the network server</u> until the next uplink event

LoRaWAN Device Class B

- Bi-directional end-devices with deterministic downlink latency
- In addition to the class A initiated receive windows, class B devices are synchronized to the network using periodic beacons, and open downlink 'ping slots' at scheduled times

LoRaWAN Device Class B

- This provides the network the ability to send downlink communications with a deterministic latency, but at the expense of some additional power consumption in the end-device
- The latency is programmable up to 128 seconds to suit different applications, and the additional power consumption is low enough to still be valid for battery powered applications

LoRaWAN Device Class C

- Lowest latency, bi-directional end-devices
- In addition to the class A structure of uplink followed by two downlink windows, class C further reduces latency on the downlink by keeping the receiver of the end-device open at all times that the device is not transmitting (half duplex)
  - Based on this, the network server can initiate a downlink transmission at any time on the assumption that the end-device receiver is open, so no latency

LoRaWAN Device Class C

- The compromise is the power drain of the receiver (up to ~50mW) and so class C is <u>suitable for applications where continuous power is available</u>
- For battery powered devices, <u>temporary mode switching</u> between classes A & C is possible and is useful for <u>intermittent tasks such as firmware over-the-air updates</u>

LoRaWAN: Gateways

- Each gateway is registered (using configuration settings) to a LoRaWAN network server
- A gateway receives LoRa messages from end devices and simply forwards them to the LoRaWAN network server
- Gateways are connected to the Network Server using a backhaul like Cellular (3G/4G/5G), WiFi, Ethernet, fiber-optic or 2.4 GHz radio links

Types of LoRaWAN Gateways

- LoRaWAN gateways can be categorized into indoor (picocell) and outdoor (macrocell) gateways
- Indoor gateways are cost-effective and suitable for providing coverage in places like deep-indoor locations
  - These gateways have internal antennas or external 'pigtail' antennas
  - Depending on the indoor physical environment some indoor gateways can <u>receive</u> messages from sensors <u>located several kilometers away</u>

The Things Indoor gateway designed to be directly plugged into an AC power outlet

Types of LoRaWAN Gateways

- Outdoor gateways provide a larger coverage than the indoor gateways
  - Are suitable for providing coverage in both rural and urban areas
- These gateways can be mounted on cellular towers, the rooftops of very tall buildings, metal pipes (masts) etc.
- Usually an outdoor gateway has an external antenna (i.e. Fiberglass antenna) connected using a coaxial cable
- You can convert some indoor gateways to outdoor gateways using water/dust proof enclosures and adding external antennas

Tektelic Enterprise Outdoor Gateway

LoRaWAN: Network Server

- The Network Server manages gateways, end-devices, applications, and users in the entire LoRaWAN network
- A typical LoRaWAN Network Server has the following features:
  - Establishing secure 128-bit AES connections for the transport of messages between end-devices and the Application Server (end-to-end security)
  - Validating the authenticity of end devices and integrity of messages
  - Deduplicating uplink messages
  - Selecting the best gateway for routing downlink messages

LoRaWAN: Network Server

- Sending ADR commands to optimize the data rate of devices
- Device address checking
- Providing acknowledgements of confirmed uplink data messages
- Forwarding uplink application payloads to the appropriate application servers
- Routing uplink application payloads to the appropriate Application Server
- Forwarding Join-request and Join-accept messages between the devices and the join server
- Responding to all MAC layer commands

LoRaWAN: Application Server

- Processes application-specific data messages received from end devices
- It also generates all the application-layer downlink payloads and sends them to the connected end devices through the Network Server
- A LoRaWAN network can have more than one Application Server
- The collected data can be interpreted by applying techniques like machine learning and artificial intelligence to solve business problems

LoRaWAN: Join Server

- Assists in secure device activation, root key storage, and session key generation
- The join procedure is initiated by the end device by sending the Join-request message to the Join Server through the Network Server
- The Join-server processes the Join-request message, generates session keys, and transfers NwkSKey and AppSKey to the Network server and the Application server respectively
- The Join Server was first introduced with LoRaWAN v1.1

Thank you. Questions?

Dr. Abdullah Aydeger