Internet of Things

Low-Power Long-Range Networks

Ioannis Chatzigiannakis

Sapienza University of Rome
Department of Computer, Control, and Management Engineering (DIAG)

Lecture 13:
Low-Power Long-Range Networks

The Need for Low-Power Long-Range Connectivity

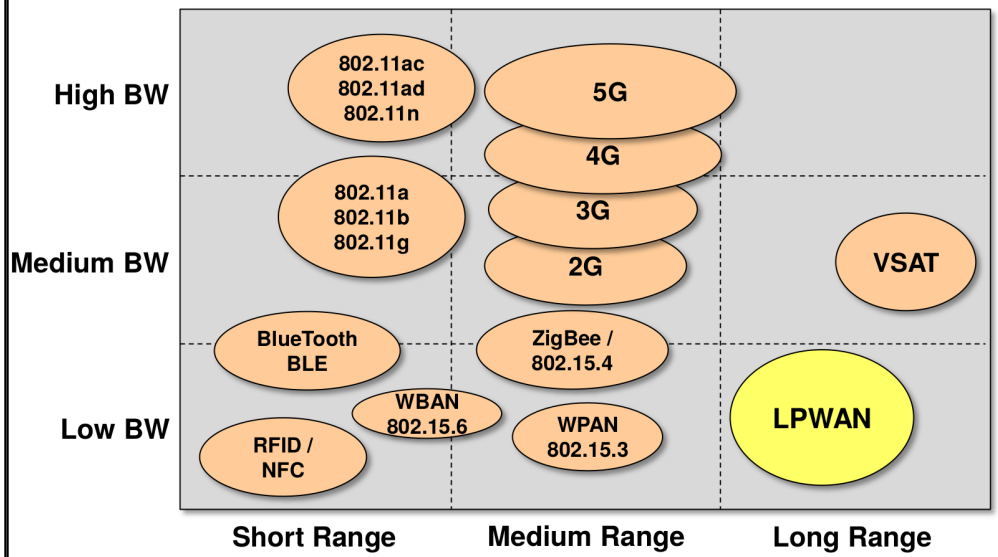
- $>$ 25 billion devices by 2020
- Bluetooth & Wi-Fi not well suited for many scenario
  $<$ 100m, high throughput & power consumption
- 3G/4G cellular not well suited as well
  \$ hardware, \$ SIM's/plans, high battery inefficiency, available spectrum.
- Endpoints costs need to be low
- Must be small for integration into everything
- Conserve wireless spectrum – duty cycle policy
- Conservative power – run on a battery – i.e. mA
- Support really low bandwidth for Bytes not MB of data
- \$ network plans

The Need for Low-Power Long-Range Connectivity

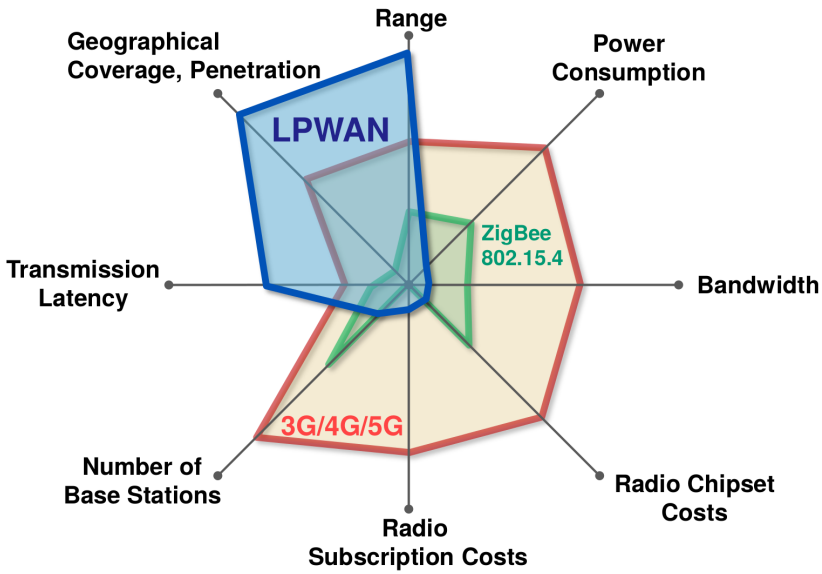
The emergence for IoT introduces new challenges that cannot be addressed by the current available connectivity protocol, such as:

- Bandwidth/Data Rate: In LPWAN, the data rate is selected by a trade-off between the communication range and the duration of the message.
- Battery Life: To maximize the life of the final device batteries, the LPWAN server controls the RF output and an output rate through an adaptive scheme for each end device.
- Range: LPWAN obtains about 2-5 km of coverage range in urban perimeters and about 45 km in rural areas.
- Latency: There is a trade-off between downlink communication latency versus battery life time that can be resolved through QoS classes in a LPWAN device.
- Throughput: Data rates between 290 bps and 50 kbps.

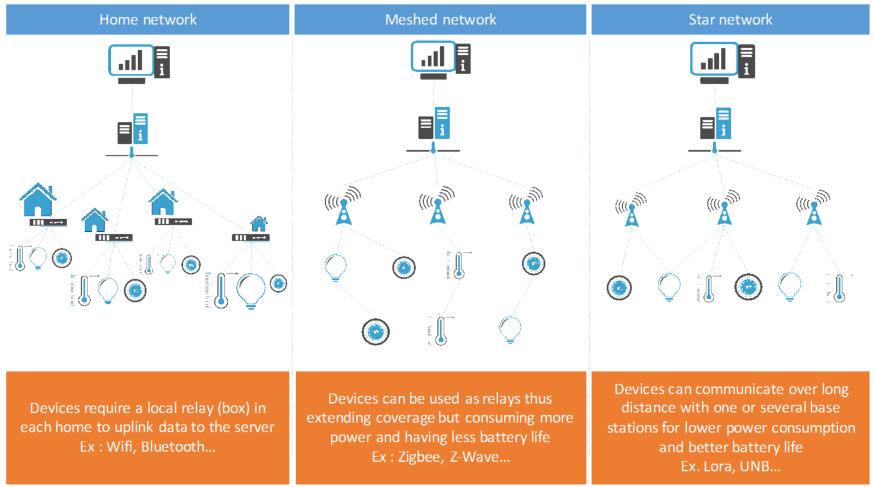
The Need for Low-Power Long-Range Connectivity



The Need for Low-Power Long-Range Connectivity



The Need for Low-Power Long-Range Connectivity



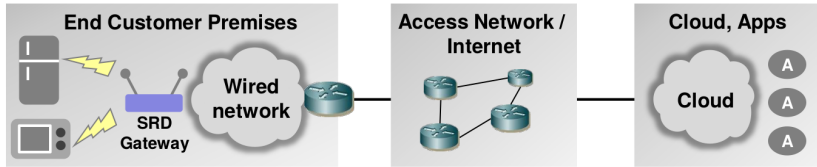
The Need for Low-Power Long-Range Connectivity

Characteristic	Target Value for LPWAN Technologies
Long range	5 – 40km in the open field
Ultra low power	Battery lifetime of 10 years
Throughput	$\sim$ a few hundred bps
Radio chipset costs	\$2 or less
Radio subscription costs	\$1 per device and year
Transmission latency	Not a primary requirement for LPWAN.
Required number of base stations for coverage	Very low. LPWAN base stations are able to serve thousands of devices.
Geographic coverage, penetration	Excellent coverage also in remote and rural areas. Good in-building and in-ground penetration (e.g. for reading power meters).

The Need for Low-Power Long-Range Connectivity

Short range radio connectivity for IoT devices:

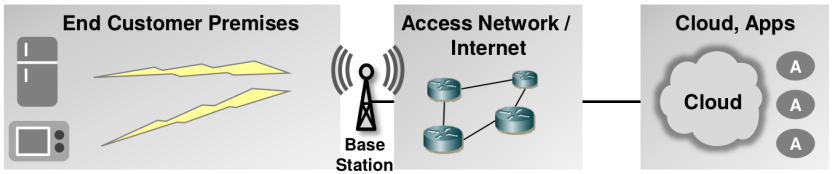
- Short range radio devices (SRD) such as ZigBee require using a gateway for long-range backhaul.
- The gateway is typically hooked up to some on-site wired network which is not under control of the IoT provider.



LPWAN Network Topology

Direct long range connectivity (LPWAN) for IoT devices:

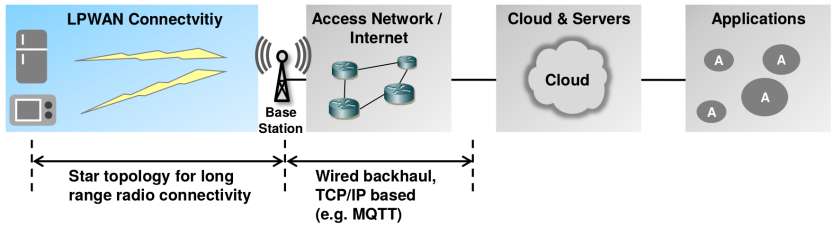
- Long range connectivity allows direct access to the devices in the field.
- The base station typically serves a large number of devices thus greatly reducing costs.



LPWAN Network Topology

Direct device connectivity (base station):

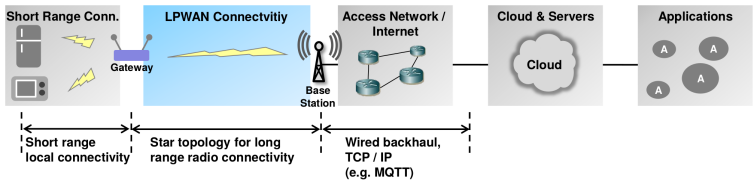
- A base station provides connectivity to a large number of devices.
- The traffic is backhauled to servers (cloud) through TCP/IP based networks (Internet).
- The base station is responsible for protocol translation from IoT protocols such as MQTT or CoAP to device application protocols.



LPWAN Network Topology

Indirect device connectivity through a LPWAN gateway:

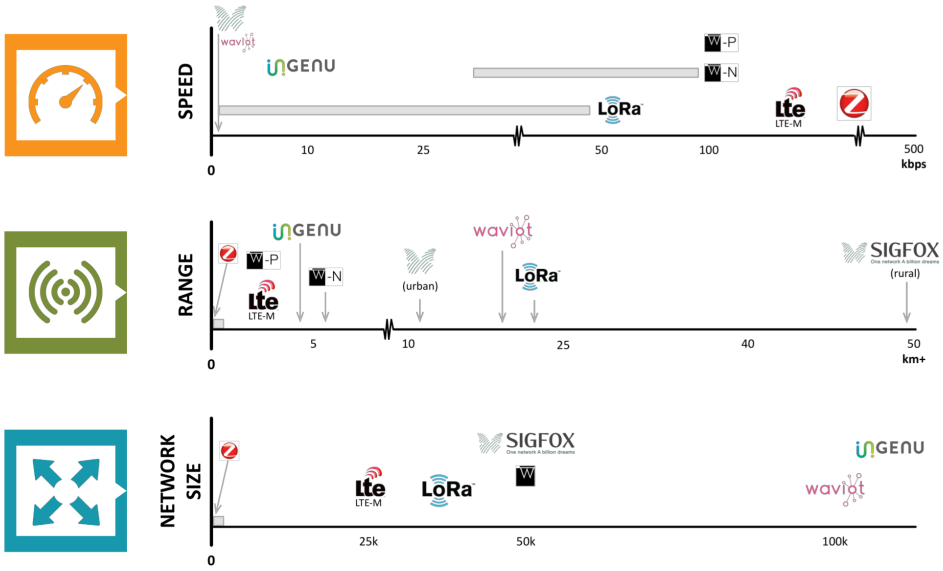
- Devices cannot be directly reached through LPWAN, a local gateway bridges LPWAN connectivity to some short range radio (SRD) technology (e.g. ZigBee, BLE).
- The gateway typically runs on mains power since it serves a larger number of devices and must convert between LPWAN and SRD radio technologies and protocols.
- Gateways may help to improve security since more powerful security algorithms can be implemented on the gateway than is possible on the constrained devices.



Available LPWAN Providers

LoRa	SIGFOX (One network A billion dreams)	waviot	INGENU
Pros	**Pros**	**Pros**	**Pros**
• Private and public networks • MAC & network layers are open • Good hardware availability • Flexible for broad uses • Inexpensive • Excellent battery life	• Easy/quick product development • Well capitalized and good network availability • Inexpensive	• Public and private networks • Great use of spectrum • Good hardware availability • Excellent link budget and performance in varied environments	• Private and public networks • Excellent bi-directional communication • Scalable base stations • Good bandwidth utilization
Cons	**Cons**	**Cons**	**Cons**
• Proprietary PHY layer • Transceivers only available from Semtech • High downstream latency	• Must use public network • Very limited data transfer • Use is limited and caters to sensor networks, status monitoring, etc.	• High latency • Very low speed • Less flexibility than LoRa, Weightless	• Works in crowded 2.4 GHz band • Higher frequency less penetrable

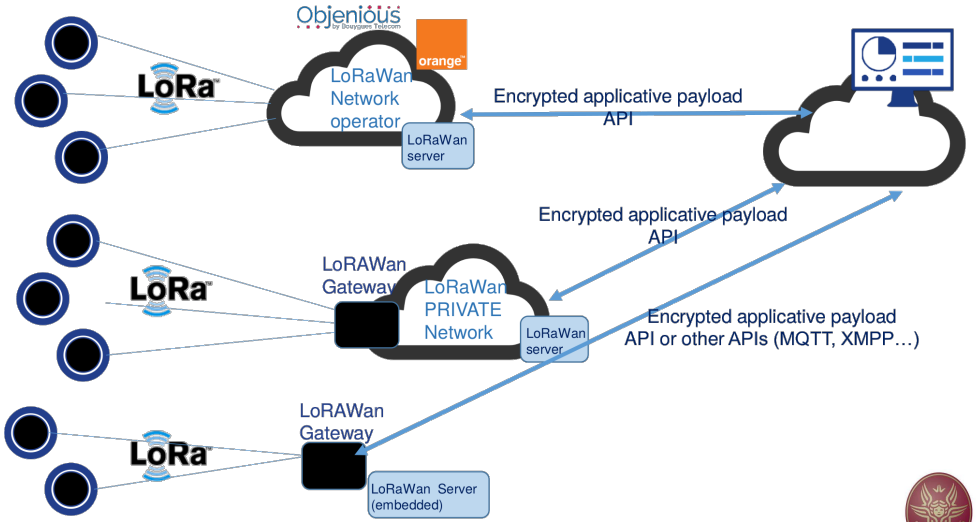
Available LPWAN Providers



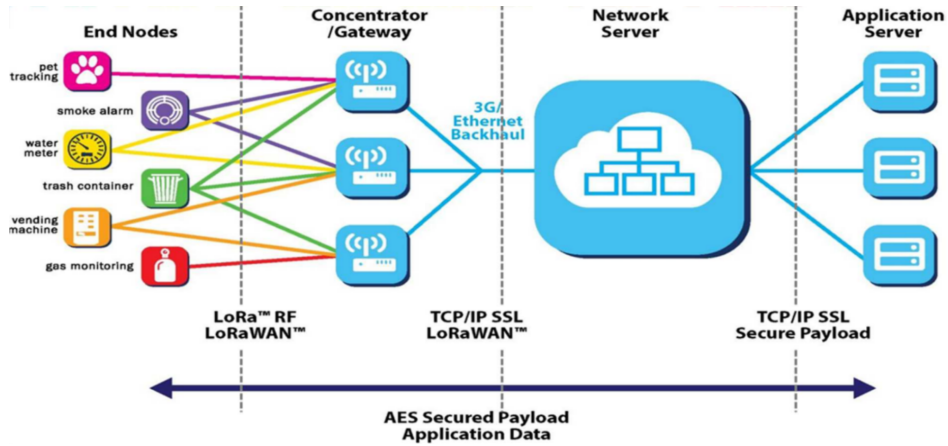
LoRa – Long Range

- Technology and protocol engineered by SEMTECH from a French technology (Cycleo)
- LoRa Alliance (founded in 2014, > 200 members in 2016)
- 2 successive versions of the protocol: LoRAMAC & LoRAWAN 1.1
- 3 classes of devices LoRAWan: A, B, C*
  - Classe A: Bi-directional end-devices
  - Classe B: Bi-directional end-devices with scheduled receive slots
  - Classe C: Bi-directional end-devices with maximal receive slots
- Chipsets exist in unidirectional (860 – 1020 MHz band) or bidirectional (High Band – 860-960MHz & Low Band – 169-510MHz) and for the moment are provided only by Semtech.
- End devices identification: IEEE EUI64 format

LoRa – Architecture Principles



LoRa – LoRaWAN protocol

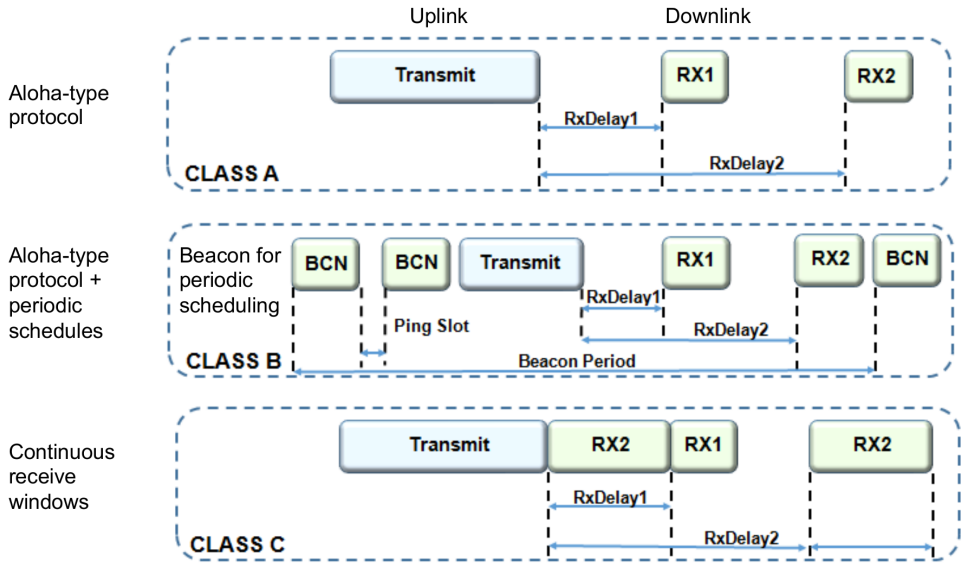


- Long range star network (same as telecom cellular networks)
- Centrally managed multi-tenant network

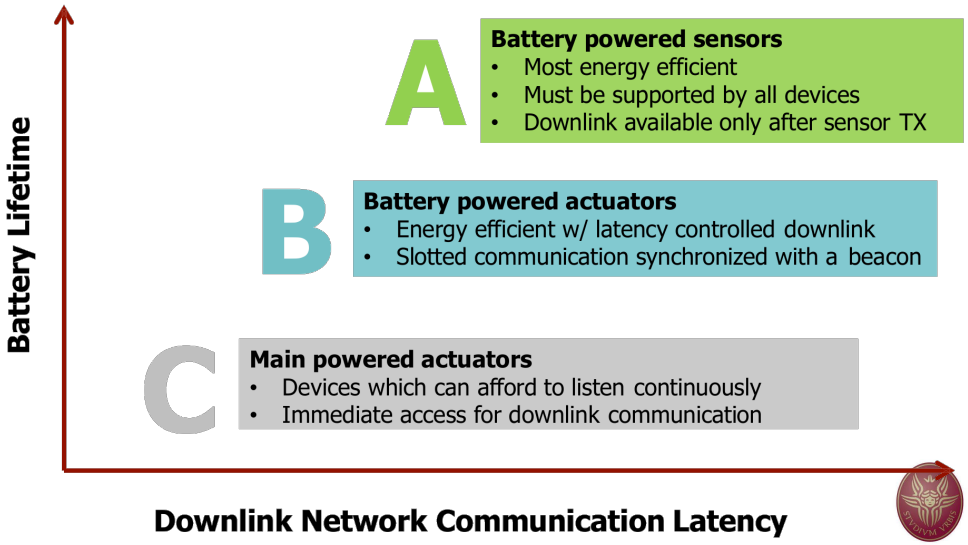
LoRa – LoRaWAN protocol

- End devices identification: IEEE EUI64 format
- Datarate of 0.3 to 50 Kb/s
- Encryption AES128 device – server & end-node – user app
- Stars of stars architecture
- 3 classes of devices (bidirectionnal communication)
  - Classe A
  - Classe B (beacon)
  - Classe C (continuous)

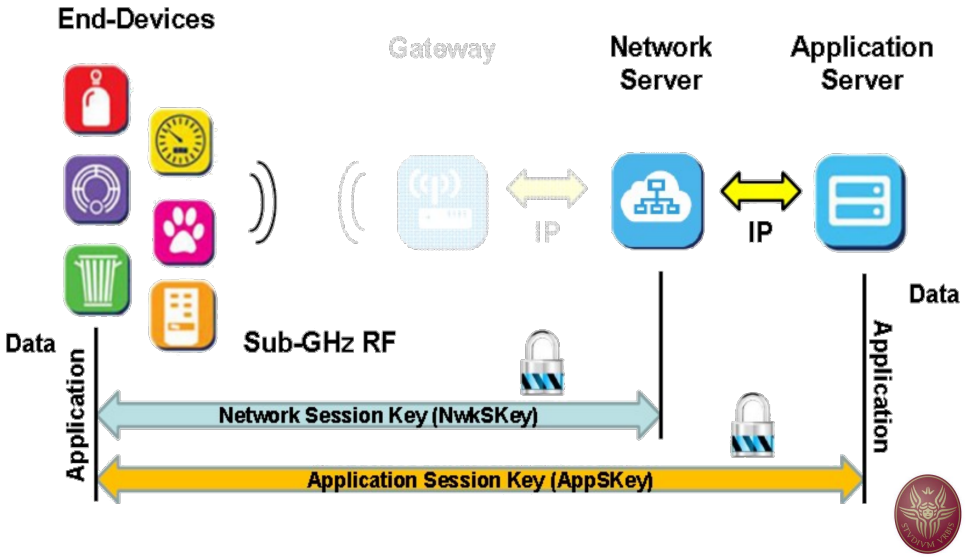
LoRa – LoRaWAN protocol



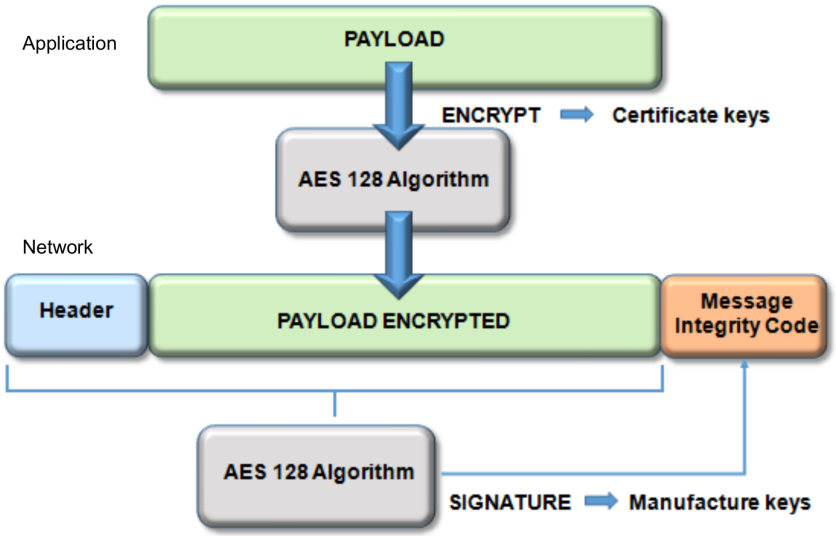
LoRa – LoRaWAN protocol



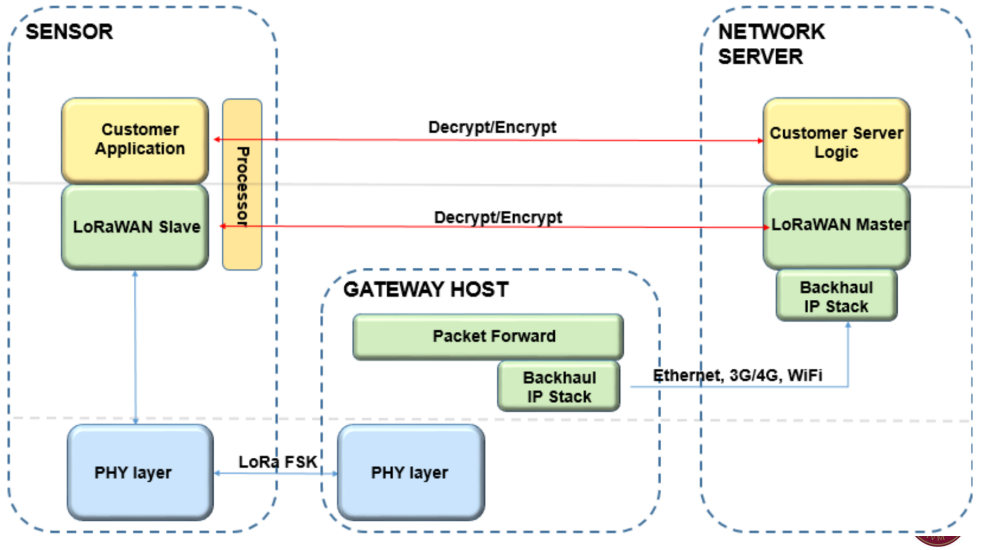
LoRa – Logical Model



LoRa – Logical Model



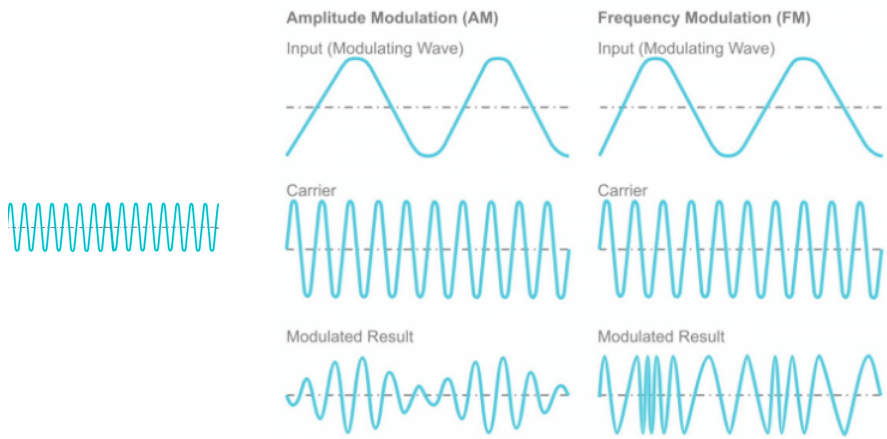
LoRa – Logical Model



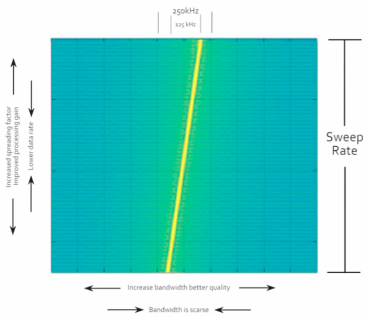
LoRaWAN ingredients – Why these performances?

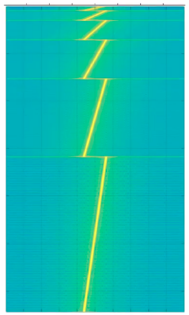
- Frequency
- Modulation - Chirp spreading factor
- Adaptive Data Rate

LoRaWAN ingredients – Modulation Technique

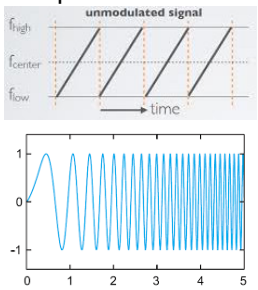


LoRaWAN ingredients – Modulation Technique



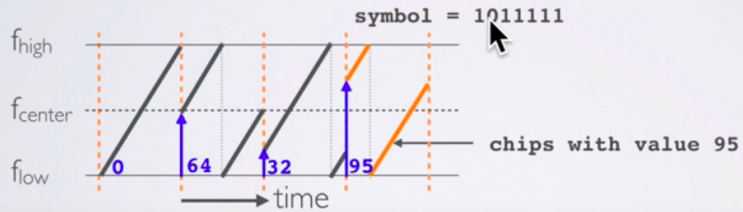


Chirp



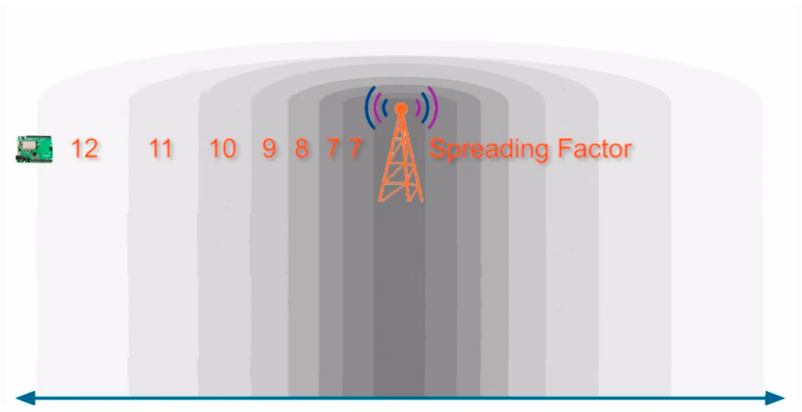
LoRaWAN ingredients – Modulation Technique

- The sweep signal is divided into 2^{SF} steps or chips.
- For example the symbol is: 1011111 (decimal value = 95)
  The number of raw bits that can be encoded by this symbol is 7 (SF=7)
  The sweep signal is divided in $2^{SF} = 2^7 = 128$ chips.



How to calculate data rate:
`https://www.youtube.com/watch?v=r84GMLeiqg8`

LoRaWAN ingredients – Spreading Factor



LoRaWAN ingredients –

LoRa Spreading Factors (125kHz bw)

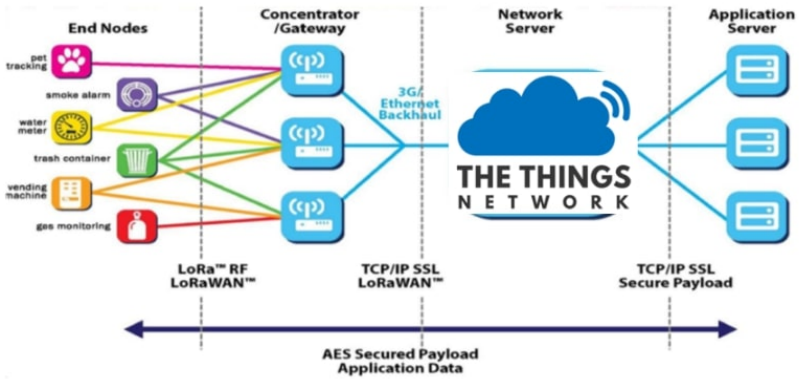
Spreading Factor	Chips/symbol	SNR limit	Time-on-air (10 byte packet)	Bitrate
7	128	-7.5	56 ms	5469 bps
8	256	-10	103 ms	3125 bps
9	512	-12.5	205 ms	1758 bps
10	1024	-15	371 ms	977 bps
11	2048	-17.5	741 ms	537 bps
12	4096	-20	1483 ms	293 bps

The Things Network – What is?

https://www.youtube.com/watch?v=U4UrXl-SGEo

The Things Network – Community

The Things Network – Architecture



LoRa Basics Station

- LoRa packet forwarder: runs on the LoRa-based gateway.
- Forwards RF packets received by the concentrator (uplinks) to a LoRaWAN Network Server (LNS) through a secured IP link.
- Transmits RF packets sent by the LNS (downlinks) through the same secured IP to one or multiple devices.