CSE570 Spring 2020

Wireless and Mobile Networks

IoT/Sensor Networks

(LoRa & LoRaWAN)

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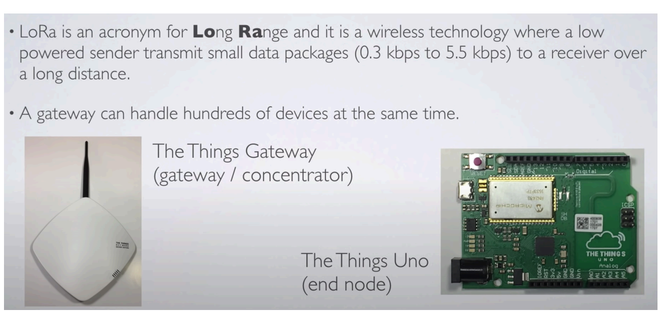
LoRA

- Wireless modulation technology
- Low bandwidth
- Low battery usage



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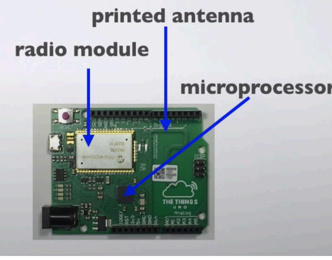
LoRA

- A LoRa end node consists of 2 parts:
  - A radio module with antenna.
  - A microprocessor to process for example the sensor data.
- End nodes are often battery powered.
- A LoRa device (end node) has a wireless transceiver.
  If this device also has sensors, this device acts as a remote sensor.
  Such a device is called a mote, short for remote.



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LoRaWAN

- Communications protocol and architecture that utilizes the LoRa physical layer
- Data rates are defined that range from 300bps to 5.5kbps
  - with two high-speed channels at 11kbps and 50kbps (FSK modulation)
- Supports
  - secure bi-directional communication,
  - mobility
  - localization.

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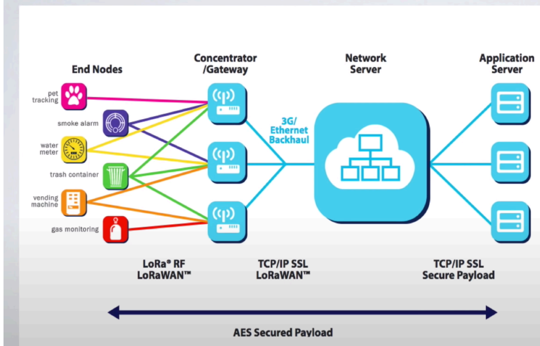
LoRaWAN



- LoRaWAN network architecture is deployed in a star topology.
- The communication between the end node and gateway is bidirectional which means the end node can send data to the gateway but it can also receive data from the gateway.

Source: https://lora-alliance.org/sites/default/files/2018-04/what-is-lorawan.pdf

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Why LoRa and Why LoRaWAN?

- Lowe Power
  - No other wireless networks support extreme low power communication
- Long range
  - Cellular supports but suffers from power consumption, licensed spectrum etc

- A class of LPWANs
  - E.g., NB-IoT

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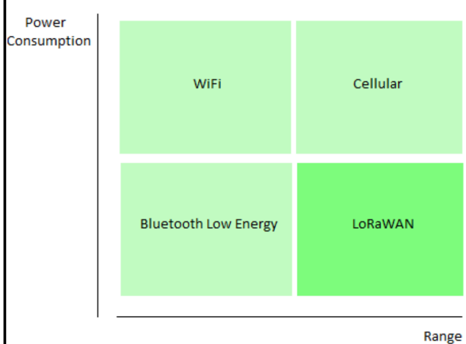
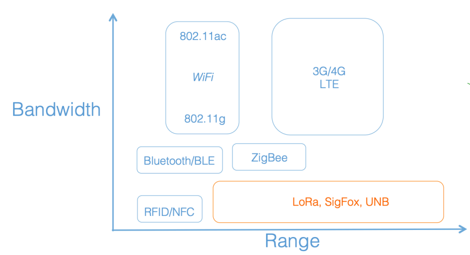
Some Notable Differences

	802.11n	4G	LoRaWAN
Throughput	< 300 Mb/s	20 Mb/s imho	< 1 Mb/s
Range	100 … 200 m	2 … 10 km	20 km and more!
Battery life	Days	Days	Years!





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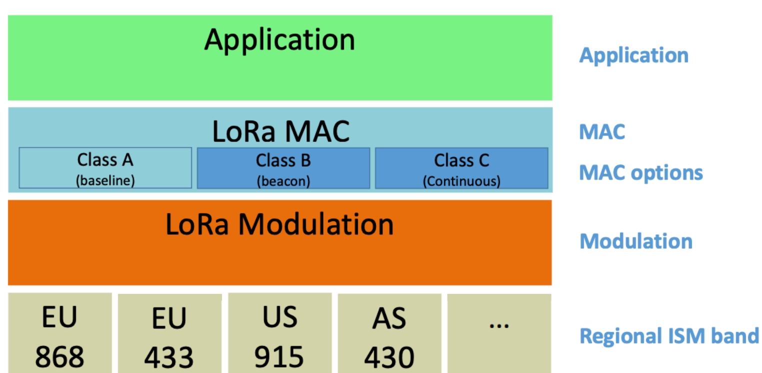
So, What is New in LoRaWAN

- **Physical Layer**
- MAC Layer



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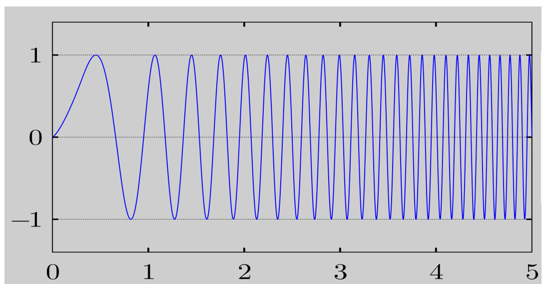
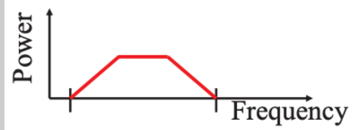
LoRa Modulation

- Chirp Spread Spectrum

  Chirp: A signal with continuously increasing (or decreasing) frequency (Whale sound)

  Chirp Spread Spectrum: signal is frequency modulated with frequency increasing (or decreasing) from min to max (or max to min) ⇒ power is *spread* over the entire spectrum





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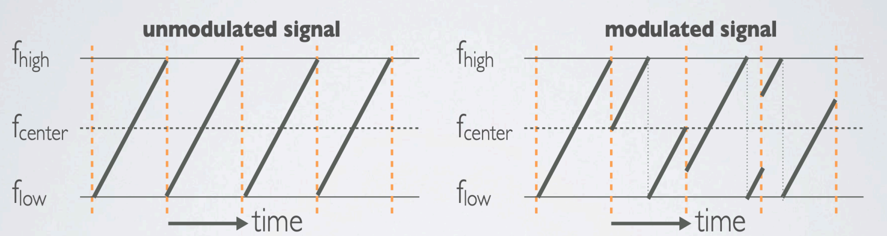
LoRa Modulation

- The chirps are cyclically-shifted, and it is the frequency jumps that determines how the data is encoded onto the chirps, aka LoRa modulation.



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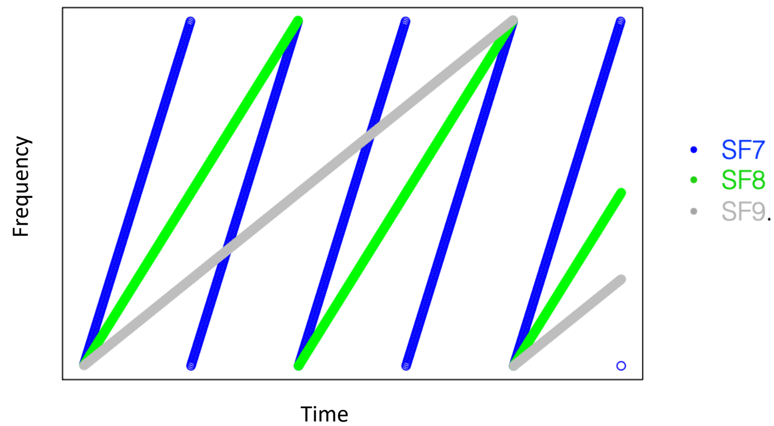
LoRa Modulation – Spreading Factors



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LoRa Modulation – Spreading Factors

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

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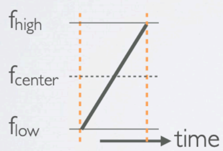
Symbols, SF, Chips

- A symbol represents one, or more bits of data, for example:
  Symbol = 1011111 (decimal = 95)
- In the example above the number of raw bits that can be encoded by the symbol is 7.
  This is the same as saying: Spreading Factor (SF) = 7
- The symbol has 2^{SF} values. If SF=7, the values ranges from 0 - 127.
  The symbol value is encoded onto a sweep signal (up-chirp).



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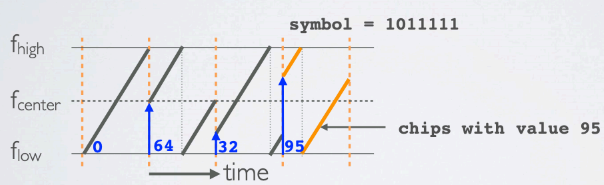
Symbols, SF, Chips

- 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.



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Symbols, SF, Chips

- Another example, lets assume SF=12
  Each symbol can carry 12 raw bits of information and there are 2^{12} = 4096 unique chip values ranging from 0 to 4095.
- **The Spreading Factor (SF) defines two values:**
  - **The number of raw bits that can be encoded by that symbol: SF**
  - **Each symbol can hold 2^{SF} chips**
- Please be aware of the difference between a **chirp** and a **chip**.
  A symbol holds 2^{SF} chips.
  Chirps are simply a ramp from f_{low} to f_{high} (up-chirp) or f_{high} to f_{low} (down-chirp).

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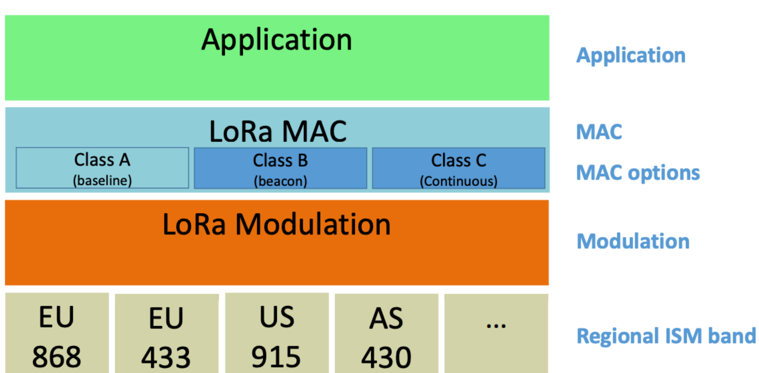
So, What is New in LoRaWAN

- Physical Layer
- **MAC Layer**



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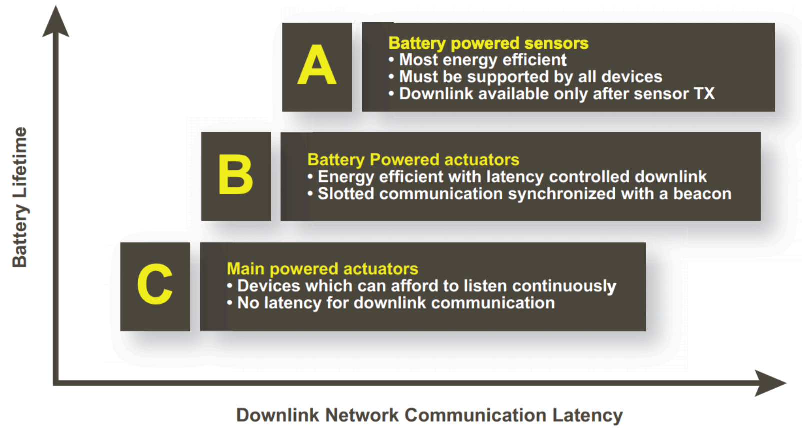
LoRAWAN MAC



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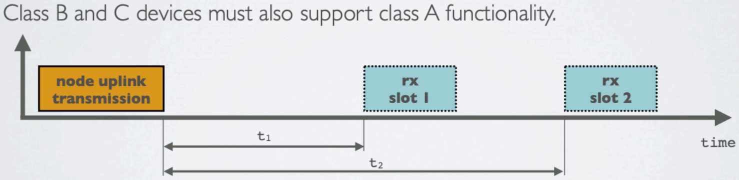
Class A

- At any time an end node can broadcast a signal. After this uplink transmission (tx) the end node will listen for a response from the gateway.
- The end node opens two receive slots at t_1 and t_2 seconds after an uplink transmission. The gateway can respond within the first receive slot or the second receive slot, but not both.
- Class B and C devices must also support class A functionality.



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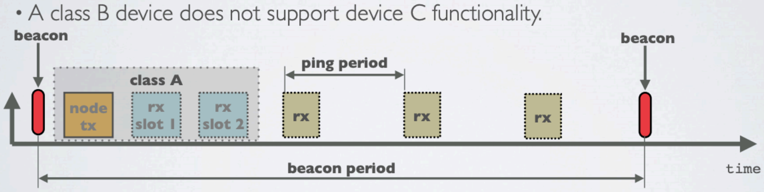
Class B

- In addition to Class A receive slots, class B devices opens extra receive slots at scheduled times.
- The end node receives a time synchronised beacon from the gateway, allowing the gateway to know when the node is listening.
- A class B device does not support device C functionality.



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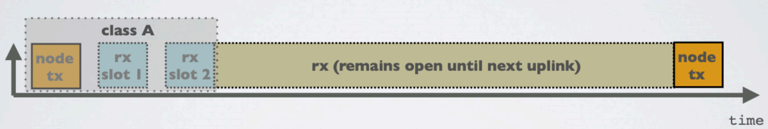
Class C

- In addition to Class A receive slots a class C device will listen continuously for responses from the gateway.
- A class C device does not support device B functionality.



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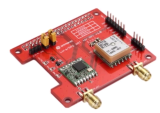
LoRa Devices in the Market

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++

mDot
868/433/915 MHz

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Why not Repurposing Cellular for LPWANs

- Narrowband (NB–IoT) architecture
  - Follows similar principles of cellular but tries to optimize for power

	LoRaWAN	NB-IoT
TX Current	24-44 mA	74-220 mA
RX Current	12 mA	46 mA
Idle Current	1.4 mA	6 mA
Sleep Current	0.1 μA	3 μA

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Readings

- https://www.mobilefish.com/developer/lorawan/lorawan_quickguide_tutorial.html
- https://www.tuv.com/media/corporate/products_1/electronic_components_and_lasers/TUeV_Rheinland_Overview_LoRa_and_LoRaWANtmp.pdf
- https://lora-alliance.org/sites/default/files/2018-07/lorawan1.0.3.pdf

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