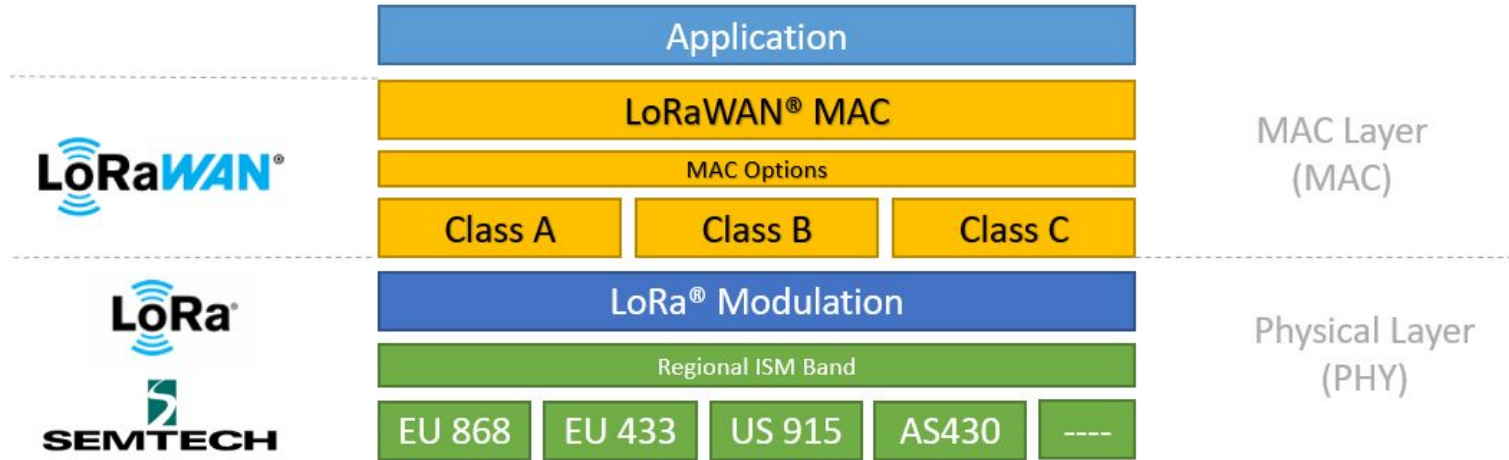


LORA and LORAWAN

By Devansh Shukla

Lora and LoRaWAN



Lora - Physical Layer

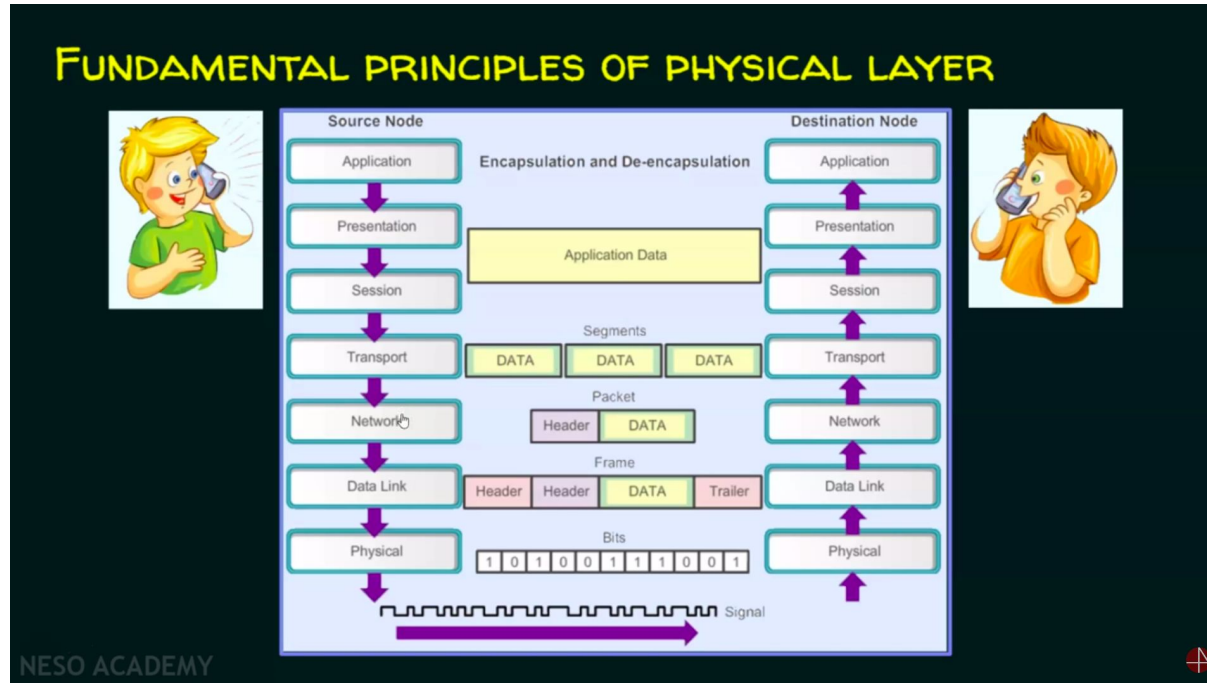
Lora Frequencies

- Unlike Wifi and Bluetooth , Lora has a non Global Frequency (ie) Lora has different Frequency for different Countries

	Europe	North America	China	Korea	Japan	India
Frequency band	867-869MHz	902-928MHz	470-510MHz	920-925MHz	920-925MHz	865-867MHz
Channels	10	64 + 8 +8	In definition by Technical Committee	In definition by Technical Committee	In definition by Technical Committee	In definition by Technical Committee
Channel BW Up	125/250kHz	125/500kHz				
Channel BW Dn	125kHz	500kHz				
TX Power Up	+14dBm	+20dBm typ (+30dBm allowed)				
TX Power Dn	+14dBm	+27dBm				
SF Up	7-12	7-10				
Data rate	250bps- 50kbps	980bps-21.9kbps				
Link Budget Up	155dB	154dB				
Link Budget Dn	155dB	157dB				

Physical Layer:

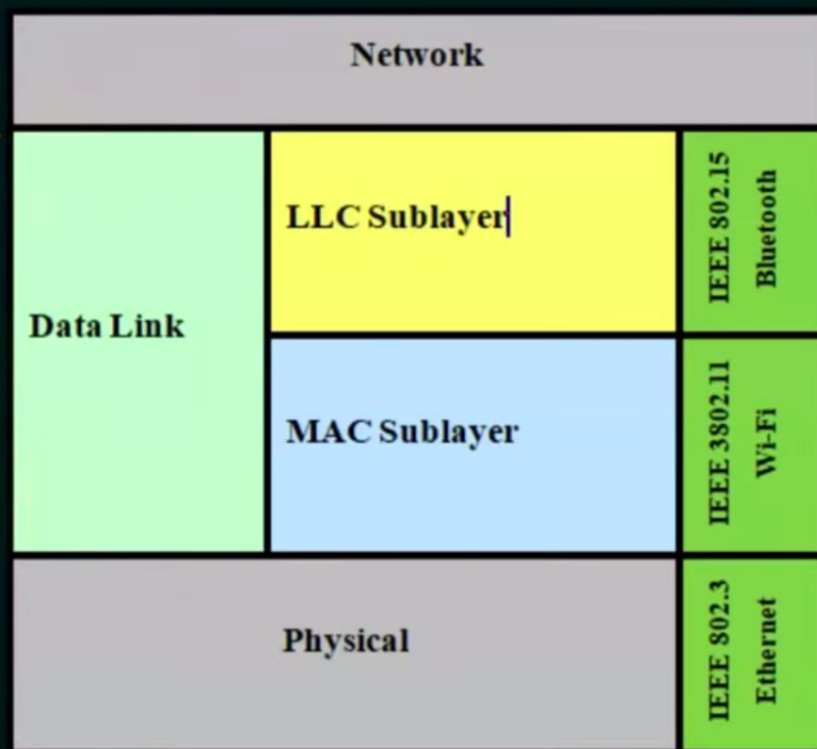
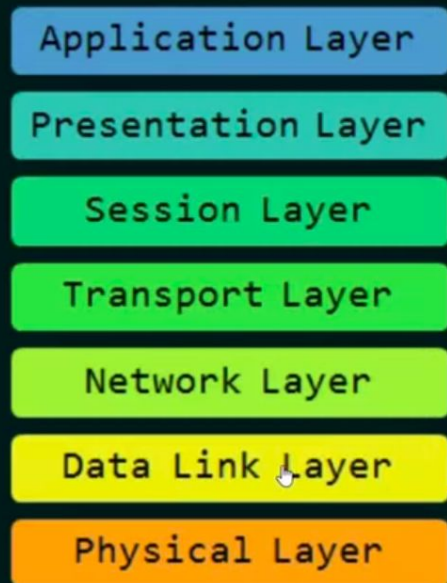
Physical layer Converts the Data frames into bits and sends it to the Receiver in Electromagnetic signals



MAC Layer:

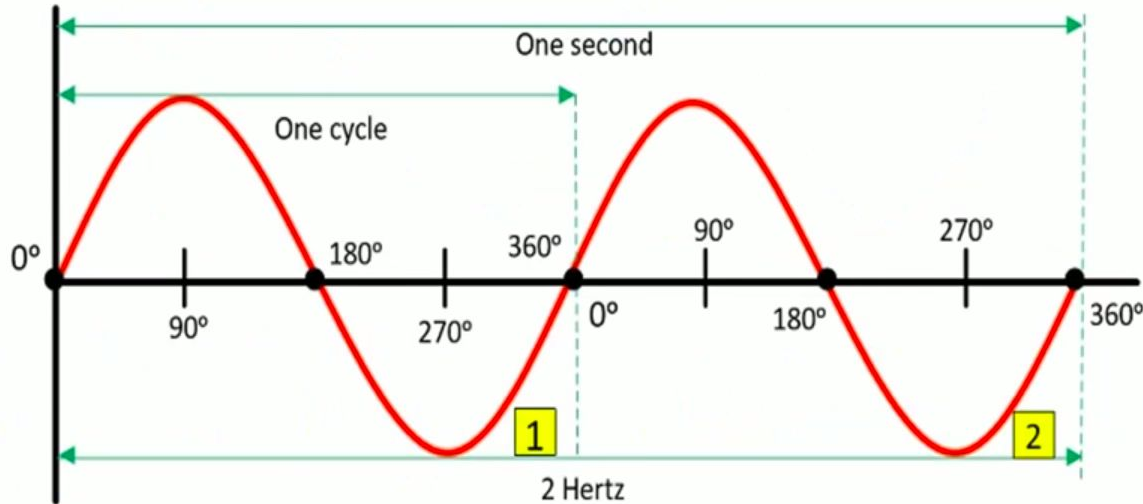
- MAC{Media Access Control Layer} : It's a Sub layer of Data-link layer which consists of Logical link control{LLC} and MAC layer.
- LLC is responsible for FLOW Control
- MAC sub Layer:
 - Data Encapsulation
 - Media Access Control
 - Consists of NIC[Network Identification Card]
 - Responsibilities
 - Framing, Physical addressing, MAC Addressing and Error Control.

DATA LINK LAYER



What is Frequency?

The number of cycles made per second by an alternating quantity is called frequency. It is measured in cycle per second (c/s) or hertz (Hz) and is denoted by (f).



Lora Modulation:

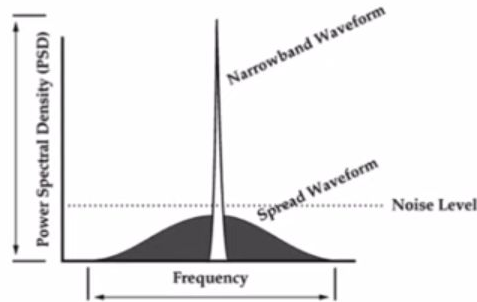
CHIRP SPREAD SPECTRUM MODULATION:

- 8 up chirps - preamble
- 2down Chirp - Synchronization
- 5up chirps - Data

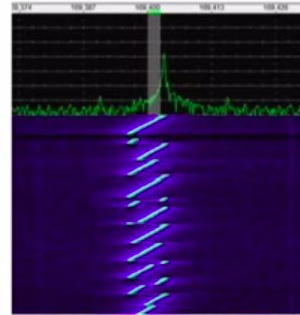
Lora Demodulation:

- Dechirping
- Spectrum Analysis

LoRa modulation



Spread-spectrum modulation



LoRa spectrogram

Image sources: "Spread Spectrum - It's not just for breakfast anymore!" (www.qsl.net),
"What is LoRa? A technical breakdown" (www.link-labs.com)

LoRa modulation

- 8 up-chirps → preamble
- 2 down-chirps → synchronization
- 5 up-chirps → data

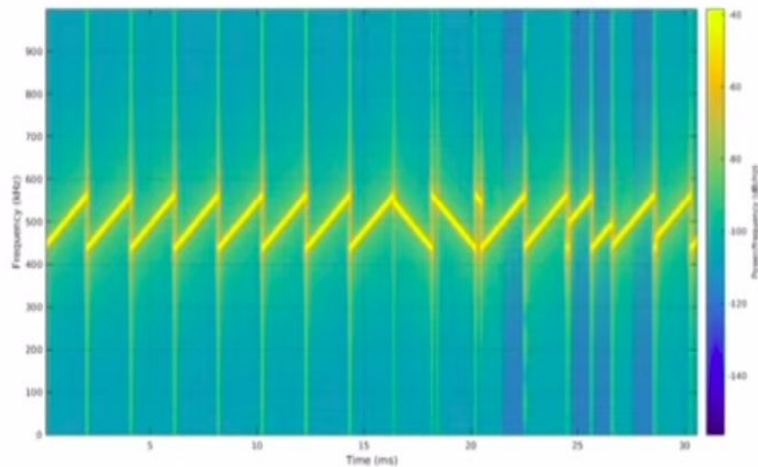


Image source: "Low power radio frequency" by Ronnie Smyth
(www.cse.dmu.ac.uk)

Benefits Of Lora

1. Bidirectional Communication
2. Adaptive Data Rate Mechanism.
 - a. SF based on Link Budget.
3. Duty cycle and Time On Air {Dwell Time}
4. Range - 850 km
 - a. The Things Virtual Conference tested with Helium balloons and the range is about 832 KM

Limitation Of Lora

1. Reflection and Diffraction
2. Fresnel Zone Factor
3. Structural Attenuation

Doesn't Get affected By **DOPPLER EFFECT**

Doppler effect

- Frequency shift due to mobility
- LoRa device moving from or towards the gateway
 - completely negligible in conditions of low data rates and high spreading factors
 - not insignificant for high data rates

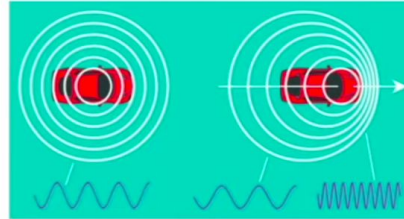


Image source: "What is the Doppler effect?" by Brad Allen Williams
(flypaper.soundfly.com)

Doesn't Get affected by **Multipath and Interference**

Interference and multi-path

- Phenomena caused by presence of the obstacles in space between transmitter and receiver
- Experimental results
 - LoRa has a high immunity to these phenomena in conditions of low data rates and higher spreading factors

	Interference	Multipath
White	Immune	Immune
Light-grey	Susceptible	Immune
Dark-grey	Susceptible	Susceptible

	Spreading factor SF						
Channel bandwidth BW	12	11	10	9	8	7	
125 kHz							
250 kHz							
500 kHz							

Image source: "LoRa performance under variable interference and heavy multipath conditions" by K. Staniec and M. Kowal
(www.hindawi.com)

RANGE:

Range - considerations

- Range depends on whether there is a line of sight, and whether the gateway is located indoor or outdoor
 - indoor ~ 500 m
 - outdoor, on top of a house roof ~ 2 km
 - outdoor, on top of a high-altitude building > 10 km
- Gateway elevation example



Image source: "How to triple the range of LoRa" by Haystack Technologies Inc.
(www.slideshare.net)

LoraWAN - MAC Layer

LoraWAN - Device Classes

Device classes

Differentiation based on the way of handling the downlink communication

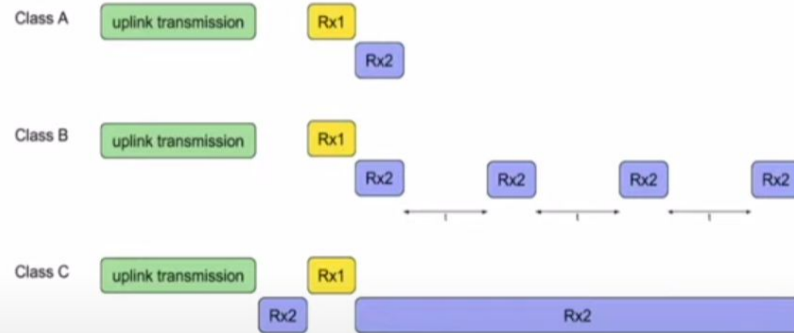


Image source: "LoRaWAN, a dedicated IoT network" article by Julien Quere (witekio.com)

Security

Three pillars of security

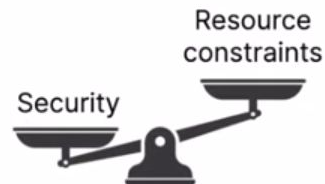


Keys in LoRaWAN version 1.1.x

Application Key (AppKey)	Application Session Key (AppSKey)
Network Key (NwkKey)	Forwarding Network Session Integrity Check (FNwkSIntKey)
	Serving Network Session Integrity Key (SNwkSIntKey)
	Network Session Encryption Key (NwkSEncKey)

OTAA vs ABP - which one is safer?

OTAA	ABP
New session on every join procedure	Fixed session, no join procedure
Supports rekey on every rejoin	Security keys stored in a persistent memory
Join any LoRaWAN network	Preconfigured network



LoRaWAN is secure by design, but implementation matters

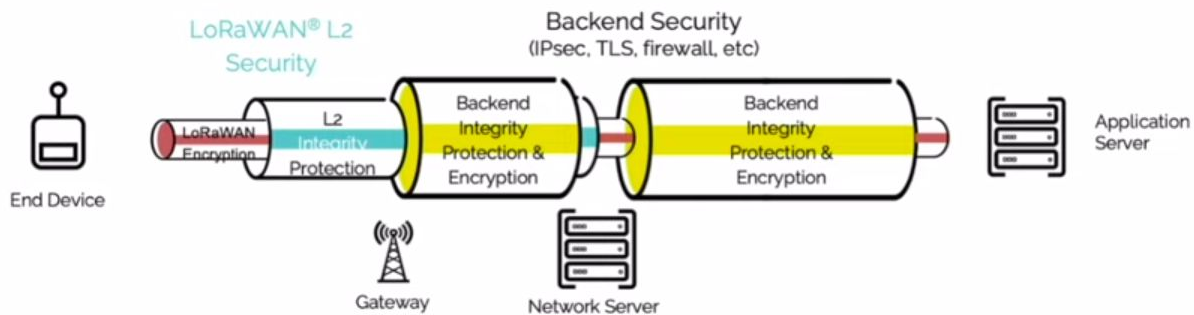


Image source: "Secure + reliable connectivity" webinar hosted by Semtech, Actility and The Things Industries

Privacy Consideration

- Join EUI {APP EUI}
 - When a device joins a network , a Join EUI is generated
- DevEUI
 - Identification of Device
- DevAddr
 - Device Address

Security Features

- Link Check MAC
 - Check Link Quality
- Acknowledgement
- Adaptive Data Rate Algorithm
 - Packet Loss reduction
- Frame Counters
 - Avoid replay , Receiver recognizes the received data and prevents re-transmission
- DevNonce
 - A Unique number incremented by one after each joining

thankyou.™