LoRa details

Ermanno Pietrosemoli

HISTORY

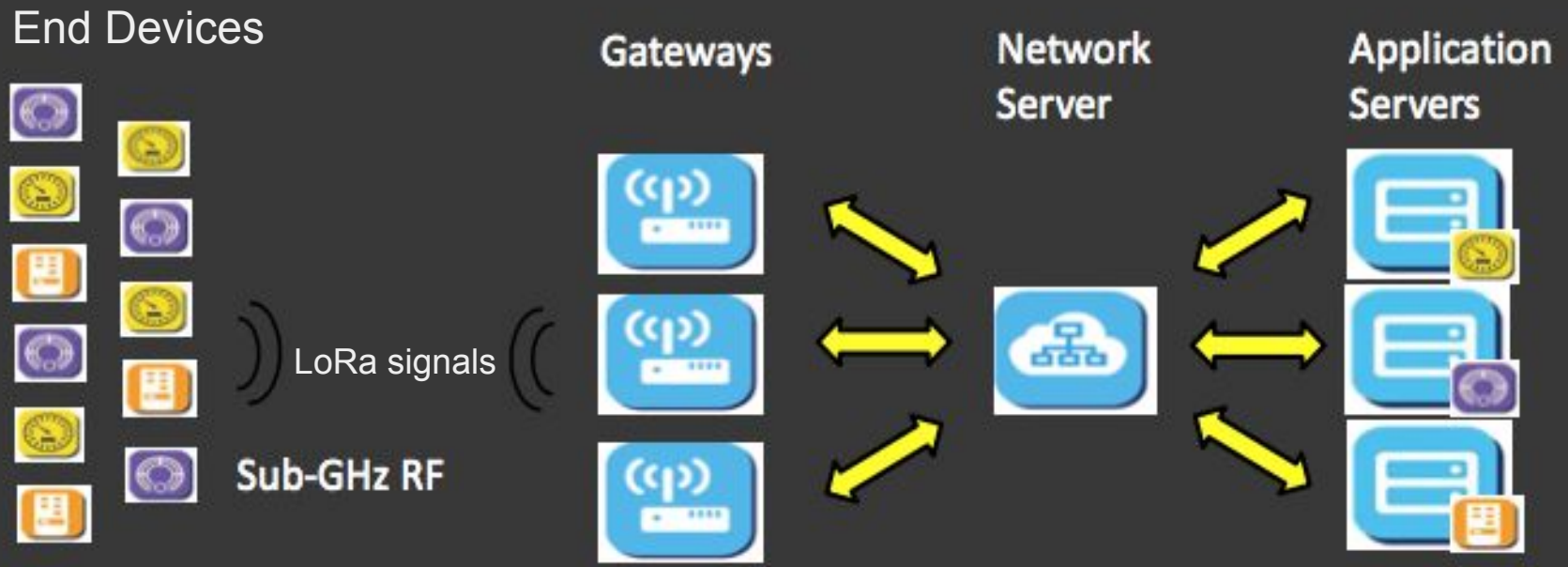
- LPWAN developed by Semtech
- PHY patented in June 2014
- LoRaWAN MAC/NWK stack released in January 2015
- Supported by LoRa Alliance

LoRa and LoRaWAN

LoRa is strictly physical layer, and is proprietary. Chip manufacturers include Semtech, Microchip and Hope RF.

LoRaWAN is an open standard that adds the MAC, networking and application layers that provide required functionalities like managing medium access, security and so on.

LoRaWAN™ Network Topology

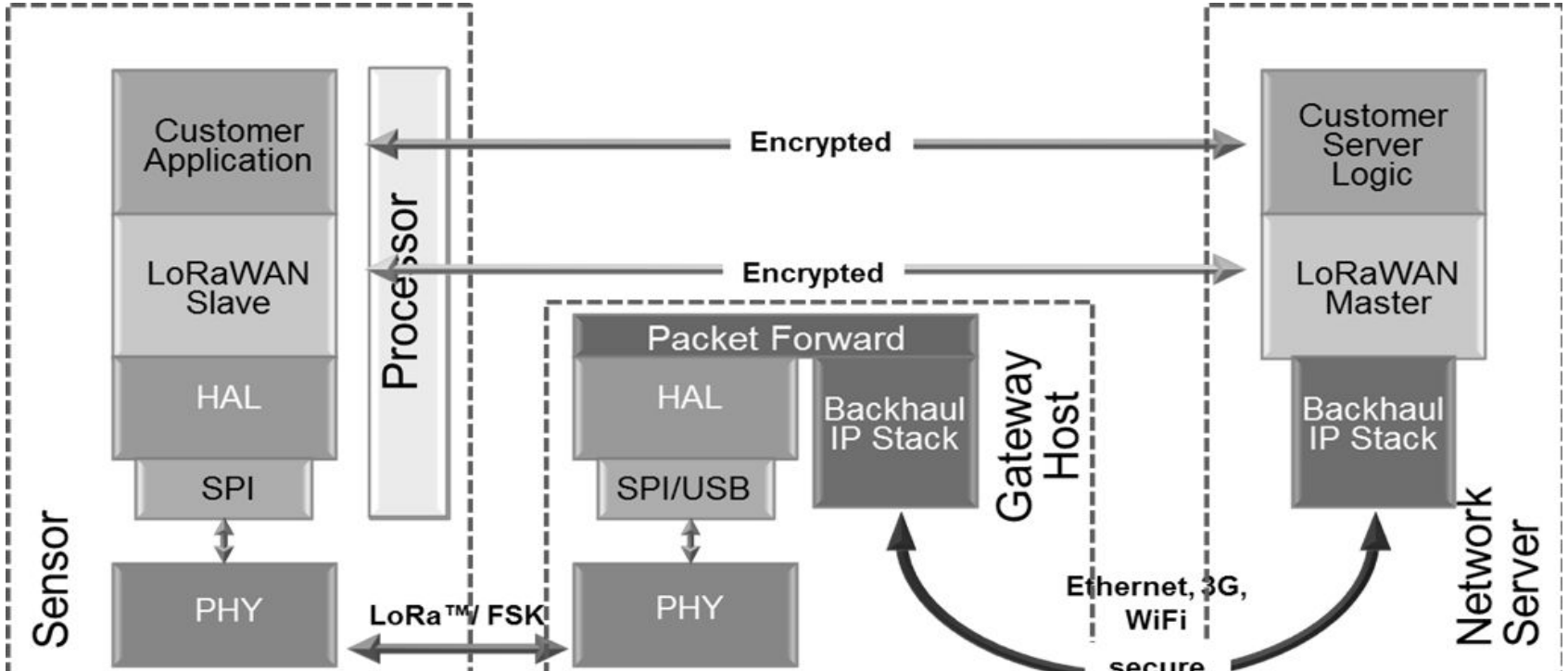


IP traffic, encrypted for security

LoRa Alliance™
Wide Area Networks for IoT

LoRa-Alliance.org

LoRaWAN


Sensor
Customer Application
LoRaWAN Slave
HAL
SPI
Processor
PHY
LoRa™/ FSK
Encrypted
Encrypted
Packet Forward
HAL
SPI/USB
Backhaul IP Stack
PHY
Gateway Host
Ethernet, 3G, WiFi
secure
Customer Server Logic
LoRaWAN Master
Backhaul IP Stack
Network Server

LoRaWAN

Gateways listen in 8 frequencies simultaneously, in every spreading factor at each frequency

Collisions prevented by maximum duty cycle limitations per frequency

If nevertheless, there is a collision, the strongest packet prevails

https://media.ccc.de/v/33c3-7945-decoding_the_lora_phy
o&t=895

LORAWAN NETWORK PROVIDERS

- Senet
  - Commercial network
- The Things Network
  - Crowdsourced
- LoRaHAM
  - Travis Goodspeed & friends

- No licensed spectrum required...!!

Forward Error Correction (FEC)

Technique of adding redundant (parity) bits to the transmission so that errors can be recovered at the reception.

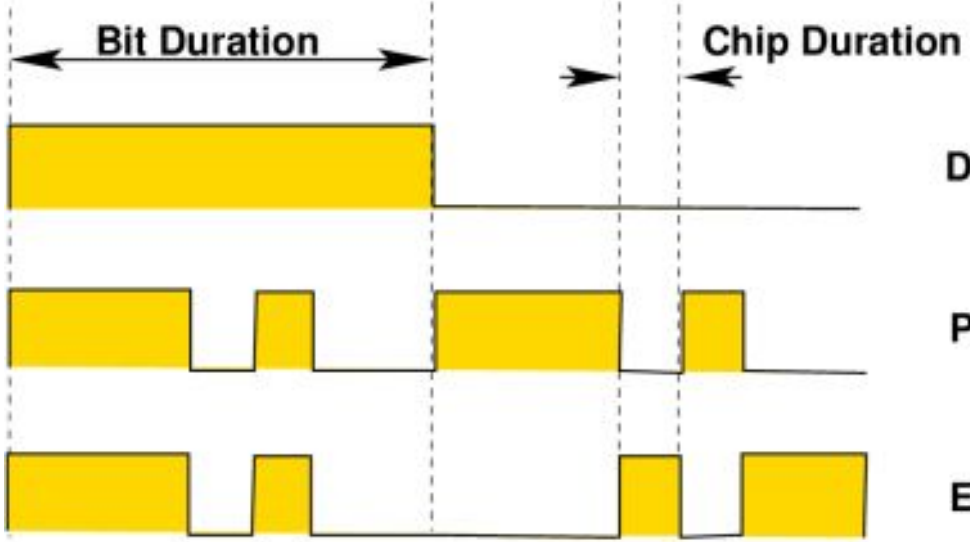
The coding rate refers to the proportion of transmitted bits that actually carry information.

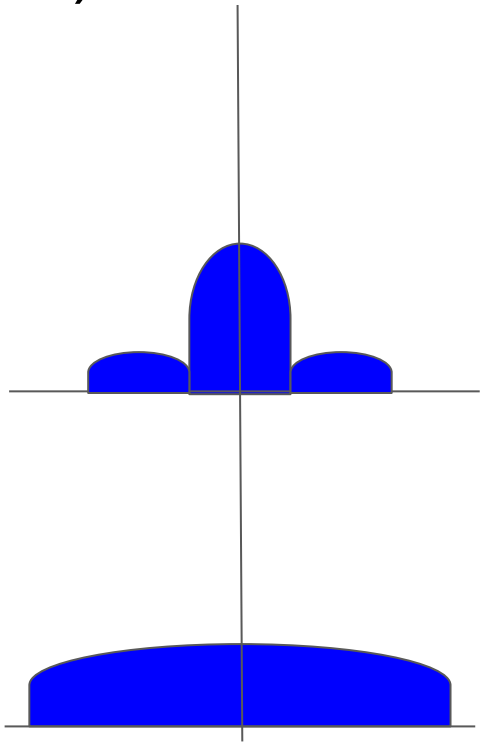
Coding rate can be 6/8, 4/8, etc…

So if CR is 4/8 we are transmitting twice as many bits as the ones containing information.

Direct Sequence Spread Spectrum (DSS)

Spreading technique used in WiFi



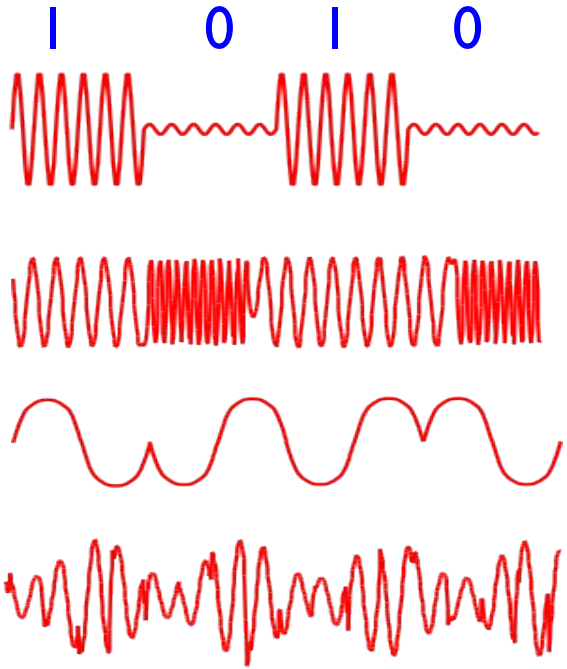


Time domain

Frequency Domain

Comparison of modulation techniques

Symbol is a discrete radio frequency energy state representing one or more bits of information



Digital Sequence

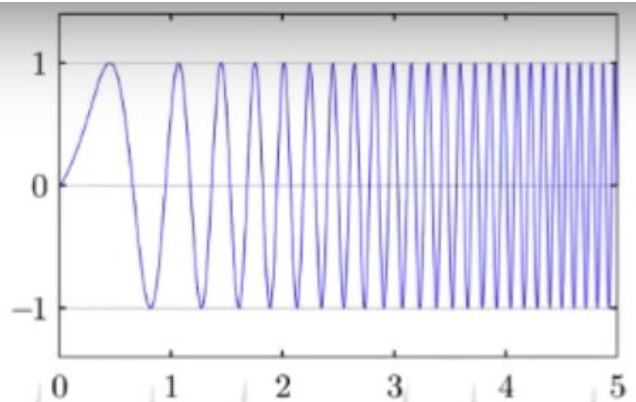
ASK modulation

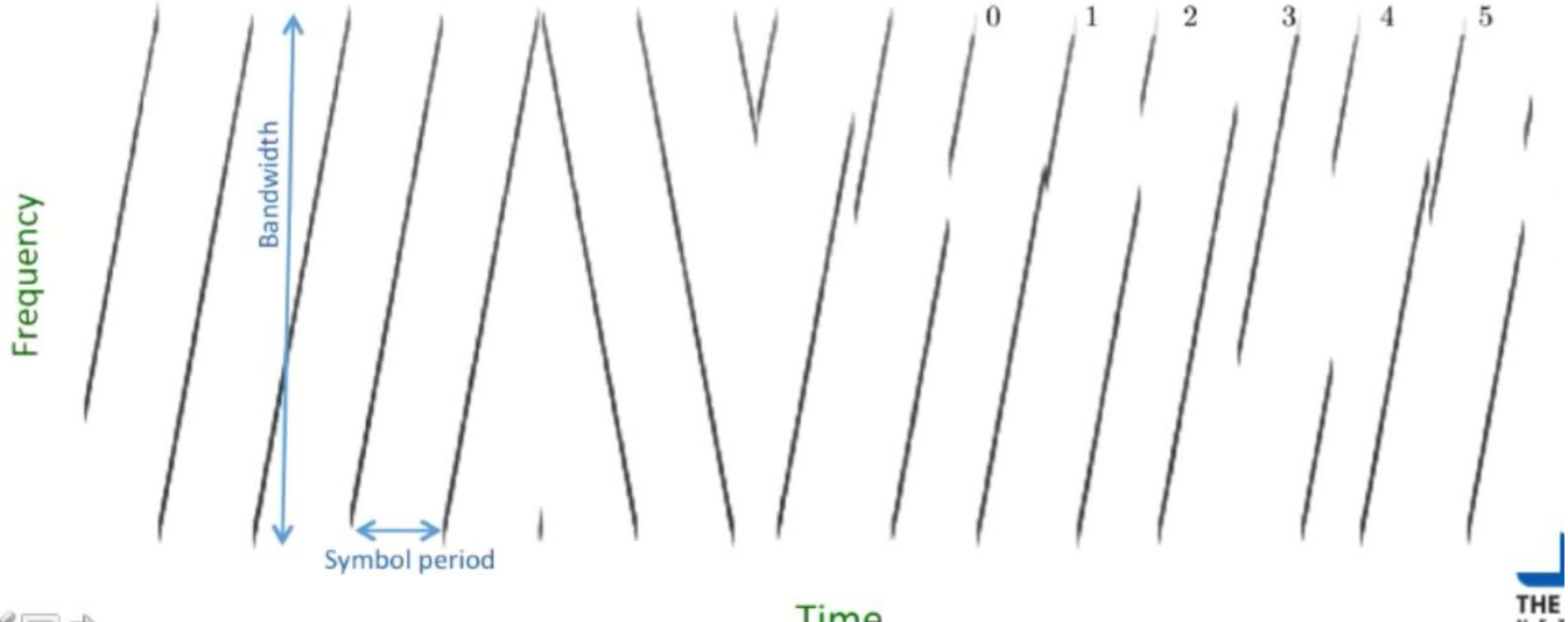
FSK modulation

PSK modulation

QAM modulation, changes both amplitude and phase

LoRa modulation





Chirp Spread Spectrum

Bandwidth (BW): difference between the upper and lower frequencies occupied by the chirp: 125 kHz, 250 kHz, 500 kHz.

Spreading Factor (SF): number of bits per symbol

Chirp rate: first derivative of chirp frequency = $BW/2^{SF}$

Nominal bit rate: $$R_b = SF * \frac{\left[\frac{4}{4+CR}\right]}{\left[\frac{2^{SF}}{BW}\right]}$$

Where:

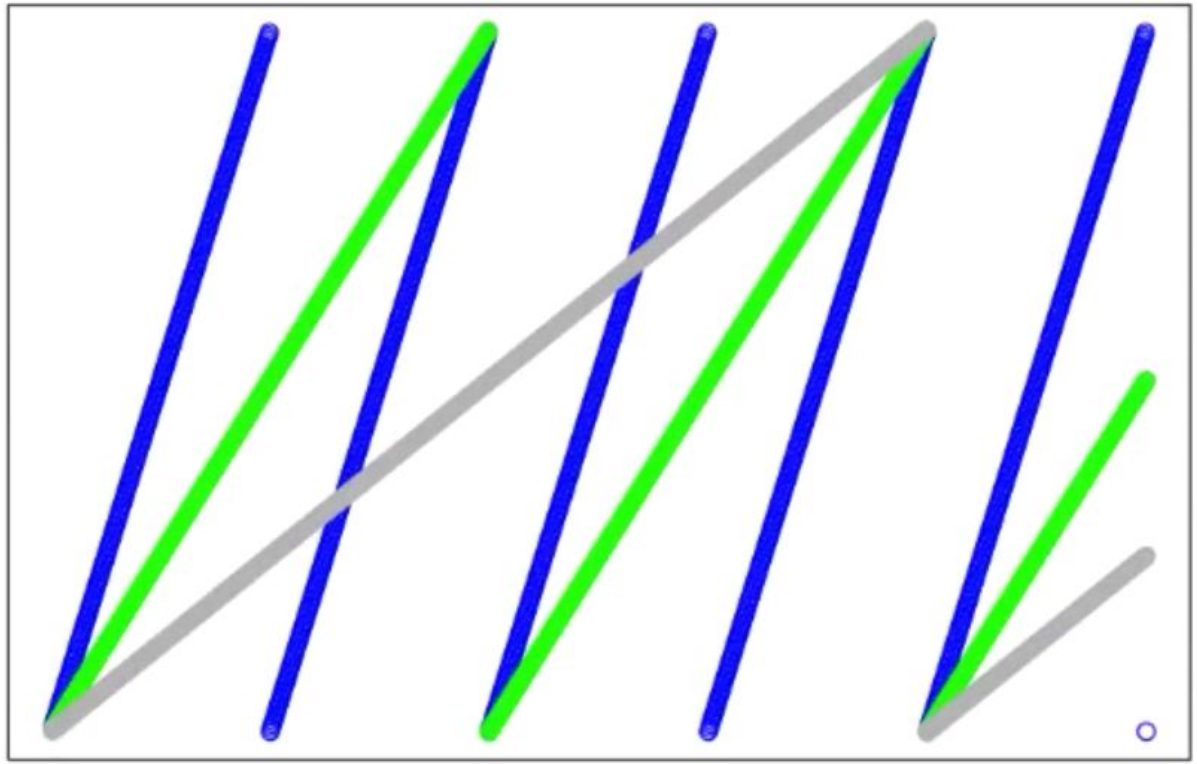
SF = spreading factor (7..12)

CR = code rate (1..4)

BW = modulation bandwidth (Hz)

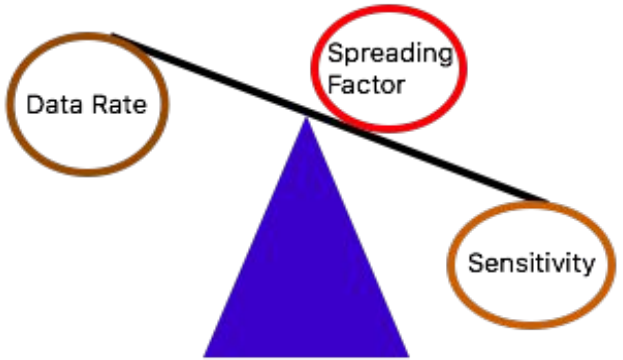
http://www.semtech.com/images/datasheet/an1200.22.pdf

Spreading Factors

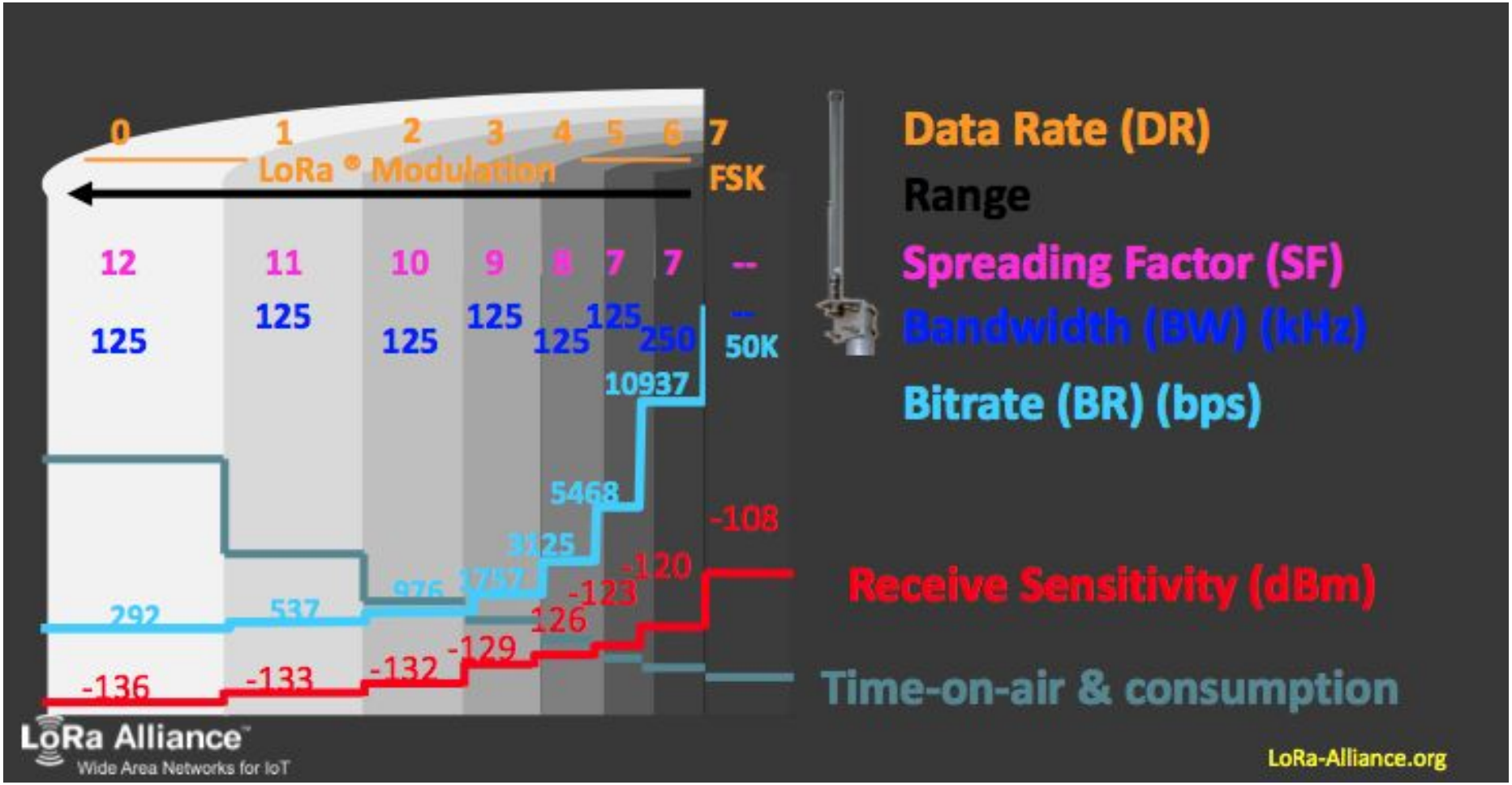


Adaptive Data Rate (ADR) at 125 kHz BW

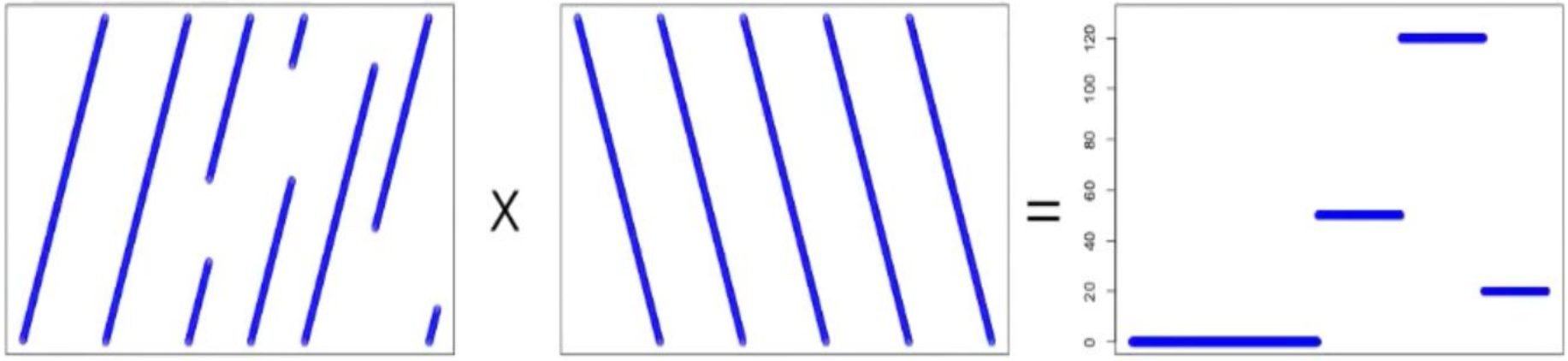
Spreading Factor	Signal/Noise	bit rate	ms per 10 byte packet
7	-7.5	5469	56
8	-10	3125	103
9	-12.5	1758	205
10	-15	977	371
11	-17.5	537	741
12	-20	292	1483



Sensitivity is proportional to S/N, since the detection is determined by the amount of energy per bit


0
1
2
3
4
5
6
7
LoRa ® Modulation
FSK
12
11
10
9
8
7
7
--
125
125
125
125
125
250
--
50K
10937
5468
3125
1757
976
-108
-120
-123
-126
-129
-132
-133
-136
292
537
Data Rate (DR)
Range
Spreading Factor (SF)
Bandwidth (BW) (kHz)
Bitrate (BR) (bps)
Receive Sensitivity (dBm)
Time-on-air & consumption
LoRa Alliance
Wide Area Networks for IoT
LoRa-Alliance.org

LoRa Demodulation

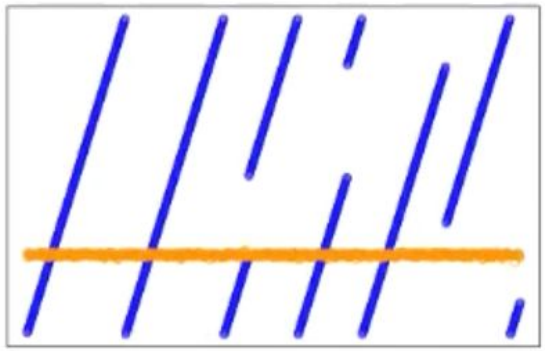


Received Lora signal

Inverse chirp

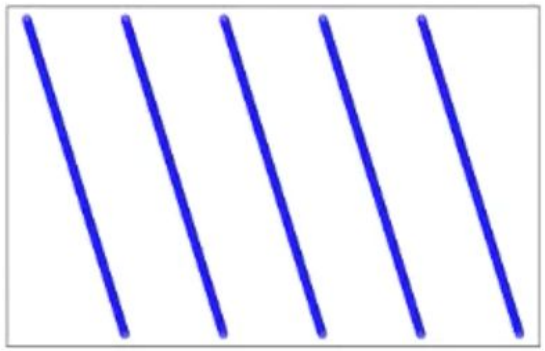
Decoded symbols

LoRa Demodulation



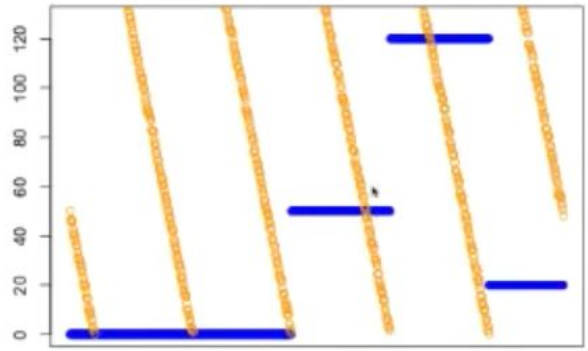
Received Lora signal
Narrowband interferer

x



Inverse chirp

=



Decoded symbols