



SORBONNE UNIVERSITÉ

CRÉATEURS DE FUTURS
DEPUIS 1257





Yann DOUZE

Twitter : @yann_douze

Linkedin :

<https://www.linkedin.com/in/yanddouze/>

The Internet Of Things

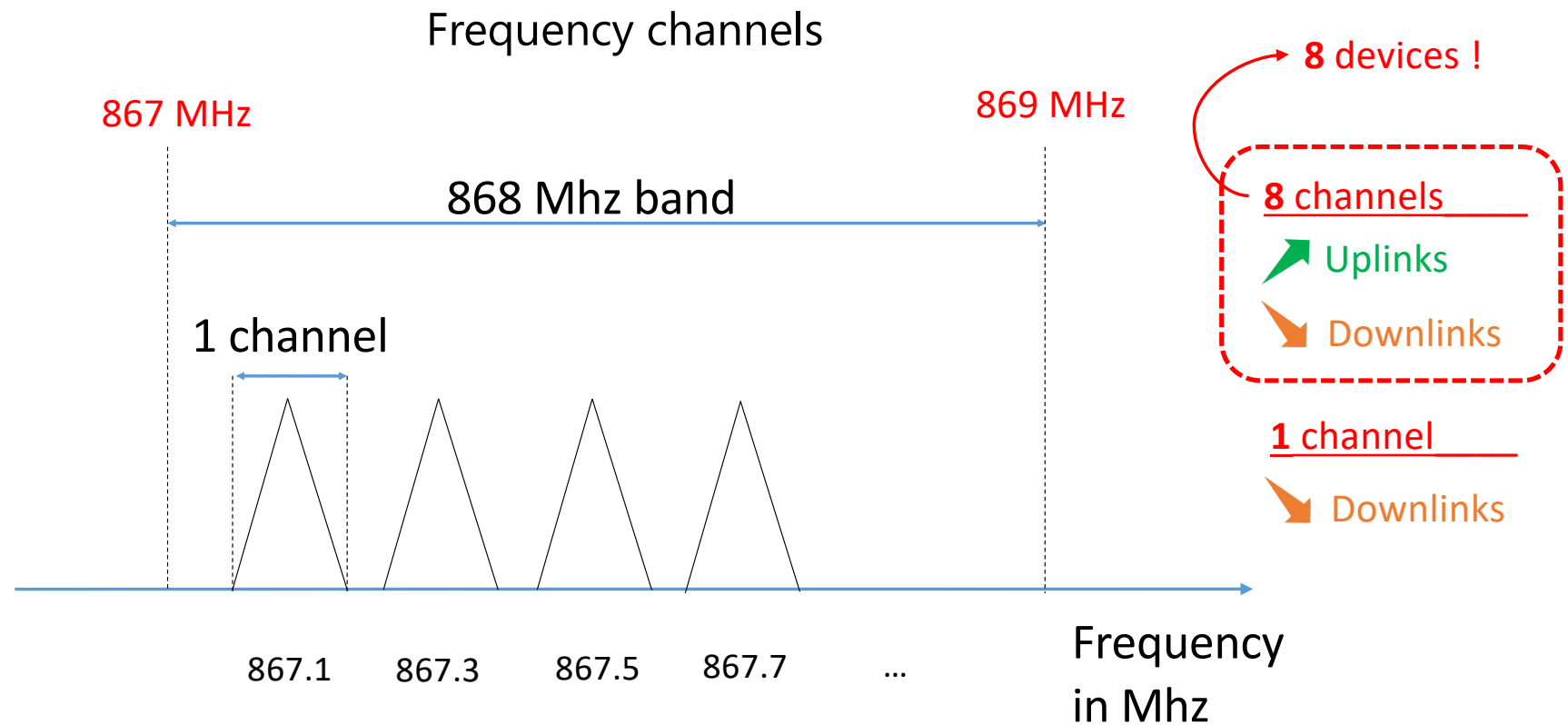
C7 : LoRaWAN Physical Layer

Introduction to what is the Internet of Things, why does it change the world where we live, what are the technologies behind the scene ?
How des it apply to your domain ?

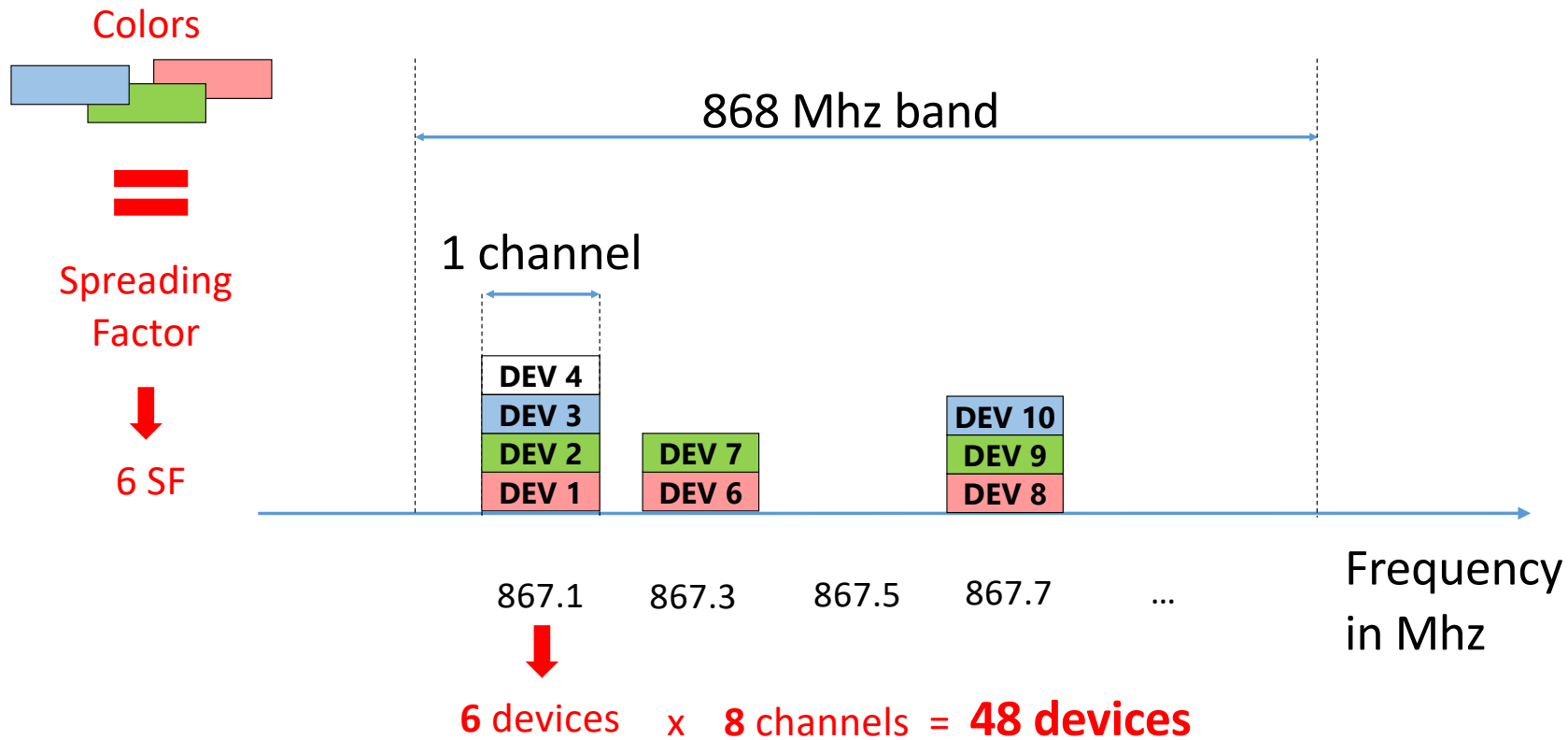
LoRa modulation Physical Layer

- ✓ The LoRa frame
- ✓ LoRa bitrate: Spreading Factor, Coding Rate, Bandwidth, Time-On-Air and Duty-Cycle
- ✓ The simulation of a LoRa transmission
- ✓ The consumption and the autonomy of a LoRa device

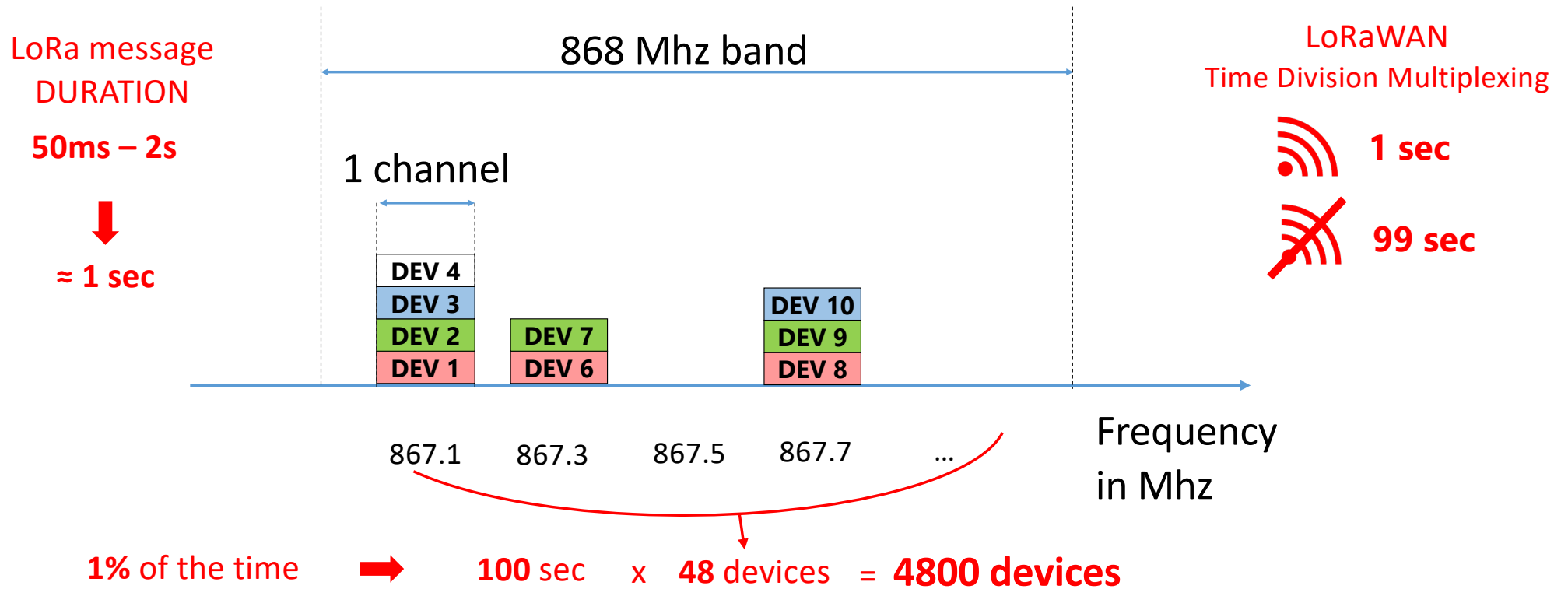
Frequency Division Multiplexing



Spread Spectrum



Time Division Multiplexing



LET'S RECAP

- ❑ LoRa is a "**long distance**" and "**low speed**" protocol
- ❑ It transmits on **channels** in the **868 MHz** band
- ❑ LoRa uses Spreading Factors :

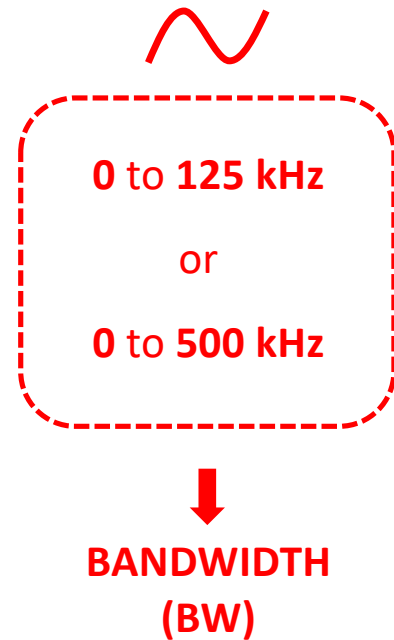
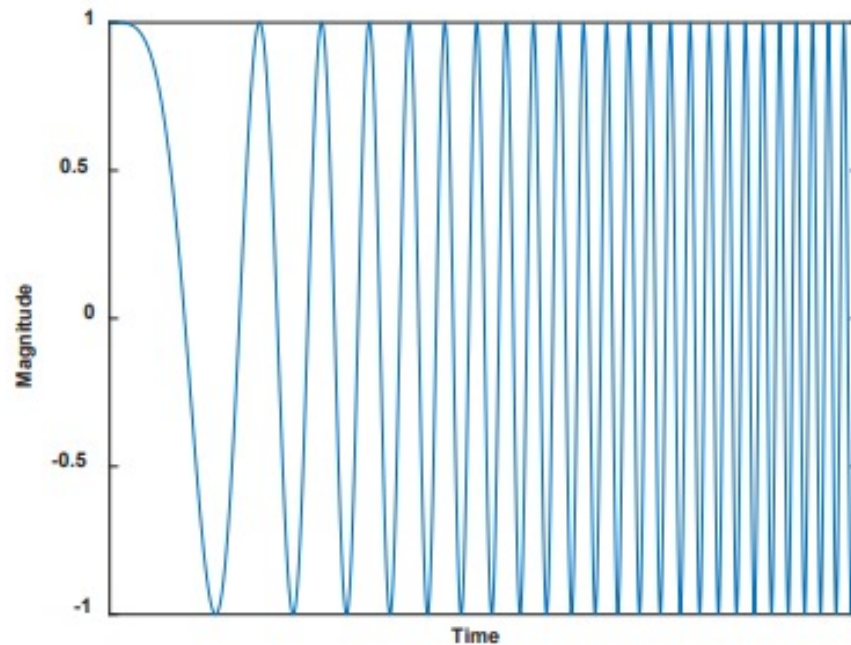


If two LoRa devices are using different SF :

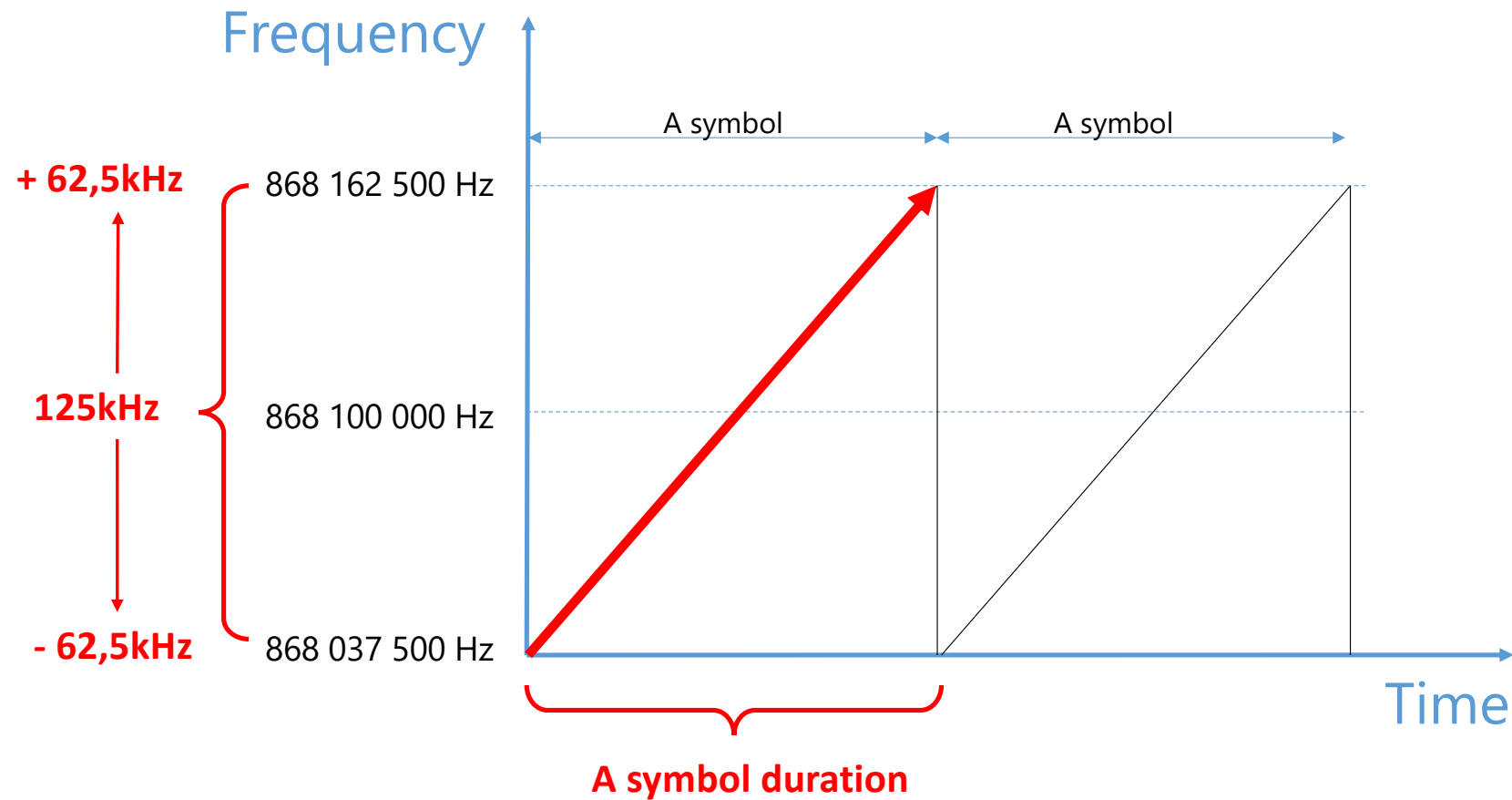
- > They can transmit at the same time on the same channel

The Chirp (symbol) - 1

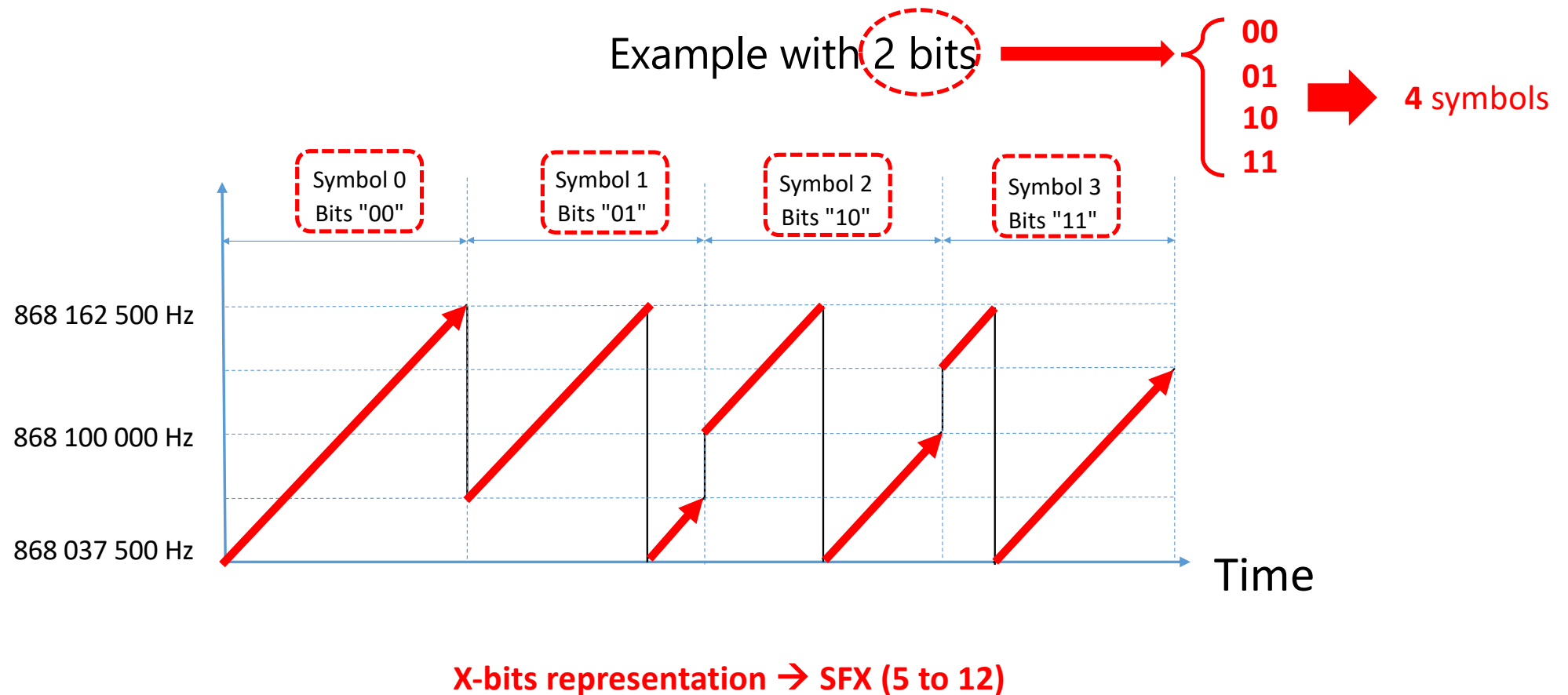
Chirp Spread Spectrum Modulation



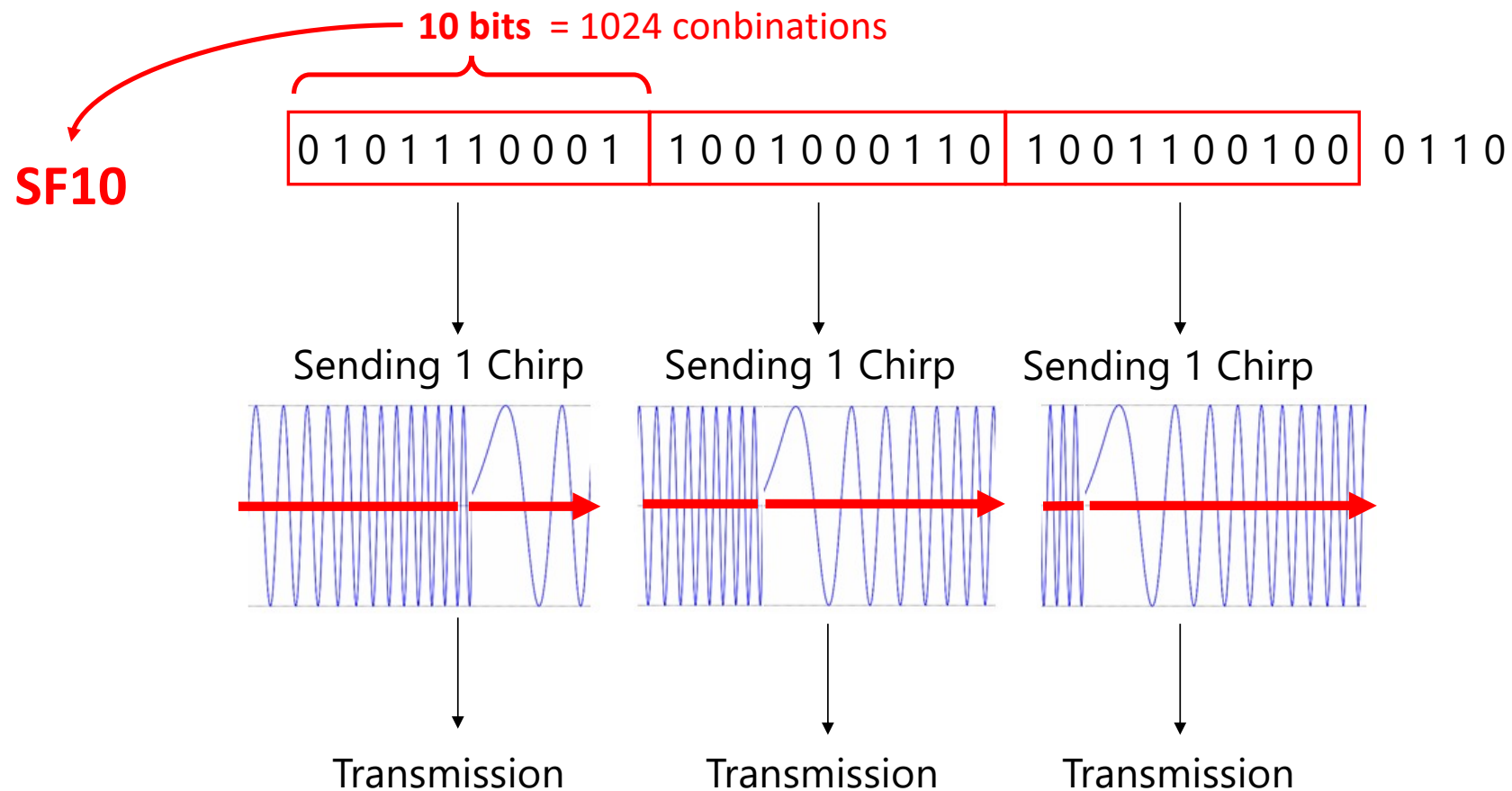
The Chirp (symbol) - 2



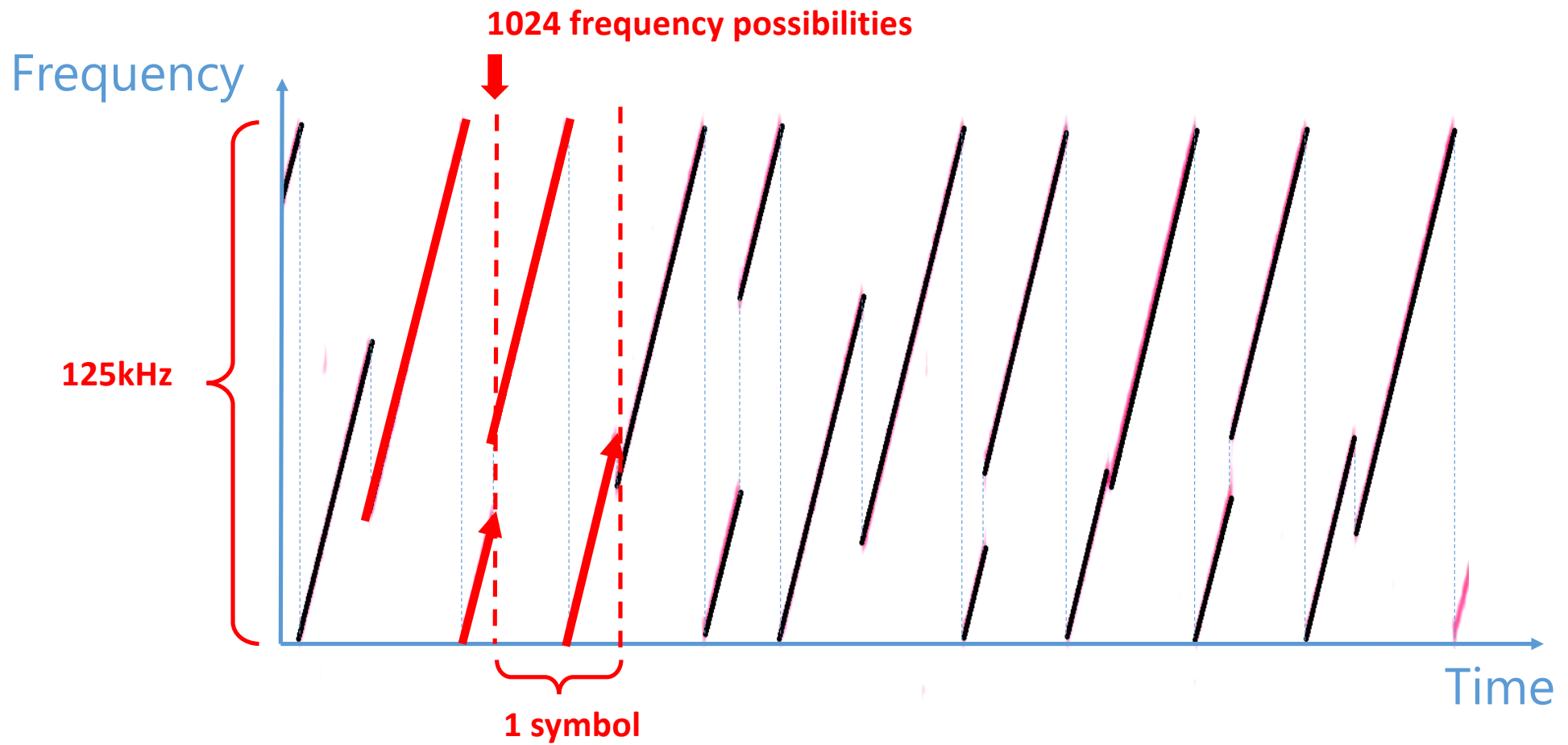
The Chirp (symbol) - 3



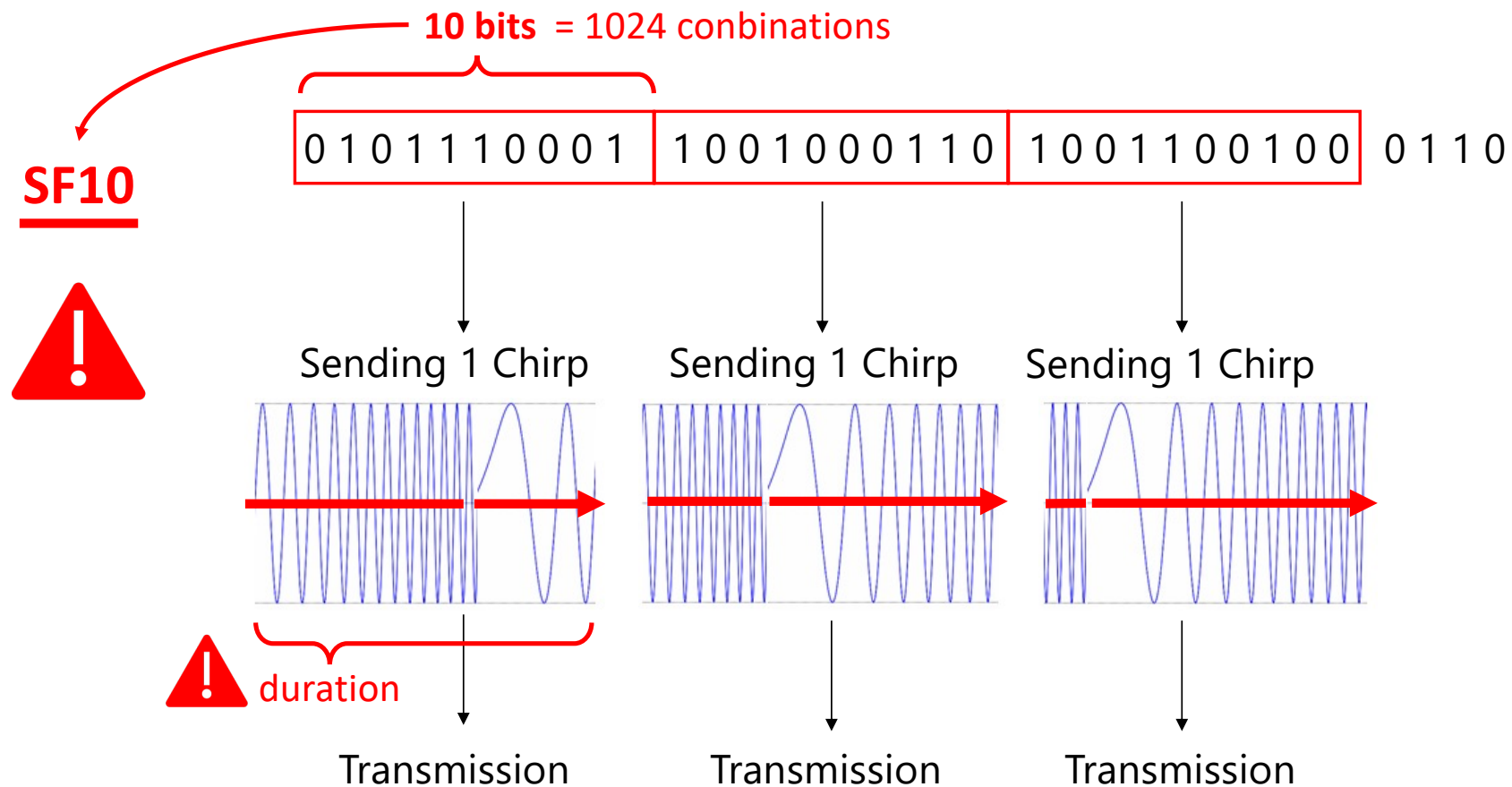
The LoRa frame - 1



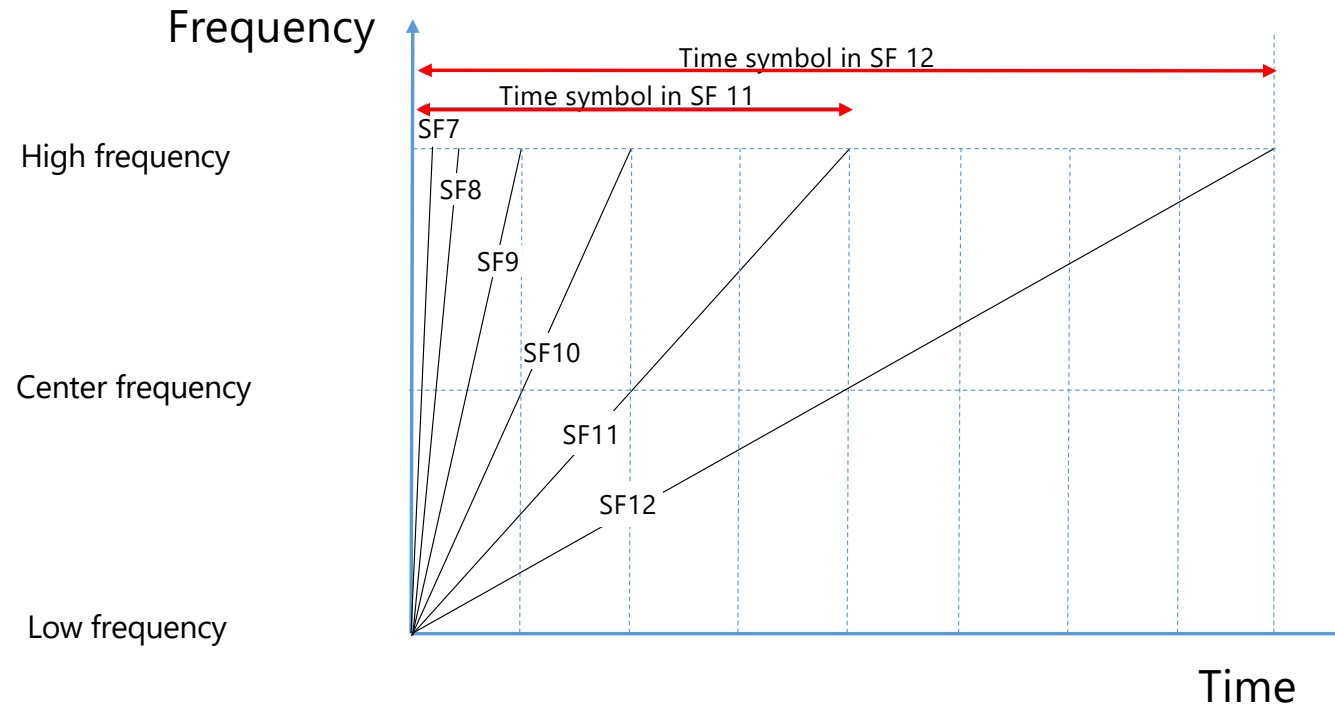
The LoRa frame - 2



The LoRa frame - 1



Symbol duration



$$T_{Symbol.SF12} = 2 \times T_{Symbol.SF11}$$

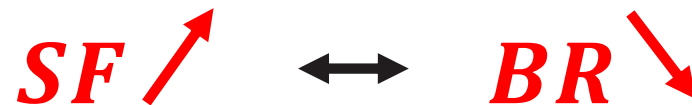
$$T_{Symbol} = \frac{2^{SF}}{Bandwidth}$$

$$Bitrate = SF \times \frac{Bandwidth}{2^{SF}}$$

LoRa bitrate

□ **Case 1:** For SF7, 125 kHz > Bit Rate = $SF \frac{Bandwidth}{2^{SF}} = 7 \frac{125 \cdot 10^3}{2^7} = 6,836 \text{ kbps}$

□ **Case 2:** For SF12, 125 kHz > Bit Rate = $SF \frac{Bandwidth}{2^{SF}} = 12 \frac{125 \cdot 10^3}{2^{12}} = 366 \text{ bps}$



Bit rate

□ **Case 1:** For SF7, 125 kHz > Bit Rate = $SF \frac{BW}{2^{SF}} = 7 \frac{125 \cdot 10^3}{2^7} = 6,836 \text{ kbps}$

□ **Case 2:** For SF12, 125 kHz > Bit Rate = $SF \frac{BW}{2^{SF}} = 12 \frac{125 \cdot 10^3}{2^{12}} = 366 \text{ bps}$

 $BR = f(SF, BW, \dots ?)$

Coding Rate

$$\text{Bit Rate} = f(\text{SF} + \text{BW} + \text{CodingRate})$$

CodingRate (RegModemConfig1)	Cyclic Coding Rate	Overhead Ratio
1	4/5	1.25
2	4/6	1.5
3	4/7	1.75
4	4/8	2

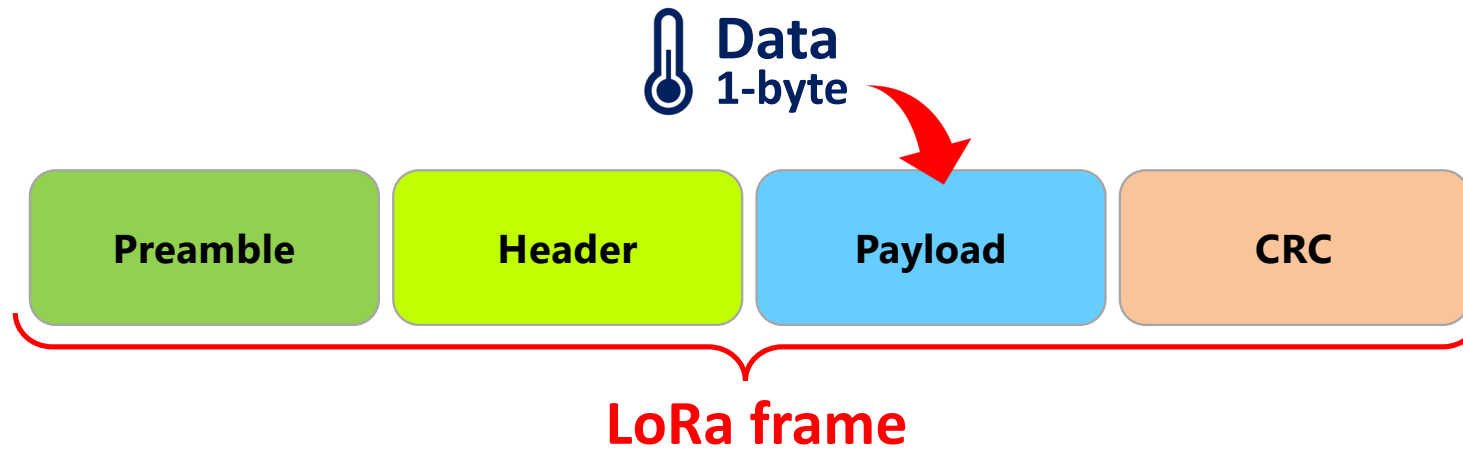
4 → 5

4 → 8

Additional bits →  Detect and correct errors  Overhead Ratio

- ❑ **Case 1:** For SF7, 125 kHz and CR4/5 > Bit Rate = $\frac{6,836 \text{ kbps}}{1,25} = 5469 \text{ bps}$
- ❑ **Case 2:** For SF12, 125 kHz and CR4/5 > Bit Rate = $\frac{366 \text{ bps}}{1,25} = 293 \text{ bps}$

LoRa Frame



Previously, Bit Rate was:

$$\text{Bit Rate} = \frac{SIZE_{payload}}{TIME_{payload}}$$

Real Bit Rate is:

$$\text{Bit Rate} = \frac{SIZE_{payload}}{TIME_{frame}}$$

TIME ON AIR

LoRa Frame

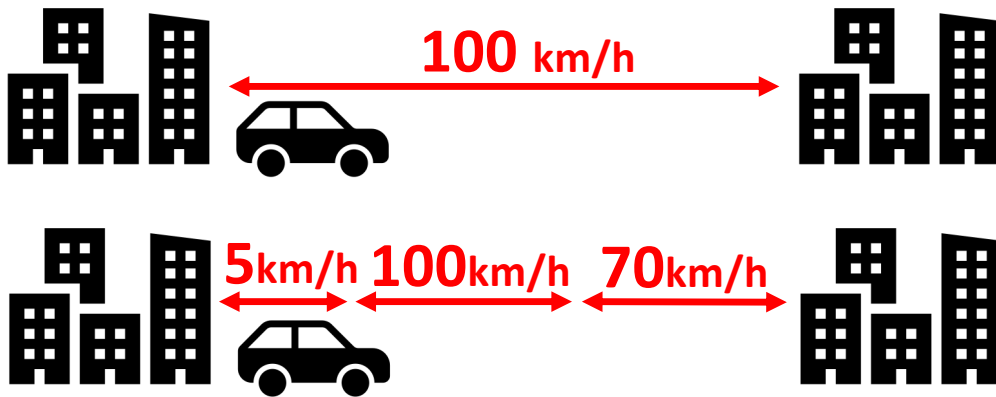
Previously, Bit Rate was:

$$\text{Bit Rate} = \frac{SIZE_{payload}}{TIME_{payload}}$$

Real Bit Rate is:

$$\text{Bit Rate} = \frac{SIZE_{payload}}{TIME_{frame}}$$

TIME ON AIR



Speed capacity

\neq

$$\text{Average speed} = \frac{\text{Journey distance}}{\text{Journey time}}$$

LoRa Frame

***LoRa Air Time Calculator :
<https://loratools.nl/#/airtime>***

LoRa Frame

Previously, Bit Rate was:

$$\text{Bit Rate} = \frac{SIZE_{payload}}{TIME_{payload}}$$

Real Bit Rate is:

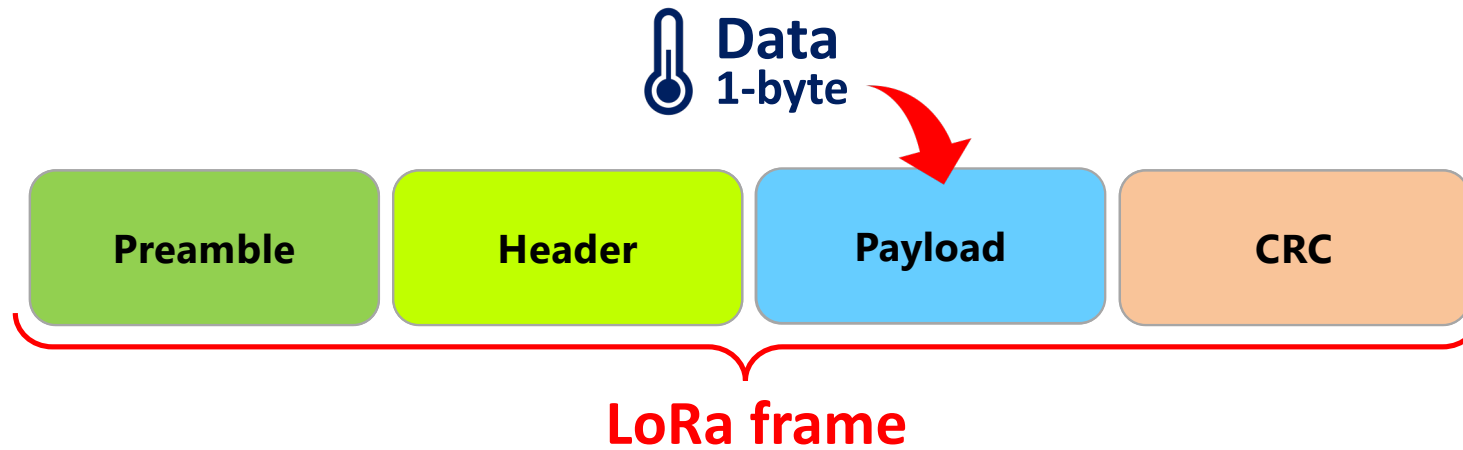
$$\text{Bit Rate} = \frac{SIZE_{payload}}{TIME_{frame}}$$


TIME ON AIR

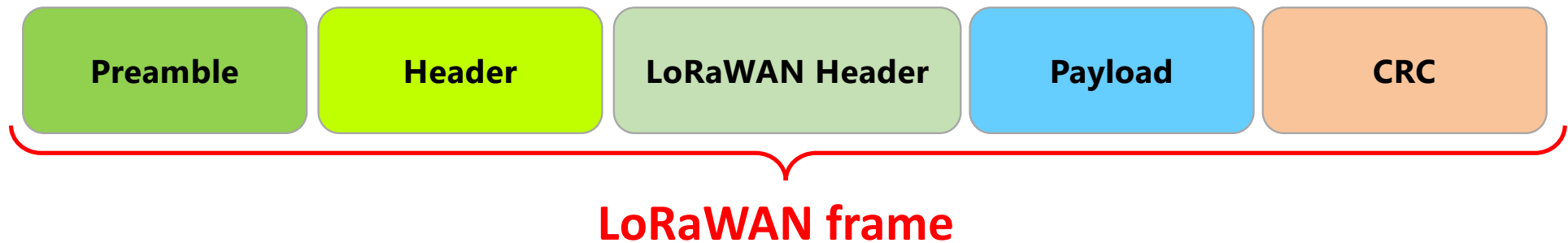
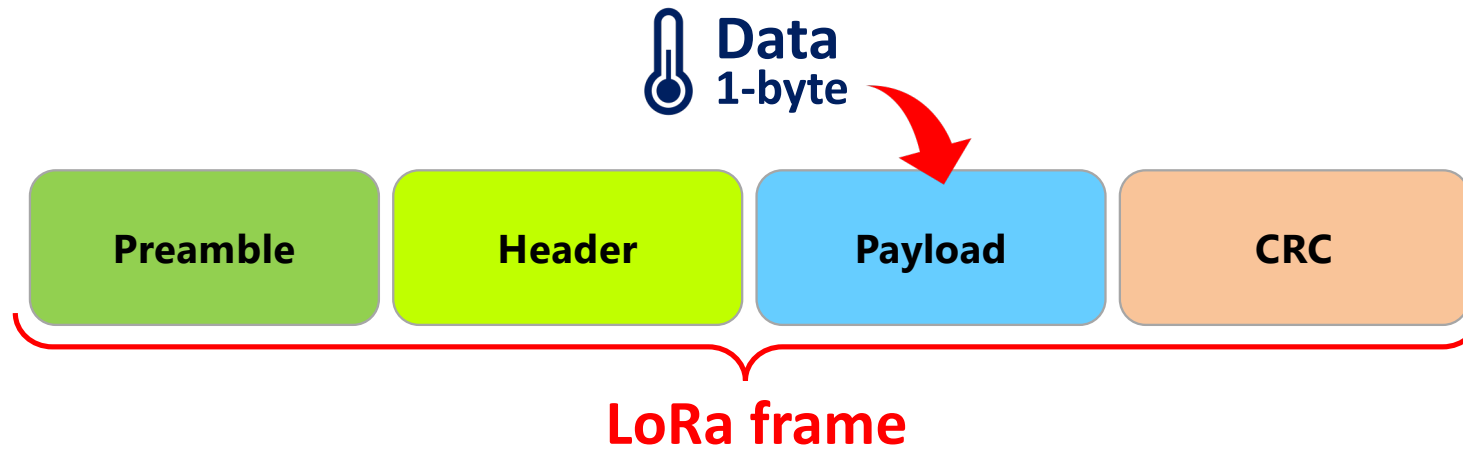
❑ **Case 1:** For SF7, 125 kHz and CR4/5 > Bit Rate = $\frac{8}{25,85 \cdot 10^{-3}} = 309,3 \text{ bps}$

❑ **Case 2:** For SF12, 125 kHz and CR4/5 > Bit Rate = $\frac{8}{827,39 \cdot 10^{-3}} = 9,6 \text{ bps}$

LoRaWAN Frame



LoRaWAN Frame



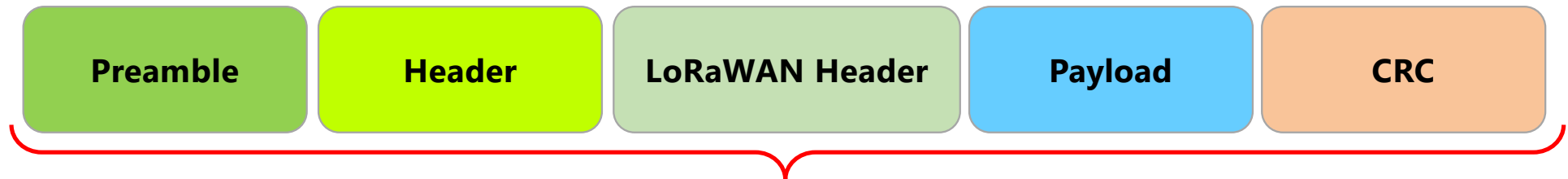
Time On Air ?

LoRaWAN Frame

LoRaWAN Air Time Calculator :

<https://www.thethingsnetwork.org/airtime-calculator>

LoRaWAN Frame



LoRaWAN frame

Time On Air

46,3 ms (SF7)

1155,1 ms (SF12)

❑ **Case 1:** For SF7, 125 kHz and CR4/5 > Bit Rate = $\frac{8}{46,3 \cdot 10^{-3}} = 172,7 \text{ bps}$

❑ **Case 2:** For SF12, 125 kHz and CR4/5 > Bit Rate = $\frac{8}{1155,1 \cdot 10^{-3}} = 6,9 \text{ bps}$

Duty-cycle in LoRaWAN (EU868)

LoRa transmission

- 8 channels
- Spreading Factor
- Limit the transmission time → **1% of the time**

❑ **Case 1:** For SF7, 125 kHz and CR4/5 > Bit Rate = $\frac{172,7}{100} = 1,73 \text{ bps}$

❑ **Case 2:** For SF12, 125 kHz and CR4/5 > Bit Rate = $\frac{6,9}{100} = 0,07 \text{ bps}$

Energy consumption



- **Time On Air**
(Spreading Factor, Data, BW, Coding Rate)
- **Collisions**
(Confirmations, retransmissions)
- **Duty-Cycle**
- **Transmit power**
- **Low power mode**

Energy consumption

Online Energy calculator :

<https://dramco.be/tools/lora-calculator/>