INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

Wireless Sensors Networks

5 ISS

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Zigbee

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Outline of the presentation

I - Introduction

II - Physical layer

III - MAC layer

IV - Network layer

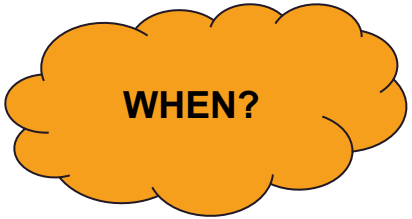
V - Power Consumption

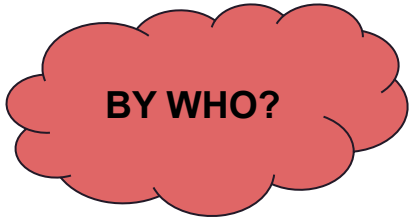
VI - Conclusion

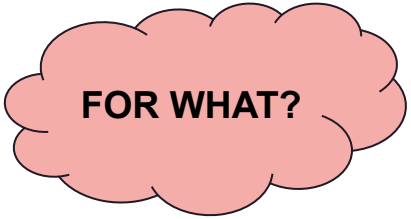
Introduction

Zigbee standardization & use cases

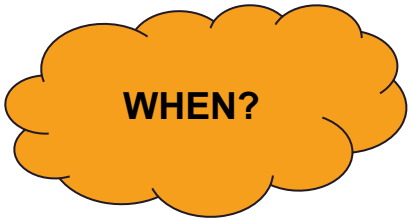
Zigbee standardization







Zigbee standardization



1998

Beginning of preliminary work

2002

Creation of the Zigbee alliance

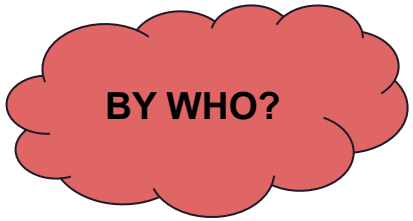
2003

Ratification of the norm 802.15.4 (physical & MAC layers)

2005

First commercialized Zigbee products

Zigbee standardization



IEEE 802.15.4:
physical and MAC layers

Zigbee Alliance:
Network and application layers

Connectivity Standards Alliance (CSA)

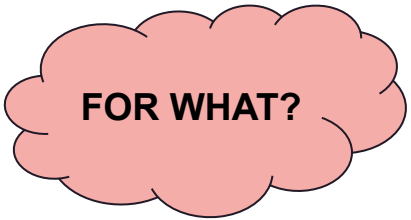
Zigbee standardization

Development after wifi and Bluetooth

Minimal use of the shared medium

Minimal energy consumption

Full stack



LP-WPAN

Zigbee use cases

Industry

Smart homes & connected buildings

Autonomous cars

Smart cities

Physical layer

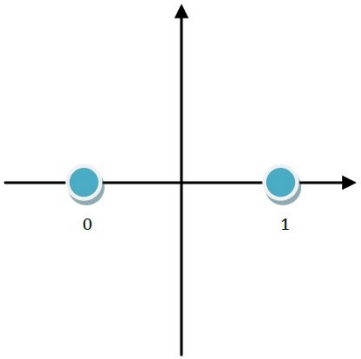
Physical Layer Generalities

Frequency Band (MHz)	Frequency Range (Mhz)	Modulation Technique	Bit Rate (Kbps)	Country	Number of channels
868	868 - 868.6	BPSK	20	Europe	1
915	902 - 928	BPSK	40	US / Australia	1-10, 13 (North America)
2400	2400 - 2483.5	O-QPSK	250	Worldwide	16

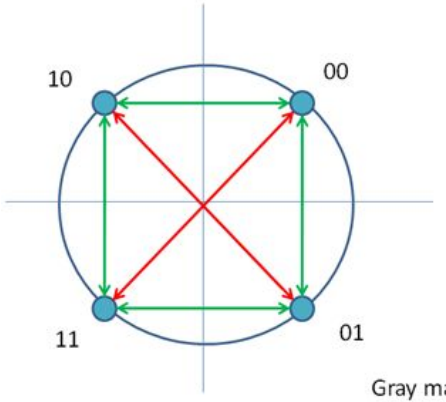
- Range : From 10 to 100 meters in urban use
- Up to 65 535 nodes in a Zigbee network

Modulation

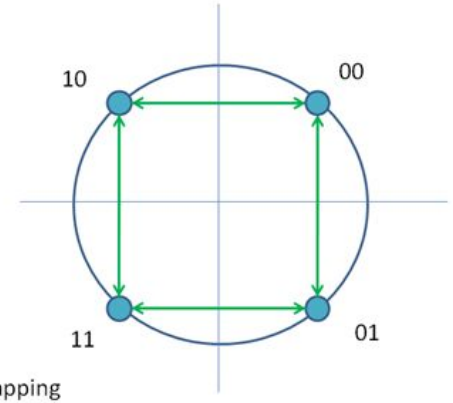
BPSK



QPSK



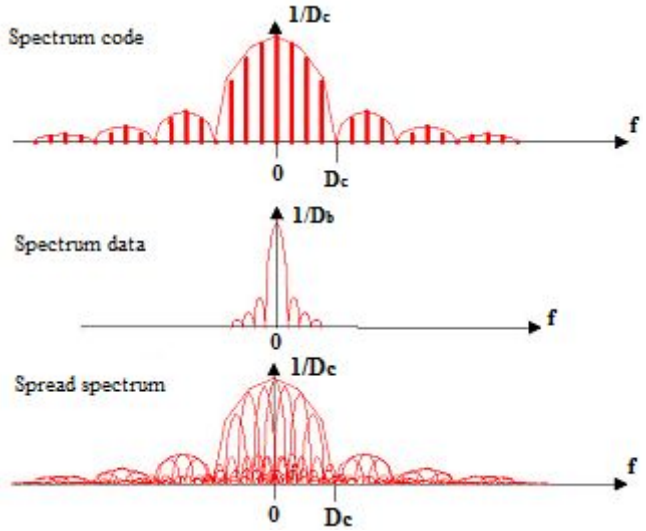
OQPSK



Gray mapping

Benefits of OQPSK against QPSK :
Less amplitude fluctuation —> Lower Bit Error Rate —> More reliable

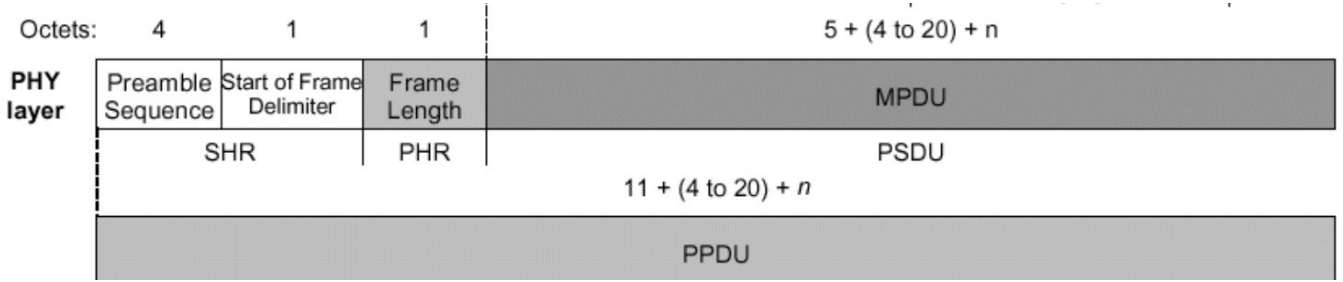
Modulation



Use of DSSS (Direct Sequence Spread Spectrum) :

- Spreads the signal across a wider bandwidth
- Reduces Narrowband interference
- More secure
- Makes Zigbee more reliable

Frame Format



SHR : Start of Header
PHR : Physical Layer Header
PPDU : Physical Protocol Data Unit
MPDU : MAC Protocol Data Unit
PSDU : Protocol Data Service Unit

preambule sequence : 32 bit of 0
SFD : Sequence that indicates a zigbee frame is starting

MAC layer

Content of a MAC frame

Zigbee’s frames are short : The MTU is 127 bytes

Content of a MAC frame

2 bytes

Specify :

- the type of the frame (ACK, Beacon, data, command)
- the address format
- the need or not for acknoledgement

Content of a MAC frame

Specify :

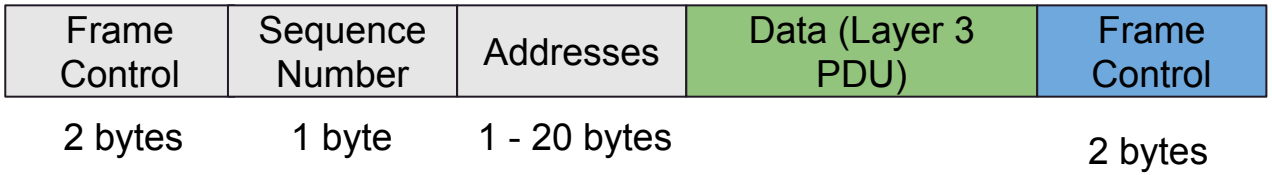
- The place of the frame in the sequence allowing to detect data loss or duplication

Content of a MAC frame

Specify :

- the source and destination of the frame

Content of a MAC frame



Specify :

- the CRC code allowing to verify the integrity of the frame

Types of access

Without coordination 

- CSMA/CA :
  - No synchronization between nodes
  - Send when medium seems available
  - Backoff time if collision
- No RTS/CTS:
  - Cannot reserve resources for transmission
  - Too costly for low bandwidth
- Similar to Wifi except for RTS/CTS

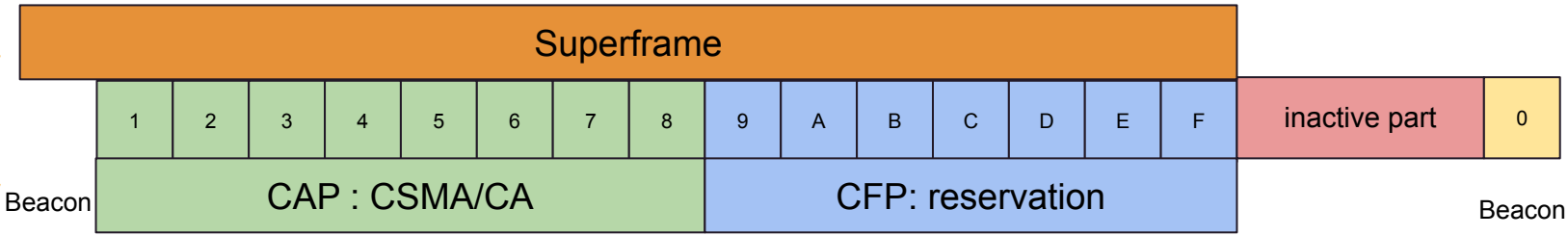
With coordination 

- Presence of a coordinator
  - Sends beacon periodically
  - Every node synchronizes on the coordinator
  - Act as a relay for end nodes
- Less power consumption
  - Nodes can sleep until next beacon

Types of access

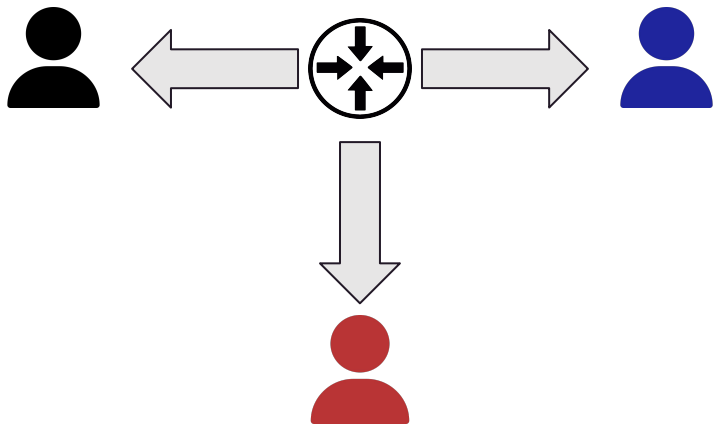
With coordination

- The superframe is the time between two beacons
  - It is composed of 16 slots
  - The first slot is dedicated to the beacon
- The first slots (Contention Access Period part) is dedicated to CSMA/CA frame transmission
- The last slots (Contention Free Period part) are reserved slot that the coordinator can allocate to some nodes



Types of access

1. Coordinator sends beacon

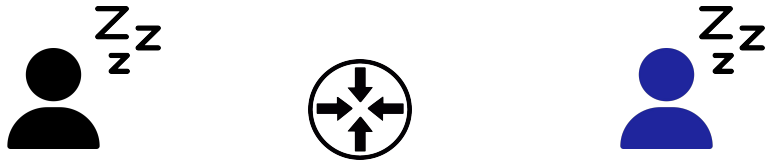


Users

Coordinator

Types of access

1. Coordinator sends beacon
2. Users that do not need to send or receive switch to sleep mode

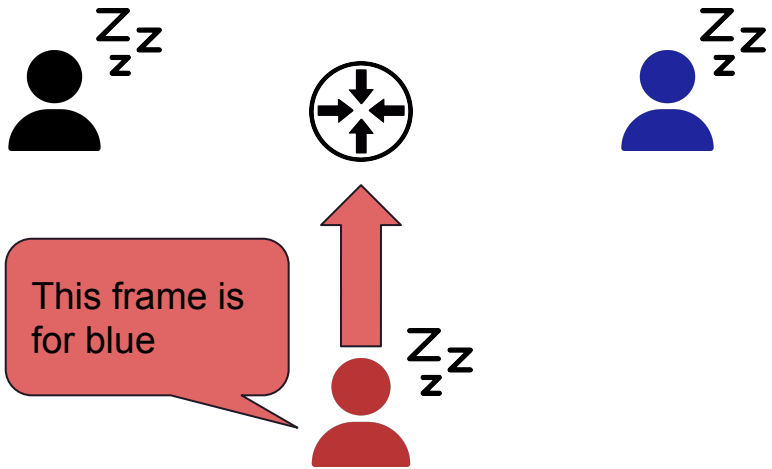


Users

Coordinator

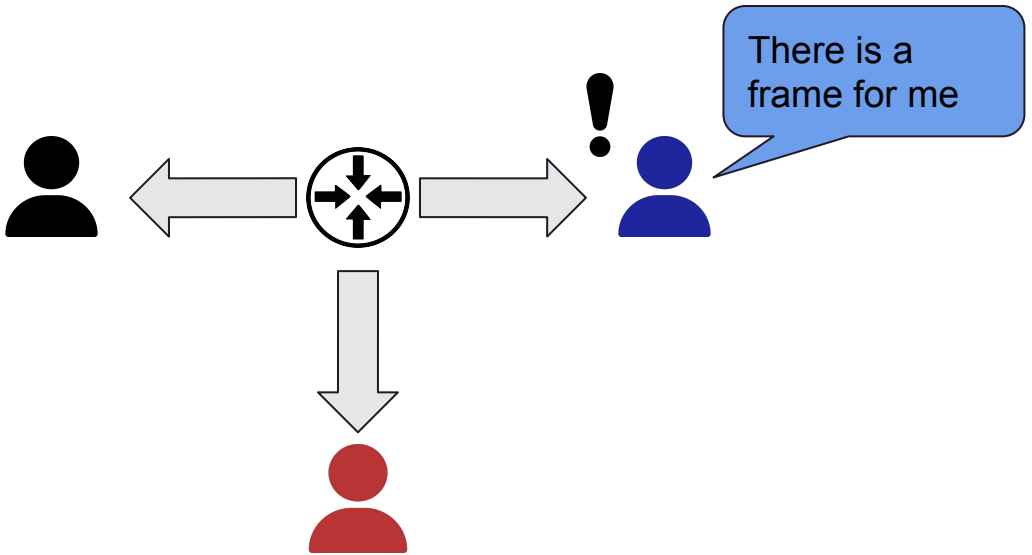
Types of access

1. Coordinator sends beacon
2. Users that do not need to send or receive switch to sleep mode
3. Users send data to the relay then go to sleep



Types of access

1. Coordinator sends beacon
2. Users that do not need to send or receive switch to sleep mode
3. Users send data to the relay then go to sleep
4. Next beacon is sent, blue user learn that there is a frame for him



Types of access

1. Coordinator sends beacon
2. Users that do not need to send or receive switch to sleep mode
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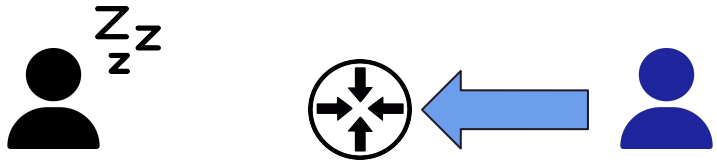
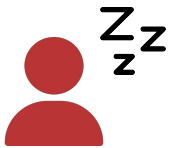
4. Next beacon is sent, blue user learn that there is a frame for him
5. Blue user request frame



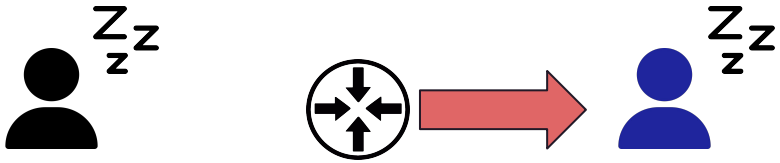
Users

Coordinator



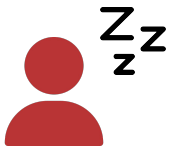
Types of access

1. Coordinator sends beacon
2. Users that do not need to send or receive switch to sleep mode
3. Users send data to the relay then go to sleep
4. Next beacon is sent, blue user learn that there is a frame for him
5. Blue user request frame
6. Relay sends frame to blue user



Users

Coordinator



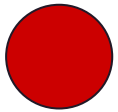
The LLC sublayer

Typical role of LLC		LLC in Zigbee (SSCS)
1) Check the integrity of frames	→	Already done by the MAC layer
2) Flow Control	→	Send & wait
3) Address convergence	→	No address convergence (L2 and L3 addresses are the same)

Network layer

Different types of nodes

- **Zigbee Coordinator :** It is a unique central node for each network. It is the first node during the creation of the network

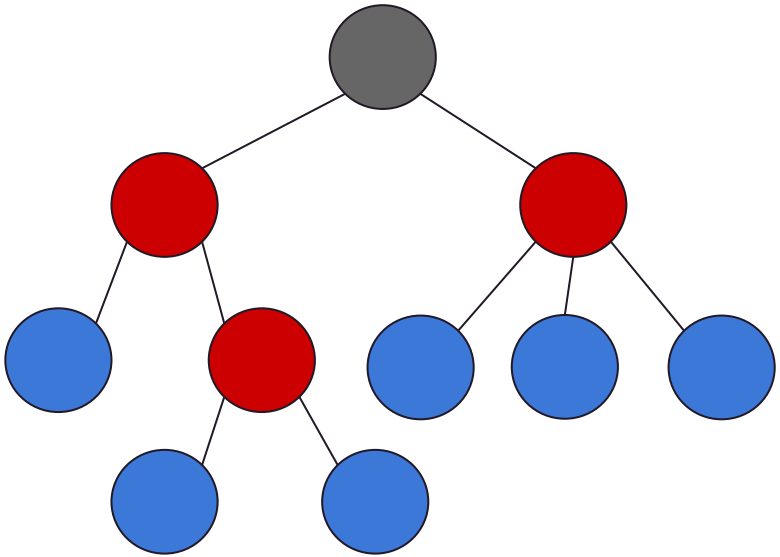


- **Zigbee Router :** It is a coordinator that will manage a small sub section of the network. It relays packets from end devices

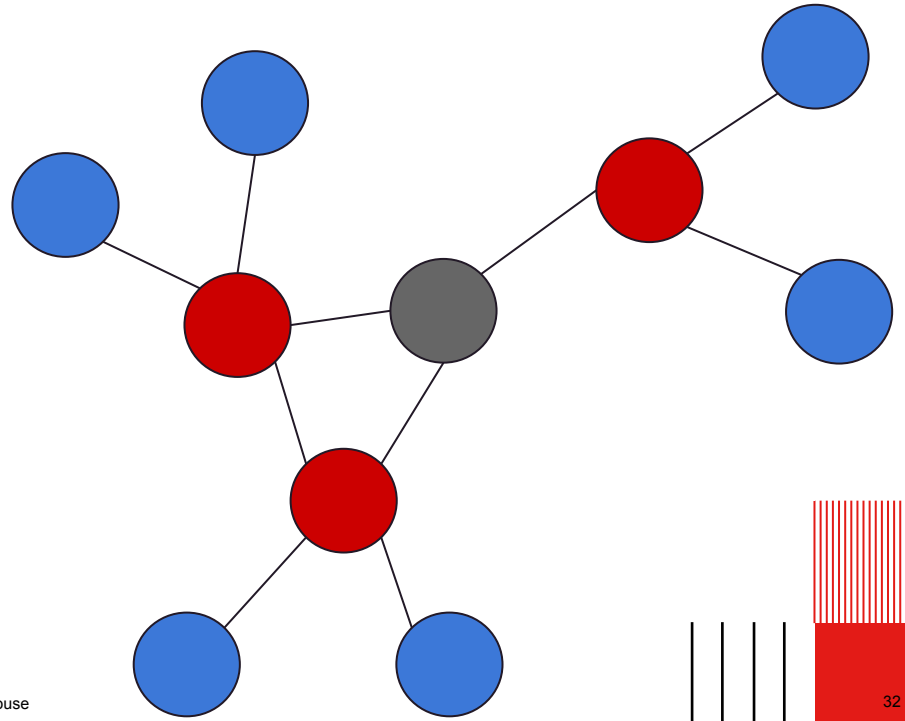
- **Zigbee End Devices :** The devices that need to send and/or receive data. They do not run any routing process.

Different topologies

The tree topology



The mesh topology



Routing protocol

The tree topology

- The addresses are given based on the depth and position of the node
- Easy to know where to send the packet in a tree topology
- More scalable

The mesh topology

- No addressing scheme
- Routing on demand using network flooding
- The nodes do not keep routes and topology information
- Expensive in large networks

Power Consumption

A standard known for its low consumption

Strong data rate : 250 kbps

Technical Specifications and Operational States of Zigbee

- Operation frequency : 2.4GHz
- Power transmission : -3.5DBm to +20dBm
- Receiver sensibility : -92dBm
- Transmission : 30mA

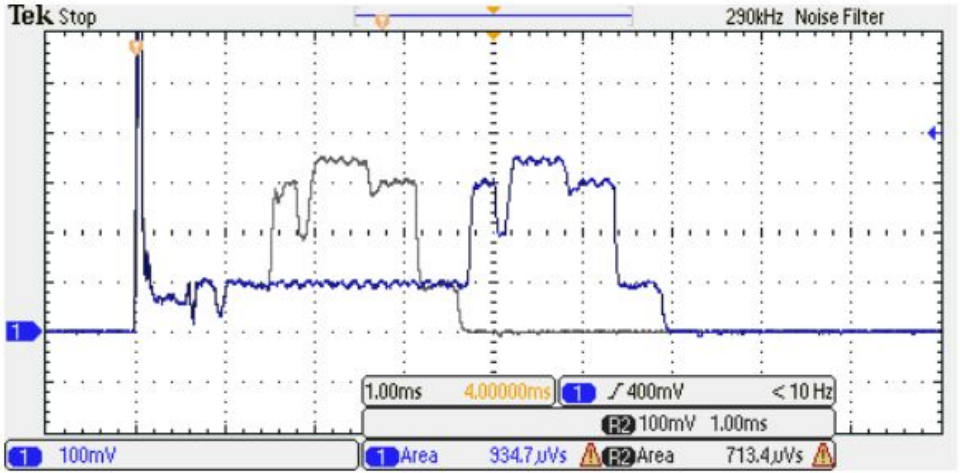


Figure 1 : Consumption in function of the Zigbee Mode on a ETRX35 Zigbee Module

Different modes :

- Transmission: Approx. 30mA (at 0 dBm)
- Receiving: 19 mA
- Standby: 1-2 µA
- Deep Sleep: < 1 µA

Energy efficiency

- Average consumption in transmission mode : 30mA
- Voltage : 3V
- Transmission time : 1s

$$P = I \times V \times t = 0{,}030A \times 3V \times 1s = 0{,}09\ J$$

With an average data rate of 250 kbps :

$$\text{Energy efficiency} = \frac{0{,}09\ J}{250\,000\ bps \times 1\ s} = 3.6\times10-7J$$

We use 0,36µJ every bit we send!

Conclusion

Choosing Zigbee for your WSN?

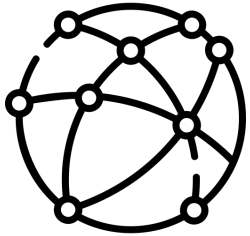
Commercial & financial model

Full stack solution designed for **IoT**

Focuses on **interoperability**

Certification of Zigbee products by the **CSA**

Place in WSN & WPAN today



One of the most **widely used** standards

Mature technology

Still in **development**

Choosing Zigbee for its low-power properties?

Use of **sleep / wakeup** cycles

3.6×10^{-7} Joule / bit

Average Data Rate: **250kbps**

Thank you for your attention

Any other questions?

Sources

- icons: www.flaticon.com
- Zigbee official website: https://csa-iot.org/all-solutions/zigbee/
- Technologie ZigBee / 802.15.4 - Protocoles, topologies et domaines d'application (Techniques de l'ingénieur): https://www.techniques-ingenieur.fr/base-documentaire/technologies-de-l-information-th9/reseaux-locaux-42292210/technologie-zigbee-802-15-4-te7508/
- WPAN standards for IoT continue to develop use cases: https://www.techtarget.com/iotagenda/feature/WPAN-standards-for-IoT-continue-to-develop-use-cases
- Zigbee standard Smart Energy datasheet: https://csa-iot.org/wp-content/uploads/2022/01/docs-07-5356-18-0zse-zigbee-smart-energy-profile-specification.pdf
- ETRX35x ZIGBEE MODULES datasheet: https://www.silabs.com/documents/public/data-sheets/TG-PM-0516-ETRX35x.pdf