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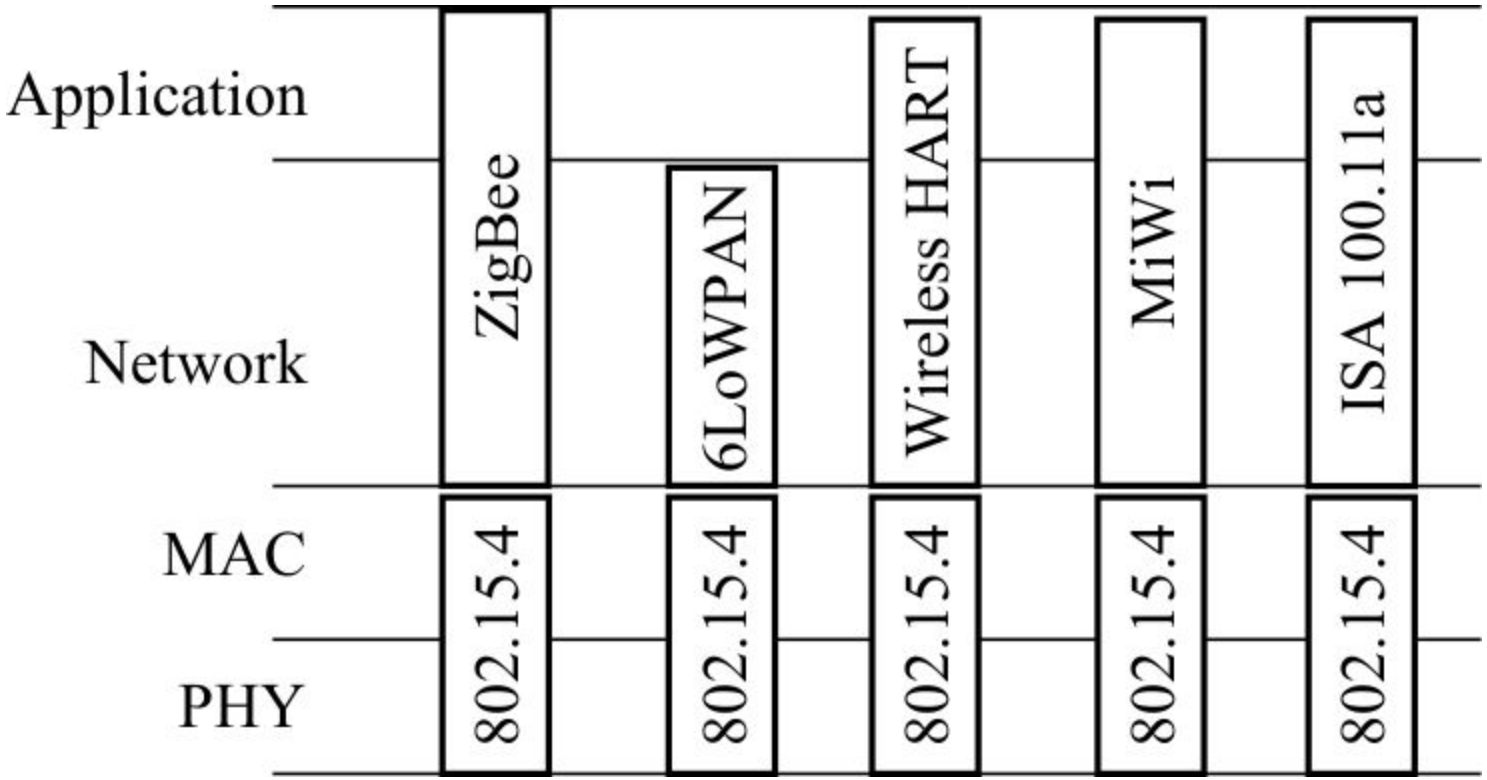
802.15.4

Networks and Protocols 1

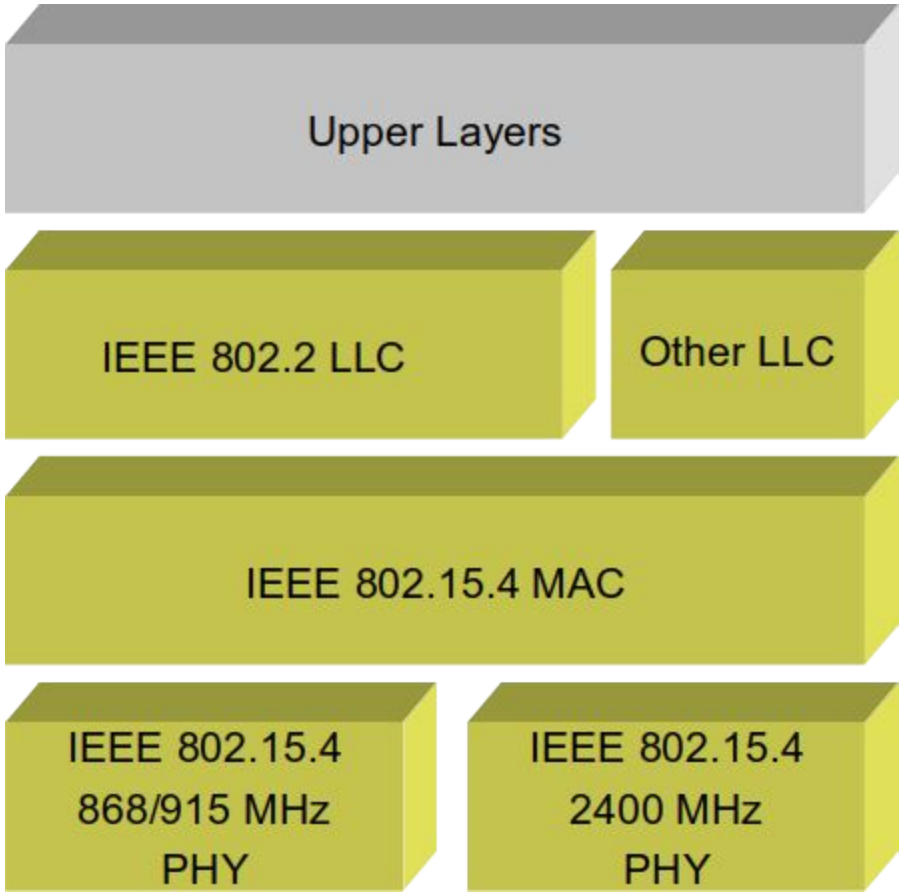
Facultad de Informática

IEEE 802.15.4

- Used by several IoT protocols
  - ZigBee, 6LowPAN, Wireless HART, MiWi e ISA 100.11a

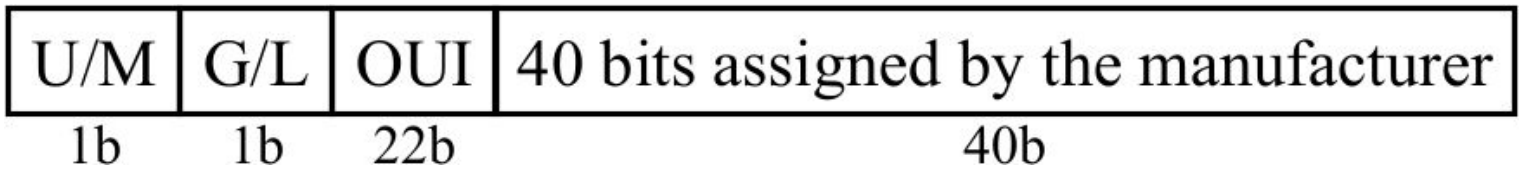


802.15.4 protocol architecture



IEEE 802.15.4 Main Characteristics

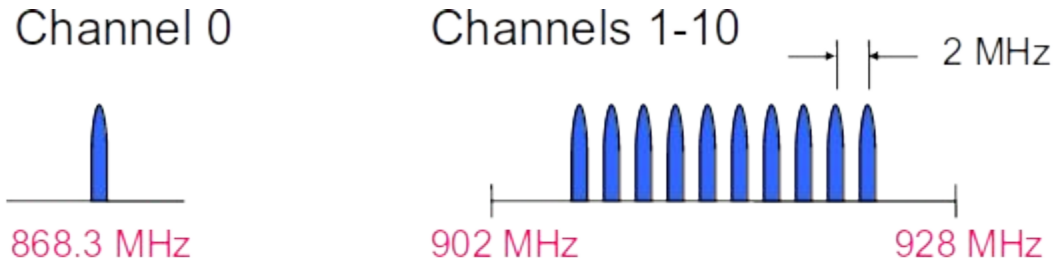
- Low Rate Wireless Personal Area Network (LR-WPAN)
  - Low Power Lossy Networks (LLN)
- ISM Bands
  - 2.4 GHz (most common): 16 channels
  - 915MHz (USA), 868MHZ (Europa), 779 MHz (China)
- Largest frame size 127B
- Transmission rate up to 250 kbps with O-QPSK
- Uses Direct Sequence Spread Spectrum (DSSS), with chips of 32 or 16 bits, depending on the frequency band
- Devices identified with a 64-bits (EUI-64) address
  - When they connect to the network they can request a 16 bits id



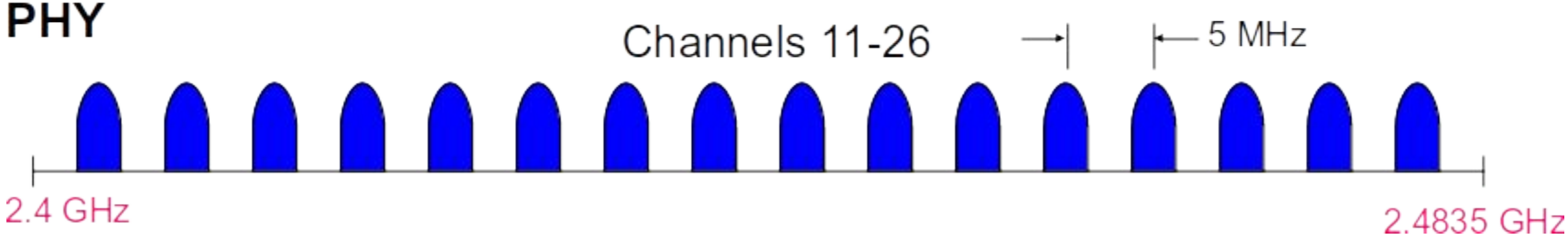
U/M: 1-Unicast/0-Multicast
G/L: 1-Global/0-Local
OUI (Organizationally Unique Identifier)

IEEE 802.15.4 PHY: channels

868MHz / 915MHz PHY



2.4 GHz PHY



IEEE 802.15.4 PHY: packets

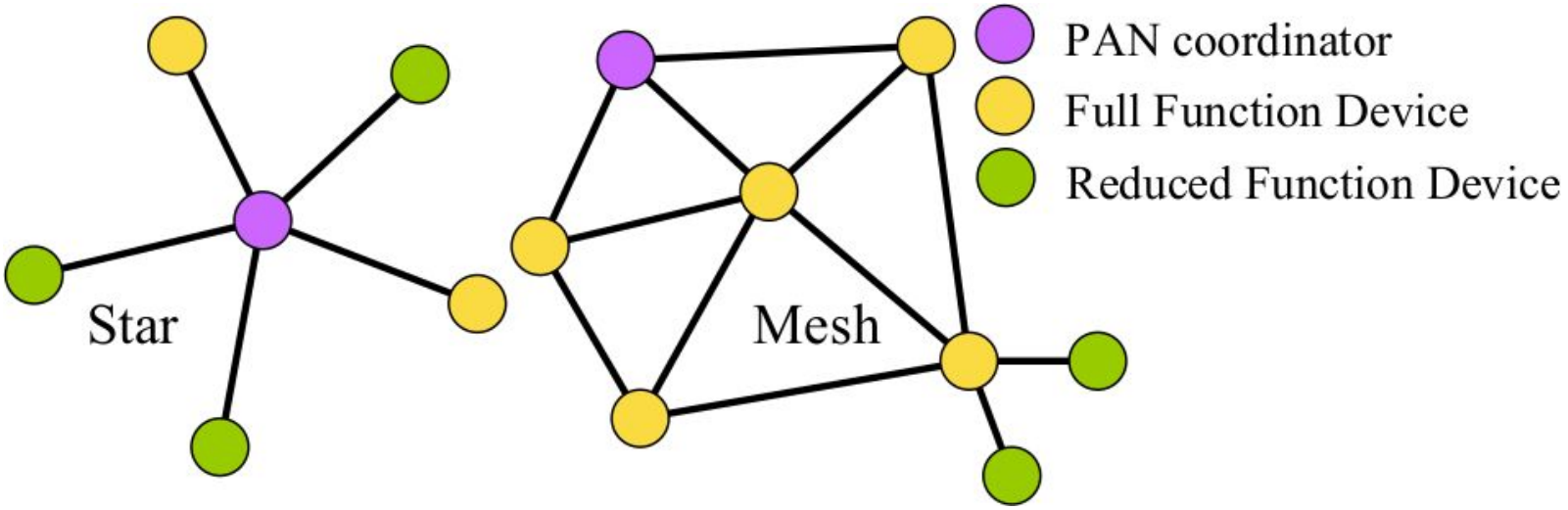
- Fields of the PHY packet:
  - Preamble (32 bits) – synchronization
  - Start of Packet Delimiter (8 bits)
  - PHY Header (8 bits) – length of the PSDU
  - PSDU (0 to 127 bytes) – Payload from the mac layer

802.15.4 PHY: modulation

PHY option	Frequency (MHz)	Type of modulation	Bit rate (kbps)	Symbol rate (ksymbols/s)
868/915	868-868.6	BPSK	20	20
	902-928	BPSK	40	40
868/915	868-868.6	ASK	250	12.5
(2006)	902-928	ASK	250	50
868/915	868-868.6	O-QPSK	100	50
(2006)	902-928	O-QPSK	250	62.5
2450	2400-2483.5	O-QPSK	250	62.5

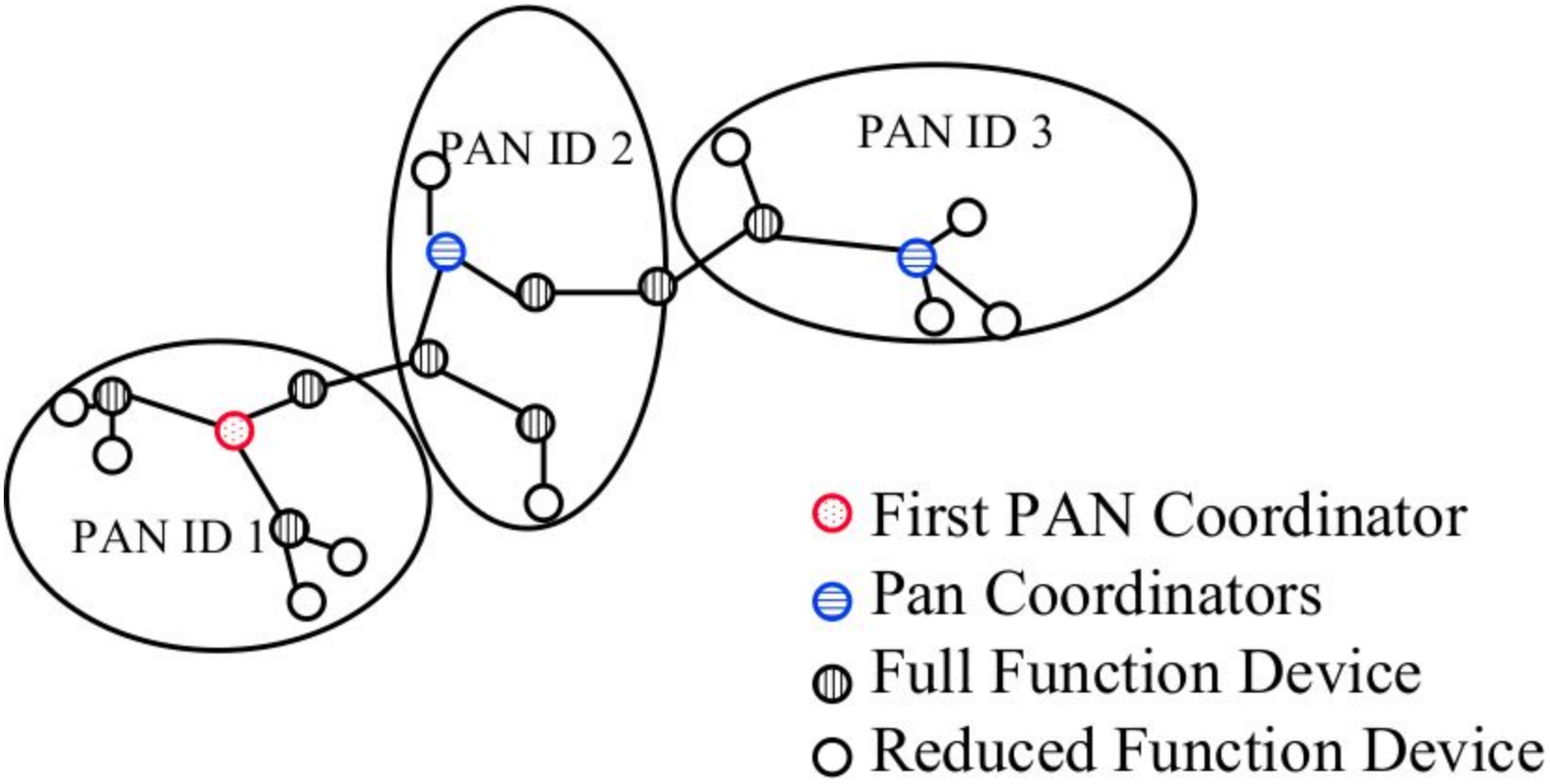
IEEE 802.15.4 Topologies

- Two topologies: star and peer-to-peer (p2p)
  - star, every communication goes through the central coordinator
  - p2p permits the construction of mesh networks
- Every pico-net has its PAN ID
- Two type of devices:
  - Full Function Device (FFD): can be coordinators, can relay packets from other nodes in mesh networks
  - Reduced Function Device (RFD): can only connect to a FFD, send and receive messages



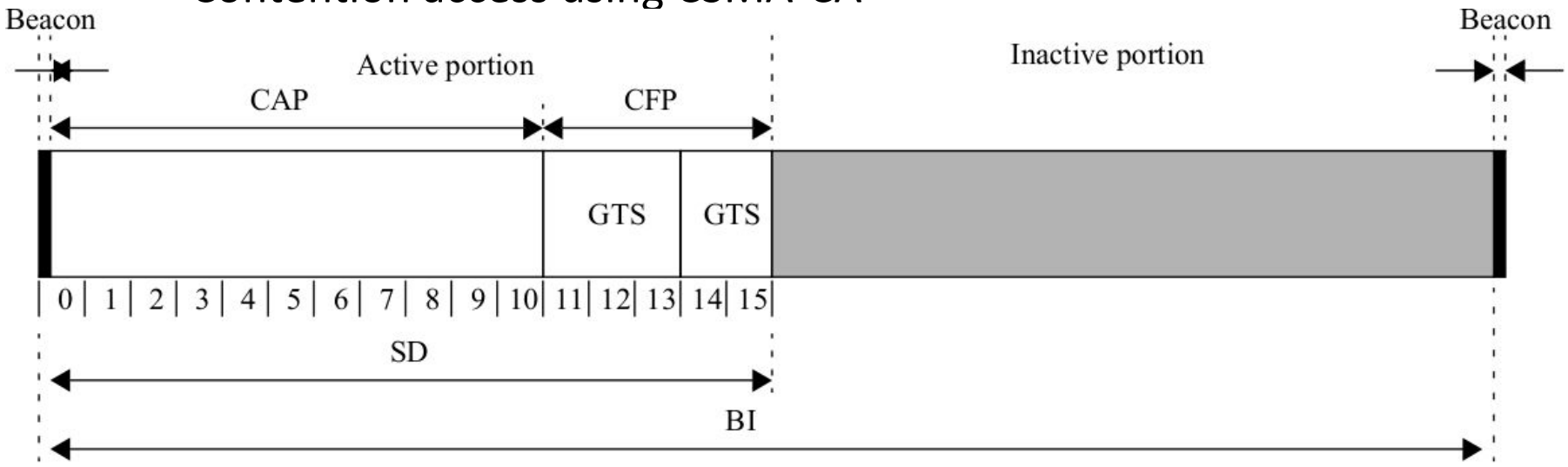
Cluster Tree Network

- A coordinator can request other FFD to become coordinators of a subset of the nodes
  - Every cluster has its own PANC and its own PAN ID



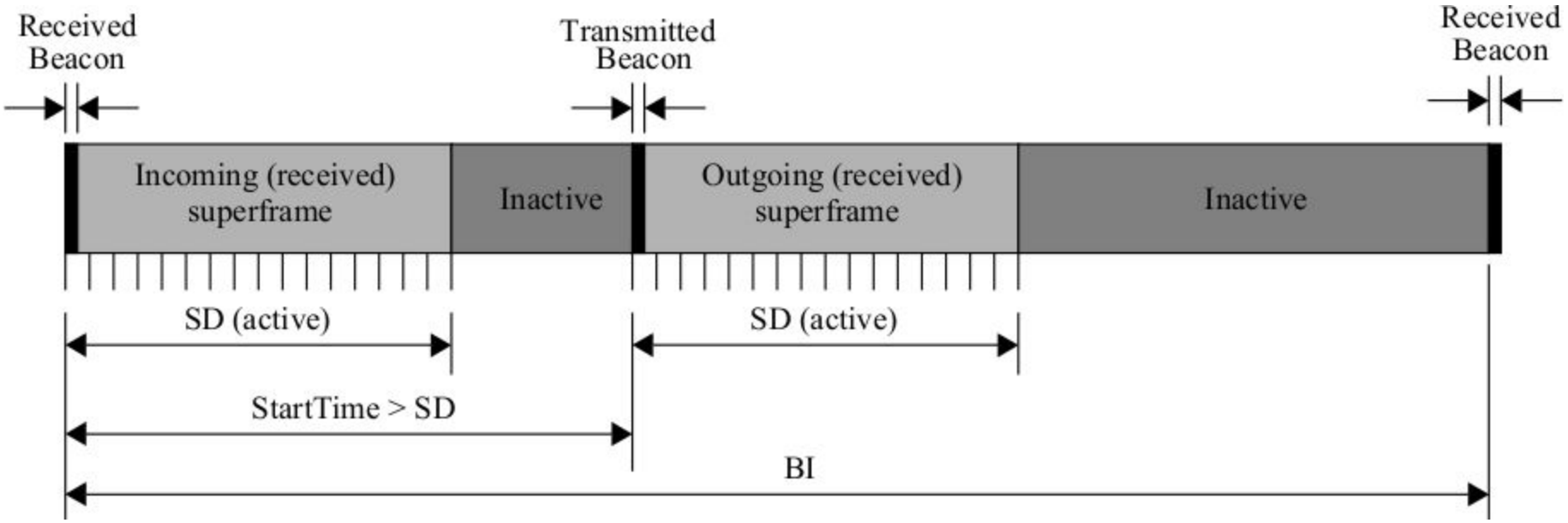
802.15.4: Two medium access modes

- Beaconed/Slotted
  - The coordinador sends periodic beacons, that divide the time in “superframes”, with an active and an inactive period
  - The active period is divided into 16 slots and is composed of two parts
    - Contention Access Period (CAP): uses slotted CSMA-CA
    - Contention Free Period (CFP): the slots are reserved by devices in what is called Guaranteed Transmission Services (GTS)
- Without beacons
  - Contention access using CSMA-CA



802.15.4: cluster interconnection

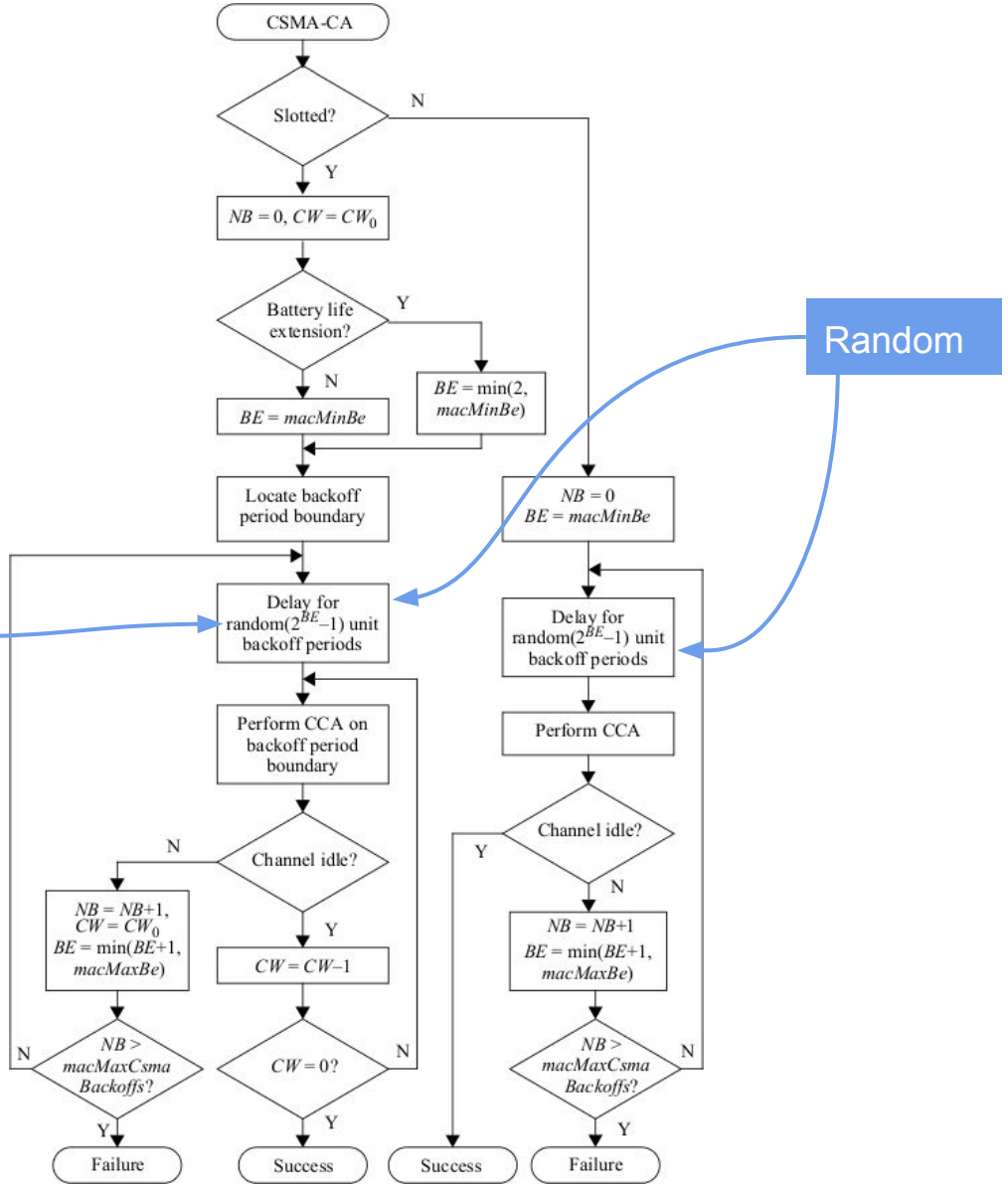
- The PANC of other clusters send its beacon in the inactive period of the superframe
  - Configured by the StartTime parameter
- All use the same channel



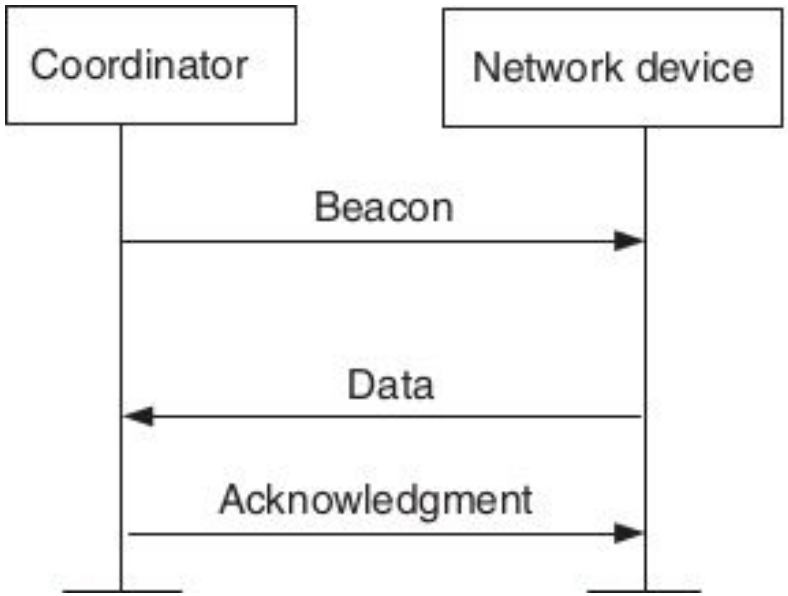
802.15.4: medium access control

NB: number of backoffs
CW: contention window length
BE: Backoff Exponent

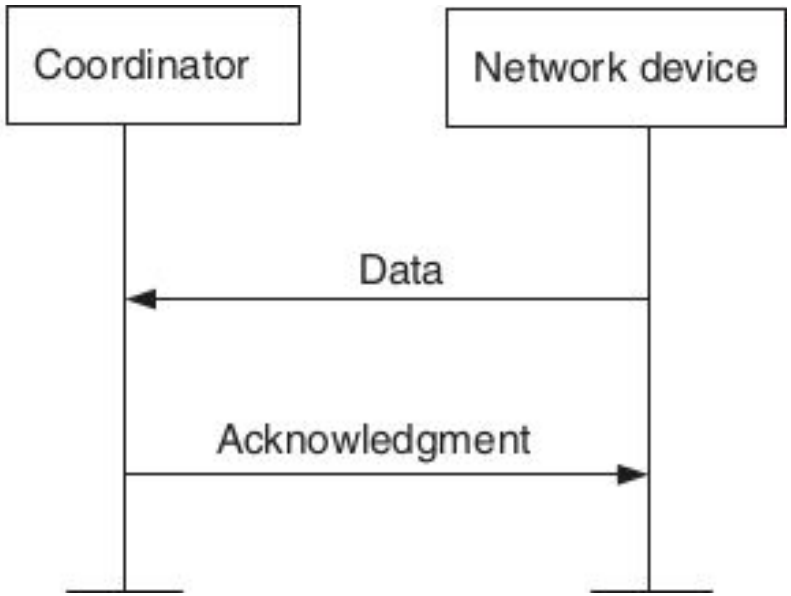
The transmission must be finished in the active period of the superframe, otherwise the station must wait until the next superframe.



802.15.4: message DEV to PANC

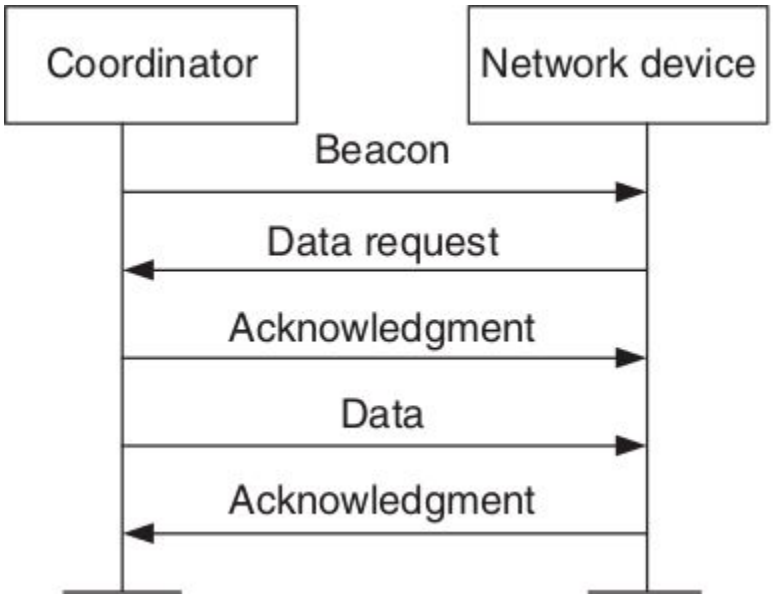


With Beacons

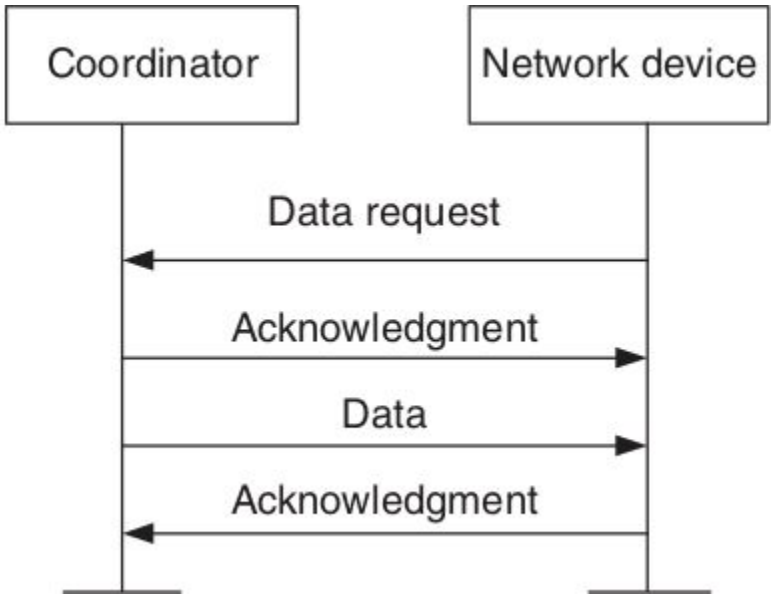


Without Beacons

802.15.4: message PANC to DEV



With Beacons

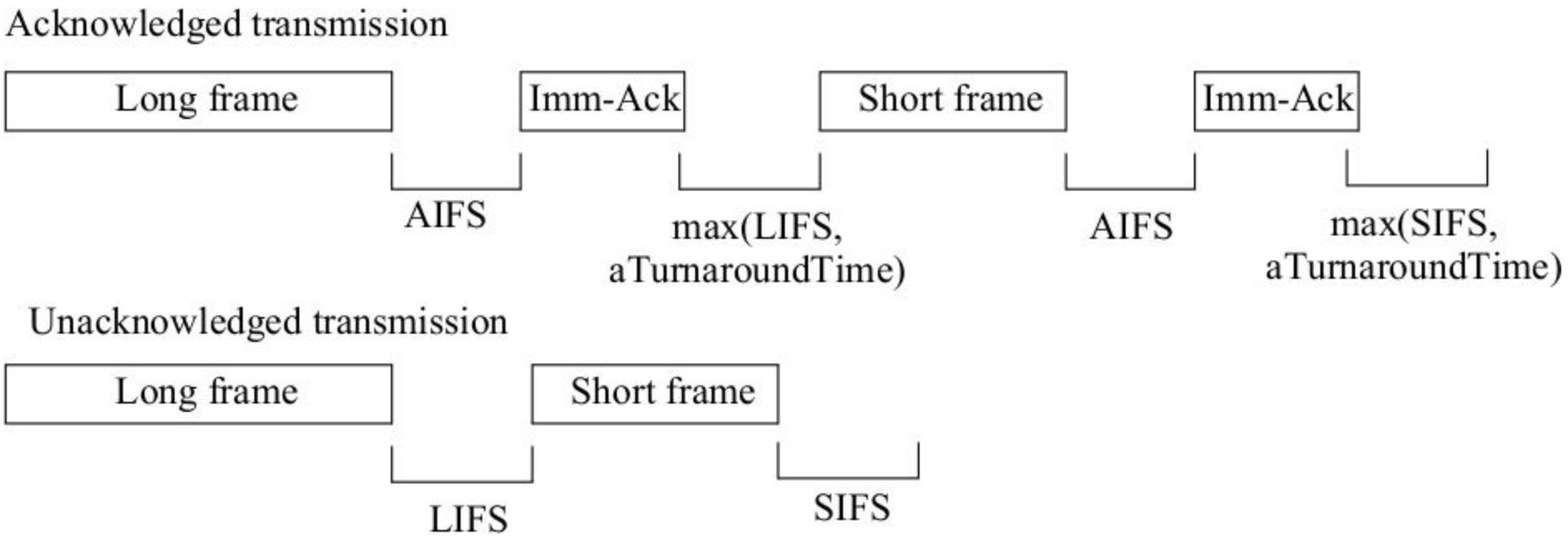


Without Beacons

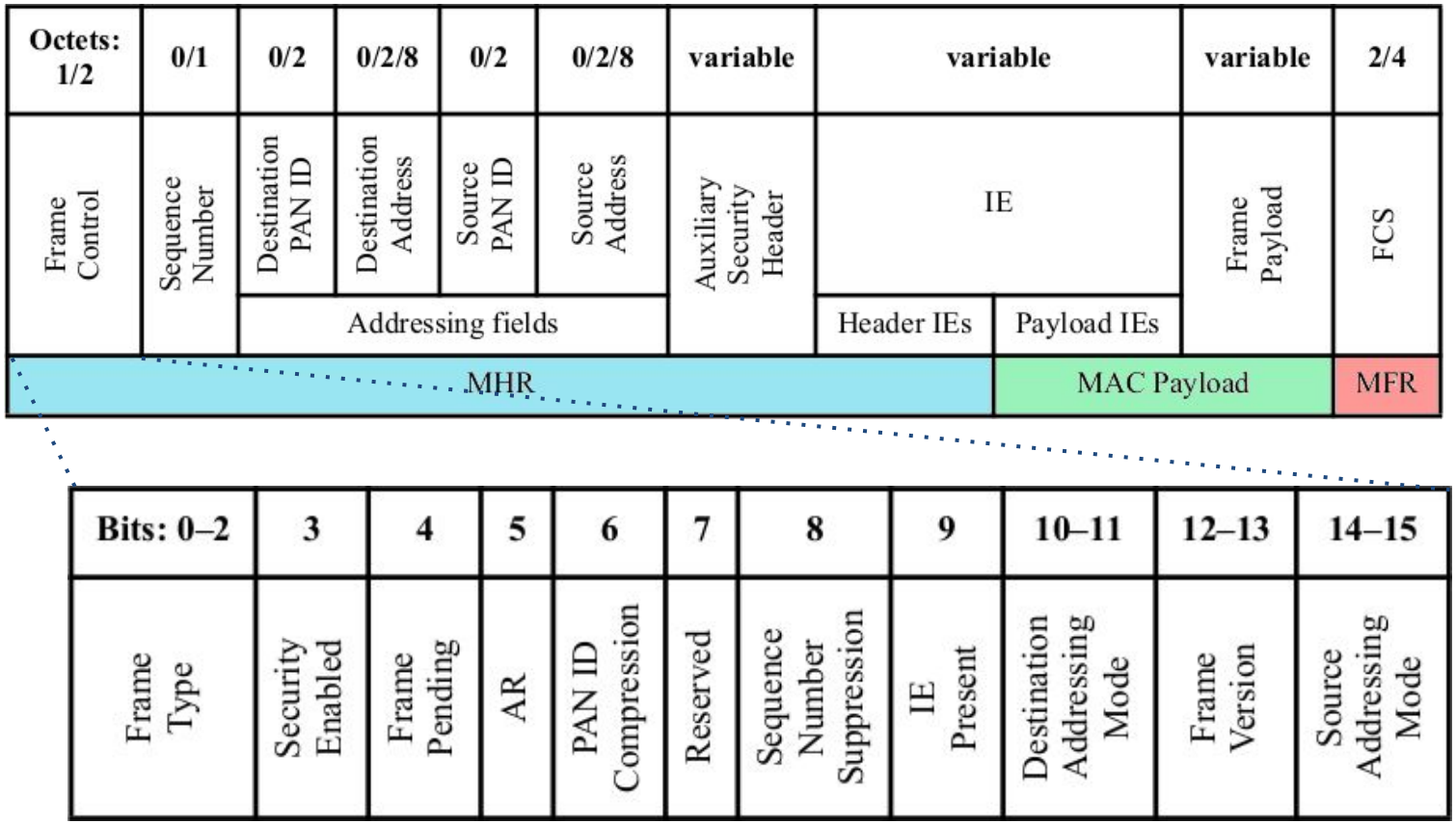
- With Beacons:
  - The PANC indicates in the beacon that it has data for a station
  - The device sends a request command in the contention period
- Without Beacons
  - The device sends a request from time to time
  - If the PANC has no data it sends an empty response

802.15.4: packet spacing

- Three inter-frame spacings (AIFS < SIFS < LIFS)
  - ACK inter-frame spacing (AIFS)
  - Short inter-frame spacing (SIFS)
  - Long inter-frame spacing (LIFS)



802.15.4 frame format

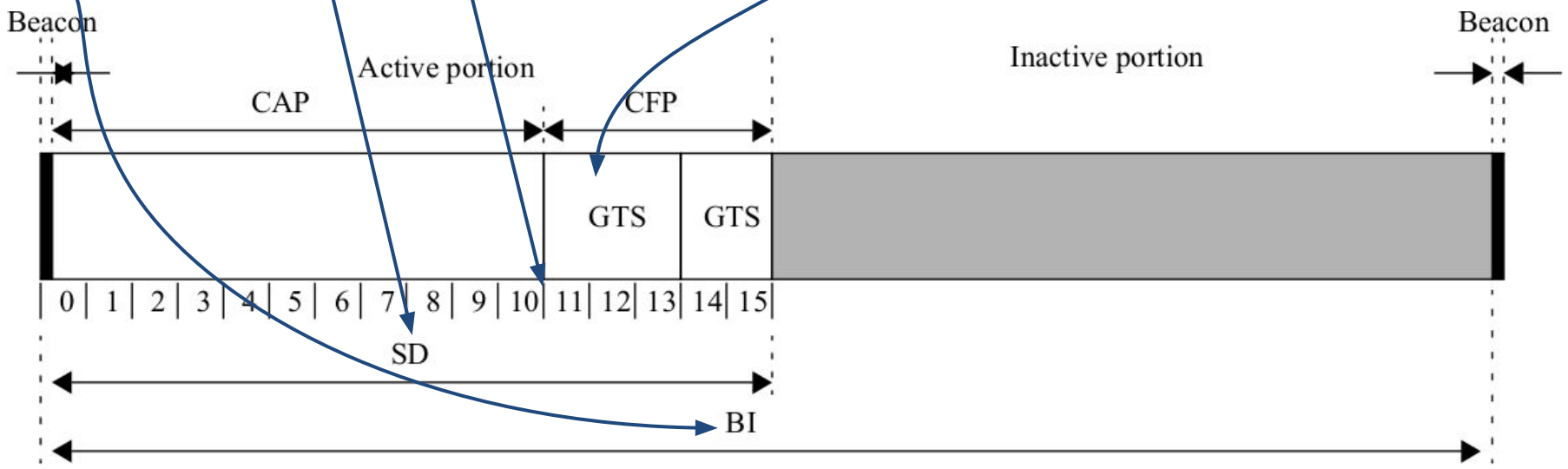


- Four types of frames: Beacon, Data, ACK and Command
- AR: ACK required
- PAN ID compression and Source/Destination Addressing Mode allow to reduce the header size eliminating address fields or making them shorter
- IE: Information Elements, permits to extend the protocol

802.15.4:Beacon Frame

Octets: 2	1	4/10	variable	2	variable	variable	variable	2/4
Frame Control	Sequence Number	Addressing fields	Auxiliary Security Header	Superframe Specification	GTS Info	Pending address	Beacon Payload	FCS
MHR				MAC Payload				MFR

Bits: 0–3	4–7	8–11	12	13	14	15
Beacon Order	Superframe Order	Final CAP Slot	Battery Life Extension (BLE)	Reserved	PAN Coordinator	Association Permit



802.15.4: other frames

DATA

Octets: 2	0/1	variable	variable	variable		variable	2/4
Frame Control	Sequence Number	Addressing fields	Auxiliary Security Header	IEs		Data Payload	FCS
				Header IEs	Payload IEs		
MHR				MAC Payload			MFR

COMMAND

Octets: 2	0/1	variable	variable	variable		1	variable	2/4
Frame Control	Sequence Number	Addressing fields	Auxiliary Security Header	IE		Command ID	Content	FCS
				Header IEs	Payload IEs			
MHR				MAC Payload				MFR

ACK

Octets: 2	1	2/4
Frame Control	Sequence Number	FCS
MHR		MFR

References

- IEEE standard
  - https://www.silabs.com/content/usergenerated/asi/cloud/attachments/siliconlabs/en/community/wireless/proprietary/forum/jcr:content/content/primary/qna/802_15_4_promiscuous-tbzR/hivukadin_vukadi-iTXQ/802.15.4-2015.pdf
  - Jelena Misic and Bokislav B. Misic. Wireless Personal Area Networks. Prformance, Interconnections and Security with IEEE 802.15.4. John Wiley& Sons, Ltd.
  - Yang Xiao, Michael J. Plyler, Ming Li and Fei Hu IEEE 802.15.4 Medium Access Control and Physical Layers