Topic 02: IEEE 802.15.4

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ICTP-ITU School on Wireless Networking for Scientific Applications in Developing Countries

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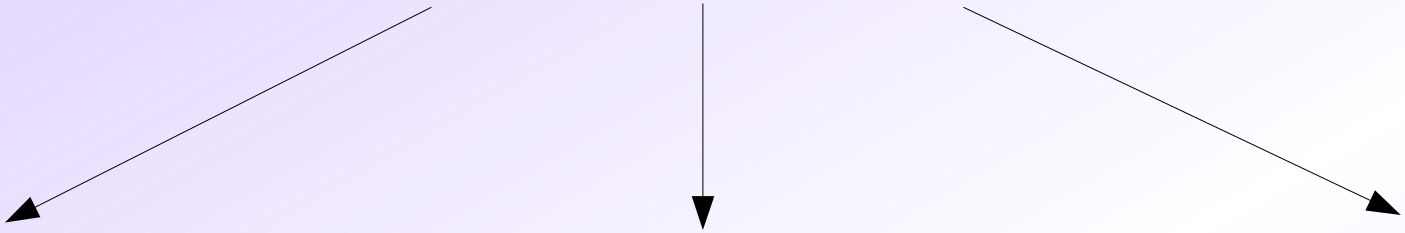
Outline

- What is 802.15.4 ? Other related technologies
- 802.15.4 PHY overview
- Device classes, network topologies
- 802.15.4 MAC
- MAC management:
  - Starting and maintaining PANs
  - Association
- Data exchange mechanisms

Personal Area Networks (PAN)

- WLAN: IEEE 802.11
  - Ethernet matching speed
  - Range: O(100m)
- WPAN:
  - Low cost
  - Low power (battery should last several months)
  - Short range O(10m)
  - Small size

IEEE 802.15 Series



802.15.3 (UWB)

High data rate
Multimedia applications

802.15.1 (Bluetooth)

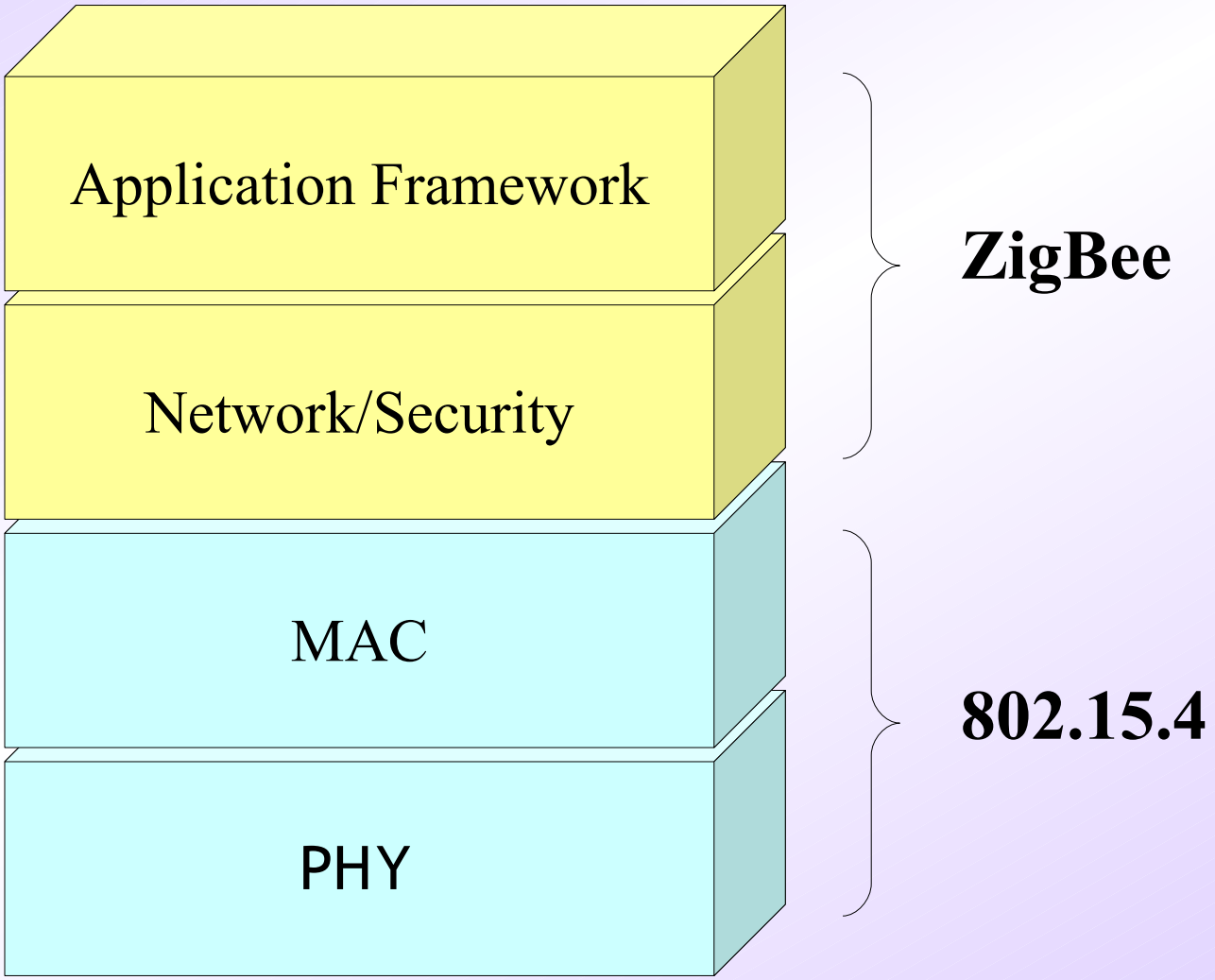
Medium rate
Cell-phones, PDA
QoS suited for voice

802.15.4 (LR-WPAN)

Low rate
Industrial, residential, medical applications
Low power
Low cost

ZigBee works hand-in-hand with 802.15.4

802.15.4/ZigBee Architecture



802.15.4 PHY

Table 1—Frequency bands and data rates

PHY (MHz)	Frequency band (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation	Bit rate (kb/s)	Symbol rate (ksymbol/s)	Symbols
868/915	868–868.6	300	BPSK	20	20	Binary
	902–928	600	BPSK	40	40	Binary
2450	2400–2483.5	2000	O-QPSK	250	62.5	16-ary Orthogonal

Source: IEEE 802.15.4 specification

1 channel

10 channels

16 channels

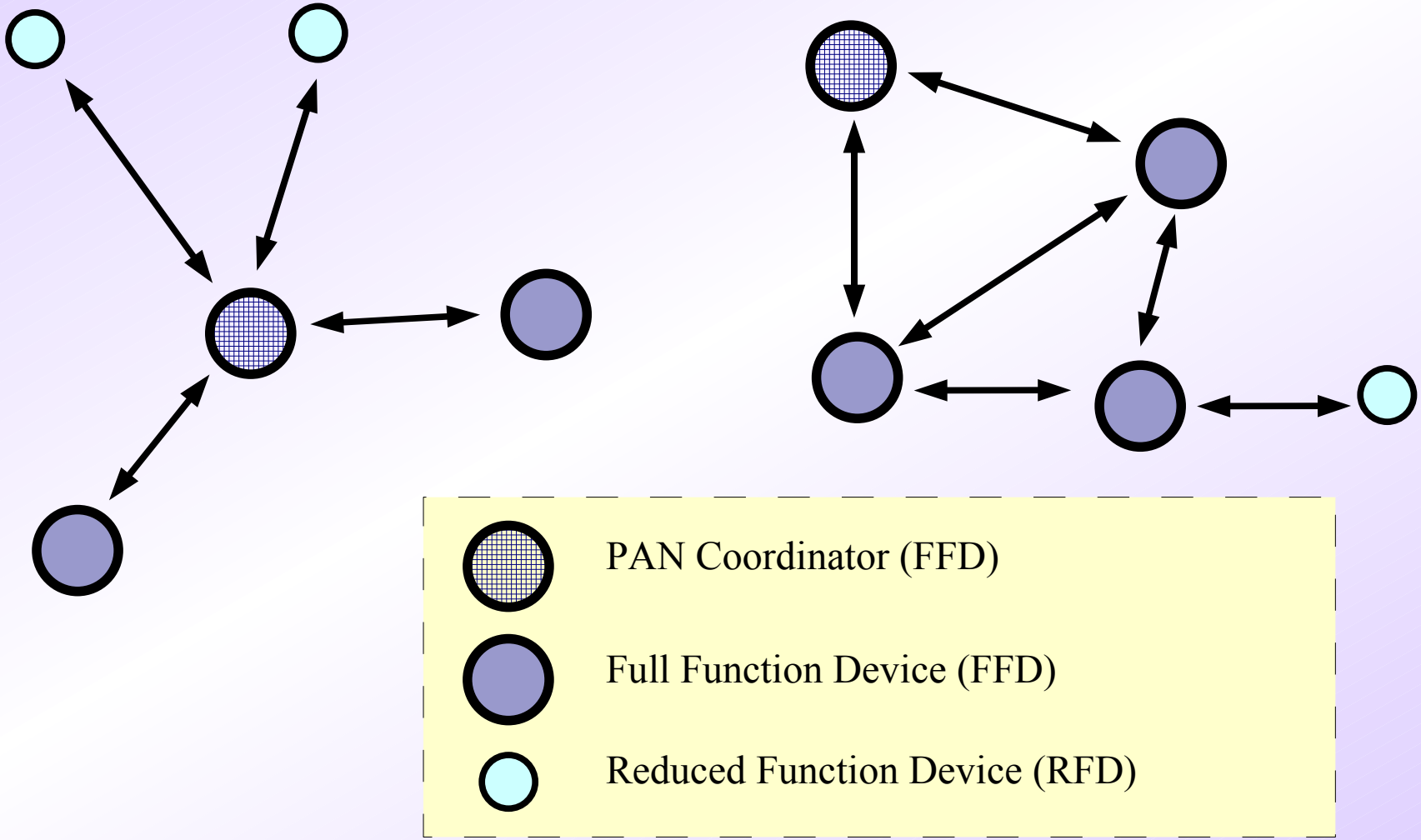
802.15.4 Device Classes

- Full Function Device (FFD)
  - Can act as PAN "coordinator"
  - Can talk to any other device
- Reduced Function Device (RFD)
  - Cannot be a "coordinator"
  - Can talk only to FFD
  - Very simple implementation

Network Topologies

Star network

Peer-to-peer network



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Optional Beacons

- A PAN can be beacon-enabled or non-beacon-enabled
  - Decided by the coordinator
  - Mechanism for power saving (if required)
- Beacon enabled ==> periodic beacons

Superframe Structure

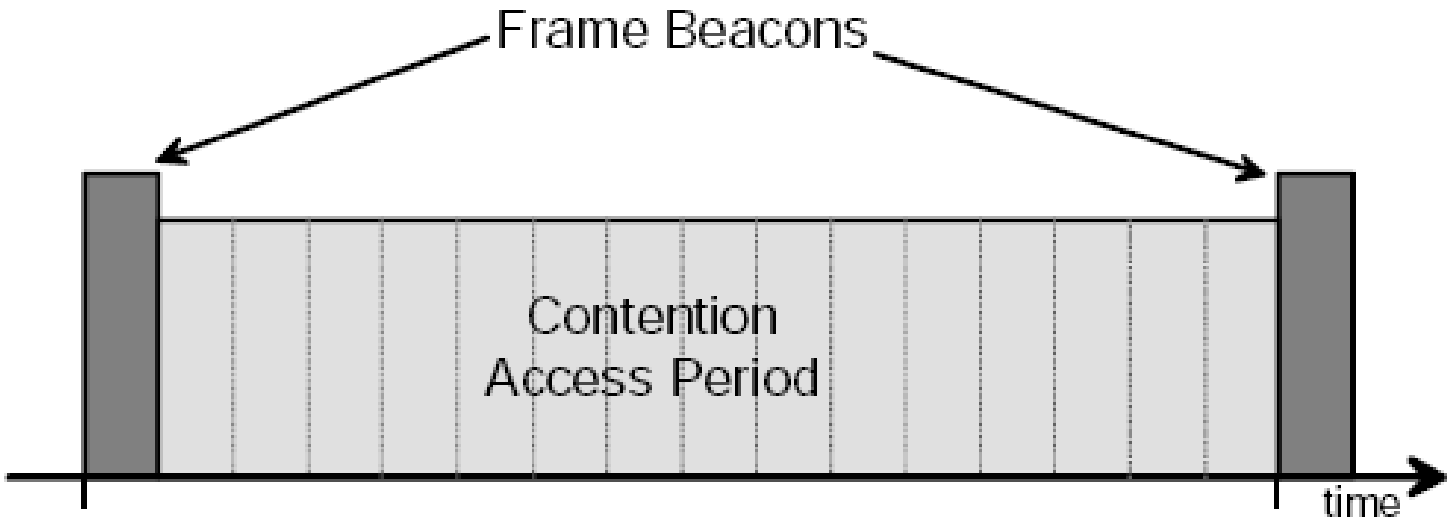


Figure 4—Superframe structure without GTSs

Guaranteed
Time-Slot

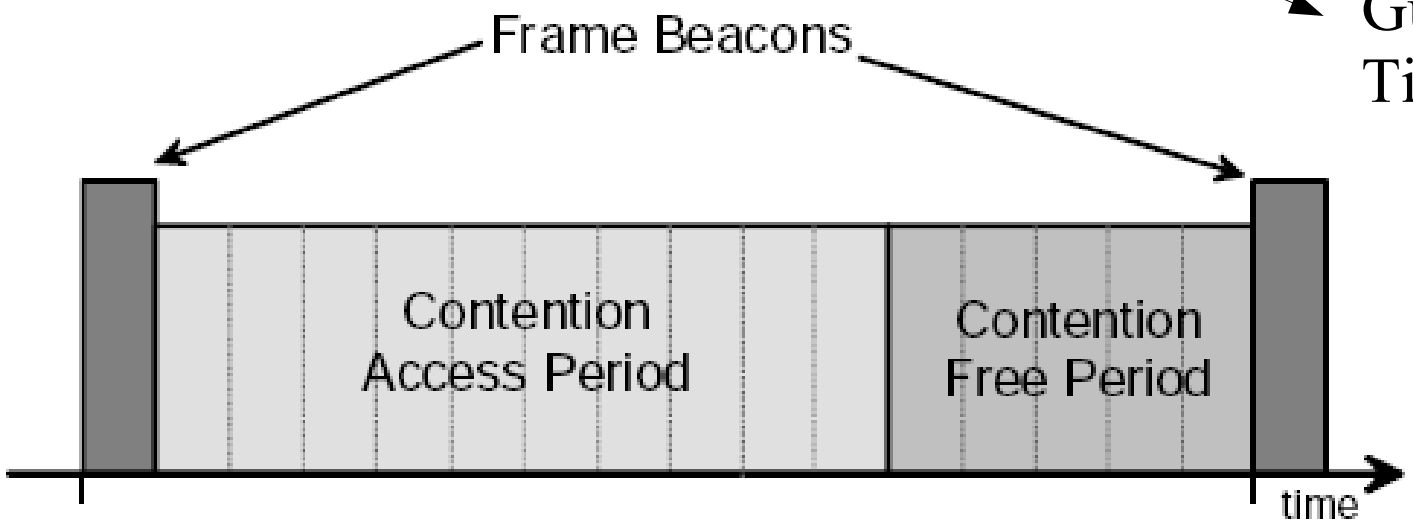
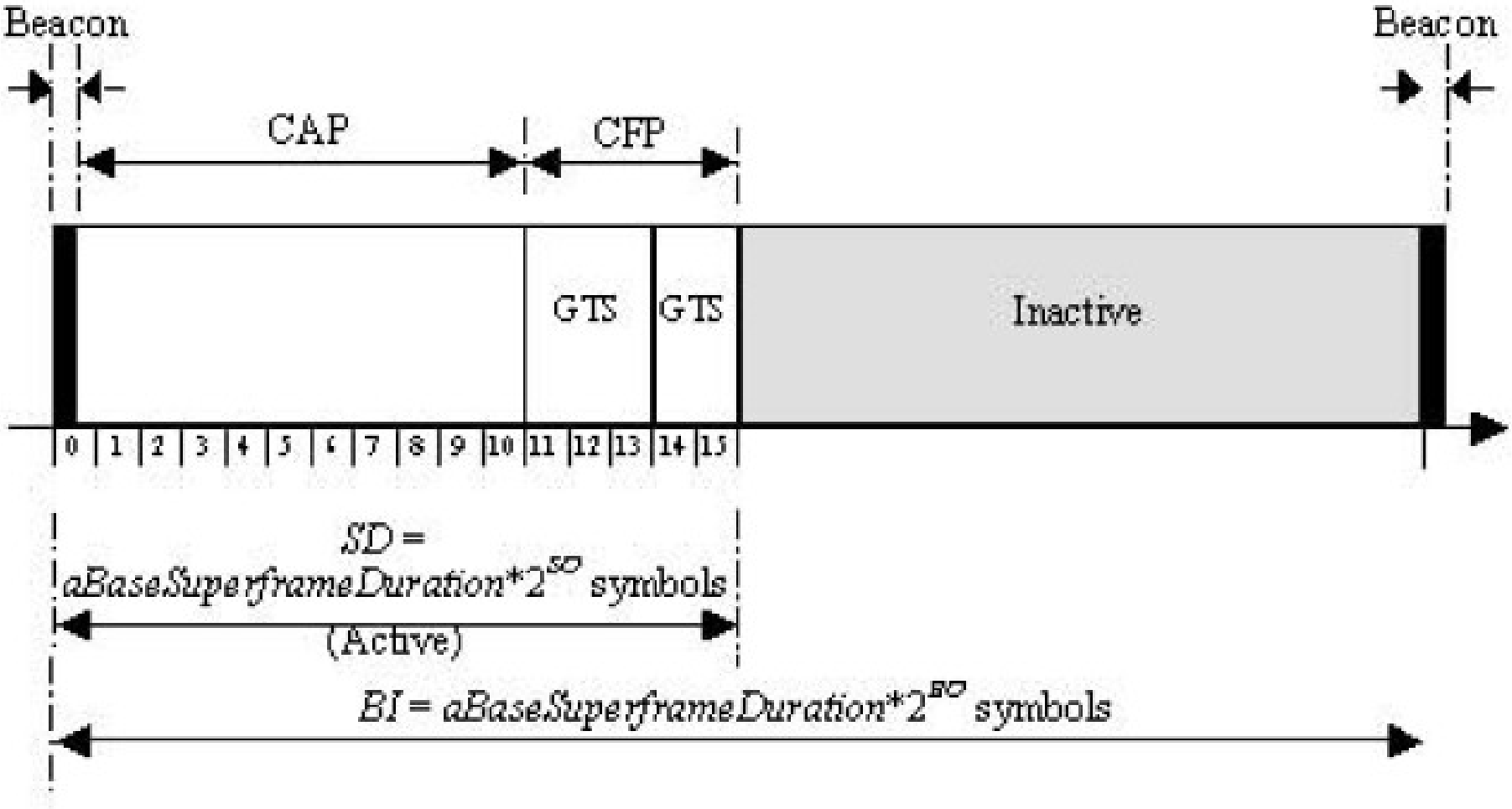


Figure 5—Superframe structure with GTSs

Source: IEEE 802.15.4 specification

Superframe Structure (Continued)



Beacon Interval (BI) can be a multiple of the Superframe Duration (SD)

Figure 59—An example of the superframe structure

Source: IEEE 802.15.4 specification

Superframe Structure: Remarks

- CAP, then CFP
- Superframe = 16 slots (slot=60 symbols when SO=0)
- A minimum of 440 symbols for CAP
- Maximum of 7 GTS allocations
- A GTS may occupy more than one slot
- All GTS tx must end before start of beacon tx
- All tx in CAP must end before CFP (or beacon)
- ACKs are optional
  - Requirement specified in a data packet

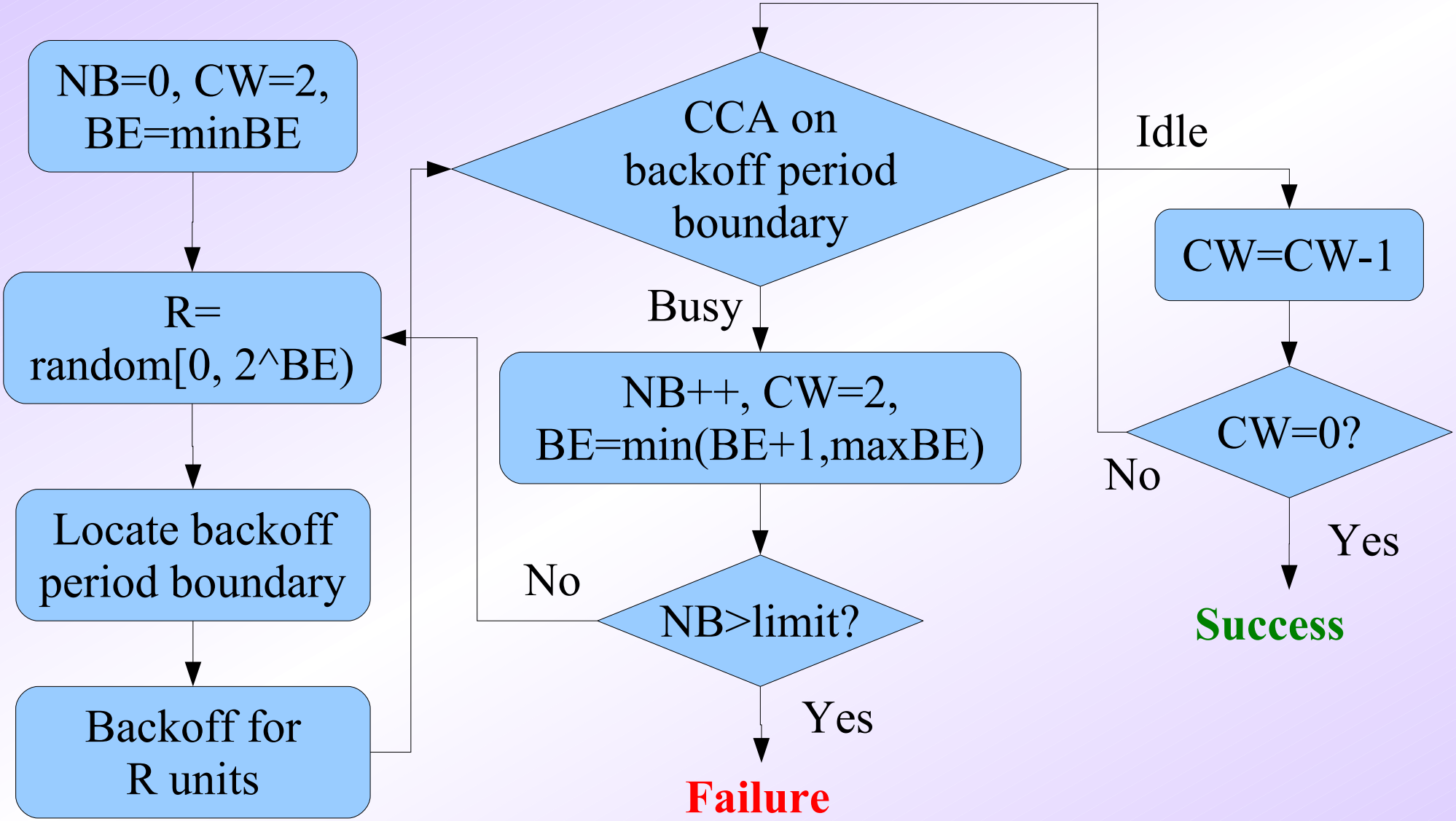
CSMA Algorithm

- Called slotted CSMA in beaconed PANs
- Unslotted CSMA in non-beaconed PANs
- But both use "units" of time ("slots" in 802.11 terminology)
  - aUnitBackoffPeriod: 20 symbols by default
- In beaconed PANs, the first backoff is aligned with the start of the super frame

CSMA: Variables Used

- BE (Backoff Exponent): backoff delay is for random[0,2^BE) units of time
- CW (Contention Window): the number of units to perform CCA (Clear Channel Assessment) after random backoff
  - Warning: do not confuse with 802.11 terminology
- NB: Number of Backoffs so far
  - Initialized to 0

Slotted CSMA

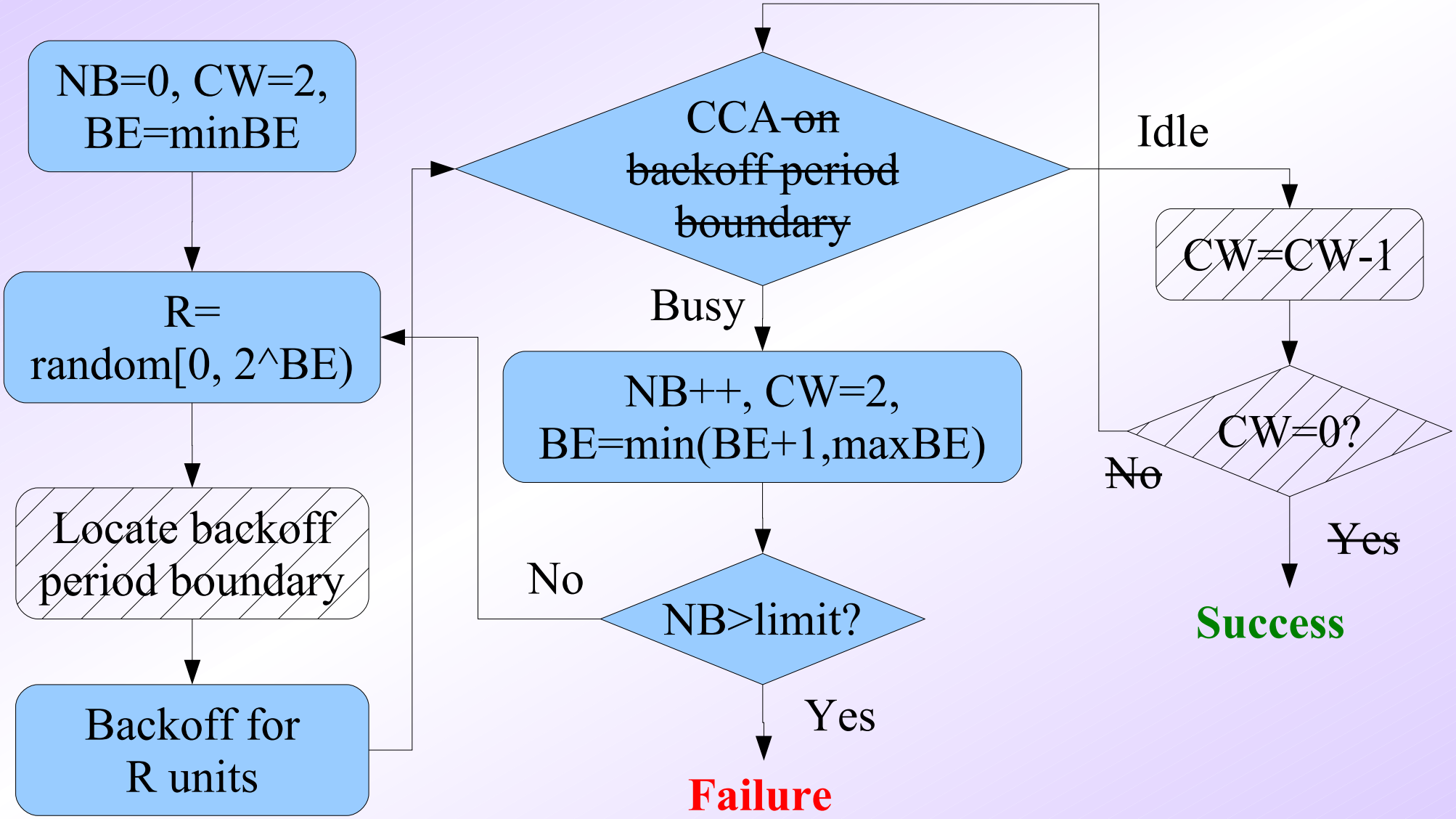


Default values: minBE=3, maxBE=5, limit=4

Differences from 802.11 CSMA

- Have to finish by a specific time
  - Otherwise continue random delay in next superframe
- 802.11 has per-delay-slot CCA
  - Why CCA for two units in 802.15.4?
- No limit on number of retries in 802.11
- During init: BE=min(2,minBE) possible
  - If device is battery constrained
  - Allows device to save power by prioritizing its tx

Unslotted CSMA (Differences)



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Scanning and PAN Creation

- Scanning procedures: active, passive
- Active scan:
  - Send beacon request
  - A beaconed PAN coordinator need not respond to the request (periodic beacon will suffice)
  - A non-beaconed PAN coordinator will respond with a beacon
- Orphan scan: orphan notification command sent by device to a coordinator
- A new PAN started only after an active scan
  - New PAN id is chosen (collision possible)

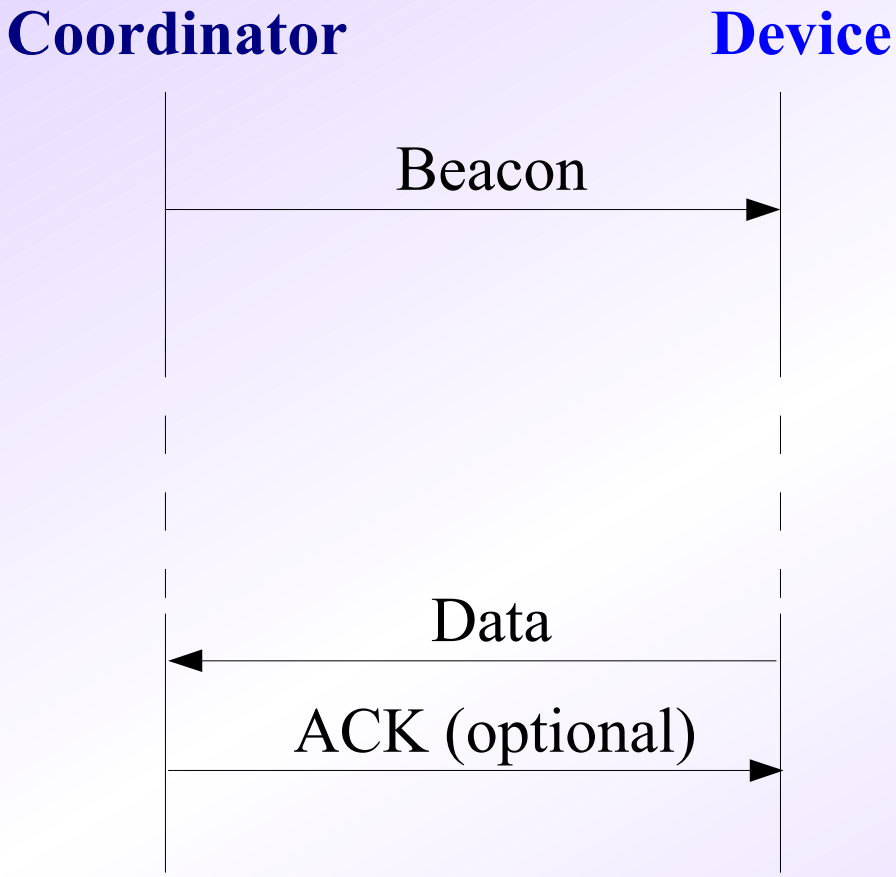
PAN id Collision

- Detection by coordinator:
  - On receiving a beacon frame with same PAN id
  - On receiving a PAN id collision notification
- Detection by device:
  - On receiving conflicting information
- Resolution:
  - Coordinator will perform active scan
  - Select new PAN id
  - Broadcast coordinator realignment message

Association

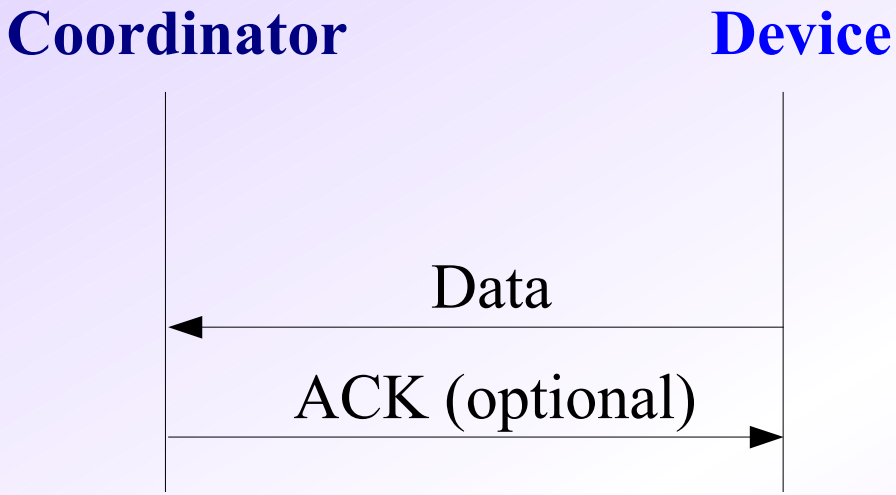
- An FFD or RFD can associate with an existing PAN
  - After active or passive scan
- Association request + ack
- Association response + ack

Data Transmission to Coordinator (Beaconed PAN)



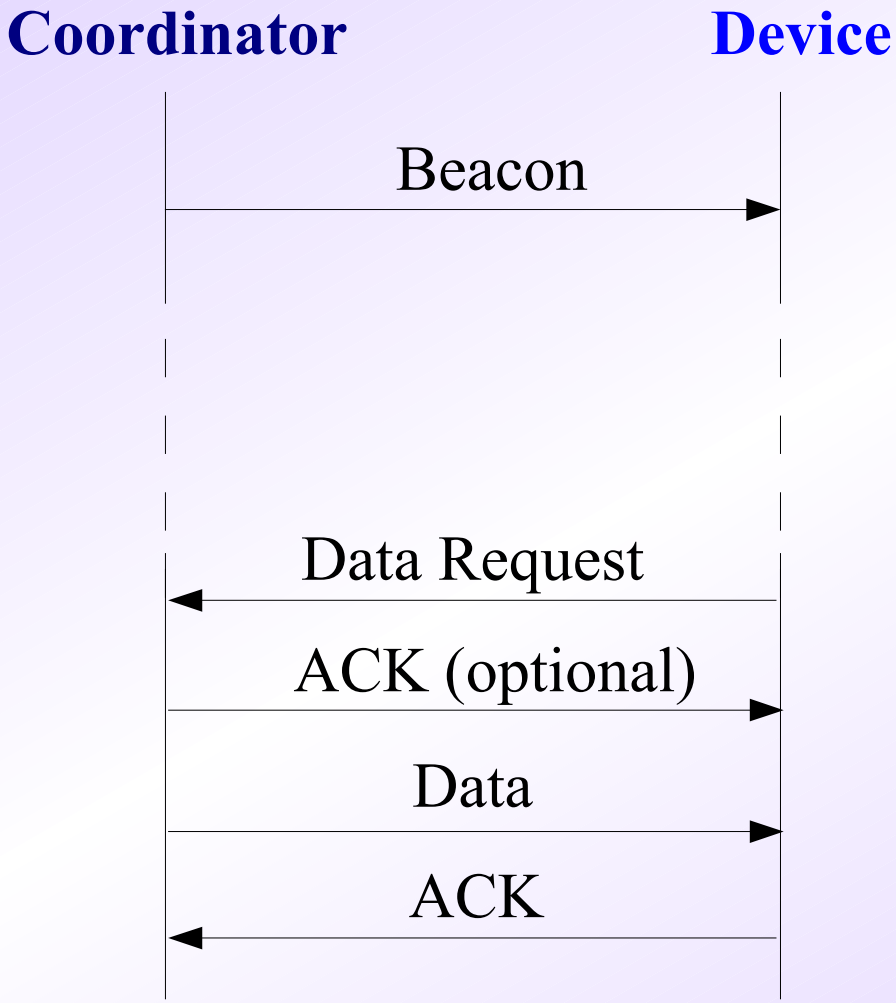
- Data uses slotted CSMA
- ACK does not use CSMA
  - Optional ACK
  - Requirement is indicated in the data packet

Data Transmission to Coordinator (non-Beaconed PAN)



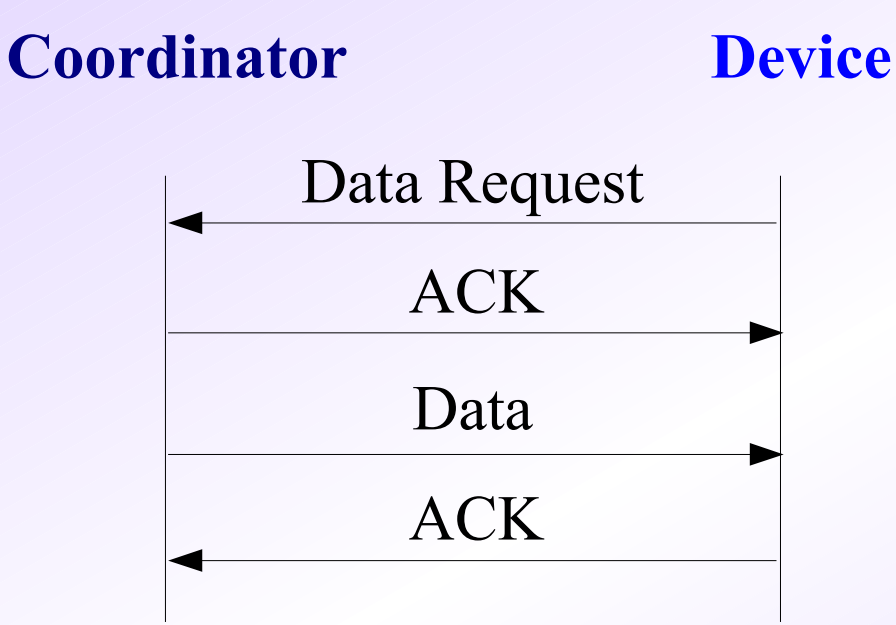
- Data uses unslotted CSMA
- ACK does not use CSMA
  - Optional ACK
  - Requirement is indicated in the data packet

Data Transmission from Coordinator (Beaconed PAN)



- Presence of downlink data is indicated in beacon
- Whenever device wakes up, it requests for data
- Data removed from coordinator queue on ACK

Data Transmission from Coordinator (non-Beaconed PAN)



- No data pending at coordinator ==> send data of length zero

Peer-to-peer Data Transfers

- Unslotted CSMA or using synchronization
  - Synchronization specification beyond the scope of 802.15.4

Concept of Primitives

- A network layer provides a service which is used by a higher layer

Summary

- 802.15.4: IEEE standard for embedded wireless (sensor) applications
  - PHY + MAC
  - MAC has CSMA/CA as well as GTS
  - Good support for low-power devices