

Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [IEEE 802.15.4 MAC Overview]

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Re: [Reflector discussions.

References: IEEE 802.15.4-2003 standard, 03036r0P802-15_WG-802-15-4-TG4-Tutorial.ppt by Jose Gutierrez, and 03057r0P802-15_TG4-Specification_summary.ppt by Pat Kinney, Paul Gorday, Phil Jamieson]

Abstract: [This document presents an overview of the IEEE 802.15.4 MAC sub-layer as currently specified in the 2003 version of the standard.]

Purpose: [For informative purpose for the IEEE 802.15.4a task group.]

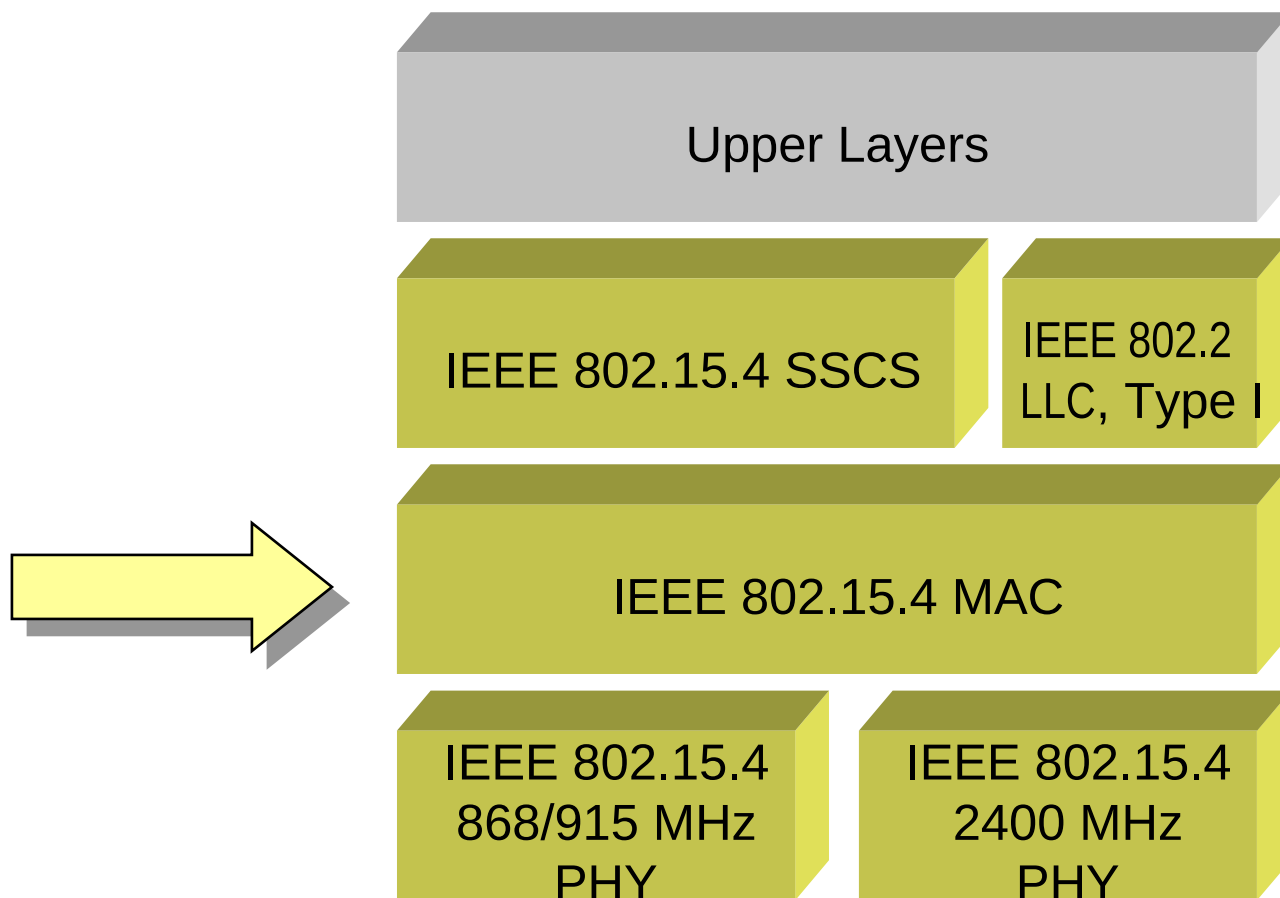
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Content

- Overview
- Topologies
- Superframe structure
- Frame formatting
- Data service
- Management service
- Interframe spacing
- CSMA procedure

802.15.4 Architecture



Protocol Drivers

- Extremely low cost
- Ease of installation
- Reliable data transfer
- Short range operation
- Reasonable battery life

MAC Overview

- Star and peer-to-peer topologies
- Optional frame structure
- Association
- CSMA-CA channel access mechanism
- Packet validation and message rejection
- Optional guaranteed time slots
- Guaranteed packet delivery
- Facilitates low-power operation
- Security

IEEE 802.15.4 Device Classes

- Full function device (FFD)
 - Any topology
 - PAN coordinator capable
 - Talks to any other device
 - Implements complete protocol set
- Reduced function device (RFD)
 - Limited to star topology or end-device in a peer-to-peer network.
 - Cannot become a PAN coordinator
 - Very simple implementation
 - Reduced protocol set

IEEE 802.15.4 Definitions

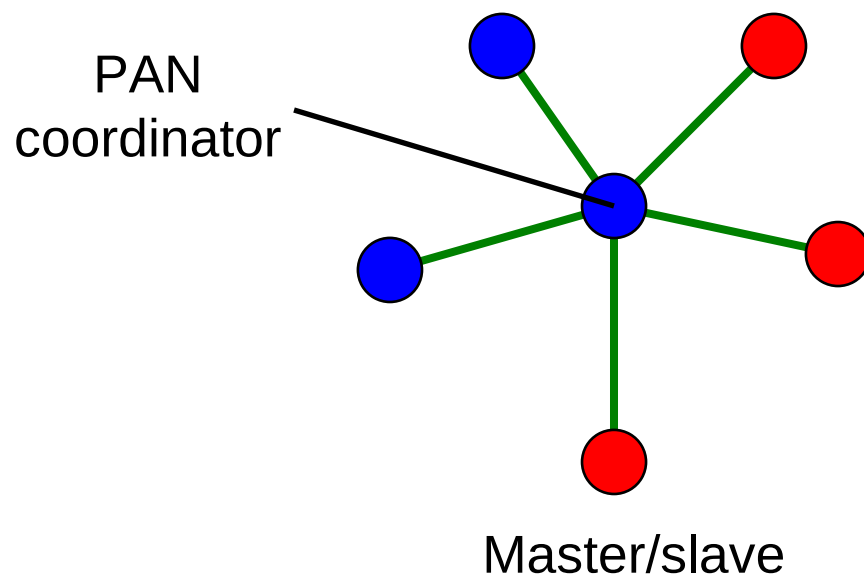
- **Network Device:** An RFD or FFD implementation containing an IEEE 802.15.4 medium access control and physical interface to the wireless medium.
- **Coordinator:** An FFD with network device functionality that provides coordination and other services to the network.
- **PAN Coordinator:** A coordinator that is the principal controller of the PAN. A network has exactly one PAN coordinator.

Low-Power Operation



- Duty-cycle control using superframe structure
 - Beacon order and superframe order
 - Coordinator battery life extension
- Indirect data transmission
- Devices may sleep for extended period over multiple beacons
- Allows control of receiver state by higher layers

Star Topology

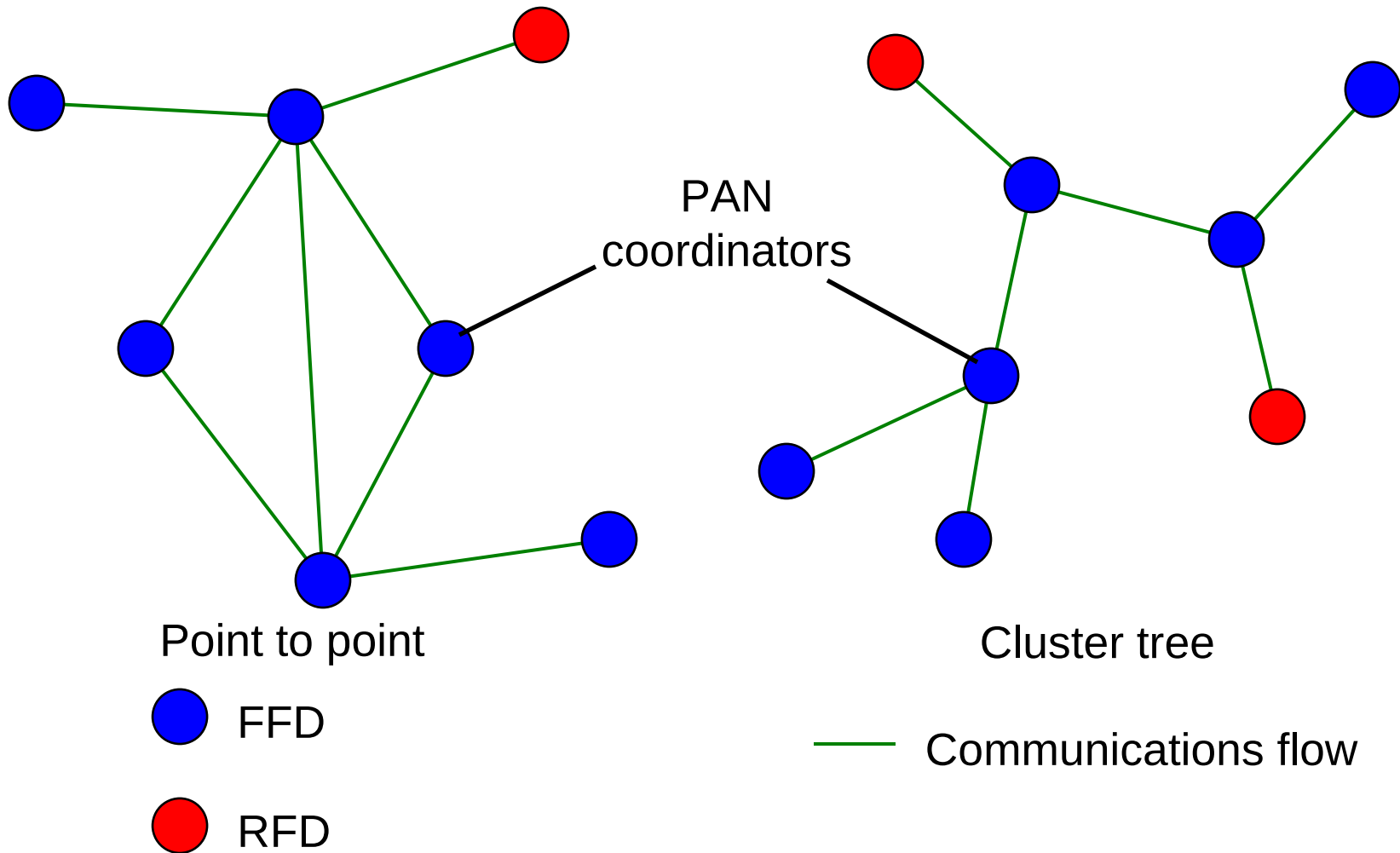


● FFD

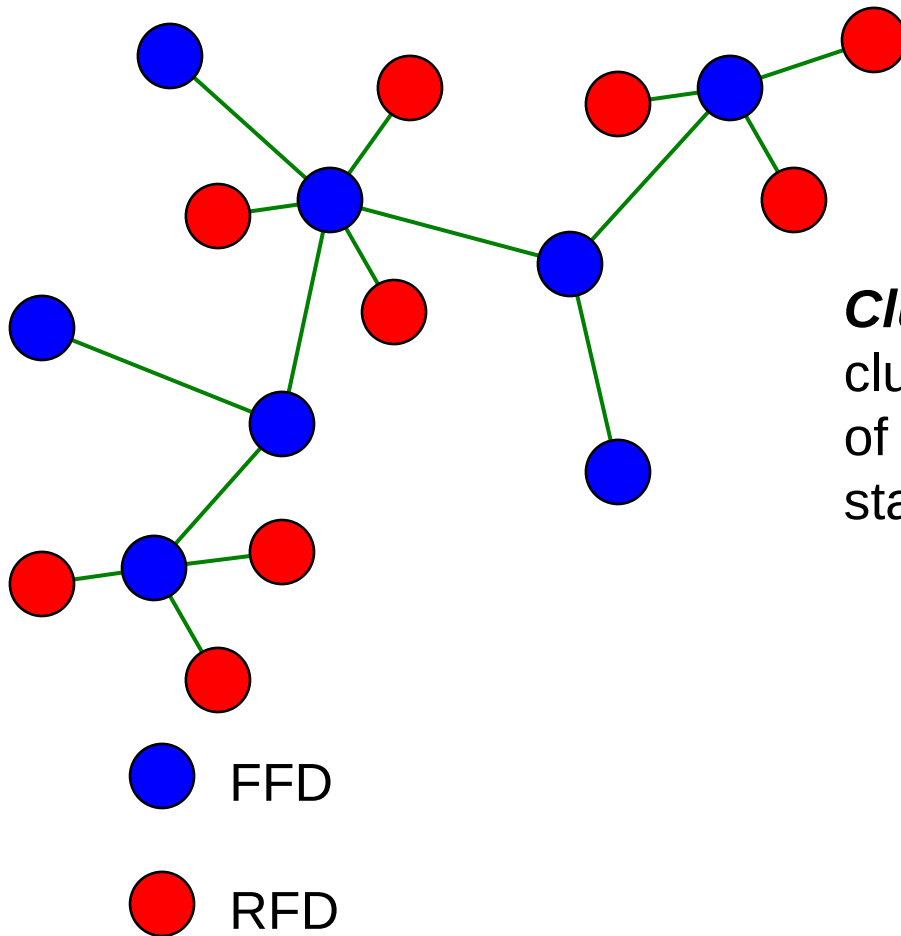
● RFD

— Communications flow

Peer-Peer Topology



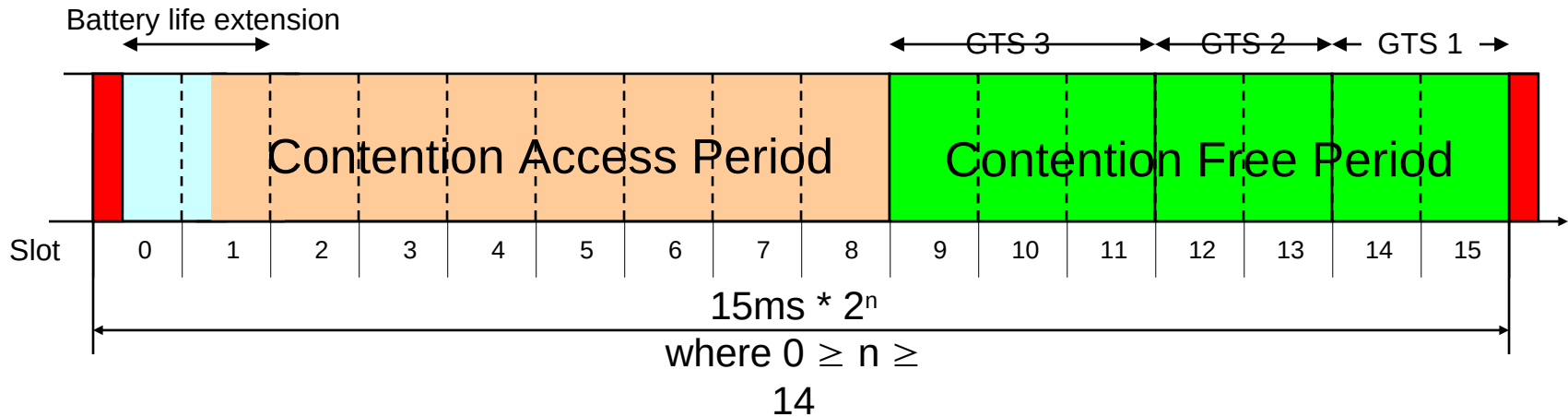
Combined Topology



Clustered stars - for example, cluster nodes exist between rooms of a hotel and each room has a star network for control.

— Communications flow

Optional Frame Structure



Network
beacon



Transmitted by PAN coordinator. Contains network information, frame structure and notification of pending node messages.

Beacon
extension
period



Space reserved for beacon growth due to pending node messages

Contention
period



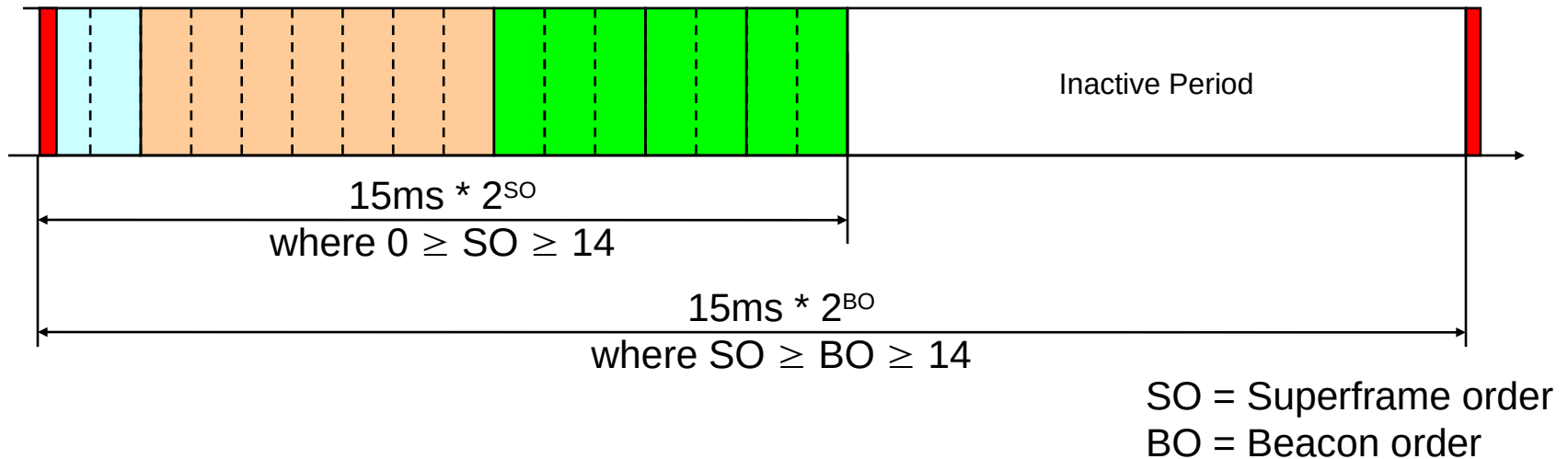
Access by any node using CSMA-CA

Guaranteed
Time Slot



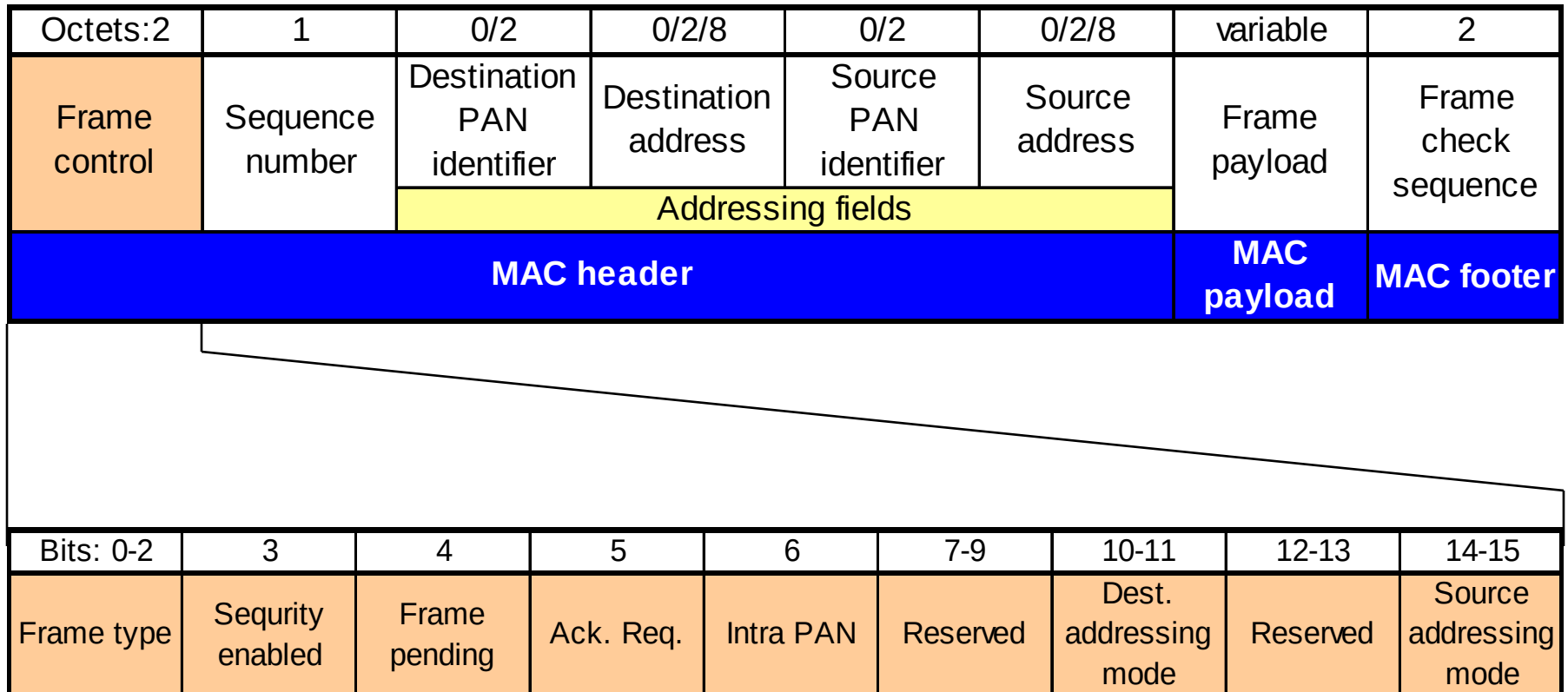
Reserved for nodes requiring guaranteed bandwidth [$n = 0$].

Optional Frame Structure



- Superframe may have inactive period

General MAC Frame Format



Frame control field

Beacon Frame Format

Octets:2	1	4 or 10	2	variable	variable	variable	2
Frame control	Beacon sequence number	Source address information	Superframe specification	GTS fields	Pending address fields	Beacon payload	Frame check sequence
MAC header			MAC payload				MAC footer

Bits: 0-3	4-7	8-11	12	13	14	15
Beacon order	Superframe order	Final CAP slot	Battery life extension	Reserved	PAN coordinator	Association permit

MAC Command Frame

Octets:2	1	4 to 20	1	variable	2
Frame control	Data sequence number	Address information	Command type	Command payload	Frame check sequence
MAC header			MAC payload		MAC footer

- Command Frame Types
 - Association request
 - Association response
 - Disassociation notification
 - Data request
 - PAN ID conflict notification
 - Orphan Notification
 - Beacon request
 - Coordinator realignment
 - GTS request

Data Frame Format

Octets:2	1	4 to 20	variable	2
Frame control	Data sequence number	Address information	Data payload	Frame check sequence
MAC header			MAC Payload	MAC footer

Acknowledgement Frame Format

Octets:2	1	2
Frame control	Data sequence number	Frame check sequence
MAC header		MAC footer

Data Service

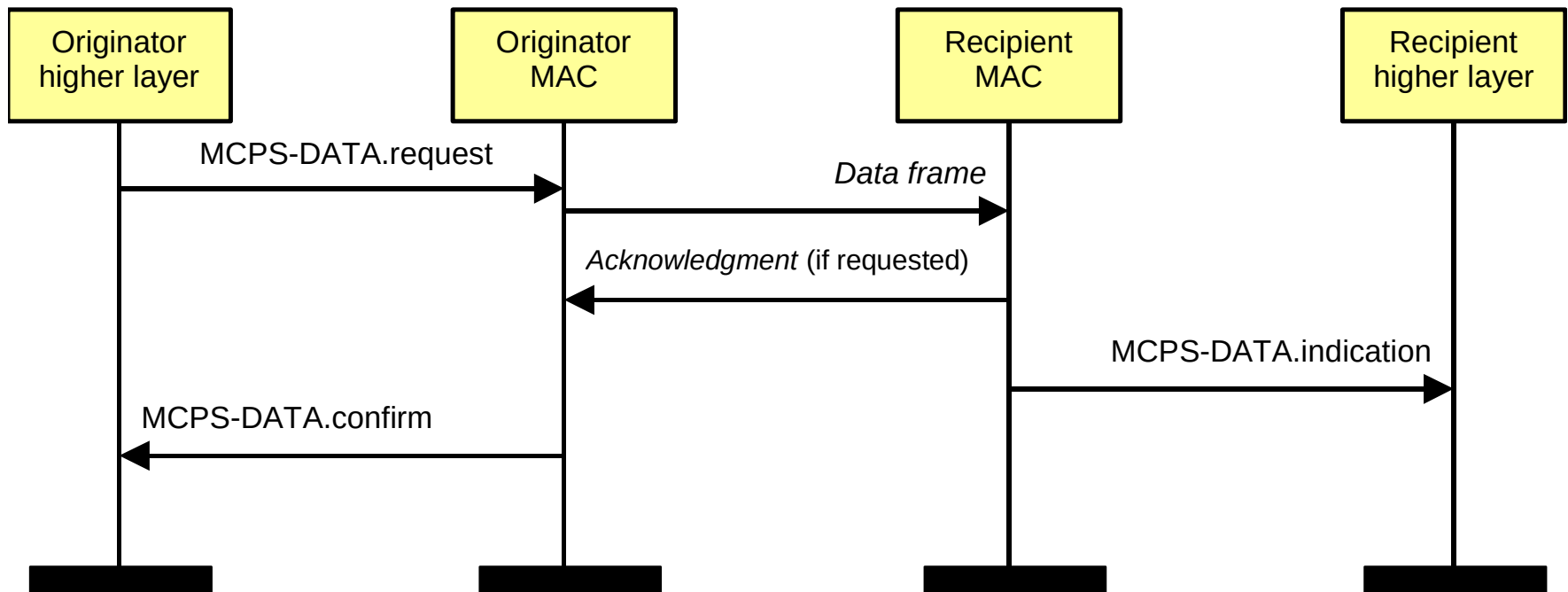
- Data transfer to neighboring devices
 - Acknowledged or unacknowledged
 - Direct or indirect
 - Using GTS service
- Maximum data length (MSDU)
aMaxMACFrameSize (102 bytes)

MAC Data Primitives

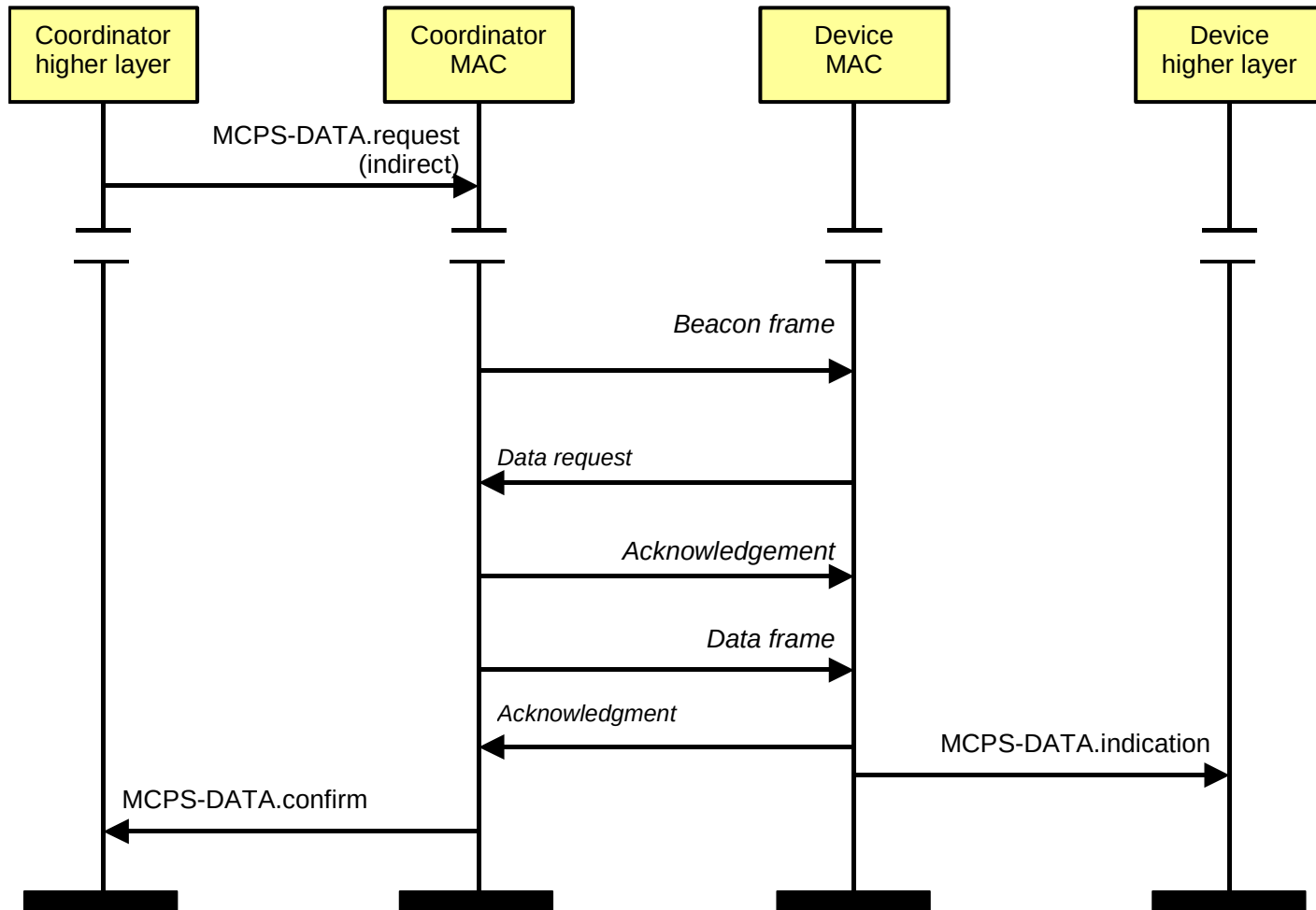
<i>Primitive</i>	<i>Request</i>	<i>Confirm</i>	<i>Indication</i>	<i>Response</i>
MCPS-DATA	Required	Required	Required	
MCPS-PURGE	Optional for RFD	Optional for RFD		

Data Transfer

Message Sequence Diagram



Indirect Data Transfer Message Sequence Diagram



Management Service

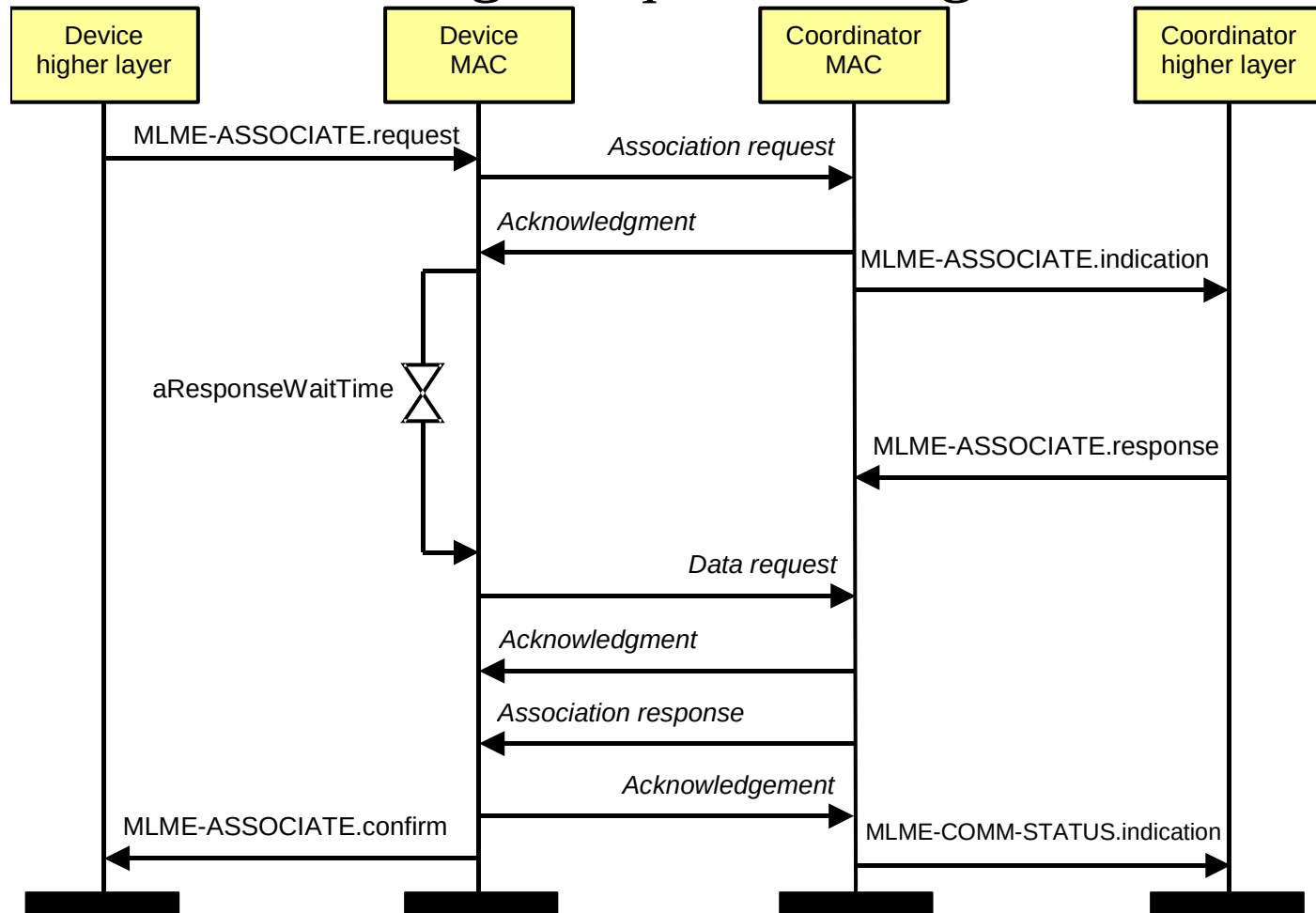
- Access to the PIB
- Association / disassociation
- GTS allocation
- Message pending
- Node notification
- Network scanning/start
- Network synchronization/search

MAC Management Primitives

<i>Primitive</i>	<i>Request</i>	<i>Confirm</i>	<i>Indication</i>	<i>Response</i>
MLME-GET	Required	Required		
MLME-SET	Required	Required		
MLME-ASSOCIATE	Required	Required	Optional for RFD	Optional for RFD
MLME-DISASSOCIATE	Required	Required	Required	
MLME-GTS	Optional for RFD	Optional for RFD	Optional for RFD	
MLME-BEACON-NOTIFY			Required	
MLME-POLL	Required	Required		
MLME-COMM-STATUS			Required	
MLME-ORPHAN			Optional for RFD	Optional for RFD
MLME-SCAN	Required	Required		
MLME-START	Optional for RFD	Optional for RFD		
MLME-RX-ENABLE	Required	Required		
MLME-SYNC	Required			
MLME-SYNC-LOSS			Required	
MLME-RESET	Required	Required		

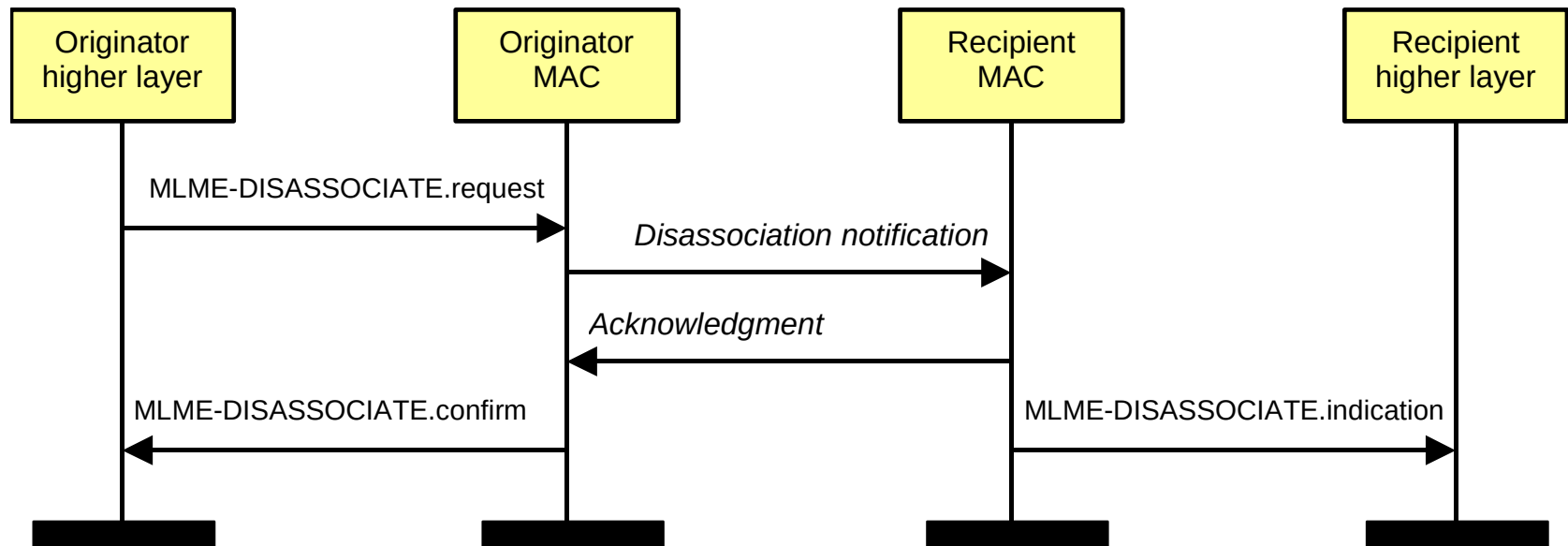
Association

Message Sequence Diagram



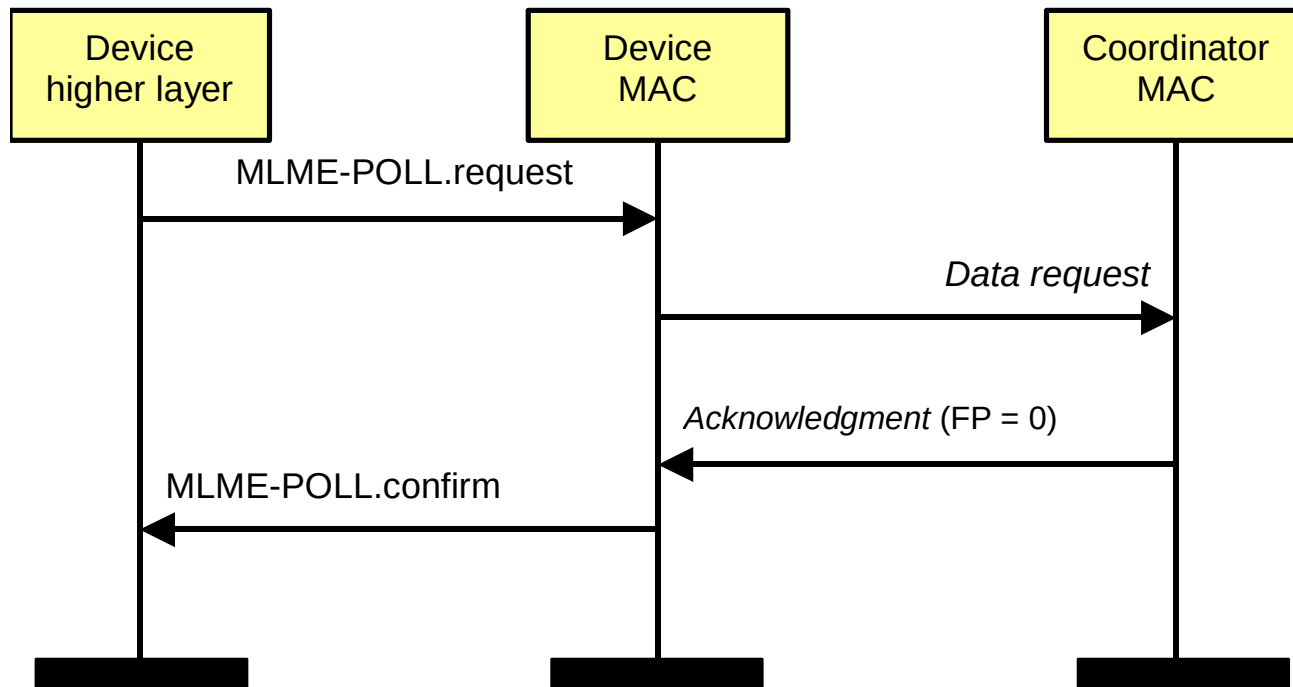
Disassociation

Message Sequence Diagram



Data Polling

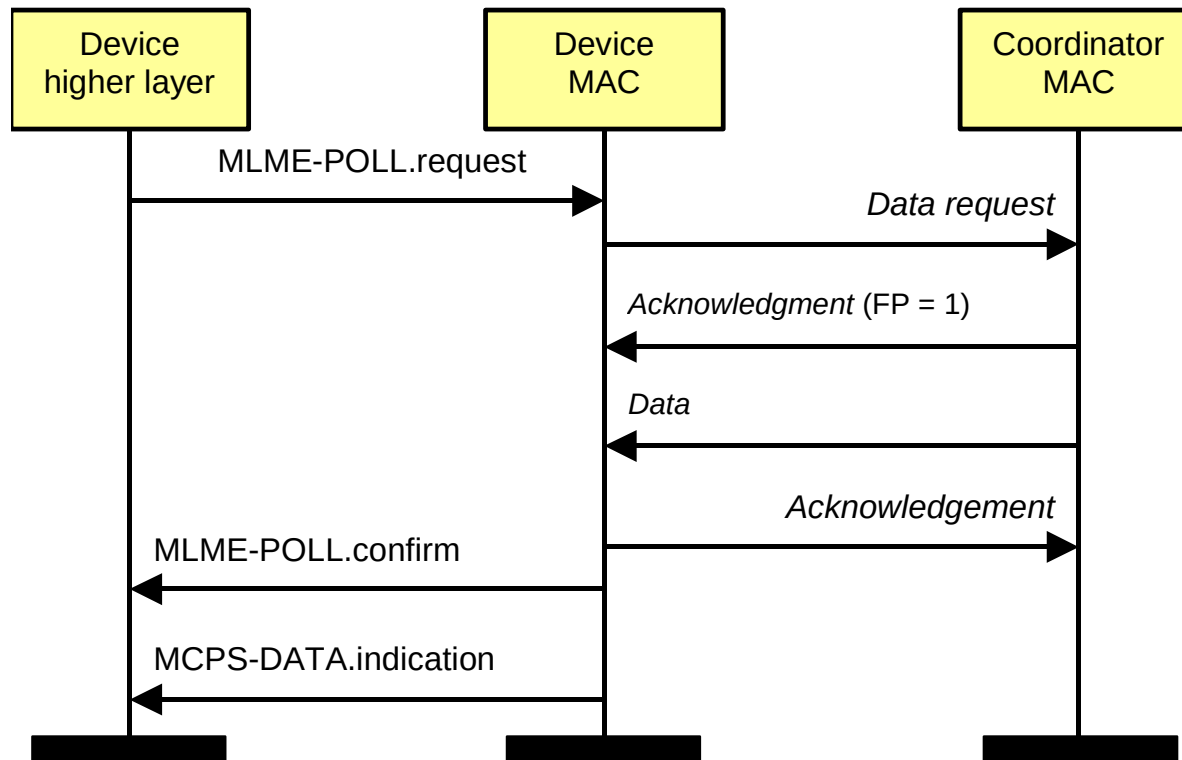
Message Sequence Chart



No data pending at the coordinator

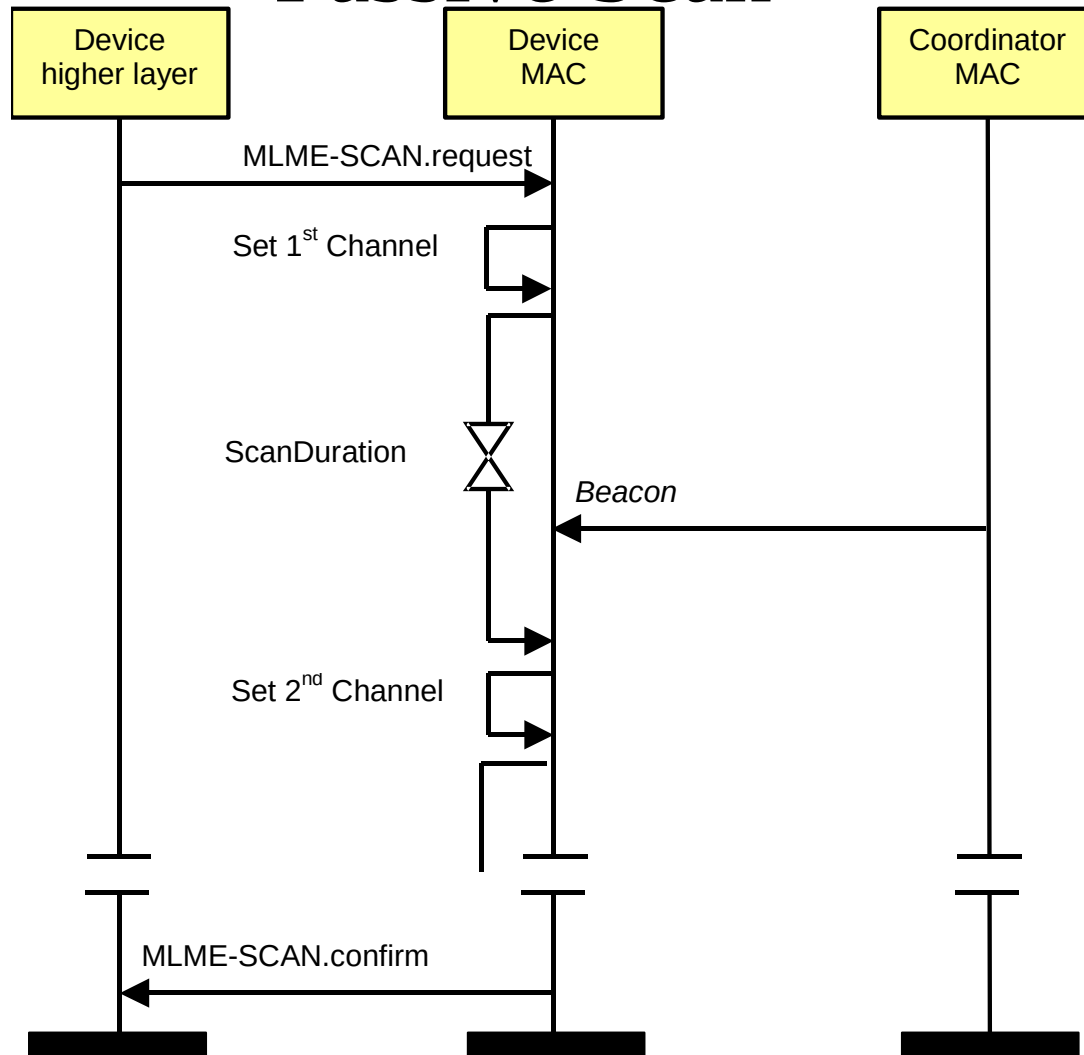
Data Polling

Message Sequence Chart

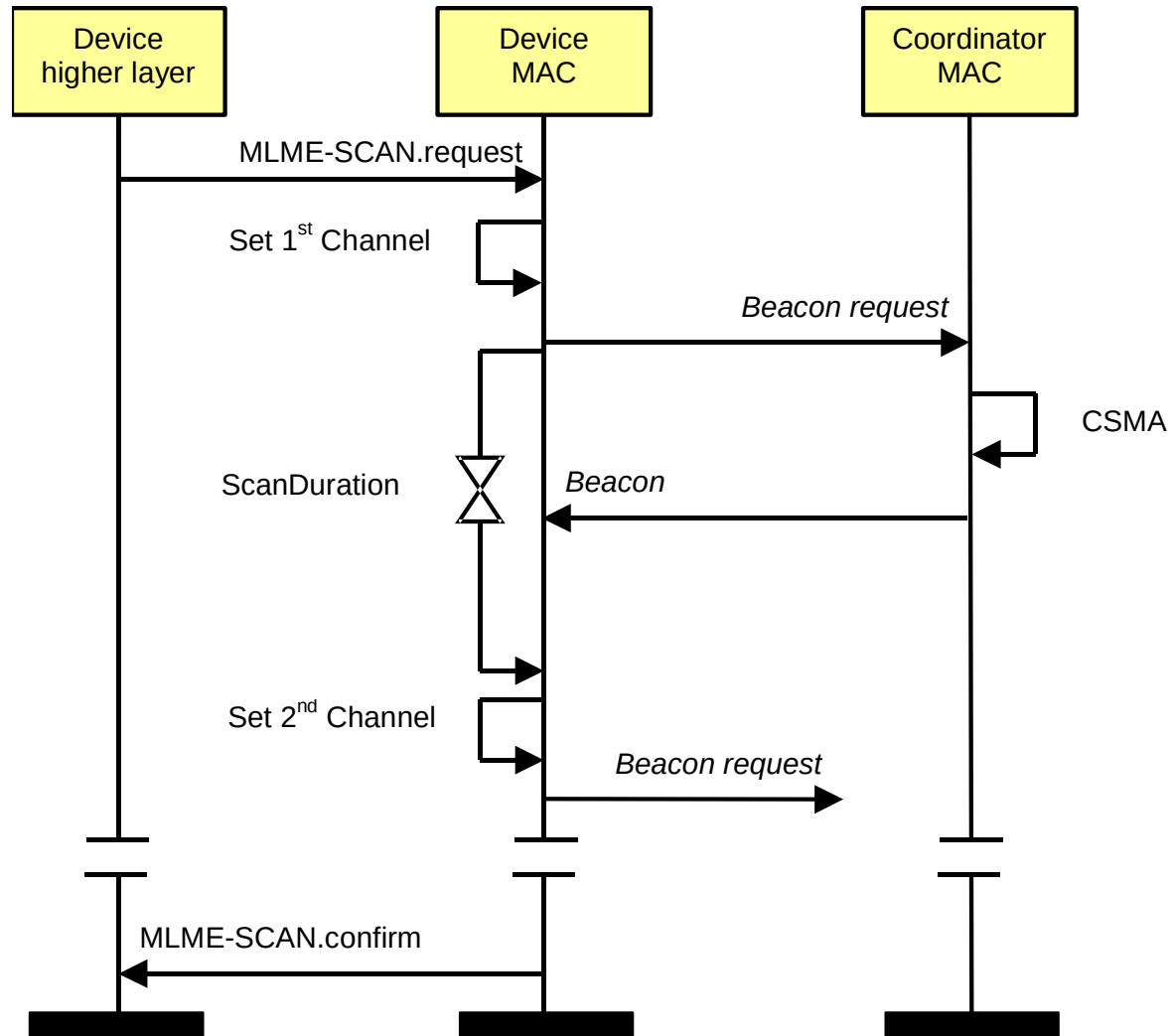


Data pending at the coordinator

Passive Scan

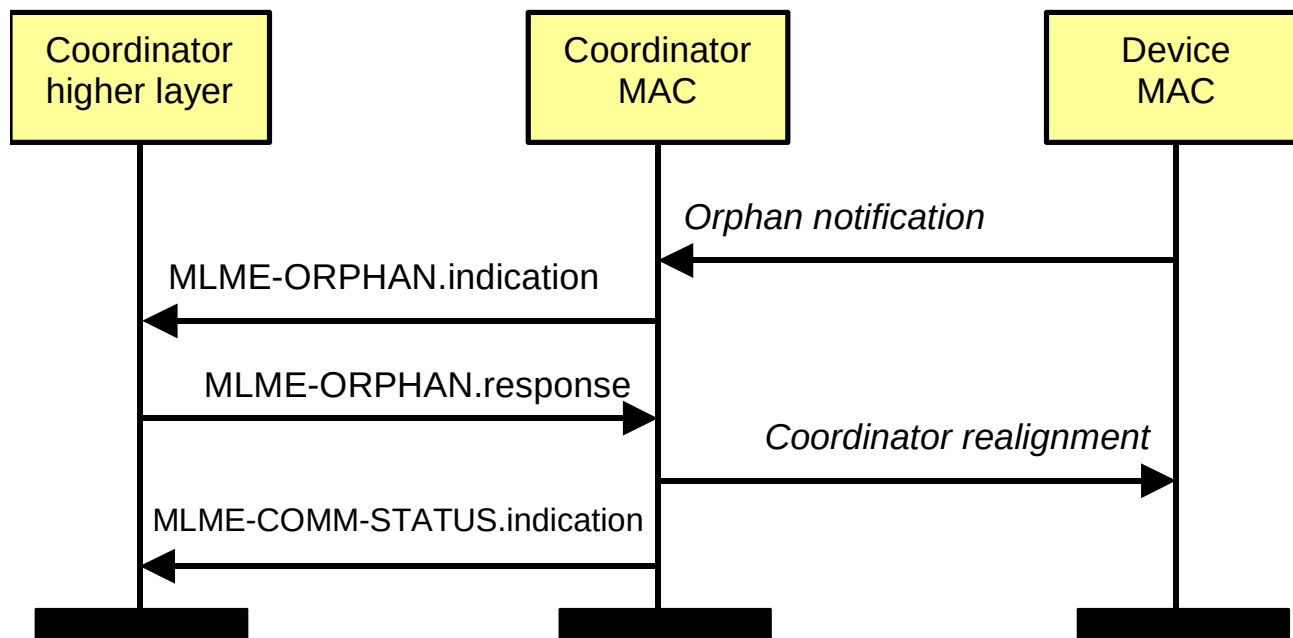


Active Scan



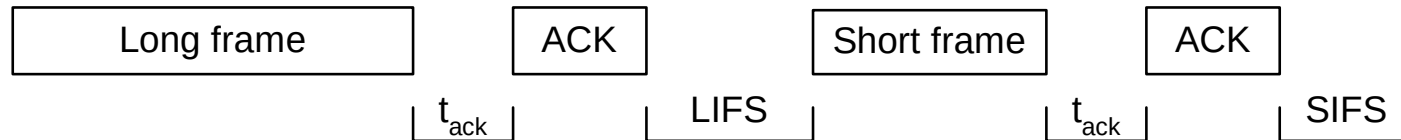
Orphaning

Message Sequence Diagram

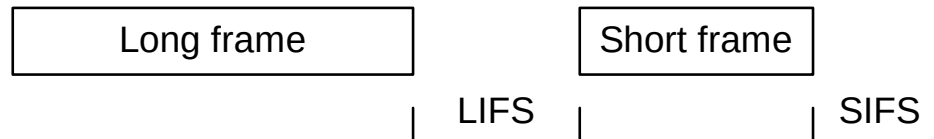


Inter-frame Spacing

Acknowledged transmission



Unacknowledged transmission



$aTurnaroundTime \leq t_{ack} \leq (aTurnaroundTime \text{ (12 symbols)} + aUnitBackoffPeriod \text{ (20 symbols)})$

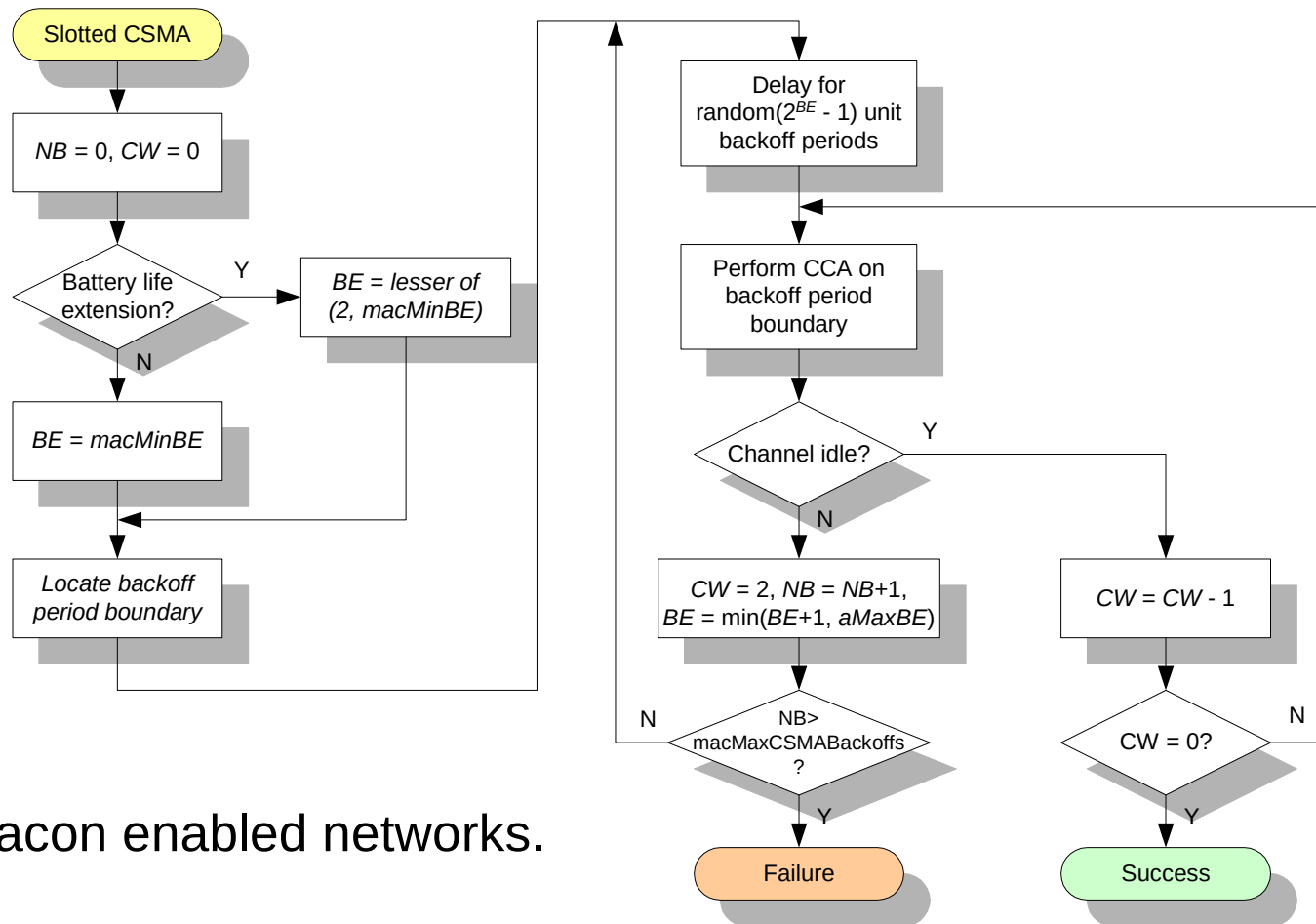
$LIFS > aMaxLIFSPeriod \text{ (40 symbols)}$

$SIFS > aMacSIFSPeriod \text{ (12 symbols)}$

For frames $\leq aMaxSIFSFrameSize$ use short inter-frame spacing (SIFS)

For frames $> aMaxSIFSFrameSize$ use long inter-frame spacing (LIFS)

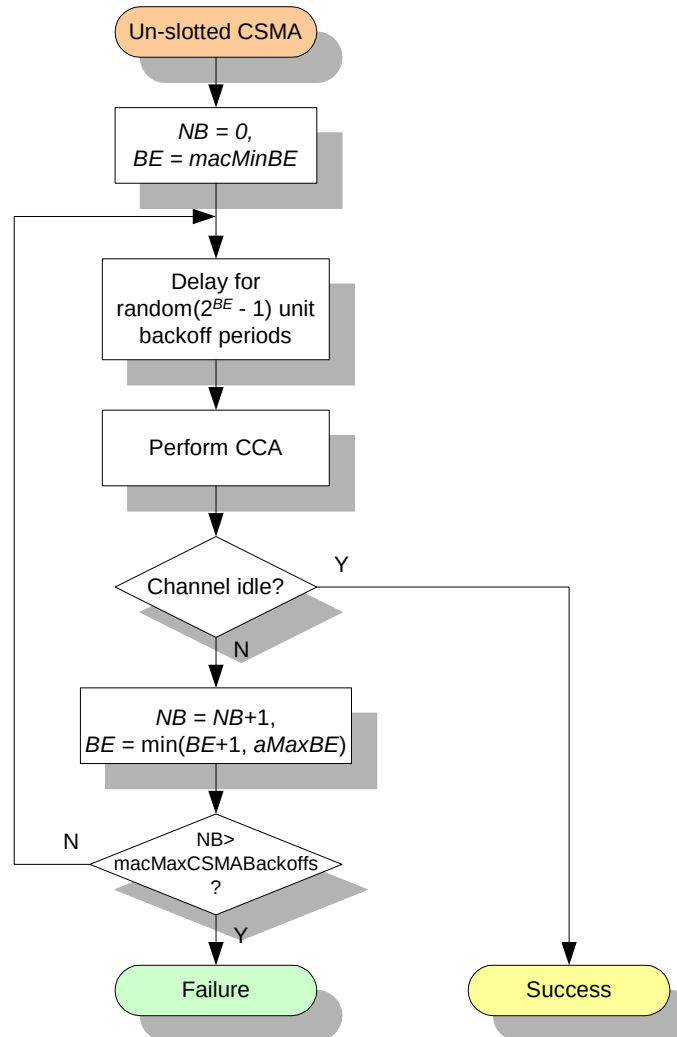
Slotted CSMA Procedure



Used in beacon enabled networks.

Un-slotted CSMA Procedure

Used in non-beacon networks.



Thank you!

Questions

