Mobile Communications

Wireless Personal Area Networks

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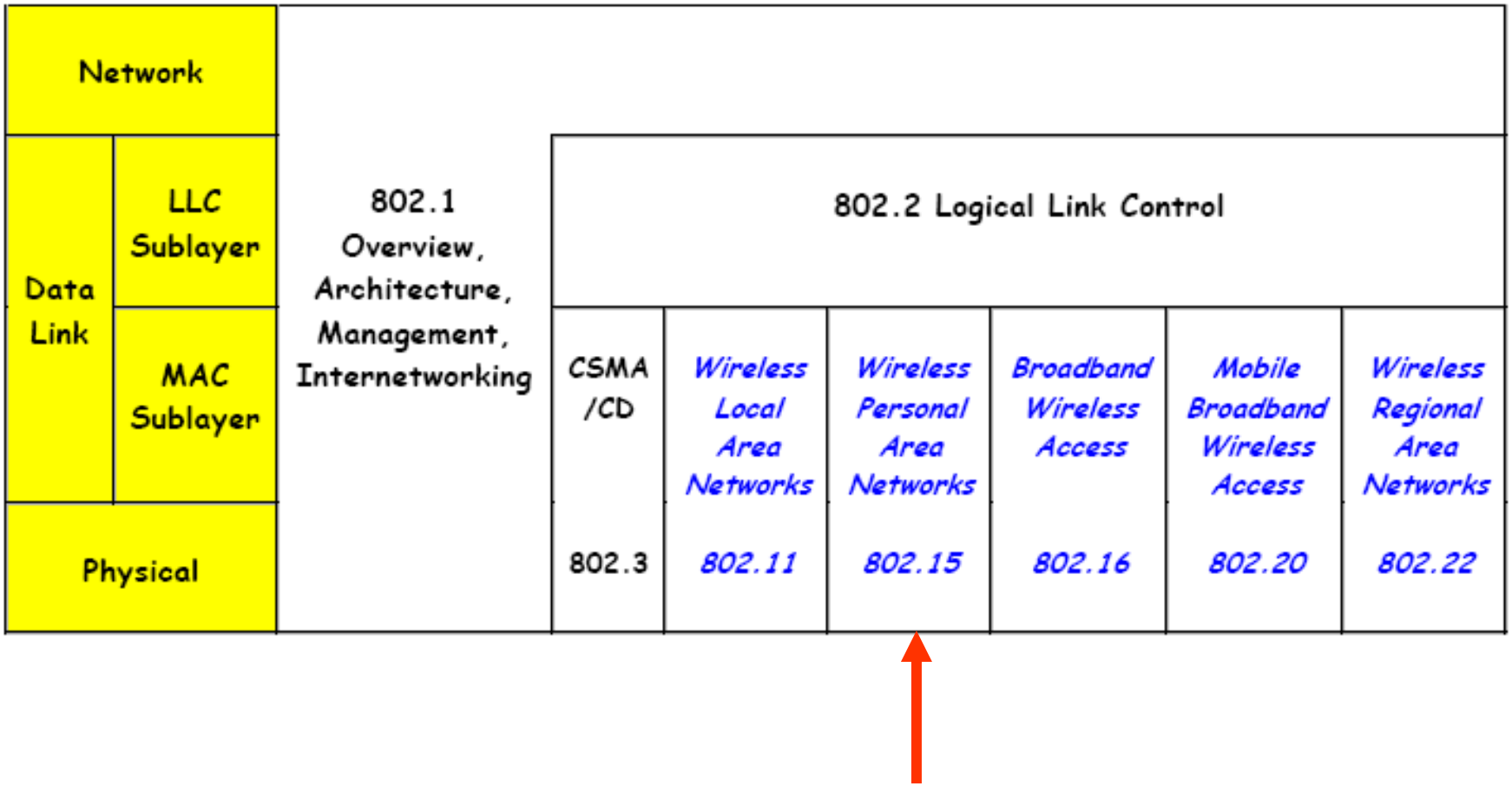
IEEE Standards



IEEE 802.15.4

Low Rate Wireless PAN (Sensor Networks)

Information

- Standard
  - » *IEEE 802.15.4 - Low-Rate Wireless Networks*
  - » *Read : Section - General Description*

Introduction

- Low Rate WPAN (LR-WPAN)
  - » Simple, low-cost communications network
  - » Wireless connectivity
  - » For applications with limited power and low throughput requirements

- Characteristics of an LR-WPAN
  - » Data rates: 250 kbit/s, 100kbit/s, 40 kbit/s, 20 kbit/s
  - » MAC addresses: 64-bit or allocated 16-bit short addresses
  - » Carrier sense multiple access with collision avoidance (CSMA-CA)
  - » Low power consumption
  - » Energy Detection (ED); Link quality indication (LQI)
  - » Radio channels
    - – 16 channels in the 2450 MHz band
    - – 30 channels in the 915 MHz band
    - – 3 channels in the 868 MHz band

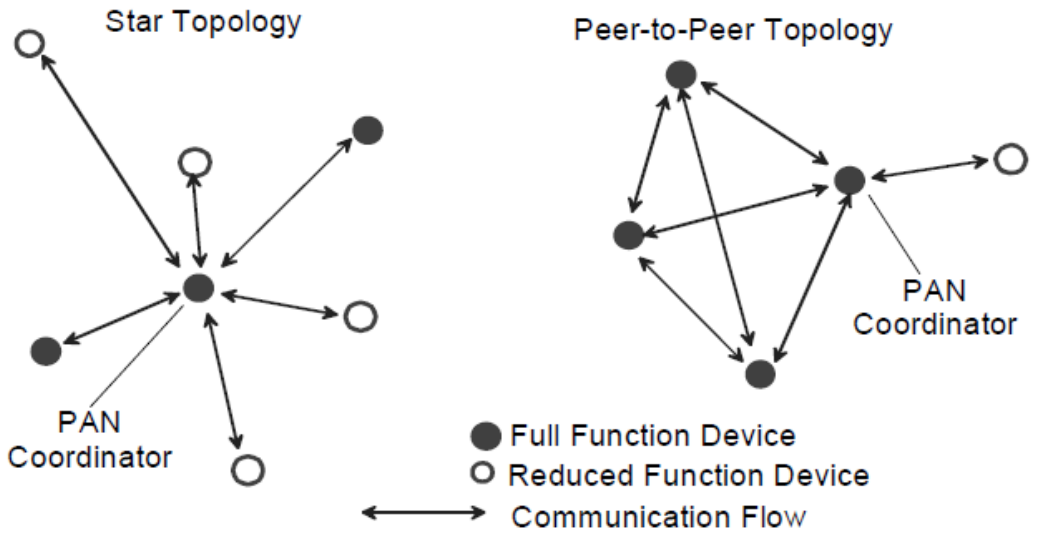
Types of Devices

- Two types
  - » FFD - Full-Function Device
    - – Can operate in 3 modes: PAN coordinator, coordinator, device
    - – FFD can talk to RFDs or other FFDs
  - » RFD - Reduced-Function Device
    - – intended for applications that are very simple (light switch , passive infrared sensor)
    - – RFD can communicate only to an FFD

- WPAN must include at least one FFD operating as the PAN coordinator

Topologies, Identifiers

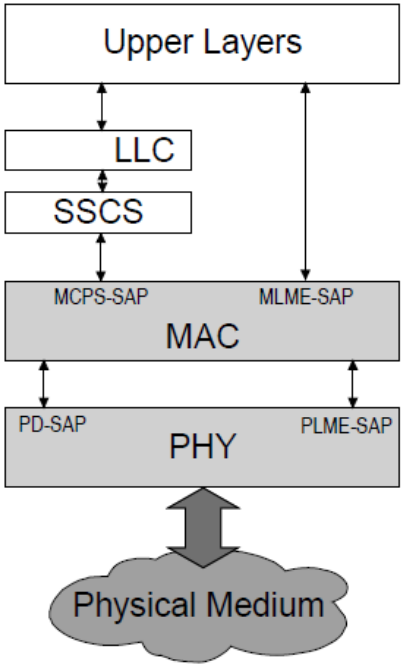
- Topologies
  - » Star topology ➔ communication between devices and PAN coordinator
  - » Peer-to-peer topology ➔ devices may communicate directly; needs PAN coordinator



- Identifiers
  - » Each device has a unique 64-bit address; short 16-bit addresses may be allocated
  - » Each PAN has an identifier

Architecture

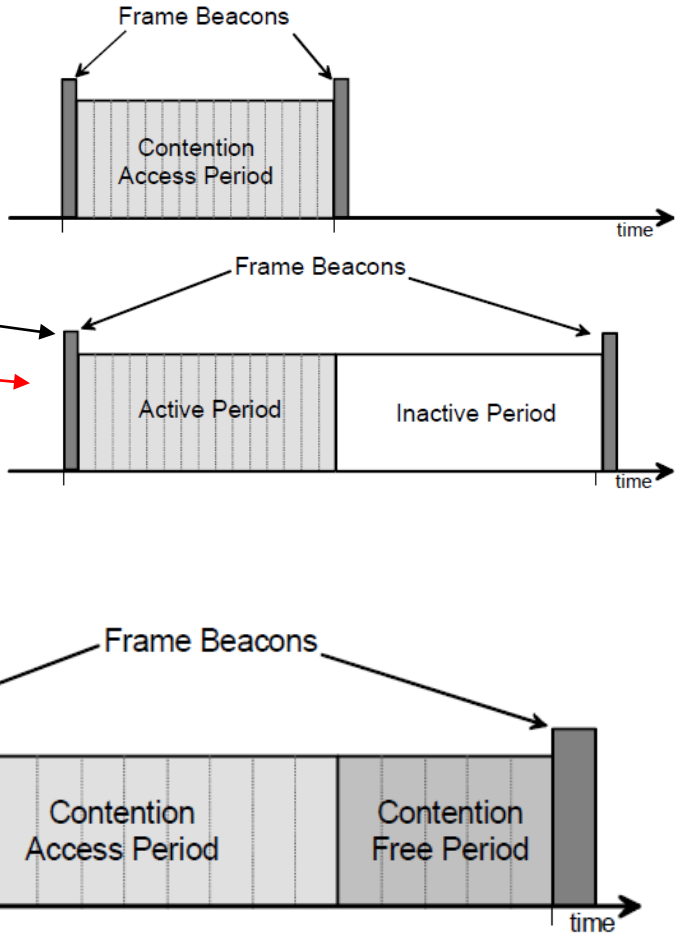
- Physical layer (PHY)
  - » Activation/deactivation of the radio transceiver
  - » ED, LQI, channel selection, clear channel assessment
  - » Transmitting and receiving data
- MAC sublayer
  - » Beacon management
  - » Channel access
  - » Frame validation, frame acknowledgement
  - » Association, disassociation



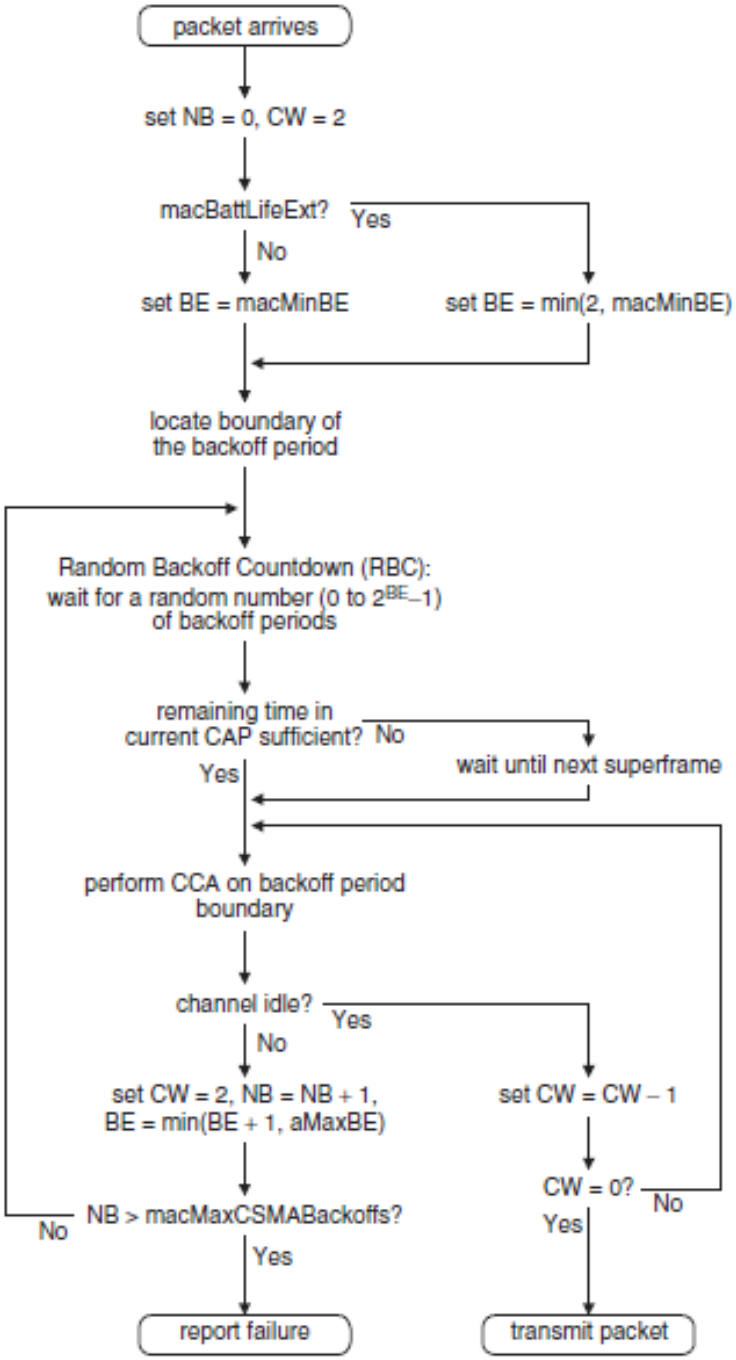
NOTE—For MCPS-SAP, see 7.1; for MLME-SAP, see 5.4.2; for PD-SAP, see 6.2; and for PLME-SAP, see 5.4.1.

Superframe Structure

- Superframe format
  - » defined by the PAN coordinator
  - » bounded by beacons
  - » can have active and inactive portions
- Beacons used to
  - » synchronize attached devices
  - » identify the PAN
  - » describe superframe structure
- Superframe may have 2 periods
  - » Contention access period
    - Devices use slotted CSMA/CA mechanism
  - » Contention-free period (CFP)
    - Guaranteed timeslots (GTS) for devices
- If coordinator desires no superframe it turns off beacon transmissions
  - » Unslotted CSMA/CA is used in this situation



Slotted MAC



NB – number of backoffs

CW – contention window

BE – backoff exponent

macBatLifeExt – device using battery

Backoff period – 20 symbols

Data Transfer to a Coordinator

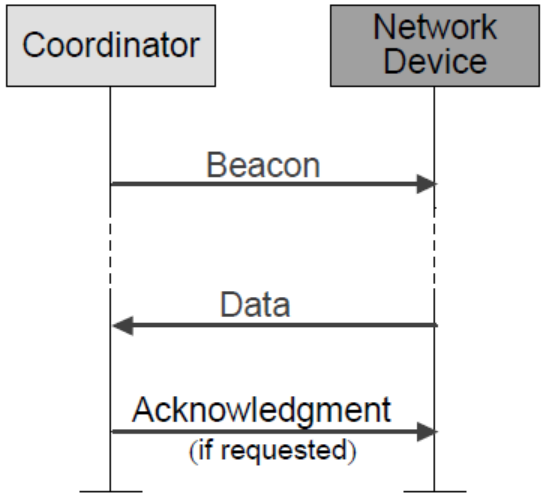


Figure 6—Communication to a coordinator in a beacon-enabled PAN

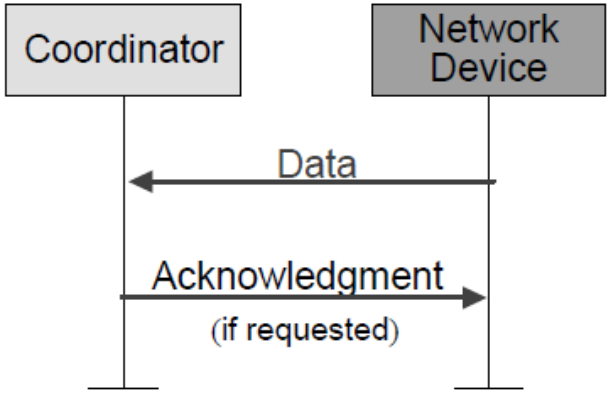


Figure 7—Communication to a coordinator in a nonbeacon-enabled PAN

Data Transfer from a Coordinator

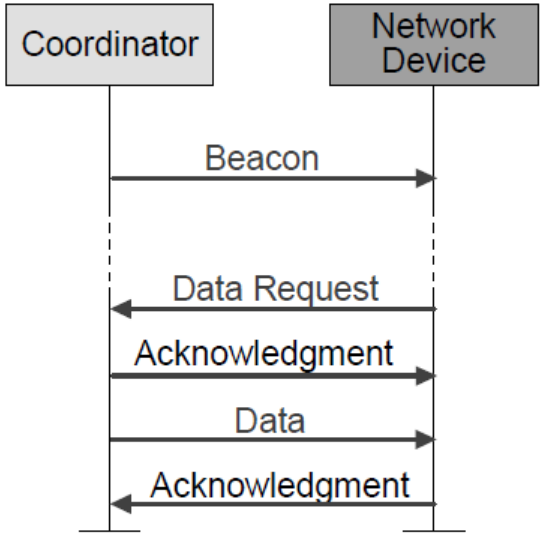


Figure 8—Communication from a coordinator a beacon-enabled PAN

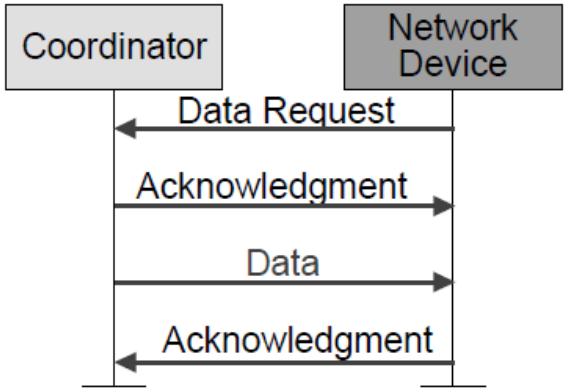


Figure 9—Communication from a coordinator in a nonbeacon-enabled PAN

Data Frame

Table 2.4 Structure of the Frame Control Field in the MAC packet header

Subfield	Bits	Allowed values and their meaning	
Frame Type	0-2	000	Beacon
		001	Data
		010	Acknowledgment
		011	MAC command
Security Enabled	3	1	frame is protected
Frame Pending	4	1	more data is pending
Acknowledgment Request	5	1	acknowledgment is requested
PAN ID Compression	6	1	destination and source PAN identifiers, equal – the latter can be omitted
Destination Addressing Mode	10-11	00	PAN ID and address not present
		10	16-bit short addresses used
		11	64-bit extended addresses used
Frame Version	12-13	00	frame compliant with 2003 standard
		01	frame compliant with 2006 standard
Source Addressing Mode	14-15	00	PAN ID and address not present
		10	16-bit short addresses used
		11	64-bit extended addresses used

Table 2.3 MAC packet structure

Element	Field	Length (in bytes)
header	Frame Control	2
	Sequence Number	1
	Destination PAN Identifier	0 or 2
	Destination Address	0, 2, or 8
	Source PAN Identifier	0 or 2
	Source Address	0, 2, or 8
	Auxiliary Security Header	0, 5, 6, 10, or 14
payload	frame payload	variable
footer	Frame Check Sequence	2

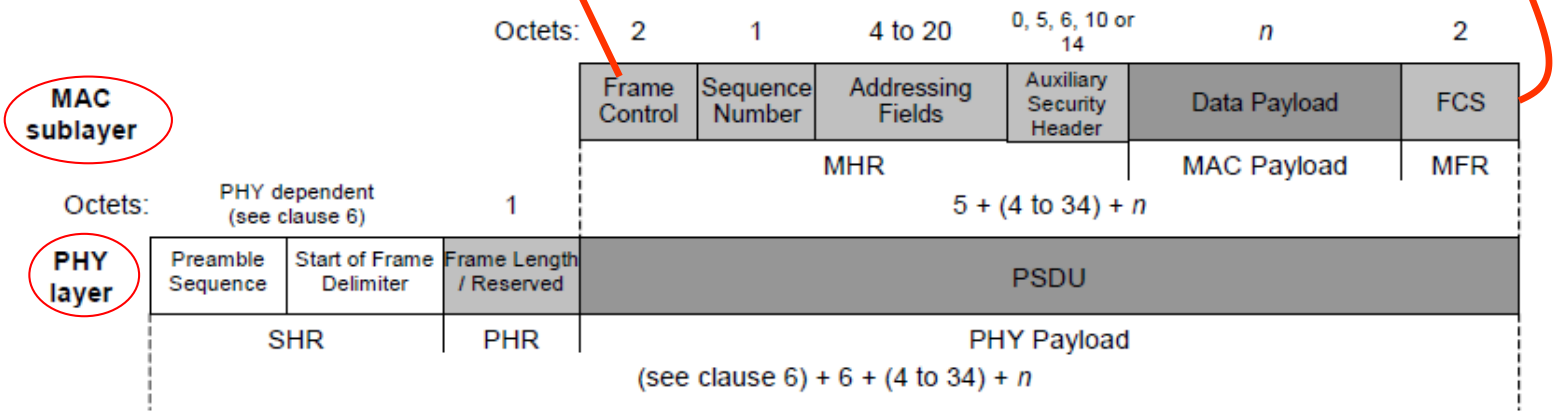


Figure 11—Schematic view of the data frame and the PHY packet

Acknowledgment and Comand Frames

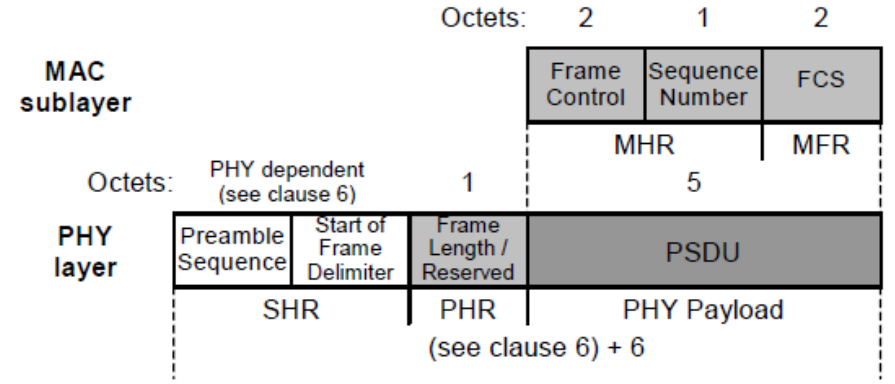


Figure 12—Schematic view of the acknowledgment frame and the PHY packet

MAC commands

- **Association request and response**
- **Disassociation notification**
- **Data request**
- **Orphan notification**
- **Beacon request (in non-beacon enabled networks)**
- **GTS request (Guaranteed Time Slot)**
- **Coordinator realignment**
- **PAN ID conflict notification**

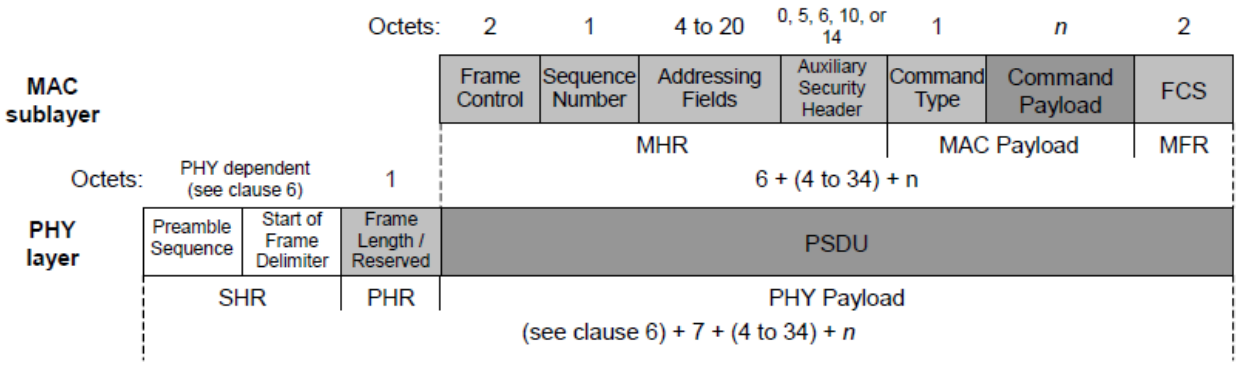


Figure 13—Schematic view of the MAC command frame and the PHY packet

Beacon Frame

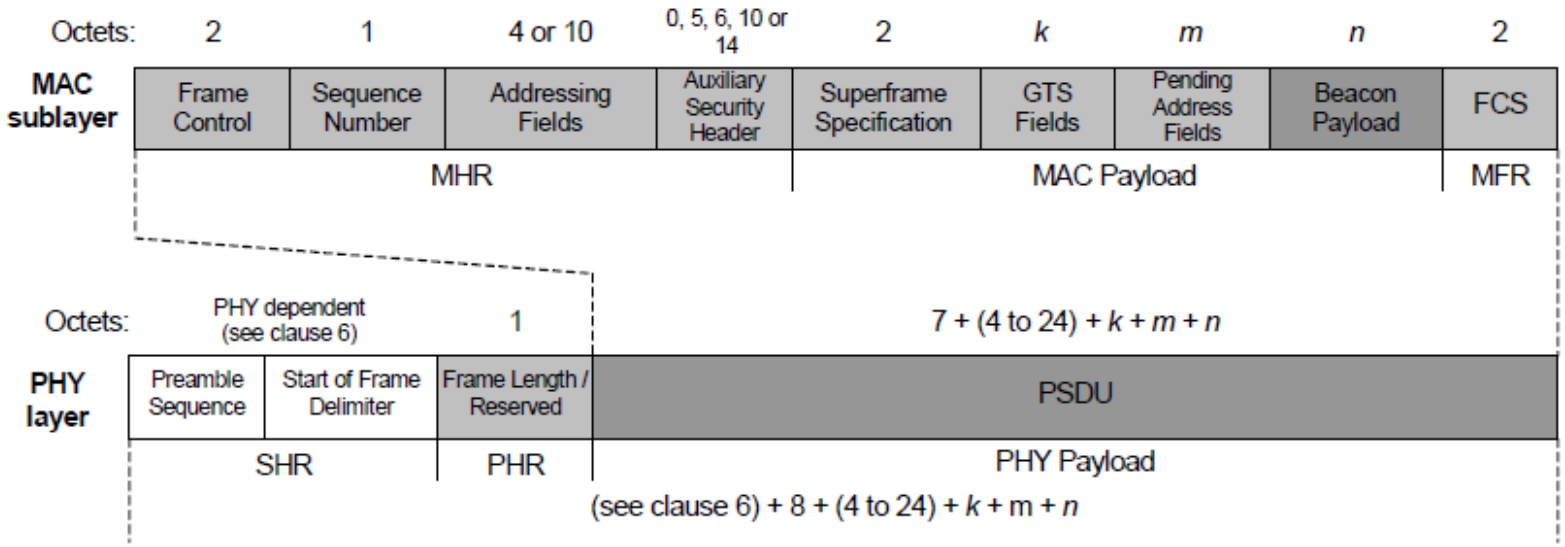


Figure 10—Schematic view of the beacon frame and the PHY packet

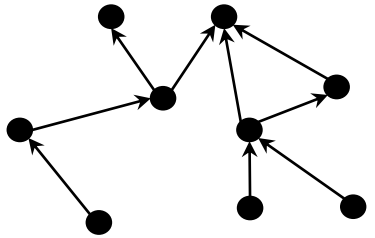
RPL –
Routing Protocol for Low-Power and Lossy Networks

- Low-power and Lossy Networks consist of constrained nodes
  - » Processing, memory and energy
- These routers are interconnected by links characterized by
  - » High packet loss ratio and low bitrate
- In common situations nodes aim to send information to sink
- RPL
  - » "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks," IETF RFC 6550

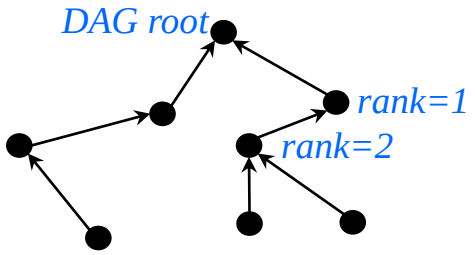
RPL – Terminology

DAG	• Directed Acyclic Graph • Directed graph in which all edges are oriented • No cycles • Edges contained in paths oriented and terminating at a root nodes
DAG root	Node within the DAG that has no outgoing edge
DODAG	• Destination-Oriented DAG • DAG rooted at a **single DAG root**
Objective Function	Aims to minimize energy, latency, …
Rank	Distance from root using specified objective
DODAG ID	IPv6 address of the root
Parent	Immediate successor towards the root
Sub-DODAG	Sub-tree rooted at this node
Storing	Nodes keep routing tables for sub- DODAG
Non-Storing	Nodes know only parent. Do not keep a routing table

DAG

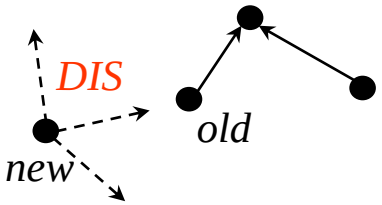


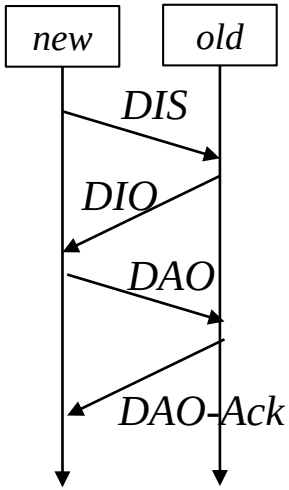
DODAG



RPL Control Messages

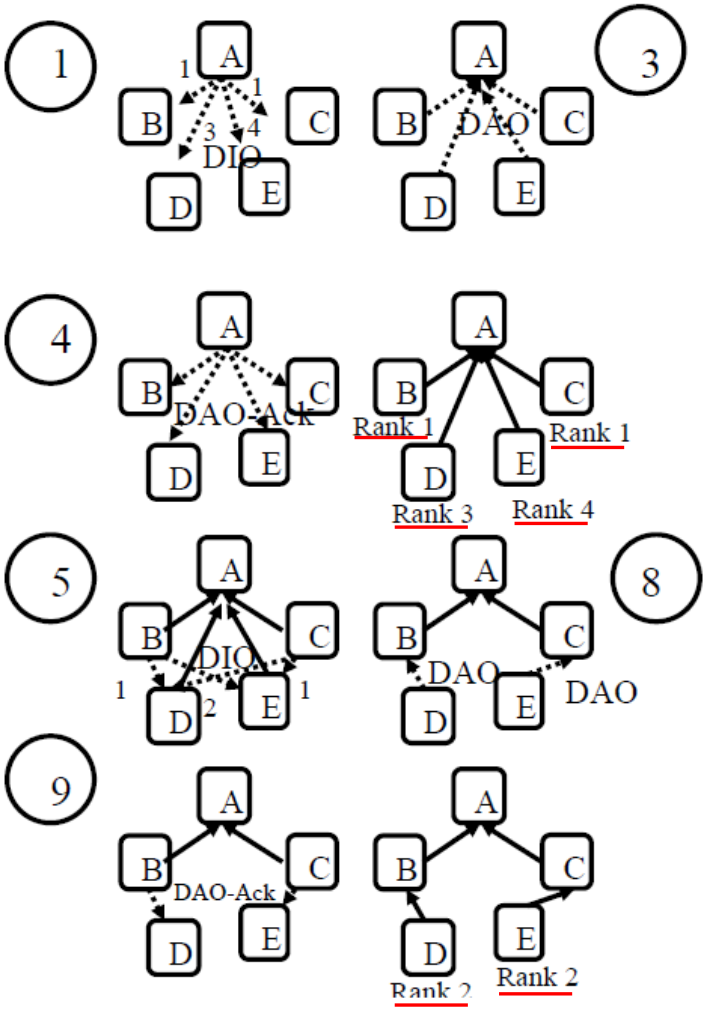
- DIO: DODAG Information Object
  - » Generated downward to announce an RPL instance
  - » Allows other nodes to discover an RPL instance and join it
- DIS: DODAG Information Solicitation
  - » Link-Local multicast request for DIO (neighbor discovery)
  - » *Do you know of any DODAGs*?
- DAO: Destination Advertisement Object
  - » From child to parents or to root
  - » *Can I join you as a child on DODAG #x?*
- DAO Ack
  - » *Yes, you can*





DODAG Formation Example

1. A multicasts DIOs
   A is member of DODAG with Rank 0
1. B, C, D, E hear and determine
   that their rank (distance) form A
   is respectively 1, 1, 3, 4
3. B, C, D, E send DAOs to A
4. A accepts all
5. B and C multicast DIOs
5. D hears DIOs and determines that
   its distance from B and C is 1, 2
5. E hears both B, C and determines that
   its distance from B and C is 2, 1
8. D sends a DAO to B; E sends a DAO to C
9. B sends a DAO-Ack to D;
   C sends a DAO-Ack to E



RPL Data Forwarding

- Case 1: To the root (n-to-1)
  - » Packet addressed to root; each node in path delivers packet to its parent
- Case 2: X to Y
  - » 2A: Storing: Every node has a forwarding table
    - – Packet forwarded up from X to a parent common to X and Y
    - – Then, packet forwarded down from common parent to Y
  - » 2B: Non-storing: no forwarding tables except at root
    - – Packet forward up from X to DODAG root
    - – Root puts a source route on packet and forwards packet down to Y
- Case 3: Broadcast from the root (1-to-n)
  - » 3A: Storing: every node know their children
    - – Broadcast to children
  - » 3B: Non-Storing: every node knows only parents but not children
    - – Root puts a source route for each leaf and forwards

Homework

- Review slides and use them to guide your lectures
- Read from Jelena Misic, and Vojislav B. Misic, “Wireless Personal Area Networks Performance – Interconnections and Security with IEEE 802.15.4”
  - » Chap. 2
- Read RFC 6550, RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks
- Answer questions at moodle