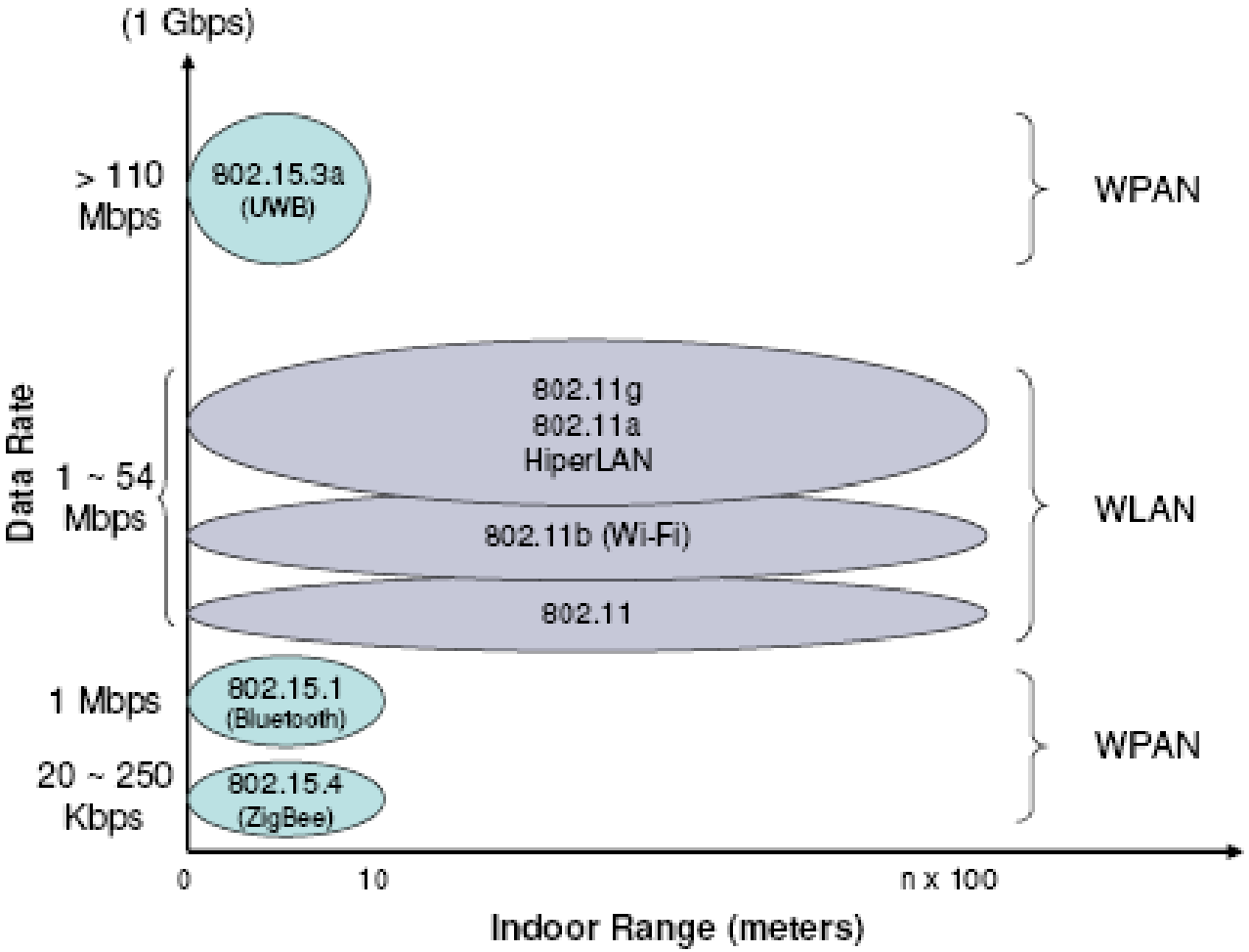
Protocols for Wireless Sensor Networks

KTH Teknik och hälsa

Protocols for wireless sensor networks

- Wireless personal area networks
  - Standards for physical and link layers
    - Bluetooth (IEEE 802.15.1)
    - IEEE 802.15.4 (physical layer + link layer)
  - Network and application layers
    - Zigbee alliance – industry standard
- Note
  - Most figures from IEEE standard documents and the CC2420 data sheet

- Comparison of range and bit rate



IEEE 802.15.4: Physical layer

- Frequencies
  - 2.4GHz band - 16 channels
- Data rate
  - 250kbps

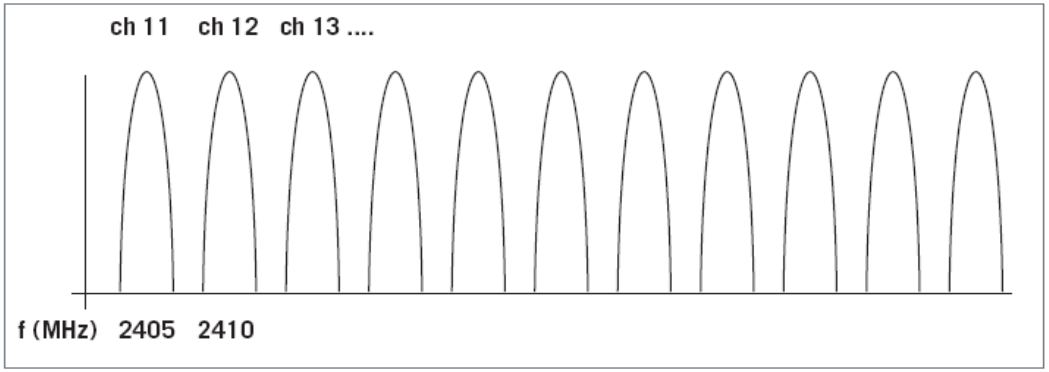


Table 1—Frequency bands and data rates

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
868/915 (optional)	868–868.6	400	ASK	250	12.5	20-bit PSSS
	902–928	1600	ASK	250	50	5-bit PSSS
868/915 (optional)	868–868.6	400	O-QPSK	100	25	16-ary Orthogonal
	902–928	1000	O-QPSK	250	62.5	16-ary Orthogonal
2450	2400–2483.5	2000	O-QPSK	250	62.5	16-ary Orthogonal

- Modulation
  - Direct sequence spread spectrum
  - Offset QPSK

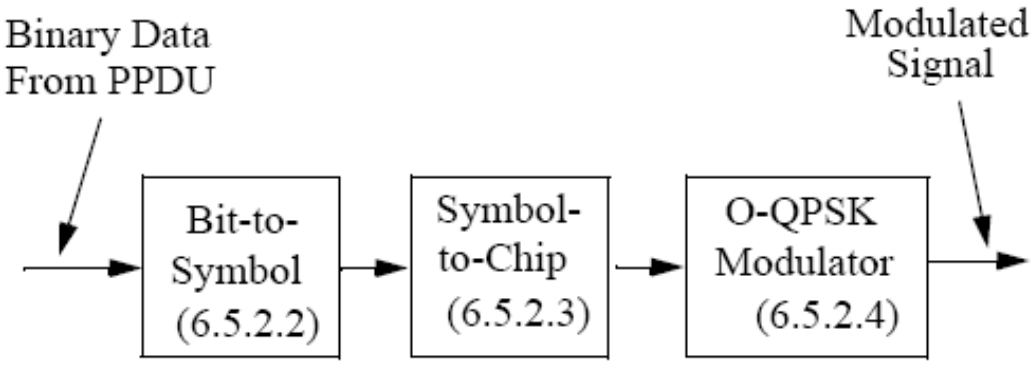


Figure 18—Modulation and spreading functions

- 16 symbols
- 4 data bits per symbol

Table 24—Symbol-to-chip mapping

Data symbol (decimal)	Data symbol (binary) (b_0 b_1 b_2 b_3)	Chip values (c_0 c_1 … c_{30} c_{31})
0	0 0 0 0	1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0
1	1 0 0 0	1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0
2	0 1 0 0	0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0
3	1 1 0 0	0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1
4	0 0 1 0	0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0 0 0 1 1
5	1 0 1 0	0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1 1 1 0 0
6	0 1 1 0	1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1 1 0 0 1
7	1 1 1 0	1 0 0 1 1 1 0 0 0 0 1 1 0 1 0 1 0 0 1 0 0 0 1 0 1 1 1 0 1 1 0 1
8	0 0 0 1	1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1
9	1 0 0 1	1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 1 1 1 0 1 1 1
10	0 1 0 1	0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 1 1 1
11	1 1 0 1	0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0
12	0 0 1 1	0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1 0 1 1 0
13	1 0 1 1	0 1 1 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0 1 0 0 1
14	0 1 1 1	1 0 0 1 0 1 1 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0 1 1 0 0
15	1 1 1 1	1 1 0 0 1 0 0 1 0 1 1 0 0 0 0 0 0 0 1 1 1 0 1 1 1 1 0 1 1 1 0 0 0

- Offset QPSK

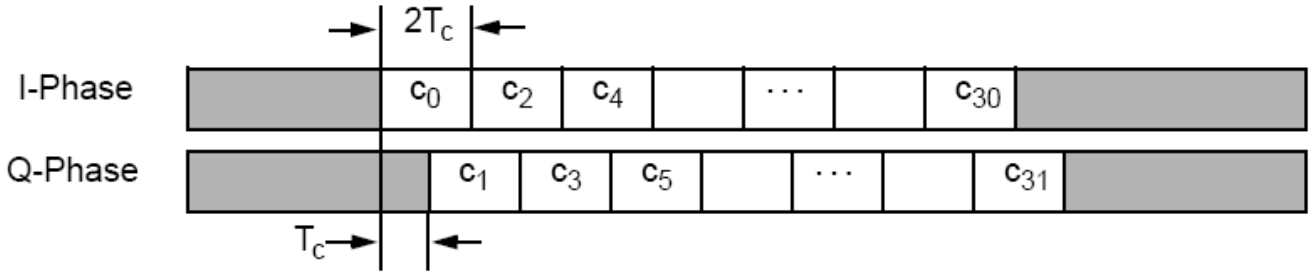


Figure 19—O-QPSK chip offsets

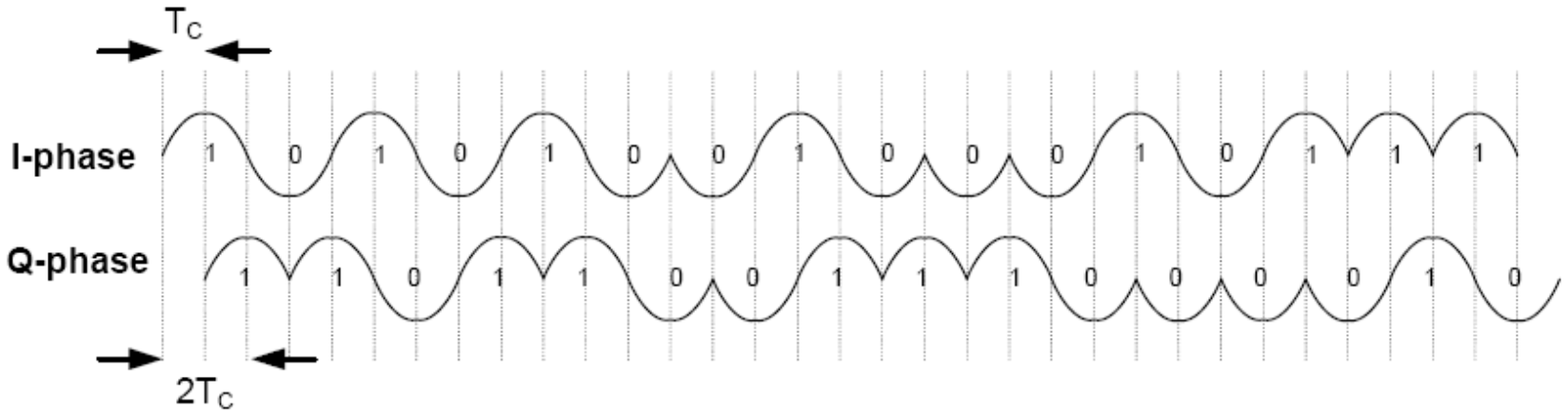
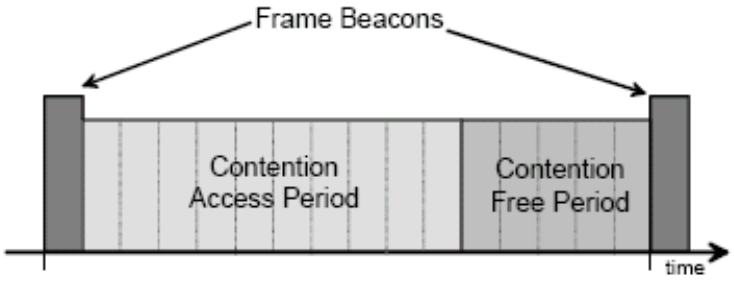
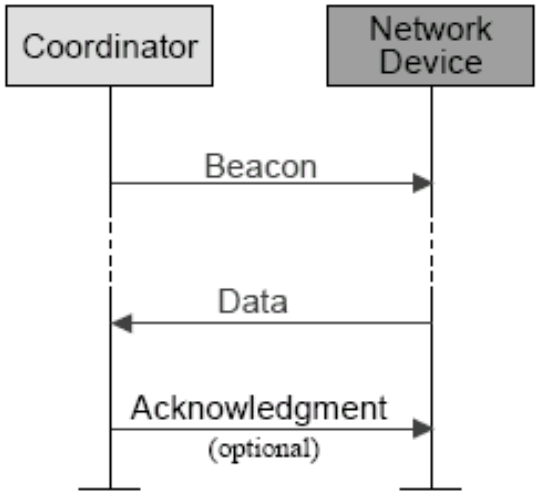


Figure 20—Sample baseband chip sequences with pulse shaping

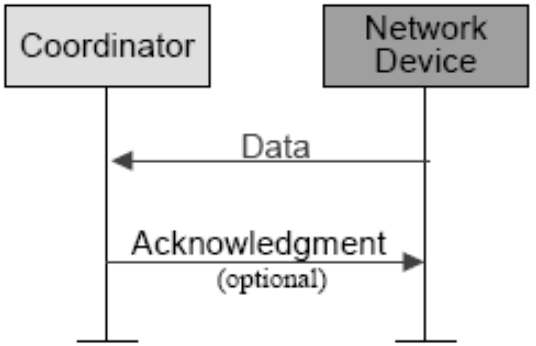
IEEE 802.15.4: MAC layer

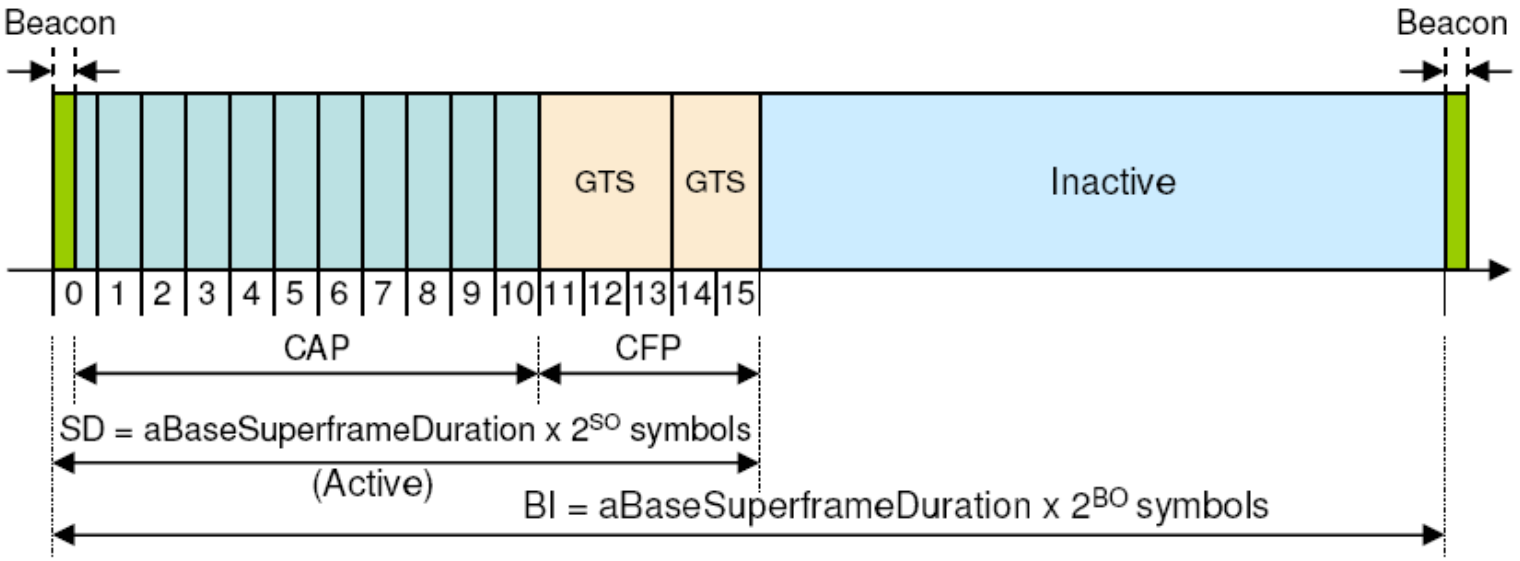
- Beacon mode





- Non-beacon mode





- Beacon order (BO)
  - Beacon interval BI=aBaseSuperframeDuration×2^{BO}
  - Beacon order: 0≤BO≤14 (BO=15 non-beacon mode)
  - aBaseSuperframeDuration=960 symbols (15.36 ms)

- Superframe order (SO)
  - Superframe duration SD=aBaseSuperframeDuration×2^{SO}
  - Superframe slot=aBaseSlotDuration×2^{SO}
  - aBaseSlotDuration=60 symbols (0.96 ms)
  - 0≤SO≤BO≤14
  - BO=15 means non-beacon order
  - SO=BO means no inactive period

- Guaranteed time slot (GTS)
  - A node can request a guaranteed timeslot
  - If accepted by the PAN coordinator
    - Use timeslots during the contention-free period and also transmit during contention access period
    - A superframe supports up to 7 GTS with one or more timeslots
    - Minimum CAP length is 440 symbols
    - In star topology

- Frame formats
  - Beacon frame format
  - Radio frame (physical layer)

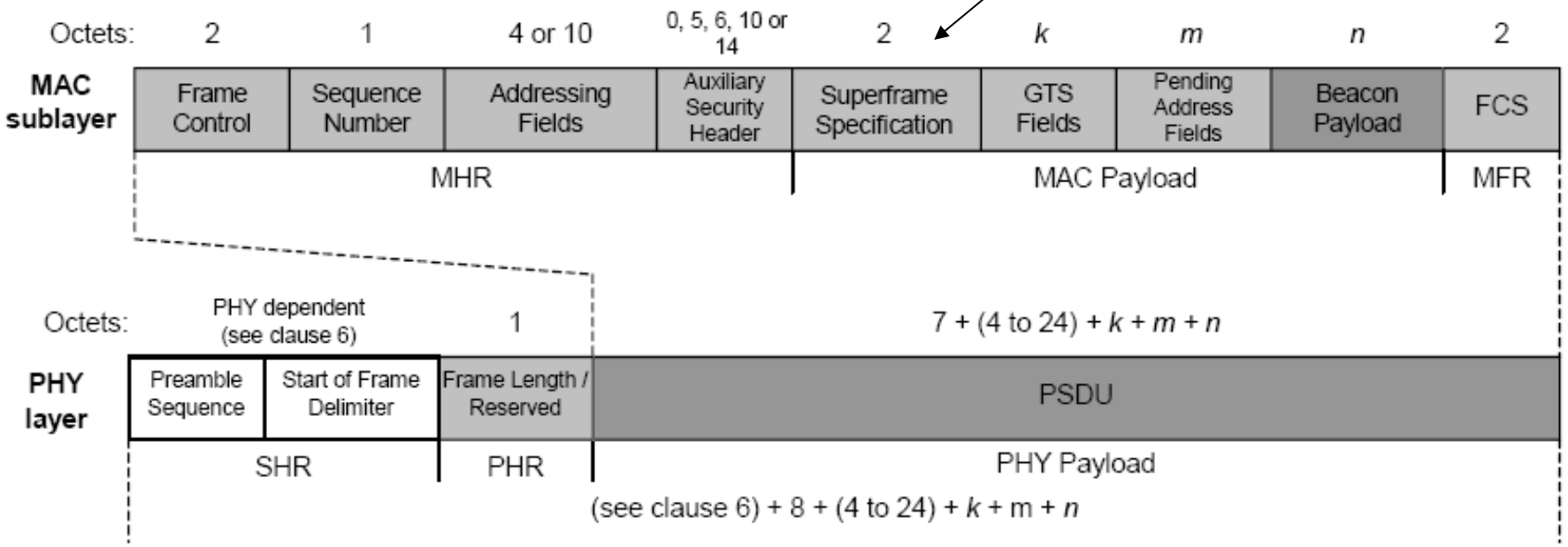


Figure 10—Schematic view of the beacon frame and the PHY packet

- Data frame format

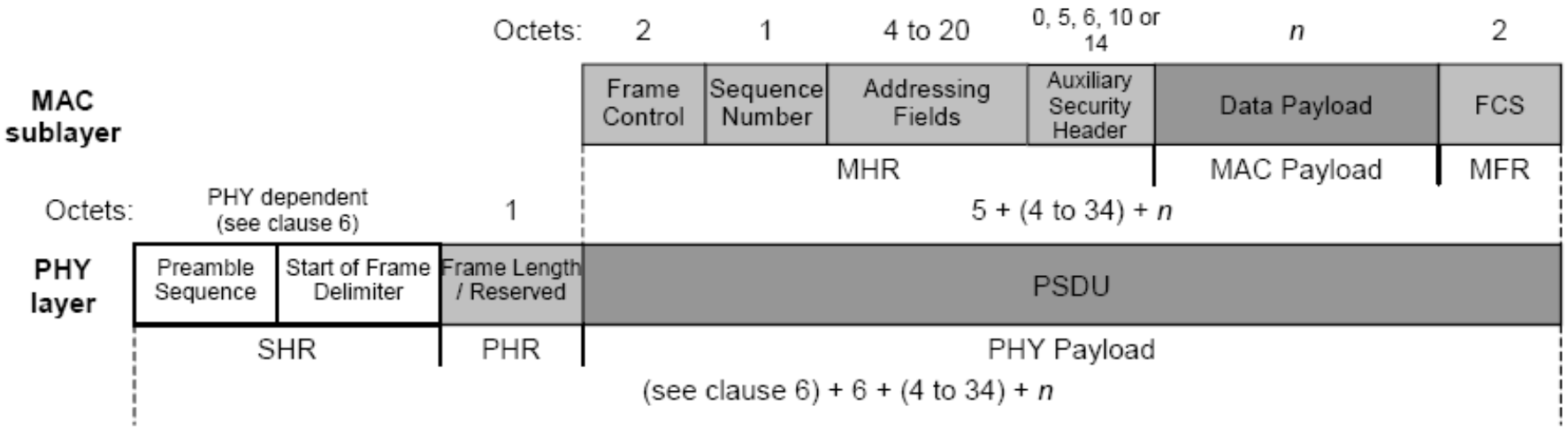


Figure 11—Schematic view of the data frame and the PHY packet

Octets: 2	**1**	**0/2**	**0/2/8**	**0/2**	**0/2/8**	**0/5/6/10/ 14**	**variable**	**2**
Frame Control	Sequence Number	Destination PAN Identifier	Destination Address	Source PAN Identifier	Source Address	Auxiliary Security Header	Frame Payload	FCS
		Addressing fields						
MHR							MAC Payload	MFR

Figure 41—General MAC frame format

- Acknowledgement frame format
  - Optional
  - “Stop and wait”
  - Retransmissions after macAckWaitDuration
    - 54-120 symbols

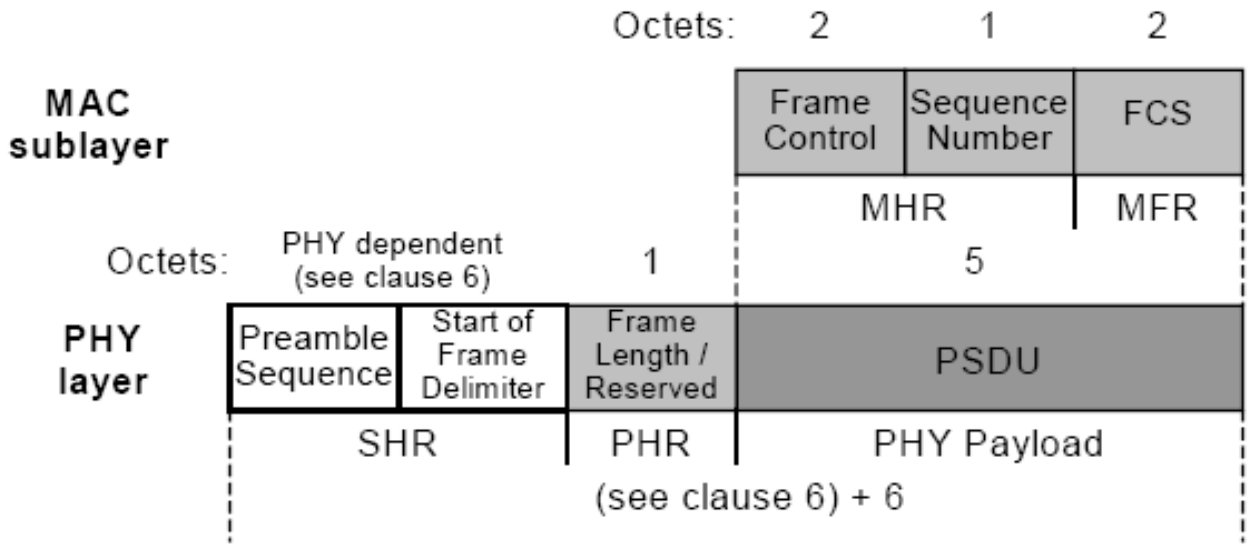


Figure 12—Schematic view of the acknowledgment frame and the PHY packet

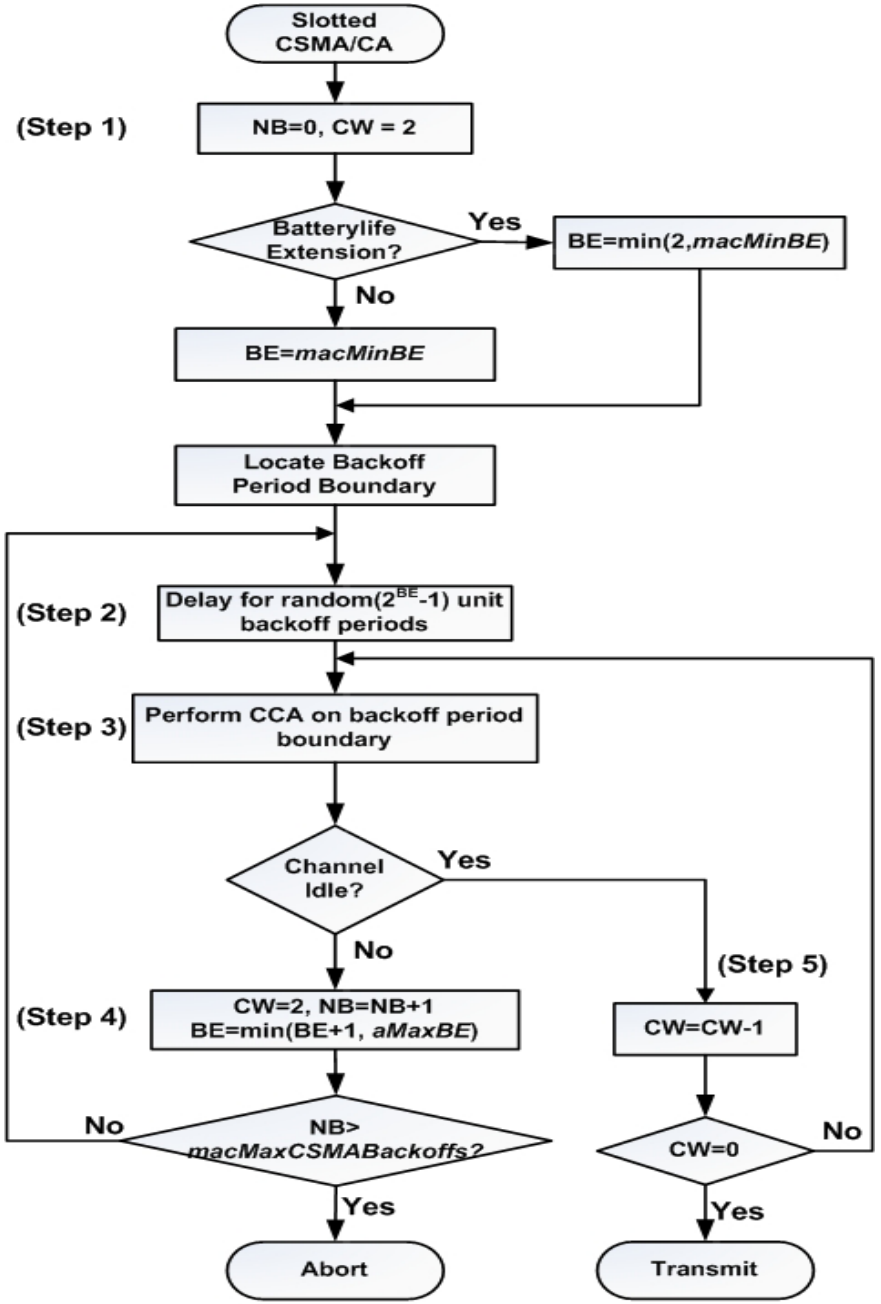
- MAC commands

Table 82—MAC command frames

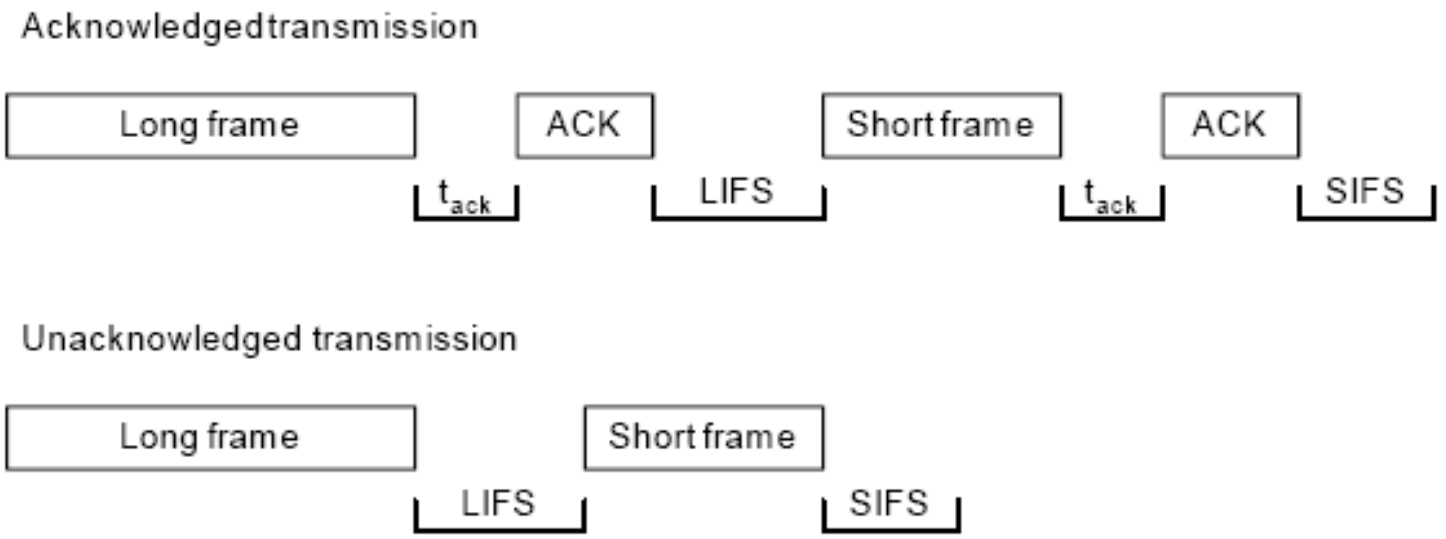
Command frame identifier	Command name	RFD		Subclause
		Tx	Rx	
0x01	Association request	X		7.3.1
0x02	Association response		X	7.3.2
0x03	Disassociation notification	X	X	7.3.3
0x04	Data request	X		7.3.4
0x05	PAN ID conflict notification	X		7.3.5
0x06	Orphan notification	X		7.3.6
0x07	Beacon request			7.3.7
0x08	Coordinator realignment		X	7.3.8
0x09	GTS request			7.3.9
0x0a–0xff	Reserved			—

- CSMA-CA
  - Unslotted
  - Slotted CSMA/CA

- Slotted CSMA/CA



- Minimum inter-frame spacing
  - Short IFS (12 symbols) for frame sizes ≤ 18 bytes
  - Long IFS (40 symbols) frame sizes > 18 bytes



- Topologies

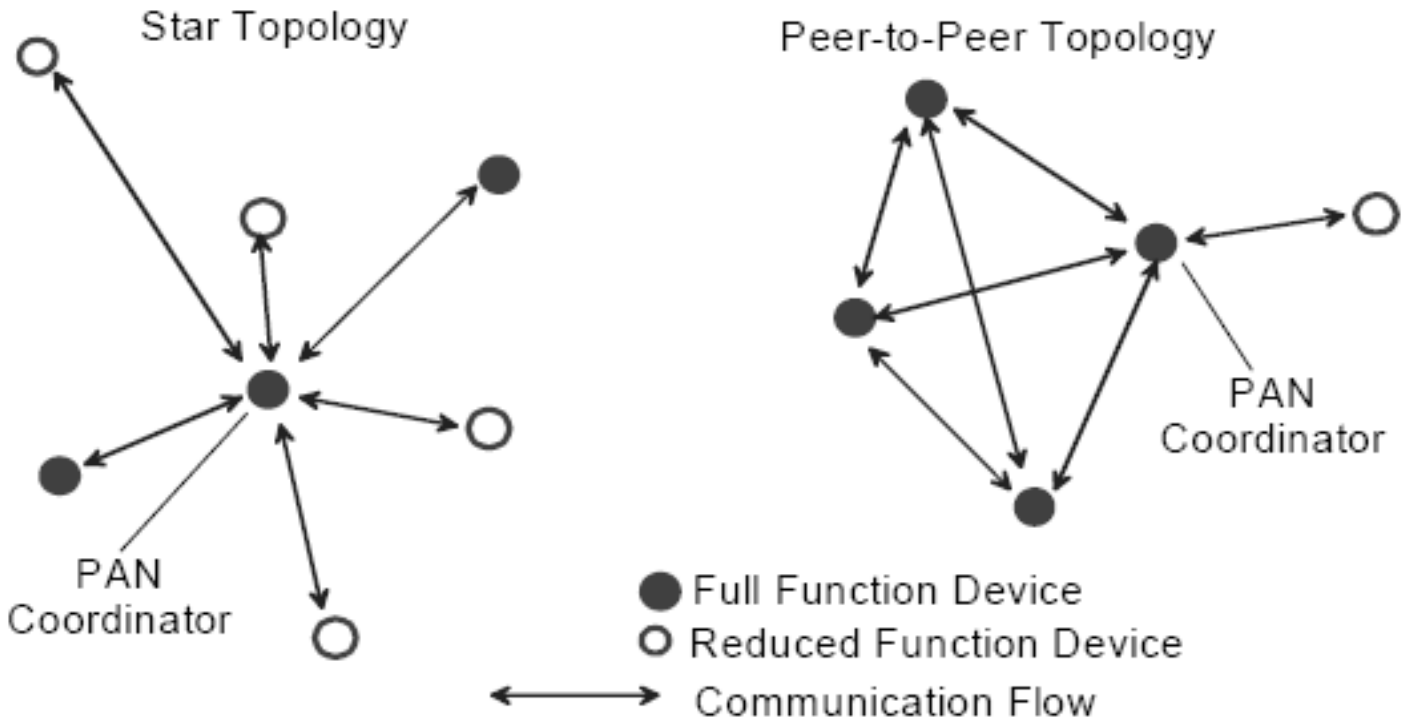


Figure 1—Star and peer-to-peer topology examples

- Transmission methods
  - Indirect data transmission
    - Energy saving
    - From co-ordinator to end-device
      - End-device sleeps most of the time
      - Co-ordinator stores pending messages until end-device wakes up
      - Beacon mode or end-device can poll the co-ordinator periodically
  - Direct transmission

Zigbee alliance protocol stack

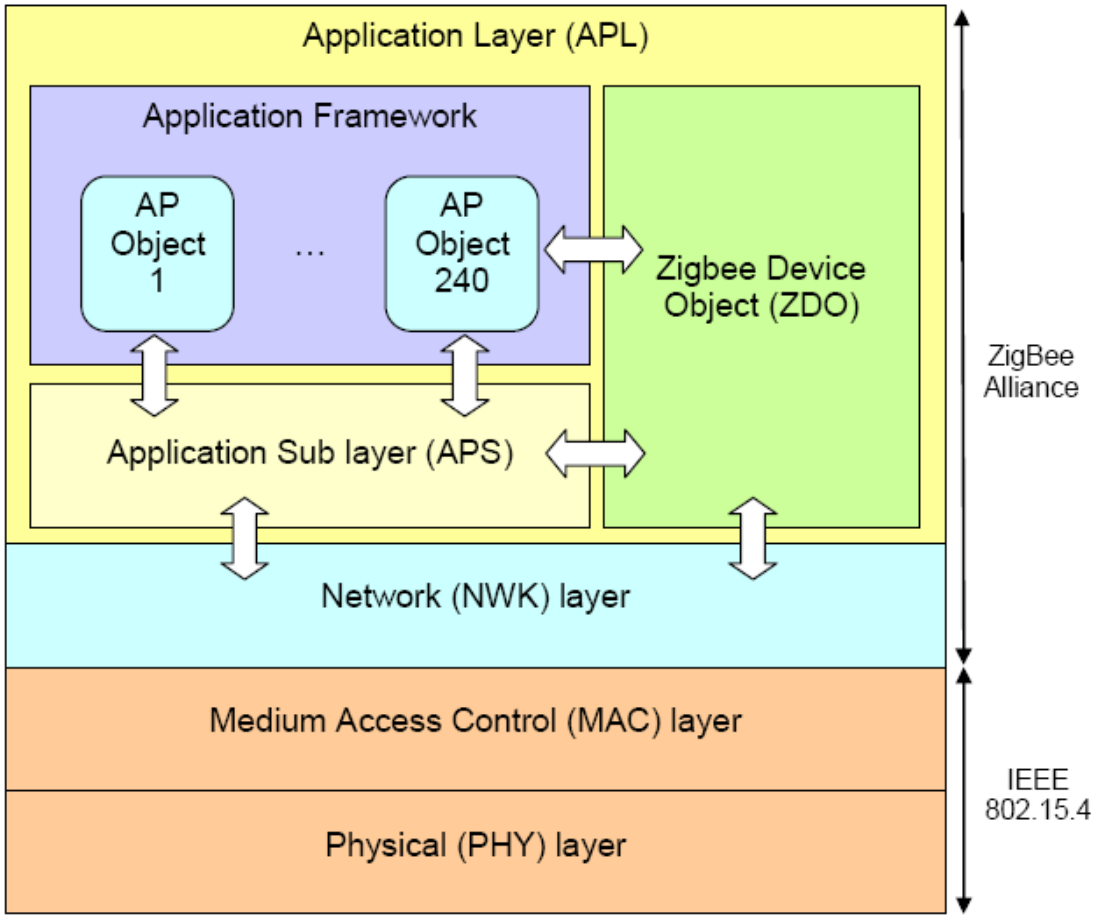
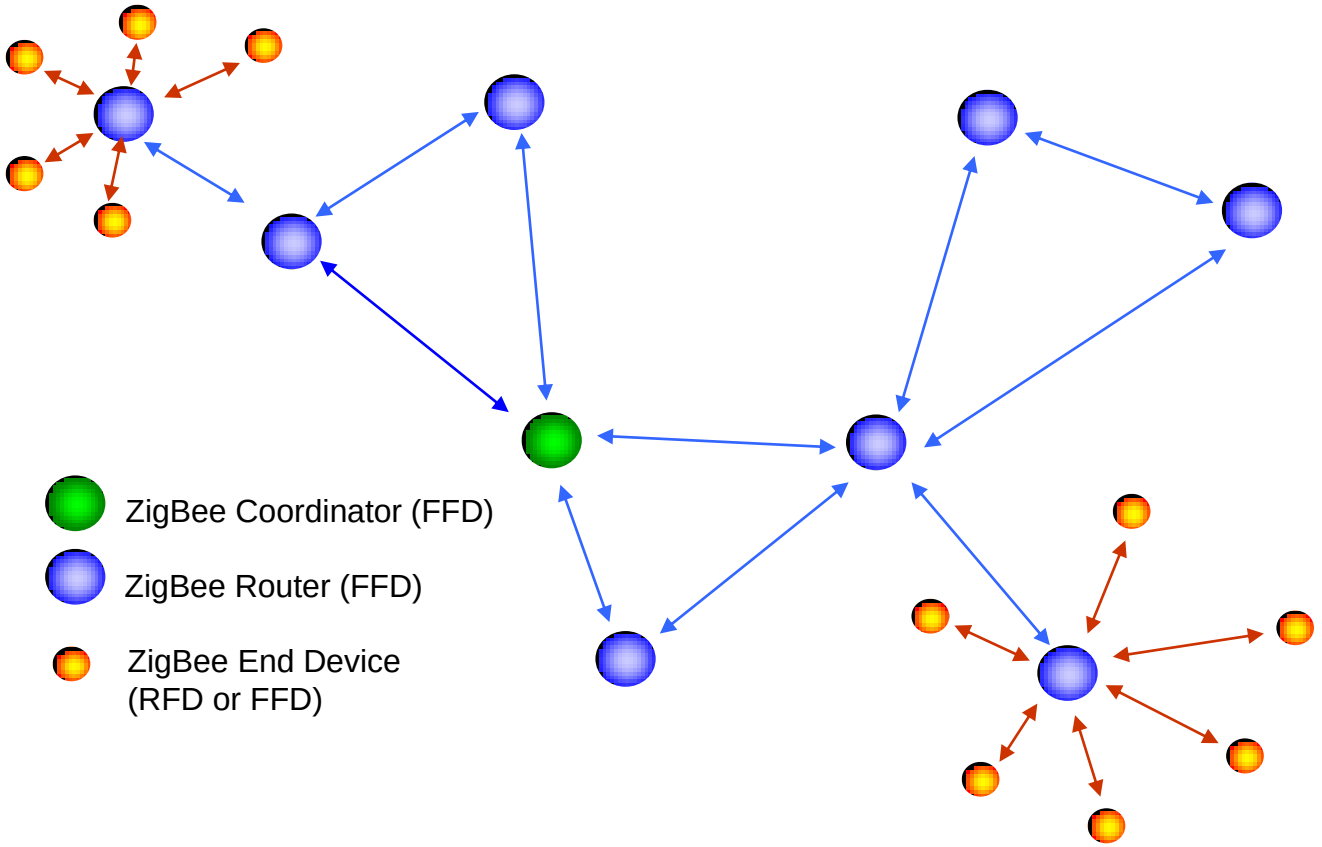


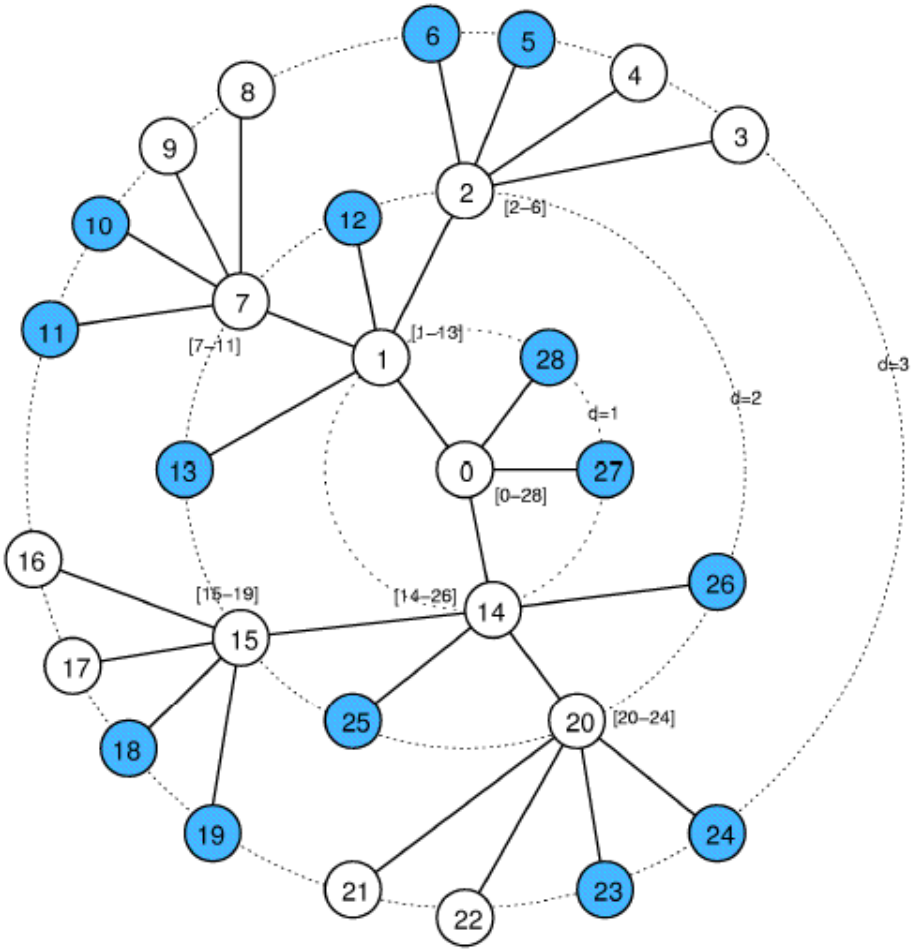
Figure 3-2: ZigBee functional layers architecture & protocol stack

- PAN co-ordinator (FFD)
- Router (FFD)
- End-device (RFD or FFD)

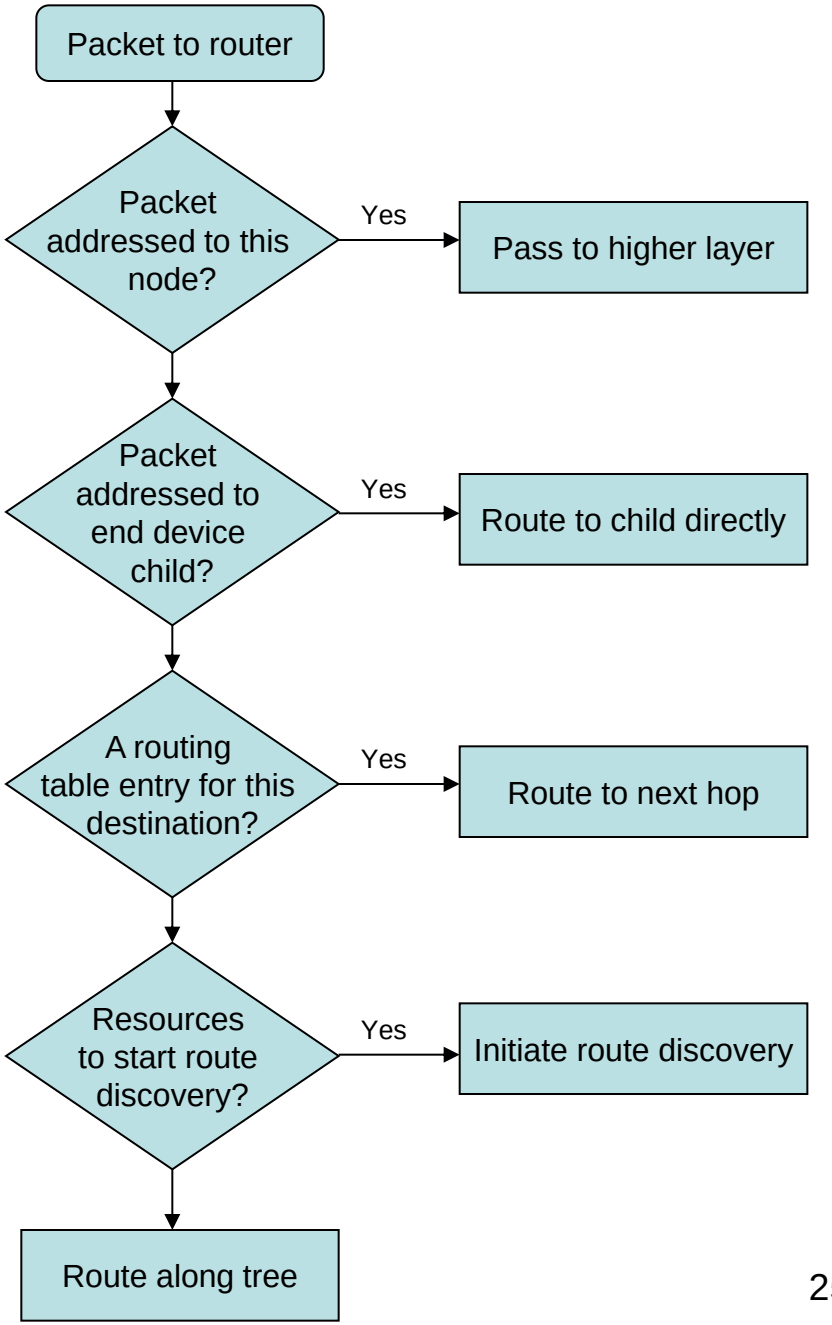


- Routing
  - Tree-based routing
  - Mesh networks
    - Table-driven
    - On-demand
      - Ad hoc On-demand Distance Vector (AODV), RFC 3561
  - A Zigbee router maintains
    - A routing table
    - A route discovery table

- Tree-based structure
  - Co-ordinator as the root
  - Routers (white)
  - End-devices (blue)



- Outline of routing protocol

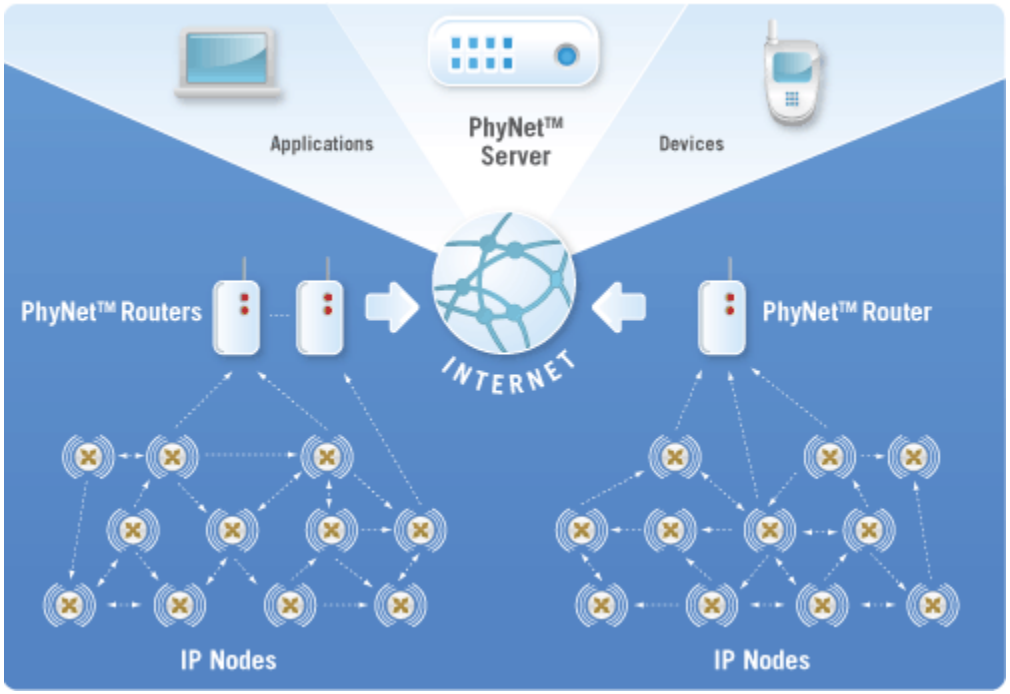


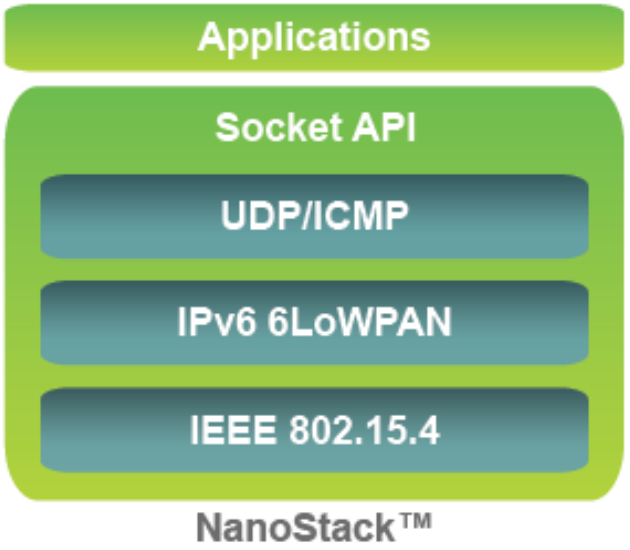
- Route discovery
  - Based on AODV
  - Router broadcasts a route request (RREQ)
  - Destination sends a route reply (RREP)
  - See homework problems

6LoWPAN

- IP protocol stack for WPAN
  - Contiki micro IP stack (SICS Sweden)
  - Sensinode (now ARM)
    - Nanostack and IPv6
  - Archrock (now Cisco)
    - PhyNet and IPv6
  - IEEE WG 6LoWPAN
    - IPv6 over Low-power WPAN
    - www.ietf.org/html.charters/6lowpan-charter.html

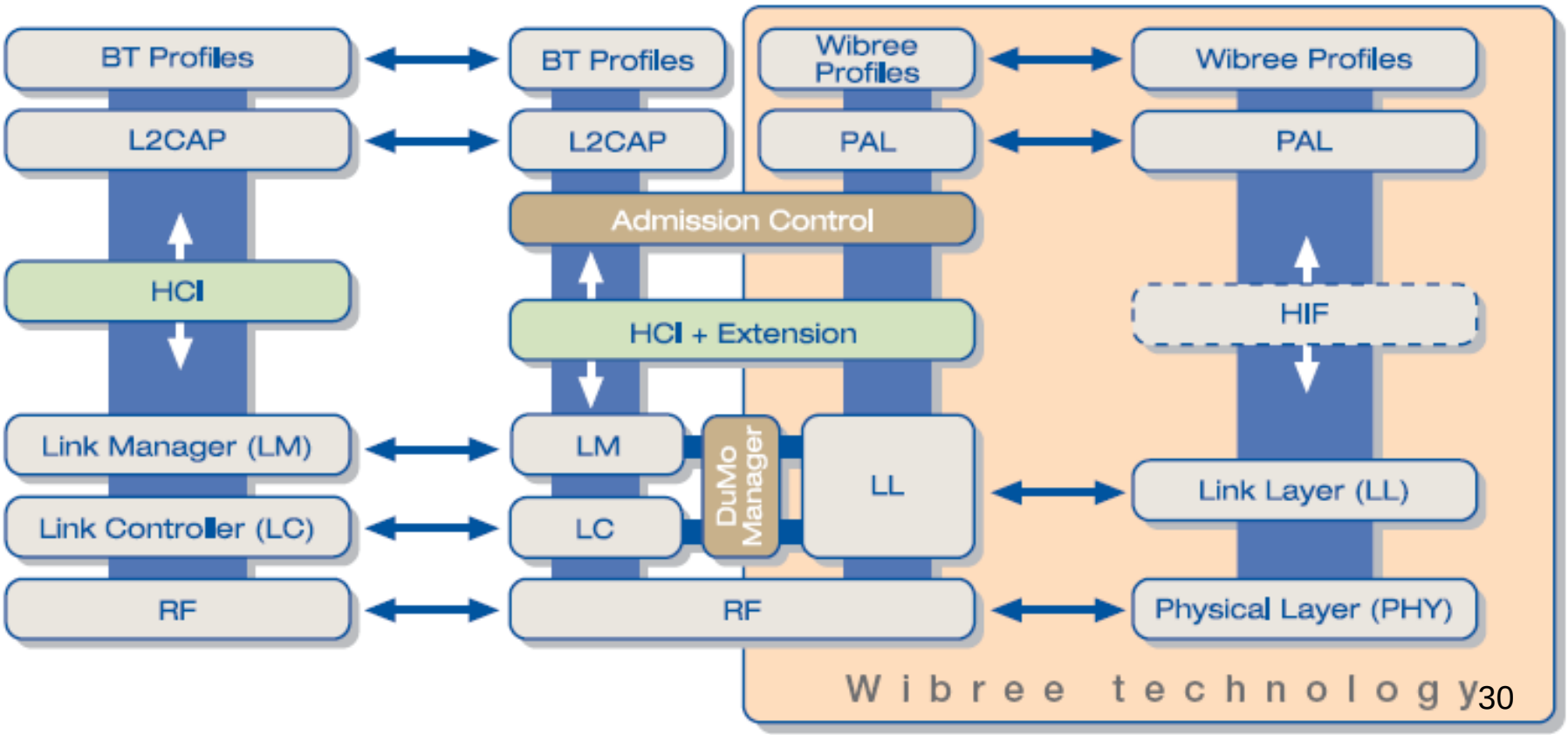
- PhyNet (Archrock, Cisco)
- Sensinode (ARM)





- Bluetooth low-energy
  - Ultra low-power Bluetooth
  - Health and medicine
  - Interworking with Bluetooth
    - Stand-alone chip
    - Dual-mode chip
  - Specifications
    - ISM band 2.4 GHz
    - 1 Mbps (phy layer)
    - 150 m range
  - Use case
    - Sports and wellness
  - Profiles
    - Watch profile
    - Human interface device profile
    - Sensor profile

Wibree Technology Protocol Stack



- Industrial environments

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DUST™ NETWORKS

IEEE 802.15.4 plus time synchronization and frequency hopping.
TDMA – Time division multiple access