IEEE 802.15.4

Introduction

- Until recently, the main concern in wireless communication was on high throughput
- Some applications need a different set of requirements
- Example: LR-WPAN (Low Rate Wireless Personal Area Network) applications

-Low cost communication network

-Limited power

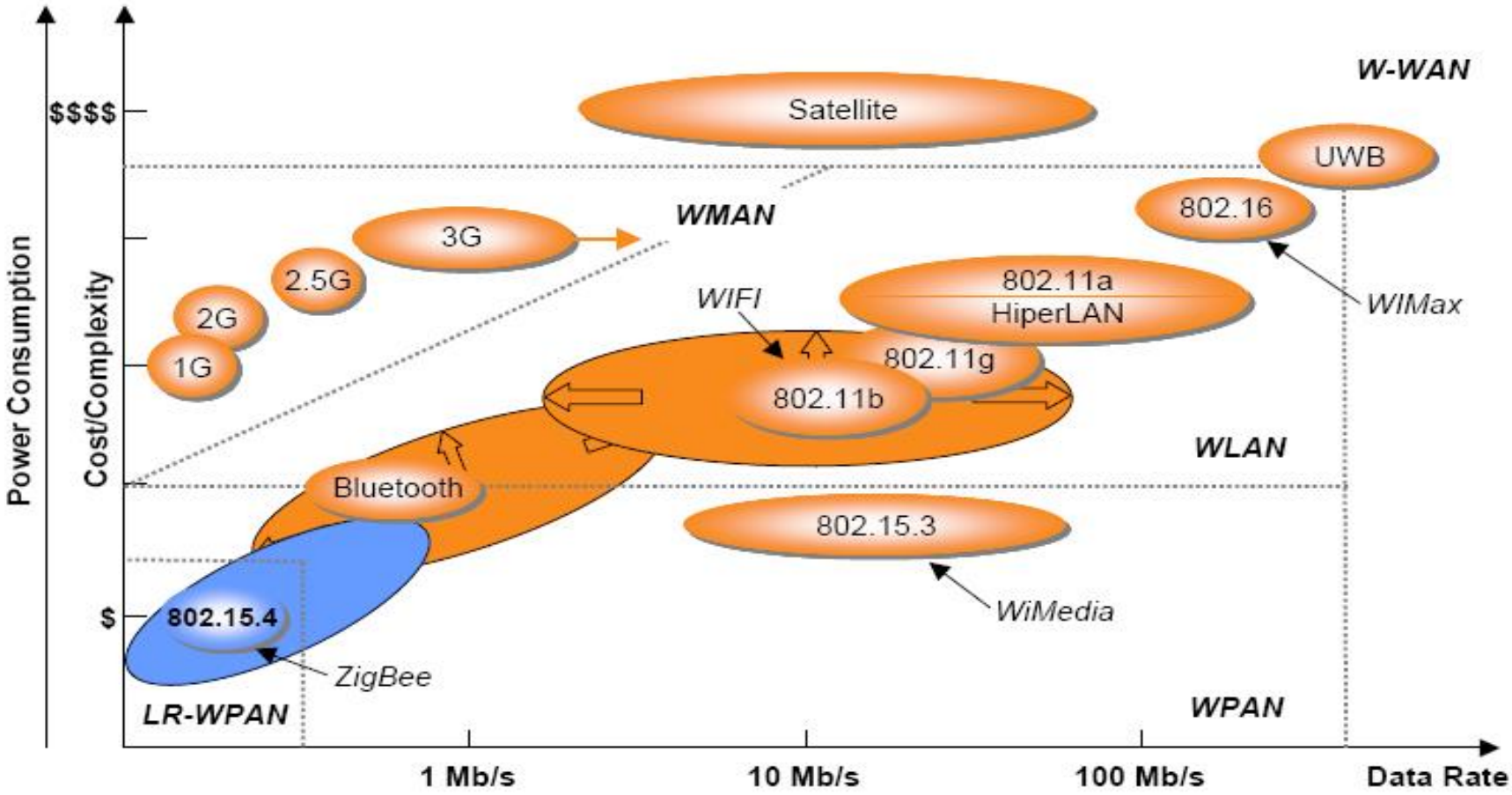
-Low throughput

- Require: reasonable battery life, extremely low cost, short range operation, reliable data transfer

LR-WPAN Applications

Home Automation	Heating, ventilation, air conditioning, security, lighting, control of objects.
Industrial	Detecting emergency situations, monitoring machines.
Automotive	Automotive sensing such as time pressure monitoring.
Agriculture	Sensing of soil moisture, pesticide, herbicide, PH levels.
Others	Controlling consumer electronics, PC peripherals, etc.

Wireless Protocol Comparison



Comparison

	LR-WPAN	Bluetooth™	WLAN
Range	10–30 m	~10–100 m	~100 m
Data Throughput	<0.25 MBPS	1 MBPS	~2–11 MBPS
Power Consumption	<BT/10	BT	>BT
Size	Smallest	Smaller	Larger
Nodes/Net	<<BT	BT	>BT
Cost	~$1	~$10–$15	~$40

LR-WPAN IEEE 802.15.4

- LR-WPAN needs a simple, flexible protocol
- IEEE 802.15.4 defines protocol via RF for PAN.
- Provides a standard with ultra-low complexity, cost, and power for low-data-rate wireless connectivity among inexpensive fixed, portable, and moving devices.

Properties of 802.15.4

- Raw Data Rate: 868 MHz, 20 kbps; 915 MHz, 40 kbps; 2.4 GHz, 250 kbps
- Range: 10-30 mtr
- Latency: Down to 15 ms
- Channels: 868 MHz, 1 Channel; 915 MHz, 10 Channels; 2.4 GHz, 16 Channels
- Frequency Band: Two PHYs: 868 MHz / 915 MHz & 2.4 GHz
- Addressing: Short 16-bit or 64-bit IEEE
- Channel Access: CSMA-CA & Slotted CSMA-CA
- Temperature: Industrial temperature range -40 °C to +85 °C

Device Types

- 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

Modes of Operation of a Device

- *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.

Network Topologies

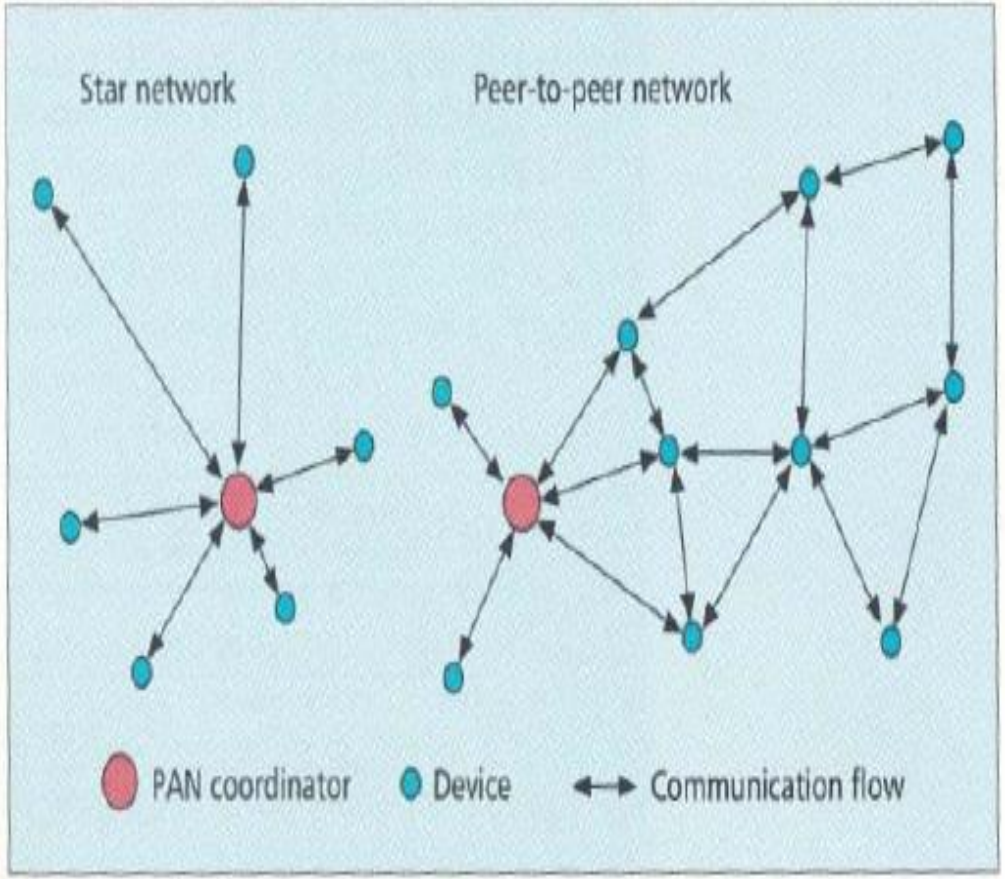
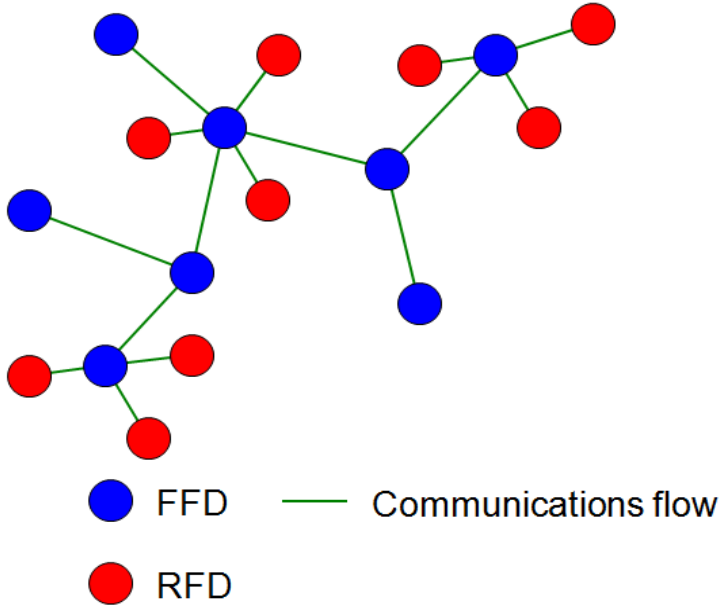


Figure 1. *Star and peer-to-peer networks.*

Combined Topology



Ex: Hotel where cluster nodes exist between the rooms of a hotel and each room has a star network for control.

Star Network Formation

Step 1: An FFD is activated

Step 2: It establishes its own network and become the PAN coordinator

Step 3: The FFD device chooses a PAN Identifier different from surrounding networks (within RF sphere of influence)

Step 4: The PAN coordinator allows other devices, potentially both FFDs and RFDs, to join its network.

Peer-to-peer Network Formation

Step 1: One Device is nominated as the PAN coordinator

Step 2: It forms the first cluster by choosing an unused PAN identifier and broadcasting beacon frames to neighboring devices.

Step 3: A candidate device receiving a beacon frame may request to join the network at the PAN coordinator.

Step 4: If the PAN coordinator permits the device to join, it adds the new device as a child device in its neighbor list.

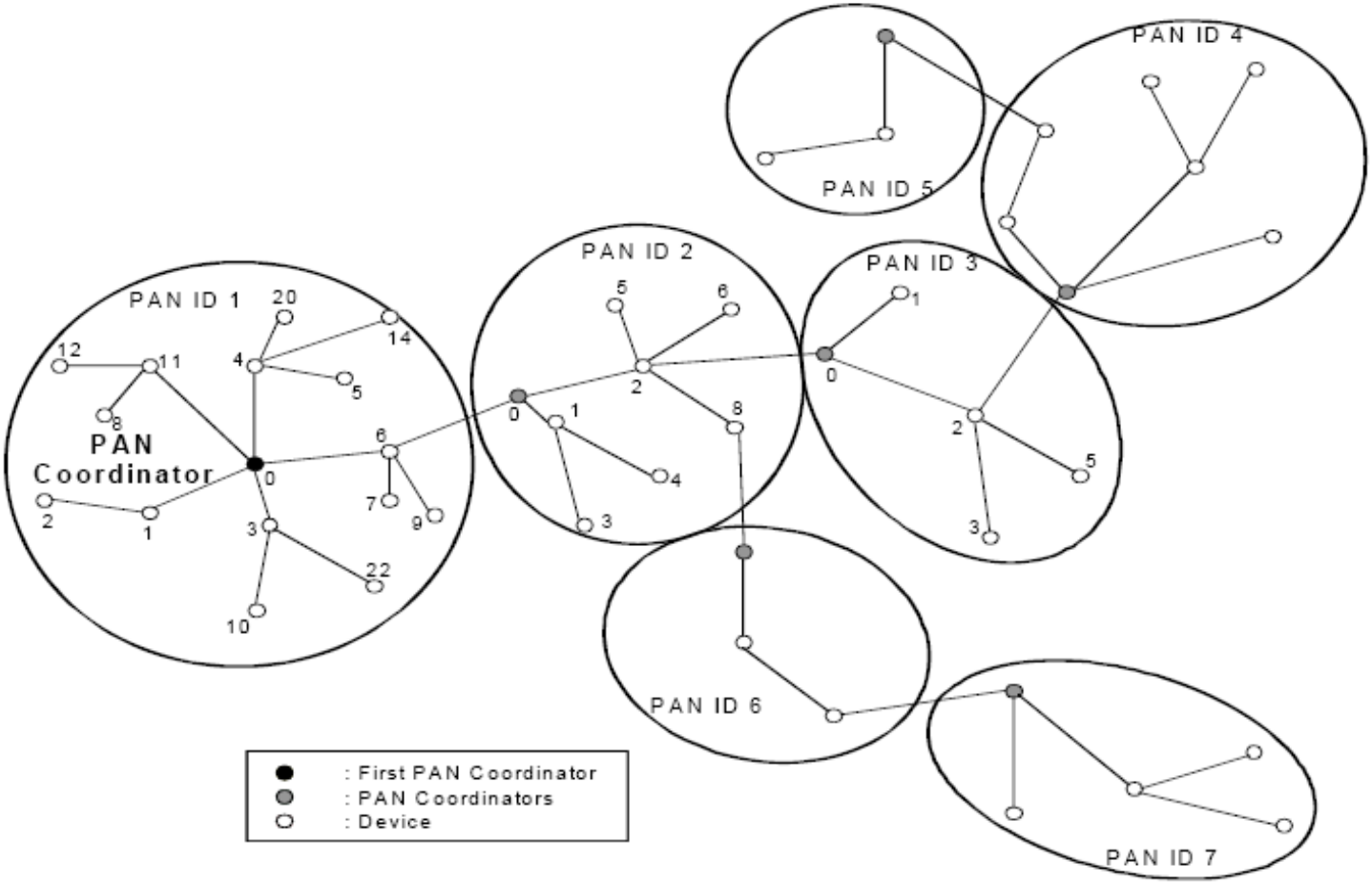
Step 5: Newly joined device adds the PAN coordinator as its parent in its neighbor list and begins transmitting periodic beacons

Step 6: Other candidate devices may then join the network at that device.

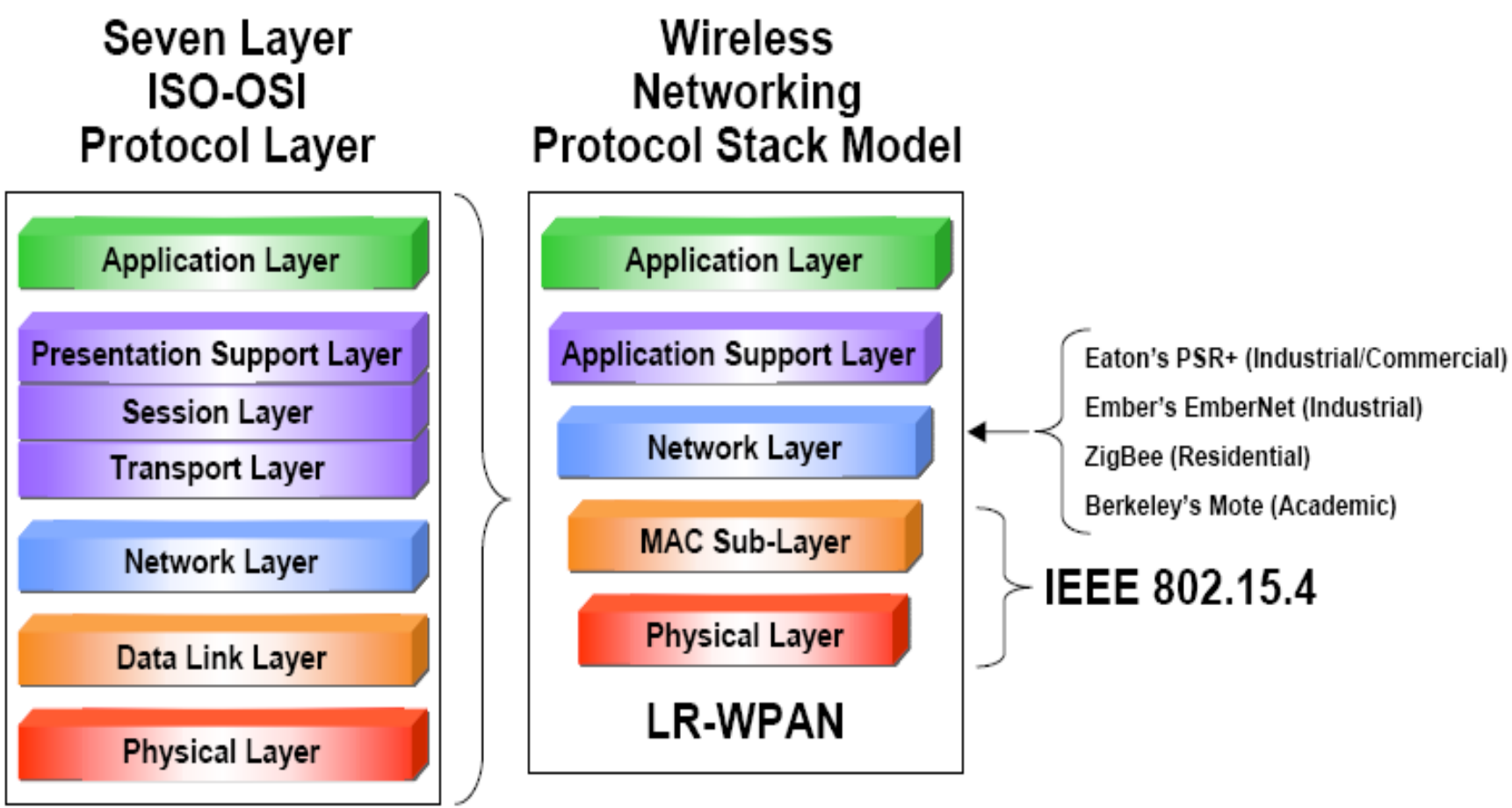
Step 7: Once predetermined application or network requirements are met, the first PAN coordinator may instruct a device to become the PAN coordinator of a new cluster adjacent to the first one.

Step 8: Other devices gradually connect and form a multi-cluster network structure

Cluster Tree Network



Architecture- 802.15.4



Data Transfer

- Three types of data transfer:

-Data transfer to a coordinator in which a device transmits the data

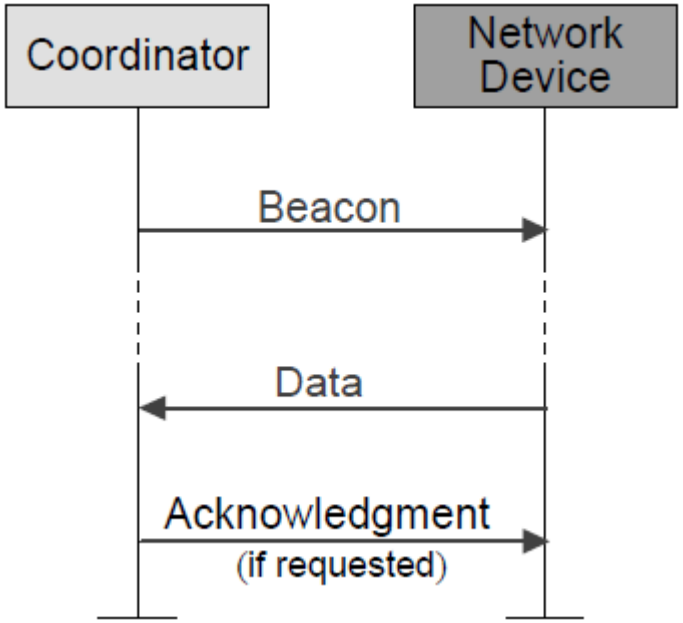
-Data transfer from a coordinator in which the device receives the data

-Data transfer between two peer devices

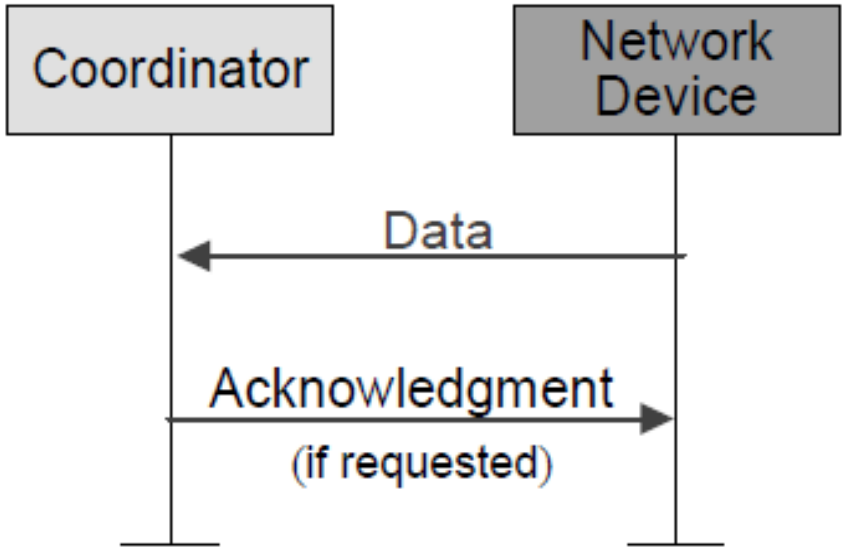
*In star topology only first two are used

*The mechanisms for each transfer type depend on whether the network supports the transmission of beacons

Data Transfer to a Coordinator

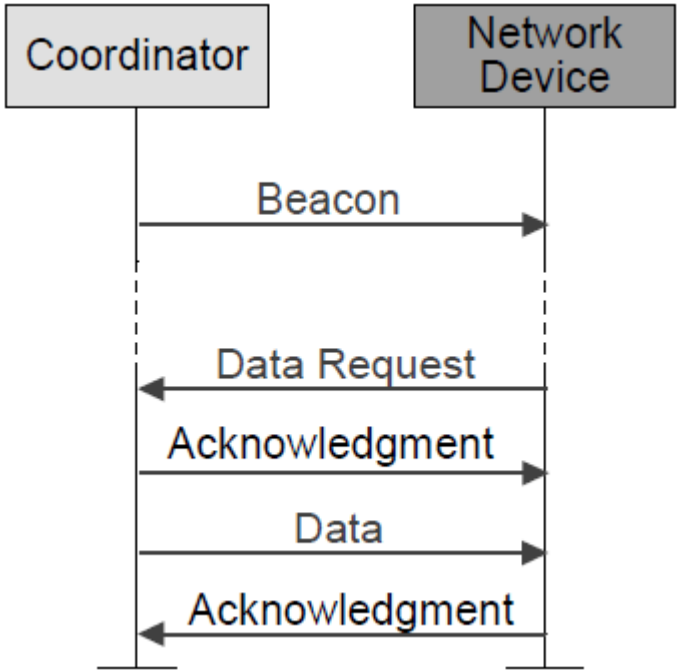


Beacon –enabled PAN
Slotted CSMA-CA

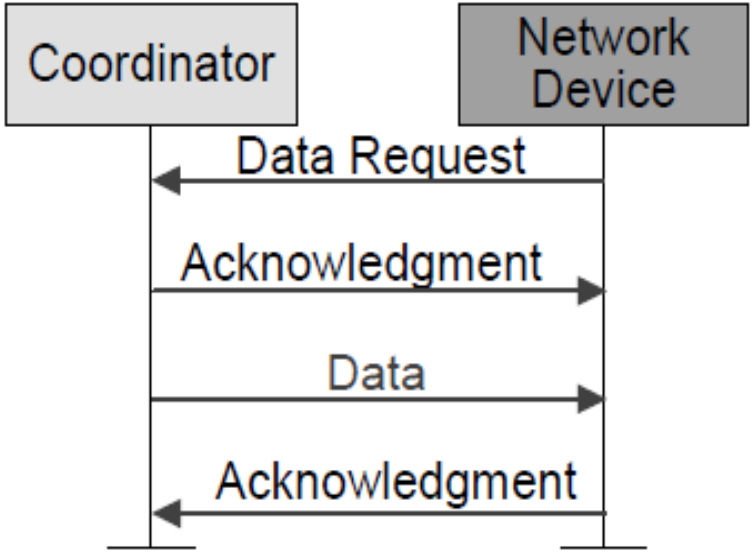


Non-Beacon PAN
Unslotted CSMA-CS

Data Transfer from a Coordinator



PAN indicates message is pending in the beacon frame



Device requests data at application-defined rate

Data Transmission Mechanism

- The IEEE 802.15.4 LR-WPAN employs various mechanisms to improve the probability of successful data transmission:

- CSMA-CA mechanism

  (Carrier Sense Multiple Access- Collision Avoidance)
- Frame acknowledgment
- Data verification

Unslotted CSMA-CA Mechanism

- Used by nonbeacon-enabled PANs
- Each time a device wishes to transmit data frames or MAC commands, it waits for a random period
- If the channel is found to be idle, following the random backoff, the device transmits its data
- If the channel is found to be busy following the random backoff, the device waits for another random period before trying to access the channel again
- Acknowledgment frames are sent without using a CSMA-CA mechanism

Slotted CSMA-CA Mechanism

- Used by beacon-enabled PANs
- Backoff slots are aligned with the start of the beacon transmission
- Device locates the boundary of the next backoff slot and then waits for a random number of backoff slots
- If the channel is busy, following this random backoff, the device waits for another random number of backoff
- If the channel is idle, the device begins transmitting on the next available backoff slot boundary

Frame Acknowledgement

- A successful reception and validation of a data or MAC (Medium Access Control) command frame can be optionally confirmed with an acknowledgment
- If the originator does not receive an acknowledgment after some period, it assumes that the transmission was unsuccessful and retries the frame transmission
- When the acknowledgment is not required, the originator assumes the transmission was successful

Data Verification – FCS Mechanism

- In order to detect bit errors, an FCS mechanism employing a 16-bit International Telecommunication Union—Telecommunication Standardization Sector (ITU-T) cyclic redundancy check (CRC) is used to detect errors in every frame

802.15.4 Low Power Operation

- The protocol IEEE 802.15.4 has been developed to favor battery-powered devices
- Battery-powered devices will require duty-cycling to reduce power consumption
- Thus will spend most of their operational life in a sleep state
- Each device periodically listens to the RF channel in order to determine whether a message is pending
- Higher powered devices have the option of listening to the RF channel continuously

Thank You!