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

Submission Title: [IEEE 802.15.4 Tutorial]

Date Submitted: [4 January, 2003]

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Re: [IEEE 802.15.4 Overview; Doc. IEEE 802.15-01/358r0, TG4-Overview; Doc IEEE 802.15-01/509r0]

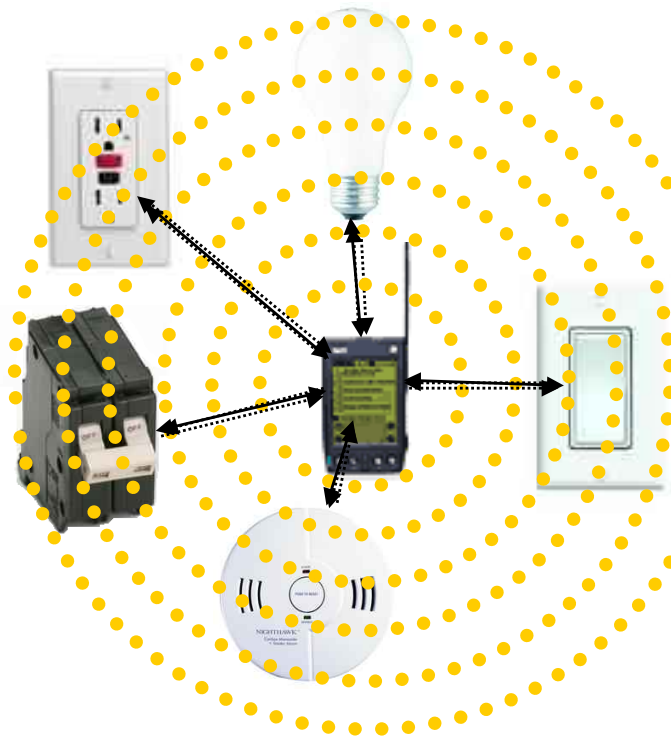**Abstract:** [This presentation provides a tutorial on the 802.15.4 draft standard.]

Purpose: []

IEEE 802.15.4
Tutorial

802.15.4 Applications Space

- Home Networking

- Automotive Networks

- Industrial Networks

- Interactive Toys

- Remote Metering
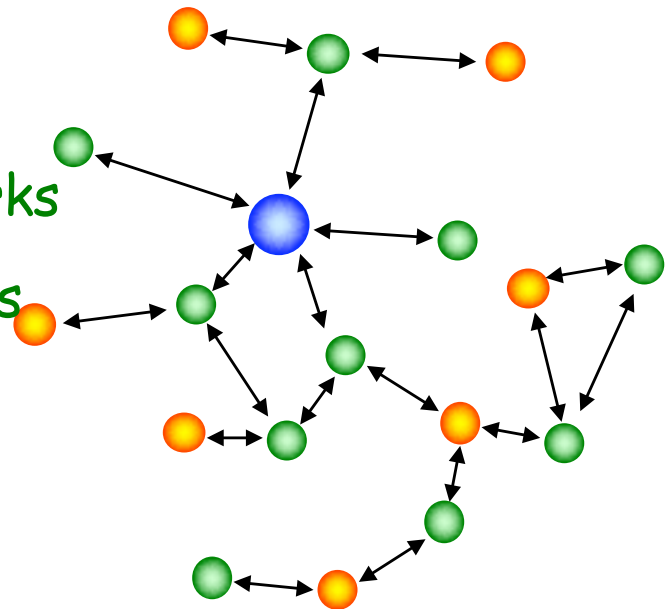
802.15.4 Applications Topology

Cable replacement - Last meter connectivity
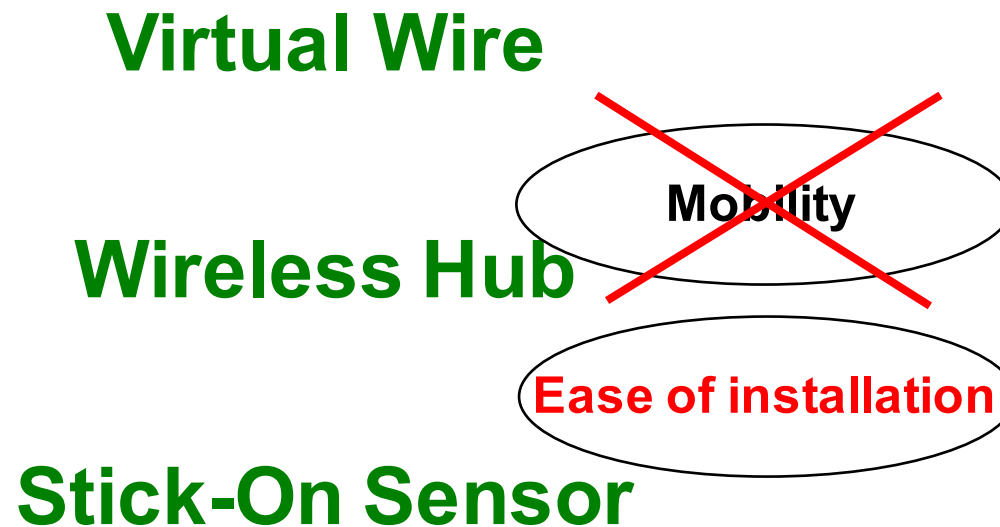
Virtual Wire

Mobility

Wireless Hub

Ease of installation

Stick-On Sensor

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Some needs in the sensor networks

Thousands of sensors in a small space ☻ **Wireless**

but wireless implies Low Power!

and low power implies Limited Range.

Of course all of these is viable if a Low Cost transceiver is required

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Solution:

LR-WPAN Technology!

By means of

IEEE 802.15.4

802.15.4 General Characteristics

Data rates of 250 kb/s, 40 kb/s and 20 kb/s.

Star or Peer-to-Peer operation.

Support for low latency devices.

CSMA-CA channel access.

Dynamic device addressing.

Fully handshaked protocol for transfer reliability.
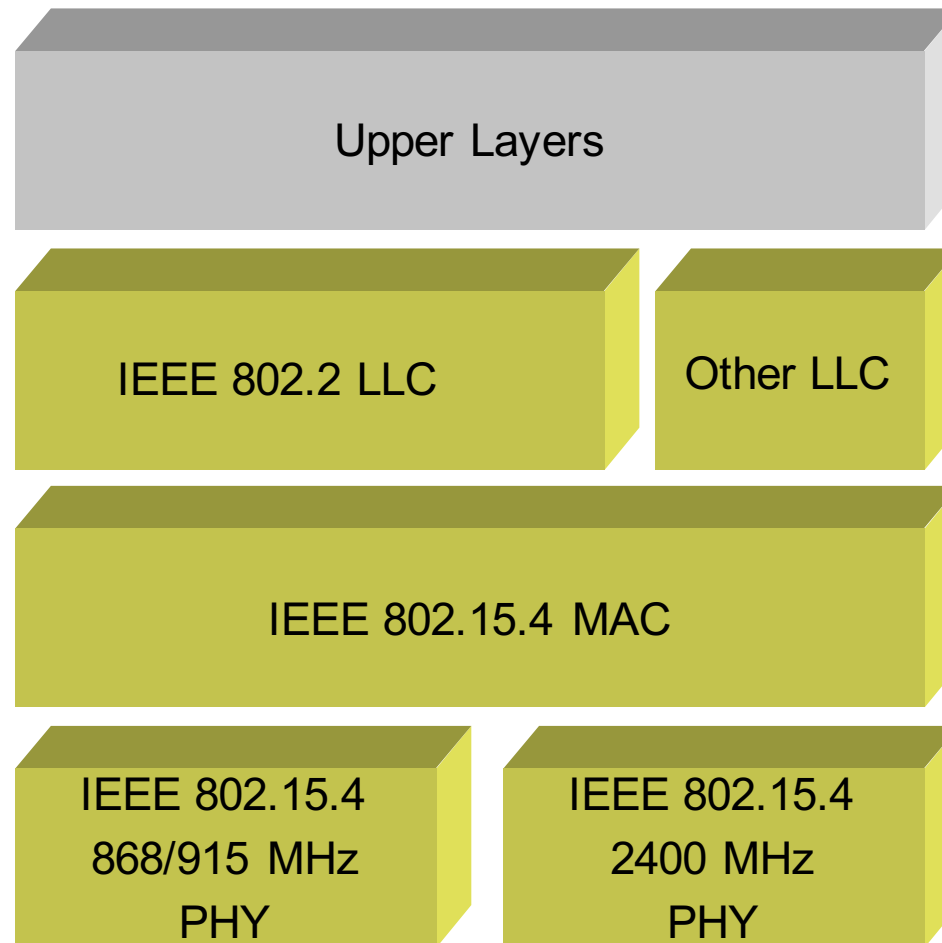
Low power consumption.

Frequency Bands of Operation

      16 channels in the 2.4GHz ISM band

      10 channels in the 915MHz ISM band

      1 channel in the European 868MHz band.

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802.15.4 Architecture

Upper Layers

IEEE 802.2 LLC

Other LLC

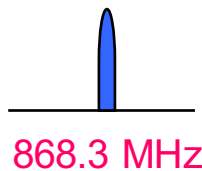IEEE 802.15.4 MAC

IEEE 802.15.4
868/915 MHz
PHY

IEEE 802.15.4
2400 MHz
PHY

IEEE 802.15.4 PHY Overview
Operating Frequency Bands

868MHz / 915MHz PHY

Channel 0

Channels 1-10

2 MHz

868.3 MHz

902 MHz

928 MHz

2.4 GHz PHY

Channels 11-26

5 MHz

2.4 GHz

2.4835 GHz

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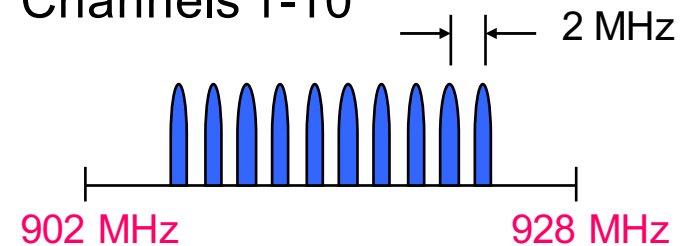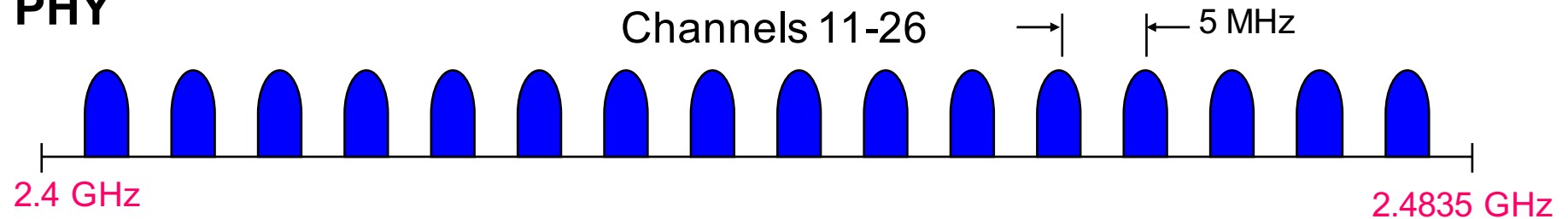
IEEE 802.15.4 PHY Overview
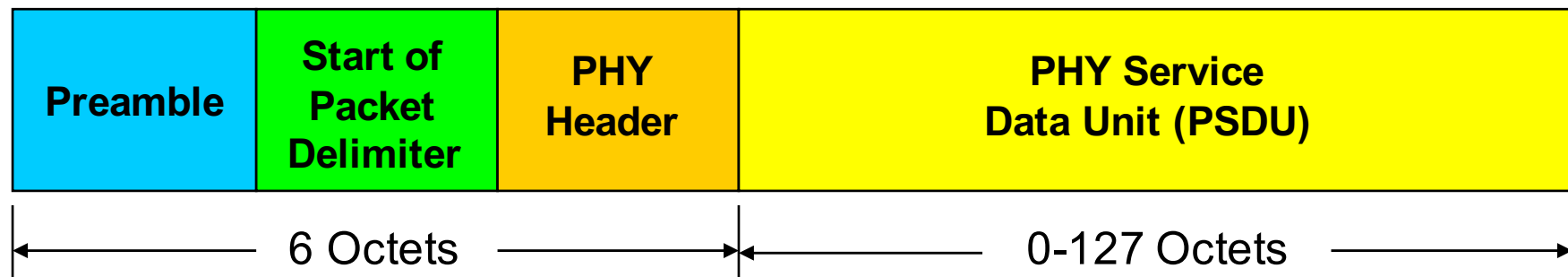## Packet Structure

PHY Packet Fields

- Preamble (32 bits) – synchronization
- Start of Packet Delimiter (8 bits)
- PHY Header (8 bits) – PSDU length
- PSDU (0 to 1016 bits) – Data field

Preamble	Start of Packet Delimiter	PHY Header	PHY Service Data Unit (PSDU)
6 Octets			0-127 Octets

IEEE 802.15.4 PHY Overview
Modulation/Spreading

2.4 GHz PHY

- 250 kb/s (4 bits/symbol, 62.5 kBaud)
- Data modulation is 16-ary orthogonal modulation
- 16 symbols are ~orthogonal set of 32-chip PN codes
- Chip modulation is MSK at 2.0 Mchips/s

868MHz/915MHz PHY

- Symbol Rate
  - 868 MHz Band: 20 kb/s (1 bit/symbol, 20 kBaud)
  - 915 MHz Band: 40 kb/s (1 bit/symbol, 40 kBaud)
- Data modulation is BPSK with differential encoding
- Spreading code is a 15-chip m-sequence
- Chip modulation is BPSK at
  - 868 MHz Band: 300 kchips/s
  - 915 MHz Band: 600 kchips/s

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IEEE 802.15.4 PHY Overview
Common Parameters

Transmit Power
- Capable of at least 1 mW

Transmit Center Frequency Tolerance
- 🎤40 ppm

Receiver Sensitivity (Packet Error Rate <1%)
- -85 dBm @ 2.4 GHz band
- -92 dBm @ 868/915 MHz band

RSSI Measurements
- Packet strength indication
- Clear channel assessment
- Dynamic channel selection

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IEEE 802.15.4 PHY Overview
PHY Primitives

PHY Data Service

- PD-DATA – exchange data packets between MAC and PHY

PHY Management Service

- PLME-CCA – clear channel assessment
- PLME-ED - energy detection
- PLME-GET / -SET – retrieve/set PHY PIB parameters
- PLME-TRX-ENABLE – enable/disable transceiver

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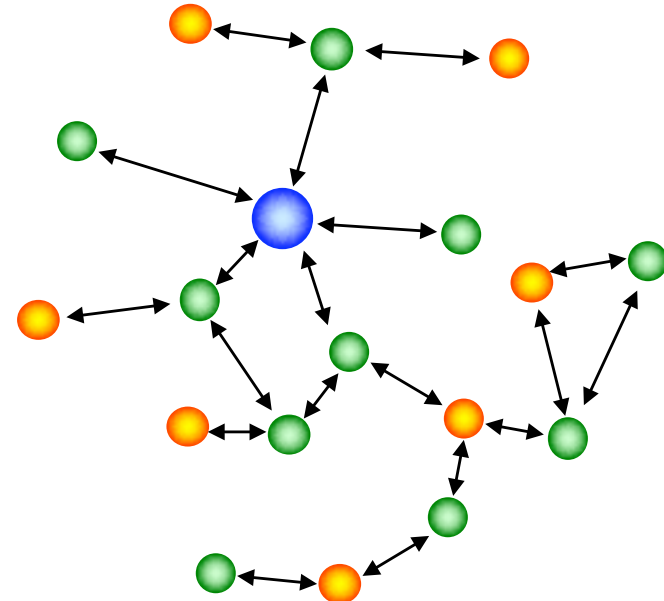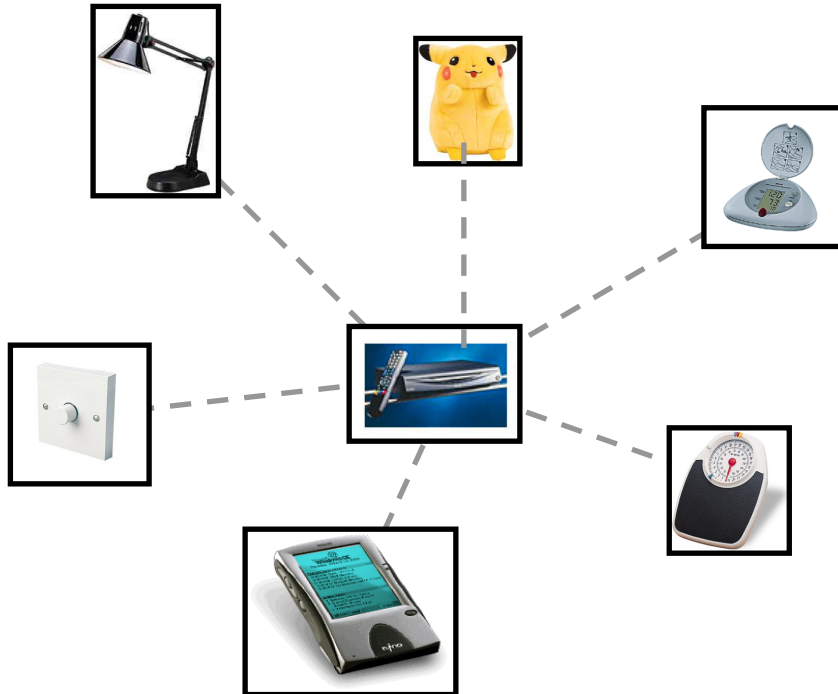# IEEE 802.15.4 MAC Overview
Design Drivers

- Extremely low cost

- Ease of implementation

- Reliable data transfer

- Short range operation

- Very low power consumption

<p style="text-align:center; color:red;">Simple but flexible protocol</p>

IEEE 802.15.4 MAC Overview
## Typical Network Topologies

IEEE 802.15.4 MAC Overview
Device Classes

- Full function device (FFD)

  – Any topology

  – Network coordinator capable

  – Talks to any other device

- Reduced function device (RFD)

  – Limited to star topology

  – Cannot become a network coordinator

  – Talks only to a network coordinator

  – Very simple implementation
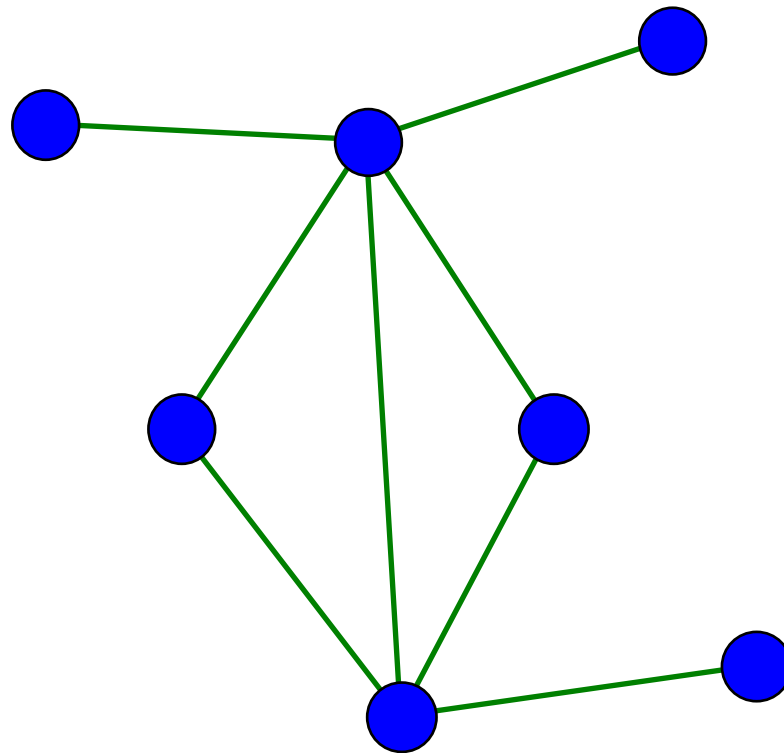
IEEE 802.15.4 MAC Overview

Star Topology

PAN
Coordinator

Master/slave
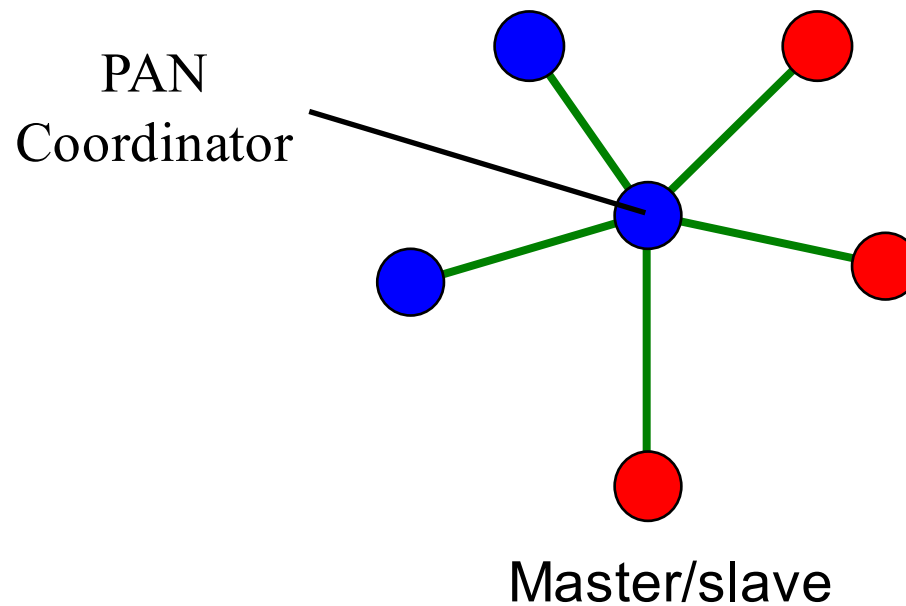
🔵 Full function device — Communications flow

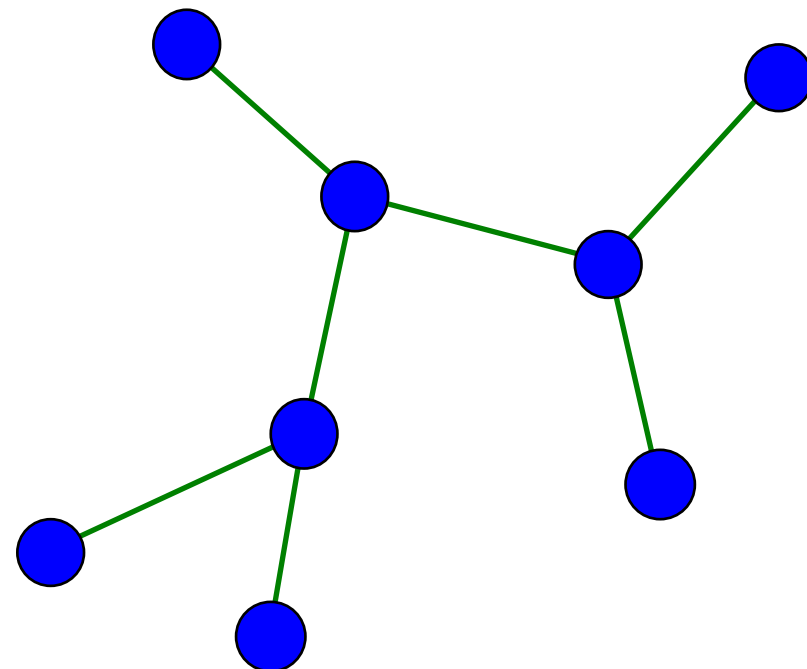🔴 Reduced function device

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IEEE 802.15.4 MAC Overview

Peer-Peer Topology
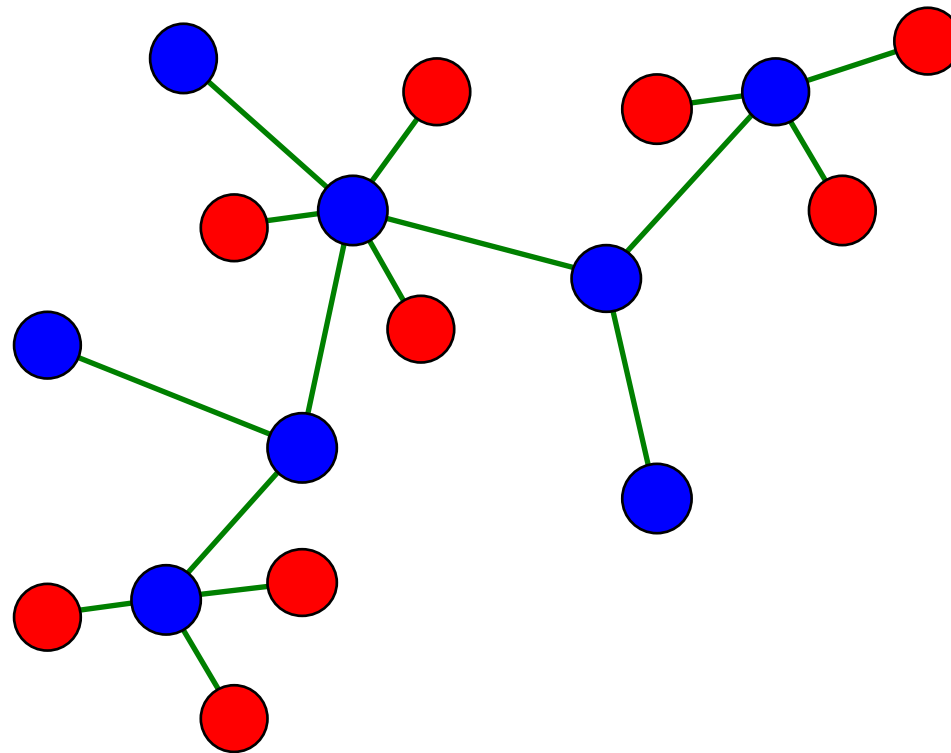

Point to point
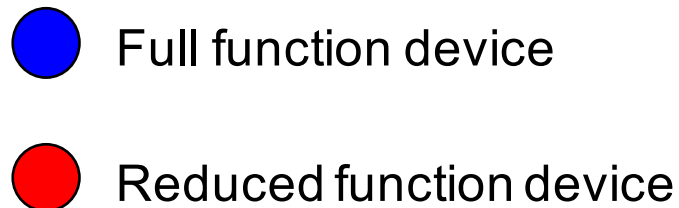
Cluster tree

● Full function device — Communications flow

IEEE 802.15.4 MAC Overview
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

🔵 Full function device

🔴 Reduced function device
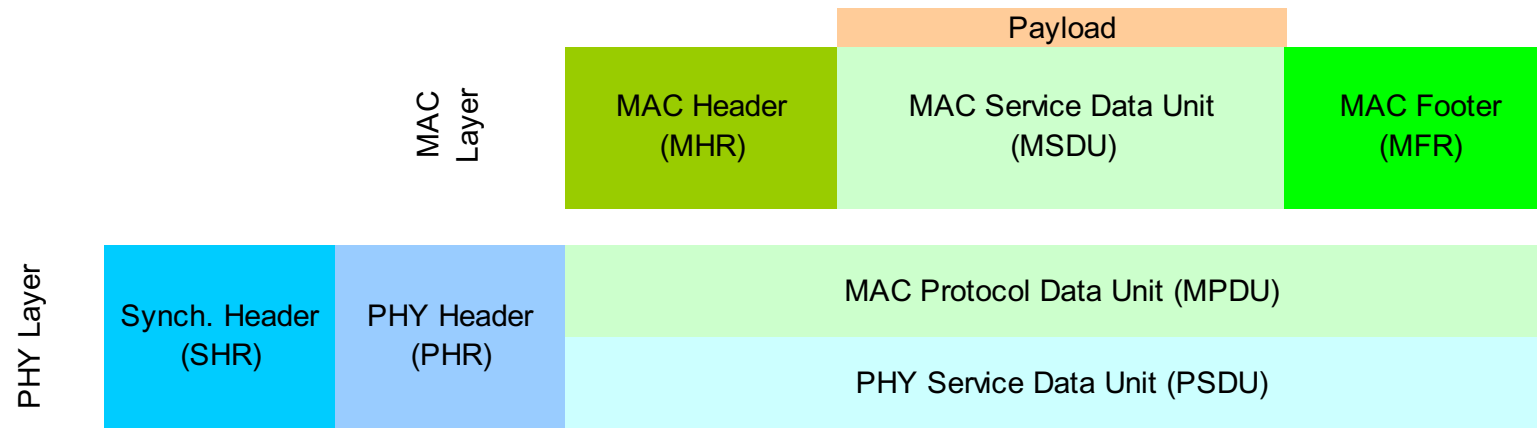
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IEEE 802.15.4 MAC Overview
Addressing

- All devices have IEEE addresses

- Short addresses can be allocated

- Addressing modes:
    - Network + device identifier (star)
    - Source/destination identifier (peer-peer)

IEEE 802.15.4 MAC Overview
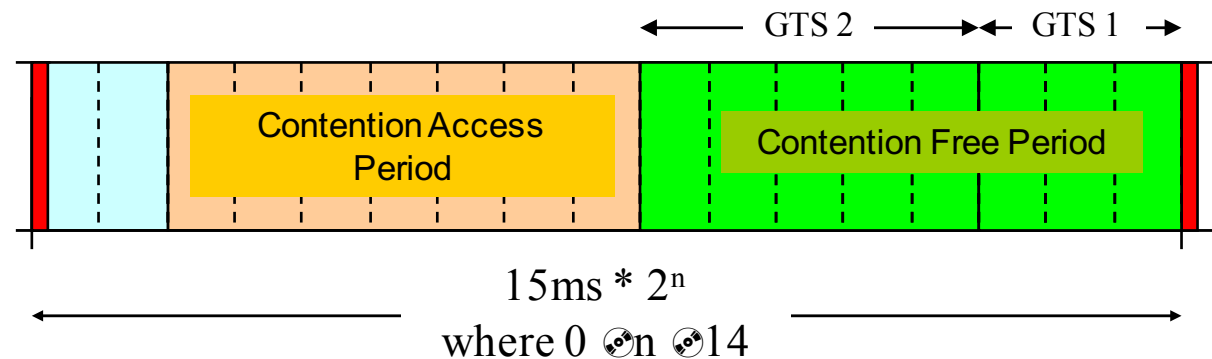## General Frame Structure

4 Types of MAC Frames:

- Data Frame

- Beacon Frame

- Acknowledgment Frame

- MAC Command Frame

IEEE 802.15.4 MAC Overview
Optional Superframe Structure

GTS 2 — GTS 1

Contention Access Period

Contention Free Period

$15ms * 2^n$
where $0 \leq n \leq 14$

Network beacon — Transmitted by network 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].
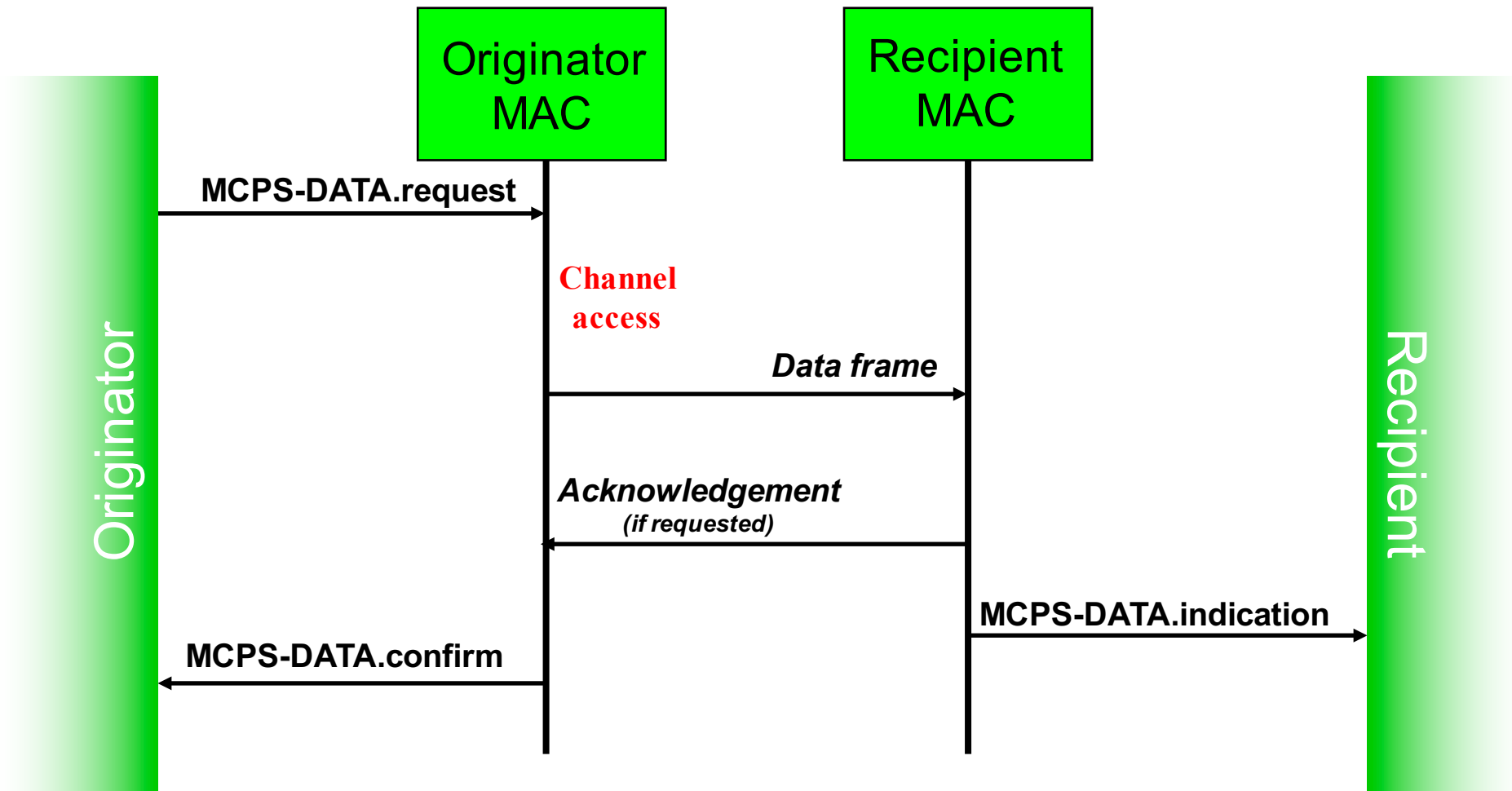
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IEEE 802.15.4 MAC Overview
Traffic Types

- Periodic data
  - Application defined rate (e.g. sensors)

- Intermittent data
  - Application/external stimulus defined rate (e.g. light switch)

- Repetitive low latency data
  - Allocation of time slots (e.g. mouse)

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IEEE 802.15.4 MAC Overview
MAC Data Service

IEEE 802.15.4 PHY Overview
MAC Primitives

MAC Data Service
- MCPS-DATA – exchange data packets between MAC and PHY

MAC Management Service
- MLME-ASSOCIATE/DISASSOCIATE – network association
- MLME-SYNC / SYNC-LOSS - device synchronization
- MLME-SCAN - scan radio channels
- MLME-GET / -SET – retrieve/set MAC PIB parameters
- MLME-START / BEACON-NOTIFY – beacon management
- MLME-POLL - beaconless synchronization
- MLME-GTS - GTS management
- MLME-ORPHAN - orphan device management
- MLME-RX-ENABLE - enabling/disabling of radio system

For more Information visit:

www.IEEE802.org

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