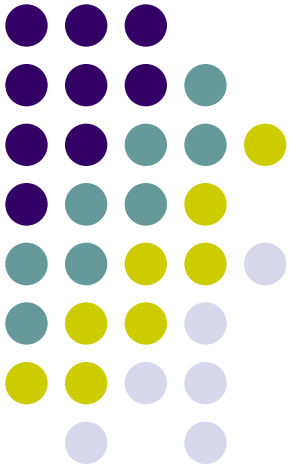
Chapter 9: Zigbee

EE2405

嵌入式系統與實驗

Embedded System Lab



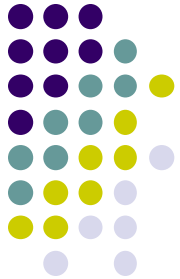
Content

- Introduction
- ZigBee/IEEE 802.15.4
  - Physical Layer
  - MAC Layer
- ZigBee Network Topologies
- ZigBee Application Profiles
- ZigBee and Bluetooth Comparison
- Technology Trends

Sensor Network Challenges

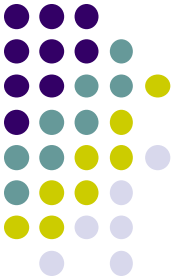
- Low computational power
  - Less than 10 MIPS
  - Low memory budget: 4-10 KB
- Limited energy budget
  - AA batteries provide ~2850 mAh
  - LiIon and NiMH batteries provide 800-2500 mAh
  - Solar cells: around 5 mA/cm^2 in direct sunlight
- Communication?

Wireless Communication



- Wireless communication standards:
  - IEEE 802.11 a/b/g
  - Bluetooth
  - GSM
- What makes them unattractive for WSN:
  - Power hungry (need big batteries)
  - Complexity (need lots of clock cycles and memory)
- New protocol for WSN:
  - 802.15.4 and Zigbee (ratified in Dec 14, 2004)

Basic ZigBee overview



- ZigBee is a specification for a high level protocol stack using small, low-power and low-cost radios.
- Based on IEEE 802.15.4 standard for Personal Area Network.
- Maintained by ZigBee Alliance (www.zigbee.org)
- ZigBee data transmission rate varies from 20 to 900kbits.

ZigBee Applications

ZigBee

Wireless Control that Simply Works

security
HVAC
AMR
lighting control
access control

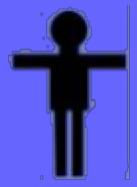
BUILDING AUTOMATION

CONSUMER ELECTRONICS

TV
VCR
DVD/CD
remote

patient
monitoring
fitness
monitoring

PERSONAL HEALTH CARE



PC & PERIPHERALS

mouse
keyboard
joystick

TELECOM SERVICES

m-commerce
info services
object interaction
(Internet of Things)

asset mgt
process control
environmental
energy mgt

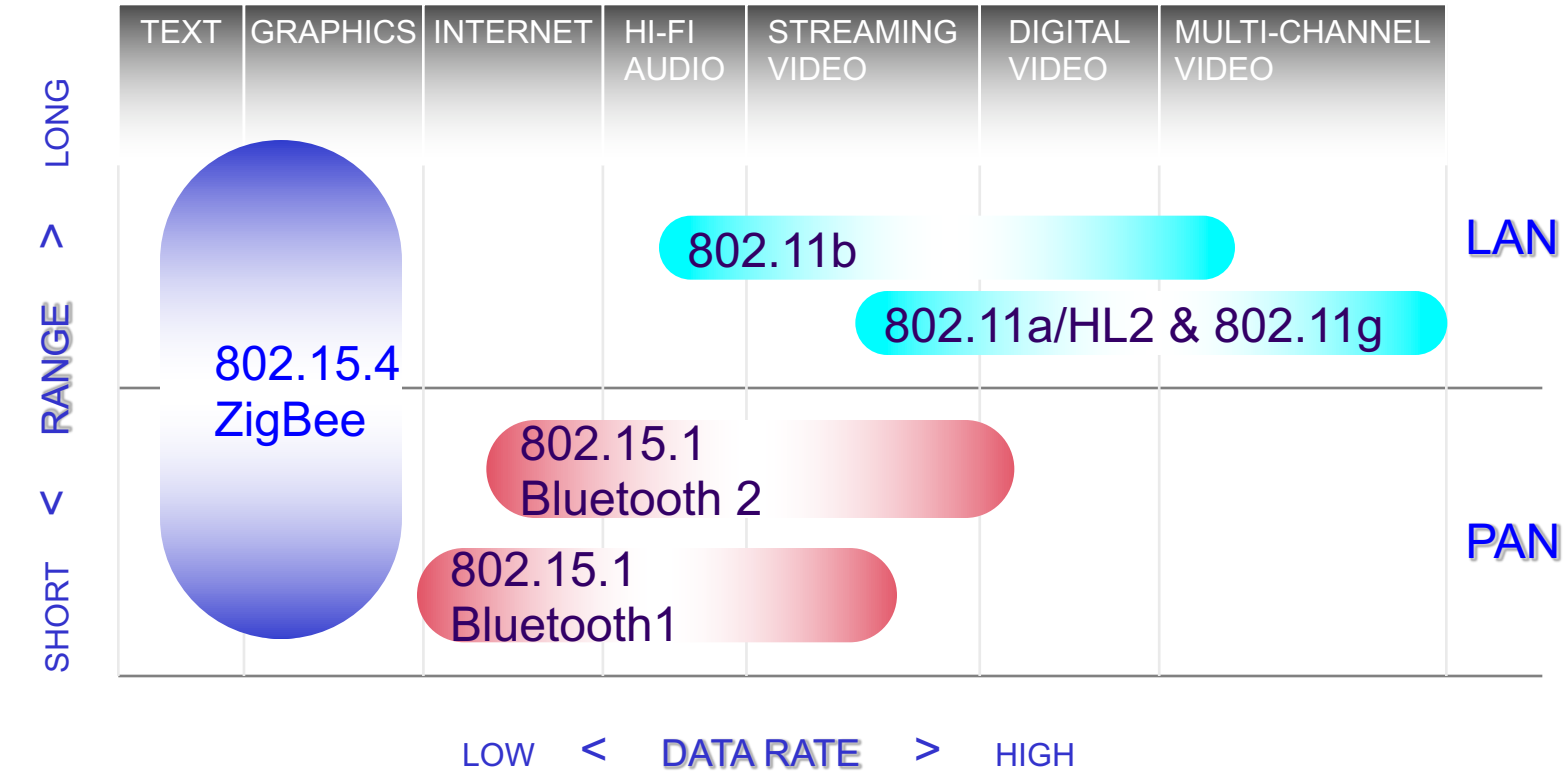
INDUSTRIAL CONTROL

HOME CONTROL

security
HVAC
lighting control
access control
irrigation

From Popular Science Magazine

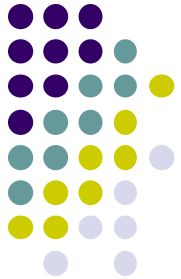
ZigBee and Bluetooth Comparison



ZigBee and Bluetooth Comparison

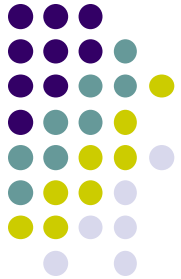
Feature(s)	Bluetooth	Bluetooth Low Energy 4.0	ZigBee	WiFi
Complexity	complex	simple	simple	high
Nodes/Master	7	undefined	65535	255 subnet
Latency	100 ms	<3 ms	<10 ms	<100ms
Range	10 -100m	10-100m	10m-200m	10-100m
Power	1 as ref.	0.01-0.5	0.1-2	10
Data Rate	1-3 Mbps	1 Mbps	250 Kbps	11M-Gbps
Network	scatter	star	star or mesh	flexible
Security	64bit, 128bit	128bit AES and Application Layer	128bit AES and Application Layer	flexible

Technology Development Trend



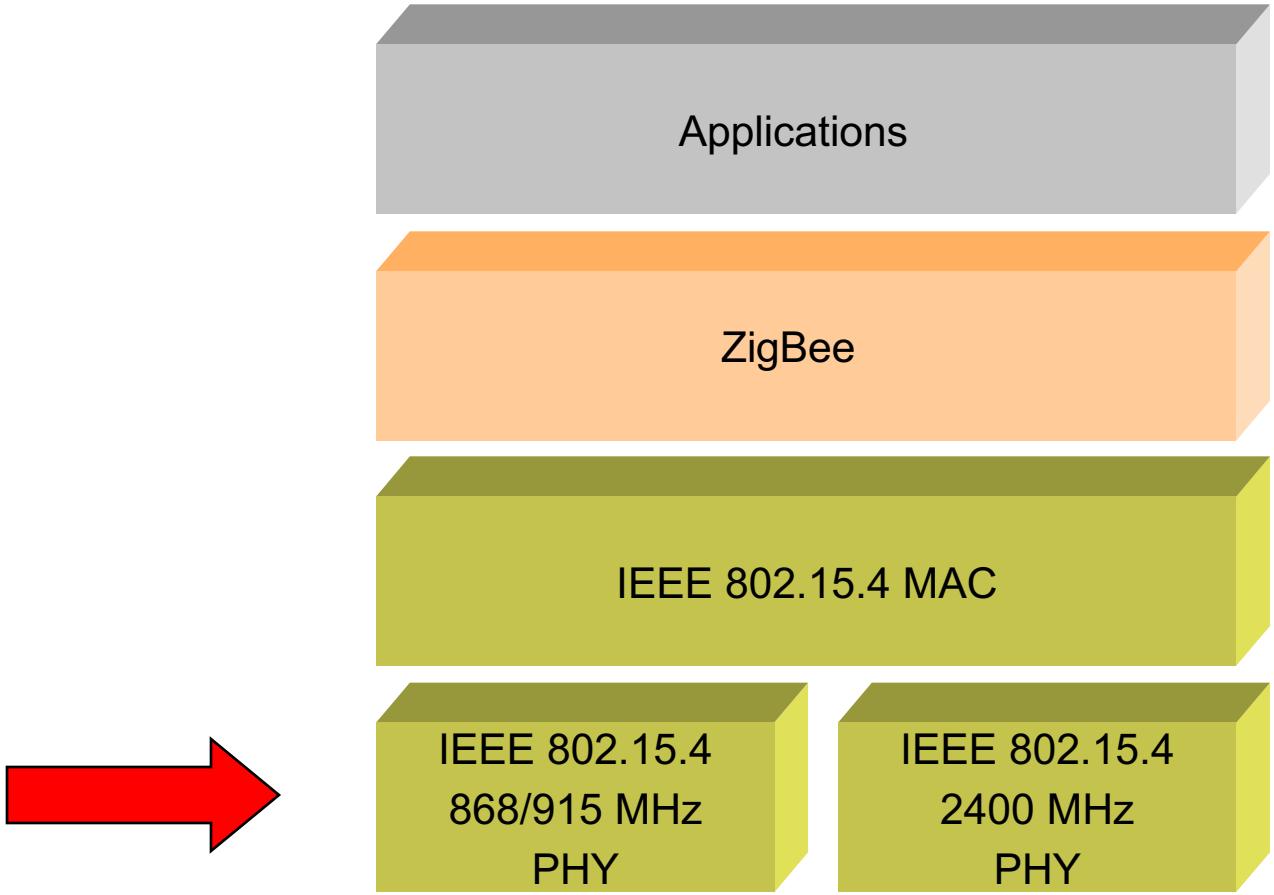
- The main trend in Zigbee development is improving power management and stack interoperability.
- Smart Energy 2.0.
- The ZigBee Alliance is developing an internet protocol (IP) networking layer called ZigBee IP, which is based on the IETF-based 6LoWPAN technology.

802.15.4 basics



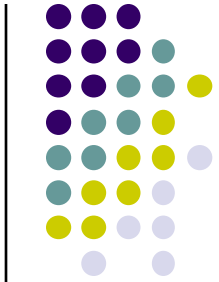
- IEEE 802.15.4 specifies physical and MAC layer of low-rate WPANs.
- It could be used as a basis for different protocols and standards. ZigBee, ISA100.11a, MiWi etc.
- IEEE 802.15.4 specification:
  - 802 = networking group
  - 15 = wireless network
  - 4 = low data rate consuming less power

802.15.4 Physical Layer



- **Packet generation**
- **Packet reception**
- **Data transparency**
- **Power Management**

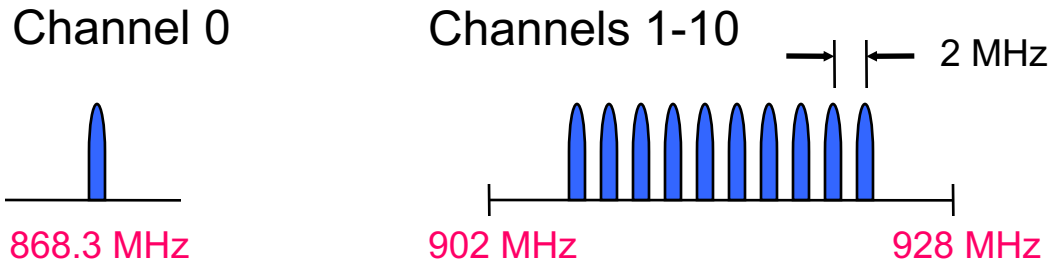
PHY functionalities



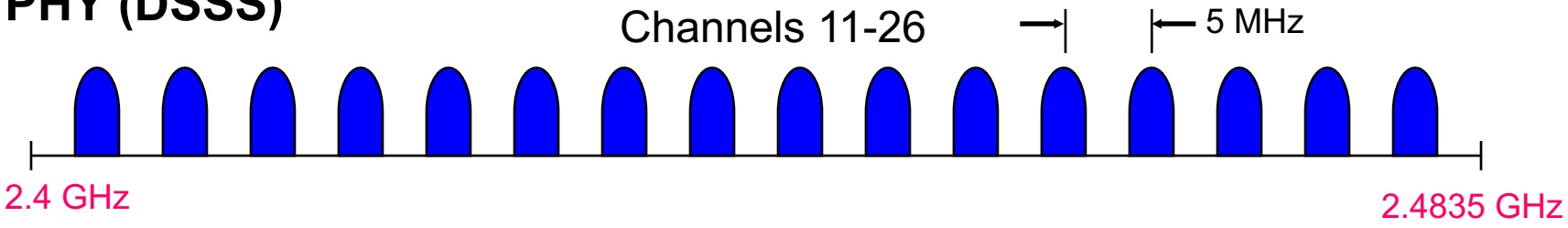
- Activation and deactivation of the radio transceiver
- Energy detection within the current channel
- Link quality indication for received packets
- Clear channel assessment for CSMA-CA
- Channel frequency selection
- Data transmission and reception

IEEE 802.15.4 PHY Overview

868MHz / 915MHz PHY (DSSS)

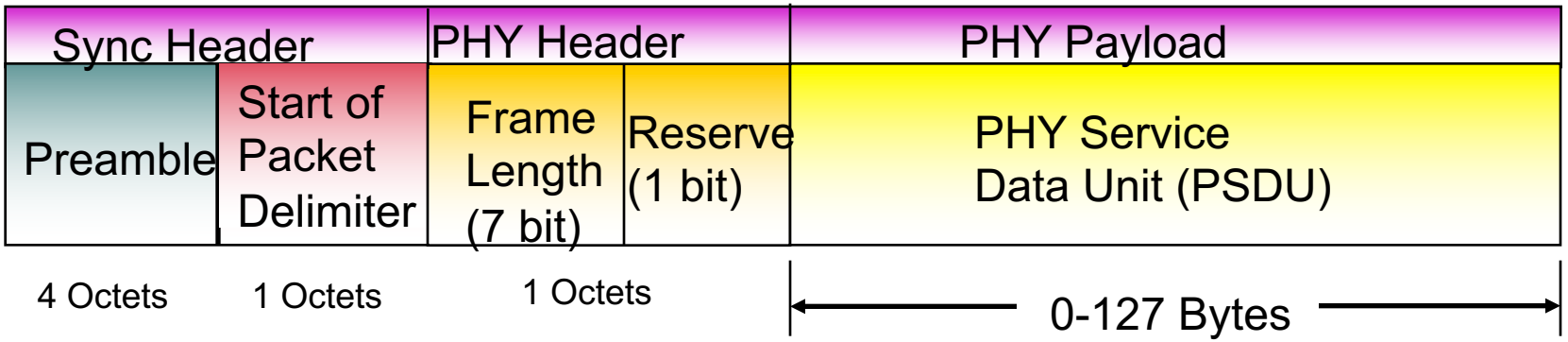


2.4 GHz PHY (DSSS)

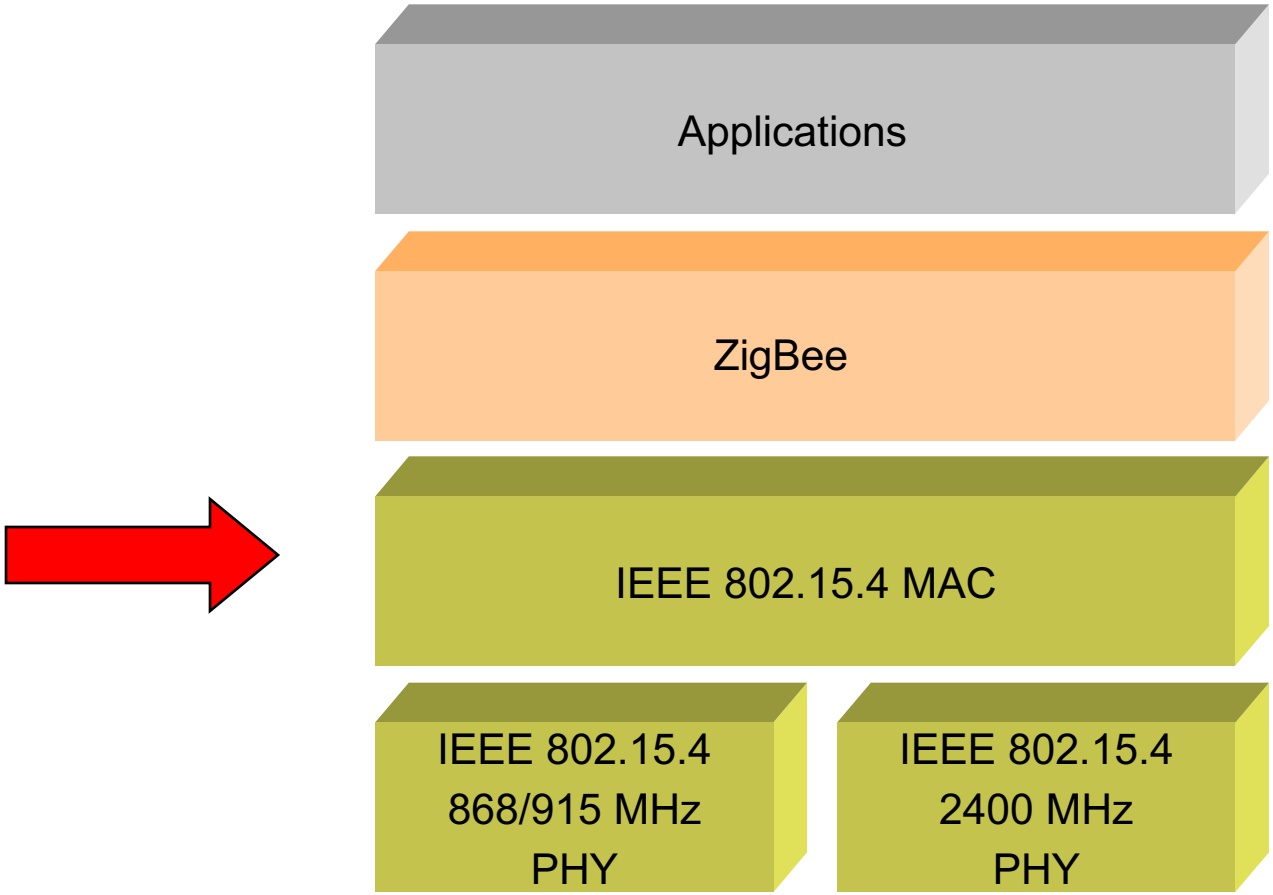


PHY frame structure

- PHY packet fields
  - Preamble (32 bits) – synchronization
  - Start of packet delimiter (8 bits) – shall be formatted as “11100101”
  - PHY header (8 bits) –PSDU length
  - PSDU (0 to 127 bytes) – data field

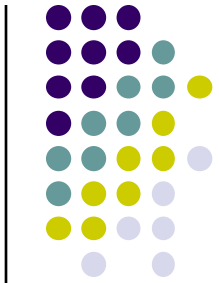


802.15.4 Architecture



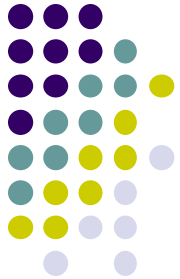
- **Channel acquisition**
- **Contention mgt**
- **NIC address**
- **Error Correction**

IEEE 802.15.4 MAC Layer



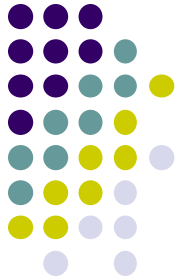
- Traffic Type
  - Periodic data
    - e.g. sensors
  - Intermittent data
    - e.g. light switch
  - Repetitive low latency data
    - e.g. mouse

IEEE 802.15.4 MAC Layer



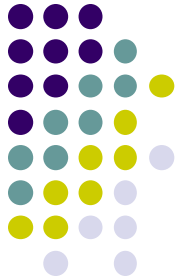
- Device Classes
  - Full function device (FFD)
    - Can function in any topology
    - Capable of being Network coordinator
    - Can talk to any other device (FFD/RFD)
  - Reduced function device (RFD)
    - Limited to star topology
    - Cannot become network coordinator
    - Talks only to FFDs
- Address
  - All devices must have 64 bit IEEE addresses
  - Short (16 bit) addresses can be allocated to reduce packet size

IEEE 802.15.4 MAC Layer



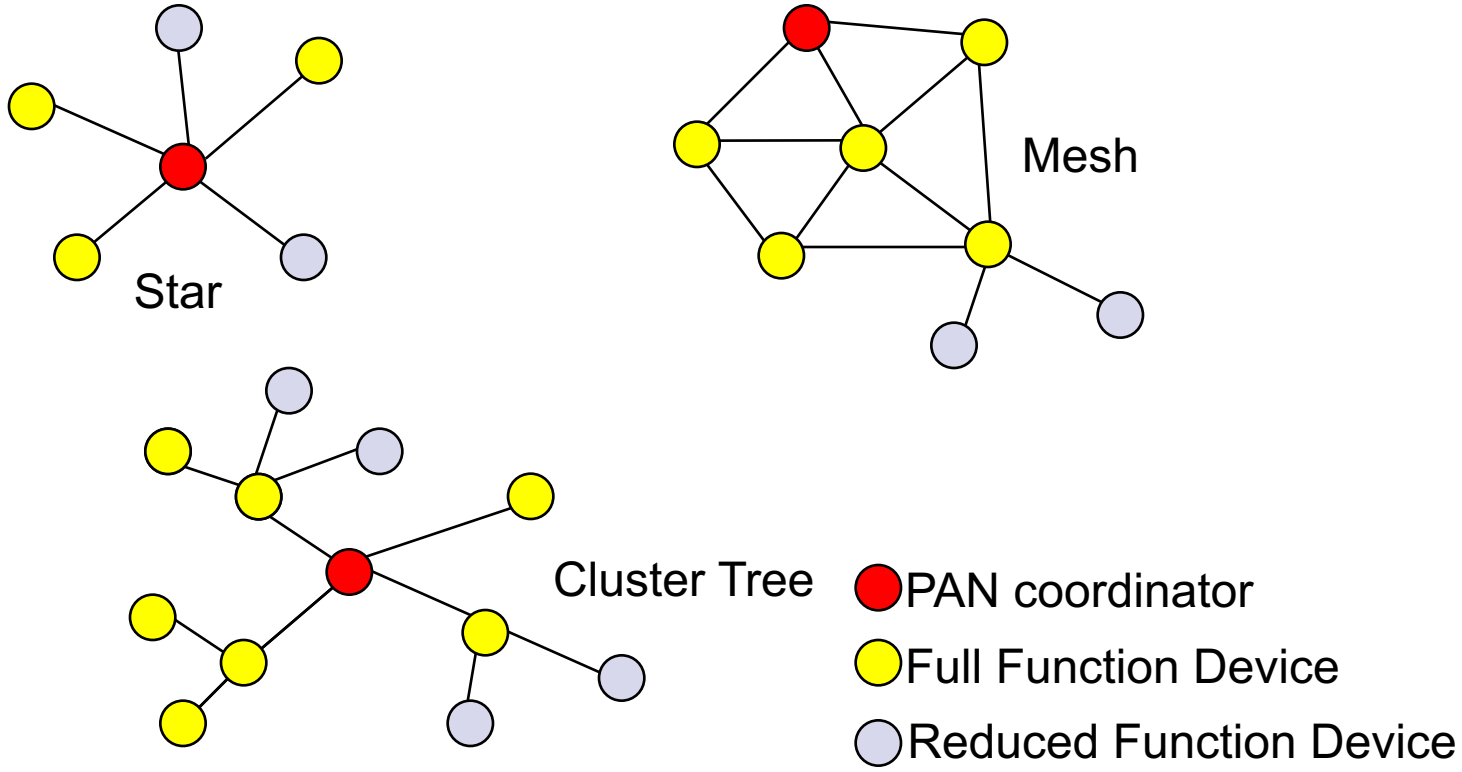
- Frame Types
  - Data Frame
    - used for all transfers of data
  - Beacon Frame
    - used by a coordinator to transmit beacons
  - Acknowledgment Frame
    - used for confirming successful frame reception
  - MAC Command Frame
    - used for handling all MAC peer entity control transfers

IEEE 802.15.4 MAC Layer



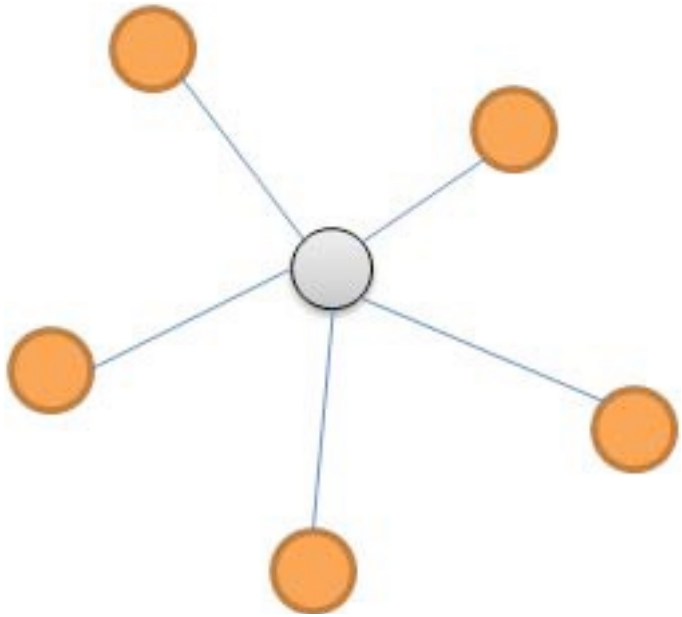
- Transmission Mode
  - Slotted (Beacon enable mode)
    - Periodic data and Repetitive low latency data.
  - Un-slotted (Non-Beacon enable mode)
    - Intermittent data.

ZigBee Network Topologies



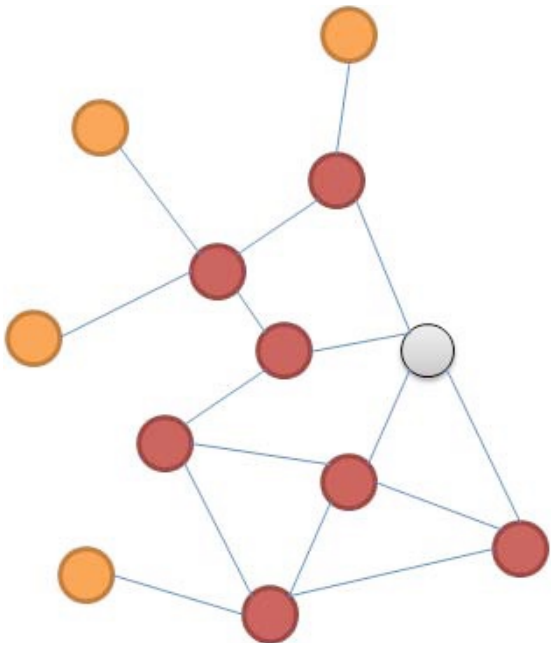
ZigBee Network Topologies

- Star Topology
  - Advantage
    - Easy to synchronize
    - Low latency
  - Disadvantage
    - Small scale



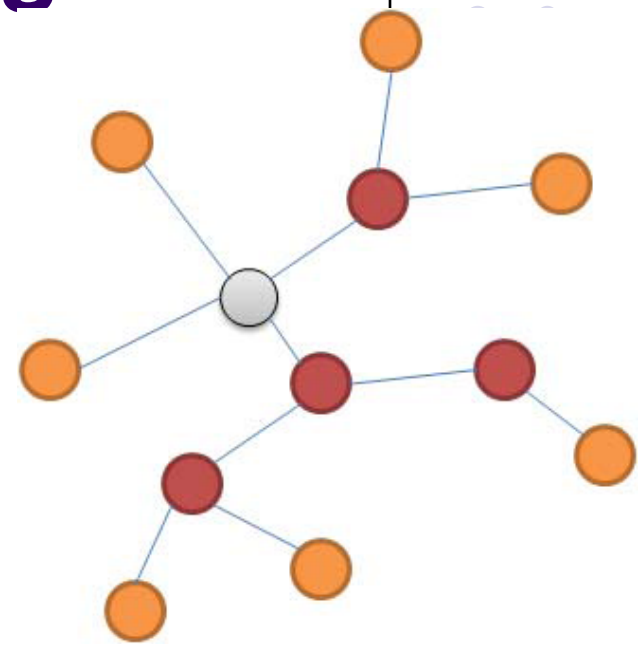
ZigBee Network Topologies

- Mesh Topology
  - Advantage
    - Robust multihop communication
    - Network is more flexible
    - Lower latency
  - Disadvantage
    - Route discovery is costly
    - Needs storage for routing table

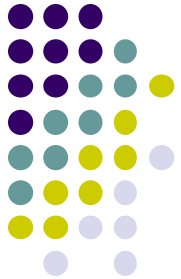


ZigBee Network Topologies

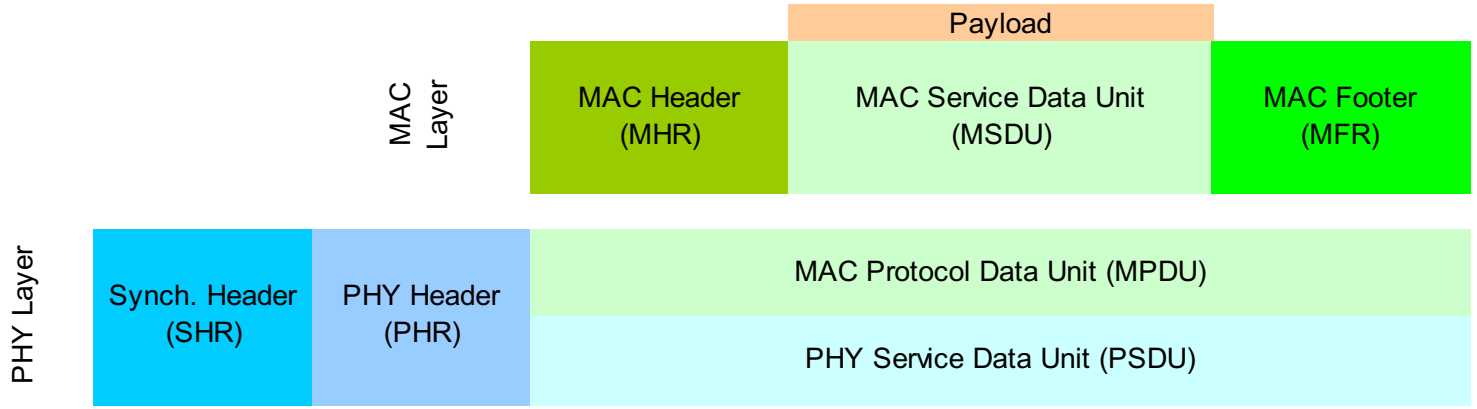
- Cluster Tree
  - Advantage
    - Low routing cost
    - Allow multihop communication
  - Disadvantage
    - Route reconstruction is costly
    - Latency may be quite long



IEEE 802.15.4 MAC Overview



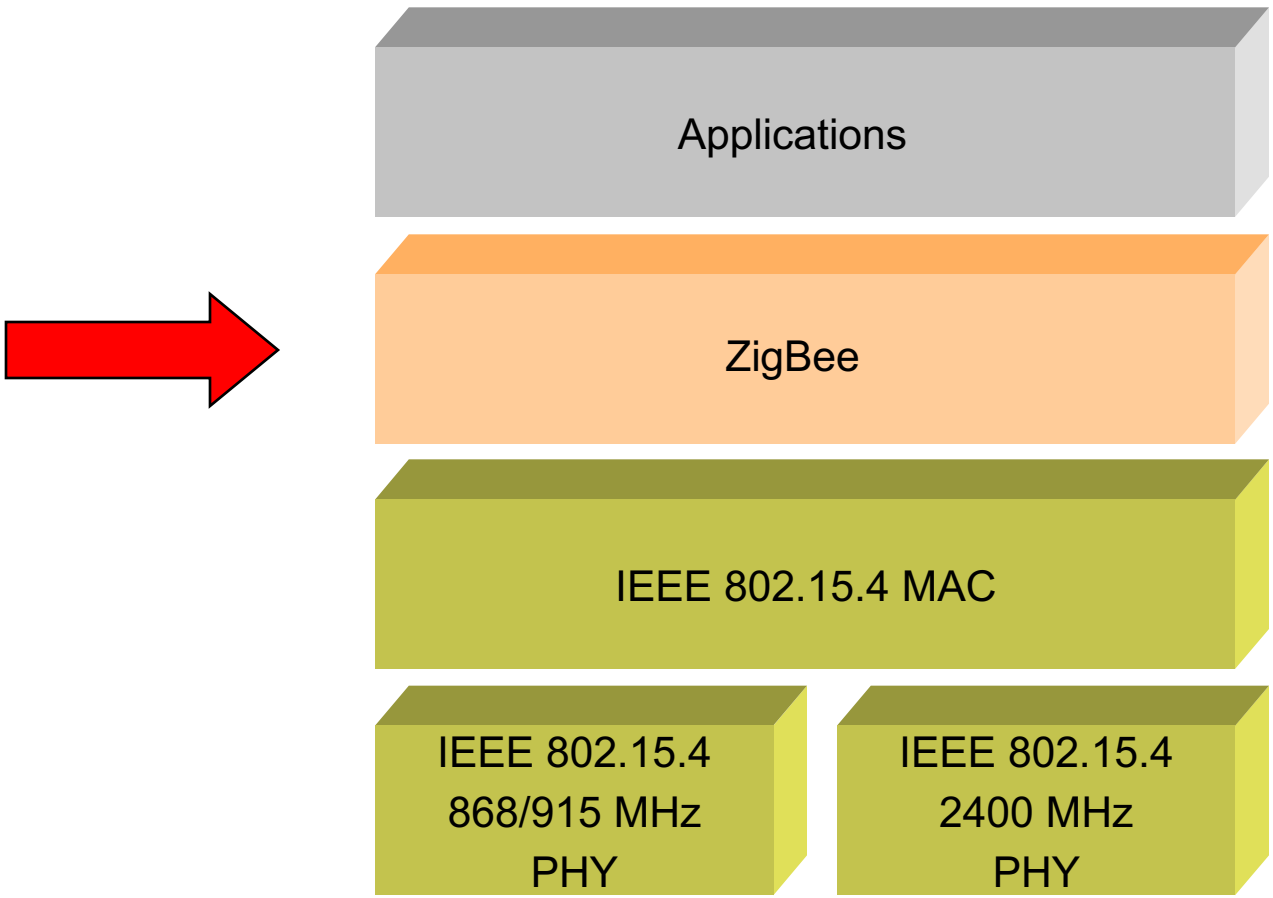
General Frame Structure



4 Types of MAC Frames:

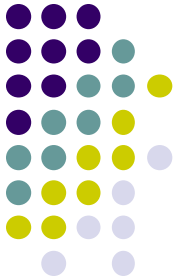
- Data Frame
- Beacon Frame
- Acknowledgment Frame
- MAC Command Frame

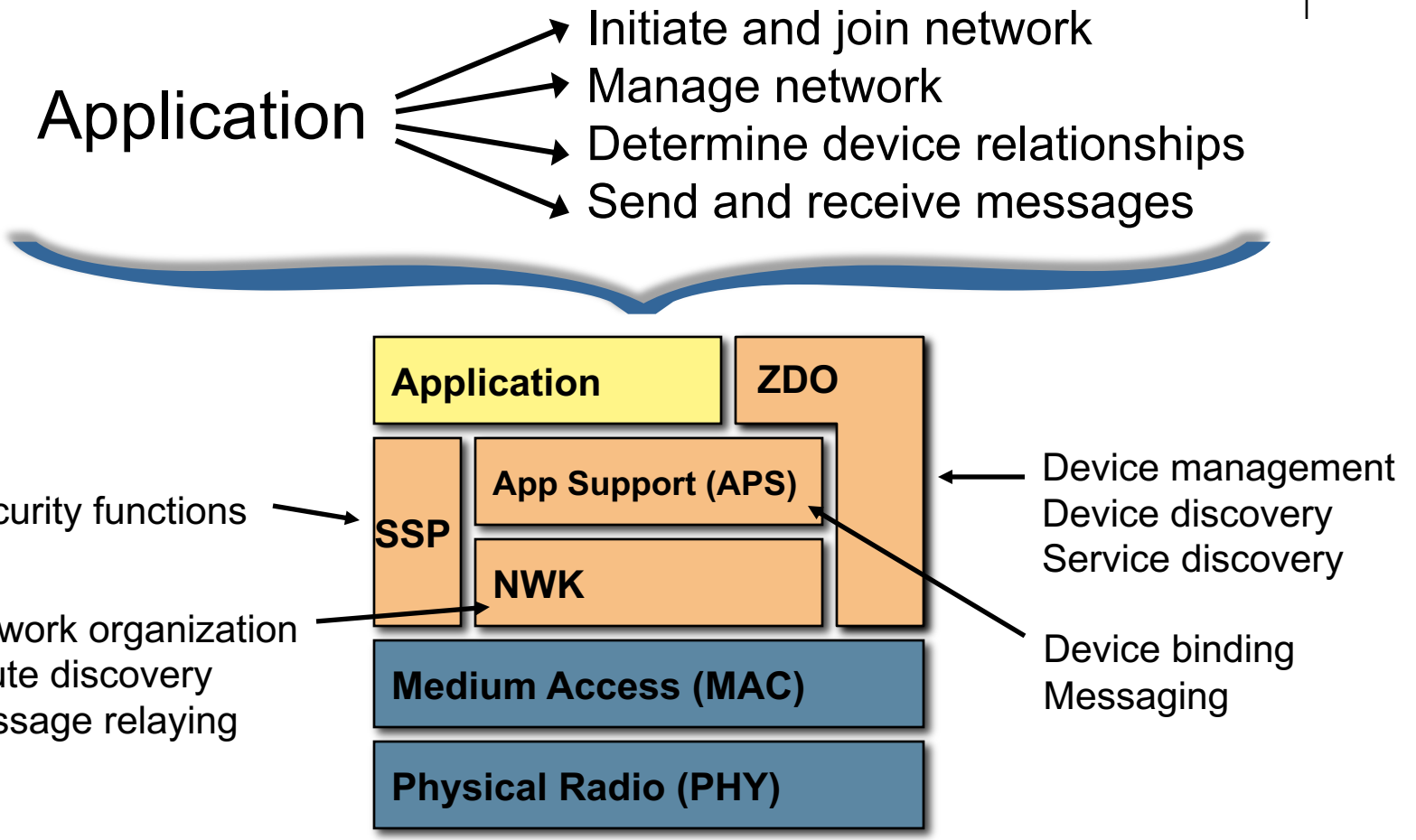
802.15.4 Architecture



- **Network Routing**
- **Address translation**
- **Packet Segmentation**
- **Profiles**

ZigBee Stack Architecture





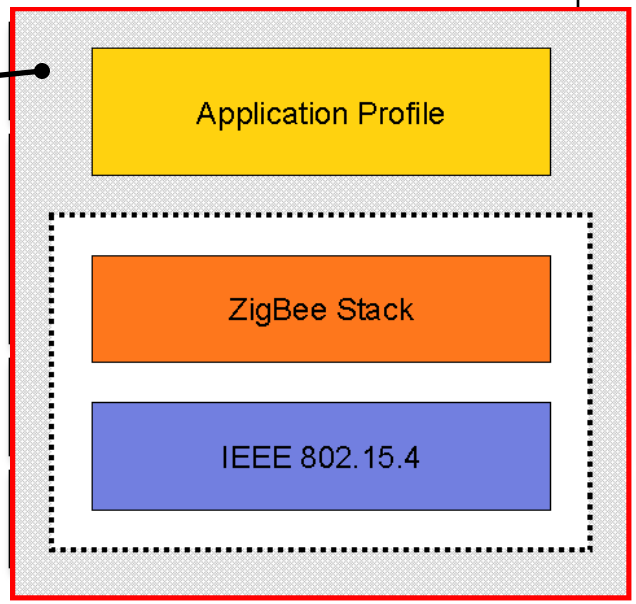
Application Profiles

Clusters

0: off
1: on
2: scene 1
3: scene 2

Clusters

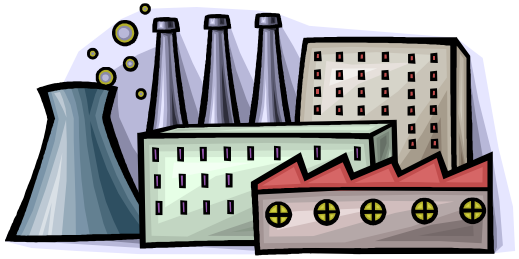
0: fan off
1: fan on
2: temp set
3: time set



- Application profiles define what messages are sent over the air for a given application
- Devices with the same application profiles interoperate end to end
- ZigBee publishes a set of public profiles, but vendors may create manufacturer specific ones as well

Some Application Profiles

- Home Automation [HA]
  - Defines set of devices used in home automation
    - Light switches
    - Thermostats
    - Window shade
    - Heating unit
    - etc.



- Industrial Plant Monitoring
  - Consists of device definitions for sensors used in industrial control
    - Temperature
    - Pressure sensors
    - Infrared
    - etc.

Reference

- Comparing Low-Power Wireless Technologies
  - https://www.digikey.com/en/articles/techzone/2017/oct/comparing-low-power-wireless-technologies