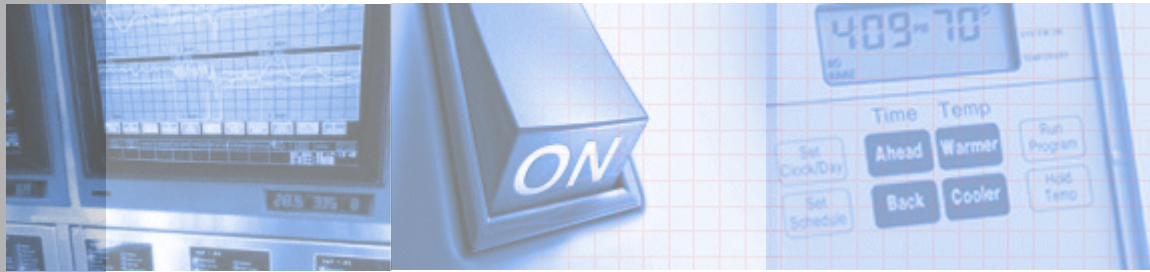




ZigBee:

An Overview of the Upcoming Standard



Introduction

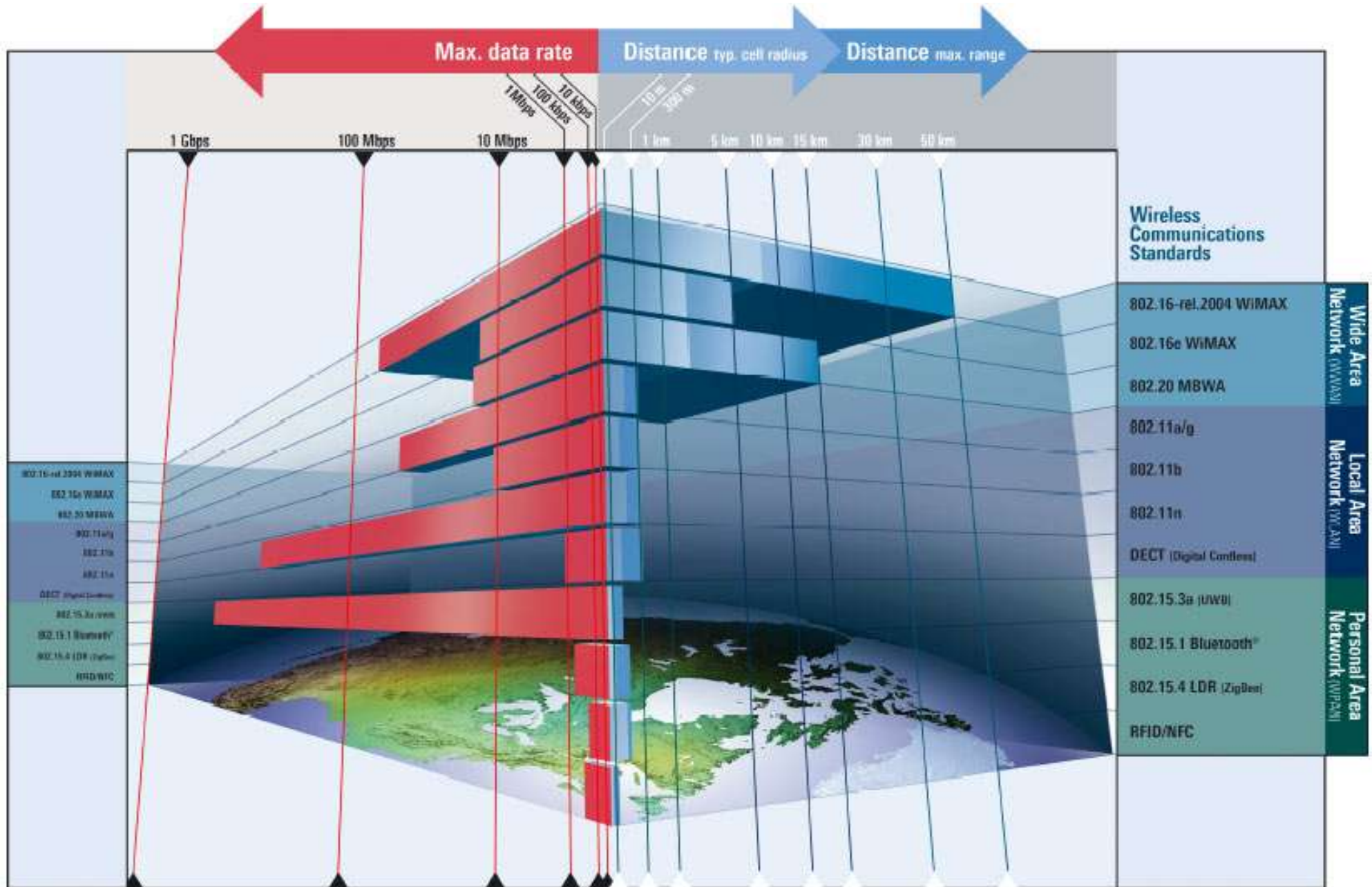
- The Wireless Market
- From Bluetooth to ZigBee
- History of ZigBee and ZigBee Alliance

Technical Aspects

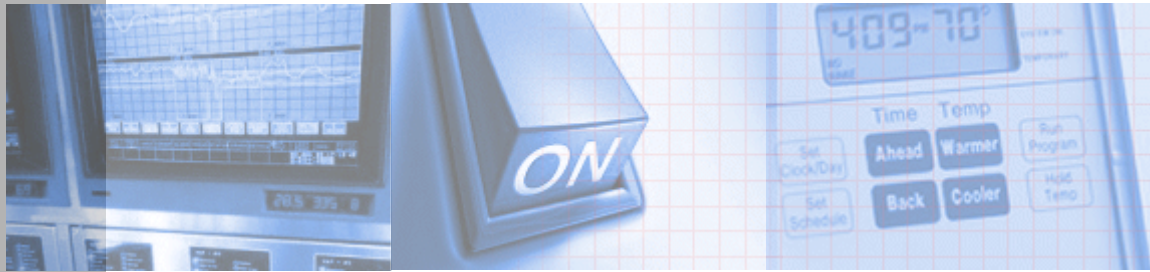
Applications & Examples

Summary

The Wireless Market



Picture: www.rohde-schwarz.com



Introduction

- The Wireless Market
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Technical Aspects

Applications & Examples

Summary



- ▶ Uses ISM-Band 2.4 GHz
- ▶ 79 Channels / Frequency Hopping
- ▶ 1600 hops/s
- ▶ One Master – up to 7 Slaves form a Piconet
- ▶ Active and “parked” devices
- ▶ Uses inquiry to find communication partners (up to several seconds)

Competition or Complementary ?

| | Bluetooth (v1) | ZigBee |
|-------------------|----------------------|------------------|
| Protocol Stack | 250 kb | < 32 kb (4kb) |
| Range | 10 - 100 meters | 30 - 100 meters |
| Link Rate | 1 Mbps | 250 kbps |
| Battery | rechargeable | non-rechargeable |
| Devices | 8 | 2 ¹⁶ |
| Air Interface | FHSS | DSSS |
| Usage | frequently | infrequently |
| Network Join Time | long | short |
| Extendability | no | yes |
| Security | PIN, 64 bit, 128 Bit | 128 bit, AES |

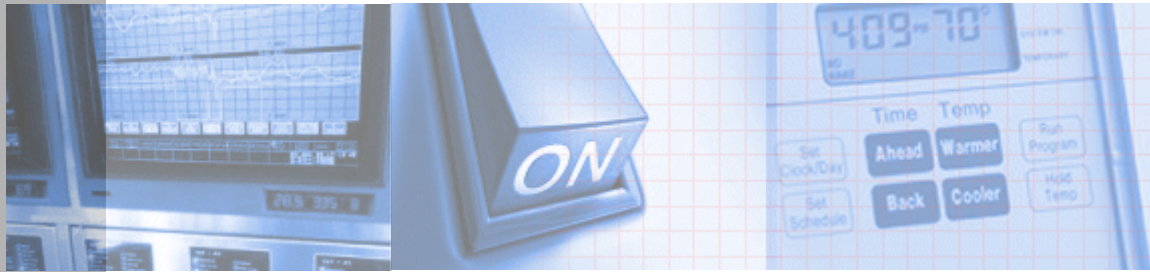
ZigBee Targets



- ▶ Low power consumption
- ▶ Simple Design
- ▶ Few costs

- ▶ Applications
 - ▶ Controlling
 - ▶ Monitoring





Introduction

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- History of ZigBee and ZigBee Alliance

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Applications & Examples

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History

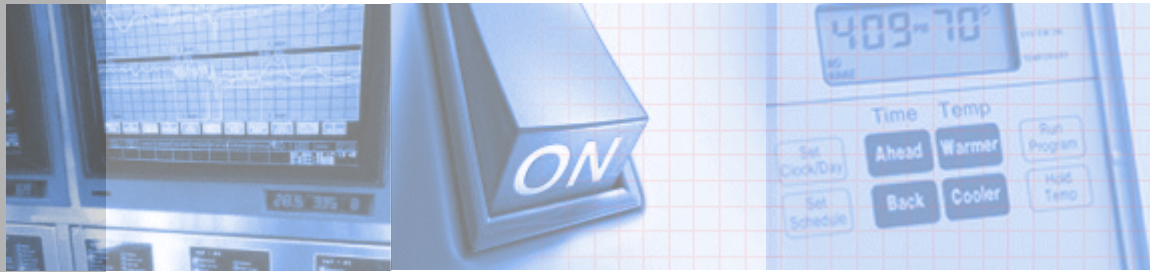


| | | | | | | | |
|------|------|------|------|------|------|------|------|
| 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|------|------|------|------|------|------|------|------|



ZigBee Alliance

- ▶ An industry consortium consisting of
 - ▶ Leading semiconductor manufacturers
 - ▶ Technology providers
 - ▶ OEM's
 - ▶ End-users
- ▶ Define a global standard for monitoring and control products
- ▶ **ZigBee is not OpenSource!**
- ▶ Membership Forms:
 - ▶ Promoter (\$ 40'000 / year)
 - ▶ Participant (\$ 9'500 / year)
 - ▶ Adopter (\$ 3'500 / year)



Introduction

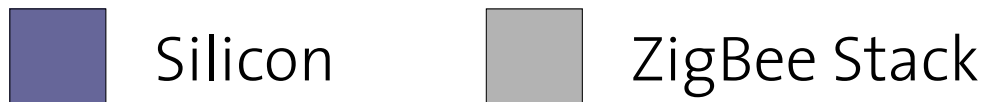
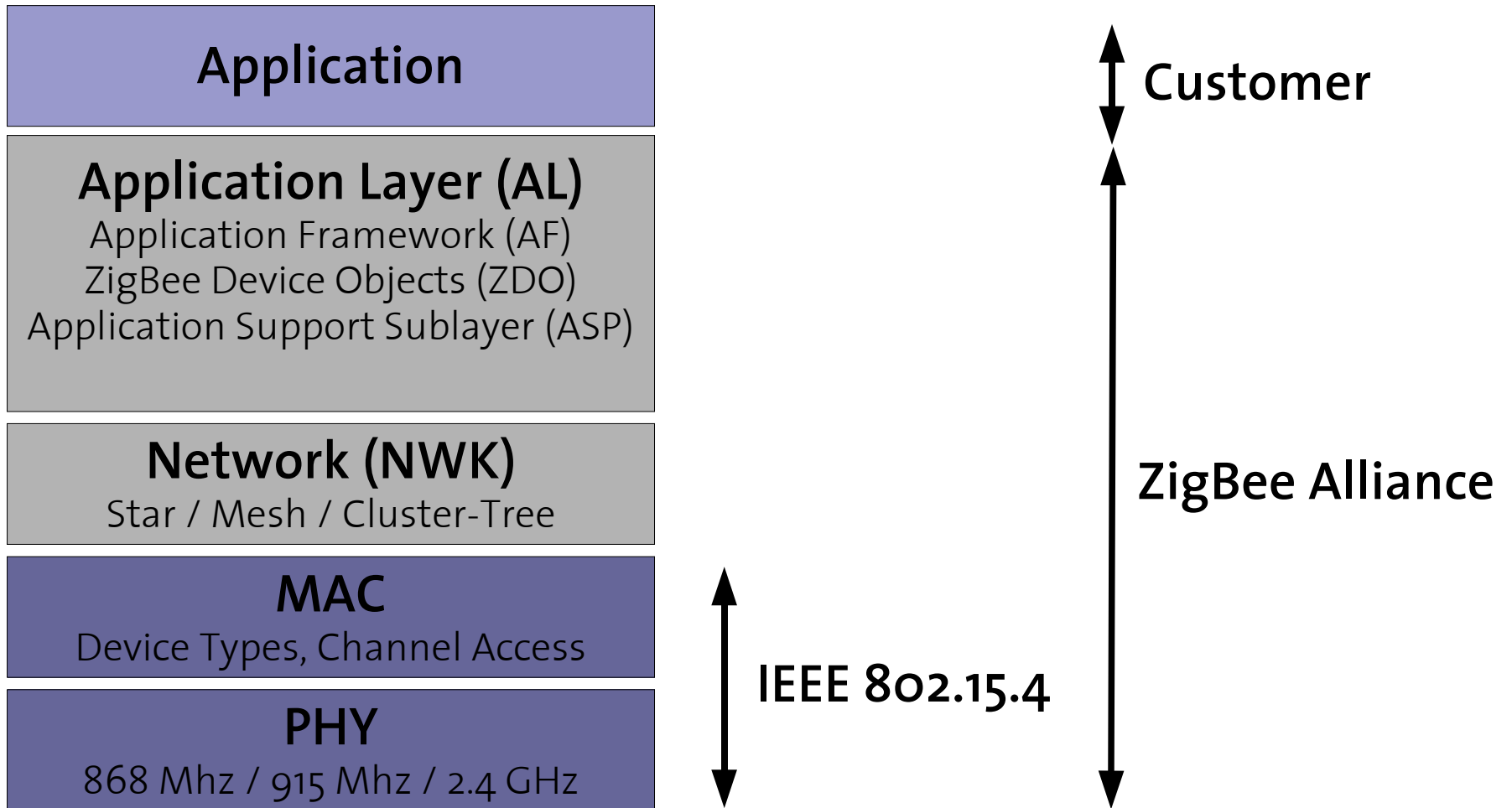
Technical Aspects

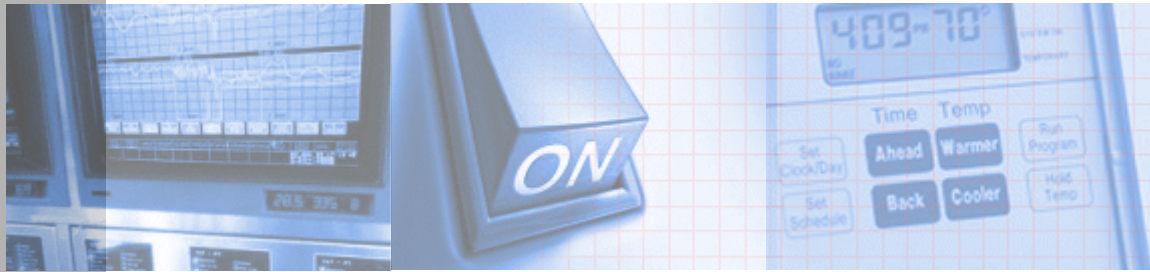
- Overview / ZigBee Protocol Stack
- IEEE-Standard 802.15.4
- ZigBee Upper Layers

Applications & Examples

Summary

ZigBee Protocol Stack





Introduction

Technical Aspects

- Overview / ZigBee Protocol Stack
- IEEE-Standard 802.15.4
- ZigBee Upper Layers

Applications & Examples

Summary

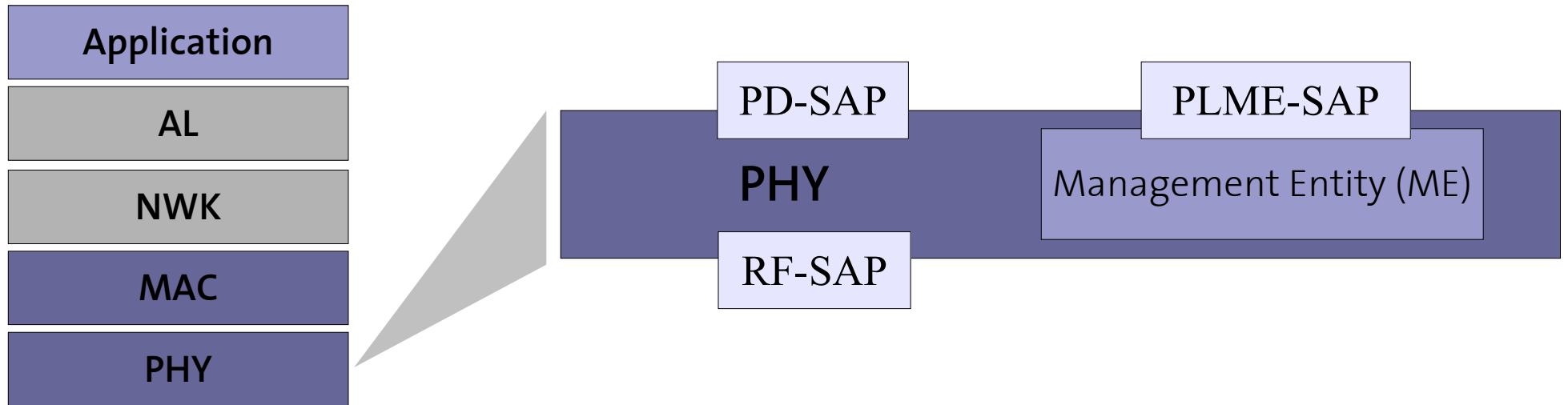
MAC

Device Types, Channel Access

PHY

2.4 Ghz / 915 Mhz / 868 Mhz
ED, LQI, CCA

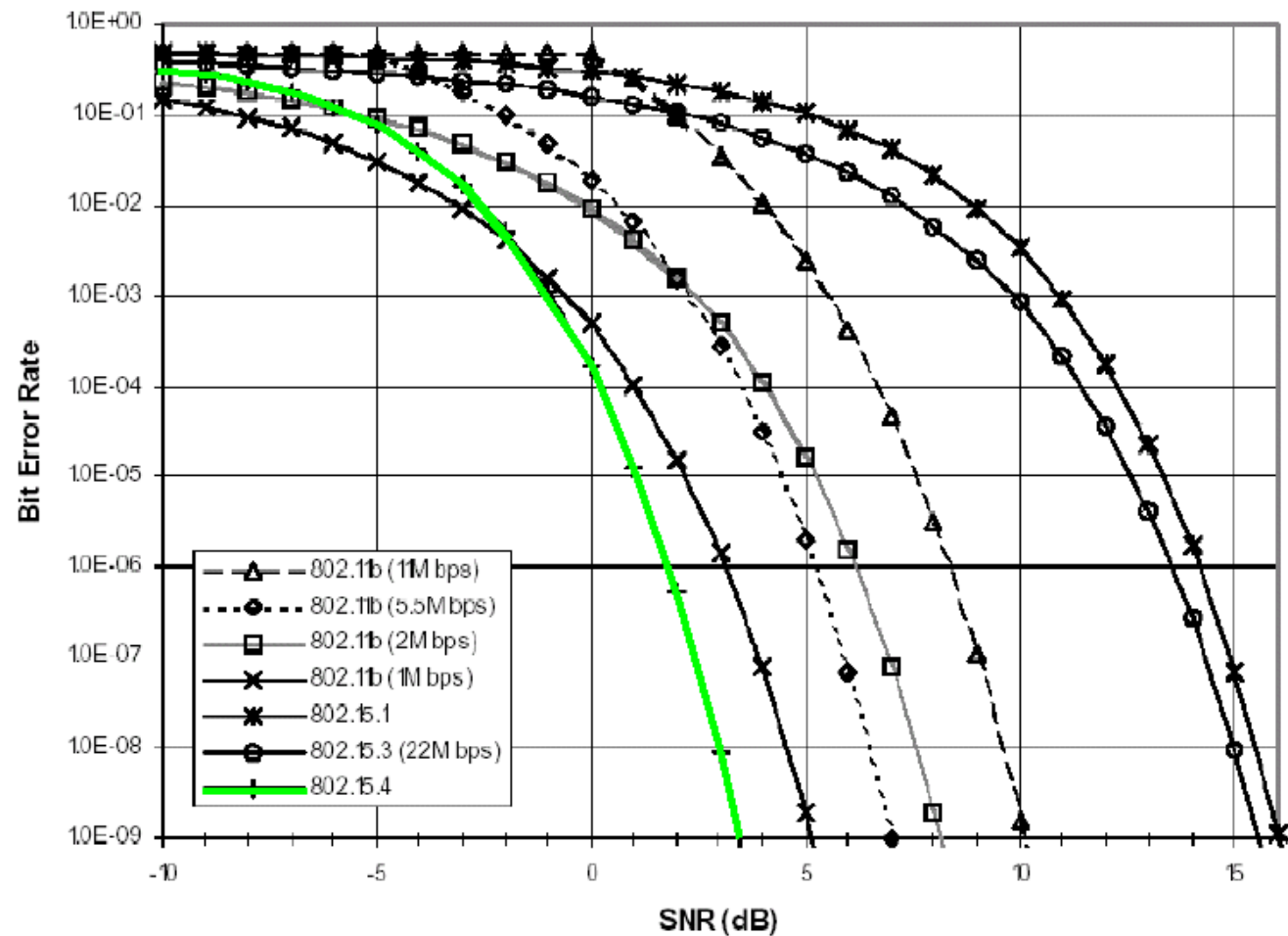
- ▶ IEEE 802.15.4 is a simple packet data protocol for lightweight wireless networks
- ▶ Focus on
 - ▶ Reliability
 - ▶ Simplicity
 - ▶ Low power
 - ▶ Low cost

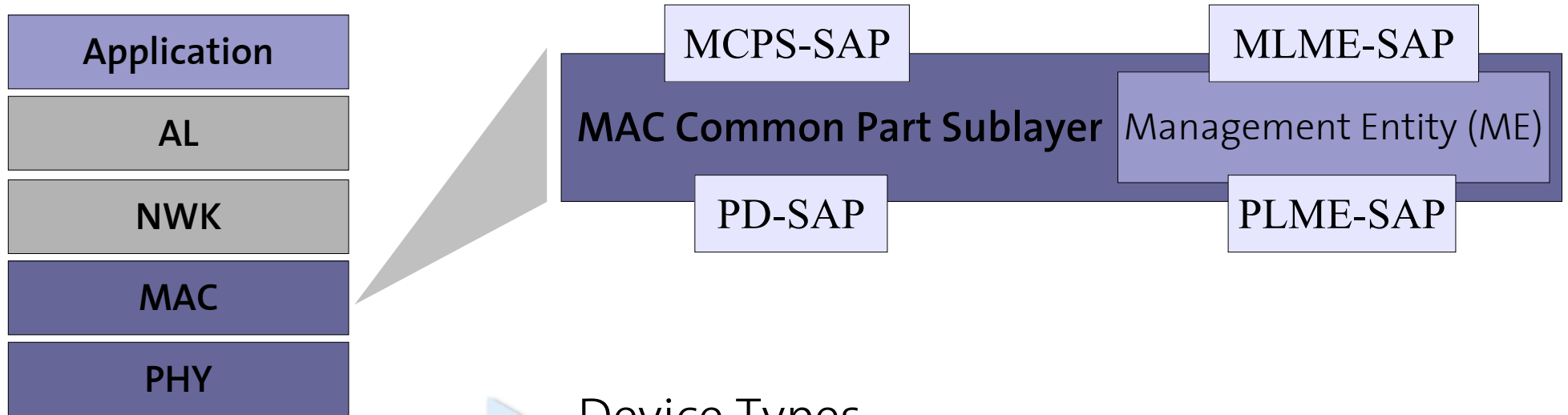


| | 2.4 GHz | 915 MHz | 868 MHz |
|-----------|-----------|---------|---------|
| Band | ISM | ISM | ISM |
| Coverage | Worldwide | America | Europe |
| Data Rate | 250 kbps | 40 kbps | 20 kbps |
| Channels | 16 | 10 | 1 |

802.15.4 has lowest error rate in environments with high noise

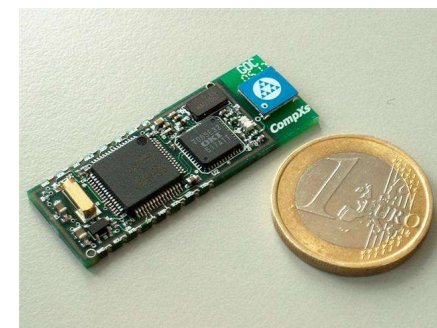
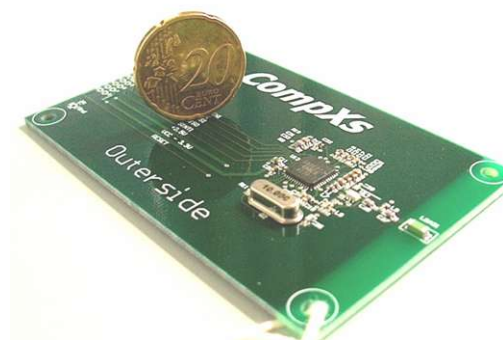
802.11b, 802.15.x BER Comparison





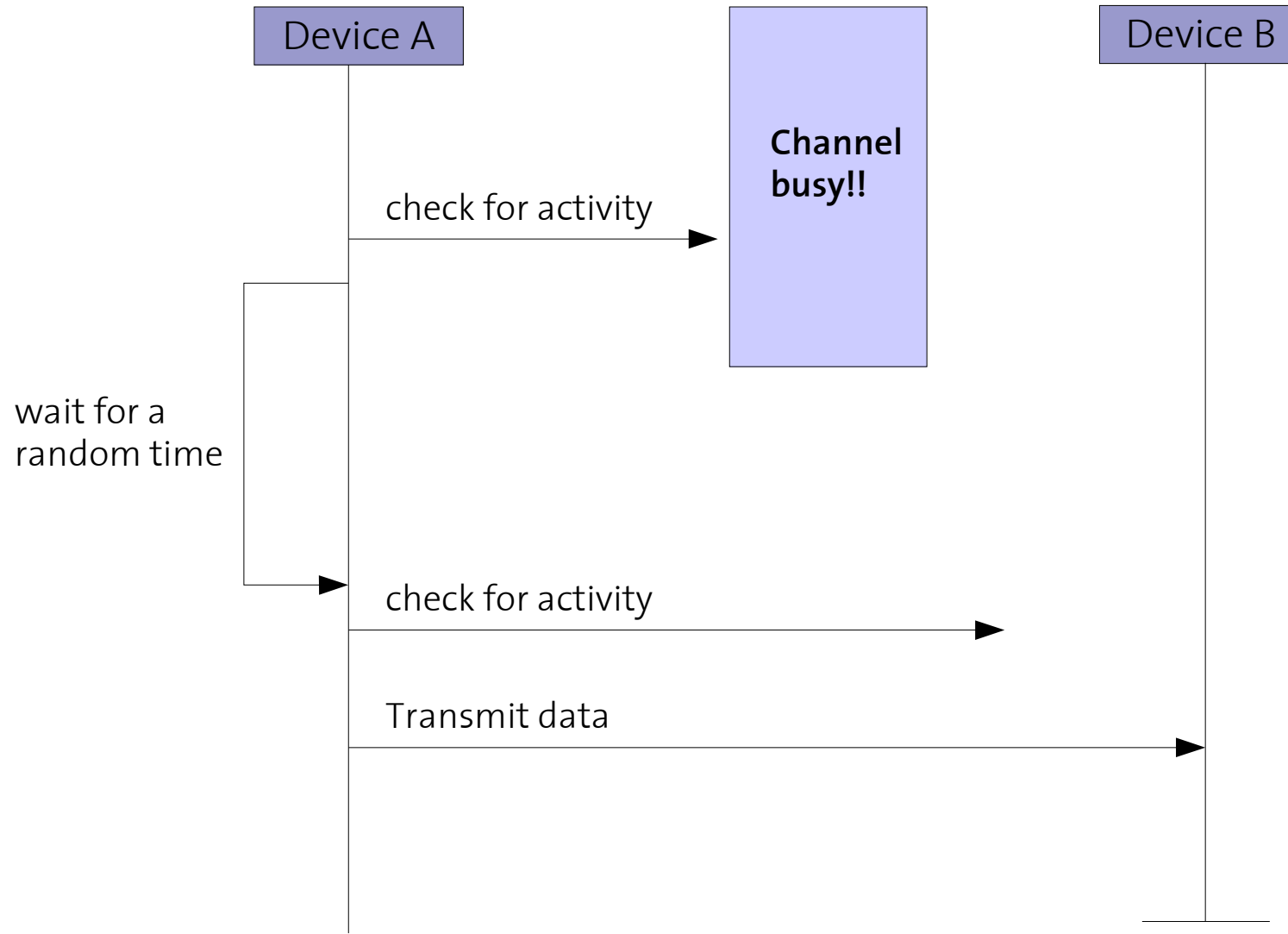
- ▶ Device Types
 - ▶ Full Function Device (FFD)
 - ▶ Reduced Function Device (RFD)
 - ▶ Network Coordinator
- ▶ Channel Access
 - ▶ Non Beacon Mode
 - ▶ Beacon Mode
- ▶ Security

- ▶ **Full Function Device (FFD)**
 - ▶ Network router function
 - ▶ Any Topology
- ▶ **Reduced Function Device (RFD)**
 - ▶ Easy and cheap to implement
 - ▶ Limited to star topology
- ▶ **Personal Area Network (PAN) Coordinator**
 - ▶ Maintains overall network knowledge
 - ▶ Needs most memory and computing power

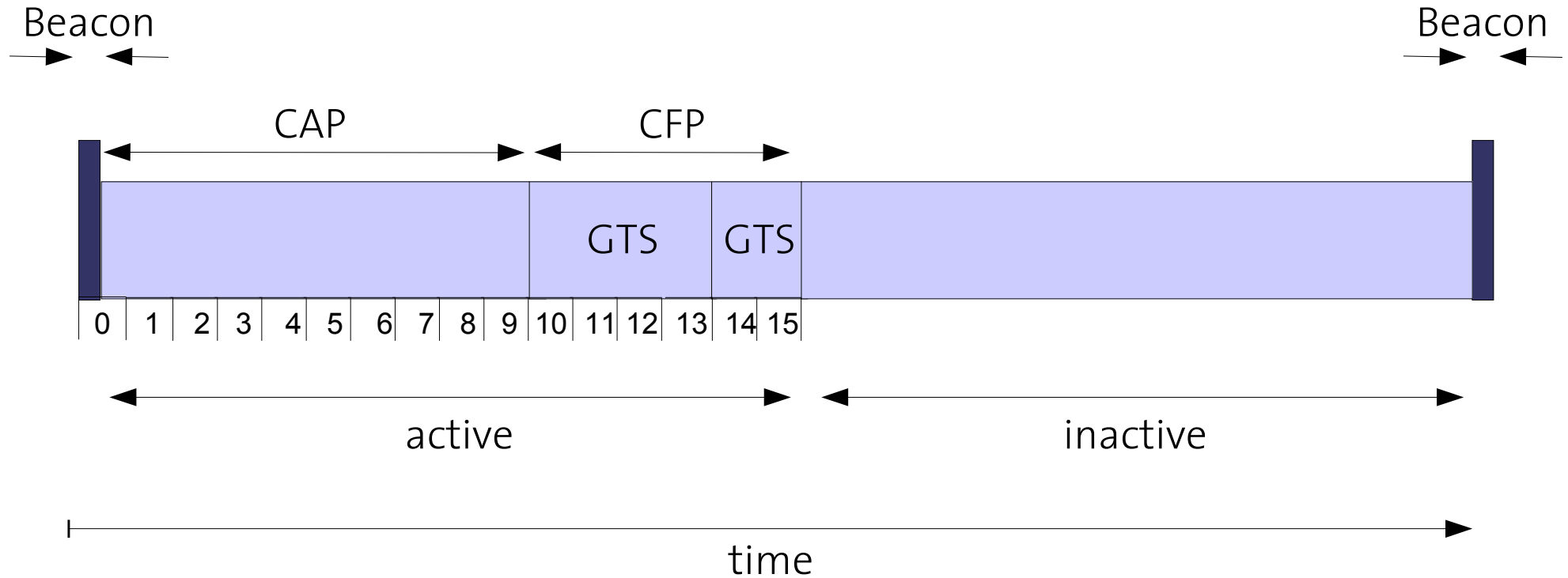


Pictures by: Integration Associates

CSMA/CA Method:



Superframe Structure:



CAP = Contention Access Period

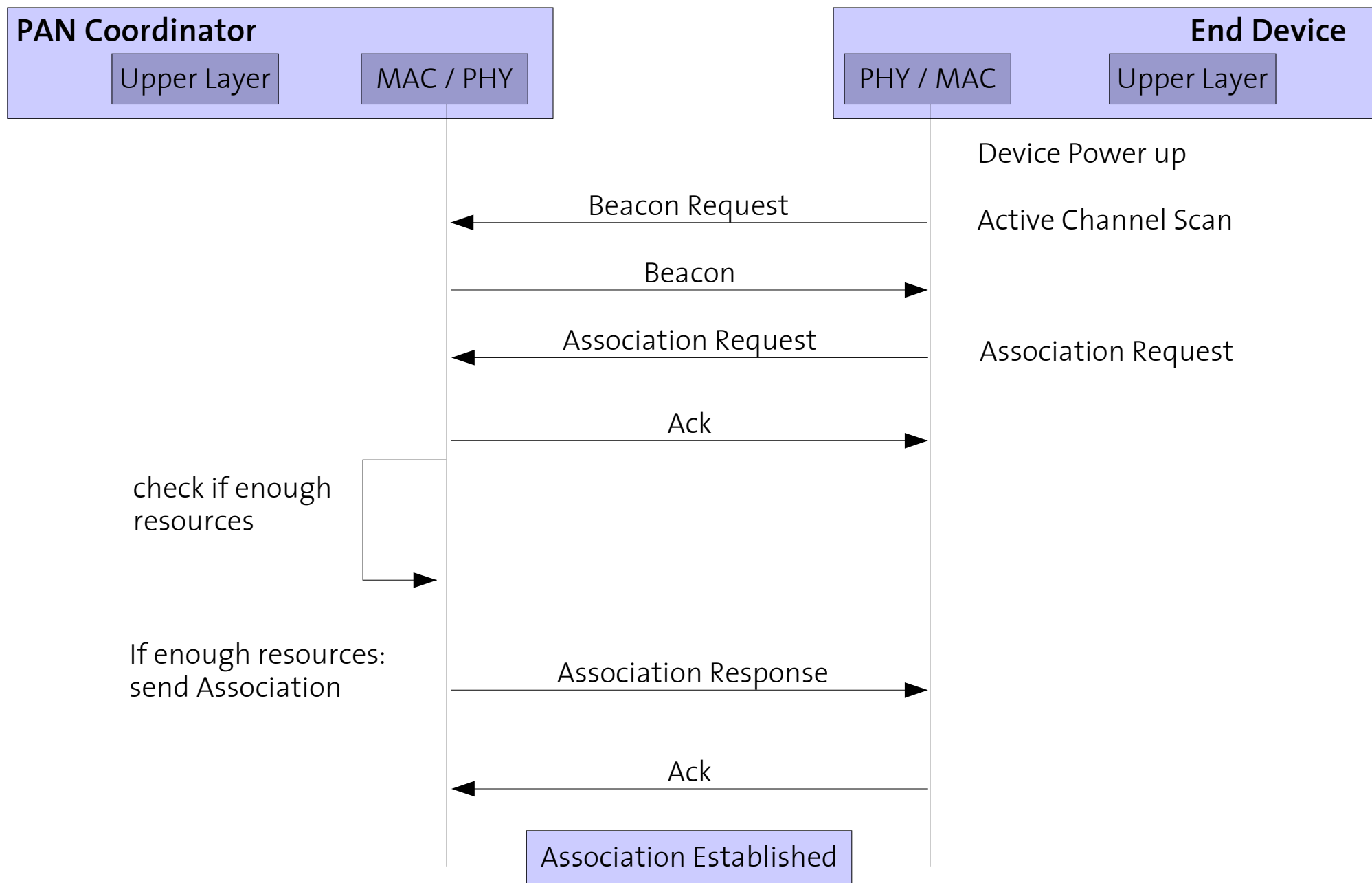
CFP = Contention Free Period

GTS = Guaranteed Time Slot

- ▶ **Device discovery**
 - ▶ Active: Send a beacon request
 - ▶ Passive: Listen on beacons
- ▶ **Association/Disassociation** is sent to the PAN coordinator
- ▶ Devices are accessed using
 - ▶ Full 64 Bit IEEE Addresses
 - ▶ Local 16 Bit Addresses



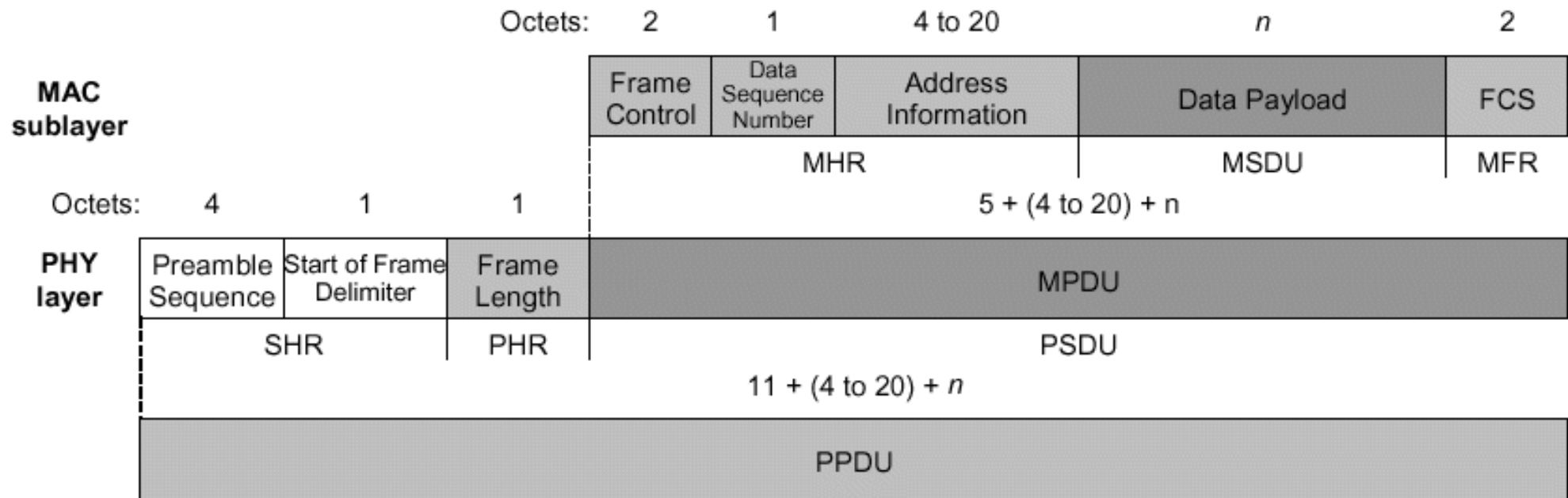
MAC Layer – Association



- ▶ **3 Security Levels**
 - ▶ Insecure
 - ▶ Access Control Lists (ACLs)
 - ▶ Symmetric Encryption
- ▶ **Advanced Encryption Standard (AES) 128 bit**
 - ▶ Confidentiality
 - ▶ Integrity
 - ▶ Authenticity
- ▶ Controlled by upper layers
- ▶ Authenticity using Message Authenticating Codes (MACs)
- ▶ Nonces are used for confidentiality
- ▶ Replay Attack resistant (freshness check)

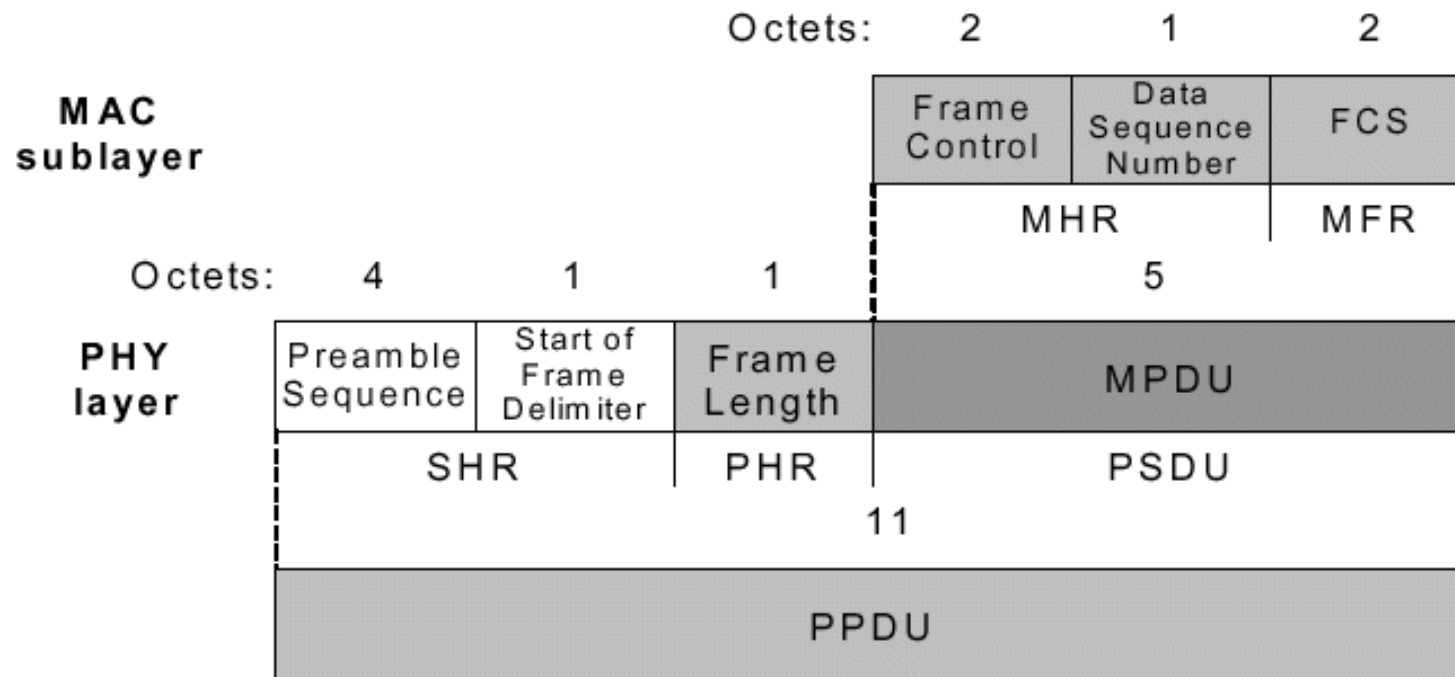


Packet Structure – Data Frame



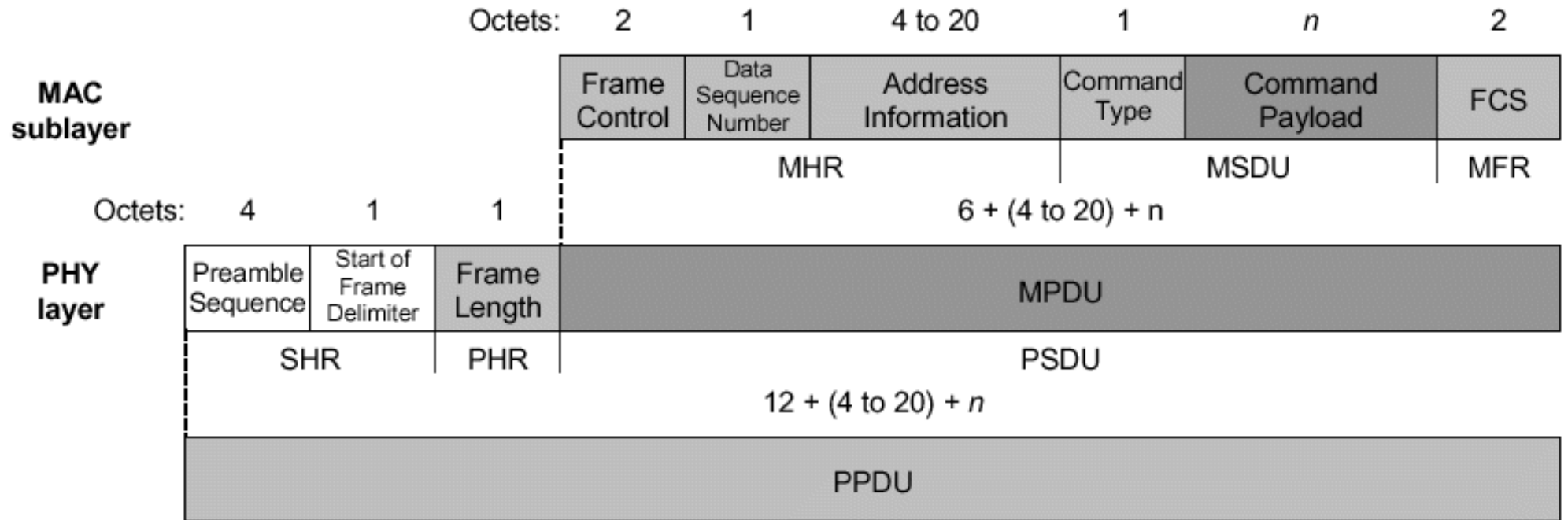
- Designed for minimum complexity
- PPDU = Physical Protocol Data Unit
- 4 different MAC Frames
 - Data Frame is most important one
 - Up to 104 byte payload
 - Data Sequence Numbering
 - FCS = Frame Check Sequence

Packet Structure – Acknowledgment Frame



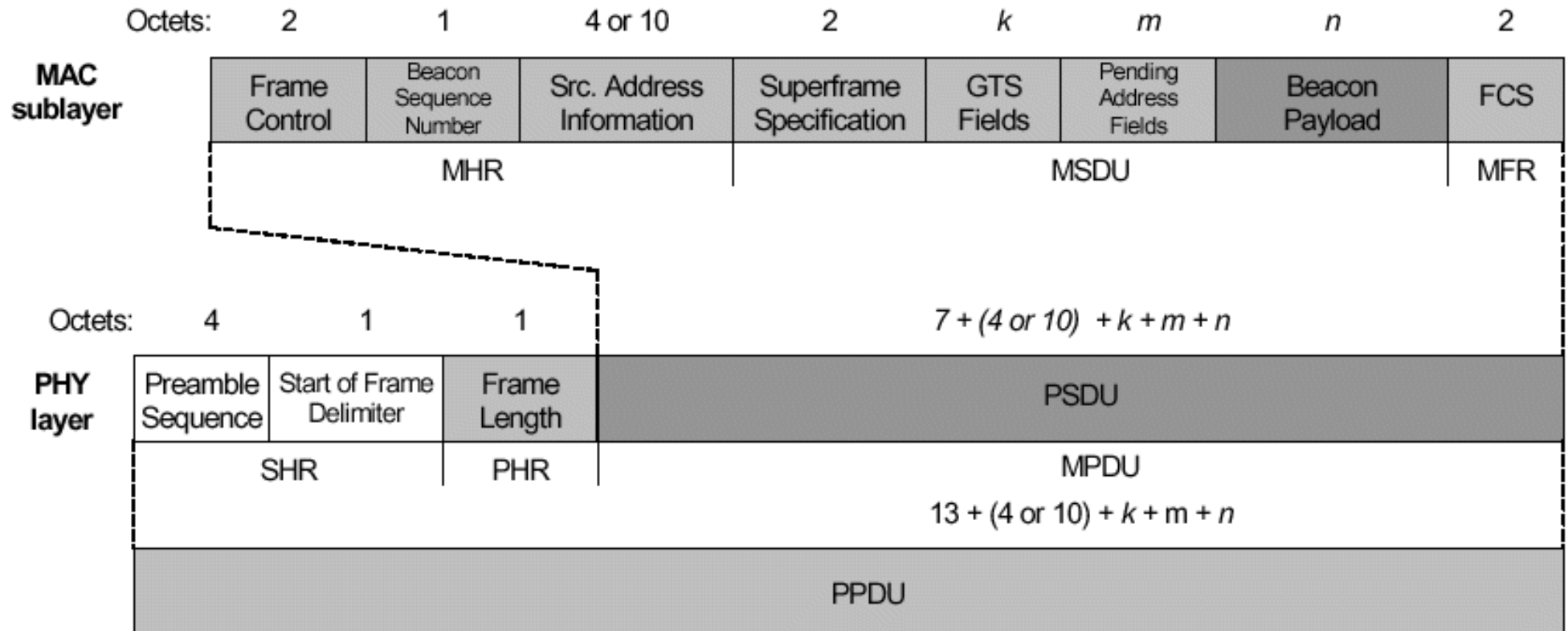
- ▶ Also very important frame
- ▶ Feedback from receiver to sender
- ▶ No payload

Packet Structure – MAC Command Frame

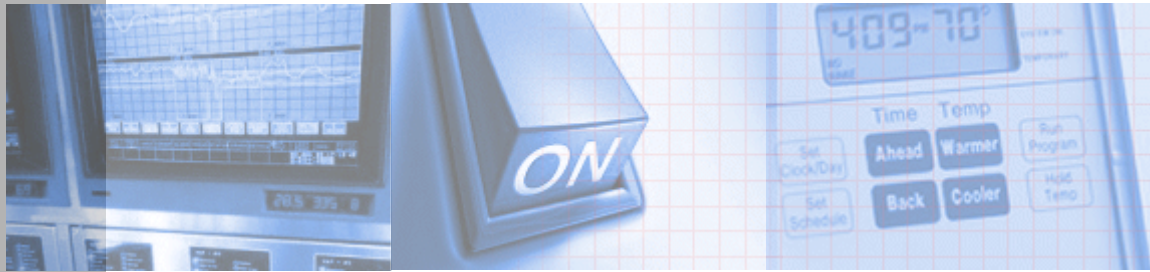


- Mechanism for remote control
- Centralized network manager can configure client

Packet Structure – Beacon Command Frame



▶ Used to transmit beacon broadcasts



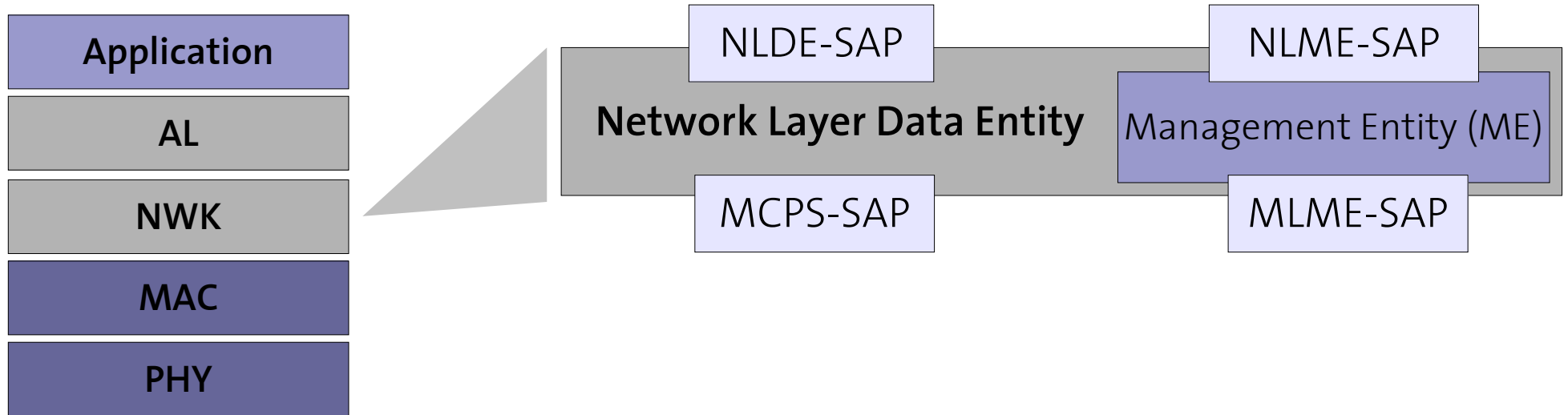
Introduction

Technical Aspects

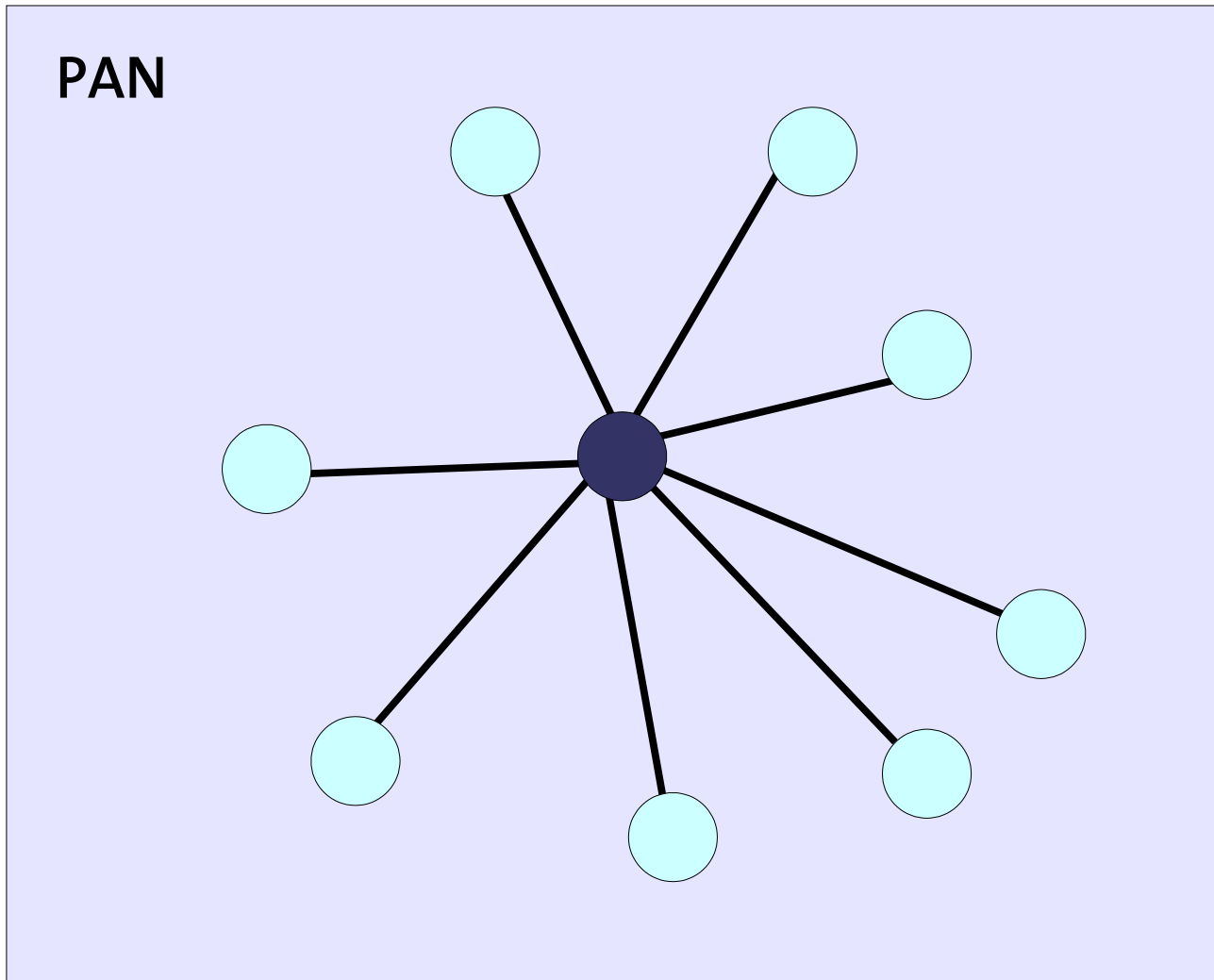
- Overview / ZigBee Protocol Stack
- IEEE-Standard 802.15.4
- ZigBee Upper Layers


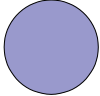
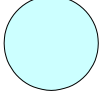
Applications & Examples

Summary

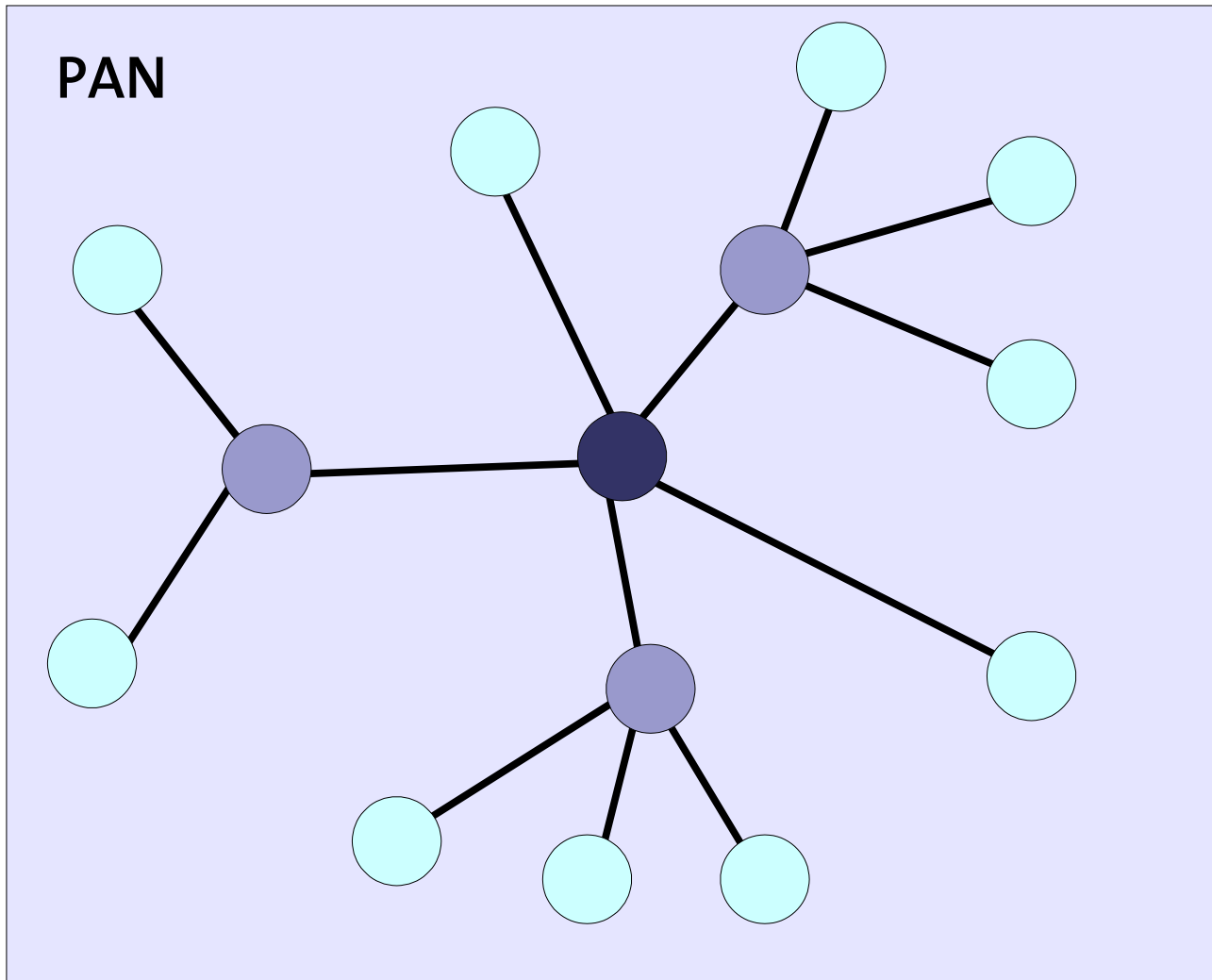



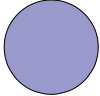
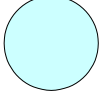
- Only in Full Function Devices (FFDs)
- Topology Models
 - Star
 - Cluster Tree
 - Mesh
- Packet Routing / Route Management
- Security



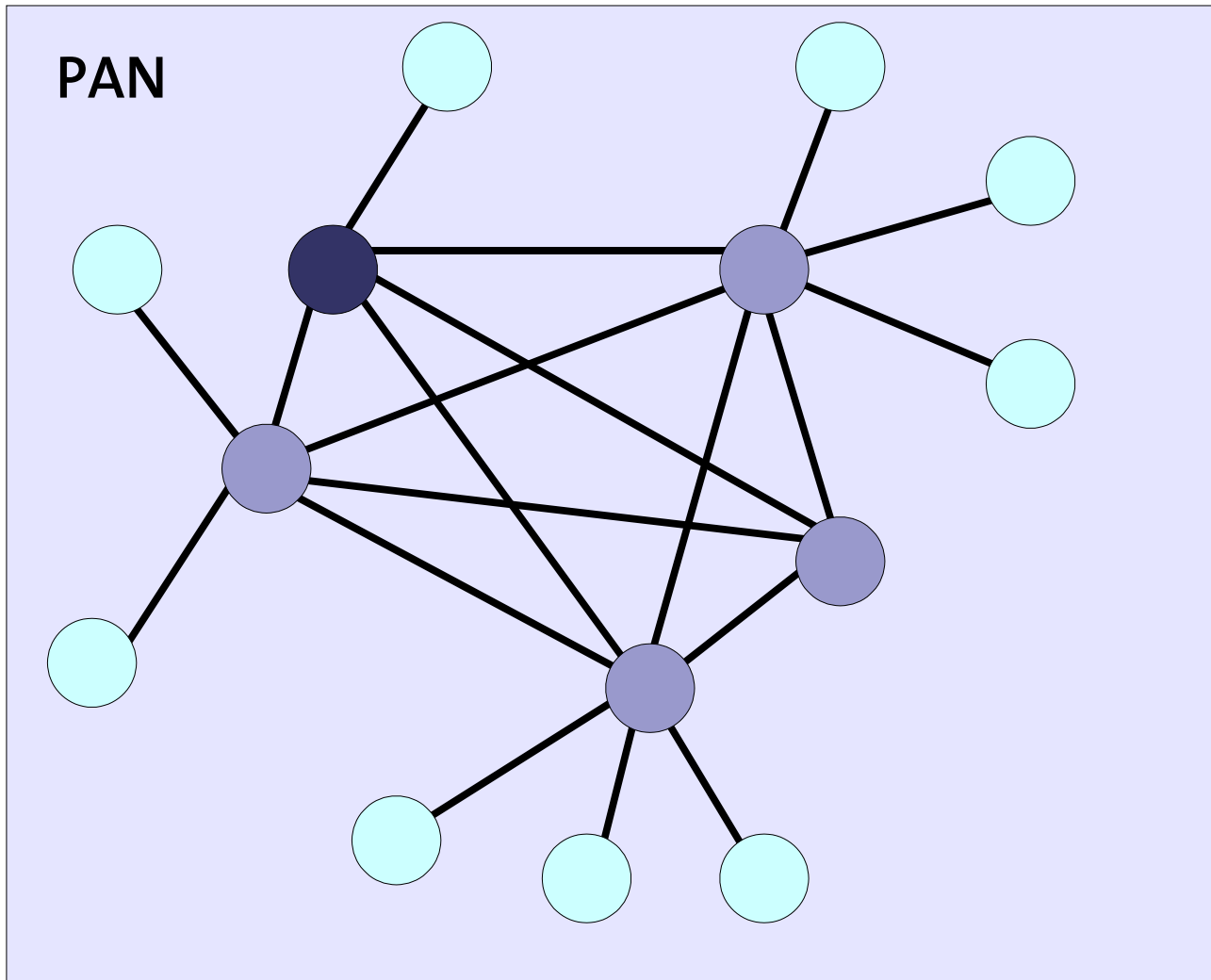
-  PAN Coordinator (FFD)
-  Router (FFD)
-  End Device (FFD or RFD)




Network Layer – Cluster Tree Topology



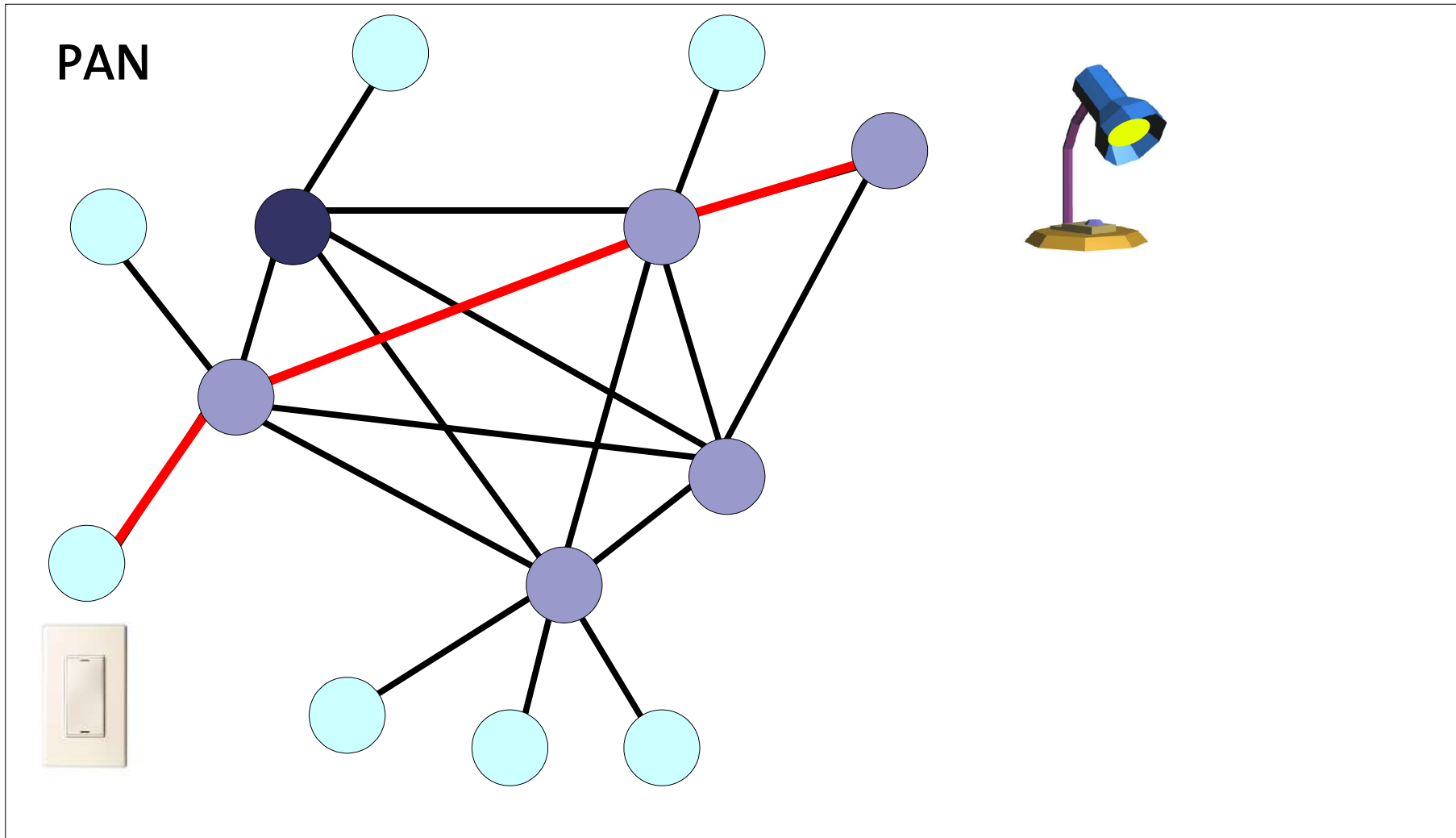
-  PAN Coordinator (FFD)
-  Router (FFD)
-  End Device (FFD or RFD)

Network Layer – Mesh Topology

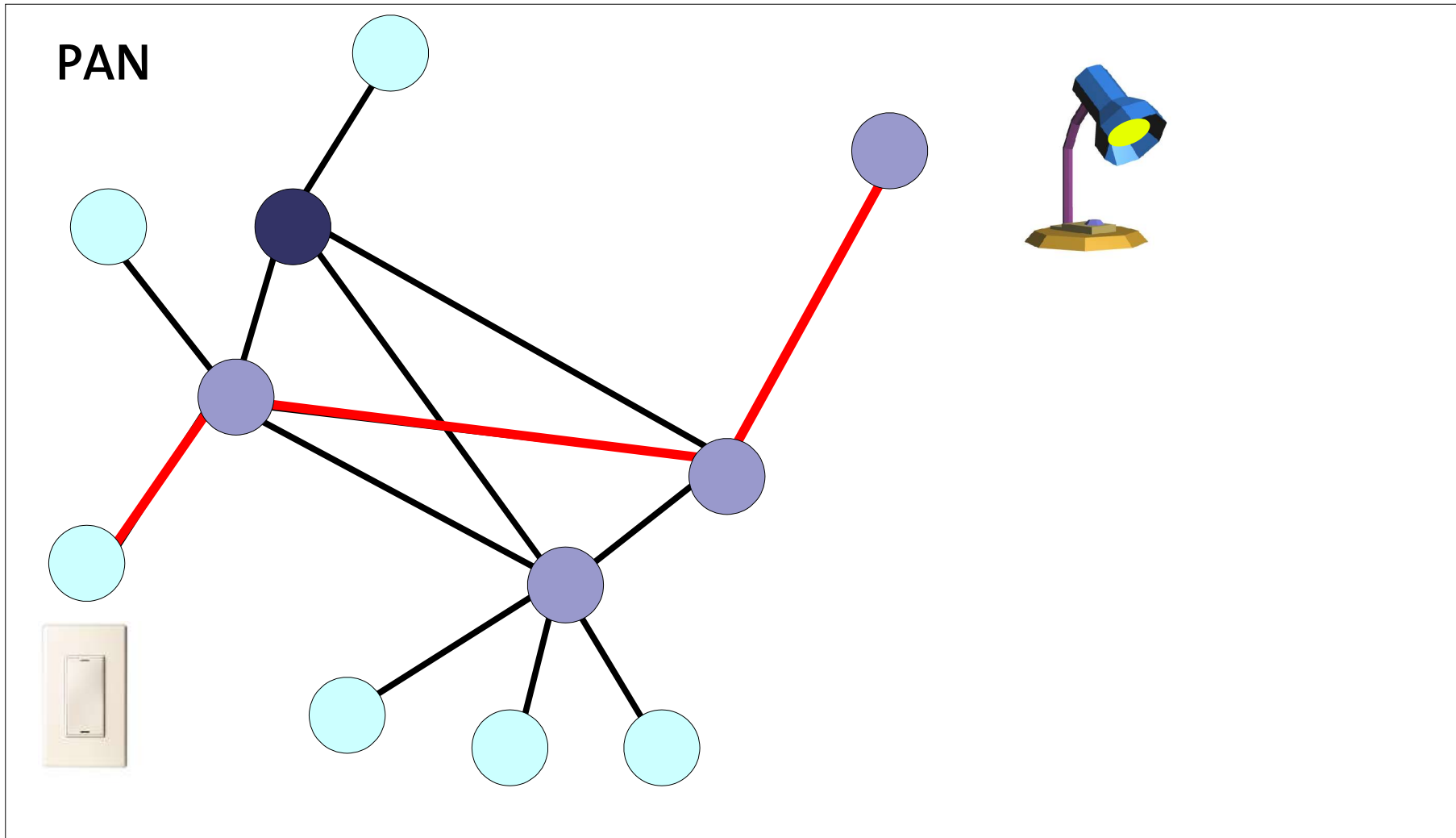


-  PAN Coordinator (FFD)
-  Router (FFD)
-  End Device (FFD or RFD)

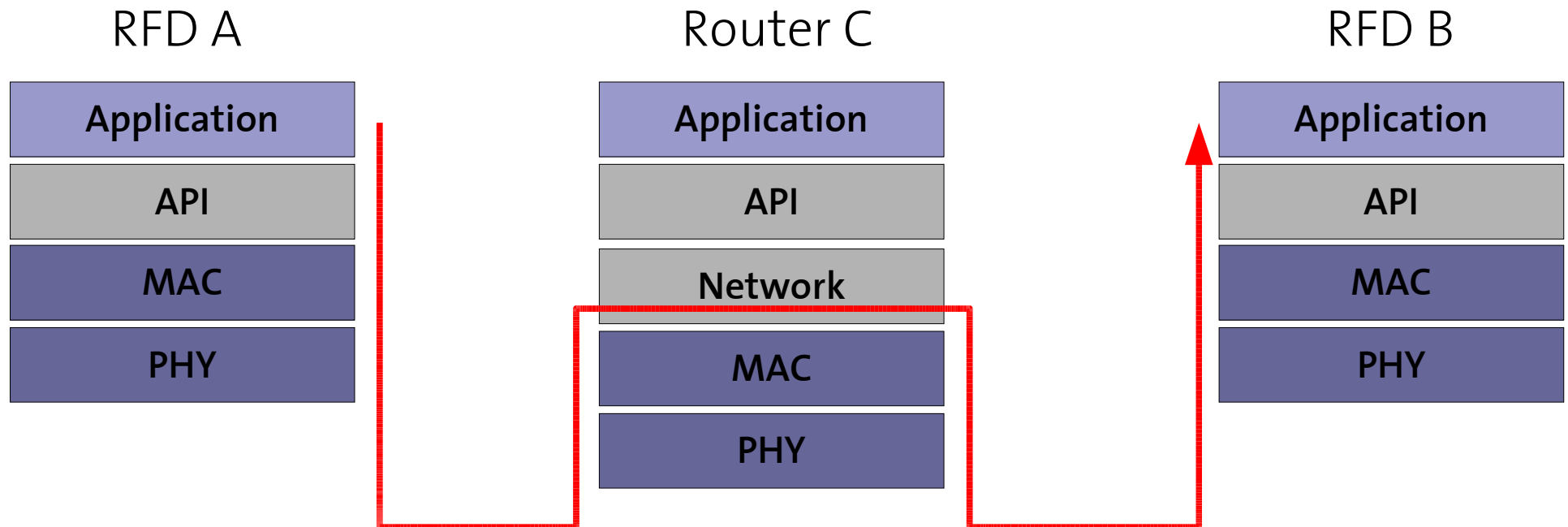
Network Layer – Mesh Topology – Example



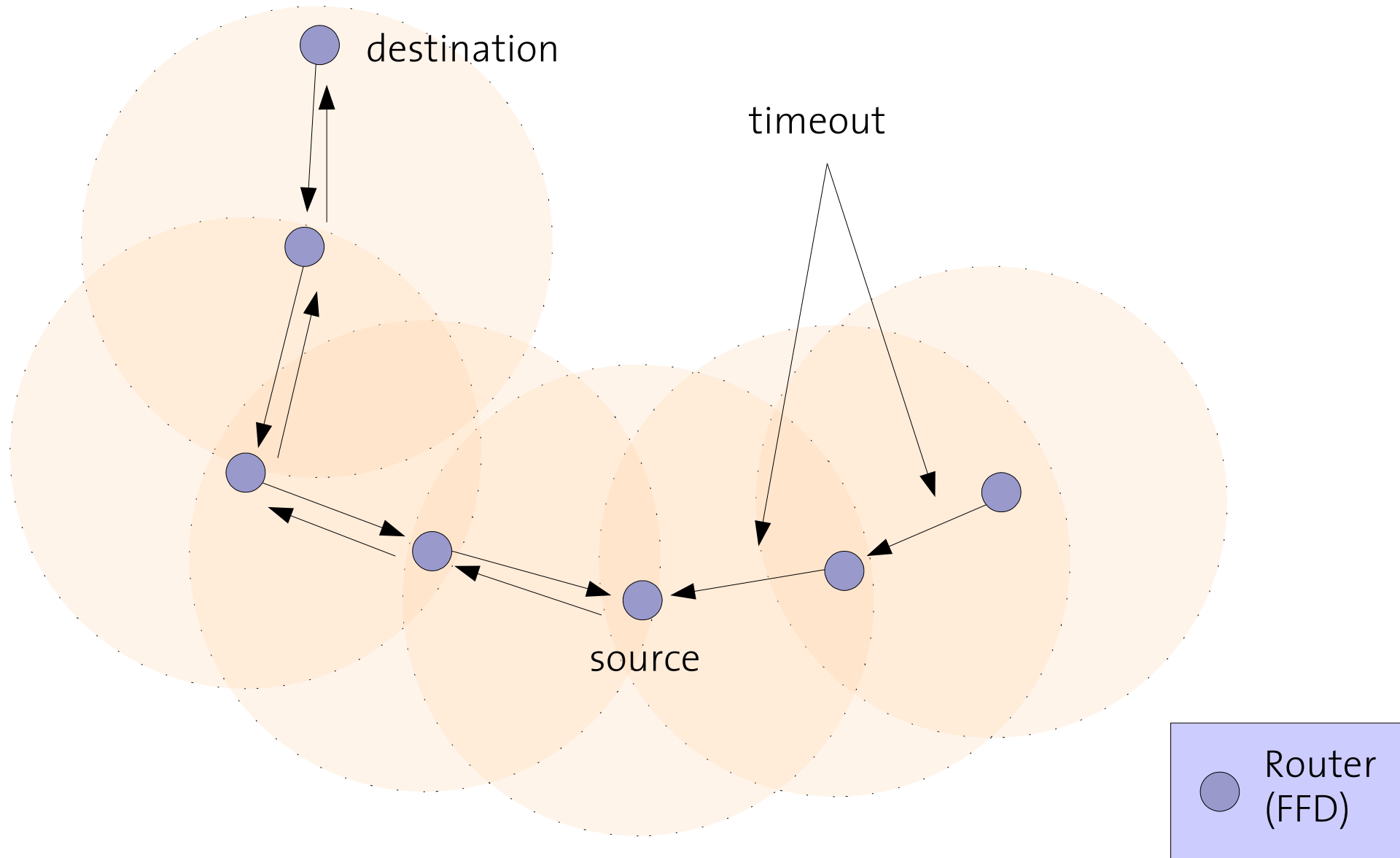
Network Layer – Mesh Topology – Example



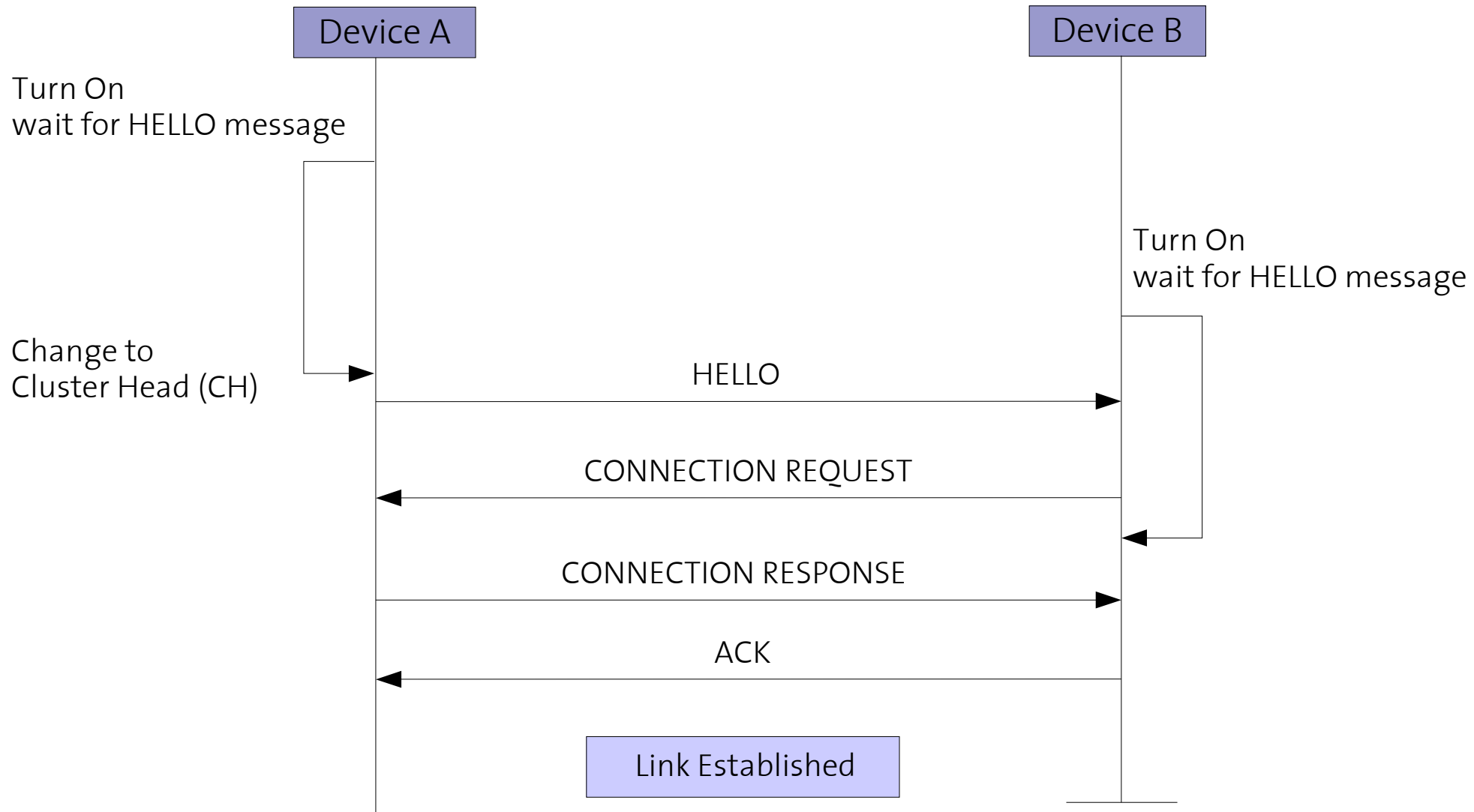
- ▶ Hierarchical Routing
- ▶ Table-based Optimizations
- ▶ Two common used algorithms
 - ▶ AODV (table based)
 - ▶ Cluster Tree Algorithm (hierarchical)



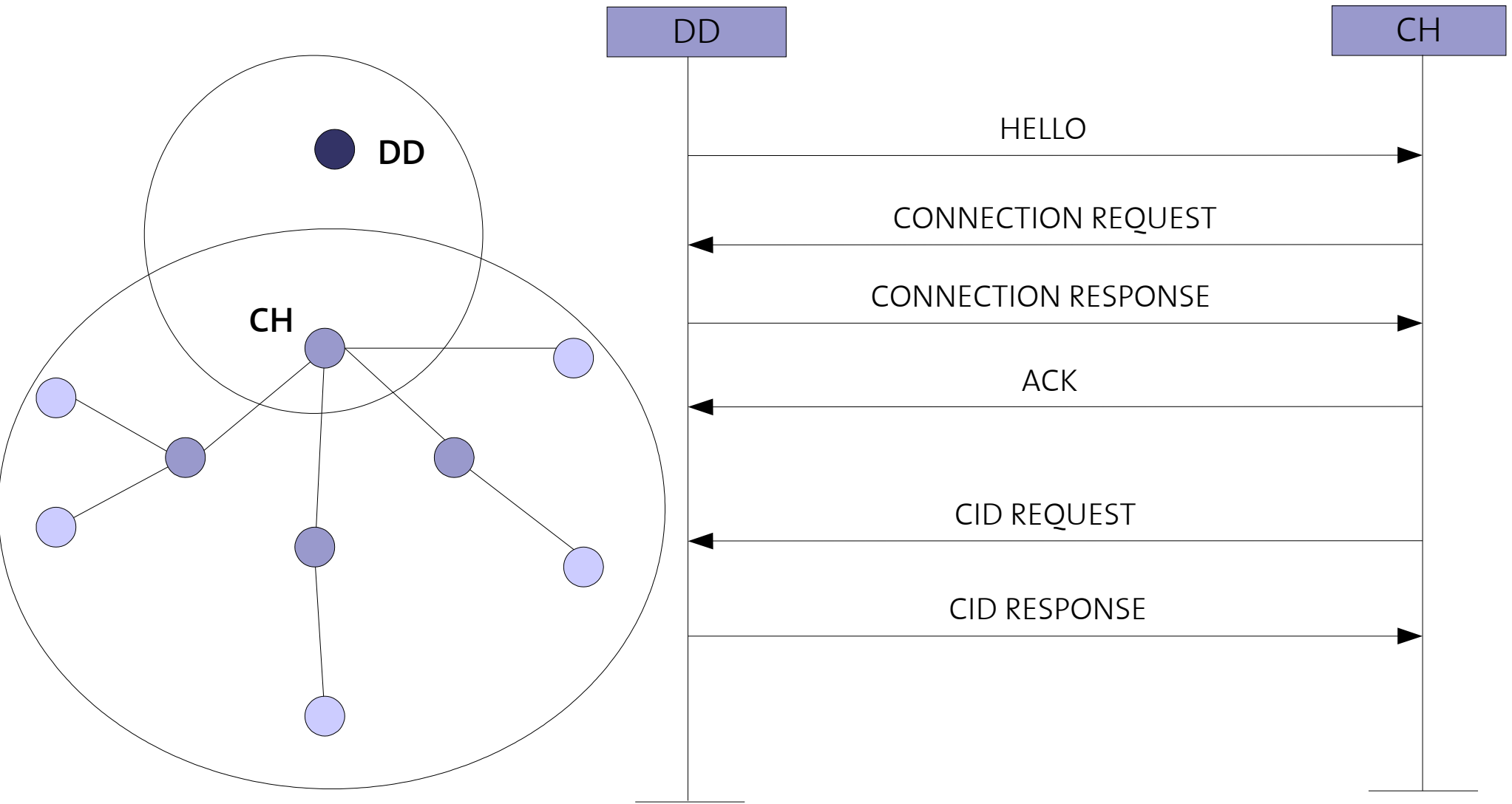
Ad hoc On Demand Distance Vector (AODV) Algorithm:



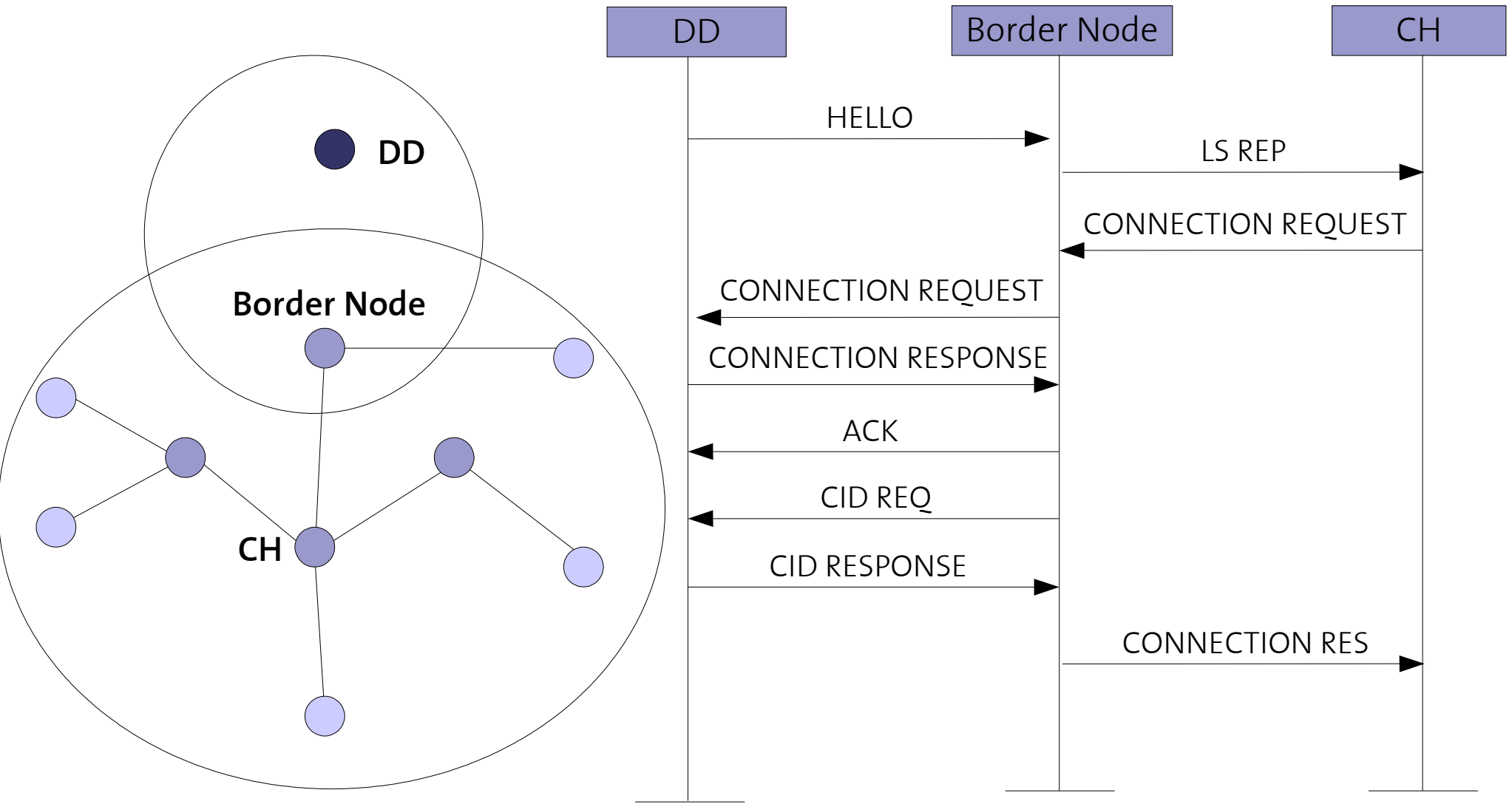
Single Cluster Network:



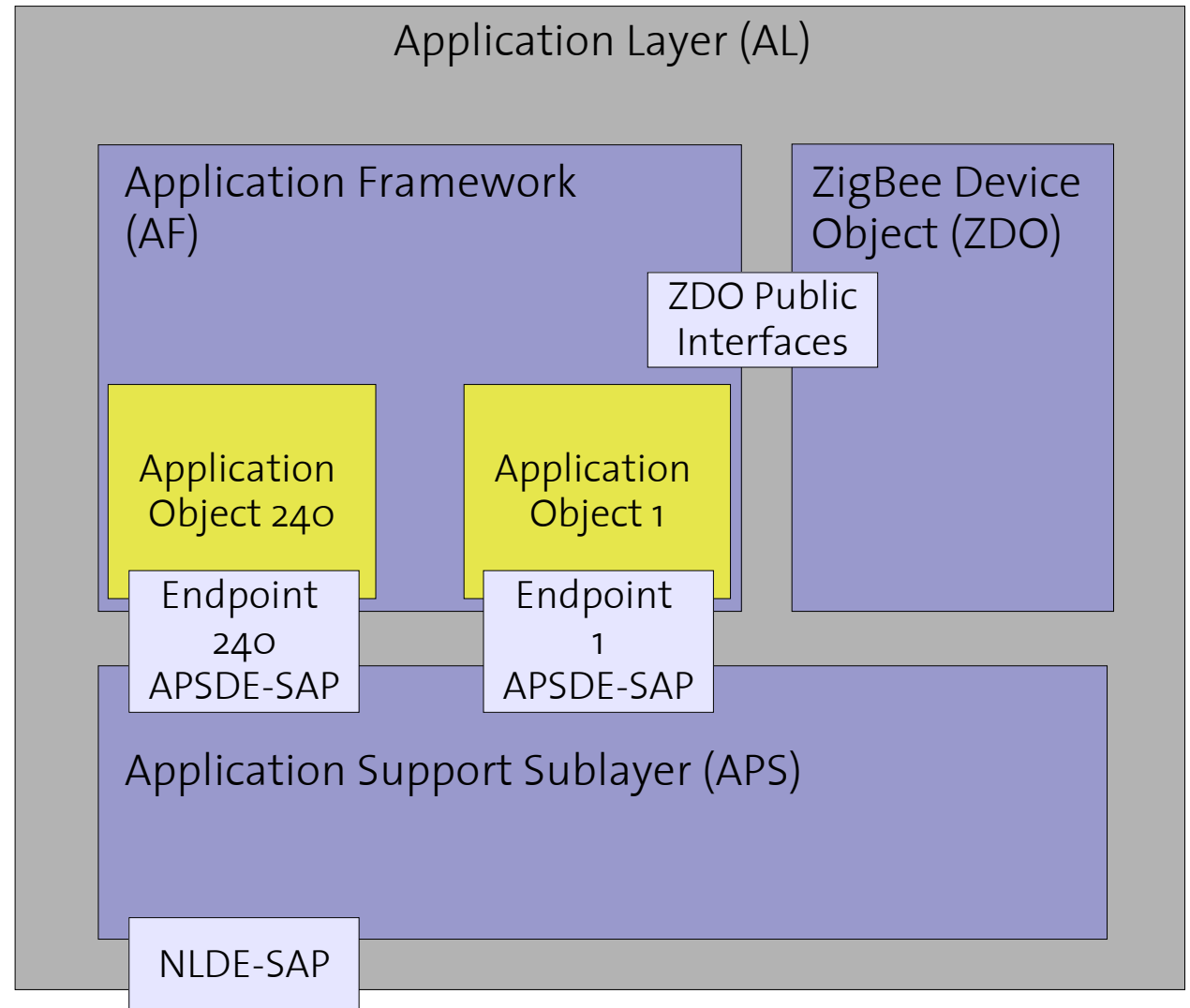
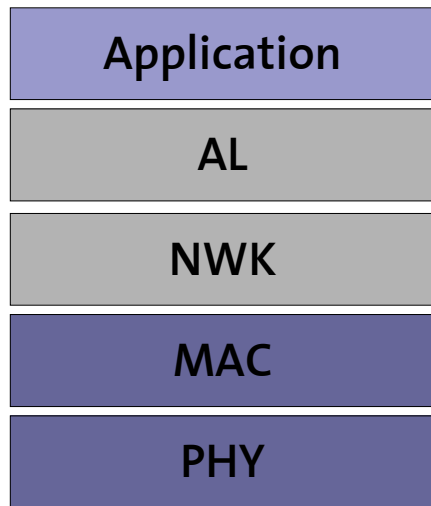
Multi Cluster Network:



Multi Cluster Network:



Application Layer

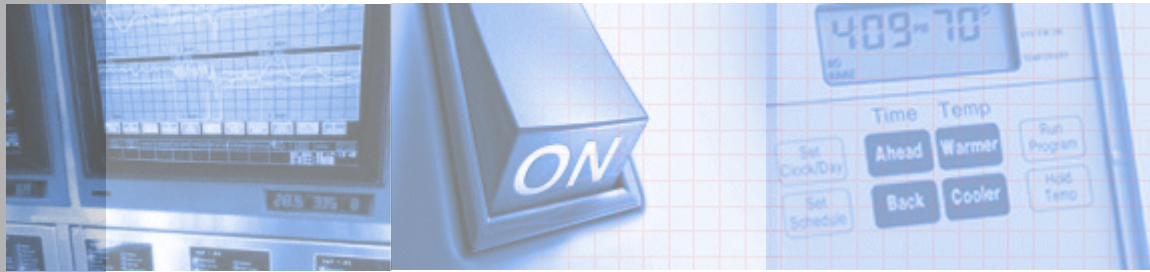


Application Layer - Profiles



- ▶ Building automation
 - ▶ Light control (light sensors, dimmers)
 - ▶ Heating control
 - ▶ Air-Condition control
- ▶ Smart Home control
- ▶ Remote Control for consumer electronic





Introduction

Technical Aspects

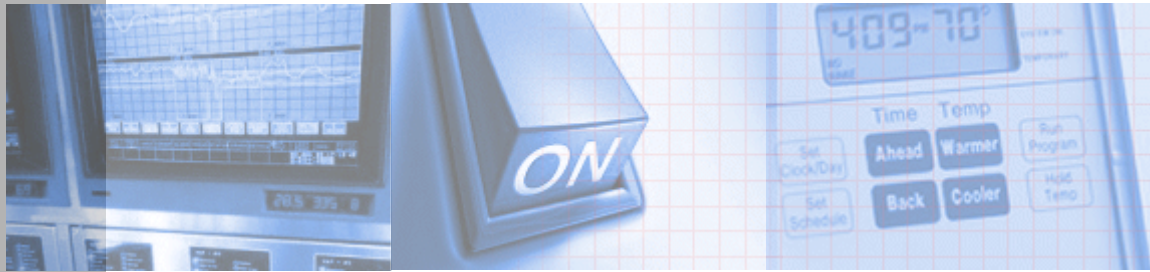
Applications & Examples

- ZigBee Core Markets
- Case Study: Mom's House
- Power Consumption Example

Summary

- ▶ **Industrial and Commercial**
 - ▶ Monitors
 - ▶ Movement Sensors
 - ▶ Automation
- ▶ **Personal Healthcare**
 - ▶ Patient monitors
 - ▶ Remote Diagnosis
 - ▶ Data loggers
- ▶ **Building Automation**
 - ▶ Security
 - ▶ Lighting
 - ▶ Fire and Safety systems
- ▶ **Automotive**
 - ▶ Service controls
 - ▶ Inventory tracking





Introduction

Technical Aspects

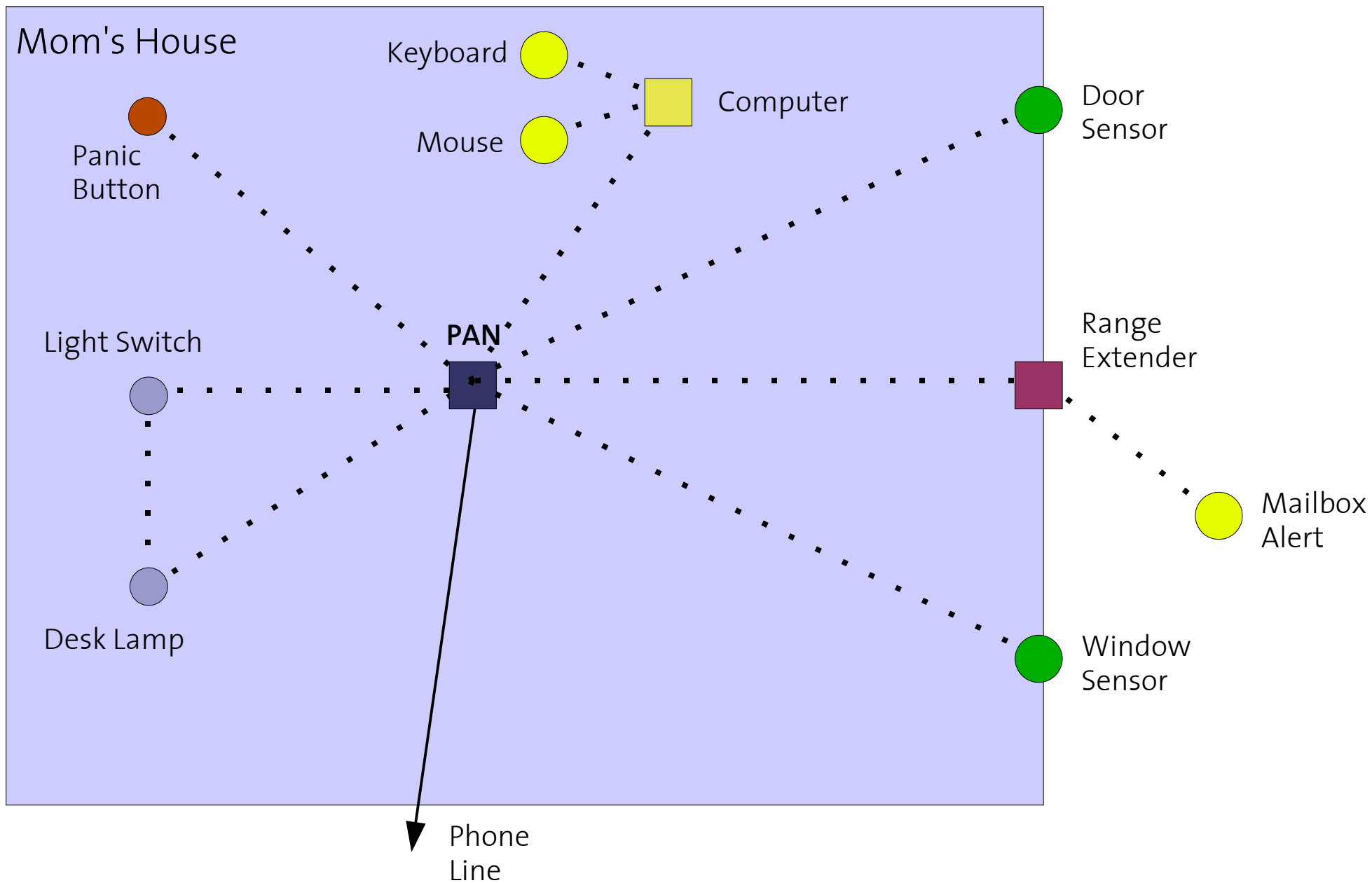
Applications & Examples

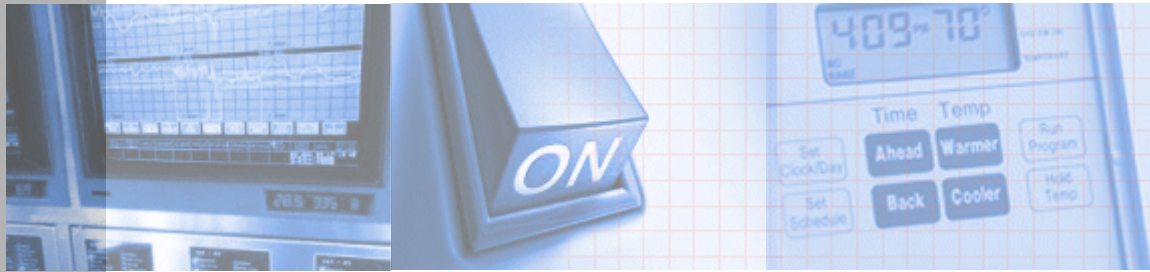
- ZigBee Core Markets
- **Case Study: Mom's House**
- Power Consumption Example

Summary

Case Study: Mom's House

Example from "ZigBee Alliance"





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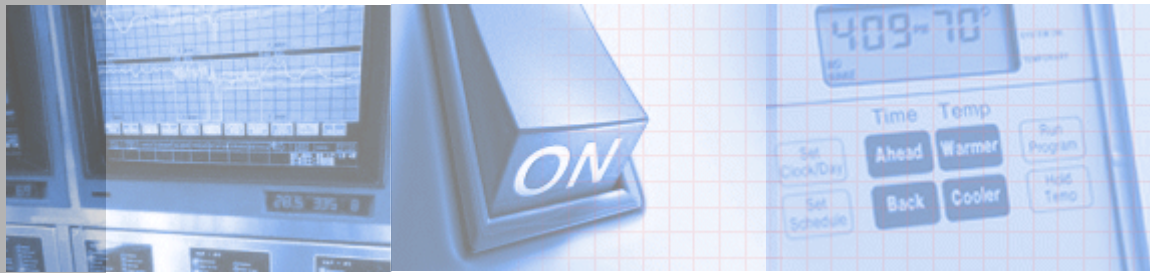
- ZigBee Core Markets
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Summary

Battery: 3V LiMn coin cell



| Application | Transmission Rate | Lifetime |
|--------------------|-------------------|-----------|
| Light switch | 6 ops / day | 10 years |
| Water level sensor | 1 op / hour | 1-2 years |
| Heart monitor | 1 op / 5ms | 1 day |



Introduction

Technical Aspects

Applications & Examples

Summary

- ▶ **IEEE 802.15.4 / ZigBee**
 - ▶ Long battery life
 - ▶ Data security
 - ▶ Simplicity
 - ▶ Cost
 - ▶ Flexible network architecture
- ▶ **ZigBee Alliance**
 - ▶ Industry consortium that defines a global standard for monitoring and control products
- ▶ **ZigBee vs. Bluetooth**
 - ▶ Two solutions for two application Areas
- ▶ **More Information**
 - ▶ www.zigbee.org
 - ▶ www.ieee802.org/15

“It's the cockroach that survives the nuclear war”

