11052 MWI

Microchip MiWi™ Wireless Protocol

UNIVERSITY OF MICROCHIP UOFM MASTERS 2007

Class Objective

- When you finish this class you will:
  - **Implement an instant message application based on Microchip MiWi wireless protocol**
    - Explain the basic concept of wireless communication
    - Introduce the IEEE 802.15.4 standard
    - Experience Microchip MiWi wireless protocol
    - Comparison between MiWi and ZigBee™ protocol

UNIVERSITY OF MICROCHIP UOFM MASTERS 2007

Agenda

- **Wireless Networking Fundamentals**
- **IEEE 802.15.4**
  - Lab 1
- **MiWi™ Protocol**
  - Lab 2
- **MiWi™ Protocol vs. ZigBee™**
- **Getting Started**

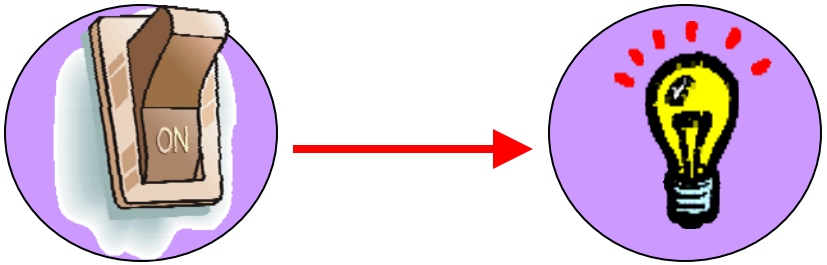
University of Microchip UofM MASTERs 2007

Wireless Networking Fundamentals

- Topologies
- Reliability
- Security
- Adaptability/Recoverability
- Mobility

Topologies

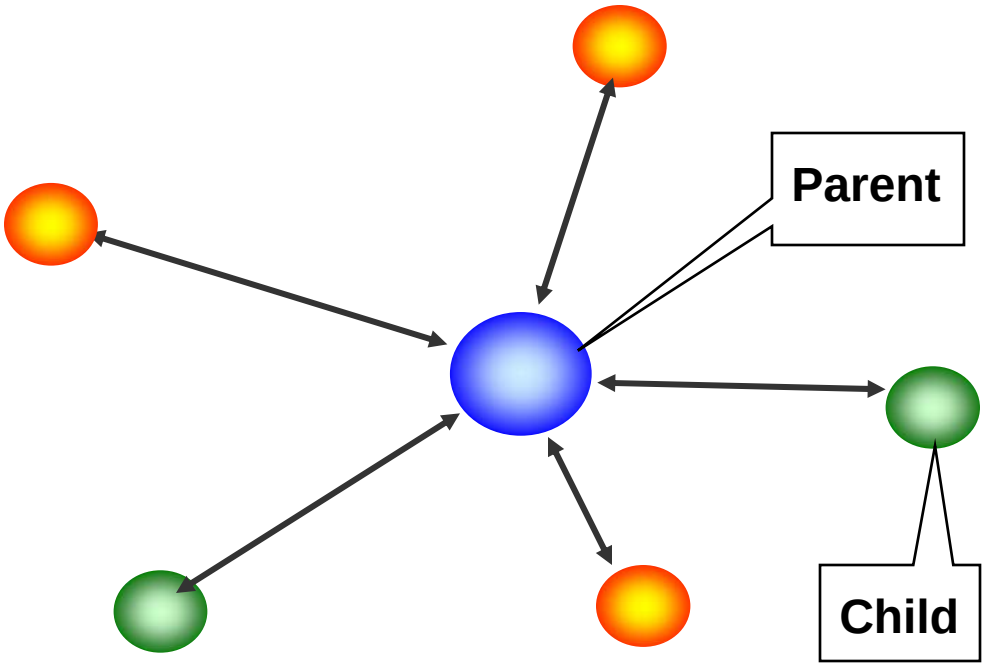
- **P2P Topology**
  - One node that talks directly to another node without having to join a network



Direct Message

Broadcast

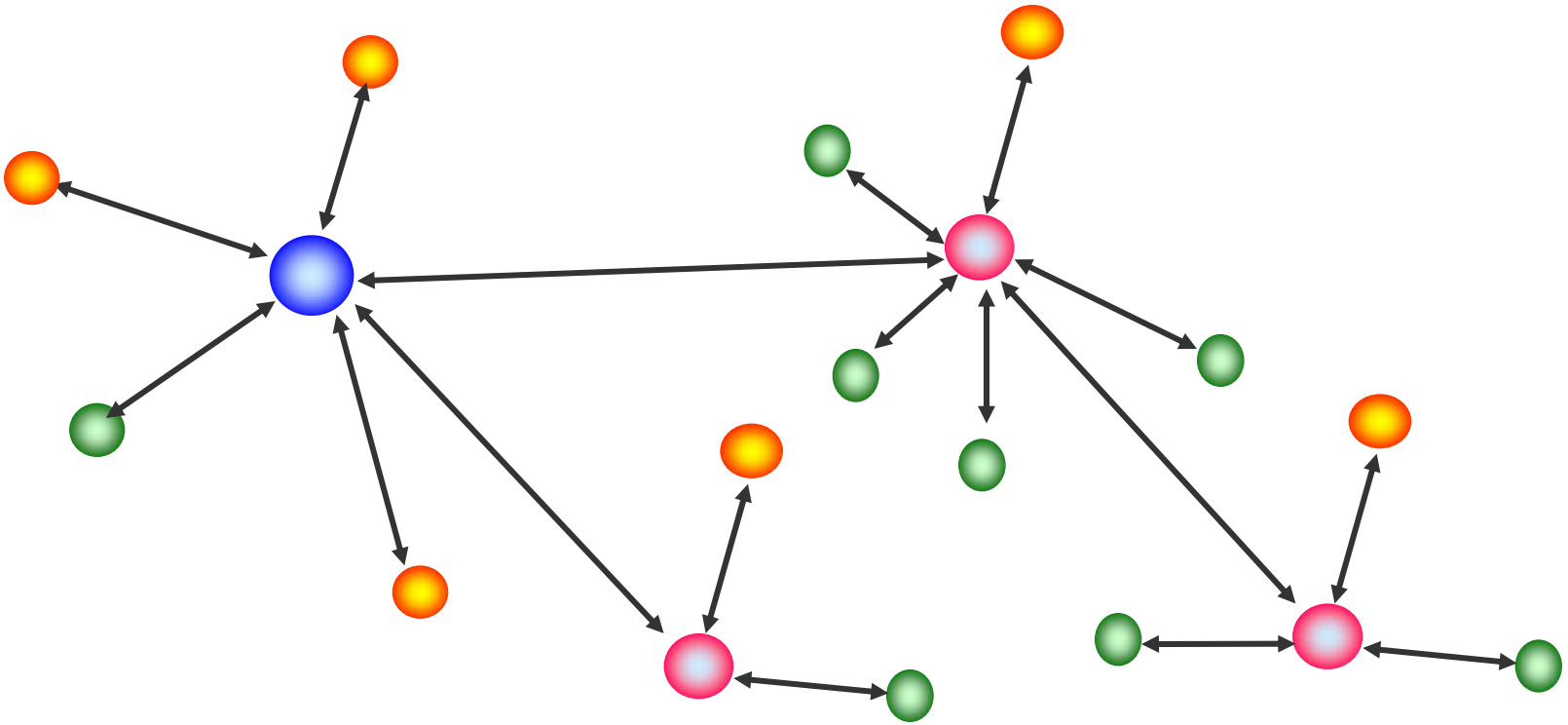
Topologies



Star Topology

- Reduced Function Device (RFD)
- Full Function Device (FFD)
- Coordinator (FFD)

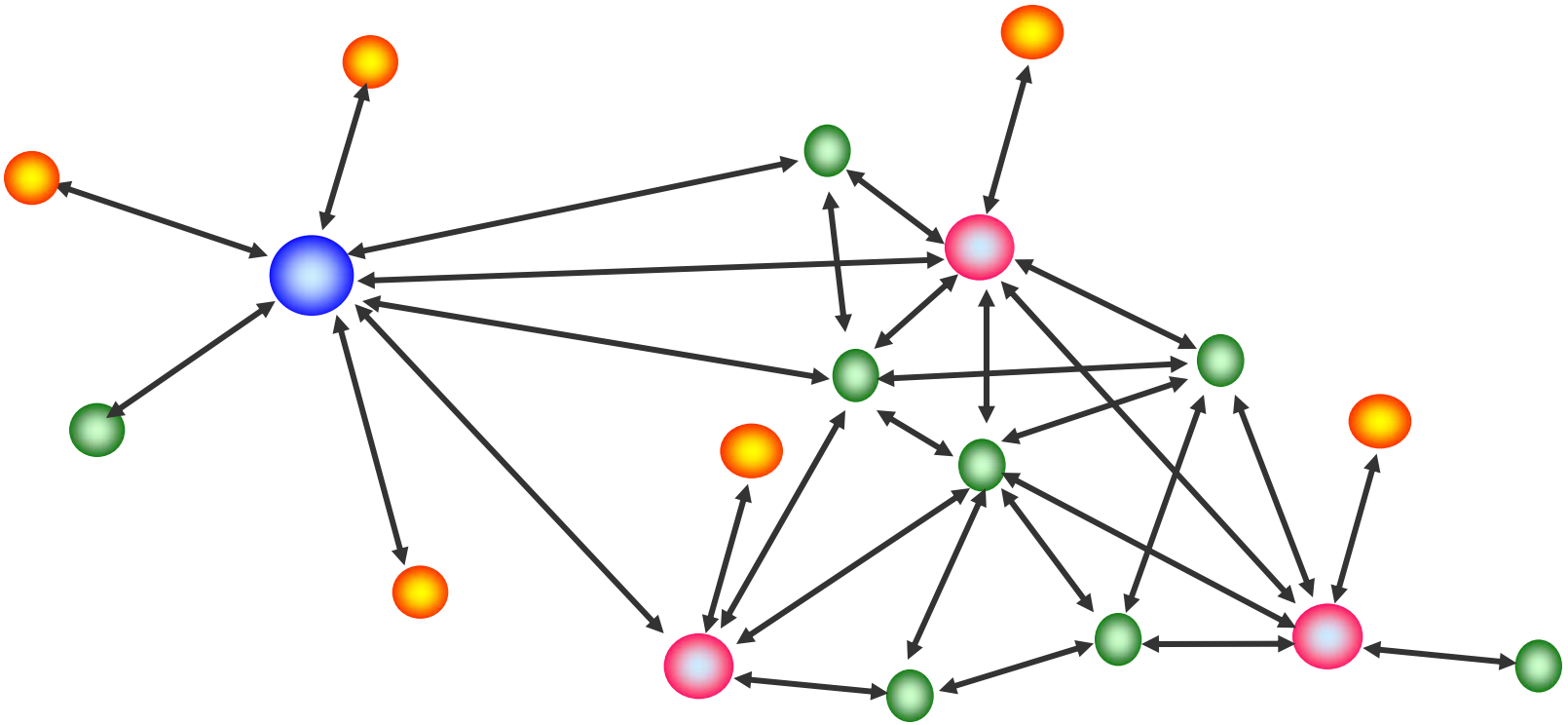
Topologies



Cluster Tree Topology

- Reduced Function Device (RFD)
- Full Function Device (FFD)
- Coordinator (FFD)
- Router (FFD)

Topologies



Mesh Topology

- Reduced Function Device (RFD)
- Full Function Device (FFD)
- Coordinator (FFD)
- Router (FFD)

Wireless Networking Fundamentals

- Topologies
- Reliability
- Security
- Adaptability/Recoverability
- Mobility

Reliability

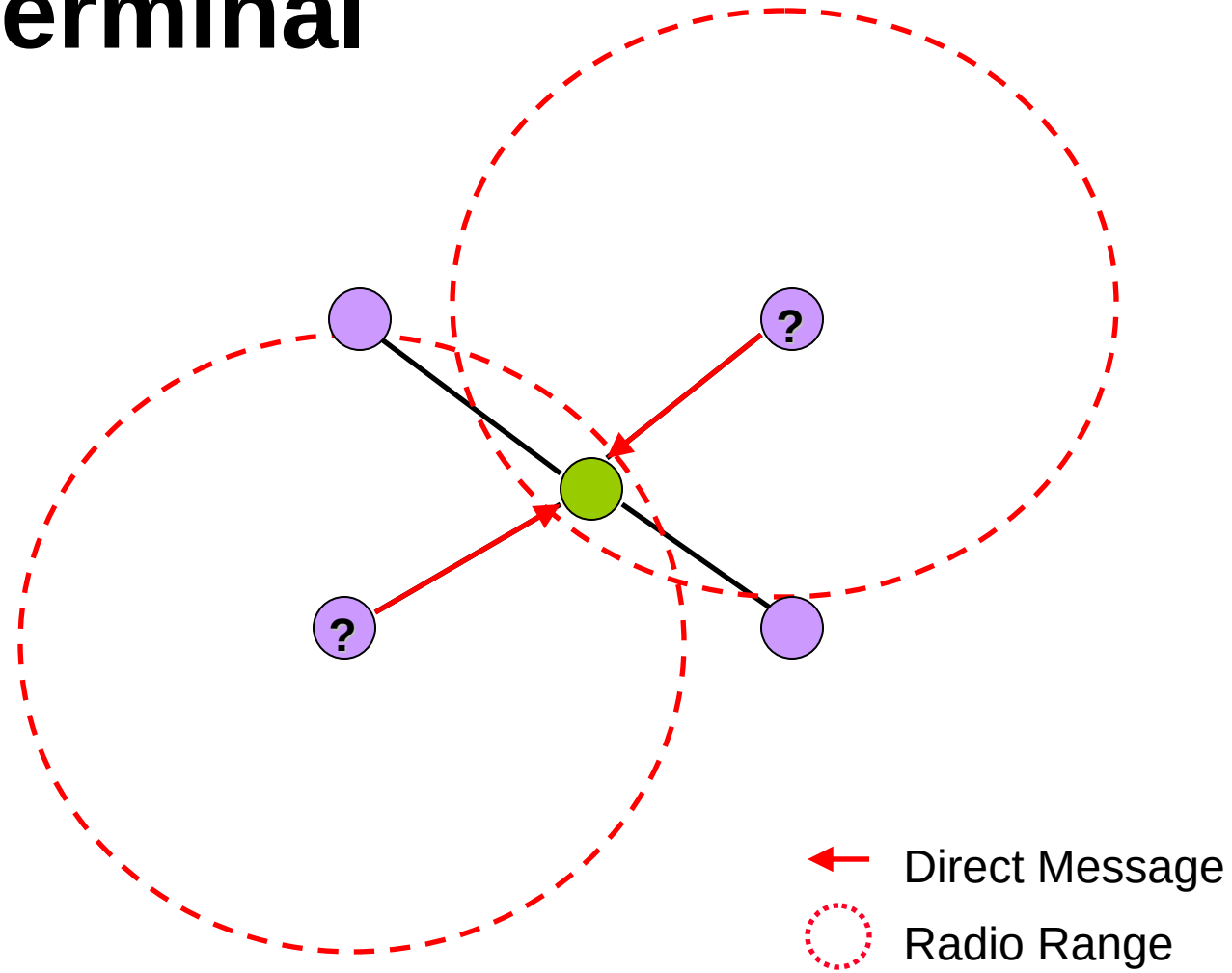
- **It may happen:**
  - Loss of packet
  - Packet collisions
- **Reliability of the Networks means**
  - Send message to the destination correctly
  - Recover from the error in the worst scenario

Reliability

- **CSMA-CA**
  - Carrier sense multiple access collision avoidance
- **CSMA-CD**
  - Carrier sense multiple access collision detection

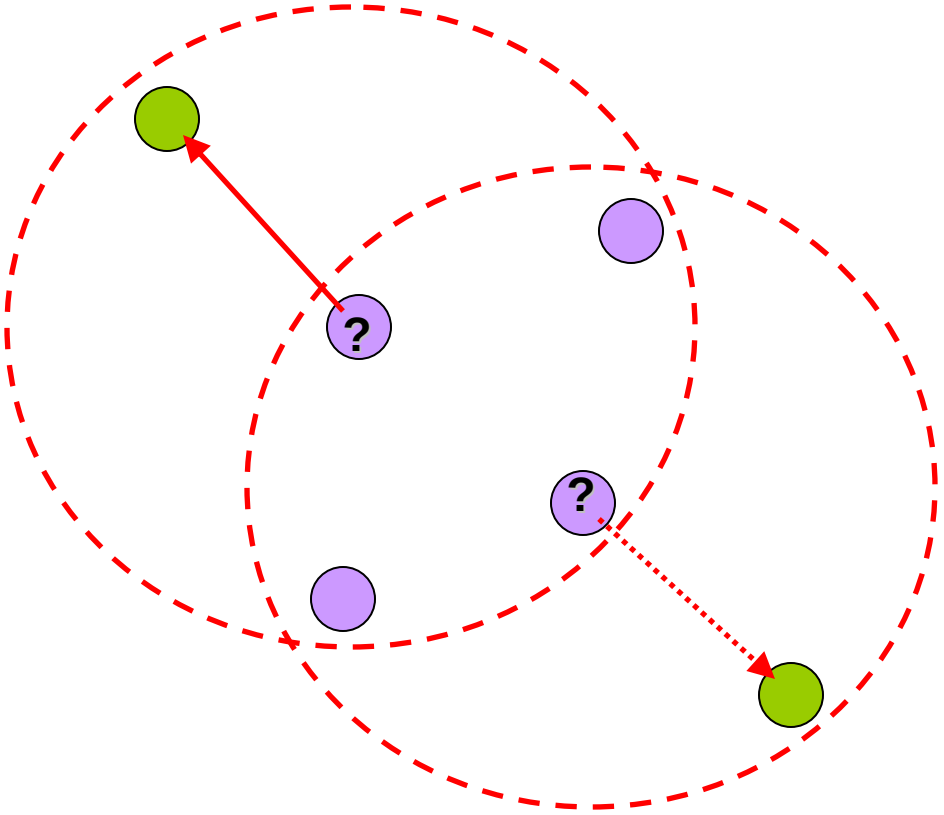
Reliability

- **Hidden Terminal**



Reliability

- **Exposed Terminal**

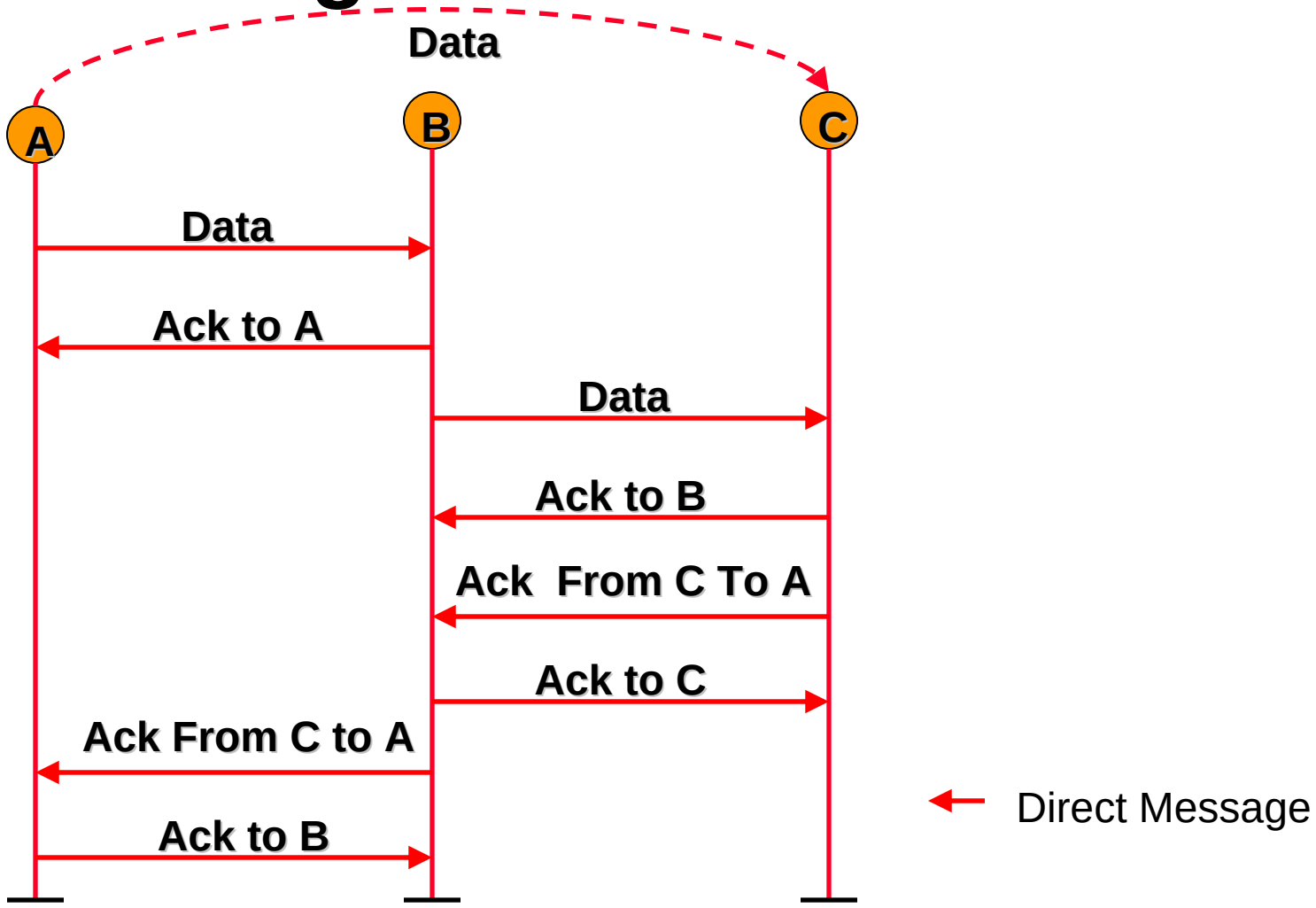


Direct Message

Radio Range

Reliability

- Acknowledgement



University of Microchip UofM MASTERs 2007

Wireless Networking Fundamentals

- Topologies
- Reliability
- Security
- Adaptability/Recoverability
- Mobility

Security

- **Connect and Authenticate Before Communicating**
  - Trust every node on the network once joined
  - Do not trust any node unless the partner's identity gets verified individually
  - Anything goes between

Security

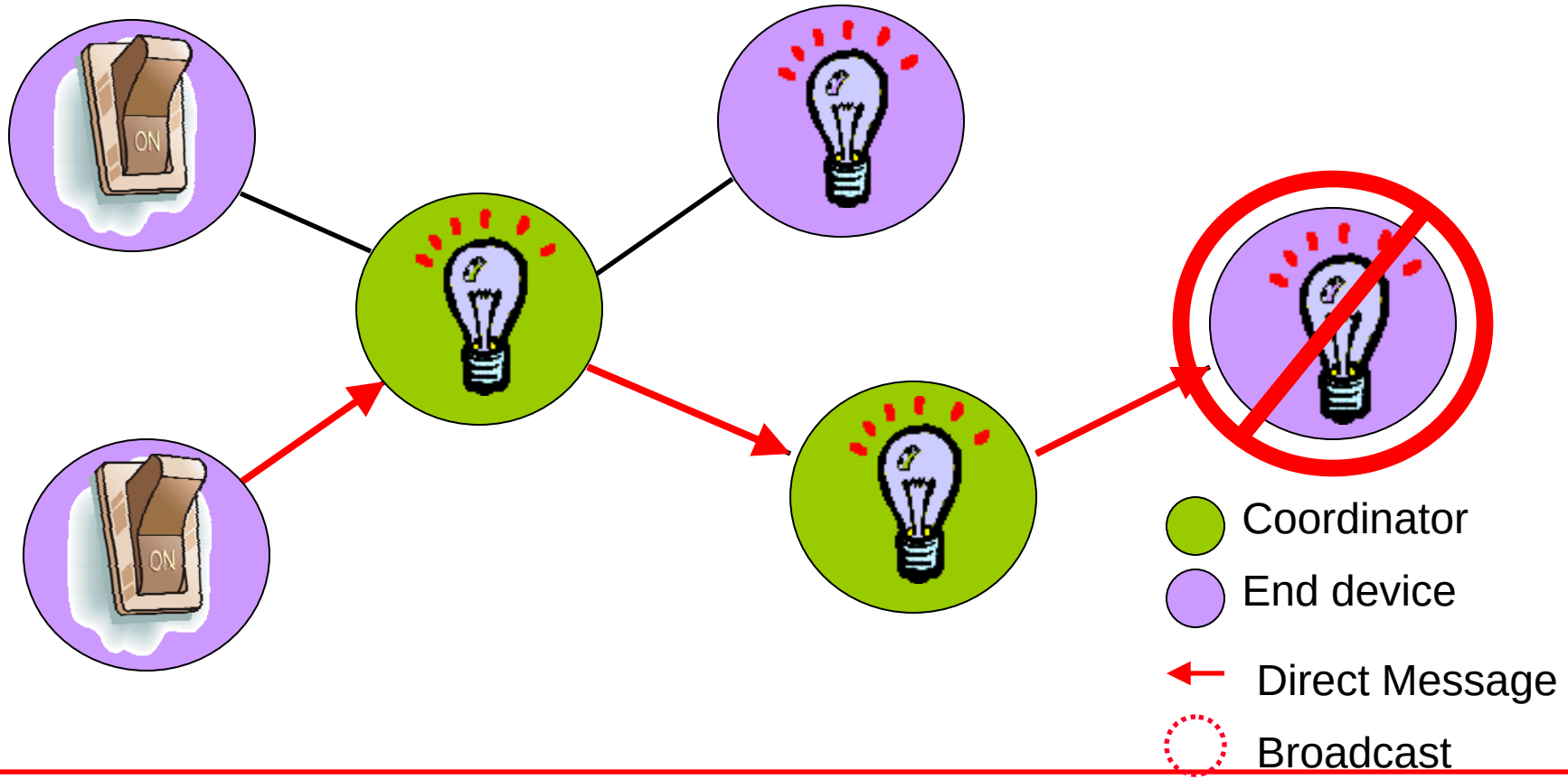
- **Application-Specific**
  - Lighting Control
  - Wireless Mouse
  - Wireless Keyboard
  - Game Pad Controller

Wireless Networking Fundamentals

- Topologies
- Reliability
- Security
- Adaptability/Recoverability
- Mobility

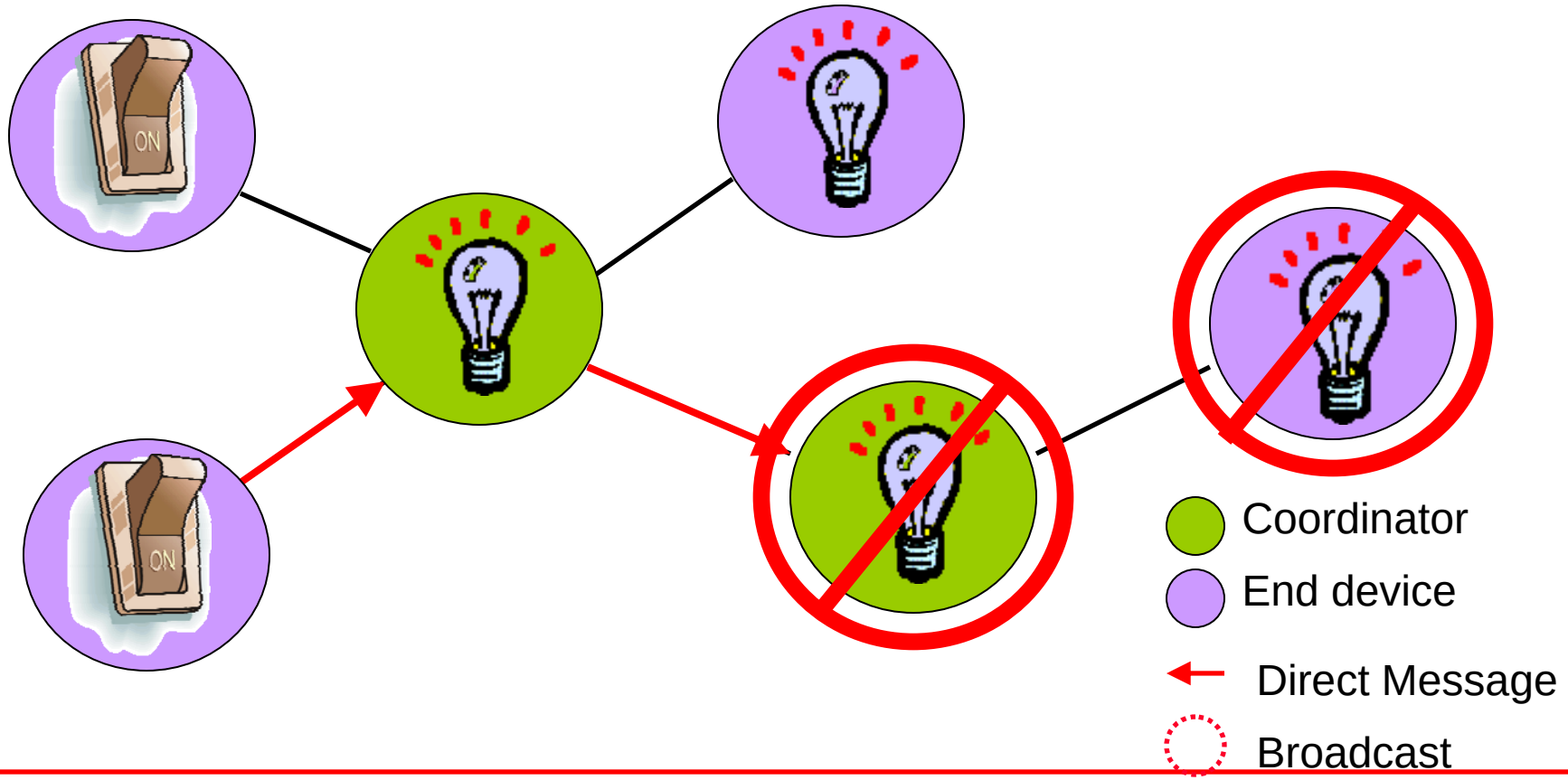
Adaptability/Recoverability

- **Failure of End Device**



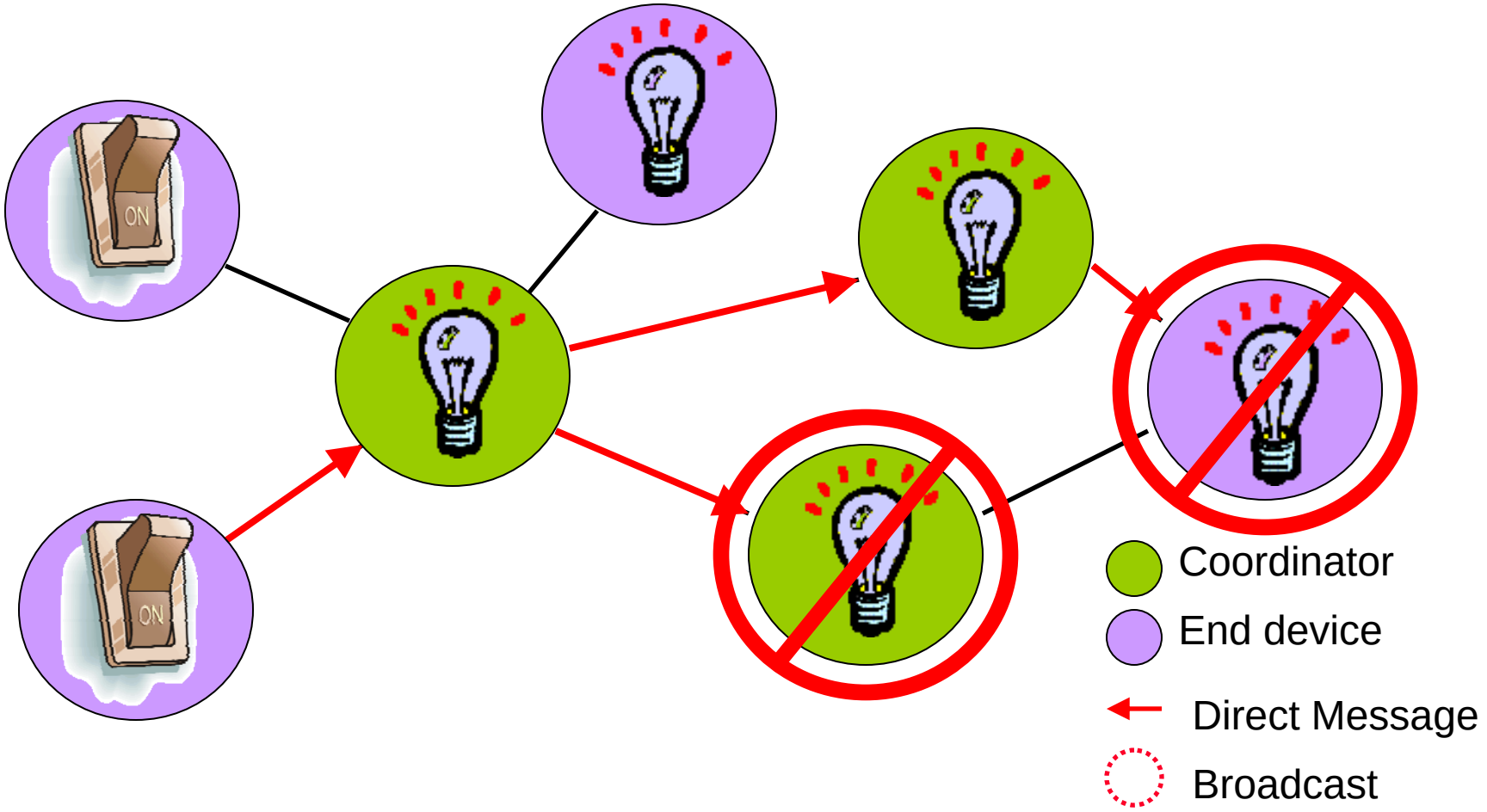
Adaptability/Recoverability

- **Failure at Join Point**



Adaptability/Recoverability

- **Failure at Join Point**



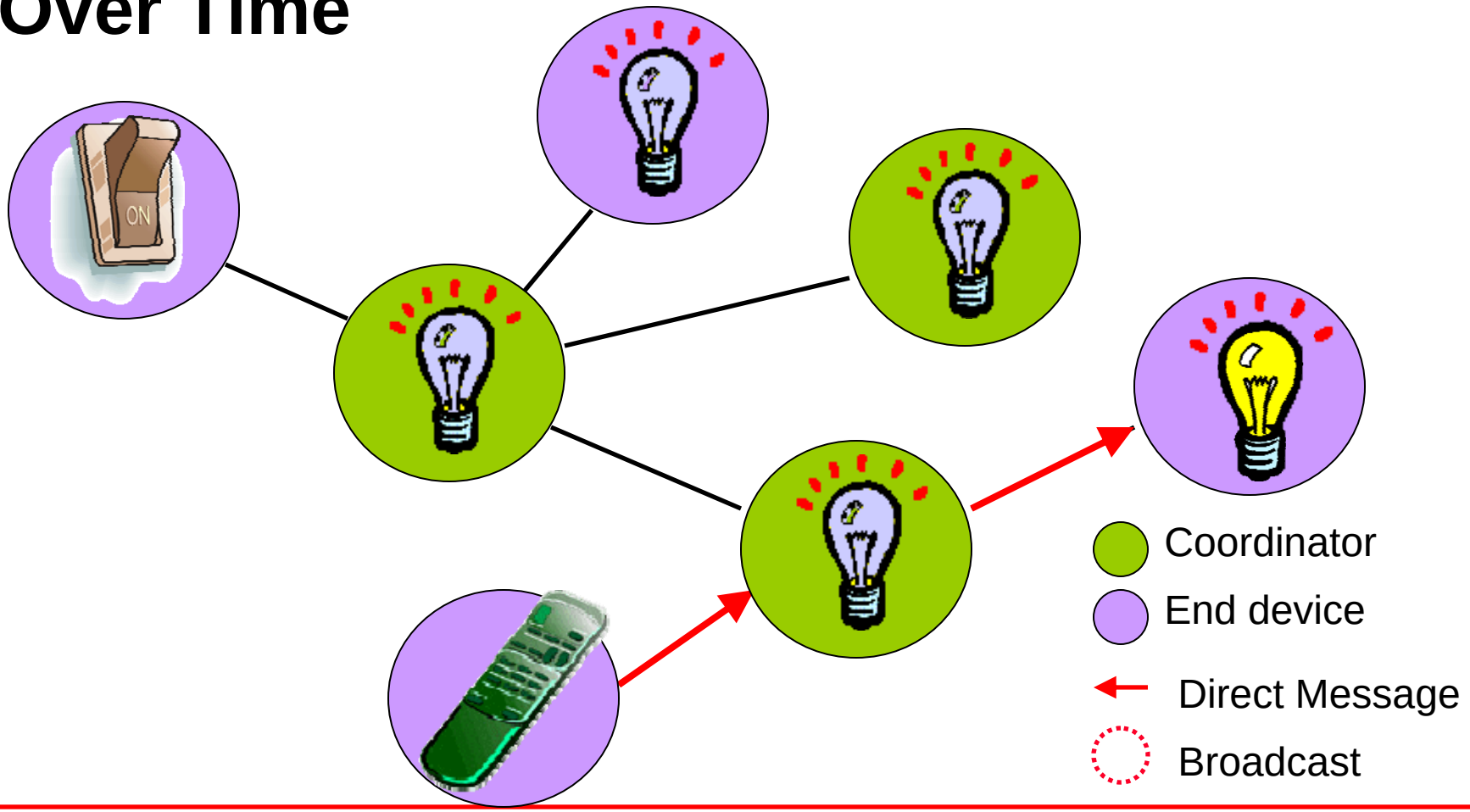
University of Microchip UofM MASTERs 2007

Wireless Networking Fundamentals

- Topologies
- Reliability
- Security
- Adaptability/Recoverability
- Mobility

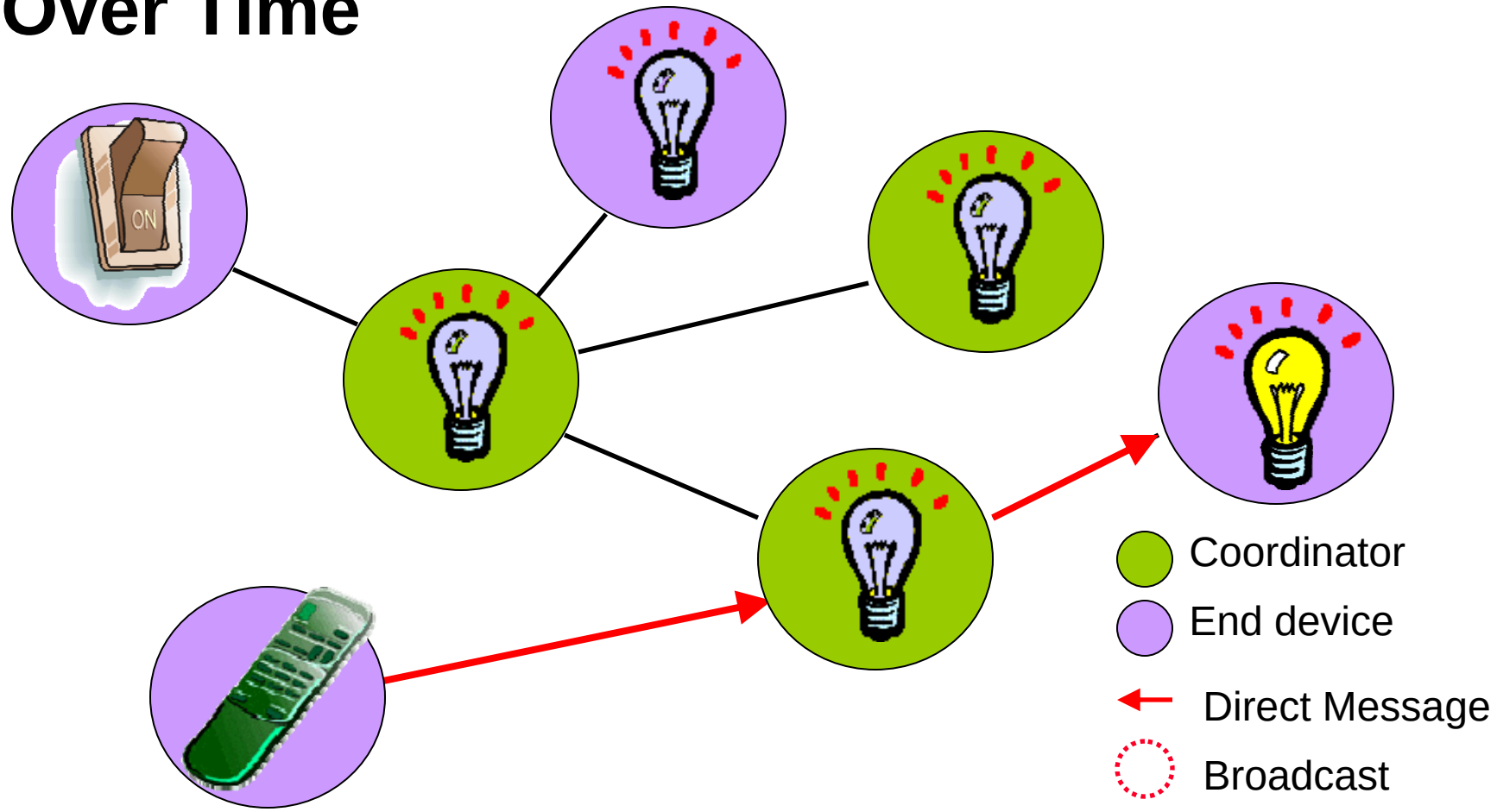
Mobility

- **Node Locations Environment may Change Over Time**



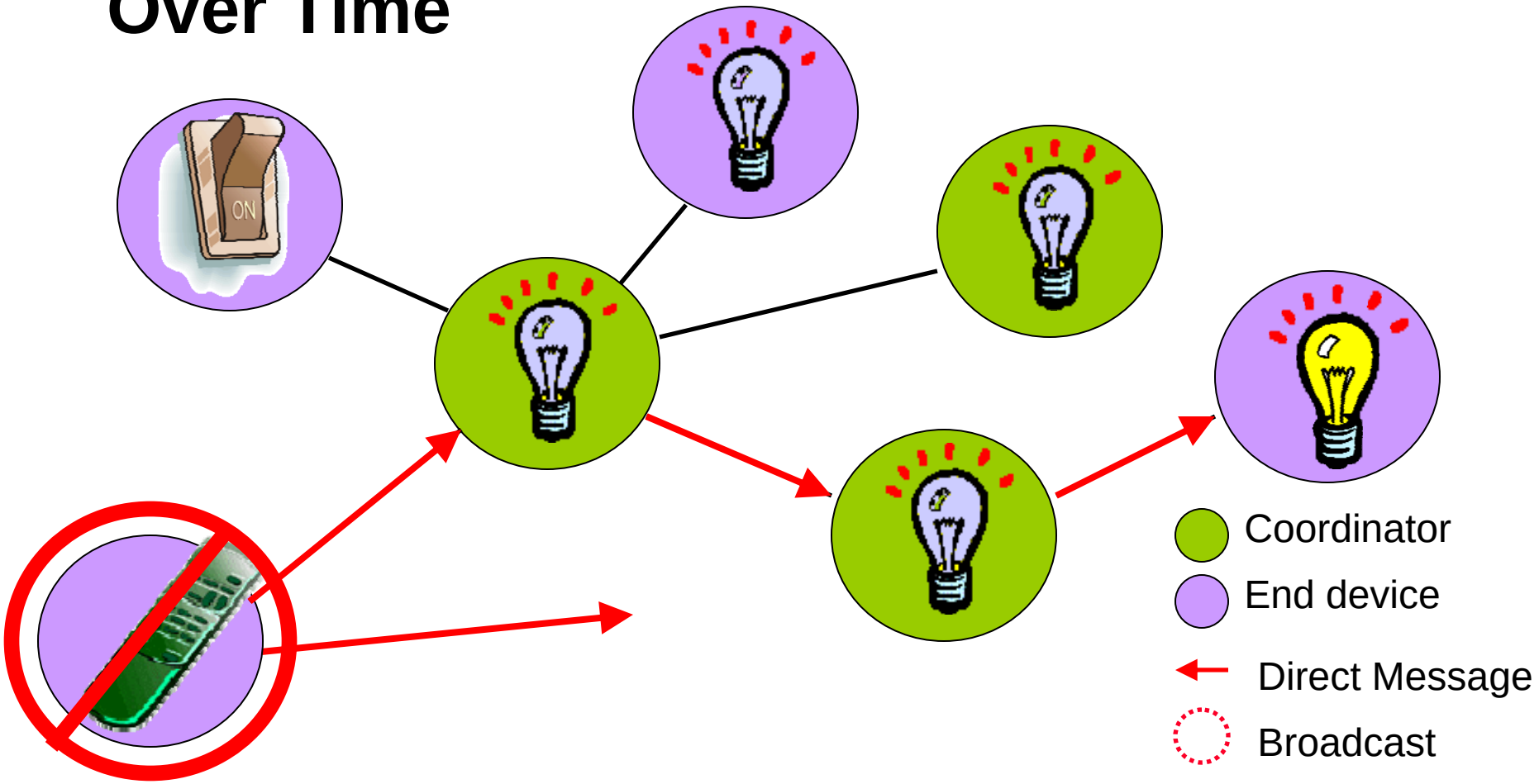
Mobility

- **Node Locations Environment may Change Over Time**



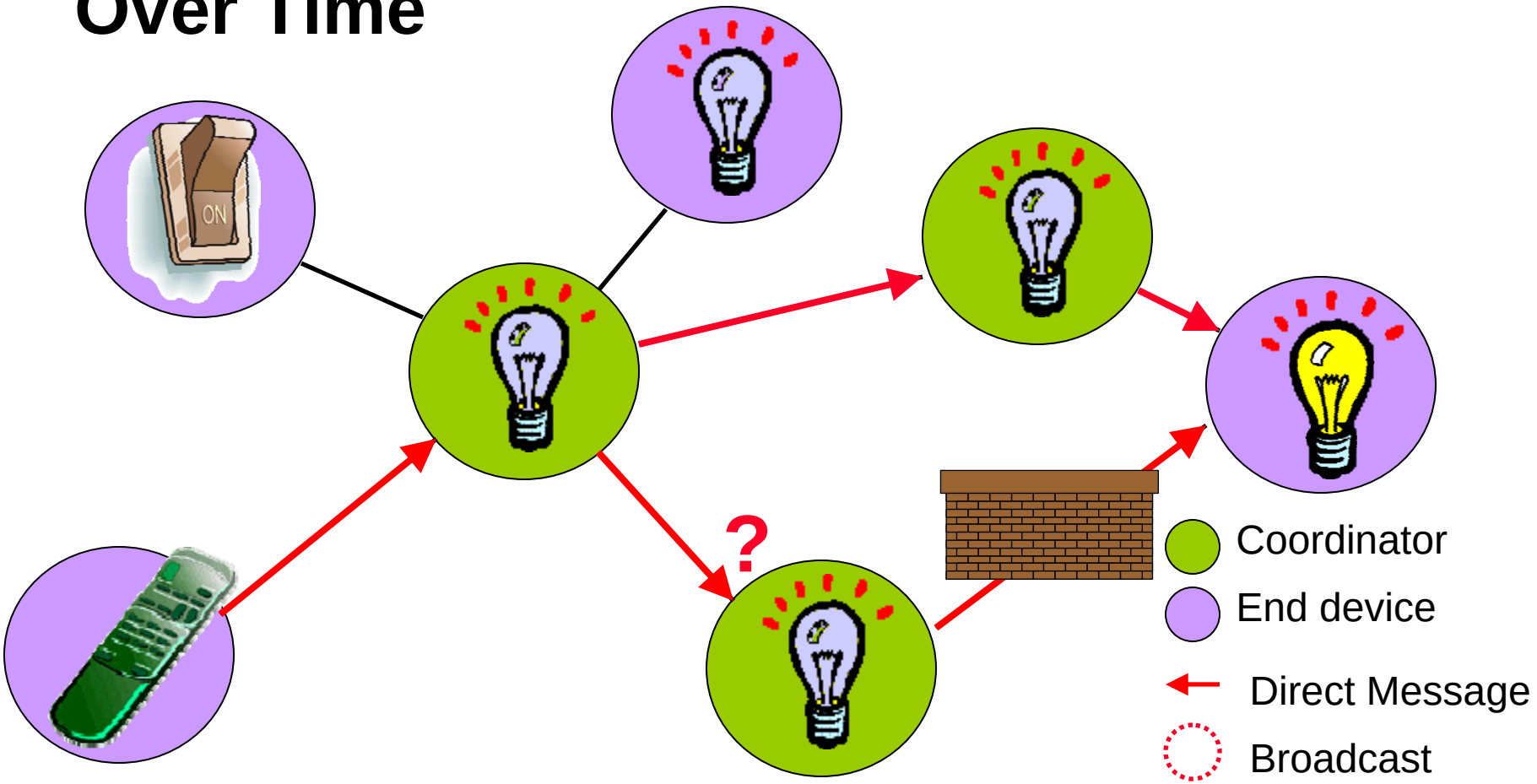
Mobility

- **Node Locations Environment may Change Over Time**



Mobility

- **Node Locations Environment may Change Over Time**



University of Microchip UofM MASTERs 2007

Agenda

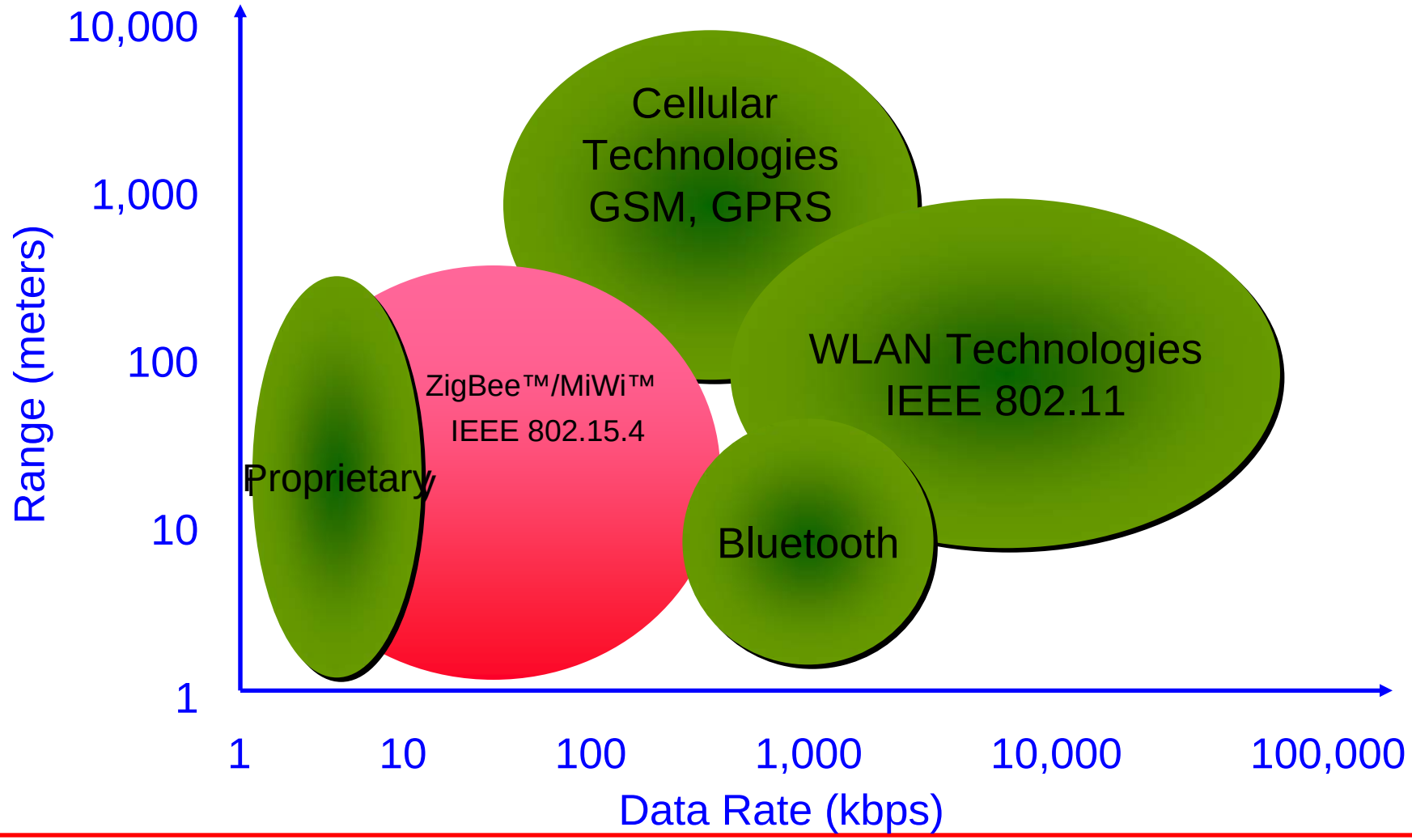
- **Wireless Networking Fundamentals**
- **IEEE 802.15.4**
  - Lab 1
- **MiWi™ Protocol**
  - Lab 2
- **MiWi™ Protocol vs. ZigBee™**
- **Getting Started**

UNIVERSITY OF MICROCHIP
UOFM
MASTERS 2007

IEEE 802.15.4

- 802.15.4 Basics
- 802.15.4 Device Types
- 802.15.4 Networking
- 802.15.4 Security

Wireless Protocols



IEEE 802.15.4

- **Star Topology**
- **Medium Access Control (MAC) + Physical Control (PHY) Layers**
- **Security**
- **Packet Types and Formats**
  - Data, Beacon, Command, ACK

IEEE 802.15.4 Addressing

- **Statically Assigned**
  - Extended Organizationally Unique Identifier (EUI) – 8 bytes long, globally unique ($1500 from IEEE)
- **Dynamically Assigned**
  - Personal Area Network Identifier (PANID) – 2 byte network address
  - Short Address – 2 byte address assigned to a device once it is joined to the network

UNIVERSITY OF MICROCHIP UOFM MASTERS 2007

IEEE 802.15.4

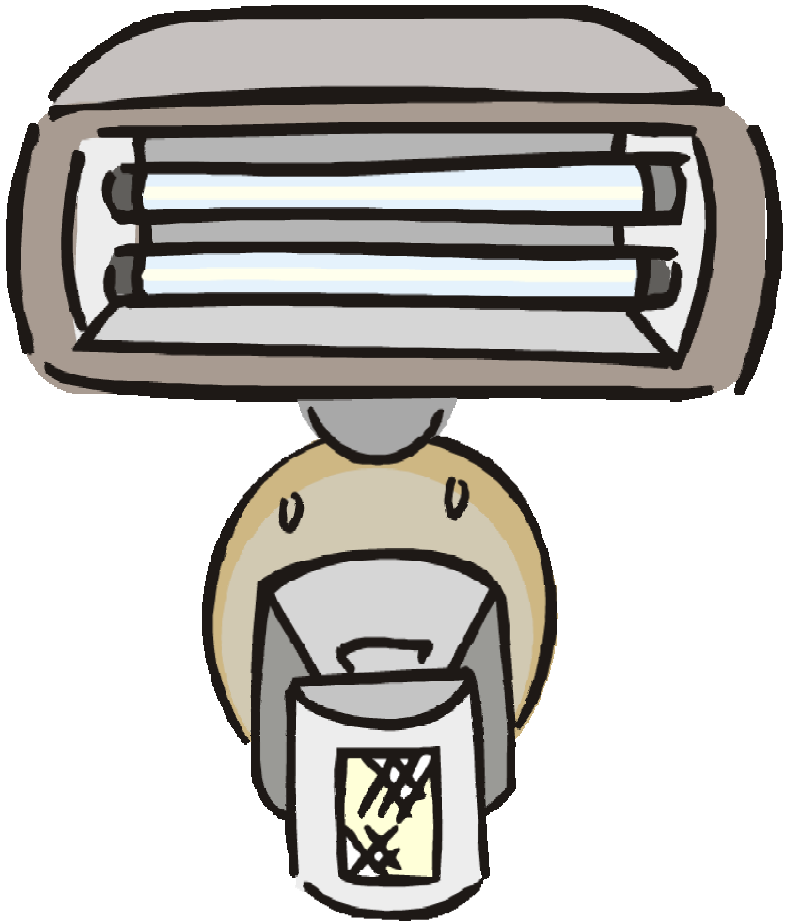
- 802.15.4 Basics
- 802.15.4 Device Types
- 802.15.4 Networking
- 802.15.4 Security

PAN Coordinator

- Forms the network
- Allows other nodes to join
- Transceiver always on
- Mains powered
- Requires relatively large amount of program and data memory

Coordinator

- Extends the physical reach of the network by allowing devices to join the network through it
- **Transceiver always on**
- **Mains powered**
- Requires relatively large amount of program and data memory

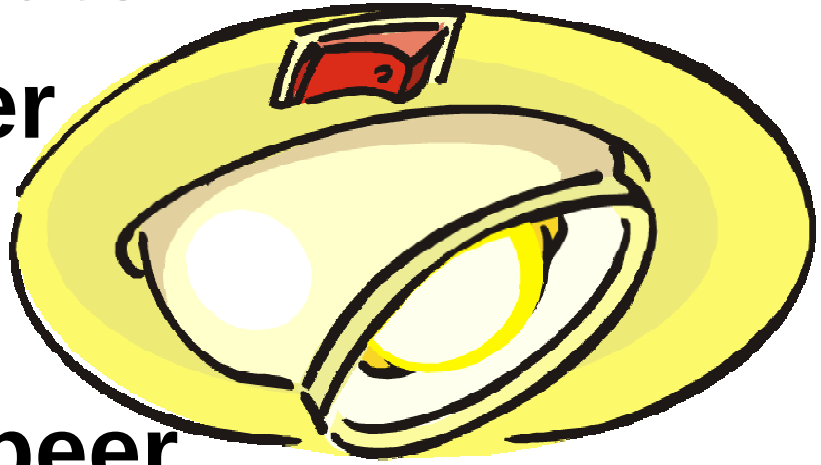


Reduced Function End Device

- **Can be battery-powered**
- **Can communicate only with its parent node**
- **Requires the least amount of RAM and ROM**

Full Function End Device

- Similar to a coordinator
- Does not allow other nodes to join the network
- Capable of peer to peer communication
- Requires less RAM and ROM than a router



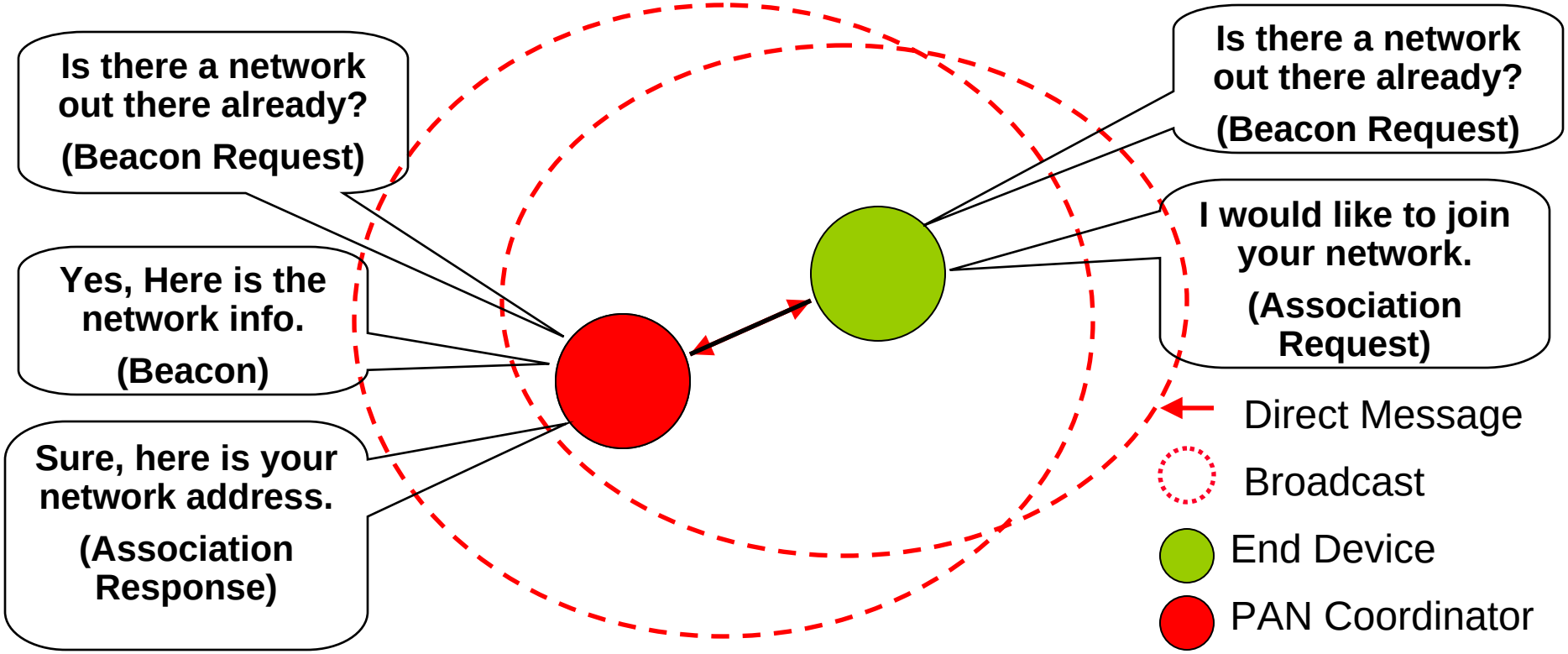
UNIVERSITY OF MICROCHIP UOFM MASTERS 2007

IEEE 802.15.4

- 802.15.4 Basics
- 802.15.4 Device Types
- 802.15.4 Networking
- 802.15.4 Security

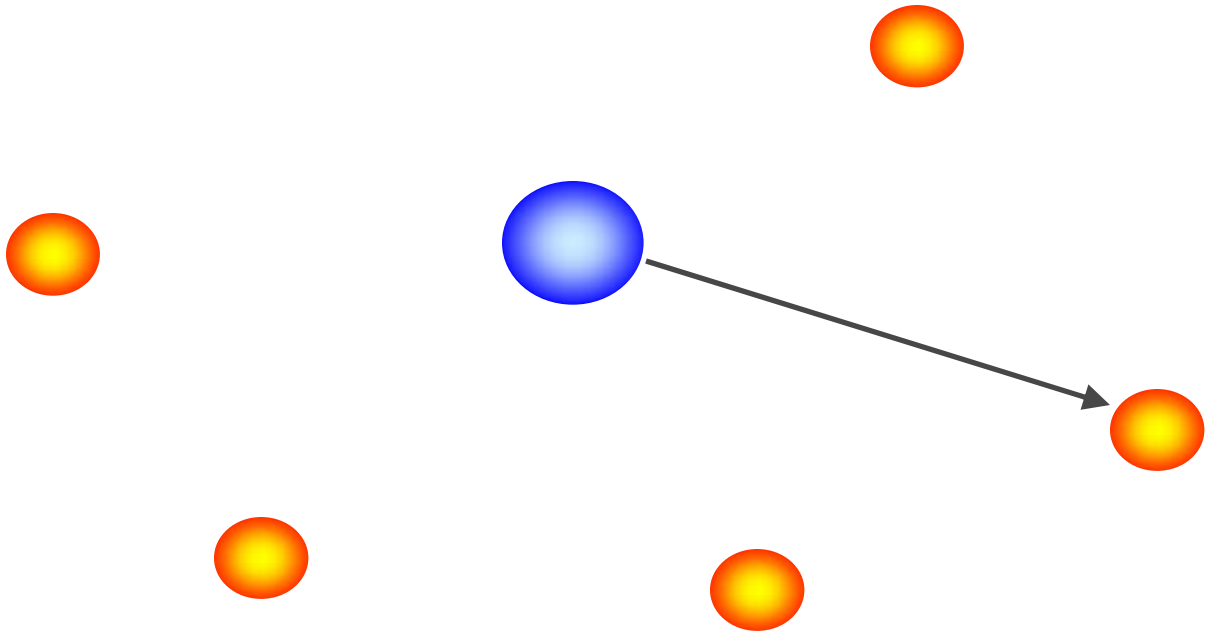
IEEE 802.15.4 Network Formation

- **Finding a Network:**
  - Beacon request
  - Beacon
  - Association Request
  - Association Response



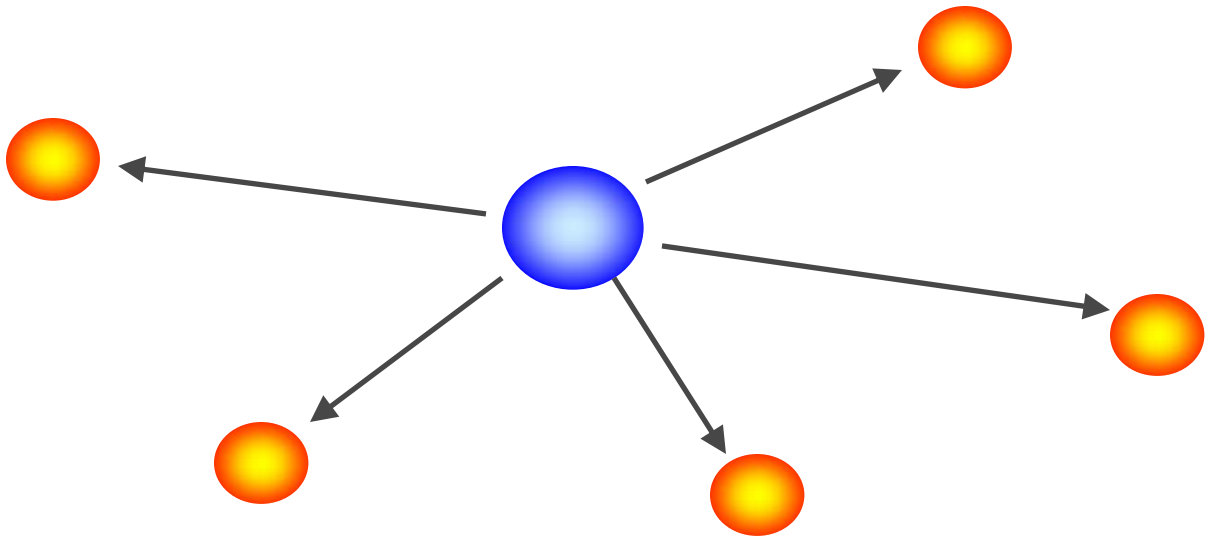
Unicast Messages

- Uses the address of the destination
- Only that device's radio will get the packet (all others will filter the packet out)



Broadcast Messages

- Everyone in radio distance receives the packet
- Packet gets retransmitted by recipients
- Exact mechanism differs by protocol



University of Microchip UofM MASTERs 2007

Agenda

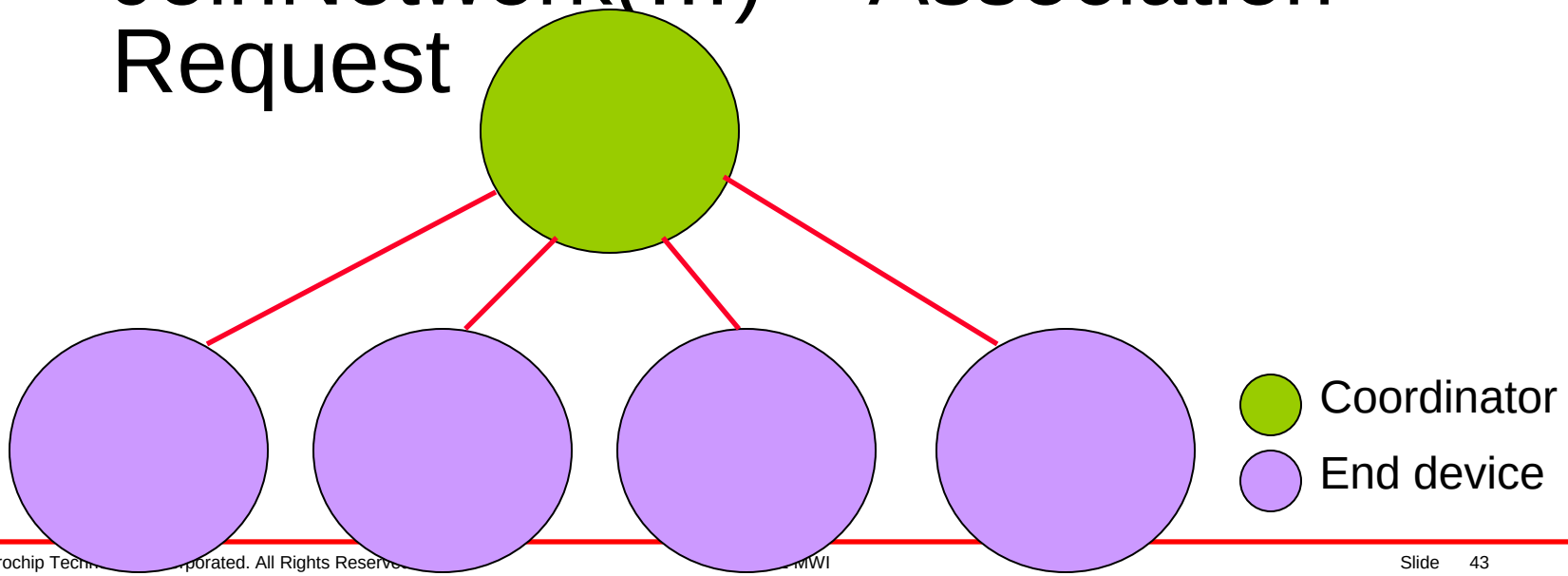
- **Wireless Fundamentals**
- **IEEE 802.15.4**
  - Lab 1
- **MiWi™ Protocol**
  - Lab 2
- **MiWi Protocol vs. ZigBee™**
- **Getting Started**

Lab 1

Stack Configuration, Network Formation and Simple Communication

Lab 1

- Configure the devices/stack to perform as required
- DiscoverNetwork(…) = Beacon Request
- JoinNetwork(…) = Association Request



Lab

- Please refer to the handout material for the instructions for the lab
- If you have any questions, feel free to ask at any time

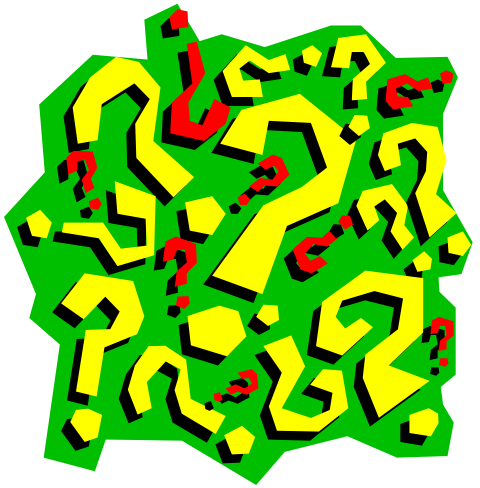
UNIVERSITY OF MICROCHIP UOFM MASTERS 2007

IEEE 802.15.4

- 802.15.4 Basics
- 802.15.4 Device Types
- 802.15.4 Networking
- 802.15.4 Security

Security

- **Message Encryption (AES-CTR)**
  - Messages are meaningless without security key
  - Replay attack

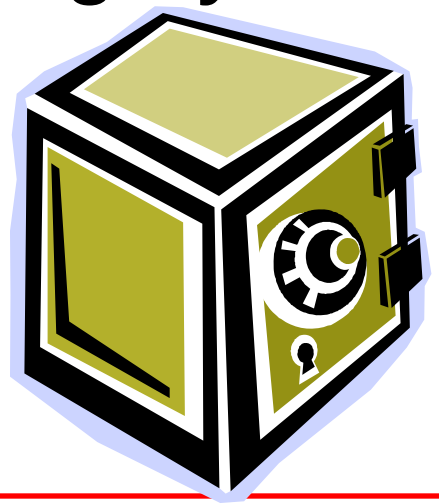


Security

- **Message Authentication (AES-CBC-MAC-32/64/128)**
  - Message hasn't changed in any way during transmission (MIC ensures integrity of the message)
  - Information exposure

Security

- **Message Encryption + Authentication (AES-CCM-32/64/128)**
  - Guarantee the message's secrecy as well as integrity



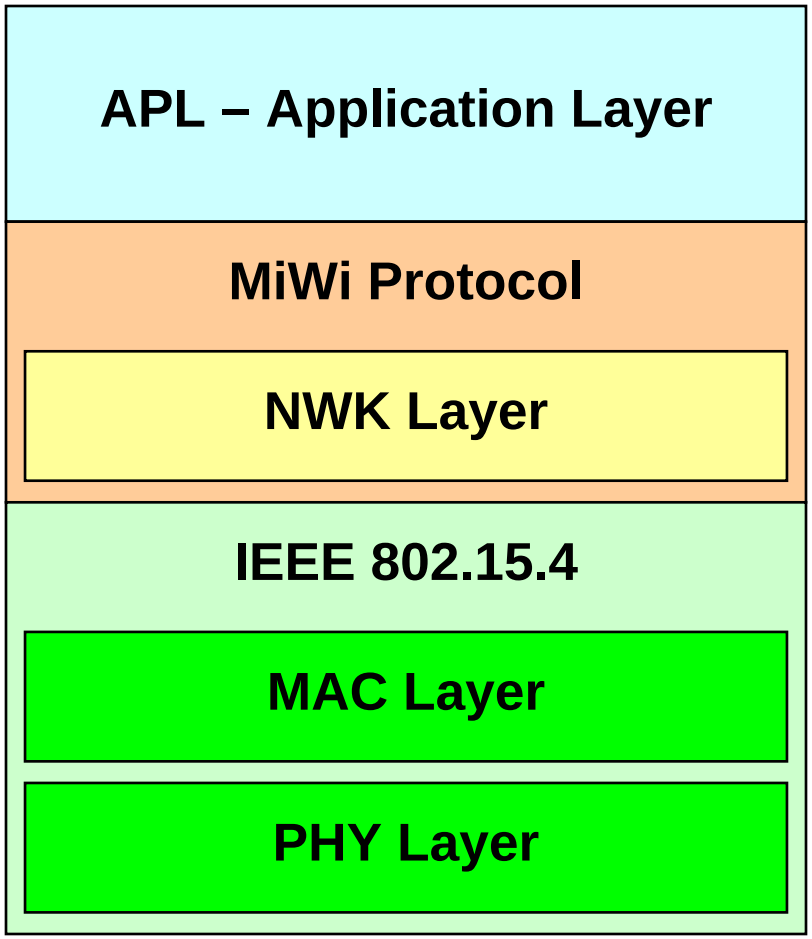
University of Microchip UofM MASTERs 2007

Agenda

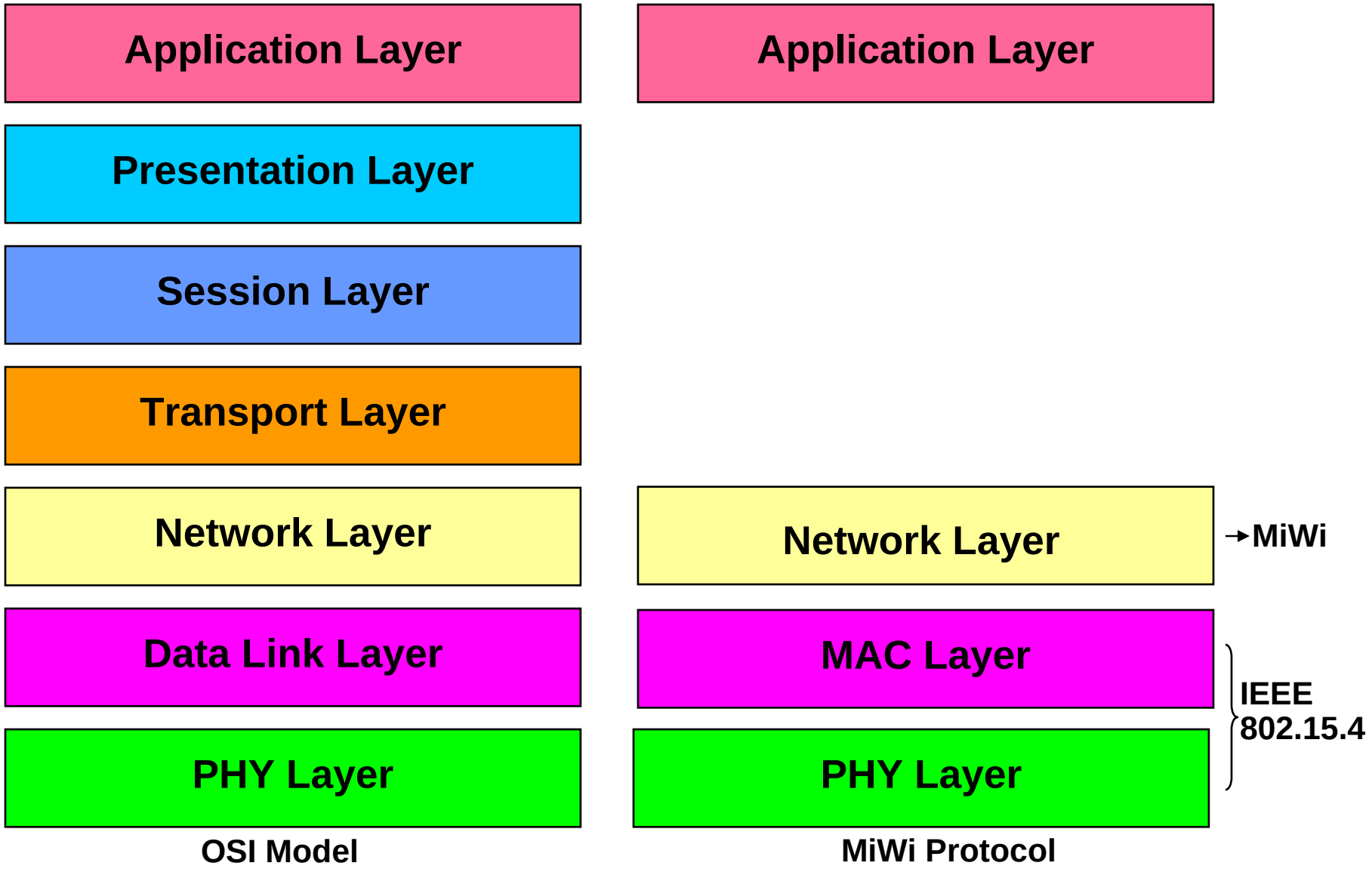
- **Wireless Fundamentals**
- **IEEE 802.15.4**
  - Lab 1
- **MiWi™ Protocol**
  - Lab 2
- **MiWi Protocol vs. ZigBee™**
- **Getting Started**

MiWi™ Wireless Protocol

- **Overview**
- **In Depth**
  - Networking
  - Reports
  - Sockets
  - Security



MiWi™ Wireless Protocol



MiWi™ Wireless Protocol

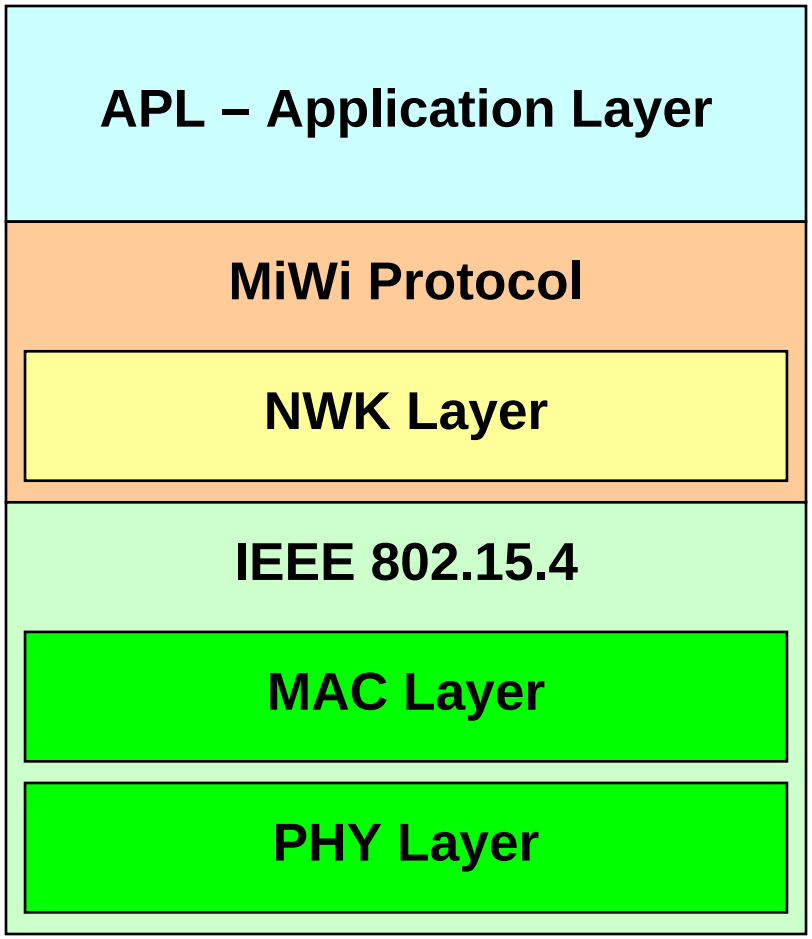
- **Based on IEEE 802.15.4**
- **What MiWi Protocol is:**
  - Simple way to achieve wireless connectivity
  - An alternative to ZigBee™
- **What MiWi Protocol isn't**
  - A replacement for ZigBee
  - Intended for large networks

MiWi™ Protocol Features

- Mesh
- Peer to Peer (P2P)
- IEEE Address Search
- Sockets

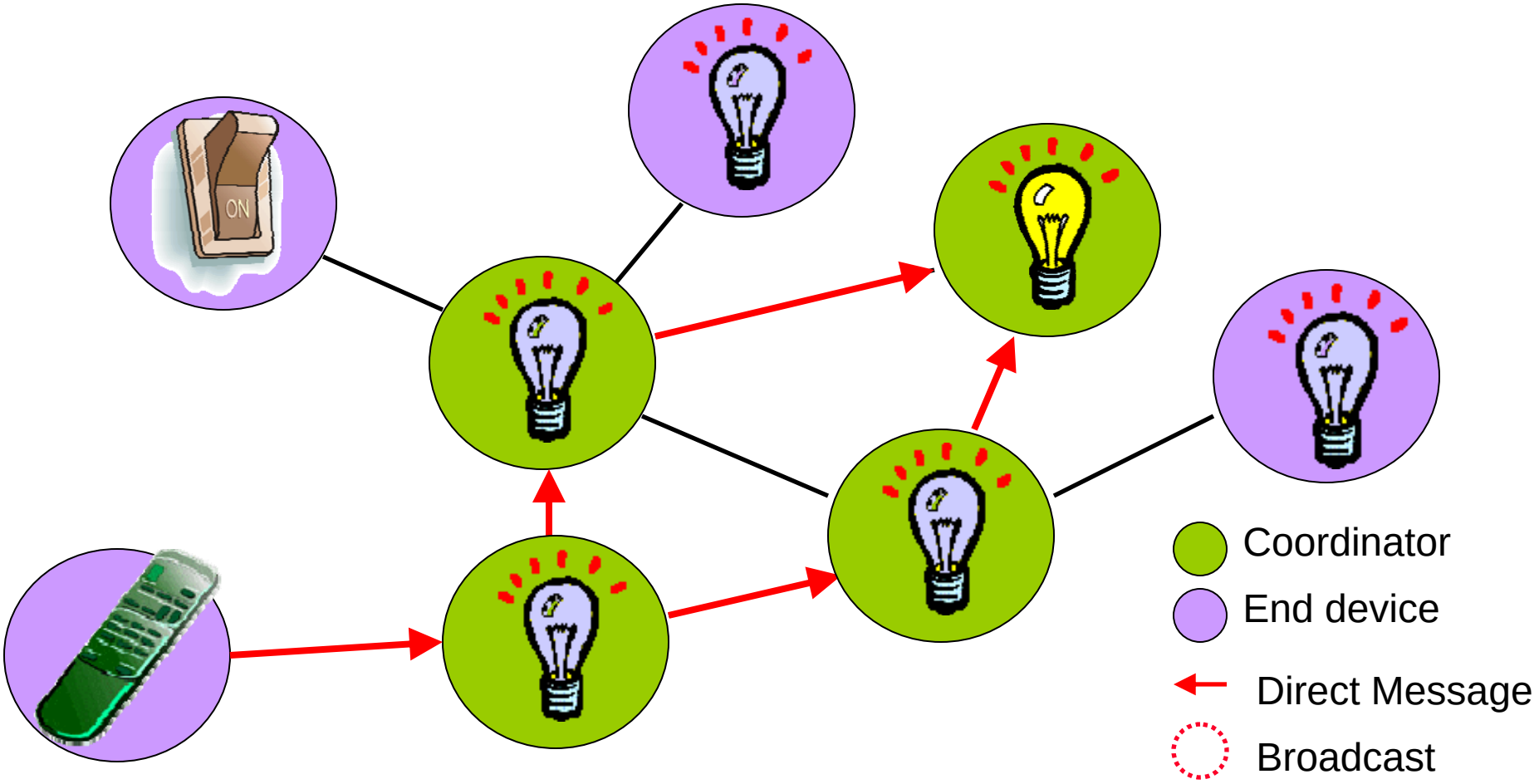
MiWi™ Wireless Protocol

- **Overview**
- **In Depth**
  - Networking
  - Reports
  - Sockets
  - Security



Mesh Network

- **Multiple Routes to a Single Destination Allowed**

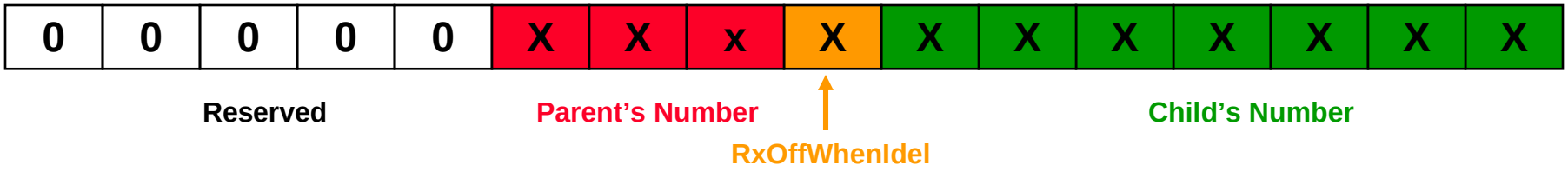


MiWi™ Networking Protocol

- Uses slight variation on IEEE join and leave mechanisms
- Allows up to 8 coordinators on the network with up to 127 children per coordinator
- Max 4 hops on a message
- Peer to Peer

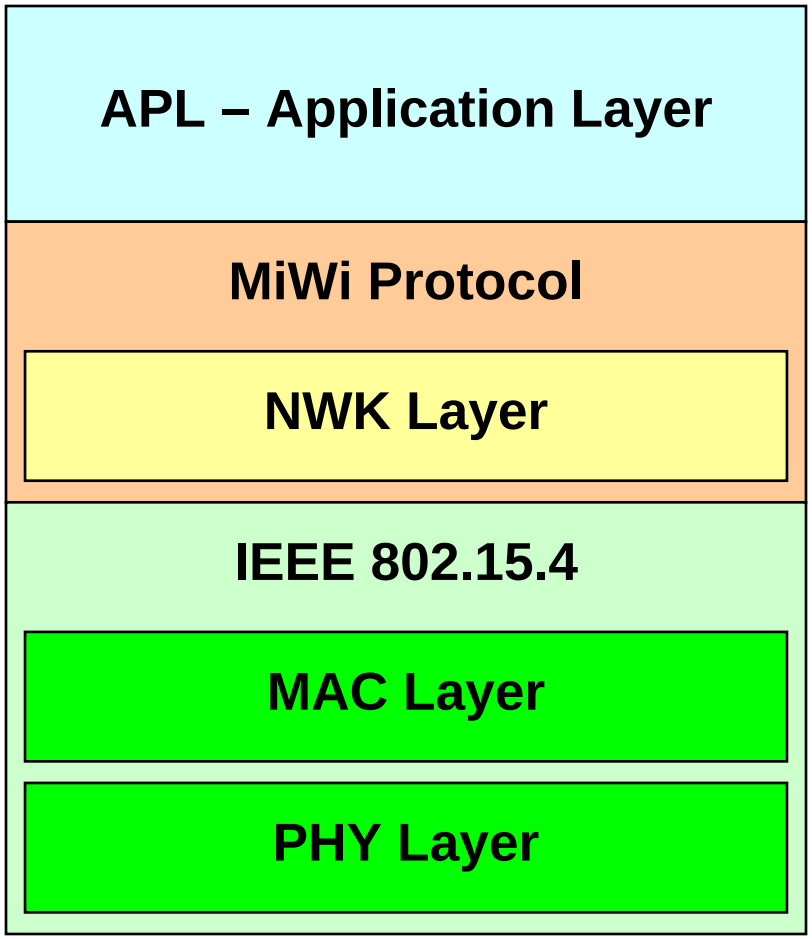
MiWi™ Protocol Short Address

- Parent's number
  - **Reserved for Coordinator**
- RxOffWhenIdle
  - **1 bit**
- Child's Number
  - **7 bits**



MiWi™ Wireless Protocol

- **Overview**
- **In Depth**
  - Networking
  - Reports
  - Sockets
  - Security

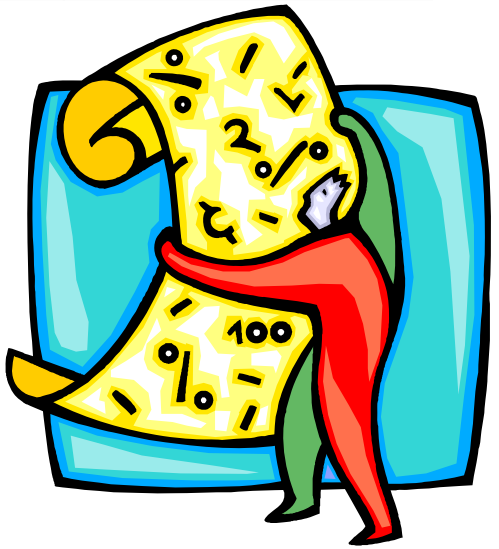


MiWi Protocol Reports

- **Report is the Format of MiWi™ Protocol to Transfer Data**

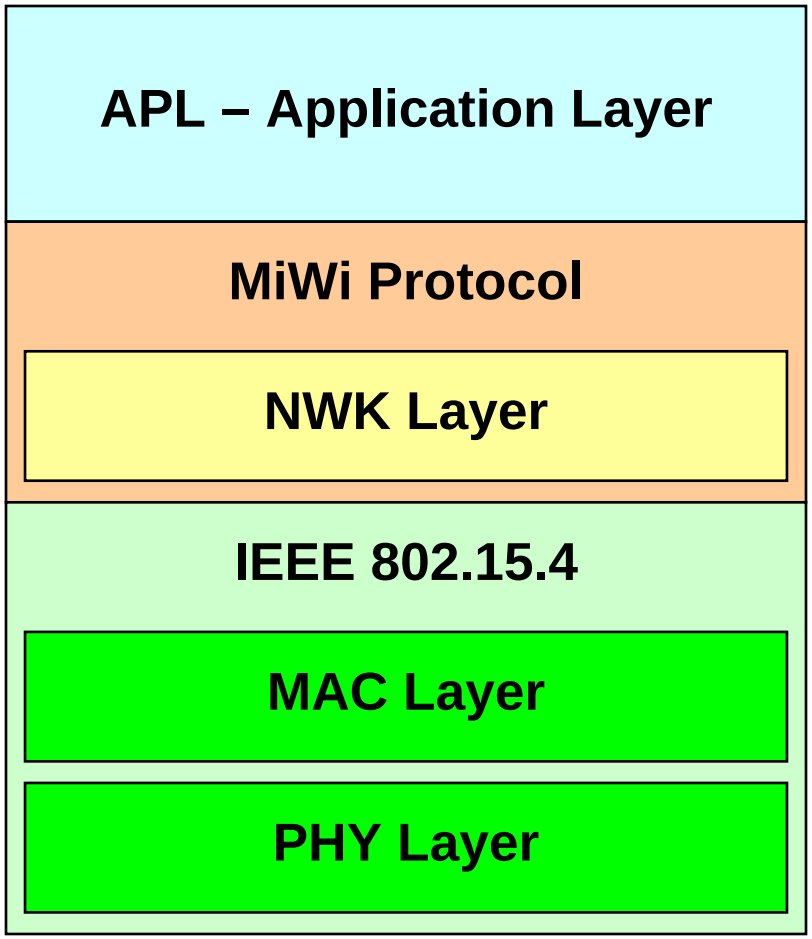
MAC Header (one hop)	MiWi Header (multi hop)	MiWi Reports

- **Consist of:**
  - Report Type
    - **0x00 for MiWi stack**
    - **0x01 to 0xFF for user**
  - Report ID
  - Payload (Depends on Report Type and Report ID)



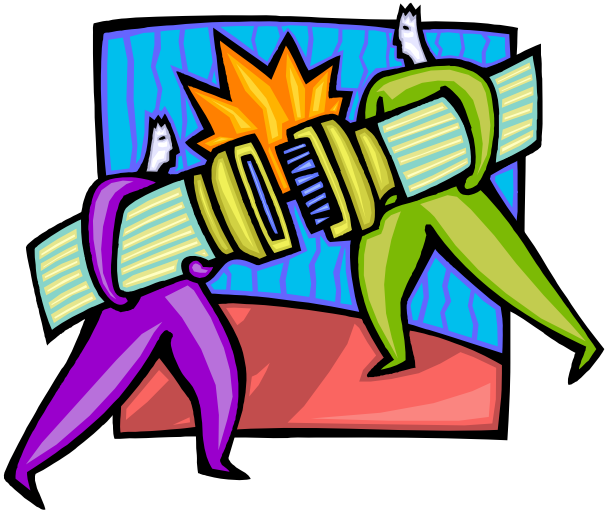
MiWi™ Wireless Protocol

- **Overview**
- **In Depth**
  - Networking
  - Reports
  - Sockets
  - Security



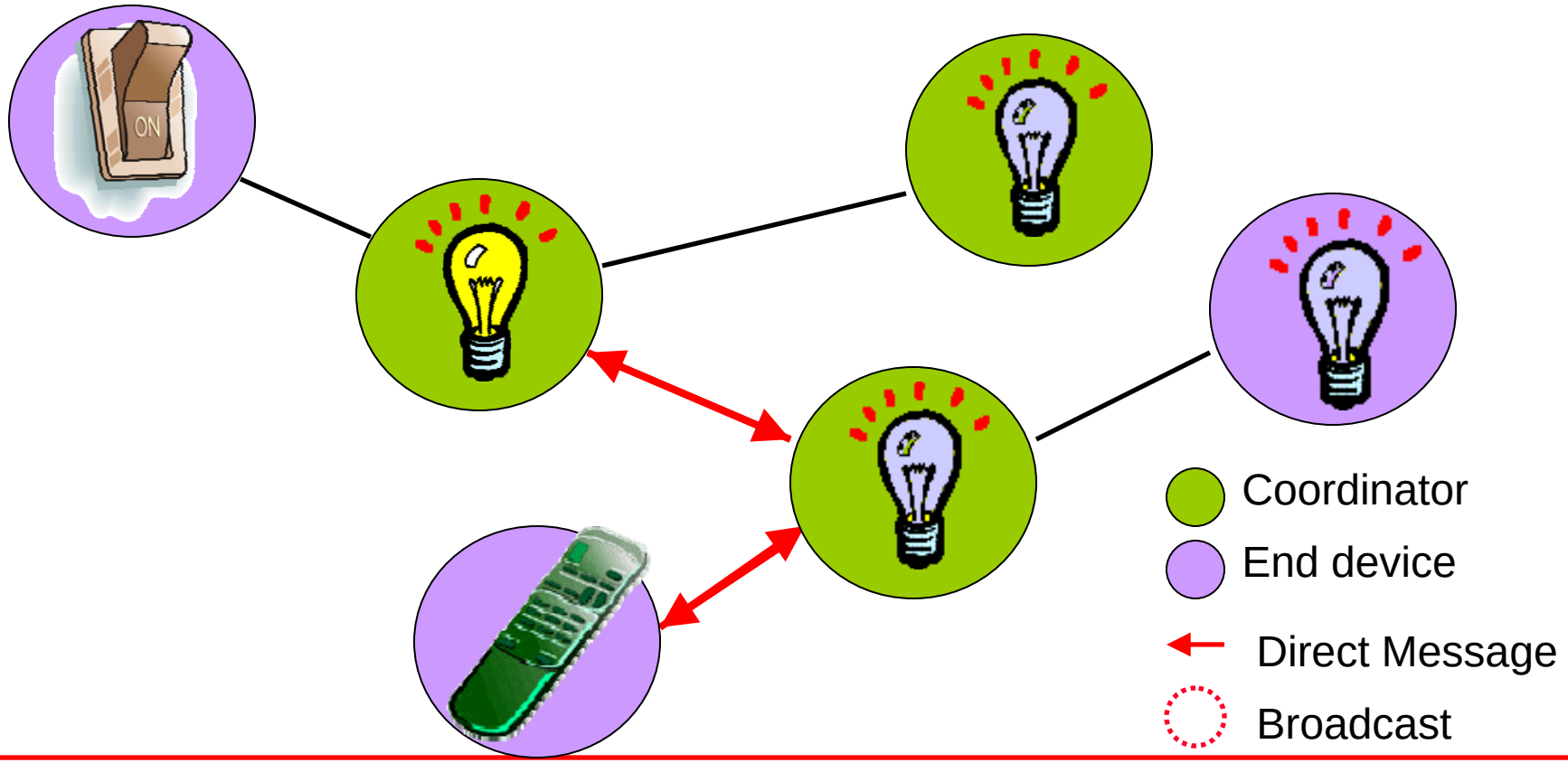
MiWi™ Protocol Sockets

- **Sockets**
  - Sockets are virtual connections between devices
- **Two Types of Sockets**
  - Peer to Peer
  - Cluster



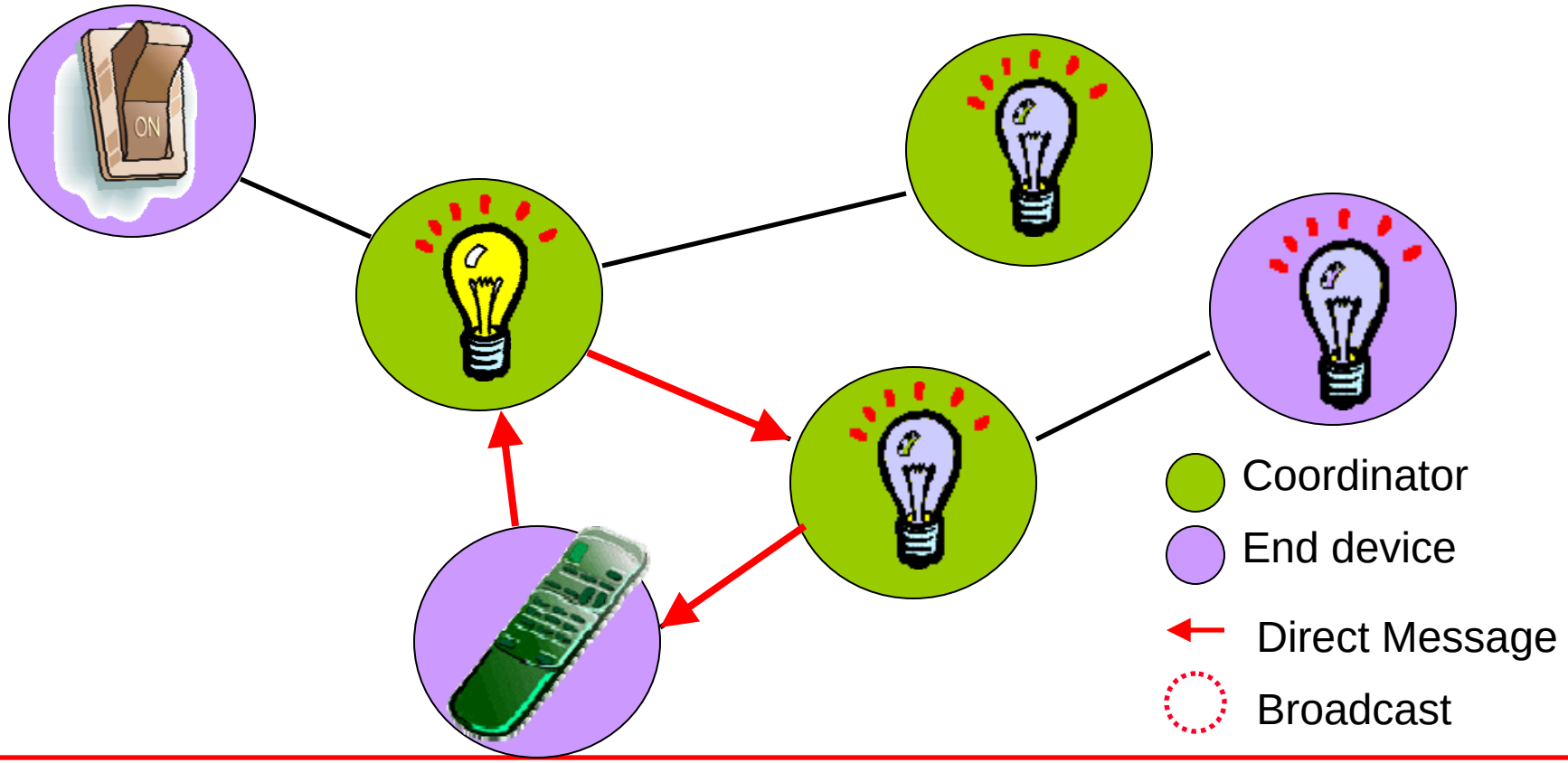
Peer to Peer Sockets

- **Peer to Peer Devices use Direct Sockets to Connect to Each Other**

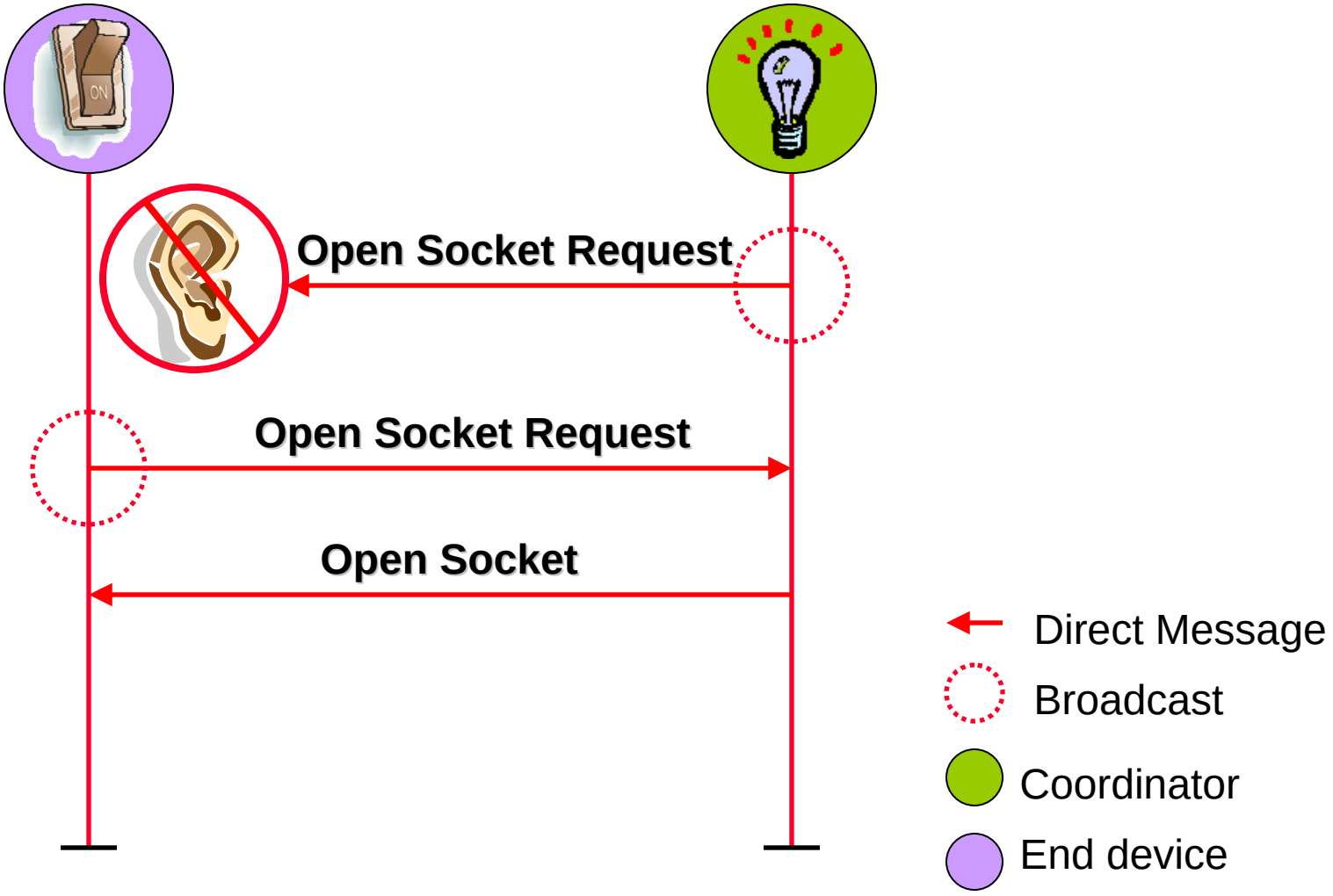


Peer to Peer Sockets

- **Peer to Peer Devices use Direct Sockets to Connect to Each Other**

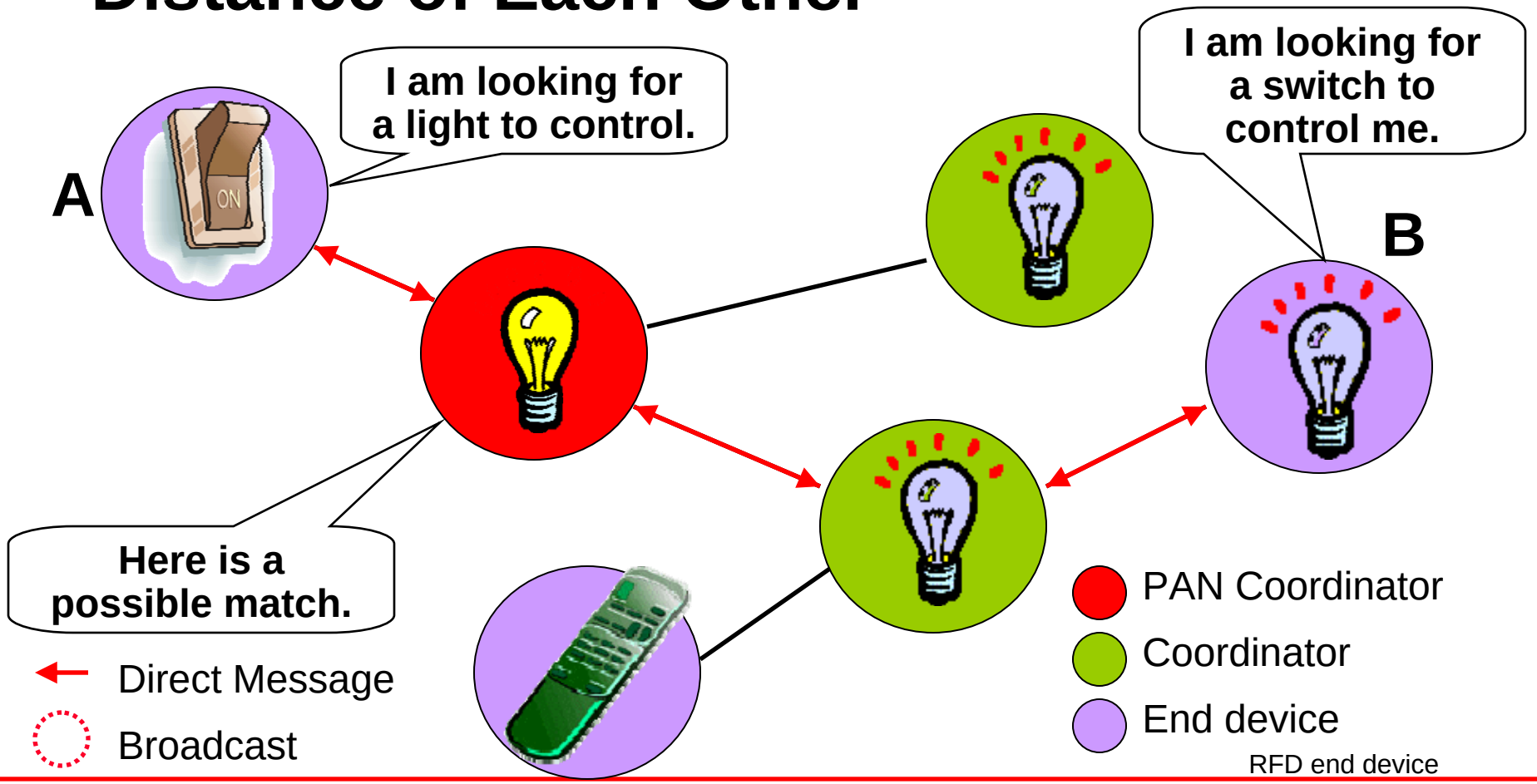


MiWi™ Protocol Sockets (Peer to Peer)



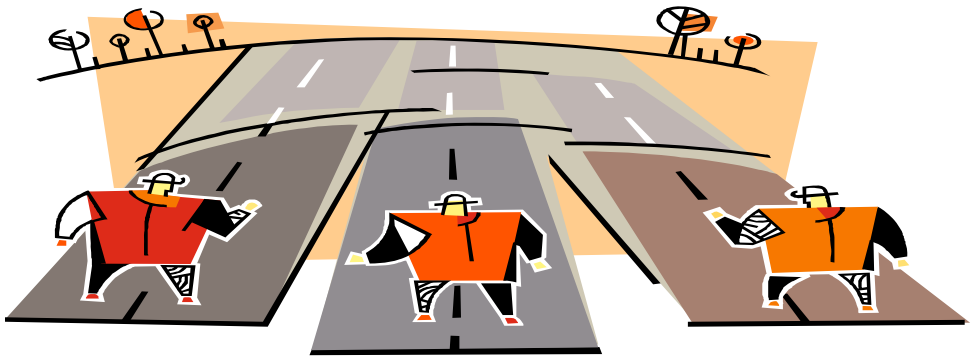
Cluster Sockets

- **Create a Socket Connection Between Two Nodes that are not in Radio Distance of Each Other**



Communications

- **Three Ways to Communicate with Another Node**
  - SendReportByLongAddress
  - SendReportByShortAddress
  - SendReportByHandle (Socket)



University of Microchip UofM MASTERs 2007

Agenda

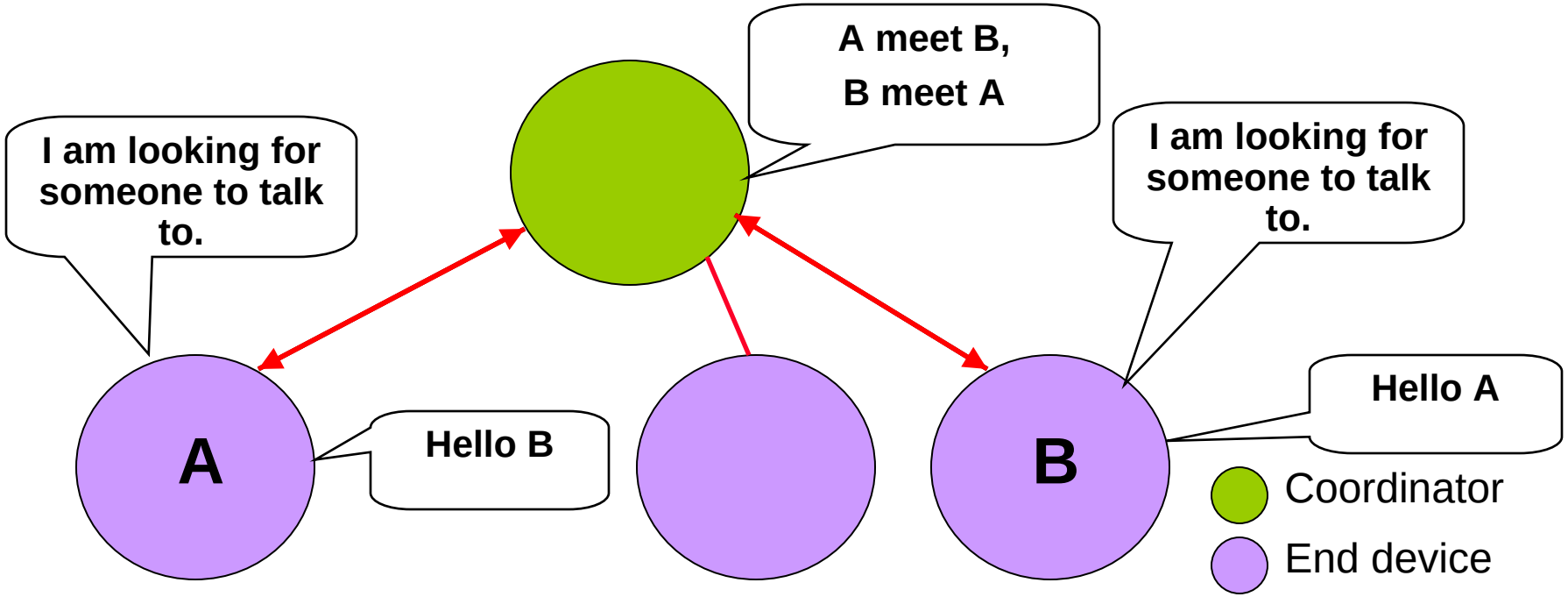
- **Wireless Fundamentals**
- **IEEE 802.15.4**
  - Lab 1
- **MiWi™ Protocol**
  - Lab 2
- **MiWi Protocol vs. ZigBee™**
- **Getting Started**

Lab 2

Sockets

Lab 2

- Use OpenSocket(…) to dynamically set up a link to another device
- Use SendReportByHandle(…) to send them a message



Lab

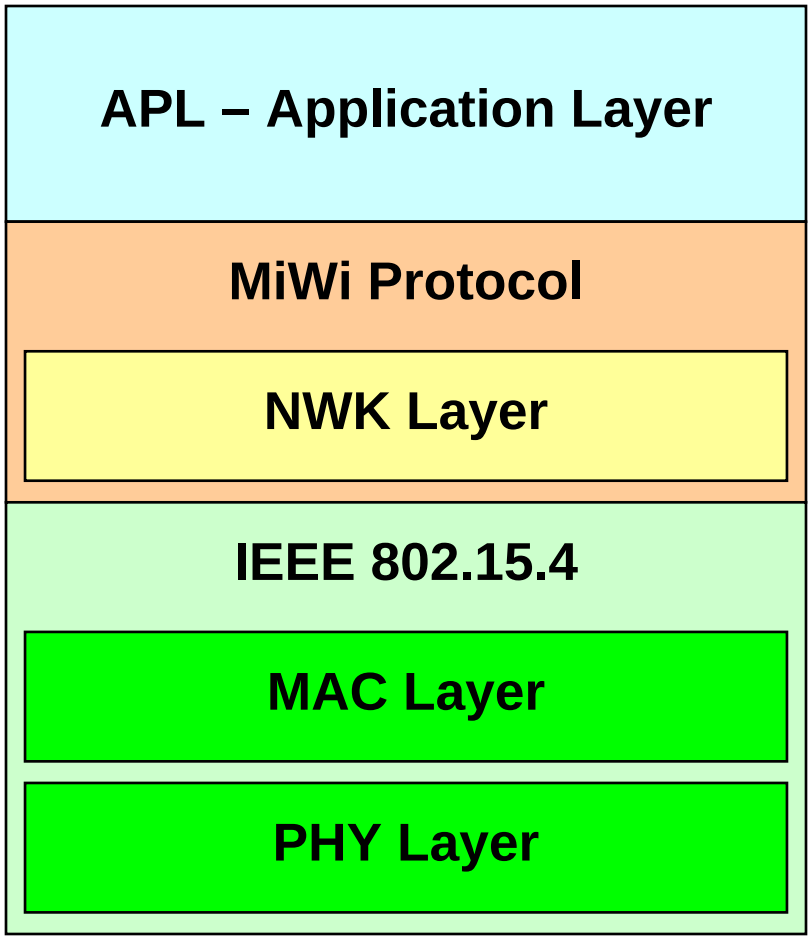
- Please refer to the hand out material for the instructions for the lab
- If you have any questions, feel free to ask at any time

MiWi™ Wireless Protocol

- **Is the Instant Message Application Good Enough?**
  - How about someone can listen to what you are saying?
  - Security is an important factor when designing a wireless network

MiWi™ Wireless Protocol

- **Overview**
- **In Depth**
  - Networking
  - Reports
  - Sockets
  - Security

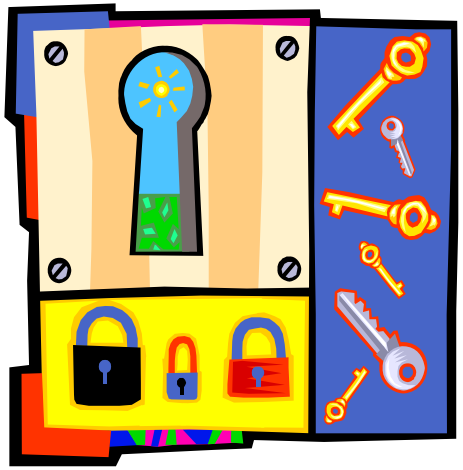


MiWi Protocol Security

- **Security Modes**
  - Single Level Security
    - Once pass the guard, no further check-up
    - Minimum system resources required

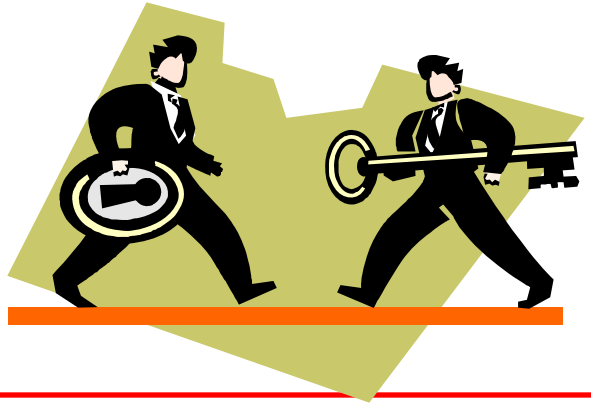
MiWi Protocol Security

- **Security Modes (Continue)**
  - Multi-Level Security
    - Permit node to do certain operation based on its security clearance
    - More system resources required



MiWi Protocol Security

- **Security Modes (Continue)**
  - Security Based on Individual Key Creation
    - Communication between each pair of nodes requires link-key generated
    - Maximum system resources required



MiWi Protocol Security

- **Security Key(s) Management**
  - Unchangeable – Programming Space
  - Changeable
    - **Programming Space**
    - **External EEPROM**
      - Key(s) encrypted in external EEPROM
      - Default key stored in programming space

MiWi Protocol Security

- **Security Key(s) Management (Continue)**
  - Preconfigured Key(s).
    - **No Mandatory Key(s) Transmission**
  - Non-Preconfigured Key(s)
    - **Key(s) to be Transferred in the Air**
      - Use default key to encrypt transferred key(s)
      - Only transfer once for the first time
      - Reduced transmission power

MiWi™ Protocol Security

- Support all 7 Security Modes Defined in IEEE 802.15.4
- Support Single Level Security Mode
- Fixed Security Key Out of Box

Agenda

- **Wireless Fundamentals**
- **IEEE 802.15.4**
  - Lab 1
- **MiWi™ Protocol**
  - Lab 2
- **MiWi Protocol vs. ZigBee™**
- **Getting Started**

MiWi™ Protocol vs. ZigBee™

- Proprietary network
- Small networks
- 4 hop max
- Dynamic topology
- Small footprint
- Low overhead
  - Device discovery
  - Socket

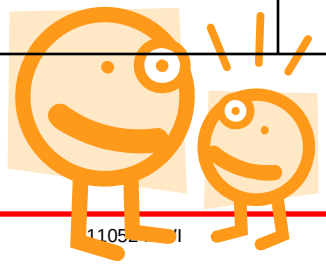
- Interoperable
- Large networks
- Infinite hops
- Dynamic topology
- Large footprint
- High overhead
  - Device discovery
  - Service discovery
  - Bindings

MiWi™ Protocol vs. ZigBee™

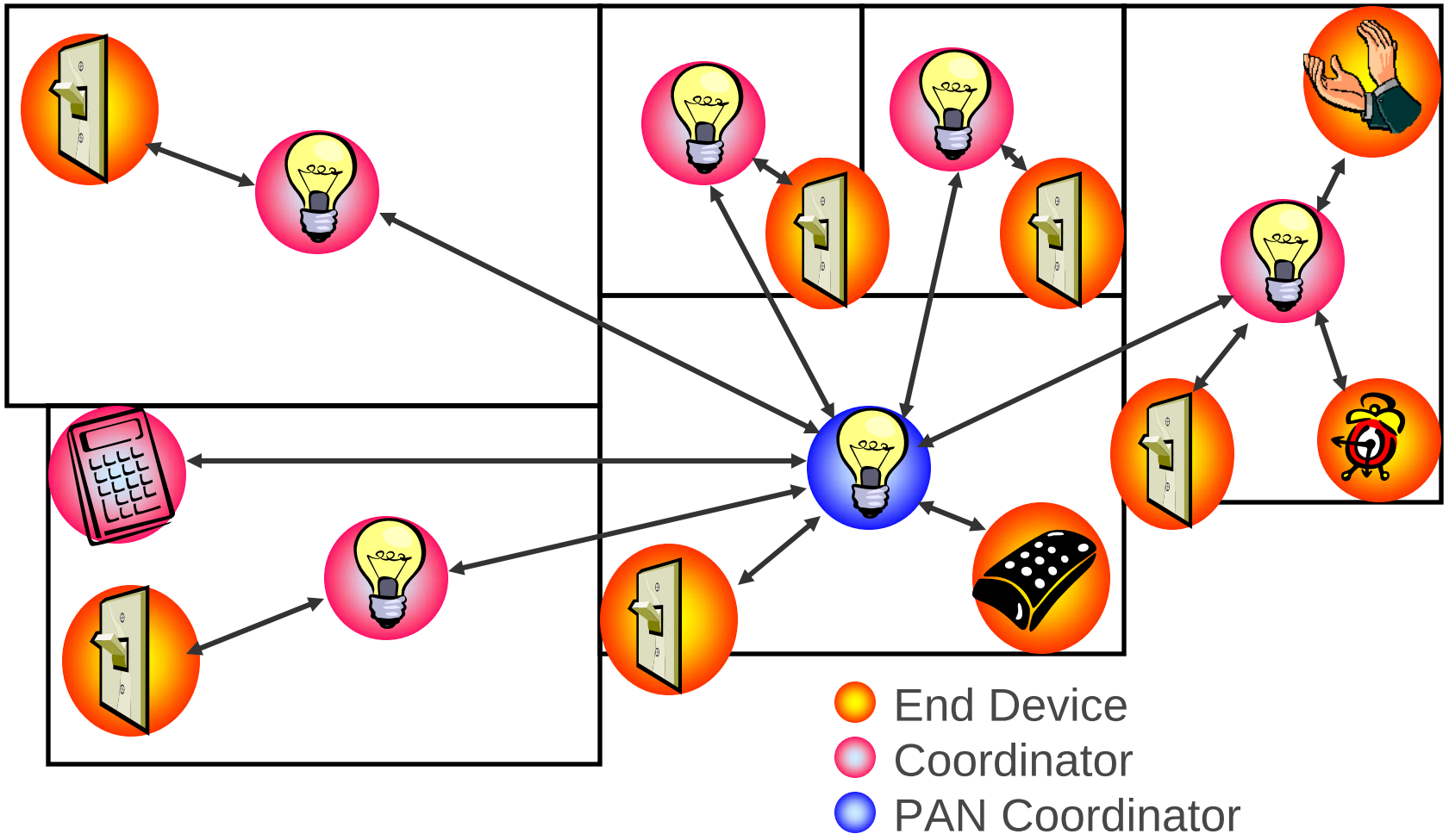
Code Size	**Coordinator <16KB** **Router <16KB** **End Device 4-10KB (depending on features supported)**	**Coordinator 40-96KB** **Router 36-64KB** **End Device 21-40KB**
System Resources	**Support PIC16/18/24 and dsPIC33** **RAM <1KB** **I/O SPI + 3 pin**	**Support PIC18/24 and dsPIC33** **RAM 4KB** **I/O SPI + 3 pin**
Standard	**Available online as an application note**	**Open standard, standardized information format for interoperability**

MiWi™ Protocol vs. ZigBee™

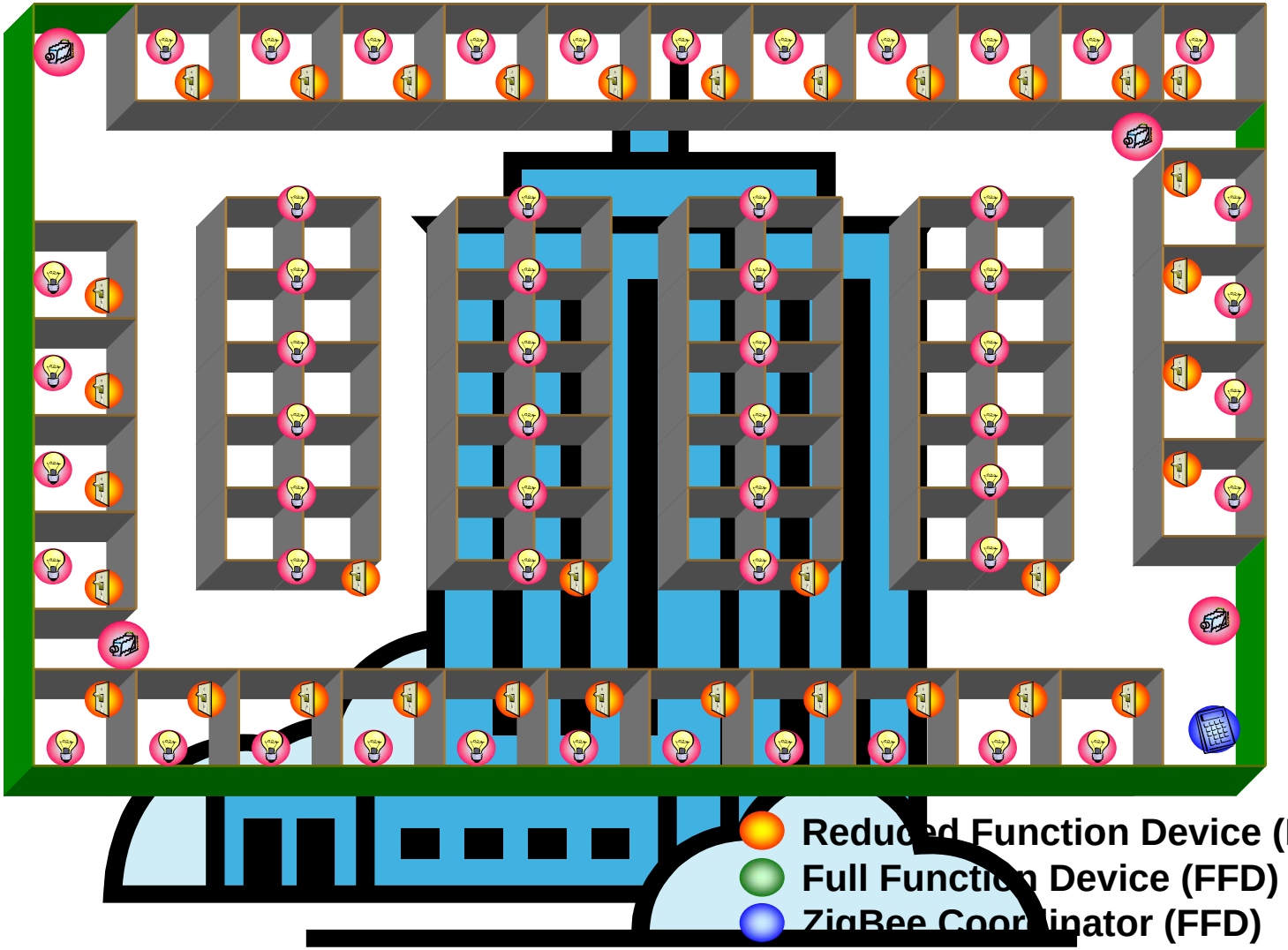
Network	**1024 nodes, 4 hops max**	**65,536 nodes, infinite hops max**
Cost	**Must use a Microchip microcontroller and transceiver (MRF24J40)**	**$3,500 per year + testing fees + certification fee** **-or-** **$9,500 per year + testing fees**
Certification	**None required other than standard wireless certification (FCC, …)**	**Compliance certification or "No Harm" certification + standard wireless certification (FCC, …)**



Typical MiWi™ Network



Typical ZigBee ™ Network



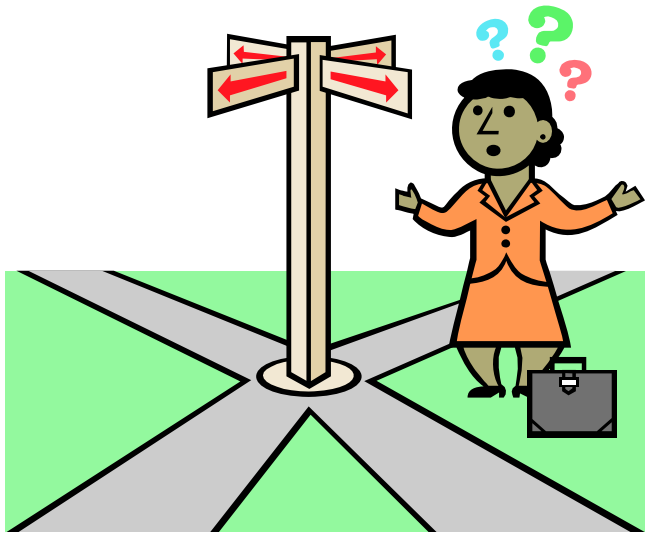
UNIVERSITY OF MICROCHIP UOFM MASTERS 2007

Agenda

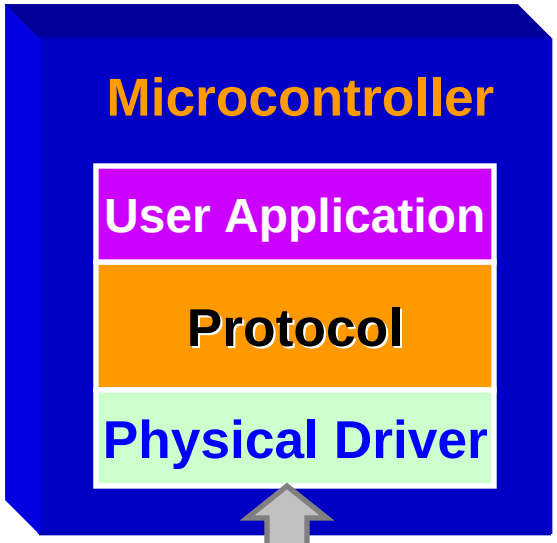
- **Wireless Fundamentals**
- **IEEE 802.15.4**
  - Lab 1
- **MiWi™ Protocol**
  - Lab 2
- **MiWi Protocol vs. ZigBee™**
- **Getting Started**

Getting Started

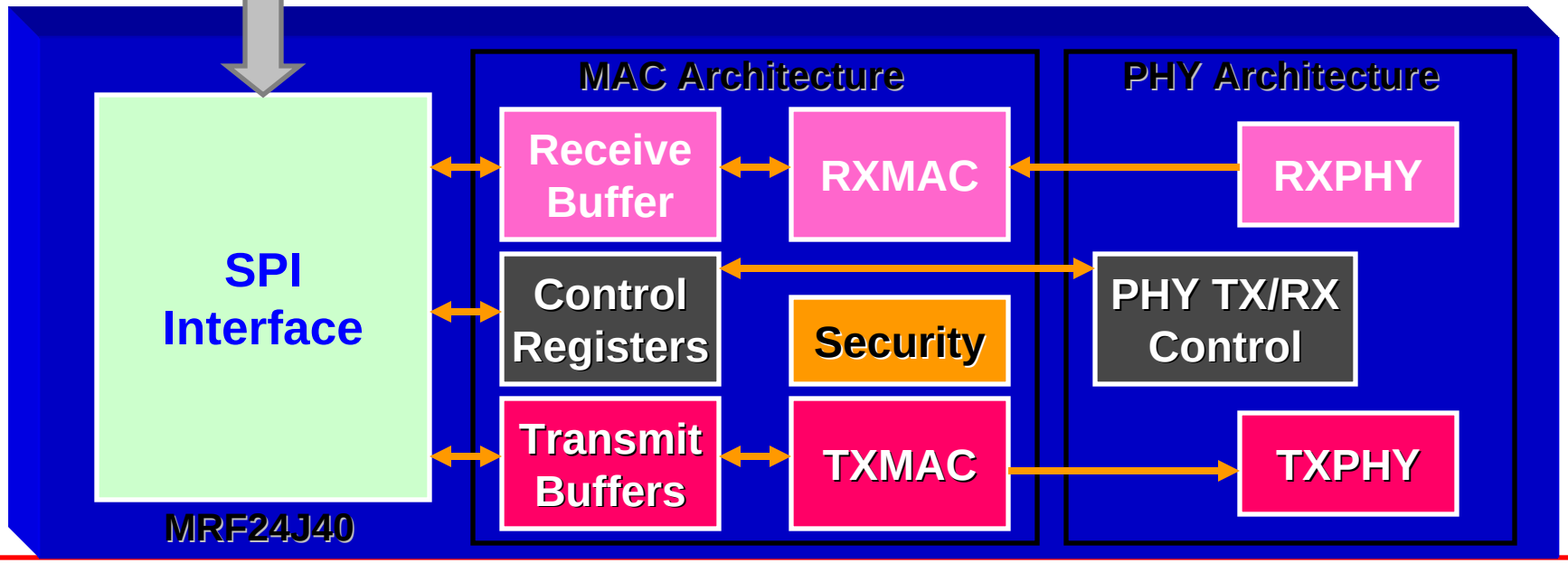
- **Download MRF24J40 Data Sheet**
- **Determine your Requirements and Design a Circuit that Fits Your Needs**
  - Lowest power
  - Low cost
  - Greatest distance
  - Smallest



MRF24J40

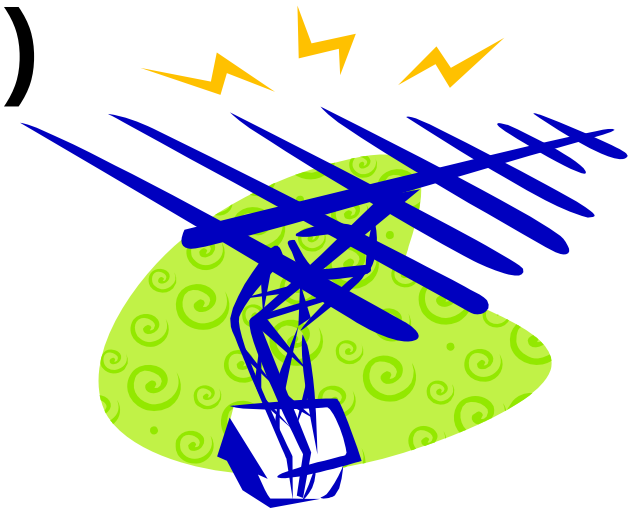


- 2.4 GHz IEEE 802.15.4 compliant
- Supports MiWi™ & ZigBee™
- 4-wire SPI interface
- In-line/stand-alone encryption
- Automatic MAC retransmit
- 18 mA(RX)/22 mA(TX)/2 µA(Sleep)

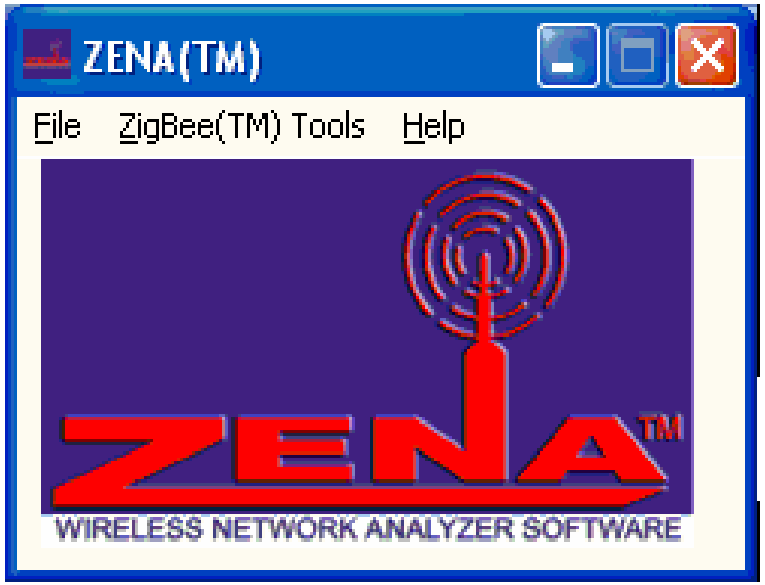


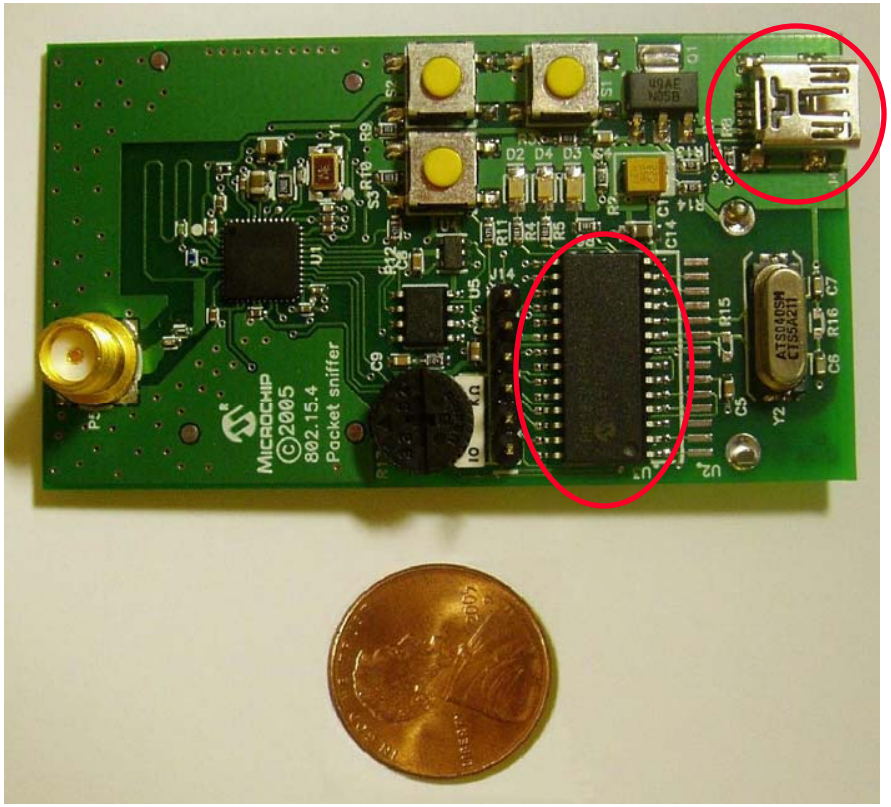
RF Design Consideration

- **RF Range**
  - Outdoor: 100-300 meters
  - Indoor: 10-50 meters
- **Need More Range? (Master Class 11053)**
  - RF Design
  - Antenna Design



ZENA™ Wireless Network Analyzer





- Windows® based software
- USB to 802.15.4 Packet Sniffer using PIC18LF2550
- $199.99 USD

University of Microchip UofM MASTERs 2007

If MiWi™ Protocol…

- Download MiWi protocol application note and corresponding source
- Order PICDEM™ Z with ZENA™ Wireless Network Analyzer
- Start development
- Submit for local RF certification - $5,000-$10,000

If ZigBee™…

- Download AN965 and corresponding source
- Order PICDEM™ Z with ZENA™ Analyzer
- Implement their ratified specification
- Become a ZigBee Alliance member – Full - $9,500 annually; Adopter - $3,500 annually
- Join Application Framework Group (AFG) that corresponds to your product

If ZigBee™…

- Submit for ZigBee Alliance certification – test house dependent (in the thousands)
- Purchase rights to use the ZigBee logo - $1,000 first SKU, $500 each additional (for adopter level only)
- Submit for local RF certification - $5,000-$10,000

Summary

- Understand general wireless networking considerations
- Know IEEE 802.15.4 basics
- Are Experienced working with the MiWi™ protocol stack
- Know the strengths and limitations of MiWi protocol and ZigBee™

University of Microchip UofM MASTERs 2007

References

- IEEE 802.15.4™ -2003
  - http://standards.ieee.org/getieee802/download/802.15.4-2003.pdf
- IEEE OUI
  - https://standards.ieee.org/regauth/oui/forms/OUI-form.shtml
- MiWi™ Protocol
  - http://www.microchip.com/MiWi
- ZigBee™ Protocol
  - http://www.microchip.com/ZigBee

University of Microchip UofM MASTERs 2007

Thank you!

UNIVERSITY OF MICROCHIP UOFM MASTERS 2007

Trademarks

The Microchip name and logo, the Microchip logo, Accuron, dsPIC, KeeLoq, KeeLoq logo, microID, MPLAB, PIC, PICmicro, PICSTART, PRO MATE, rfPIC and SmartShunt are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AmpLab, FilterLab, Linear Active Thermistor, Migratable Memory, MXDEV, MXLAB, SEEVAL, SmartSensor and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Application Maestro, CodeGuard, dsPICDEM, dsPICDEM.net, dsPICworks, ECAN, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, Mindi, MiWi, MPASM, MPLAB Certified logo, MPLIB, MPLINK, PICkit, PICDEM, PICDEM.net, PICLAB, PICtail, PowerCal, PowerInfo, PowerMate, PowerTool, REAL ICE, rfLAB, Select Mode, Smart Serial, SmartTel, Total Endurance, UNI/O, WiperLock and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

All other trademarks mentioned herein are property of their respective companies.