802.15.4 ZIGBEE

Overview

- Introduction to ZigBee
- Technologies That Came Before
- 802.15 Standard
- 802.15.4 and ZigBee
- The 802.15.4 Standard
- ZigBee Packet Analysis
- Topologies
- Routing

ZigBee

- ZigBee is a working group much the same as the WiFi alliance or the WiMAX forum for the promotion of the 802.15.4 standard

ZigBee™ Alliance
Wireless Control That Simply Works

ZigBee's Role

- Wireless monitoring, control of lights, security alarms, motion sensors, smoke detectors. In fact anywhere that low power, 'low' bandwidth wireless comms are required
- Far lower power than Bluetooth

Do We Need Another Wireless Standard?

- Simpler
  - The most complex ZigBee node requires only 10% of the code required by a typical Bluetooth node
  - The simplest ZigBee node requires only 2% of the code required by a typical Bluetooth node
- Cost
  - You could buy Five ZigBee nodes for the price of one Bluetooth node

Home Control with X10

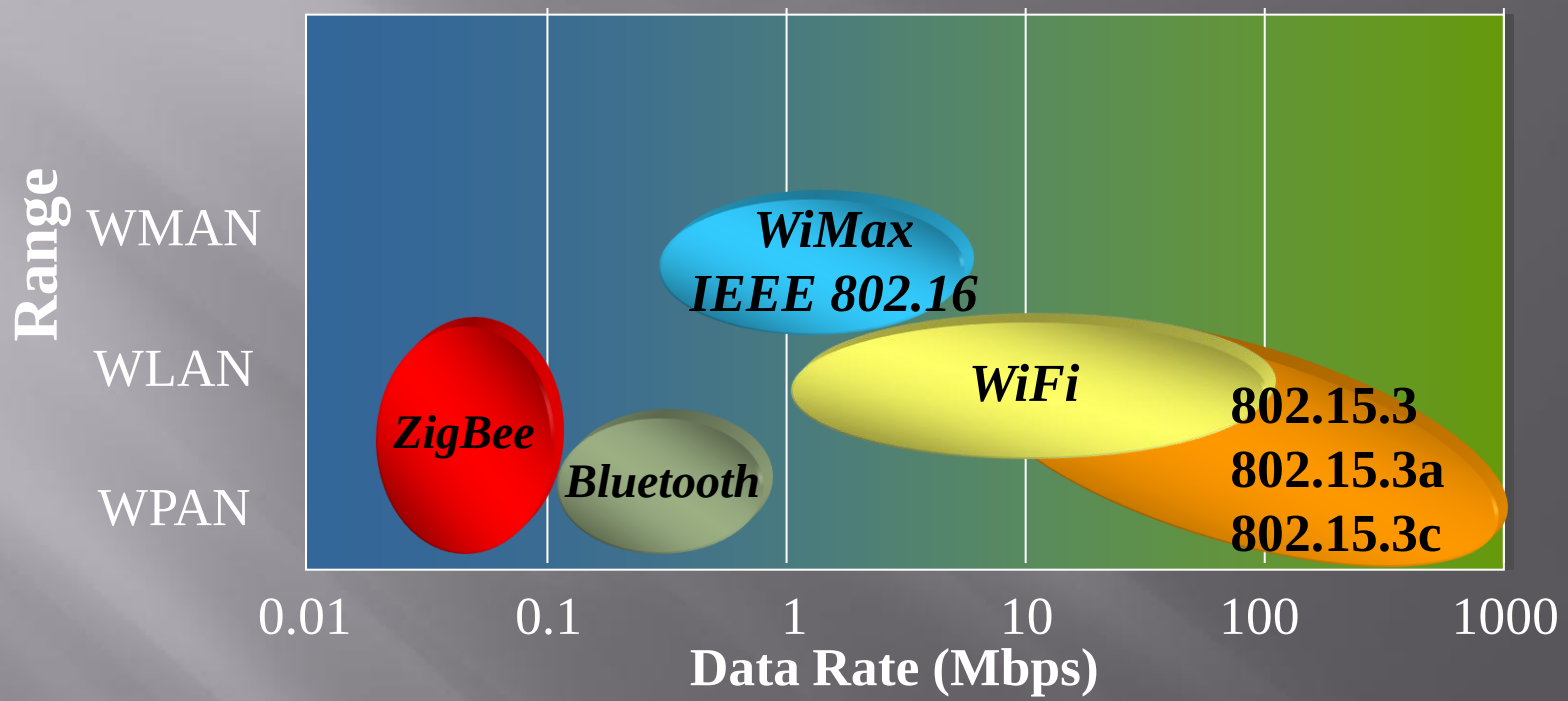
- Used the AC power lines as a transmission mechanism
- Addressing was “house” A through P and “module” codes 1 through 16
- Slow speed effective rate of 60bps
- Not reliable!
- Allowed web based control

Some 802 standards

	802.16a WiMAX	802.11 WLAN	802.15 WPAN
Frequency	*2 – 11GHz*	*2.4GHz*	*Varies*
Range	*31 miles*	*100 Meters*	*10 Meters*
Data Rates	*70 Mbps*	*11 - 110Mbps*	*20k – 55Mbps*
Nodes	*Thousands*	*Dozens*	*Dozens*
Notes	*Large antennae----------→Small antennae*		
	High power----------→Low power		

BUT! Shorter range does necessarily mean lower bandwidth requirements

Some 802 standards



- ZigBee has a lower data rate than Bluetooth, but extends into WLAN territory in terms of range

Ref: ZigBee Alliance

Review 802.15 Alphabet Soup

802.15	Wireless Personal Area Networks (WPAN)
802.15.1	WPANs based on Bluetooth
802.15.2	Coexistence of WPAN's and WLAN's
802.15.3	High data rates 20Mbps+ on WPAN
802.15.3a	High speed PHY enhancements (imaging and Multimedia)
802.15.3b	High speed MAC enhancement (implementation and interoperability)
802.15.4	**Low data rate, simple, multi year battery life**
802.15.5	Mesh Networking (arrangements for mesh and partial-mesh in PHY and MAC layers of WPAN)

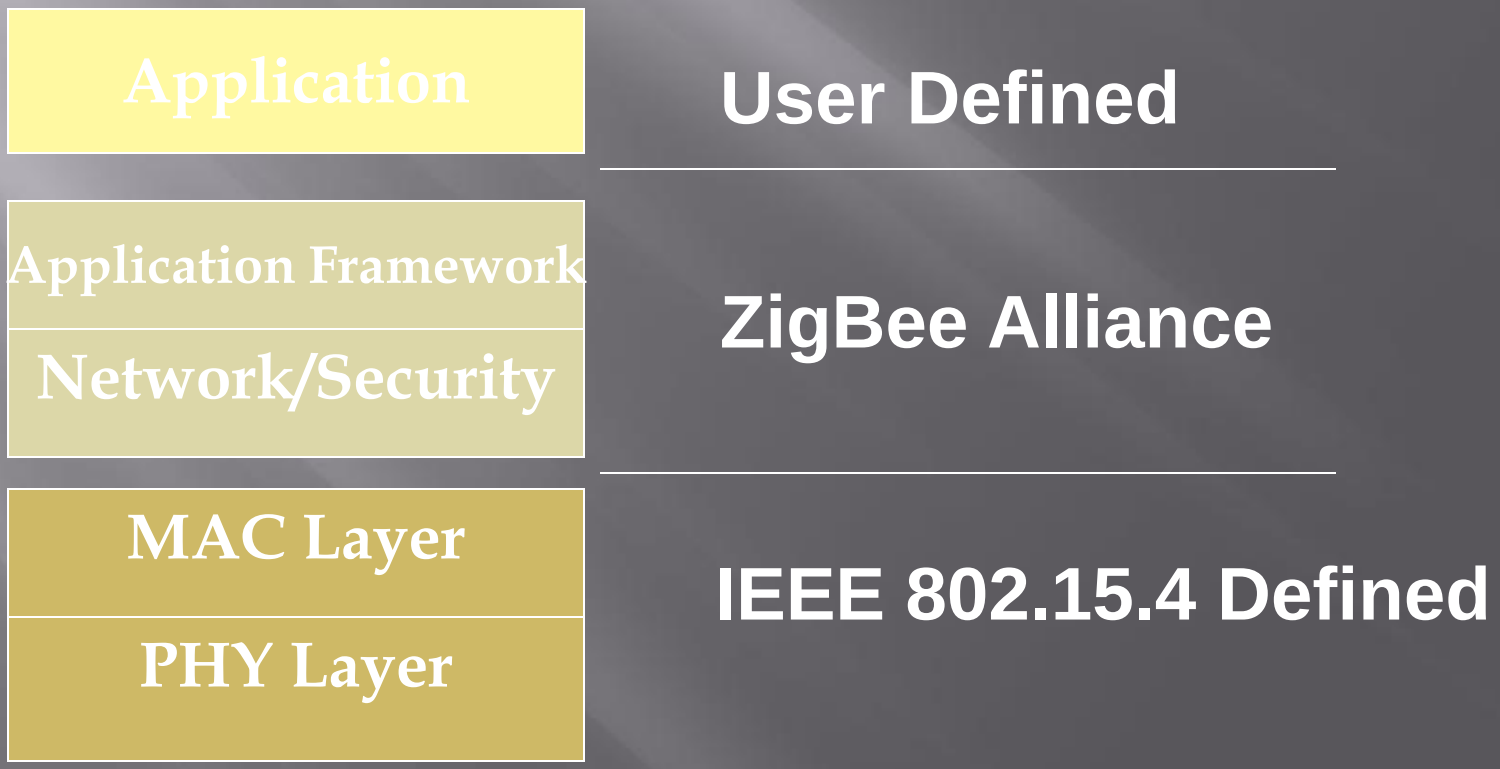
IEEE 802.15.4/ZigBee Standard

802.15.4 - Low data rate, simple, multi year battery life

802.15.4/ZigBee – "Consortium of many companies working together to enable reliable, cost-effective, low-power, wirelessly networked, monitoring and control products based on an **open global standard**."

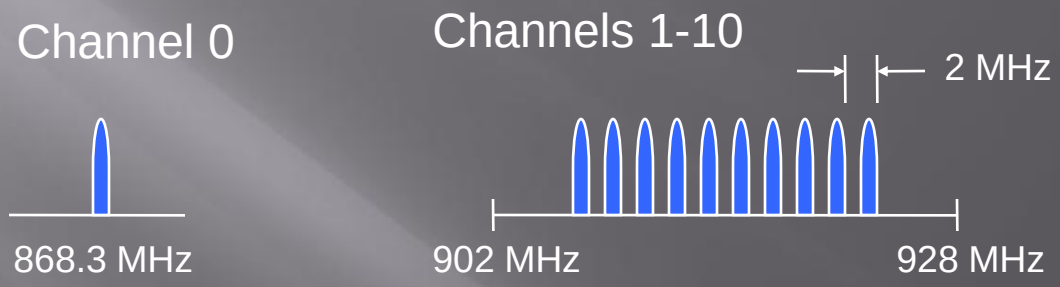
IEEE 802.15.4/ZigBee Standard

- IEEE 802.15.4 - Defines only the PHY (physical layer) and the MAC (media access controller)
- ZigBee builds on this



IEEE 802.15.4 Channel Division

BPSK
868MHz/
915MHz
PHY



2MHz channel with 2Mhz spacing

QPSK
2.4 GHz
PHY

2MHz channel with 5Mhz spacing

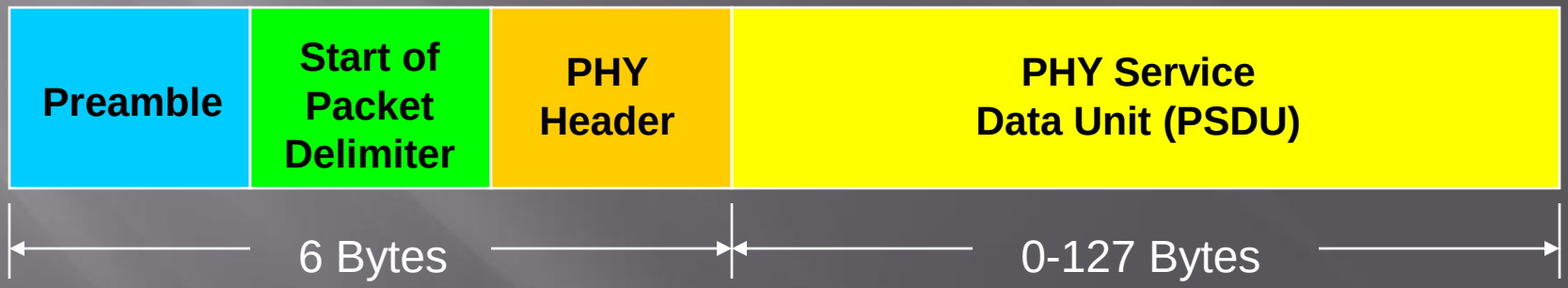
Courtesy Anton Kruger – The University of Iowa

Transmitting Information

- 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)

Packet Structure

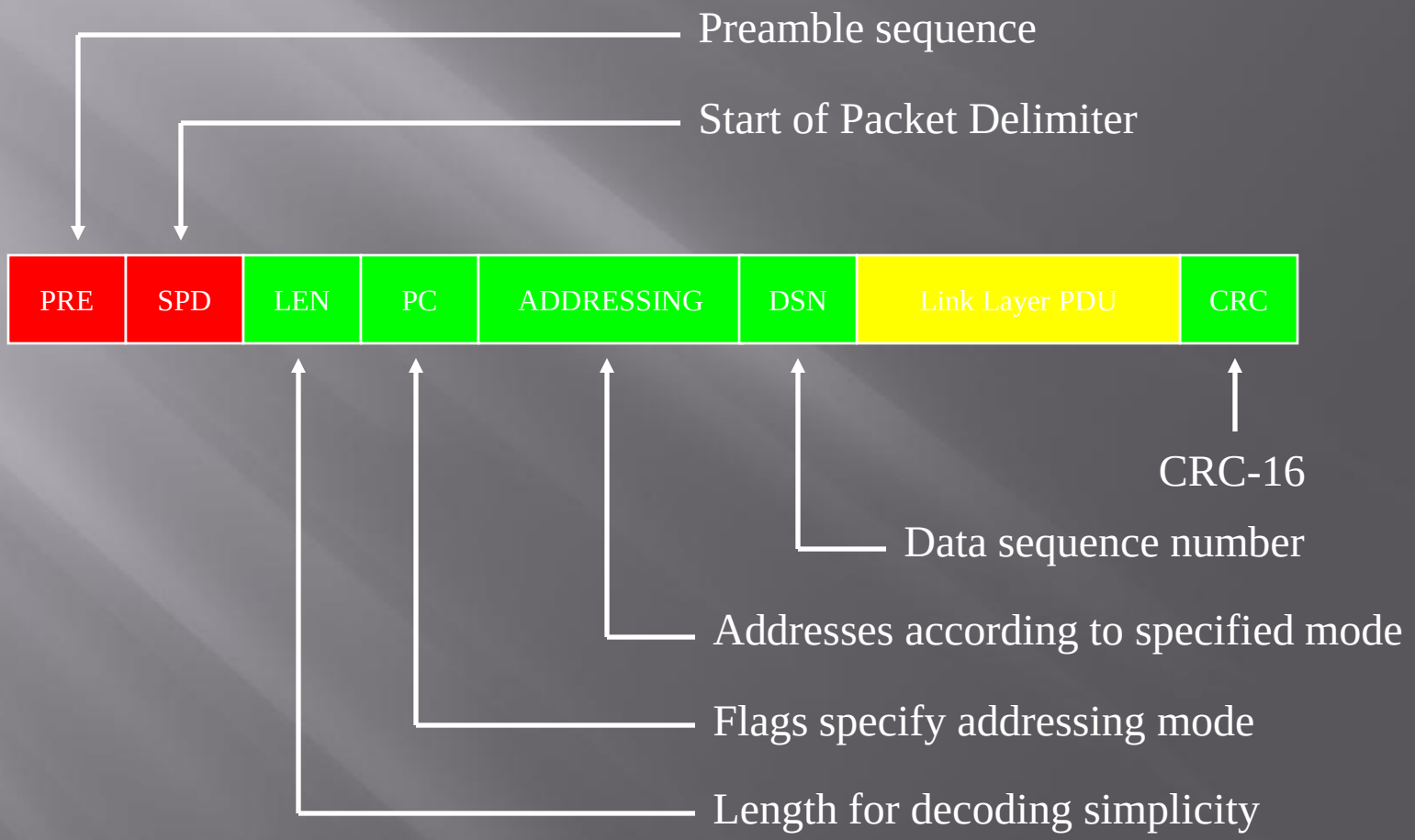
- Packet Fields
  - Preamble (32 bits) – Used for synchronisation
  - Start of Packet Delimiter (8 bits) - specifies packet type
  - PHY Header (8 bits) - Sync Burst flag, PSDU length
  - PSDU (0 to 127 bytes) - Data



Addressing

- All devices have IEEE addresses
- Short addresses can be allocated
- Addressing modes:
  - Network + device identifier (star network)
  - Source/destination identifier (peer-peer network)
  - Source/destination cluster tree + device identifier (cluster tree network)

General Data Packet Structure



Courtesy Anton Kruger – The University of Iowa

ZigBee Device Types

- Full function device (FFD)
  - Available in any topology
  - Capable of becoming a network coordinator
  - Talks to any other device
  - Typically continuously active looking for stimuli
- Reduced function device (RFD)
  - Limited to only star topologies
  - Cannot become a network coordinator
  - Communicates only to a network coordinator
  - Simple implementation efficient and low power

ZigBee Device Types

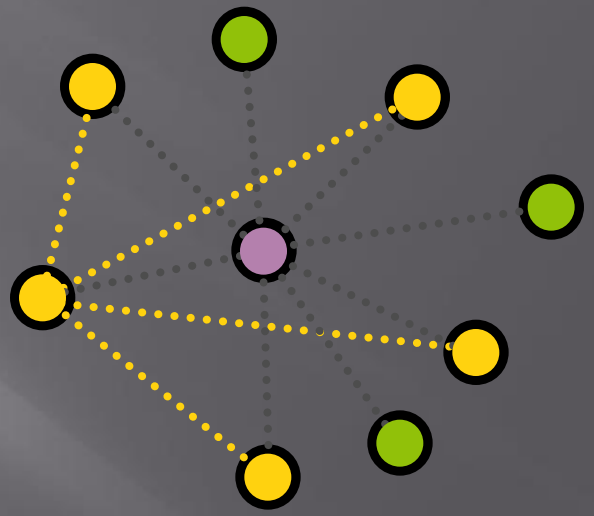
- Why have multiple types?
  - RFD reduces the amount of time radio is on
  - Radio comms is a huge drain on power
- Beaconing networks
  - network synchronises nodes, telling them when to talk and listen IF they have anything to hear or say.
- Non-beacon enabled networks
  - Power consumption is decidedly asymmetrical; some devices are constantly active, while others (if present) are almost always asleep.

Specifications*

		XBee™	XBee-PRO™
Performance	Indoor/Urban Range	1 - 30+ m (3 - 100 ft.)	1 - 100+ m (3 - 300 ft.)
	Outdoor RF line-of-sight Range	1 - 100+ m (3 - 300 ft.)	1 - 300+ m (3 - 1000 ft.)
	Transmit Power Output	1 mW (0 dBm)	100 mW (20 dBm)
	RF Data Rate	250,000 bps	250,000 bps
	Receiver Sensitivity	-92 dBm (1% PER)	-100 dBm (1% PER)
Power Requirements	Supply Voltage	2.0 – 3.4 V	2.8 – 3.4 V
	Transmit Current	40 mA	250 mA @ 2.8 V
	Receive Current	45 mA	50 mA @3.0 V
	Power Down Current	< 1 µA	< 1 µA
General	Frequency	ISM 2.4 GHz	ISM 2.4 GHz
	Dimensions	2.49cm x 2.44cm (0.981" x 0.960")	3.06cm x 2.44cm (1.191" x 0.960")
	Operating Temperature	0 - 70 C° (commercial) or -40 to 85° C (industrial)	0 - 70 C° (commercial) or -40 to 85° C (industrial)
	Antenna Options	RF Connector, Chip Antenna, or Wire Antenna	RF Connector, Chip Antenna, or Wire Antenna
Networking and Security	Supported Network Topologies	Mesh, Peer-to-Peer (Point-to-Point), Point-to-Multipoint, Multidrop	Mesh, Peer-to-Peer (Point-to-Point), Point-to-Multipoint, Multidrop
	Number of Channels	16 Direct Sequence Channels (software selectable)	16 Direct Sequence Channels (software selectable)
	Network Filtration Layers	VID, Channel, Destination Address	VID, Channel, Destination Address

Basic Network Characteristics

- Theoretical 65,536 network (client) nodes
  - Why 65,536?!?
- Optimised for timing-critical applications
  - Network join time:
    30 ms (typical)
  - Sleeping slave changing to active: 15 ms (typical)
  - Active slave channel access time: 15 ms (typical)

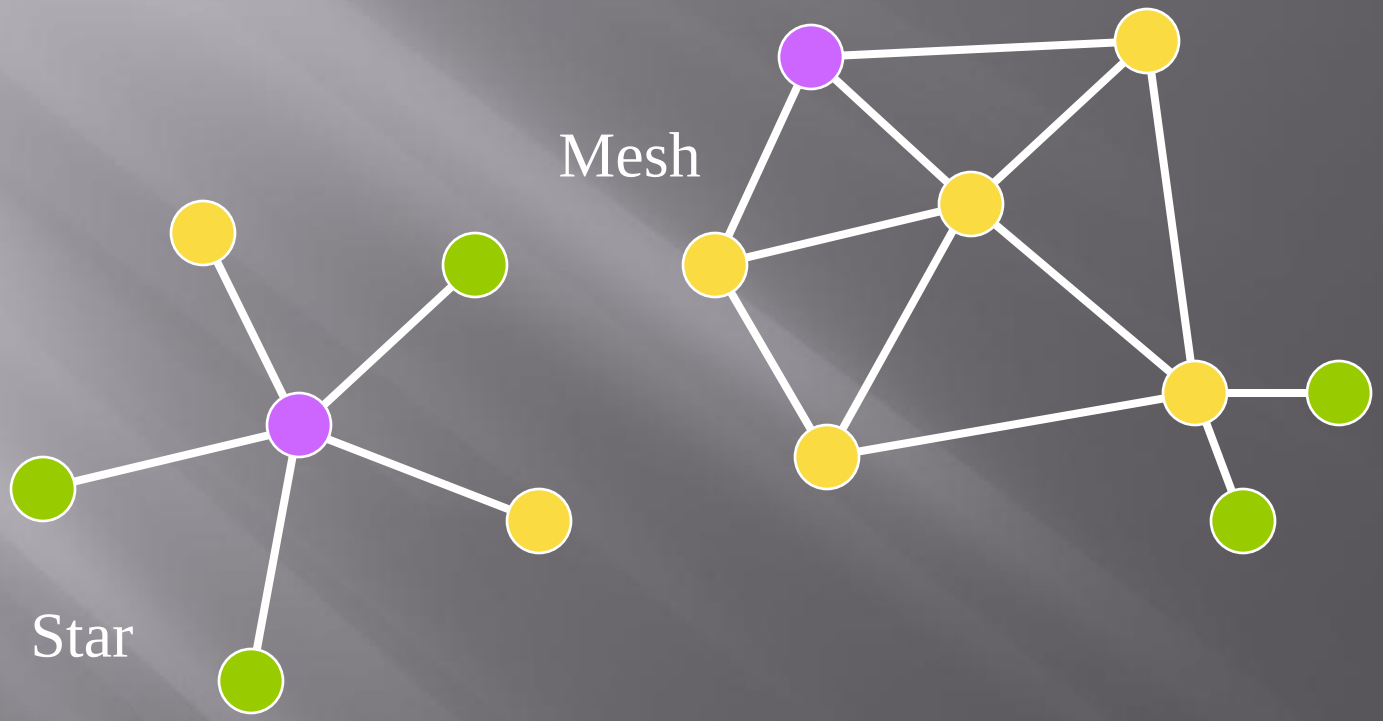


Courtesy the ZigBee Alliance

Topology Models

- Star Networks (Personal Area Network)
  - Home automation
  - PC Peripherals
  - Personal Health Care
- Peer-to-Peer (ad hoc, self organizing & healing)
  - Industrial control and monitoring
  - Wireless Sensor Networks
  - Intelligent Agriculture

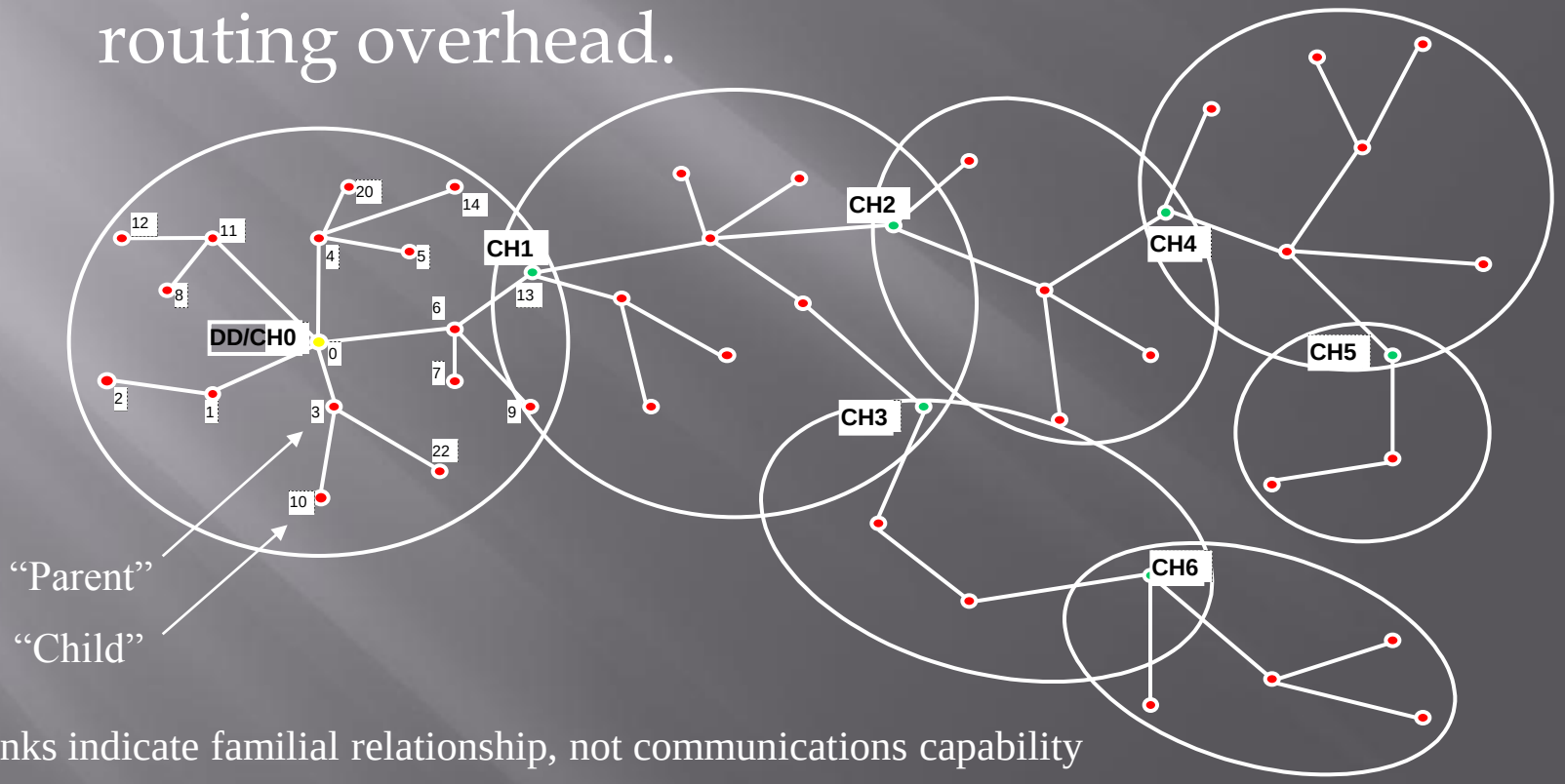
Topology Models



Courtesy the ZigBee Alliance

Cluster Tree Networks

- Cluster tree networks enable a peer-peer network to be formed with a minimum of routing overhead.



Links indicate familial relationship, not communications capability

Courtesy IEEE

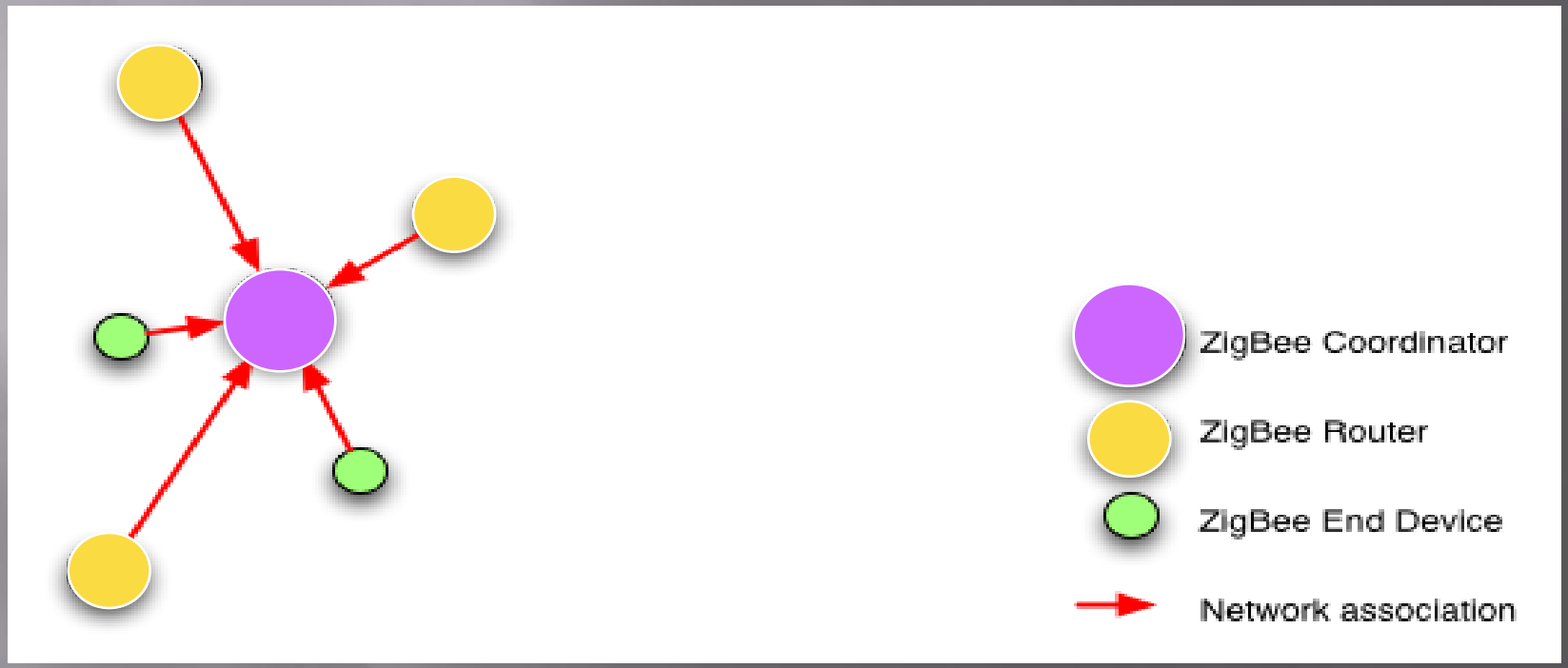
Cluster Tree Networks

- Employ multi-hop routing
- Can be very large: 255 clusters of 254 nodes each = 64,770 nodes
- May span physically large areas
- Suitable for latency-tolerant applications

ZigBee Device Types

- ZigBee Coordinator (ZC)
  - Most capable device and Initiates network formation
  - One and only one required for each ZB network.
  - Acts as 802.15.4 2003 PAN coordinator (FFD).
  - May act as router once network is formed.
- ZigBee Router (ZR)
  - Optional network component.
  - May associate with ZC or with previously associated ZR.
  - Acts as 802.15.4 2003 coordinator (FFD).
  - Acts as an intermediary in multihop routing of messages.
- ZigBee End Device (ZED)
  - Contains just enough functionality to talk to its coordinator
  - Optional network component.
  - Shall not allow association.
  - Shall not participate in routing hence cannot relay messages

Network Structure



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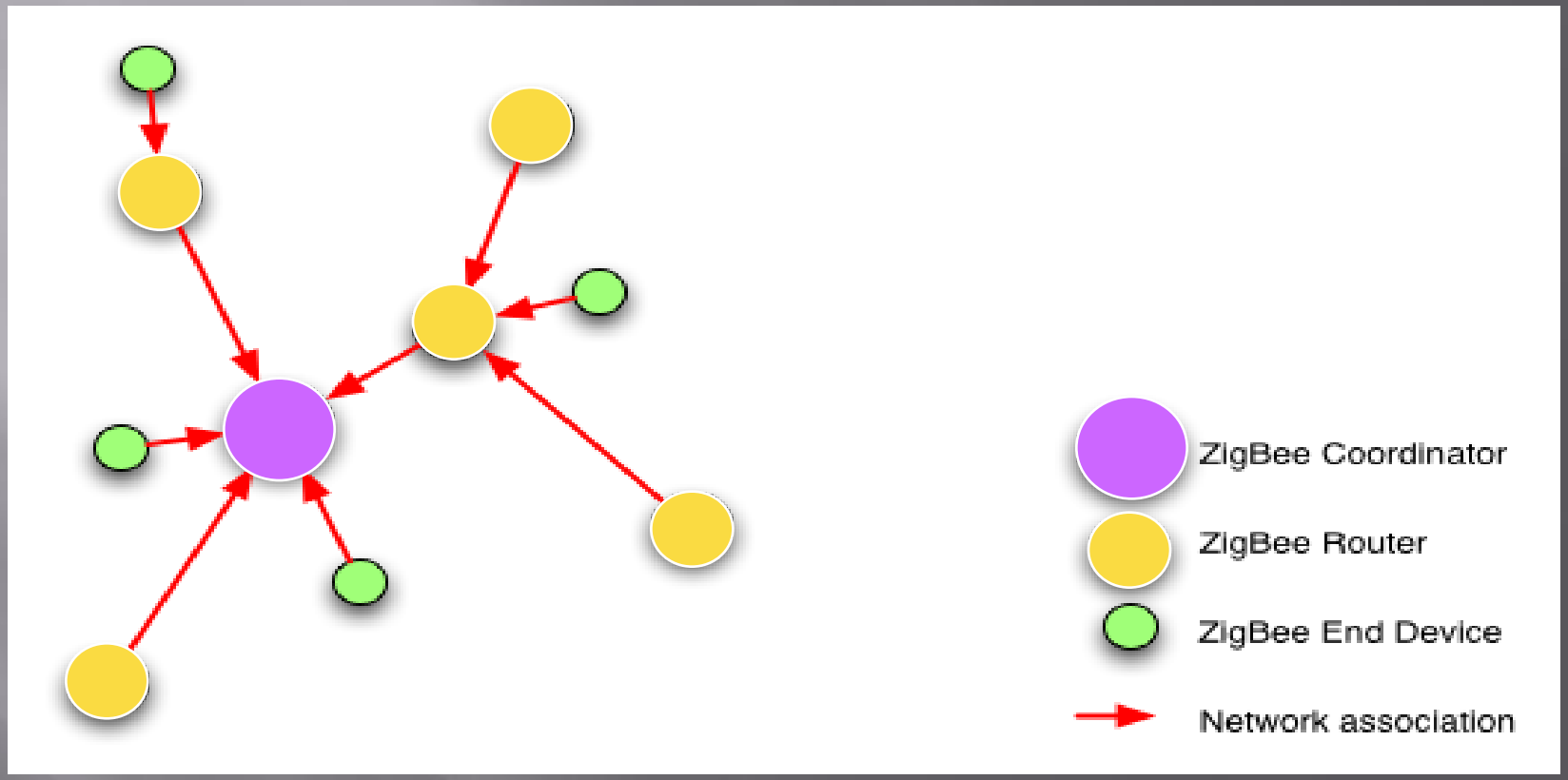

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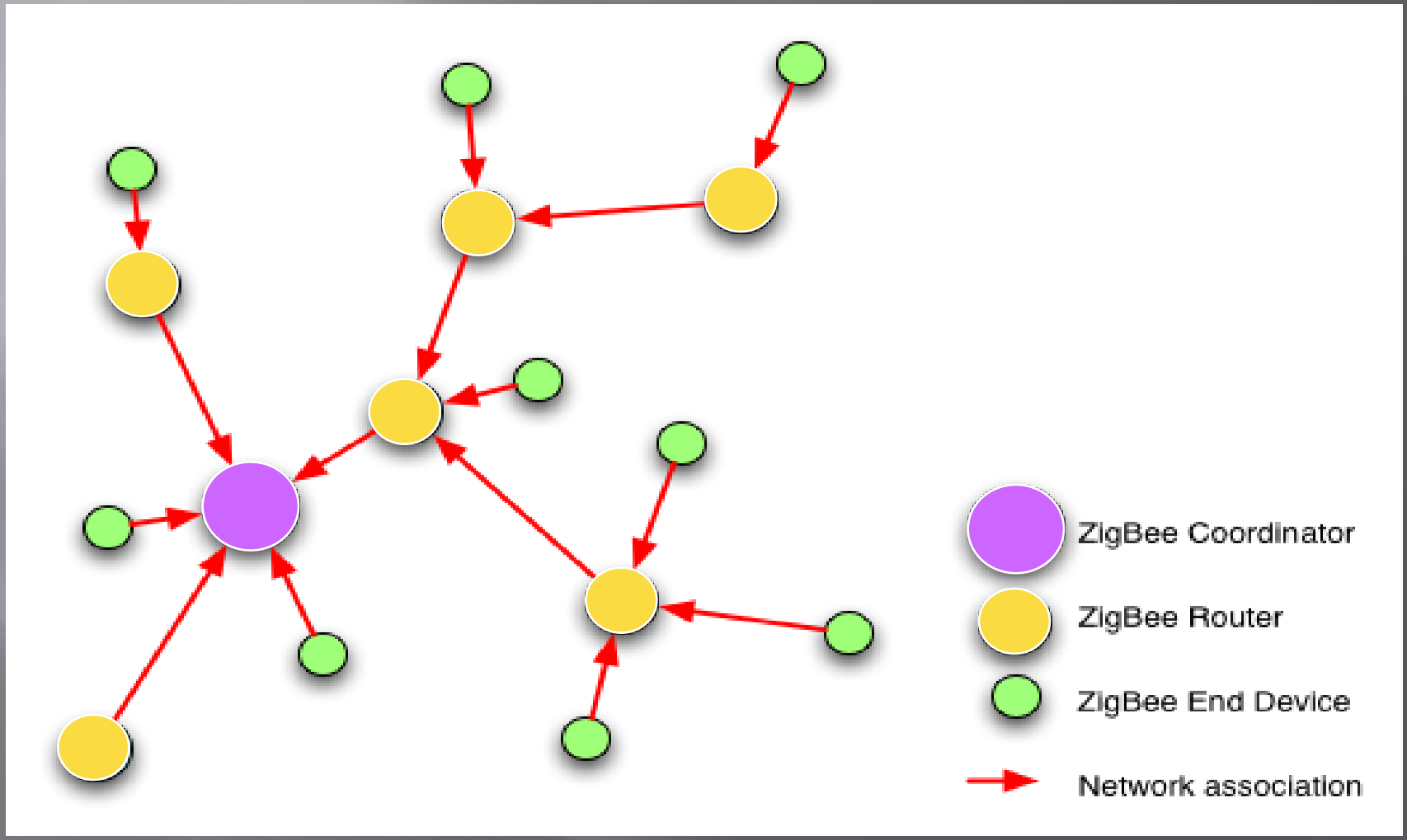
Network Structure



Courtesy ZigBee Alliance

ZigBee Routing

- Uses AODV (Ad-hoc On-Demand Distance Vector)
- Capable of both uni/multi-cast routing
- Reactive protocol, establishes route to destination on demand NOT proactively like IP routing on the usage of a particular paths
- Network is silent until a connection is needed
- When a link fails, a routing error is passed back to a transmitting node, and the process repeats.

ZigBee Routing – Frame Format

Octets: 2	2	2	1	1	Variable
Frame Control	Destination Address	Source Address	Broadcast Radius	Broadcast Sequence Number	Frame Payload
	Routing Fields				
NWK Header					NWK Payload

Bits: 0-1	2-5	6-7	8	9	10-15
Frame type	Protocol version	Discover route	Reserved	Security	Reserved

Frame Control

Courtesy ZigBee Alliance

Route Discovery

A device wishing to discover (or repair) a route issues a route request command frame which is broadcast throughout the network.

When the intended destination receives the route request command frame it responds with at least one route reply command frame.

Potential routes are evaluated with respect to a routing cost metric at both source and destination.

Routing Options

- Tree routing may be disallowed *(nwkUseTreeRouting)*.
- Link cost reported during route discovery may be constant or based on likelihood of reception.
- Links may be assumed to be symmetrical or not *(nwkSymLink)*.

Future of ZigBee

ZigBee has the potential to unify methods of data communication for sensors, actuators, appliances, and asset-tracking devices.

Zigbee offers a means to build a reliable but affordable network backbone that takes advantage of battery-operated devices with a low data rate and a low duty cycle.

Home automation is likely the biggest market for ZigBee-enabled devices. This follows from the number of remote controlled devices (or devices that may be connected wirelessly) in the average household.