The Standard for the IoT

zigbee alliance

Our vision:

We believe all objects can work together in a way that enhances the way we live, work, and play

Our mission:

The Zigbee Alliance ignites creativity and collaboration in the Internet of Things, by creating, evolving, and promoting universal open standards that enable all objects to connect and interact.

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We are the standard bearer of the open IoT

Established in 2002, our wide-ranging global membership collaborates to create and evolve universal open standards for the smart networks in our homes, businesses, and neighborhoods.

Our standards are the only complete IoT solution – from mesh network to the universal language that allows smart objects to work together.

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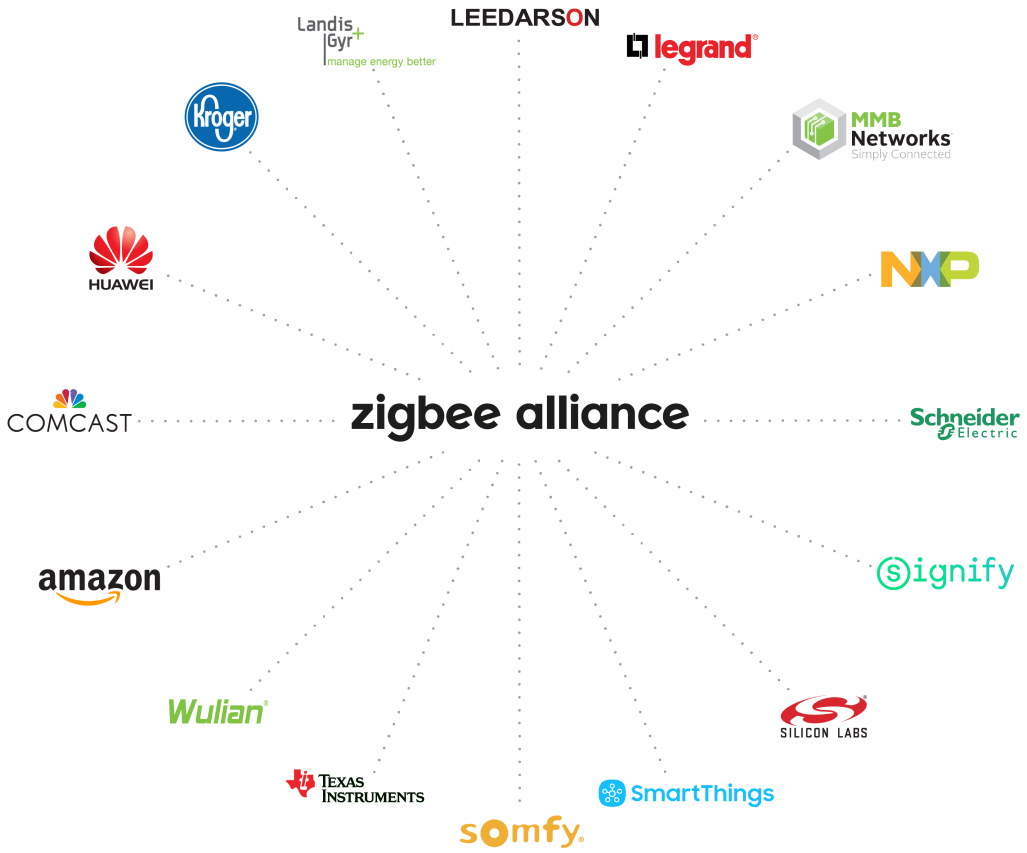
Our Board of Directors

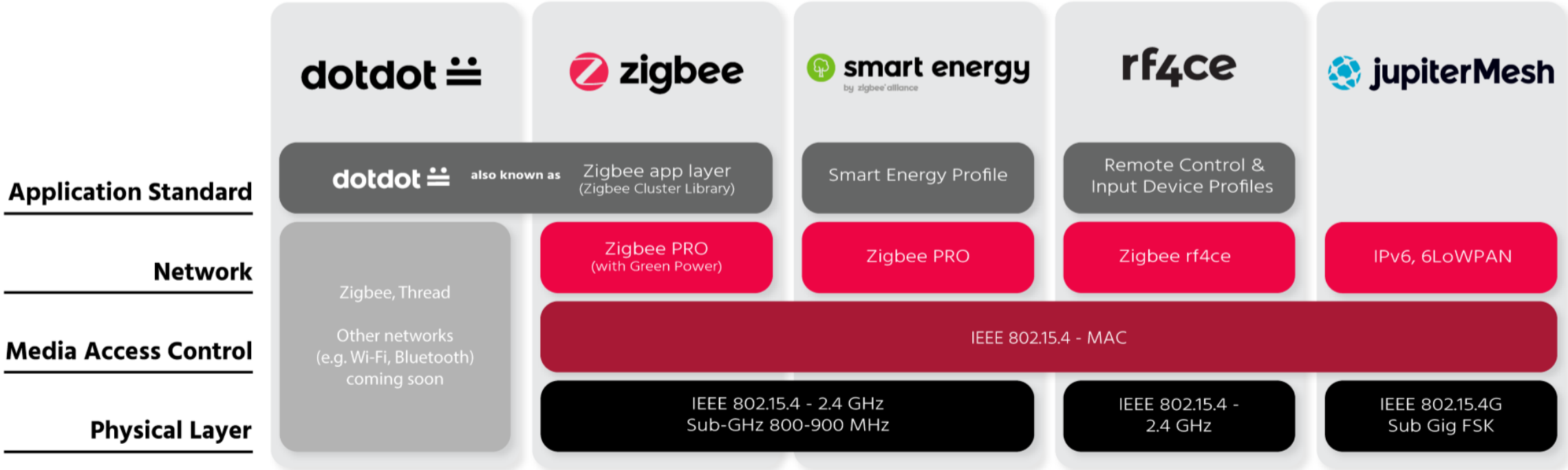


What we do

Develop open, global standards for wireless connectivity and device-to-device communication, enabling IoT devices.

Certify products built to our standards to ensure interoperability between them.

zigbee alliance Technologies



Major initiative: Zigbee

20+ Compliant Platforms (silicon)

Half a billion chipsets sold worldwide

Over 2,500 Certified Products on the market.

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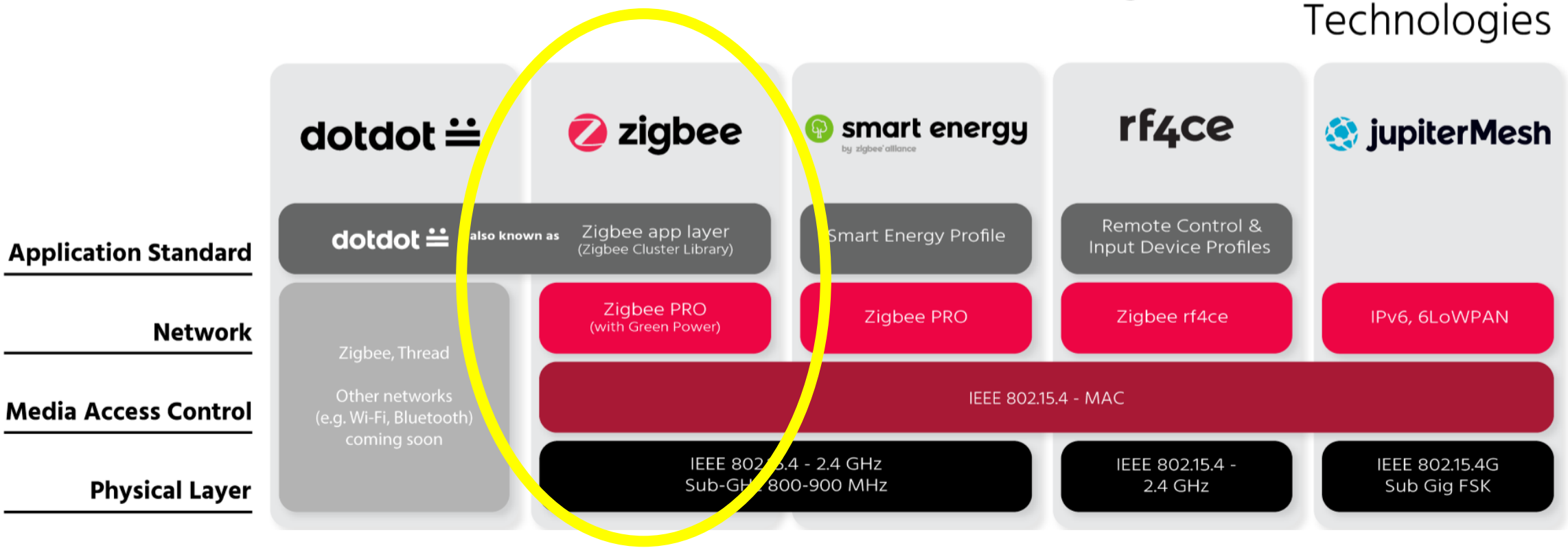
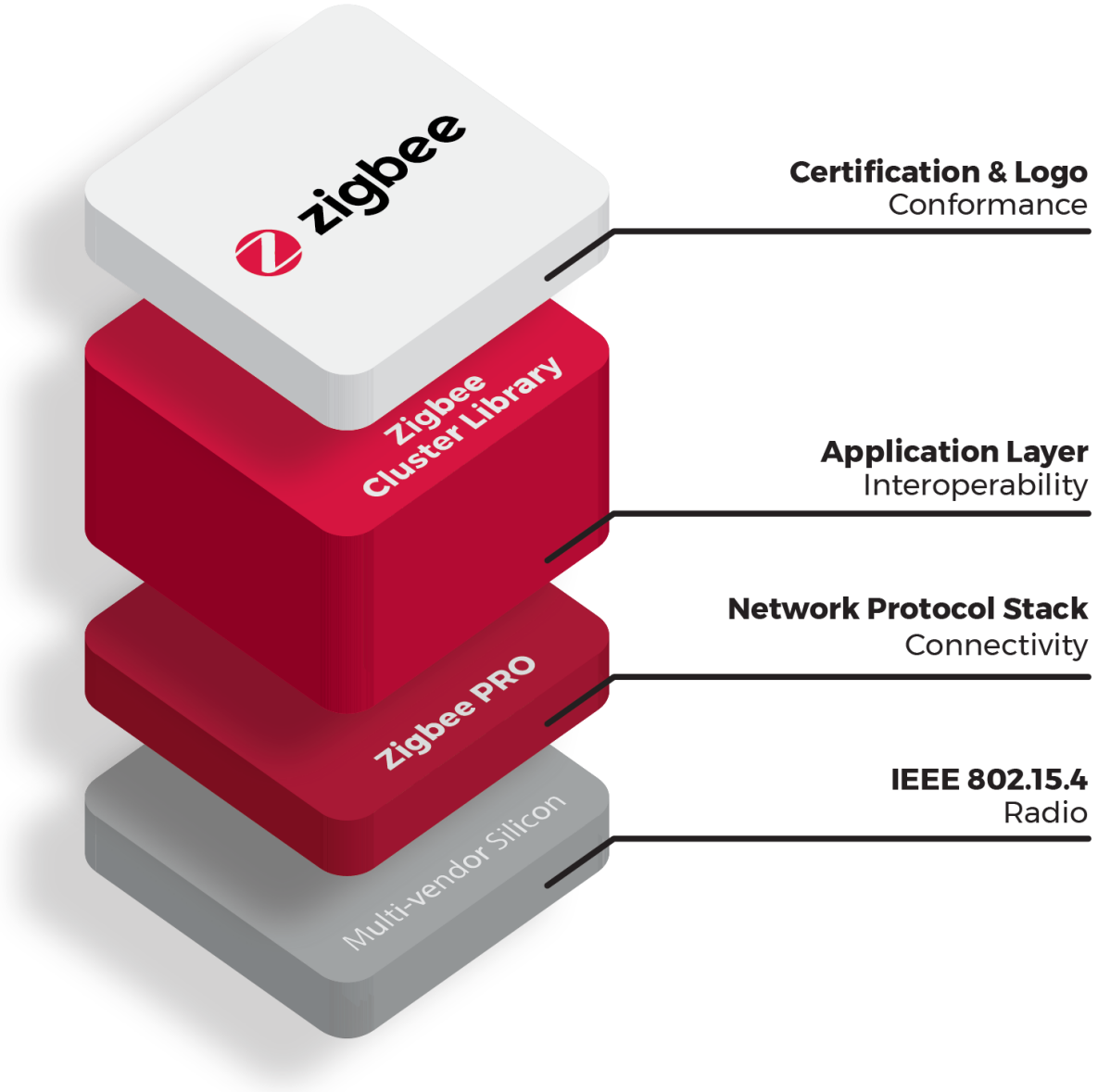
Technologies



Zigbee is the only complete IoT solution — from mesh network to the universal language that allows smart objects to work together.

Zigbee increases choice and flexibility for users and developers, and delivers the confidence that products and services will work together through standardization and testing of all layers of the stack.



Zigbee leading the industry

Zigbee Certifications growing exponentially

- Includes lighting, sensors, reference designs, with more in the pipeline.
- 75+ device types and growing

Zigbee products are backwards-compatible with existing Zigbee products built to previous specifications

- They can connect *and* communicate using the same IoT language with each other, and millions of Zigbee products already deployed in smart homes and buildings.

How Zigbee works

IEEE 802.15.4

Frequency Band	License Required?	Geographic Region	Data Rate	Channel Number(s)
868.3 MHz	No	Europe	20kbps	0
902-928 MHz	No	Americas	40kbps	1-10
2405-2480 MHz	No	Worldwide	250kbps	11-26

IEEE 802.15.4 2003

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IEEE 802.15.4 Data Frame Format

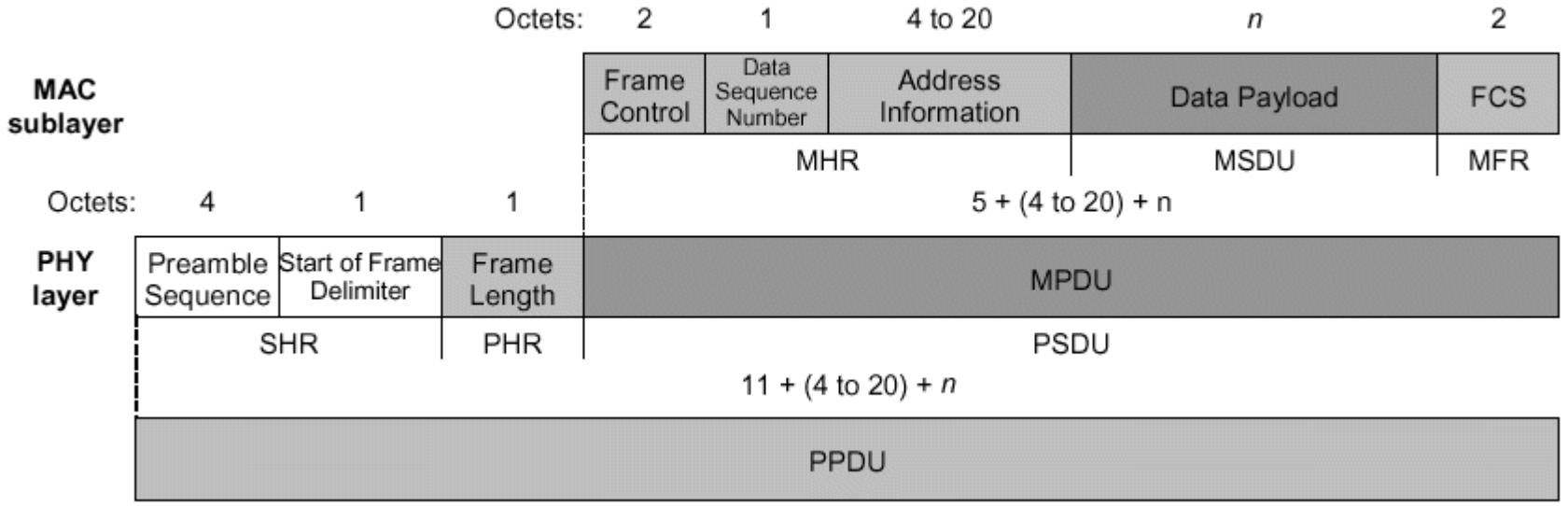
Provides up to 102 Byte data payload capacity

Data sequence numbering to ensure that packets are tracked

Frame Check Sequence (FCS) validates error-free data

min. 16 Bytes = 128 bits = 0.512 ms @ 250 kbps

max. 133 Bytes = 1064 bits = 4.256 ms @ 250 kbps



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IEEE 802.15.4 Device Types

802.15.4 Device Types

- Full function device (FFD)
  - Talks to several devices
  - Normally main powered (always on)
  - Can route messages
- Reduced Function Device (RFD)
  - Carries limited functionality to control cost and complexity
  - Talks to parent

- Requires less memory
- Can be a sleeping device
- General usage will be in network edge devices

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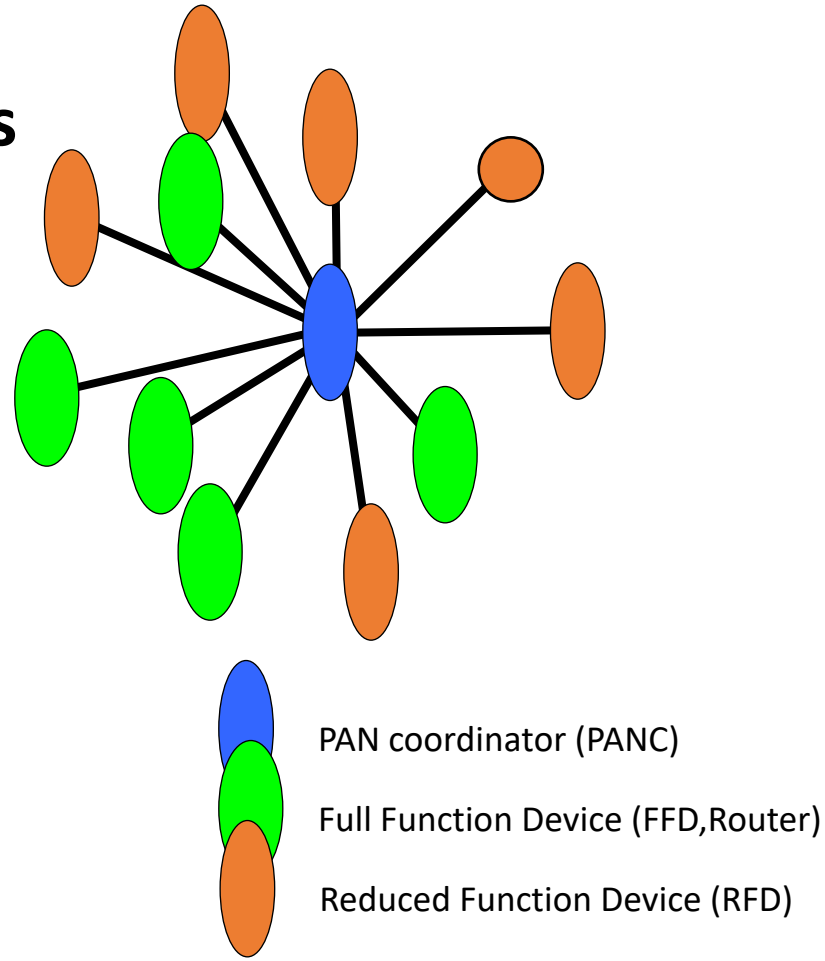
Network Topology Models

Three Common 802.15.4 Networks

Star Network

- Lowest complexity
- Limited Range
- Coordinator can become bottleneck

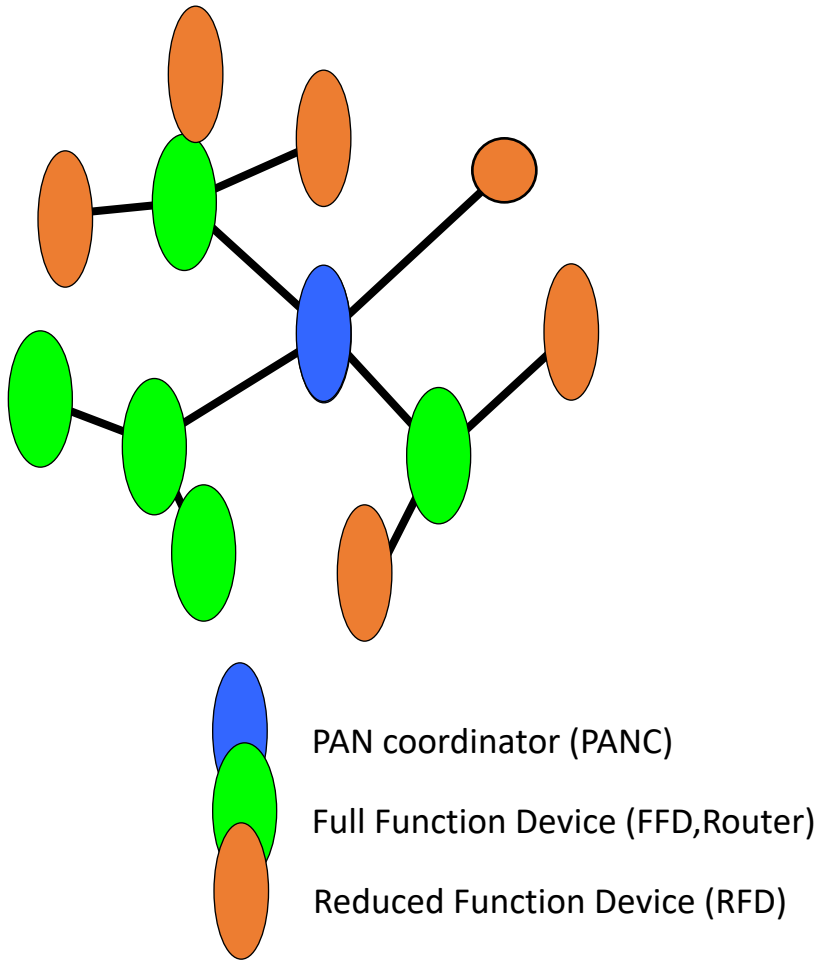


Network Topology Models

Three Common 802.15.4 Networks

Tree Network

- Extends range of network
- More predictive
- Bottlenecks still exist



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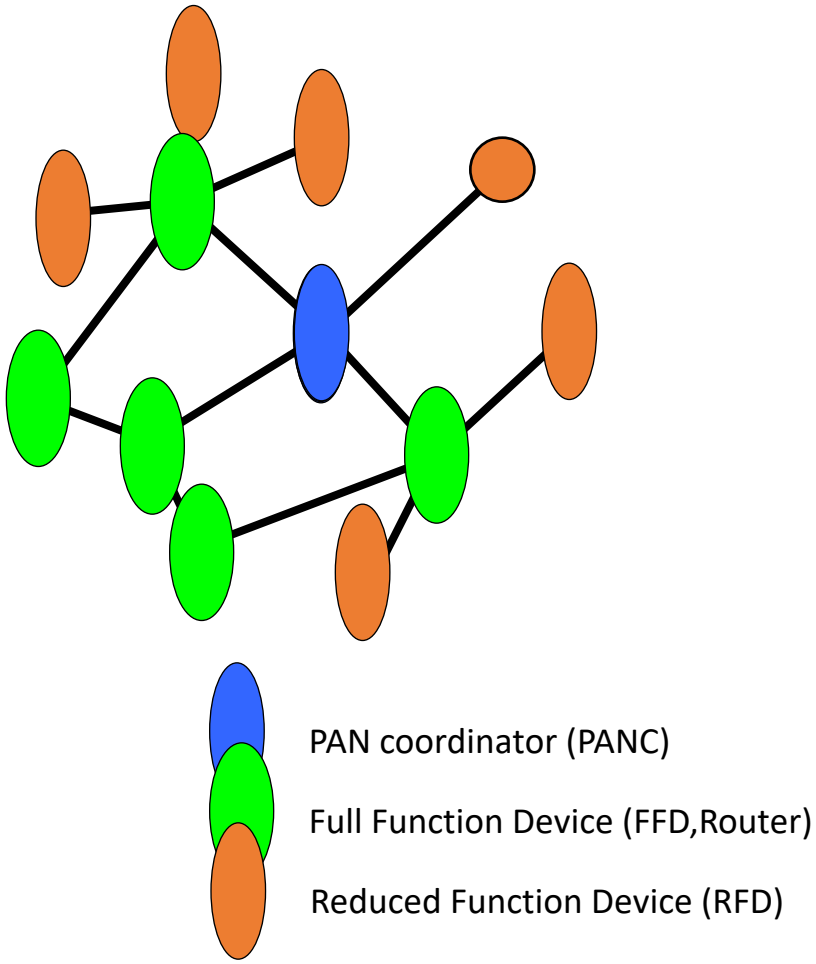
Network Topology Models

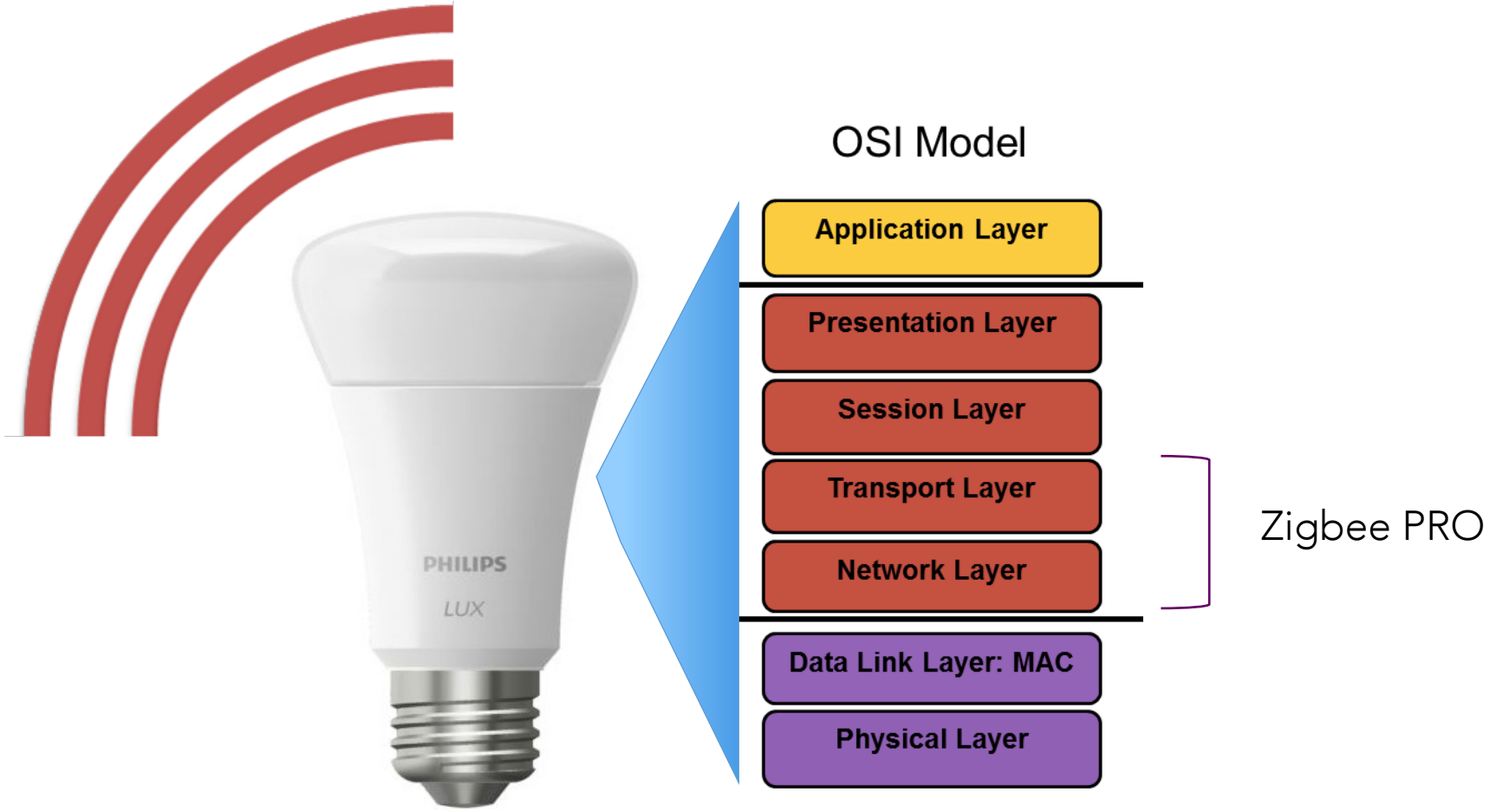
Three Common 802.15.4 Networks

Mesh Network

- Most complex
- Highest reliability
- Reduces bottlenecks



Standardized at all Layers



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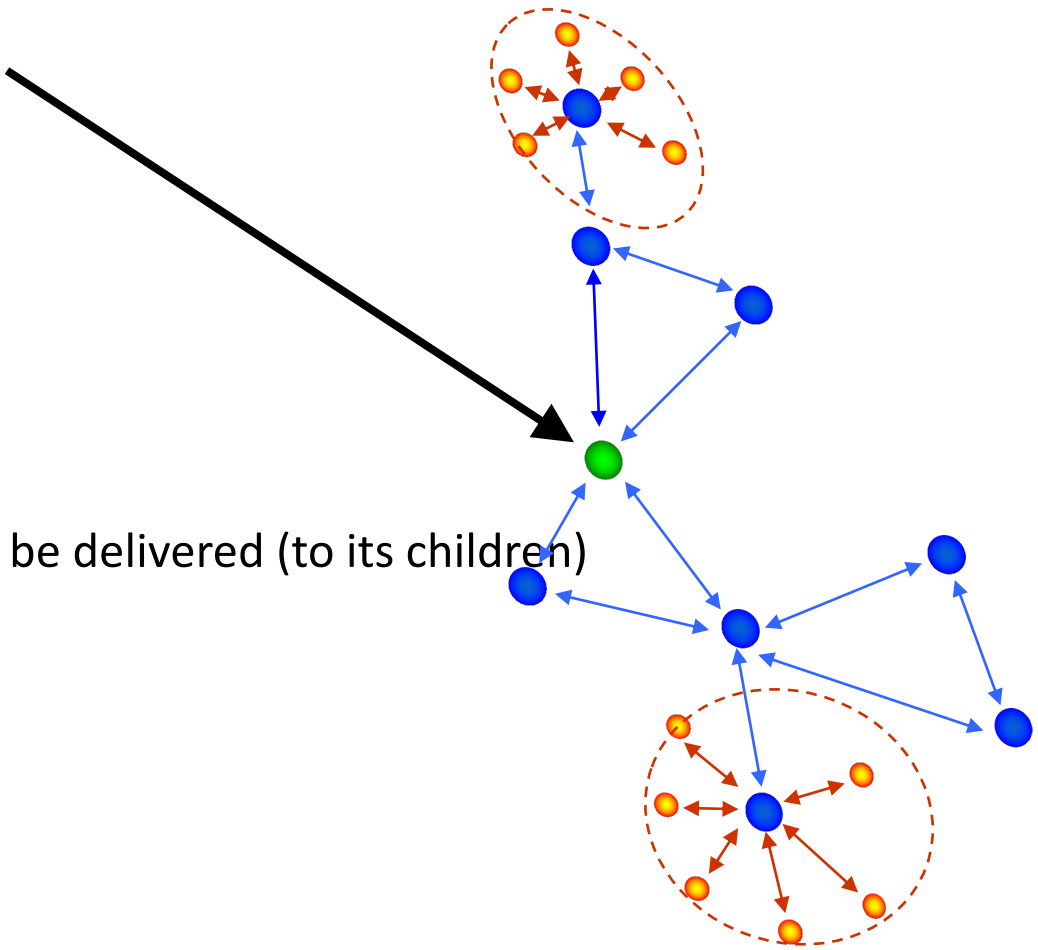
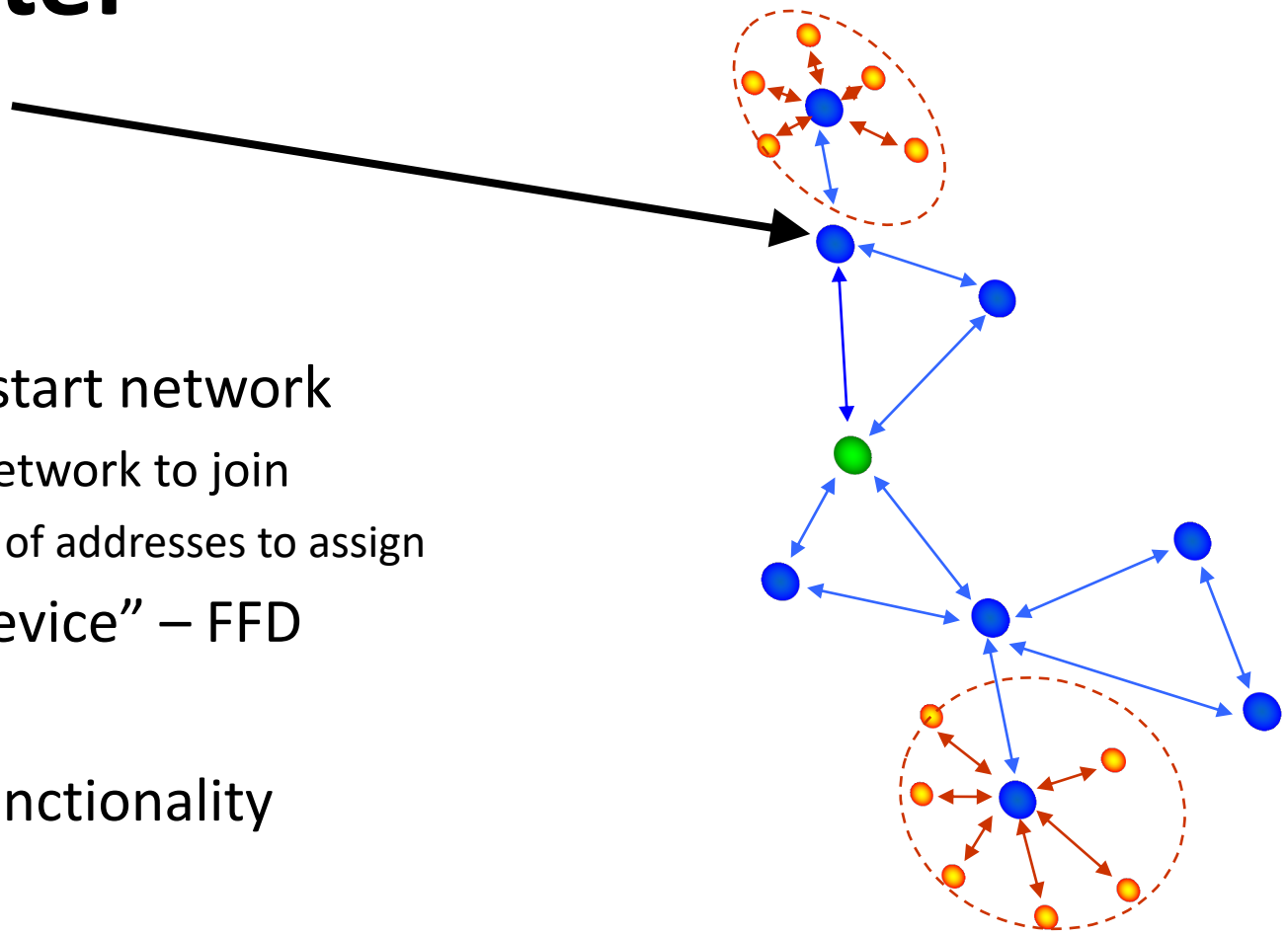
Zigbee – PAN Coordinator



PAN Coordinator

- "Owns" the network
  - Starts it
  - Opens the network for joining
  - Allocates address
  - Saves messages until they can be delivered (to its children)
  - Can function as Trust Center
- A "full-function device" – FFD
- Mains-powered
- Can have other functionality
  - Sensor
  - Monitor

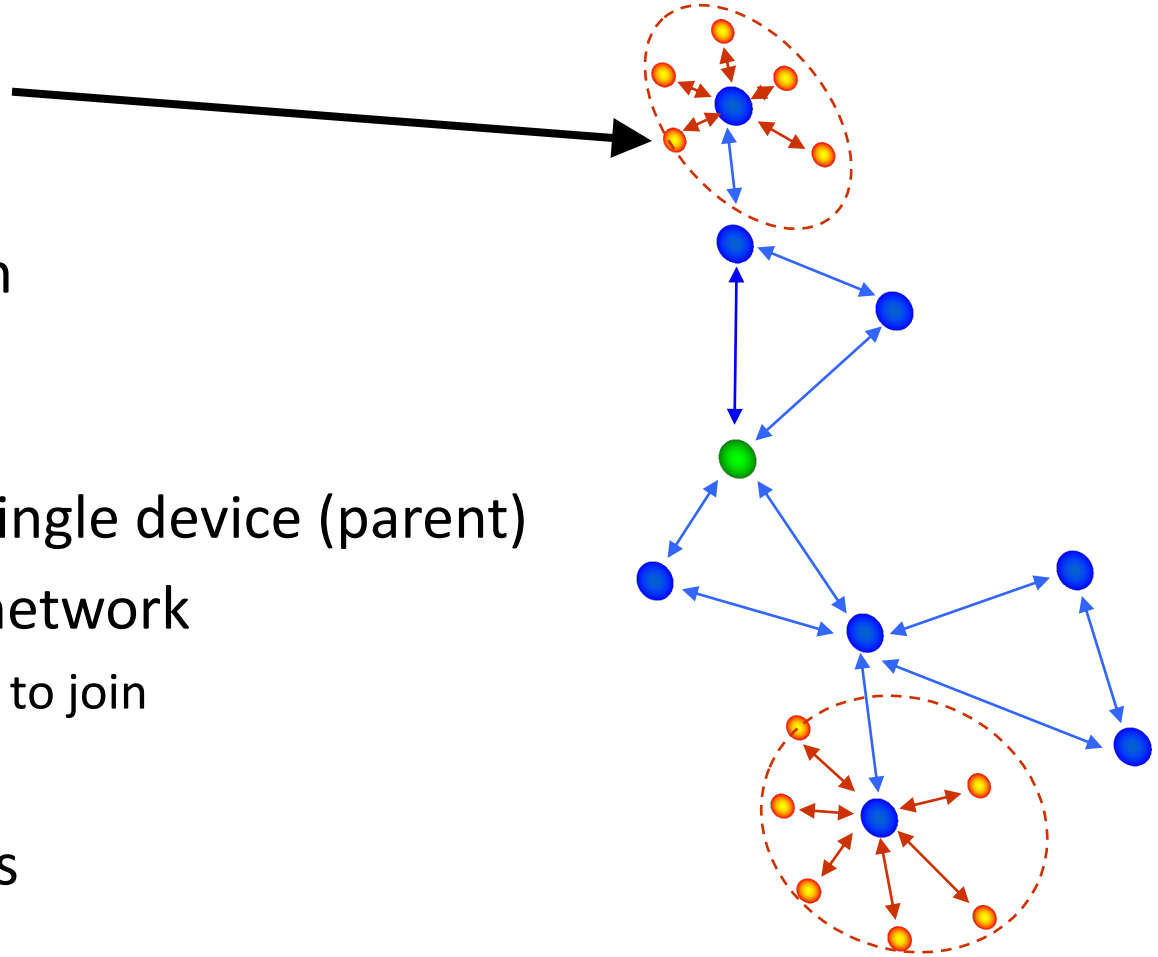
Zigbee - Router



Routers

- Routes messages
- Does not own or start network
  - Scans to find a network to join
    - Given a block of addresses to assign
- A “full-function device” – FFD
- Mains-powered
- Can have other functionality
  - Sensor
  - Monitor

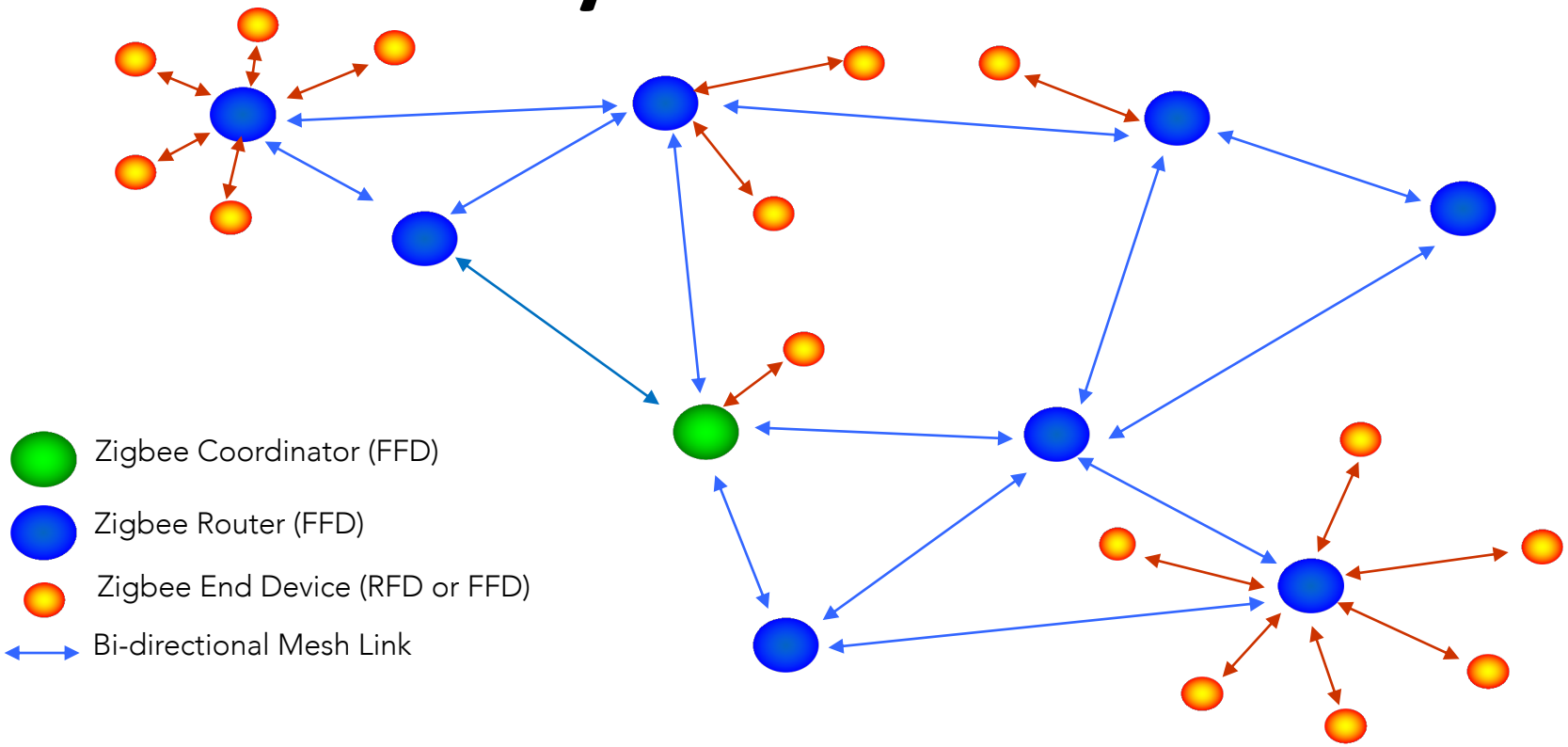
Zigbee – End Device



End Device

- Specific Device function
  - Sensor
  - Monitor
- Communicates with a single device (parent)
- Does not own or start network
  - Scans to find a network to join
- Can be an FFD or RFD
- Does NOT route packets
- Often battery-powered

Zigbee PRO Network Communication Model – Centralized Security

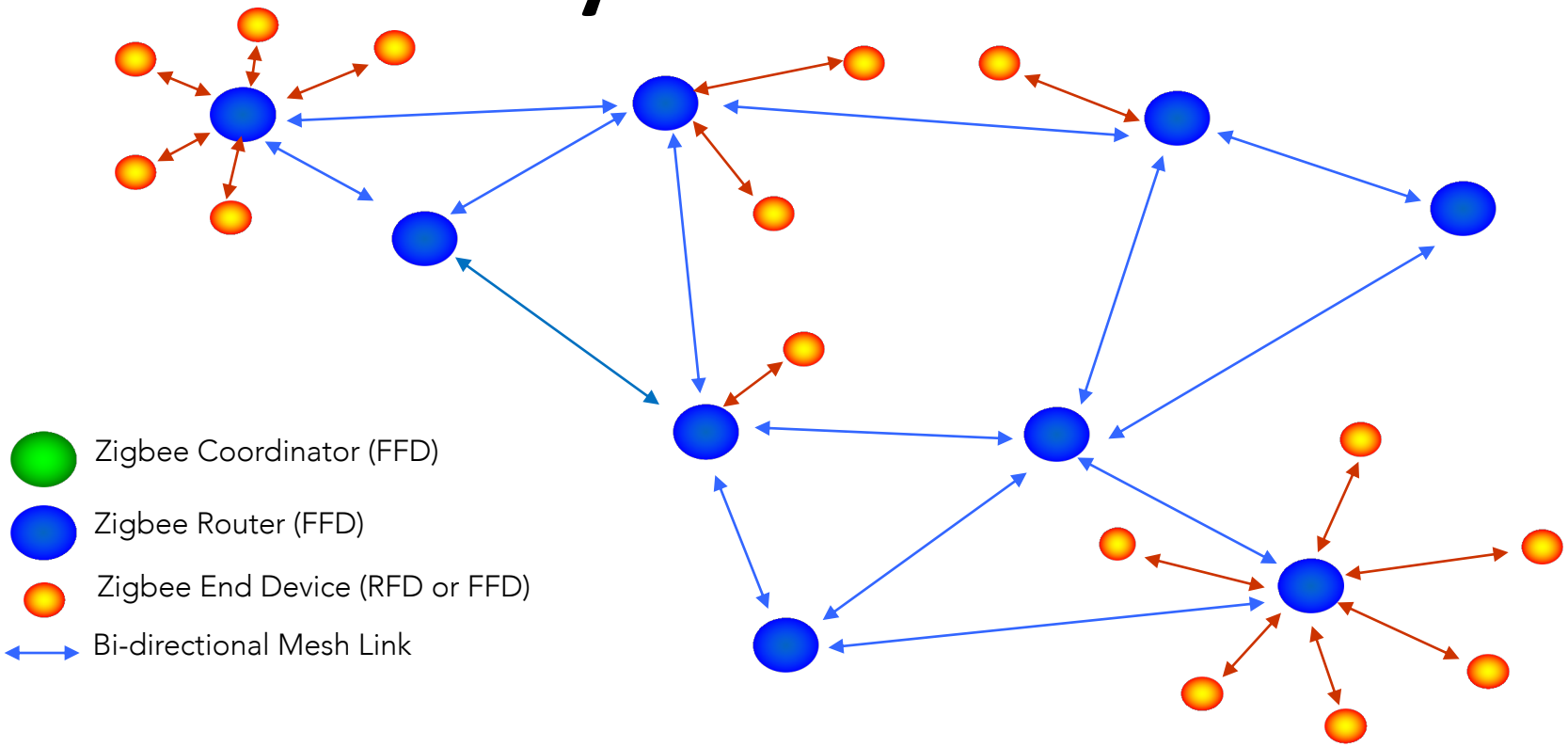


Mesh, self-organizing, self-healing topology scalable to thousands of nodes

Interference tolerance via clear channel assessments, retries, etc.

Point to Point communication gives range > 100 m, and full mesh deployment can have several kilometer range

Zigbee PRO Network Communication Model – Distributed Security



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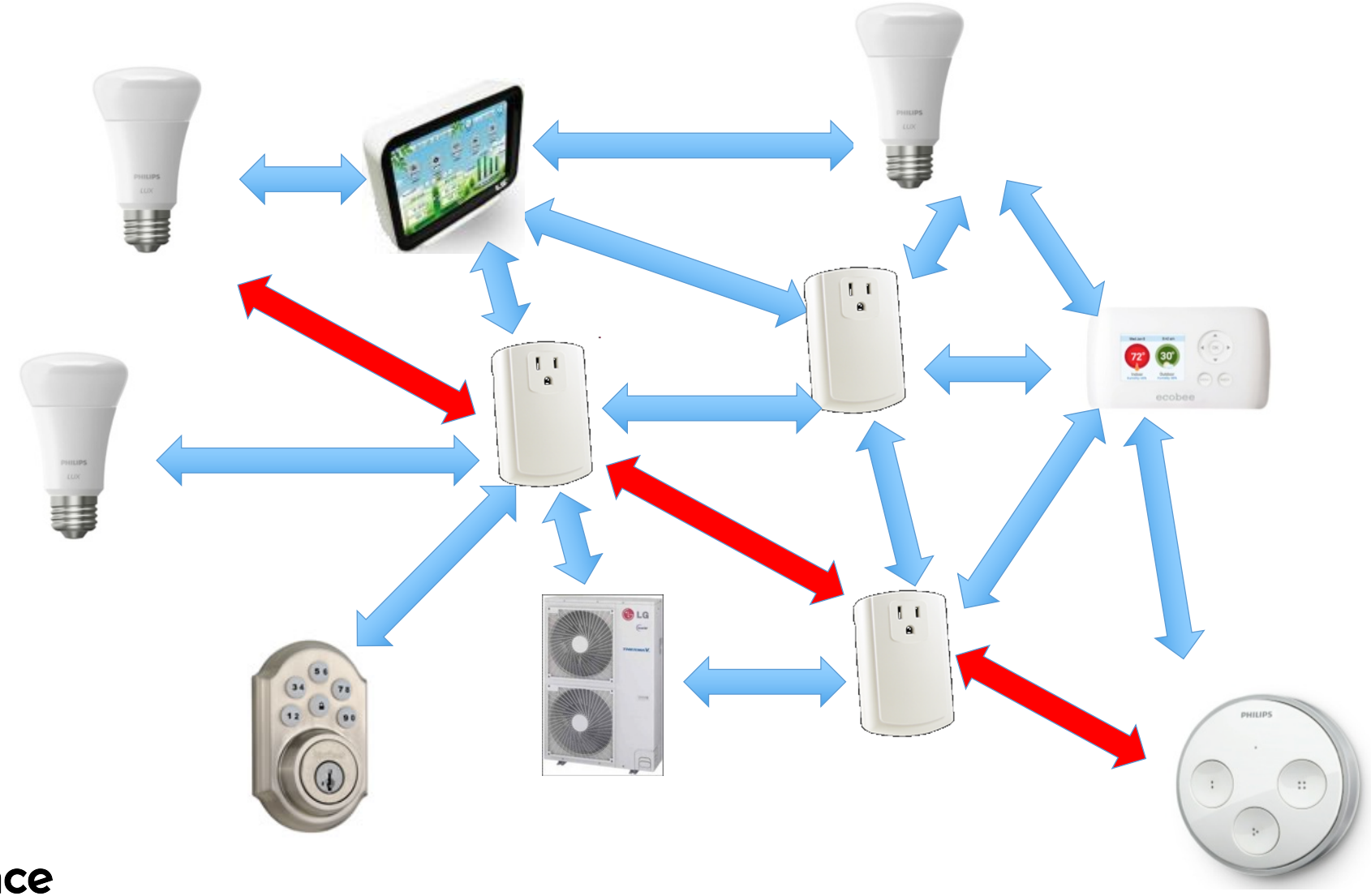
The Power of the Mesh



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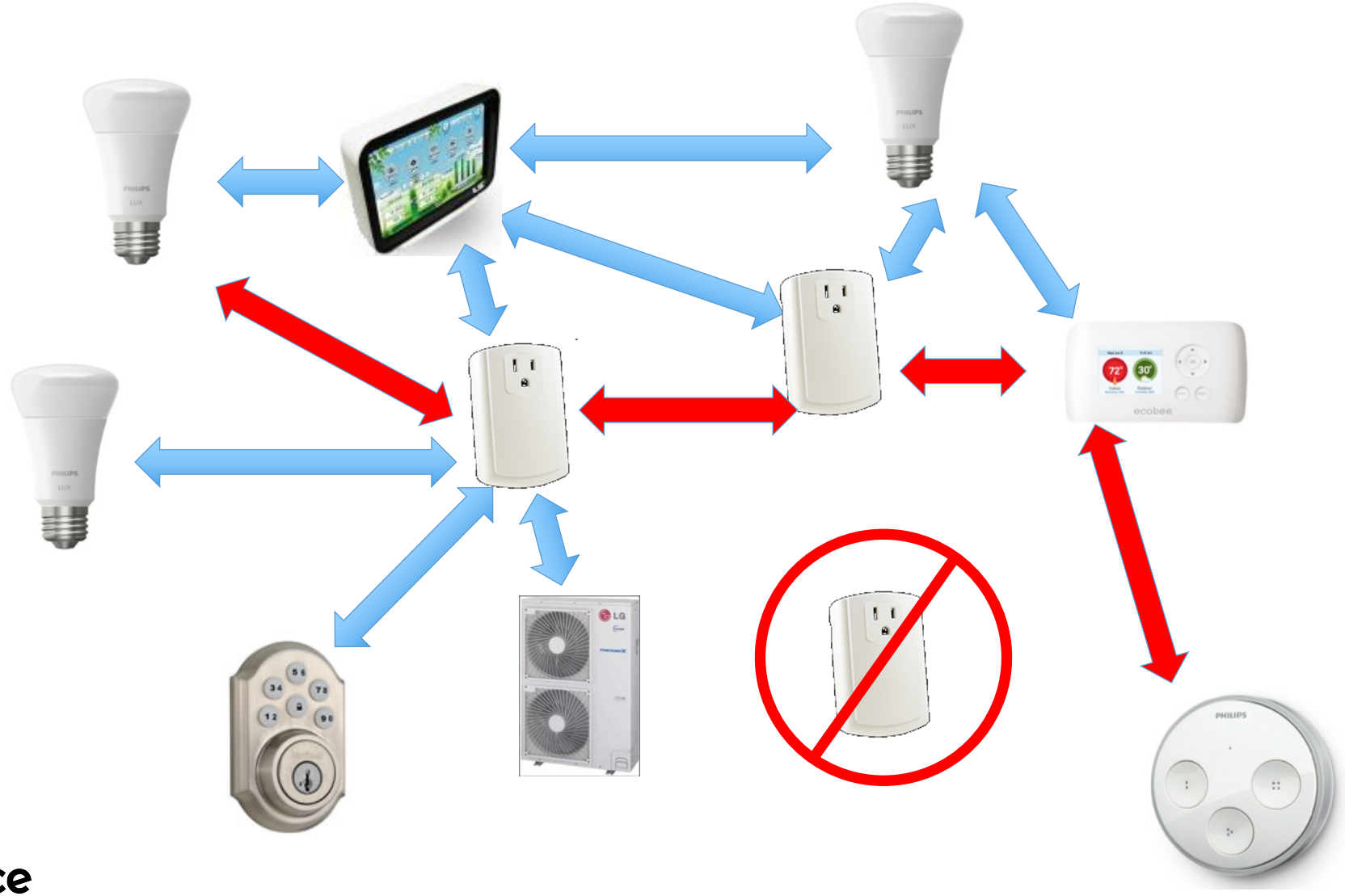
The Power of the Mesh: Self Healing



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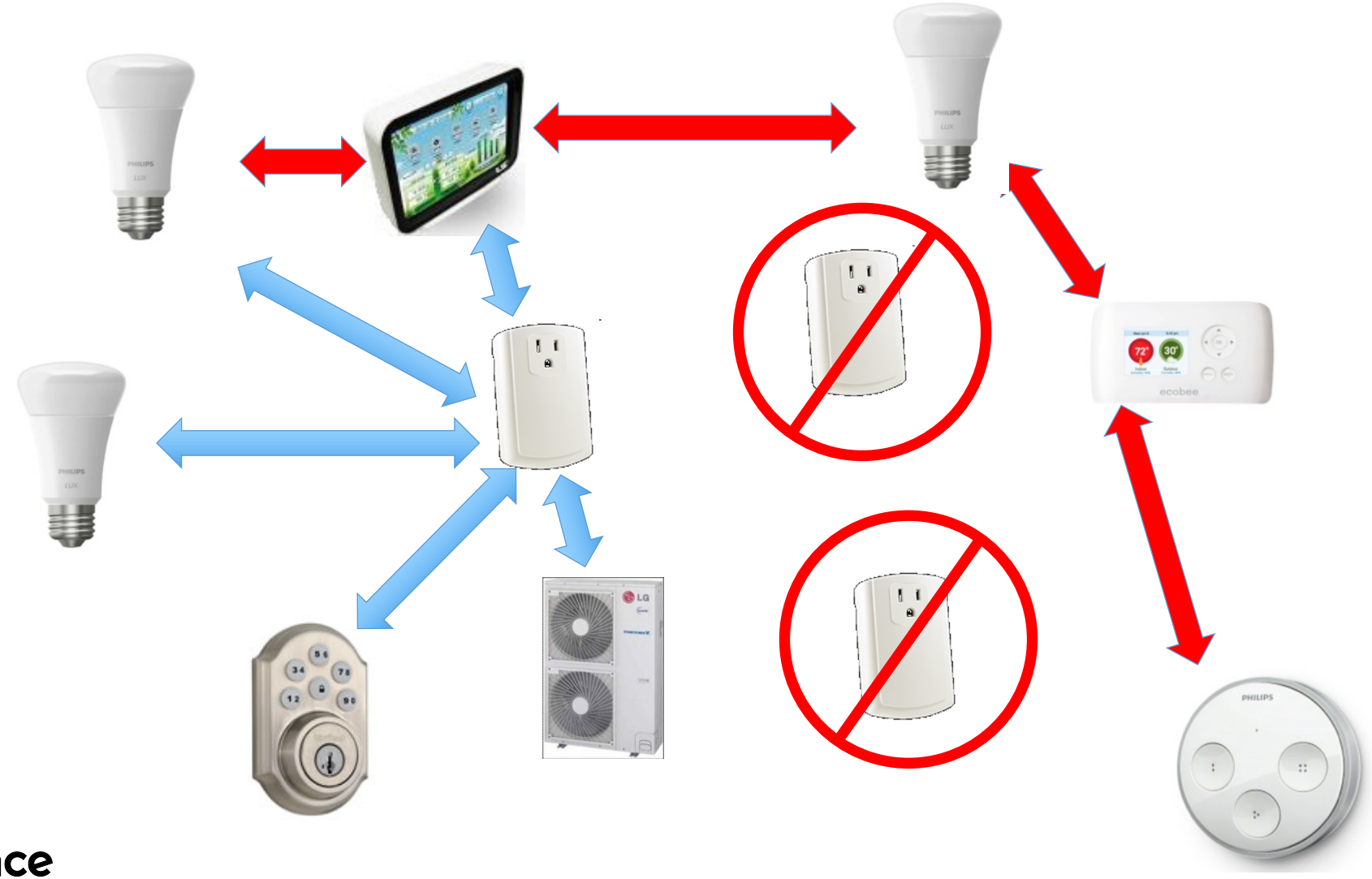
The Power of the Mesh: Self Healing



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Zigbee Wireless Networking Basics

Network Scan

- Device scans the available 16 2.4 GHz channels to determine the best channel to occupy

Creating/Joining a PAN

- Device can create a network (coordinator) on a free channel or join an existing network

Device Discovery

- Device queries the network to discover the identity of devices

Service Discovery

- Device scans for supported services on devices within the network

Binding

- Devices communicate via command/control messaging

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Zigbee Stack Architecture Basics

Addressing

- Every device has a unique 64 bit MAC address
- Upon association, every device receives a unique 16 bit network address
- Only the 16 bit network address is used to route packets within the network
- Devices retain their 16 bit address if they disconnect from the network. However, if they LEAVE the network, the 16 bit address is re-assigned.
- NWK broadcast implemented above the MAC

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Zigbee Stack Architecture Basics

Devices

- Pre-programmed for their network function
  - Coordinator
    - Scans to find an unused channel to start a network
  - Router (mesh device within a network)
    - Scans to find an active network to join, then permits other devices to join
  - End Device
    - Always tries to join an existing network
- Discover other devices in the network providing complementary services
  - Service Discovery can be initiated from any device within the network
- Can be bound to other devices offering complementary services
  - Binding provides a command and control feature for specially identified sets of devices

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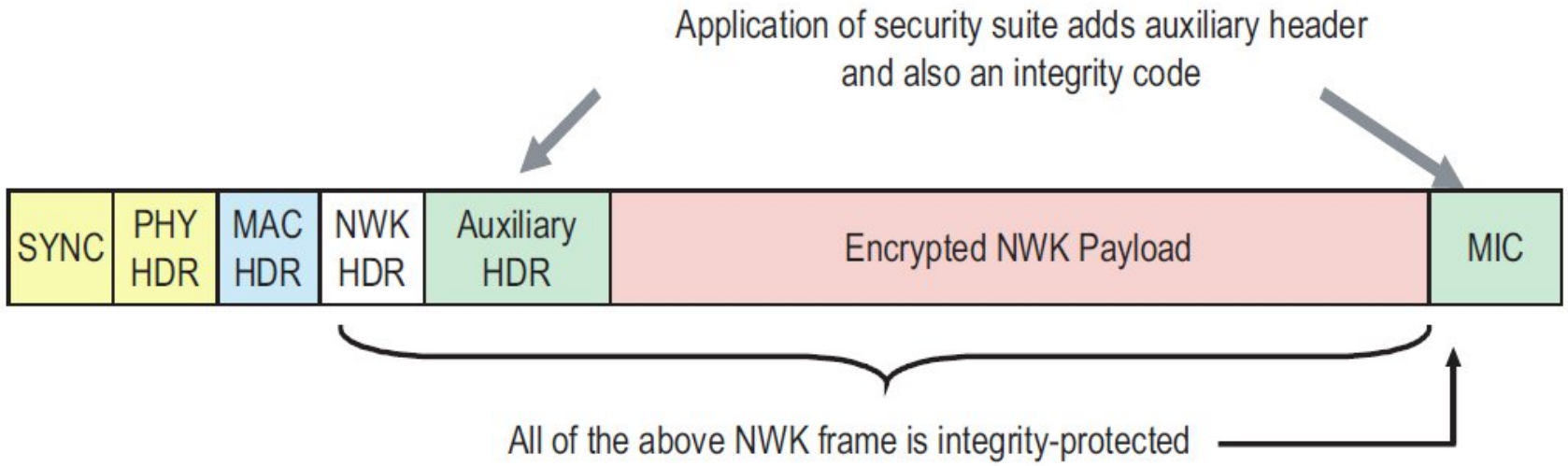
Zigbee PRO Communications Model



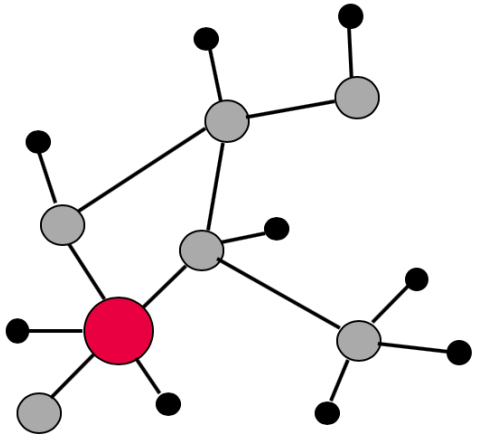
Standard Frame Format builds on the 802.15.4 format to add network and application specific commands/responses as part of the 802.15.4 payload

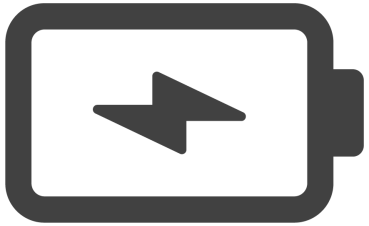
Secure (AES-128 encryption) at network level for all nodes

Additional application layer security available with a single key for every node pair

zigbee

Security & Safety
HVAC
Lighting
Retail
Sensing
Commissioning
Energy metering
Appliances
Telecommunication





Flexible self-organizing mesh + **Ultra low-power** + **Library of applications**

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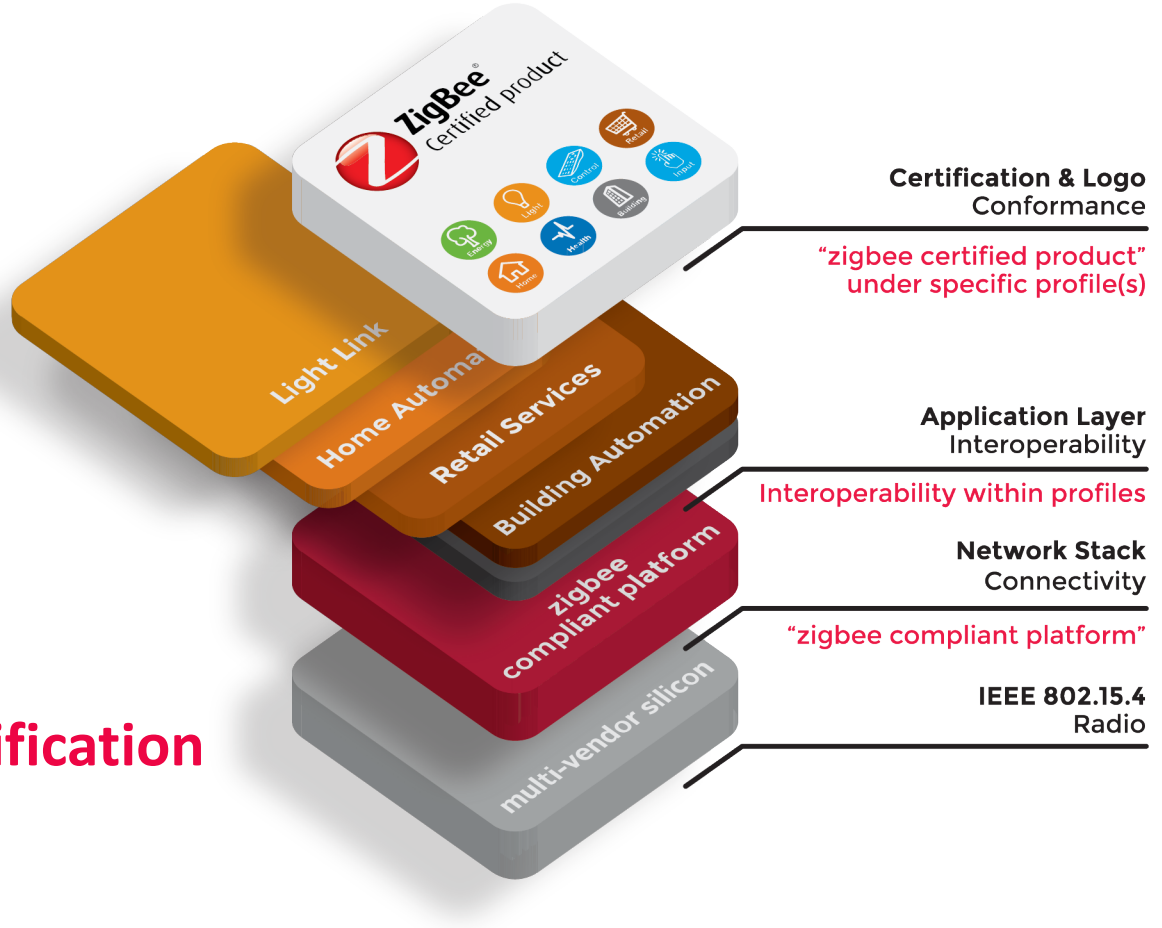
Incorporation of legacy profiles

zigbee certified product



One device = one specification
Backward-compatible

Zigbee Base Device Behavior: Uniform mandatory commissioning method

Covers the aspects of:

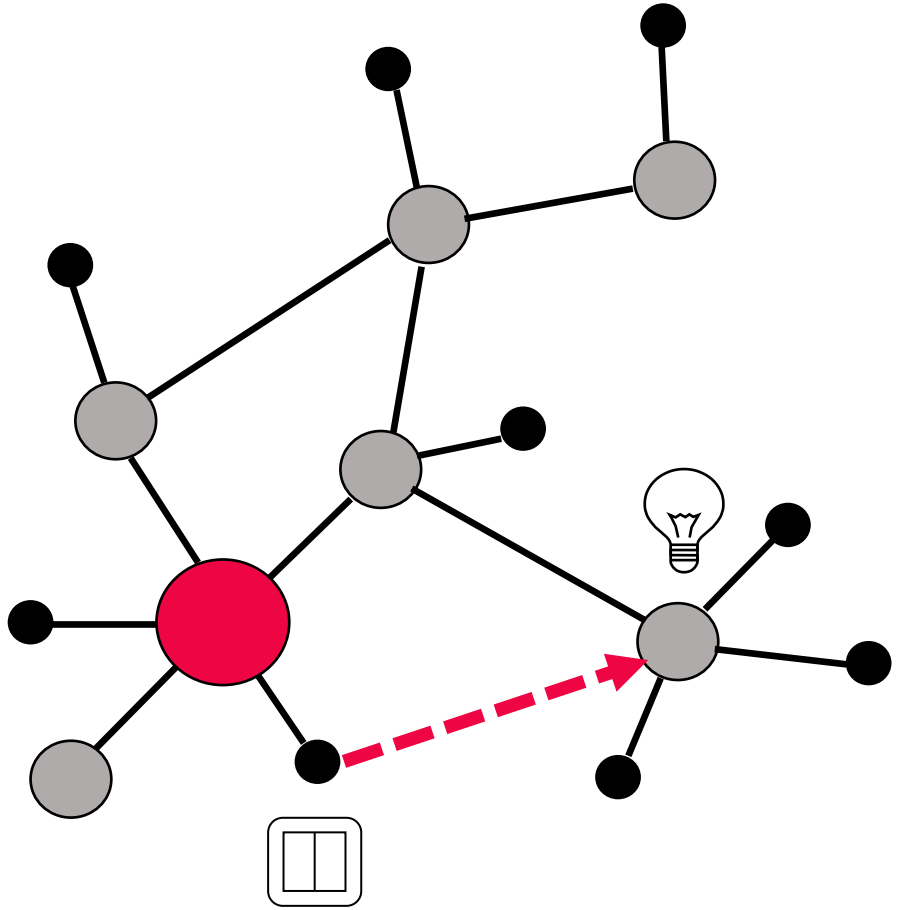
Network formation

Network joining (steering)

Network security

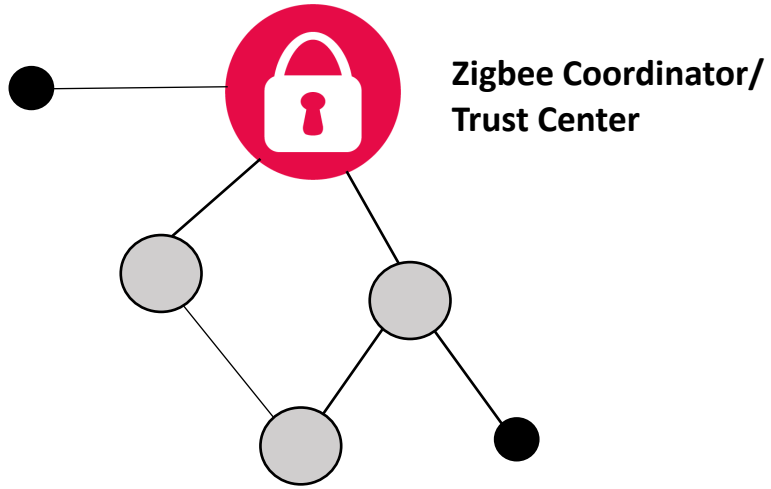
Establishment of application layer control relationships (finding & binding)

Aligned operation



Zigbee Base Device Behavior: Supported network security models

Centralized security network

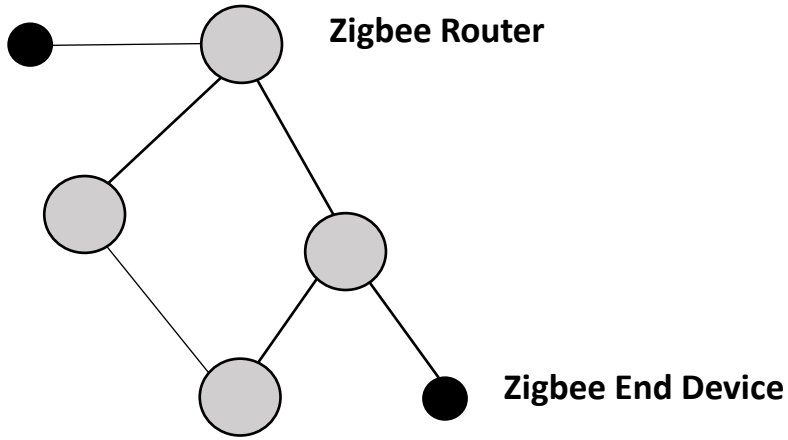


Only Zigbee Coordinators/Trust Centers can start centralized networks

Nodes join & receive the network key and establish a unique Trust Center link key

Nodes must support install codes

Distributed security network



- No central node/Trust Center
- Routers are able to start distributed networks
- Nodes join and receive the network key

Nodes adapt to the model of the network to which they join

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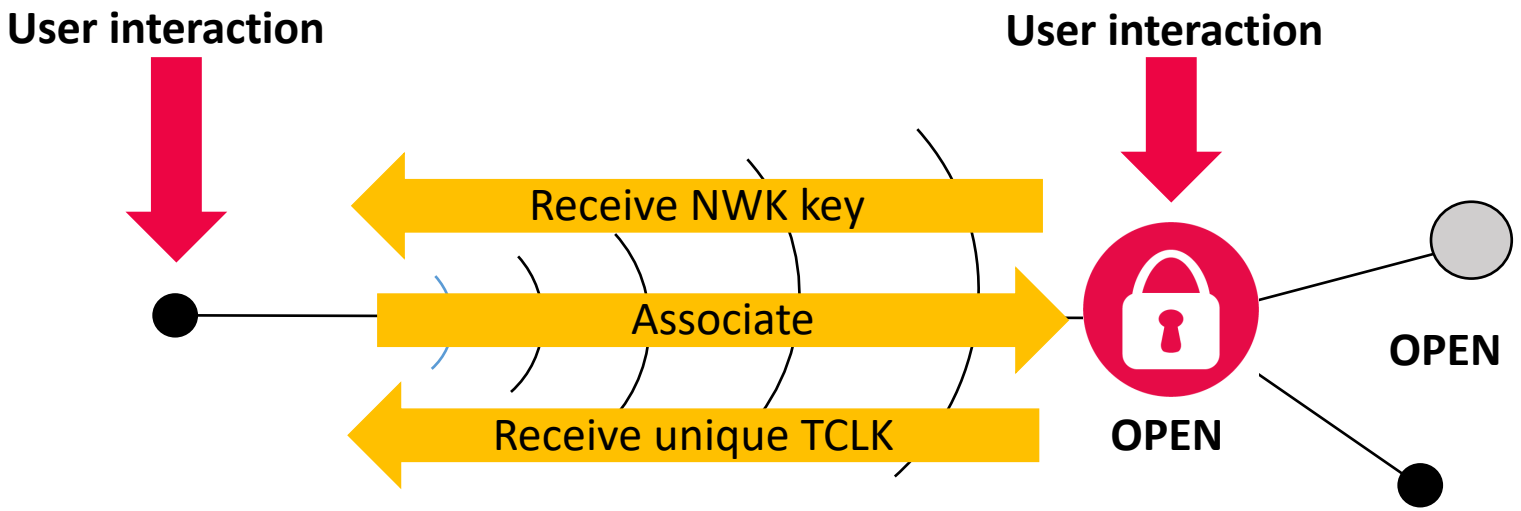
Zigbee Base Device Behavior: Joining a Zigbee network



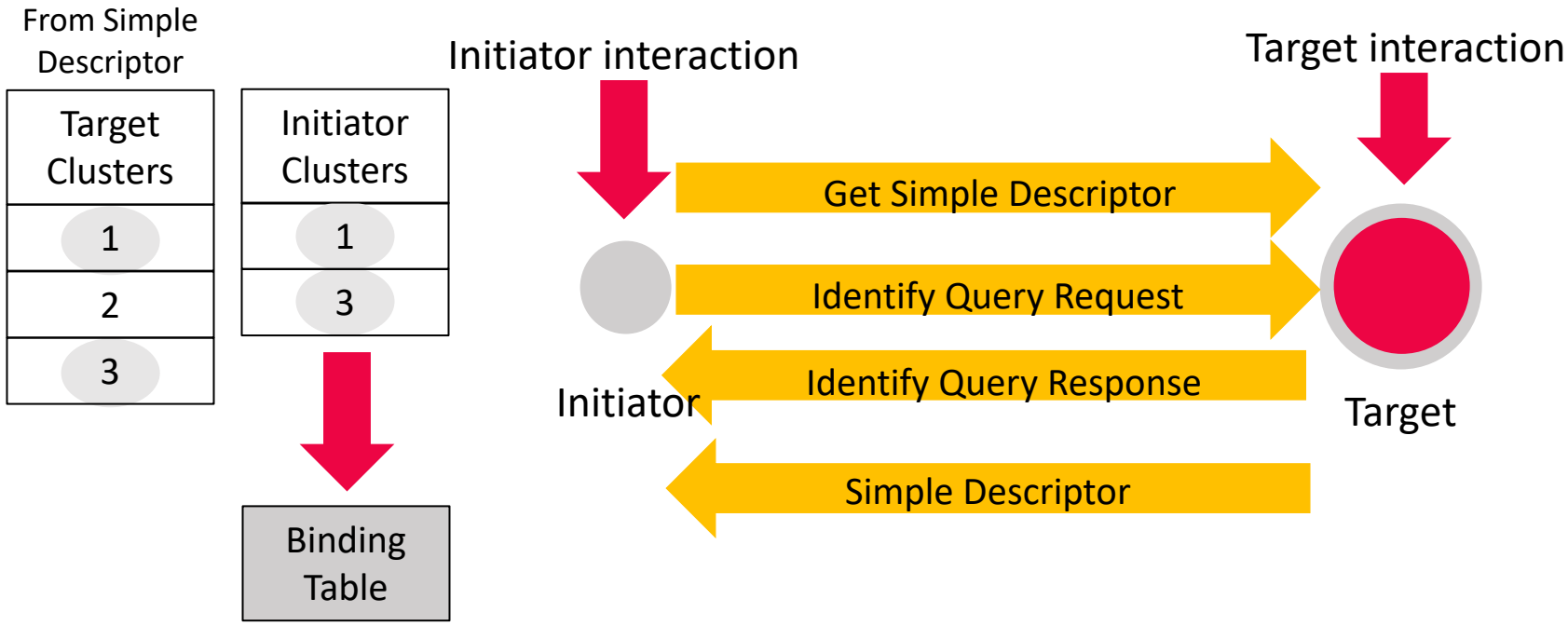
Node not on a network

- Perform a channel scan
- Select an open network & associate
- Receive the network key
- If joining a centralized security network, exchange TCLK

Node on a network

- Open the network for 180s
- Participate in the association as parent
- Participate in the key exchange as parent and/or coordinator
- Close the network

Zigbee Base Device Behavior: Finding & binding: Control relationships



Initiator endpoint

- Broadcast identify query request & receive responses
- Request simple descriptor for an endpoint on the target
- Match initiator and target clusters
- Create entries in the binding table

Target endpoint

- Identify for 180s
- Respond to requests from the initiator

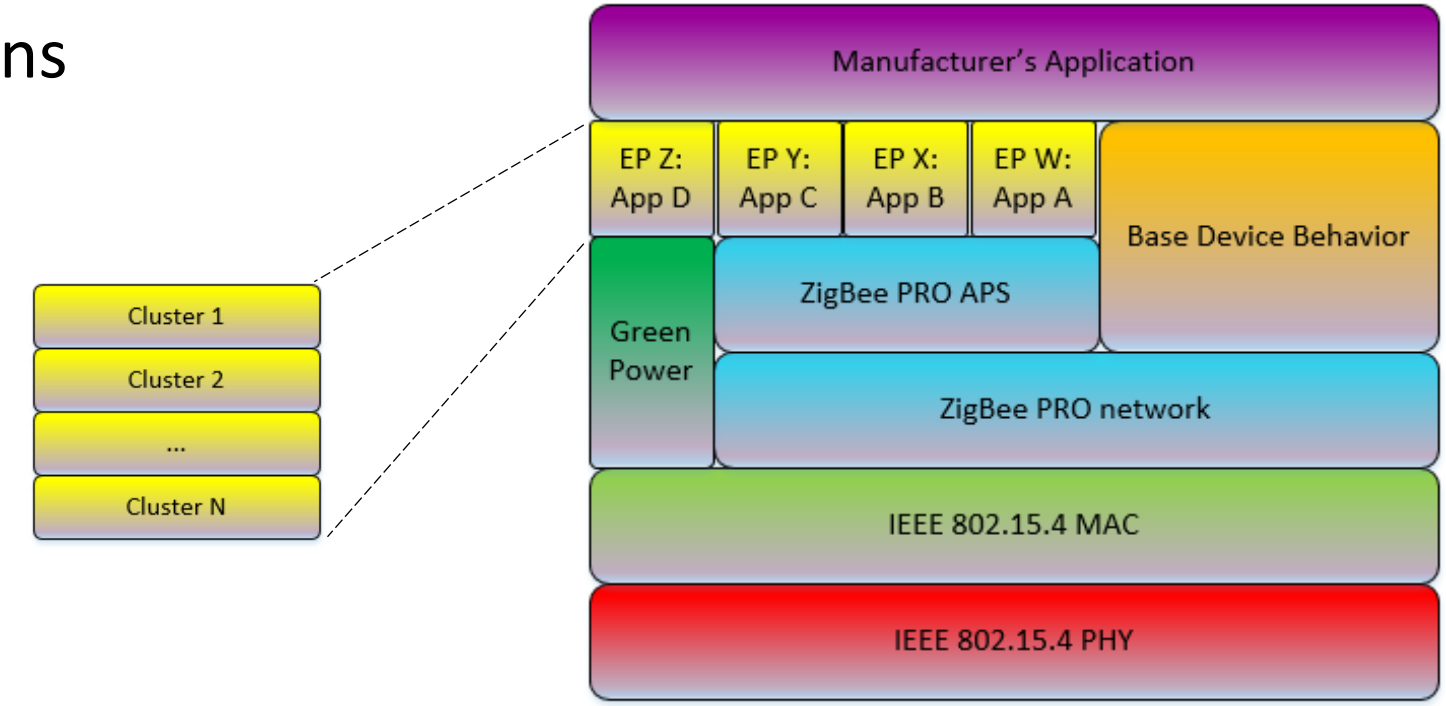
Zigbee: aligning the application

Bringing together device definitions from various profiles

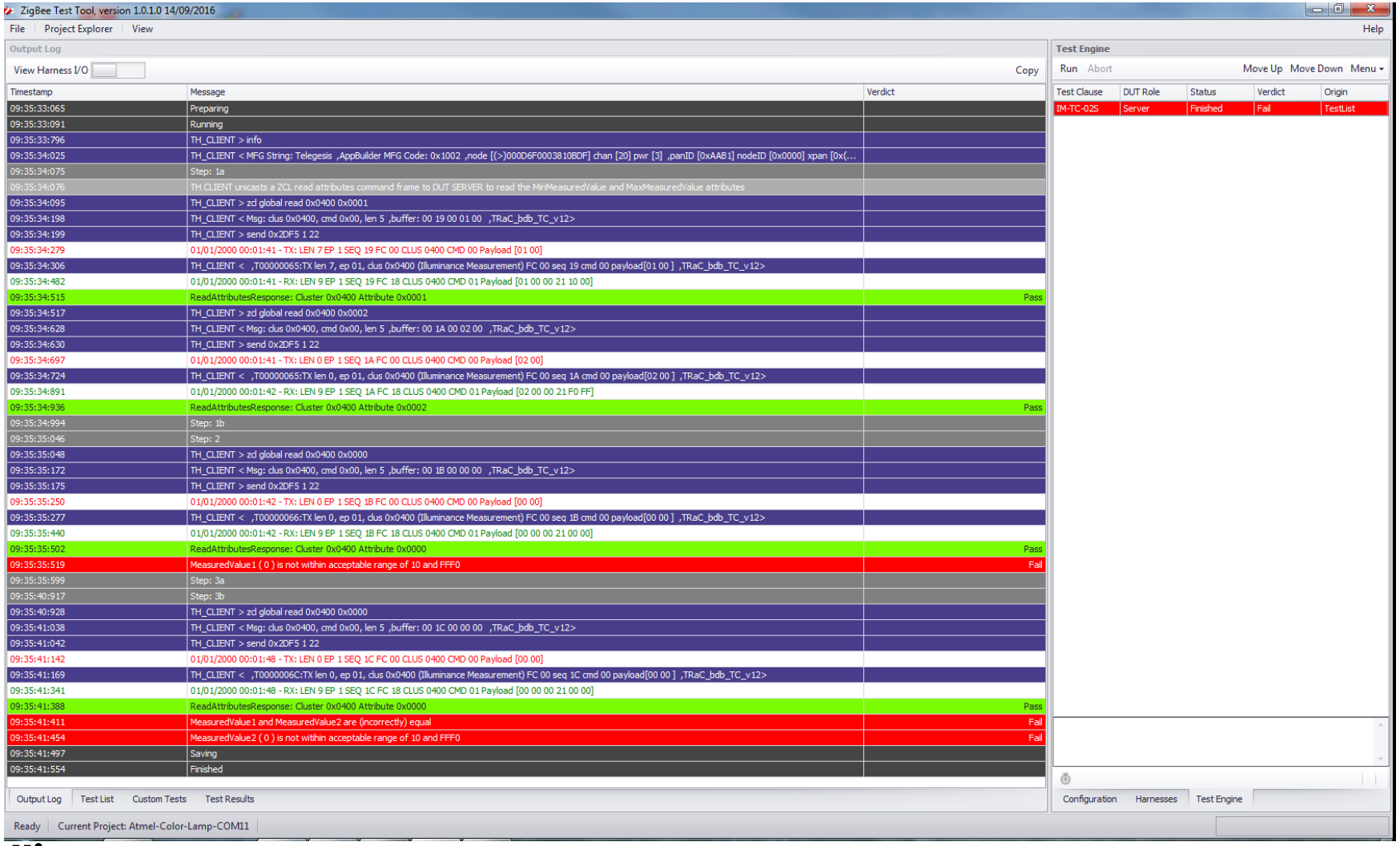
Aligning the DeviceIDs

Aligning the device definitions and requirements

Uniform cluster usage



Zigbee: automated testing



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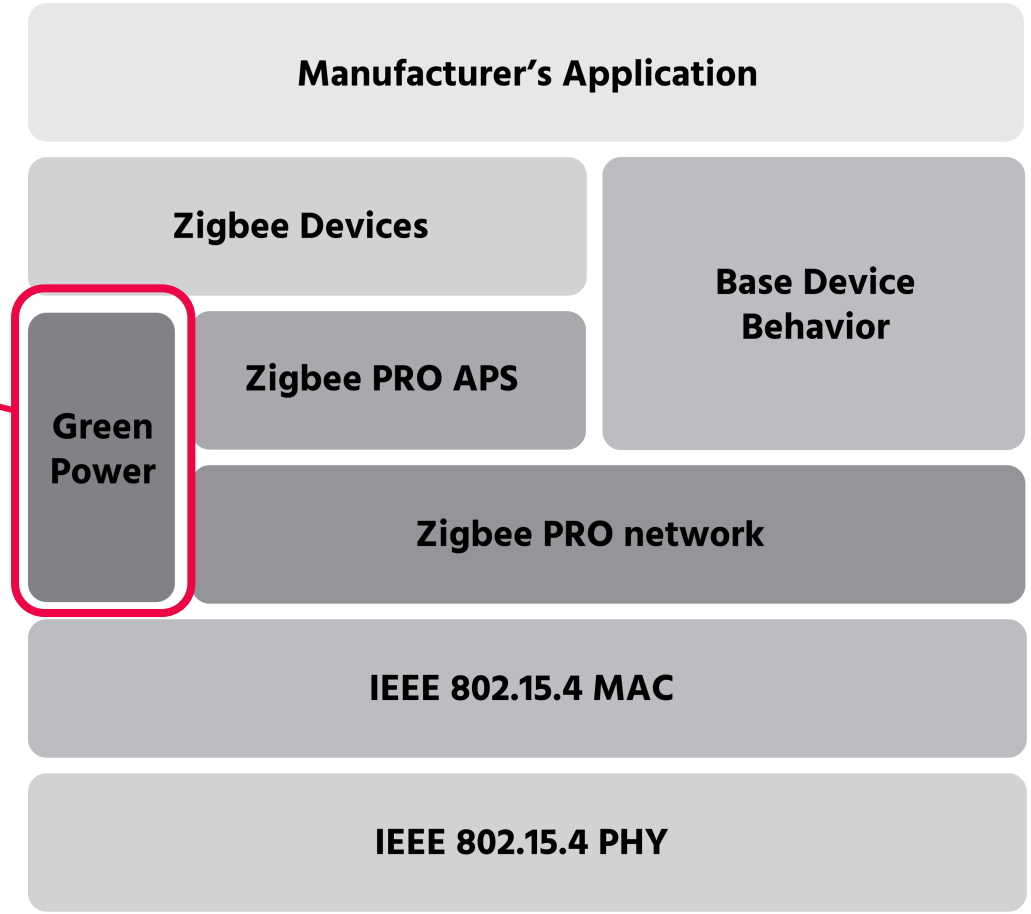
Zigbee Green Power

Proxy functionality mandatory for Zigbee routing devices



Available for automated testing

* Limited to implemented Clusters being already supported in Zigbee Test Tool

Device Id	Description
0x0000	On/Off Switch
0x0001	Level Control Switch
0x0002	On/Off Output
0x0003	Level Controllable Output
0x0004	Scene Selector
0x0005	Configuration Tool*
0x0006	Remote Control*
0x0007	Combined Interface *
0x0008	Range Extender
0x0009	Mains Power Outlet
0x0100	On/Off Light
0x0101	Dimmable Light
0x0102	Color Dimmable Light
0x0103	On/Off Light Switch
0x0104	Dimmer Switch
0x0105	Color Dimmer Switch

Device Id	Description
0x0106	Light Sensor
0x0107	Occupancy Sensor
0x010A	On/Off Plug In Unit
0x010B	Dimmable Plug In Unit
0x010C	Color Temperature Light
0x010D	Extended Color Light
0x0201	Shade Controller
0x0202	Window Covering Device
0x0203	Window Covering Controller
0x0302	Temperature Sensor
0x0800	Color Controller
0x0810	Color Scene Controller
0x0820	Non-Color Controller
0x0830	Non-Color Scene Controller
0x0840	Control Bridge
0x0850	On/Off Sensor

Evolution of our Application Layer

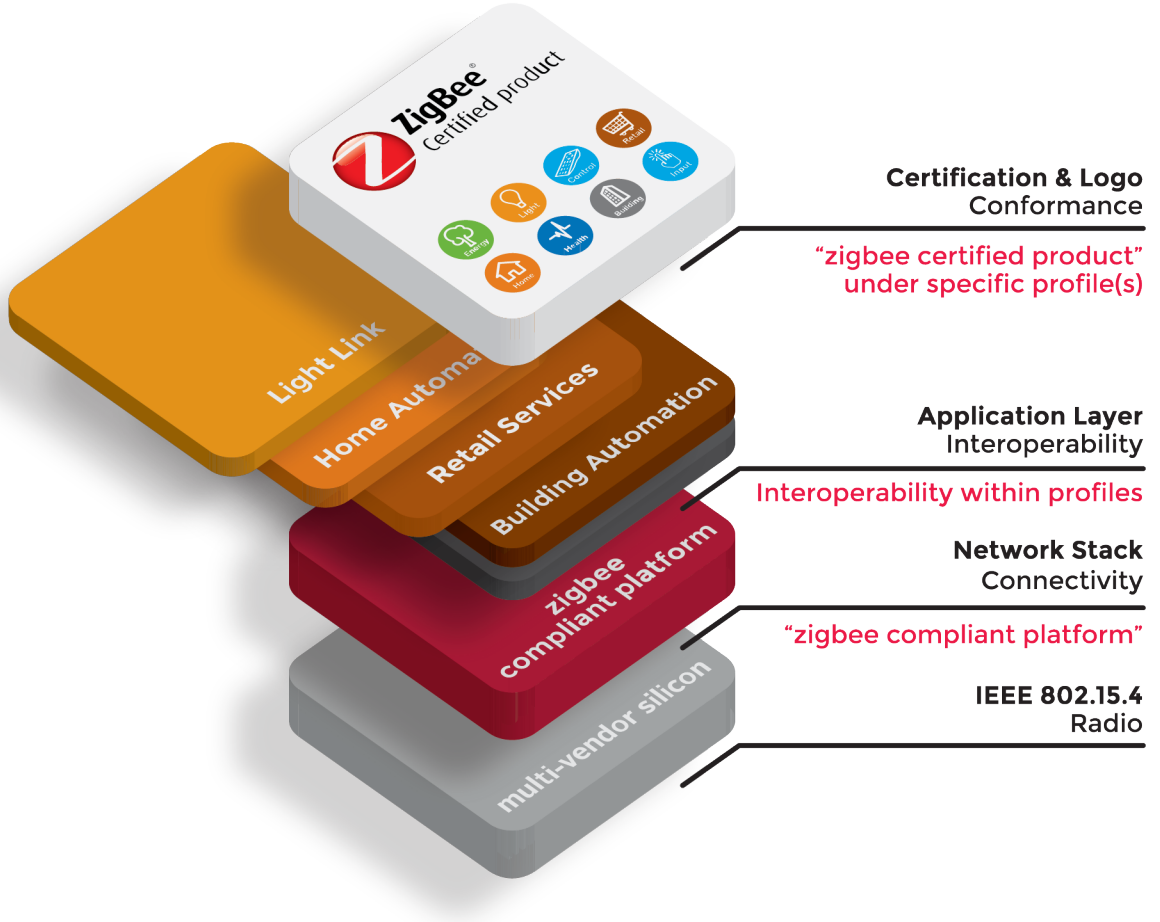
Evolution of our Application Layer

Interoperable app layer

- The Alliance developed the first open, interoperable, certified application layer for multiple key verticals
- Major successes in smart energy, smart home, & lighting

Lessons

- As IoT evolved, interoperability between verticals became increasingly important



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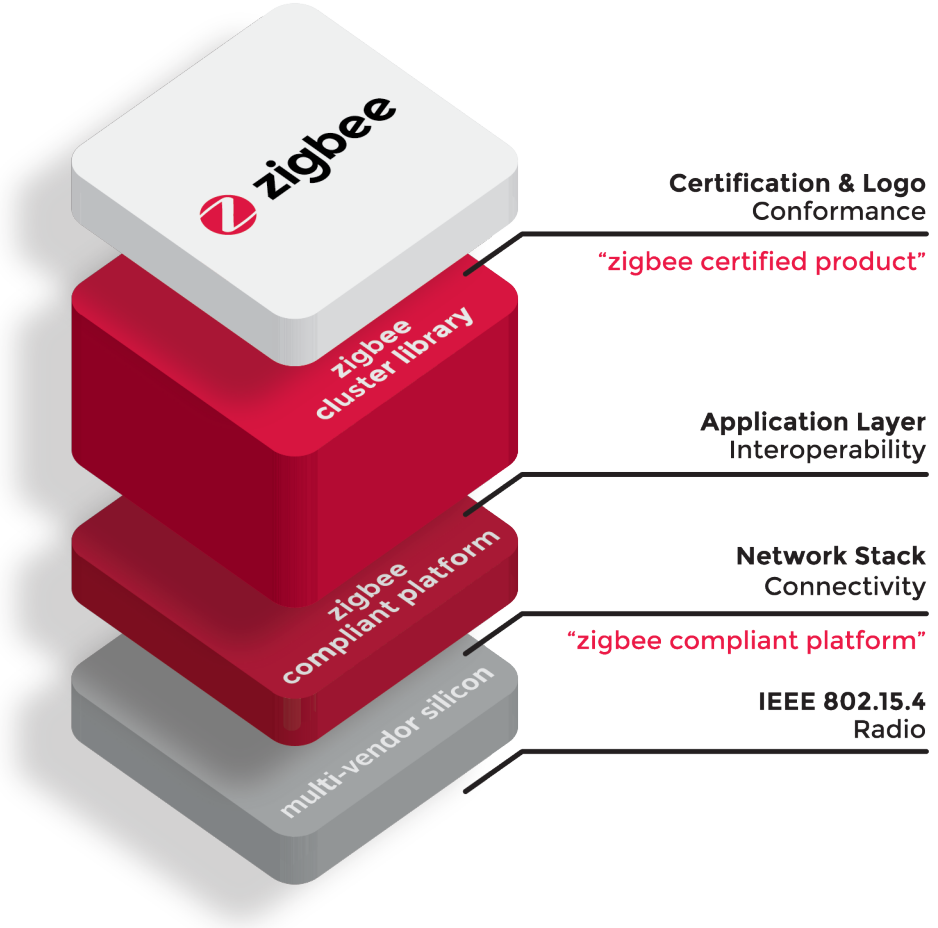
Evolution of our Application Layer

Consolidated App Layer

- With Zigbee, we've brought all our profiles under one technology
- Evolution of the most mature, widely-deployed, well-supported application layer

Lessons

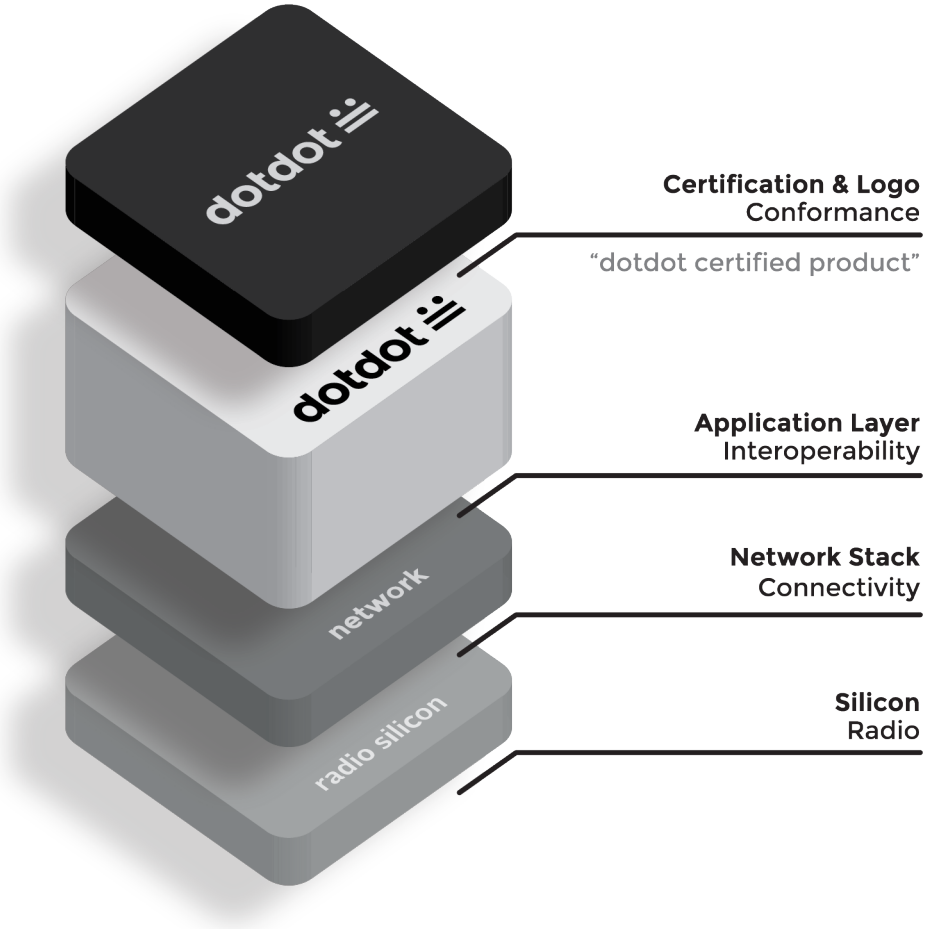
- IoT needs a universal language, and Zigbee's Cluster Library is the most robust
- High demand to expand this across other networks.



Evolution of our Application Layer

Meet dotdot

- The new name for our application layer (formerly ZCL), that can be built across Zigbee, IP, and other transports
- Comes to market with maturity, and an ecosystem of suppliers, manufacturers, and experts
- Product vendors' investment in Zigbee & Dotdot will scale across multiple markets and applications.



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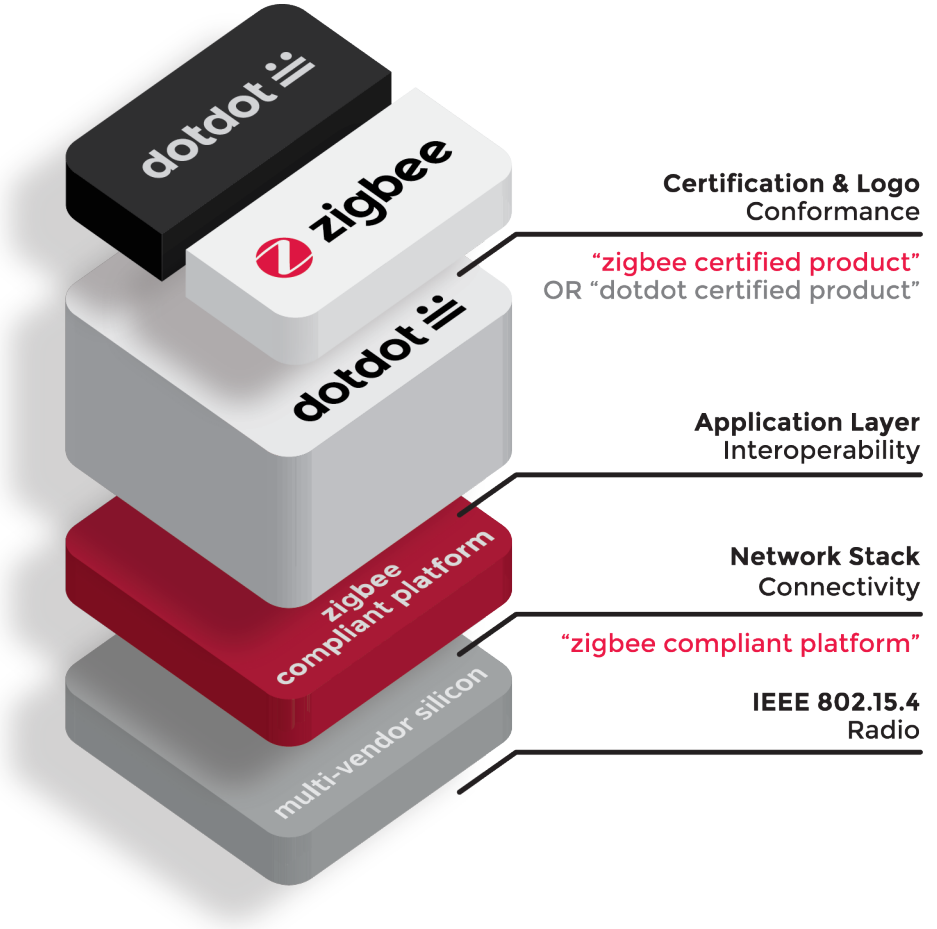
dotdot

Dotdot and Zigbee

- Zigbee devices today already use Dotdot
- We will be launching a certification and logo program for Dotdot in 2018
- Products will be able to certify & label as both, for continuity and to indicate connectivity.



Green Power

What is Green Power?

Green Power is a feature of Zigbee PRO networks

Integrating battery-less (energy harvesting-based) or life-long battery operated devices into the Zigbee network

- **Key benefit**: adds nodes/devices to the network that are virtually completely maintenance free

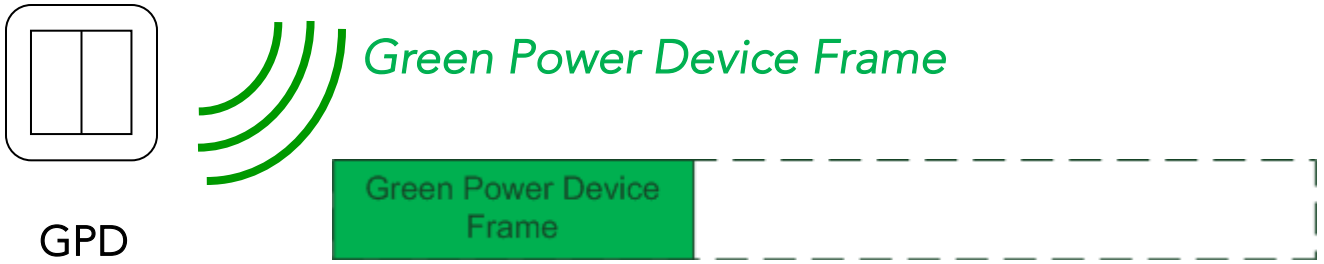
Green Power adds green capability to Zigbee by eliminating battery usage and waste

Green Power applications

(Light) switch: flipping the switch generates the energy for data-communication

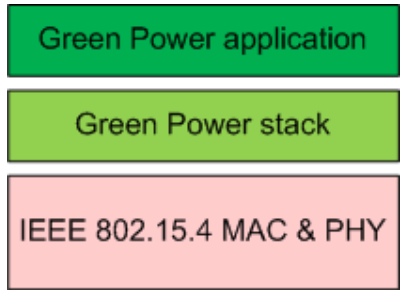
Sensors, open/close detectors, emergency buttons, industrial switches, …

Green Power Device (GPD)



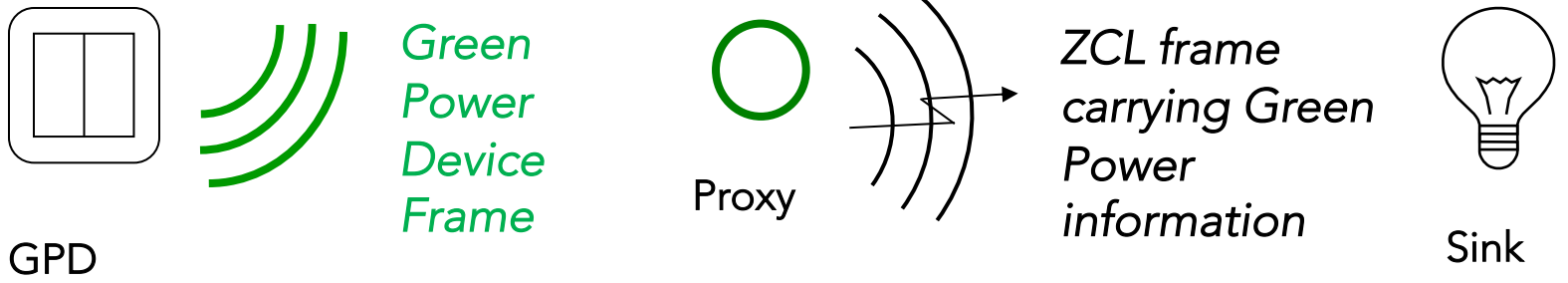
Compact frame with:

- unique identification of the Green Power Device (GPD)
- Scalable security
- Future-proof application framework

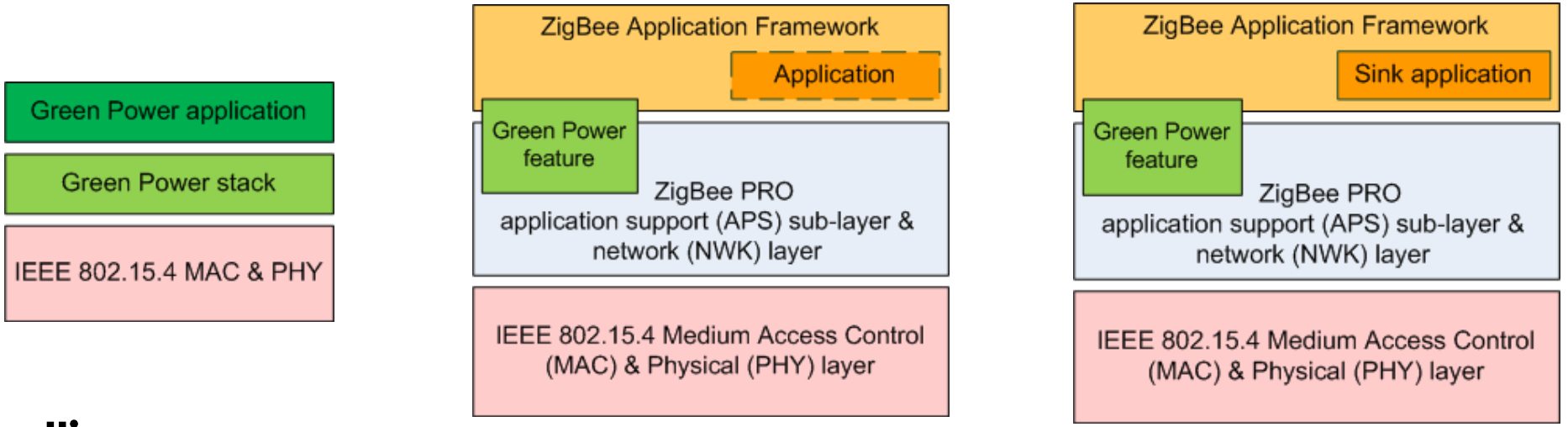


*GPD is *NOT* a ZED! It's less.*

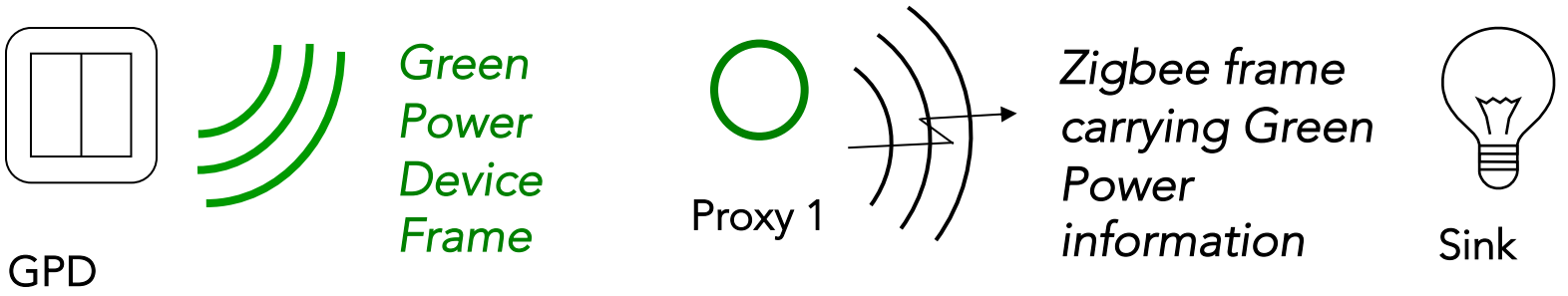
Green Power & Zigbee PRO: Proxy & Sink



Application-agnostic



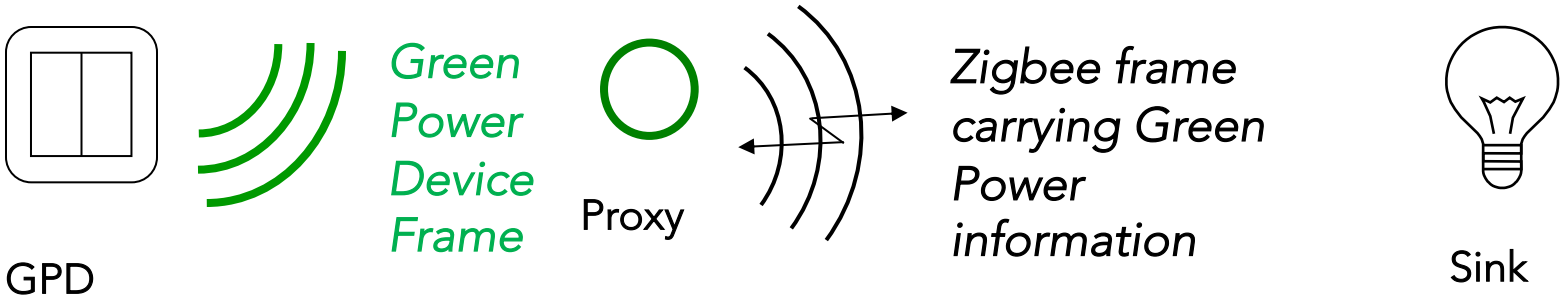
Green Power: Proxy functionality



Proxy forwarding:

- to paired sinks (unicast or group)
- reliably: using multiple proxies in range of the GPD (no single parent problem)
- efficiently (bandwidth usage)

Green Power: Commissioning

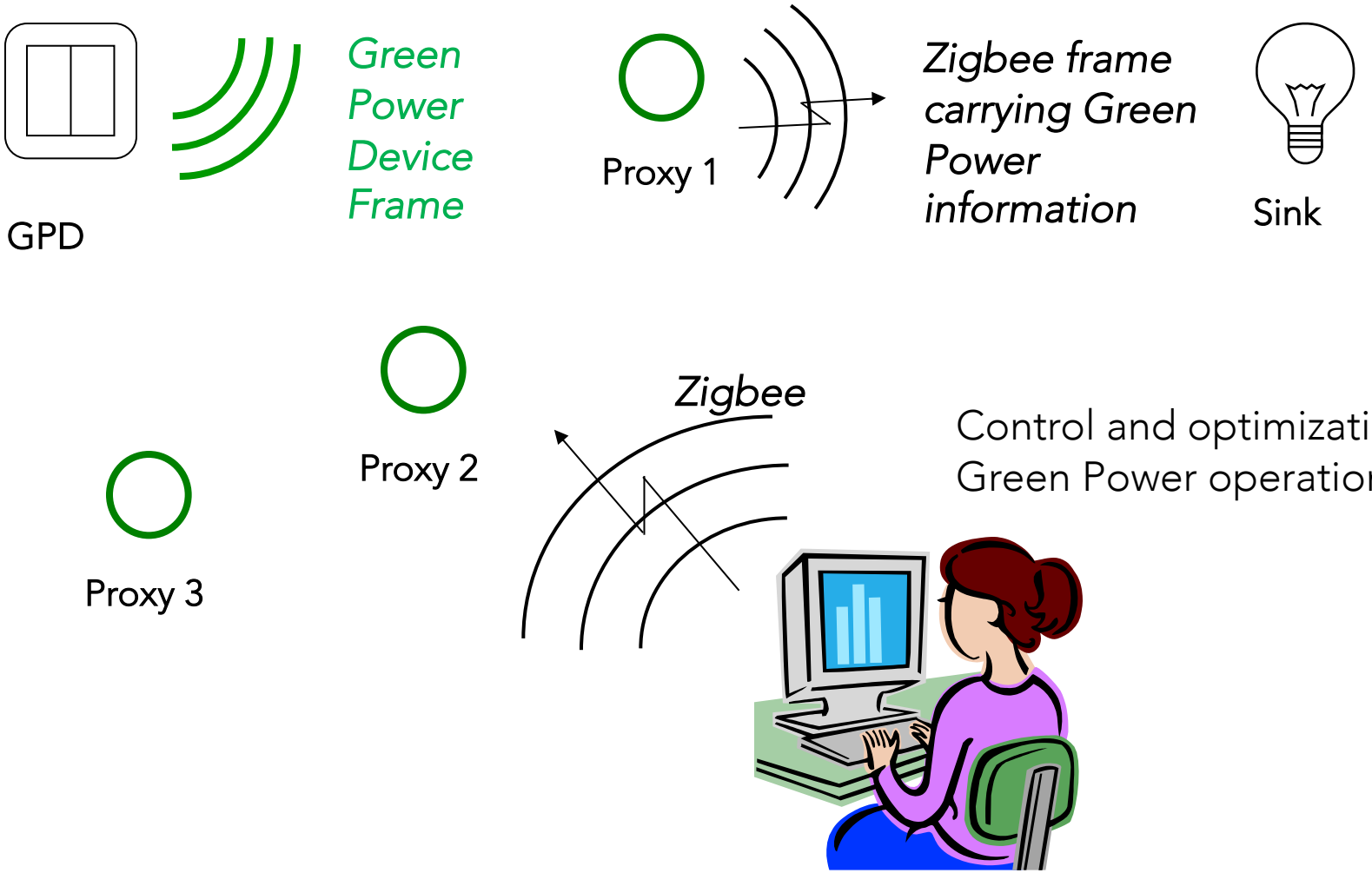


Commissioning:

- brings the Green Power Device on the operational channel;
- bootstraps GPD security;
- creates a control relationship between the Green Power Device and the sink – at the sink;

Without tools; in the same simple user interaction

Green Power: Management



Zigbee Green Power

where mains and battery are impractical or for lifelong battery life

Zigbee Coordinator & Trust Center

- A router dedicated to managing security credentials and performing other network management tasks in a centralized manner

Zigbee Router

- Mains powered, always on

Zigbee End Device

- Battery powered, fully bi-directional

Zigbee Green Power Device

- Energy-harvesting (battery-less) or life-long battery; may be transmit-only;
- E.g. switches, setpoint controllers, sensors

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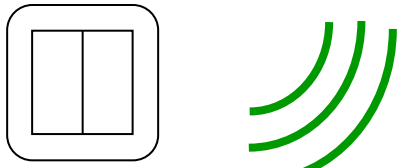
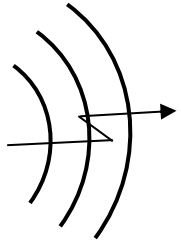
Zigbee Green Power explained



Green Power Device

Green Power Device Frame

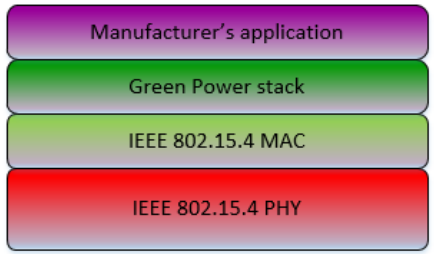
Proxy

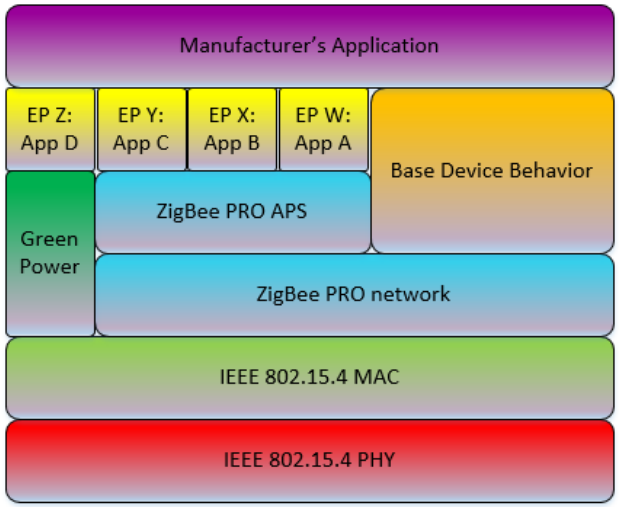


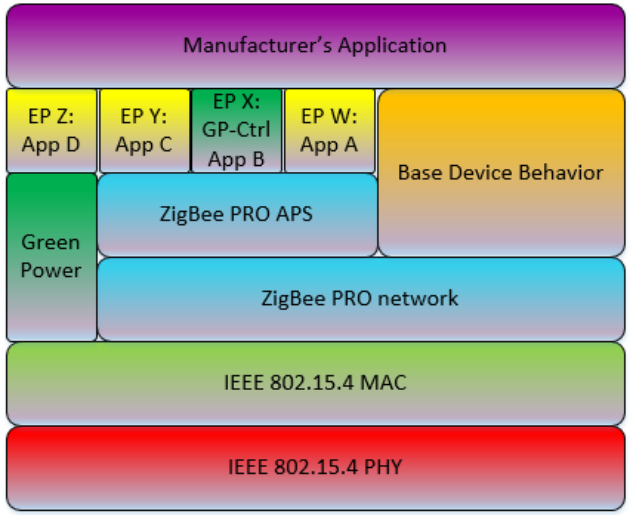
Zigbee frame carrying Green Power information

Sink

Application-agnostic







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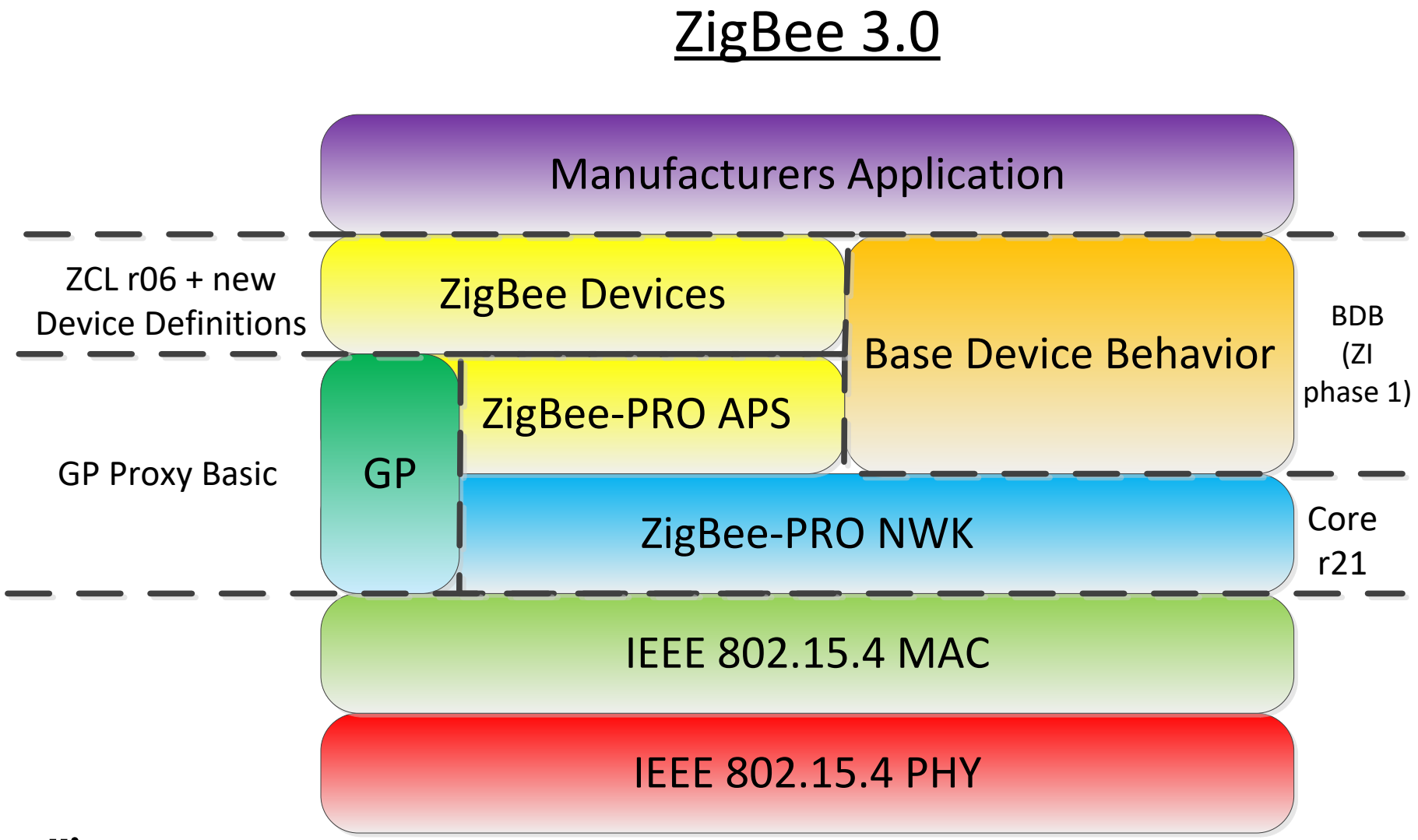
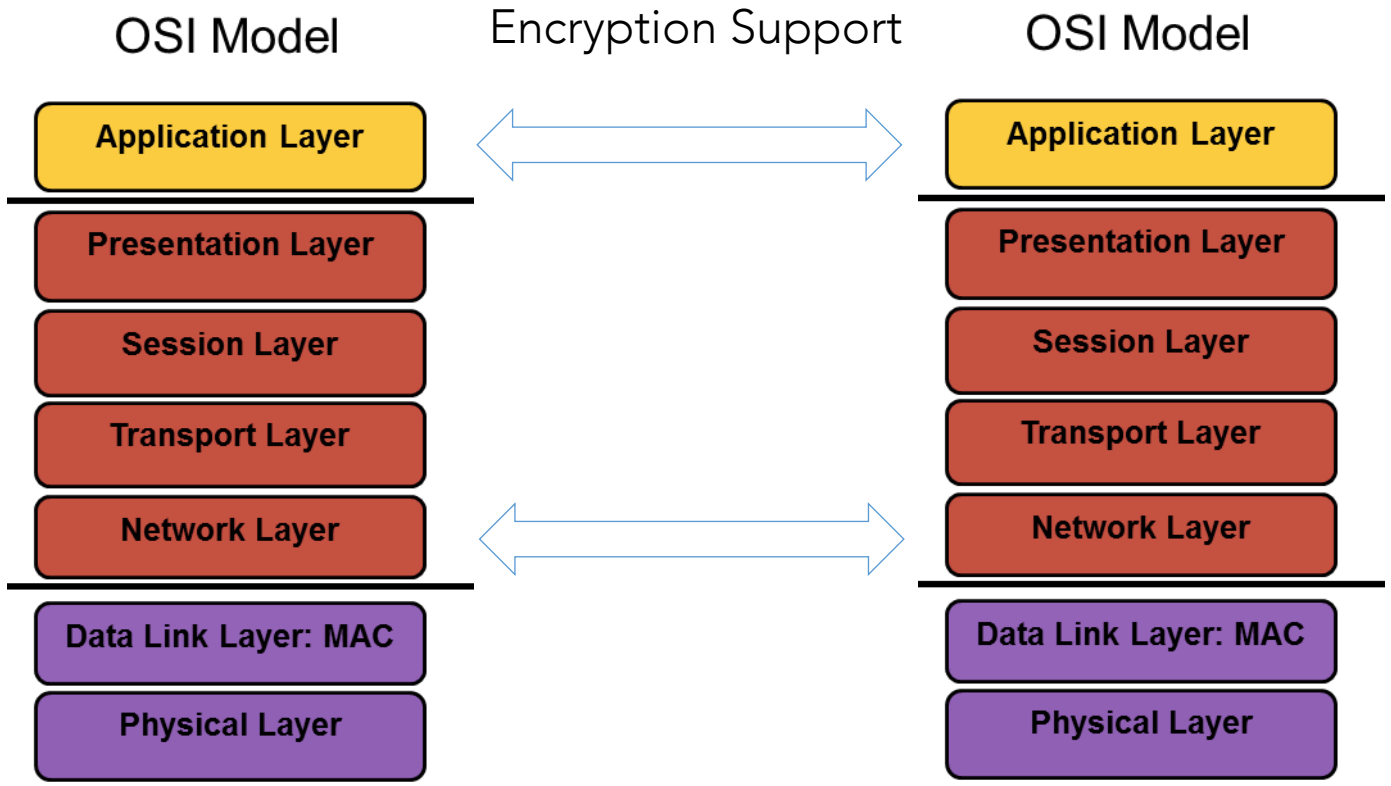
Green Power in Zigbee 3.0



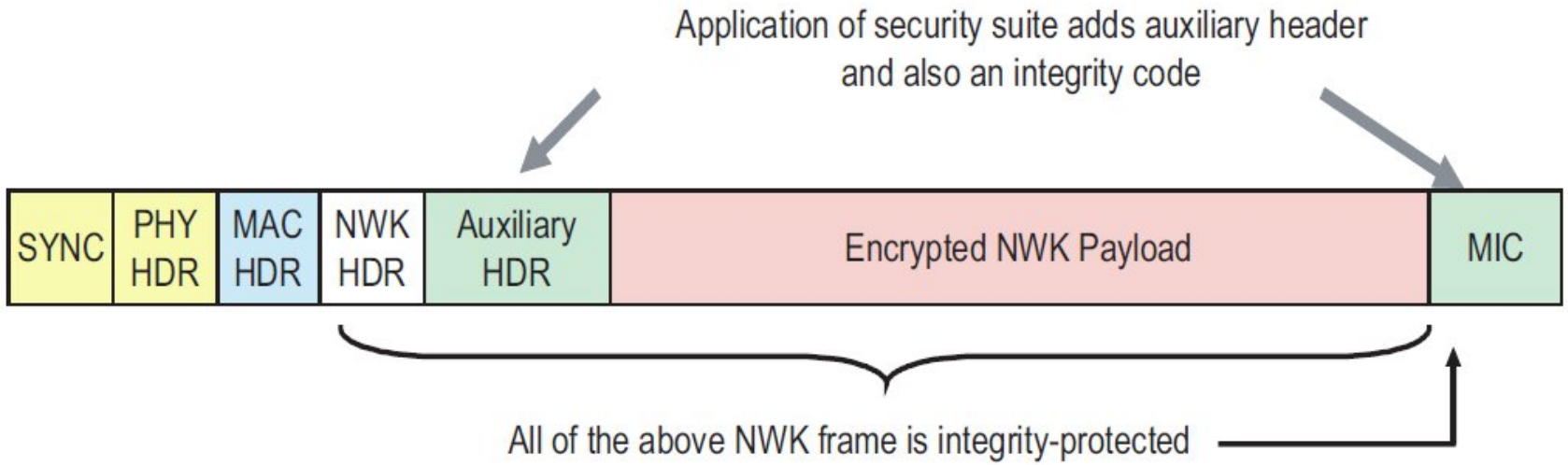
Security Considerations

Standardized at all Layers



AES 128 Security with varying keys

Zigbee PRO Communications Model



Standard Frame Format builds on the 802.15.4 format to add network and application specific commands/responses as part of the 802.15.4 payload

Secure (AES-128 encryption) at network level for all nodes

Additional application layer security available with a single key for every node pair

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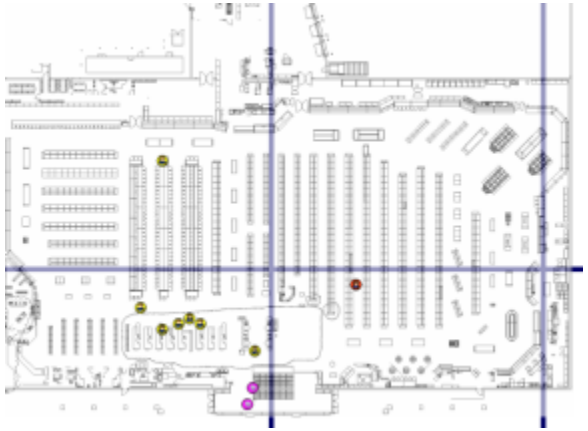
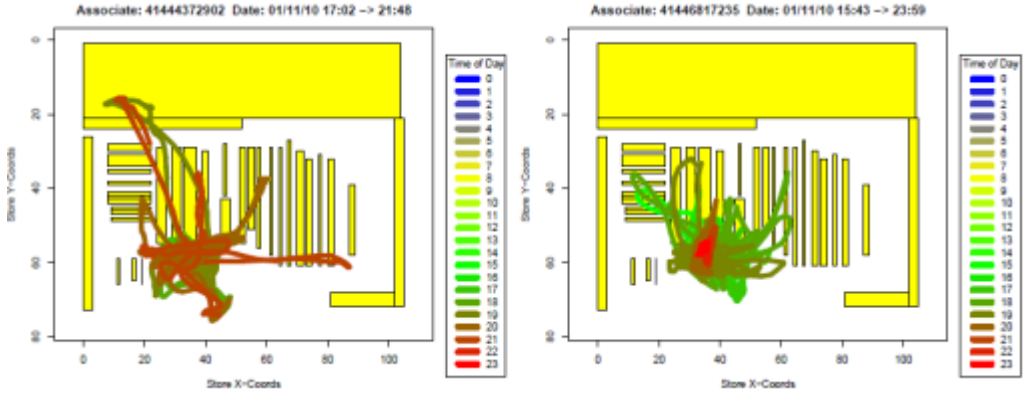
Location Awareness

Zigbee Service Information

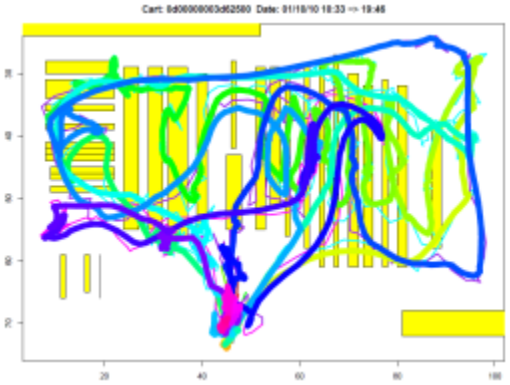
Real-time Information



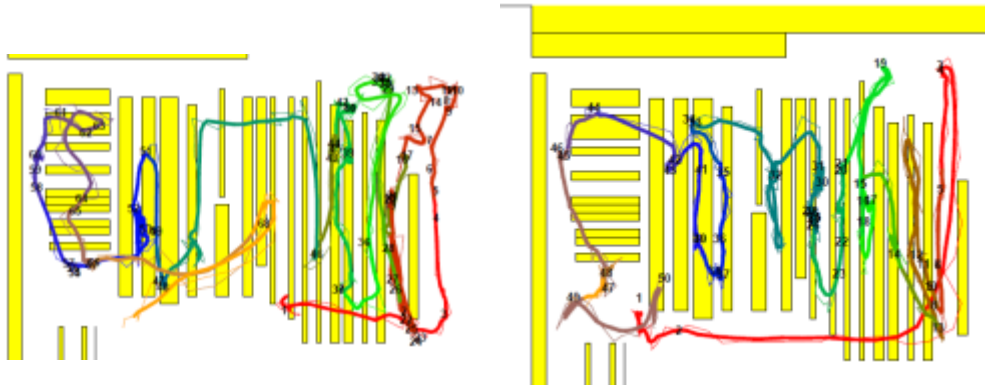
Associate Tracking



Trolley Tracking



Customer Tracking



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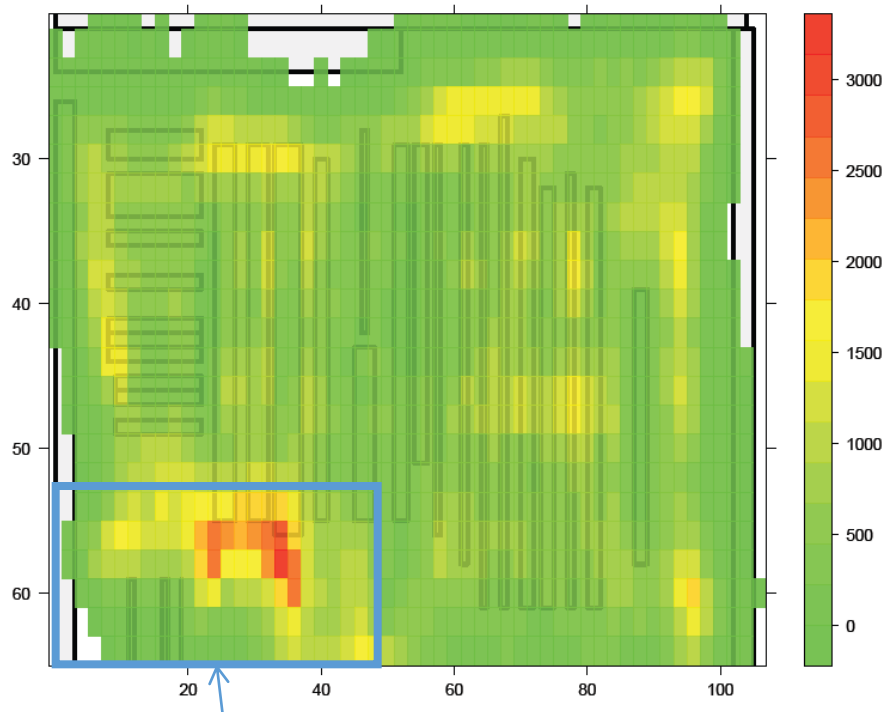
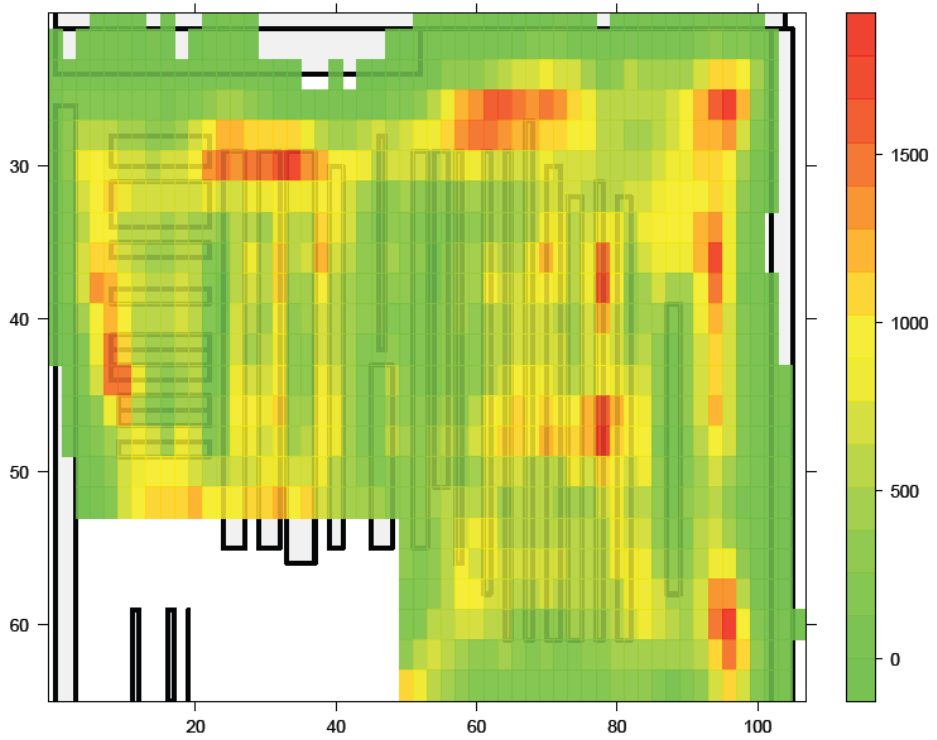
Store Heat Maps



Checkout Area



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Wireless Coexistence

The Challenge

Co-existence in a crowded spectrum is a major concern for any wireless network

There is a multitude of products in use today that operate in the 2.4 GHz ISM band

- **Bluetooth**
- **Wi-Fi**
- **Microwave ovens**
- **Etc.**

IEEE 802.15.4 standard (and protocols based on it) is equipped with system attributes that are key to surviving the interference rich 2.4 GHz environment

IEEE 802.15.4 Pedigree

Global standard

Variety of sources

Technology in mass production since 2003

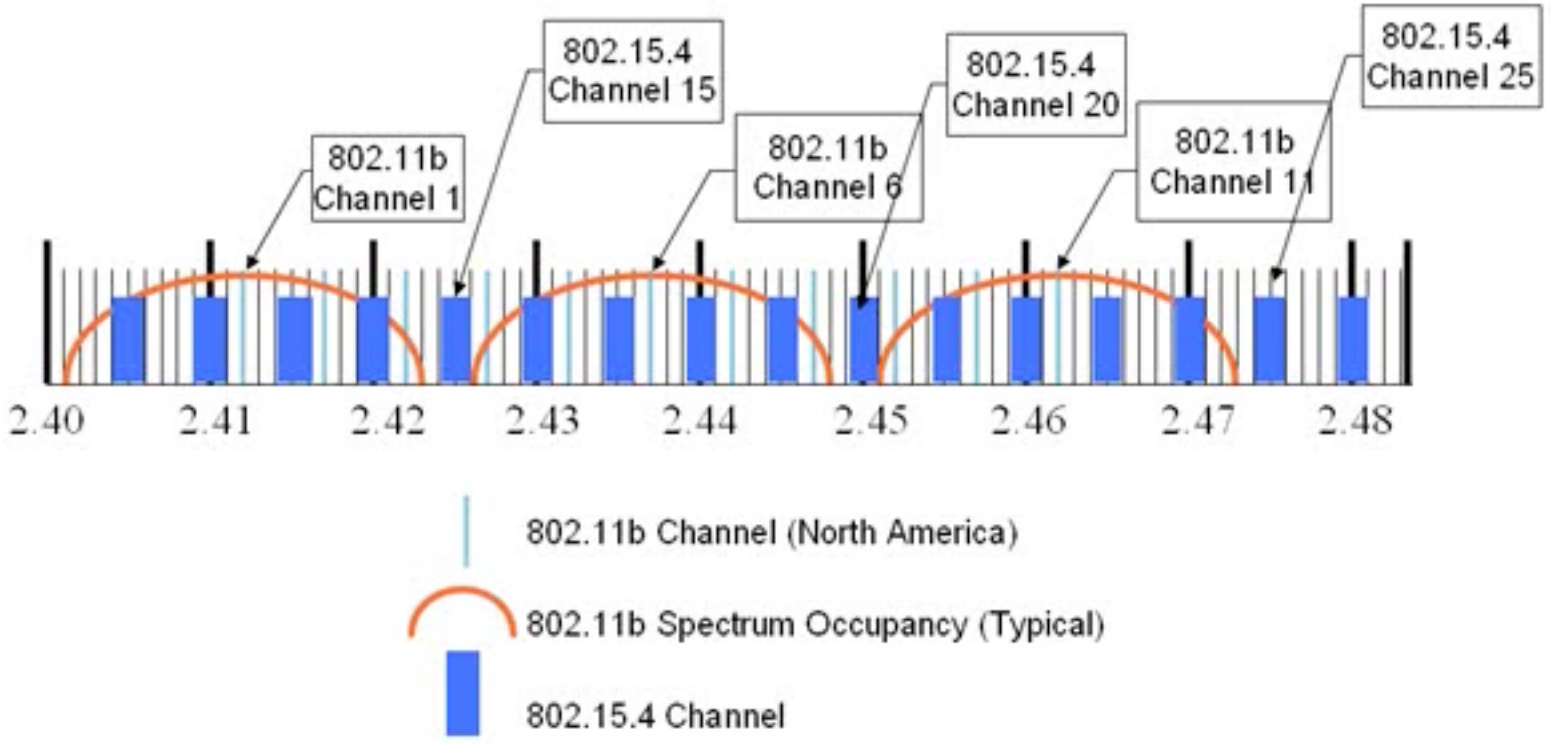
Optimized for low duty cycle application

- **Longer battery life (months to years)**
- **Small packets (short Tx times)**

Interference avoidance

- **DSSS**
- **CSMA-CA**
- **Short burst transmission**
- **Retries**

IEEE 802.15.4 Spectrum Usage



IEEE 802.15.4 CSMA-CA

Wi-Fi Speaks at less than 100% duty cycle

802.15.4 uses CSMA-CA to speak in the quiet periods

CSMA-CA Algorithm (Carrier Sense Multiple Access – Collision Avoidance) listens before transmitting and "backs off" in the presence of interference

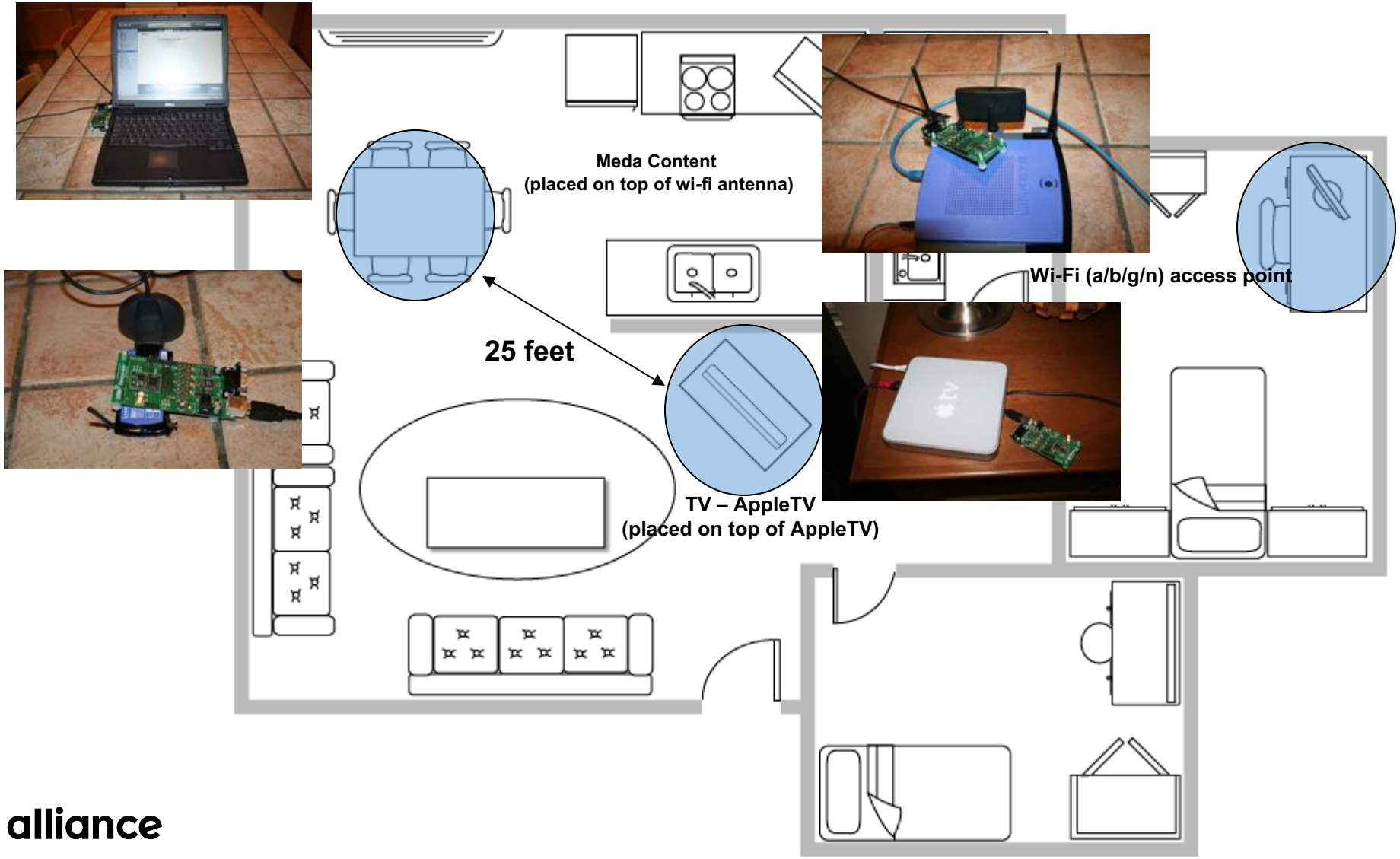
Symbol rate is 62.5 kHz so a symbol only last 16 µs

Network Level Enhancements

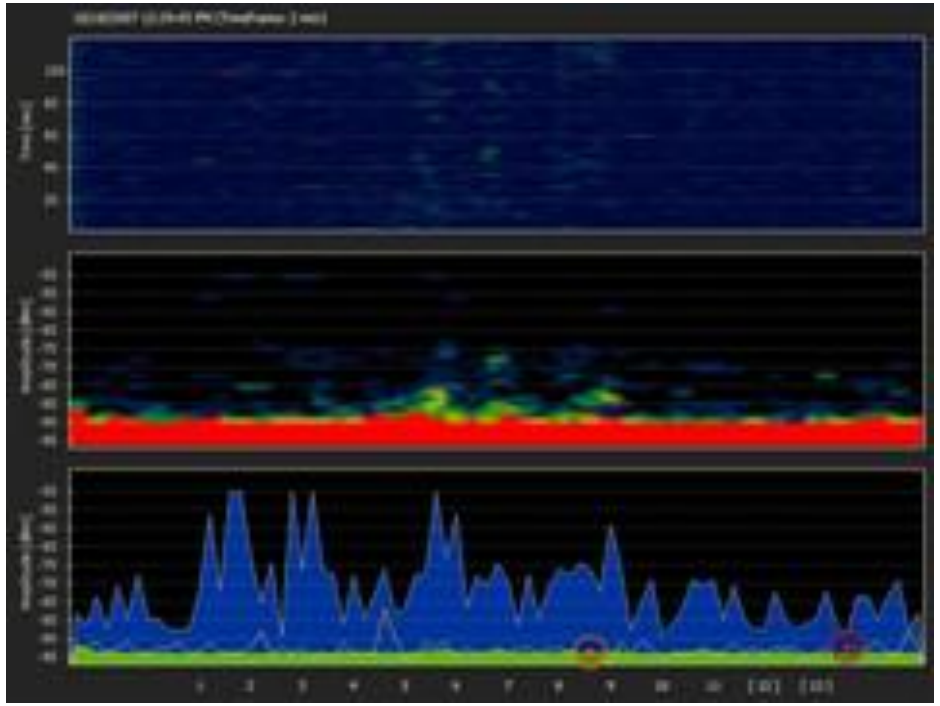
Networking Protocols can extend the interference avoidance capabilities of IEEE 802.15.4 by providing advanced protocol features to deal with interference sources

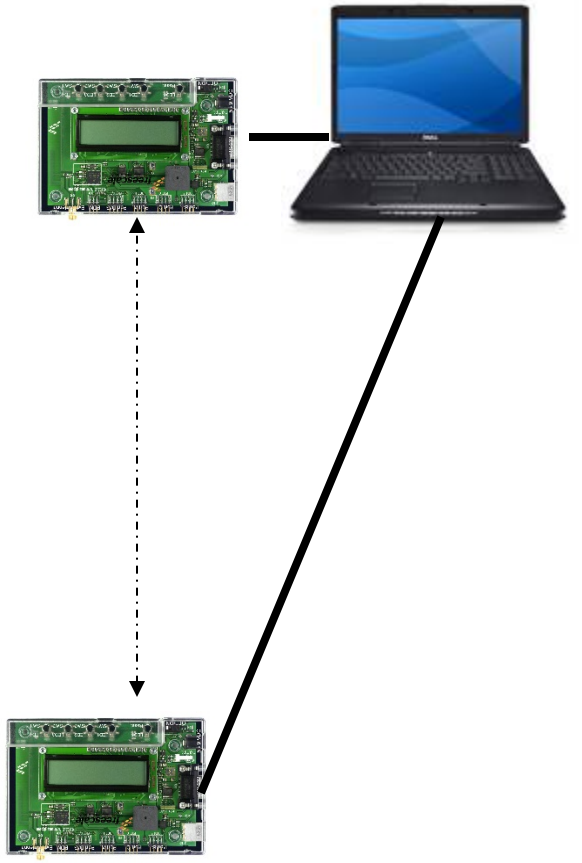
- Zigbee PRO
  - Network level acknowledgements
  - Network Level re-tries
  - Frequency Agility
    - Network Moves to “cleaner” spectrum
- Zigbee RF4CE
  - Multi-channel operation
    - IEEE 802.15.4 channels 15, 20, and 25

Testing the Theory



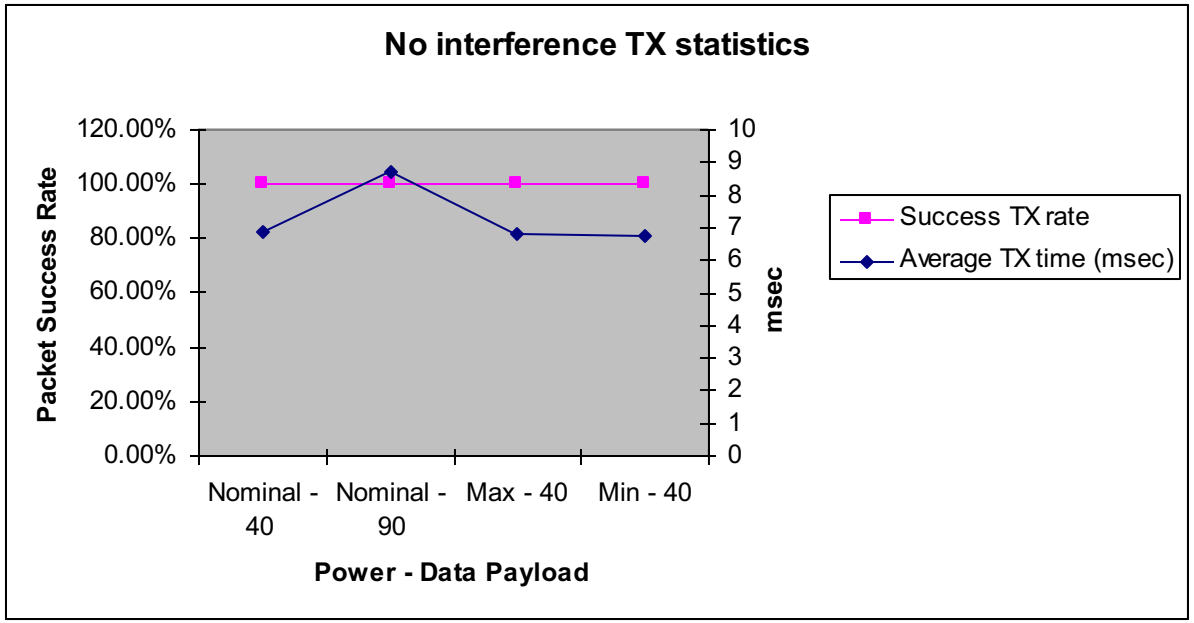
No Interference

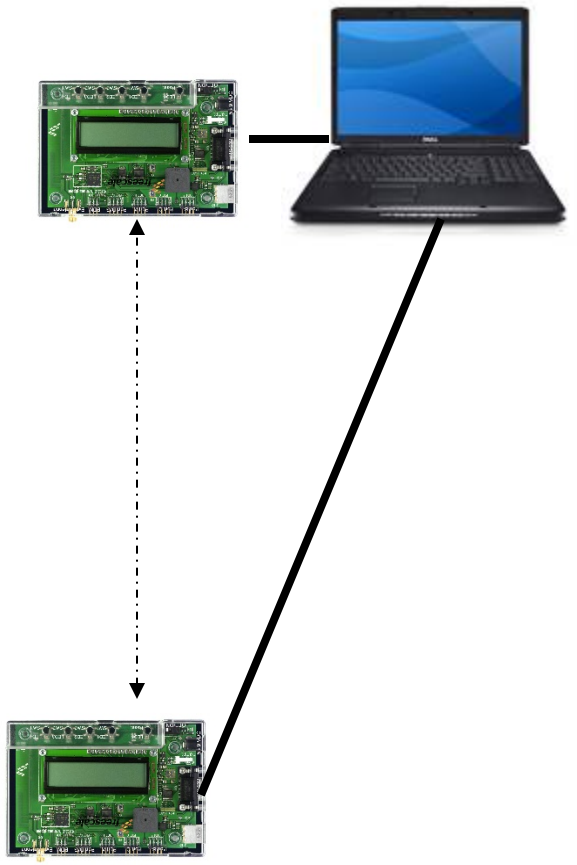




- PER testing: 1000 packets with 40/90 Bytes of payload
- PER testing: output power set to min/nominal/max
- Packet success rate and average TX time recorded

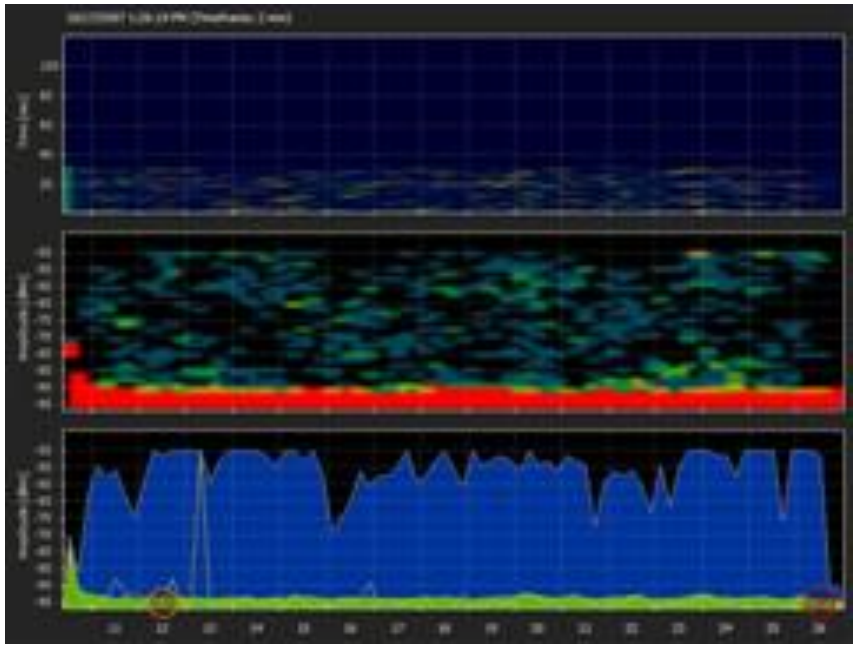
No Interference Results

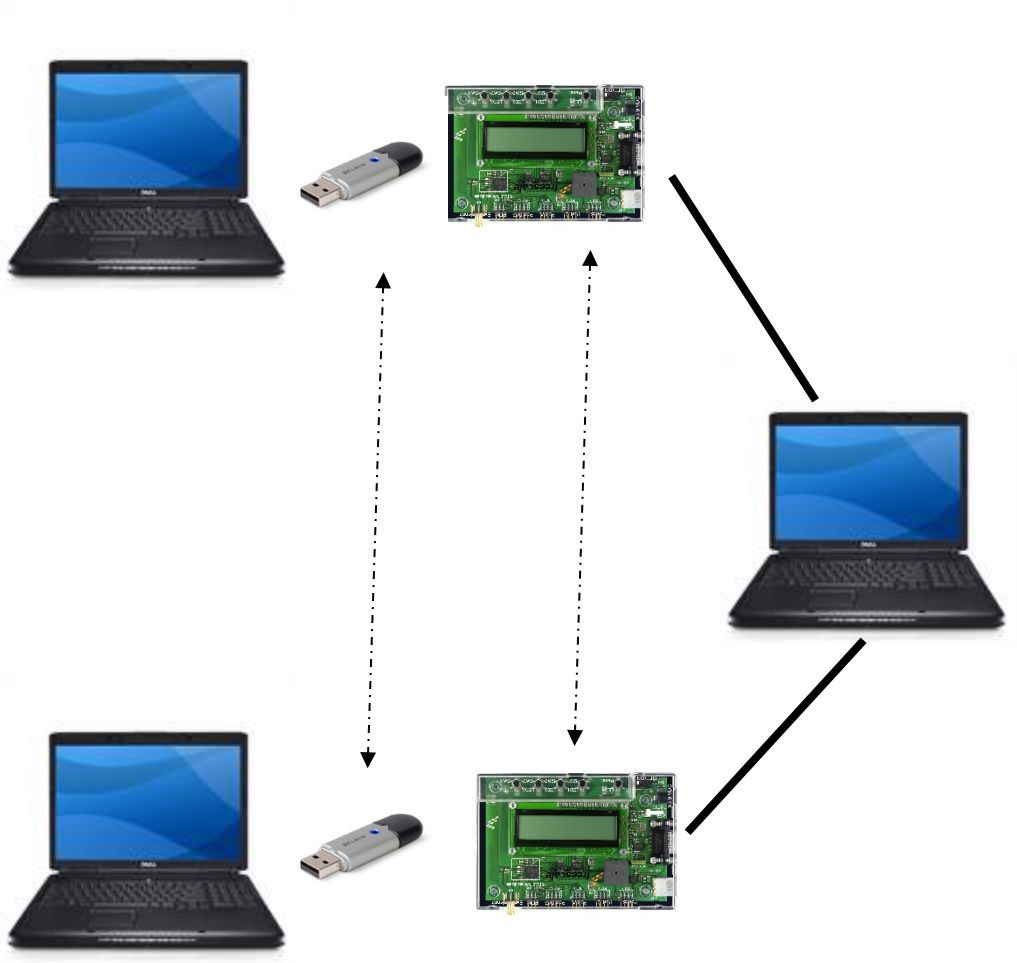




- PER testing: 1000 packets with 40/90 Bytes of payload
- PER testing: output power set to min/nominal/max
- Packet success rate and average TX time recorded

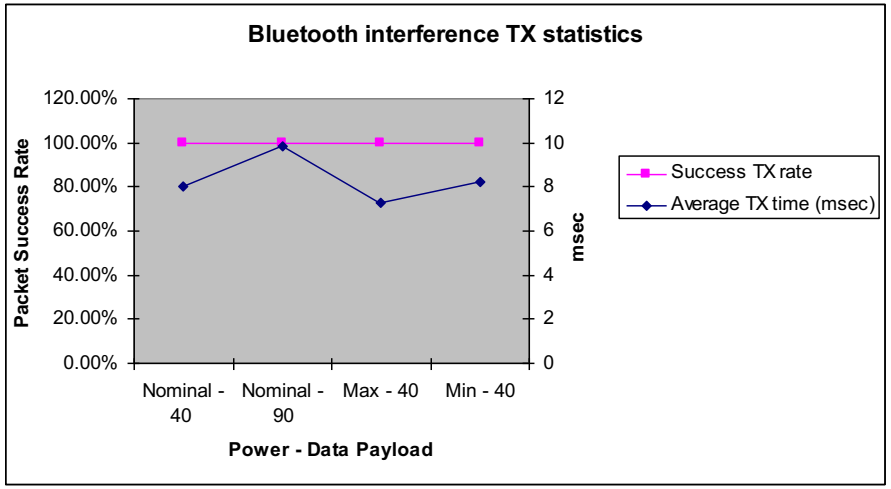
Bluetooth Interference

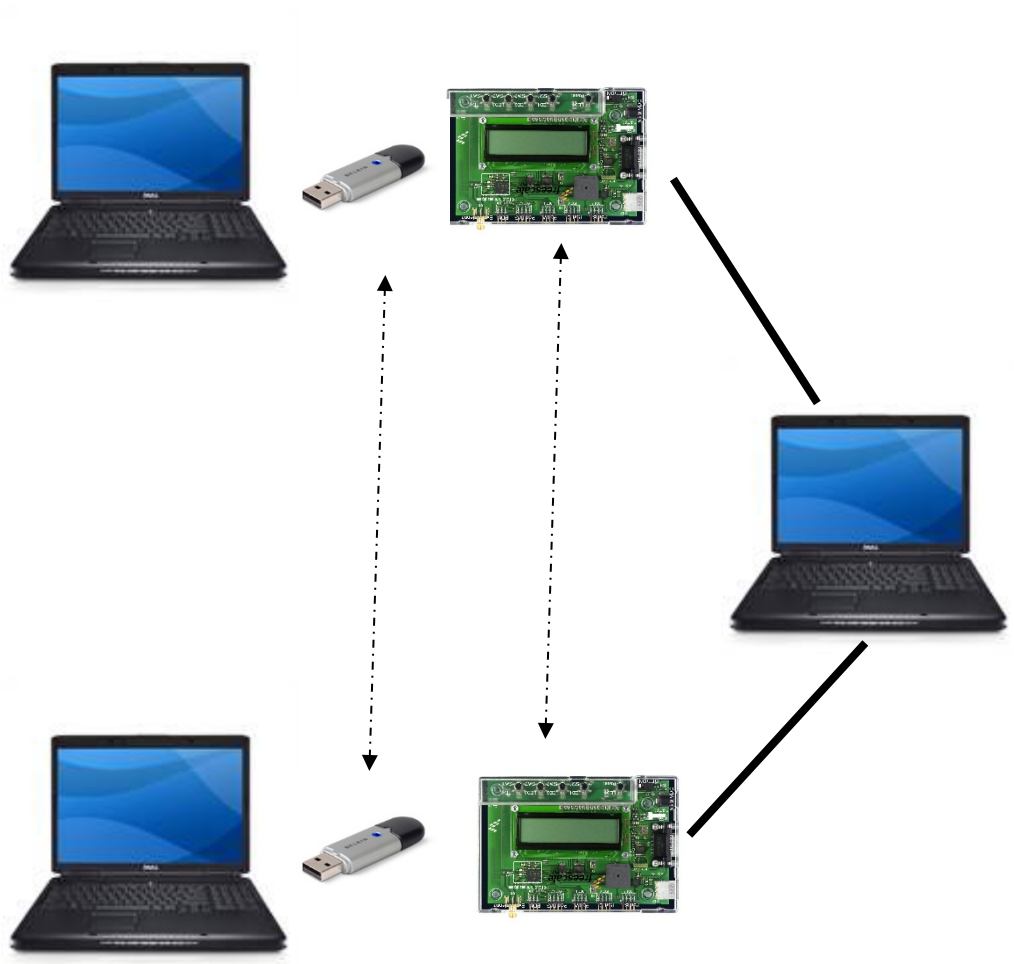




- PCs doing Bluetooth file Transfer
- PER testing: 1000 packets with 40/90 Bytes of payload
- PER testing: output power set to min/nominal/max
- Packet success rate and average TX time recorded

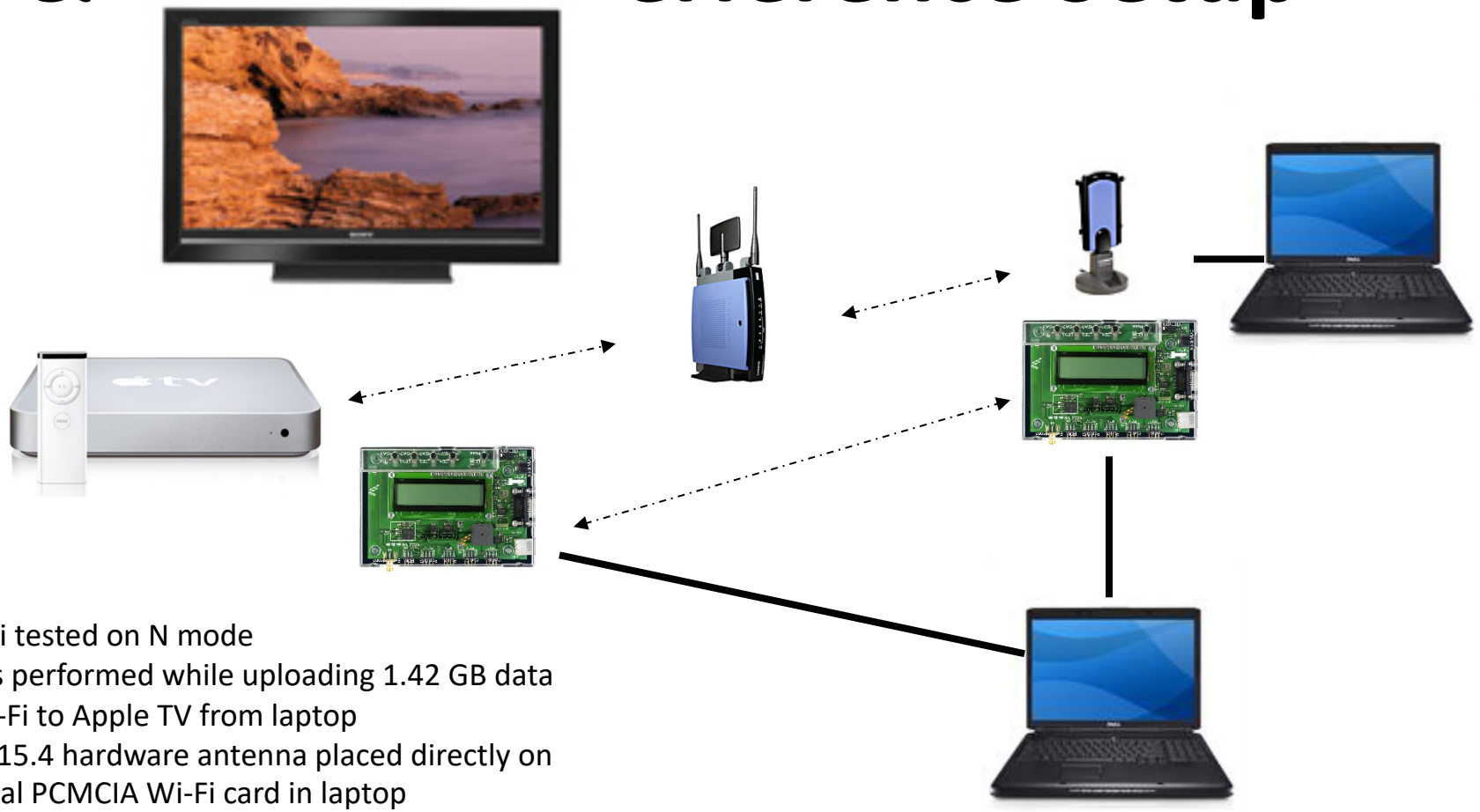
Bluetooth Interference Results





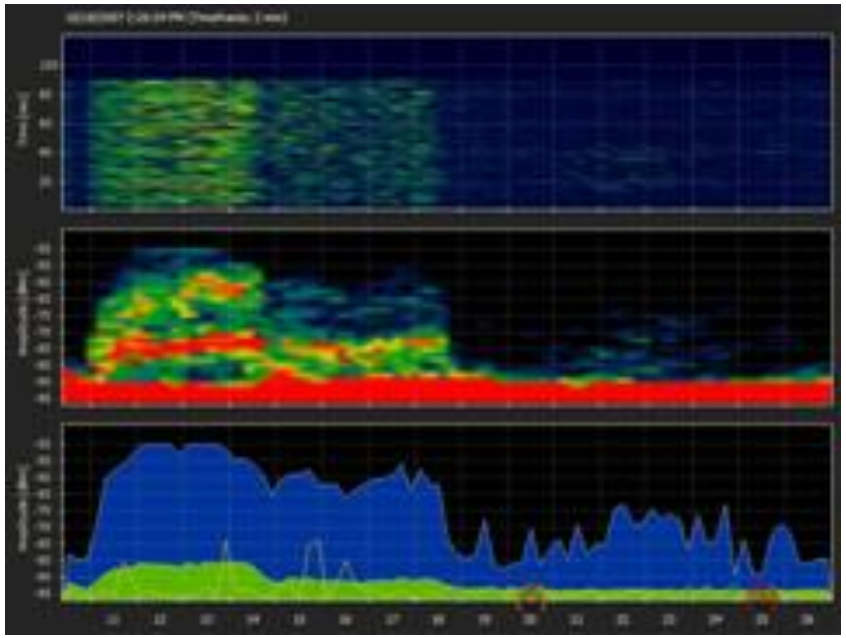
- PCs doing Bluetooth file Transfer
- PER testing: 1000 packets with 40/90 Bytes of payload
- PER testing: output power set to min/nominal/max
- Packet success rate and average TX time recorded

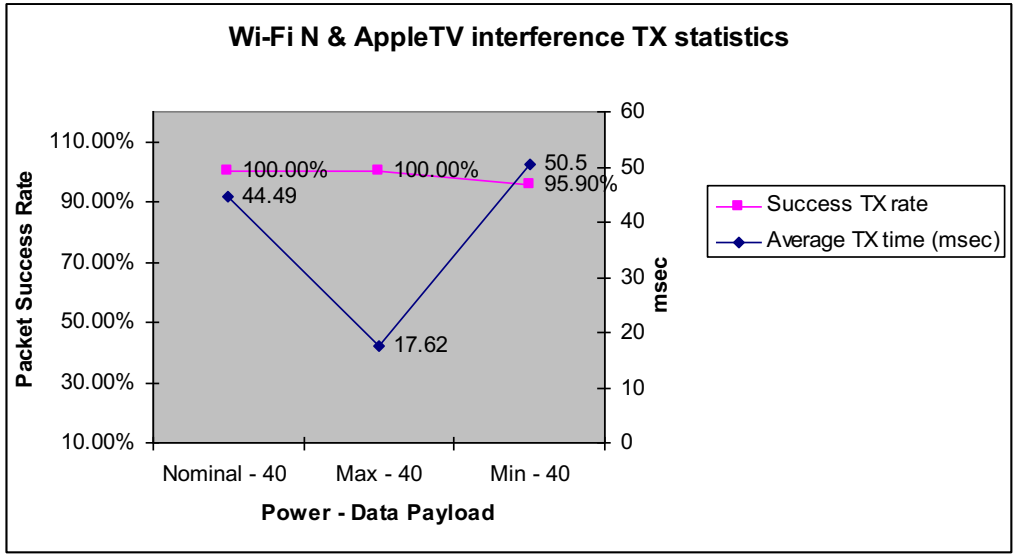
Wi-Fi N & AppleTV Interference Setup



- Wi-Fi tested on N mode
- Tests performed while uploading 1.42 GB data via Wi-Fi to Apple TV from laptop
- 802.15.4 hardware antenna placed directly on external PCMCIA Wi-Fi card in laptop
- PER testing: 1000 packets with 40 Bytes of payload
- PER testing: output power set to min/nominal/max
- Packet success rate and average TX time recorded

Wi-Fi N & AppleTV Interference Results





Zigbee: A toolbox

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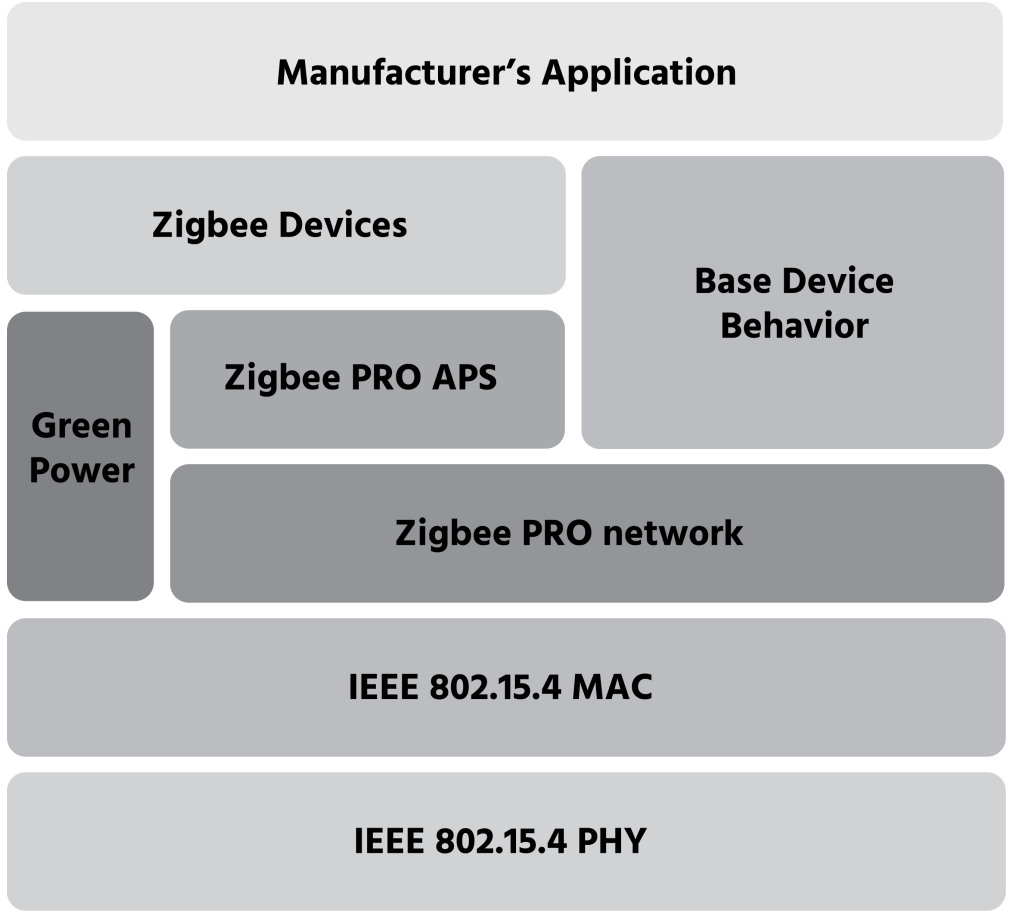
Zigbee 3.0: flexibility of Zigbee PRO
A toolbox for many needs



Routing:
Table routing?
Many to one routing?
Source routing?

Security:
Centralized?
Distributed?

Addressing:
Unicast?
Groupcast?
Broadcast?

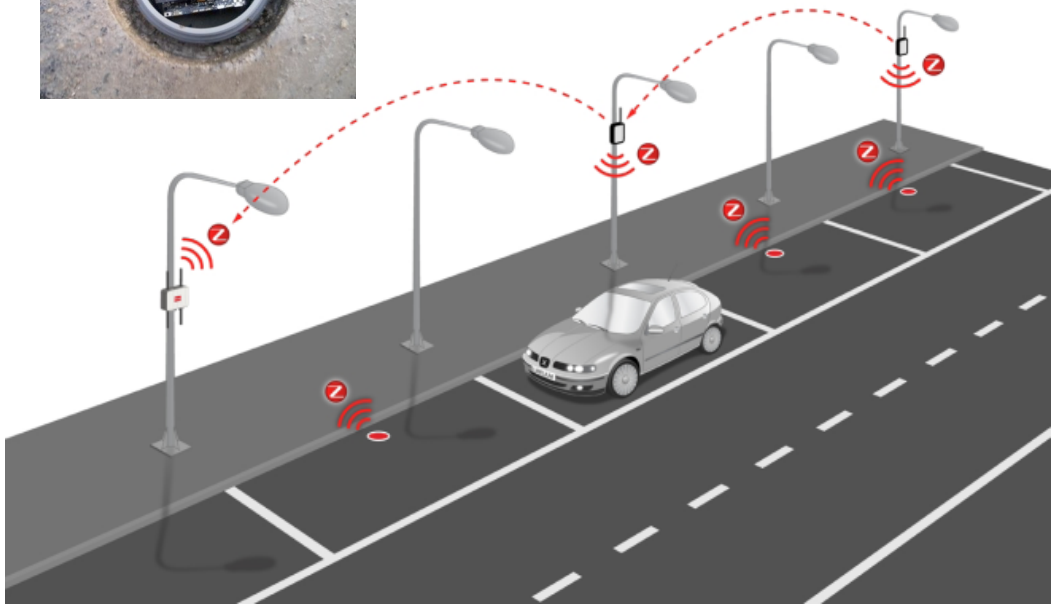
Applications

Applications

GM Spring Hill Plant:
28,773 connected lights,
20 million square feet

Aria Hotel City Center, Las Vegas:
+ 100,000 Zigbee devices

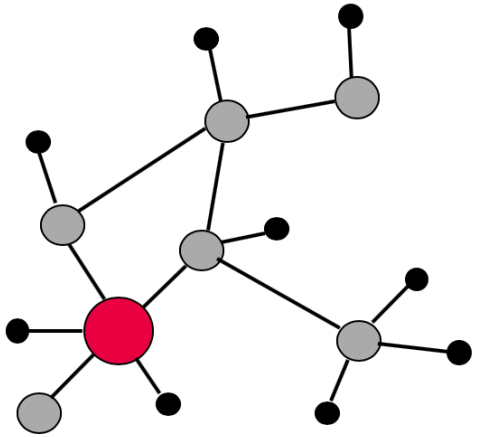
Hampshire City Council, Hampshire UK:
90,000 connected street lights

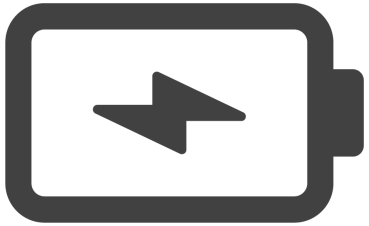


Summary

zigbee

- Security & Safety
- HVAC
- Lighting
- Retail
- Sensing
- Commissioning
- Energy metering
- Appliances
- Telecommunication





Flexible self-organizing mesh + **Ultra low-power** + **Library of applications**

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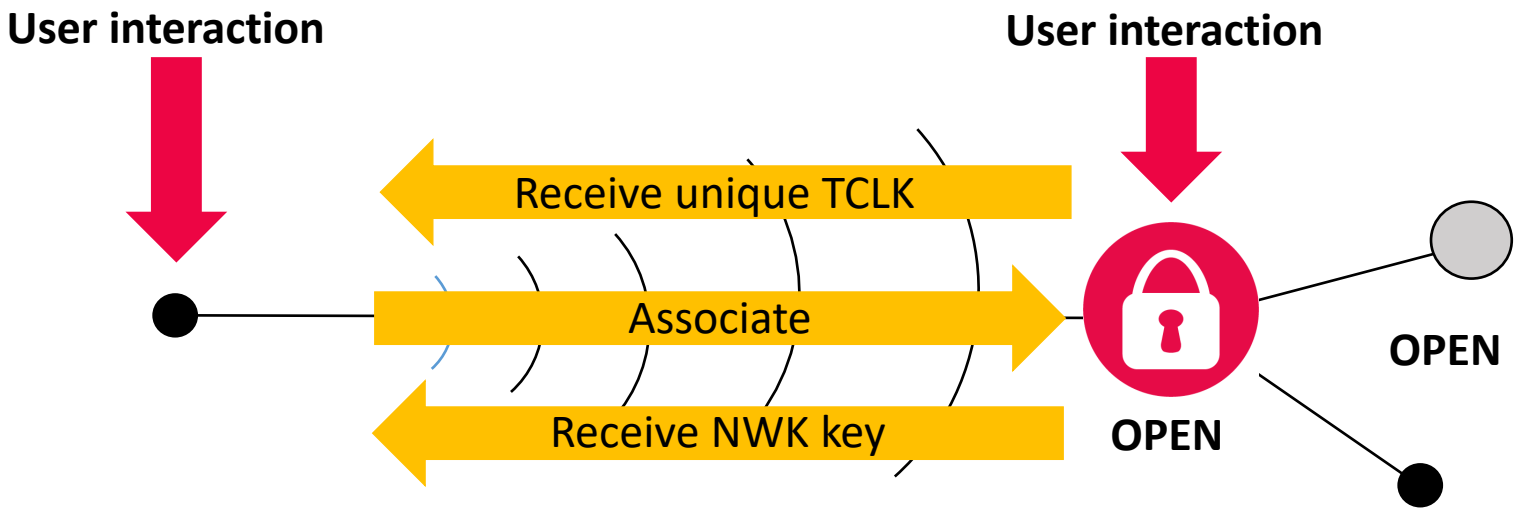
Zigbee Base Device Behavior: Joining a Zigbee network



Joining device

- Perform a channel scan
- Select an open network & associate
- Authenticate
- Receive the network key
- If joining a centralized security network, exchange TCLK

Node on a network

- Open the network for 180s
- Participate in the association as parent
- Participate in the key exchange as parent and/or coordinator
- Close the network

The Alliance has made building Zigbee devices easy

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Building a Zigbee device

1. Development
Zigbee Compliant Platforms

More than 2,500 Zigbee products have been built and certified on our Compliant Platforms.

- Includes 250 manufacturers using Zigbee standards for smart home, smart building, and connected city

More than 20 Compliant platforms to choose from that support Zigbee & wide industry support

Silicon from eight major vendors now certified, with many more module, software and integration support members ready to help product developers build Zigbee products

1. Development
Technical Specifications

Solution	Description
Network Protocol	Zigbee PRO 2015 (or newer)
Network Topology	Self-forming, Self-healing MESH
Network Device Types	Coordinator (routing capable), Router, End Device
Network Size (# of nodes)	Up to 65,000
Radio Technology	IEEE 802.15.4-2011
Frequency Band / Channels	2.4 GHz (ISM band) 16-channels (2 MHz wide)
Data Rate	250 Kbits/sec
Security Models	Centralized (with Install Codes support) Distributed
Encryption Support	AES-128 at Network Layer AES-128 available at Application Layer
Communication Range (Average)	300+ meters (line of sight) 75-100 meters indoor
Low Power Support	Sleeping End Devices Zigbee Green Power Devices (energy harvesting)
Legacy profile support	Zigbee 3 devices can join legacy Zigbee profile networks. Legacy devices may join Zigbee 3 networks (based on network's security policy)
Logical device support	Each physical device may support up to 240 end-points (logical devices)

2. Testing

The Zigbee Test Harness

The Test Harness is an affordable way to enable product developers to check the functionality of their implementations before starting the official testing process.

This brings a common test platform to all labs, and is available to members

2. Testing

Authorized test service providers

Zigbee devices can be tested at any of its five authorized test service providers, at any of their worldwide locations

3. Certification

Certification Programs

After testing, the Zigbee Alliance will review submissions.

Approved devices will then be able to display the Zigbee Certified logo, and **join the global ecosystem of half a billion Zigbee devices with confidence that the device will be interoperable.**

zigbee certified product

Thank you.

For more information, please contact
help@zigbee.org

zigbee alliance