Internet of Things: Protocols and Networks

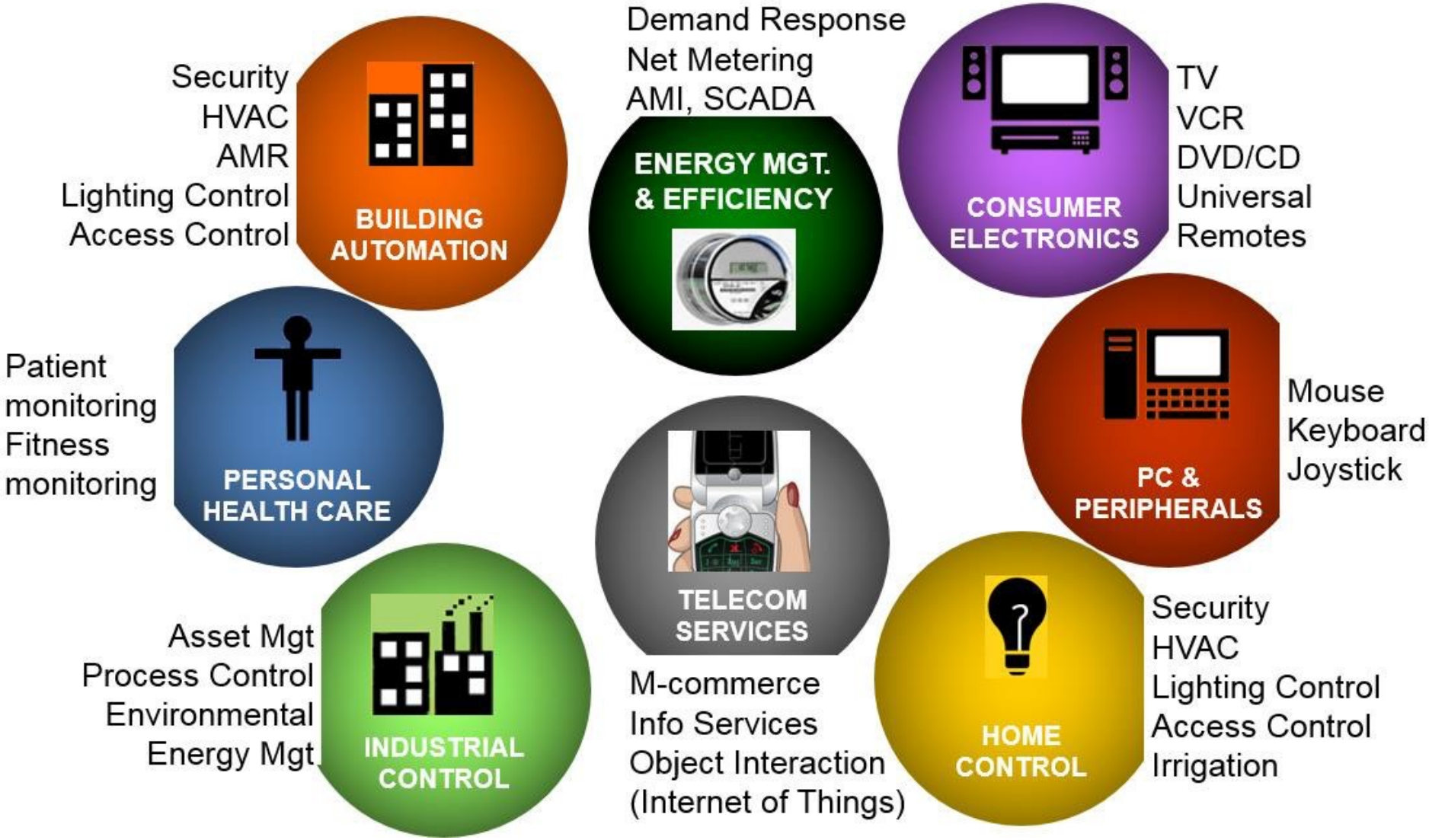
(CSC2106)

ZigBee and Z-Wave

Recent Protocols for IoT

Session	**MQTT**, SMQTT, CoRE, DDS, AMQP , XMPP, **CoAP**, IEC,…	**Security**	**Management**
Network	Encapsulation **6LowPAN**, 6TiSCH, 6Lo, Thread…	IEEE 1888.3, TCG, Oath 2.0, SMACK, SASL, EDSA, ace, DTLS, Dice, …	IEEE 1905, IEEE 1451, IEEE 1377, IEEE P1828, IEEE P1856
	Routing RPL, CORPL, CARP		
Datalink	**WiFi**, **802.11ah**, **Bluetooth Low Energy (BLE)**, **Z-Wave, ZigBee Smart**, DECT/ULE, 3G/LTE, NFC, Weightless, HomePlug GP, 802.15.4e, G.9959, WirelessHART, DASH7, ANT+, LTE-A, **LoRaWAN**, ISA100.11a, DigiMesh, WiMAX, …		

ZigBee Markets



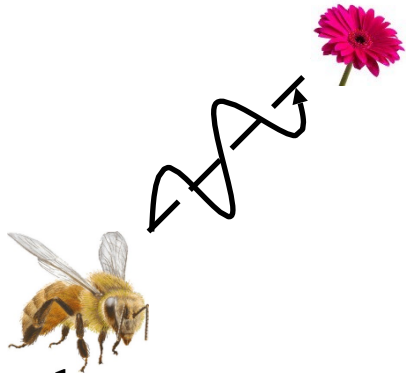
Zigbee Overview

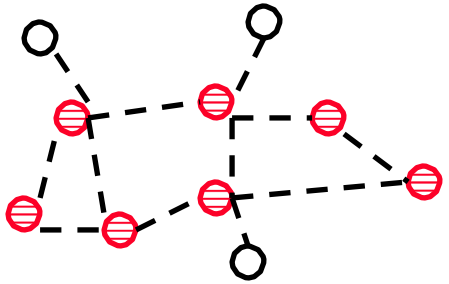
- Industrial monitoring and control applications requiring small amounts of data, turned off most of the time (<1% duty cycle), e.g., wireless light switches, meter reading, patient monitoring
- First standard was published in 2004
- Ultra-low power, low-data rate, multi-year battery life
- Power management to ensure low power consumption.
- Zigbee Protocol is less Complex. 32kB protocol stack vs 250kB for Bluetooth
- Range: 1 to 100 m, up to 65000 nodes.
- Tri-Band:
  - 16 Channels at 250 kbps in 2.4GHz ISM
  - 10 Channels at 40 kb/s in 915 MHz ISM band (Americas)
  - One Channel at 20 kb/s in European 868 MHz band
  - 920 MHz in Japan

Ref: http://www.cse.wustl.edu/~jain/cse574-20/

Zigbee Overview

- IEEE 802.15.4 MAC and PHY (Except for Zigbee Smart Energy 2.0)
  - Higher layer and interoperability by Zigbee Alliance
- Up to 254 devices or 65,536 simpler nodes
- Named after zigzag dance of the honeybees
  - direction of the dance indicates the location of food
- Multi-hop ad-hoc mesh network
  - Multi-Hop Routing: message to non-adjacent nodes
  - Ad-hoc Topology: No fixed topology. Nodes discover each other
  - Mesh Routing: End-nodes help route messages for others
  - Mesh Topology: Loops possible





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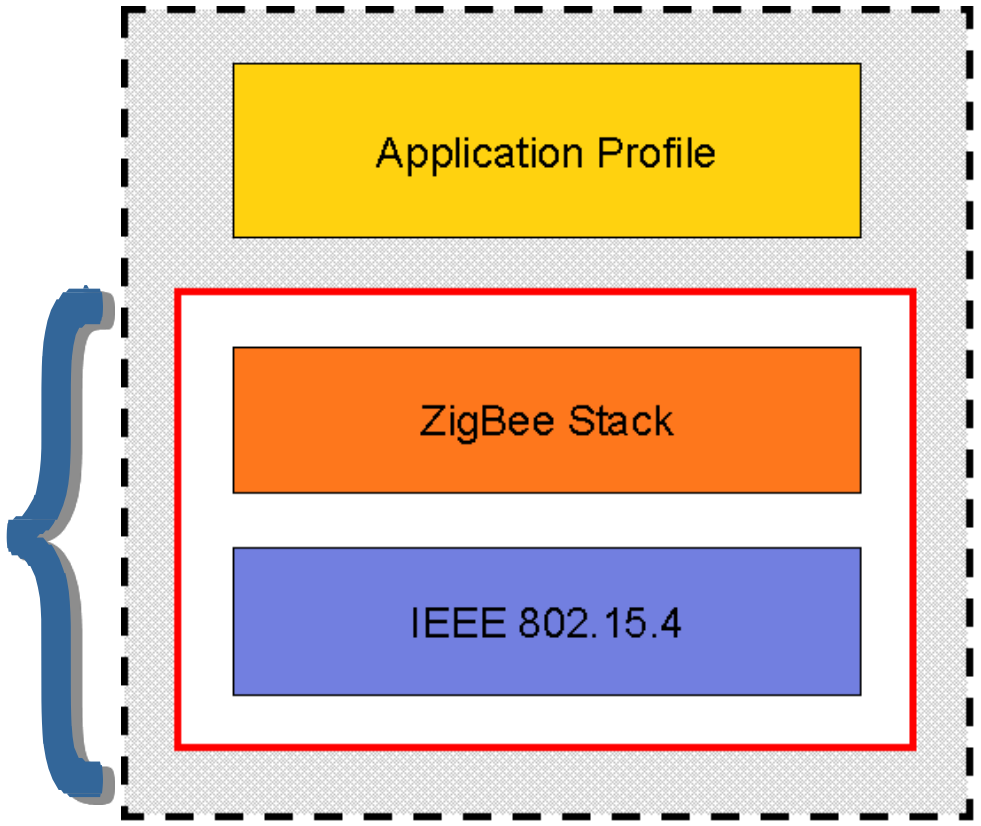
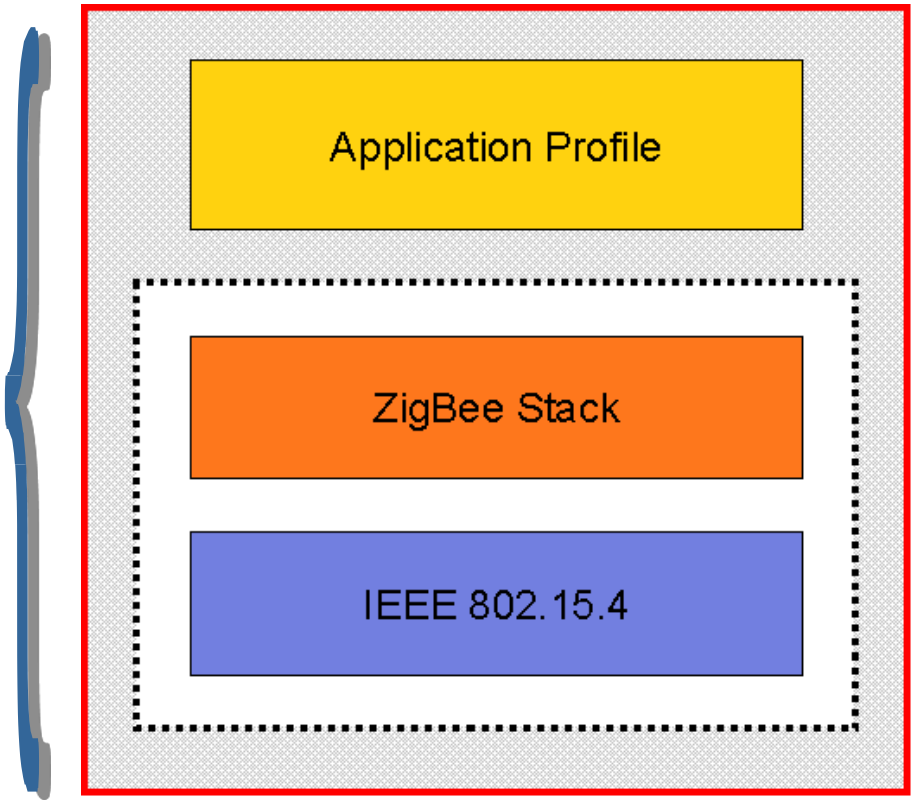
ZigBee Platform Interoperability



Ensures Network interoperability but does not imply application layer interoperability
(There are multiple Compliant Platforms to choose from)

ZigBee Product Interoperability

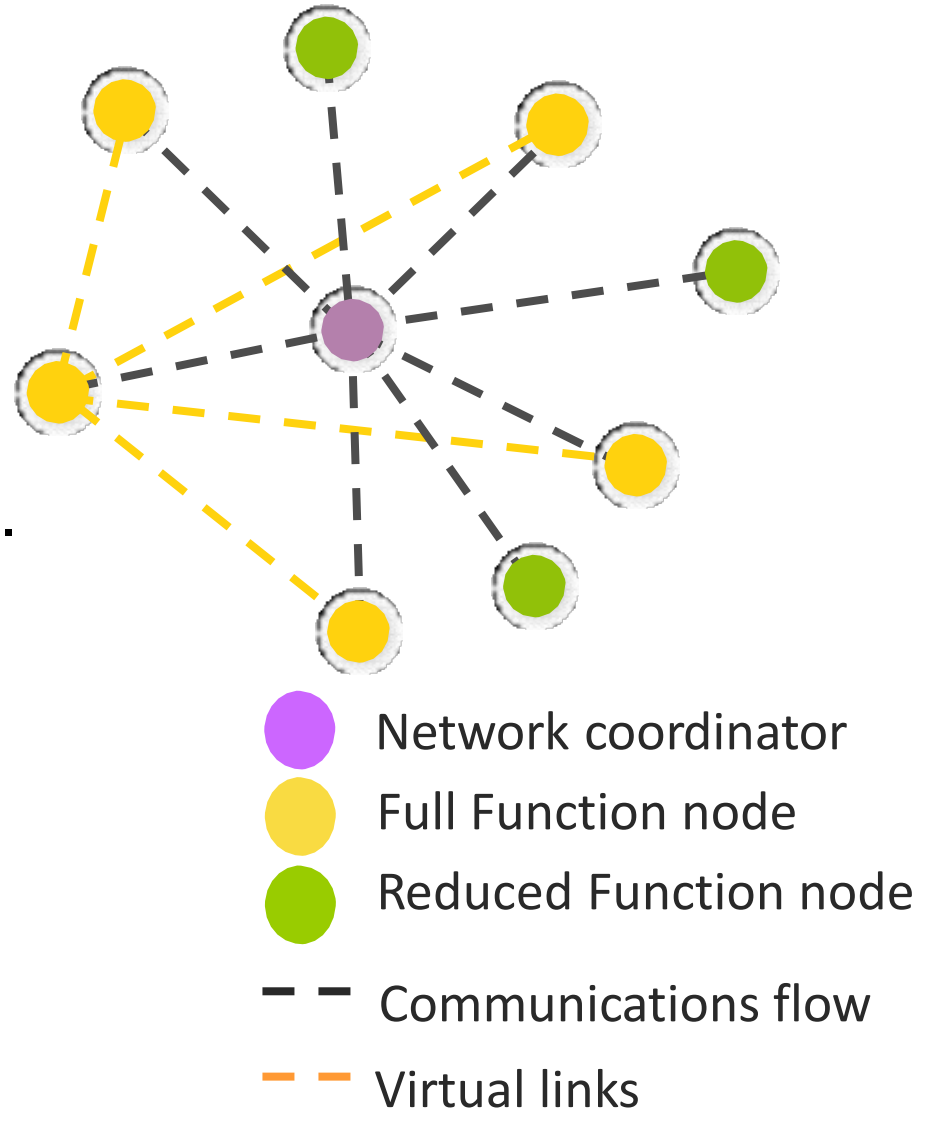
ZigBee Compliant Product



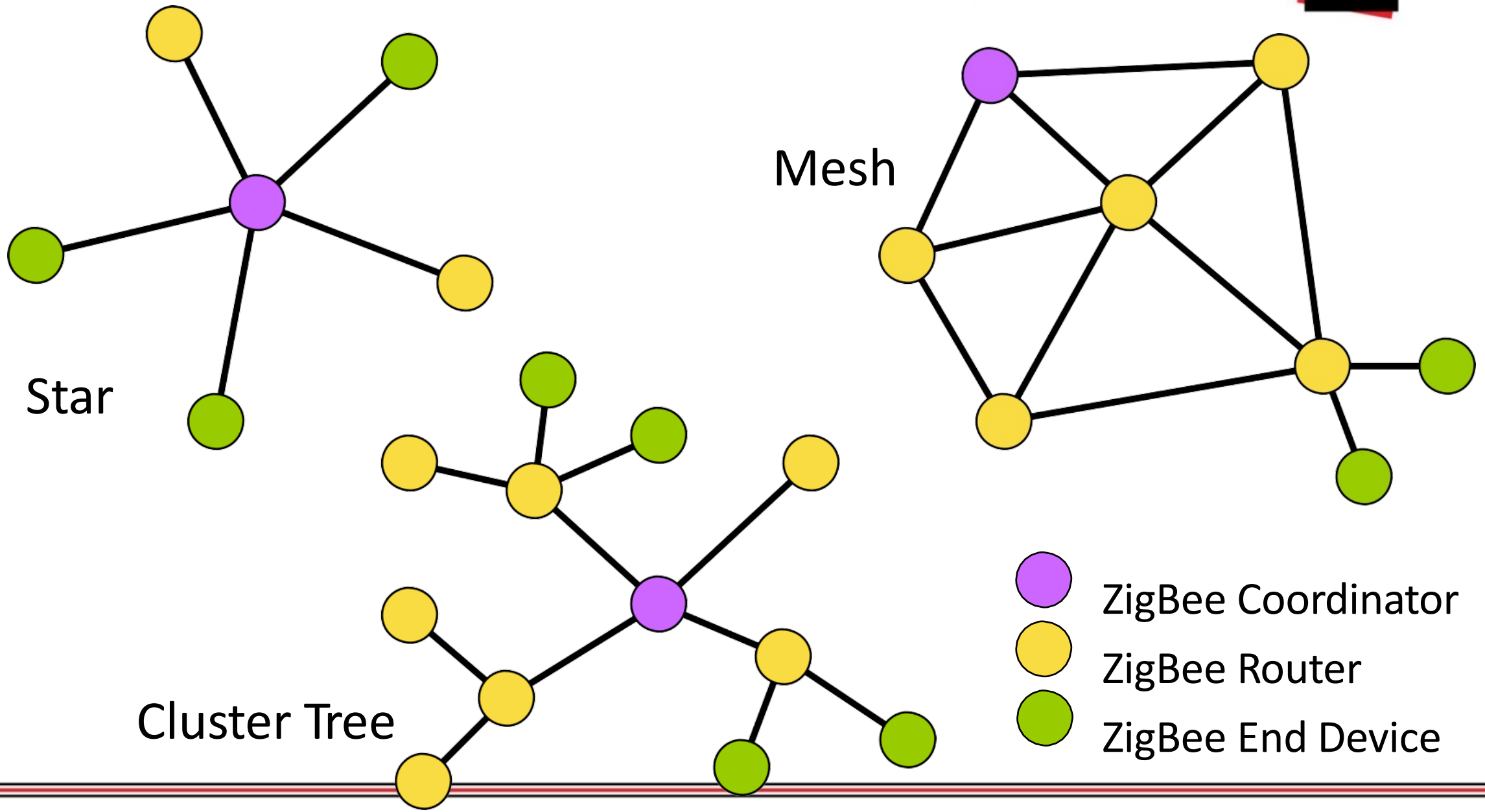
Products with the same application profiles interoperate end to end. ZigBee has published a set of Public Application Profiles ensuring end product interoperability.

ZigBee Device Types

- ZigBee Coordinator (ZC)
  - One required for each ZB network.
  - Initiates network formation.
- ZigBee Router (ZR)
  - Participates in multi-hop routing of messages.
- ZigBee End Device (ZED)
  - Does not allow association or routing.
  - Enables very low-cost solutions



ZigBee Network Topologies

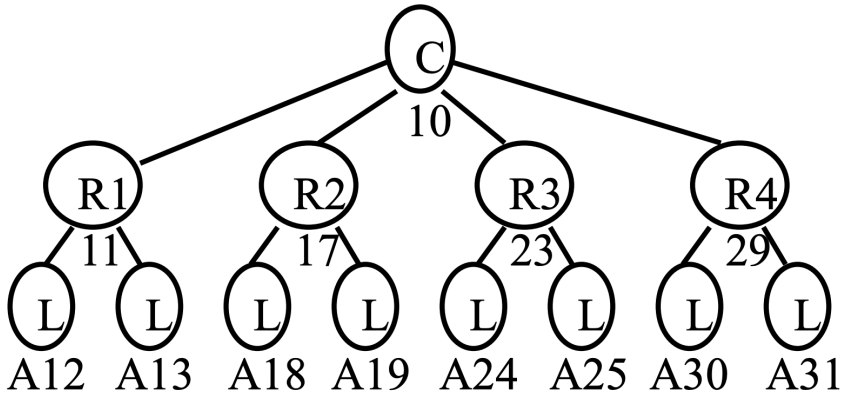


Zigbee – Routing

- Ad-Hoc On-Demand Distance Vector
  - On-demand ⇒ Reactive ⇒ Construct a route when needed
  - Source broadcasts Route-Request (RREQ) command to all its neighbors containing source, destination, broadcast ID
  - Each node determines if this is a new request or if this copy has a lower cost. If yes, it makes a “reverse route” entry for the source in its table w the previous node as the optimal reverse path.
  - The node then checks if it has a route to the destination. If yes, it sends “route-reply” to the source. Otherwise, it forwards the request to all its neighbors except where it came from.
  - When the source receives a “route reply,” it selects the lowest cost path and sends the packet
  - If a node cannot forward the packet, it sends a “Route Error” back to the source, which will re-initiate route discovery.
- Tree Hierarchical Routing
- Many-to-one routing

Zigbee – Routing

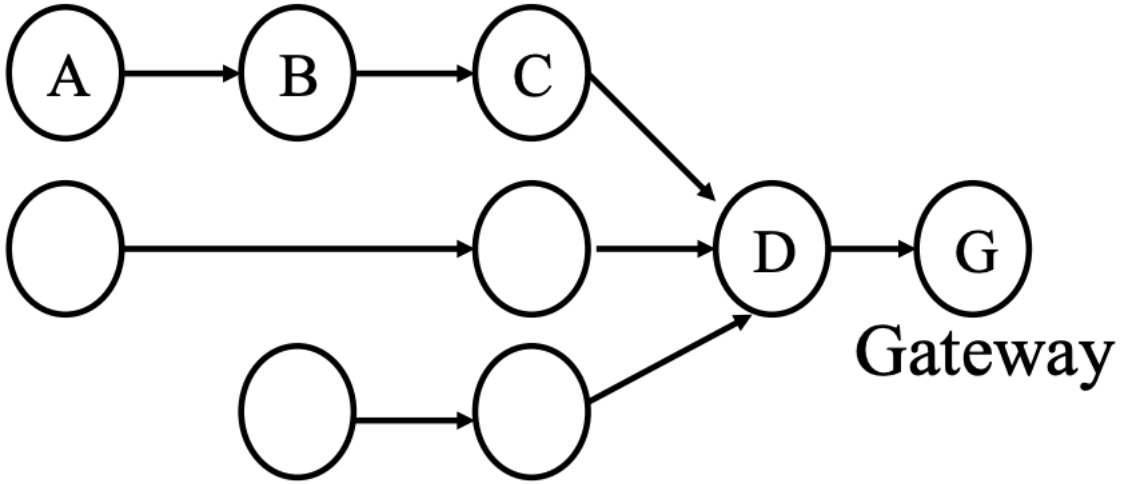
- Ad-Hoc On-Demand Distance Vector
- Tree Hierarchical Routing
  - All leaf nodes send the packet to their parent
  - Each parent checks the address to see if it is in its subrange.
    - If yes, it sends to the appropriate child.
    - If not, it sends to its parent
  - Example: A12 to A30. A12 → R1 → Coordinator → R4 → A30



- Many-to-one routing

Zigbee – Routing

- Ad-Hoc On-Demand Distance Vector
- Tree Hierarchical Routing
- Many-to-one routing
  - Used for sensor data collection. All data goes to a concentrator or a gateway
  - Gateway has a large memory and can hold complete routes to all nodes
  - But each node only remembers the next hop toward gateway



ZigBee Mesh Networking – Self-Healing Property

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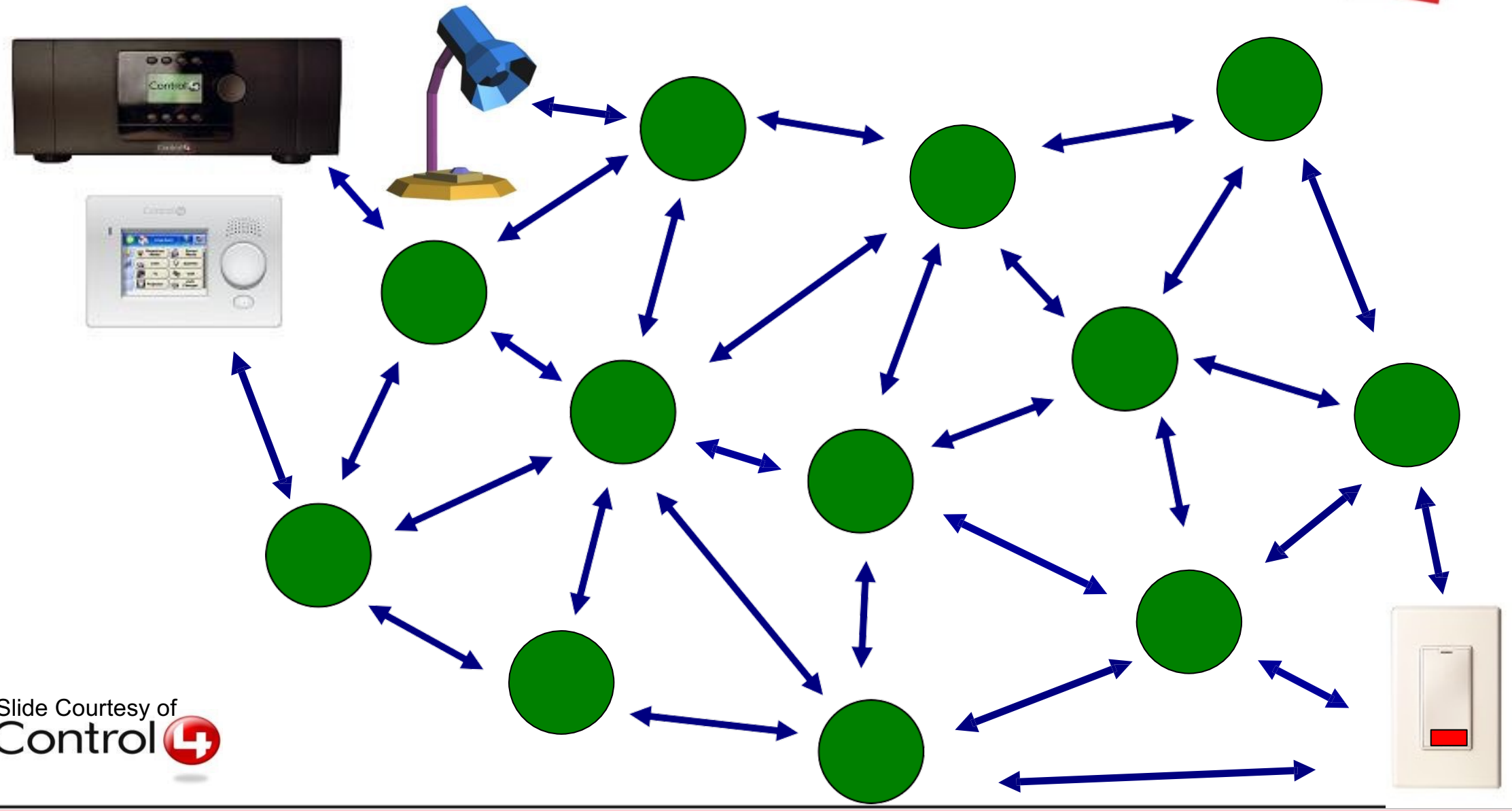
ZigBee Mesh Networking – Self-Healing Property



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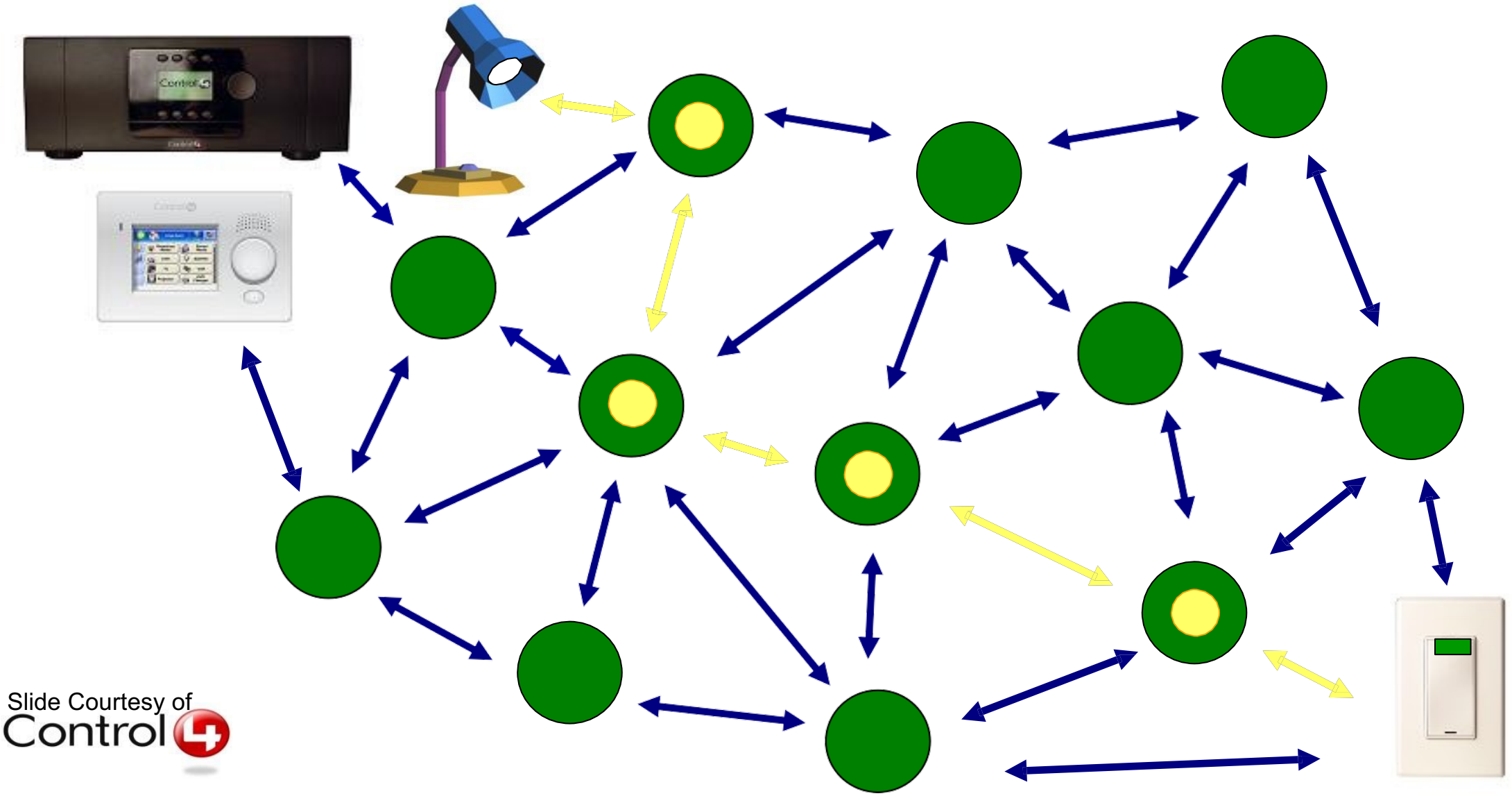

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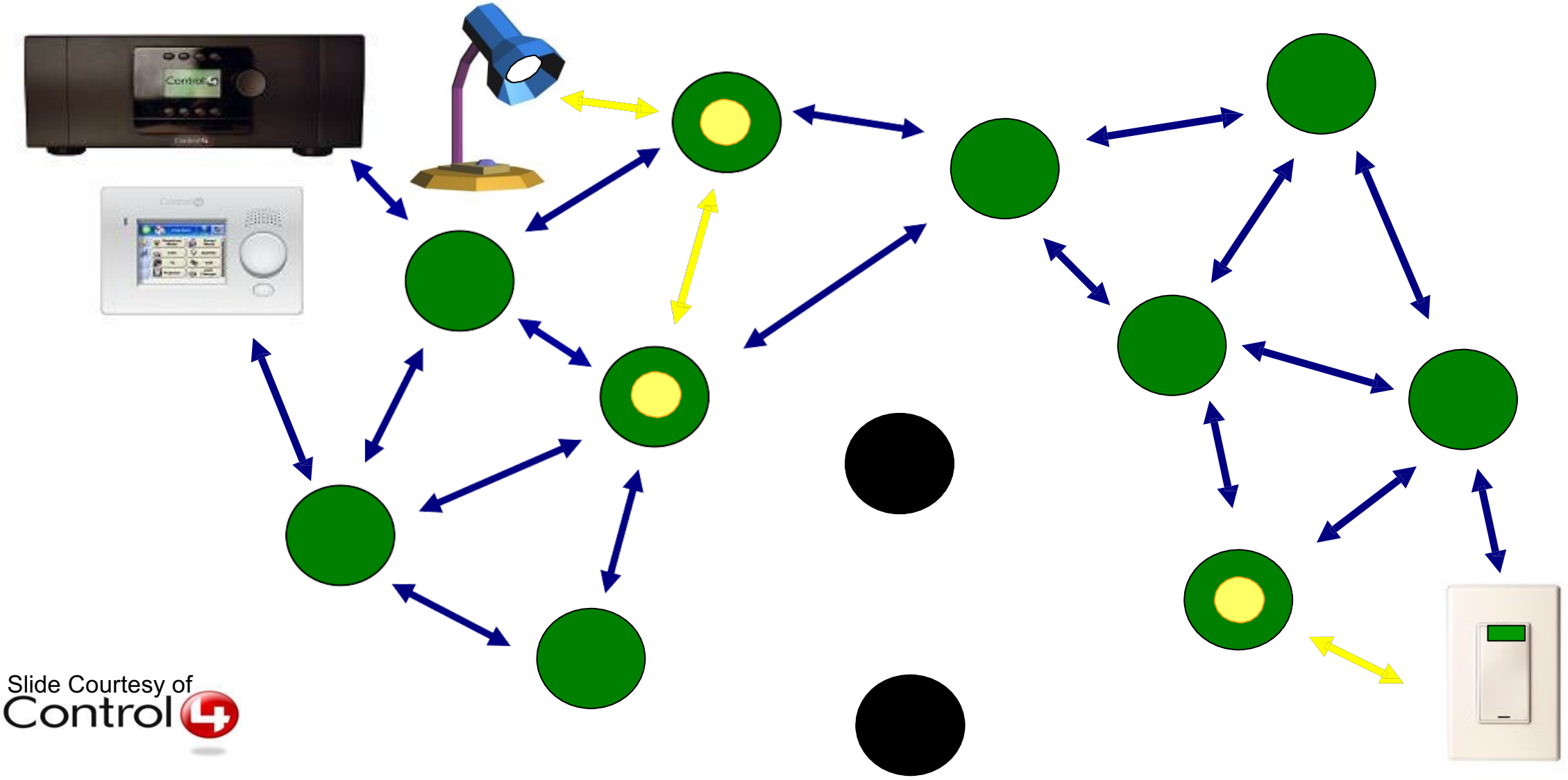

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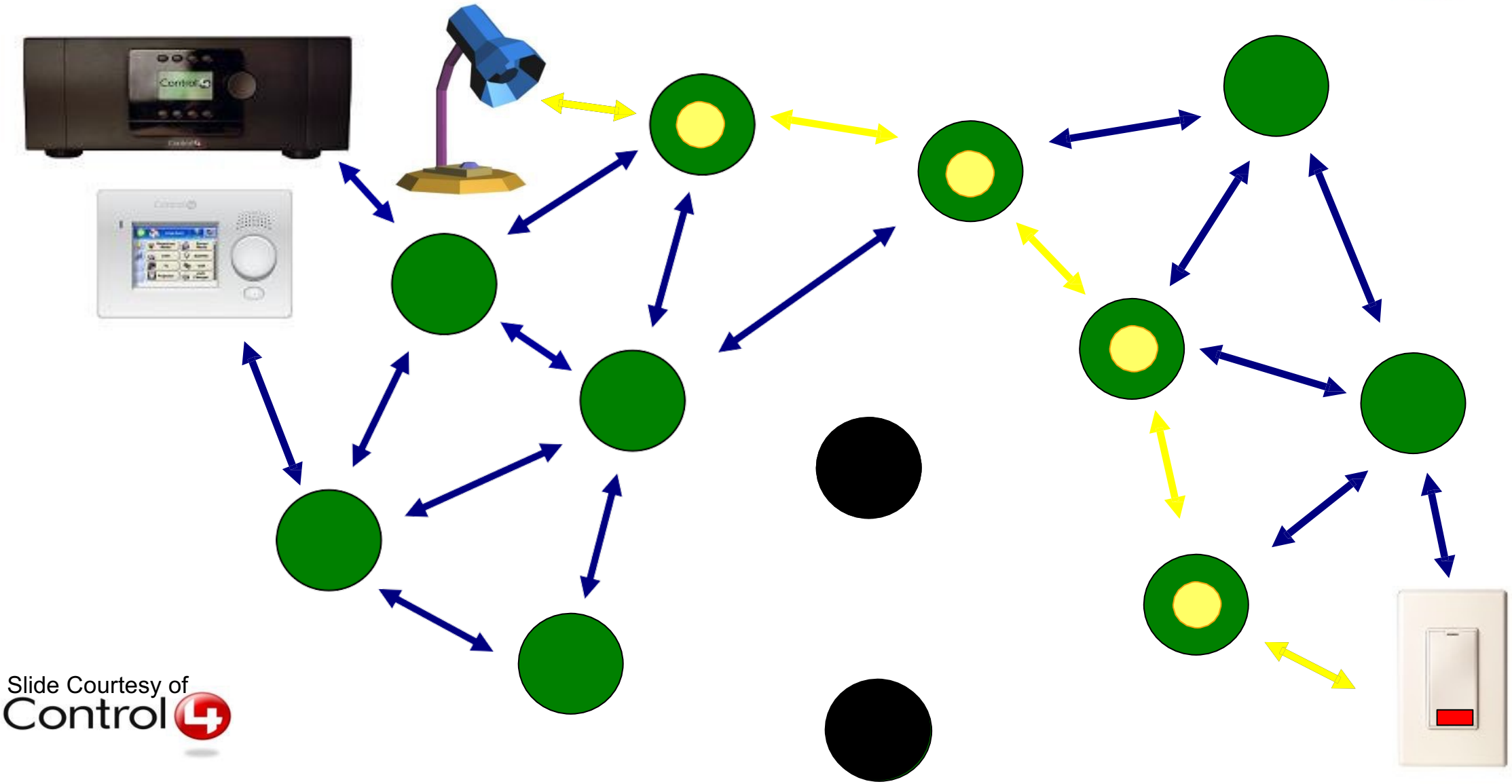

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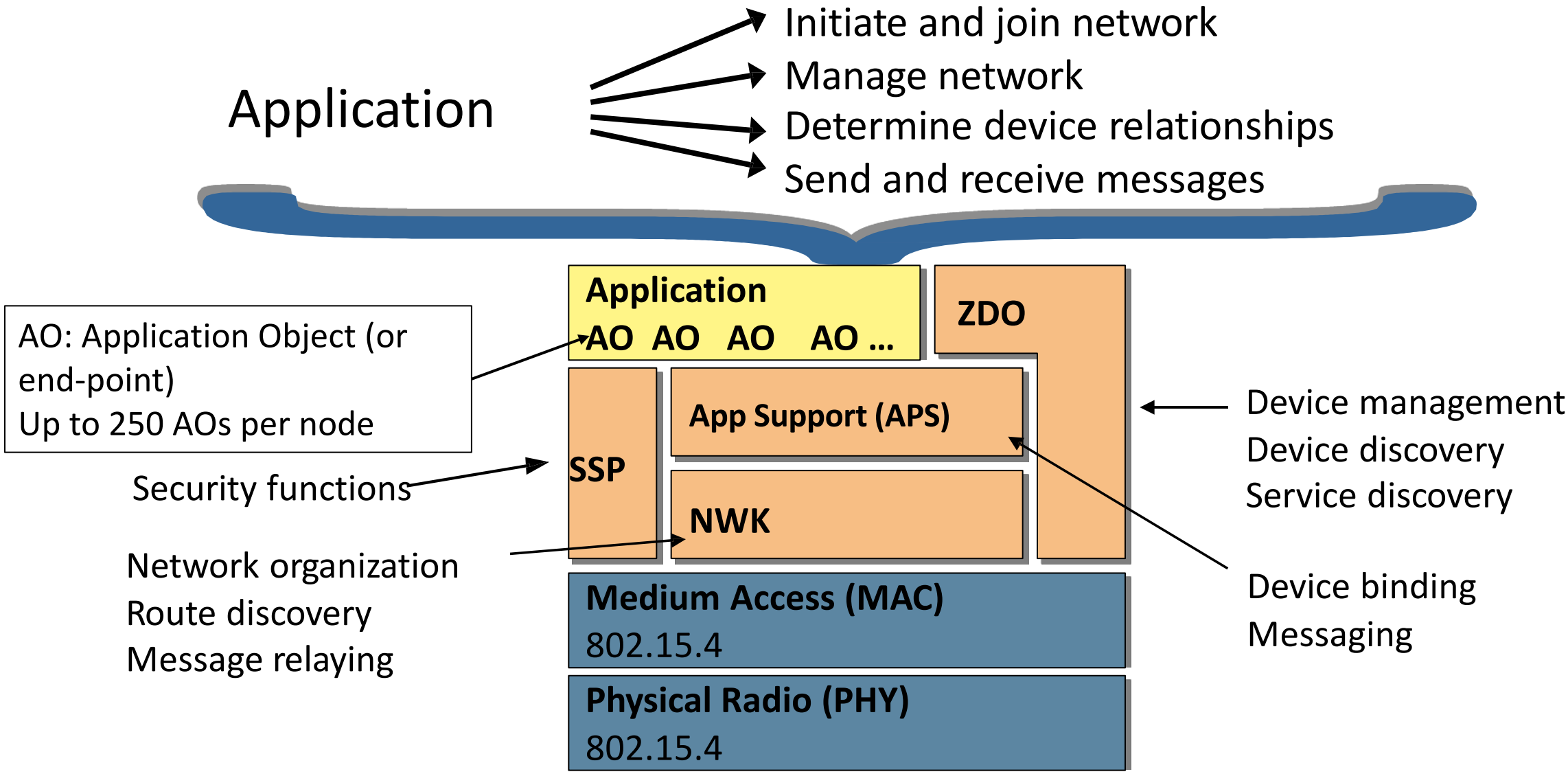
ZigBee Stack Architecture



Zigbee Application Layer

- Application layer consists of application objects (aka end points) and Zigbee device objects (ZDOs)
- 256 End Point Addresses:
  - 240 application objects: Address EP1 through EP240
  - ZDO is EP0
  - End Points 241-254 are reserved
  - EP255 is broadcast
- Each End Point has one application profile, e.g., light on/off profile
- Zigbee forum has defined several profiles. Users can develop other profiles
- **Attributes**: Each profile requires several data items. Each data item is called an “attribute” and is assigned a 16-bit “attribute ID” by Zigbee forum

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ZigBee Public Profiles

- Home Automation (HA)
- Smart Energy (SE)
- Commercial Building Automation (CBA)
- ZigBee Health Care (ZHC)
- Telecom Applications (TA)

- ZigBee RF4CE Remote Control

- +Future profiles proposed by member companies…

ZigBee Home Automation: for Home Control

TV/Display

Set-top-box

Lighting

Closures

Remote access

Switches

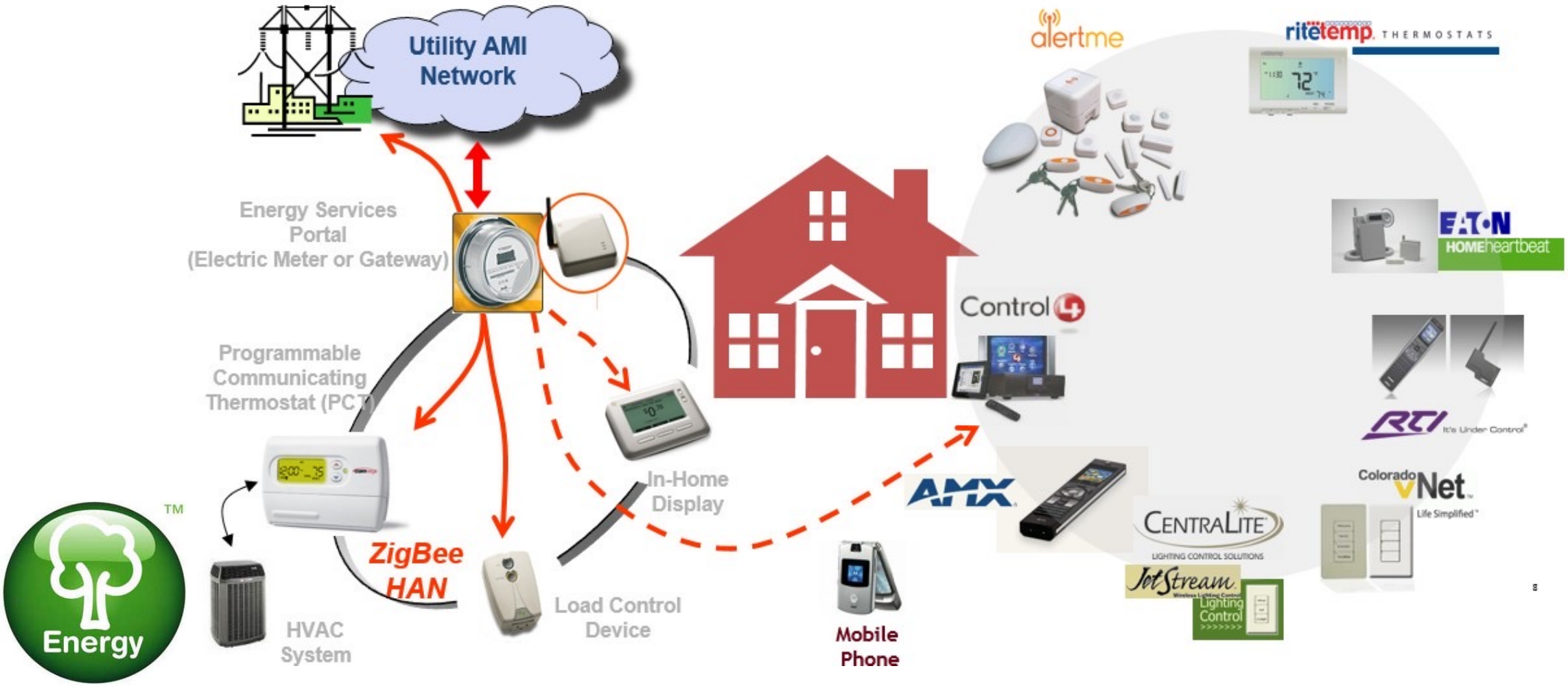
Security

Heating/cooling

ZigBee Home Area Network (HAN)

Smart Energy & Home Automation

Urgent demand for Smart Energy + compatibility with mainstream Home Automation systems enables customer choice



Z-Wave

- Z-Wave is a low-power MAC protocol designed for home automation and has been used for IoT communication, especially for smart home and small commercial domains
- It covers about 30-meter point-to-point communication and is suitable for small messages in IoT applications, like light control, energy control, wearable healthcare control and others
- It uses **CSMA/CA** for collision detection and ACK messages for reliable transmission
- It follows a **master/slave architecture** in which the master controls the slaves, send them commands, and handling scheduling of the whole network

Z-Wave Vs. Zigbee: What do they have in common?

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- Both technologies are mesh networks
  - Each node in the system acts as both a wireless data source and a repeater. Information from a single sensor node hops from node to node until the transmission reaches the gateway
- Both technologies use the IEEE 802.15.4 low-rate personal area network (LR-PAN) protocol
  - for the unified physical layer (OSI layer 1) and structuring packets
- Both are widely used in local area sensor data networks
  - like in security systems, urban smart grid controllers, HVAC control
  - systems, home automation, and lighting controls

Z-Wave Vs. Zigbee: How are they different?

- Z-wave has a tightly controlled product ecosystem that caters to the smart home and smart building space, whereas Zigbee can be used for several applications
- Zigbee uses the global standard 2.4GHz ISM frequency band, whereas Z-Wave uses the 915 MHz ISM band (in the U.S.) and the 868 MHz RFID band (in Europe).
  - 2.4 GHz band can be subject to intense interference from Wi-Fi and Bluetooth systems, whereas the sub-GHz bands in Z-Wave do not face the same interference issues
- Lots of providers make Zigbee radios, but Z-Wave uses a proprietary radio system from Sigma designs
- Z-Wave uses frequency-shift keyed modulation (FSK), whereas Zigbee modulation is carried out through direct sequence spread spectrum (DSSS)

Extra Reading: https://www.electronicdesign.com/technologies/communications/article/21796052/whats-the-difference-between-zigbee-and-zwave

Summary

- Zigbee is an IoT protocol for sensors, industrial automation, remote control using IEEE 802.15.4 PHY and MAC
- Up to 250 kbps and supports a large number of devices
- Newer Zigbee protocols support many-to-one routing, fragmentation, and mesh topologies.
- Several application profiles have been defined with control and management provided by ZDOs.
- Z-Wave uses the sub-GHz band that is less susceptible to interference and occlusions, but Z-Wave is a proprietary protocol

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