ZigBee®
Control your world

ZigBee Technology Overview

Skip Ashton
Senior VP Engineering
Ember Corporation

Agenda

- ZigBee Stack and Features
- Application Profiles
- Application Profile Use of the Stack
- ZigBee Certification and Testing

ZigBee Feature Set

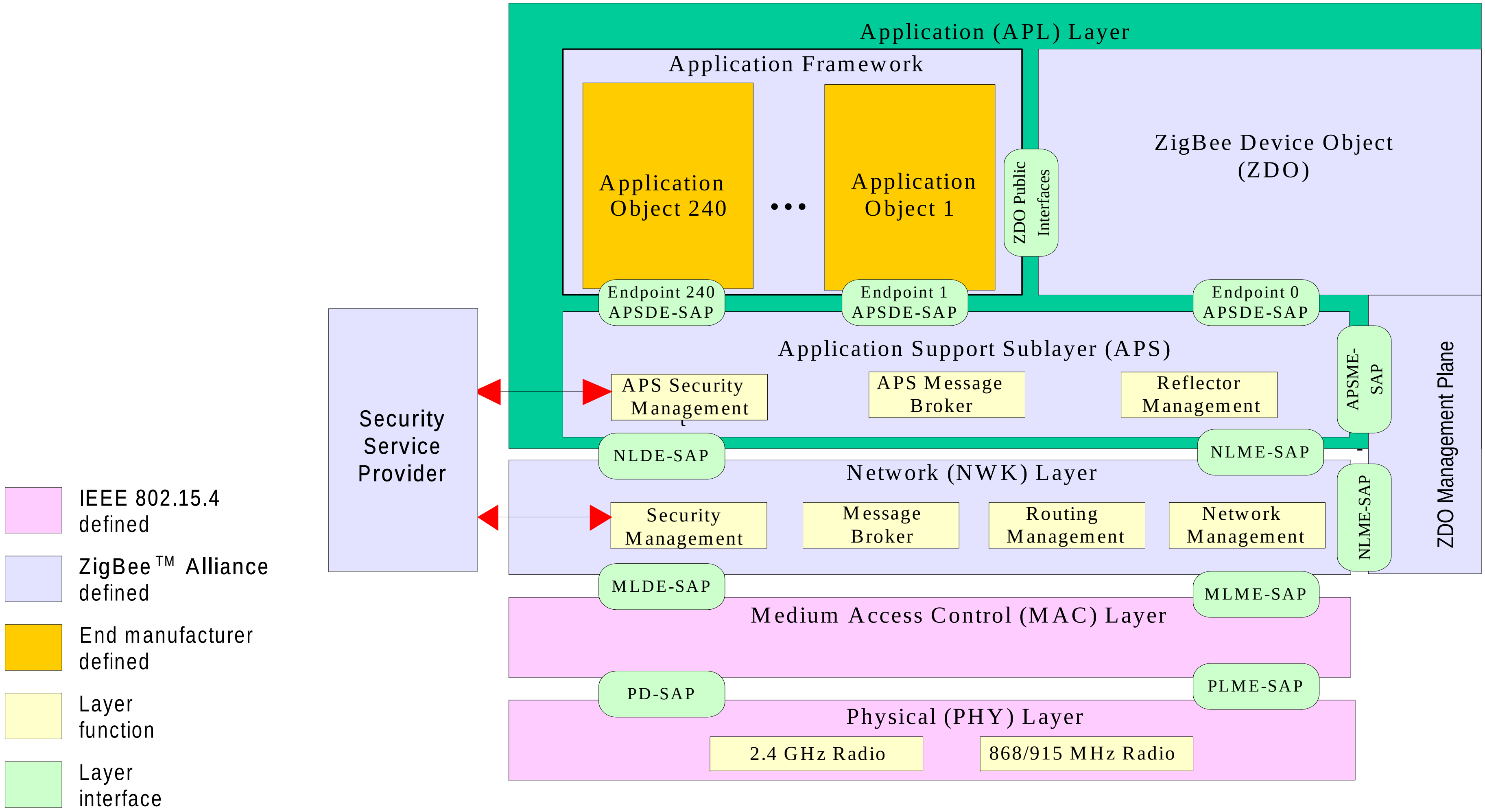
- **ZigBee Feature Set**
  - Ad-hoc self forming networks
    - Mesh and Cluster Tree
    - Unicast, broadcast and groupcast
    - ZigBee PRO - Many to One and Source Routing Enhancements
    - ZigBee PRO - Network layer multicast
  - Logical Device Types
    - Coordinator, Router and End Device
    - Network Manager for PAN ID conflict and frequency agility
  - Standard Application Services
    - Device and Service Discovery
    - Optional acknowledged service
    - Optional fragmentation/re-assembly service
    - Cluster Library support to standard definition of application messages

ZigBee Feature Set

- **ZigBee Feature Set (continued)**
  - Security
    - Authentication and Encryption at Network and Application levels.
    - Symmetric Key with AES-128
    - Key Hierarchy: Master Keys (optional), Link Keys (optional), and Network Keys

ZigBee and ZigBee PRO Protocol Stack

Stack Architecture



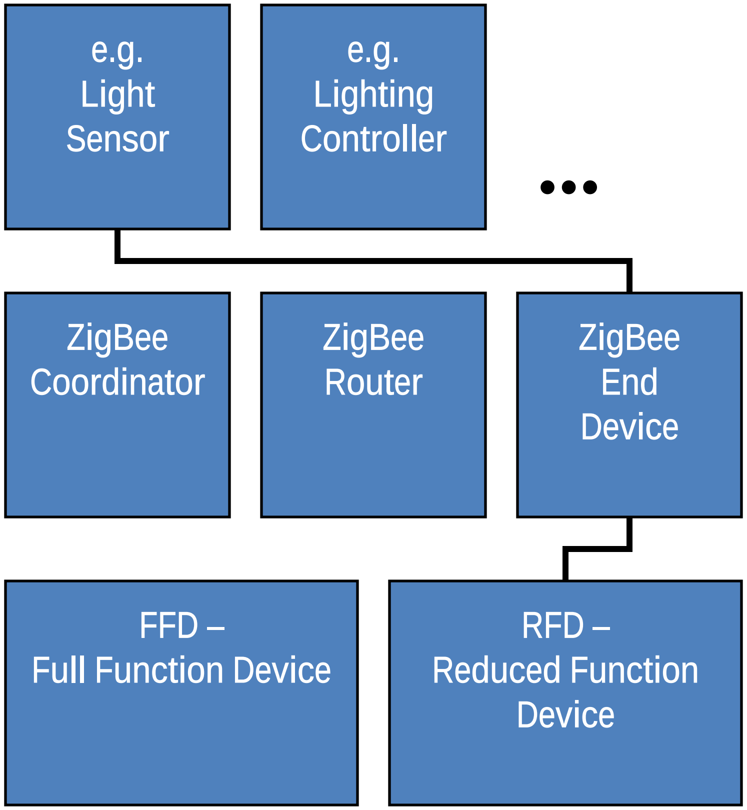
ZigBee
Control your world

Application Device Type Model

Application Device Type

Logical Device Type

802.15.4 Device Type



e.g. Light Sensor

e.g. Lighting Controller

…

ZigBee Coordinator

ZigBee Router

ZigBee End Device

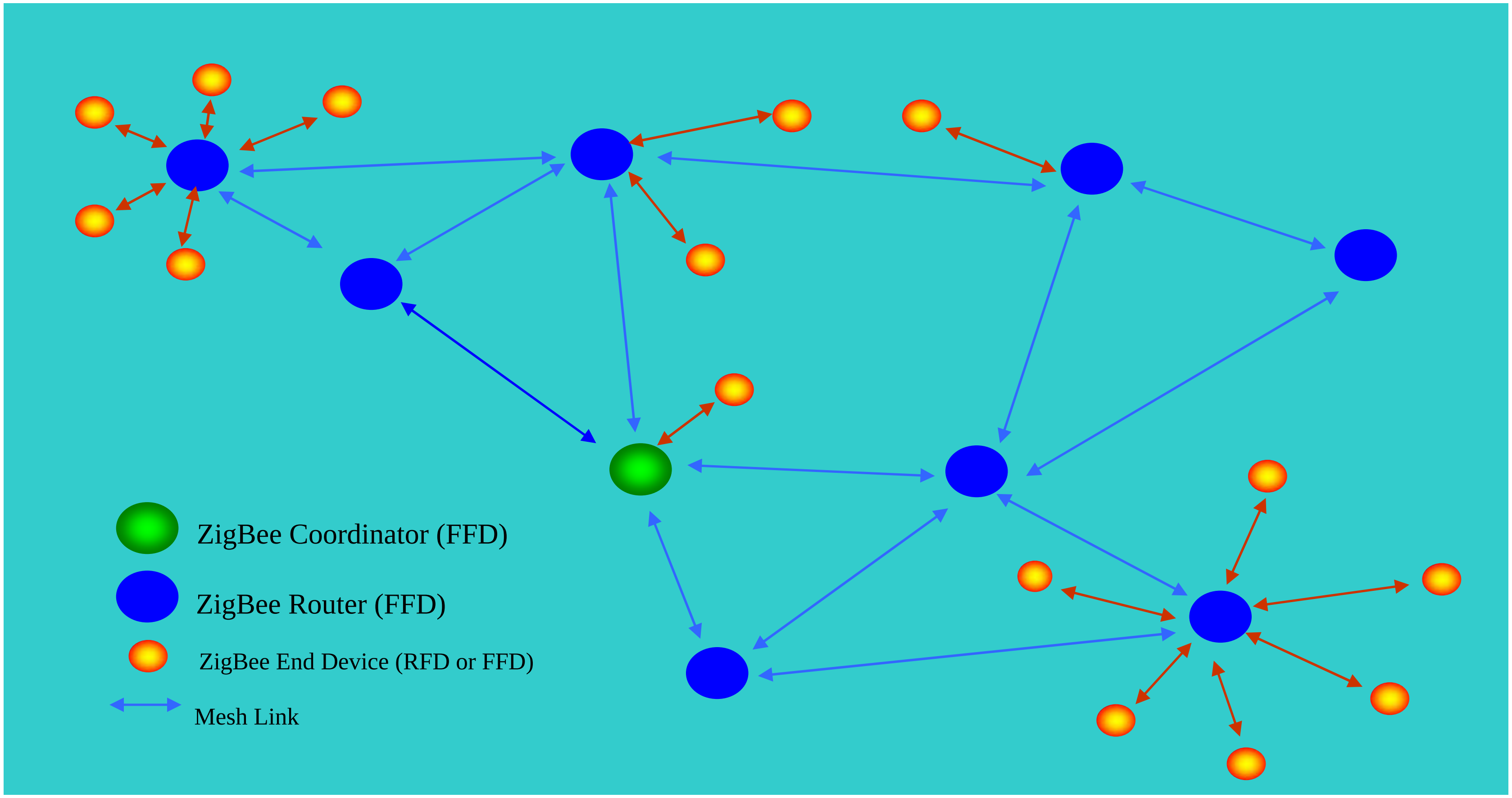
FFD – Full Function Device

RFD – Reduced Function Device

- Distinguishes the type of device from an end-user perspective
- Distinguishes the Logical Device Types deployed in a specific network
- Distinguishes the type of hardware platform

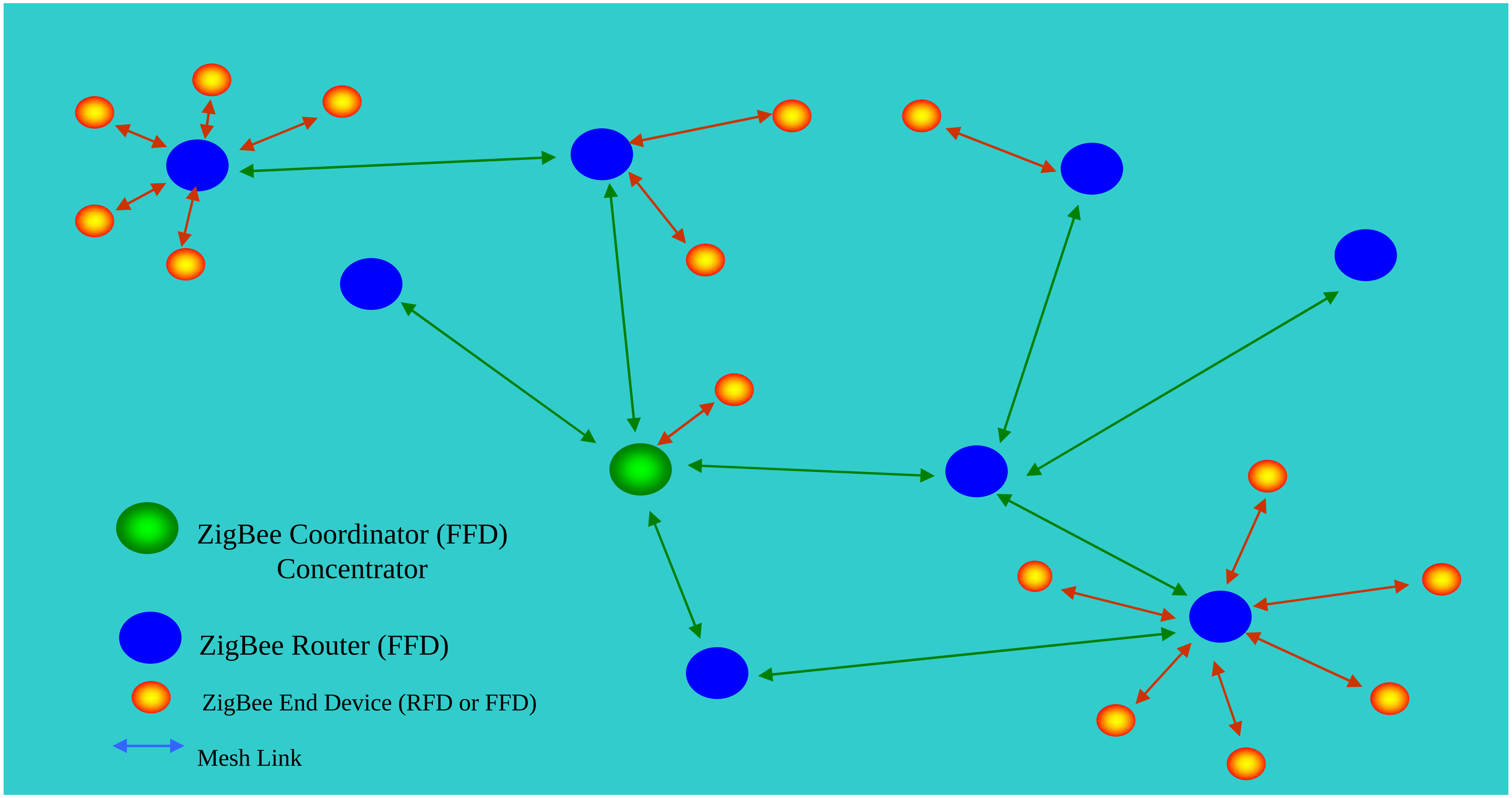
- **ZigBee products are a combination of Application, Logical, and Physical device types**
- **Profiles may define specific requirements for this combination, but can also leave this up to manufacturers**

ZigBee and ZigBee PRO Network Communication Model (Mesh Routing)



Note: Mesh networking is a bandwidth and RAM efficient routing method. Mesh is supported by both ZigBee and ZigBee Pro networks.

ZigBee PRO Network Communication Model (Many to One and Source Routing)



Note: Concentrators may be any router in the network (not just the ZC). Source routing allows scaling in large networks with limited RAM in most nodes.

ZigBee and ZigBee PRO
Network Topologies and Routing

- ***Mesh*** network routing permits path formation from any source device to any destination device via a path formed by routing packets through neighbors
  - Table routing employs a simplified version of Ad Hoc On Demand Distance Vector Routing (AODV), an Internet Engineering Task Force (IETF) Mobile Ad Hoc Networking (MANET) submission
  - Used in both the ZigBee and ZigBee PRO feature sets
- ***Cluster tree*** network routing directs packets up and down the tree structure created through network formation until they reach their destination
  - Must use "netmask" type tree routing (up and down the parent/child links)
  - Fails if parent/child links are not usable over time
  - Used only in the ZigBee feature set
- ***Many to One*** and ***Source Routing*** features address limitations in ***Mesh*** network routing where table size requirements are large in certain data transmission scenarios
  - Many to One allows any device in the network to route data to a well known concentrator through a single routing table entry in every device
  - Multiple concentrators in a single network are possible
  - Source routing allows a concentrator to route responses back to each device supplying a Many to One data request without additional route table entries
- **End Devices are low power** in either feature set since they don't participate in routing and only communicate through their parent (routers or coordinator) at application specified times

Security Services Provider (SSP)

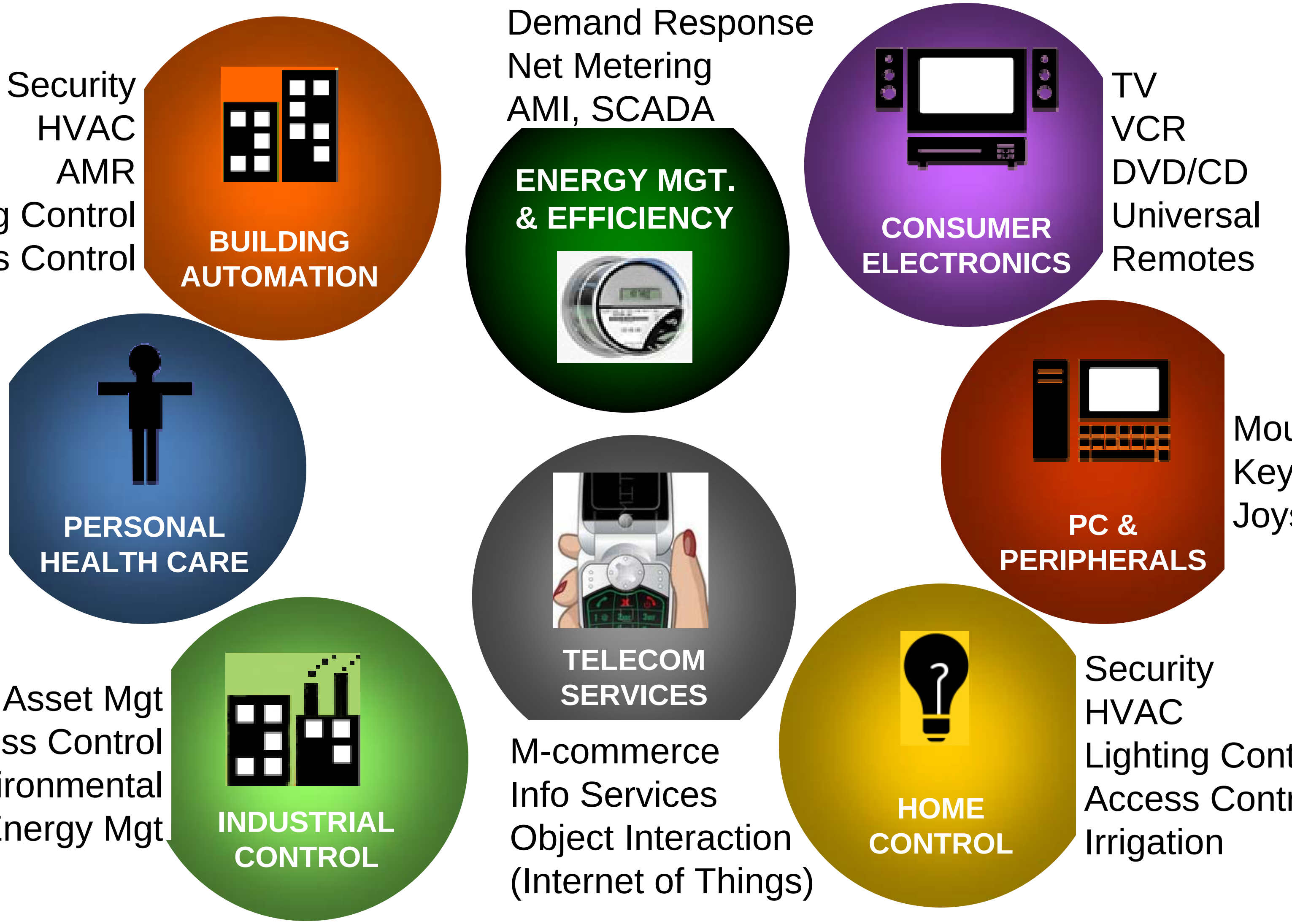
- **Security at each layer:**
  - Network (NWK) layer security for network command frames (route request, route reply, route error)
  - Application (APL) layer security for Application Support Sub-layer (APS) frames
- **Security Mode**
  - Standard Mode (ZigBee and PRO feature sets) – Mandatory Use of Network keys, Application security can be done via network key. Ability to switch network keys. Optional use of Application Link Keys for pairs of communicating devices at APL.
- **Security Implementation**
  - Trust Center –Creates and distributes the Network Keys. Manages switch from active to secondary Network Key.
  - Optionally supports Master Keys and Trust Center Link Key establishment and transport
  - Application profile determines security level in use in a given network – SE uses ECC to device secure application link keys

Security Services Provider (SSP)

- Key Hierarchy
  - Master Key (could be programmed in or provided *in the clear* from the Trust Center)
  - Network Key (used for all NWK commands from any device and for APS messaging)
  - Link Keys (used for each pair of communicating devices)
- Features in either Security Mode
  - Authentication and Encryption
  - Freshness (frame counters)
  - Message Integrity

Application Profiles

Where are Profiles Targeted?



BUILDING AUTOMATION

Security
HVAC
AMR
Lighting Control
Access Control

ENERGY MGT. & EFFICIENCY

Demand Response
Net Metering
AMI, SCADA

CONSUMER ELECTRONICS

TV
VCR
DVD/CD
Universal
Remotes

PERSONAL HEALTH CARE

Patient monitoring
Fitness monitoring

PC & PERIPHERALS

Mouse
Keyboard
Joystick

INDUSTRIAL CONTROL

Asset Mgt
Process Control
Environmental
Energy Mgt

TELECOM SERVICES

M-commerce
Info Services
Object Interaction
(Internet of Things)

HOME CONTROL

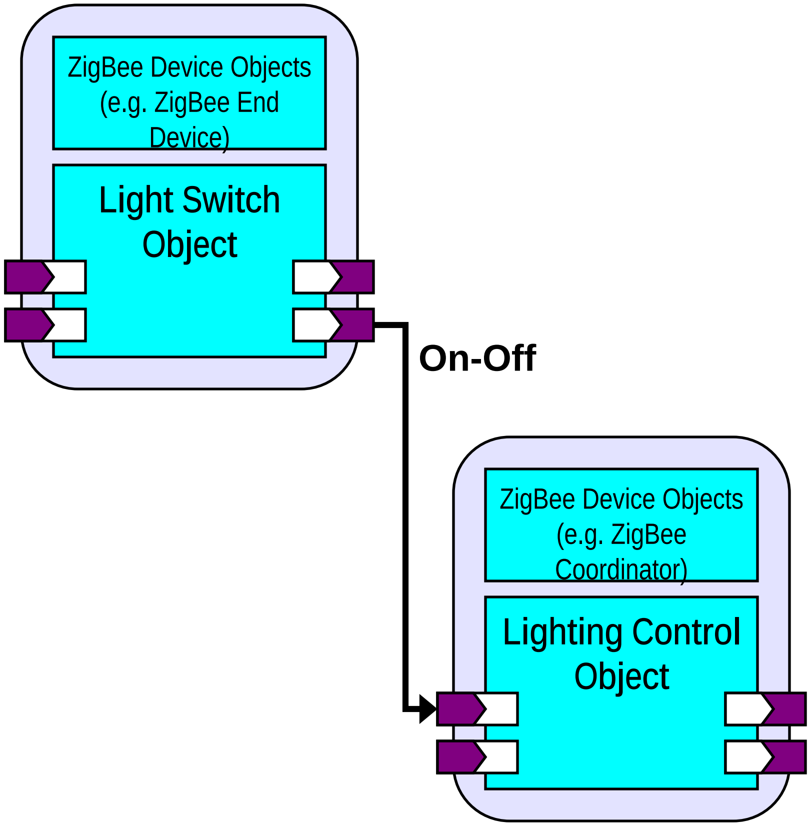
Security
HVAC
Lighting Control
Access Control
Irrigation

ZigBee®
Control your world

ZigBee Application Model

- ***Application Profiles*** are an agreement on
  - A set of network and security policies to allow interoperability while providing the appropriate controls
  - Definition of specific device types related to that application (using items from a library of functions or creating new if necessary)
  - Defining a series of messages and attributes for a device
- Profiles define how to use the underlying stack features
- Designed by end users, equipment providers, service providers with assistance from stack providers

ZigBee Application Model


ZigBee Device Objects (e.g. ZigBee End Device)
Light Switch Object
On-Off
ZigBee Device Objects (e.g. ZigBee Coordinator)
Lighting Control Object

- Devices are modeled through ***Application Objects***
- Application Objects communicate through the exchange of ***Clusters*** and ***Attributes***
- Each Profile Object can contain single or multiple Clusters and Attributes
- Binding mechanism ensures interoperable exchange of Clusters/Attributes
- Clusters/Attributes are sent
  - Directly to destination application objects (thereby to target device)
- Generic ZigBee device functions are provided through ZigBee Device Objects

ZigBee Certification

- ZigBee Qualification Group oversees ZigBee certification efforts
- 3 Independent Test Labs for Certification
- Qualification at each Layer of the Device
    - IEEE 802.15.4 Certification of device
    - Platform Conformance Certification for stack
    - Public Profile Product Certification for device
- Certification Tests developed by Profile Group
    - Experts on device functionality
    - Reviewed by ZQG to ensure coverage
- Specification not issues until initial certification testing is complete
- Regularly Scheduled Interoperability Events

Current ZigBee Status

- ZigBee stack complete and widely available from a number of suppliers
- Application Profiles in various stages
- Smart Energy –
  - Profile V1.0 complete and products certified and in the market
  - V1.x enhancements being developed
  - V2.0 also underway
- Home Automation
  - Profile complete and products certified and in the market
- Commercial Building, Telecom, Health Care all moving to profile completion

Smart Energy 2.0

- Currently in development to meet US end user demand and Federal Regulatory framework
  - Using international standards like IETF, IEEE, IEC
  - Updating ZigBee stack
  - Updating Application Profile
  - Adding new Application objects for new devices or new features (prepayment, electric vehicles, distributed storage etc)
- Target is to upgrade 1.x devices to SE 2.0

ZigBee®
Control your world