



# IoT Access Technologies

- there are many IoT technologies in the market today



# Need of ZigBee

- Bluetooth and Wi-Fi are used to connect devices but not suitable for IoT applications.
- **IoT applications require**
  - Battery operated devices
  - Large number of connected device
- Wi-Fi working on IEEE 802.11 have **high power consumption**.
- Bluetooth network commonly known as Piconets, uses point-to-point connection. One master node can connect **maximum up to 7 slave nodes**.
- Need of something that can meet both requirements of IoT.
  - Solution is the Zigbee.



# IEEE 802.15.4

- IEEE 802.15.4-2003 is a **wireless Access Technology** for
  - ✓ low-cost and low-data-rate devices
  - ✓ devices powered by batteries
- It enables **easy installation** using a compact protocol stack
- Several **network communication stacks** **leverage this technology** for many IoT use cases in both the consumer and business markets.
  - **ZigBee / ZigBee IP**
  - 6LoWPAN
  - WirelessHART
  - Thread
  - 6TiSCH
- **ZigBee** shows how 802.15.4 can be leveraged (at the PHY & MAC) independent of the protocol layers above.

# ZigBee

- First ZigBee specification was ZigBee-2004
- ZigBee technology follows
  - Low data rate
  - Low power consumption
  - Low cost
  - Wireless networking
  - Mesh networking topology
- Well-known application domains:

ZigBee in Digi's  
Xbee radio module



## Industrial and Commercial Automation

measuring temperature and humidity, and tracking assets

## Smart Home Applications

control lighting, thermostats, and security functions

## Smart Energy or Utility Applications

monitor and control the use and delivery of utilities, such as electricity and water

# Other ZigBee Applications

monitors  
sensors  
automation  
control



**INDUSTRIAL & COMMERCIAL**



TV VCR  
DVD/CD  
Remote control

**CONSUMER ELECTRONICS**

monitors  
diagnostics  
sensors



**PERSONAL HEALTH CARE**

**ZigBee**  
LOW DATA-RATE  
RADIO DEVICES



mouse  
keyboard  
joystick

**PC & PERIPHERALS**

consoles  
portables  
educational



**TOYS & GAMES**



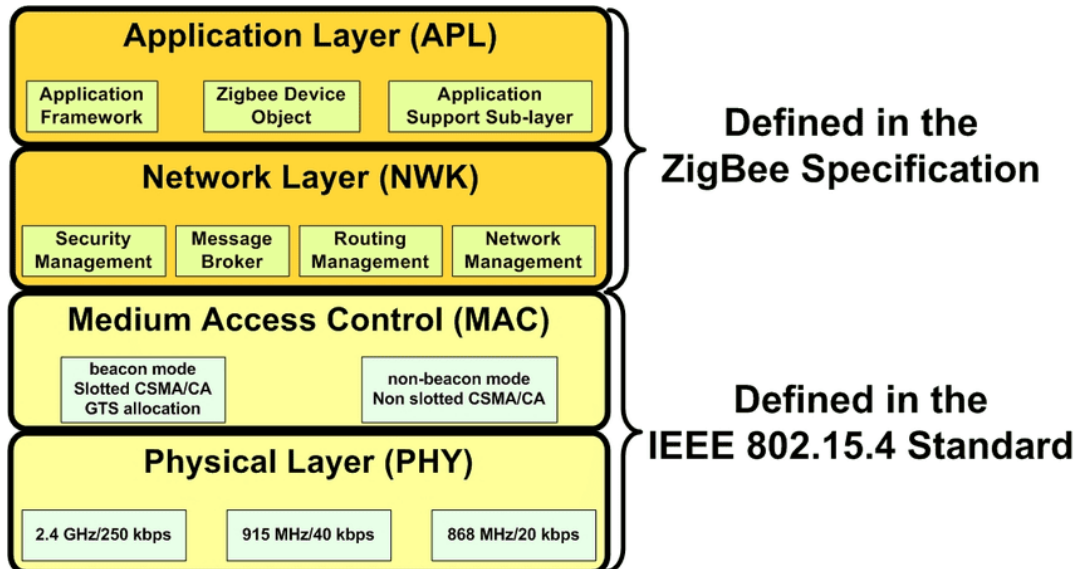
security  
HVAC  
lighting  
closures

**HOME AUTOMATION**

# ZigBee Protocol Stack

**IEEE** and **ZigBee Alliance** jointly specifies the entire ZigBee protocol stack for communication

- ✓ **IEEE 802.15.4** focuses on the specification of the lower two layers of the protocol (physical and data link layer)
- ✓ **ZigBee Alliance** aims to provide the upper layers of the protocol stack (from network to the application layer)



# ZigBee Alliance



- An **alliance of organizations** with a **mission** to define
  - reliable,
  - cost effective,
  - low-power,
  - wirelessly networked,
  - monitoring and control products
  - based on an open global standard
- Alliance **provides**
  - **interoperable** data networking,
  - interoperability compliance **testing**,
  - **branding** or marketing of the standard,
  - a range of wireless home and building **control solutions**,
  - security services
  - advanced engineering for the evolution of the standard



**ZigBee™ Alliance**  
Wireless Control That Simply Works

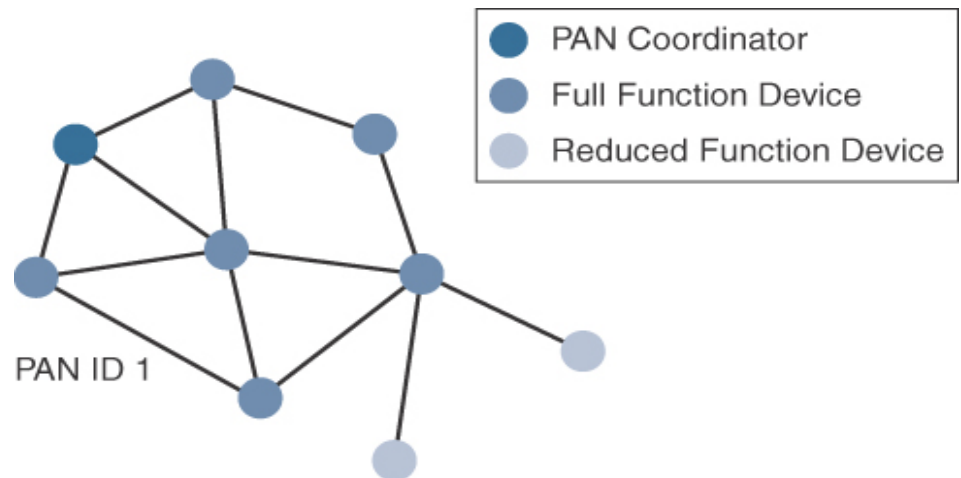
- ZigBee Alliance
  - **45+ companies**: Semiconductor mfrs, IP providers, OEMs, etc.



# Device Type

- The most basic component of a ZigBee system is the **device**
  - A device can be a **full-function device** (FFD) or **reduced-function device** (RFD).
  - The FFD can operate in three modes:
    - a personal area network (PAN) coordinator
    - a coordinator
    - a device.
  - An FFD can talk to RFDs or FFDs.
  - An RFD can only talk to an FFD.

A network shall include **at least one FFD**, operating as the PAN coordinator.



# Network Topologies

Three types of topologies that ZigBee supports:

## ✓ Star topology

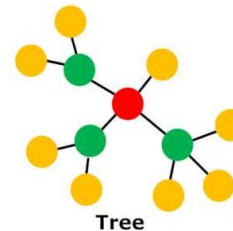
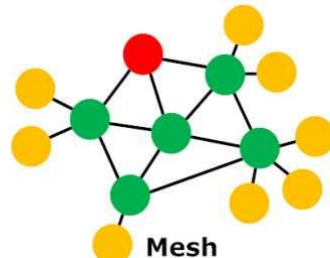
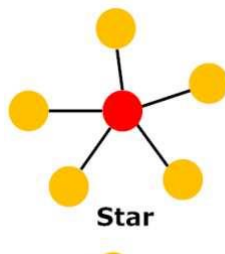
- communication is established between devices and a single central controller (PAN coordinator).
- each start network has an unique PAN identifier

## ✓ Peer-to-peer topology

- there is also one PAN coordinator
- unlike star, any device can communicate with any other device if they are in range of one another
- peer-to-peer network can be ad hoc, self-organizing and self-healing
- It allows multiple hops to route messages from any device to any other device in the network.
- It can provide reliability by multipath routing

## ✓ Cluster tree

- Cluster-tree network is a special case of a peer-to-peer network
- The PAN coordinator forms the first cluster by establishing itself as the cluster head (CLH)
- Devices join successively in multi-hop fashion i.e. successive clusters
- If required, PAN coordinator may instruct a device to become the CLH of a new cluster

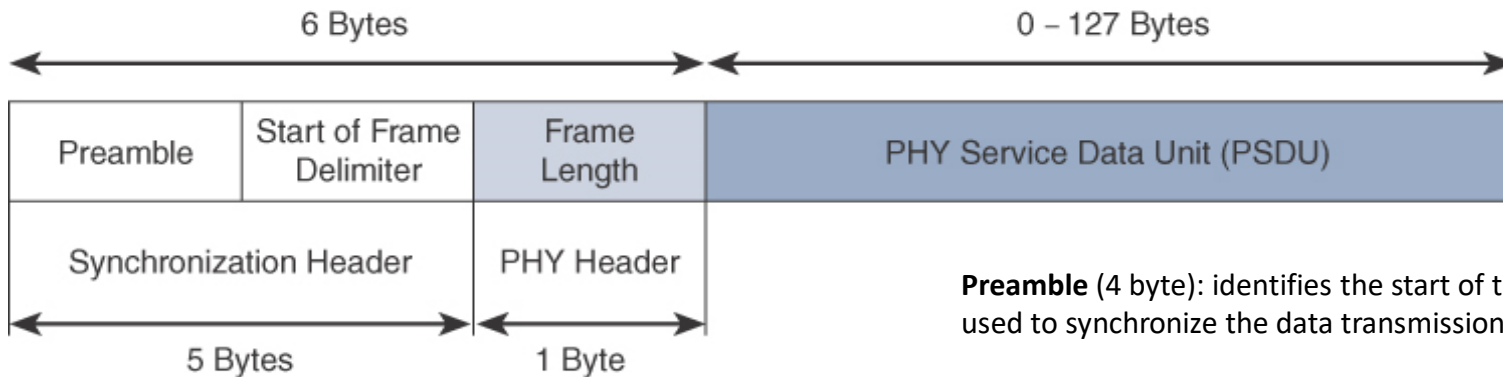


# IEEE 802.15.4 PHY Layer



IEEE 802.15.4 PHY provides the **PHY data service** and **PHY management services**.

- The **PHY data service** enables the **transmission** and **reception** of **PHY protocol data units (PPDU)** across the physical radio channel.



PPDU Frame Format

**Preamble** (4 byte): identifies the start of the frame; used to synchronize the data transmission

**SFD** (1 byte): informs the receiver about the starting point of frame content

## Services of PHY

- radio transceiver activation/deactivation,
  - radio channel selection,
  - energy level detection (ED),
  - received signal quality (RSI) or link quality indicator (LQI),
  - clear channel assessment (CCA),
  - transmitting and receiving packets in 2.4-GHz band.
- Transmission options
    - 2.4 GHz**, with a data rate ~ 250 kbps
    - 915 MHz**, with a data rate ~ 40 kbps
    - 868 MHz**, with a data rate ~ 20 kbps
  - Modulation schemes
    - Offset quadrature phase-shift keying (O-QPSK)
    - Binary phase-shift keying (BPSK)
    - Amplitude shift keying (ASK)

# Key Features of ZigBee PHY

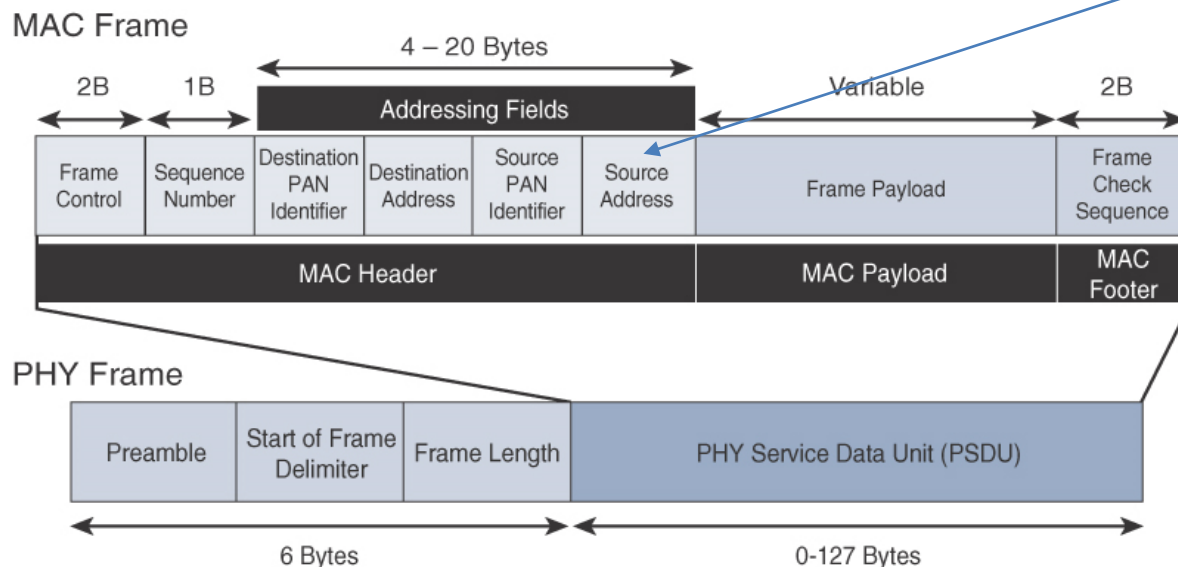


- **Energy Detection (ED)**
  - It is an estimate of the received signal power within the bandwidth of an IEEE 802.15.4 channel.
  - No attempt is made to identify or decode signals on the channel.
  - The ED time should be equal to 8 symbol periods.
  - The ED result shall be reported as an 8-bit integer
  - The ED measurement is intended for use by a network layer as part of channel selection algorithm.
- **Link Quality Indication (LQI)**
  - The LQI measurement is a characterization of the strength and/or quality of a received packet.
  - The measurement may be implemented using receiver ED, a signal-to-noise ratio (SNR) estimation or a combination of these methods.
  - The LQI shall be reported as an 8-bit integer
  - The use of LQI result is up to the network or application layers.
- **Clear Channel Assessment (CCA)**
  - CCA is performed according to at least one of the following three methods:
    - Energy above ED threshold.
    - Carrier sense only (i.e. based upon the detection of a signal with modulation and spreading characteristics)
    - Carrier sense with energy above ED threshold.

# IEEE 802.15.4 MAC layer

- IEEE 802.15.4 MAC provides the **MAC data service** and **MAC management services**.
  - The **MAC data service** enables **transmission** of **MAC protocol data units** (MPDU) across the PHY data service.
  - The **MAC sublayer features** include
    - beacon management,
    - channel access,
    - GTS management,
    - frame validation,
    - ACK frame delivery, and
    - association and disassociation.

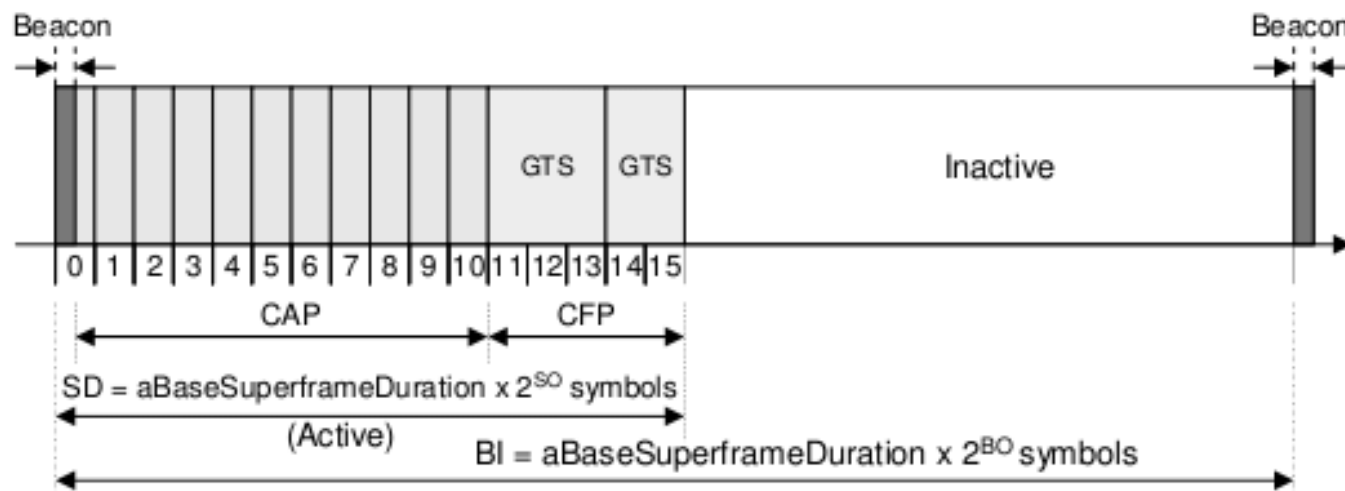
16-bit short address  
OR  
64-bit extended address



- **MAC frame types:**
  - Data frame
  - Beacon frame
  - ACK frame
  - Command frame

# MAC Features

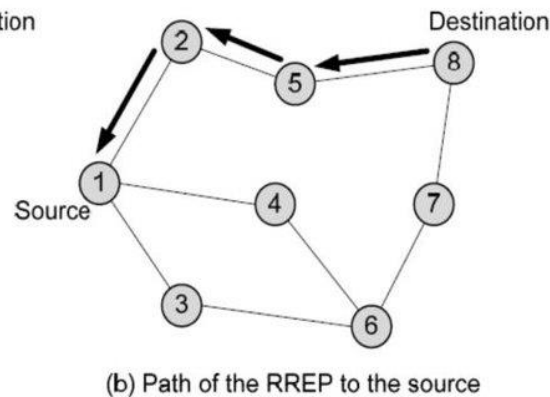
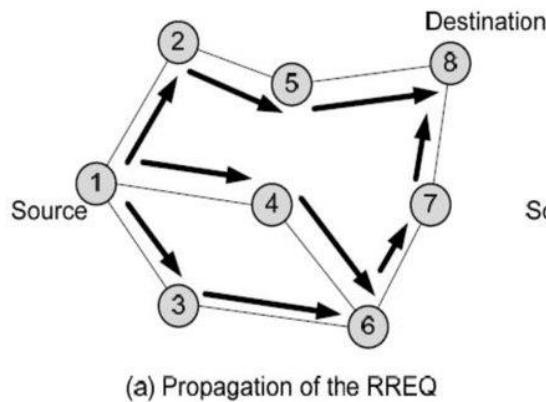
- Superframe Structure for data transmission
- Beacon Generation



- Slotted / Unslotted CSMA-CA as channel access mechanism
- Starting and Maintaining PANs
- Association and Disassociation
- Synchronization
- GTS Allocation and Management

# ZigBee Routing Layer

- Routing Algorithms: (i) AODV, (ii) Cluster Tree Algorithm, (iii) Few others....
- **AODV** (Ad-hoc On-demand Distance Vector)
  - It is a pure on-demand route acquisition algorithm
    - Nodes **do not lie on active paths**, neither maintain any routing information nor participate in any periodic routing table exchanges
    - A node **does not discover** and **maintain** a route to another node until the two need to communicate



- RREQ is broadcasted
- RREP is unicasted
- Routing table entry:
  - Dest. Node
  - Next Hop
  - No. of hops
  - Seq. no. for the dest.
  - Active neighbours for this route / dest.
  - Expiration time

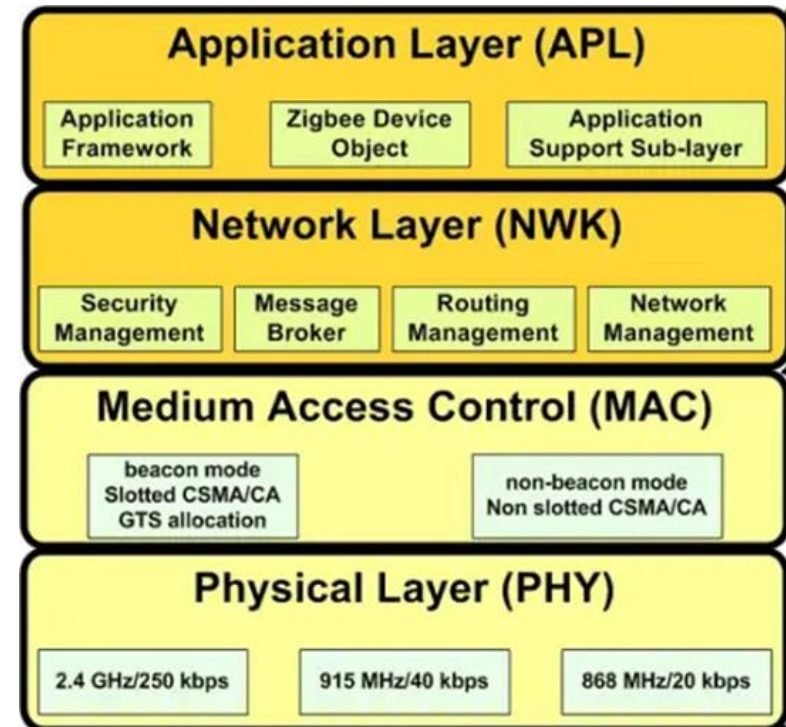
**Route Request Packet** = {*source addr, source seq. no., broadcast id, dest. addr, dest. seq. no., hop count*}

**Route Reply Packet** = {*source addr, dest. addr, dest. seq. no., hop count, lifetime*}

# ZigBee Application Layer

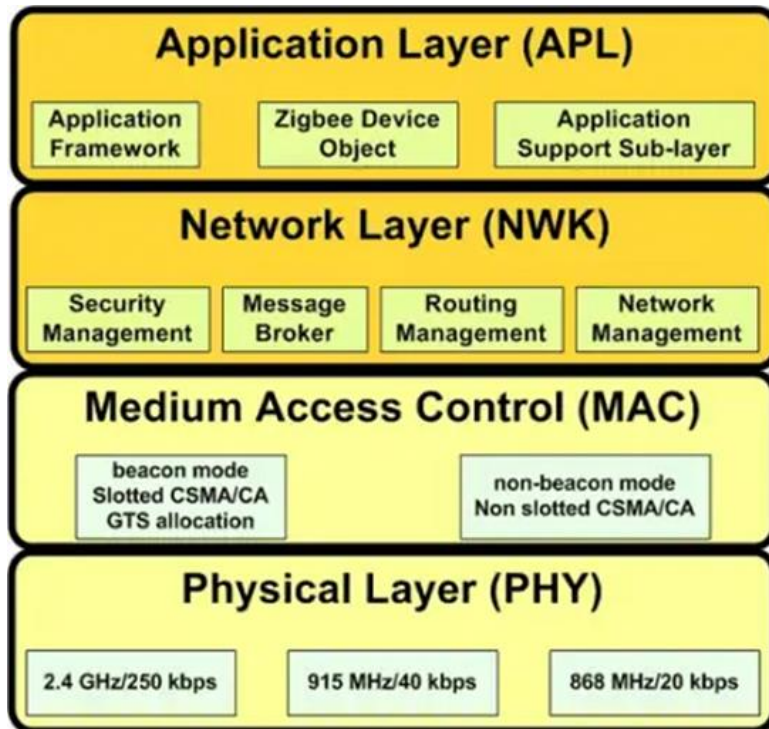


- The Application Layer in Zigbee architecture consists of sub layers namely:
  - ❖ Application Support Sub Layer
  - ❖ Application Framework
  - ❖ Zigbee Device Object
- **Application Support sub layer (APS)** responsible for :
  - ✓ Maintaining **binding** tables
    - ✓ Binding is the connection between the endpoint on a node to one or more endpoints on other nodes.
  - ✓ **Address** definition, mapping and management.
    - ✓ address mapping associates a 64-bit MAC address with a ZigBee 16-bit Network address.
  - ✓ **Filtering** out packets
    - ✓ Coming from non-registered end devices, or
    - ✓ device profiles that don't match
  - ✓ **Reassembling** of the packets.
  - ✓ Providing **data service** to the applications
  - ✓ Performs **automatic retries** wherever applicable





# Cont...



At the application level, the standardization of functionality is addressed per market sector through application profiles (e.g., [Home Automation](#), [Smart Energy](#), [Health Care](#)), with the aim of allowing interoperability.

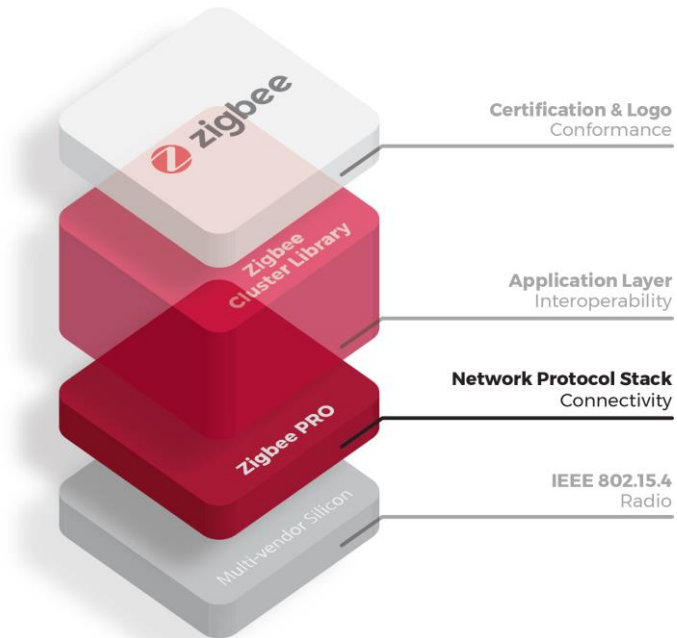
- **Application Framework**

- ✓ Provides a **framework** for building and running application
- ✓ It describes how to build an application profile on to the zigbee stack for an application
- ✓ End points are provided with **mechanism to distinguish** one application from another.

- **ZigBee device object**

- ✓ Defining **role of a device** within a network
- ✓ provides **local network** management and **over-the-air (OTA)** network management
- ✓ provides services to **discover other nodes & services** in the same network automatically

# ZigBee Cluster Library



**ZigBee Cluster Library (ZCL)** is introduced in ZigBee-2006.

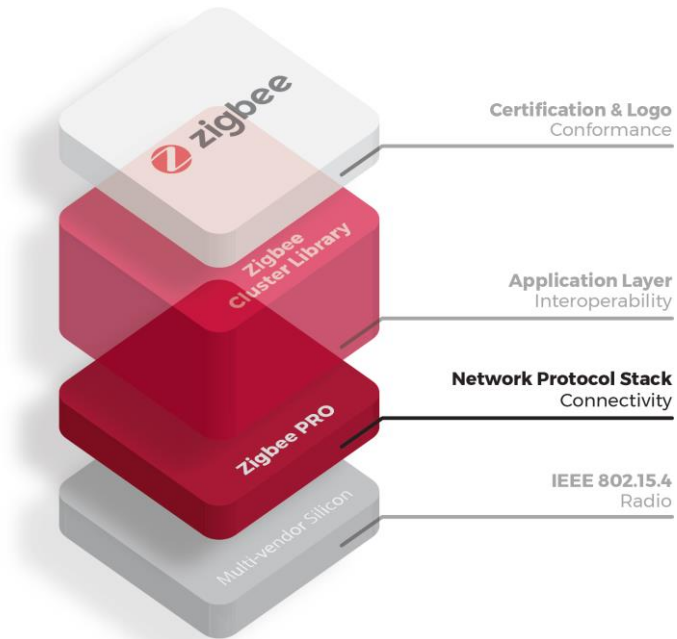
The ZCL is intended to **act as a repository** for cluster functionality that is developed by ZigBee

**Need of ZCL:** A developer constructing a new application **SHOULD use the ZCL** to find relevant cluster functionality that can be incorporated into the new application so as **not to “re-invent the wheel”**

## Examples of ZCL

- ***Door Lock Cluster*** : provides an interface to set values representing the states of door lock.
- ***Thermostat Cluster*** : provides an interface for configuring and controlling the functionality of a thermostat.
- ***Fan Control Cluster*** : used to control the speed of a fan
- ***Temperature Measurement Cluster*** : provides an interface to an temperature measuring device, allowing the configuration of measuring and the reporting of measurements.

# ZigBee PRO



**ZigBee PRO** is the enhanced version of ZigBee-2006. Initially published in 2007.

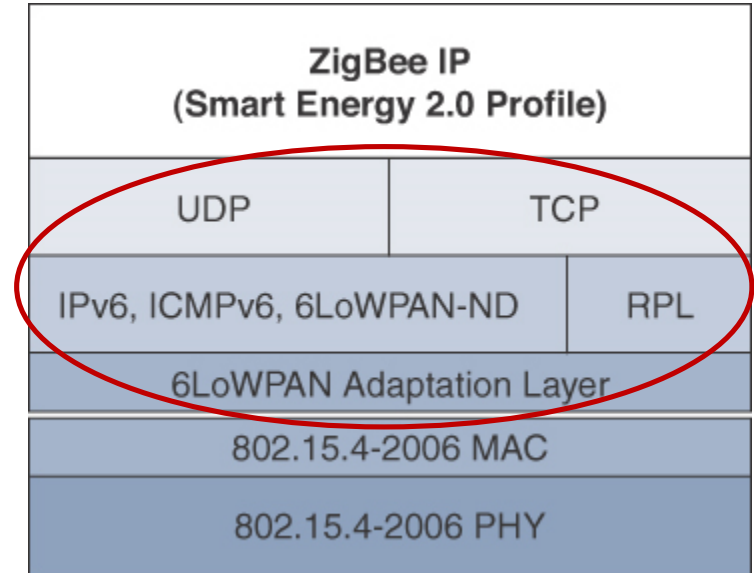
## ZigBee PRO Features:

- **Multi-band communication** across 2.4GHz and sub-GHz bands with multi PHY support
  - Incorporates **power saving mechanisms** for all device classes,
- 
- **Discovery** mechanism , **Pairing** mechanism with full application confirmation
  - Various **transmission options** -- broadcast, groupcast and unicast
  - Security **key generation** mechanism
  - Utilizes the industry standard **AES-128** security scheme
  - Sub-GHz channels transmission **ranges up to 1km.**

# ZigBee IP



- Initially, ZigBee did **not provide interoperability** with other IoT solutions or open standards
- ZigBee IP** was created to embrace the open standards at the Network and Transport layers
- Open standards** designed by **IETF's work on LLNs**, such as 6LoWPAN and RPL.
- ZigBee IP** optimizes the standard for **IPv6**-based full wireless mesh networks, **offering internet connections** to control low-power, low-cost devices.
- ZigBee IP routes standard IPv6 traffic over IEEE 802.15.4 using **6LoWPAN** header compression.



- ZigBee IP nodes support
  - ✓ IPv6,
  - ✓ ICMPv6,
  - ✓ 6LoWPAN,
  - ✓ Neighbour Discovery (ND), and
  - ✓ RPL for the routing of packets.

# ZigBee RF4CE

- In 2009, the Radio Frequency for Consumer Electronics (RF4CE) consortium and ZigBee Alliance agreed to deliver jointly a standard for radio frequency remote controls
- consumer electronics products, such as TVs and set-top boxes.
- Advantages:
  - richer communication,
  - increased reliability,
  - enhanced features and flexibility,
  - interoperability,
  - no line-of-sight barrier,
  - can run on smaller memory configurations in lower-cost devices



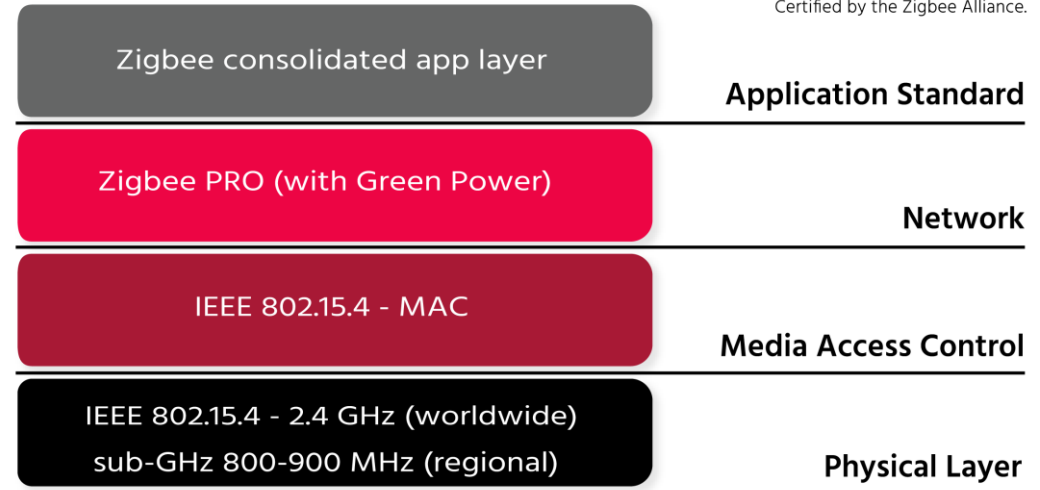
# ZigBee Green Power



- Zigbee Green Power (ZGP) is included in the Zigbee specification
- ZGP **enables battery-less** (energy-harvesting) or ultra-long battery devices to securely join Zigbee PRO networks.
- Common ZGP devices include switches, sensors, detectors, and buttons.
- ZGP uses a **new compact packet format** that minimizes the amount of energy used to transmit data
- GPDF (Green Power Device Frame) is shorter than a standard ZigBee frame. This allows a GPD (Green Power Device) to **transmit a GPDF using less power than a standard ZigBee frame.**



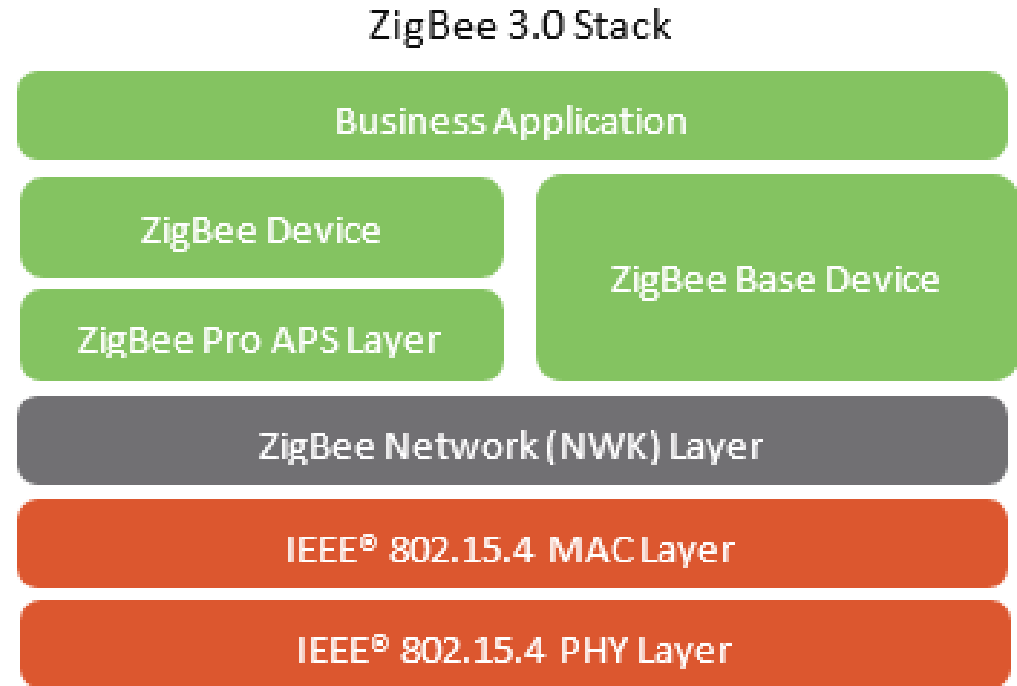
Zigbee is the only complete IoT solution, from mesh network to the universal language that allows smart objects to work together. Certified by the Zigbee Alliance.



# ZigBee 3.0



- Aims to **break the barriers** between low-power wireless devices from different market sectors, to allow **fully integrated networks** as well as **Internet connectivity**
- So, it removes restrictions that prevent nodes in different application areas from participating in the same network.
- ZigBee 3.0 **redefines ZigBee PRO** to allow **increased interoperability**
- ZigBee 3.0 provides **enhanced network security**
- ZigBee 3.0 supports with **large local networks** of greater than 250 nodes.



The ZigBee 3.0 software stack **incorporates** a ‘**base device**’ feature that provides consistent behaviour for commissioning nodes into a network.

Source: <https://www.nxp.com/docs/en/brochure/75017677.pdf>

# Thanks!

