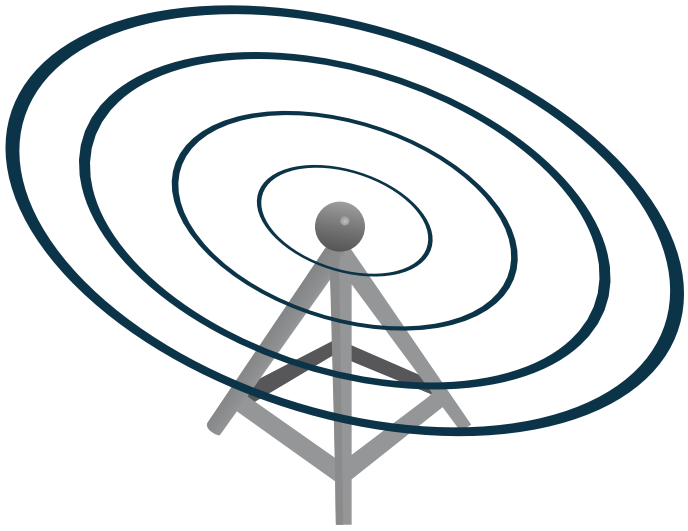

Wireless Zigbee Communication Technology

By

EDGEFX KITS & SOLUTIONS

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In this present communication world, there are numerous high-data rate communication standards that are available, but none of these meet the sensors' and control devices' communication standards. These high-data rate communication standards require low-latency and low-energy consumption even at low bandwidths. The available proprietary wireless systems' Zigbee technology' s low-cost and low-power consumption and its excellent and superb characteristics make this communication best suited for several embedded applications, industrial control systems, and home-automation systems, and so on.

What is Zigbee Technology?

Zigbee communication is specially built for control and sensor networks with IEEE 802.15.4 standard for wireless personal area networks (WPANs), and it is the product of the Zigbee Alliance. This communication standard defines physical and Media Access Control (MAC) layers to handle many devices at low-data rates. These Zigbee's WPANs operate at 868 MHz, 902-928MHz and 2.4 GHz frequencies. The data rate of 250 kbps is best suited for periodic as well as intermediate two-way transmission of data between sensors and controllers.

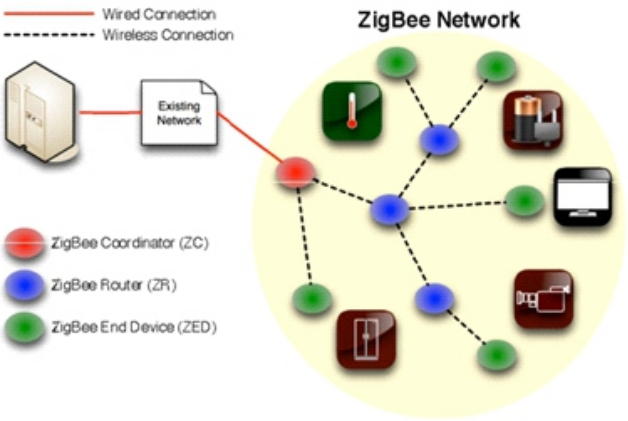
Zigbee is low-cost and low-powered mesh network widely deployed for controlling and monitoring applications wherein it covers 10-100 meters within the range. This communication system is less expensive and simpler than the other proprietary short-range wireless sensor networks such as Bluetooth and WI-Fi.

Zigbee supports different network configurations for master to master or master to slave communications. And also, it can be operated in different modes, as a result, the battery power can be conserved. Zigbee networks are extendable with the use of routers and allow many nodes to interconnect with each other for building a wide area network.
Zigbee addresses the periodic and intermittent data at application defined rates and low-latency repetitive data by allocating time slots. The beacon system handles Periodic data (sensor data). The intermittent data (light switch) is handled either by beaconless system or in disconnected fashion, and the guaranteed time slots are for low-latency data applications.

Features of Zigbee Technology

- Simple protocol and global implementation
- High density of nodes per network 18,450,000,000,000,000,000 devices (64 bit IEEE address) and 65,535 networks
- Data rates of 250 kbps at 2.4 GHz, 40 kbps at 915 MHz and 20 kbps at 868 MHz
- Low power consumption and long battery life
- Multiple topologies: star, mesh, peer-to-peer
- Optional guaranteed time slot for low latency applications
- Range: Typically 50m (Based on the environment, it is 5-500m)

Zigbee Architecture

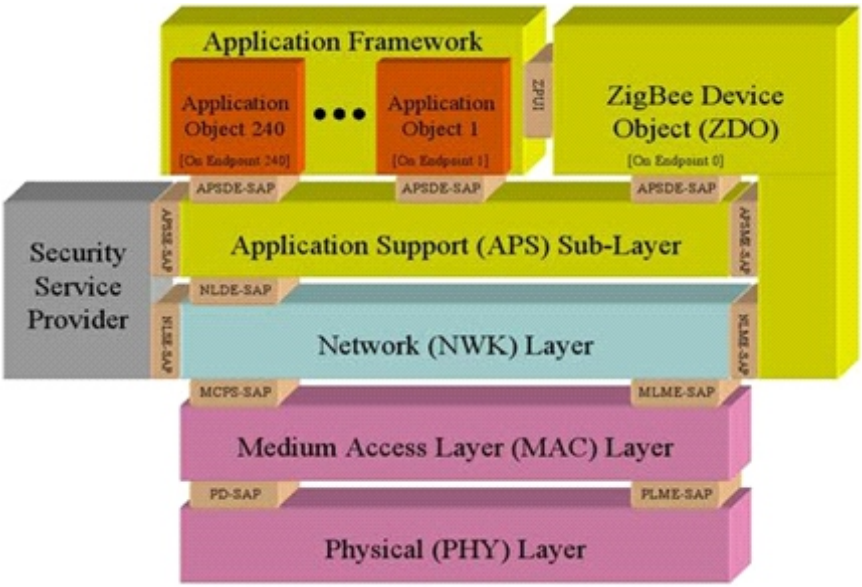


Zigbee System Structure

The Zigbee system structure consists of three different types of devices: Zigbee coordinator, Router and End device.

- Every Zigbee network must consists of at least one coordinator, which acts as a root and the bridge of the network. The coordinator is responsible for handling and storing the information while performing receiving and transmitting data operations.
- Zigbee routers act as intermediary devices that permit data to pass to and fro through them to other devices.
- End devices have limited functionality to communicate with the parent nodes such that the battery power is saved, as shown in the figure. The number of routers, coordinators and end devices depends on the type of network such as star, tree and mesh networks.
- Full function device (FFD) can function in any topology like star, peer to peer, etc and it's also capable of being either coordinator or network coordinator. This is capable of communicating with any other device with network. Full MAC is implemented to this device and it can be a PAN coordinator, coordinator or a device.
- Reduced Function Device (RFD) is limited only to star topology; and, it is a device which cannot become a network coordinator. Partial MAC is implemented to these devices.

Zigbee protocol architecture consists of a stack of various layers wherein IEEE 802.15.4 is defined by physical and MAC layers while this protocol is completed by accumulating a Zigbee's own network and application layers.

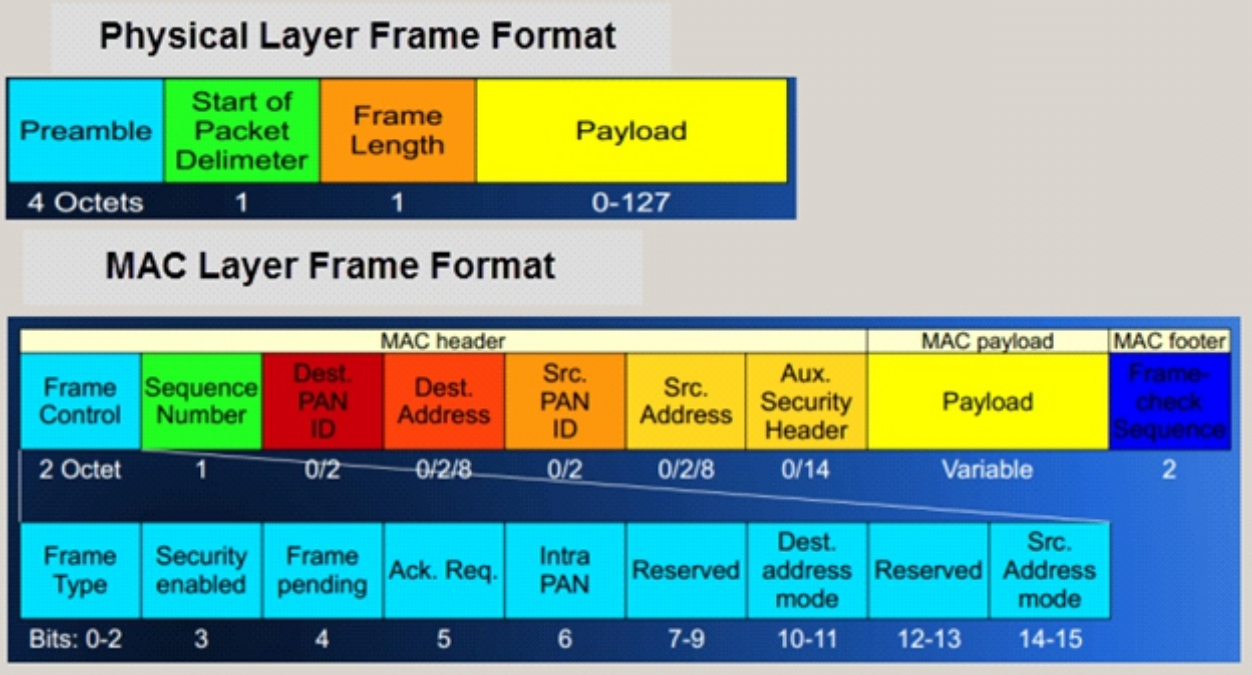


- **Physical Layer:** This layer does modulation and demodulation operations up on transmitting and receiving signals respectively. This layer's frequency, date rate and the number of channels are given below.

	BAND	COVERAGE	DATA RATE	CHANNEL NUMBERS
2.4 GHz	ISM	Worldwide	250 kbps	11-26
868 MHz		Europe	20 kbps	0
915 MHz	ISM	Americas	40 kbps	1-10

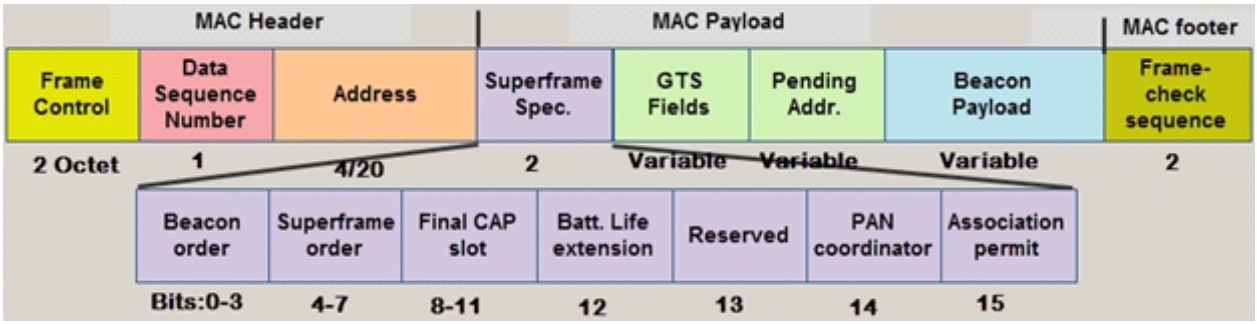
- **MAC Layer:** This layer is responsible for reliable transmission of data by accessing different networks with the carrier sense multiple access collision avoidance (CSMA). This also transmits the beacon frames for synchronizing communication.

MAC layer of IEEE 802.15.4 defines four frame structures, namely beacon frame which is used by the coordinator for transmitting beacons, data frame for transferring of data, acknowledgement frame for confirmation of successful reception of a frame, and a MAC command frame for handling all entity control transfers of MAC peers, which are given below. The overheads of physical and MAC layers are given in the below figure, wherein the data frame uses 15 to 31 Octets of overhead for single packet, which is approximately 120 bits.

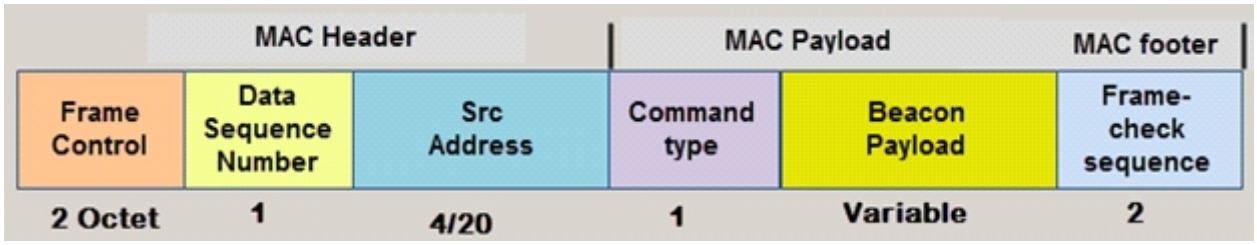


When the beacon-enabled mode is selected by the coordinator, then it uses superframe structure to manage communication between the network devices. This superframe format is defined by the coordinator and is bounded by network beacons. It is divided into 16 slots with equal length - and, in each superframe, the beacon frame is transmitted in the first slot, as shown in the figure. The coordinator automatically turns off the beacon transmission if it does not wish to use a superframe structure.

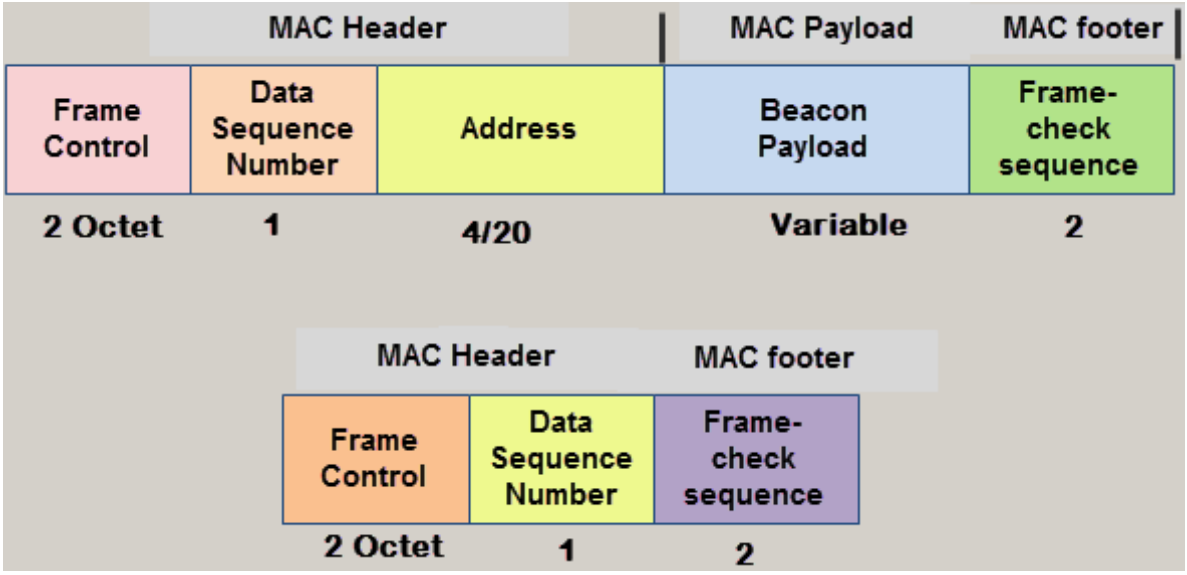
The beacons synchronize the attached devices, identifie the PAN, and describe the structure of the superframes. A slotted CSMA-CA mechanism comes into action whenever any device wishing to communicate between the two beacons shall compete with other devices during the contention access period (CAP). For applications that require specific data bandwidth or low latency applications, the PAN coordinator may dedicate portions of the active superframe to that application; these are called guaranteed time slots (GTSs).



Beacon Frame Format of MAC Layer



Command Frame Format of MAC layer



Data /Acknowledgement frame formats

- **Network Layer:** This layer takes care of all network related operations such as network setup, end device connection and disconnection to network, synchronizing the devices with other devices, configuring a new device, addressing, routing, security to the network, etc.

A coordinator does an energy scan for finding the best RF channel for its new network when the coordinator attempts to establish a Zigbee network. The coordinator assigns a PAN ID or logical network identifier to the channel chosen by it, and then applies the network identifier to all the devices that want to join the network. It is possible for a node to join directly or through association to the network. To join directly, the node's extended address has to be added into the neighbor table of a device by the system's designer, whereas to join through the association, the node sends a beacon request to a channel and repeats it to all channels until it finds a network which is acceptable to join.

- **Application Layer** This layer consists of the application sub-layer, Zigbee device object (ZDO) and the manufacture-defined application objects.

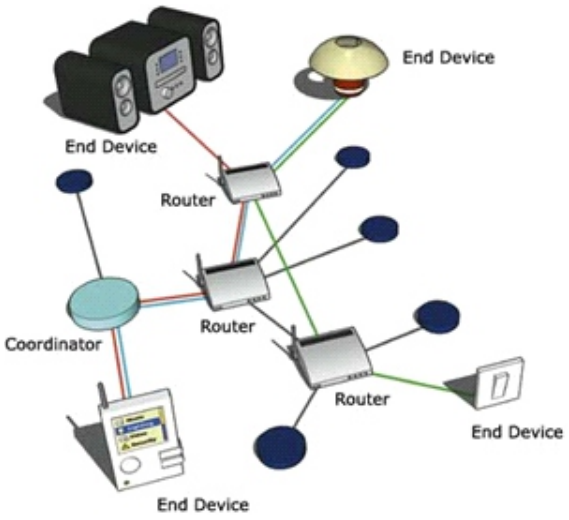
Application Support Sub-Layer enables the services necessary for Zigbee device object and application objects to interface with the network layers for data managing services. This layer is responsible for matching two devices, according to their services and needs.

Application Framework provides two types of data services as a key value pair and generic message services. A generic message is a developer defined structure, whereas the key value pair is used for getting attributes within the application objects.

Zigbee Device Object (ZDO) provides an interface between the application objects and APS layer in Zigbee devices. It is responsible for detecting, initiating and binding other devices to the network. It is responsible for establishing a security based relationship between the devices of the network using a public key and symmetric key: security methods of Zigbee.

Based on the ZigBee-defined application descriptions, the manufacture-defined application objects implement the actual applications.

Zigbee Operating Modes and Its Topologies



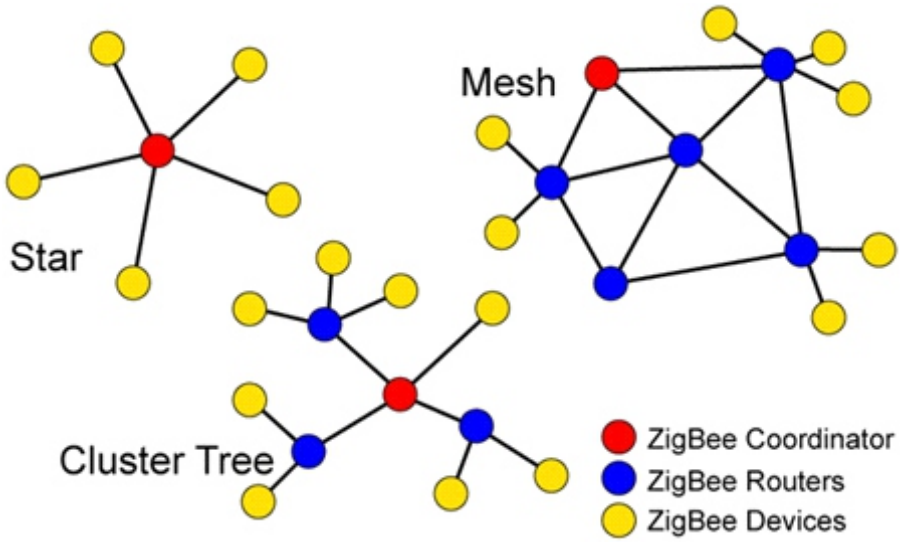
Zigbee two way data is transferred in two modes: Non-beacon mode and Beacon mode.

- In a beacon mode, the coordinators and routers continuously monitor the active state of the incoming data, hence more power is consumed. In this mode, the routers and coordinators do not sleep because at any time any node can wake up and communicate. However, it requires more power supply and its overall power consumption is low because most of the devices are in an inactive state for over long periods in the network.

- In a beacon mode, when there is no data communication from end devices, then the routers and coordinators enter into a sleep state. Periodically this coordinator wakes up and transmits the beacons to the routers in the network. These beacon networks work for time slots, which means, they operate when the communication needed results in lower duty cycles and longer battery usage. These beacon and non-beacon modes of Zigbee can manage periodic (sensor data), intermittent (Light switches) and repetitive data types.

Zigbee Topologies

- Zigbee supports several network topologies; however, the most commonly used configurations are star, mesh and cluster tree topologies. Any topology consists of one or more coordinator. In a star topology, the network consists of one coordinator, which is responsible for initiating and managing the devices over the network. All other devices are called end devices that directly communicate with the coordinator. This is used in industries where all the endpoint devices are needed to communicate with the central controller, and this topology is simple and easy to deploy.



- In mesh and tree topologies, the Zigbee network is extended with several routers wherein coordinator is responsible for storing them. These structures allow any device to communicate with any other adjacent node for providing redundancy to the data. If any node fails, the information is routed automatically to another device by these topologies. As the redundancy is the main factor in industries, hence mesh topology is mostly used.

- In a cluster-tree network, each cluster consists of a coordinator with leaf nodes, and these coordinators are connected to a parent coordinator that initiates the entire network.

Due to the advantages of Zigbee technology like low cost and low power operating modes and its topologies, this short range communication technology is best suited for several applications compared to other proprietary communications, such as Bluetooth, WI-Fi, etc. some of these comparisons such as range of Zigbee, standards, etc., are given below.

	ZibBee	Sub-Ghz	Wi-Fi	Bluetooth
Physical Layer Standard	802.15.4	Proprietary / 802.11	802.11	802.15.1
Application Focus	Monitoring & control	Monitoring & control	Web, email, video	Cable replacement
Battery Life (days)	100 - 1,000+	1,000+	0.5-5	1 - 7
Network Size	100s to 1,000s	10s to 100s	32	7
Bandwidth (Kbits/s)	20 - 250	0.5 - 1,000	11,000+	720
Range (meters)	100 - 100+	1 - 7,000+	1 - 30+	1 - 10+
Network Architecture	Mesh	Point-to-point, low cost	Star	Star
Optimized For	Reliability, low power, low cost, scalability	Long range, low power, low cost	Speed	Low cost, convenience
Silicon Labs Products	**Ember ZibBee Em35x Series**	**EZRadio, EZRadioPRO Si10xx wireless MCUs**	N/A	N/A

Applications of Zigbee Technology

Industrial Automation: In manufacturing and production industries, a communication link continually monitors various parameters and critical equipments. Hence, Zigbee considerably reduces this communication cost as well as optimizes the control process for greater reliability.

Home Automation: Zigbee is perfectly suited for controlling home appliances remotely as a lighting system control, appliance control, heating and cooling system control, safety equipment operations and control, surveillance, and so on.

Smart Metering: Zigbee remote operations in smart metering include energy consumption response, pricing, support, security over power theft, etc.

Smart Grid monitoring: Zigbee operations in this smart grid involve remote temperature monitoring, fault locating, reactive power management, and so on.

About the Edgefx Team

The credit for each and every bit of information added to this document goes to the team of Edgefx technical writers and authors. The team of Edgefx, has been relentlessly working to ensure that the researched and practically implemented and pragmatically proven written work of this document must serve the purpose of its readers. With the unmatched technical expertise and pioneering works in the field of electronics, electrical and robotic engineering Edgefx Kits and solutions is providing technical solutions and project kits to millions of engineering students around the globe, since 1997. The credit for the projects and the circuits goes to the technical team of the Edgefx.

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