ZigBee Technology

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Abstract: **ZigBee is a mesh network specification for low-power wireless local area networks (WLANs) that cover a large area. ZigBee was designed to provide high data throughput in applications where the duty cycle is low and low power consumption is an important consideration. Because ZigBee is often used in industrial automation and physical plant operation, it is often associated with machine-to-machine (M2M) communication and the Internet of Things (IoT). ZigBee devices are designed to communicate via radio frequencies. ZigBee devices are of 3 types, Coordinators, Routers, and End Devices. Coordinators control the network formation and security. Routers pass on the signal and extend the network range. End Devices perform specific tasks such as turning on a light or taking a reading.**

Keywords: ZigBee, IEEE802.15.4, Medium Access Control (MAC), Physical Layer (PHY), Wireless Personal Area Networking(WPAN)

1. INTRODUCTION

ZigBee is a new standard developed by the ZigBee Alliance for personal-area networks (PANs). Consisting of more than 270 companies (including Free scale, Ember, Mitsubishi, Philips, Honeywell, and Texas Instruments), the ZigBee Alliance is a consortium that promotes the ZigBee standard for a low-rate/low-power wireless sensor and control network. The ZigBee protocol stack is built on top of IEEE 802.15.4, which defines the Media Access Control (MAC) and physical layers for low-rate wireless personal-area network (LR-WPAN). The ZigBee standard offers a stack profile that defines the network, security, and application layers. Developers are responsible for creating their own application profiles or integrating with the public profiles that were developed by the ZigBee Alliance. The ZigBee specification is an open standard that allows manufacturers to develop their own specific applications that require low cost and low power.

ZigBee is the most popular industry wireless mesh networking standard for connecting sensors, instrumentation and control systems. ZigBee, a specification for communication in a wireless personal area network (WPAN), has been called the "Internet of things." ZigBee is an open, global, packet-based protocol designed to provide an easy-to-use architecture for secure, reliable, low power wireless networks. ZigBee and IEEE 802.15.4 are low data rate wireless networking standards that can eliminate the costly and damage prone wiring in industrial control applications. Flow or process control equipment can be place anywhere and still communicate with the rest of the system. It can also be moved, since the network doesn't care about the physical location of a sensor, pump or valve.

The ZigBee RF4CE standard enhances the IEEE 802.15.4 standard by providing a simple networking layer and standard application profiles that can be used to create interoperable multi-vendor consumer electronic solutions.

ZigBee targets the application domain of low power, low duty cycle and low data rate requirement devices. Figure below shows the example of a ZigBee network.

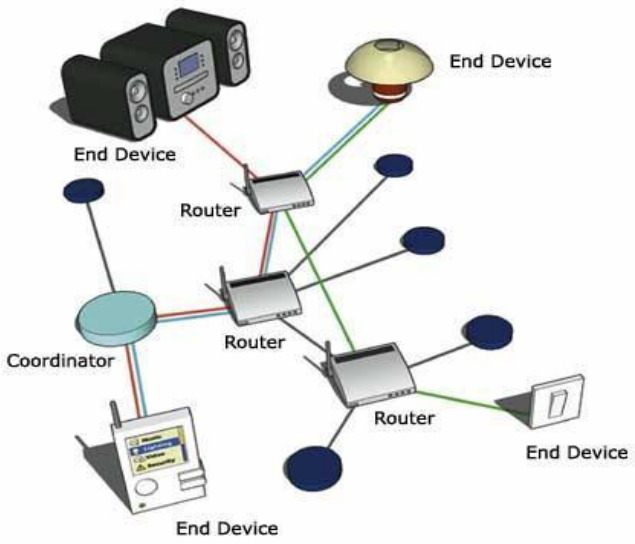


Figure 1: ZigBee Network

II. ZIGBEE CHARACTERISTICS

ZigBee is poised to become the global control/sensor network standard. It has been designed to provide the following features:

- Low power consumption, simply implemented
- Users expect batteries to last many months to years
- Bluetooth has many different modes and states depending upon your latency and power requirements such as sniff, park, hold, active, etc.; ZigBee/IEEE 802.15.4 has active (transmit/receive) or sleep
- Even mains powered equipment needs to be conscious of energy. ZigBee devices will be more ecological than its predecessors saving megawatts at it full deployment.

Low cost (device, installation, maintenance): Low cost to the users means low device cost, low installation cost and low maintenance. ZigBee devices allow batteries to last up to years using primary cells (low cost) without any chargers (low cost and easy installation). ZigBee's simplicity allows for inherent configuration and

redundancy of network devices provides low maintenance.

High density of nodes per network: ZigBee's use of the IEEE 802.15.4 PHY and MAC allows networks to handle any number of devices. This attribute is critical for massive sensor arrays and control networks.

Simple protocol, global implementation: ZigBee's protocol code stack is estimated to be about 1/4th of Bluetooth's or 802.11's. Simplicity is essential to cost, interoperability, and maintenance. The IEEE 802.15.4 PHY adopted by ZigBee has been designed for the 868 MHz band in Europe, the 915 MHz band in N America, Australia, etc; and the 2.4 GHz band is now recognized to be a global band accepted in almost all countries.

III. HOW ZIGBEE WORKS?

ZigBee basically uses digital radios to allow devices to communicate with one another. A typical ZigBee network consists of several types of devices. A network coordinator is a device that sets up the network, is aware of all the nodes within its network, and manages both the information about each node as well as the information that is being transmitted/received within the network. Every ZigBee network must contain a network coordinator. Other Full Function Devices (FFD's) may be found in the network, and these devices support all of the 802.15.4 functions. They can serve as network coordinators, network routers, or as devices that interact with the physical world. The final device found in these networks is the Reduced Function Device (RFD), which usually only serve as devices that interact with the physical world. As mentioned above several topologies are supported by ZigBee, including star, mesh, and cluster tree. As can be seen in above figure 3, star topology is most useful when several end devices are located close together so that they can communicate with a single router node. That node can then be a part of a larger mesh network that ultimately communicates with the network coordinator. Mesh networking allows for redundancy in node links, so that if one node goes down, devices can find an alternative path to communicate with one another

IV. ZIGBEE SPECIFICATION

ZigBee, its specification and promotion, is a product of the ZigBee Alliance. The Alliance is an association of companies working together to ensure the success of this open global standard .ZigBee is built on top of the IEEE 802.15.4 standard. ZigBee provides routing and multi-hop functions to the packet-based radio protocol.

4.1 Logical Device Types : The ZigBee stack resides on a ZigBee logical device. There are three logical device types:

Coordinator
Router

End device

It is at the network layer that the differences in functionality among the devices are determined. It is expected that in a ZigBee network the coordinator and the routers will be mains-powered and that the end devices can be battery-powered.

In a ZigBee network there is one and only one coordinator per network. The number of routers and/or end devices depends on the application requirements and the conditions of the physical site. Within networks that support sleeping end devices, the coordinator or one of the routers must be designated as a Primary Discovery Cache Device. These cache devices provide server services to upload and store discovery information, as well as respond to discovery requests, on behalf of the sleeping end devices.

4.2 ZigBee Stack Layers: As shown in figure 6 above, the stack layers defined by the ZigBee specification are the network and application framework layers. The ZigBee stack is loosely based on the OSI 7-layer model. It implements only the functionality that is required in the intended markets.

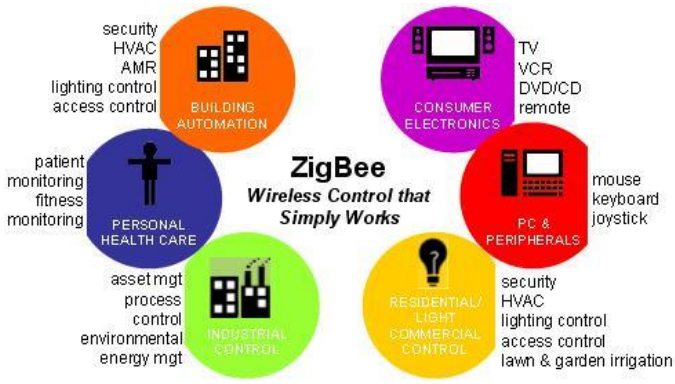


Figure 2: ZigBee Stack

4.2.1 Network (NWK) Layer: The network layer ensures the proper operation of the underlying MAC layer and provides an interface to the application layer. The network layer supports star, tree and mesh topologies. Among other things, this is the layer where networks are started, joined, left and discovered.

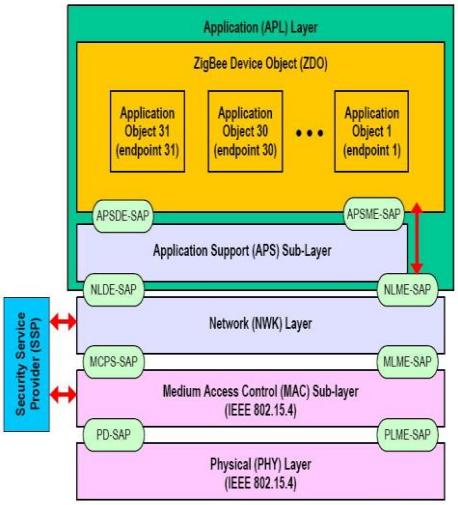
When a coordinator attempts to establish a ZigBee network, it does an energy scan to find the best RF channel for its new network. When a channel has been chosen, the coordinator assigns the logical network identifier, also known as the PAN ID, which will be applied to all devices that join the network.

A node can join the network either directly or through association. To join directly, the system designer must somehow add a node's extended address into the neighbor table of a device. The direct joining device will issue an orphan scan, and the node with the matching extended address (in its neighbor table) will respond, allowing the device to join.

To join by association, a node sends out a beacon request on a channel, repeating the beacon request on other channels until it finds an acceptable network to join. The network layer provides security for the network, ensuring both authenticity and confidentiality of a transmission.

4.2.2 Application (APL) Layer

The APL layer is made up of several sublayers. The components of the APL layer are shown in figure 7 and discussed below. The ovals symbolize the interface, called service access points (SAP), between different sublayer entities.



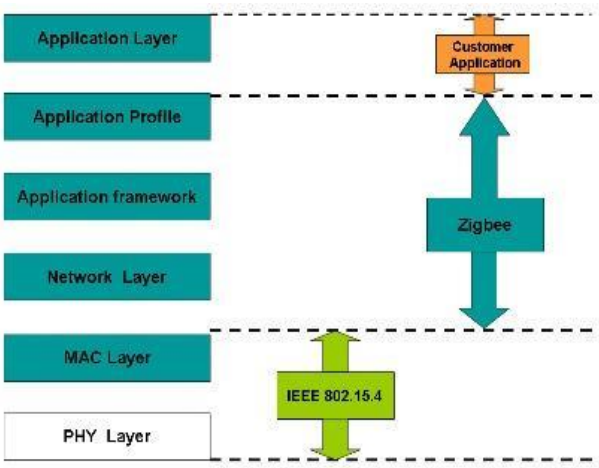


Figure 3: ZigBee-Defined Part of Stack

4.2.2.1 Application Support Sublayer (APS): The APS sub layer is responsible for:

- binding tables
- message forwarding between bound devices
- group address definition and management address mapping from 64-bit extended addresses to 16-bit NWK addresses
- fragmentation and reassembly of packets
- reliable data transport

The key to interfacing devices at the need/service level is the concept of binding. Binding tables are kept by the coordinator and all routers in the network. The binding table maps a source address and source endpoint to one or more destination addresses and endpoints. The cluster ID for a bound set of devices will be the same.

4.2.2.2 Application Framework: The application framework is an execution environment for application objects to send and receive data. Application objects are defined by the manufacturer of the ZigBee-enabled device. As defined by ZigBee, an application object is at the top of the application layer and is determined by the device manufacturer. An application object actually implements the application; it can be a light bulb, a light switch, an LED, an I/O line, etc. The application profile is run by the application objects.

Each application object is addressed through its corresponding endpoint. Endpoint numbers range from 1 to 240. Endpoint 0 is the address of the ZigBee Device Object (ZDO). Endpoint 255 is the broadcast address, i.e., messages are sent to all of the endpoints on a particular node. Endpoints 241 through 254 are reserved for future use. ZigBee defines function primitives, not an application programming interface (API).

4.2.2.3 ZigBee Device Object (ZDO): The ZDO is responsible for overall device management, specifically it is responsible for:

- initializing the APS sub layer and the NWK layer
- defining the operating mode of the device (i.e., coordinator, router, or end device)
- device discovery and determination of which application services the device provides
- initiating and/or responding to binding requests
- security management

Device discovery can be initiated by any ZigBee device. In response to a device discovery inquiry end devices send their own IEEE or NWK address (depending on the request). A coordinator or router will send their own IEEE or NWK address plus all of the NWK addresses of the devices associated with it. (A device is associated with a coordinator or router if it is a child node of the coordinator or router.). Device discovery allows for an ad-hoc network. It also allows for a self-healing network.

Service discovery is a process of finding out what application services are available on each node. This information is then used in binding tables to associate a device offering a service with a device that needs that service.

V. CONCLUSION

ZigBee technology could form the basis of future wireless sensors, offering data reliability, long battery life, lower system costs and good range through flexible networking. In terms of protocol stack size, ZigBee's 32 KB is about one-third of the stack size necessary in other wireless technologies (for limited capability end devices, the stack size is as low as 4 KB. The ZigBee Alliance targets applications "across consumer, commercial, industrial and government markets worldwide". Unwired applications are

highly sought after in many networks that are characterized by numerous nodes consuming minimum power and enjoying long battery lives. ZigBee technology is designed to best suit these applications, for the reason that it enables reduced costs of development and very fast market adoption

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