"A Study Based On ZigBee Technology"

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Abstract: Wireless Sensor Networks are being gradually introduced in different application scenarios. ZigBee is one of the most widely used transceiver standard in wireless sensor networks. ZigBee over IEEE 802.15.4., defines specifications for low data rate WPAN (LR-WPAN) to support low power controlling devices. This paper presents a detailed study of ZigBee wireless standard, IEEE 802.15.4 specification, ZigBee device types, the protocol stack architecture and monitoring and its applications.

IndexTerms - ZigBee, IEEE802.15.4. Standard, LR-WPAN.

I. INTRODUCTION

Wireless Technology is being developed rapidly nowadays. Advancement in microelectromechanical systems brings integration of sensing, signal processing and RF capability on very small devices. All kind of portable applications tend to be able to communicate without the use of any wires. Aim of wireless communication is to gather information or perform certain task in the environment. A typical sensor node contains three C's, are Collection, Computation and Communication units. Based on the request of sink, gathered information have transmitted wirelessly. The collection unit has series of sensors. Computation unit contains microcontroller and memory. Finally, the communication unit contains transceiver to transmit and receive data; various transceivers (such as RFM TR1000 family, Hardware accelerators, Chipcon CC1000 and CC2420 family, in neon TDA 525x family, IEEE 802.15.4/Ember EM2420 RF transceiver, Conexant RDSSS9M) used for this purpose. The reasons for using ZigBee are,

• Reliable and self-healing
• Supports large number of nodes.
• Easy to deploy
• Very long battery life
• Secure
• Low cost
• Can be used globally
• Vibrant industry support with thirty or more vendors supplying products and services
• Open Standards protocol with no or negligible licensing fees
• Chipsets available from multiple sources
• Remotely upgradeable firmware
• No new wires

Low power (ability to operate on batteries measured in years)

• Low maintenance (meshing, self-organizing)
• Standards based security [AES128]
• Ability to read gas meters

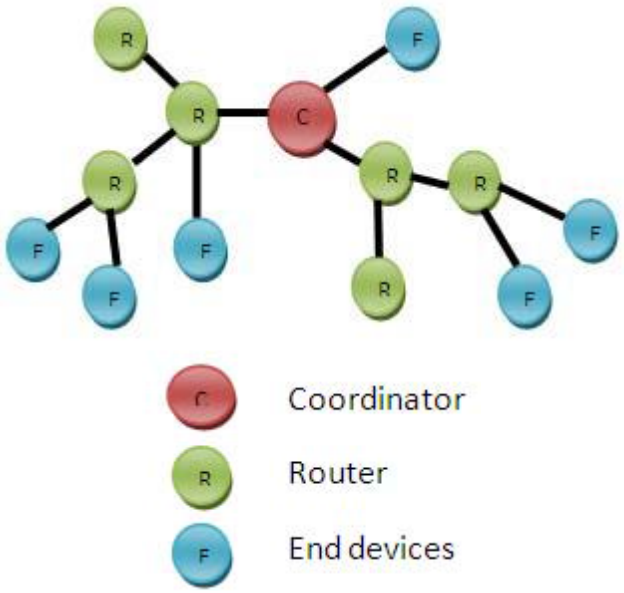
II. ZIGBEE AND IEEE 802.15.4

ZigBee is developed by ZigBee alliance, which has hundreds of member companies (Ember, Freescale, Chipcon, Invensys Mitsubishi, CompXs, AMI Semiconductors, ENQ Semiconductors), from semiconductor and software developers to original equipment manufacturers. ZigBee and 802.15.4 are not the same. ZigBee a standard based network protocol supported solely by the ZigBee alliance that uses the transport services of the IEEE802.15.4 network specification. ZigBee alliance is responsible for ZigBee standard and IEEE is for IEEE802.15.4. It's like TCP/IP using IEEE 802.11b network specification. ZigBee's alliance (software) defines the network, security and application layers. IEEE802.15.4 (hardware) defines the physical and media access control layers for LR-WPAN.

Power needed for ZigBee is very small. In most cases it uses 1mW (or less power). But still it is providing range up to 150 meters in outdoor which is achieved by the technique called direct sequence spread spectrum (DSSS). Also DSSS consumes less power compared to Frequency Hopping Spread Spectrum (FHSS). It works in the 868 MHz (Europe), 915 MHz (North America and Australia) and 2.4 GHz (available worldwide) ISM band with up to 20kbps, 40kbps and 250kbps data rate respectively.

III. ZIGBEE STANDARD

ZigBee device are the combination of application (such as light sensor, lighting control etc.), ZigBee logical (coordinator, router, end device), and ZigBee physical device types (Full Function Device and Reduced Function Device).



A. ZigBee Physical Device Types

Based on data processing capabilities, two types of physical devices are provided in IEEE 802.15.4: Full Function Devices (FFD) and Reduced Function Devices (RFD). Full Function Devices can perform all available operations the standard, including routing mechanism, coordination tasks and sensing task.

B. ZigBee logical device types

1*)* Coordinator: Forms the root of the network tree and might bridge to other networks. There is exactly one coordinator in each network. It's responsible for initiating the network and selecting the network parameters such as radio frequency channel, unique network identifier and setting other operational parameters. It can also store the information about network, security keys.

2) Router: Router acts as intermediate nodes, relaying data from other devices. Router can connect to an already existent network, also be able to accept connections from other devices and be some kind of re-transmitters to the network. Network may be extended through the use of ZigBee routers.

3) End Devices: End Device can be low-power / battery-powered devices. They can collect various information from sensors and switches. They have sufficient functionality to talk to their parents (either the coordinator or a router) and cannot relay data from other devices. This reduced functionality allows for the potential to reduce their cost. They support better low power models. These devices do not have to stay awake the whole time, while the devices belonging to the other two categories have to. Each end device can have up to 240 end nodes which are separate applications sharing the same radio.

C. Access Modes

Two ways of multi-access in ZigBee protocol, are Beacon and Non-beacon. In non-beacon enabled network, every node in the network can send the data when the channel is free. In beacon enabled network, nodes can transmit in predetermined time slots. Here PAN coordinator allocates guaranteed time slots (GTS) for each device; therefore, devices will transmit their data during their own slot. All devices should be synchronized for this process. This will be achieved by sending beacon signal. The coordinator is responsible to transmit beacon signals to synchronize the devices attached to it. Network in which the coordinator does not transmit beacon signal is known as non-beacon network. It cannot have GTS and contention free periods,because the devices are not synchronized. Battery life is better than beacon enabled network, because the devices are
wake up less often.

IV. ZIGBEE PROTOCOLS STACK

Protocol architecture is based on Open system interconnection (OSI). ZigBee builds on IEEE standard 80215.4 which defines the physical and media access control (MAC) layers. ZigBee alliance defines the network layer and application layer. Fig.2 shows protocol stack of ZigBee system.

B. Physical Layer

The physical layer of the IEEE802.15.4 standard is the closest layer to the hardware, which control and communicate with the radio transceiver directly. It handles all tasks involving the access to the ZigBee hardware, including initialization of the hardware, channel selection, link quality estimation, energy detection measurement and clear channel assessment to assist the channel selection. Supports three frequency bands, 2.45GHz band which using 16 channels, 915MHz band which using 10 channels and 868MHz band using 1 channel. All three using Direct Spread Spectrum Sequencing (DSSS) access mode.

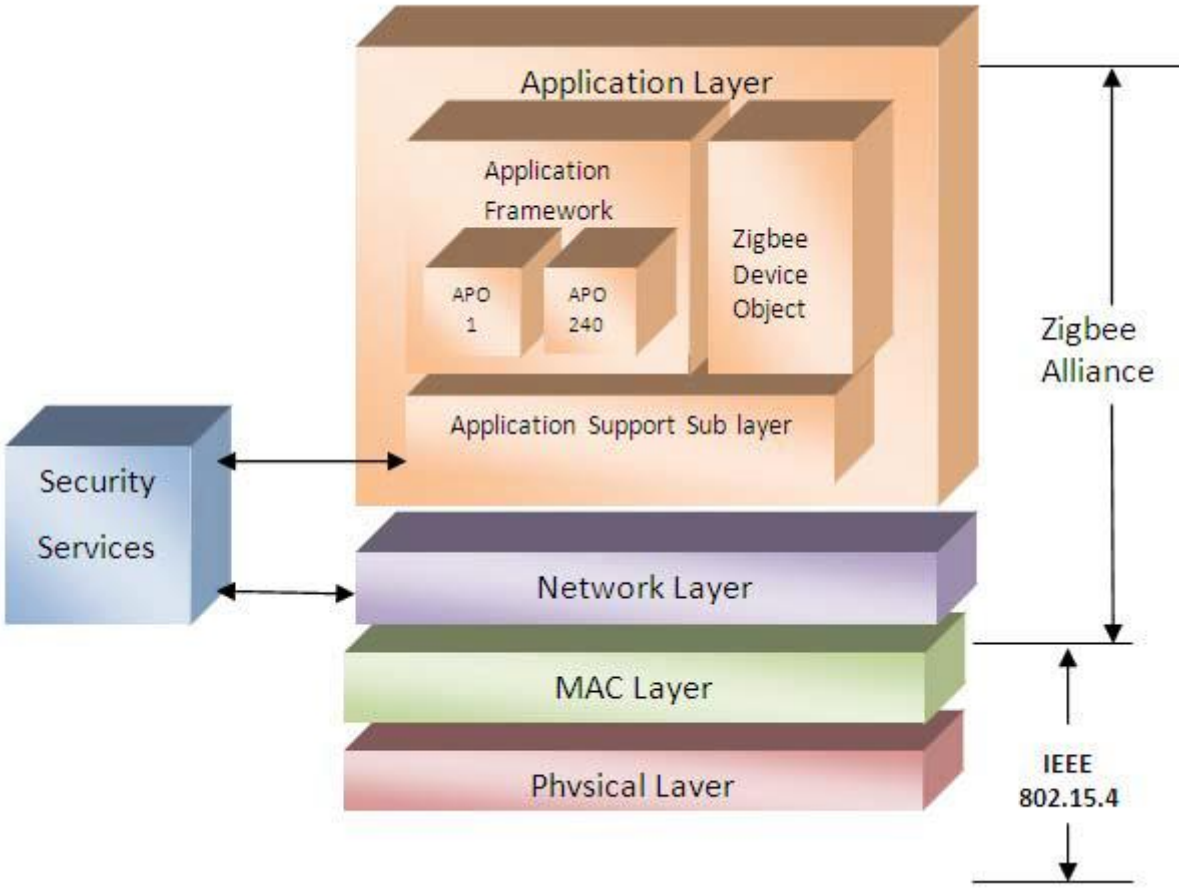


Figure 1. ZigBee Protocol Stack

C. MAC Layer

This layer provides interface between physical layer and network layer. This provides two services; MAC data services and MAC management service interfacing to the MAC sub Layer Management Entity (MLME) Service Access Point called (MLME-SAP). The MAC data service enables the transmission and reception of MAC Protocol Data Units (MPDUs) across the PHY data service. MAC layer is responsible for generating beacons and synchronizing devices to the beacon signal in a beacon enabled services.

D. Network Layer

Network layer interfaces between application layer and MAC Layer. This Layer is being responsible for network formation and routing. Routing is the process of selection of path to relay the messages to the destination node. This forms the network involving joining and leaving of nodes, maintaining routing tables (coordinator/router), actual routing and address allocation. ZigBee coordinator or router will perform the route discovery. This layer Provides network wide security and allows low power devices to maximize their battery life. From the basic topologies, there are three network topologies are considered in IEEE802.15.4 are star, cluster tree and mesh.

D. Application Layer

The application Layer is the highest protocol layer and it is hosts the application objects. ZigBee specification separates the APL layer into three different sub-layers: The Application Support Sub layer, the ZigBee Device Objects, and Application Framework having manufacturer defined Application Objects.

1) The application objects (APO): Control and manages the protocol layers in ZigBee device. It is a piece of software which controls the hardware. Each application objects assigned unique end point number that other APO's can use an extension to the network device address to interact with it. There can be up to 240 application objects in a single ZigBee device. A ZigBee application must conform to an existing application profile which is accepted ZigBee Alliance. An application profile defines
message formats and protocols for interactions between application objects. The application profile framework allows different vendors to independently build and sell ZigBee devices that can interoperate with each other in a given application profile.

2) ZigBee Device Object: The key definition of ZigBee is the ZigBee device object, which addresses three main operations; service discovery, security and binding. The role of discovery is to find nodes and ask about MAC address of coordinator/router by using unicast messages. The discovery is also facilitating the procedure for locating some services through their profile identifiers. So profile plays an important role. The security services in this ZigBee device object have the role to authenticate and derive the necessary keys for data encryption. The network manager is implemented in the coordinator and its role is to select an
existing PAN to interconnect. It also supports the creation of new PANs. The role of binding manager is to binding nodes
to recourses and applications also binding devices to channels.

3) Application support sub layer: The Application Support (APS) sub layer provides an interface between the NWK and the APL layers through a general set of services provided by APS data and management entities. The APS sub layer processes outgoing/incoming frames in order to securely transmit/receive the frames and establish/manage the cryptographic keys. The upper layers issue primitives to APS sub layer to use its services. APS Layer Security includes the following services: Establish Key, Transport Key, Update Device, Remove Device, Request Key, Switch Key, Entity Authentication, and Permissions Configuration Table.

4) Security service provider: ZigBee provides security mechanism for network layer and application support layers, each of which is responsible for securing their frames. Security services include methods for key establishment, key transport, frame protection and device management.

E. Topologies

• Star Topology -Star topology consists of one coordinator and any number of end devices. In star topology a master-slave network model is adopted where master is the ZigBee coordinator which is FFD and slave will be either FFD or RFD. ZigBee end devices are physically and electrically separated from each other end devices and pass information through coordinator. Devices can only communicate with the coordinator. This is does not provide multi-hop networking and mesh networking.

• Cluster Tree Topology: The cluster tree topology is similar to the star topology. The difference is that other nodes can communicate with each other so that more RFD/FFDs can be connected to non-coordinator FFDs. The advantage of this topology is the possible geographical expansion of network.

• Mesh Topology: In mesh topology, each node can communicate any other node within its range. Mesh topology is complex to maintain and beaconing is not allowed here. But it is more robust and tolerance to fault.

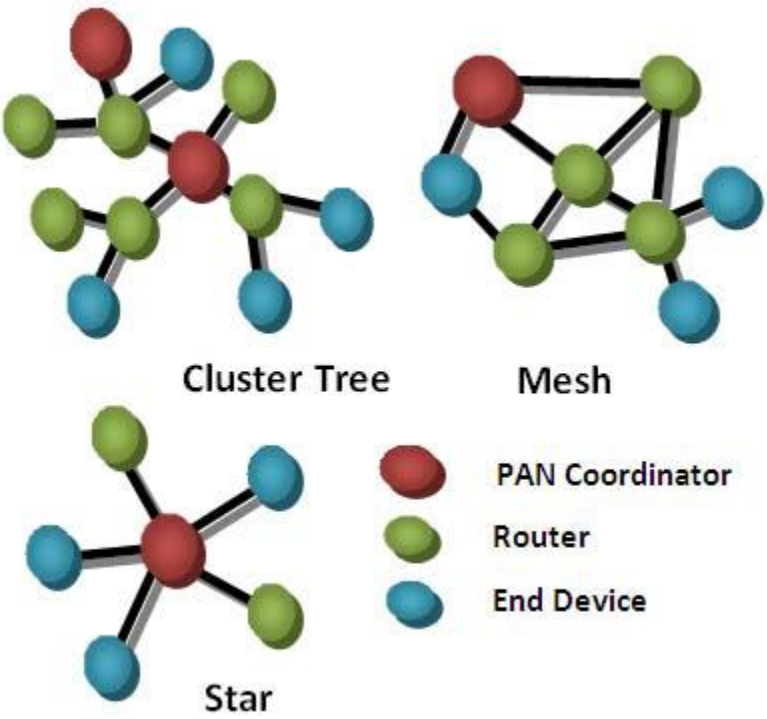


Figure 2. Topologies

V. ZIGBEE APPLICATION

Throughput of ZigBee is low rate of data transfer is about 250kbps. So this ZigBee system is useful for applications need low data rate. Some of its applications are; Home Automation and Control, Automatic Meter Reading, Residential & commercial utility systems, Building Automation, Personal health care, Body area networks, Fitness monitoring: home, gym, on-the-move, ZigBee Smart Energy, Hospital & institutional, Patient monitoring, Cable replacements, Automotive, In vehicle control: vehicular & entertainment, Status monitoring, Telecom Services.

VI. CONCLUSION

Since there are no global standards so far in wireless sensor networks, the ZigBee plays vital role in most of the wireless application. In most industries it is observed, there's an increasing demand of ZigBee based wireless applications. This paper presents description of ZigBee wireless standard. The protocol stack architecture, topologies and some of its applications are also discussed.

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