ZIGBEE: A LOW POWER WIRELESS TECHNOLOGY FOR INDUSTRIAL APPLICATIONS

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ABSTRACT:

The great potential of Wireless Sensor Network is being seen in industrial, consumer and commercial application. The wireless technology is becoming one of the most prominent areas of research. This paper focuses on the most widely used transceiver standard in Wireless Sensor Networks, a ZigBee technology. ZigBee over IEEE 802.15.4 defines specifications for low data rate WPAN (LR-WPAN) to support low power monitoring and controlling devices. This paper presents a Zigbee wireless standard, IEEE 802.15.4specification, ZigBee device types, the protocol stack architecture and its applications.

KEYWORDS:

ZigBee, IEEE802.15.4

1. Introduction

With the development of network and communication technology, the WSN has solved the inconvenience into people's life.WSN has good functions of data collection, transmission, and processing. It has many advantages compared to traditional wired network, for example, convenient organizing network, small influence to environment, low power dissipation, low cost, etc. At present, near field wireless communication technology has been used widely, especially Bluetooth, wireless local area network (WLAN), infrared, etc. But, they have a number of disadvantages, for example, complexity, large power dissipation, short distance, networking in small scale. In order to satisfy the demand of low power dissipation and low speed among wireless communication devices, a new type of wireless net technology-Zigbee emerges as the times require. Outline,of the paper is, starts with description of ZigBee and IEEE802.11.4 specifications. Next describes ZigBee device types and protocol architecture and applications based on ZigBee in conclusion.

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2. ZIGBEE AND IEEE802.11.4 SPECIFICATIONS

Zigbee Alliance was established in August, 2001,The ZigBee specification, officially named ZigBee 2007.It offers full wireless mesh networking capable of supporting more than 64,000 devices on a single network. It's designed to connect the widest range of devices, in any industry, into a single control network. The ZigBee specification has two implementation options or Feature Sets: ZigBee and ZigBee PRO. The ZigBee Feature Set is designed to support smaller networks with hundreds of devices in a single network. The ZigBee PRO Feature Set is the most popular choice of developers and the specification used for most Alliance developed ZigBee Feature Set, plus facilitates ease-of-use and advanced support for larger networks comprised of thousands of devices. Both Feature Sets are designed to interoperate with each other, ensuring long-term use and stability.The ZigBee specification enhances the IEEE 802.15.4 standard by adding network and security layers and an application framework. From this foundation, Alliance developed standards, technically referred to as public application profiles, can be used to create a multi-vendor interoperable solutions. For custom application where interoperability is not required, manufacturers can create their own manufacturer specific profiles.

Some of the characteristics of ZigBee include:

- Global operation in the 2.4GHz frequency band according to IEEE 802.15.4
- Regional operation in the 915Mhz (Americas) and 868Mhz (Europe).
- Frequency agile solution operating over 16 channels in the 2.4GHz frequency
- Incorporates power saving mechanisms for all device classes
- Discovery mechanism with full application confirmation
- Pairing mechanism with full application confirmation
- Multiple star topology and inter-personal area network (PAN) communication
- Various transmission options including broadcast
- Security key generation mechanism
- Utilizes the industry standard AES-128 security scheme
- Supports Alliance standards (public application profiles) or manufacturer specific profiles

3. ZIGBEE STANDARD DEVICE TYPES

ZigBee devices 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)[1].

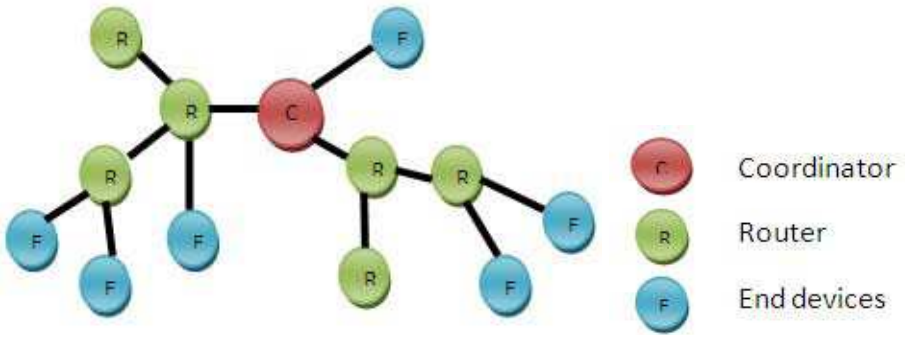

Figure1: ZigBee Network

3.1 ZigBee logical device types

There are three categories of nodes in a ZigBee system.They are Coordinator, Router and End devices.

1) Coordinator : Forms the root of the network tree and might bridge to other networks. There is exactly one coordinator in each network. It is 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 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.

3.2 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 within the standard, including routing mechanism, coordination tasks and sensing task. The FFD plays role of coordinator or router or end devices (It can be either FFD or RFD depends on its intended application). A typical FFD in a ZigBee network will be powered from an AC-fed mains supply, as it must always be active and listening to the network. Reduced Function Devices, on the other hand, implements a limited version of the IEEE 802.15.4 protocol. The RFDs do not route packets and must be associated with an FFD.

These are end devices such as sensors actuators which only doing limited tasks like recording temperature data, monitoring lighting condition or controlling external devices. The current ZigBee standard requires FFDs to be always on, which in practice means that FFDs must be constantly powered. Battery-powered FFDs have a lifetime on the order of a few days.

3.3 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 only 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 [2]. 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.

4. ZIGBEE PROTOCOL ARCHITECTURE

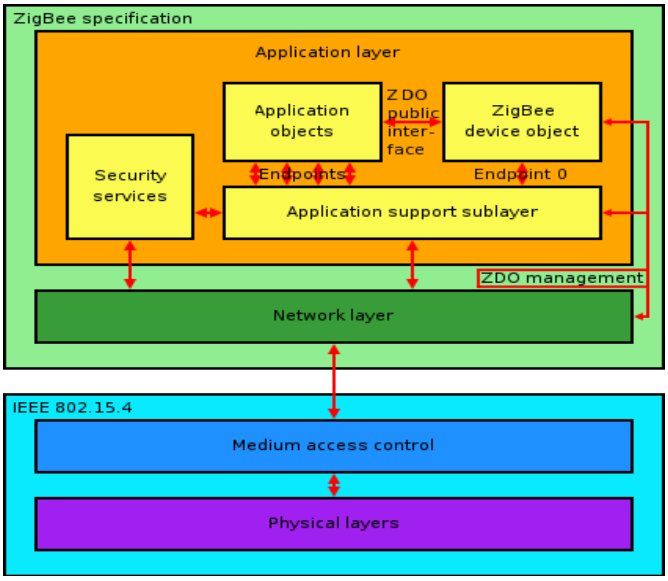

Figure 2: Zigbee protocol Architecture

4.1 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 andclear channel assessment to assist the

channel selection.Supports three frequency bands, 2.45GHz band which using16 channels, 915MHz band which using 10 channels and 868MHz band using 1 channel. All three using Direct Spread Spectrum Sequencing (DSSS) access mode.

PHY Packet Fields

- Preamble (32 bits) – synchronization
- Start of Packet Delimiter (8 bits)
- PHY Header (8 bits) – PSDU length
- PSDU (0 to 1016 bits) – Data field
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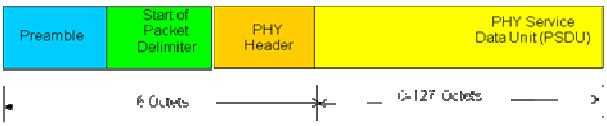

Figure 3: Packet structure

4.2 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. It is also performing association and dissociation function. It defines four frame structures, are Beacon frame, Data frame, Acknowledge frame, MAC command frame. Basically there are two types of topology; star and peer to peer. Peer to peer topology can take different shapes depends on its restrictions. Peer to peer is known as mesh, if there is no restriction. Another form is tree topology. Interoperability is one of the advantages of ZigBee protocol stack. ZigBee has wide range of applications, so different manufacturer provides ZigBee devices. ZigBee devices can interact with each other regardless of manufacturer (even I if the message is encrypted).

4.3 Network Layer

Network layer interfaces between application layer and MAC Layer. This Layer is 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, tree Network and mesh.

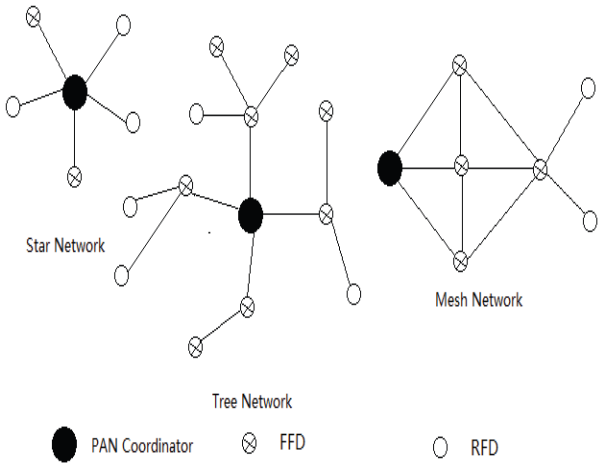

Figure 4: ZigBee topology

4.4 Application Layer

The application Layer is the highest protocol layer and it 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.

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 [6]. 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.

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 [5].

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.

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.

5. CONCLUSION

Throughput of ZigBee is low; rate of data transfer is about 250kbps. So this ZigBee system is useful for Application that needs low data rate. Some of its applications are A Design of Greenhouse Monitoring & ControlSystem Based on ZigBee Wireless Sensor Network[3], ZigBee Based Multi-Level Parking Vacancy Monitoring System[4], Design of intelligent warehouse Measure and Control System Based on Zigbee WSN[4] Research of Wireless Sensor Networks based on ZigBee for Miner Position[5] Applications of Wireless Sensor Networks in Environmental Monitoring[6]. Also the standard applications supported 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.

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