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A Review on Wireless Networking Standard-Zigbee

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Abstract - *ZigBee/IEEE 802.15.4 is a global hardware and software standard designed for WSN requiring high reliability, low cost, low power, and low data rate. It has been developed to meet the growing demand for capable WPAN between numerous low-power devices. This new level of communications allows finely-tuned remote monitoring and controlling. Such way the manual operations are replaced by automatic systems to perform efficient communication. ZigBee is an IEEE 802.15.4 standard for data communication with business and consumer devices. It employs a suite of technologies to enable scalable, self-organizing, self healing networks that can manage various data traffic standards. In this paper the concept of Zigbee, its advantages and applications are discussed.*

Key Words: **Zigbee, IEEE 802.15.4, Zigbee protocol stack, zigbee network topologies.**

1. INTRODUCTION

The ZigBee technology was introduced by the ZigBee Alliance. Zigbee Alliance is an association of companies working together to define an open global standard for making low-power wireless networks [1]. The ZigBee protocol was developed to provide low-power, wireless connectivity for a wide range of network applications concerned with monitoring and control. The ZigBee standard builds on the established IEEE 802.15.4 standard for packet based wireless transport. ZigBee enhances the functionality of IEEE 802.15.4 by providing flexible, extendable network topologies with integrated set-up and routing intelligence to facilitate easy installation and high resilience to failure.

The ZigBee standard takes full advantage of the IEEE 802.15.4 physical radio specification and operates in unlicensed bands worldwide at the following frequencies: 2.400–2.484 GHz, 902-928 MHz and 868.0–868.6 MHz. The ZigBee protocol was designed to carry data through the hostile RF environments that routinely exist in commercial and industrial applications. A key component of the Zigbee protocol is the ability to support wireless mesh networks form to transmit data over longer distances, passing data through intermediate devices to reach more distant ones[2].

1.1 Why named ZigBee?

ZigBee takes its name from the zigzag flying of bees that forms a mesh network among flowers. It is an individually simple organism that works together to tackle complex tasks. The technique that honey bees use to communicate new-found food sources to other members of the colony is referred to as the ZigBee principle.

1.2 ZigBee and ZigBee PRO

ZigBee is robust mesh network defined by the core ZigBee specification. It is an innovative, self healing, self-configuring system, with battery-free nodes that provide ease of use, flexibility and mobility [3]. ZigBee / ZigBee Pro are mesh communication protocols that sits on top of IEEE 802.15.4 PHY. ZigBee PRO is an enhancement of the original ZigBee protocol, providing a number of extra features that are particularly useful for very large networks (that may include hundreds or even thousands of nodes). The new innovative feature of ZigBee PRO is the Green Power which supports energy harvesting devices without external power supplies.

1.3 Digi XBee & XBee-PRO Modules

Digi is a member of the ZigBee Alliance and has developed OEM solutions based on the ZigBee architecture. XBee / XBee Pro are product names for radio communications modules made by Digi. The XBee and XBee-PRO modules provide an easy-to-implement solution and a powerful boost to range and reliability to companies looking to offer ZigBee.

2. ZIGBEE PROTOCOL STACK

ZigBee stack architecture follows the standard OSI model; ZigBee's protocol stack is structured in layers. The first two layers, physical (PHY) and media access (MAC), are defined by the IEEE 802.15.4 standard. The layers above them are defined by the ZigBee Alliance. The model has five layers namely: Physical (PHY) layer, Media access control (MAC) layer, Network (NWK) and security layers, Application framework, Application profiles as shown in Fig 1.

The top layer in zigbee protocol stack is the Application layer; it includes an Application Support Sub-layer (APS), the ZigBee Device Object (ZDO), and the ZigBee applications defined by the user or designer. Whereas the ZDO is responsible for overall device management, the APS provides servicing to both ZDO and ZigBee applications. ZDO contains a ZigBee Device Profile (ZPD) that can be considered as another ZigBee application profile but designed for network management and not to exchange application specific data. ZDP provides formats for command requests and responds necessary to support networking functionality common for all devices in a ZigBee network.

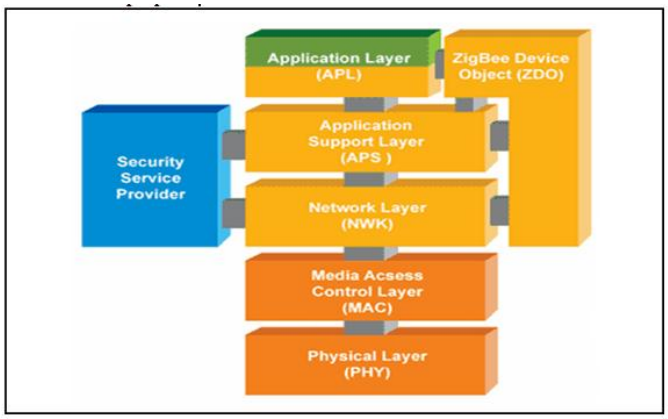

Fig -1: Structure of ZigBee protocol stack

The **NWK layer** provides routing and multi-hop functions needed for creating different network topologies. The IEEE802.15.4 MAC **Media access control layer** permits use of several topologies without introducing complexity and is meant to work with large numbers of devices. The IEEE802.15.4 PHY **Physical layer** accommodates high levels of integration by using direct sequence to permit simplicity in the analog circuitry and enable cheaper implementations.

3. ZIGBEE DEVICE TYPES

ZigBee networks use three device types:

1. **The network coordinator** maintains overall network knowledge. It's the most sophisticated of the three types and requires the most memory and computing power.
2. **The full function device (FFD)** supports all 802.15.4 functions and features specified by the standard. It can function as a network coordinator. Additional memory and computing power make it ideal for network router functions or it could be used in network-edge devices (where the network touches the real world).
3. **The reduced function device (RFD)** carries limited (as specified by the standard) functionality to lower cost and complexity. It's generally found in network-edge devices.

4. ZIGBEE NETWORK TOPOLOGIES

Three Types of topologies that ZigBee supports: star topology, peer-to-peer topology and cluster tree as shown in fig 2.

1) **Star Topology:** In the star topology, the communication is established between devices and a single central controller, called the PAN coordinator. The PAN coordinator may be mains powered while the devices will most likely be battery powered. Applications that benefit from this topology include home automation, personal computer (PC) peripherals, toys and games. After an FFD is activated for the first time, it may establish its own network and become the PAN coordinator. Each start network chooses a PAN identifier, which is not currently used by any other network within the radio sphere of influence. This allows each star network to operate independently.

2) **Peer-to-peer Topology: In** peer-to-peer topology, there is also one PAN coordinator. In contrast to star topology, any device can communicate with any other device as long as they are in range of one another. A peer-to-peer network can be ad hoc, self-organizing and self-healing. Applications such as industrial control and monitoring, wireless sensor networks, asset and inventory tracking would benefit from such a topology. It also allows multiple hops to route messages from any device to any other device in the network. It can provide reliability by multipath routing.

3) **Cluster-tree Topology:** Cluster-tree network is a special case of a peer-to-peer network in which most devices are FFDs and an RFD may connect to a cluster-tree network as a leave node at the end of a branch. Any of the FFD can act as a coordinator and provide synchronization services to other devices and coordinators.

Only one of these coordinators however is the PAN coordinator. The PAN coordinator forms the first cluster by establishing itself as the cluster head (CLH) with a cluster. identifier (CID) of zero, choosing an unused PAN identifier, and broadcasting beacon frames to neighboring devices. A candidate device receiving a beacon frame may request to join the network at the CLH.

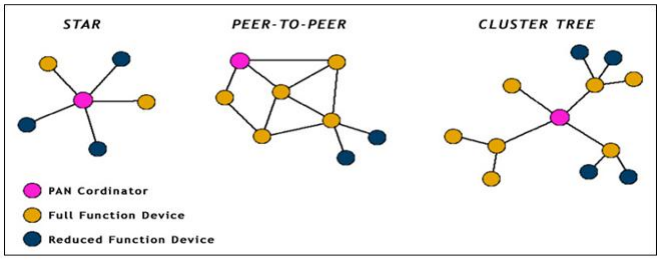

Fig -2: **Zigbee Topology**

5. TRAFFIC TYPES

ZigBee/IEEE 802.15.4 addresses three typical traffic types. IEEE 802.15.4 MAC can accommodate all the types.

1) **Data is periodic:**The application dictates the rate, and the sensor activates check for data and deactivates.

2) **Data is intermittent:** The application, or other stimulus, determines the rate, as in the case of say smoke detectors. The device needs to connect to the network only when communication is necessitated. This type enables optimum saving on energy.

3) **Data is repetitive, and the rate is fixed a priori**: Depending on allotted time slots, called GTS (guaranteed time slot), devices operate for fixed durations ZigBee employs either of two modes, beacon or non-beacon to enable the to-and-fro data traffic. Beacon mode is used when the coordinator runs on batteries and thus offers maximum power savings, whereas the non-beacon mode finds favor when the coordinator is mains-powered.

6. ZIGBEE SECURITY

ZigBee's security services include methods for key establishment and transport, device management, and frame protection. The ZigBee specification defines security for the MAC, NWK and APS layers. Security for applications is typically provided through Application Profiles.
Security and data integrity are key benefits of the ZigBee technology. ZigBee leverages the security model of the IEEE 802.15.4 MAC sub layer which specifies four security services:

- access control—the device maintains a list of trusted devices within the network
- data encryption, which uses symmetric key 128-bit advanced encryption standard
- frame integrity to protect data from being modified by parties without cryptographic keys
- sequential freshness to reject data frames that have been replayed—the network controller compares the freshness value with the last known value from the device and rejects it if the freshness value has not been updated to a new value .

There are three keys that need to be considered:
• **Master key-** They are preinstalled in the device/ node. Their function is to keep the link keys exchange confidential in the Key Establishment procedure.
• **Link keys-** These are unique in each node and are managed by the application layer. More memory resources are required because there is a need for encrypting the information shared between two devices.
• **Network Key-** It's a key that is shared among all the nodes in the network. It is generated at different intervals. Only if the node has the network key they can join the network. The new network key is shared using the old network key.

There are two policies that the trust centre (the one which generates the network key) follow:
• **Commercial mode:** Shares the master and link keys with any devices in the network.
• **Residential mode:** Share only the Network key (this is done in order to cope with low memory resources).

7. ZIGBEE ADVANTAGE

The ZigBee protocol was designed to carry data through the hostile RF environments that routinely exist in commercial and industrial applications.
ZigBee protocol features:

- Low duty cycle - Provides long battery life
- Low latency
- Support for multiple network topologies: Static, dynamic, star and mesh
- Direct Sequence Spread Spectrum (DSSS)
- Up to 65,000 nodes on a network
- 128-bit AES encryption – Provides secure connections between devices
- Collision avoidance
- Link quality indication
- Clear channel assessment
- Retries and acknowledgements
- Support for guaranteed time slots and packet freshness

8. ZIGBEE APPLICATION

ZigBee is the wireless technology that:

- Enables broad-based deployment of wireless networks with low cost, low power solutions.
- Provides the ability to run for years on inexpensive primary batteries for a typical monitoring application.
- Addresses the unique needs of remote monitoring & control, and sensory network applications.

Fig 3. shows the ZigBee application areas. However, ZigBee technology is well suited to a wide range of building automation [4], industrial automation [5], medical [6] and residential control & monitoring applications [7] [8]. Essentially, applications that require interoperability and/or the RF performance characteristics of the IEEE 802.15.4 standard would benefit from a ZigBee solution.

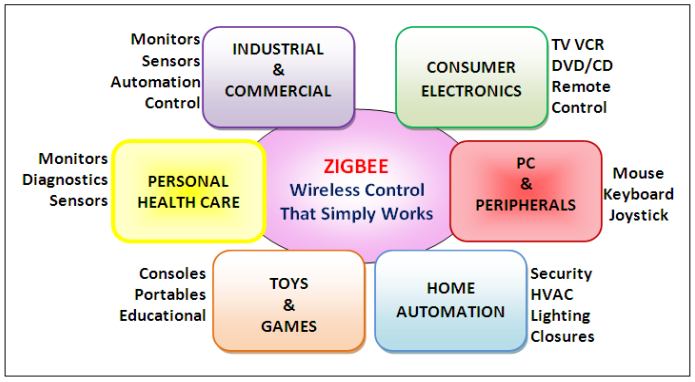

Fig -3: ZigBee application areas

9. CONCLUSIONS

Zigbee is the only open, global wireless standard to provide the foundation for the internet of things by enabling simple and smart object to work together, improving comfort and efficiency in everyday life. The zigbee standard provides network, security and application support services operating on top of the IEEE 802.15.4 MAC and PHY wireless standard. These networks are easy to deploy which is cheaper as compared to other technologies. This new level of communications allows finely-tuned remote monitoring and controlling. Such way the manual operations are replaced by automatic systems to perform efficient communication. In this paper the basic concept of ZigBee protocol in terms of its network topologies, architecture in terms of protocol stack, its advantages and applications are discussed.

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