A SURVEY ON ZIGBEE TECHNOLOGY

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ABSTRACT

The IEEE 802.15.4 is a new standard defined for LR-WPAN which provides a low cost and very less complicated solution. ZigBee is the name of a specification for a suite of high level communication protocols using small, low power digital radios based on the IEEE 802.15.4 standard. It is designed for low power consumption enabling batteries to last forever. The ZigBee standard provides network, security, and application support services operating on top of the IEEE 802.15.4 Medium Access Control (MAC) and Physical Layer wireless standard. It employs a group of technologies to enable scalable, self-organizing, self-healing networks that can manage various data traffic patterns. ZigBee is a low-cost, low-power, wireless mesh networking standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications, the low power-usage allows longer life with smaller batteries, and the mesh networking which promises high reliability and larger range. ZigBee has-been developed to meet the growing demand for capable wireless networking between numerous low power devices. In industry. This paper focuses on ZigBee as a technology innovation which would bring about low cost connectivity. This paper also contains the comparative study on different energy efficient routing protocols for ZigBee network, where authors have compared different routing protocols considering different performance metrics to find the most energy efficient routing protocol.

Keywords : ***IEEE802.15.4, LR-WPAN, Mesh, Protocol, Zigbee Protocol***

I. INTRODUCTION

An LR-WPAN is a simple, low-cost communication network that allows wireless connectivity in applications with limited power and relaxed throughput requirements. The main objectives of an LR-WPAN are ease of installation, reliable data transfer, short-range operation, extremely low cost, and a reasonable battery life, while maintaining a simple and flexible protocol. ZigBee is a specification for a suite of high level communication protocols using tiny, low-power digital radios based on an IEEE 802 standard for personal area networks. ZigBee has a defined rate of 250 Kbit/s best suited for periodic or irregular data or a single signal transmission from a sensor or input device. ZigBee based traffic management system have also been implemented[1] . The name refers to the waggle dance of honey bees after their return to the beehive. ZigBee is a low-cost, low-power, wireless mesh network standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications. Low power-usage allows longer life with smaller batteries. Mesh networking provides high reliability and more extensive range. ZigBee chip vendors typically sell integrated radios and microcontrollers with between 60 KB and 256 KB flash memory. The ZigBee network layer natively supports both star and tree typical networks, and generic mesh networks. As shown in figure 1. Every network must have one coordinator device, tasked with its creation, the control of its parameters and basic maintenance. In star networks, the coordinator must be the central node. Both trees and meshes allow the use of ZigBee routers to extend communication at the network level.

Need for ZIGBEE

1) There are a multitude of standards that address mid to high data rates for voice, PC LANs, video, etc. However, up till now there hasn't been a wireless network standard that meets the unique needs of sensors and control devices. Sensors and controls don't need high bandwidth but they do need low latency and very low energy consumption for long battery lives and for large device arrays [2].

2) There are a multitude of proprietary wireless systems manufactured today to solve a multitude of problems that also don't require high data rates but do require low cost and very low current drain.

3) These proprietary systems were designed because there were no standards that met their requirements. These legacy systems are creating significant interoperability problems with each other and with newer technologies

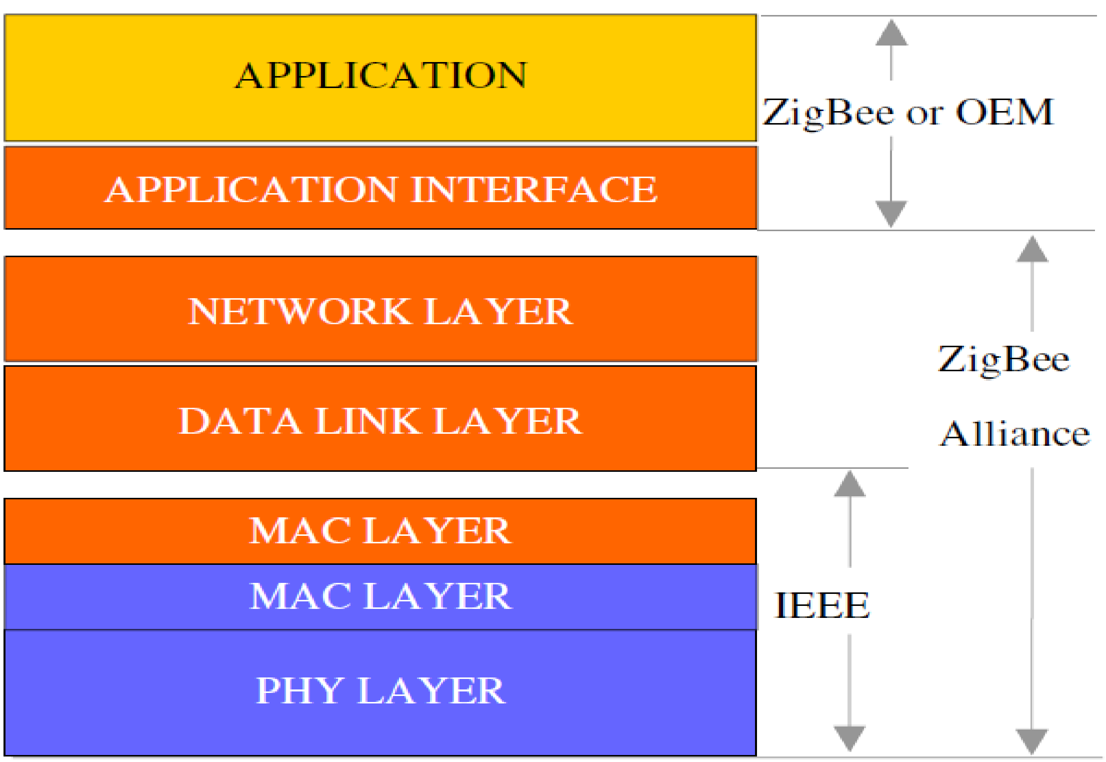
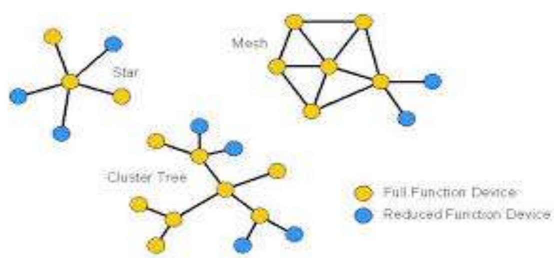


Fig 5.1 ZigBee's Protocol Stack

II. OVERVIEW OF IEEE802.15.4 STANDARD BASED ZIGBEE

2.1 Network topology

An IEEE 802.15.4 LR-WPAN [3], mainly three types of network topologies is supported. In the star topology network, all communications, even those between the devices themselves, must go through the PAN coordinator. In the peer-to-peer topology, the devices can communicate with one another directly, but the PAN coordinator must be present. Cluster tree is the combination of both star and the mesh networks, so it has the properties of both topologies. Network topologies are shown in figure 2.



III. ZIGBEE DEVICE TYPES, PROTOCOLS AND ADVANTAGES

3.1 Device Types

Zigbee devices are of three types:

1) ZigBee coordinator (ZC): The most capable device, the coordinator forms the root of the network tree and might bridge to other networks. There is exactly one ZigBee coordinator in each network since it is the device that started the network originally. It stores information about the network, including acting as the Trust Center & repository for security keys.

2) ZigBee Router (ZR): As well as running an application function, a router can act as an intermediate router, passing on data from other devices.

3) ZigBee End Device (ZED): Contains just enough functionality to talk to the parent node (either the coordinator or a router); it cannot relay data from other devices. This relationship allows the node to be asleep a significant amount of the time thereby giving long battery life. A ZED requires the least amount of memory, and therefore can be less expensive to manufacture than ZR or ZC.

3.2 Protocols

The protocols build on recent algorithm (Ad-hoc On-demand and Distance vector, nueRFon) to automatically construct a low-speed ad-hoc network of nodes[4]. In most large network instances, the network will be a cluster of clusters. It can also form a mesh or a single cluster. The current ZigBee protocols support beacon and non-beacon enabled networks. In nonbeacon-enabled networks, an unslotted CSMA/CA channel access mechanism is used. In this type of network, ZigBee Routers typically have their receivers continuously active, requiring a more robust power supply. However, this allows for heterogeneous networks in which some devices receive continuously, while others only transmit when an external stimulus is detected. The typical example of a heterogeneous network is a WIRELESS SWITCH: The ZigBee node at the lamp may receive constantly, since it is connected to the mains supply, while a battery-powered light switch would remain asleep until the switch is thrown. The switch then wakes up, sends a command to the lamp, receives an acknowledgment, and returns to sleep. In such a network the lamp node will be at least a ZigBee Router, if not the ZigBee Coordinator; the switch node is typically a ZigBee End Device. In beacon-enabled networks, the special network nodes called ZigBee Routers transmit periodic beacons to confirm their presence to other network nodes. Nodes may sleep between beacons, thus lowering their duty cycle and extending their battery life. Beacon intervals depend on data rate; they may range from 15.36 milliseconds to 251.65824 seconds at 250 Kbit/s, from 24 milliseconds to 393.216 seconds at 40 Kbit/s and from 48 milliseconds to 786.432 seconds at 20 Kbit/s.

ZigBee/IEEE 802.15.4 - General Characteristics

1) Dual PHY (2.4GHz and 868/915 MHz) , Data rates of 250 kbps (@2.4 GHz), 40 kbps (@ 915 MHz), and 20 kbps (@868 MHz) , Optimized for low duty-cycle applications (<0.1%) ,CSMA-CA channel access.

2) Yields high throughput and low latency for low duty cycle devices like sensors and controls

3) Low power (battery life multi-month to years)

4) Multiple topologies: star, peer-to-peer, mesh

5)Addressing space of up to:18,450,000,000,000,000,000 devices (64 bit IEEE address) and 65,535 networks

6)Optional guaranteed time slot for applications requiring low latency

7)Fully hand-shaked protocol for transfer reliability

8) Range: 50m typical (5-500m based on environment)

3.3 Advantages of Zigbee

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

1)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. Application software needs to focus on the application, not on which power mode is optimum for each aspect of operation

2)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 [5].

3) 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.

4) 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.

IV. FORMING ZIGBEE NETWORK AND ARCHITECTURE

The Co-ordinator is responsible for starting a ZigBee network. Network initialization involves the following steps:

1. Search for a Radio Channel-The Co-ordinator first searches for a suitable radio channel (usually the one which has least activity). This search can be limited to those channels that are known to be usable - for example, by avoiding frequencies in which it is known that a wireless LAN is operating[6], [7].

2. Assign PAN ID- The Co-ordinator starts the network, assigning a PAN ID (Personal Area Network identifier) to the network. The PAN ID can be pre-determined, or can be obtained dynamically by detecting other networks operating in the same frequency channel and choosing a PAN ID that does not conflict with theirs. At this stage, the Co-ordinator also assigns a network (short) address to itself. Usually, this is the address 0x0000

3. Start the Network- The Co-ordinator then finishes configuring itself and starts itself in Co-ordinator mode. It is then ready to respond to queries from other devices that wish to join the network

4.1 ZigBee Stack Architecture

The ZigBee standard defines a stack shown in figure 3 which has a layered structure with four distinct layers, the physical layer, the MAC layer, the network layer and the application layer. The two lowest layers are defined by the IEEE 802.15.4 standard [3]. This standard defines a protocol for wireless device to be low-power consuming. The IEEE 802.15.4 standard

defines how to associate to a coordinator, disassociate from a coordinator and how to send messages between an end device and a coordinator. The network layer is the lowest layer defined by the ZigBee standard which provides network configuration, manipulation, and message routing. An application layer provides the intended function of the device.

The PHY [3] provides two services: the PHY data service and the PHY management service interfacing to the physical layer management entity (PLME) service access point (SAP) (known as the PLME-SAP). The PHY data service enables the transmission and reception of PHY protocol data units (PPDUs) across the physical radio channel. The features of the PHY are activation and deactivation of the radio transceiver, ED, LQI, channel selection, clear channel assessment (CCA), and transmitting as well as receiving packets across the physical medium. The radio operates at one or more of the unlicensed frequency bands of 868–868.6 MHz (e.g., Europe), 902–928 MHz (e.g., North America), 2400–2483.5 MHz (worldwide).

The MAC sub layer [3] provides two services: the MAC data service and the MAC management service interfacing to the MAC sublayer management entity (MLME) service access point (SAP) (known as MLME-SAP). The MAC data service enables the transmission and reception of MAC protocol data units (MPDUs) across the PHY data service. The features of the MAC sublayer are beacon management, channel access, GTS management, frame validation, acknowledged frame delivery, association, and disassociation

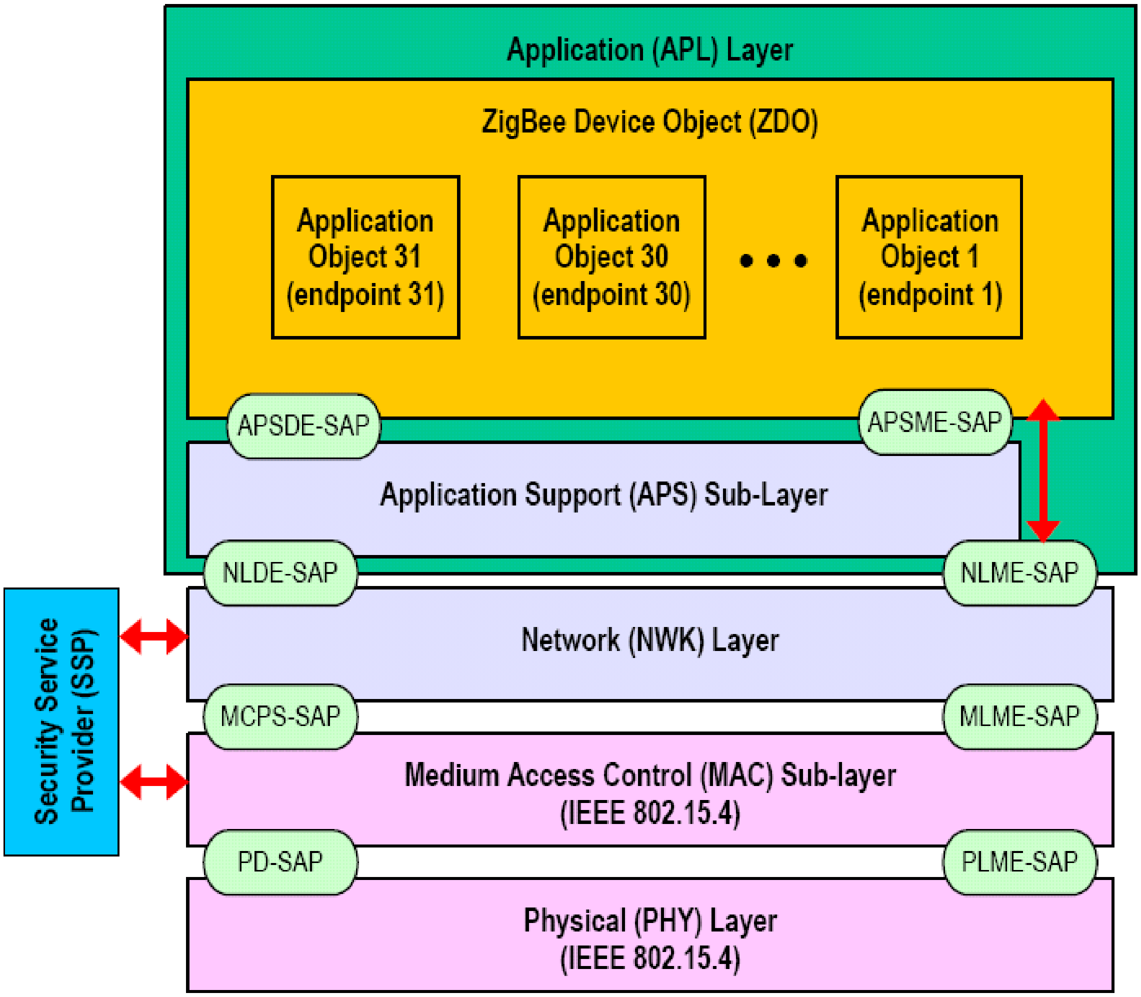


Fig 3. Layered architecture of Zigbee

V. COMPARATIVE STUDY ON DIFFERENT ENERGY EFFICIENT ROUTING PROTOCOLS

YiGong Peng et al. [8] have proposed an energy-aware routing mechanism EA-AODV which was the improvement and perfection of ZigBee-AODVjr, maximizes the use of the limited energy and prolong the lifetime of ZigBee network. In order to analyze the efficiency of the proposed mechanism, YiGong Peng et al. [9] have compared the EA-AODV results with original AODV-jr using the same scenarios. The simulation results shows that the method about EA-AODV is feasible for saving energy and could improve the performance of ZigBee network as compare to AODVjr.

Jun Xiao et al. [10] have introduced an improved E-AOMDVjr algorithm over the traditional AODVjr algorithm based on the on-demand distance vector routing (AODV) algorithm. The proposed E-AOMDVjr algorithm is based on the AOMDV algorithm applicable for Ad hoc network. Jun Xiao et al. [10], adopting the energy balance algorithm shows that the improved algorithm can improve the reliability of the network transmission, reduce the energy consumption of the network and can also extend the lifetime of the network.

Zhao Hong-tu et al. [11] have combined the traditional AODVjr and the Cluster- Tree algorithm to get an optimal improved algorithm which deals the problems like RREQ packets flooding in AODVjr and the non optimal routing in Cluster- Tree as some nodes may use up all the energy because of heavy transmissions. They have presented an improved algorithm based on the traditional AODVjr algorithm combined with Cluster- Tree algorithm. The simulation results shows that the algorithm have saved the network's overall energy consumption by controlling the PREQ packet, residual energy of the node during data transfer and also considering the neighbor table.

Juan-Carlos Cano et al. [12] have offered a performance comparison of the Ad-hoc on demand Distance Vector (AODV) [13], Direct Source Routing (DSR) [14], Temporally-Ordered Routing Algorithm (TORA) [15] and Destination-Sequenced Distance-Vector Routing (DSDV) [d]. In their work, they have evaluated and compared the behavior of these four routing protocols in terms of energy consumption. After comparing the four routing protocols, they concluded that with respect to energy consumption, DSR and AODV perform better as compare to DSDV and TORA.

Liu Dan et al. [16] have proposed an improved tree routing algorithm (NTR) over the traditional tree routing by using the neighbor table. Authors have made the comparison between NTR and traditional TR performance by doing the Simulation in NS-2 and shown that by using the neighbor table, the packet reaches the destination with the less hops without the coordinator. So the end to end delay is reduced and the energy of the coordinator is saved at the same time.

M.Al-Harbawi et al. [17] introduces an enhanced TR protocol called Improved Tree Routing (ImpTR) protocol. In TR protocol, the packets follow the tree topology for forwarding the data to the descend node only. The new ImpTR protocol determines the shortest path to the descend node on the basis of neighbor table instead of using the tree topology. The packets are forwarded to the neighbor node if the path to the destination through neighbor node is shorter than the path through PAN coordinator. Simulation Results of NS-2 shows that the proposed ImpTR algorithm provides lesser average end-to-end delay, increased throughput, decreased energy consumption from the network and end to end delay as compare to traditional TR routing protocol

5.1 Comparative analysis of different technologies providing similar services and their trade-offs

Category	ZigBee	Bluetooth	Wi-Fi
Distance	50-1600m	10m	50m
Extension	Automatic	None	Depend on the existing network
Power supply	Years	Days	Hours
Complicity	Simple	Complicated	Very complicated
Transmission speed	250Kbps	1Mbps	1-54Mbps
Frequency range	868MHz, 916Mhz, 2.4GHz	2.4GHz	2.4GHz
Network nodes	65535	8	50
Linking time	30ms	Up to 10s	Up to 3s
Cost of terminal unit	Low	Low	High
Cost of use	None	None	None
Security	128bit AES	64bit, 128bit	SSID
Integration level& reliability	High	High	Normal
Prime cost	Low	Low	Normal
Ease of use	Easy	Normal	Hard

1 Features
http://bbs.cechina.cn/showtopic.aspx?id=25736 (Chinese)

VI. CONCLUSION

It is likely that ZigBee will increasingly play an vital role in the future of computer and communication technology. In terms of protocol stack size, ZigBee's 32 KB is about one third of the stack size necessary in other wireless technologies. The IEEE 802.15.4–based ZigBee is designed for remote controls and sensors, which are very many in number, but need only small data packets and, extremely low power consumption for longer life. Therefore they are naturally different in their approach to their respective application arenas. ZigBee and the underlying 802.15.4 communications technology could form the basis of future wireless sensors, offering data reliability, long battery life, lower system costs, and good range through flexible networking. This paper presents the overview of ZigBee protocol in terms of its network topologies, architecture, and the functional overview. This paper also contains the comparative study on different energy efficient routing protocols for ZigBee network, where authors have compared different routing protocols considering different performance metrics to find the most energy efficient routing protocol.

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