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8.A Review of high speed data communication over Zigbee Networks

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Abstract

The cellular network was a natural extension of the wired telephony network that became pervasive during the mid-20th century. As the need for mobility and the cost of laying new wires increased, the motivation for a personal connection independent of location to that network also increased. Coverage of large area is provided through (1-2km) cells that cooperate with their neighbors to create a seemingly seamless network. ZigBee is an established for wireless personal area networking (WPAN), i.e., digital radio connections between computers and related devices. This kind of network eliminates use of physical data buses like USB and Ethernet cables. The devices could include telephones, hand-held digital assistants, sensors and controls located within a few meters of each other. ZigBee is one of the global standards of communication protocol formulated by the relevant task force under the IEEE 802.15.4.[2] The fourth in the series, WPAN Low Rate/ZigBee is the newest and provides specifications for devices that have low data rates, consume very low power and are thus characterized by long battery life. Other standards like Bluetooth and IrDA address high data rate applications such as voice, video and LAN communications.

The IEEE 802.11 working group for WLANs is formed to create a wireless local area network standard. Whereas IEEE 802.11 was concerned with features such as Ethernet matching speed, long range(100m), complexity to handle seamless roaming, message forwarding, and data throughput of 2-11Mbps, WPANs are focused on a space around a person or object that typically extends up to 10m in all directions. WPAN's are currently defined three classes of WPANs that are differentiated by data rate, battery drain and quality of service(QoS). The high data rate WPAN(IEEE 802.15.3) is suitable for multi-media applications that require very high QoS. Medium rate WPANs (IEEE 802.15.1/Blueetooth) will handle a variety of tasks ranging from cell phones to PDA communications and have QoS suitable for voice communications.

Key words: Zigbee, WPAN,IEEE 802.15.4

1.INTRODUCTION

1.1 ZigBee, Bluetooth or Wi-Fi?

ZigBee, Bluetooth and Wi-Fi are all relatively new wireless technologies. The key comparison points are shown in table 1.[1] Essentially, ZigBee is best suited for low-cost, low data rate and battery powered applications. Point-to-point range is limited, but mesh networking provides an alternative stepping-stone approach to communicating over large distances. Where a PC or cellphone is involved, there is some overlap between Bluetooth and ZigBee. For example, either technology could be used for activating your garden lights from your cellphone. ZigBee can do the job more cheaply, but Bluetooth is more likely to be compatible with the phone you have in your pocket today. Where you don't want to go with ZigBee is time-critical, high data rate applications such as audio and video links.

Network	Wi-Fi	Bluetooth	Zigbee
Frequency bands	2.4GHz	2.4GHz	2.4GHz 868/915 MHz
Stack Size	1Mb	1 Mb	20 Kb
Raw data rate	11 Mbps	1Mbps	250kbps,(2.4GHz) 40kbps (915MHz) 20kbps (868MHz)
Number of Channels	11-14	79	16 (2.4GHz) 10 (915MHz) 1 (868MHz)
Data types	Digital	Digital Audio	Digital Key-Value Pairs
Inter –node range	100m	10m-100m	10m-100m
# of devices	32	8	255/65535
Power requirements	Medium- hours on one battery	Medium – days on one battery	Very low-years on one battery
Current market penetration	High	Medium	None
Architectures	Star	Star	Star, Tree, Cluster
Best Applications	Internet inside buildings	Computer& phone peripherals	Low cost control and monitoring

Table 1 : Comparison of Wireless Technologies

1.2 Zigbee Standard

When two devices bind, the output cluster of one device is connected with the input cluster of another device. For example, the light sensor has one output cluster (Output:LightLevelLSM), and the switching load controller has the same cluster as input (Input:LightLevelLSM), thus the two devices can bind, ensuring that the light sensor will supply the switching load controller with periodical light sensor readings.

Binding can either be initiated by a coordinator/ router directly, making the binding entry, or by the end devices themselves. The latter approach is known as simple binding, and is generally initiated by the press of a button on both of the two end devices wishing to bind two application objects. When two bound application objects communicate, they do so via indirect addressing. The message is passed through the coordinator which identifies the recipient using the source address, source endpoint and cluster identifier. This way end devices need no knowledge of the addresses of the device(s) used in the communication.

To minimize power consumption (using duty cycling), end devices turn off their radio when it is not needed, e.g. after having binded. As messages can be sent to an end device at any time, the coordinator, with which the end device is joined, receives messages on behalf of the sleeping end devices. When an end device wakes up and is ready to receive a message, the end device polls the coordinator for available messages.

1.3 Descriptors

To describe the capabilities of devices within a network, the ZigBee protocol defines three mandatory descriptors: the node, power and simple descriptor.

A descriptor is a set of attributes that other devices can request in order to obtain information about a device, e.g. the remaining power level or the services provided. The three descriptors are characterized by:

• **Node Descriptor** _ A node has one node descriptor which describes the type and capabilities of the node. The type of a node is coordinator, router or end device. The capabilities of a node are properties such as frequency band, maximum buffer size, whether the receiver is on at all times or not, etc.

• **Power Descriptor**_ A node has one power descriptor which describes the current power source in use, current power source level, etc.

• **Simple Descriptor** _ A node has one simple descriptor for each endpoint. The simple descriptor holds information about the application residing on an endpoint. This includes the profile identifier, the number of input and output clusters, etc.

ZigBee protocol stack is illustrated in Figure 1. The two lower layers are defined by the IEEE 802.15.4 standard while the remaining two layers are defined by the ZigBee Alliance:

1. The Physical (PHY) Layer is the lowest layer and is de_ned in the IEEE 802.15.4 standard [3]. It consists of two PHY-layers, operating in two separate frequency ranges: 868/915 MHz and 2.4 GHz.

2. The Medium Access Control (MAC) Layer is defined in the IEEE 802.15.4 standard [3]. The responsibility of the MAC layer is to control access to the radio channel using CSMA/CA8. The MAC layer provides support for transmitting beacon frames, network synchronization and reliable transmission using CRC and retransmissions.

3. The Network (NWK) Layer defined by the ZigBee Alliance [7], sends and receives data to and from the application layer. Furthermore, it performs the task of associating to and disassociating from a network, applying security and (on ZigBee coordinators) starting networks and assigning addresses. These services are provided through two interfaces the Network Layer Management Entity Service Access Point (NLME-SAP) and the Network Layer Data Entity Service Access Point (NLDE-SAP).

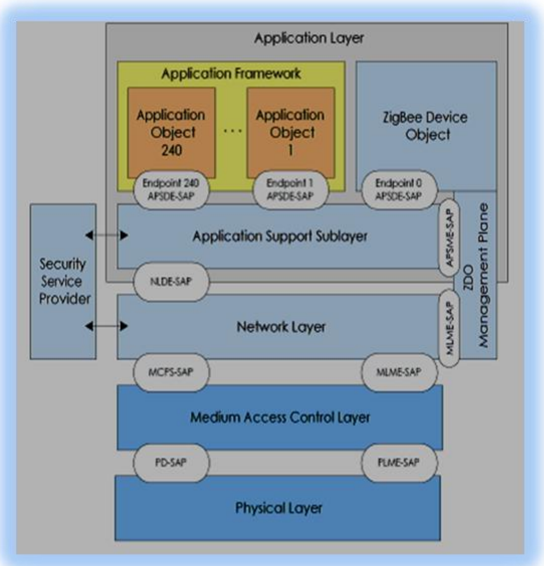


Figure 1: Standard Zigbee Network

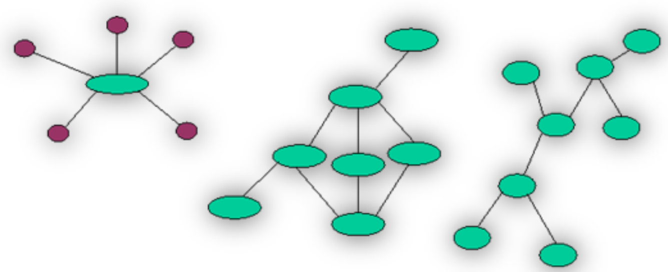
4. The Application (APL) Layer is the top layer, and is defined by the ZigBee Alliance. It consists of the Application Support Sublayer (APS) [6], the ZigBee Device Object (ZDO) [8] and the Application Objects implemented on the given device:

(a) The Application Support Sublayer (APS) provides two interfaces the APS Management Entity Service Access Point (APSME-SAP) and the APS Data Entity Service Access Point (APSDE-SAP). The former is used to implement security, and by the ZDO of coordinators to retrieve information from the APS layer, while the latter is used by the application objects and the ZDO to send data.

(b) The ZigBee Device Object (ZDO) provides an interface to the Application Objects used for discovering other devices and the services provided by these. Furthermore the ZDO sends responses to other devices requesting information about the device itself and the services provided by it. To support this, the ZDO uses the APSDESAP of the APS layer and the NLME-SAP of the NWK layer. The ZDO is a special Application Object, implemented on endpoint 0.

(c) Application Objects are the actual manufacturer applications running on top of the ZigBee protocol stack. Endpoints, in conjunction with the address of the device, provide a uniform and unambiguous way of addressing individual application objects in the ZigBee network.

2. ZIGBEE TOPOLOGIES



STAR
PEER TO PEER
CLUSTER

Figure 2.1: Different network topology in Zigbee

IEEE 802.15.4WPAN

The main features of this standard are network flexibility, low cost, very low power consumption, and low data rate in an adhoc self-organizing network among inexpensive fixed, portable and moving devices [11]. It is developed for applications with relaxed throughput requirements which cannot handle the power consumption of heavy protocol stacks.

2.1 Components of WPAN

A ZigBee system consists of several components. A device can be a full-function device (FFD) or reduced-function device (RFD). A network shall include at least one FFD, operating as the PAN coordinator.

The FFD can operate in three modes: a personal area network (PAN) coordinator, a coordinator or a device. An RFD is intended for applications that are extremely simple and do not need to send large amounts of data. An FFD can talk to RFDs or FFDs while an RFD can only talk to an FFD.

2.2 Network Topologies

Figure 2.1 shows 3 types of topologies that ZigBee supports: star topology, peer-to-peer topology and cluster tree.[12]

2.2.1 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.

2.2.2 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.

2.2.3 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. If the PAN coordinator permits the device to join, it will add this new device as a child device in its neighbor list. The newly joined device will add the CLH as its parent in its neighbor list and begin transmitting periodic beacons such that other candidate devices may then join the network at that device. Once application or network requirements are met, the PAN coordinator may instruct a device to become the CLH of a new cluster adjacent to the first one. The advantage of this clustered structure is the increased coverage area at the cost of increased message latency.

3. ROUTING PROTOCOL

3.1 Cluster-Tree Algorithm

The cluster-tree protocol is a protocol of the logical link and network layers that uses link-state packets to form either a single cluster network or a potentially larger cluster tree network [5]. The network is basically self-organized and supports network redundancy to attain a degree of fault resistance and self-repair. Nodes select a cluster head and form a cluster according to the self-organized manner. Then self-developed clusters connect to each other using the Designated Device (DD).

3.2. Single Cluster Network

The cluster formation process begins with cluster head selection. After a cluster head is selected , the cluster head expands links with other member nodes to form a cluster.

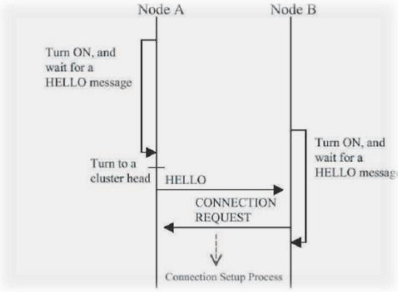


Figure :3.2.1 Cluster Head Selection Process

After a node turns on, it scans the channels to search for a HELLO message form other nodes (HELLO messages correspond to beacons in MAC layer of IEEE 802.15.4). If it can't get any HELLO messages for a certain time, then it turns to a cluster head as shown in Figure 3.2.1 and sends out HELLO messages to its neighbors. The new cluster head wait for responses from neighbors for a while. If it hasn't received any connection requests, it turns back to a regular node and listens again. The cluster head can also be selected based on stored parameters of each node, like transmission range, power capacity, computing ability or location information. After becoming the cluster head (CH), the node broadcasts a periodic HELLO message that contains a part of the cluster head MAC address and node ID 0 that indicates the cluster head. The nodes that receive this message send a CONNECTION REQUEST message to the cluster head. When the CH receives it, it responds to the node with a CONNECTION RESPONSE message that contains a node ID for the node (node ID corresponds to the short address at the MAC layer). The node that is assigned a node ID replies with an ACK message to the cluster head. The message exchange is shown in Figure 3.2.2.If all nodes are located in the range of the cluster head, the topology of connection becomes a star and every member nodes are connected to the cluster head with one hop. A cluster can expand into a multi-hop structure when each node supports multiple connections. If the cluster head has run out of all node IDs or the cluster has reached some other defined limit, it should reject connection requests from new nodes. The rejection is through the assignment of a special ID to the node. The entry of the neighbor list and the routes is updated by the periodic HELLO message. If a node entry does not update until a certain timeout limit, it should be eliminated. A node may receive a HELLO message from a node that belongs to different cluster. In that case, the node adds the cluster ID (CID) of the transmitting node in the neighbor list and then sends it inside a LINK STATE REPORT to the CH so that CH knows which clusters its cluster has intersection.

The LINK STATE REPORT message also contains the neighbors node ID list of the node so that the CH knows the complete topology to make topology optimizations. If the topology change is required, then the CH sends a TOPOLOGY UPDATE message. If a member receives a TOPOLOGY UPDATE message that the different parent node is linked to the node, it changes the parent node as indicated in the message. And it also records its child nodes and the nodes below it in the tree at this time.

If a member node has trouble and becomes unable to communicate, the tree route of the cluster would be reconfigured. The CH knows the presence of a trouble by the periodic LINK STATE REPORT. When the cluster head has trouble, the distribution of HELLO message is stopped and all member nodes know that they have lost the CH. The cluster would then be reconfigured in the same way as the cluster formation process.

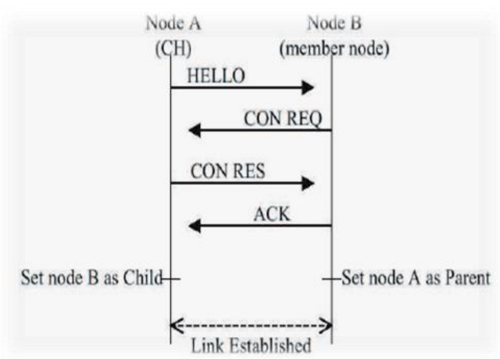


Figure :3.2.2 Link setup between CH and member node

3.2.2 Multi-Cluster Network:

To form a network, a Designated Device (DD) is needed. The DD has responsibility to assign a unique cluster ID to each cluster head. This cluster ID combined with the node ID that the CH assigns to each node within a cluster forms a logical address and is used to route packets. Another role of the DD is to calculate the shortest route from the cluster to the DD and inform it to all nodes within the network.

CONCLUSION

The goal is "to provide the consumer with ultimate flexibility, mobility, and ease of use by building wireless intelligence and capabilities into every day devices. ZigBee technology is a low data rate, low power consumption, low cost, wireless networking protocol targeted towards automation and remote control applications[10]. ZigBee technology will be embedded in a wide range of products and applications across consumer, commercial, industrial and government markets worldwide. For the first time, companies will have a standards-based wireless platform optimized for the unique needs of remote monitoring and control applications, including simplicity, reliability, low-cost and low-power".

The target networks encompass a wide range of devices with low data rates in the Industrial, Scientific and Medical (ISM) radio bands, with building-automation controls like intruder/fire alarms, thermostats and remote (wireless) switches, video/audio remote controls likely to be the most popular applications.

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