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Low Power Consumption in ZigBee Wireless Networks: A Survey

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Abstract
The ZigBee technology is an IEEE 802.15.4 standard for data communications dealing with business and consumer devices. 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. 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. In industry ZigBee is being used for next generation automated manufacturing, with small transmitters in every device on the floor, allowing for communication between devices to a central computer. This new level communication technology permits finely-tuned remote monitoring and manipulation.

Keywords:- ZigBee, MAC, Wireless mesh networking, High reliability, Communication technology etc.

I   INTRODUCTION

The ZigBee technology is the wireless mesh networking standard created for connecting sensors, instrumentation and control systems. This is based on the IEEE 802.15.4 Standard and used in Wireless Personal Area Networks (WPANs) for high level communication. This technology is created by the ZigBee Alliance. Wireless sensor networks (WSN) consists of light-weight, low power and small size sensor nodes (SNs) [3]. They have ability to monitor, calculate and communicate wirelessly. The ZigBee Alliance organized as an independent, neutral and non profit corporation in 2002, it is open and global and any one can join and participate, membership is global. An organization with a mission to define reliable, cost effective, low-power, wirelessly networked, monitoring and control products based on an open global standard. Alliance provides interoperability, certification testing, and branding [15].

IEEE 802.15.4 is a standard which specifies the physical layer and media access control for low-rate wireless personal area networks (LR-WPANs). It is maintained by the IEEE 802.15 working group, which defined it in 2003 [3]. IEEE standard 802.15.4 as specifications for low-data-rate wireless connectivity with fixed, portable, and moving devices with no battery or very limited battery consumption requirements typically operating in the personal operating space (POS) of 10m [15]. It is foreseen that, depending on the application, a longer range at a lower data rate. The ZigBee wireless networks targets the application domain of low power, low duty cycle and low data rate requirement devices. Figure-1 below shows the example of a ZigBee networks. The ZigBee Networks, Coordinators are the most capable of the three node types. There is exactly one coordinator in each network and it is the device that establishes the network originally. It is able to store information about the network with including security keys. Routers act as intermediate nodes, relaying data from other devices.

Table-1: ZigBee 802.15.4 standard specifications

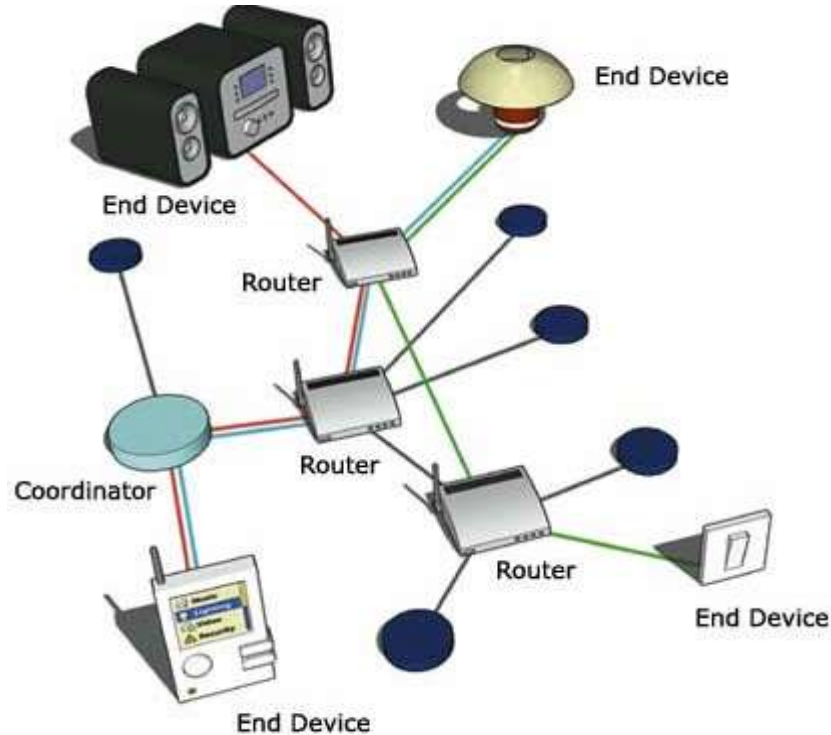| Parameter	Range
Transmission Range(meters)	1-100
Battery Life (days)	100-1,000
Network Size(# of nodes)	>64,000
Throughput(kb/s)	20-250

Figure-1: ZigBee Networks[15]

End Devices can be low-power battery powered devices. 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 [6].The above Table-1 shows general specifications of ZigBee 802.15.4 standard.

II   ZIGBEE CHARACTERISTICS

The ZigBee 802.15.4 standard provides following services:
- Standards based.
- Low cost.
- Simple protocol, global implementation.
- Reliable data transfer.
- Supports large number of nodes.
- Easy of installation.
- Very long battery life.
- Secure.
- Low power consumption.
- Short range operation.
- Flexible protocol design suitable for many applications.

ZigBee Frequencies [8]:
- Operates in Unlicensed Bands
- ISM 2.4 GHz Global Band at 250kbps
- 868 MHz European Band at 20kbps
- 915 MHz North American Band at 40kbps

III   ZIGBEE APPLICATIONS

A set of applications require simple wireless connectivity, relaxed throughput, very low power, short distance and inexpensive hardware.
- Industrial

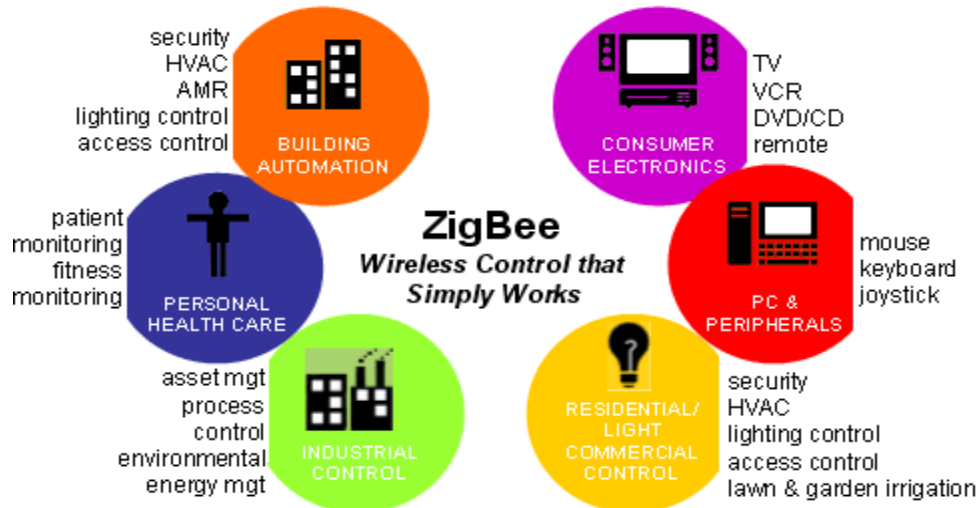- Agricultural
- Vehicular
- Residential
- Medical
- *etc*

Figure-2: ZigBee network applications [15]

From figure -3, Application on Home Automation [HA]
Defines set of devices used in home automation

- Light switches.
- Thermostats.
- Window shade.
- Heating unit.
- etc.

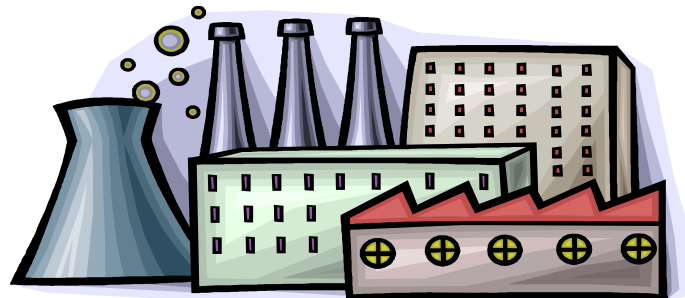Figure-3: Applıcatıon on home automation

Figure-4: Application on industrial plant monitoring

In figure-4, Industrial Plant Monitoring consists of device definitions for sensors used in industrial control

- ■ Temperature
- ■ Pressure sensors
- ■ Infrared
- ■ etc.

Figure-5: In-Home Patient Monitoring

The above figure -5 patients receive better care at reduced cost with more freedom and comfort.

- ❑ Patients can remain in their own home:
  - ■ Monitors vital statistics and sends via internet.
  - ■ Doctors can adjust medication levels.
- ❑ Allows monitoring of elderly family member:
  - ■ Sense movement or usage patterns in a home.
  - ■ Turns lights on when they get out of bed.
  - ■ Notify via mobile phone when anomalies occur.
  - ■ Wireless panic buttons for falls or other problems.
- ❑ Can also be used in hospital care:
  - ■ Patients are allowed greater movement
  - ■ Reduced staff to patient ratio

IV   ZIGBEE ARCHITECTURE

In the figure-6, ZigBee architecture has showed a layered design in which every layer offers services to the next higher layer through Service Access Points (SAPs). There are two kinds of SAPs: one is the Data Entity (DE), it is dedicated to the transmission of data between layers, other is the Management Entity (ME) for the transmission of control and services administration commands.
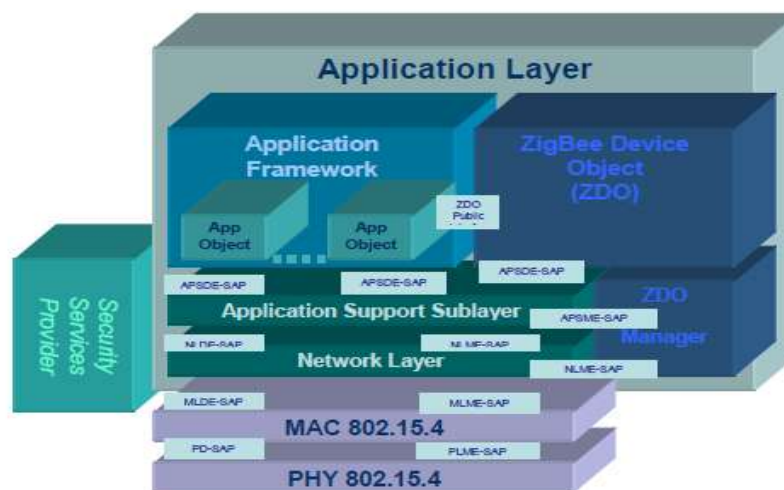

Figure-6: ZigBee Architecture[1]

The ZigBee protocol contain top of IEEE 802.15.4 PHY and MAC layers. The above MAC 802.15.4, next higher layer is the network layer (NWK) in responsible of the formation of the network, manage addresses administration, routing, new devices discovery, as well as security application and services. On the top of the network layer there is the Application Support Sub layer (APS) and the ZigBee Device Object (ZDO) with its vertical management plane [1]. The APS layer with its two SAPs (APSDE (Service Access Points the Data Entity) and APSME (Service Access Points the Management Entity)) offers an interface between the network layer and the upper layers; its main task is to generate the Protocol Data Unit (APDU). It is also in charge of group address filtration, secure transportation of messages, rejection of duplicates from the application, authentication of links, security keys, and administration of devices to groups. The ZigBee Device Object (ZDO) is a basic functionality class that offers an interface between the application objects, the profile and the APS layer. It initializes the APS and network layers and the Security Services Provider (SSP), this last one used to encrypt and decrypt messages. The main objective of the ZDO is the administration of basic functions of any application device and it is also an interface to the variety of functionalities of ZigBee.

The ZigBee protocol contains an application framework for the application objects. To define the framework for the specific application environment there is an application profile and a ZigBee Cluster Library (ZCL). The application profile describes the types of devices and the specific clusters from the ZigBee library needed to implement a standard functionality. A cluster is defined as the specification of a distributed functionality in two types of devices: a server and a client. This way a developer can use the standard functionality of the ZCL and also create its own clusters for his own profile, these clusters can also be registered as part of the ZigBee protocol and obtain a specific identification number for the profile.

V   IEEE 802.15.4 DEVICE TYPES

- There are two different device types[15] :
    - A full function device (FFD)
    - A reduced function device (RFD)

- The FFD can operate in three modes by serving as
    - Device
    - Coordinator
    - PAN(Personal area Networks) coordinator

- The RFD can only serve as:
    - Device

(Full Function Device) **Vs** (Reduced Function Device)
- Full function device (FFD)
    - Any topology
    - Network coordinator capable
    - Talks to any other device

- Reduced function device (RFD)
    - Limited to star topology
    - Cannot become a network coordinator
    - Talks only to a network coordinator
    - Very simple implementation

In IEEE 802.15.4 standard two types of devices can participate in a low-rate wireless personal area networks (LR-WPAN): First is a full function device (FFD) and second is a reduced function device (RFD) [6]. An RFD does not have routing capabilities. RFDs can be configured as end nodes only. They communicate with their parent, which is the node that allowed the RFD to join in the network. An FFD has routing capabilities and can be configured as the PAN coordinator. In a star network all nodes communicate with the PAN coordinator only so it does not matter if they are FFDs or RFDs. In a peer to-peer network there is also one PAN coordinator, but there are other FFDs which can communicate with not only the PAN coordinator, but also with other FFDs and RFDs. There are three operating modes supported by IEEE 802.15.4: PAN coordinator, coordinator, and end device. FFDs can be configured for any of the operating modes. In ZigBee terminology the PAN coordinator is referred to as simply "coordinator". The IEEE term "coordinator" is the ZigBee term for "router".
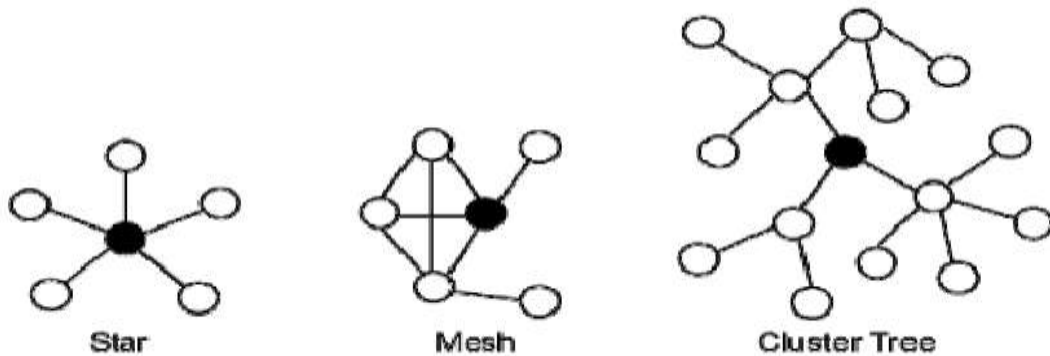
VI   ZIGBEE NETWORK TOPOLOGIES

Figure-7: ZigBee Network Topology[15]

From figure-7, IEEE 802.15.4 standard supports star and peer-to-peer topologies. The ZigBee specification supports star and two kinds of peer-to-peer topologies, mesh and cluster tree. ZigBee-compliant devices are sometimes specified as supporting point-to point and point-to-multipoint topologies.

VII   ZIGBEE FRAME STRUCTURE

In figure-8 mention the four basic frame types used in 802.15.4 standard: data, ACK, MAC command, and beacon. The data frame provides a payload of up to 104 bytes. The frame is numbered to ensure that all packets are tracked. A frame-check sequence ensures that packets are received without error [2].
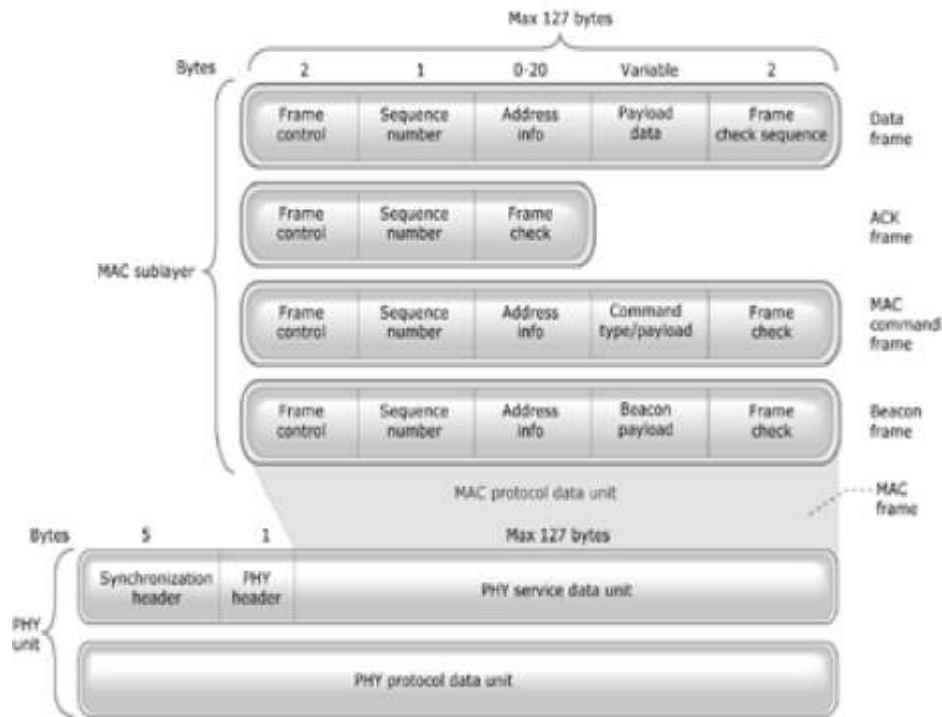

Figure -8: ZigBee Frame Structure [2]

This frame structure improves reliability in difficult conditions. Acknowledgment (ACK) frame. It provides feedback from the receiver to the sender confirming that the packet was received without error. The device takes advantage of specified "quiet time" between frames to send a short packet immediately after the data packet transmission. A MAC command frame provides the mechanism for remote control and configuration of client nodes. A centralized network manager uses MAC (Media Access Control) to configure the individual clients command frames no matter how large the network. Finally, the beacon frame wakes up client devices, which listen for their address and go back to sleep if they don't receive it. Beacons are important for mesh and cluster-tree networks to keep all the nodes synchronized without requiring those nodes to consume precious battery energy by listening for long periods of time [8].

VIII   ZIGBEE NETWORKS COMPARATIVE ANALYSIS WITH OTHER WIRELESS TECHNOLOGIES

From Table-2, we have seen the ZigBee standard comparison with Bluetooth and Wi-Fi wireless technologies basis on different parameters. Finally we conclude that ZigBee Wireless technology is better performance than Bluetooth and Wi-Fi technologies in context of battery power, cost, security, reliability and Complicity.

Table-2: ZigBee Technology Comparison with other Wireless Technologies

Parameter	ZigBee	Bluetooth	Wi-Fi
IEEE standard	802.15.4	802.15.1	802.11b
Application	Monitoring and Control	Cable Replacement	Web applications
Battery Life(Days)	100-1000	1-7	Hours
Network Size	264	7	32
Distance(meter)	50-1600m	10m	50m
Bandwidth	250Kbps	720kbps	Upto 54mbps
Power Consumption	30mA TX, standby 3#&956:A	40mA TX, standby 0.2mA	400+mA TX, standby 20mA
Stronghold	Long battery life, Low cost	Interoperability	High data rate
Key characteristics	Stability, Low Consumption, Low cost	Price, Easy use, High data rate	Very High speed , Large network
System Resource	4-32KB	250KB	1MB+
Interference avoidance method	DSSS(Direct Sequence Spread Spectrum)	FHSS(Frequency Hopping Spread Spectrum)	DSSS(Direct Sequence Spread Spectrum
Number of Channels	16	19	13
Typical network joining time	30ms Typically	>3sec	Variable , 1 sec Typically
Frequency Range	868MHz,916MHz,2.4GHz	2.4GHz	2.4GHz
Security	128 bit AES	64bit, 128bit	SSID
Integration level and Reliability	High	High	Normal
Complicity	Simple	Complicated	Very Complicated
Cost of terminal unit	Low	Low	High

CONCLUSION

It is likely that ZigBee will increasingly play a vital role in the future of computer and communication technology. The ZigBee Alliance targets applications across consumer, commercial, industrial and government markets in worldwide, consuming minimum power and enjoying long battery lives. ZigBee technology is designed to best suit these applications, for this reason that it enables less cost of development and very swift market adoption. Its most important advantage of being available at a very less cost enables it to be deployed in wireless control and monitoring applications. The ZigBee standard is better than Bluetooth and Wi-Fi wireless technologies.

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