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Zigbee versus Radio Frequency Identification (RFID)

By

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ABSTRACT

The growth of Telecommunication in the world has brought about the need for regular update, research and findings, to meet the demands of the global world. With the rising demand of home automation and sensor network, the ZigBee protocol has been identified to target on low power devices, Personal Area Network (PAN) and sensor nodes. Wireless wearable systems crave room for new user interface components. This fosters the ease of mobility and availability of devices, in order to accomplish things when necessary.

Since the technology of the global world is fast changing, it therefore brings about a very high level of competition and challenges among developers, programmers, systems engineers, telecommunication engineers and a host of others. When people fail to measure up to the present day demand, their design and market structure tends to drop.

Wireless systems are gradually phasing out wired systems due to the ease of operation and usage. Also, with the existence of wireless systems, there tend to be the need to invest as little as possible and then having an operation that can be maximally effective and reliable.

This research work talks about the ZigBee versus RFID technology and how they are correlated. Zigbee is solely targeted at Radio Frequency Identification (RFID) applications, requiring a low data and battery life and also a secure network. At a technical level, it is more reliable, supports larger networks and is more fully featured. However, a very good comparison is made between ZigBee and RFID. The choice therefore of a company, individual or organization is determined by their utmost priorities in line with some factors like performance output, implementation cost, security, usability and profit marginalization.

Keywords: ZigBee, RFID, Telecommunication, WPAN and wireless systems

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Table of Contents

List of figures

List of table

List of Abbreviations

AC	Alternating Current
A/C	Air Conditioning
API	Application Programming Interface
APS	Application Support
BAS	Building Automation Systems
CAD	Computer-Aided Design
CAGR	Compound Annual Growth Rate
CSMA	Carrier Sense Multiple Access
DoD	Department of Defense
ETSI	European Telecommunication Standards Institute
FCC	Federal Communications Commission
GHz	Gigahertz
GPS	Global Positioning System
HomeRF	Home Radio Frequency
HVAC	Heating Ventilation Air Conditioning
IEEE	Institute of Electrical Electronic Engineers
Kbps	Kilobits Per Second
LCD	Liquid Crystal Display
LLC	Logical Link Control
MAC	Medium Access Control
MARS	Mac Address Registration System
MCU	Multipoint Control Unit
MHz	Megahertz
mW	Milliwatt
OEM	Original Equipment Manufacturer
PAN	Personal Area Network
PC	Personal Computer
PHY	Physical
PLC	Power Line Control
PURLnet	Persistent Uniform Resource Locator Network
RFID	Radio Frequency Identification
RSSI	Received Signal Strength Indicator
RS232	Radio Standard-232
SED	Service Enabled Devices
SiP	System-in-Package
SOA	Service-Oriented Architecture
SoC	System-on-Chip
SOS	A call or signal for help
STAR	Sharing Treatment And Recovery
UART	Universal Asynchronous Receiver Transmitter
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
Wi-Fi	Wireless Fidelity
X-10	X Window dump Bitmap graphics
ZDO	ZigBee Device Object
ZCP	ZigBee-Compliant Platform

1. Background

With the world's rising demand for network access and computing, Wireless Local Area Network (WLAN) used to be popularly recognized. But today, in order to convey information over a relatively short distance, several wireless technologies and Wireless Personal Area Networks (WPANs) are proposed, extensively discussed and put into practice. This brings to our knowledge the existence and application of both ZigBee and Radio Frequency Identification (RFID).

Wireless systems are gradually phasing out wired systems due to the ease of operation and usage. Also, with the existence of wireless systems, there tend to be the need to invest as little as possible and then having an operation that can be maximally effective and reliable.

Connections effected via WPANs, require little or no infrastructure unlike WLANs. This enables small power-efficient and inexpensive solutions being met for a wide range of devices. The Institute of Electrical Electronic Engineers (IEEE) for the low rate WPAN approved this standard in 2003 as 802.15.4. This standard conforms to the new ultra-low power wireless standard/technology called ZigBee.

With the implementation of modern applications of Wireless Personal Area Network (WPAN), with reference to ZigBee/RFID, there tend to appear a greater reliability, convenience, usability and cost effectiveness in the world of communication and technology. This is simply because, companies are more interested in making profit at the lowest possible expense with the accomplishment of desired quality and values.

The objectives of this thesis are:

- Meeting the required standard for the present day demand of telecommunication and its applications.
- Being able to have an in-depth knowledge of telecommunications of today, and how applicable it is with ZigBee and RFID when subjected to company choice and that of private individuals.
- Identifying the differences between ZigBee and RFID for the one that adds more value to their progress and growth, especially in areas like cost, implementation, profit margin, reliability and level of security.
- Identifying the factors that are considered by most companies in terms of their choice for an improved level of communication, within and outside their organization. Also, figuring out ways to maximize profit with little expenses in communication.
- Enhancing both theoretical and practical knowledge of the course/program in Electrical Engineering with emphasis in Telecommunication.

However, this thesis work exposes us to their requirements and output in terms of usability, with comparison on the different existing solutions. An evaluation is also done about their merits and challenges between their different approaches in terms of performance, usability, cost, scalability and flexibility.

The question here is that "which edge do they have over themselves and how feasible are they?" Which different measures can be taken to improve on their challenges? And what makes one a better choice than the other?

2. Introduction

Zigbee and Radio Frequency Identification (RFID) are making great impact in telecommunications of today and so there is the need to update and improve our knowledge about them.

2.1 ZigBee

ZigBee is a new ultra-low power wireless networking technology, which conforms to the IEEE 802.15.4 standard. It defines the hardware and software, described in networking terms as the physical (PHY) and Medium Access Control (MAC) layers. It also embeds wireless communications into virtually any commercial building-automation product - from lighting ballasts to Heating Ventilation Air Conditioning (HVAC) systems to smoke and security alarms - all without the prohibitive cost and disruptive hassles of wired connections.

ZigBee was formerly known as Firefly, PURLnet, HomeRF Lite and RF-Lite. With a maximum speed of 250kbps at 2.4 GHz, it is slower than Wi-Fi and Bluetooth. However, it is capable of operating for years on low power batteries. It has a range of about 50meters, depending on weather changes.

It is solely targeted on bringing about the existence of a broad range of interoperable consumer devices. This is carried out by establishing open industry specifications for unlicensed, untethered peripheral, control and entertainment devices that require the lowest cost and power consumption communications between other devices that are compliant.

Since it is able to serve the needs of several applications even with more sophistication, it makes it differ from other wireless standards. The devices operate typically at 0 to 1% duty cycles and the network uses a line-powered infrastructure and battery-operated end devices operating as sensors, thermostats, light switches etc. This allows the Carrier Sense Multiple Access (CSMA) scheme to produce robust results with the sensors always asleep but wakes up for periodic, timed status updates.

2.1.1 ZigBee Architecture

There are three types of Zigbee architecture. They are: Network and Application Support layer, Media Access Control (MAC) layer and Physical (PHY) layer. [1]

Network and Application Support layer: The network layer handles huge number of nodes as it permits growth of network sans high power transmitters. It includes the ZigBee Device Object (ZDO), Application Support (APS) and the user-defined application profiles. The ZDO defines the nature of the device, commences and replies requests and then ensures a secure relationship between devices. The Application Support sub-layer maintains tables that fulfils matching and communication between two devices and also execute discovery of devices operating in the operating space of any device. While the user-defined application, is solely about the end device that conforms to the ZigBee standard.

Media Access Control (MAC) layer: This is the IEEE802.15.4, which works with large number of devices and permits the use of several topologies without complexity introduced.

Physical (PHY) layer: This uses direct sequence to allow simplicity in the analogue circuitry in other to accommodate high levels of integration and also enable cheaper implementations.

2.1.2 ZigBee Topologies

There are three types of Zigbee networks. These are: Star topology, Cluster topology and Mesh topology. [2]

Star Topology: In this case, each node connects to a single central coordinator, which is the Zigbee Coordinator or Personal Area Network (PAN) coordinator. All forms of communications between the nodes are done via the Zigbee Coordinator.

Cluster Topology: This consists of different star networks, all connected to a single Zigbee Coordinator or PAN coordinator by their central nodes.

Mesh Topology: This is a network of nodes communicating with each other forming a closed loop.

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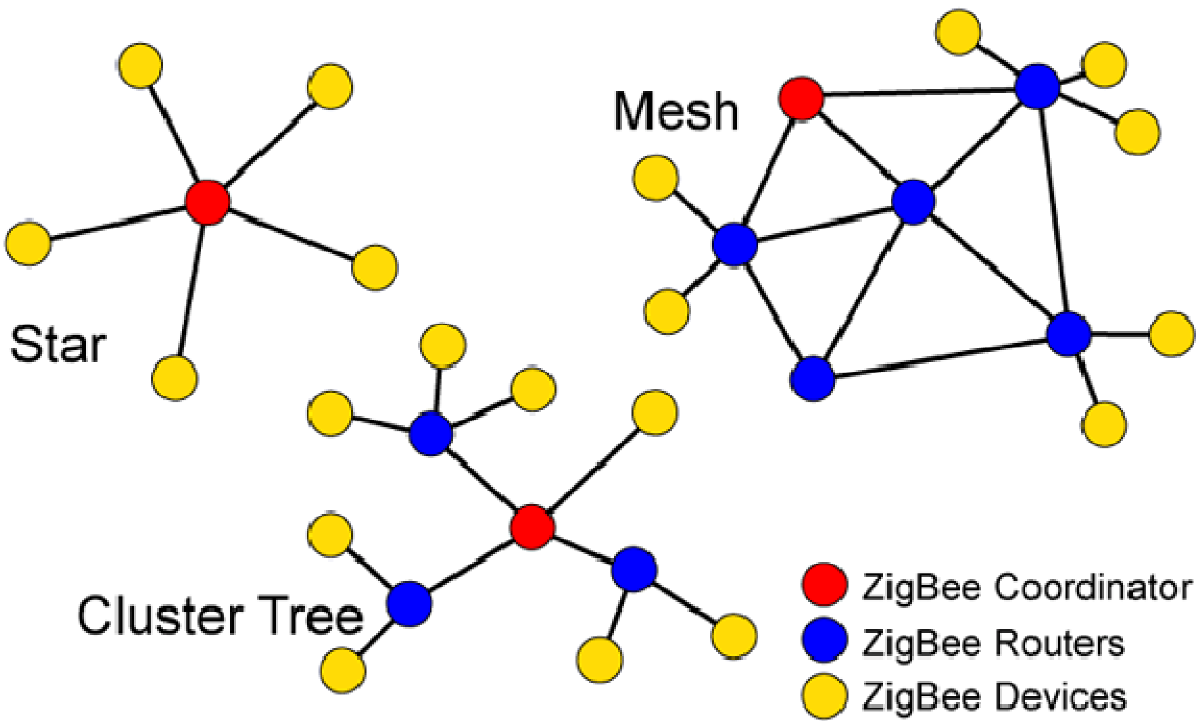


Figure 2.1 shows the Zigbee topology network. [3]

2.1.3 ZigBee Applications

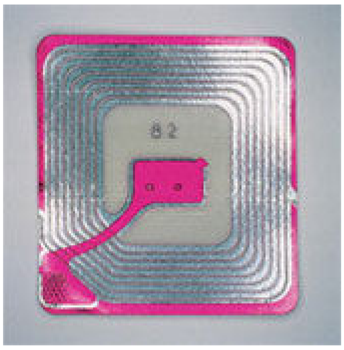
Zigbee can be applied in several areas. Some of such areas are as follows:

- Residential and Light commercial control
- Building Automation
- Industrial control
- Personal health care
- Consumer electronics
- PC and peripherals
- Precision Agriculture

2.2 Radio Frequency Identification (RFID)

Radio frequency identification (RFID) is a Dedicated Short Range Communication (DSRC) technology used in automatic identification of people, animals or objects using radio waves. It does not rely on the line-of-sight scanning for its operation, unlike that of bar code scanning which is similar to it. It works well for the collection of multiple pieces of data on items for tracking and counting purposes in a cooperative environment.

An RFID has a tag, which contains an integrated circuit that stores and processes information. It also has an antenna that receives and transmits signals. The antenna uses radio frequency waves in transmitting signals that activates the transponder and then the tag transmits data back to the antenna. [4]



RFID microchip internal

RFID tag

Figure 2.2 shows RFID tag and microchip internal. [5]

2.2.1 RFID Architecture

The architecture is a function of an incorporation/integration of already existing infrastructures of different organizations, as long as they attain a reasonable level of security, interoperability, management scalability, extensibility and a host of others. This anywhere component of the architecture is a middleware/edge ware platform. There is also the hardware area where we have the devices. [6]

In the lower hardware layer we have the RFID readers that read the RFID tags. The read data is transferred to the edge ware layer, which can then be implemented on a server in a warehouse. The vital data for a higher layer is sent to the middleware installed in the data centre. The middleware plays the role of a bridge to business applications in the back end.

2.2.2 RFID Topology

The RFID topology is basically concerned with the RFID tag, reader, and a host to control the reader and gather responses respectively.

The RFID network topology contains important data about the devices within the network. Such data is stored in a configuration database on the Premises server. The configuration is retrieved by the Edge Controller who then uses it to set all of the Manager Bundle parameters including the Device Manager, Controller Manager, and Digital I/O Manager. [7]

2.2.3 RFID Applications

RFID is applicable to several areas, but not limited to the ones listed below:

- Inventory Control
- Container / Pallet Tracking
- ID Badges and Access Control
- Fleet Maintenance
- Equipment/Personnel Tracking in Hospitals
- Parking Lot Access and Control
- Car Tracking in Rental Lots
- Product Tracking through Manufacturing and Assembly
- Department of defense (DoD)/Surveillance
- Airport security check (passports and baggage) presumed
- Livestock and pets
- Sports for timing

[8, 9, 10]

2.2.4 Highlight

This work is not meant to make choice for anyone about which should be depended upon at the expense of the other. This is because; technologies are always improved/upgraded depending on the societal needs. It is not also meant to bring out one as 100% efficient or reliable as no one can be 100% reliable or efficient. Also, there is no final judgment on what the future holds for both in this work, but just an overview of what can likely come up in near future.

This work is more of a research from findings. The rest of this thesis has been organized as follows in preceding chapters:

- The next chapter gives an insight to ZigBee/RFID definition, architecture, topology and applications for a better understanding.
- The third chapter identifies Zigbee principles; advantages, challenges, security systems, products and evaluation.
- The fourth chapter talks about the Principles of RFID; advantages and challenges.
- The fifth chapter talks about Zigbee Positioning.
- The sixth chapter gives a comparison between Zigbee and RFID
- The final chapter gives a summary of the entire work and conclusions drawn.

3. Principles of ZigBee

The principles of Zigbee have been presented here in terms of its advantages over other applications, challenges, security services and products.

3.1 Advantages of ZigBee over other applications

Zigbee has numerous advantages over other applications. The following are some of the advantages:

- ZigBee networks provide reliability and security mechanisms that make them highly dependable - that is, you can depend on ZigBee to provide a secure environment in which the network operates reliably (with minimal disruption). Monitoring a large number of inexpensive sensors will offer improved control information, and capabilities to prevent failure and avoid system downtime.
- Tiny size and low power consumption, which enables many of the sensors and nodes to operate using standard batteries for years.
- No new wire needed so it reduces cost and time spent in this manner. In addition, robust, self-configuring mesh networks will save on maintenance costs. This also fosters rapid commissioning.
- Builders and contractors can easily reconfigure heating, lighting, and security systems to accommodate additional sensors and nodes. This is a case of flexibility because; placement of sensors in optimal locations allows a network to be adaptable and reconfigurable. Moreso, placing sensors on all parts of an operation will allow applications before considered for manufacturing, warehouses, and operational facilities.
- Product interoperability
- Vendor independence
- Increased product innovation as a result of industry standardization
- A common platform is more cost effective than creating a new proprietary solution from scratch every time
- Companies can focus their energies on finding and serving customers

3.2 Challenges of ZigBee over other applications

A ZigBee node consists of a combination of hardware and software. So many companies are concerned with the software, but not with the consumer electronics. But ZigBee applications/usage requires both the software and the hardware because the products are still in the making.

ZigBee companies are being reluctant to enter the consumer arena, as some are waiting for ratification of the standard and for the home market to grow.

INSTEON™ wireless technology challenges ZigBee for “home run” in home automation market with no risk identified. It is designed with a signal booster in each node. It simply means that adding INSTEON™ nodes into an X-10 installation results to an increase in the network stability and robustness. It is the only dual band RF/Powerline Control (PLC) solution presently in the market. This is a big challenge to ZigBee. Its product cycle is an imminent reality with sound technological footing. [11]

ZigBee standard has a barrier to entry for developers, irrespective of the fact that it has reached the critical mass. This does not apply to many other wireless standards as they only serve a small number of high-volume applications rather than the broad range of applications and markets covered by ZigBee. [12]

For vendors to offer solutions for the application rather than ZigBee products is a key challenge to the adoption of the standard on a wider scale in many different markets it is suitable for. This is because; the standard is not so transparent to users yet.

Extending the low-power networking feature of the ZigBee protocol to include routers and the coordinator is also a challenge.

3.3 ZigBee Security Services

The key benefits of the ZigBee technology are security and data integrity. ZigBee supplements the security model of the IEEE 802.15.4 MAC sub layer specifying four security services [13]:

- Access control whereby a list of trusted devices within the network is maintained by the device
- Data encryption by the use of symmetric key 128-bit advanced encryption standard
- Frame integrity in order to protect data from being modified by parties without cryptographic keys
- Sequential freshness in order to track updated new value by way of rejecting 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 is yet to be updated

However, the implementer using a standardized toolbox of ZigBee security software specifies the actual security implementation.

3.4 ZigBee Products

Zigbee products have been making an increasing impact in several areas. Research work has been executed in terms of the market values and drive, analysis and implementation.

3.4.1 ZigBee Market values and drive

The market for the ZigBee specification network layer and 802.15.4 is poised for a good growth. However, 802.15.4 nodes/chipsets could grow by a Compound Annual Growth Rate (CAGR) of 200% within the year 2004 to 2009. The worldwide Building Automation Systems (BAS) market was nearly $22 billion in 2004 and is expected to exceed $25 billion by 2009, according to ARC Advisory Group study as at 2005. [14]

Building automation systems help in the reduction of unnecessary overhead costs for systems like lighting and heating to about half on the average. However, wireless system is sure of reducing initial cost of system ownership as well as recurring utility costs, since 20 to 80 percent of the system costs are incurred by wiring. [15]

ZigBee technology is getting attention from many companies involved in industrial control, home automation, and commercial building control, spanning everything from nuclear power plants to hotels. The first residential products are just barely emerging on the scene. From the look out, commercial building control is likely to capture the lion's share of the 802.15.4 market, in terms of node/chipset volumes, but not in terms of design. With the combination of System-in-Package (SiP) and System-on-Chip (SoC) solutions, the drive for the system/product development will be easier and also lower the costs of adding this wireless capability to sensor networks. [15]

ZigBee's potential in WPAN is of great importance and so, it is considered the ideal standard for control and sensing applications. This drives its implementation in the home-embedded wireless networking space. Built on the 802.15.4 spectrum, ZigBee provides an option of a low-cost to existing proprietary solutions in the WPAN space with the advantage of high-energy conservation. From the onset, ZigBee's biggest target market among a host of others is home automation. Also, is the industrial and building automation sector, where it is likely to be employed for short-range device-to-device communication and control.

3.4.2 ZigBee Analysis

IEEE802.15.4 and ZigBee addresses wireless sensor networks required for three targeted market areas in a general approach: residential home control, commercial building control, and industrial plant management – but then all are on a professional level. So many ZigBee companies develop and give priority to other applications like: medical, security, environmental, automated meter reading, energy management, telecommunications and other consumer uses. ZigBee targets on low power and cost, and the need for networking devices.

It has been identified that only ZigBee through IEEE802.15.4 allows the direct integration into the IEEE802-family and its LLC-APIs. But this one is however not often used. ZigBee follows the most open and flexible approach in terms of its stack, as its specification document is much shorter and so allows a small and simple stack. [16]

ZigBee uses 2.4 GHz and sub-GHz-frequency bands. This allows designers to decide on which frequency band best fits their application. It uses this frequency band for higher bandwidth and worldwide acceptance in line with the ETSI 868 MHz and FCC 900 MHz bands. It also uses spread-spectrum technology for the avoidance of multi-path fading and increase in robustness. This craves for improved signal immunity where radio interference is present. Its address is IEEE compatible.

A variety of routing algorithms are offered by ZigBee, which includes hierarchical tree, neighbor and table-based routing. The protocol has the display of a high degree of flexibility and stability, with explicit functions of entering and leaving a network. Automatically, a large part of it manages orphaned devices. ZigBee gives a definition of a lighting-control public profile for use as a template. Activities are driven within the ZigBee Alliance by members to develop many public application profiles for use by all Alliance members.

In terms of security, ZigBee uses a tiered approach. At the lower level, IEEE802.15.4 provides AES encryption. ZigBee also defines a security toolbox for key generation and distribution, which is able to support multiple modes for residential, commercial and industrial applications.

Platforms and products are two certification programs implemented by ZigBee. 13 ZigBee-Compliant Platforms have been certified. The need for ZigBee is attributed to a large number of choices the standard permits on each level. For a guaranteed interoperability, it requires OEMs that wishes to establish interoperability for “private” application profiles to use ZigBee Public Application Profiles or pre-defined stack and application profiles. From analysis, ZigBee unite large semiconductor and OEM manufacturers. Also, a substantial worldwide scientific and engineering community works with and for ZigBee. [16]

3.4.3 ZigBee implementation

There are several implementations of Zigbee. These include Hardware and firmware considerations, profile considerations and certification/testing.

Hardware and firmware considerations

There exist three basic options for ZigBee hardware implementation. These are chipset reference design, chipset custom designs and design-in modules.

- **Chipset reference designs**

  Chipset reference designs are offered by ZigBee chipmakers, which are expected to be relevant to as many other different applications as possible. They are known to be broad and helps to avoid the time and expense of customized designs.

- **Chipset custom designs**

  This design saves space and recurring expenses from products when built around a chipset. It is recommended to work with a well-known chipset as current ones do consist of RF chip paired with a microchip. RF and digital design engineering knowledge is of great importance in this approach.

- **Design-in modules**

  A good number of modules by OEM manufacturers have ZigBee-compliant chipsets. This makes RF task to be optimized in terms of its output performance. By way of reducing development cost, if a module supports an application, it is advisable to quickly market it. This is simply because; a module built in large quantity may eventually become less than the cost of a chipset solution.

Profile considerations

A profile defines the module application by completing the chipset and stack. There are two types: the **public and private profiles**. ZigBee logo certification is for public while that of private is not meant to interoperate, so it cannot be certified.

However, there is only one public profile for ZigBee, which is for lighting. Private profiles with stacks integrated into them, have been created by some chipmakers. It is typically the general-purpose serial UARTs. Module manufacturers offer/produce something similar to the needs of the users based on application-specific private profiles. Most module manufacturers provide the hardware abstraction libraries, which helps in reducing the effort to create your own profile and also reduce cost. Some also offer customized profile services for their customers, which helps to simplify the development effort and shorten the time to market.

Every ZigBee network needs a coordinator, but not all need a gateway. As for the lighting example, ZigBee network does not need to interface to another network. However, for most sensing and monitoring applications (and many other industrial/commercial applications), ZigBee network needs to interface to another network, either Modbus or Ethernet. In this case, we ensure that our solution is available with a compatible gateway that implements the same profile.

- **Certification, Testing**

Testing follows after the hardware, firmware and profile considerations. We have the FCC, ETSI and ZigBee tests. This can only be executed by being a member of the ZigBee alliance, which gives access to the IP embodied in the ZigBee technology.

It is recommended that one of two testing levels which are; ZigBee-friendly and ZigBee-Logo certified be passed, in order to market products based on the ZigBee technology. They both require that the ZigBee-Compliant Platform (ZCP) testing be successfully completed first. As long as ZigBee implementation uses the stack profile used for the ZCP testing, it does not need to be repeated. There is need to repeat the ZCP tests, if however, a different stack profile is needed for a device in which the stack profile was not tested by the chipset or module manufacturer.

ZigBee-Friendly testing concerns products that implement private profiles to ensure they have no problem with other ZigBee networks nearby. If changes are made to a profile after testing, then it has to be submitted once again for retesting. Otherwise, there is no need. Note that module configuration settings are not considered changes to the profile.

ZigBee Logo Certification testing is performed on a ZigBee-Compliant platform by the use of a public profile and it concerns interoperability with other device manufacturers' products .It has the highest level of testing. After the testing is passed, the product carries the ZigBee logo along with the icon relating to the application profile (home control/lighting for example). If a profile goes public, there has to be three vendors that have implemented the profile, otherwise none of the vendors can get the ZigBee Logo Certification.

3.5 ZigBee Evaluation

Zigbee is a standard for low-power, mesh sensor networks, which has been promoted by Zigbee alliance. The product allows a rapid evaluation and deployment of wireless sensor networks of 100 nodes or more in real-world industrial, office and home environments by the customers. The product comprises of wireless sensor nodes, software and network monitoring tools.

A building monitoring application is provided by the wireless sensor nodes with the provision of temperature, humidity and light sensors coupled with switches and lights. The nodes are found useful as endpoints, routers, coordinators and gateways. Also, it can be mixed with standard and high-power modules, which can be battery powered or mains AC. The nodes are preconfigured with a building monitoring application, which runs on Jennic standard ZigBee network stack and each provides a RS232 serial port for configuring and monitoring. They can be modified with Jennic's Integrated Developer Environment allowing users to migrate towards their own application. [17]

Many customers want to evaluate large-scale deployments of wireless sensor networks due to the provision of ZigBee evaluation kit. The core requirements of customers are; stable, robust, wireless communication in a variety of challenging environments, particularly commercial buildings, industrial environments and co-existence with Wi-Fi networks. The issues of market need for low-cost and easy development were once addressed but now, we complement this by simplifying large-scale deployments with mature, stable hardware and software. Industrial and commercial acceptance of ZigBee has progressed greatly over that of the consumer in terms of the technology.

4. Principles of RFID

The principles of RFID have been discussed here with respect to the advantages and challenges.

4.1 Advantage of RFID

There is always the need for an automated data capture analysis system in order to keep track of valuable assets and equipment. This is irrespective of whether tracking in a warehouse or maintaining fleet of vehicles.

Unique solutions to difficult logistical tracking of inventory or equipment have been provided by ActiveWave RFID. This is particularly in applications where optically based systems can not perform accordingly and when read/write capabilities are required. This has been identified as a stable technology evolving with open architectures which is becoming increasingly available. [18]

4.1.1 RFID Benefits vs. Barcode

A barcode reader is expected to have clean, clear optics including the label being clean and free of abrasion. The reader and label are also expected to be properly oriented with respect to each other in order to function properly. RFID technology enables tag reading from a greater distance, even in harsh environments.

The advantages of RFID vs. barcode technology are listed below:

- No line of sight requirement.
- The tag can stand a harsh environment.
- Long read range.
- Portable database
- Multiple tags read/write.
- Tracking people, items, and equipment in real time.

4.2 Challenges of RFID

RFID is faced with several challenges. Of such challenges of RFID are; data explosion, extensibility and innovation, interaction of the physical and IT world, putting data into a meaningful form, geographic distribution and data exchange. [19]

I. **Data Explosion**: This implies that there is so much data to contend with. For example, from pallet-level (bar code) identifier to case-level identifiers is a 50–100x increase in data and also, from case-level to item-level identifiers is another 10–100x increase.

II. **Extensibility and innovation:** There is the need for RFID and unique object identity which are transformative technologies to be designed not only for the present day, but also for the future. Instead of basing top-down design on one “killer app” for RFID, companies must design an RFID infrastructure that anticipates future needs, while insulating early applications from infrastructure changes as the technology advances and develops.

III. **Interaction of physical and IT world:** With the use of RFID, observations and information are gathered in an environment where it was not feasible to do so before, such as at the front-room/back-room doorway of a retail store. This implies that so many operational processes taking place outside the data centre—in factories, warehouses, stores, etc.—are now computerised as well as physical, thereby leading to new information processing outside the vicinity of the data centre.

IV. **Putting data into a meaningful form:** Observations from RFID tags are not usually business related and do not give out immediate information in this regard. These raw data from RFID devices must be turned into application-ready events by the filtration of redundant or irrelevant information, coordinating with other aspects of an operational process such as human-machine interaction, and then making available the appropriate business context.

V. **Geographic distribution:** RFID computation goes farther than being imagined geographically as it distributes computation far beyond traditional IT facilities. This applies to organizations that maintain multiple regional data centres. For example, an airline might deploy RFID infrastructure at several airports, maintenance hangars, regional parts depots, and so on. This brings about the challenge of proper maintenance.

VI. **Data exchange:** The business benefits/purpose of RFID can be fulfilled if both the manufacturer and retailer can assess and exchange information at their own end with their reader. But with the presence of shortcomings, this does not actualize the desire for RFID.

4.2.1 Meeting the challenges of RFID

There are lots of challenges of RFID, but they can be met with an appropriate architectural foundation. The BEA RFID architecture is founded on three principles:

I. **Edge computing:** A clear difference between RFID and other enterprise computational challenges is the computation of RFID at the edge of an enterprise, which means at the remote facilities outside the data center: factories, warehouses, retail stores, transportation hubs, supply depots etc; wherever the handling of physical objects take place and an RFID reader is placed. The BEA RFID architecture commences with a platform for edge computing, which recognizes and responds to the unique requirements of computing outside the data centre.

II. **Service-Oriented Architecture (SOA):** Enterprise-scale deployment of RFID applications requires the arrangement of events that attempts to achieve a maximum effect of many different components. Hardware and software components are deployed at each edge location. Data from the edge must be coordinated with data from other enterprise applications at the data center, and exchanged with trading partners. A way of bringing under control this complexity, while simultaneously providing for extensibility and innovation, requires a Service-Oriented Architecture approach. Through SOA, businesses can be transformed and optimized by moving data between infrastructure components and applications, integrating existing applications, and creating new applications.

III. **Open standards:** Open standards has to be adopted as the foundation of their architecture in order to meet the full potentials of RFID by an enterprise. These standards are very vital for enterprise to exchange data as found useful in many RFID usages. They also foster extensibility and innovation, thereby offering a common basis for multiple applications to interact and meet the needs of business. The BEA RFID architecture has a solid ground in terms of industry standards, from RFID-specific standards to the XML and Web services standards that enable SOA.

5. Zigbee Positioning

The RF infrastructure in ZigBee network helps in calculating the position or location of assets and people. In comparison with GPS, the location engine is integrated in single chip RF transceivers with MCU at less than 10 percent of the cost and a fraction of the power consumption of GPS hardware. The technology works for both indoors and outdoors with a Zigbee network in place, without the need for free line-of-sight to the sky. [20]

The following are typical applications:

- Remote control to turn lights on and off when moving from room to room in a house
- Track containers in shipping terminals
- Track equipment from a Web site

Location engines also help in simplifying the set-up of wireless networks as it determines the physical position of new equipment when it is in the network.

There is the need to identify the nodes that should exchange data directly with each other, or with a central data collection point. This applies to most wireless networks.

Where software-based calculations determine the network node positions, market solutions exist. This method is advisable in calculating position for smaller networks and a limited number of nodes, because the amount of traffic required to perform the calculation grows exponentially with the number of nodes. High-traffic load and lack of bandwidth creates a hindrance to the use of this method in battery-powered networks.

The results here are based on measurements done in ZigBee networks, but they also apply to simpler networks based on IEEE 802.15.4.

5.1 Technology Concept in Network

The location engine calculates its position based on the received signal strength indicator (RSSI) values from about 16 radios in order to have an accurate position result. This helps to get a good average when using a large number of nodes. In a RF network, location engine radios with known locations are referred to as reference nodes, while the nodes that calculate its position are referred to as blind nodes. [21]

ZigBee is likely to have more widespread use in home and office automation, since it allows wireless control, with an increasing number of its devices installed in building's infrastructure. Some applications require reference nodes as part of infrastructure set-up.

ZigBee-enabled equipment can be used to control temperature and A/C ducts with temperature sensor in a typical office set-up with each room also having Zigbee-controlled light switches and fixtures. Such equipment can act as reference nodes for location engine.
The location engine uses data collected from 16 different nodes to calculate the position. It uses the RSSI values from the 16 strongest reference nodes. The location engine has a range of 64 x 64 meters.

There are two ways to increase the range of covering areas for applications, as most of them require larger areas:

- Positioning reference nodes throughout a larger area and then performing location calculations relative to the reference node having the strongest signal
- By increasing the output power of the reference nodes and then reducing the resolution of the calculations made by the location engine

A broadcast message is sent by the blind node, which collects data from all neighbouring reference nodes. It then selects the X and Y coordinates of the strongest reference node signal, based on the strength of the signal of these reference nodes. Then it calculates the coordinates of the other nodes relative to this reference node.

The offset value is added to get the actual position in the large network from the closest reference node. This is done after processing the data in the location engine, (*Figure 5.1*).

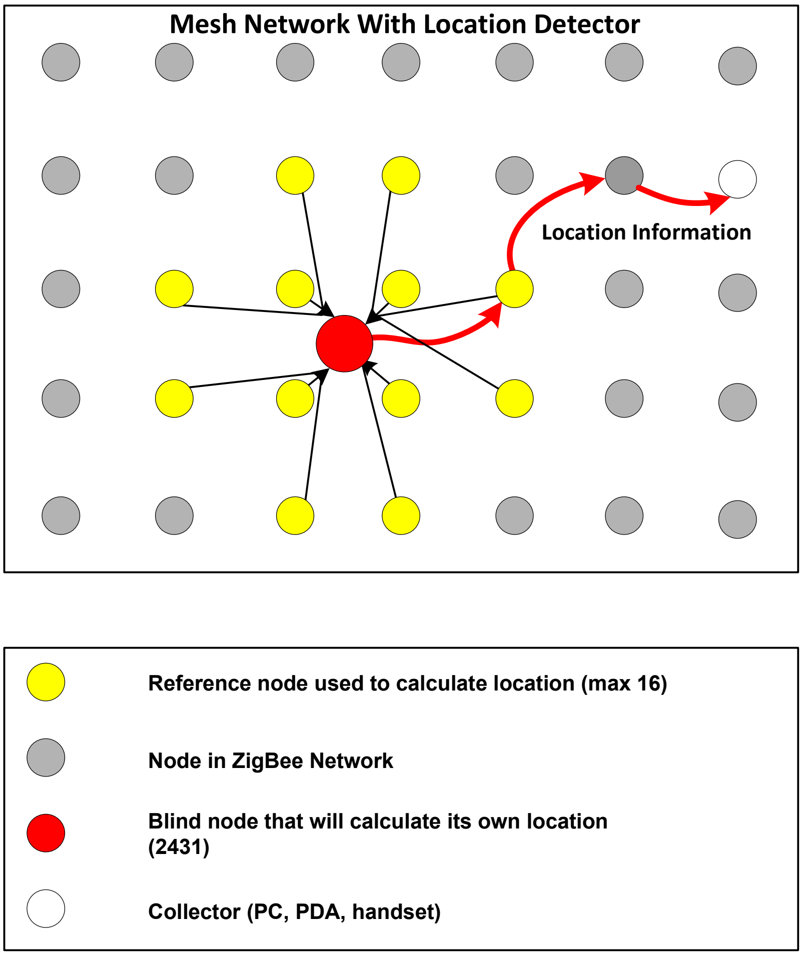


Figure 5.1: ZigBee network with positioning and routing of messages. [20]

In other to achieve best range, all nodes should be at equal height from ground, ceiling and walls. Though, this is difficult in a realistic deployment, but however, one should ensure proper precaution when placing reference nodes with respect to ceiling/floor absorption in both indoor and outdoor environment. Hence, try to place reference nodes at or below ceiling height with antennas inverted (propagates RF signals outward and downward), with blind nodes (hand-carried or affixed to equipment) placed anywhere between waist and head height of a person standing in the environment. This setup craves for reduced absorption by ceiling and floor and also, a minimal interference from moving objects like humans.

5.2 Findings/Conclusion

The location engine helps in achieving "room like" accuracy of radios in a ZigBee network with low current consumption and a minimum of communication overhead. It can use existing ZigBee infrastructure to determine the position within the network. A central data point can easily collect this information for tracking purposes, or it can be enabled by a user to navigate within a building.

5.2.1 For buildings

In a building, fire fighter sensors mounted use an active 2.4 GHz RFID tags with a read range of up to 100 feet. Such sensors send out an RF signal every two seconds in order to identify and locate fire fighters with their air tank. The air tanks are equipped with wireless sensor transceivers that exchange signal to and from the building sensors installed. The sensor in the air tank has a unique number, which is communicated to the building sensor as it passes by. This establishes the fire fighter's location. This information is sent via a wireless ZigBee network to chiefs' or incident commanders' tablet PCs. The PCs will have access to AutoCAD drawings, provided by the city, of buildings in which the sensors have been installed, and fire fighters' locations will be seen on the screen as dots. Having the knowledge of where the fire fighter is located, helps to enhance tactical decisions by the commanders on how to handle the scene.

The in-building sensors can also determine the level of smoke and temperature and then alert fire fighters about the conditions around. Joel Wilson has developed a system known as FireEye, which includes a head-mounted display screen attached to the nose guard inside the helmet of a fire fighter. The FireEye displays an interactive floor plan map that helps to communicate the fire fighter's current location, or that of other members, on a postage stamp-sized LCD screen positioned below the right eye of the fire fighter. This is for efficiency, safety and effectiveness of the first responders. [22]

In the meantime there will be a continuous test of the technology to ascertain the FIRE system works effectively.

5.2.2 For patients

RFID tags are put inside the badges of patients which periodically "listens" for strategically placed RF transceivers, called beacons, each about the size of a residential smoke alarm, attached to ceilings in rooms, bays and hallways throughout the emergency centre. The tags and beacons communicate with each other using ZigBee, based on the IEEE 802.15.4 wireless communication standard. The beacons transmit this data to a location engine that calculates room-level position, which was sent, via a standard Ethernet connection, to the PanGo location-management software that runs on a hospital server. The software so as to eliminate redundancies filters the data and any bad reads, and then forwards it to the STAR system. This has been in use by hospital employees to track patients and the length of their stays, manage bed capacities and run historical reports for the purpose of productivity and performance rating.

The PanGo Locator software serves as the middleware between the STAR and Inner Wireless systems. This is because, there is no a master language that the [STAR] application could understand. Patient location helps to improve customer's satisfaction by knowing where their family member is, as well as clinical-staff efficiency when they can definitively know where the patient is that they are planning to see. It also provides room-level location with a high level of confidence, but requires tuning to ensure that the RF location is certainly where the patient is.

6. ZigBee versus Radio Frequency Identification (RFID)

ZigBee is a wireless protocol built upon IEEE 802.15.4 and it relates to several other wireless protocols. It is useful for setting up WPANs (Wireless Personal Area Networks) of SEDs (Service Enabled Devices). Basically, Zigbee allows enabled "appliances" to communicate with each other wirelessly, irrespective of the manufacturer. This has many uses in RFID applications. Its protocol also provides a low-speed and power communication for wireless devices within a 10-meter (33-foot) range (i.e., a WPAN). WPAN clusters can be connected together for the extension of such range. [23]

Bit transfer rates are provided differently by three frequencies. The commonest is 2.4 GHz that provides 250 Kbps (Kilobits per second). As for other shorter-wave frequencies, they provide lower transfer rates. This protocol enhances communication with Wi-fi, Bluetooth and other wireless networks also.

ZigBee is not recognised as an alternative for RFID, but a network platform that enables RFID devices to communicate with each other and also other networked devices. With this ability of ZigBee, it has allowed hospital staff to locate patients wearing RFID-enabled badges. RFID readers query for badges, and if any are present, transmit signals over the ZigBee WPAN network. The system has allowed doctors, nurses, and other staff to find patients, on different floors, with a high degree of accuracy.

These results bode well. Besides closed systems such as unwired hospitals, a similar RFID + ZigBee set-up could be used by miners or any environment where the safety of individuals is enhanced by non-intrusive tracking methods.

6.1 Zigbee versus RFID

The table below shows a comparison between RFID and Zigbee technology as they applied to standards. [24]

	RFID	ZIGBEE
Frequency	13.6 MHz	2.4 GHz
Power	1-3W	1mW and 100mW
Wireless Reading Distance	10-30 Meters	70-100 Meters
Card Frequency Power	50mW	1mW
Construction Style	Passive	Active
Information Capacity	Low	High
Security	Low	High
Anti-jamming	Low	High
Two way communication capabilities	Not available	Available
Staff Identification Number	Low	High
Life card consumption	1year	Chargeable
System cost	High	Low
Applications	Less	Several/More

From the table, the Frequency of RFID technology is 13.6 MHz, a relatively longer wavelength band that is more likely to be absorbed and better suited for short distance communications. But for Zigbee, the 2.4 GHz relies on wave reflection, making it more suitable for wireless communications quality. [25]

The Power rating of 1-3W for RFID and 1mW and 100mW for Zigbee gives the standard power rating as for low and high applications. [26] Zigbee operates for several years under low power unlike RFID.

The wireless reading distance under normal power for RFID can cover roughly 5 meters, and up to 25 meters with high power output. But Zigbee reads at distances between 70 and 100 meters under normal power output.

In terms of the Card Frequency Power for Zigbee, the standard module has 0 dBm (1mW) output power, while the Plus module's output power is +20 dBm (100mW). [27, 28]

For construction style, due to the passive one way nature of RFID tags, employees must carry multiple articles for identification and communication – thus increasing the changes for lost and misplaced items and forcing false or no readings into the system. The information capacity for RFID products storage capacity is between 16B - 2KB while that of Zigbee storage capacity is 64KB.

In the case of security, a typical RFID technology carries low encryption rates and is open to confidentiality concerns and external malicious attacks against the system. These attacks could lead to system paralysis. Zigbee carries high encryption, high security performance, and can truly achieve safe usage. Zigbee also has a higher level of data integrity. This is one of its unique benefits.

RFID technology, due to low frequency operations, is susceptible to many industrial scene interference signals when compared to the high Frequency of Zigbee technology. This gives the Zigbee a better performance than RFID in terms of anti-jamming.

RFID technology cannot process two-way transmissions. Zigbee can identify, upload staff signals (such as SOS calls, etc.), but also process the administrator's instructions (such as evacuation alarm, and illegal entry). RFID systems can generally recognize 40-80 people, while Zigbee has a recognition capacity of 200 people and a success rate of 100%.

Built-in high-power RFID products are generally three to four button batteries, such products are generally sealed and the batteries cannot be replaced without destroying the frame. The Zigbee system uses built-in high-energy lithium ion rechargeable batteries, charging can power for up to one month. Cost for total systems is typically 1/3 of the existing product cost. Invariably, the incurable cost for RFID is higher than that for Zigbee.

Considering the applications for Zigbee and RFID, Zigbee serves the needs of several applications even with more sophistication than RFID. This also bores down to the fact that Zigbee implements the technology of RFID much more to enhance its performance and operations.

Zigbee undergoes minimal disruption when compared to that of RFID.

7. Summary

A general overview of Zigbee and RFID has been given in this thesis. It fosters the awareness of wireless technology that targets on low power devices. This however results to as little investment as possible on the part of the investor, thereby having an operation that is highly effective and reliable. Hence, a better profit margin can be achieved by the investor or establishment.

This thesis identified the standards for the present day demand of telecommunications and its applications. Moreso, the advantages and challenges of Zigbee and RFID has been addressed and how their challenges can be met, since some industrial environments have made wireless the only viable networking option. In such cases, the notion of hardwire or wired network is not only impractical but also prohibitively expensive.

We have identified in this thesis that Zigbee operates in line with RFID by implementing RFID technology to improve on the efficiency and reliability of certain operations. On this note, power consumption, implementation cost, performance, operation, usability, security and profit margin have all been put into consideration. As companies seek ways to reduce operational and support costs and capital investments in today's competitive global markets, production equipment must deliver reliability, availability, and maintainability. Networked wireless sensors and manufacturing devices can enable real-time data sharing throughout a facility while adjusting to changing conditions to limit major failures.

In this work, IEEE802.15.4 and ZigBee follow a general approach in addressing wireless sensor networks required for three targeted market areas: residential home control, commercial building control, and industrial plant management – all on a professional level. Many Zigbee companies develop and consider other applications. Examples include:-medical, security, environmental, automated meter reading, energy management, telecommunications and other consumer uses. Zigbee targets on low power and cost, and the need for networking devices as opposed to the point-to-point networks found for most Bluetooth and Wi-Fi applications.

Both Zigbee and RFID use RF-technology for communication with each taking a different approach with its implementation. ZigBee is the only technology that uses 2.4 GHz and sub-GHz-frequency bands. This approach allows designers to choose the best frequency band for their application. ZigBee uses the 2.4 GHz frequency band for higher bandwidth and world-wide acceptance along with the ETSI 868 MHz and the FCC 900 MHz bands.

This work has shown that telecommunication is practically put in place with the use of Zigbee and RFID. It also highlights the architecture, principles: merits, challenges, and security systems of both Zigbee and RFID, products, implementations and evaluations.

The nature of RF design and the ideology of the typical RF design engineer, means there will invariably be a proprietary system that offers a better fit for a particular application. With good measurement and management implementation, a huge revenue generating market is likely to come up with Zigbee technology in collaboration with RFID technology.

Zigbee has a dominant role over RFID in several aspects. This thesis has identified what companies do place their priorities upon, which is efficiency by way of low cost of investment and better performance and profit margin.

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