

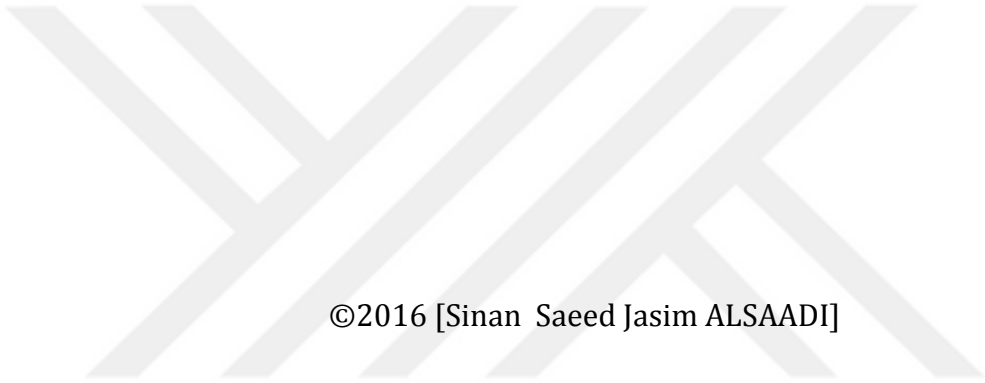
**T.C.
SÜLEYMAN DEMİREL ÜNİVERSİTESİ
GRADUATE SCHOOL OF NATURAL AND
APPLIED SCIENCES**

**DESIGN AND IMPLEMENT A REMOTE CONTROL ROBOT
CONTROLLED BY ZIGBEE WIRELESS NETWORK**

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**MASTER THESIS
ELECTRONIC AND COMMUNICATIONS ENGINEERING DEPARTMENT
ISPARTA - 2016**



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THESIS APPROVAL

This thesis is prepared by Sinan ALSAADI, thesis named “DESIGN AND IMPLEMENT A REMOTE CONTROL ROBOT CONTROLLED BY ZIGBEE WIRELESS NETWORK” by the approval of the jury in Süleyman Demirel University Science institute in Electronic And Communication Engineering Department as A MASTER THESIS was defended successfully.

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This thesis has written in accordance to the academic and ethical rules and used all the literature I declared in the thesis with a reference.

Sinan Saeed Jasim ALSAADI



CONTENTS

	Page
CONTENTS.....	i
ÖZET.....	iii
ABSTRACT	iv
ACKNOWLEDGEMENT	v
LIST OF FIGURES	vi
LIST OF TABLES	viii
LIST OF ABBREVIATIONS	ix
1.INTRODUCTION.....	1
1.1. Extend Of This Thesis	1
1.2. Wireless Control Networks	3
1.3. Wireless Automation	4
1.4. Wireless Control Systems Simulation.....	5
1.5. Wireless Control Network Applications	7
1.5.1. Wireless network for control.....	8
1.5.2. Current standards for wireless automation.....	10
1.5.3. Wireless Sensor Networks	13
1.6. Wireless Control Network Technology.....	15
2.ZIGBEE WIRELESS NETWORK TECHNOLOGY	19
2.1. Introduction	19
2.2. History	20
2.3. Application	20
2.4. Comparing Between Zigbee, Bluetooth And IEEE 802.11	22
2.5. Short-Range Wireless Networking Classes	22
2.6. The relationship Between ZigBee And IEEE 802.15.4 Standards	24
2.7. Operating Frequencies And Data Rates	25
2.8. Interoperability	28
2.9. Device Types	28
2.10. Device Roles	28
2.11. ZigBee Network Topology	29
3.ZIGBEE TRANSCIEVER DESIGN	33
3.1. Introduction	33
3.2. Wireless Communication Channel	35
3.3. Coherent And Non-Coherent Detection	36
3.4. ZigBee Transceiver Requirements	37
3.4.1. Spread spectrum technique	37
3.4.2. Digital modulation technique	41
3.4.2.1. Phase shift keying	43
3.4.3. Serial to parallel converter	47
4. MOBILE ROBOT SETUP AND RESULT	49
4.1. Definition And Purpose Of The Robots	49
4.2. Our Robot Construction And Design	51
4.2.1. Technical specifications of our robot	51
4.2.2. Design of the robot base.....	52
4.2.3. Power supply	53
4.2.4. X-BEE	53
4.2.4.1. X-Bee communication	53

4.2.4.2. Forming a network with X-Bee.....	54
4.2.4.3. X-Bee configuration	55
4.2.5. Arduino	59
4.2.5.1 Arduino programming	61
4.2.6. Design the control unit for our robot	61
4.2.7. Motor Driver Circuit	63
4.2.7.1 L298 Motor driver card	63
4.2.8. Ultrasonic sensors (HC-SR04)	64
4.2.9. Representation circuit of our robot	65
4.3. Results from our robot design	66
4.3.1. X-bee range test	66
4.3.2. Signals testing from ultrasonic sensors	67
4.3.3. Our robot final form	68
5. CONCLUSION AND FUTURE WORK	69
5.1. Conclusion	69
5.2. Future work	70
REFERENCES	71
APPENDIX	77

ÖZET

Yüksek Lisans Tezi

ZİGBEE KONTROLLÜ BİR ROBOT TASARIMI VE UYGULAMASI

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Günümüzde haberleşme ve erişim sistemleri birçok yöntemle yapılabilmektedir. Bu yöntemler Wifi, Wimax, Bluetooth, GPS ve GPRS gibi standartlardır. Bu standartları kullanan cihazlar sistem kaynaklarını da iletim hızlarıyla doğru orantılı olarak fazla miktarlarda kullanırlar. Fakat her zaman büyük boyutlarda veri haberleşmesine ihtiyaç duyulmayabilir. Bu durumlarda bu tarz küçük paket verilerin iletimini sağlamak ve bu tip cihazların kontrolünü sağlamak için sistem kaynaklarını mümkün olduğunca az kullanacak, akıllı ağ topolojilerini destekleyecek bir teknolojiye ihtiyaç duyulmuştur. Bu ihtiyaç üzerine IEEE, 802.15.4 standardını çıkarmıştır, bu standartta temel alan Zigbee protokolü ve bu protokolü destekleyen cihazların üretilmesini sağlamıştır. Yaptığımız proje de ise bu haberleşme protokolü tercih edilmiştir.

Projemiz dahilinde bu çalışmanın amacı robotumuzun sahadan anlık veri aktarımını sağlamak hedeflenmiştir. Ve robotla yapılacak olan haberleşmeyi Zigbee Protokolü ile sağlanması hedeflenmiştir. Bilgisayarın başında iken robotun bulunduğu bölgeden istenen verileri almak esas alınmıştır. Aracımız da kontrol mekanizmasını sağlayan Arduino Uno R3 mikrodenetleyicisi, motor sürücü olarakda l298 shield kullanılmıştır.

Anahtar Kelimeler: ZigBee, kablosuz Ağlar, Uzaktan Kontrol, Ziraat, Tıp ve Endüstriyel Uygulamaları.

2016, 85 sayfa

ABSTRACT

M.Sc. Thesis

DESIGN AND IMPLEMENT A REMOTE CONTROL ROBOT CONTROLLED BY ZIGBEE WIRELESS NETWORK

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Communication and access systems can be made with many methods in today's world. These systems are such standards as Wifi, Wimax, Bluetooth, GPS and GPRS. Devices which use these standards also use system resources excessively in direct proportion to their transmission speed. However, large scale data communication is not always needed. In such cases, a technology which will use system resources as little as possible and support smart network topologies has been needed in order to enable the transmissions of such small packet data and provide the control for this kind of devices. IEEE issued 802.15.4 standard upon this necessity and enabled the production of Zigbee protocol which takes these standards as its basis and devices which support this protocol. In our project, this communication protocol was preferred.

The aim of this study is to provide the immediate data transmission of our robot from the field within the scope of the project. In addition, making the communication with the robot through Zigbee Protocol has also been aimed. While sitting on the computer, obtaining the desired data from the region where the robot is located has been taken as the basis. Arduino Uno R3 microcontroller which provides the control mechanism, 1298 shield as the motor driver .

Keywords: ZigBee, wireless network, remote monitoring, commercial, medical health care, agricultural industry, smart home, industrial application.

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LIST OF FIGURES

	Page
Figure 1.1. A Bluetooth chip.....	15
Figure 1.2. A UWB chip.....	16
Figure 1.3. The wireless fidelity (Wi-Fi) chip.....	16
Figure 1.4. The ZigBee chip models	17
Figure 2.1. An example for home automation of ZigBee	21
Figure 2.2. Comparing the ZigBee standard with Bluetooth and IEEE 802.11b.	23
Figure 2.3. Short-range wireless networking classes	23
Figure 2.4. ZigBee wireless networking protocol layers	25
Figure 2.5. Device Roles in IEEE 802.15.4 and ZigBee standards	29
Figure 2.6. Star network topology.....	30
Figure 2.7. Peer-to-peer network topology.....	31
Figure 2.8. Mesh network topology	32
Figure 3.1. Block diagram of ZigBee transceiver system.....	35
Figure 3.2. (A) the sine wave without the effect of AWGN, (B) the sine wave with the effect of AWGN.....	36
Figure 3.3. The signal spreading in DSSS	39
Figure 3.4. Signal spreading and despreading can help improve SNR and reduce the effect of interferers	41
Figure 3.5. Basic digital modulation types	43
Figure 3.6. The constellation of BPSK and QPSK	44
Figure 3.7. The effect of half-sin pulse-shaping on the signal	45
Figure 3.8. Block diagram of OQPSK modulation	46
Figure 3.9. Block diagram of OQPSK demodulation	46
Figure 3.10. The circuit for generation of the inphase and quadrature data	47
Figure 4.1. X-Bee is a wireless RF module which uses ZigBee protocol	50
Figure 4.2. Exploration robot called RHEX which has been designed By Boston Dynamics firm	51
Figure 4.3. Our mobile robot design	52
Figure 4.4. The board we used in our project	52
Figure 4.5. A power supply battery of 7.4v	53
Figure 4.6. A network formed with 1 coordinator, 3 routers and 15 end devices	54
Figure 4.7. Coordinator interface during X-Bee configuration	56
Figure 4.8. Router interface while X-Bee configuration is made	57
Figure 4.9. Multi-point network design	58
Figure 4.10. Crossing destination address of X-Bee	58
Figure 4.11. Arduino	59
Figure 4.12. Arduino programming for our robot.....	61
Figure 4.13. Visual studio programming for our robot	62
Figure 4.14. The control unit that we created for serial port control	62
Figure 4.15. L28N Motor Driver Card	64
Figure 4.16. Ultrasonic sensors (HC-SR04)	64
Figure 4.17. Work principle of ultrasonic sensor	65
Figure 4.18. Representation circuit of our robot	65

Figure 4.19. Range test of X-Bee in X-CTU	66
Figure 4.20. Testing our robot's sensors	67
Figure 4.21. The received signals from our robot's sensors	67
Figure 4.22. Final form of our robot	68



LIST OF TABLES

	Page
Table 1.1.Compression between the wireless technologies	18
Table 2.1.Details of the frequency bands used in IEEE 802.15.4	27
Table 5.1. Comparison between wireless control network protocol	69



LIST OF ABBREVIATIONS

AM	Amplitude modulation
ASK	Amplitude shift keying
AWGN	Additive white Gaussian noise
BER	Bit error rate
BPSK	Binary phase shift keying
BSS	Basic service set
CSMA	Carrier sense multiple access
DSSS	Direct sequence spread spectrum
ESS	Extended service set
FDMA	Frequency division multiple access
FFDs	Full function devices
FHSS	Frequency hop spread spectrum
FM	Frequency modulation
FSK	Frequency shift keying
HR-WPANS	High rate wireless personal area networks
HVAC	Heating, ventilation and air conditioning
I	In-phase data stream
IBSS	Independent basic service set
IEC	International electro technical commission
ISM	Industrial, Scientific and Medical radio frequency bands
LAN	Local area network
LR-WPANS	Low rate wireless personal area networks
MAC	Medium access control
MR-WPANS	Medium rate wireless personal area networks
NCSs	Network control systems
O-QPSK	Offset quadrature phase shift keying
OSI	Open system interconnect
PA	Power amplified
PAN	Personal area network
PHY	Physical
PM	Phase modulation
PN	Pseudorandom noise
POS	Personal operating space
PSD	Power spectral density
PSK	Phase shift keying
PSSS	Parallel sequence spread spectrum
Q	Quadrature data stream
QoS	Quality of service
QPSK	Quadrature phase shift keying
RFDs	Reduced function devices
SIR	Signal to interferer ratio
SNR	Signal to noise ratio
TDMA	Time division multiple access
TSMP	Time synchronized mesh protocol
Wi-Fi	Wireless fidelity
WLAN	Wireless local area network
WNCSs	Wireless network control systems

WPAN	Wireless personal area network
WSAN	Wireless sensor and actuator network
WSN	Wireless sensor network



1.INTRODUCTION

1.1 Extent Of This Thesis

In the first chapter of this thesis, we have taken a general survey on wireless control network, as our main subject is to manipulate this technology to serve our purposes in our project. Therefore, we need to know the general information, work fields and applications about WCNs technology. Also how many types of wireless control technology are in field work and their properties. The goal behind the remote monitoring and control wireless sensor network introduces in this thesis is to prove that the wireless sensor network can be used for the cultural heritage preservation purpose with high stability.

In the second chapter, it is taken the ZigBee wireless control network technology, as our main selection for this project. Because the main properties that presented for us by ZigBee are a good choice in modern life wireless control network technology. Since the Zigbee technology has a low data rate with a low power consumption and cheap. Its considered to be a good choice for many applications that can be much useful in the future. Also, in this chapter it has taken the historical view of ZigBee technology. Moreover, we present a full survey of ZigBee's applications. Also we can find the frequency bands that worked on ZigBee. Also, we explained the work principle and The main role of each router and end device in ZigBee's network. Also, we explained the network topologies types in ZigBee networks with their explanations.

In the third chapter, we had taken our survey into the transmitter and receiver system of the ZigBee wireless network and work principle of both parts. Also, we explained the wireless communication channel AWGN (Additive White Gaussian Noise) and her effects on the signal. Moreover, we presented the receiver types as coherent and non-coherent and what is the difference between them. In other hand, the main ZigBee transceiver system we had to start of how it deals with the information and what change could be happened to the information. Therefore, first information will be presented to the spread

spectrum technology, and in this section it revealed to us what type of spread spectrum technology we have used. Also, in the next section is explaining the digital modulation technology we used and what type of digital technology we have already used in the system. Moreover, we presented a study of how is this modulation technique work also we presented a block diagram of each part modulation and demodulation. Then, we have explained serial and parallel convertor and what is the work principle of this convertor.

In the fourth chapter we have explained our project the mobile robot controlled with X-BEE chip that work with ZigBee wireless network technology. Also, we have defined the robot purposes and his applications field of work. Then we have presented basic material that we have used in our project. Such an example on our materials the microcontroller we have already used is Arduino. Also, the work principle of this microcontroller with programming part. Moreover, we presented a study on our sensors that we used “Ultrasonic sensors” as a protection and detection purpose for our robot from the surrounding areas. Also, the sensors proved a successful resultes in sending the sensed information to the control unit by using the ZigBee communication technology in our X-BEE chip. Also, we have presented a study on the configuration program of our X-BEE chip called “XCTU program”. As a result for our project we have already tested the strength of the communication between the two chip. We have also presented a much further study of how it can be used in different topology connection with the same configuration program. Finally, the project presented a good results in full control and monitoring with enough communication range.

In the fifth chapter we have presented our conclusion on our thesis and the future ideas for our project and what are the ways to be developed for serving in much more application fields.

1.2 Wireless Control Network

Nowadays, there is a great use of wireless technology in many areas such as agricultural industry, mechanical measurement, and surveillance (Ikram, Et al,2010). Wireless sensor network (WSN) is a high research topic of these years. The challenges in the scientific research level is not just the only motivation for the interest in this topic but also because of it's huge application possibility. Generally, the development of WSN (Wireless sensor network) is aiming at low power consumption, low price and robust network. The advantage of Wireless sensor network (WSN) is already presented by its name, when we compared it with the canonical wired network. A Wireless sensor network (WSN) can provide much more communication mobility and flexibility, by replacing the cable with the wireless radio signal. For example, when testing the rotation speed of an engine, a wireless sensore node mounted with an accelerometer can be placed in the spinning axis. The measured data from the sensor module can be sent wirelessly to the receiver. There are two kinds of communication patterns are mainly applied nowadays, by the radio communication methodology point of view, the synchronized and unsynchronized network (Shashin,2008).

The synchronized network involves the time slot method to coordinate the communication interval. Wireless sensor network (WSN) allows the message relay to go to sleep periodically because of It is a more power efficient. The non-synchronized network is different from the synchronized network, because it requires the message relay to work all the time. As a result, this type of a network provides higher performance on processing sensor information. Otherwise, different wireless network protocols are developed base on different communication methods. The star network topology, from the network topology point of view(Faludi,2010) is supported by almost all the communication protocols. More advanced protocol, like ZigBee, supports multi-hop mesh network(Akyildiz and Wang,2009). As a result, after the network establishment the coverage of the sensor network can be largely expanded. Nevertheless, the wireless sensor network is designed as a local area network

(LAN). The wireless sensor network can forward the message to any place around the world, when connected with the internet. Meanwhile, in the deploy location the wireless sensor network can be used for control purposes. The message relay can be connected with the control devices, i.e., radiator or ventilation. People at any place around the world can send a control command to the wireless sensor network to control the indoor climate, as long as the internet is available. As a result, the two way communication realizes a remote wireless monitoring and control system. The goal of the remote monitoring and control wireless sensor network introduces in this thesis is to prove that the wireless sensor network can be used for the cultural heritage preservation purpose with high stability. The most interesting factors to be monitored and manipulated is the temperature and relative humidity. Besides the functions, the stability of the system should be good enough when it is compared with the wired system in the market. Additionally, the ZigBee protocol is used for the communication protocol of the wireless sensor network(Zhang,2011).

1.3 Wireless Automation

We called it “wireless automation”, because of the use of wireless network in control applications, also it’s an emerging application area(Moyne and Tilbury,2007), (Flammini and et al,2009), with the possibility to revolutionize the automation industry(Bond,2006). The primary benefit of wireless control technology is reduced installation cost, as a considerable investment is made in the wiring of factories, both financially and labor. The cables replacement is not the only reason for using the wireless technology; the benefits go beyond that. Increasing the flexibility is gained as sensors can be placed more freely, even on rotating machines, all of these with wireless devices. Failure of cables is eliminated, as the communication can be done over several paths in mesh network and robustness will be increased. Finally, there are the opportunities for new applications that are enabled by wireless control. Some existing or emerging applications are remote control of devices, for example cranes or dexterous and mobile robots, mobile applications, and wireless monitoring of large plants for fault detection, maintenance, production quality monitoring,

and compliance to environmental regulations(Gungor and Hancke,2009). There is a strong aim to develop and deploy wireless network control systems(WNCS), where a control system communicate over a wireless network, in factory and home automation(Antsaklis and baillieul,2004), (Egan,2005), (Flammini and et al,2009), (Gungor and Hancke,2009), (Kumar,2001), (Willig,2005). Sensor network applications have as well received much attention, in a related field (Akyildiz and Et al,2002), (Baronti and Et al,2007), (Vieira and et al,2003), (Yick and Et al,2008). Today, in monitoring applications, wireless automation technology is mostly applied, because the network requirements in terms of real time performance are low in these applications. Due to the unreliability issues of wireless networks, the industry is cautious to apply wireless to closed-loop control(Björkbom,2010).

1.4 Wireless Control Systems Simulation

Sensors, controllers and actuators are connected with a computer network, in the network control system(Antsaklis and baillieul,2004) Connecting all the devices through a shared network, because the standard approach in automation is to use fieldbus. Reducing the cabling cost is one of the benefits of network control systems (NCSs)(Neumann,2007), which removed completely by the introduction of wireless devices. Other advantages include ease of adding field devices, introducing two-way communication with field devices for remote configuration, device status, diagnostics and health monitoring, and utilizing more advance control strategies because of improved field data (Gungor and Hancke,2009), (Neumann,2007).

The cheap and proven technology from office environment is being applied to automation. Ethernet networks are becoming regularly used and have to some extent replaced fieldbus technology in control application (Moyne and Tilbury,2007). The “Industrial Ethernets” or RTE(Decotignie,2005), (Neumann,2007) which allow for real-time operations, where an operation is guaranteed to be executed in a given time, are gradually being applied. By means of wireless technology the same benefits are also available, with the

addition of accessing the data wirelessly using handheld device, enabling in-situ inspection of the process(Brooks,2001).

The terms wireless networked control system or wireless sensor and actuator network (WSAN) refer to a control system, which communicates over a wireless network. More benefits in terms of flexibility and cost compared to NCSs as there are no wires delivered by these systems, but also more problems, mainly because of the open air and shared communication medium. The general convention to distinguish between these two terms is related to the background of the researchers working in the field. WSAN refers to a wireless sensor network (WSN)(Baronti and Et al,2007) with the addition of actuators, where a wireless network control system (WNCS) is more aimed at wireless industrial automation.

An overview of network control systems (NCSs) can be found in(Antsaklis and baillieul,2004) and (Hespanha and Et al,2006). Cabling is reduced that are the benefits of network control systems (NCSs), similarly as using an automation fieldbus, and cheaper office grade hardware is used(Cena and Vasques,2005). The general development and philosophy of a networked control systems is presented in(Cena and Vasques,2005) and (Flammini and et al,2009). There are many technological and social obstacles to utilizing wireless networks in control. Because of the uncertainty of communication is the reason for the main concern against deploying wireless networks for control, co-existence with other wireless networks (Flammini and et al,2009) and security. The real concern is the inability to guarantee a sufficient quality of service for the control system. Since failure in control can cause physical damage, the control engineers are hesitant to apply technology that cannot be trusted. Therefore the real-time and constant operation must be provided by the network (Moyne and Tilbury,2007). The problems happened which causes for the control system design when the real-time operation may not always be guaranteed(Lian and Et al,2006). From this chapter we can see that the hard real-time operations is not necessarily needed in practical application. Soft real-time operation is enough, if it is taken into account in the control design, for instance the adaptation.

Another concern obstruction the adoption of wireless technologies is security, since the wireless medium is open for eavesdropping and interference (Mustard,2006).

1.5 Wireless Control Network Applications

The wireless roadmap developed because of the needed technological and social development for the adoption of wireless technology in automation, is summarized in (Koumpis and Et al,2005). An inclusive overview of current technologies, future issues, and research topics of wireless industrial networking is given in(Gungor and Hancke,2009) and (Willig,2008). Several wireless standards had been presented and the expectation promising research topics had been introduced. Some of them are: network architecture and scalability, network standards, quality of service measures, provisioning and analysis of wireless industrial networks, real-time and reliability, security, and energy efficiency. Another source of information on industrial wireless control is the report (Eriksson and Et al,2005), where the whole field is reviewed starting from wireless communication to control issues and theories, and finally simulation tools. The wires NCS case with similar MAC, QoS and other issues as the wireless case, is discussed on(Moyne and Tilbury,2007).

There are many other papers giving an overview of the current wireless technologies and networks for control, e.g. (Gungor and Hancke,2009), (Irwin and Et al,2006), (Pellegnru and Et al,2006). Reviews of challenges, design goals, and technical solutions for industrial wireless sensor networks can be found in(Gungor and Hancke,2009). A discussion of several properties and challenges of using wireless in real-time control applications can be found in(Willig,2005). Some of the network related issues are: interference, path loss, timing and timeliness, co-existence of other wireless networks, and connection to an existing wired automation system. A discussion of the requirements and features for using wireless at the device level in an automation system, including power consumption, security, and connection to the wired control

system can be found in (Pellegnru and Et al,2006). The necessity of wireless protocols aimed specifically at control applications is also pointed out.

Wireless communication has been applied in many control applications in process control and factory automation. The reduced wiring and installation costs is the first benefit (Brooks,2001). The savings certainly will increase with increasing plant size such as oil refineries and with increasing number of sensors. The ability that is given by using wireless technologies in automation is one to more freely place sensors in a factory and even places where it previously was expensive or impossible, such as explosive environments and rotating devices.

As the wires are removed, industrial robots will also become more graceful(Steigmann and Endresen,2006). There will be new applications to emerge with using wireless communication , such as mobile applications.

1.5.1. Wireless network for control

The main role to use wireless networks for control applications are exactly envisioned to use standard existing wireless devices such as Bluetooth, ZigBee (based on IEEE 802.15.4 radio) (Baronti and Et al,2007), and WLAN (IEEE 802.11). The wireless network design problems are presented for instance in (Kumar,2001). The use of carrier sense multiple access (CSMA) type medium access control (MAC) with exponential back-off in case of collisions, was in the traditional computer networks, such as Ethernet and WLAN. The suitability for control purposes are evaluated and also compared on several MAC- types in (Cervin and Henningsson,2008), where among the compared protocols, because of the immediate transmission opportunity the carrier sense multiple access (CSMA) type was found to be the best. Where collisions triggers back-offs this result does not hold in high traffic conditions, which were not taken into account in (Cervin and Henningsson,2008). For wireless control applications the nondeterministic exponential back-off of the default carrier sense multiple access (CSMA) protocol is not suitable, since the communication delay, which is

for the control stability is important (Cervin and Et al,2004), cannot be packet dropped and bound because of crowding decreases the performance (Liu and Goldsmith,2003). The actual favorite solution is to utilize deterministic networks, by using polling (e.g. Bluetooth) or scheduling (WirelessHART and ISA100.11a).

Wireless network are already used for control. Some early adoptions of wireless devices as cable replacements are listed in (Koumpis and Et al,2005). The first wireless was using a Bluetooth for deployments that have been mostly utilized for cable replacements. Bluetooth has, however, given way to ZigBee, as ZigBee has low power consumption and more flexible networking. An over view of ZigBee/IEEE 802.15.4 can be found in (Baronti and Et al,2007). ZigBee has truly been criticized for being unreliable, lacking techniques to mitigate the communication problems, and unsuitable for industrial control (Lennvall and Et al,2008). ZigBee is more suitable for small applications, and there are separate industrial standards for wireless automation. Using standard wireless hardware for automation is considered in (Pellegnru and Et al,2006), where two application layer protocols suitable for real-time control are designed and evaluated.

The current radios typically operate in the open ISM frequency band (the industrial, scientific and medical (ISM) radio bands), in wireless automation applications. The ISM band is very crowded, as also the office networks (WLAN, Bluetooth) operate at the same frequencies. In the future, to enable proper, interface free wireless control operation, we need to separate frequency band that could be reserving world-wide exclusively for industrial automation applications.

The use of various networks spanning the whole automation system from low level devices to high level functions, such as production monitoring, is considered in (Moyne and Tilbury,2007), where the applicability of different networks at the different levels and tasks are evaluated. For higher level functions, such as trend analysis, plant monitoring and production planning, or

gathering of batch information, real-time operation is not necessary, and office grade wireless networks are suitable for these tasks. The only device level wireless networks, in the current wireless automation standards, where sensor devices report their measured values and possible health data to a gateway and the rest of the automation system, are considered. Only at the lowest device level where the network is used in the whole automation system (Steigmann and Endresen,2006). In practice, we could use the office grade IEEE 802.11 standard and plant it on a wide wireless networks with proprietary protocols based on this standard.

The devices may have wired power, in spite of the wireless communication, because of large power requirements of the sensor or, more often, the actuator. We could make the power source local, for genuinely wireless devices. By using a battery holds a finite amount of energy, and therefore the device lifetime is limited, or energy must be collected during operation from environment with energy harvesting techniques. If we are looking for a source of auxiliary energy we could find it for example in electromagnetic, light, vibration, or temperature differences(Paradis' o and Stainer,2005). We have also another solution to completely dispose of cables is wireless power transportation. An existing solution is inductive power transfer to devices located inside a cage (Scheible and Et al,2007). The cage walls induce a rotating magnetic field that solenoids in the devices convert to current. Typical power transfer ranges from 10 to 100mW (Steigmann and Endresen,2006).

1.5.2. Current standards for wireless automation

Currently, there are two kind of standards for industrial wireless automation applications: WirelessHART and ISA100.11a. Both of the industrial standards are based on the IEEE 802.15.4 radio . The suitability of the IEEE 802.15.4 is the reason we use it for the building automation (Kintner-Meyer,2005), industrial monitoring, and control applications (Egan,2005), (Wheeler,2007). The important characteristics are the low bit rate and low power consumption. For some details in the implementation of WirelessHART standard are discussed in

(Song and Et al,2008)[44]. The similarity in design goals and using the same radio, we can consider that the ISA100.11a is in practice very similar to WirelessHART, but also the two standards are not compatible with each others.

The design of each industrial wireless network standards embody sensing element nodes, wireless routers communication with one another, and a gateway, that is connected to the automation fieldbus and therefore the remainder of the automation system. Mesh networking is feasible for reliability, however all communication between devices within the wireless network is routed via the gateway. This routing constraint makes the network planning and routing design easier.

WirelessHART was approved by the International Electro technical Commission (IEC) as a full international standard (IEC 62591Ed. 1.0) in March 2010. Currently, several manufacturers had released devices for the WirelessHART standard and at this point it had been used for control applications. The ISA100.11a standard was published in September 2009, gained IEC approval in 2010. Thus, the field of modern remote control has made its initial steps. The tradition control applications can easily be applied because these standards are designed for determinism purposes. In spite of the fact that determinism is the principle outline objective, this is never completely guaranteed and is on the cost on execution and adaptability.

WirelessHART utilizes a blend of time division multiple access (TDMA) and frequency division multiple access (FDMA) MAC protocol. The TDMA slot is 10 ms, in which the data packet with sensor or control information and an acknowledgement are exchanged between two nodes. The network and transport layers are based on the Time Synchronized Mesh Protocol (TSMP) originally developed by Dust Networks . Each and every node pair is assigned a particular time/frequency slot for contention free communication by a centralized network manager .

The centralized network manager is the way that give a contention for free communication also each and every node pair is assigned a unique time/frequency slot. For communicating rare event messages or retransmissions in case of dropped packets, some slots can be reserved for contention based access using carrier sense multiple access (CSMA). Furthermore, frequency hopping is utilized to modify interference on a few channels. For more detailed presentation of WirelessHART can be found in (Song and Et al,2008).

We will find that scheduling and routing are left open in the WirelessHART and ISA100.11a networks standards. We will be able to have a constant bounds on the communication may also be advertized, although no longer assured, because of the determinism of the TDMA process with predetermined schedule. If the information exceed the delay bound, then it may caused in the case of packet drops , also the retransmission will probably needed. Retransmission can take place on the slots allocated for random entry, or on further slots allocated within the schedule. The schedule and retransmissions assess when information is available to the control system, and as a result affect the control operation. There exists work where the actual network MAC protocol and related functions such as duty-cycle (Marco and Et al,2010), or routing and schedule (Sami and Et al,2009), (Weiss and Et al,2009) are taken into account in the control stability proof.

The present standards are designed for reliability and are as a consequence conservative, which means that closed-loop control of quick processes isn't possible. The design choices of each standards make sure a relatively easy network design. The usage of TDMA ensures determinism (Dismissing packet drop due to interference) and the routing via gateway constraint outcome in a less complicated routing design. Current research involving the standards is for illustration the optimality of the time/frequency-slot scheduling and routing (Weiss and Et al,2009). The room for improvement is as a result limited.

In the future, WCS control methods with low efficiency requisites are more likely to emerge. These can be headquartered on industrial off-the-shelf hardware, via adopting powerful control algorithms. Today's COTS hardware, such as WLAN, Bluetooth, and IEEE 802.15.4, makes use of more commonly carrier sense multiple access (CSMA) type communications (Irwin and Et al,2006). This means that the network is inherently nondeterministic and unreliable. There are not any first-class of provider guarantees, equivalent to distinct transmission slots. This doesn't imply that wireless purposes on this hardware are unimaginable; it's as a substitute a study opportunity. Several useful functions may also be proven to work satisfactorily, using simulations and pilot implementation.

1.5.3. Wireless sensor networks

Wireless sensor networks are a subject closely concerning wireless network control systems (WNCSs), with a plenty of ongoing study. To deliver situation awareness to the user in WSNs a low powered wireless network with a hundreds or thousands of nodes are sensing or observing some phenomenon and collaborating on environment monitoring (Karl and Willi,2005). The sensing nodes characteristic's are small and low cost with a limited operational time (Vieira and Et al,2003). For enabling along lifetime of the application the limited power source of wireless sensor network (WSN) nodes it demands for algorithms with low computational and communication requirements(Gungor and Hancke,2009). The applications range from environmental, agricultural or structural health monitoring (forest, crop, earthquakes, bridges, buildings, among others), asset management (inventory surveillance, plant monitoring, and maintenance), to military and battlefield applications (detection of events such as enemy activity, poisonous gases, or radioactivity) (Baronti and Et al,2007). The network associated study subject matters in wireless sensor networks (WSNs) are generally medium access control or routing(Karl and Willi,2005). The networking problems are just like wireless network control system (WNCS), however there is commonly no closed-loop control and for this reason the Real-time operation requirement shouldn't be as strict as in wireless

automation. Reliability is obtained with redundancy and distributed computation. For saving the battery life the necessary factor is the low power consumption of the tiny network nodes. This boils down to hardware and MAC protocol design, for example in the Wise NET sensor network (Enz and Et al,2004), or TUTVVSN developed at the Tampere University of Technology, Finland (Kohvakka,2009). Other topics in sensor networks are data compression, storage, transportation, processing and enhancing (Ganesan and Et al,2003). Sensor networks can be utilized as a monitoring system for plants, where the sensors deliver extra measurements of plants, separate of the automation system. The increased demand on high efficiency and ecological production require new, low-cost, and flexible construction monitoring technologies. Industrial wireless sensor networks can be used for production monitoring of power efficiency and compliance to environmental regulations(Gungor and Hancke,2009). Another similar application is the "mobile wireless industrial worker," where a serviceman can walk in a factory and monitor the nearby sensors and actuators with a wireless handheld device(Brooks,2001). Such classes are useful for the deployment of wireless control in industrial environments, as the conditions could also be fairly harsh, together with shadowing and interference from motors and devices (Willig and Mitschke,2006). There are some reports on the experiences of sensor network deployments in industrial environments. A four month continuous monitoring campaign of a plant has been reported, where power management protocols and periodic system resets were used (Krishnamurthy and Et al,2005). Another example is a sewage overflow control system called CSOnet. This is a metropolitan wide sensor and actuator network, consisting of about 150 wireless sensor nodes, used to control sewage overflow by measuring the water levels in the sewage and controlling storm water flow to prevent overflow, in case of heavy rain (Montestruque and Lemmon,2008).

1.6 Wireless Control Network Technology

Wireless network provides as we were shown the flexibility and mobility , also reducing the cable restriction ; therefore, the needing of the wireless technology has become an irresistible trend for intelligent home system. In general way of speaking, we can say that the short range wireless is currently held by four protocols: the Bluetooth , UWB, ZigBee, and Wi-Fi (Dou and Et al,2009).

Bluetooth technology, also known as 2.4 ISM band , is based on a wireless radio system for low cost, single chip implementation. It is mainly used in short range of language and data transmission business. Bluetooth system has enough high anti-interference ability, simple equipment and superior performance. The two connectivity topologies are defined in Bluetooth: one is the piconet and the other is scatternet. Apart from fast frequency hopping and short data packets avoids interference, it provides link layer security between any two Bluetooth radios at the same time (Dou and Et al,2009). A Bluetooth chip is seen in Figure 1.1.



Figure 1.1 A Bluetooth chip

UWB has recently attracted much attention on account of its bandwidth which is considered to be “expected to replace the Bluetooth and wireless LAN wireless communication technology” (Dou and Et al,2009). A UWB chip is seen below in Figure 1.2.

The characteristics of UWB are:

- Powerful anti-disturbing capability. UWB provide adaptive frequency hopping to avoid channel collision.
- High speed of data transmission.
- A wide bandwidth, over GHz (up to several Mbps).
- The small of energy consumption.
- Good secrecy.



Figure 1.2 A UWB chip

Wireless fidelity (Wi-Fi), also known as IEEE 802.11a/b/g standards, has been applied extensively for wireless local area networks (WLAN). The IEEE 802.11 architecture is made up of several components. The basic cell is called a basic service set (BSS), which is a set of mobile or fixed stations. Based upon the BSS, it employs the independent basic service set (IBSS) and extended service set (ESS) network configurations(Dou and Et al,2009). A wireless fidelity (Wi-Fi) chip is seen in figure 1.3.

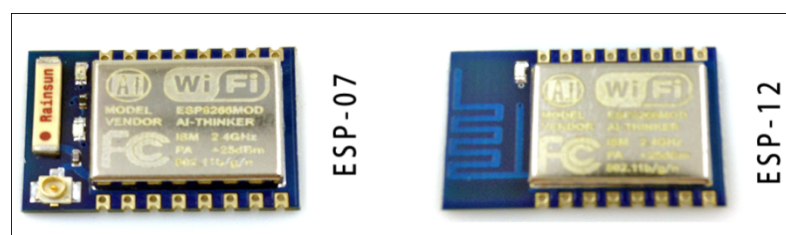


Figure 1.3 The wireless fidelity (Wi-Fi) chip

ZigBee technology is a low data rate, low power consumption, low cost, wireless networking protocol target towards home automation, building automation, industrial monitoring and control. It has developed to become the global control/sensor network standard(Dou and Et al,2009). A ZigBee chip model is seen below in Figure 1.4.



Figure 1.4 The ZigBee chip models

The main characteristics of Zigbee are as follows:

- Low power consumption: because of extremely low duty-cycle (< 10 ppm) capability, sending and receiving messages on low-power and adopting Hibernation Mode, ZigBee Technology can run for six months to two years on just two AA batteries.
- Reliability: MAC layer using the fully handshake protocol for transfer reliability.
- Supports large network orders ($\leq 65k$ nodes).
- Security (using AES-128): ZigBee provides functions of checking data integrity and Sender authentication.
- Support for low latency devices: ZigBee is optimized for time-critical applications. Meanwhile ZigBee devices don't have to synchronize with other nodes before beginning communication. Thus, devices require only 30 milliseconds to join a network and 15 milliseconds to access and start communicating(Dou and Et al,2009).

Table 1.1 provide a compression between the wireless technologies:

	Bluetooth	UWB	ZigBee	Wi-Fi
IEEE spec.	IEEE802.15.1	IEEE802.15.3a	IEEE802.15.4	IEEE802.11b
Max signal rate	1Mb/s	110Mb/s	250Kb/s	+11Mb/s
Frequency band	2.4GHz	3.1-10.6GHz	2.4GHz, 868MHz 915MHz	2.4GHz
Transmission	10m	10m(110Mbps)	10-75m	30-100m
Distance	10m	4m(200Mbps)	10-100m	100m
Power index	120mw	100mw	60mw	
Price	\$3.5	Unknown	\$2-3	3-20\$

2.ZIGBEE WIRELESS NETWORK TECHNOLOGY

2.1 Introduction

ZigBee is a standard that defines a set of communication protocols for low-data-rate short-range wireless networking. ZigBee-based wireless devices operate in 868 MHz, 915 MHz, and 2.4 GHz frequency bands. The maximum data rate is 250 K bits per second (Shashin,2008).

ZigBee standard contains a set of tools and properties that has been designed especially for wireless networked sensors and controllers. The physical(PHY) and medium access control (MAC) layers are standardized by the IEEE 802.15 wireless personal area network (WPAN) working group under the designation of 802.15.4 (Sohraby and Et al,2008). The standard target mainly the low cost, low data rate and low power wireless network. The higher layers are described by the ZigBee Alliance (2006), which is an industry alliance consisting of a full spectrum of companies, ranging from ZigBee chip providers to solution providers. In comparing with other wireless communication technology, ZigBee is designed particularly for supplying the wireless network an ability for battery-powered, low-cost, low capability sensor and controller nodes, typically powered only by an eight-bit microcontroller. In many ZigBee applications, the total time the wireless device is engaged in any type of activity is very limited; the device spends most of its time in a power-saving mode, also known as *sleep mode*. As a result, ZigBee enabled devices are capable of being operational for several years before their batteries need to be replaced.

The ZigBee technology is planned to provide a simple and low-cost wireless communication and networking solution for low-data rate and low power consumption applications, such as home monitoring and automation, environmental monitoring, industry controls, and emerging low-rate wireless sensor applications.

2.2 History

- In 1998, ideas have been generated for new communication network technology called ZigBee, because engineers realized that in many application both Wi-Fi and Bluetooth were going to be unsuitable. Engineers accepted the idea for needing new technology has the ability to self organizing ad-hoc digital radio networks.
- In May 2003, a new standard was been established called IEEE 802.15.4-2003, but it was canceled by the publication of IEEE 802.15.4-2006.
- In 2004, the ZigBee alliance membership had more than doubled, and then it start to grow larger more than 100 member companies, in 22countries. By April 2005 membership had grown to more than 150 companies, and by December 2005 membership had passed 200 companies.
- The ZigBee technology was approved in 14 December 2004.
- The ZigBee 1.0 has been announced for public availability in 13 June 2005 by the ZigBee alliance, known as ZigBee 2004 specification.
- A new version developed by ZigBee Alliance and it has been announced for availability of ZigBee standard in September 2006, known as ZigBee 2006 specification.
- The enhanced ZigBee specification was finalized, known as ZigBee PRO, during the last quarter of 2007.

The name of the brand was “ZigBee”, originated with reference to the behavior of honey bees after their return to the bee hieve.

2.3 Applications

Commercial Building and Home Automation

- It is used in HVAC (Heating, Ventilation and Air Conditioning Systems).
- Lighting control.
- Door-window-shutter locking controls.
- Music and cinema systems control in home automation.

- Indoor entrance-exit controls.

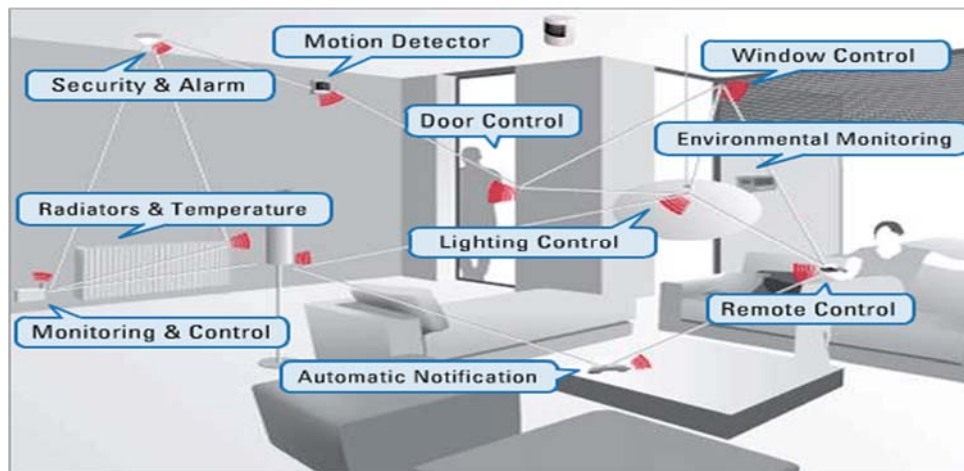


Figure 2.1 An example for home automation of Zigbee

Safety

- It is used in Safety Alarm,
- Fire- gas-water detector systems,
- Entrance-exit controls.

Health Sector

- It is used for following and controlling the body functions of patients and athletes.

Vehicles

- It is used for the controlling of the mechanisms in vehicles especially where wires cannot reach. For example, it used to monitor the tire pressure.

Agriculture

- It provides optimization for growing crops by giving an opportunity to obtain data related to humidity, water, heat, fertilizer etc.

Industry

- It is used for production control, energy management, and industrial vehicle controls. Besides, it is also used for online payment and online control systems of mobile services and devices.

2.4 Comparing Between ZigBee, Bluetooth, IEEE 802.11

By comparing these standards ZigBee with Bluetooth and IEEE 802.11 WLAN will make us understand the reason behind how ZigBee is different from other established standards. Figure 2.2 will present the basic characteristics of these three standards(Shashin,2008).

IEEE 802.11 is a family of standards; first of all is the operating frequency band is 2.4 GHz, this frequency is common in IEEE 802.11 b also Bluetooth, and ZigBee. But there is some differences like the IEEE 802.11b has a high data rate (up to 11 Mbps), also one of its typical application is to provide an internet connection. It's typical range from 30 to 100 meters indoor range. As for Bluetooth has a lower data rate (less than 3 Mbps) and the indoor range is typically 2-10 meters. But for Bluetooth application there is a famous one and it's the wireless headsets, by connecting the Bluetooth with a mobile phone or a hand free headset. Last of these standards is ZigBee who has the lowest data rate and complexity among them and also providing a longer battery life(Shashin,2008).

ZigBee is not wise choice for operating a wireless internet connection because it has a low data rate. Anyway, our choice depends on our goal of using this wireless technology, in case we want a wireless communication for transmitting and receiving or a simple commands and/or, also collecting information from sensors such as temperature or humidity sensors, ZigBee is the best choice it will provide the most power and the most cost-efficient solution compared to Bluetooth and IEEE 802.11 b.

2.5 Short-Range Wireless Networking Classes

We can classified the wireless networking methods into two main categories: wireless local area network (WLANs) and wireless personal area network (WPANs) (Shashin,2008).

WLAN is an development for wired local area networks (LANs) as an example Ethernet (IEEE 802.3). A WLAN device is capable to be included with a wired LAN network, and when the WLAN device became part of the network, the treatment of each WLAN device and wired device will be the same within the network (IEEE 802.11 WLAN MAC and PHY specification), (Shashin,2008). The main aim for using WLAN is to maximize the range and data rate.

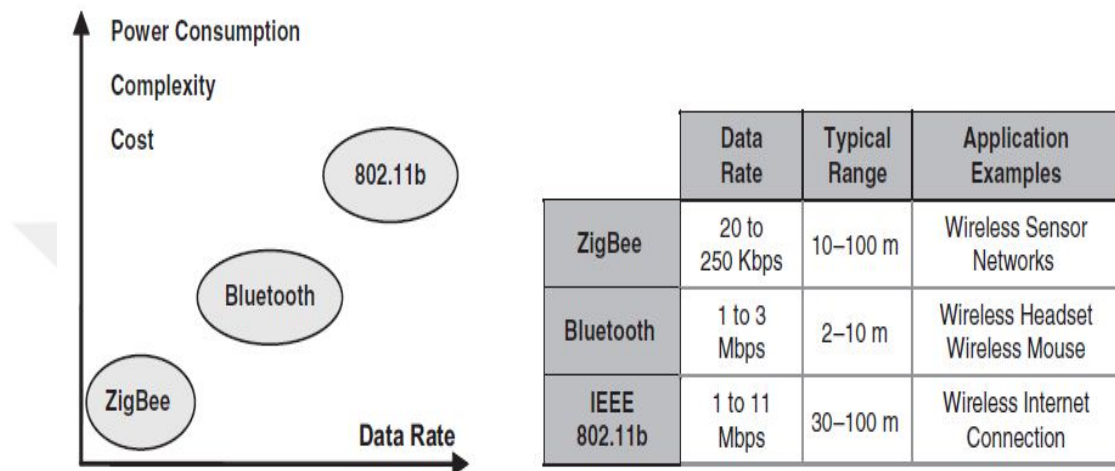


Figure 2.2 Comparing the ZigBee standard with Bluetooth and IEEE 802.11b

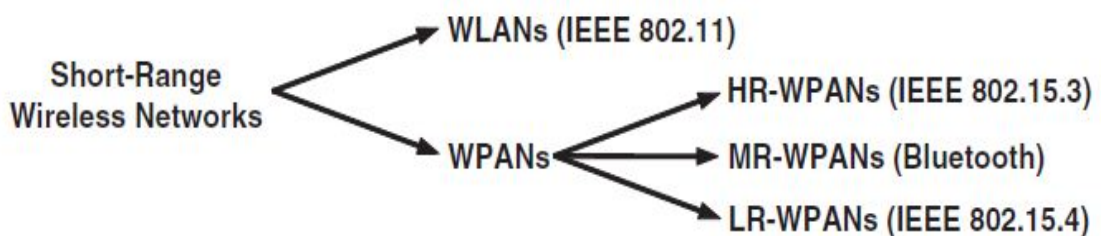


Figure 2.3 Short-range wireless networking classes

WPANs, in contrast, are not created to exchange the existing of wired LANs. WPANs are developed to present the abilities for power-efficient wireless communication within the personal operating space (POS) without the demands for any infrastructure. POS is the sphere-shaped area that surrounds a wireless device and has a radius of 10 meters (33 feet) (IEEE 802.15.4 LR-WPANs specifications,2006).

WPANs can classified into three classes (see Figure 2.3): high-rate (HR) WAPNs, medium-rate (MR) WAPNs, and low-rate (LR) WAPNs (Gutierrez and Et

al,2007). As an examples for each classes for HR-WAPN is IEEE 802.11.3 with a data rate of 11 to 55 Mbps(IEEE 802.15.3 HR-WPANs specifications,2003). The high data rate in this class helps in an application such as real-time wireless video transmission directly from camera to a nearby TV. For a MR-WLAN a Bluetooth with a data rate 1 to 3 Mbps, is a good example for this class and it could be used for high quality voice transmission in wireless headsets. As for LR-WAPN, ZigBee is an example for this class with a maximum data rate 250Kbps(Shashin,2008).

2.6 The Relationship Between ZigBee And IEEE 802.15.4 Standards

The main way to build or establishing a communication network (wireless or wired) is to use the concept of network layers. Each of the network layers have their own responsibility to do a certain tasks in the network. Normally, the data and command movement inside the layers pass directly to the above or below layers only (Shashin,2008).

The network protocol layers used in a ZigBee wireless networking are shown in figure 2.4. ZigBee protocol layers are based on the Open System Interconnect (OSI) basic reference model(The basic model ISO/IEC,1994) . The advantage in ZigBee wireless network we have it by separating the network protocol into layers. As for example if anything wrong or changed in the ZigBee protocol, it will be easier for us to modify or replace the layer that has been affected by this change also it will be rather than replacing the entire protocol. In addition, if we want to develop any application, in the protocol the lower layers are independent of the application and it would be able to calculate from a third party, so that all what we can do is changing the application layer of the protocol. The software implementation of a protocol is known as protocol stack software.

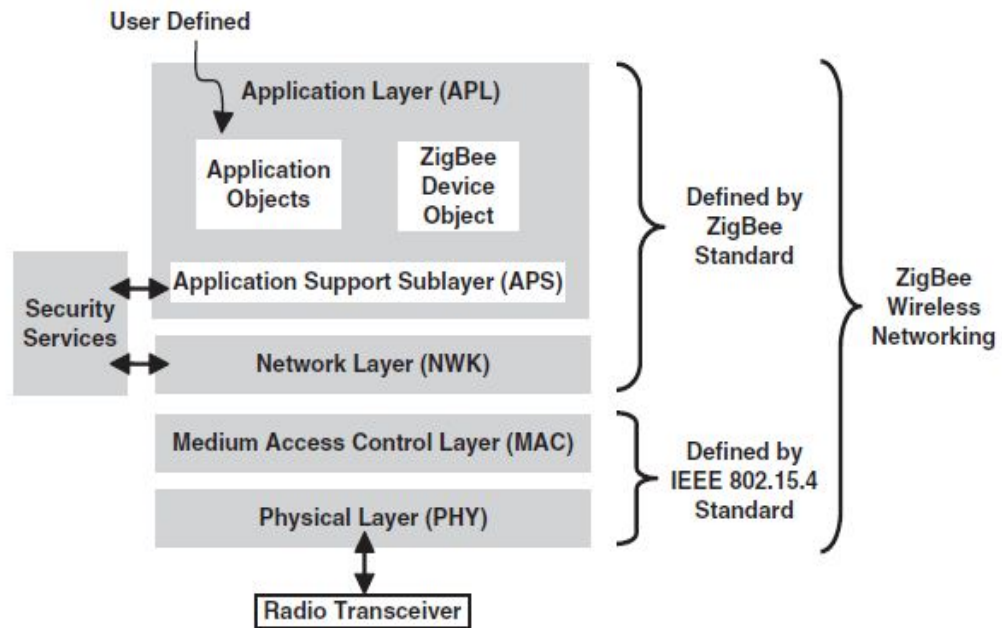


Figure 2.4 ZigBee wireless networking protocol layers

From figure 2.4, we can see that the last two networking layers in the bottom are defined by the IEEE 802.15.4 standard (IEEE 802.15.4 Wireless MAC and PHY specifications for LR-WPANs, 2006). The IEEE 802 standards group have the responsibility for the developing of IEEE 802.15.4 standard, also it was primarily going to be published in 2003. Both of the PHY and MAC layers of wireless networking are defined by the IEEE 802.15.4 standard, but it does not specify any requirements for higher networking layers.

In ZigBee standard, we can see that the networking, application, and security layers are defined by the ZigBee standard protocol and also ZigBee adopts IEEE 802.15.4 PHY and MAC layers as part of the ZigBee networking protocol. So that, any ZigBee-compliant device conforms to IEEE 802.15.4 as well.

2.7 Operating Frequencies And Data Rates

There are three frequency bands used for IEEE 802.15.4 (Guimarães, 2009):

- 868 – 868.6 MHz (868MHz band)
- 902 – 928 MHz (915MHz)
- 2400 – 2483.5MHz (2.4GHz band)

In Europe, the 868MHz band is used for a number of application, including short range wireless networking.

The 915MHz and 2.4GHz bands are part of industrial, scientific and medical (ISM) frequency bands. In north America they used mainly the 915MHz frequency band, while the 2.4GHz band is used worldwide.

Table (2.1) given below provides additional details regarding the ways in which these three frequency bands are used in IEEE 802.15.4 standard (Shashin,2008). IEEE 802.15.4 demands that if a transceiver supports 868MHz band, it has to support 915MHz band as well, and vice versa. Therefore, each of the two bands are bundled together as the 868/915MHz frequency bands of operations. IEEE 802.15.4 has one mandatory and two optional specifications for the 868/915MHz bands. The mandatory requirements are simpler to implement but yield low data rates (20Kbps and 40Kbps, respectively). If a users implement by choosing the optional modes of operation, IEEE 802.15.4 still demands that it accommodate the low data rate mandatory operation in the 868/915MHz bands as well. In addition, the transceiver must have the ability to switch dynamically between optional and modes of operation in 868/915MHz bands.

A 2.4GHz transceiver might be able to support 868/915MHz bands, except it is not desired by IEEE 802.15.4. Although, in 868MHz band there is a room for only a single channel. Also The 915MHz band has 10 channels which are not included in the optional channels. However, The total number of channels in the 2.4GHz band is 16.

The 2.4GHz ISM band is accepted worldwide and has the maximum data rate and number of channels. For these properties, the development of a transceiver operate in 2.4GHz band is a popular choice for many manufactures. However,

IEEE 802.11b operates in the same 2.4GHz band and coexistence can be an issue in some applications. Although, the lower the frequency band is, the better since signal penetrates walls and various objects. For that reason, the 868/915MHz band may be found by some users is much better selection for their application.

We can classified the modulation types that has been used in IEEE 802.15.4 into three types: binary phase shift keying (BPSK), amplitude shift keying (ASK), and offset Quadrature phase shift Keying (O-QPSK). In BPSK and O-QPSK, the phase of the signal contains the digital data. In ASK, in contrast, the amplitude of the signal contains the digital data.

The advantage of both techniques, direct sequence spread spectrum (DSSS) or parallel sequence spread spectrum (PSSS) have been taken for used by all wireless communication methods in IEEE 802.15.4. The reason for using DSSS and PSSS because it helped in the improvement of the receiver performance in a multipath environment. Table (2.1) below provide details about the frequency bands that has been used in IEEE 802.15.4.

Table 2.1 Details of the frequency bands used in IEEE 802.15.4

Frequency (MHz)	Number of Channels	Modulation	Chip Rate (Kchip/s)	Bit Rate (Kb/s)	Symbol rate (Ksymbol/s)	Spreading method
868-868.6	1	BPSK	300	20	20	Binary DSSS
902-928	10	BPSK	600	40	40	Binary DSSS
868-868.6	1	ASK	400	250	12.5	20 Bit PSSS
902-928	10	ASK	1600	250	50	5 Bit PSSS
868-868.6	1	OQPSK	400	100	25	16-array Orthogonal
902-928	10	OQPSK	1000	250	62.5	16- array Orthogonal
2400-2483.5	16	OQPSK	2000	250	62.5	16-array Orthogonal

2.8 Interoperability

Since the ZigBee has been spread widely in many applications area; therefore, several manufacturers must provide ZigBee –enable solutions. The most important job in The ZigBee devices is that, they must be able to interact with one another without paying attention to the manufacturers origin. One of the key advantages of the ZigBee protocol stack, is that the ZigBee devices should be able to interoperable with one another. Also we must mention that each of ZigBee-based devices are able to interoperable even when the messages are encrypted for security reasons(Shashin,2008).

2.9 Device Types

We can classified the IEEE 802.15.4 wireless network devices into two types : full-function devices (FFDs) and reduced-function devices (RFDs). We will take an overview on FFD and RFD work, the FFD device's type is capable of making all the tasks described in the IEEE 802.15.4 standard and can produced acknowledgement to any role in the network. About an RFD device's type his work focusing on a limited circle of capabilities. As an example of both devices types, an FFD has a capabilities to communicate with any other device in a network, but an RFD has a capabilities to communicate only with an FFD device. RFD devices are designed for a small work functions such as implementing a switch to turn the light on and off. Also we need to mention that an RFD device normally has a processing power and memory size less than those in an FFD devices(Shashin,2008).

2.10 Device Roles

An FFD device role in an IEEE 802.15.4 network standard can be taken three different roles: coordinator, PAN coordinator, and device. We can defined a coordinator as an FFD device that has the capabilities of sending commands. Also if the coordinator is the manager of controlling a personal area network

(PAN), it will be called as a PAN coordinator. In the other hand if any device did not act as a coordinator, it is basically called a device (Shashin,2008).

A different terminology had been used for the ZigBee standard as we can see it in Figure 2.5. A ZigBee coordinator will be acting similar to IEEE 802.15.4 PAN coordinator. Also a ZigBee router is a device that has a capability to act as a IEEE 802.15.4 coordinator. In the end, a ZigBee end device is a device that is neither a coordinator nor a router. Also we had to mention that a ZigBee device have a less memory size and slowest processing capabilities and features. The end device is normally the cheapest device in the network.

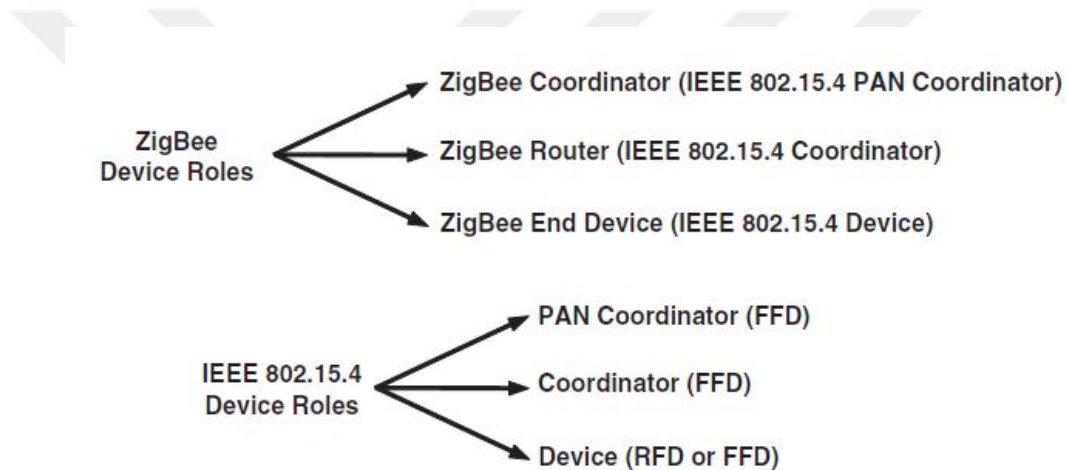


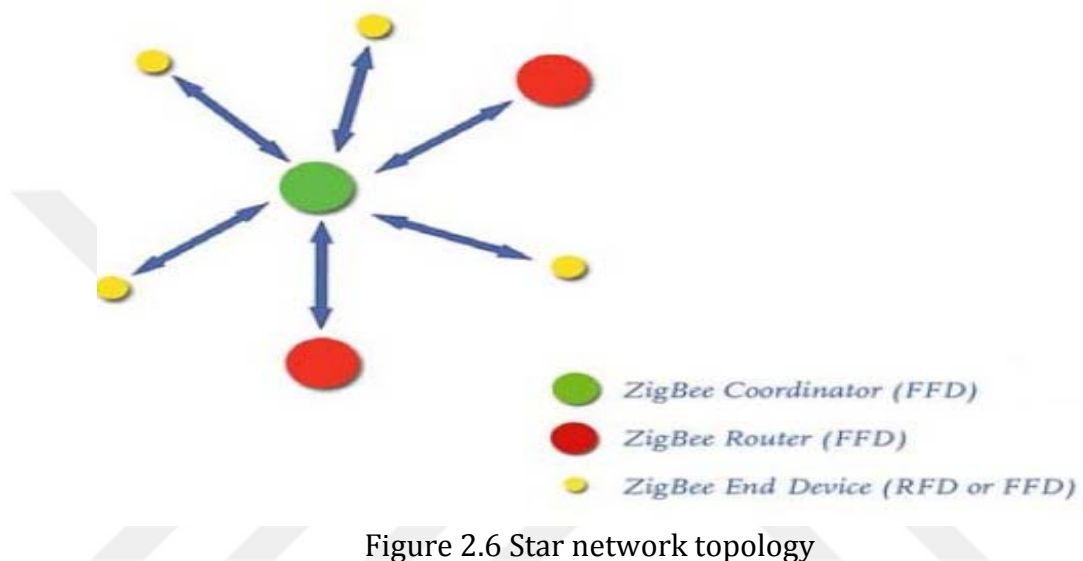
Figure 2.5 Device Roles in IEEE 802.15.4 and ZigBee standards

2.11 Zigbee Network Topology

The management of the network topology is supervised by the ZigBee network layer. IEEE 802.15.4 has specified one of two networking topologies to working in the ZigBee network topology these topologies are: star and peer-to-peer (Shashin,2008).

In star topology we can find that the first FFD runs for work it will create its own network and becomes a personal area network (PAN) coordinator. After establishing the network by the first FFD, we can see that both of the FFD and RED devices can connect to the PAN coordinator. Figure 2.6 below shows a typical star network of this type (Lönn and Et al,2005). The PAN coordinator job

start by selecting a unique PAN identifier and make sure it will not be used by any other network in its radio sphere of influence (the region around the device in which its radio can successfully communicate with other radios) (Shashin,2008). Also all the devices in a PAN network must communicate with PAN coordinator(Lönn and Et al,2005). Star network topology can be seen in figure 2.6.



In peer to peer topology, in this type we also has a PAN coordinator, but it is different from the star topology in this type of topology we can say that any devices can have a communication with any other devices only if they were in the network range of one another. Peer to peer network can be seen below in figure 2.7. Also one of this type advantage is that in peer to peer network topology it has the capability to allow more complex formation for a network to be implemented, for example the mesh topology that shown in Figure 2.8(Lönn and Et al,2005).

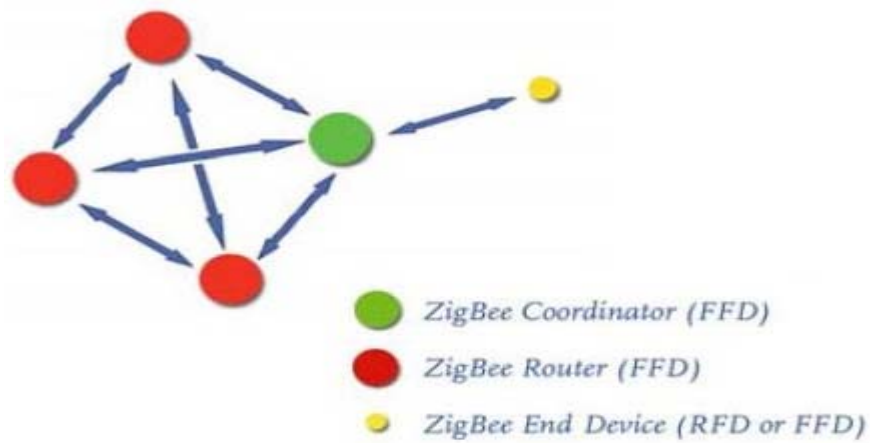


Figure 2.7 Peer-to-Peer network topology

For mesh topology it can be constructed by making combination of star and peer-to-peer network topologies both of the two will produce a more reliable and extend in range topology called mesh network topology (Lönn and Et al,2005). As shown in figure 2.8 below, the ZigBee coordinator (PAN coordinator) establishing to initial the network, also there is a ZigBee routers acts as branches for relying the messages. ZigBee end devices act as leaves for the network but they don't take part in message routing. ZigBee has the ability to extend and grow beyond the initial network that has been established by ZigBee coordinator(Shashin,2008). This network topology has an advantage for extending in range for a large area and also it could be contain a thousand nodes. Another advantage for this type is the reliability, each of the FFD in the network will act as a router for directing the messages. Also the routing of the network can be changed dynamically. This will produce an extremely reliability for the network, in view of the fact that a network has the ability to heal itself so that if a node has been disabled. We will see that a new node will be recognized and linked in about 30 ms (Lönn and Et al,2005). This 30 ms is been divided as a 15 ms for waking a sleeping nodes, then it goes for accessing a channel or transmitting date. This capability has its own benefits for ZigBee application because it is attached and detach date quickly and then go to sleep, this will result to a low power consumption and also extend the battery life(Lönn and Et al,2005). Figure 2.8 below shown the mesh network topology.

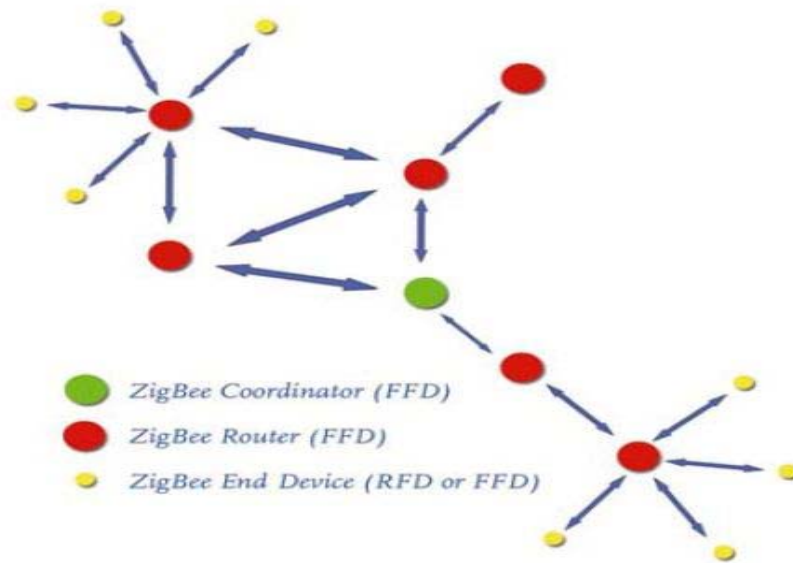


Figure 2.8 Mesh network topology

3.ZIGBEE TRANSCEIVER DESIGN

3.1 Introduction

In this chapter, we will explain the block diagrams of ZigBee transmitter and receiver that is seen in figure 3.1. Also we will explain the major function in both parts transmitter and receiver like, bit to symbol mapping, chip mapping, serial to parallel conversion, performing half sine pulse shaping and performing modulation will be discussed in the transmitter part, RF to baseband conversion, sampling and hold, parallel to serial conversion and despreading will be discussed in the receiver part.

In the transmitter section, as seen in figure 3.1 in the block diagram we will use input data with a bit stream that have a data rate of 250Kbps. Then we will mapping 4 input data bits to a symbol that have a symbol rate of 62.5Kilo symbol per second. After that the symbol will be used to select one of 16 nearly orthogonal 32-chip PN sequences for transmitting and the results will be a chip rate of two mega chips per second. Then this resultant chip sequence will be sent to the serial to parallel converter(Nam and Sang,2006), it will be explained in section 3.4.3. This converter is used to separate the even indexed chips and odd indexed chips. Following this, a half sine pulse shaping will be performed and a signal modulation with a 2.4 GHz carrier on In phase and Quadrature data stream, plus we introduce an offset delay in Quadrature data stream, and then add both of Inphase and Quadrature data stream for getting the require transmitter output signal. This section will be explained briefly in this chapter.

In the receiver section, the receiver block diagram is seen in figure 3.1, the received signal will be applied to two synchronous demodulators, that contain a multiplier followed by a low pass filter. Then one of the multiplier will be supplied by a signal , which is the multiplied signal of carrier $\cos \omega_o t$ and $\cos (2\pi \frac{t}{4t_b})$. Another multiplier will be supplied with Quadrature signals i.e., with $\sin \omega_o t * \sin(2\pi \frac{t}{4t_b})$. This multiplier output has the baseband data and higher frequency harmonics. That is why we need the multiplier signal to pass through

a low pass filter for avoiding harmonics. After this, a third order Butterworth filter contains a cutoff frequency of $\frac{2}{T_b}$ Hz that will be used for extracting of baseband data. Then the resultant data will be passed through a sampler. We will use a simple zero order sample and hold circuit that will be enough for this purpose. The device will simply holds the data for one bit period. The sampled data will be transferred to a decision device. This decision device having a simple comparator which has a threshold value for making a decision. At the transmitter, we are introduced an offset delay in Quadrature data stream. For compensating that delay effect, at the receiver, we have to introduce same one bit delay at the output of comparator in inphase side. Then, we use a multiplexer or a parallel to serial convertor, for multiplexing the data coming from comparator. This data having a data rate of 2 Mbps which is nothing but transmitted Direct Spread Spectrum data. After that, we must pass the result through a multiplier. The multiplier will be supplied by the same PN sequence data that has been used in the transmitter part. Then the data from the parallel to serial convertor will have a data rate of 2 Mbps. The original data will be extracted by multiplying this data with the PN sequence data. But the obtained 2 Mbps data from the output of parallel to serial converter will have some offset delay. This offset delay have to be introduced to the PN sequence data during multiplying with 2 Mbps. The final step we calculate the bit error rate (BER) in which we can evaluate the system performance, then we will be able to recover the output signal which it contains original bit stream without errors.

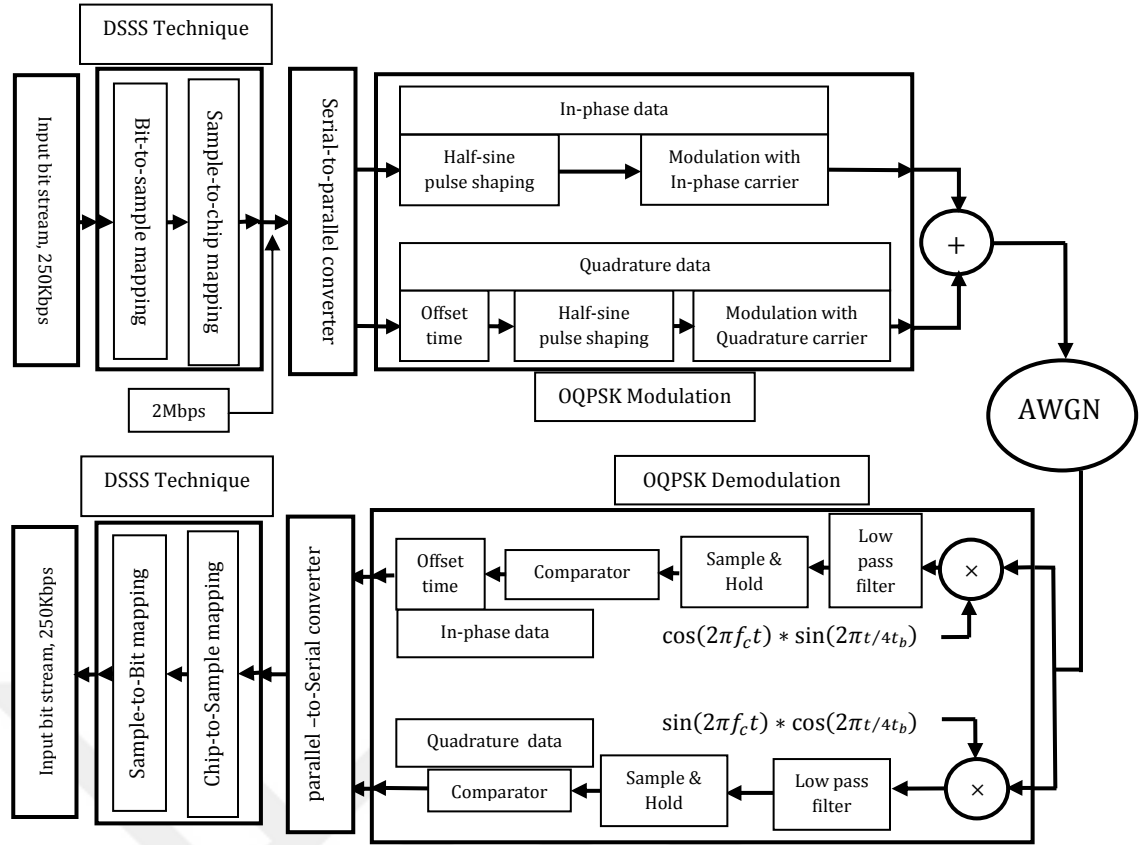


Figure 3.1 Block diagram of ZigBee transceiver system

3.2 Wireless Communication Channel

AWGN is (Additive White Gaussian Noise) one of the wireless communication channel, is also part of the fading channel model which is referred to the distortion experience of a telecommunication signal when the modulated carrier pass throw a certain propagation media, it is also the simplest radio environment that could be used for wireless communication system (Proakis, 2001). Additive white Gaussian noise (AWGN) was usually used for transmitting a signal and after the signal travel from channel then simulating the background noise of channel.

As for the AWGN channel when the modulated signal in equation (3.1)

$$s(t) = \text{Re}\{u(t)e^{j2\pi f_c t}\} \quad (3.1)$$

Travel throw it, it will have noise $n(t)$ added to it, before receiving the modulated signal. Therefore, the mathematical expression for the received signal when it passed through the AWGN channel (eq.2) is

$$r(t) = s(t) + n(t) \quad (3.2)$$

Where $r(t)$ is the received signal, $n(t)$ the background noise and $s(t)$ the transmitted signal. As we mention before that the transmitted signal was corrupted by this noise 'n', as we referred to as Additive White Gaussian Noise (AWGN) (Proakis, 2001).

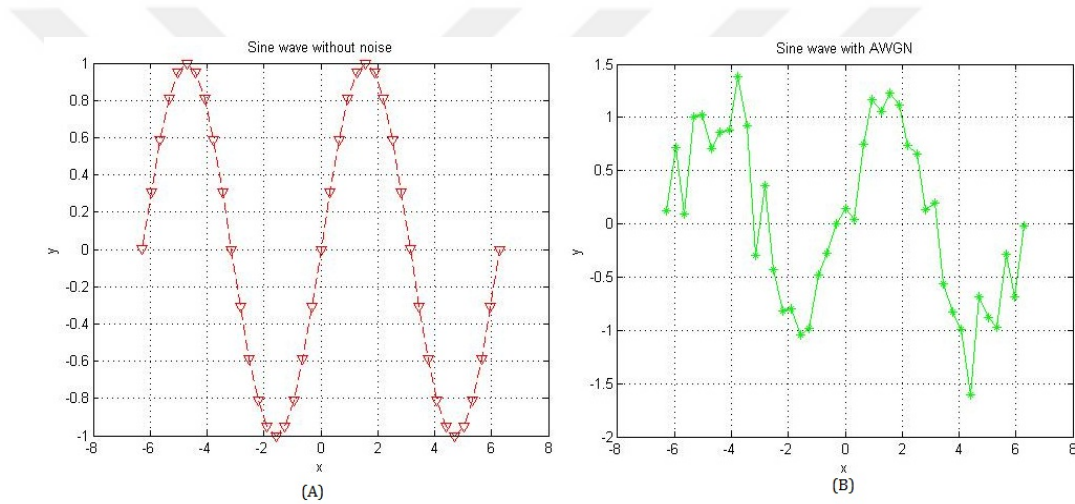


Figure 3.2 (A) The sine wave without the effect of AWGN, (B) The sine wave with the effect of AWGN

3.3 Coherent And Non-Coherent Detection

The transmitted signal will experience phase changing while travelling, because of the propagation delay or fading in the communication channel. And for that reason, performing a carrier synchronization between the transmitter and the receiver is important, and for any modulation technique that makes use of this synchronization known as coherent detection. As for the non-coherent type it does not have to use the carrier synchronization.

Coherent detection can be performed but with a certain cost, that first it need a carrier recovery circuit, in return it will make the system more complex, also it will increase the size and power consumption of system. Furthermore, there is no ideal carrier recovery circuit. Also until now there is no practical digital communication that can perform with a perfect phase coherence. As for the non-coherent detection type is more simple than the coherent type, but it has some problems with the performance comparing with the coherent type. But these differences can be smaller in practice with some modulation techniques and the incoming penalty from the imperfections of carrier recovery process. And that is why we have no need for the carrier recovery circuit in non-coherent detection type(Guimar~aes,2009).

3.4 ZigBee Transceiver Requirements

This section will describe the design of a ZigBee transmitter system, as shown in figure 3.1 before transmission design we have to know the major function that has been used for implementing in transmitter such a functions are symbol mapping, symbol to chip mapping, serial to parallel conversion, half sine pulse shaping and modulation with a high frequency carrier. Initially bit to chip conversion can be achieved by employing a DSSS (Direct Sequence Spread Spectrum) technique(Nam and Sang,2006). And the high frequency modulation we used OQPSK modulation technique to achieve our goal of high frequency carrier. Now the spread spectrum technique, serial to parallel conversion, sine pulse shaping, and OQPSK modulation will be explained briefly in this section. Figure 3.1 shown the block diagram of ZigBee transmitter.

3.4.1 Spread spectrum technique

The spread spectrum modulation may be stated as two parts (Herber and Schilling,1999).

1. Spread spectrum is a means of transmission in which the data sequence occupies a bandwidth in excess of the minimum bandwidth necessary to send it.
2. The spectrum spreading is accomplished before transmission through the use of a code that is independent of data sequence. The same code is used in the receiver for despreading the received signal so that the original data sequence may be recovered.

At the beginning Spread spectrum was originally developed for military application, where the major concern was to resist of jamming signals. In other hand , for civilian applications this technique was having a real benefit income because of the unique properties of the spread spectrum modulation. Such application, in case of sharing a common communication channel by a group of independent users in multiple access communications without the external synchronism mechanism, So that spread spectrum became robust today.

There are two types of the spread spectrum techniques.

1. Direct Sequence Spread Spectrum (DSSS)
2. Frequency Hop Spread Spectrum (FHSS)

As for IEEE 802.15.4 spreading methods has been used for increasing the receiver sensitivity level and that will lead to increase the jamming resistance that will reduce the effect of the multipath(Shashin,2008). The requirement of spreading method's for IEEE 802.15.4 with 2.4GHz frequency band is the Direct sequence spread spectrum (DSSS). As for the implementation of DSSS in an IEEE, every 4 bits are grouped together and referred as a symbol (see in figure 3.3). Then a lookup table has been used to map each symbol by a unique 32-bit sequence. This 32-bit sequence are also called as the chip mapping sequence or pseudorandom noise (PN) sequence. Now as we had each 4-bits mapped to a unique chip sequence, then the lookup table contains 16 chip sequence. Each of these chip sequence will be shown as a random sequence of zeros and ones

(random noise) and also there is a procedure for selecting each sequence to minimize the similarity to the other 15 sequences and this procedure called the *cross correlation function*(Shashin,2008).

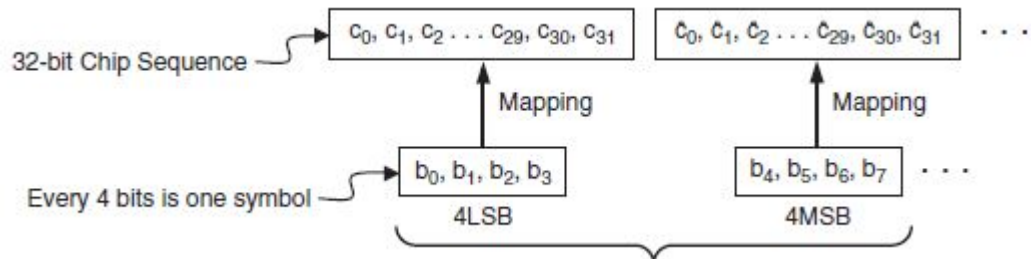


Figure 3.3 The signal spreading in DSSS

As we knew that each 4-bit has been mapped into a 32-bit chip sequence, we need to consider that the effective over the air bit rate will be increased by a factor of eight. And also since the bandwidth is proportional to the signal then the bandwidth also will be increased by a factor of eight. Figure 3.4a shows the basic concept of signal spreading. Let's consider that if the original signal before spreading has a bandwidth of 250KHz then after spreading the bandwidth will be increased by a factor of eight, the bandwidth after spreading will be 2MHz. However since the spreading of the signal doesn't add any physical energy to the signal, then the peak of the PSD signal (Power Spectral Density) will be less after the spreading because the same power will be distributed over a large bandwidth(Shashin,2008).

At the receiver part we need to mention that since the signal with 2MHz bandwidth travelling over the air, undesired noise and interferers can be added to it. For recovering the original signal at the receiver a certain procedure can be used called *despreading*. in this despreading procedure, will be taken place by comparing each of the 32-bits of the received signal with a 16 possible chip sequences, and the chip sequence that having the most similarity will be chosen as the received chip sequence. Also we need to mention that the same lookup table has been used in the transmitter, will be used in the receiver for recovering the original 4 bits of the packet.

After despreading, the signal energy will be returned back to the original bandwidth of 250KHz, except that the despreading procedure will not effect on the noise level in the 250 KHz band of interest. Because the signal energy has been increased to the desired band without increasing the noise level, and that will lead to increase the effectiveness of SNR by signal despreading also this improvement in the SNR signal will improved the receiver sensitivity(Shashin,2008). This improvement in SNR signal is also called *processing gain*, the value of the processing gain is obtained from the ration of the signal bit rate before spreading and the signal bit rate after spreading as for example :

$$\begin{aligned} \text{Processing gain} &= 10 * \log_{10} \left(\frac{2 \text{ Mbps}}{250 \text{ Kbps}} \right) \\ &\cong 9\text{dB} \end{aligned} \quad (3.3)$$

As for the interferer signals problems we can say that by the spreading of the signal in the transmitter side and despreading in the receiver side that's also will be helpful in reducing the effect of the interferers. Figure 3.4b show that the interferer signal has the same frequency as the desired signal. And at the receiver point when both of the signals arrived the despreading procedure will be focusing of the desired signal to return it to 250KHz. on the other hand, the despreading procedure results will be spreading the interferer signal energy over a large bandwidth, and then the filter will remove anything outside the frequency of interest (250KHz).

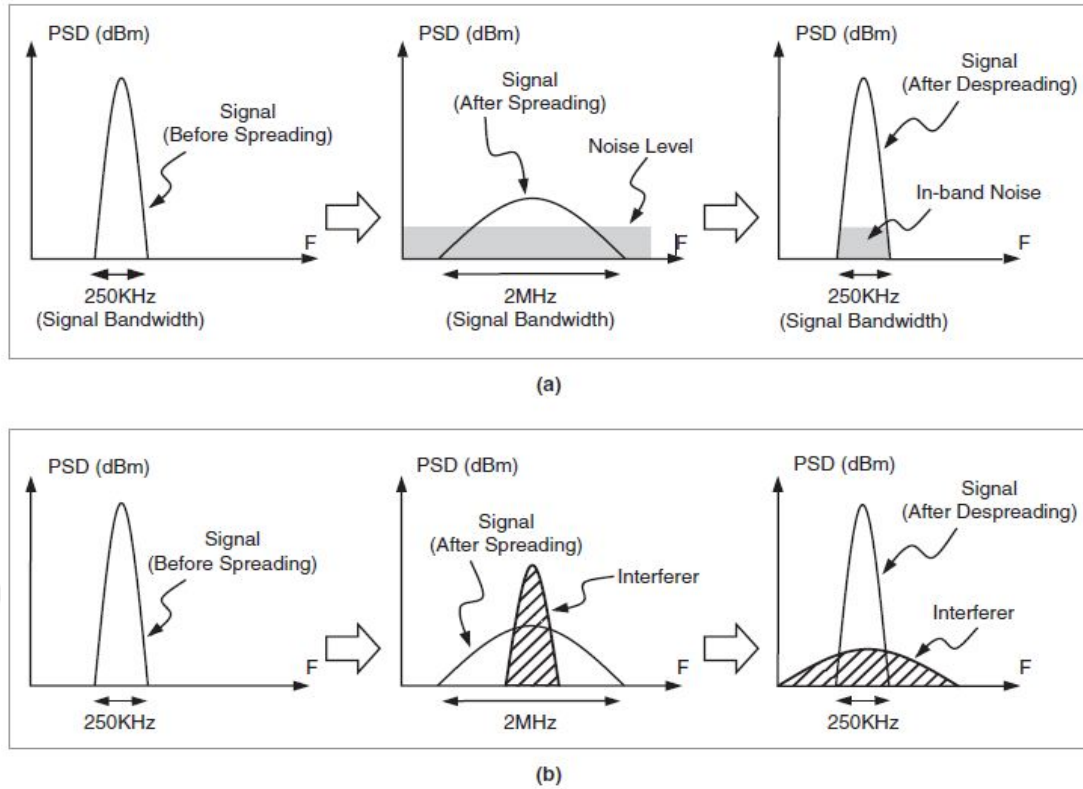


Figure 3.4 Signal spreading and despreading can help improve SNR and reduce the effect of interferers

And at the end the remaining power of the interferer signal will be much lower than the original interferer signal. This capability of signal spreading will also increasing the resistance of the receiver against the interferer signals(Shashin,2008). There is one way to calculate the quality of the signal with include of the interferer is by *signal-to-interferer ratio* (SIR),which is the ratio between the desired signal power over the total interferences power in the frequency band of interest:

$$SIR = \frac{\text{Desired signal power}}{\text{total interferences power}} \quad (dB) \quad (3.4)$$

3.4.2 Digital modulation technique

ZigBee transceiver uses the phase shaft keying which is a type of digital modulation technique so that we have to do some review on this technique. As for IEEE802.15.4 we required the use of offset quadrature phase shift keying

(OQPSK) as a modulation and demodulation technique for 2.4GHz frequency system(Shashin,2008). Generally, we will be analyzing the phase shift keying (PSK) for modulation and demodulation that has been used for digital communication. And for each modulation technique there is a mathematical representation of the waveforms, the generation and detection, the signal space, the spectral content and the performance over the AWGN channel. AWGN channel will be explained in section 3.1. the transmission with the use of modulation is referring to pass-band signaling, also it could be defined as the process of transmitting the information signal modulated onto a carrier. In addition, around the carrier frequency f_c there is a concentration of frequency spectrum related to the pass-band waveform. Also we had to refer to the generation process of the pass-band signal as digital modulation, when the modulating signal is digital. In theoretical view, we could use any baseband digital signal to be modulated a carrier, as direct or indirect, and generate a pass-band signal. Therefore, for each case of baseband waveforms, there will be a specific digital modulations that have the suitability for the given channel or it will be enough to satisfy design properties. However, the transmission of the pass band will be enough for communication channels with frequency response usually have a band-pass effect, like wireless channels. But, part of these band-pass channels were also carrying pass band waveforms, commonly they had moderated to a low frequency carriers(Nam and Sang,2006). We can classify the digital modulation type into three kinds:

- Amplitude Shift Keying (ASK).
- Phase Shift Keying (PSK).
- Frequency Shift Keying (FSK).

In the binary ASK modulation, the carrier amplitude is switched between two levels according to the modulating data bits. In the binary PSK modulation, the carrier phase is switched between two values according to the data bits. In the binary FSK modulation, the carrier frequency is switched between two values according to the modulating data bits. These modulations are the digital counterparts are the analog AM (amplitude modulation), PM (phase

modulation) and FM (frequency modulation), respectively. The digital modulation types can be seen below in figure 3.5.

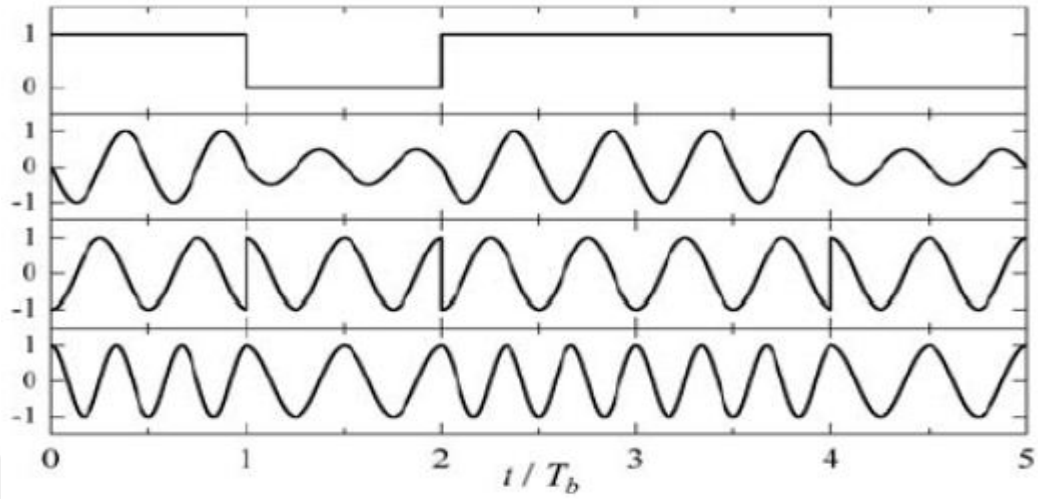


Figure 3.5 A basic digital modulation types

Since we are concentrating on phase shift keying (PSK), it will be explained briefly below.

3.4.2.1 Phase shift keying

Phase shift keying is one of the digital modulation technique, it has been used for transmitting the digital information between the transmitter and the receiver with corresponding of each signal phase to the binary number(Shashin,2008). If we considered that $s(t)$ with a carrier frequency f_c and phase of $\theta(t)$ then:

$$s(t) = A \times \sin(2\pi f_c t + \theta(t)) \quad (3.5)$$

Where A is the amplitude that does not carry any information in PSK. The PSK modulation begin with the simplest called BPSK (binary PSK). This type of PSK has a phase $\theta(t)$ that take only two values, zero and 180 degrees. In the end these two phases will represent the binary level of one and zero. As figure 3.6 show the constellation of BPSK. As for the second type of PSK called QPSK (Quadrature phase shift keying) in this type it allows four phases: 45° , 135° , -45° and -135° . so that each phase will be representing a 2 bits, and

correspond to binary number 00,01,10,11(Shashin,2008). Also this type is considered to the main goal of digital communication design to achieve low probability of error and effective use of the channel bandwidth(Haykin,2001). The constellation of QPSK can be seen in figure 3.6 below.

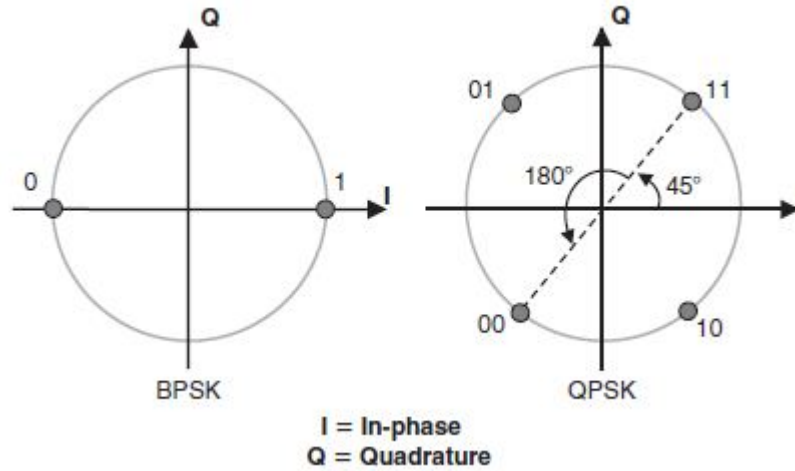


Figure 3.6 The constellation of BPSK and QPSK

Let us see the QPSK representation:

$$\begin{aligned}
 \theta(t) = 45^\circ \quad s(t) &= A \times \sin\left(2\pi f_c t + \frac{\pi}{4}\right) = \frac{A}{\sqrt{2}} \times (\sin(2\pi f_c t) + \cos(2\pi f_c t)) \\
 \theta(t) = 135^\circ \quad s(t) &= A \times \sin\left(2\pi f_c t + \frac{3\pi}{4}\right) = \frac{A}{\sqrt{2}} \times (-\sin(2\pi f_c t) + \cos(2\pi f_c t)) \\
 \theta(t) = -45^\circ \quad s(t) &= A \times \sin\left(2\pi f_c t + \frac{-3\pi}{4}\right) = \frac{A}{\sqrt{2}} \times (-\sin(2\pi f_c t) + \cos(2\pi f_c t)) \\
 \theta(t) = -135^\circ \quad s(t) &= A \times \sin\left(2\pi f_c t + \frac{-\pi}{4}\right) = \frac{A}{\sqrt{2}} \times (\sin(2\pi f_c t) + \cos(2\pi f_c t))
 \end{aligned}$$

From the representation of QPSK modulation we see that each of the four phases can build QPSK modulation either by the summation or the subtraction of $\sin(2\pi f_c t)$ and $\cos(2\pi f_c t)$ functions. The A amplitude does not carry any information and that's will lead us into the scaling factor of $\sqrt{2}$ has no effect of changing information in the signals. Also this advantage has been used in the implementation of the QPSK modulator in transmitter. The signal will be multiplied by $\sin(2\pi f_c t)$ and $\cos(2\pi f_c t)$ functions, then the results are added together to form the modulated signal $s(t)$. Then the modulated signal will be amplified by a power amplified (PA) before transmission. There is two

components forming the modulated signal $s(t)$: a quadrature component ($\pm \sin(2\pi f_c t)$) and an in-phase component ($\pm \cos(2\pi f_c t)$) (Shashin,2008).

There are some problems in the implementation of the QPSK modulator. The first problem related to the shape of PSD (power spectral density) of the generated signal by QPSK modulator. Because of sharing the frequency spectrum by many users, it will be important to minimize the bandwidth of the signal and also we need to suppress the signal power outside the frequency band of interest. Because of these reasons the QPSK modulator need a filter for shaping the PSD of the signal. And it will be located before the multiplier of signal. According to IEEE 802.15.4 it is demanding the use of a certain filters for that purpose called (half-sin filter, raised cosine filter, and square-root cosine filter). There is another definition for these filters referred by a pulse- shaping filters and the reason behind this because of the modifying of the binary pulses that taken place by these filters(Shashin,2008). Figure 3.7 show the effect of the half-sin pulse-shaping filter over the signal. Each sharp pulse will be replaced by the half-sin pulse shaping filter with one half of sinusoid signal.

$$p(t) = \begin{cases} \sin\left(\frac{\pi t}{2T_c}\right) & 0 \leq t \leq 2T_c \\ 0 & \text{otherwise} \end{cases} \quad (3.7)$$

Where $2T_c$ is the width of the pulse.

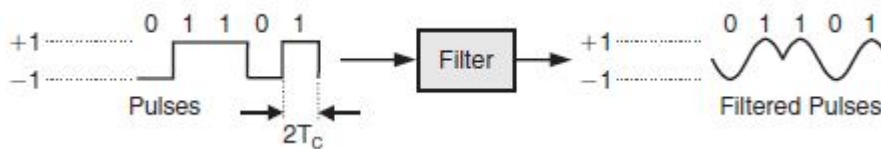


Figure 3.7 The effect of half-sine pulse-shaping on the signal

The second problem is the maximum phase shift of $s(t)$ every time when a new pair of bits enters the modulator. If we consider from figure 3.6 that, if the first pair of bits enters the modulator 11 and the next pair is 00, then the modulated signal $s(t)$ phase will change 180° . Then a large amplitude variation in $s(t)$ will be taking place because of that sudden phase changing. As a matter of a fact, the

smaller the variation in amplitude the easier implementation of PA (power amplifier). As a result, for limiting the maximum sudden phase shift in $s(t)$, the QPSK modulation was modified into an Offset-QPSK (OQPSK). The OQPSK have an offset time delay equal to one-half of pulse period between the in-phase and quadrature pulses. therefore, this small difference between OQPSK and QPSK has the ability to limit the sudden maximum phase shift of signal modulated by using OQPSK to 90° . This advantage make the OQPSK a better choice over QPSK for most of implementations(Shashin,2008). Figure 3.8 show the block diagram of OQPSK modulation.

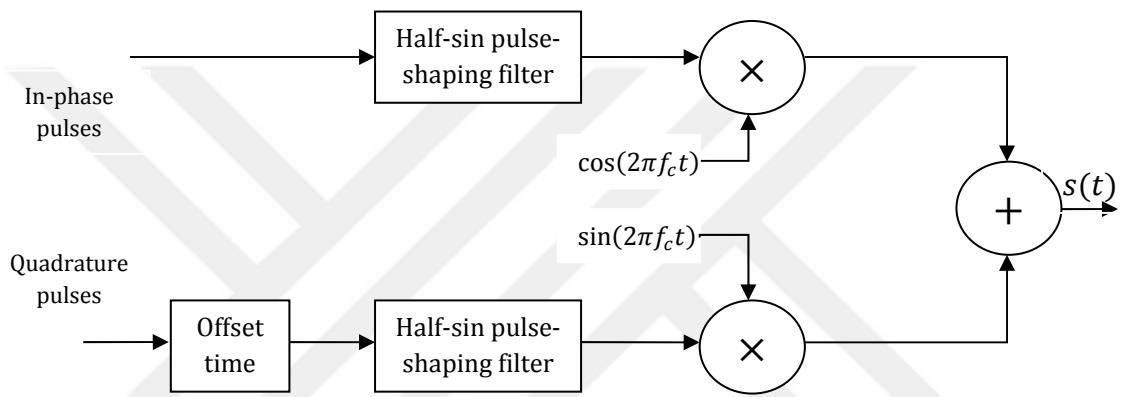


Figure 3.8 block diagram of OQPSK modulation.

In other hand, the demodulation of OQPSK it will continue with the same procedure but with an offset time delay on the in-phase side. Figure 3.9 show the block diagram of OQPSK demodulation.

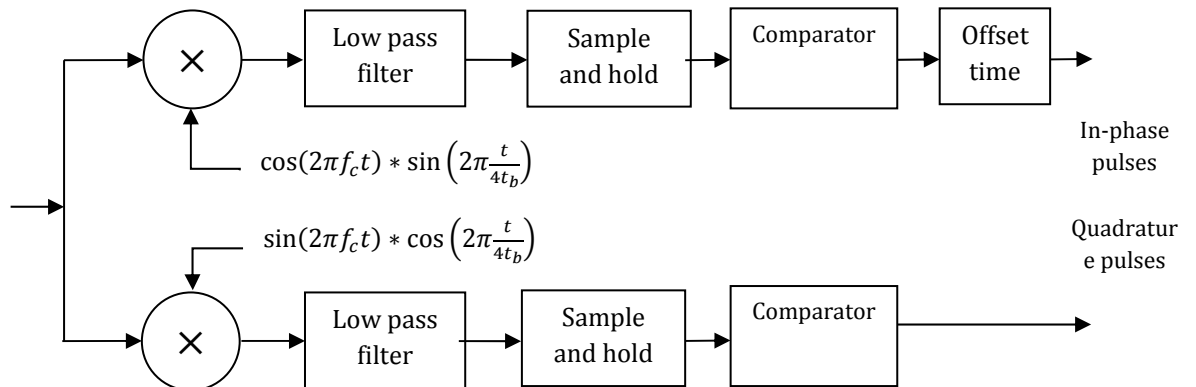


Figure 3.9 block diagram of OQPSK demodulation.

After the demodulation process the data will be transferring to the parallel to serial convertor which it will be explain briefly below.

3.4.3 Serial To Parallel Converter

This is a simple method that has been used for converting the serial data that has been entered to the circuit into a parallel data, and the reverse parallel to serial can be done with the same principle. The serial to parallel convertor can be implemented by a predefined configuration of flip flops, which are being explained below (Haykin,2001), (Abuelmaatti and Et al,2007). The flip flop can be defined as a one bit storage device. As for the device's operation it can be explained as the active edge of the clock waveform, then the logic level at D will be transferred to the output Q. Actually, the changing of date $d(t)$ will be taken place slightly after the active clock edge. When the flip-flop is responded to an active clock edge, and at the same time has registered a data bit, the action of the flip-flop will be holding to that bit until the next update by the occurrence of the next succeeding clock edge.

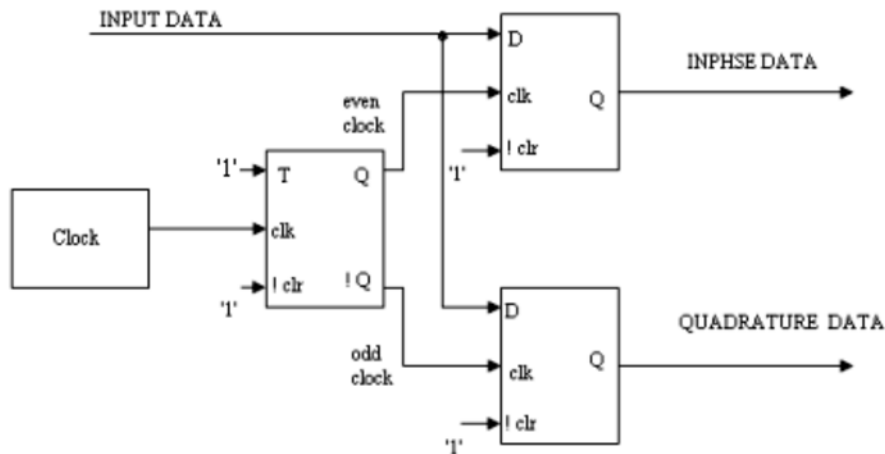


Figure 3.10 The circuit for generation of the inphase and quadrature data

As of what we concerned about is the generating of the inphase data and quadrature data by using serial to parallel convertor, in figure 3.10 can be seen the fundamental circuit of generating inphase and quadrature data by generating even and odd clock. Also we could have a QPSK signal, by adding

another an extra d-flip flop after the D-flip flop at the inphase component. Also we need to mention that a half of bit duration should be provided as the delay by the D-flip flop.

As it is shown in figure 3.10 We have used the T flip-flop as a clock for the two D-flip flop we used for both data inphase and quadrature. Since we all knew that when the input is '1', then the T-flip flop toggles it's output. From the figure above we can see that, a clock waveform with a period of bit time T_b has been used for driving the toggles flip-flop. Also when the toggle flip-flop is being operated, it generated an even and an odd clock waveform. A $2T_b$ is the bit period of these clocks so when the active edge having one of the clocks and the other active edge has been separated by the bit time T_b . as for example to the operation, the data in which the bit stream $b(t)$ is represented, is being applied to both of the D-flip flop as the data input, these two flip flops has been driven by a clock waveform, one is driven by the even clock waveform and the other is driven by the odd clock waveform. In the bit stream $b(t)$ the bits will be alternative by the flip-flop register then for two bit period each such registered will be hold, that is for a time of $2T_b$. If there are input bit sequence numbered 1,2,3,4 etc., then the bit stream $b_o(t)$ registers bit 1 and holds that bit for time $2T_b$ and next it registers bit 3 for time $2T_b$ and next bit 5 for $2T_b$, etc. The even bit stream $b_e(t)$ holds, for times $2T_b$ each, it results the alternate bits numbered 2,4,6 etc.

4.MOBILE ROBOT SETUP AND RESULTE

Here in this chapter we have presented a study on our robot design. Also, we explain in section 4.1 robot definition and purpose. Since, our wireless technology that we used considered to be ZigBee we have explained before in chapter two. Here, in section 4.2 we have presented a study on ZigBee and also ZigBee's applications. Also, in section 4.3 we have presented a study on our robot construction and design. in section 4.4 we have presented our results from our robot for testing the X-bee range and sensors received signals.

4.1 Definition And Purpose Of The Robots

Robots are multifunctional and skillful devices which can be reprogrammed and which make the preprogrammed moves in order to be able to fulfill different tasks. (American Robot Institute). The word 'Robot' comes from "Robota" which means a slave in Czech Language.

How does it work?

They basically work on three functions

1. Detection
2. Deciding
3. Applying

First of all, robots should have a detection function and some sensors are used for this purpose. These can be sensors which detect such factors as distance, sound, light, pressure or heat.

The robot should decide what to do after data sent through these sensors are detected and microprocessors are used for this purpose. There are algorithms which are preprogrammed in these processors and they constitute the brain which is the thinking mechanism of the robot. In addition, these microprocessors give command for power to be supplied to the required

motors. Finally, power is needed to carry out the application process. The application process is completed with the help of various motors.

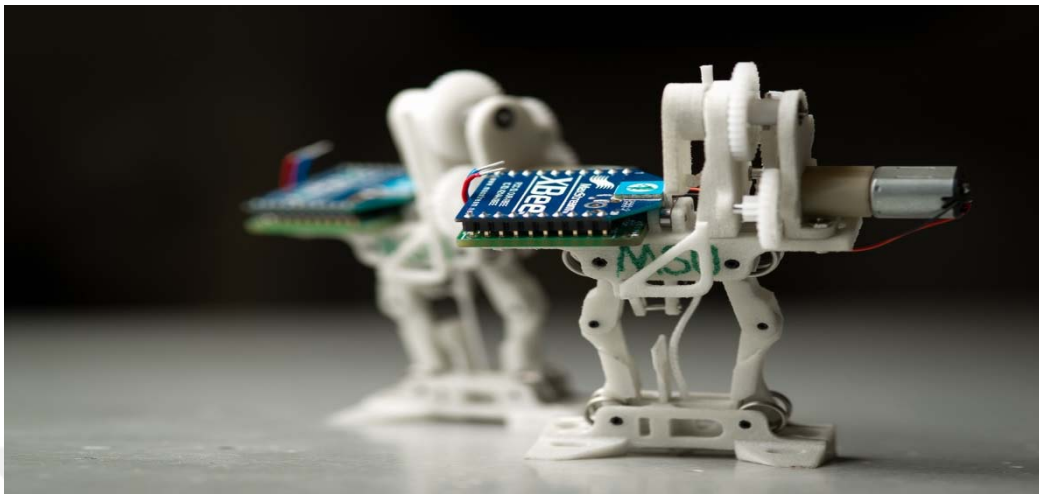


Figure 4.1 X-Bee is a wireless RF module which uses Zigbee protocol.

Exploration Robots

The unmanned vehicles and robots in the security sector are commonly used as a result of the negative actions increasing day by day. Technology which develops every day has made it possible to create unmanned products which can fulfill some certain functions not only in the military field but also in daily life. Search and rescue robots along with the exploration robots are designed with in line with these needs.

Search And Rescue Robots Used Today

Many national or international firms spend a huge amount of R&D budget on search and rescue robots at present time. For example; Darpa, Irobot, Boston Dynamics are the leading firms. Although they are widely used for the developments in the field of military, they are also developed as wreckage search robots and exploration robots. The required specifications for these robots are remote control stability and distance, time for staying in the field, mobility and data transmission capacity etc.

Staying in the field for a long time is the most significant specification for these robots. Putting more qualified and system supplies which have high powers on the devices is not a solution any more. It is because systems intended for not spending the current battery power instead of spending it started to be developed. It started with the studies to minimize the energy spent on the system. Controlling the energy consumed in the sensors, motor power, microprocessor and communication kit has come to the forefront in the research and development activities.



Figure 4.2 Exploration robot called RHEX which has been designed by Boston Dynamics Firm.

4.2 Our Robot Construction And Design

4.2.1 Technical specifications of our robot

Our robot is a robot which will be designed using the zigbee technology and controlled with X-Bee module. Control of the robot along with the transmission of the sensor information has been provided through this protocol. Our robot is a robot which has 2 motors and 2 wheels. Atmel Atmega328p as the microcontroller was used in our robot.

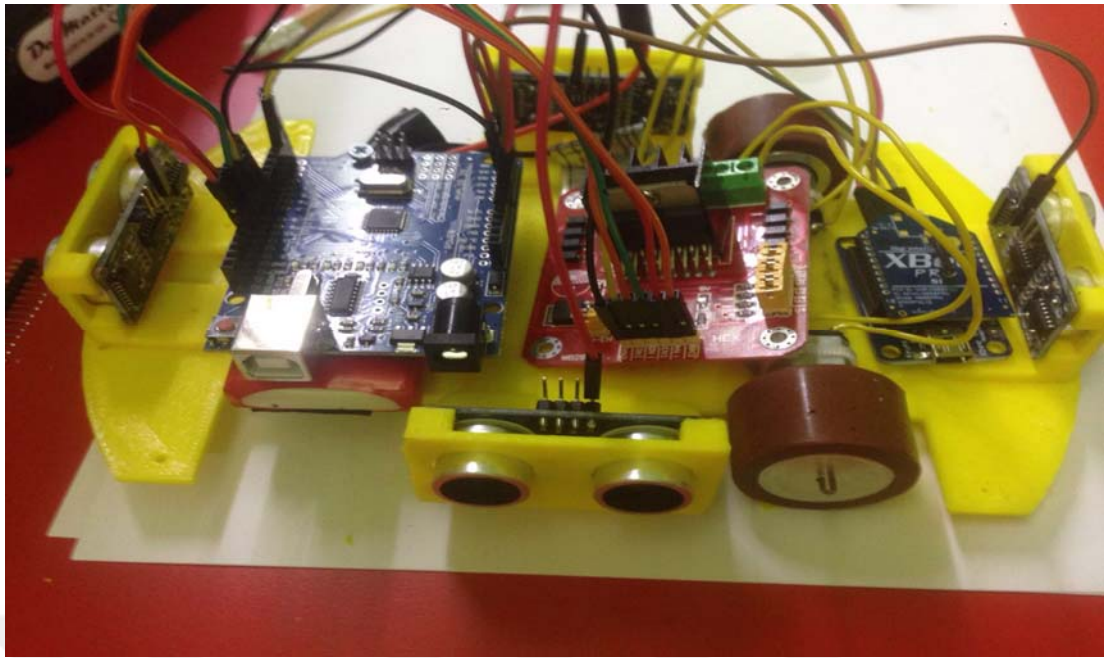


Figure 4.3 Our mobile robot design

4.2.2 Design of the robot base

The most difficult and significant aspect of the robot is probably the mechanical parts and its design. The quality of this part determines the capacity of the robot along with the yield we will get with the robot. Many designs have been tried for the exploration robots created before such as systems with pallets or systems with wheels.

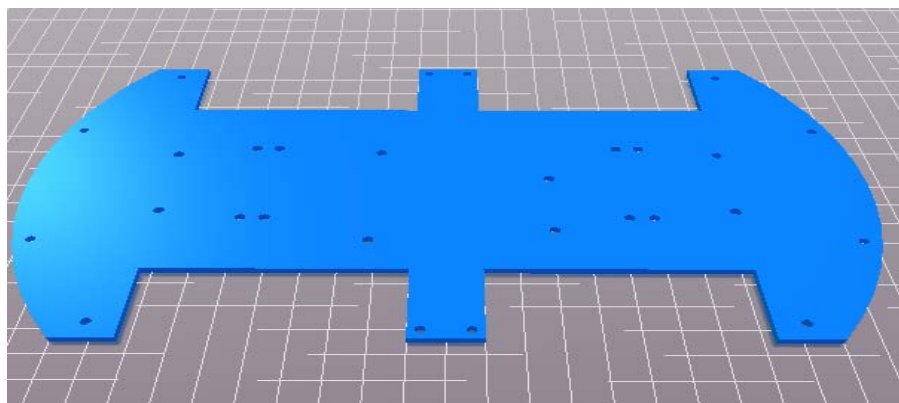


Figure 4.4 the board we used in our project

4.2.3 Power supply

We have used a battery of 7.4v capacity as shown in figure 4.5 below. It can provide the motor with enough speed. Also, we have added an external circuit has a voltage regulator for supplying both the Arduino and Xbee circuit with 5v energy.



Figure 4.5 A power supply battery of 7.4v

4.2.4 X-Bee

The significance of RF with respect to the technology in today's world is an indisputable fact. Zigbee is a communication protocol which has come to existing in recent years in this field. Xbee is the hardware which carries this communication protocol. For example; Jennet protocol of Jennic Firm.

4.2.4.1 X-Bee communication

PAN (Personal Area Network)

All the communication process is carried out through a PAN in X-Bee modules. There must be a PAN-ID in order to enable the communication. If PAN is not created, X-Bee devices will not be in service and be active. A PAN can only be created by a "Coordinator".

All the devices within a PAN should have a PAN-ID. In other words, PAN-IDs of all the devices that will join in the PAN created by the “coordinator” should be the same with the PAN-ID of the “coordinator” device. Otherwise, device will not be able to join into the network.

4.2.4.2 Forming a network with X-Bee

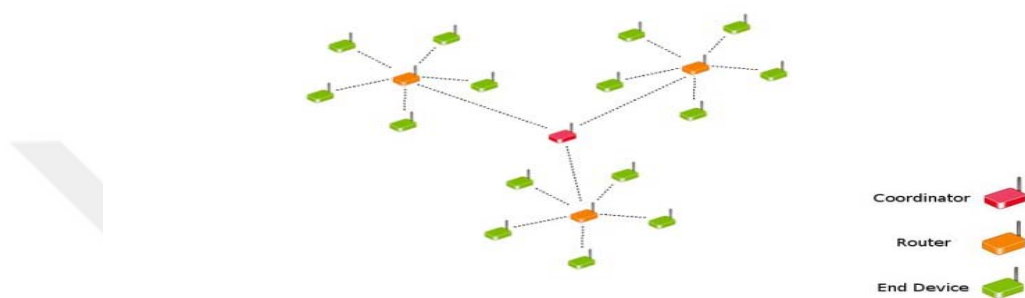


Figure 4.6 A network formed with 1 Coordinator, 3 Routers and 15 End Devices

You can see a network model (PAN) which includes Coordinator, Router and End Device.

- C, “Coordinator”:
It determines the communication channel and its PAN-ID. The “coordinator” is in charge of starting a PAN. After starting the PAN, Coordinator decides for End Device and Routers to join into PAN. Coordinator can make data transfer or transfer the data to other devices within the mesh network. Since the coordinator manages the whole network, batter supply or operating in low power modes is not appropriate. Coordinator should be supplied with a fixed power plant. If the coordinator loses its function, it results in collapse of the whole network.
- R, “Router”:
In order for a router to function, it should join into a PAN. After joining in the PAN, Router can let other Routers or End Devices join in the PAN. As it

can include the other devices in the routers, it should not be operated at low-power mode.

- E, "End Device":

It does not have the power to manage like Routers or Coordinators. It is only in charge of data transfer in Network (PAN). It can be operated in low-power mode. They should join a PAN in order to function in End Device like as in Router.

4.2.4.3 X-Bee configuration

There are not enough tools to configure X-Bees. The most reliable and frequently used one among these tools is digi firm's X-CTU software of which production belongs to the firm itself. We can fulfill all the processes related to X-Bee with this serial communication software which is completely free. This program can be downloaded from the web site of the producing firm. X-Bee configurations can be Point-to-Point or Multi-Point.

- Point to Point

C Configuration:

We launch C in broadcast mode. What we should do is written below:

PAN ID is set, (ID)

Scan Channels are set, (SC)

Scan Duration is set (optional) (SD)

Destination Low Address is set: it is set as DL = 409C103E.

Destination High Address is set: it is set as DH = 13A200.

NI is set: NI = coordinatormode

The related configuration screen is like the following:

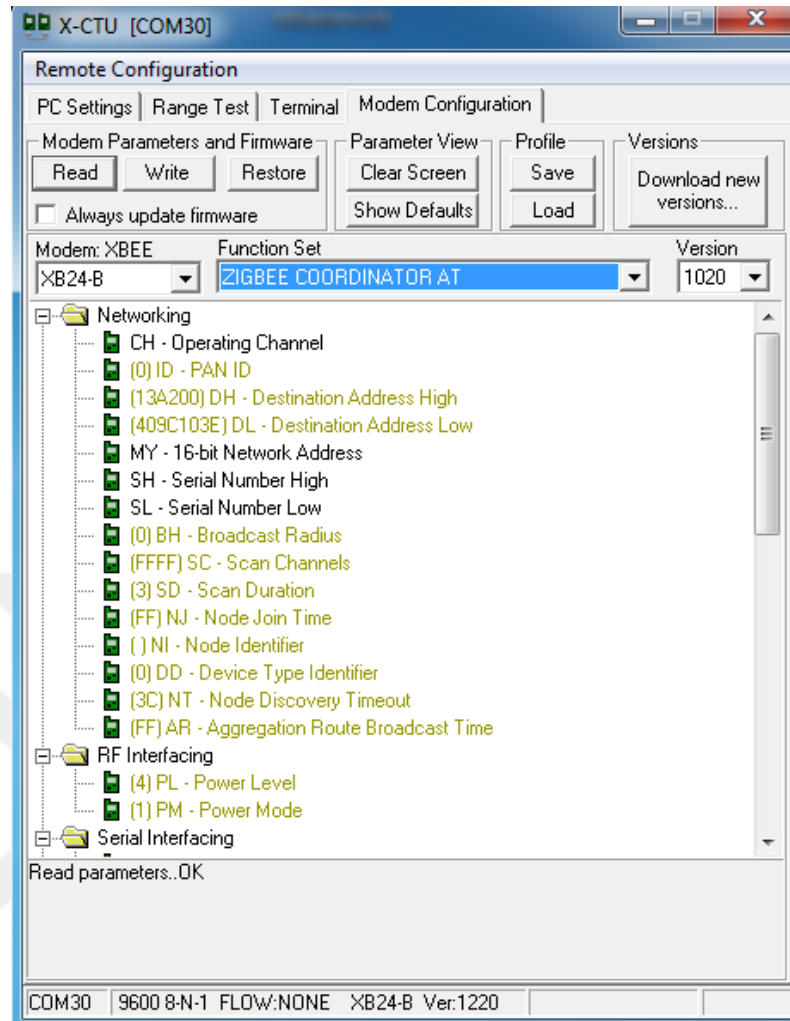


Figure 4.7 Coordinator interface during X-Bee Configuration

R Configuration:

R should be programmed in unicast mode.

SC and ID values are set. (According to PAN which means according to C)

CH and OP are controlled.

MY is set, it is 16 bit network address of router.

It should be DH = 0.

It should be NI = routermod.

The screen is like the following:

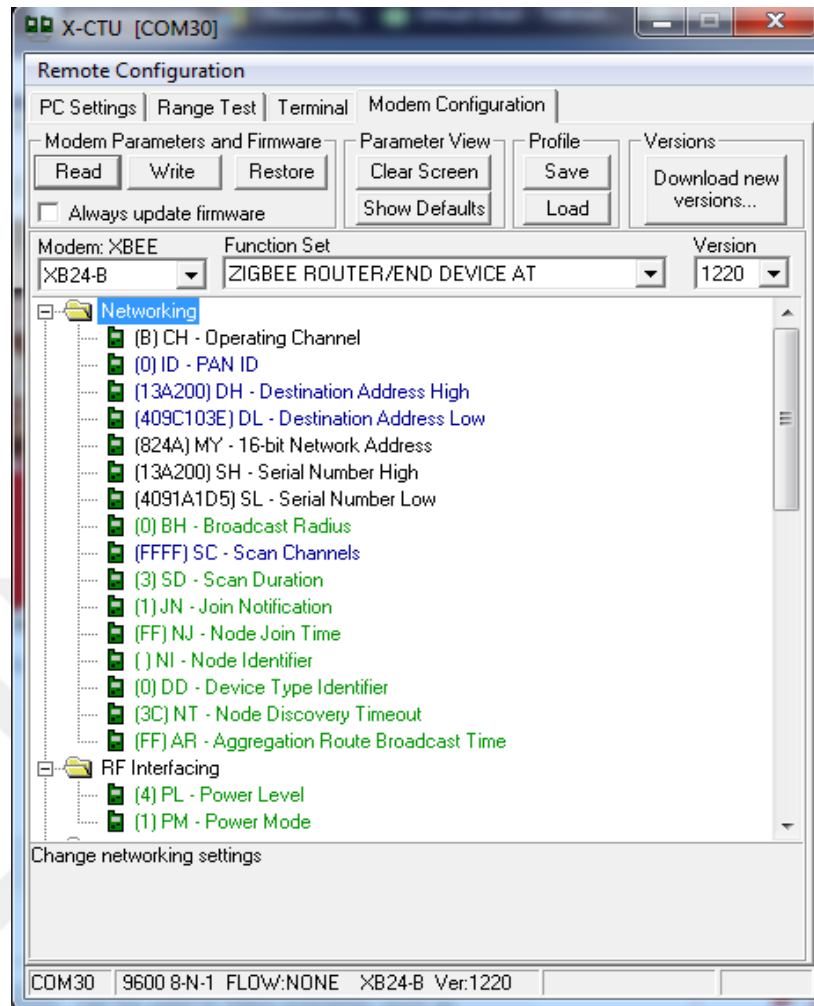


Figure 4.8 Router Interface While X-Bee Configuration is made.

- Multi point

X-Bees provide an opportunity to set up Multi-Point network in addition to setting up Point-to-Point network. Generally, Multi-Point is preferred in most of the projects. For example; if we assume that there is more than one End Device in smart home systems, this method is frequently preferred. These systems also communicate with one Coordinator and more than one Router.

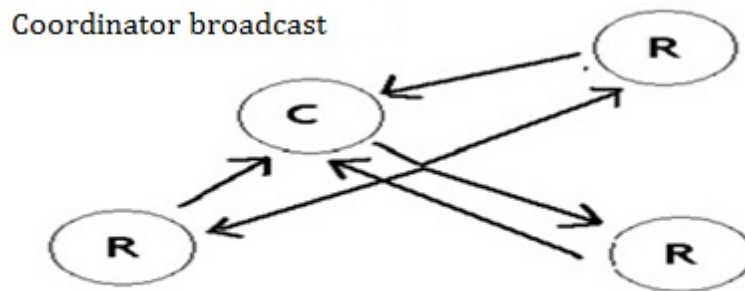


Figure 4.9 Multi-Point Network Design

As it can be seen in the diagram drawn above, coordinator broadcast to router devices and router devices can transfer data to the coordinator. A common PAN is also set in this system and all devices get the same PAN-ID. Destination Low address which belongs to Coordinator is given to routers and Destination High address is given to routers and they are crossed. Consequently, multi network is set up. An example of crossing is shown in the figure.

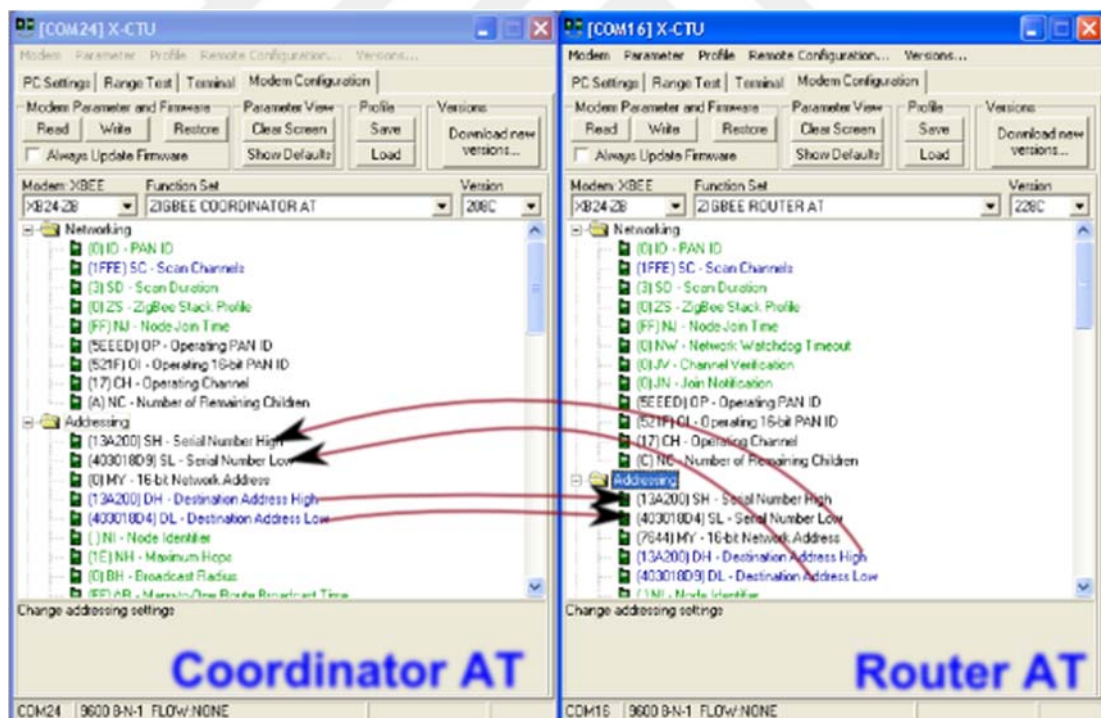


Figure 4.10 Crossing Destination addresses of X-Bees.

4.2.5 Arduino

Arduino, developed by Italian electronics engineers as open-sourced, is an electronic prototyping platform which is flexible, easy to use hardware and software based. Everybody can buy Arduino of which components could be placed as stylish-looking and ready printed or if one can print his own circuits downloading the printed circuits(Monk,2012).

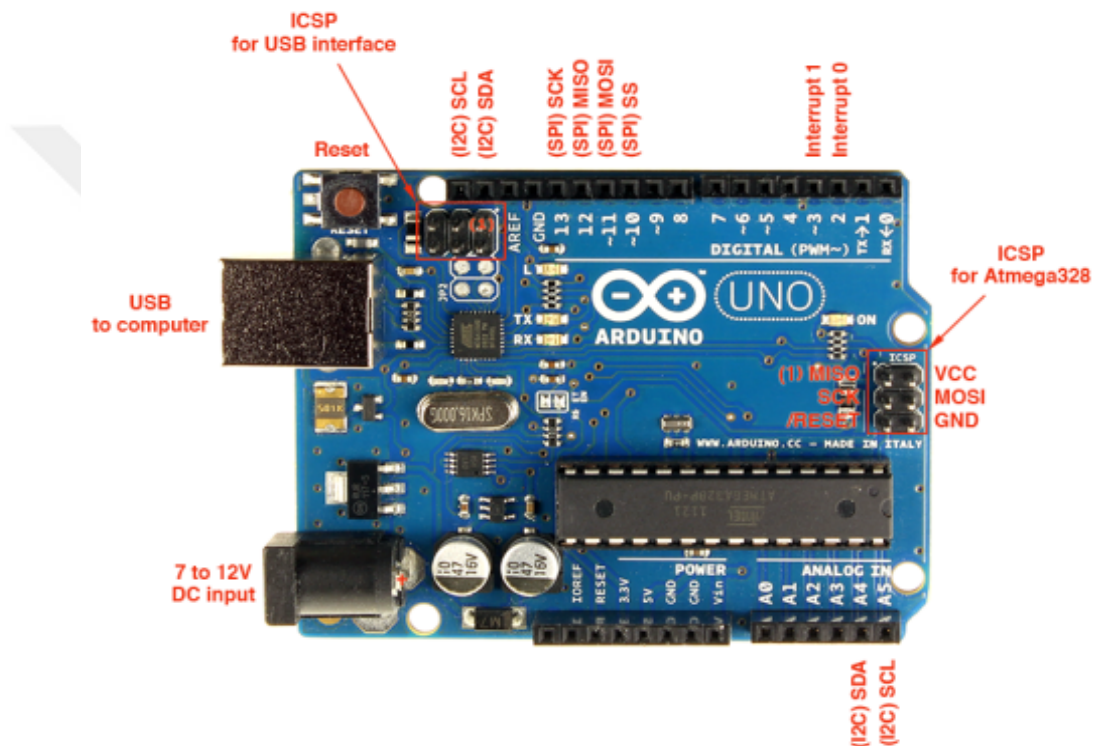


Figure 4.11 Arduino

When we take a look at the definition of open-source, it can be said that it is a platform of which circuit diagrams, pcb printed circuits, location plans, codes of programmable components on it if there is any along with the other details are publicly available and open to share without having any commercial concern. Microprocessor on the Arduino development card (AtmegaXX) is programmed with Arduino programming language (wiring based) and this program is uploaded to card with the help of Processing based Arduino Software Development Environment (IDE). When it comes to the language that Arduino uses, it is considerably easy, we can directly program our microcontroller

through a USB with a basic C information and run real-time applications. There is an editor which is good, plain and smart written on java while programming and there are many libraries in this editor. Since the editor is updated by its developers all the time, it can be seen that the editor is becoming much more useful and functional every day. When we take all these points into consideration, we make a lot of application by using Arduino without the necessity of being an advanced software developer. One of the important aspects of Arduino is that they have rich libraries prepared by its developers. We can use codes of the project that we want to work on thanks to these library files which provide an opportunity to get rid of the burden of many codes. When we have a look at the hardware, Arduino uses Atmel processors on the cards. Since our microcontroller comes with Bootloader program, there is no need for an external programming device. This is a great opportunity for us as an additional programming device is not required(Margolis,2011).

There are many types of Arduino, we can choose one of these types according to our application. When you are in a long research process, you will encounter with a lot of types and these are cards are still being renewed and developed. However, we can say that there are additional hardware called shield which are developed appropriate for Arduino's present boards or cards (Bluetooth, Ethernet, Wireless, Motor driver layers etc.). Therefore, I do not think that there will be great changes for the present boards with respect to the hardware. Because, shields will not be used any more if there are great changes on the hardware of the boards(Margolis,2011).

4.2.5.1 Arduino programming



```
XBeeArd | Arduino 1.6.7
File Edit Sketch Tools Help

XBeeArd

#include <SoftwareSerial.h>
SoftwareSerial BT(2, 3); // RX, TX

/*
AO Onsensor
A1 arkasensor
A2 solsensor
A3 sagsensor
*/

char yon;
int sagmotor, solmotor;
int in1 = 9;
int in2 = 8;
int in3 = 7;
int in4 = 6;
int enA = 5;
int enB = 10;

int onsensortrig = 12;
int arkasensortrig = 13;
int sagsensortrig = 11;
int solsensortrig = 4;
```

Figure 4.12 Arduino programming for our robot

4.2.6 Design the control unit for our robot

We have used the visual studio program to design the control for our robot as you can see in figure 4.13 below. However, in this control unit we can control the robot movement also we can see the sensors received signal. The reason for using such a programe in design a control unit is the low hardware cost, it's simple structure, standardization and easy to use feature. Data that will be sent in serial communication is divided into bits and they are sent to other devices. The bits received from there are converted into a byte string and processed. If we want to make connections on the interface we designed, we choose ComPort and then we can set the connection Baud rate. We make the connection with the

connect button. And then we will have a full control on our robot design. Figure 4.14 show the control unit for our robot.

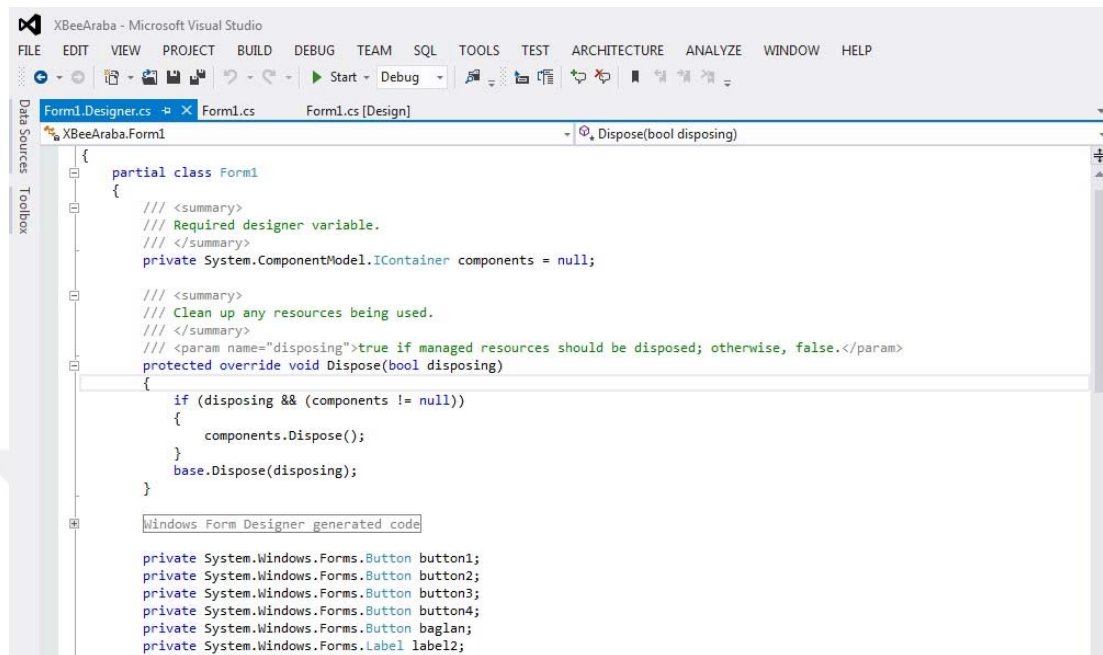


Figure 4.13 Visual studio programming for our robot

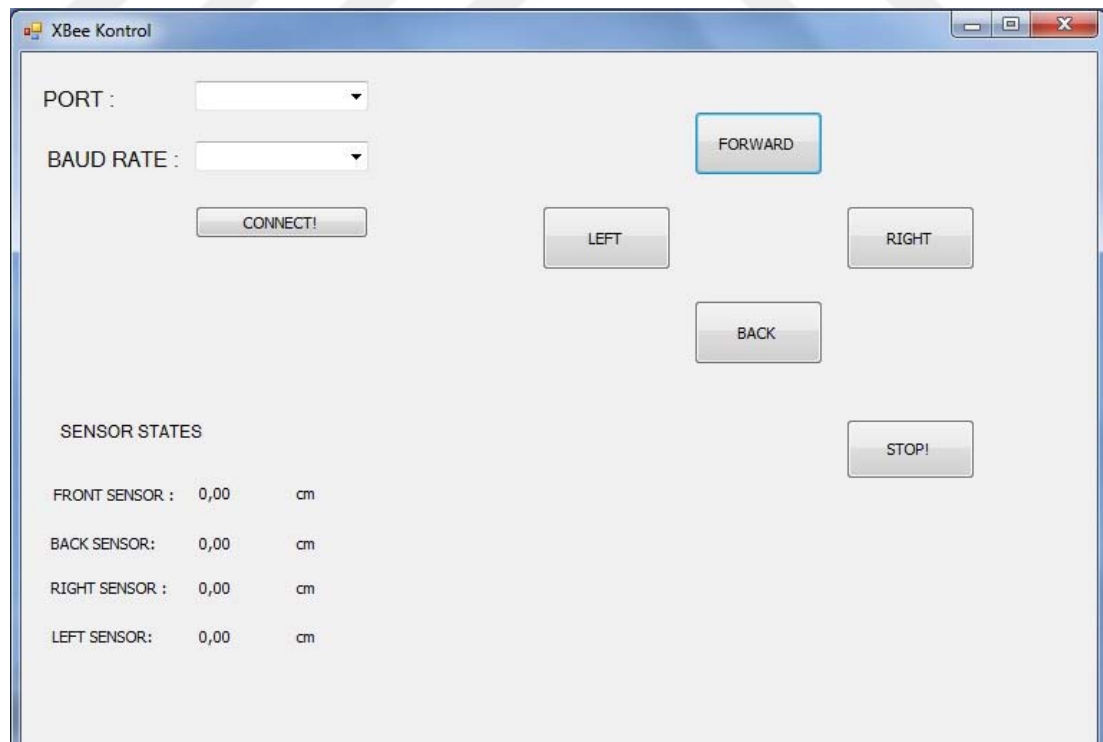


Figure 4.14 The control unit that we created for Serial Port control

4.2.7 Motor driver circuit

Since outputs, DC motors and step motors of microcontrollers are inadequate to control the motors directly, motor driver circuits are used. Motor controls are provided by increasing the signals received from outputs of microcontrollers along with the motor driver circuits. Motor driver circuits can be prepared by using transistors as H Bridge or similar ways. However, motor driver integrated circuits are generally preferred in terms of convenience. For instance, an average microcontroller can supply 25mA current as output but it is not enough to revolve a motor. In addition, motor feedback can overload current on the microcontroller and burn it. In order to avoid such problems, motor drivers are used.

The main features for choosing motor driver integration are such features as usage voltage and current limit. The most frequently used motor driver integrated circuits in robotics are L293D, L293B, L298N motor driver integrations for DC motor controls. Different drivers can be used for some professional applications. I used L298N motor driver card in my own project.

4.2.7.1 L298N motor driver card

L298DC & STEP MOTOR DRIVER is a motor driver card prepared to drive two motors between 4.8 V-46V. This two channeled motor driver card supplies 2A current per channel. L298N motor driver integration was used on the card. It can control two separate motors. It can supply 2A current per channel. There is an internal regulator on it. It has protection against high temperature and short circuit. It has led lights which flash according to the rotation direction of the motor. There is an internal cooler on the card. Current sense pins are protuberant(Pawar and Poddar,2012).



Figure 4.15 L28N Motor Driver Card

4.2.8 Ultrasonic sensors (HC-SR04)

We have used the ultrasonic sensors for detecting any solid subjects surrounding the robot. Figure 4.16 show the ultrasonic sensor's chip.



Figure 4.16 Ultrasonic sensors (HC-SR04)

Working Principle:

The work principle of the sensors can be shown in figure 4.17. Also, it shows the mechanism of sending and receiving the detecting signal.

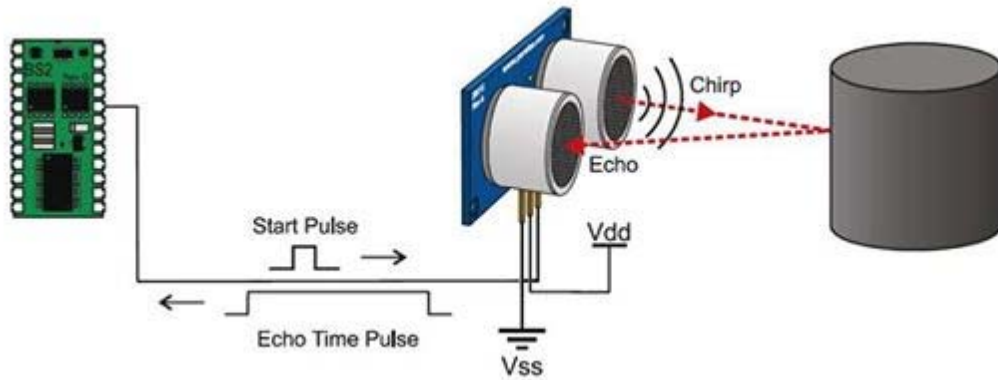


Figure 4.17 Work principle of ultrasonic sensor

- Sound signal which has 40 kHz frequency (as human ear is able to hear sounds between 20Hz- 20 kHz, sound that ultrasonic sensors give to the environment is not perceived) is sent through loud speaker(Carullo and Parvis,2001).
- When the sound signal sent encounters with an obstacle and comes back, the echo is received through the microphone(Carullo and Parvis,2001).
- Time difference between the sent and received signal is calculated(Carullo and Parvis,2001).
- The calculated time difference is multiplied with the speed of the sound in the environment to which it was sent ($X=V.T$) and distance is determined. (Sound speed is 340 m/s in air environment under normal conditions(Carullo and Parvis,2001)).

4.2.9 Representation circuit of our robot

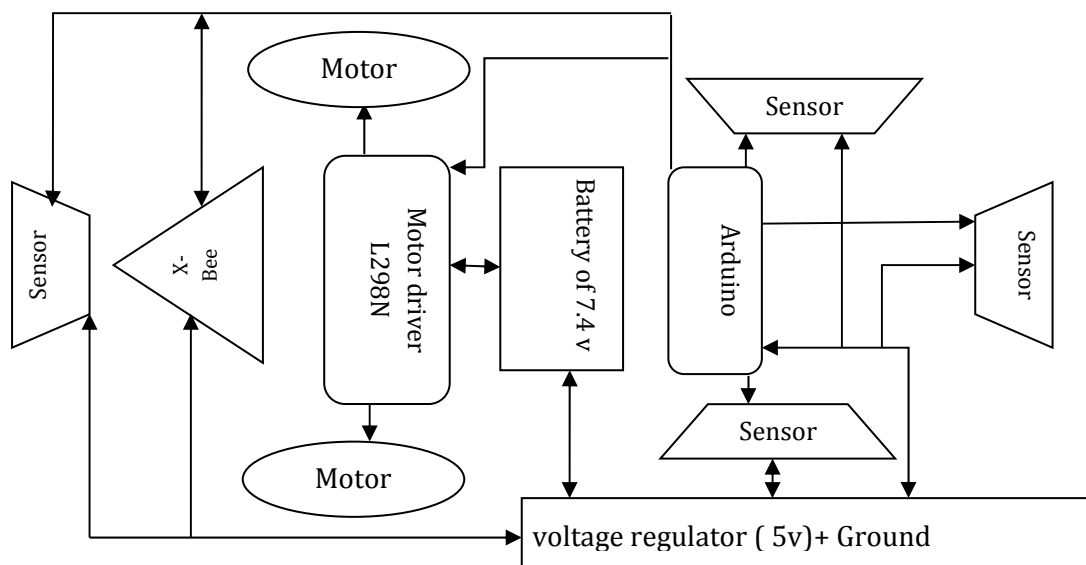


Figure 4.18 Representation circuit of our robot

4.3 Resultes From Our Robot Design

4.3.1 X-bee range test

One of the significant reasons for preference of X-Bee kit is the coverage range. There are many kits appropriate for it. The kits produced by X-Bee firms are generally FCC, u.FL and DSSS types. They have different features and suggest the one we need such as distance, data rate transmission, security.

Another feature of X-CTU is that it can carry out a measurement test for the influence range of X-Bee. It measures range quality by sending and receiving immediate data packets through the Range Test interface. As it can be seen below, there is not a loss in the sent and received data packet. Namely, there is enough range between two kits to make active communication.

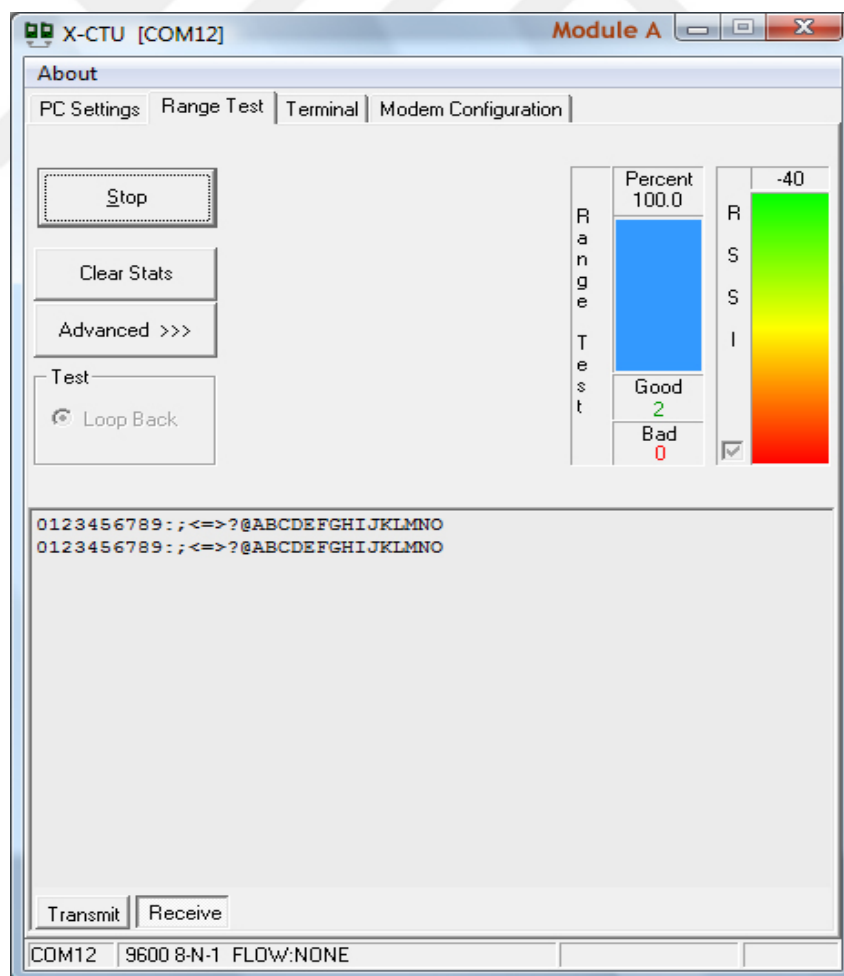


Figure 4.19 Range test of X-Bee in X-CTU

4.3.2 Signal testing from ultrasonic sensors

We have tested the sensors by putting subjects around the robot as you can see in figure 4.20 below .

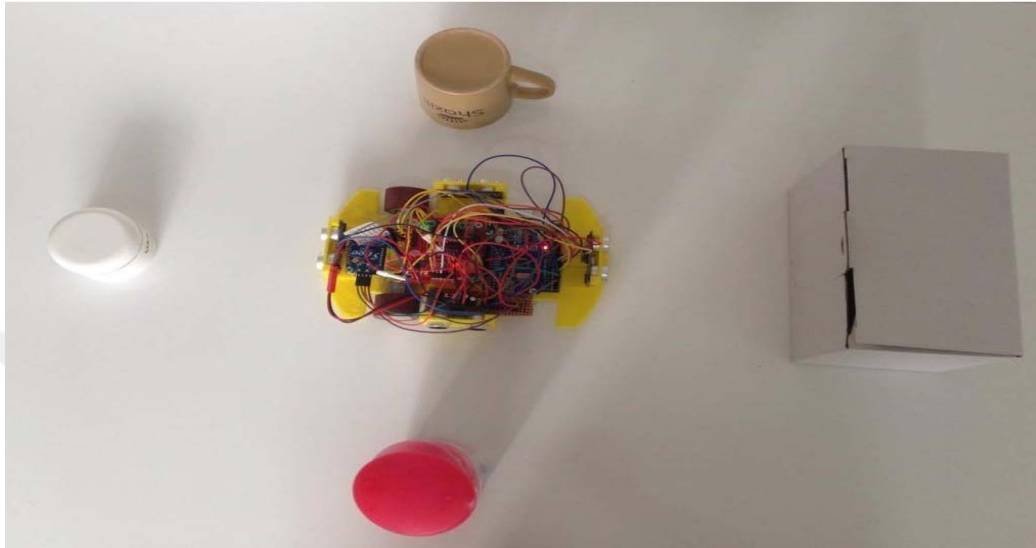


Figure 4.20 Testing our robot's sensors

And the received signals from the robot's sensors has been shown in figure 4.21 below.

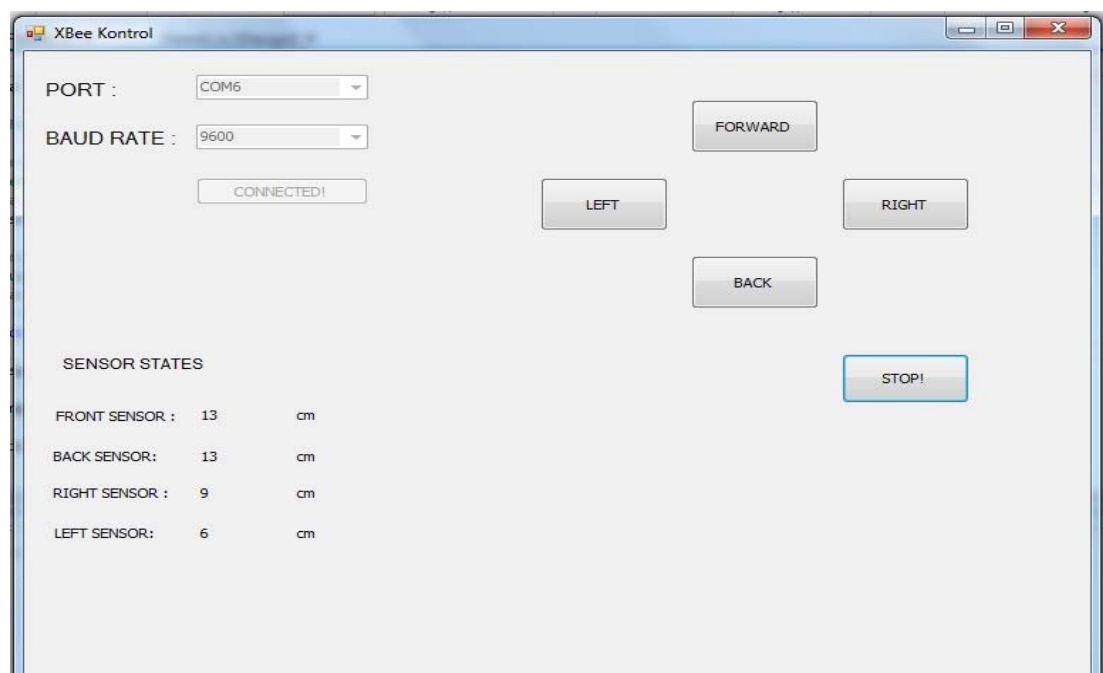


Figure 4.21 The received signals from our robot's sensors

4.3.3 Our robot final form

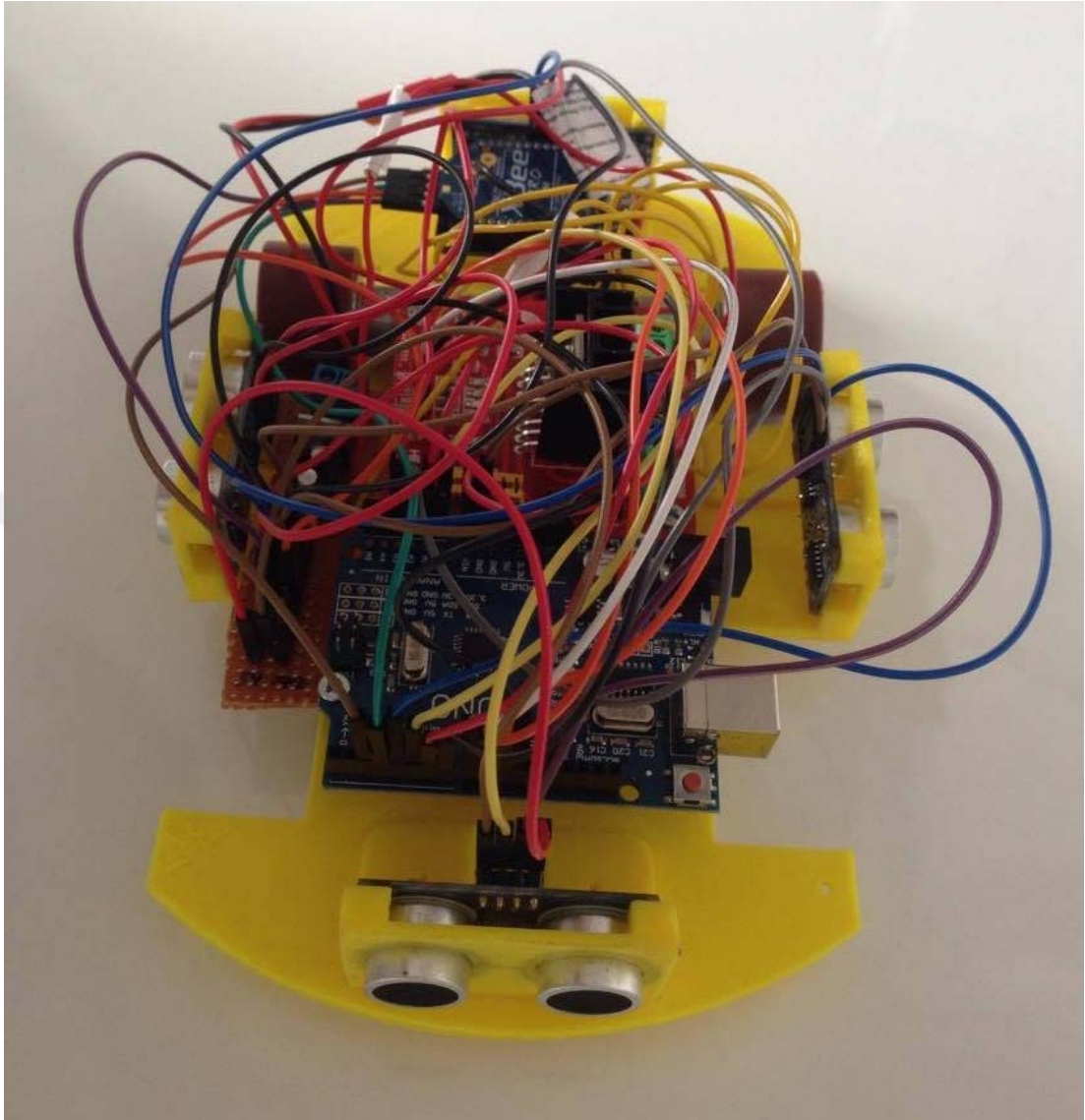


Figure 4.22 Final form of our robot

5.Conclusion And Future Work

5.1 Conclusion

Wireless networks provides as we were shown in our pervious chapters the flexibility and mobility , also reducing the cable restriction; and since the ZigBee technology has a low data rate, low power consumption, low cost, also the wireless networking protocol target towards monitoring and control purposes and as we were explained in chapter two a ZigBee wireless control network has a successful achievement in this field.

As for our robot project the results were achieved successfully for the robot's controlling part and also the ultrasonic sensors transmitting the results to the controller screen. A ZigBee-based test application of a robot with ultrasonic sensor has been evaluated, showing the success to use our ZigBee wireless control with Arduino as a microcontroller modules for quickly development of new applications.

Also if we want to see the compression between our ZigBee protocol and other wireless control protocol it can be shown in table 5.1 below.

Table 5.1 compression between wireless control network protocol

Market Name Standard	Wi-Fi™ 802.11b	Bluetooth™802.15.1	ZigBee™802.15.4
Application Focus	Web, Email and video	Cable replacement	Monitoring and control
System Resources	1MB+	250KB+	4KB-32KB
Battery Life(days)	0.5-5	1-7	100-1000+
Network Size	32	8	65000
Bandwidth(KB/s)	11000+	720	20-250
Transmission Range(meters)	1-100	~10	~100
Success Metrics	Speed, Flexibility	Cost, Convenience	Reliability, Power, Cost

5.2 Future Work

A ZigBee wireless control network has proven a successful control and monitoring properties in our robot and it can be developed to be more effective in the field to serve us in conquering the difficulties in a dangerous fields of work. As for the development for our project we can add a small digital camera for display and discover the area surrounded our robot. Also we can use the same idea that we used in our project for making a robot that work in fields that will give much serve for the humans such fields are swears a robots that his purpose is clean and fixing any damages in pipe line and also monitoring , also in the affected area by poison gas or nuclear reactor it can be developed to fit our purposes in this field in case of monitoring or controlling.

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APPENDIX

A. Control unit Design Codes in visual studio program

```
this.components = new System.ComponentModel.Container();
    this.button1 = new System.Windows.Forms.Button();
    this.button2 = new System.Windows.Forms.Button();
    this.button3 = new System.Windows.Forms.Button();
    this.button4 = new System.Windows.Forms.Button();
    this.baglan = new System.Windows.Forms.Button();
    this.label2 = new System.Windows.Forms.Label();
    this.label1 = new System.Windows.Forms.Label();
    this.comboBox2 = new System.Windows.Forms.ComboBox();
    this.comboBox1 = new System.Windows.Forms.ComboBox();
    this.label3 = new System.Windows.Forms.Label();
    this.label4 = new System.Windows.Forms.Label();
    this.label5 = new System.Windows.Forms.Label();
    this.label6 = new System.Windows.Forms.Label();
    this.label7 = new System.Windows.Forms.Label();
    this.onsensor = new System.Windows.Forms.Label();
    this.arkasensor = new System.Windows.Forms.Label();
    this.sagsensor = new System.Windows.Forms.Label();
    this.solsensor = new System.Windows.Forms.Label();
    this.label12 = new System.Windows.Forms.Label();
    this.label13 = new System.Windows.Forms.Label();
    this.label14 = new System.Windows.Forms.Label();
    this.label15 = new System.Windows.Forms.Label();
    this.serialPort1 = new System.IO.Ports.SerialPort(this.components);
    this.dur = new System.Windows.Forms.Button();
    this.timer1 = new System.Windows.Forms.Timer(this.components);
    this.SuspendLayout();
```

PRINTING DATA FORM THE SERIAL PORT WITH X-BEE

```
private void button1_Click(object sender, EventArgs e) // forward
{
    serialPort1.WriteLine("1");
}

private void button2_Click(object sender, EventArgs e) //left
{
    serialPort1.WriteLine("3");
}

private void button3_Click(object sender, EventArgs e) //right
{
    serialPort1.WriteLine("4");
}

private void button4_Click(object sender, EventArgs e) // back
{
    serialPort1.WriteLine("2");
}
```

B. Arduino Codes

```
#include <SoftwareSerial.h>
SoftwareSerial BT(2, 3); // RX, TX

/*
A0 Onsensor
A1 arkasensor
A2 solsensor
A3 sagsensor
*/
```

```
char yon;
int sagmotor,solmotor;
int in1 = 9;
int in2 = 8;
int in3 = 7;
int in4 = 6;
```

```
int enA = 5;  
int enB = 10;
```

```
int onsensortrig = 12;  
int arkasensortrig = 13;  
int sagsensortrig = 11;  
int solsensortrig = 4;
```

```
long onsensordeger, onsensoruzaklik;  
long arkasensordeger,arkasensoruzaklik;  
long solsensordeger,solsensoruzaklik;  
long sagsensordeger,sagsensoruzaklik;
```

```
void setup() {  
  // put your setup code here, to run once:  
  Serial.begin(9600);  
  BT.begin(9600);  
  pinMode(13,OUTPUT);  
  digitalWrite(13,LOW);
```

```
  pinMode(enA, OUTPUT);  
  pinMode(enB, OUTPUT);  
  pinMode(in1, OUTPUT);  
  pinMode(in2, OUTPUT);  
  pinMode(in3, OUTPUT);  
  pinMode(in4, OUTPUT);  
  pinMode(A0,INPUT);  
  pinMode(A1,INPUT);  
  pinMode(A2,INPUT);  
  pinMode(A3,INPUT);  
  pinMode(onsensortrig, OUTPUT);
```

```
pinMode(arkasensortrig, OUTPUT);  
pinMode(sagsensortrig, OUTPUT);  
pinMode(solsensortrig, OUTPUT);
```

```
}
```

```
void loop() {
```

```
    digitalWrite(onsensortrig, LOW);  
    delayMicroseconds(2);  
    digitalWrite(onsensortrig, HIGH);  
    delayMicroseconds(10);  
    digitalWrite(onsensortrig, LOW);  
    onsensordeger=pulseIn(A0,HIGH);  
    onsensoruzaklik=onsensordeger/58.2;
```

```
    digitalWrite(arkasensortrig, LOW);  
    delayMicroseconds(2);  
    digitalWrite(arkasensortrig, HIGH);  
    delayMicroseconds(10);  
    digitalWrite(arkasensortrig, LOW);  
    arkasensordeger=pulseIn(A1,HIGH);  
    arkasensoruzaklik=arkasensordeger/58.2;
```

```
    digitalWrite(solsensortrig, LOW);  
    delayMicroseconds(2);  
    digitalWrite(solsensortrig, HIGH);  
    delayMicroseconds(10);  
    digitalWrite(solsensortrig, LOW);  
    solsensordeger=pulseIn(A2,HIGH);
```

```
solsensoruzaklik=solsensordeger/58.2;
```

```
digitalWrite(sagsensortrig, LOW);  
delayMicroseconds(2);  
digitalWrite(sagsensortrig, HIGH);  
delayMicroseconds(10);  
digitalWrite(sagsensortrig, LOW);  
sagsensordeger=pulseIn(A3,HIGH);  
sagsensoruzaklik=sagsensordeger/58.2;
```

```
if( onsensoruzaklik > 5 && onsensoruzaklik < 25 )  
{  
  BT.print(onsensoruzaklik);  
  BT.print(":");  
}  
if (onsensoruzaklik < 5 && onsensoruzaklik > 25 )  
{  
  BT.print("--");  
  BT.print(":");  
}
```

```
if( arkasensoruzaklik > 5 && arkasensoruzaklik < 25 )  
{  
  BT.print(arkasensoruzaklik);  
  BT.print(":");  
}  
if (arkasensoruzaklik < 5 && arkasensoruzaklik > 25 )  
{  
  BT.print("--");  
  BT.print(":");  
}
```

```
if( sagsensoruzaklik > 5 && sagsensoruzaklik < 25 )
```

```

{
  BT.print(sagsensoruzaklik);
  BT.print(":");
}
if (sagsensoruzaklik < 5 && sagsensoruzaklik > 25 )
{
  BT.print("--");
  BT.print(":");
}

```

```

    if( solsensoruzaklik > 5 && solsensoruzaklik < 25 )
    {
      BT.print(solsensoruzaklik);
      BT.print(":");
    }
    if (solsensoruzaklik < 5 && solsensoruzaklik > 25 )
    {
      BT.print("--");
      BT.print(":");
    }

```

```

if(BT.available()){
  yon = BT.read();
}

```

```

if(yon == '1') {

  digitalWrite(in1, HIGH);
  digitalWrite(in2, LOW);
  digitalWrite(in3, HIGH);
  digitalWrite(in4, LOW);
}

```

```

sagmotor =125;
solmotor =125;
delay(50);
    }

else if(yon == '2') {

digitalWrite(in1, LOW);
digitalWrite(in2, HIGH);
digitalWrite(in3, LOW);
digitalWrite(in4, HIGH);
sagmotor =125;
solmotor =125;
delay(50);
    }

else if (yon=='3') //sol
{
    digitalWrite(in1, HIGH);
    digitalWrite(in2, LOW);
    digitalWrite(in3, LOW);
    digitalWrite(in4, HIGH);
    sagmotor =125;
    solmotor =75;
    delay(50);

}

else if (yon== '4') // sag
{
    digitalWrite(in1, LOW);
    digitalWrite(in2, HIGH);
    digitalWrite(in3, HIGH);

```

```
digitalWrite(in4, LOW);
sagmotor =75;
solmotor =125;
delay(50);

}
else if (yon == '5' ) // geri

{
    digitalWrite(in1, LOW);
    digitalWrite(in2, LOW);
    digitalWrite(in3, LOW);
    digitalWrite(in4, LOW);
    sagmotor =125;
    solmotor =125;
    delay(50);
}

    analogWrite(enA, sagmotor);
    analogWrite(enB, solmotor);

}
```

RESUME

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