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MANAGEMENT OF WIRELESS COMMUNICATION SYSTEMS USING ARTIFICIAL INTELLIGENCE-BASED SOFTWARE DEFINED RADIO

MASTER DEGREE THESIS

FAIQ AHMED MOHAMMED BARGARAI
163111008

Department of Electrical and Electronics Engineering

Supervisor: Asst. Prof. Dr. Volkan Müjdat TİRYAKİ
Co-Supervisor: Prof. Dr. Adnan Mohsin ABDULAZEEZ

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THESIS ACCEPTANCE AND APPROVAL

This thesis entitled as "**Management of Wireless Communication Systems Using Artificial Intelligence-Based Software Defined Radio**", prepared by Faiq Ahmed Mohammed BARGARAI under the supervision of Assist. Prof. Dr. Volkan Müjdat TİRYAKİ has been accepted as a MASTER DEGREE THESIS on 8/5/2019 in the Department of Electrical and Electronic Engineering of the Graduate School of Natural and Applied Sciences at Siirt University by the jury members given below.

Jury Members	**Signature**
President Assist. Prof. Dr. Davut SEVİM	....
Supervisor Assist. Prof. Dr. Volkan Müjdat TİRYAKİ	....
Member Assist. Prof. Dr. Yılmaz KAYA	....

I confirm the above results.

Doç. Dr. Fevzi HANSU
Director of the Graduate School of
Natural and Applied Sciences

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Faiq Ahmed Mohammed Bargarai

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ABBREVIATIONS AND SYMBOL LISTS

Abbreviation	Explanation
ADC	Analog to Digital Converter
AI	Artificial Intelligence
ANN	Artificial Neural Networks
BNU	Basic Networking Utilities
CDMA	Code Division Multiple Access
DAC	Digital to Analog Converter
dB	decibel
DOA	Direction-of-Arrival
DSP	Digital Signal Processing
DVB-T	Digital Video Broadcasting-Terrestrial
FM	Frequency Modulation
FPGA	Field Programmable Gate Array
GA	Genetic Algorithm
GHz	Gigahertz
GPS	Global Positioning System
HA-NFS	High Availability – Network File System
HSDPA	High-Speed Downlink Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
LNA	Low Noise Amplifier
LO	Local Oscillator
LTE	Long Term Evolution
MFSK	M-ary Frequency Shift Keying
MHz	Megahertz
MPSK	M-ary Phase Shift Keying
MQAM	M-ary Quadrature Amplitude Modulation
OS	Operating System
POSIX	portable operating system interface for UNIX
QoS	Quality of Service
RBF	Radial Basis Function
RF	Radio Frequency
RTL	Register-Transfer Level
SDN	Software Defined Network
SDR	Software Defined Radio
SFDR	Spurious-Free Dynamic Range
SINAD	Signal to Noise and Distortion Ratio
SNR	Signal to Noise Ratio
SRC	Sample Rate Conversion
TCP/IP	Transmission Control Protocol/InternetProtocol
TDMA	Time Division Multiple Access
THD	Total Harmonic Distortion
TSP	Traveling Salesman Problem
UHF TV	Ultra High-Frequency Television
USB	Universal Serial Bus
VLSI	Very-large-scale integration
WSRN	Wireless Sensor and Robot Networks

ÖZET

YÜKSEK LİSANS TEZİ

YAPAY ZEKA TABANLI YAZILIM TANIMLI TELSİZ KULLANARAK KABLOSUZ AĞ SİSTEMLERİ YÖNETİMİ

Yüksek Lisans Tezi
Faiq Ahmed Mohammed BARGARAI

Siirt Üniversitesi Fen Bilimleri Enstitüsü
Elektrik-Elektronik Mühendisliği Anabilim Dalı

Danışman: Dr. Öğr. Üyesi Volkan Müjdat TİRYAKİ
II. Danışman: Prof. Dr. Adnan Mohsin ABDULAZEEZ

Mayıs 2019, 61 sayfa

Kablosuz haberleşme sistemlerinin yönetimi için yeni yöntemler yoğun bir şekilde araştırılmaktadır ve yazılım tabanlı yöntemler donanım tabanlı yöntemlerin önüne geçmiştir. Yazılım Tanımlı Telsiz (YTT) kablosuz haberleşme protokollerinin geliştirildiği ve uygulandığı yaygın platformlardan biridir. Bu çalışmada ileri sürülen yapay zeka tabanlı YTT sisteminde kablosuz düğümler sadece yerel bilgiler kullanılarak kendiliğinden organize edilmektedir. İleri sürülen yazılım tabanlı yöntem kanal frekansını, bant genişliğini ve modülasyon formatını kontrol etmek için kullanılabilmektedir. Yazılım tabanlı yöntemin avantajları açıklanmıştır. Sistemin genel performansı, kablosuz düğümler tarafından desteklenen YTT özelliklerine ait olan ve aynı zamanda kontrollü bir mobilite işlevi olan bağlantı açısından geliştirilmiştir. YTT kullanarak sınırlı bağlantı gereksinimleri, azami kapsama alanı bakımından daha iyi hale getirilmiştir.

Anahtar kelimeler: YTT, yapay zeka, genetik algoritma, mobil düğümler.

ABSTRACT

M.Sc. Thesis

MANAGEMENT OF WIRELESS COMMUNICATION SYSTEMS USING ARTIFICIAL INTELLIGENCE-BASED SOFTWARE DEFINED RADIO

FAIQ AHMED MOHAMMED BARGARAI

The Graduate School of Natural and Applied Science of Siirt University
Master of Science Thesis
In Electrical-Electronics Engineering

Supervisor: Asst. Prof. Dr. Volkan Müjdat TİRYAKİ
Co-Supervisor: Prof. Dr. Adnan Mohsin ABDULAZEEZ

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Management of wireless communication systems has been investigated thoroughly with novel methods, which led to the development of mainly software based methods rather than hardware. Software-Defined Radio (SDR) is a common method for developing and implementing wireless communication protocols. In the proposed artificial intelligence based SDR system, wireless nodes are made self-organized in distributed form by using only local information. The proposed software based method can be used to control the channel frequency, bandwidth, and modulation format. The advantages of the software based system are explained. The general performance of the system is improved in terms of connectivity which belong to the SDR capabilities supported by wireless nodes, as well as a controlled mobility function. The requirements for the restricted connectivity by using SDR are made more stringent with regard to the maximum coverage.

Keywords: SDR, artificial intelligence, genetic algorithm, mobile nodes**.**

1. INTRODUCTION

The interest in the research of the use of artificial intelligence ANN and software-defined radio (SDR) has gained momentum in the management of networks and communication systems in the last couple of years. The reason for extensive research in SDR concepts is to transfer the radio engineering problem mainly to the software domain rather than the hardware domain. However, the idea of coming up with new communication devices has introduced the ability to adapt to a self-regulated fashion in terms of work, whether proper modulation selection for a signal transmitted and demodulation for the signal received. As well as the appropriate distribution of nodes in a given area noted that there is more attention that given to the wireless network research (Guerriero et al., 2017).

The introduction of powerful hardware platforms and software reconfiguration marks a new chapter on communication advancement. The trend of new communicate; however, takes into account the SDR paradigm to confront the communication networks and wireless devices. The capabilities of SDR are the only hopes for the anticipated future wireless devices, which can be enhanced through coupling while addressing controlled mobility. The following suggestion of the genetic algorithm only substantiates the computation of the node positions while engaging the modulation schemes.

Besides, the scope of networks as well as communication management attracts the impact of the users and system management to interact with various network communication tasks. While incorporating SDR and the ANN, most of the administrators would be interested in the functions behind the configuration of the transmission control protocol/internet protocol (TCP/IP) settings, system monitoring as well as network security. Notably, users can work through information and communication applications while operating the system (Cho et al., 2014).

Other system configurations, a user would expect from a system include the basic networking utilities (BNU), the High Availability – Network File System (HA-NFS), TCP, the message handler and the network file system (NFS).

Apart from the configurations, users would be more concerned with the nature of networks noted in the system. In the primary network, a user would interact with the physical network, which has the cables including the fiber optic, coaxial cable, and the telephone lines among others. The physical systems radically vary in terms of size and hardware.

The second area of concern includes wireless network systems. Such systems incorporate both software and hardware. In most cases, the hardware part would consist of the physical equipment that typically connected to the available physical network. On the other hand, the software part includes the device drivers and programs that accommodate the system operation.

Learning more about the integration of the hardware and software goes back to the SDR capabilities, where the genetic algorithm and neural network approaches are involved in designing an appropriate algorithm for the system (Zhou et al., 2017). Across the extensive coverage, however, there is still a research gap that needs more attention.

The coverage on the application of the SDR and ANN in the management of the networks and the communication systems seem to be the untouched part. While most of the researches would cover the functionality of the system and how various components integrate, it is scarce to realize the management across the system. This forms the ground for this thesis.

The reason for extensive research in SDR concepts is to transfer the radio engineering problem mainly to the software domain rather than the hardware. The advancements in artificial neural networks (ANN) research has led to the idea of designing new communication equipment that is capable of adapting their functionalities in a self-organizing fashion. ANN can be used to come up with the best position of each node using algorithms (Guerriero et al., 2017). SDR can be combined with an artificial neural network/genetic algorithm (ANN/GA) technique to manage wireless communication systems.

Before the advent of digital signal processing technology, the radio systems relied on analog circuitry to perform the majority of the functions. The use of analog signals and devices had limitations that needed to be solved using new technological advancements that depended on digital signal processing. The performance of analog systems depended on the external environment since it was affected by temperature, noise, etc. Analog systems were not reconfigurable (Lee, 2007). Modification of such systems was only possible through physical intervention. Another problem of the analog communication system was that the implementation of complex communication algorithms was hard because of the cost incurred, the power that is used, and the size of the components. The application of analog functions in digital signal circuitry became possible with the increase in processing speed of signal processors and data converters.

Researchers in radio and wireless communication were interested in ways that would completely digitize the radio frequency (RF) signal directly at the point of the output of the antenna receiving the signal. The received signal is further processed via both software and hardware. The desire to have the RF signal at the output of the receiving device gave rise to the SDR concept. The software is used for the modulation and demodulation of radio signals (Lee, 2007).

There has been a need to change radio devices due to the exponential growth that has been experienced in the ways and means people use to communicate- data communications, audio-visual communications, control communications, broadcast messaging, emergency response communications, etc. (Pejovic and Belding, 2014).

Businesses have also become critical in the methods they choose for communication and prefer cost-effective means. SDR technology offers cost efficiency, flexibility and the ability to push communication systems forward.

SDR is a radio communication system that uses software to implement components on an embedded system or personal computer that had been traditionally implemented in the hardware. Such components include detectors, mixers, filters, modulators and amplifiers (Marpanaji et al., 2007).

A majority of the existing wireless networks are hardware based and use architectural designs that are closed or inflexible. They make scalability hard, and it is difficult to add new hardware devices in such a wireless network. When communication systems have an inflexible hardware-based architecture, it takes a 10-year cycle to deploy and standardize it with a new generation of wireless networks.

The wireless network research community has been looking for ideas that will assist them in designing communication devices that will function in a self-organized and adapt to the changes that experienced in a working environment. Researchers are also interested in the availability and deployment of a novel general purpose and practical hardware frameworks that can be reconfigured using the software in communication environments that have various challenges (Guerriero et al., 2017).

The existing wireless networks pose a challenge when developers try to adopt new technologies that would maximize the capacity of the network and its coverage area. The existing commercial systems have also prevented the provision of truly-differentiated services that could fit in highly uneven and growing traffic patterns. For instance, the (5G) cellular network requirements for the ultra-high capacity is 1000-fold capacity/km^2 different from the long term evolution (LTE). This fundamental transformation of the system needs time and also a significant cost that affects the commercial networks, prompting the researchers in thinking to select a more flexible network system, (Akyildiz et al., 2015).

The ultra-high data rates give a 100-fold rise in the user throughout that is experienced. The user-plane latency maintained below (1 ms) less than the radio access network. The current network architectures continue to experience challenges that can only be solved using a radical paradigm shift that will modify the next-generation communication systems (Akyildiz et al., 2015).

The concept of designing new communication devices that can confirm their operational roles in a self-organized way to cope with rapid changes in the work environment has gained considerable attention from the wireless research community (Perera et al., 2013).

Likewise, the availability of a new general purpose and powerful hardware platforms can dynamically reconfigure it through a program (Akyildiz et al., 2006). It paved the way for new research trends where complex communication scenarios can be deployed (Blümm et al., 2012).

By this new direction of communication systems, the advantages offered by SDR models were taken into account as envisioned in (Akyildiz et al., 2016; Akyildiz et al., 2015).

Researchers thought about designing self-propagation strategy on adaptation communications network where many wireless devices are distributed in a specific area and can perform a common task according to the particular network requirements in terms of coverage or connectivity. The management system advantages of SDR is that it is the most suitable modulation scheme can be achieved effectively. A single SDR system can be implemented to many radio systems (or radars) with different devices, by only changing the software (Godbole and Aldar, 2010; Aloi et al., 2011).

Another aspect of the present research is to investigate the advantages of system management by software, which in turn leads to a high-quality result by changing the capacity of the channel. Switching modulation scheme can increase the rate of baud or reduce it to the maximum use of channel capacity. In addition, the general performance of the system can be improved in terms of connectivity, which belong to the SDR capabilities supported by a wireless node, as well as a controlled mobility function, where the requirements for the restricted QoS connectivity are more stringent with regard to the maximum coverage (Perera et al., 2013; Loscri et al., 2014).

SDR is expected to be utilized in the next generation of wireless networks and introduced new architectural frameworks for wireless software. The radio devices of the traditional hardware era make cross-functionality harder and only modified through physical intervention. Such a constraint makes traditional communication have higher production costs and also lacks the flexibility to cope with multiple waveform standards.

SDR technology ensures that communication is inexpensive and efficient. It allows multi-functional wireless devices, and multi-mode wireless devices to incorporate in a network through software upgrades.

As part of this research, mobility in the nodes, which lead to a high degree of coverage in the communications scenario, often related to applications such as pollution control or fire detection and control of terrorism (Guerriero et al., 2017).

1.1 Problem Statement

The need for the flexible system and the high performance in wireless communications has led to the research on SDR. SDR was developed to make cost-efficient communication systems and also to increase the flexibility of communication channels.

The standard architecture of SDR used because it allows interoperability with other network devices. SDR has been used in the wireless industry and the military because of its ability to change the protocols in real time. (Lee, 2007).

The increase in terrorism, border incidents, natural disasters and other emergencies in the world have contributed to the need for wireless communications that use SDR. These emergencies caused the need for information sharing among institutions.

The conventional hardware-based wireless network communication is limited to support one type of network (Takashi et al., 2015).

Conventional communication networks have problems like frequency bands, use of base stations, protocols and waveforms. It obstructs communication and emergencies may be difficult when there is interference in communication. SDR eliminated communication challenges in times of emergencies.

SDR can support multiple air communication interfaces, through a change in its communication software. Emergency mobile radio can rapidly switch the mode of an ad-hoc network given in Figure 1.1 and the infrastructure of a trunked radio by user operations (Takashi et al., 2015).

Critical situations require information sharing on the site where there is no operational wireless infrastructure due to natural disasters, breakdown, fire, tsunami, or power outages. It is difficult to move the base station rapidly because the earthquake interrupts traffic in many locations. Rescue teams are in contact with each other through the dedicated wireless network, and the nodes are deployed in the specific area and distributed according to the algorithm chosen in this research. The mobile emergency radio organizes a dedicated broadband network having a capacity of 640 kbps. Response time is low enough to provide voice over the system because of the capabilities of both SDR and mobility of nodes (Takashi et al., 2015).

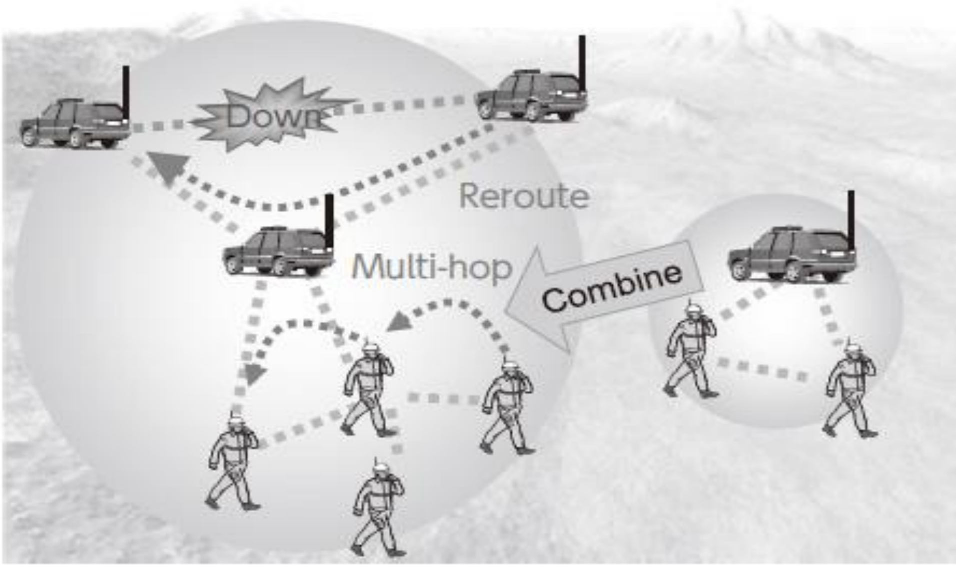

Figure 1.1. Ad-hoc network example (Takashi et al., 2015).

1.2. Hypothesis

SDR can be used to compute the best modulation scheme and a suitable position for network nodes to improve the coverage and connectivity in a specific area. When an SDR combined with mobility support, and it is configured using an artificial neural network/genetic algorithm technique, wireless network nodes can be self-organized in a distributed manner. The hypothesis to be tested is whether and how artificial neural network/genetic algorithm and SDR can be combined to improve the performance and efficiency of a wireless communication network.

1.3. Research Focus

Reconfiguration can be partial, complete, dynamic, or static and is an essential aspect of software-defined technology. The need for flexibility in SDR is investigated in this thesis. A wireless network should give the ability to automatically select the best demodulation scheme for any signal received that is unknown.

The thesis will focus firstly on increasing channel capacity by performing the switching of the demodulation schemes, and such an increase depends on the intended usage and expected needs. A demodulation scheme switching algorithm that will be based on SDR and will be proposed and simulated using ANN.

1.4. Purpose Statement

This thesis presents how the SDR capabilities can be supported by wireless node mobility to improve system performance through connectivity and achieving a certain quality of service QoS after it is integrated with ANN/GA method.

The potential of mobile SDR communication equipment by assessing operation flexibility and dynamical re-configuration is sought. It is necessary as previous wireless communications, were complex and difficult to reconfigure, and this will serve as a point of comparison.

This thesis also contributes to SDR by designing an optimization model using a common communication scenario by validating a proposed ANN/GA algorithm via a simulation analysis. The algorithm validated through a self-developed simulator based on MATLAB where the proposed strategy simulated in different scenarios by varying both the number of SDR nodes and mobile nodes so that the impact of having a large number of mobile/SDR nodes on system performance can be measured.

In the future, devices that support SDR functionality will be developed and used increasingly. These devices that will support SDR that form wireless networks with abilities to self-evolve. The objectives of such wireless networks will include increasing the coverage and the rate of data transfer. It will also have better connectivity between devices where the communication environment is spread out and diverse. This research is focused on developing a fixed sensor node or a simple mobile sensor node that has been installed with IEEE 802.15.4/ZigBee compliant RF transceiver.

The thesis will also analyze complex mobile devices that can perform high processing and the ability to alter the modulation pattern dynamically across two transmitters/receivers through the use of SDR support as depicted in (Guerriero et al., 2017) figure 1.2.

SDR components are traditionally performed on devices such as mixers, filters, amplifiers, modulators/demodulators, detectors through the use of a program on a PC or an embedded system. While the SDR concept is not new, the potential for the rapid development of digital electronics makes many operations a process that was theoretically impossible (Dillinger, 2003).

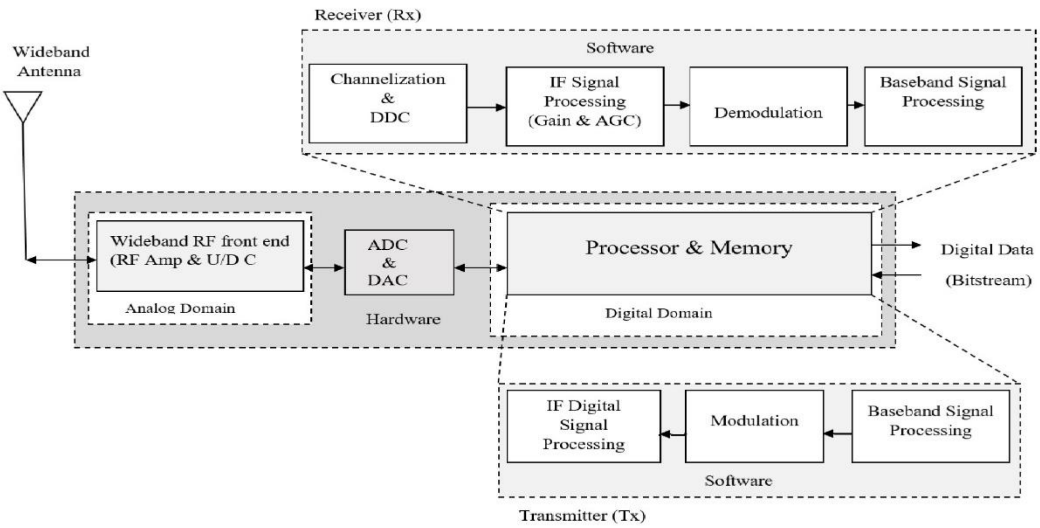

Fig 1.2. SDR architecture for the relay node (Loscri et al., 2014).

1.5. Scope and limitations of the study

Software analysis and system integration have performed in this study. The idea of exploring the relevant details accompanied the essence of connecting the capabilities of SDR and AI for the management of the network and wireless communication systems. The objectives include the integration of ANN to the genetic algorithm, and the impact of SDR and AIs on the management of network and communication system can increase.

1.6. The aim of the study

This research aims at dealing with novel communication systems scenarios, using a new technology to enhancing the potential of future wireless devices in a synergistic way, by using the SDR capabilities to compute the most suitable modulation/demodulation scheme dynamically, supported by wireless devices mobility to choose the best position for the nodes to improve QoS in both terms of coverage and connectivity in a specific area.

1.7. Thesis Outline

This thesis is organized in five chapters. Chapter 1 provides an overview of the thesis. Revised literature and theory in brief is given in Chapter 2. The materials and methods are presented in Chapter 3. The results and discussion is given in Chapter 4. The conclusions and future work are presented in Chapter 5.

2. LITERATURE REVIEW

Joseph Mitola was the first to introduce SDR in 1991 which is also known shortly as software radio. SDR represented a category of radio class that could be reprogrammed and reconfigured using software and in turn, alter the frequency and mode of a wireless communication application. SDR is introduced because it could offer scalability, support multi-mode flexibility and reconfigurability. SpeakEasy was a US military SDR technology that enabled communication with many types of military radios.

SDR and ANN is a subject of interest for researchers. SDR started in the 1980s, and one of the major developments was SpeakEasy, which acted as a transceiver platform. Motorola and Hazeltine essentially designed the platform by the SDR technology. The design provided important and tactical military communication from almost 2 MHz to around 2 GHz. The range provided interoperability between separate interface standards. The achievement of this goal marked a milestone and SpeakEasy could use as techniques used in the multi-modes and multi-band of operations. Most of the researchers have continuously been contributing towards both the concept and the subsequent software.

Later on, SpeakEasy was developed into SDR with fair say of simplicity as well as more rudimentary forms. The subsequent evolution of such technologies like code division multiple access (CDMA) and global system for mobile (GSM) has been a developmental aspect. CDMA is essentially captured in the Asian and the North American standard while GSM covers Europe as well as the rest of the world. SDR largely represented a special class of radio, which could be reprogrammed as well as reconfigured by using significant software in the process. The changes aimed at adjusting the mode of the wireless communication application and the frequency as well.

SDR was essentially introduced to offer support to reconfigurability, scalability and the multi-mode flexibility. The architecture of SDR captures the basis of conventional radio formulations, which are slightly different from the known traditional radio. The critical component in the building SDR includes the significant placement of ADC and DAC which play a crucial role in diving the analog as well as the digital domains (Dillinger, 2003).

The proposed method in this research enables the processing of the functions of the signal. In terms of architecture, the DAC/ADC usually brought close to an antenna as well as the processor, whereby the distance is made convenient enough for signal processing (Sinha et al., 2016).

SDR architecture is based on conventional radio formulations. It is different from the traditional radio since the conventional signal radio processes are done in the hardware completely. However, in SDR architecture signal processing is done by software as much as possible. The key in building SDR is the placement of DAC and ADC components to serve as a divider between digital and analog domains, to enable the processing of signal functions to be done by software (Marpanaji et al., 2007).

In SDR, transceiver, receiver, and the ADC/DAC is placed close to the antenna and processor to allow digital signal processing and performing of radio functions (figure 2.1). It is made possible to have software upgrades and updates in case there is a change in the communication standard.

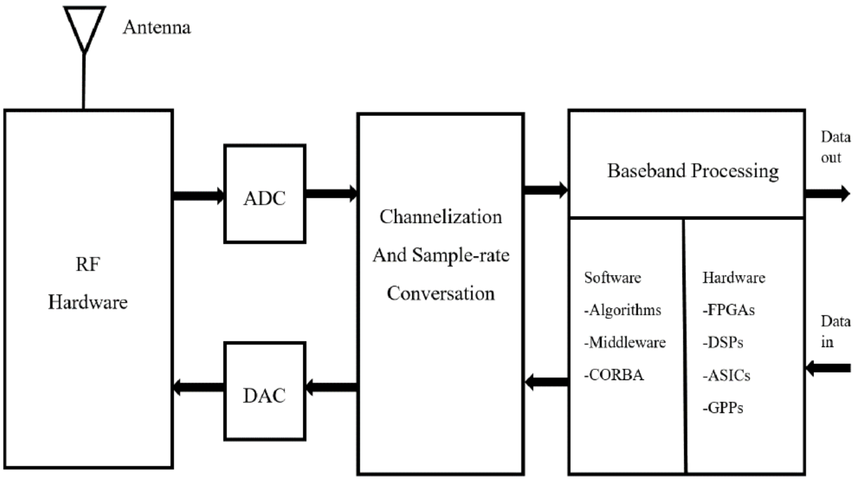

Fig 2.1 SDR transceiver and receiver (Sinha et al., 2016).

2.*1.* SDR and its capabilities

SDR can essentially be defined as a paradigm that explores wireless communication devices. According to Guerriero et al. (2017), the structure and functionality of SDR can attribute to the efforts of Joseph Mitola who recognized the term as the identifier of the class of radios.

These radios could be reprogrammed as well as reconfigured by use of the software. Notable, Joseph Mitola must have envisioned the development of the ideal SDR that had two simple physical components that included an antenna as well as the ADC. The conception of the idea could be taken seriously in the 1990s, and SDR became a viable device that was primarily defined by software. The description of SDR cannot leave without exploring the hardware part. First, the traditional receiver has three roles to play. The characters include carrier frequency tuning to select the desired signal, amplification to compensate for the transmission losses, and finally the filtration.

Most of the traditional receivers have always made use of conventional heterodyne schemes. Secondly, the SDR receiver is another hardware that has different functions (Loscri et al., 2014; Guerriero et al., 2017) underlines the fact that RF tuner, which converts most of the analog signal to the intermedia frequency (IF) while performing the same operations in more than three times (Figure 2.2).

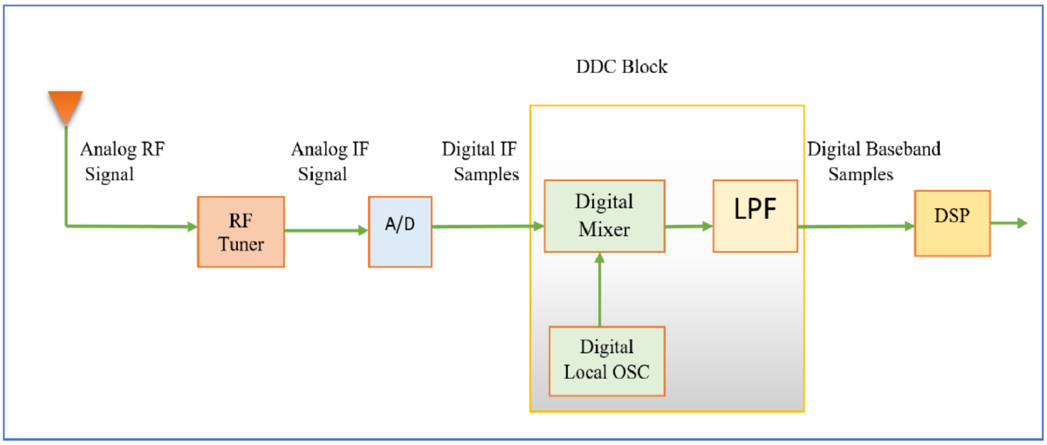

Fig 2.2 The block diagram of the SDR Receiver (Hosking, 2016).

Besides, SDR constitutes the SDR transmitter, which is purposed to receive the baseband signal. The first block of the transmitter is the Digital up Converter which transfers the baseband signal to the IF.

On the other hand, the RTL 2832U device is an excellent choice and can operate in the ultrahigh-frequency (UHF) and the very high-frequency (VHF) bands and thereby paving the way for the exploration of the spectrum applied in the national broadcast. Apart from the SDR hardware, the SDR software is also important in the sense that it enables the automated functionality of SDR.

The SDR frameworks are implemented using FPGA, which runs the digital signal processing. The frameworks capture some libraries with the first one appearing in the year 2001. This one established for the Linux operating system and its popularity has gained mileage in the Windows and the GNU Radio2001. Other frameworks work better on the basis of the MATLAB software (Loscri et al., 2014; Guerriero et al., 2017).

The prime purpose of the SDR device is communication, especially with a personal computer. The idea of a unified platform and the significant potential of correcting errors well captured in the typical applications. A series of researches have, however, captured different forms that include the spectrum regulation, cost reduction, and dynamic Spectrum Positioning. Another use appears in the Opportunity Driven Multiple Access among other SDR applications. On the other hand, (Machado-Fernández, 2015) takes note of the fact that SDR shares the ability to be transformed by the use of re-definable logic or software. The transformation is made possible for the general purpose FPGA and DSP. Also, SDR is the potential candidate to be used as the multi-mode transceivers, multi-carrier, the single band as well as multi-band transceivers. It is of note that SDR capabilities can capture in different aspects.

The first aspect includes the multi-band where the traditional radio architecture can operate in a range or a single band of frequencies. Most of the applications have made it possible for the operation of the multiple frequencies. Notably, the multi-band radio has the capability of operating two or more bands as seen in the case of the base station.

The SDR is also a multi-carrier, commonly referred to as the multi-channel radio. It can essentially happen through the same band. Also, SDR can operate on a multi-mode platform, which narrows down to separate types of standards. Such standards include CDMA, AM, FM, and GMSK.

An SDR can work with all these standards and many others while paving the way for reprogramming. Multi-mode scenario exemplifies changeable modes of operation. An extra ability can study under the multi-rate situation where the radio engages different styles with separate data rates. Lastly, the variable bandwidth captures the idea of flexible digital filters and analog filters.

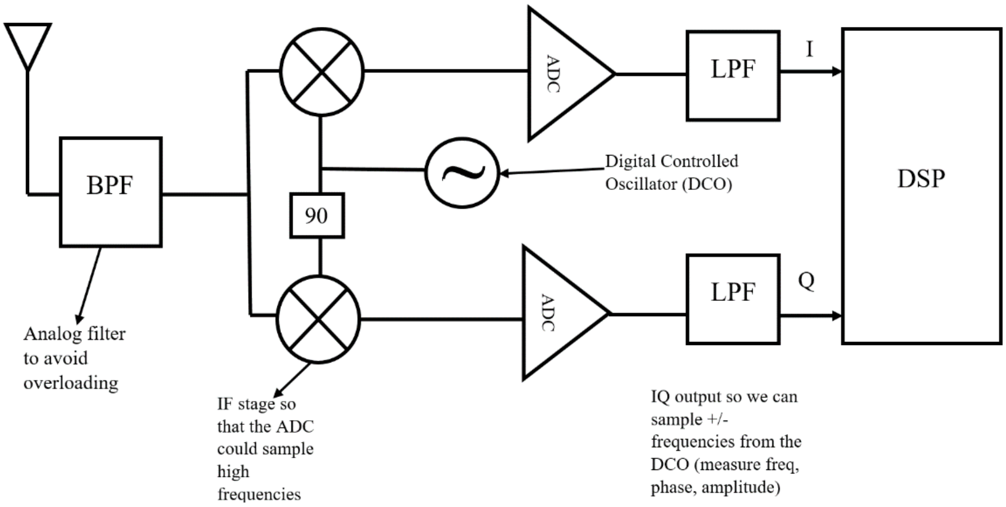

Fig 2.3 The pictorial representation of SDR (Mukesh et al., 2014).

Other capabilities shared by Mukesh et al. (2014) include the ones studied under the cognitive radio. Some of the capabilities include the general purpose processing capability, which involves the DSP and FPGA processing resources. The resources never optimized for the noted protocol applications. The same applies to the AI applications. The SDR performance has the resources programmed in terms of the high-level languages.

Secondly, the cryptographic capabilities are seen in the military radios for security functions. They have an assurance system dedicated to the hardware. The programmable cryptographic processors were normally available to perform the security functions.

Another ability embedded in the SDR is the software architecture. The structure has a real-time operating system integrated with a standard interface like the portable operating system interface for UNIX (POSIX) (Moessner et al., 2006). Sometimes, genetic algorithms can be applied to explore the action space. It can be understood in terms of the knowledge-based system while making an excellent decision. This SDR capability is largely based on machine learning.

2.*2.* The application of SDR

SDR has been advantageous to most of the wireless communication systems. First, SDR plays a frontal role in terms of reducing manufacturing costs and development time. The application of the identical hardware platform for most of the terminals and protocols has the possibility of reducing the development costs and time to market by using SDR. The second advantage is that SDR allows most of the service providers to upgrade the infrastructure with no additional costs. The wireless protocols can be improved to avail better services.

Typical examples include the W-CDMA protocol and the high-speed downlink packet access (HSDPA) channel. Also, the SDR avails seamless wireless connections to most of the end users. These services form the key features of the 4G communication system (Popescu et al., 2017).

2.*3.* The impact of SDR in network management and communication system

SDR technology has been applied in communication and network systems. According to the study done by Wang and Liu (2011), on the advancement noted in most of the cognitive radio networks, most of the devices are operating by the SDR principles.

New technologies, as well as new algorithms, have bolstered the accuracy and efficiency of the wireless communication systems. While reviewing the impact of SDR on communication and network systems, it is essential to look at the air interface where the (2G) cellular systems seem to have narrowed down to the CDMA and TDMA techniques. However, modification of these systems would have enhanced the capabilities based on the conditions and the characteristics that are affected in case of any changes.

The advancement has seen changes in data rates with subsequent generations enjoying the better use of improved systems. Under the SDR technology, the next generation will have hopes of a faster and accurate method that runs on the gigabyte interface. Another area of focus, while fostering the impact of SDR technology, is the wireless technologies.

The progress and evolution of wireless technologies can attribute to the desire for a system with advanced reliability, usability as well as the availability. To some extent, the argument of management through radio access networks especially in densely populated areas can be justified (Sun et al., 2015). Using a flexible approach is more recommended with such properties seen through what SDR technology can offer.

Notably, the network nodes present in mobile communication networks need to be reconfigured. This need can align with the growing demand for functional independence of various layers across the network modes. Reconfiguration is quite essential in managing the network and communication system in the sense that radio functionality and protocol modularization are made possible. The SDR forum has the required resources that can be used in radio configurations.

The research covered by Cho et al. (2014) takes an extra milestone in covering the integration of SDR with other technologies to impact the management process of the communication and network system. The coverage on the software-defined network (SDN) and the scope of the mobile network is essentially a new area of interest with regards to establishing a better and stronger management scheme. It is noticeable that every system has its own strengths and weaknesses, which is also a phenomenon witnessed in human beings.

In the network and communication world, the SDR system has been at the center of scheduling the channel priority while the SDN system is essentially engaged in monitoring and distributing traffic. Both the SDN and SDR have their specific elements, architecture, and connection, which are relevant to the central management. The recent development of SDR, however, sends a strong message of efficient decisions with more centralized systems coming in play.

In 2011, the conventional technique that was in use included the 4G, which is slightly different from the 5G. It has compelled some researchers to set more preference on the service-oriented cognitive networks compared to the IP multimedia subsystems.

The proposed system set more preference for radio channel scheduling while obtaining the most effective service experience. Based on the coverage by Cho et al. (2014), the SDR layer has devices that can suit the expected properties of future mobile phones. It is due to some features that give it an upper hand compared to other systems.

The administration component for this layer determines the frequency band and takes measures while eliminating any incident that can cause interference. On the other hand, the cross-layer controller only knows the request made for the frequency spectrum usage, which means that it can also determine the authorization of the device.

2.*4.* Artificial neural networks

AI was introduced in 1943 when McCulloch and Walter Pitts wrote a document on the working of the neurons. The subsequent modeling of the electrical circuits brought out the picture of the neural network, which reflected the neurons in the brain. The concept of neurons was later reinforced by Donald Hebb who noted the neural pathways.

The advancement of computers in the 1950s made the beginning of the modeled rudiments possible, which attracted different theories concerning human thought (Piccinini, 2004).

At the same time, Nathanial Rochester went ahead and simulated the artificial neural networks (ANN) with the first attempt being unsuccessful. The subsequent attempts came out more successful.

More researchers came on board to contribute to AI. Some of them are Frank Rosenblatt, Bernard Widrow, Marcian Hoff and John Hopfield among others. The AI and GA simply invented as a copy of the biological metaphor. The entire ANN mostly symbolized the human brain, which emanated into a computing model that constituted small interconnected units. In simple terms, AI is mere computing systems believed to carry out the activities in a more defined connection system in the absence of the programming instructions. The network is typically trained to reflect samples of signals seen or observed in the human brain (Abraham, 2002).

ANN is defined as an essential system that constitutes the interconnected processing elements, which operate in parallel with the function determined through the network structure, the performed computation, processing elements, and the connection strengths.

The emergence of ANN came into play as a result of the failure witnessed with the conventional programming techniques, which include the rule-based AI (Paliwal and Kumar, 2009). ANN was used to solve such problems as continuous speech recognition, machine vision, and machine learning.

ANN is naturally parallel, which makes them solve the "hard" problems that demand vast amounts of serial, conventional as well as computational power. The introduction of ANNs paves the way for real-time computation. Secondly, ANN has the ability to learn through a supervised mode, in which the provision of the network provides the correct sense. The system can organize as well as extract patterns from the presented data. In general, the network can yield the right sense following the input computations. The third capability is that it can perform the continuous non-linear mapping as one way of emulating the deterministic classifier. Paliwal and Kumar (2009) also take note of the capabilities in robotics, vision, signal processing, and speech.

According to the studies conducted by Hafiane et al. (2009), the realization of the ANN has enabled detecting the nonlinearities in wavelength sensing, and compensation. ANN has gained interest in many engineering applications. Some of the capabilities noted from the ANN includes the idea of fault tolerance, universal approximation as well as a generalization.

The study of ANN has also shared in terms of the benefits and capabilities noted in different systems. Haykin (2008) shares the properties and capabilities of ANN. Haykin (2008) and Hafiane et al. (2009) explored the capability and the nonlinearity. Activation functions can be nonlinear or linear. Nonlinearity is noted as a special kind in terms of the characteristic distributed network. Nonlinearity has a broader impact in terms of impacting the generation of the speech signal, which is also the input signal under most circumstances. Secondly, the idea of input-output mapping has received increased attention. The exploration of supervised learning encompasses the synaptic weights noted in the ANN. The third capability includes adaptability; this can align with the fact that ANN carry a built-in capability, which makes it easier to adapt to most of the synaptic weights.

ANN is trained in a way that enables the design to change the synaptic weights. Notably, the original architecture for control applications, signal processing, and pattern classification bolsters ANN while making it a useful tool in terms of adaptive signal processing, adaptive control, and adaptive pattern classification. The adaptive system is characterized mainly by short time constants, which can change rapidly thereby responding spurious disturbances.

The fourth capability noted by Haykin (2008) and Hafiane et al. (2009) is the evidential response, which captured in the settings of pattern classification. Based on this capability, ANNs are in a position to provide information or details connected to the selection and confidence. The data can be applied in denying ambiguous patterns while bolstering the classification performance. The fifth capability is contextual information, which is represented by the activation state and the structure behind the neural network. Each neuron is affected by global activities engaged by other neurons.

The six capabilities define the fault tolerance that heavily noted behind hardware form. ANNs are inherently fault tolerant, which is characteristic, learned through robust computation and the ability to perform degrades while engaging various operating conditions. ANN can also exhibit graceful degradation in terms of performance, which is much better when compared to a catastrophic failure. Also, ANN has extensive scale integration (VLSI) implementation ability, which conforms towards specific tasks. Such tasks bear beneficial value if capturing complex behavior in a notable hierarchical fashion. Moreover, ANN can also realize the uniformity of the analysis as well as design. It is likely to manifest in different ways including the fact that neurons represent an additional ingredient of establishing commonality across the neural networks. The same argument can share on the grounds of modular systems, which can build through the seamless integration of the relevant modules. Hafiane et al. (2009) further take note of neurobiological analogy with the design reflecting the brain network.

2.*5*. The ANN architecture

The study of ANN is essential in the field of communication. Graves et al. (2005) consider the fact that the essence of ANN can realize through structures, which are evident in most of the hybrid systems. Such frameworks are well captured in the ANN technologies while solving problems related to the application domains.

ANN software plays a critical role in developing models. Notably, Glorot and Bengio (2010) reflect on a topology that assumes a flexible architecture. Training specific architecture requires the application of certain steps of the ordinated steps believed to adjust the thresholds and the weights of the neurons. The adjustment mode well captured in a process that referred to as the learning algorithm tune the entire network to move the outputs close to the desirable or the expected values.

Based on the research undertaken by Glorot and Bengio (2010) and Graves et al. (2005), the primary structures and architecture of ANNs find relevance in three significant layers. The first one includes the input layer, which plays a critical role in tapping or receiving signals, measurements, features, and data. The inputs need to be normalized in the provided scope of limited values for the purposes of attaining the activation functions.

The second one is the hidden layer, which constitutes the neurons involved in extracting the patterns linked to processes under analysis. Lastly, the output layer also entails neurons that produce and present final network outputs.

Some of the ANN architecture include the single-layer feed-forward architecture which Graves et al. 2005 confirms that they have a single output layer. The single neural layer also acts as the output layer. The architecture has m outputs and n inputs. When the information flows along one direction, one can realize the fact that networks that belong to the architecture will coincide with the number of neurons noted at the output end. Among other networks, the common ones include the Adaline and Perceptron where the learning algorithms are involved in some of the training processes by Delta and Hebb's rules.

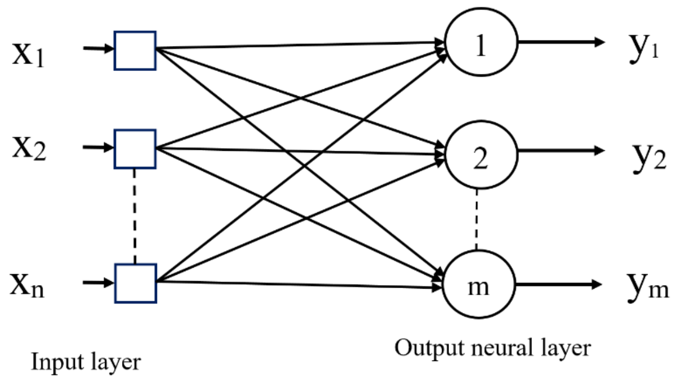

Fig 2.4 A single-layer feed-forward neural network.

The second architecture of ANN is the multiple-layer feed-forward architecture, most of the feed-forward architecture would always have a hidden layer. The multiple layers mostly applied in handling a variety of problems such as system identification, process control, robotics, function approximation, and pattern classification.

This architecture has an input with several sample signals while the hidden neural layers can assign multiple neurons, an output layer can have one neural layer with m neurons. Among many networks that use this type of architecture, the most noted ones include the Radial Basis Function and the Multilayer Perceptron denoted as (RBF) and (MLP) respectively. The learning algorithms applied in the training process depend on both the delta rule as well as the competitive rule. It is notable that for one to realize the hidden layers and the neurons assigned to each, the complexity and the nature of the problem under consideration needs be mapped. The same goes to the quality as well as the quantity of the data that is in use.

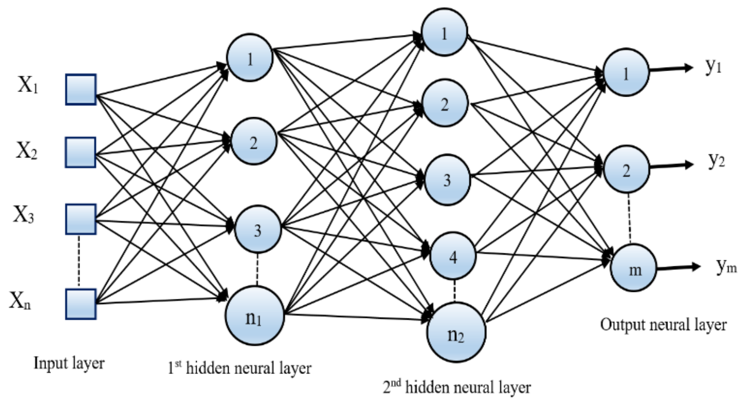

Fig 2.5 Multi-layer feed-forward ANN.

Other architectures that are still under study include the feedback architecture, which sometimes referred to as the recurrent architecture. In this context, the output of the involved neurons doubles as the feedback inputs for the next set of neurons.

The repetitive nature justifies the reason as to why the dynamic information processing can apply in the time-variant systems. Some systems include the process control, system identification and series prediction among others. Among many networks, the feedback type consists of the Perceptron and Hopfield. The algorithms for the two can utilize in the training processes by the generalized delta rule and the function minimization.

The mesh architecture, on the other hand, resides behind the spatial arrangement of the neurons assigned the critical role of pattern extraction. The extraction process is referred to as spatial localization and can relate to the thresholds and the synaptic weights, which can adjust at any point.

The mesh architecture serves different functions while solving such problems that involve system optimization, pattern recognition, and data clustering. The primary example of the mesh architecture includes the Kohonen network, which usually performed on a competitive process.

2.6. The impact of ANN in the management of a wireless communication system

ANNs were used in the management of the network and communication systems. According to Botoca and Budura (2003), some of the intelligent tools under ANNs have made a significant impact in terms of solving the telecommunication problems. The limited bandwidth largely restricted to the enormous growth of the well-managed telecommunications system. Both the receiver and the transmitter can impact the transmission channel. In most cases, managing the communication and network system involves eliminating any form of disturbances. ANN stands out as an intelligent structure that can compensate for the interference. Therefore, the networks are good at ensuring that the system has effective control.

There has been significant research on Antenna Array Signal Processing, which mainly narrows down to direction-of-arrival DOA estimation as well as beamforming. The DOA problem has been associated with mapping while conducting the Beamforming function. Some of the conventional methods that have been used in handling the DOA estimations and issues include the linear-algebra based or the intensive matrix inversion. These traditional methods have not been convenient enough in eradicating the DOA issue. However, the intervention of the ANN has been a reliable solution based on its properties. ANNs have further received attention in their contribution towards CDMA, which has been convenient in handling the inherent channel noise.

The impact of ANN on the network and communication system also captured in the research done by Sharma and Chopra (2013). ANNs have been a solution to most of the systems such as alarms. They have played key roles in terms of maintaining the service model, where the service topology is involved.

The networks also have a stake in maintaining the impact rules as far as extensive programming is concerned. It based on the fact that AI is essentially an algorithm served with the ability of advanced pattern recognition. This advantage has made it more applicable in the alarm-priority patterns. Besides, the extensive study of machine learning has been useful in terms of impacting the emerging applications attached to communication technology, which witnessed in smart cities. The same sense applies to the emergence of the Internet of Things.

According to the research conducted by Samek et al. (2017), the utilization of modern learning algorithms is an added milestone in communication as far as privacy matters put into consideration. These machine learning methods have a big impact on the security section of the communication platform. The use of autoencoders provides the state-of-art approach towards enhancing some number of components such as video encoding and bit allocation.

2.7. Modulation schemes in SDR

The analysis of the fixed node and the support was given to SDR by Guerriero et al. (2017). SDR capabilities reviewed before common modulations that have appeared before including the MFSK, MQAM, and MPSK, which can also take different symbols. The analysis of the mobile nodes can recommend any of the schemes. Over a third of the nodes might work in favor of PSK, QAM, and FSK. Such systems like the MFSK usually are called as the M-ary signaling system that has the M-tones noted with the transmitter as one of the tones is selected for transmission (Miranda et al., 2016). However, the performance, as well as the characteristics of the system, is primarily determined through the modulation scheme chosen in the beginning.

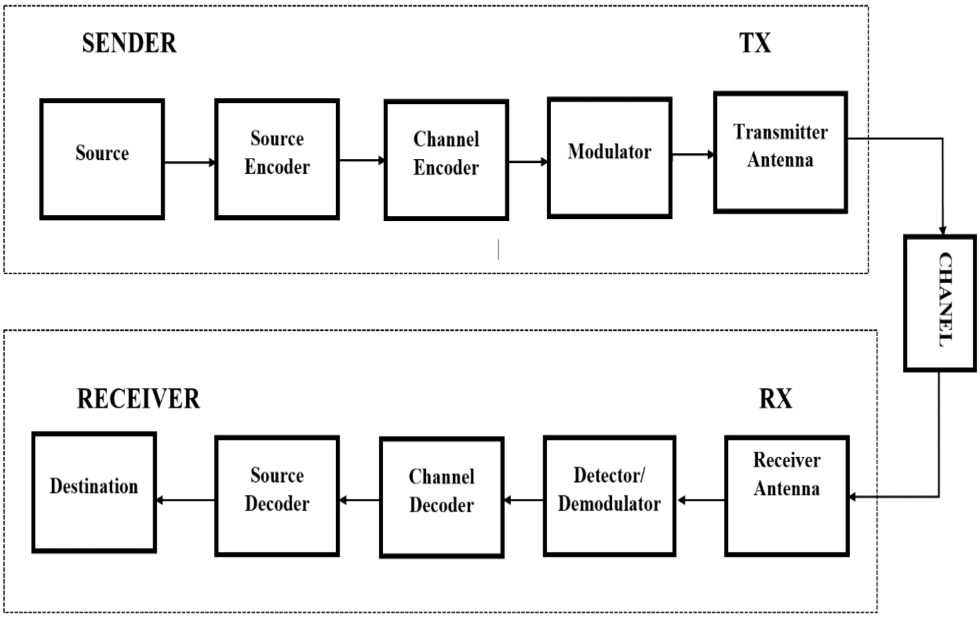

Fig 2.6 The communication system elements (Hannan et al., 2012)

3. MATERIALS AND METHODS

In this part, a clear definition for the system theory is given. In this part, a clear explanation for the system theory is presented throughout describing all used tools and proposed software and hardware aspects.

3.1. Work steps:

Through this work, the SDR was used to manage and monitor the radio signal and update its parameters according to the environment.

3.2. The Description of the Wireless Mobile Platform

The mobile platform for wireless communication systems experimentation described in this work consists of:

- A Register Transfer Level - software-defined radio (RTL-SDR).
- A PC, which is used to program RTL-SDR.
- Software packages and libraries installed in the PC for programming the SDR board.

3.3. SDR

The SDR is a tool used widely in wireless system optimization.

3.4. The system structure

The flowchart of the system that shown in figure (3.1) step by step work simulated, by drawing the process for the overall proposed method, the SDR components fixed at the first step then the ANN and GA take place after the signal where recorded. The step condition determined depending on the degree of signals processing by RTL-SDR.

An AI controls the behavior of each node to obtain results which in turn controls determining the direction of node movement, as well as the role of a (GA for TSP) in distributing nodes in a specific area to improve QoS in terms of coverage and connectivity.

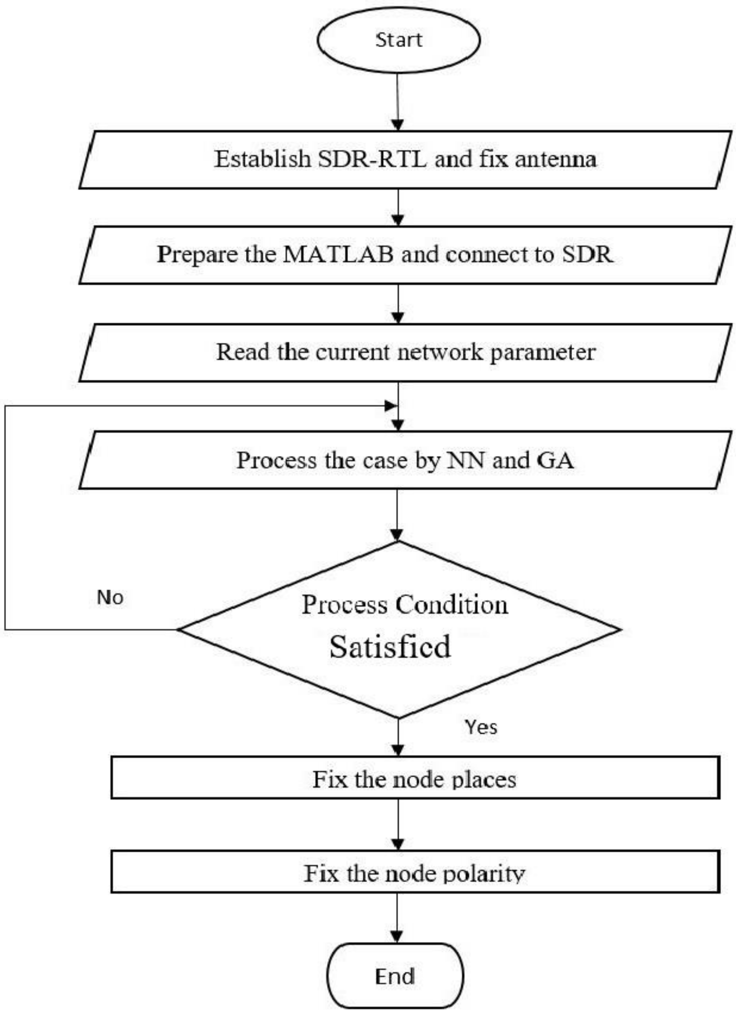

Fig 3.1 SDR and ANN/GA Operation in System

3.4.1. Purchase

The SDR-RTL device used in the research purchased through the Amazon site according to the predefined specifications. The functional and industrial specifications installed according to the type of work assigned to it. The usage limits for the radio signal frequency is between 24 MHz and 5 GHz, and now the available SDR is only from 24 MHz to 1.766 GHz. The frequency range of the present study is selected in this range.

The device delivered to the mentioned specifications to the work site. It started by the practical aspect of the research and included receipt of the available signal and processed, then the signal is sent the second time with new dimensions and different variables from the original signal. This process is to get rid of unwanted signals, which negatively affect the quality signal.

The RTL-SDR radio receiver is Realtek (RTL 2832U) chip, which receives frequencies from 24 MHz to 1.766 GHz, and bandwidth of 3.2MHz and has an 8-bit ADC resolution. It is a USB dongle thumb drive radio receivers used in different implementations, such as FM radio, UHF TV broadcasting, 4G, LTE, and GPS systems as shown in Figure 3.2.

Fig 3.2 RTL-SDR equipment.

3.4.2. Host PC and Enabling Software

RTL-SDR must be connected to a host computer and programmed using a software package such as the present Matlab/Simulink work to set the type of radio that it will emulate. A Visio laptop is used with a 64-bit Core i5 processor and Windows 10 and is shown in Figure 3.3. The necessary RTL-SDR drivers is installed. For RTL-SDR this is done by using the Zadig software, and once the system drivers are installed, the actual programming of the RTL-SDR can be done using Matlab/Simulink (Math Works, Natick, MA). Matlab Communication System Toolbox has support packages for the RTL-SDR that can process wireless signals such as FM radio, over-the-air TV or amateur radio.

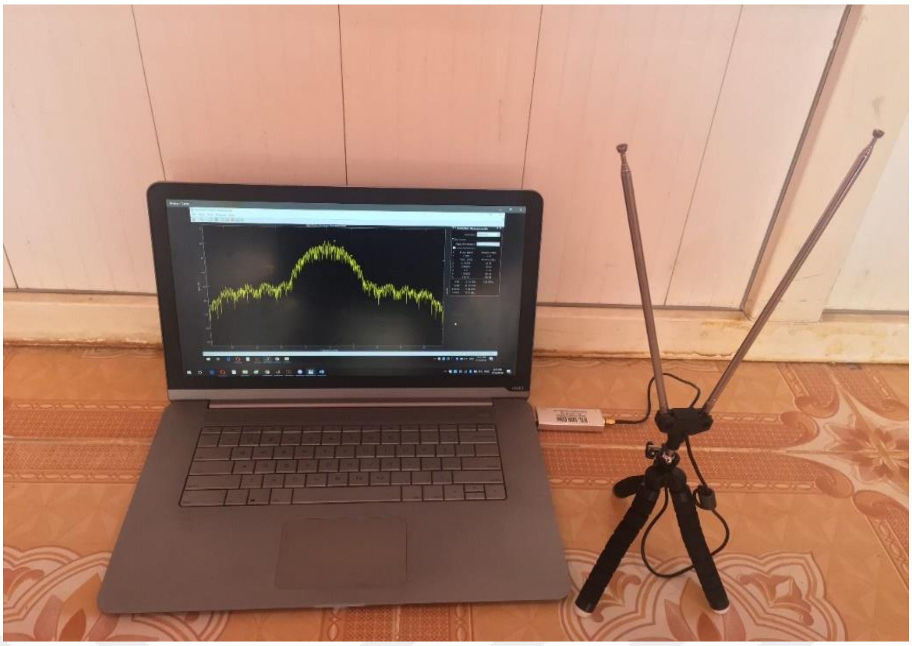

Fig 3.3 Host Vizio laptop, RTL-SDR and communication software

3.4.3. Connecting the RTL-SDR

To receive and process signals we follow these steps:

1. Establish the connection

To implement features in the communications toolbox support package for RTL-SDR radio, communication between the host and the radio hardware must establish.

2.USB Driver Installation

When you install USB, the installer prompts you for the support package by installing the drivers required to use the RTL-SDR as a specific radio receiver SDR. Before starting the installation, remove all unnecessary USB devices from your computer so that you do not accidentally replace the driver with another device.

3. Connecting the RTL-SDR into the USB port

Connect the RTL-SDR into the available USB port on your computer. If the OS automatically installs a device driver as a DVB-T receiver, wait for the operating system to finish installing before proceeding.

4. Install the USB driver with Zadig

If Zadig displays a user control account prompt, the program requires administrative privileges to install the USB driver. Click yes to continue.

5. RTL-SDR Install the driver

RTL-SDR driver installation if you see this page, the installer uses the files that you downloaded during Setup to install the RTL-SDR library. The installation process requires permission to copy the data to the system directories. You may prompt for your password before continuing with the installation. If prompted, enter your password in the MATLAB® Command window, and then return to the installer.6. Insert RTL-SDR

6. Radio into USB Port

a. Insert the RTL-SDR radio into an available USB port on your computer.

b. Click next.

7. Check the hardware setting

This step helps you verify that MATLAB can be connected to the RTL-SDR using the support package. If successful, MATLAB can relate to the radio, and the receiver is ready to use.

3.4.4. RTL-SDR Ready to Receive and Process FM Signals

The installation and setup of the software and hardware completed the FM radio is ready to receive the FM signals on the personal computer and process. The steps of receiving and processing signals explained step by step:

1. Determine Operation Frequency

The receiver portion of the system was focused, to provide further details on the received signal and their processing.

From the receiver point of RTL–SDR when the signal is received it passes through several stages to be processed and obtain a pure signal, this RF signal is sampled and demodulated, then decoded.

2. Central Freq. (102 MHz, 486 MHz)

An antenna is connected to RTL-SDR dongle to receive radio signals. The signal is converted from analog to digital by RTL-SDR and then transferred to the computer. The signal is received in the software and then can be listened. The radio tuner converts the analog radio signal captured through the antenna to an analog frequency (IF) signal as shown in figure 3.4.

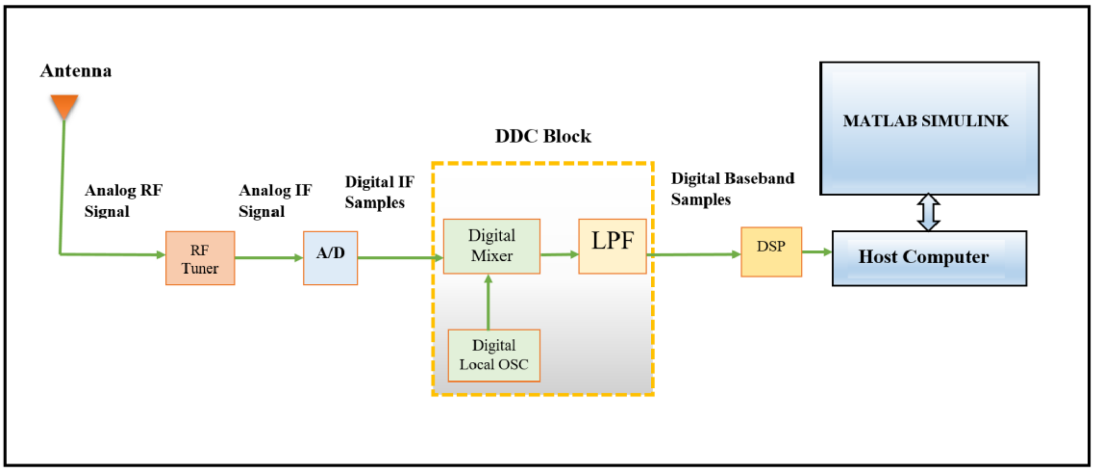

Fig 3.4 SDR-Receiver architecture (Hosking, 2016).

After antenna captured the radio frequency signal which is connected to the RF Front End using a suitable circuit to ensure the transmission of ideal signal power to pass through Low Noise Amplifier (LNA), which resides near the antenna, to amplify weak signals and reduce the noise level.

3. Front End (RF)

It is a circuit whose primary function is to receive signals at different operating frequencies and change it to the (IF).

4. Analog-to-Digital Conversion

When the frequency reaches this part of the circuit that is the part of radio receivers it converts the signals from analog to digital, then external digital samples feed the next phase input, which is the digital signal-frequency down converter (DDC).

5. Digital Front End

This section has two main functions: Sample Rate Conversion (SRC) and channelization.

6. SDR Receive and Process the Signal

Encoding-decoding, modulation-demodulation are performed in this block. This chip contains an ADC and DSP in which the signal is demodulated, together with all other operation needed to accomplish this, like filtering, decimation, amplification, etc. It also contains channel decoding which recovers data information from this bit stream generated. In this stage, a forward error correction mechanism is implemented, with convolutional or block codes, together with an interleave to reduce the probability of burst errors.

3.5. The Mathematical Model

Total Harmonic Distortion (THD) is defined as the ratio of the sum of the harmonic signal power to the fundamental frequency power. THD degradation means a pure signal emission without causing interference to other electronic devices. The problem of distorted radio transmission is very important in the context of spectrum sharing and spectrum sensing.

The relationship between SINAD, SNR, and THD is given below. RTL-SDR reduces harmonic distortion to obtain the pure signal (Kester, 2009).

$$SNR = 20log(\frac{S}{N}) \quad (3.1)$$

$$THD = 20log(\frac{S}{D}) \quad (3.2)$$

$$SINAD = 20log(\frac{S}{N+D}) \quad (3.3)$$

The simple model for the effective parameters on the signal:

ADC dynamic performance are quantified using SINAD (signal-to-noise-and-distortion ratio), SNR, THD, THD + N (total harmonic distortion plus noise), and SFDR (spurious-free dynamic range). There are some exceptions for these specifications. It is important to understand the relationships between these specifications.

THD is measured and processed in this work by the SDR, nearly six harmonic signals detected with different amplitude. The RTL-SDR tacked place of the complex hardware devices, which are used by the companies to eliminate the harmonic, effects on the overall signal (Collins et al., 2018).

3. 6. ANN steps

An integrated system was built and managed by ANN and SDR technology and the system is improved by the GA for TSP. ANN was used to find the strength of each individual in the group, which in turn led to a sub-optimal solution to the problem. Information that flows through the network affects the weight coefficients of ANN in a sense based on information of input and output layers, as shown in figure 3.5

The type of ANN used in this thesis is the backpropagation ANN. It is the most widely used ANN architecture. Many applications can be modeled using a back propagation network. Backpropagation ANN has been successfully tested in this research and obtained a very high performance although the network does not contain links to the feedback, the errors are backward spread during the training process. The errors in the output layer determine error measurements in the hidden layer, which are used as a bias to modify the weights of the connection between the input layer and the hidden layer. Each repeat processing involves the adjustment of at least two sets of weights between a pair of layers and the rotation of the outputs. This treatment continues until the errors fall below the permitted threshold level. The ANN model used in this study shown in figure 3.5. It consists of two hidden layers in addition to input and output layers.

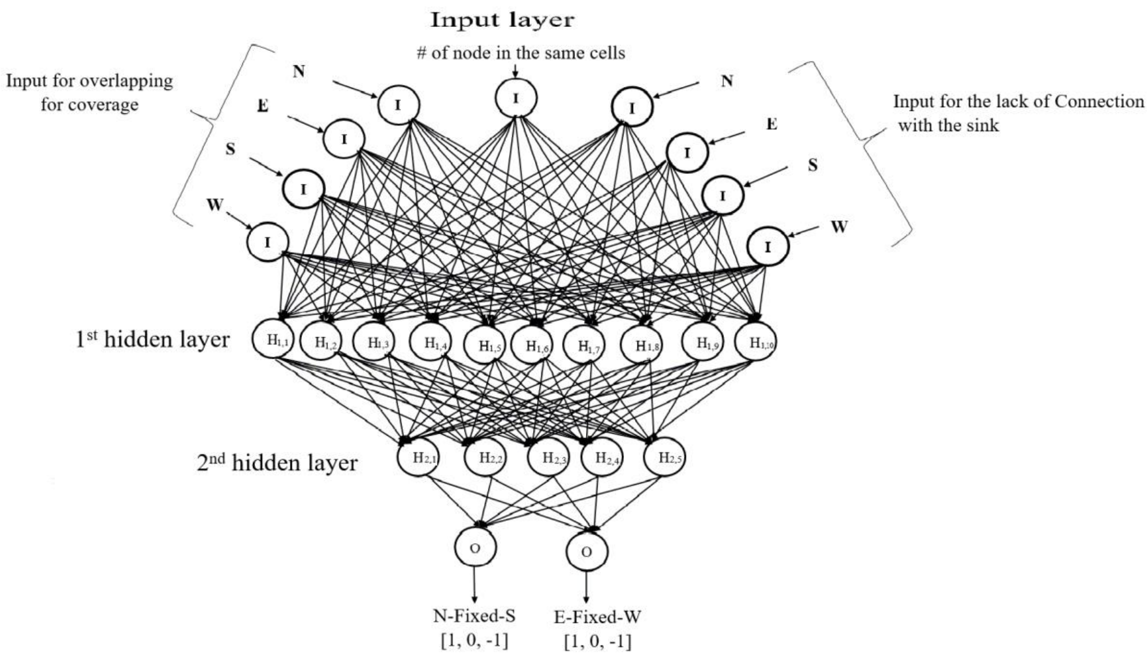

Fig 3.5 Backpropagation ANN architecture of one node.

For each node the output of the ANN is given from 9 inputs, 2 hidden layers, and 2 output neurons and it consists of 3 integer numbers that vary in the range $[1, 0, -1]$ as it is clear from figures (3.5) and (3.8) based on these 3 values, the node chooses the action to do. The node can move in one of the four directions or remain stable.

The ANN inputs are divided into three sections:

- The first set is one input that shows the number of nodes which are in the same cell.
- The second input set is four inputs to detect the missing of sink connection and to avoid obstacles where one operates in a specific direction.
- The third set subdivision is four inputs that detect overlapping of sensing zone with a neighborhood sensing zone, where one operates in a specific direction.

All inputs listed in each node of the distance measurement were calculated with the other nodes as well as the distance between the node and obstacles:

- The first set of input is useful to determine the number of nodes in the same cell.
- The second set of inputs is a target to make the node spread, and, which maximizes coverage by avoiding overlapping.
- The third one allow nodes to learn avoiding obstacles.

The signals received by RTL-SDR is sufficient to record the received and transmitted signals to monitor problems in sending and receiving between the nodes to find solutions to these problems.

After collecting the data in a table, it was processed by ANN and obtained results which determine the direction of the movement of the node. One of the advantages of the traveling salesman problem (TSP) algorithm works to select the best way to visit specific cities. The purpose of using TSP in this research is to make the nodes moving to the specified places, to increase the strength of the signal between the adjacent nodes and to increase the QoS, in terms of coverage and connectivity. The signals received by RTL-SDR and the relative distances in the GA for TSP to feed ANN and make the algorithm work see equation 3.4 and figure 3.6.

$$a = tansig(n) = \frac{2}{(1+e^{(-2\times n)})-1} \qquad (3.4)$$

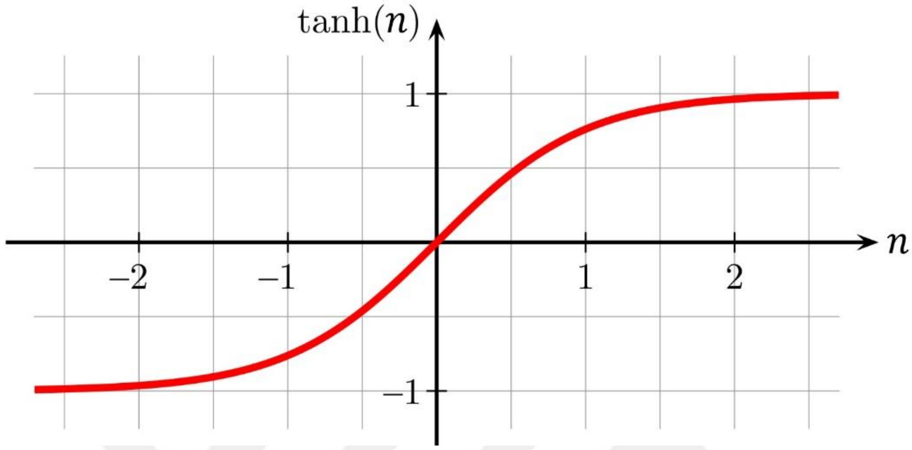

Fig 3.6 Tangent-Sigmoid Transfer Function

In order to map the n-dimensional input signal into the m-dimensional output which determines the direction of the movement of the nodes, each neuron uses an activation function and a connection with every other neuron of the network.

$$\text{Out}j(n) = F(\sum i \in N\, Wij \cdot out\ i(n-1) + bj). \qquad (3.5)$$

At the time step (n) is the same for all the connections originating in (j). N is the set of all neurons of ANN and (w_{ij}) is the weight of the incoming connection from neuron (i) to neuron (j) and bj is the bias of neuron (j). The activation function (F) is expressed in equation 3.6.

$$F(x) = \begin{cases} -1 & if\ \ x \leq -1 \\ 0 & if\ -1 < x < 1 \\ 1 & if\ x\ \geq 1 \end{cases} \qquad (3.6)$$

The neural network was trained to decide the new coordination of the cell depending on the SDR situation and load on network service. The set of possible actions is to move in one of the four directions or stay in the current cell.

The whole process is performed in a one-time step, for each node of the Wireless Sensor and Robot Networks (WSRN) and shown in Figure 3.6. The training of the ANN consists of the performing the described process until a termination condition is satisfied, as in figure 3.7 (Costanzo et al., 2012).

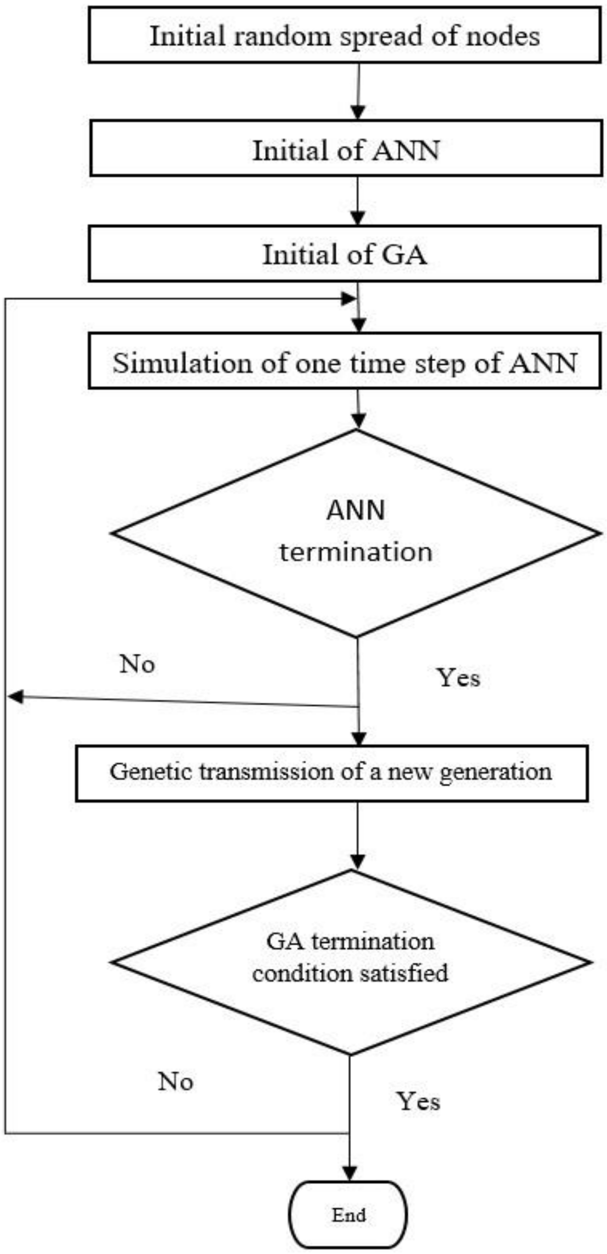

Fig 3.7 Training phase of ANN (Costanzo et al., 2012).

In a specific area, the node distribution has been identified so that it can cover this area with the minimum number of mobile wireless nodes based on GA for the TSP, where some routes and cities selected at random, which determines the path of the node to reach the right place. The direction of the movement of the nodes depends on the outputs of the neural obtained from the mobile wireless signal nodes. Each distance between the two cities is a step of the movement of the node and be in the four directions (North - South - East - West). Four secondary directions (north-east, north-west, south-east, and south-west) were included as shown in Figure 3.8. However, the set of possible movements can be extended to include missing directions in a future work.

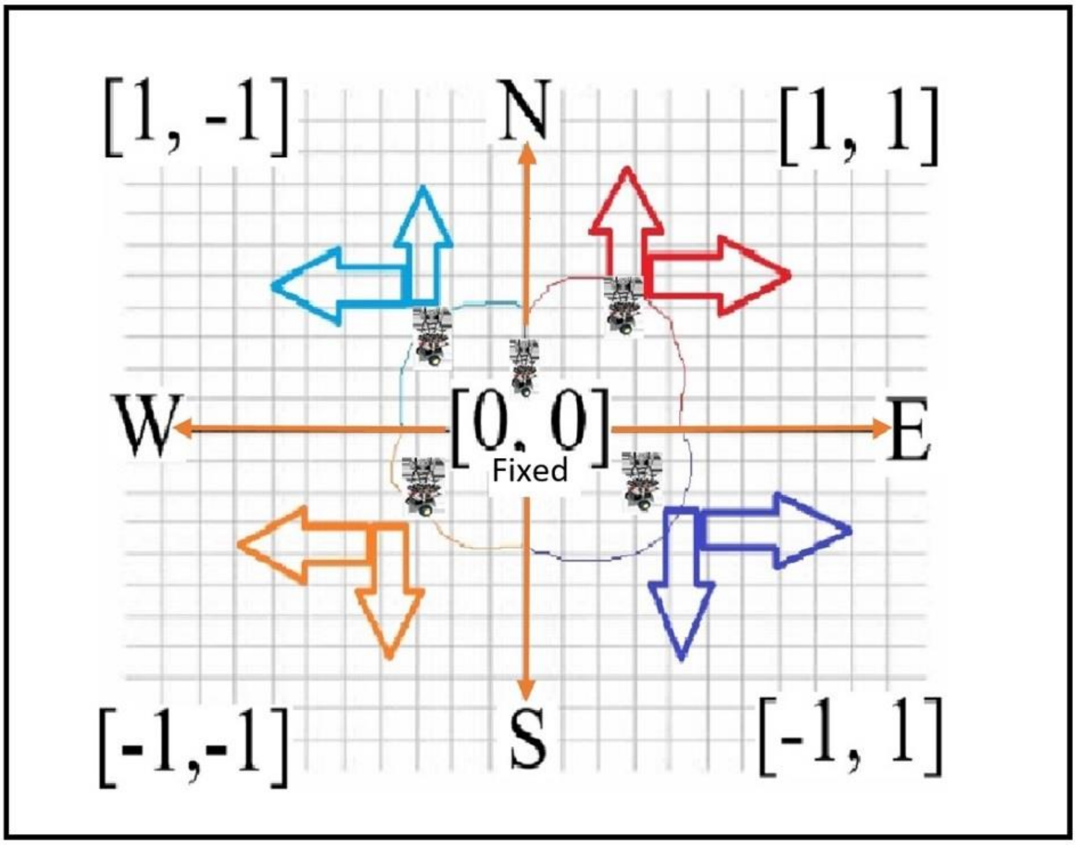

Fig 3.8 The possible directions of the mobile node

3.7. The GA for TSP

Traditional GA for TSP in these theses used for training the ANN. The genes linked to the weight of the connections between each pair of neurons and the bias of each neuron. Different neuronal weights selected in future generations through genetic methods (selection, crossover, and mutation). The chromosome chosen for the next generations is the one that fits best (Loscri et al., 2014).

GA is encoded in the ANN through the genes and are the values of the connection weights. The chromosome consists of an advanced set of genes, and the population consists of a specific number of chromosomes. The purpose of GA in this work is to improve the function of fitness by transferring the genes of part of the current population from the current generation to the next, to get a better generation, gene transmission to new generations continues until the condition of termination of the genetic algorithm occurs.

In this work, GA is terminated after a fixed number of generations. The transmission of genes to the new generation depends on selection, crossover, and transformation of members of the older generation that has earned the highest value for fitness functions (Keresztury, 2017). Thus, the function of fitness has a significant role in the process of evolution, where it used as observations for successive generations. The goal of this work is to improve the coverage of the field based on the improvement of fitness in this algorithm. In this work the link of the fitness function to the coverage of every individual; thus fitness function can simply be represented as a matrix of distances and nodes.

The coverage reaches the maximum depending on the speed of the chromosome. Fitness evaluation has a fast calculation of paths length. It is calculated as a distance matrix. The matrix of distances (i_1,i_2) are the distance between node i_1 and node i_2. To describe shorter tours with higher fitness, the fitness function is selected as f(x) = 1/d (Ahmed, 2010).

4. RESULTS AND DISCUSSION

4.1 The SDR installation and signal processing

The SDR was installed as mentioned in chapter 3, and began to read the available signals. The main function of SDR is to discover the RF signals with the specific frequency, which has determined in advance.

During the spectrum analysis, which was achieved by the SDR, distortion will be detected and removed by the software process on the generated signal. Firstly; the spectrum analyzer for the demodulated signal is recorded and monitored for different central frequencies starting from (100 MHz) and higher range, see figure 4.1.

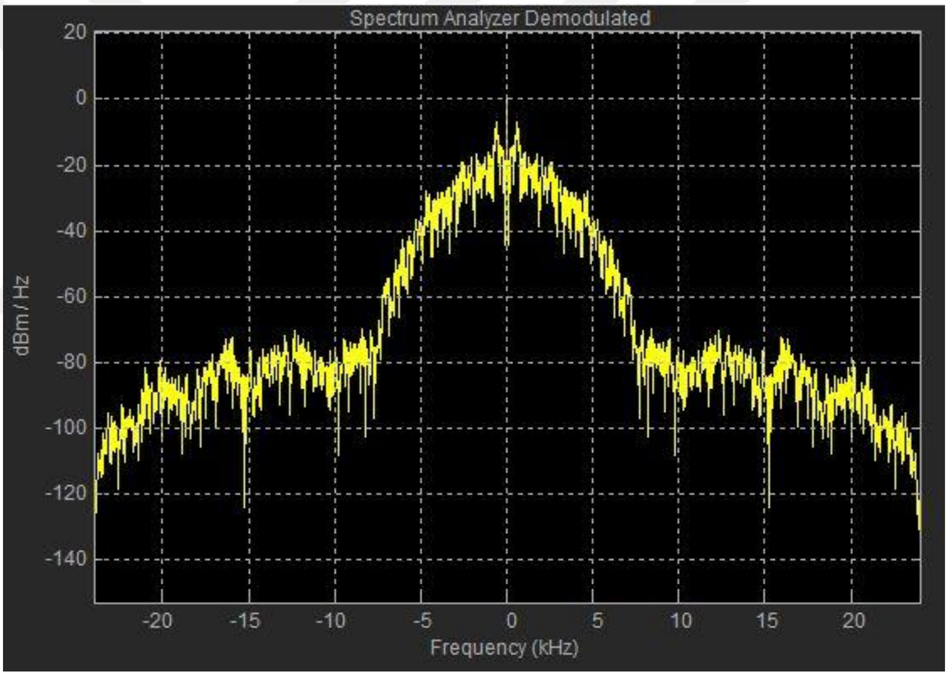

Fig 4.1 The power spectrum of the demodulated signal.

The main attenuation signals that have fixed are the harmonic signals, which affect the signal quality. Figure 4.2 shows the spectrum for the demodulated signal with six harmonic signals.

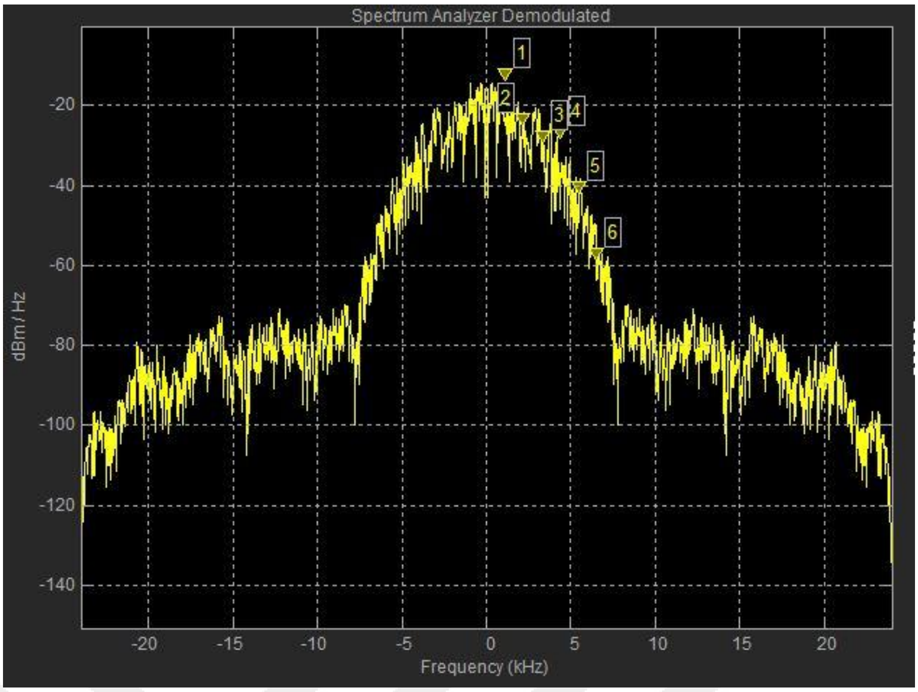

Fig 4.2 The power spectrum of the demodulated signal with 6 harmonics shown.

The effect of the attenuation on the main signal is recorded in additional form by the signal discriminator that compounded all the signals shown in figure 4.3.

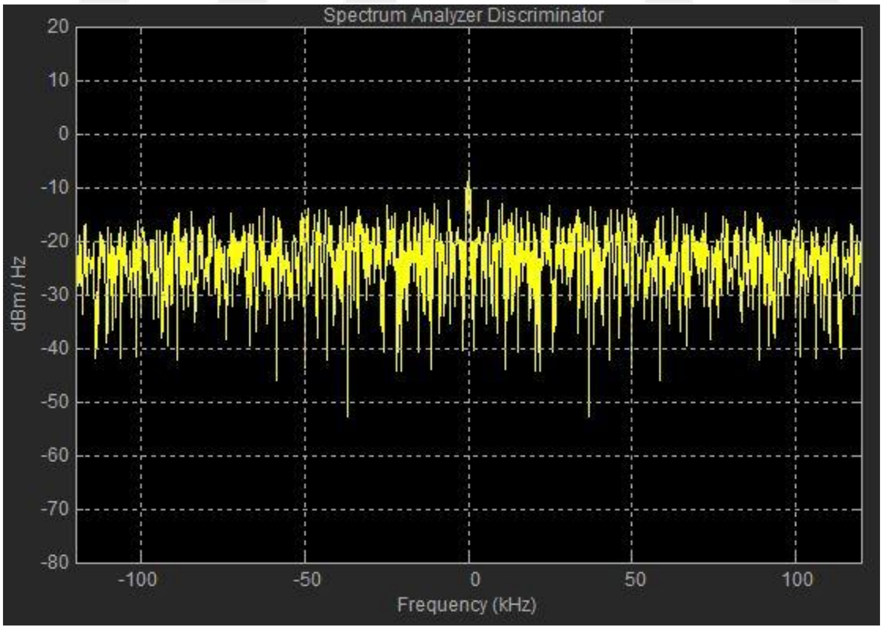

Fig 4.3 The spectrum of the discriminator.

Secondly; the signal will process by SDR and filtered from all unnecessary components, to be ready for the new sender device as shown in figure 4.4. There is only one harmonic signal that refers to the main carrier one and there are not any unwanted components on the newly generated signal.

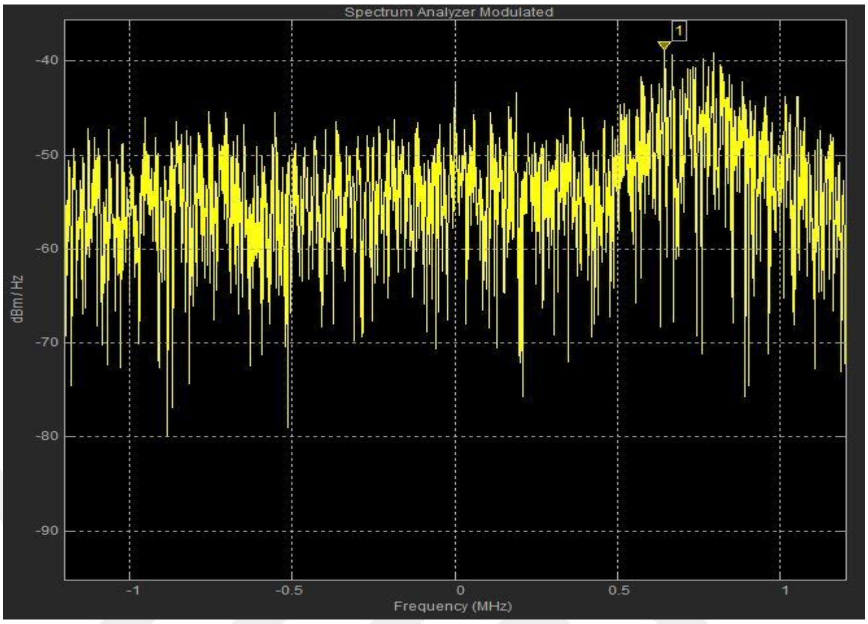

Fig 4.4 Spectrum for the modulated signal.

The data recorded for the harmonic signals that was discovered by (RTL-SDR) receiver to receive signals with a different central frequency and fixed, to demodulate it as shown in figure 4.4, and that the result record in table 4.1 shows the harmonic signal parameters when the fundamental frequency is (102 MHz).

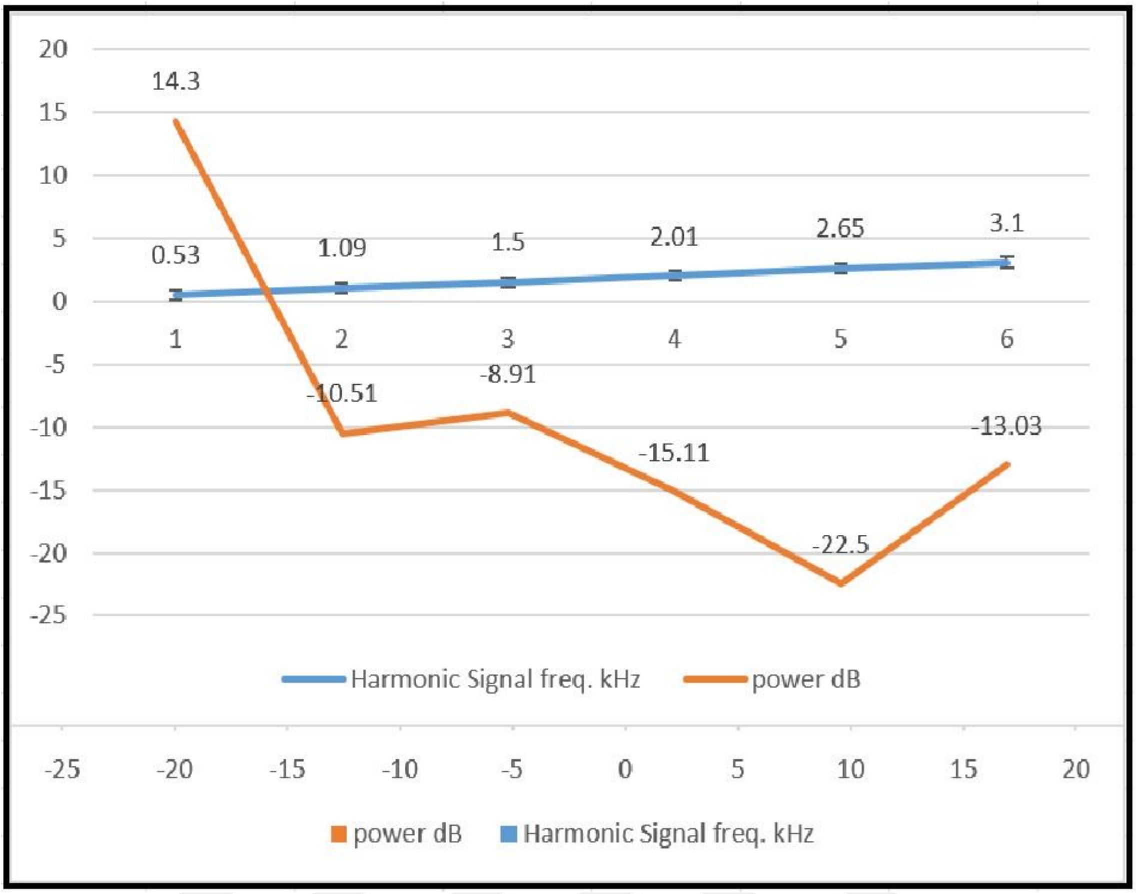

Fig 4.5 The power dB and the harmonic signal for frequency (102 MHz).

Table 4.1 RTL-SDR command with (102 MHz) central frequency in the morning.

No.	Harmonic Signal freq. kHz	power dB
1	0.53	14.3
2	1.09	-10.51
3	1.5	-8.91
4	2.01	-15.11
5	2.65	-22.5
6	3.1	-13.03

Another record for the parameters of the harmonic signal in the different day time, at night. There is a difference in frequency and power values.

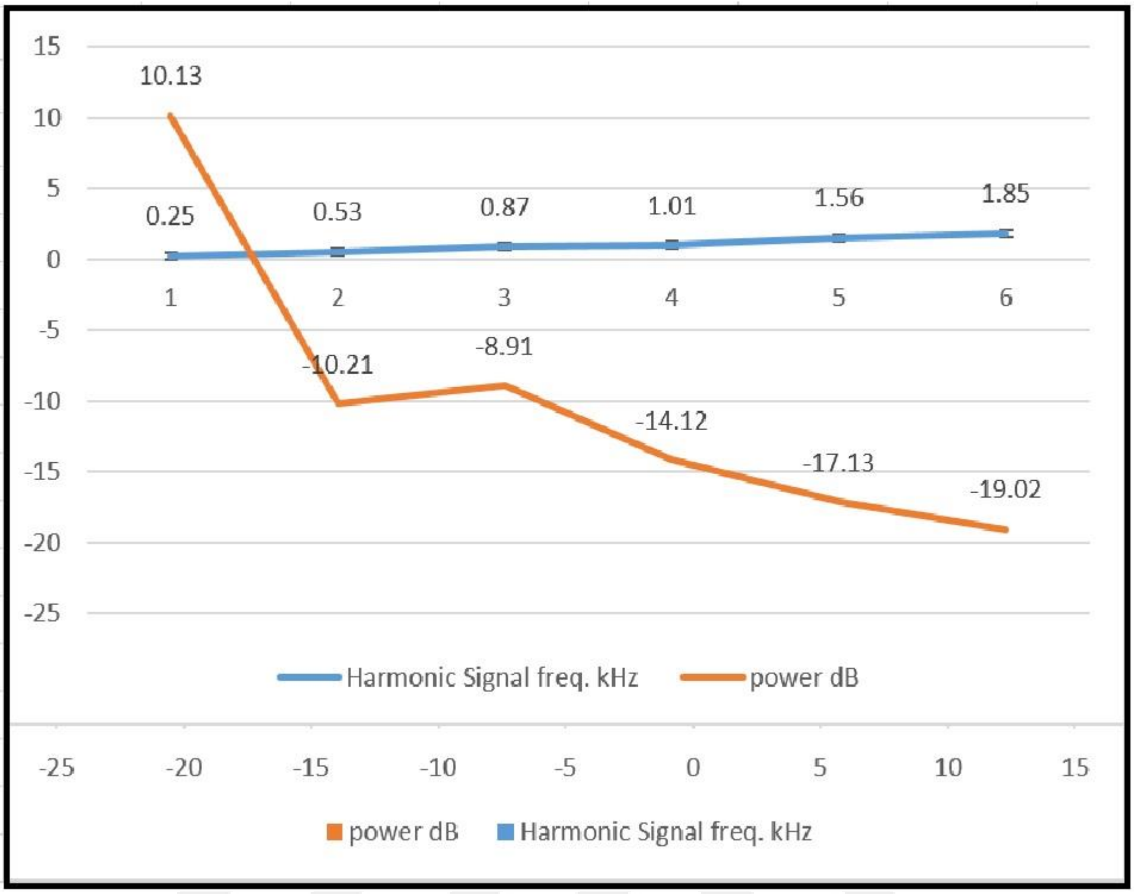

Fig 4.6 The power dB and the harmonic signal for frequency (102 MHz) at night.

Table 4.2 RTL-SDR command with (102 MHz) central frequency at night.

No.	Harmonic Signal freq. kHz	power dB
1	0.25	10.13
2	0.53	-10.21
3	0.87	-8.91
4	1.01	-14.12
5	1.56	-17.13
6	1.85	-19.02

The Simulink data for the same manner recorded for two central frequency (486 and 600 MHz), see tables 3.3 and 3.4.

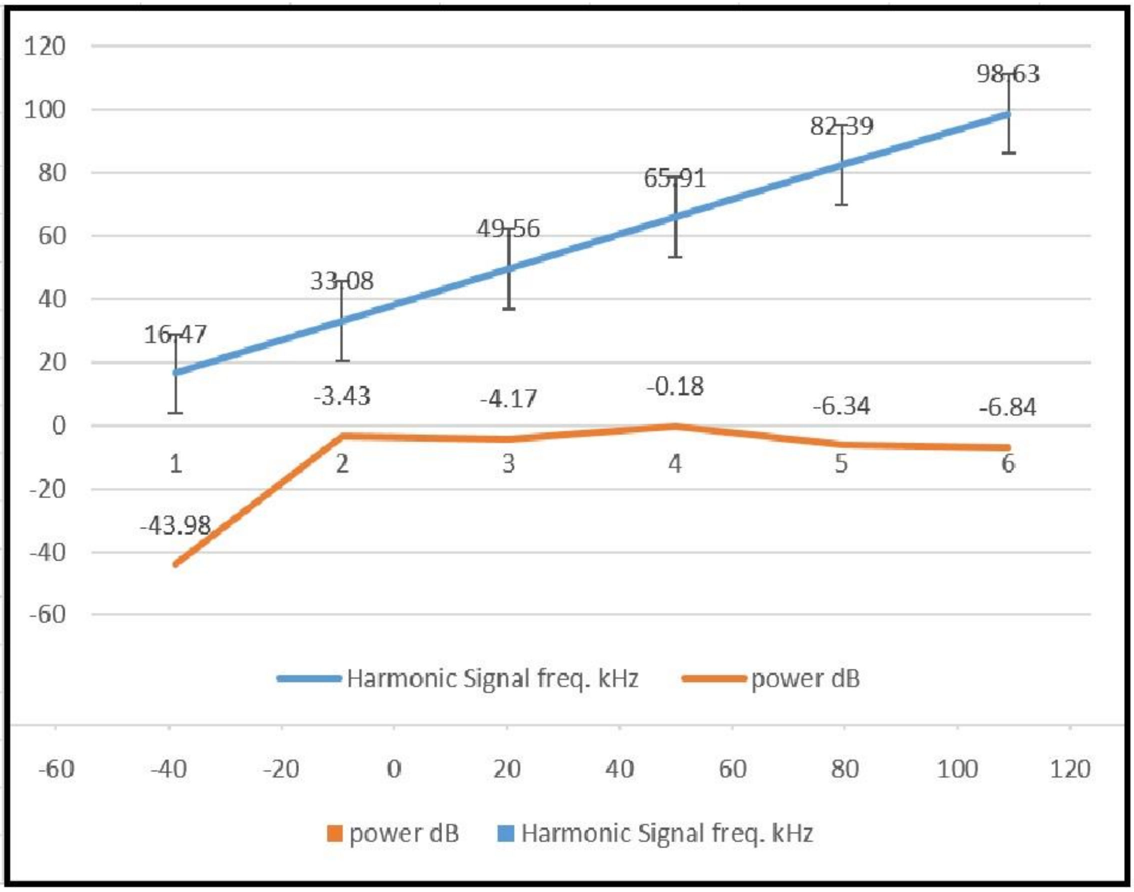

Fig 4.7 The power dB and the harmonic signal for frequency (486 MHz).

Table 4.3 The harmonic signals parameters for (486 MHz) central freq.

No.	Harmonic Signal freq. kHz	power dB
1	16.47	-43.98
2	33.08	-3.43
3	49.56	-4.17
4	65.91	-0.18
5	82.39	-6.34
6	98.63	-6.84

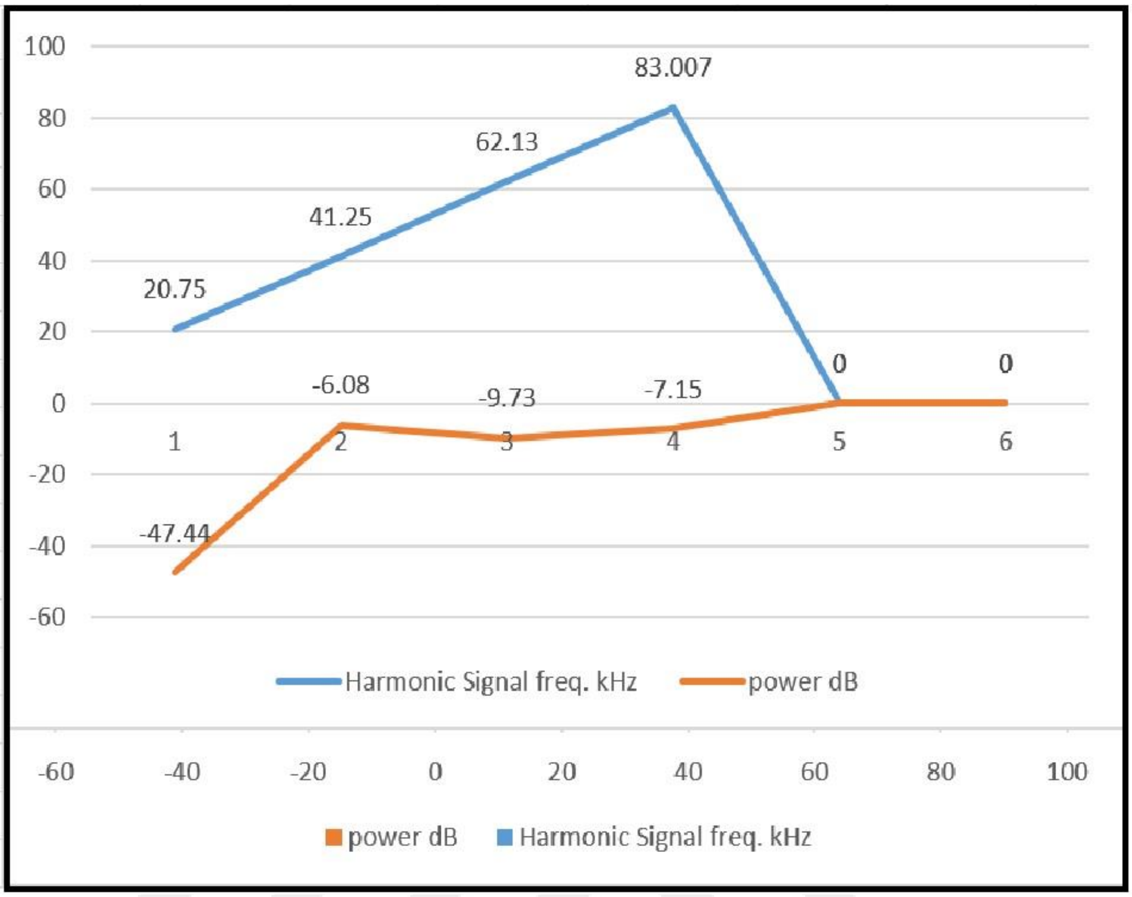

Fig 4.8 The harmonic removed for frequency 486 MHz

Table 4.4 The harmonic signal parameters for 486 MHz central freq.

No.	Harmonic Signal freq. kHz	power dB
1	20.75	-47.44
2	41.25	-6.08
3	62.13	-9.73
4	83.007	-7.15
5	0	0
6	0	0

During the last two tables, it is clear to see that the central frequency affects two of the harmonic signal. Therefore, the SDR process the signal parameters and select the optimum one depending on the surrounded case. It is one of the SDR benefits that clear most unwanted components from the signal.

The last dashes in the table are some removed harmonics from the original signal and do not appear to be ready to send a signal.

In the end, as shown in table 4.3, where the removal of Harmonic in the signal received after the process of demodulation, where traditional devices do the processing, where the device RTL-SDR in this search for processing and get the target signal and using the software instead of hardware. It is one of the objectives of the search.

The general parameters that affect the carrier signal such as the THD, SNR, signal to noise and distortion ratio (SINAD), and spurious-free dynamic range (SFDR). SNR is ratio of signal to the level of background noise and it is often expressed in decibels (dB). THD is a measurement of the harmonic distortion. SINAD is a measure of the quality of a signal from a communications device, defined as:

$$SINAD = \frac{P_{signal} + P_{noise} + P_{distortion}}{P_{noise} + P_{distortion}} \qquad (4.1)$$

where P is the average power of the signal, noise and distortion components. SFDR is the strength ratio of the fundamental signal to the strength of spurious signal in the output.

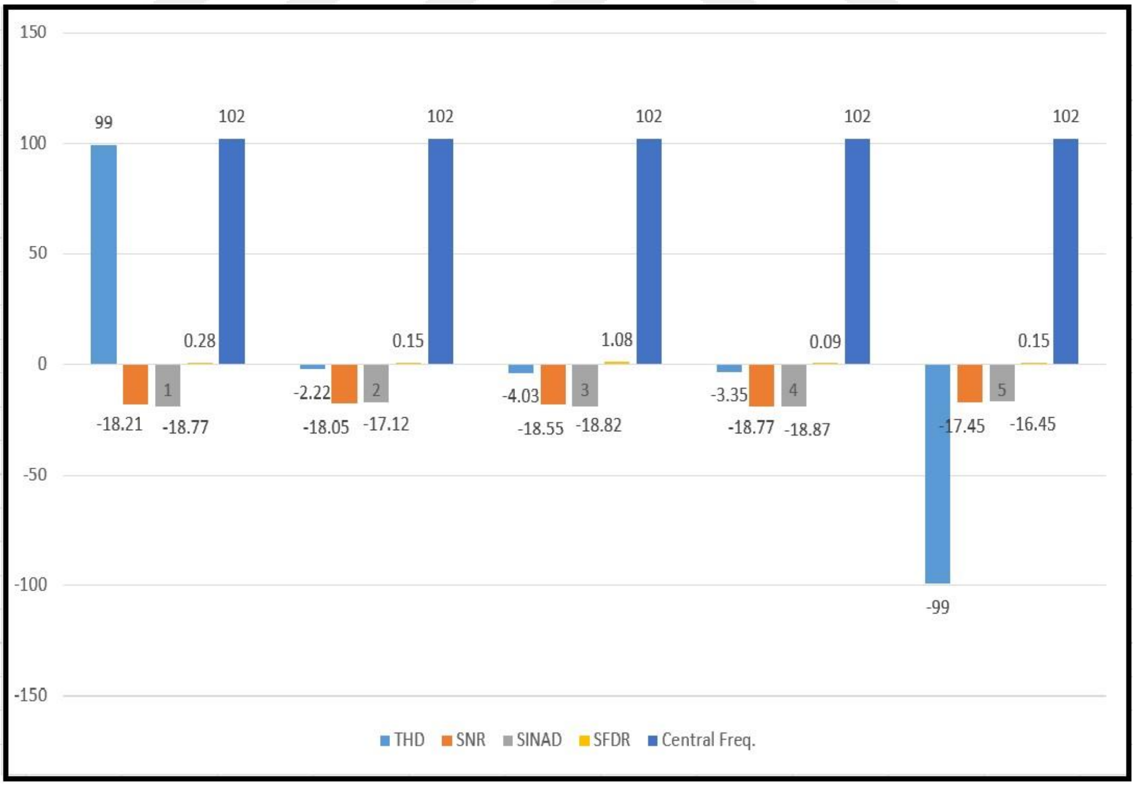

Fig 4.9 The general affected parameters on the received signal

Table 4.5 The general affected parameters on the received signal.

No.	THD	SNR	SINAD	SFDR	Central Freq.
1	inf dB	-18.21 dB	-18.77 dB	0.28 dB	102 Mhz
2	-2.22 dB	-18.05 dB	-17.12 dB	0.15 dB	102 Mhz
3	-4.03 dB	-18.55 dB	-18.82 dB	1.08 dB	102 Mhz
4	-3.35 dB	-18.77 dB	-18.87 dB	0.09 dB	102 Mhz
5	-inf dB	-17.45 dB	-16.45 dB	0.15 dB	102 Mhz

Another record of the general affected parameters for the prepared to send a signal that optimized or regenerated signal shown in table 3.6.

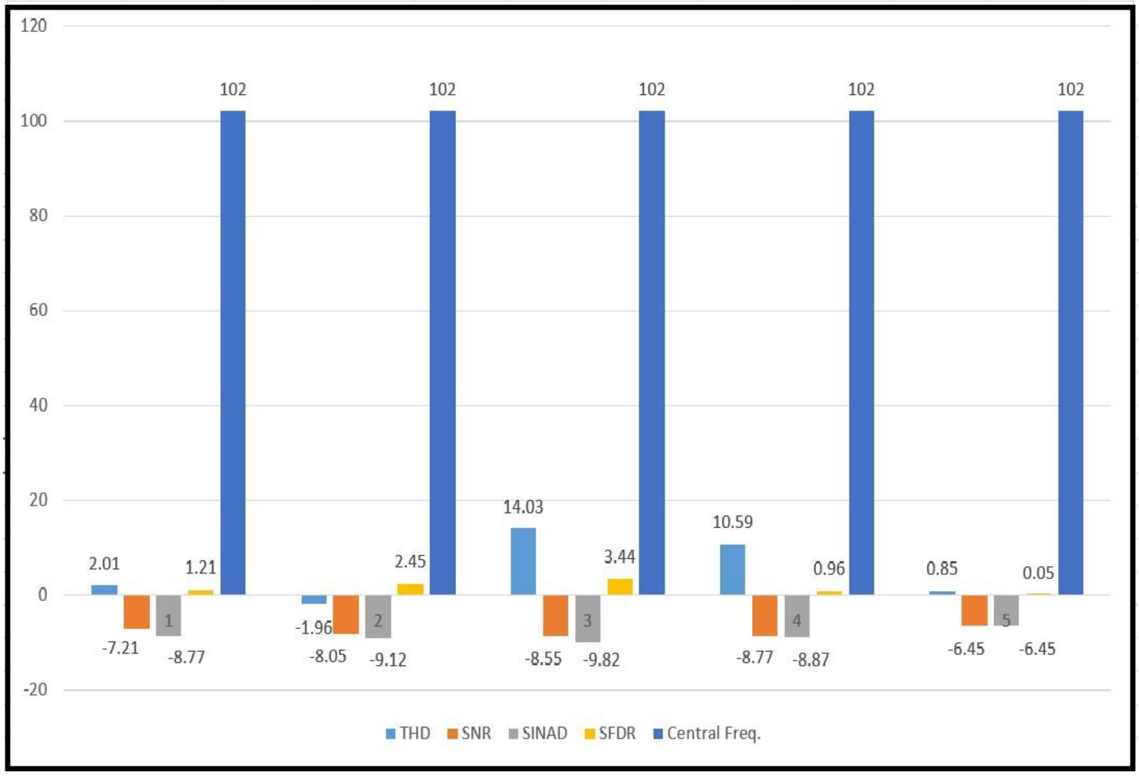

Fig 4.10 The general affected parameters on the signal demodulated by RTL-SDR

Table 4.6 The general affected parameters on the signal (ready to send).

No.	THD	SNR	SINAD	SFDR	Central Freq.
1	2.01 dB	-7.21 dB	-8.77 dB	1.21 dB	102 Mhz
2	-1.96 dB	-8.05 dB	-9.12 dB	2.45 dB	102 Mhz
3	14.03 dB	-8.55 dB	-9.82 dB	3.44 dB	102 Mhz
4	10.59 dB	-8.77 dB	-8.87 dB	0.96 dB	102 Mhz
5	0.85 dB	-6.45 dB	-6.45 dB	0.05 dB	102 Mhz

Finally, as shown in the tables (4.5 and 4.6) and figure (4.9 and 4.10) where the harmonic removed in the signal received after the demodulation process, where the focus was on signal processing using SDR, there is a significant difference in signal measurements recorded during the last two tables.

The signal received contains more distortion and unwanted components compared with the signal that is demodulated by the RTL-SDR, and it is possible to compare the two results tables from THD, SNR, SINAD, SFDR where a typical signal obtained for the purity. It is due to the SDR technique.

4.2. ANN results

In this section, all ANN and GA for TSP result data will be shown with all related tables that contain the response and proposed method efficiency. ANN was used in this work to find the fitness value related to each chromosome in the GA for TSP population. Therefore, the first step in action is the ANN response to the best solution. The GA for TSP algorithm is the primary way that used to re-divide the nodes over the given cities.

4.2.1 ANN training results

In order to train and test the presented network, 303 recorded signals were used. These data were divided into two parts, the 70% for training and 30% for testing. The aim of the training is to change the weights of the network, to obtain the required outputs for the given entries. The network is trained on target vector input with a vector of training pairs. Before starting the training process, all weights start with small random numbers. Training data is processed in the network during the training phase, and prepares input modules for the GA for TSP to select the shortest distance for the city to visit. The final direction prediction accuracy is 98.9% which is a high-performance (figure 4.11).

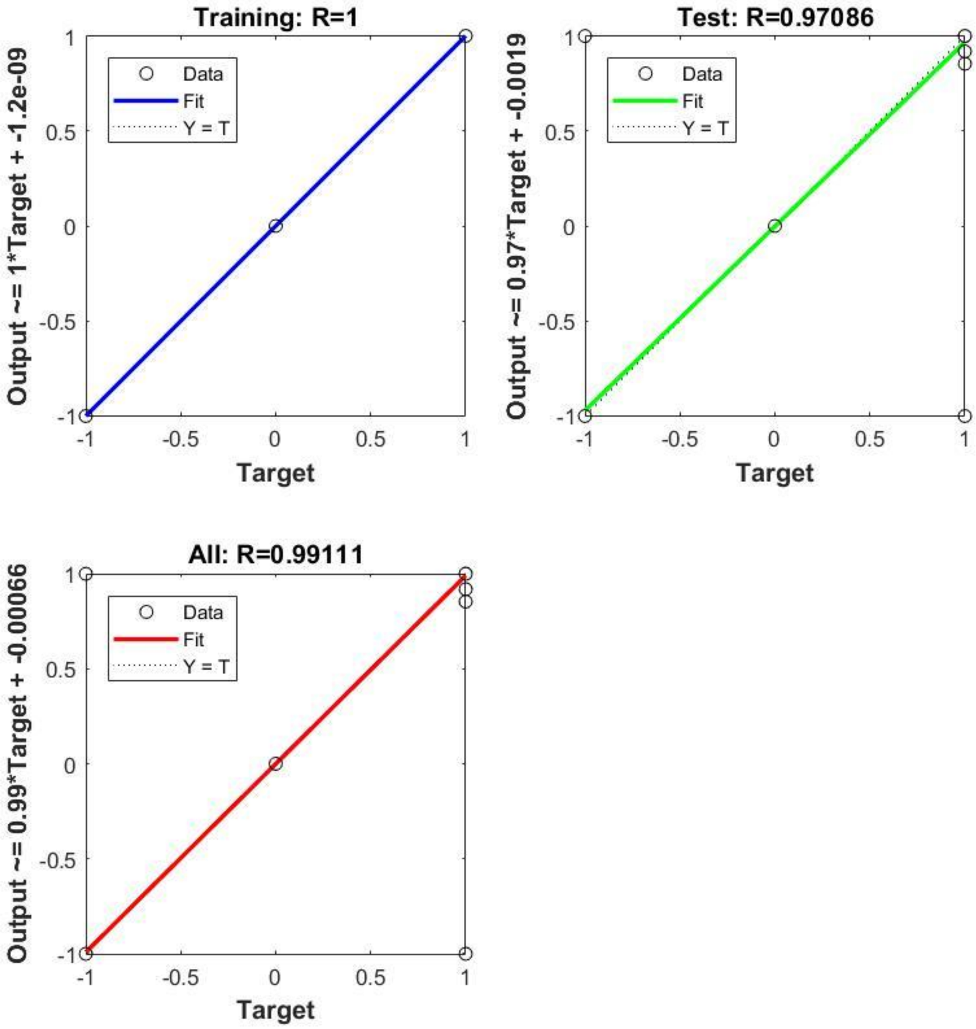

Fig 4.11 ANN training results

Table 4.7 shows some cases recorded for the affected general parameters with RTL-SDR signals analyzed by ANN. Based on this, the results in the table below, which determine the direction of the movement of the node, were obtained.

Table 4.7 The output of ANN for selecting the direction of nodes

N-S-F	E-W-F	N-E	N-W	S-E	S-W
0	0	No	No	No	No
1	1	Yes	No	No	No
1	-1	No	Yes	No	No
-1	1	No	No	Yes	No
-1	-1	No	No	No	Yes

As shown in Table 4.7, the results obtained by RTL-SDR analyzed by ANN. When the result (0, 0) means that the node remains fixed depending on the signal received. If the result is (1, 1), this means that the movement is going to north-east if the result (1, -1) indicates that the action is the north-west direction if the result (-1, 1) indicates that the movement is towards the south-east. If the result is (-1, -1), this indicates that the action is south-west.

After determining the direction of the movement by ANN, the role of the GA for the TSP begins to select the shortest way to go to the specified position, and this is the object of the movement in this research.

4.2.2 GA for TSP Results

The routes proposed by the GA to the 3 salesman were fixed in the figure 4.12, which show the links and location to pass through and return to the start point. Figure 4.13 show the number of iteration and more details for route finding.

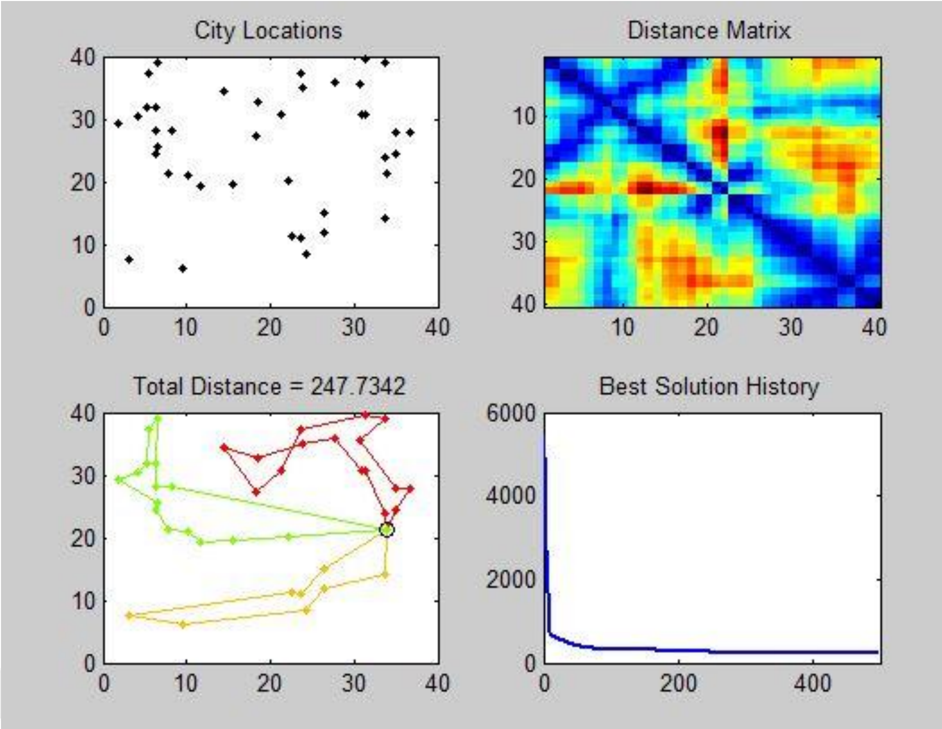

Fig 4.12 The route finding and sales point determination using ANN and GA for STP.

Four parts in the above figure, the 40 cities are the locations that TSP must visit, distance matrix contains the specific kilometers between any two nodes locations and expressed by colors each of them represents a particular value of distance. The blue color is the nearest one, and the yellow is the furthest location.

Total distance is the total distance which the salesman throughout from start point till the end for all roads. Finally, the best solution shows the total distance in km required to take to visit all mobile nodes position given by the paths, which was selected paths randomly in this area and starting from (0 to 6000) paths, as these paths are selected by the TSP to visit the nearest city.

As shown in Figure 4.12, three nodes were selected and each of them moving in a specific direction depending on the output of the AI, as each node visits a respective position specified in the same direction, as it leads to coverage of the area identified using three nodes.

Another tries to find the optimum routes for the salesman and sales location fixed in the figure 4.13, which show a different map and new distribution for the locations, where the specific area covered and with fewer distances.

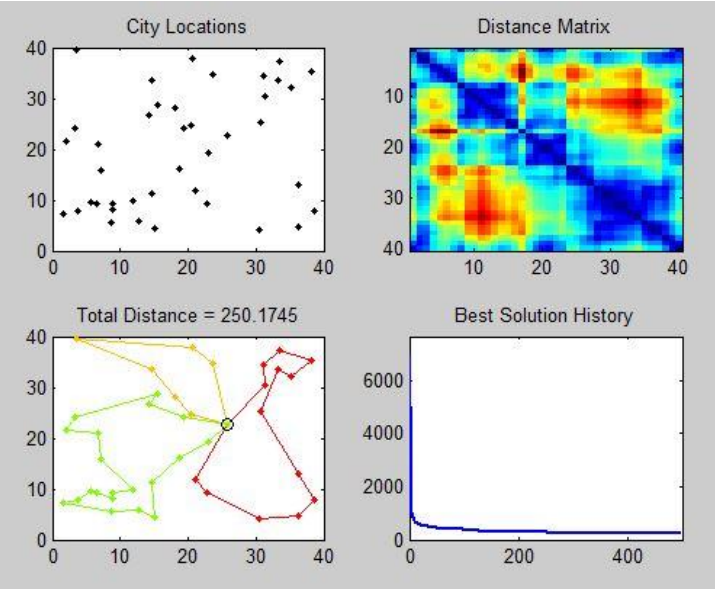

Fig 4.13 Another solution for the mobile node route determination.

The figures above show how the three salesmen cover the whole the given region and smooth transition between them to produce optimum service. The figures 4.14 and 4.15 give more details about the routes and locations determination. In these two figures, the effect of selecting four nodes on the coverage shown. The movement of each node in a specific direction increases coverage in the specified area, but increase the number of nodes leading to increasing the cost and the length of the path.

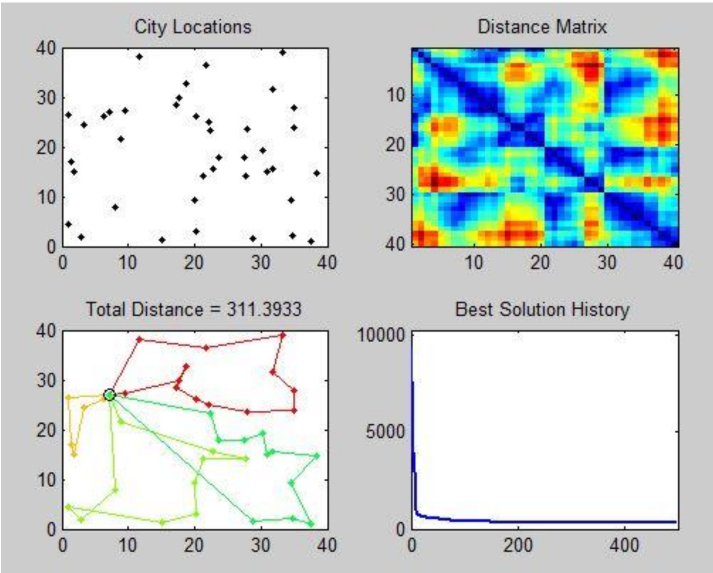

Fig 4.14 Mobile node plan for the routes when the number of TSP is four.

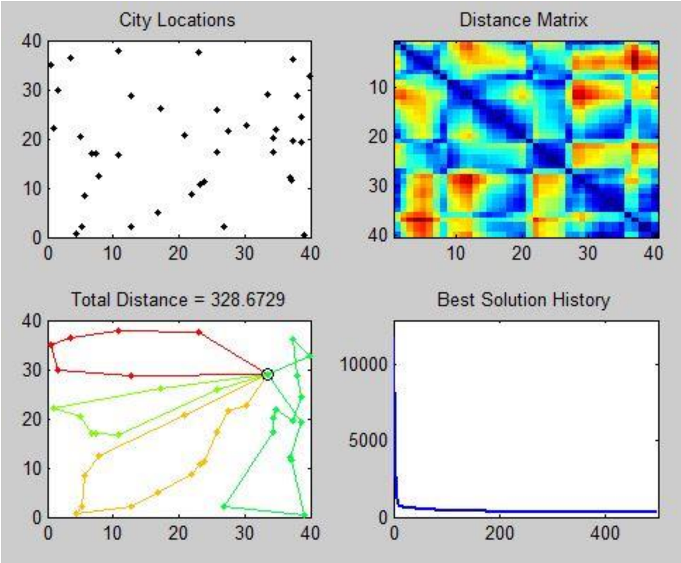

Fig 4.15 Mobile node plan for the 4 mobile nodes route.

The distribution of the nodes in Figure 4.14 differs from Figure 4.15 of the position, the direction of movement and length of distance, where this distribution based on the decision of ANN and the genetic optimization for TSP.

4.2.3 The ANN and GA for one TSP to select nodes locations

Based on TSP, the nodes management and re-division of the locations fixed. The plan of the node determined by using the ANN to find the fitness for the GA for TSP population then the new locations are extracted depending on the surrounding conditions, such as the signal strength between adjacent nodes which determines the direction of the movement of the node. Figure 4.16 show the first proposed plan for the nodes in the given region. The links and the number of iteration to reach the optimum solution fixed.

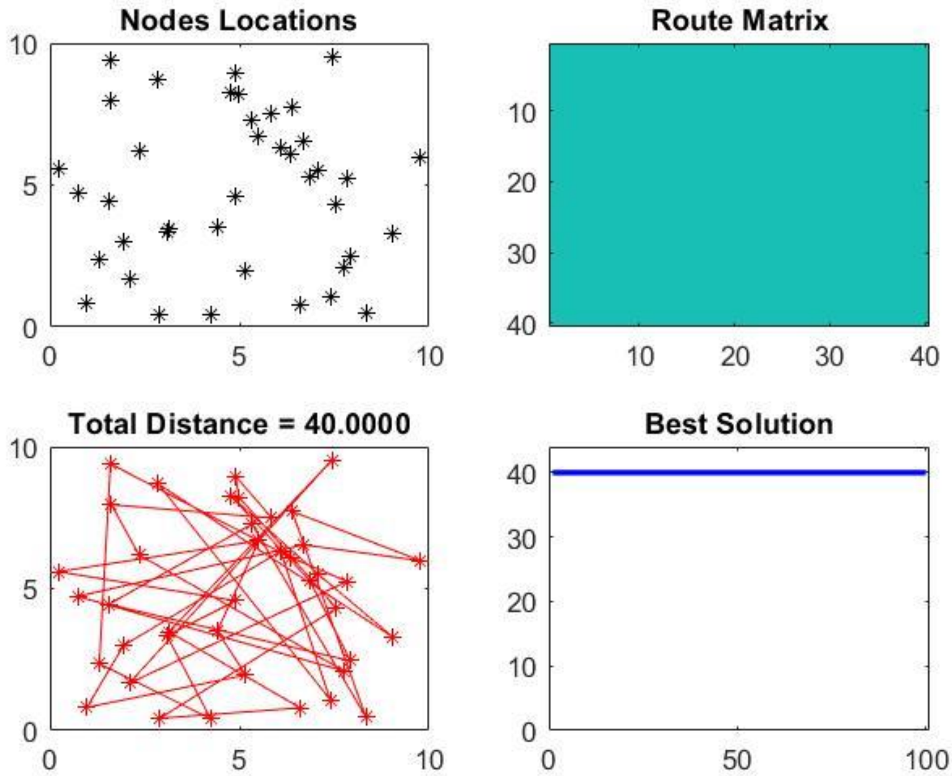

Fig 4.16 The nodes plane using ANN and GA for a single TSP.

4.2.4 GA for TSP optimization nodes distribution in the specific area

Firstly; nodes location refer to the proposed coordinates for the service nodes that receive and transmit the user information after fixed nodes on these points. Secondly; route matrix refers to the link prolonged way that the nodes communicate with each other and it represents paths. The total distance is the complete distance from the start point for node location till reached the last position for node location. Finally; the best solution, translate the learning response for the system and how to reach the best node distribution and smallest link distance. The ANN and GA for MTSP effect on coverage.

In this thesis, the interactive combination of controlled mobility for nodes and SDRs in a fully distributed fashion allowed a high degree of self-configuration, which increased the QoS in terms of coverage and connectivity, the nodes randomly distributed in a specific area.

This research is focused on the performance of the best service and lowest cost; this is due to the mobility capabilities of the nodes and SDR flexibility. The number of nodes was reduced in the same area respectively, as shown in figure 4.17 the 40 nodes were chosen and show that the coverage is high but expensive because of the increase in the number of nodes. When the number of nodes was reduced to 20 nodes as shown in figure 4.19 in the same area where the coverage was also high, but the number of nodes is also significant. The continuous reduction of the number of nodes to 10 nodes as shown in figure 4.19 and follow-up result, the coverage was also high.

Finally, the nodes were reduced to 4 nodes as shown in figure 4.20 and there was the coverage high at the same time. This service due to the mobility of the nodes, according to the algorithm specified in this thesis, which moves towards the appropriate place to increase the coverage and connectivity in the specific area and perform the best service, this is the research objective.

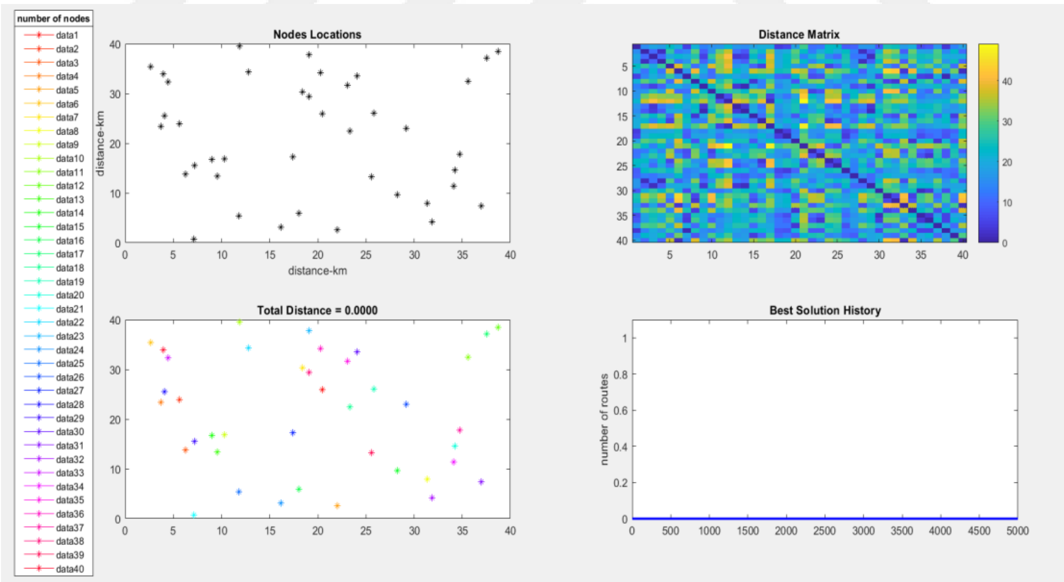

Fig 4.17 Node determination results using AI and GA for TSP when n=40.

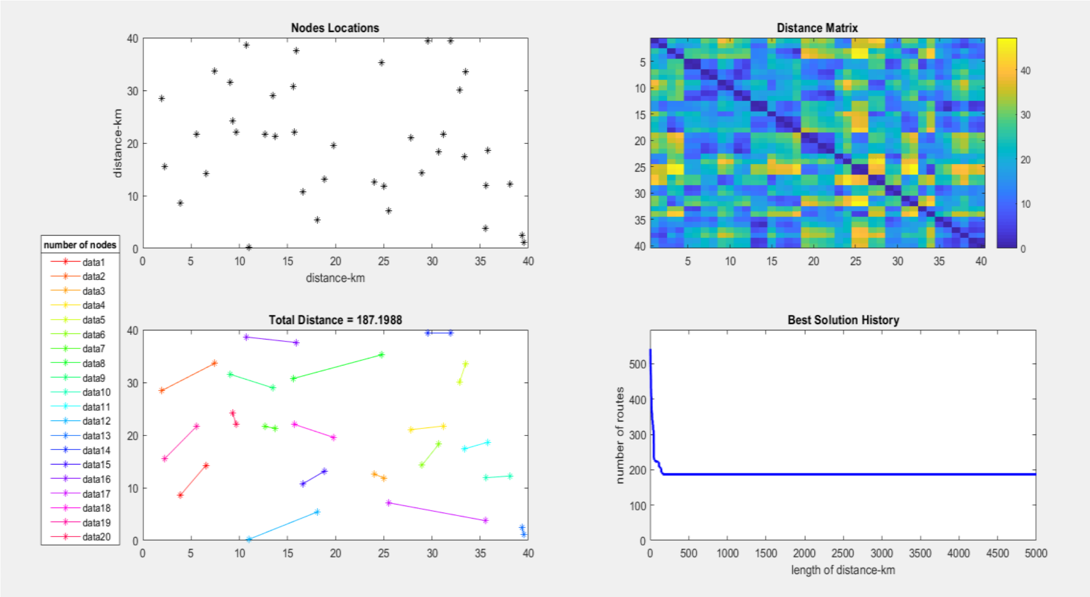

Fig 4.18 Node determination results when n=20.

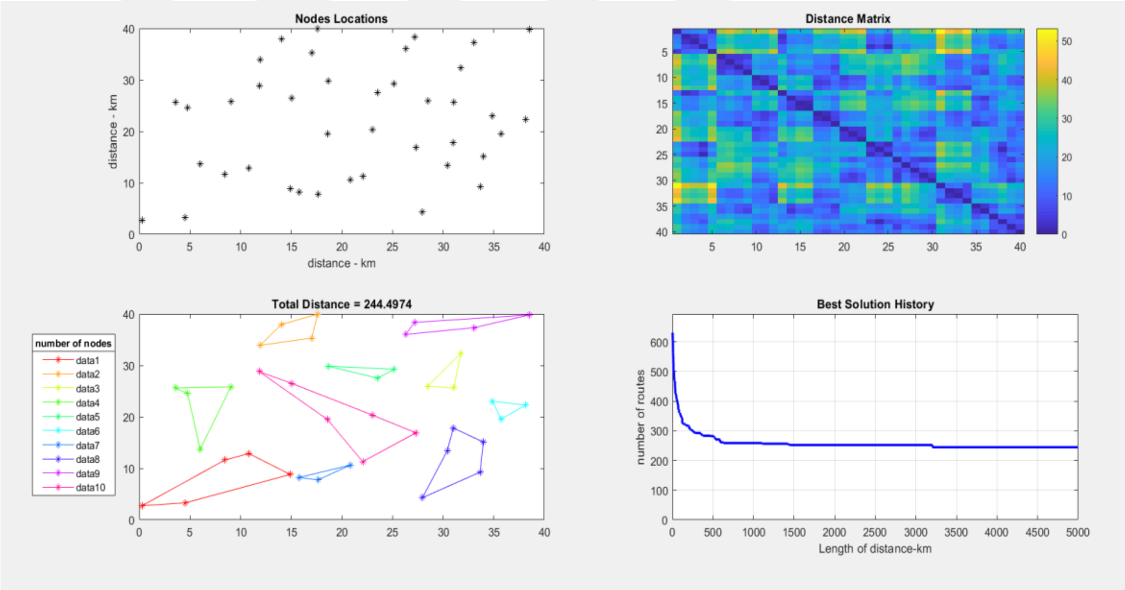

Fig 4.19 Node determination results when n=10

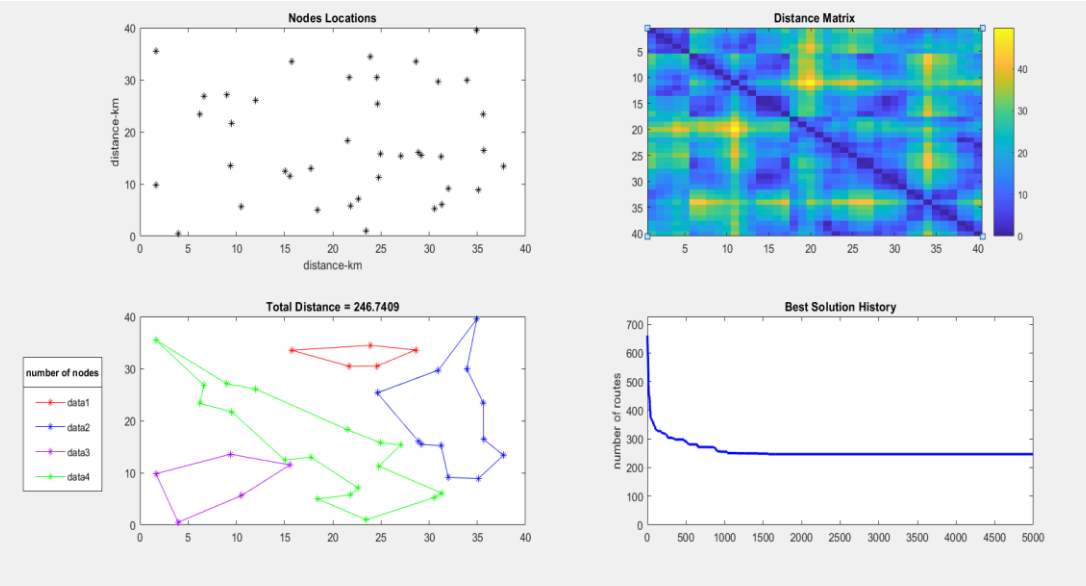

Fig 4.20 Node determination results when n=4.

5. CONCLUSIONS AND FUTURE WORK

5.1. Conclusions

In this thesis, the distribution capabilities of both ANN and GA for TSP has been proposed to select the most suitable positioning for the mobile nodes equipped with SDR capabilities. The node studied in this work could move towards new locations by applying the concept of controlled mobility by using only local information. The interactive combination of controlled mobility and SDRs in a fully distributed fashion allowed a high degree of self-configuration; which increased the QoS in terms of coverage and connectivity. The combination of SDR and ANN allowed to improve the management of wireless communication systems.

5.2. Future Work

It is necessary to analyze the impact of the SDR devices on network performance, as well as to study the effect of the site with the specification of the signal. SDR equipment is expensive, but the flexibility and efficiency have made the researchers interested in this topic. Challenges for practical application can be investigated as future work.

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CURRICULUM VITAE

PERSONAL INFORMATION

Name and surname : Faiq Ahmed Mohammed Bargarai

Nationality : IRAQI

Birthplace and date : 6 April 1976

Telephone : 05314527547 - 009647504608326

Email : faiq.bargarai@gmail.com

Job : Computer and communication engineer at TarinNet and teaching assistant in Duhok Polytechnic University.

EDUCATION

8-2-2016 I started in Turkey to study M.Sc. in the Department of Electrical and Electronic Engineering at Siirt University.

DEGREE	INSTITUTATION	YEAR OF GRADUATION
High school	Al-Had'b high school	2007
B. Eng.	College of Al-Hadb'a University	2013
M.Sc.	Siirt University	2019

RESEARCH INTERESTS

Routing algorithm in a computer network, wireless communication.

FOREIGN LANGUAGE

Kurdish, Arabic, and English.