UNIVERSITY OF TURKISH AERONAUTICAL ASSOCIATION
INSTITUTE OF SCIENCE AND TECHNOLOGY

A NEW APPROACH IN ENERGY CONSUMPTION BASED ROUTING PROTOCOL FOR WSN

MASTER THESIS

Ali Adnan Wahbi ALWAFI

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

PROGRAM OF ELECTRICAL AND ELECTRONICS ENGINEERING

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I hereby declare that all the information in this study I presented as my Master's Thesis, called: A New Approach In Energy Consumption Based On Routing Protocol For Wireless Sensor Networks, has been presented in accordance with the academic rules and ethical conduct. I also declare and certify with my honor that I have fully cited and referenced all the sources I made use of in this present study.

27.12.2017
Ali Adnan Wahbi ALWAFI

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Thanks to the most compassionate, gracious and merciful. May Allah's blessings and peace be upon our prophet Mohammed who protects us from the depths of darkness and leads us forth into light, and his house hold.

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December 2017 Ali Adnan Wahbi ALWAFI

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LIST OF ABBREVIATION

LEACH	:	Low Energy Adaptive Clustering Hierarchy
WSN	:	Wireless Sensor Network
SON	:	Self-organizing networks
MIMO	:	Multiple input-multiple output
CA	:	Carrier Aggregation
WCDMA	:	Wideband Code Division Multiple Access
ITU	:	International Telecommunications Union
CR-WSNs	:	Cognitive radio wireless sensor networks
CRNs	:	Cognitive radio networks
Qos	:	Quality of Service
LTE	:	Long Term Evolution
3GPP	:	Third Generation Partnership Project
IMT	:	International Mobile Telecommunications
4G	:	4^{th} generation systems
Rel-10	:	Release 10
FCC	:	Federal Communications Commission
MANETs	:	mobile ad hoc networks
DSA	:	Dynamic Spectrum Access
SSDF	:	Single Station Dual-Frequency
CHs	:	Cluster Heads
FCM	:	Fuzzy C-means
ANFIS	:	Adaptive neuro fuzzy inference system
GA	:	Genetic Algorithm

ABSTRACT

A NEW APPROACH IN ENERGY CONSUMPTION BASED ROUTING PROTOCOL FOR WSN

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Clustering wireless sensor networks is an effective approach for achieving energy efficiency. In clustering-based routing protocols, clusters are formed by electing cluster heads among all sensor nodes in the network and then allocating each node to the nearest cluster head. The Distribution of cluster heads over the network is uncontrollable, that is the main disadvantage. In addition to the problem of forming unbalanced clusters, almost all routing protocols are intended for a specific application scope, and could not cover all applications. In this thesis, we prepared a new protocol as follows, we used the fuzzy logic Mamdani method for finding the best cluster heads and forming balanced clusters. We used two input for fuzzy, energy and distance. For the output, we used the probability value of the cluster head, and for routing the sensors we used the Genetic Algorithm. This new protocol has more energy efficiency compared to other cluster-based protocols in terms of creating balanced clusters, maximizing cluster internal areas, extending network lifetime, and maximizing the total number of data packets received in the sink.

Keywords: Wireless Sensor Network, Genetic Algorithm, Clustering method.

ÖZET

KABLOSUZ ALGILAYICI AĞLARI İÇİN ENERJİ TÜKETİMİ TABANLI YÖNLENDİRME PROTOKOLÜNE YENİ BİR YAKLAŞIM

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Kablosuz algılayıcı ağlarının kümelenmesi, enerji verimliliğini elde etmek için etkili bir yaklaşımdır. Kümeleme tabanlı yönlendirme protokollerinde, kümeler, ağdaki tüm algılayıcı düğümlerinden küme başları seçerek ve daha sonra her düğümü en yakın küme başlığına tahsis ederek oluşturulur. Ana dezavantajı, ağ üzerinde küme baslarının dağıtımında herhangi bir kontrolün bulunmamasıdır. Dengesiz kümeler oluşturma sorununa ek olarak, hemen hemen tüm yönlendirme protokolleri belirli bir uygulama kapsamı için tasarlanmıştır ve tüm uygulamaları kapsamamaktadır. Bu tezde, yeni bir protokol hazırladık, bulanık mantık Mamdani yöntemini en iyi küme başlarını bulmak ve dengeli kümeler oluşturmak için kullandık. Bulanık için iki girdi, enerji ve mesafe kullandık. Çıktı için, küme başının olasılık değerini, ve algılayıcıları yönlendirmek için Genetik Algoritma kullandık. Bu yeni protokol, dengeli küme oluşturmak, küme iç alanlarını en üst düzeye çıkarmak, ağ ömrünü uzatmak, ve ana alıcıda alınan toplam veri paket sayısını maksimuma çıkarmak açısından diğer küme tabanlı protokollere göre daha fazla enerji verimliliğine sahiptir.

Anahtar Kelimeler: Kablosuz Algılayıcı Ağı, Genetik Algoritma, Kümeleme yöntemi.

CHAPTER ONE

INTRODUCTION

1.1 Background

Cognitive radio wireless sensor networks (CR-WSNs) have awakened great interest recently in the field of emerging spectrum scarcity issue. This section outlines the difference between CR-WSNs and conventional wireless sensor networks such as ad-hoc cognitive radio networks, the objective, requirements and etc. are defined. The intention of the study is to grasp the capabilities in this new emerging type of cognitive radio wireless networks.

1.1.1 Cognitive Radio Wireless Sensor History

The cognitive radio system was a unique path in the field of wireless communications published by Joseph Mitola in 1998. This system is designed as a wireless transceiver, which has the capability to be reconfigured in an automatical manner for the parameters of the given network and user. There is also another consideration for cognitive radio systems, the research is based on the dynamics of spectrum access. This approach was born out of the fact that all radio frequencies are not used efficiently enough, such as frequencies reserved for special branches like the military. The argument is to determine if there would be any interference for licensed users when unlicensed ones are permitted to the same frequencies for efficient use of them. The publication of the cognitive radio wireless regional area network standard was in 2011. It basically declares that the geological location in combination with a database of licensed transmitters will define the frequencies, which are available for the cognitive radio to be used. Frequencies that are not available to be accessed for the cognitive radio are identified by spectrum sensors. The standard also defines the time for the frequency to be occupied by the cognitive radio as the availability is changing with time, doing this is necessary to prevent interference with the licensed user [1, 2].

1.1.2 Cognitive Radio Wireless Sensor Networks (CR-WSNs) Features and Definition

Cognitive wireless sensor networks is a kind of sensor networks. They have cognitive abilities of sensors that is wireless sensor networks. They can adapt to changes in communication parameters by following the surrounding environment changing the appropriate communication parameters. They have a big difference with the traditional wireless sensor networks. This technology uses the unused frequencies (empty frequencies) to their transmissions in underlay or overlay methods, this thing is the key to this technology [3].

1.2 New Paradigm of WSN with CR: Cognitive Radio Wireless Sensor Networks (CR-WSN)

The ad hoc CRN have normally a spatial distribution of energy constraints, self-configuration and need cognitive capacities. The cognitive capacities organize the extent of cooperation and adaptation for a smooth operation, these operations include a transfer of data, in addition, to the securing of the license. Another form of approach to explaining is that a CR-WSN perceives a signal in a defined frequency in a specific region and interacts these in the dynamic system for meeting the specific requirements [4].

1.3 Advantages of Using CR in WSNs

The CR-WSN target for explosive traffic efficiently, a new network paradigm that uses a source spectrum in the field of WSN. The system has the capacity for packet loss reduction and power waste reduction, the ability to a high degree, and the better quality of communication. This part talks about the benefits of using the cognitive radio in WSNs [5].

In WSNs, they have a big amount of power consumption for package retransmission compared to losses. CR wireless sensors can switch their parameters to be accommodated with the channel conditions. Thus, energy wasting due to package crash and retransmission can be reduced.

1.4 Differences Between Ad Hoc CRNs, WSNs, and CR-WSNs

The differences and similarities of ad hoc CRNS, WSNs, and CR-WSNs are going to be displayed in the following table. The factors of comparison listed in the table show some differences and issues, as we see the fault tolerance is same for the WSNs and CR-WSNs. The table depicts these in a very organized and easily comprehensible manner. The comparison of ad-hoc CRNs, WSNs and CR-WSNs as shown in figure 1.1 [3].

Factor	*Ad Hoc*CRNs	WSNs	CR-WSNs
Wireless medium	Licensed spectrum bands (Data channels) Licensed or ISM band (control channel)	ISM bands	Licensed spectrum bands (Data channels) Licensed or ISM band (control channel)
Traffic	Random	One to many, many to one, many to many	One to many, many to one, many to many
Hardware constraints	Intelligent *ad hoc* mobile devices with cognition capability	Small, low processing capacity, low memory capacity	Intelligent, cognition capabilities, small, moderate processing capacity, moderate memory capacity
Availability	Under development	Readily available	Not readily available (under conceptual phase)
Bandwidth deficient	Yes	Sometimes	Yes
Identification	Unique ID by its MAC address	Not unique	Not unique
Standards	Not yet defined	ZigBee, IEEE 802.15.4, ISA100, IEEE 1451	Not yet defined
Fault tolerance	Less critical points of failure	High fault tolerance required	High fault tolerance required
Communication Range	Long	Short	Short (intelligently controllable)
Communication	Broadcast	Point-to-Point	Point-to-Point
Failure rate	Low	High	Moderate (*expected)
Population of nodes	Sparsely populated	Densely populated	Densely populated
Interaction	Close to humans e.g. laptops, PDAs, mobile radio terminals, *etc.*	Focus on interaction with the environment	Focus on interaction with the environment
Topology changes	Frequent	Less frequent	Less frequent
Seamless operation	Depends on the PUs	Not concerned with PUs	Depends on the PUs
Suitable for	Where ISM band is overcrowded	Where ISM band is not crowded	Where ISM band is overcrowded
Whitespace utilization concern	Yes	No	Yes
Data centric	Generally address-centric networking	Generally data-centric	Generally data-centric
Application specific	Generally not	Yes	Yes
Self-organization	Cognitive decision support system	Yes, but no cognitive decision support system	Cognitive decision support system
Multi-hop communication	Often	Often	Often
Energy conservation	Concern	Highly concern	Highly concern
Trust Security	Usually, no central coordinator	One administrative control	One administrative control
Mobility	Often (MANET)	Less mobile or stationary	Less mobile or stationary
Routing	All-to-all	Broadcast Echo from to sink	Broadcast Echo from to sink
Multichannel	Required	Possible	Required
CCC requirement	Mostly Required (except some exceptions) [17]	Not really	Mostly Required (except some exceptions)
In-network processing	Supposed to deliver bits from one end to the other	Expected to provide information on the other end, but not necessarily original bits	Expected to provide information on the other end, but not necessarily original bits
Scalability	Not many (10s to 100s of nodes)	Very large (10s to 1,000s)	Very large (10s to 1000s)
QoS interpretation	Receipt rate, Dissemination, Speed, Spectrum utilization, Interference to PUs	Energy consumption, Redundancy Efficiency, Latency, Scalability, Robustness - Event detection reporting probability - Event classification error, detection delay - Probability of missing a periodic report - Approximation accuracy - Tracking accuracy	Energy consumption Redundancy Efficiency, Latency, Scalability, Robustness Throughput Delay - Event detection reporting probability - Event classification error, detection delay - Probability of missing a periodic report - Approximation accuracy - Tracking accuracy - Spectrum utilization - Interference to PUs
Research direction	Many areas are still to explore Currently focus of research is predominantly directed towards – Game theoretic approaches for spectrum utilization – Predictions for the PU's arrival – Energy efficient routing and MAC protocols – Development of middleware architectures – Distributed aggregation applications – Design of cross-layer algorithms for improved power efficiency	Although, there is always room for improvement, most of the areas are explored and now research focus on – QoS, – reliability, – performance enhancement – trust and security – etc.	Research is still in infancy Almost all area are still to explore Currently focus of research is predominantly directed towards – Game theoretic approaches for spectrum utilization – Predictions for the PU's arrival – Energy efficient routing and MAC protocols – Development of middleware architectures – Distributed aggregation applications – Design of cross-layer algorithms for improved power efficiency

Figure 1.1: Comparison of ad hoc CRNs, WSNs and CR-WSNs.

Wireless Sensor Network (WSN) is typically a subclass of ad-hoc networks. It is a network of sensors with the aim of monitoring some phenomenon. This network of sensors has great applications especially in inaccessible places or dangerous areas.

In the Military, it used for monitoring, tracking, security, control and maintenance functions. In the Aviation, it used for replacing wired networks. In the Environment, it used for monitoring environmental variables in buildings, ocean forests, etc. And it has been used in other fields like traffic, engineering, and industrial for many reasons.

The main characteristics of a sensory network are; the sensor, the observer and the phenomenon. The sensor is the one that monitors the phenomenon being analyzed, it consists of a processor, radio for communication, memory, and battery. It reads (measured) the phenomenon and passes this information on to the observer. It worth's mentioning that extending the distance of the phenomenon in relation to the sensor, leads to reducing the accuracy of this sensor.

The observer is the end user who wishes to study and obtain answers about the phenomenon. The phenomenon is the object of study by the observer, that has been monitored by the sensory network.

Due to the great difficulty that usually encountered in replacing batteries from sensor nodes, power consumption becomes a critical factor in WSN, thus it requires efficient protocols in energy consumption for extending the life of the system.

Another important point in WSN is the fault tolerance since sensors are often located in inaccessible or dangerous areas, it requires routing algorithms and techniques for self-organization of the devices.

In sensor networks, the main metrics for evaluating its protocols are energy efficiency and system life, latency, precision, fault tolerance, scalability, and sensor exposure.

A network of sensors must receive and transmit data in a safe way, obeying some requirements, such as:

Data confidentiality - the transmission will be guaranteed only within the same network, i.e. neighbor networks cannot have an access to this information.

Data authentication - ensures that the received data is from a secure source.

Data integrity - ensures that the received data was not changed during its transmission.

Recent data - avoids the replay attack, which uses old broadcasts to change a network, viz., it ensures that the incoming data is recent.

Although WSNs are usually associated with ad-hoc networks, that is, without necessarily needing topological planning, this aspect has been changed in recent years. Many of today's networks have been implemented taking into account topological planning, in particular considering the distance limits for communication links. In such cases, natively ad-hoc communication protocols can be replaced by network protocols that assume the existence of a pre-existing infrastructure, similar to that of wireless networks involving traditional computers. However, such WSNs continuous to be a different class of networks because of the severity of energy aspects of the nodes.

A network of sensors is a network of very small computers ("nodes"), fitted with sensors, that cooperate in a mutual work.

The sensor networks are formed by a group of sensors with certain sensory and wireless performance capabilities which allows the formation of ad hoc networks, without pre-established physical infrastructure or central administration.

The wireless sensor networks, abbreviated (WSN), also called wireless sensor and actuator networks (WSAN), are spaciously distributed independent sensors to monitor physical or environmental circumstances, such as temperature, water level, pressure, etc. and to pass the collected data in an effective way through the network to other locations. The most recent networks are bi-directional, which allows control of sensor performance.

A mobile wireless sensor network (MWSN) is a wireless sensor network (WSN) in which the nodes of the sensors are mobile. MWSNs networks are smaller than their predecessors. MWSNs are much more versatile than static sensor networks and can be deployed in any scenario and face rapid technological changes.

These networks of wireless sensors and actuators are used in many industrial and consumer fields, such as monitoring and control of industrial processes, health monitoring by machines, cyber-physical systems, home automation, environmental detection, etc.

They are characterized by their ease of deployment and by being self-configuring, being able at any moment to become sender, receiver, offer routing services between nodes without direct vision, as well as register data referring to the local sensors of each node. Another of its characteristics is its efficient management of energy, which allows them to obtain a high rate of autonomy that makes them fully operational [1].

The growing miniaturization of computers gave birth to the idea of evolving very small and cheap computers that connected wirelessly and are controlled independently. The idea of these networks is to randomly distribute these nodes in a large territory, which the nodes observe until their energy resources are exhausted. The attributes "small", "cheap" and "autonomous" made the idea known as smart dust [2, 3].

For the time being, sensor networks are a very active subject of research in several universities, although commercial applications based on this type of networks have already begun to exist. The largest sensor network to date consisted of 800 nodes and was commissioned on August 27, 2001, for a brief duration at the University of Berkeley to demonstrate the power of this technique in a presentation. Some systems have proven to be applicable but unevenly, for example, Berkeley Motes, Pico-Radio, Smart-Dust, and WINS.

Sensor networks have been designed as a military early warning system for monitoring pipelines and national borders. However, modern research also sees it as a substitute for costly sensor assemblies in vehicle manufacturing, warehousemen in warehouses, and monitors of natural areas for pollutants, forest fires and animal migration; the conceivable applications are just as varied as the available sensors (see sensors according to a measured variable).

Sensor networks are always in the development stage; practical applications are available for experimental and demonstration purposes. Commonly used sensor networks are available for professional applications. The best-known sensor network is that used in weather stations of various providers, but the networking is done by conventional telecommunications networks. Comparable networks of actuators are not known because of the required energies for actuators and the protection against malfunctions considerably higher demands on the networking and the nodes.

The smallest existing sensor node has a diameter of one millimeter (as of 2007) [2], the largest sensor network to date covers about 1,300 sensor nodes with a surface area of 1,300 meters (as of Dec 2004) [3].

In 1952, Sound Surveillance System (SOSUS) has been produced, a network of underwater buoys installed by the United States during the Cold War, which detects submarines using sound sensors. Although SOSUS is not a computer network, it did produce the idea of a nationwide sensor array.

Studies on sensor networks began around 1980 with Distributed Sensor Networks (DSN) and Sensor Information Technology projects from the Defense Advanced Research Projects Agency (DARPA) of the United States. DARPA works with military and academic research institutions to develop new military and economic technologies. Their results are usually not subject to secrecy, which also applies to the sensor network research.

In the 1990s, the sensor network research experienced a boom, promoted by the ever smaller and more powerful computer hardware. Today, sensor networks are being researched by research institutes around the world. Results have been presented since 2003 at the "ACM Conference on Embedded Networked Sensor Systems".

CHAPTER TWO

LITERATURE REVIEW

2.1 Literature Review

2.2.1 Background

Nowadays, the wireless technology developed so far and started to be used in too many sectors of electronic devices, the demand for wireless radio spectrum has grown. The assigned spectrums via government institutions started to create problems with these developments. This assigned spectrum policy started to be inefficient and the institutions in charge of the radio spectrum assignment started to reconsider their policy. The cognitive radio is addressing this issue and making a more efficient usage of the spectrum range. The new cognitive radio, also called "Next Generation Radio" is adapting according to the surrounding radio environment. The development started in 1999 by Joseph Mitola III, since then the topic attracted the attention of scientific minds, and many studies have taken place on this topic [6].

Radio transmissions have been used since WWI. The usage of the radio spectrum is limited and regulated by government institutions (Federal Communications Commission in the United States, and RTUK in Turkey). These institutions assign the spectrum to companies and establishments according to their licenses, for a large area and longtime intervals. However, there is also non-licensed users, which are called "secondary users", which can use spectrums for a limited time. In the latest years, the regulation institutions started to be more relaxed and flexible with the usage of the available spectrums, and the usage of the cognitive radio technology [7]. The spectrum usage for WSN is shown in figure 2.1.

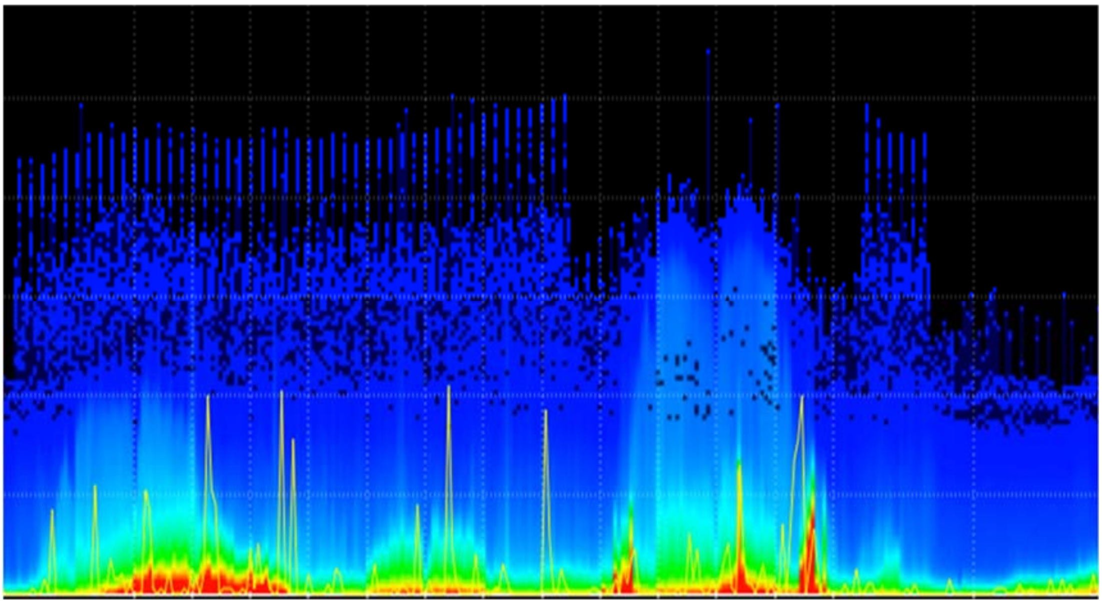


Figure 2.1: Spectrum usage.

2.1 Fundamentals

The basic fundamental of the cognitive radio technology is to be more efficient in the spectrum also with an increase of the quality. The studies about this topic are centered about new networking paradigms which can intelligently and efficiently transmit. The efficient spectrum usage is important for future networks and communication systems. The main difference between a traditional and a cognitive radio is that cognitive radio can adapt the parameters accordingly, such as frequency, modulation type, transmission power and many other parameters [8].

The cognitive radios have to gather the required information about the radio environment, before adjusting accordingly. The characteristic of the cognitive radio is called, “Cognitive Capability”, which results from the cognitive radio to be conversant with the radio frequency, spectrum, waveform, communication network type, communication network protocol, geographical information, local resources that are available, demands of the user, security policies and so on. When cognitive radio fulfills the gathering of the required information from the radio environment, it can change the transmission parameters accordingly to the environment variations dynamically, and achieve the optimal performance, which called “reconfigurability” Functions [9].

A duty cycle of the cognitive radio is in the following;

1) Spectrum sensing and analyzing.

2) Spectrum management and handoff.

3) Spectrum distributing and sharing.

While sensing and analyzing the spectrum, a cognitive radio can find the spectrum's white spaces, which are not used by a license holder at that moment, and utilize the white space spectrum. Cognitive radio can also detect the spectrum sensing when a license holder (primary user) starts to use its licensed spectrum again and does not interfere with the secondary user [10].

After finding the white space spectrum, the cognitive radio provides a secondary user to choose the best frequency available, change between multiple frequency bands according to the time-varying characteristics of the channel and to meet the Quality of Service (QoS) requirements. When a primary user starts modulating its licensed frequency band, secondary user redirects its transmission to an available frequency band, the optimal band is automatically chosen according to the channel capacity, noise, path loss, interference level, holding time, channel error rate, and so on [11].

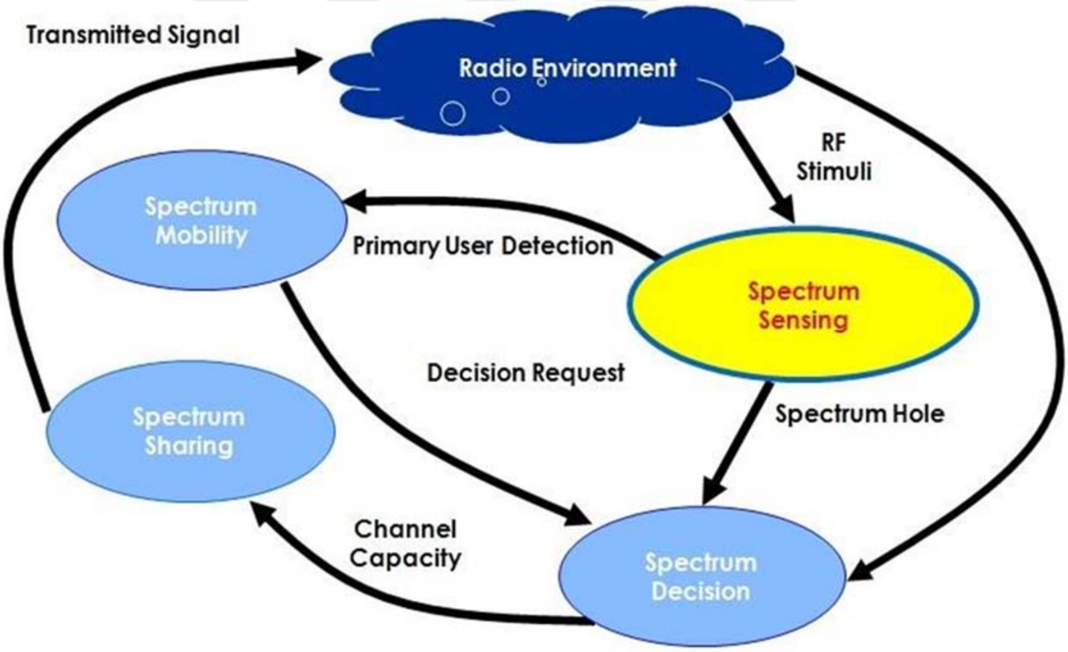


Figure 2.2: Cognitive cycle.

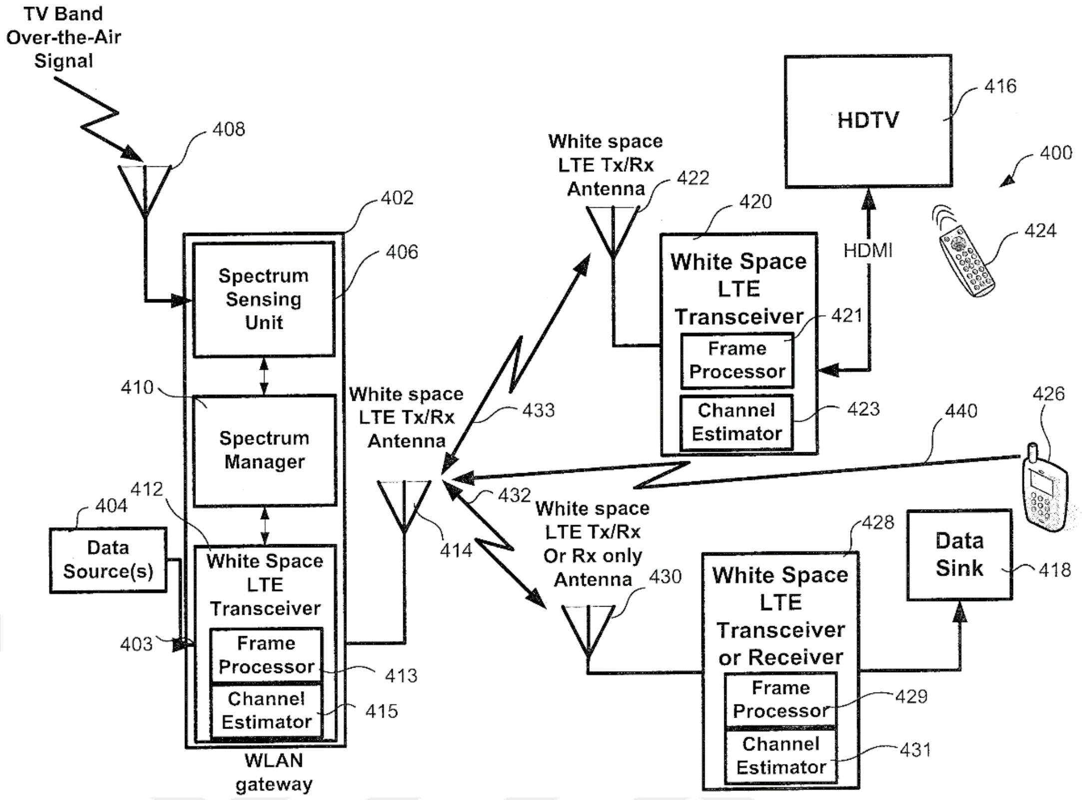


Figure 2.3: Illustration of spectrum white space.

Temporarily unused licensed frequency sets up for the band operating parameters and adapts to environmental changes, cognitive radio technology provides a new generation of wireless devices with additional bandwidth, reliable broadband communications and versatility for rapidly growing data applications [12].

2.2 LTE-Advanced and the Evolution to Beyond 4G Systems

The cellular data transfer has been improving in the recent years. With the commercial usage of Rel-8 and LTE (Long Term Evolution) starting worldwide, the new studies have been focused on cellular data usage standardization and improvements. The work for LTE-Advanced was started by 3GPP (Third Generation Partnership Project) with the Rel-10. The main target was to meet the IMT-Advanced (International Mobile Telecommunications-Advanced) standards, which was set by ITU (International Telecommunication Union). These standards defined the 4G, also known as 4th generation systems. But the predictions, based on the growing demand for wireless data usage, forced 3GPP to work furthermore. Rel-11 and Rel-12 were the results of these works [13].

The recent technological improvements in cellular and wireless connection has brought us many new concepts. The most recent of these concepts is the 4G wireless connection. The “G” stands for generation. The 3G cellular network was completed in 1997 by ITU (International Telecommunications Union), in 1997. But for customer usage, it waited a few years to be released. After the development, the 3GPP (Third Generation Partnership Project) started to work on a new system, 4G or LTE as we know it today. The LTE stands for Long Term Evolution. 3G was a huge success and was revolutionary for its time of release. But as 4G/LTE hit the market, it was even more revolutionary than the 3G. LTE connection was capable of achieving data transfer rates up to 300Mbps. However, upon this success, the LTE Rel-8 and Rel-9 was not up to IMT Advanced requirements, which was set by ITU [13].

LTE-Advanced made downloading up to 1Gbps and uploads at 500Mbps possible. Table 2.1 shows the LTE, LTE-Advanced, and IMT-Advanced standards [14].

Table 2.1: LTE, LTE-Advanced and IMT-Advanced standards.

Item	**Trans. path**	**Antenna Conf.**	**Rel. 8 LTE**	**LTE-Advanced**	**IMT-Advanced**
Peak data rate (Mbps)	DL	8 x 8	300	1000	1000
	UL	4 x 4	75	500	-
Peak spectrum efficiency (bps/Hz)	DL	8 x 8	15	30	15
	UL	4 x 4	3.75	15	6.75
Capacity (bps/Hz/cell)		2 x 2	1.69	2.4	-
	DL	4 x 2	1.87	2.6	2.2
		4 x 4	2.67	3.7	-
	UL	1 x 2	0.74	1.2	-
		2 x 4	-	2.0	1.4
Cell-edge user throughput (bps/Hz/cell/user)		2 x 2	0.05	0.07	-
	DL	4 x 2	0.06	0.09	0.06
		4 x 4	0.08	0.12	-
	UL	1 x 2	0.024	0.04	-
		2 x 4	-	0.07	0.03

The future systems are going to be far more advanced than ITU established 4G, as it seems. The higher demand for faster data usage which caused by cloud services and applications is making the faster connection mandatory. The traffic is predicted to grow up to 30 times from the current traffic. At this rate, without changing or improving the systems, the cellular data connection systems will not meet the demand [15].

To meet the requirements and overcome the challenges, 3GPP has been organizing their researchers based on the new releases. The Rel-10 has been released first time in 2010, but it was functionally frozen in the year 2011 after the approval of ITU for meeting IMT-Advanced requirements. After these releases, Rel-11 was started and more enchantments were made for the basic LTE-Advanced which was developed to meet Rel-10. After the work of Release-11 was done and completed, Rel-12 LTE-Advanced standardization started taking place until September 2014. New technologies and enchantments were planned in the meetings [16].

2.3 Carrier Aggregation

Improving the performance of cellular data transfer will be achieved by utilizing from bandwidth amounts that have been increased. To achieve that and meet the IMT-Advanced requirements, LTE-Advanced uses bandwidth up to 100 MHz in frequency bands. These are set by ITU for IMT and the frequencies are as follows; 450–470, 698–960, 1710–2025, 2110–2200, 2300–2400, 2500–2690, 3400–3600 MHz. The ability to support various frequency bands increase the LTE-Advance d's ability to be flexible. This also causes fragmentation. Countries choose and utilize different frequency bands for commercial usage. This results in the devices to be not compatible in every country. However, this can be bypassed by designing the devices to be able to support multiple frequency usages. The designing and processing of devices, and enabling them to use different frequencies leads to increasing costs, this considers as a drawback [17, 18].

A device that has LTE-Advanced feature can aggregate as much as 5 carriers individually, each one has up to 20 MHz. This is shown in the following figure:

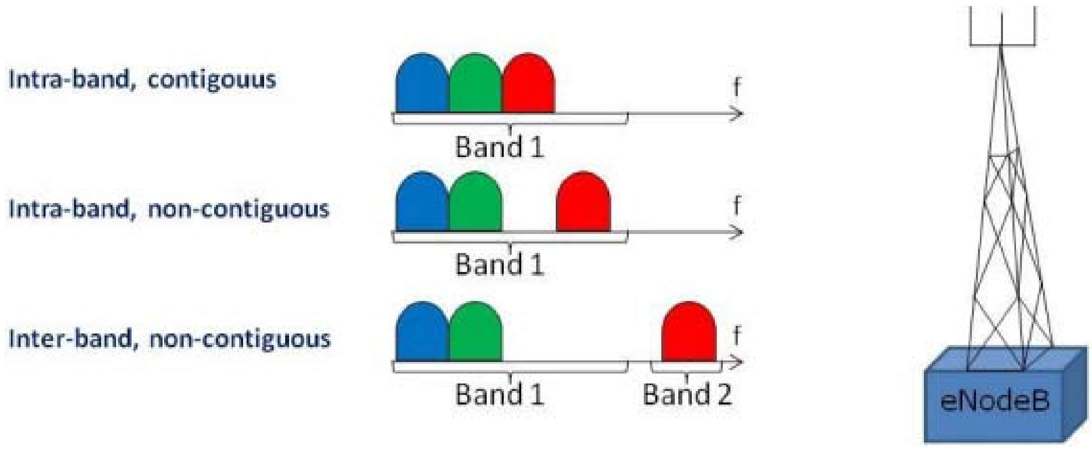


Figure 2.4: Intra-band contiguous carrier aggregation.

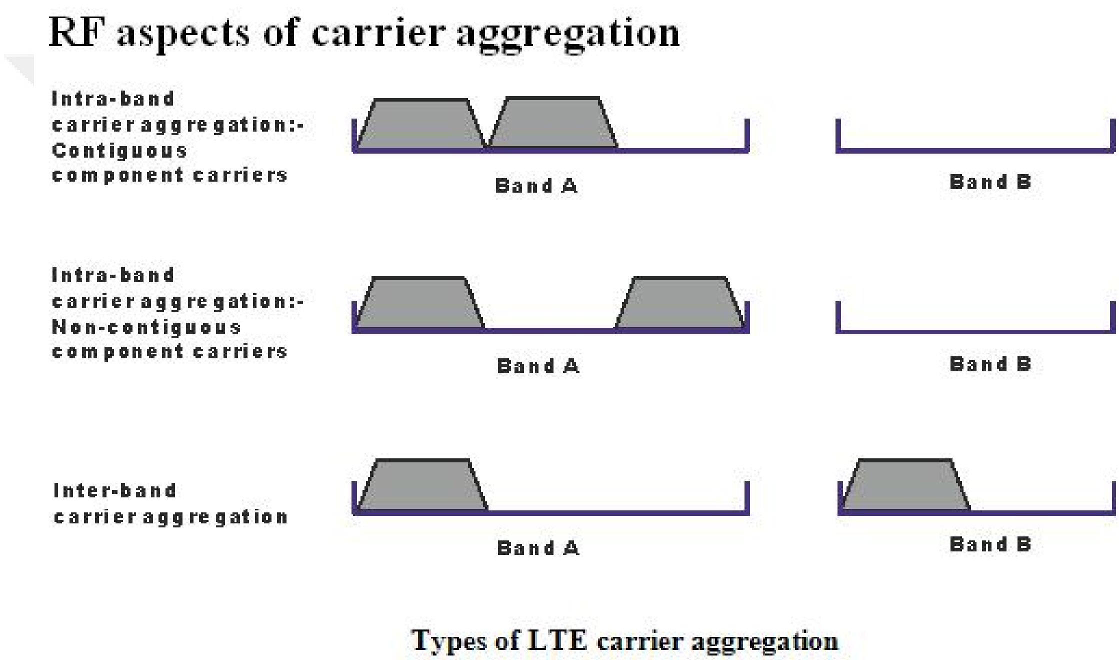


Figure 2.5: Intra-band non-contiguous carrier aggregation.

The LTE-Advanced standardization is one of the most important technological improvement in cellular networks, since the release of WCDMA (Wideband Code Division Multiple Access). After Rel-10 and meeting the requirements set up by ITU (International Telecommunications Union), LTE-Advanced became the biggest shift in the cellular data transfer industry. Regardless, the industry continued to research for more improvements in LTE-Advanced with enchantments in the core technology of carrier aggregation, MIMO (Multiple Input and Multiple Output), relaying, and cooperative multipoint communications. To be able to keep up with increasing demands for high-speed transfer with a wide range of cellular coverage, the recent studies mainly centered around improving and supporting of heterogeneous networks, device-to-device (peer to peer) communications, and machine-type communications. With these new technologies, self-organizing networks which can adjust itself automatically will be able to achieve the best service for commercial usage. The improvements will continue with introducing new ones, alongside with improving the existing technologies, as long as the demand for higher data usage with faster and more ubiquitous connection in increase [19-21].

High demand on the radio frequency bands has led to the development of cognitive radios. Cognitive radios have the ability to sense the environment and adapt accordingly. The ability to change their internal parameters result in more efficient frequency band usage. The ability to use licensed frequencies for secondary users while license holders are not using, and not interfering with the license holders is a huge benefit of the cognitive radio technology. The more recent studies, which have been made by observing biological activity, have given us more efficient ways. With the newer developments, secondary users do not need to set up a centralized CR-MANET node anymore [22].

The recent increase in wireless communication demands has led to the usage of frequency bands more efficiently, which has limited spectrum sources. The communities in charge of regulating the frequency band spectrums, such as FCC (Federal Communications Commission) are planning to let licensed (primary) bands to be used by unlicensed (secondary) users, for operations that have non-interfering with the license holders. This non-interference usage is made possible with the Cognitive Radios, which are able to sense the surrounding environment and adapting its internal parameters accordingly. The MANETs (mobile ad hoc networks), give the ability to the wireless devices to create a network without using a fixed infrastructure, which was mandatory before the development of cognitive radios. In networks, which organize themselves, each and every one of the nodes existing have the ability to transfer the necessary information and manage the packages between two neighbors. With the increase in the potential applications, CR-MANETs are getting more and more important. Some of these applications are; disaster relief, military battlefield communications, autonomous vehicular communications and so on [22].

The regulating authorities do not demand infrastructure change from the license holders, and this task is required for the unlicensed secondary users. The CR's

MANETs of the secondary users take the task to realize the usage of a license holder, through spectrum sensing. This can be done by Cognitive Radios cooperatively or individually. Most recently, the cooperative spectrum sensing attracted attention, caused by the efficiency of it, compared to the individual spectrum sensing. Compared with the non-cooperative-individual spectrum sensing, the cooperative spectrum sensing has many advantages [23].

A. Spectrum Sensing:

The radio spectrums have been owned and used only by licensed users for years. Majority of the radio spectrum has been largely occupied by license holders. Statistics given by Federal Communication Commission show that most of the time, these radio spectrums stay idle. This results in a shortage of radio spectrum. CR enables these radio bands to be used by secondary users while it stays idle [24].

The DSA (Dynamic Spectrum Access) is one of the most important improvements of the cognitive radios, which gives the opportunity to the secondary users to use the radio frequency while limiting the usage to avoid the interference with the license holders and prevent causing any harm or loss to the license holders. The idle spectrums are detected by the secondary users in the time and frequency domain. There are three ways to sense these spectrums. The first and theoretically most optimal way is Matched Filtering, but it requires prior information of the primary user, and this results in a higher cost to develop and more complex circuits. The second method is Energy Detection, which is considered as sub-optimal. It requires more basic circuits compared to the matched filtering system and less information is required about the primary user. The third way is Cycle stationary system, which can detect the radio signals with very low electromagnetic noise. However, it still requires some prior information about the primary user, so it is not ideal either [25, 26].

B. SSDF Attack Models in Cooperative Spectrum Sensing:

Cooperative Spectrum Sensing is as it named, a group of secondary users gather together their locally gathered information, and perform a spectrum sensing altogether. However, some users with bad intentions may interfere by sending wrong or manipulated information and resulting harm and wrong spectrum sensing. This called an SSDF attack (Single Station Dual-Frequency). Explanation of three types of SSDF attacks will be presented in the following [27].

In this first attack type, a user with bad intention sends out high energy, disguising like a primary user. The secondary users that searching for an idle frequency will sense the attacked frequency as occupied by a primary user, even though it is not, and make a wrong decision. This attack is called selfish SSDF.

The second type is interference SSDF. In this attack, a malicious user sends a low primary user energy, falsely causing other users to sense the absence of the primary user, while there are primary users using the spectrum at the time. With the wrong information, secondary users use the frequency with the primary users at the same time, causing interference in the primary user's broadcast [28, 29].

The third type is called confusing SSDF. In this attack model, a user with bad intentions sends out primary user's energy randomly, some of these energies are low and others are high, causing many wrong decisions, sometimes it may be right, when a primary user is in presence, and randomly the malicious user sends out high primary user energy, the attack will cause no wrong decisions, and vice versa. The intention of this attack is to confuse other secondary users at the time [30].

C. Consensus-Based Spectrum Sensing Scheme:

This type of spectrum sensing is based on biological life forms. This spectrum sensing scheme does not use a centralized center. It improves the sensing performance and counters the SSDF attacks in CR-MANETs at the same time. It is done in two stages; the stages are explained in the following.

In the first stage, all secondary users individually sense the target spectrum band, the sense based on the spectrum sensing models. The equation is this; user i, user's measurement Yi at time instant k = 0 by xi (0) = Yi

In the second stage, the secondary users create a wireless connection and exchange the primary user's energy values all together with their neighbors. The processing is done with iterations. The status updates of the users take place at discrete time k=0,1,2…. And it is done with a given sample period. In each k, every received energy value xj(k) is taken and deviation is calculated, to spot and exclude an SSDF attacker. The iteration continues with xi (k + 1) and so on. The iteration takes place until xi(k) diverge to a constant value. Starting from k=0, the consensus algorithms is the following;

$$x_i(k+1) = x_i(k) + \varepsilon \sum_j (x_j(k) - x_i(k)) \tag{3.1}$$

In the equation; $0 < \varepsilon < \Delta-1$ and Δ is the maximum degree of the network.

After comparing the consensus result x^* with a predefined threshold λ, each secondary user gets the final result data from the system. If $x^* > \lambda$, there is a primary user in the frequency, and if $x^* < \lambda$ there is no primary user in the frequency band.

If no attack takes place, and ε is chosen such that $0 < \varepsilon < 1/\Delta$, the average consensus will be sure that all received values converges to x^* as the average. It can be presented more by above algorithm reaching the exponential convergence ratio. By this method, uncertainty is reduced to minimum.

However, when an attack happens, the basic consensus may not be certain. This caused by the misguidance of wrong values sent by the attacker.

This situation requires algorithm modifications on the standard procedure. The attacker should be rejected. This modification will allow fewer attackers to successfully attack and will filter out more wrong information. Another method to identify an attacker is to find the maximum deviation from the mean value of the neighbors, so the attacker would be revealed. The following simulation shows the counter to the SSDF attacks;

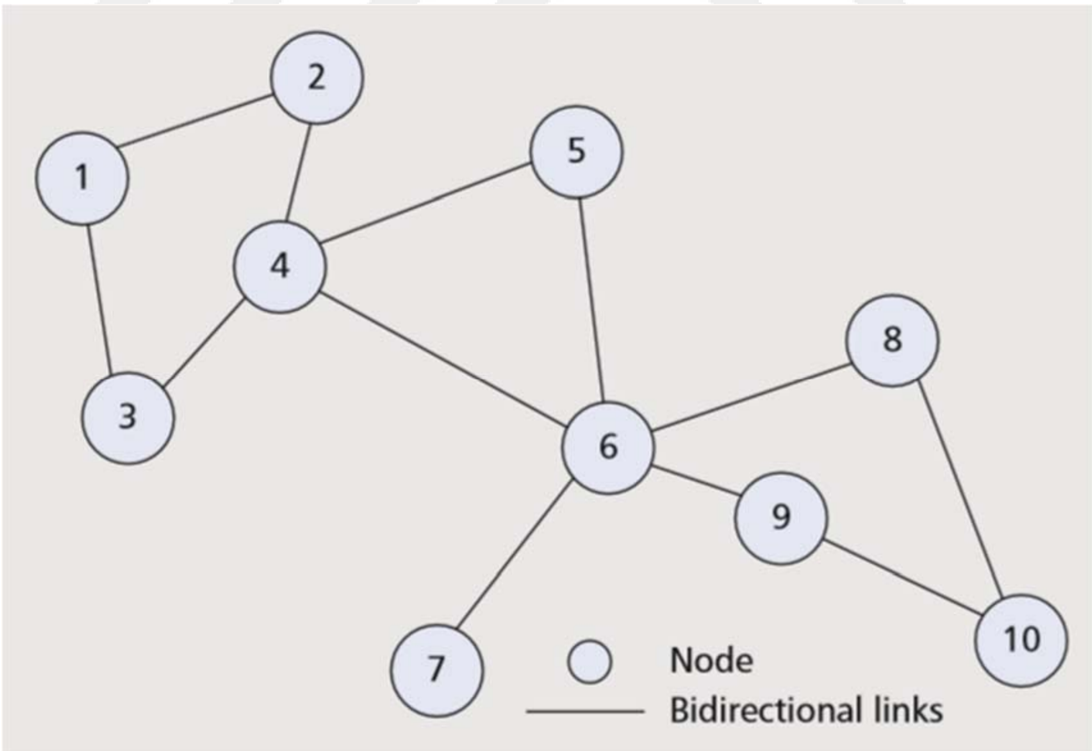


Figure 2.6: A 10-node network without malicious attack.

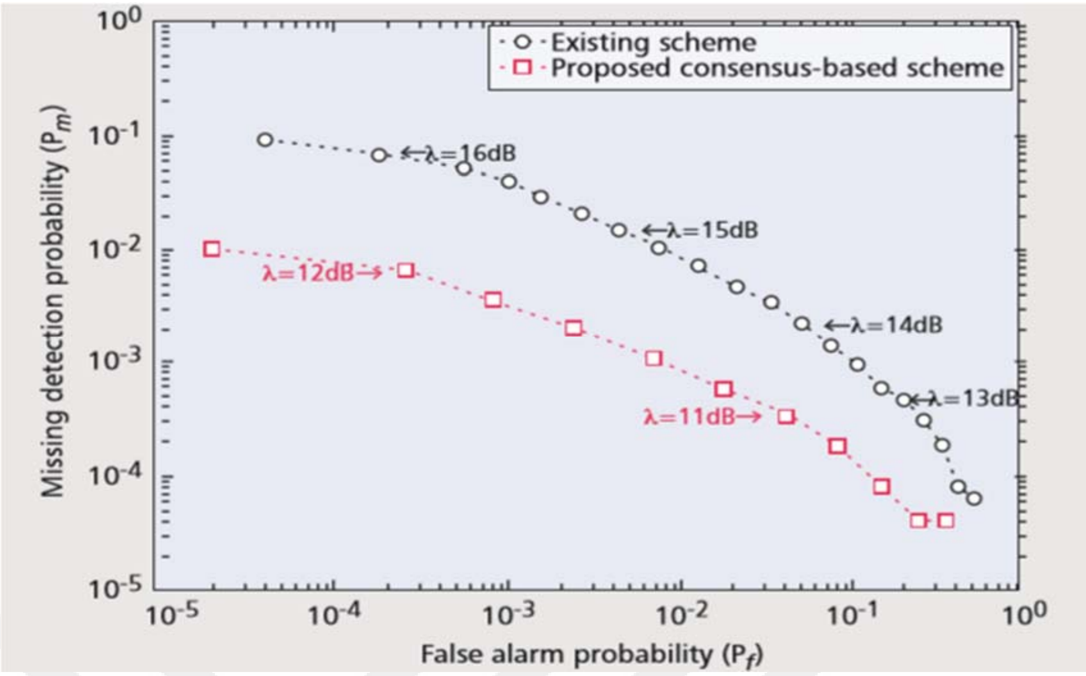


Figure 2.7: Missing detection probability (Pm) vs. false alarm probability (Pf) in the 10-node network without malicious attack.

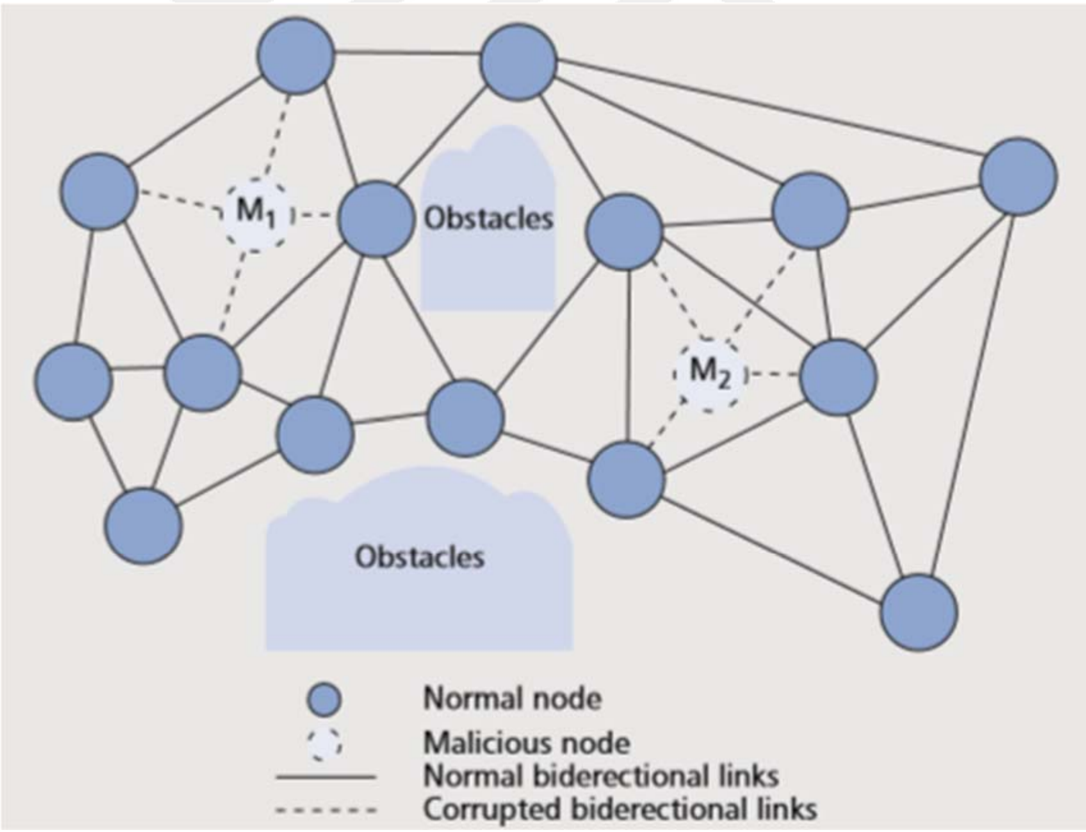


Figure 2.8: A 17-node MANET with two malicious SSDF attacks.

In [22], the drawbacks and new implementations of CR technologies have been shown. The process of cooperative spectrum sensing, which is gathering information from several groups of secondary users and processing them with iterations and comparison, have been explained, alongside with attacks, which are selfish SSDF, confusing SSDF and interference SSDF have been shown and explained, and several ways to counter the specific type of attacks have been shown and simulation results were featured. It was shown that the missing detection probability and false alarm probability reducing could be shown by comparing the proposed scheme with an existing scheme. It was also shown that the trustworthiness of the spectrum sensing may differentiate, varying according to the proposed schemes, and make the system stronger against several SSDF attacks [22].

CHAPTER THREE

GENETIC ALGORITHM

3.1 Introduction

An algorithm is a series of organized steps that describe the process that must be followed to solve a specific problem.

Genetic algorithms are part of the evolutionary algorithms, which also include evolution strategies, the evolutionary programming and genetic programming [31].

The 2006 antenna of the NASA ST5 spacecraft. This complicated form was found by an evolving computer design program to create the best radiation pattern. It is known as an evolved antenna.

In the 1970s, with the help of John Henry Holland, one of the most promising lines of artificial intelligence emerged, that was genetic algorithms, (GA) [32, 33].

These algorithms make a population of individuals that evolve by subjecting them firstly, to random actions similar to those that act in the biological evolution, then to a selection according to some criterion, a function that decides which of the individuals are more adapted, that survive, and which ones less adapt, those discarded.

Genetic algorithms are framed within evolutionary algorithms, which also include evolutionary strategies, evolutionary programming, and genetic programming.

The problem defines an environment in which there is a certain population of individuals. Each one of the individuals is assigned a certain set of information constituting its genotype, which is the basis for creating the phenotype. The phenotype is a set of features subjected to the assessment of adaptive function, modeling the environment. In other words, the genotype characterizes the suggested solution to the issue, and the modification function estimates how good this solution is.

The genotype consists of chromosomes, where the phenotype and possibly some auxiliary information for the genetic algorithm are encoded. The chromosome consists of genes.

Common features of evolutionary algorithms that distinguish them from other traditional optimization methods are:

1. The use of genetic operators that are adapted to the form of solutions,
2. Processing a population of solutions, leading to parallel search of space solutions from different points,
3. In order to direct the search process, the quality of current solutions is sufficient information,
4. Intentional introduction of random elements.

Coding is a very important stage in the design of algorithm. The method of chromosomes coding information, about the proposed solution, greatly affects the speed and quality of the results. The reason for this phenomenon is the impact of coding on the way that the solution space is searched. Bad coding can cause that you will never search the space where the best solutions are. The most commonly used chromosome encoding, gene vector, each of them can be a one-bit or multi-bit integer, or a real number and uses woody data structures.

There are many selection methods. For example, you can present the so-called roulette method. We are constructing a virtual circle; the sections are done according to the corresponding of individuals. The best one of the individuals is the largest section of the circle occupies. The size of the slices may depend on the value of the assessment function if the value of the mark is high it means high adaptation. In such a pattern, the individual that has better probability will be chosen as its parent is greater.

Unfortunately, the evolution of such an algorithm slows down with each step. If the individuals are similar, then each one receives an equal slice of the wheel of fortune and the selective pressure drops. The algorithm is less able to distinguish between good and weak individuals.

The ranking method is devoid of this disadvantage. We calculate the assessment function for each individual and set it in the best-worst rank. The first one on the list gets the right to reproduce, and the rest are removed from the population. The disadvantage of this method is its insensitivity to the differences between successive individuals in the queue. It may turn out that the neighboring solutions have different values of the assessment function, but they get almost the same amount of offspring.

There are also methods for multi-criteria selection. We create several different assessment functions (assessing some selected characteristics of individuals separately). For example, individuals can be arranged not in one, but in several ranks the best-worst, and the selection process will be more complex.

As you can see, selection gives a higher probability of reproduction to individuals with high adaptation, so subsequent generations are getting better adapted. However, the diversity of the population genotype decreases - the population with time becomes monopolized by slightly different (or even identical) variations of the same individual. This is manifested in the convergence of successive, best solutions to a certain limit. Sometimes the convergence is premature, and the evolution gets stuck and the solutions obtained represent some local extrema. They may be far from the expected global solutions, i.e. the best ones in the entire searched space. A partial solution to this problem is a random mutation for the genotype of individuals.

3.1.1 Operation

Genetic algorithms (GA) works between a set of solutions about a problem called phenotype, and a set of individuals about a natural population, coding the information of each solution in a chain, usually binary, called chromosome. The symbols that make up the chain are called genes. When the representation of the chromosomes is done with strings of binary digits it is known as genotype. The following generations (new chromosomes) are generated by applying the genetic operators repeatedly, these are the selection operators, crossing, mutation, and replacement.

The genetic algorithms are proven effective in case of wanting to calculate non-derivable functions (or very complex derivation) although its usage is possible with any function [34].

The following considerations should also be taken into account:

If the function to be optimized has many local maximums/minimums, more iterations of the algorithm will be required to "ensure" the global maximum/minimum.

If the function to be optimized contains several points that are very close in value to the optimum, we can only "ensure" that we will find one of them (not necessarily the optimum) [35].

3.1.2 Operation of a Basic Genetic Algorithm

In general, the pseudo code consists of the following steps:

a. Initialization: he initial population is generated randomly, which is constituted by a set of chromosomes that represents the possible solutions to the problem. If it is not done randomly, it is important to ensure do it within the initial population, you have the structural diversity of these solutions to have a representation of as much of the population as possible or at least avoid premature convergence [36].

a) Evaluation
b) Term condition
c) Selection
d) Recombination or crossing
e) Mutation
f) Replacement

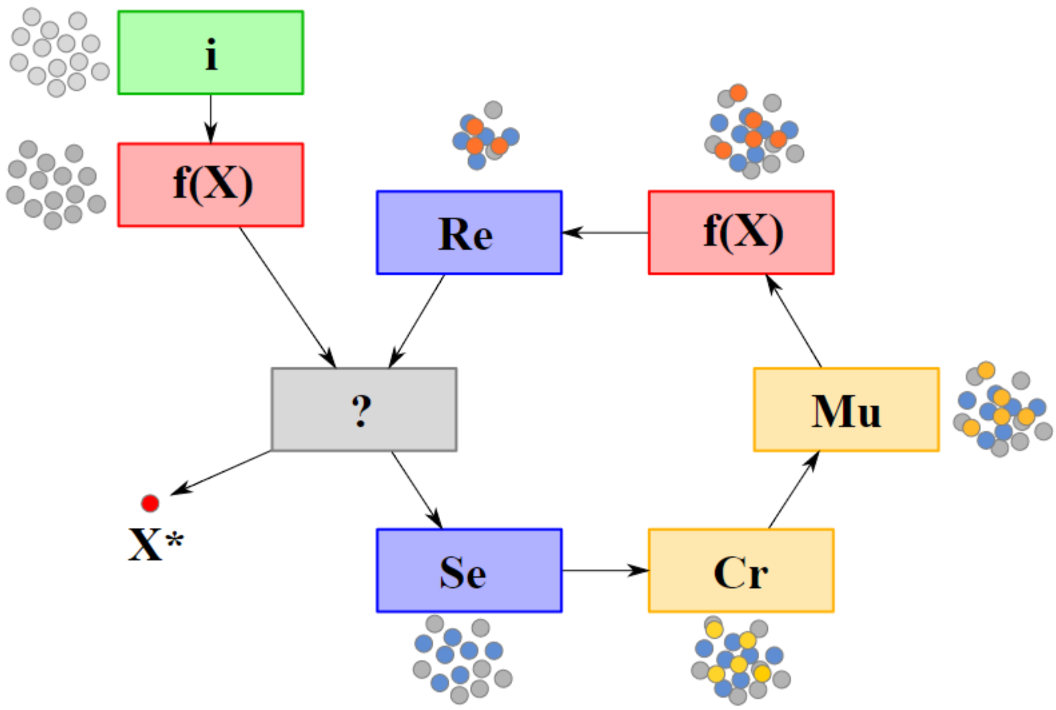


Figure 3.1: Genetic Algorithm i: initialization, f (X): evaluation, Term condition, Se: selection, Cr: crossover, Mu: mutation, Re: replacement, X *: best solution.

3.1.3 Disadvantages and Limitations

For problems of high complexity, the evaluation function can become too costly in terms of time and resources. For example, there are some cases in real life which recreates a simulation of the solution proposed by an iteration that may take many days and consume a large amount of processing and associated resources. There may be cases which depend on the parameters used for the evaluation, the algorithm may not converge on an optimal solution or ends in a premature convergence with unsatisfactory results (premature convergence could mean a convergence in a local optimum or arbitrary point affecting long-term results).

It said that they do not have a good scalability with complexity, for example, the systems that are composed of many variables, components or elements, their respective search space grows exponentially due to, among other things, the relationships that may arise, therefore the problem of the design of an aircraft must be broken down into simple representations, such as aerodynamic profiles, taking into account that the recombination of the elements can impair individual performance. The solution is "better" only in comparison to other solutions, so it is not very clear when the criterion stops because there is no specific solution.

It is not advisable to use them with problems that seek for answers to other problems that converge in simple solutions like Correct / Incorrect, the algorithm will hardly converge and the result will be as valid as in random selection. The design, the creation of the fitness function (fitness) and the selection of the criteria of mutation among others, need some expertise and knowledge of the problem to obtain good results [37, 38].

3.1.4 Applications

a) Automated design, including research in materials design and multi-objective design of automotive components: better shock-resistance, weight savings, aerodynamic improvement, etc.
b) Automated design of the industrial equipment.
c) Construction of phylogenetic trees.
d) Optimization of container loading.
e) Design of water distribution systems.

f) Design of printed circuit topologies.
g) Design of computational network topologies.
h) In game theory, balance resolution.
i) Analysis of gene expression.
j) Learning robot behavior.
k) Learning of fuzzy logic rules.
l) Elimination of ambiguity in meaning.
m) The infrastructure of mobile communications networks.
n) Optimization of molecular structures.
o) Multi-criteria production planning.
p) Prediction.
q) Application of genetic algorithms to the dilemma of the iterated prisoner.
r) Optimization.
s) Prediction.
t) Layout Optimization.
u) Prediction of RNA structure.
v) In bioinformatics, multiple sequence alignment.
w) Applications in industrial process planning, including job-shop planning.
x) Optimal selection of mathematical models for the description of biological systems.
y) Solid waste management.
z) Software engineering.
aa) Construction of schedules in large universities, avoiding class conflicts.
bb) Traveler's problem.
cc) Finding errors in programs.
dd) Optimization of production and distribution of electrical energy.
ee) Design of geodetic networks (design problems).
ff) Calibration and detection of damages in civil structures.

3.1.5 Genetic Operators

The next step is to generate a population for the second generation, solutions of the selected ones through a combination of genetic operators: chromosomal intercrossing (also called crossover or recombination) and mutation [37, 39].

Each cycle (each generation) is subjected to "processing" with the help of evolutionary operators. The goal of this stage is to generate a new generation based on the previous one, which may be better suited to the intended environment.

The cross-breeding operator is supposed to combine features from different individuals in different combinations, and the operator of the mutation is to increase the diversity of these individuals. The participation of each algorithm in the class of genetic algorithms is mainly determined by using of the crossover operator and works with entire populations of individuals (the idea of randomly linking the genotypes of non-randomly selected individuals). The mutation operator is equally important, if crossbreeding is a way of exploiting the solution space, then the mutation is a way to explore it.

An example about hybridization of binary-encoded chromosomes in genetic algorithms is shown in figure 3.2.

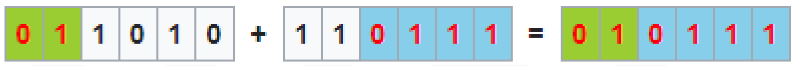


Figure 3.2: Hybridization of binary-encoded chromosomes in genetic algorithms.

Crossing involves combining some (randomly selected) genotypes into one gene. Pairing is to make the offspring of two parents have a set of features that is a combination of their traits.

The method of crossing depends on the chromosomal coding and the specificity of the problem. However, you can indicate several standard methods for crossing: cutting two chromosomes and creating a new one by gluing the left part of one parent with the right part of the second parent (for chromosomes with binary and integer coding), applying logical operations (binary coding), calculating the average number of genes (real numbers coding).

Mutation introduces random changes to the genotype. Its task is to introduce diversity in the population, i.e. to prevent (at least partially) the premature convergence of the algorithm. The mutation occurs with some accepted probability, usually in the order of 1%. It is low because, too strong mutation brings the opposite effect to the intended one, instead of subtly differentiating good solutions, it destroys them. Thus, in the process of evolution, the mutation is of secondary importance, especially in the case of long chromosomes. In the case of binary-coded chromosomes, two genes are usually drawn and changed in places or, for example, they negate a selected gene.

In the case of genotypes encoded with integers, permutations are used. In the case of genotypes encoded with real numbers, random changes to a given distribution are introduced into random genes, usually normal ones.

CHAPTER FOUR

SIMULATION RESULT AND DISCUSSION

4.1 Proposed Method

In this thesis, we used the genetic algorithm for routing the wireless sensor network.

The data which used in this thesis is shown in table 4.1.

Table 4.1: The parameter and their value.

Parameter	value
xm	100 [m]
ym	100 [m]
Sink.x	50 [m]
Sink.y	50 [m]
Number of Nodes in the field	100
Initial Energy	0.5 Joule
Energy of transmitter	50*0.000000001
Energy of receiver	50*0.000000001
Energy of free space	10*0.000000000001
Energy of multi path	0.0013*0.000000000001
Energy of Data Aggregation Energy	EDA=5*0.000000001
Percentage of nodes than are advanced	0.1
maximum number of rounds	4000

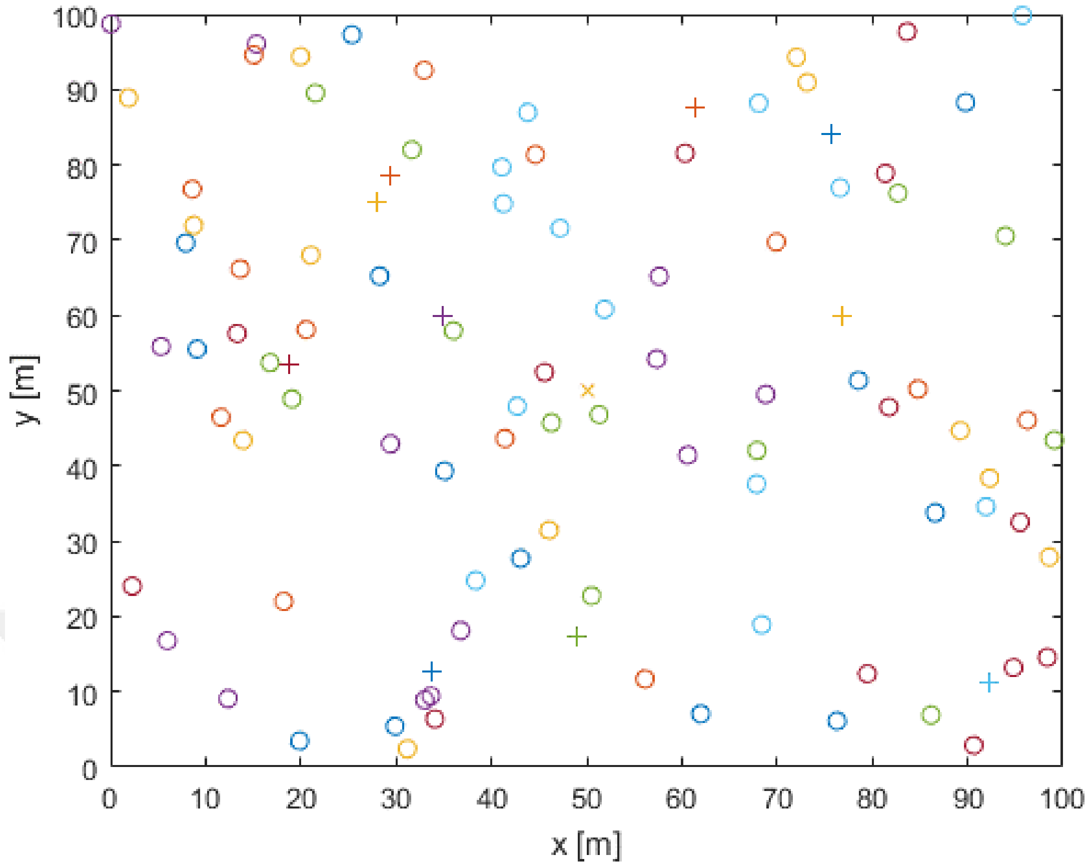


Figure 4.1: Initial area for the proposed method.

In the setup step, we used the counter for bit transmitted to Bases Station and to Cluster Heads. Also in beginning, all values are tuned to zero. For the nodes, we used the normal nodes and advanced nodes. The normal nodes have 0.5 Joule energy but the advanced nodes have 1 Joule energy. This method is followed by the stable election protocol method. With this method, we can use and save more energy in the network.

4.2 Fuzzy Structure

For the fuzzy, we used the fuzzy toolbox in the Matlab. This tool is shown in figure 4.2.

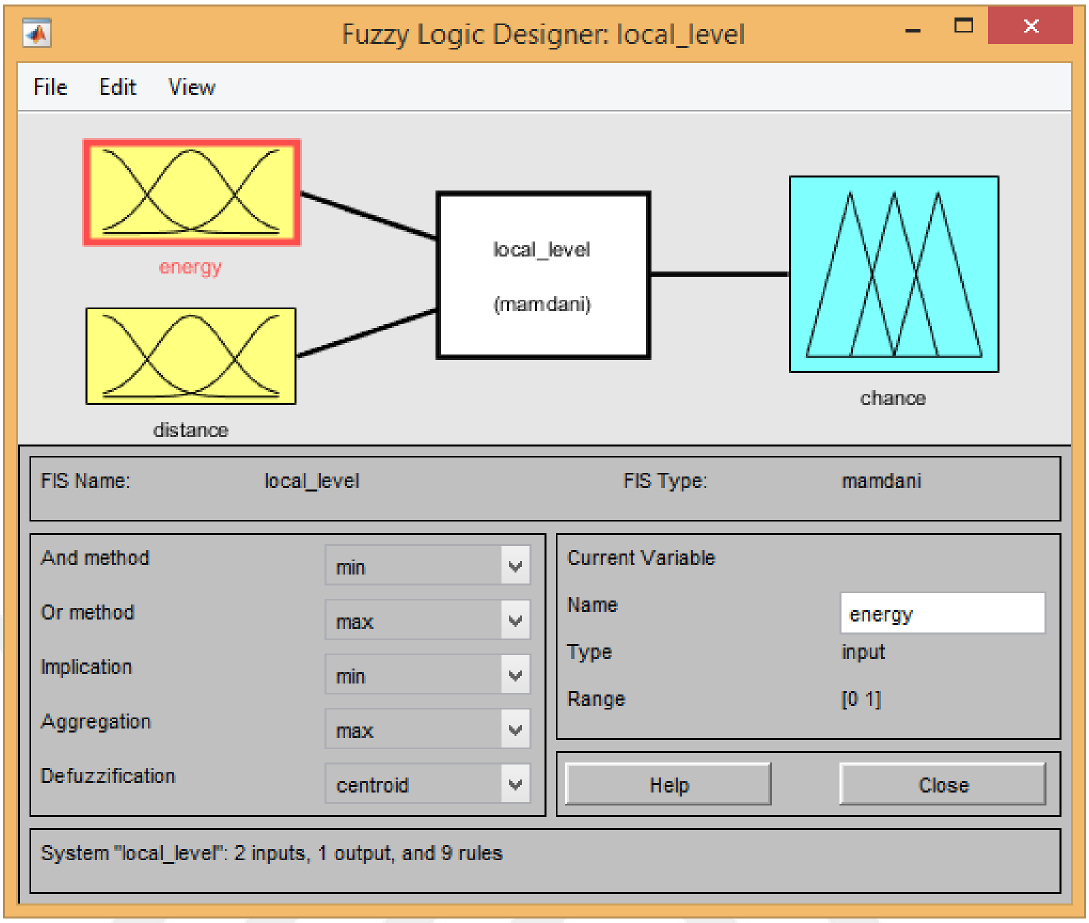
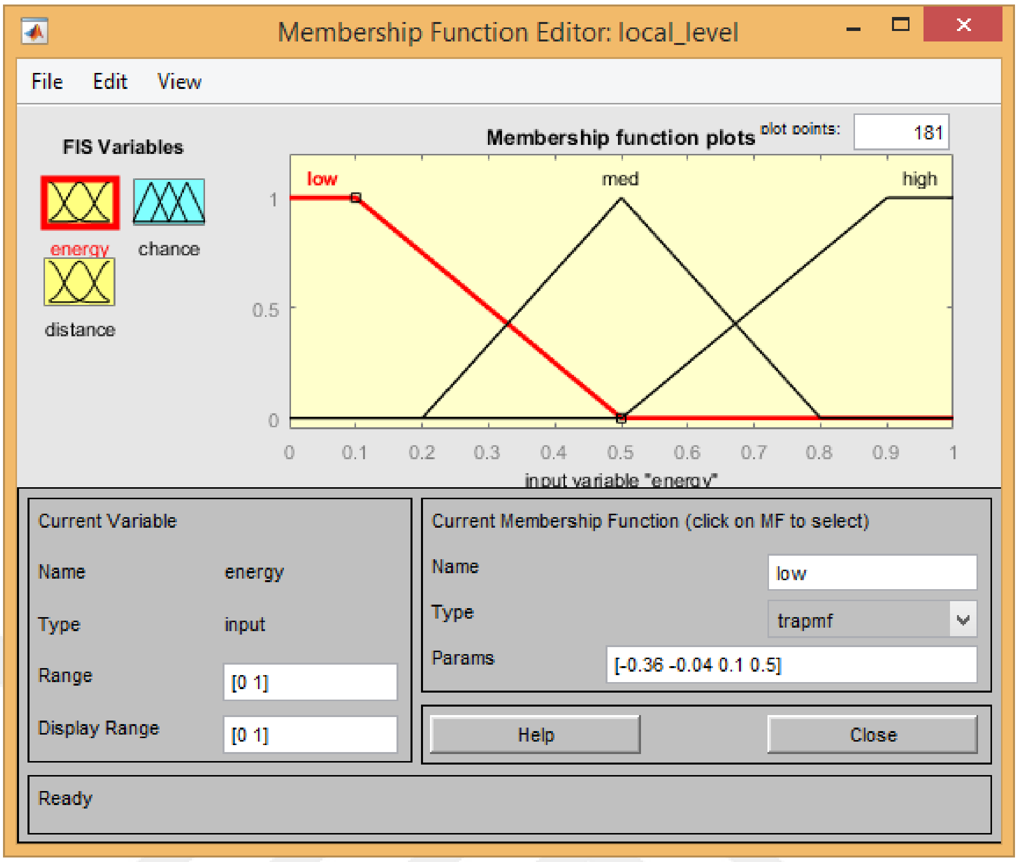


Figure 4.2: Fuzzy toolbox which used for getting the probability value.

As shown in this figure we used the Mamdani fuzzy model with two inputs and one output. For the input, we used the energy and the distance vectors. For output, the probability value or the chance value is selected.

For the membership function of the inputs and outputs, we used the triangular membership function.

This scenario is shown in figure 4.3.


Membership Function Editor: local_level
File
Edit
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FIS Variables
energy
chance
distance
Membership function plots
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1
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0
0
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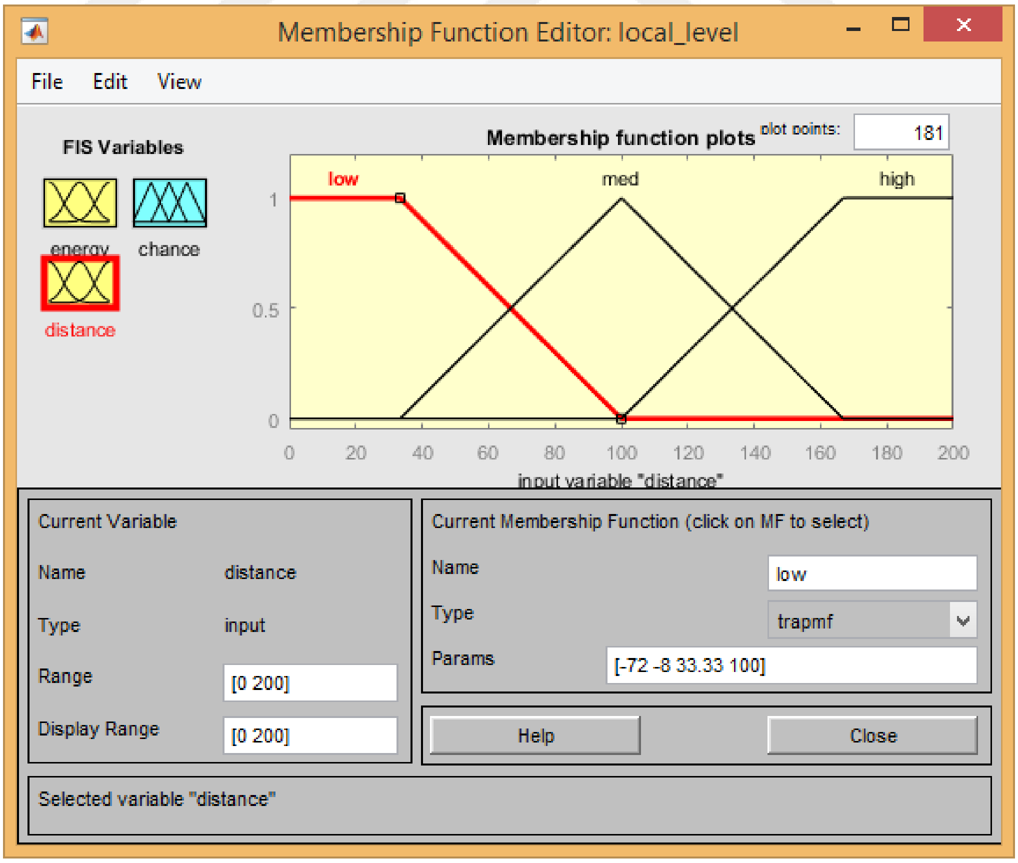
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
input variable "energy"
Current Variable
Name
energy
Type
input
Range
[0 1]
Display Range
[0 1]
Current Membership Function (click on MF to select)
Name
low
Type
trapmf
Params
[-0.36 -0.04 0.1 0.5]
Help
Close
Ready

(a)


Membership Function Editor: local_level
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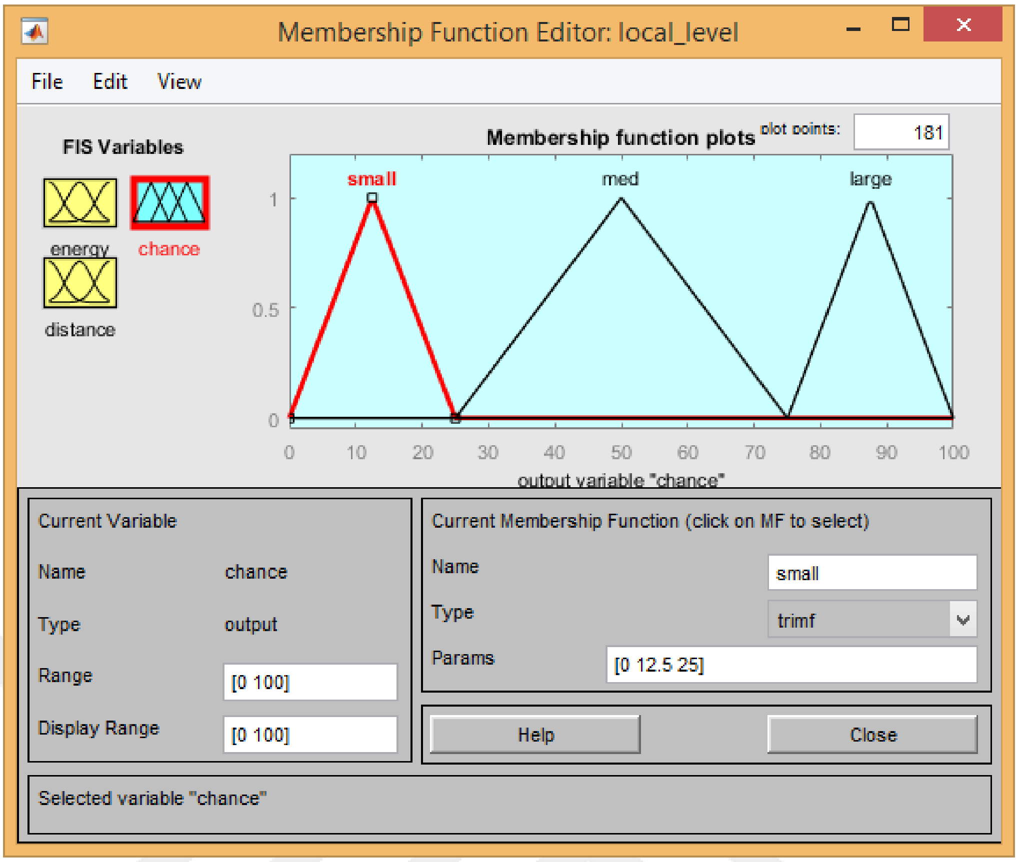
80
100
120
140
160
180
200
input variable "distance"
Current Variable
Name
distance
Type
input
Range
[0 200]
Display Range
[0 200]
Current Membership Function (click on MF to select)
Name
low
Type
trapmf
Params
[-72 -8 33.33 100]
Help
Close
Selected variable "distance"

(b)



(c)

Figure 4.3: Membership function for the a) Energy, b) Distance and c) Probability value.

We selected three ranges for both inputs and outputs. For the energy, the range is selected between 0 and 1. For the distance, the range is selected between 0 up to 200. Finally, the probability range is selected between 0 to 100. Also, small medium and high are selected for all ranges. The parameters of the triangular membership function are selected randomly but these data values are depended on the results of the program.

The surface of the rules is shown in figure 4.4.

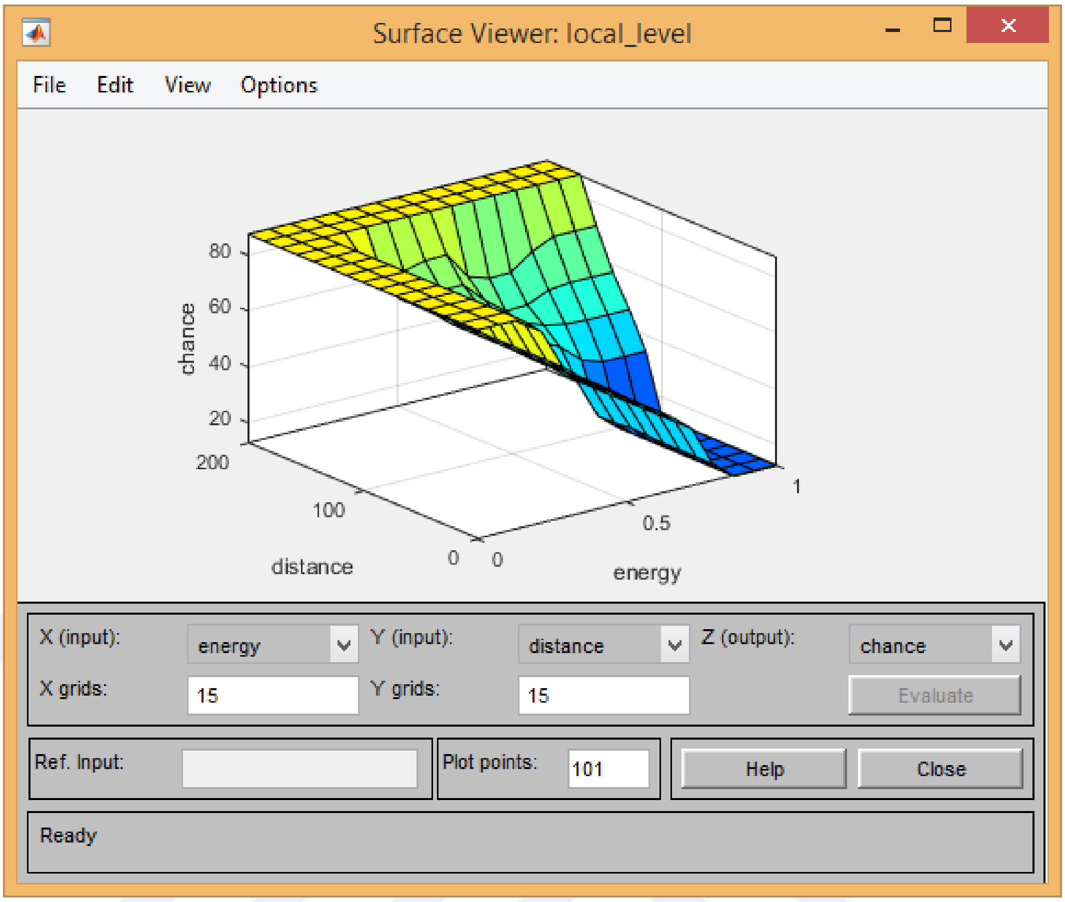


Figure 4.4: Surface of the rule

As shown in this figure the chance or probability of the cluster head is depended on the energy and distance. For example, when the energy is low and the distance between sensor and sink is low then the chance is low, this chance presents the value of the probability for the CH. If the chance value is high, then the sensor will be a cluster head but if it is low then the sensor may not be a cluster head

The rules of the fuzzy system is shown in figure 4.5.

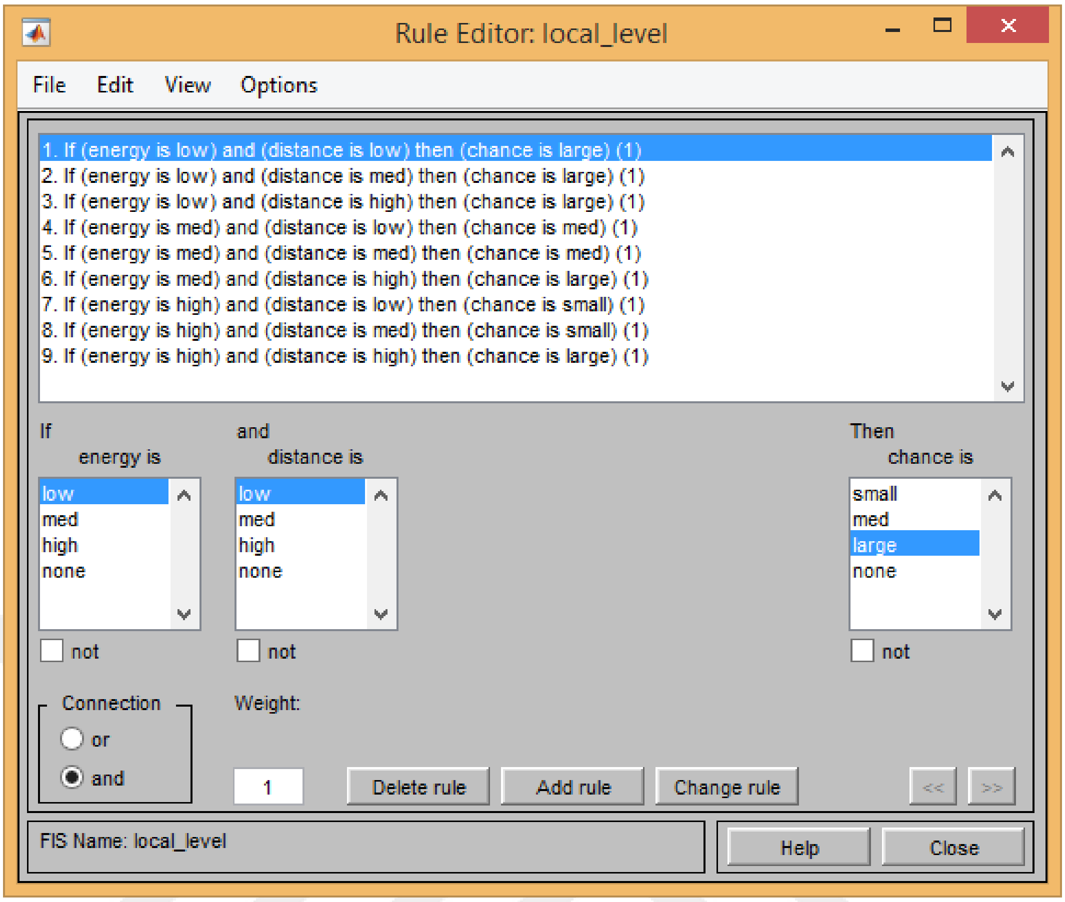


Figure 4.5: Rules for the fuzzy system.

In this thesis, we chose 9 rules. Because we have three stages for each input. These three stages are small, medium and high.

The specification of the fuzzy which we used in this thesis is as follow:

```
[System]
Name='local_level'
Type='mamdani'
Version=2.0
NumInputs=2
NumOutputs=1
NumRules=9
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

[Input1]
Name='energy'
Range=[0 1]
NumMFs=3
MF1='low':'trapmf',[-0.36 -0.04 0.1 0.5]
```

```
MF2='med':'trapmf',[0.2 0.5 0.5 0.8]
MF3='high':'trapmf',[0.5001 0.9 1.13 1.45]

[Input2]
Name='distance'
Range=[0 200]
NumMFs=3
MF1='low':'trapmf',[-72 -8 33.33 100]
MF2='med':'trapmf',[33.33 100 100 166.7]
MF3='high':'trapmf',[100 166.7 206.7 270]

[Output1]
Name='chance'
Range=[0 100]
NumMFs=3
MF1='small':'trimf',[0 12.5 25]
MF2='med':'trapmf',[25 50 50 75]
MF3='large':'trimf',[75 87.5 100]

[Rules]
1 1, 3 (1): 1
1 2, 3 (1): 1
1 3, 3 (1): 1
2 1, 2 (1): 1
2 2, 2 (1): 1
2 3, 3 (1): 1
3 1, 1 (1): 1
3 2, 1 (1): 1
3 3, 3 (1): 1
```

With this values, we got good results and the accuracy of the alive nodes versus the round was better than the LEACH method. Which in the future step we will compare the results.

4.3 Genetic Algorithm Structure

For the genetic algorithm, we used the clustering cost as the:

$$z = \sqrt{(Sink.x - X)^2 + (Sink.y - Y)^2} \tag{4.1}$$

The genetic parameter which we used in this thesis is shown in the table 4.2.

Table 4.2: Parameter which used in the GA.

Parameter	**Value**
Maximum Number of Iterations	5
Population Size	100
Crossover Percentage	0.8
Number of Offspring	2*round(0.8*100/2)
Mutation Percentage	0.3
Number of Mutants	round(0.3*100)
gamma	0.2
Mutation Rate	0.02
Selection Pressure	8

After selecting the parameters, the initialization value is done. The steps of the Genetic algorithm are illustrated in following steps.

1. Initialize Position
2. Evaluation
3. Sort Population
4. Store Best Solution
5. Array to Hold Best Cost Values
6. Store Cost

The parent index will calculate by:

$$p = \frac{e^{\frac{-\beta C}{W_c}}}{\sum e^{\frac{-\beta C}{W_c}}} \quad (4.2)$$

In this equation, the β is the Pressure Selection, C is the Costs, and the w_c is the Worst cost.

In the main loop, we have the following steps:

1. Crossover
2. Select Parents Indices
3. Select Parents
4. Apply Crossover

5. Evaluate Offspring
6. Mutation
7. Select Parent
8. Apply Mutation
9. Evaluate Mutant
10. Create Merged Population
11. Sort Population
12. Update Worst Cost
13. Truncation
14. Store Best Solution Ever Found
15. Store Best Cost Ever Found

The results of GA after the first iteration is shown in figure 4.6.

As shown in this figure from the first iteration up to the 4th iteration the best cost is 0.1654, in the last iteration this value is 0.05395.

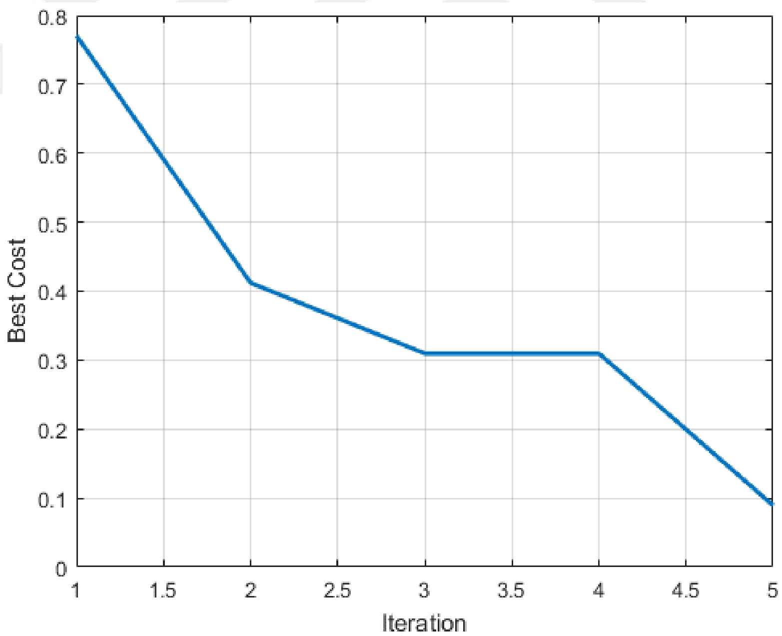


Figure 4.6: The result for the GA after first round.

After this step, we have done the cluster formation by Fuzzy. Then we will check the cluster head counter by Fuzzy.

The alive node situation is shown in figure 4.7. As shown in this figure the result of the proposed method is better than the LEACH method. In LEACH method, the first node starts to die in round 507 and all nodes are dead in round 759. In the proposed method, the first node is dead in 801 and the last node is dead in round 4000. This situation is shown in figure 4.8. As shown in this results our method is better than the LEACH method.

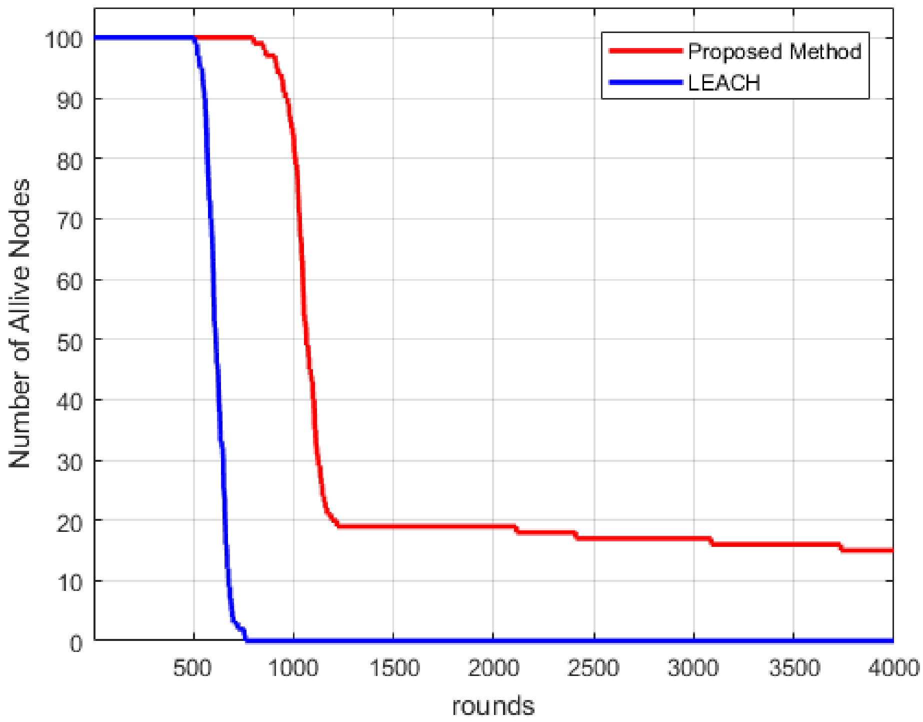


Figure 4.7: Number of alive node vs. rounds.

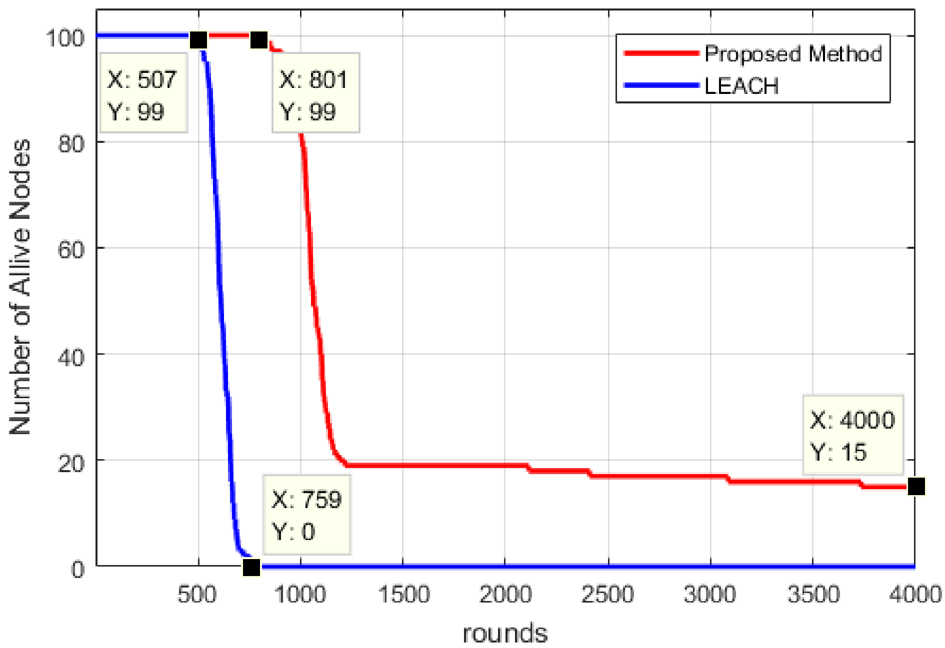


Figure 4.8: The sensitive point for deaden the nodes.

The result of the packet transmitting to the base station vs. number of rounds is shown in figure 4.9.

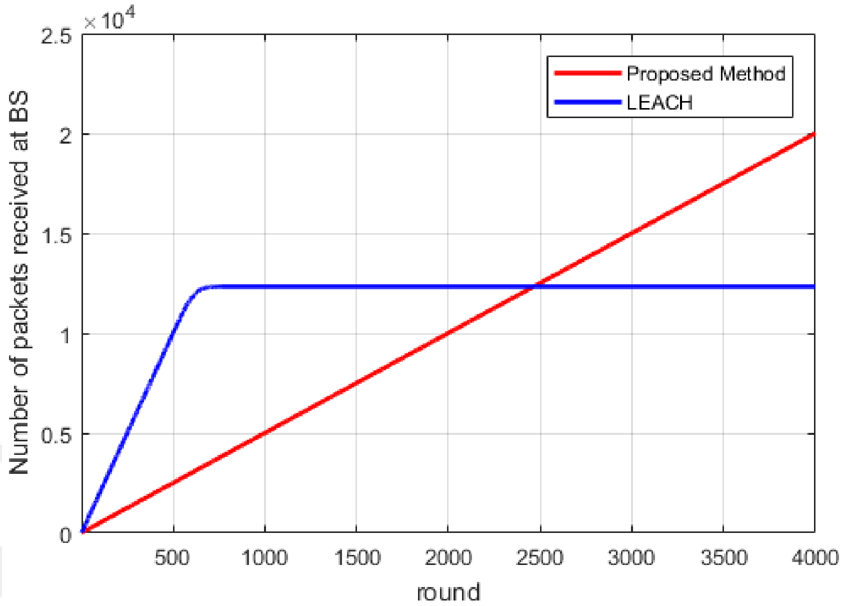


Figure 4.9: Packet to Base station vs. number of rounds.

As seen in this figure the proposed method sends more information than the LEACH method to the base station. This is the advantage of our method that makes it better than the other methods.

The cost function for 100 iterations is shown in figure 4.10.

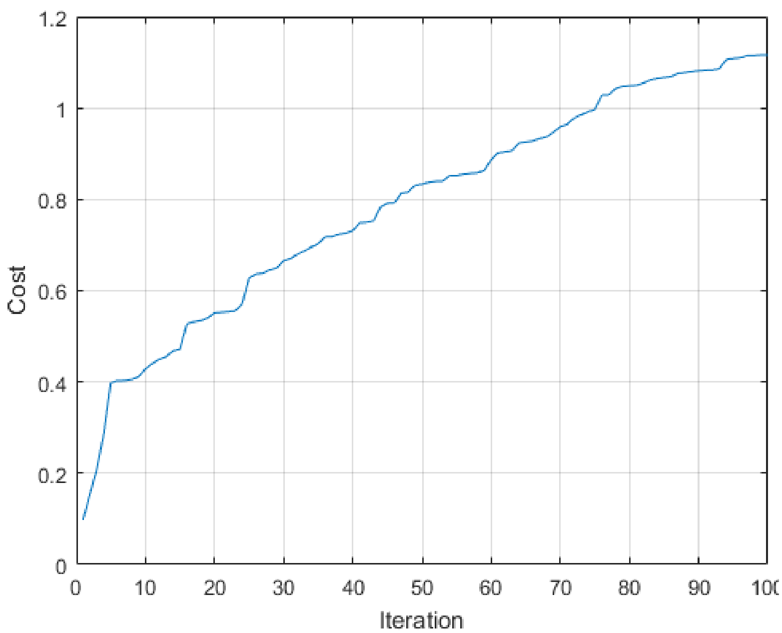


Figure 4.10: Cost function for 100 iteration.

CHAPTER FIVE

CONCLUSION

5.1 Conclusion

The most modern networks are bi-directional, which allow control of sensor activity. A mobile wireless sensor network is a wireless sensor network that the nodes of sensors are mobile. These networks are smaller than their predecessors, and much more versatile than static sensor networks and could be deployed in any scenario and face rapid technological changes. The networks of wireless sensors and actuators are used in many industrial and consumer fields, such as monitoring and control of industrial processes, health monitoring by machines, cyber-physical systems, home automation, environmental detection, etc.

In this thesis, we have proposed an energy-efficient cluster-based routing protocol, using the genetic algorithm and fuzzy logic to benefit from the least energy amount available on the network. For forming balanced clusters and choosing the best cluster heads, Mamdani fuzzy method is used. for the fuzzy, we used three rules for each input and output, small, medium and high. The overall fuzzy rules are 9, which came from, 3 (the three rules of fuzzy) to the second (we have two inputs energy and distance) power equals 9. As we mentioned above we used two inputs, one of them is the energy of each node and the other is the distance between nodes. The output of the fuzzy was the chance value of cluster heads. That means the probability of each sensor is dependent on the energy and the location of the sensors. For routing, we used the genetic algorithm. In the genetic algorithm, the maximum number of iterations used is 5. The population size that used is 100. For crossover percentage, we used 0.8. For mutation percentage, we used 0.3 also for Mutation Rate and pressure selection we used 0.02 and 8 respectively.

We used MATLAB to simulate and perform our work and find the results.

5.2 Future Works

This proposed protocol can be extended to the networks of mobile sensor nodes by making some topology changes, also trying to extend it with multi-hop routing in order to cope with large topological areas. We plan to, use Fuzzy C-means (FCM) clustering algorithm for forming balanced clusters over the network, use Adaptive neuro-fuzzy inference system (ANFIS) For selecting appropriate cluster heads (CHs), utilize artificial bee colony algorithm for optimizing the fuzzy rules that leads to prolonging the network lifetime. Also, other algorithms (e.g., PSO, ABC) could be used for the optimization of this proposed protocol.

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