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Intitulé

**Comparative study of multi-frequency protocols
for wireless sensor networks**

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CONTENTS

ACKNOWLEDGEMENTS	i
CONTENTS	ii
LIST OF FIGURES.....	iii
LIST OF TABLES.....	v
GENERAL INTRODUCTION	vi
1. GENERALITIES ABOUT WSN	1
1.1. Introduction.....	2
1.2. Definition of Wireless Sensor Networks (WSN).....	2
1.3. Architecture of layers of wireless sensor networks (Protocol Stack)	3
1.4. Topologies of Wireless Sensor Networks	4
1.5. Domains of wireless sensor network	8
1.6. Communication in WSN	11
1.7. Conclusion	13
2. MULTICHANNEL COMMUNICATION	14
2.1. Introduction.....	15
2.2. Definition of multichannel.....	15
2.3. Benefits of multichannel communication	15
2.4. The centralized approach.....	16
2.5. Hybrid channel assignment:	20
2.6. Decentralized approach.....	24
2.7. Conclusion:	29
3. IMPLEMENTATION AND EXPERIMENTATION.....	30
3.1. Introduction.....	31
3.2. Our Work:	31
3.3. Implementation	36

3.4. Implantation of methods	37
3.5. Simulation results	41
3.6. Conclusion:	47
GENERAL CONCLUSION	48
BIBLIOGRAPHY	49

LIST OF FIGURES

Figure 1.1: Architecture of WSNs

Figure 1.2: Protocol Stack of WSNs

Figure 1.3: Star topologie

Figure 1.4 : Tree topologie

Figure 1.5 : Mesh topologie

Figure 1.6 : Circular topologie

Figure 1.7: The most of application domains

Figure 1.8 : Military application

Figure 1.9 : Home control application

Figure 10 : Health-care application

Figure 1.11 : Single-hop and Multi-hop

Figure 1.11 : Single-hop and Multi-hop

Figure 2.1 : Frequency assignment in TMCP

Figure 2.2 : Comparison between TMCP and MMSN

Figure 1.3 : comparison between MCRT simple and MCRT and Node based by Deadline-based

Figure 2.4 : comparison between MCRT simple and MCRT and Node based by Inter packet time-based

Figure 2.5: EM MAC communication process

Figure 2.6 : Channel allocation in MMSN MAC protocol.

Figure 2.7: Time frame used by the MMSN protocol

Figure 2.8 : A light weight-channel hopping mechanism.

Figure 2.9 : Y-MAC protocol architecture

Figure 2.10 : Control message in Y-MAC

Figure 2.11 : Conceptual diagram of DRCS.

Figure 3.1 Channel selection

Figure 3.2 : The shortest path selection

Figure 3.3 The path selection energy-based

Figure 3.4. comparison between shortpath and energy method by Total energy consumption test 1

Figure 3.5: comparison between shortpath and energy method by Packet delivery ratio test 1

Figure 3.6. comparison between shortpath and energy method by Total energy consumption test 2

Figure 3.7: comparison between shortpath and energy method by Packet delivery ratio test 2

Figure 3.8. comparison between shortpath and energy method by Total energy consumption test 3

Figure 3.9: comparison between shortpath and energy method by Packet delivery ratio test 3

Figure 3.10 : comparison between shortpath and energy method by Dead nodes.

LIST OF TABLES

Table 2.1 : Comparison of EM MAC versus Y-MAC and PW-MAC

Table 3.1 Comparison between shortpath method and energy method .

GENERAL INTRODUCTION

Many years ago, a type of network emerged, it is called Wireless Sensor Networks (WSNs), the latter is the most interesting researches fields. this type belongs to Ad Hoc networks but with the development in the technics which are known as MEMS (Micro-Electro-Mechanical Systems), we have owned small nodes, we may make them smaller. these devices detect different things like environment, humidity, sound ...etc. the structure of these nodes varies according to its environment, it has four main units which are: processing unit, sensing unit, transceiver unit, Power unit.

This network is used in various application such as Military applications, medical applications, and industrial applicationsetc.

These nodes transmit information to single or multiple base-station. after that, they are sent to the internet, Elements of this network are cheap in cost calculating, transmission and energy saving.

Through these characteristics, protocols have been developed and many researchers have written many articles.

In the WSNs the nodes are equipped with simple radios, which usually use only one channel despite the existence of several channels offered by the standard IEEE 802.15.4 which proposes three bands of frequencies: 2.4GHz, 915MHz and 868MHz. The 868 / 868.6MHz band is composed of a single channel, the 902 / 928MHz band of 10 channels, while the 2.4 / 2.4835GHz band is made up of 16 channels.

As well as the large number of packets generated, in using a single channel, in a short period led to a high degree of contention and collisions and therefore delay in communication and consumption in addition to energy.

On the other hand, nodes with multiple radios in conventional ad hoc networks make multi-frequency communications more efficient in terms of bandwidth and end-to-end delays. Nevertheless, it consumes a lot of energy because the main source of energy consumption is the operation of sending and receiving radio [6]. For this, and in order to reduce contention effects as well as collisions while preserving maximum energy, multifrequency protocols have been developed, in recent years, especially for the WSNs based on various competitive communication techniques using an only radio that cannot transmit and receive on different channels at the same time.

GENERAL INTRODUCTION

In this memory, we are going to comparative study between two protocols, each protocol is from different classification, in this study, we used a specified simulator WSN “Jsensor” we are going to define later in chapter 03.

We have divided the structure of the thesis into 3 chapters: The first chapter presents generalities about WSN, definitions and application domains. In the second chapter we are going mention classification WSN MAC protocols according to channel. In the last chapter, we are going to evaluate simulating the performance of our method in terms of three factors: packet delivery ratio and energy consumption. Finally, we conclude our work by a general conclusion.

CHAPTER 01

1. GENERALITIES ABOUT WSN

1.1. Introduction

With technological developments, it is now possible to produce systems of very small size and carry low-cost computing and communications units. As we know WSN is network which contains a large of small nodes.in this chapter We will talk about generalities about WSNs that's mean study the most domains application and the most topologies as we will touch the means of communication in WSNs.

1.2. Definition of Wireless Sensor Networks (WSN)

Wireless Sensor Networks is are a special type of Ad-hoc network, consist of large number of small size sensor nodes having low cost distributed over a targeted region to collect the information by doing wireless communication. [1]. Since a sensor node has limited sensing and computation capacities, communication performance and power, a large number of sensor devices are distributed over an area of interest for collecting information. These nodes can communicate with each other for sending or getting information either directly or through other intermediate nodes and thus form a network, so each node in a sensor network acts as a router inside the network. In direct communication routing protocols (single hop), each sensor node communicates with a control center called Base Station (Sink) and sends gathered information. The base station is fixed and located far away from the sensors [2] shown in Figure. 1

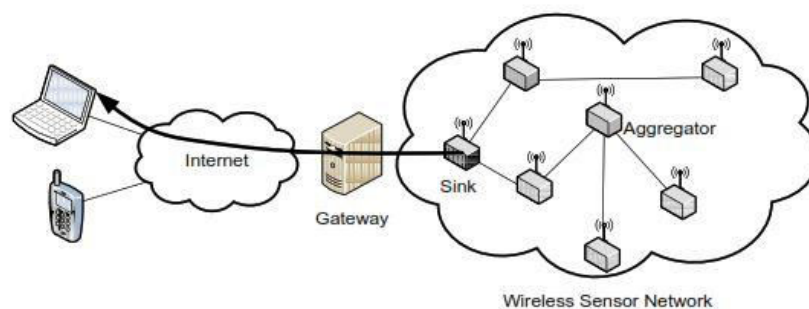


Figure 2.1: Architecture of WSNs

1.3. Architecture of layers of wireless sensor networks (Protocol Stack)

A recent survey [3] is detailed protocol stack of WSNs as flow:

The protocol stack used by the sink and sensor nodes shown in Figure. 1.1 is given in Figure: 1.2 This protocol stack combines power and routing awareness, integrates data with networking protocols, communicates power efficiently through the wireless medium, and promotes cooperative efforts of sensor nodes. The protocol stack consists of the physical layer, data link layer, network layer, transport layer, application layer, power management plane, mobility management plane, and task management plane.

1.3.1. The physical layer

addresses the needs of simple but robust modulation, transmission, and receiving techniques. Since the environment is noisy and sensor nodes can be mobile, the medium access control (MAC) protocol must be power aware and able to minimize collision with neighbors' broadcasts.

1.3.2. Data link layer

The data link layer is responsible for the multiplexing of data streams, data frame detection, medium access and error control. It ensures reliable point-to-point and point-to-multipoint connections in a communication network.

The MAC protocol in a wireless multihop self-organizing sensor network must achieve two goals. The first is the creation of the network infrastructure. This forms the basic infrastructure needed for wireless communication hop by hop and gives the sensor network self-organizing ability. The second objective is to fairly and efficiently share communication resources between sensor nodes.

1.3.3. Network layer

takes care of routing the data supplied by the transport layer.

1.3.4. Transport layer

helps to maintain the flow of data if the sensor networks application requires it. Depending on the sensing tasks.

1.3.5. Application layer

different types of application software can be built and used on the application layer. In addition, the power, mobility, and task management planes monitor the power, movement, and task distribution among the sensor nodes. These planes help the sensor nodes coordinate the sensing task and lower overall power consumption.

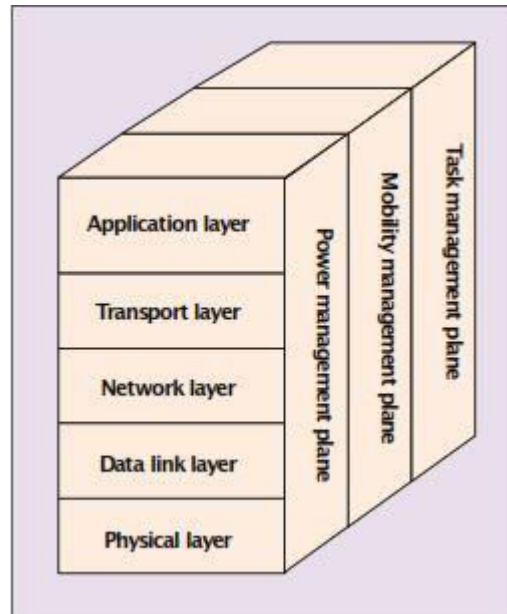


Figure 1.3: Protocol Stack of WSNs

1.4. Topologies of Wireless Sensor Networks

1.4.1. Star topology:

It is used mostly when there are few nodes in the network. The network consists of a central node, to which all other nodes are connected the central node provides a common connection point for all other nodes and coordinates the traffic. Thus, the central node is the sink node which requires that all nodes in the network are within the radio range, of the base station the nodes directly transmit the gathered data to the sink without needing other nodes to act as a relay[c4]. An example of a star network is shown in figure 1.3.

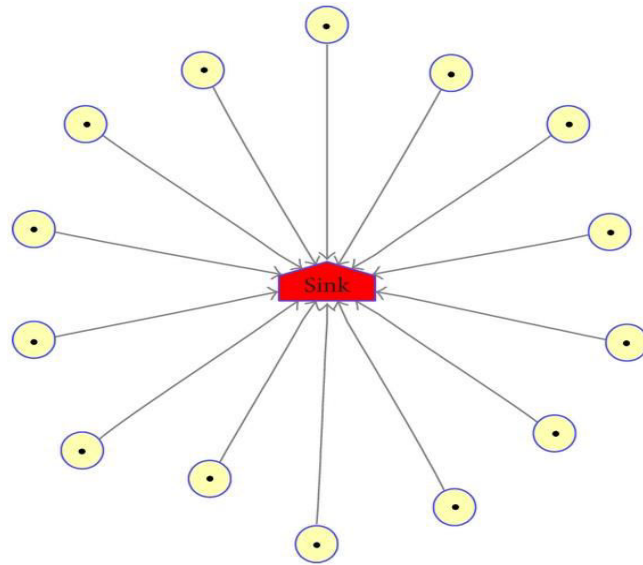


Figure 1.4: Star topology

1.4.2. Tree topology

The network uses a central hub called a root node as the main communication router. In the hierarchy, central hub is one level below from the root node. This lower level forms a star network. The tree network can be considered a hybrid of both the Star and Peer to Peer networking topologies as shown in Figure 1.4. In sensor network path may be single hop or multi hop, sensor node for getting data sense the environment and sent them to the sink and sensor forwards them to its parent after receives data messages from its children. It is important to find an optimal shortest path tree with maximum lifetime and shorter delay but slightly high time complexity and but more suitable for distributed implementation.

There is problem into the load balancing scheme at each level of the fat tree and there is communication in between two nodes. If there is a link break in the unipath on the active route then communication also breaks. [5]

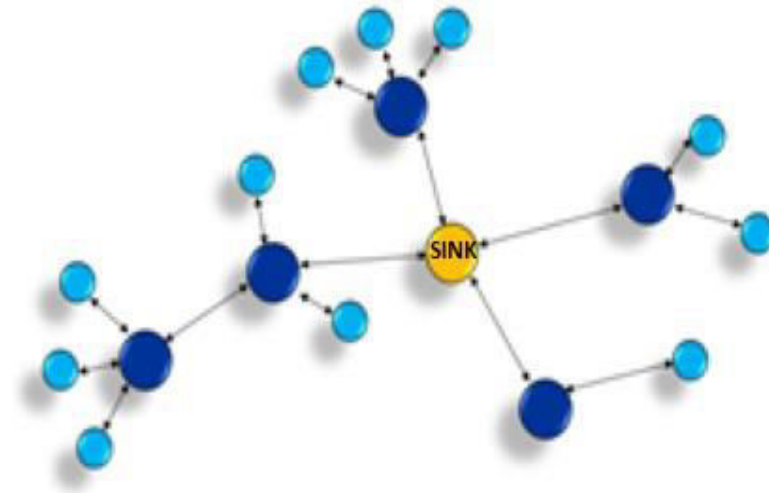


Figure 1.5 : Tree topology

1.4.3. Mesh topology

Mesh networks are the ad-hoc topology of large WSN. When a node far from the sink (not within its radio range) has data to send, the data has to be forwarded hop by hop toward its final destination. Each node has two major roles: collecting data and cooperating in order to relay data originating from other nodes. Thus, there is our hierarchy like in tree topology and all sensor nodes are supposed identical in terms of functionality. The network is self-organized. It establishes routes to the sink and builds its own topology. This type of networks raises routing and optimization challenges: Finding the best routes to the sink and balancing the traffic in an energy efficient fashion are responsibilities of the network. A mesh network whose nodes are all connected to each other is a fully connected network. An example of a mesh network is shown in figure 1.5 [4].

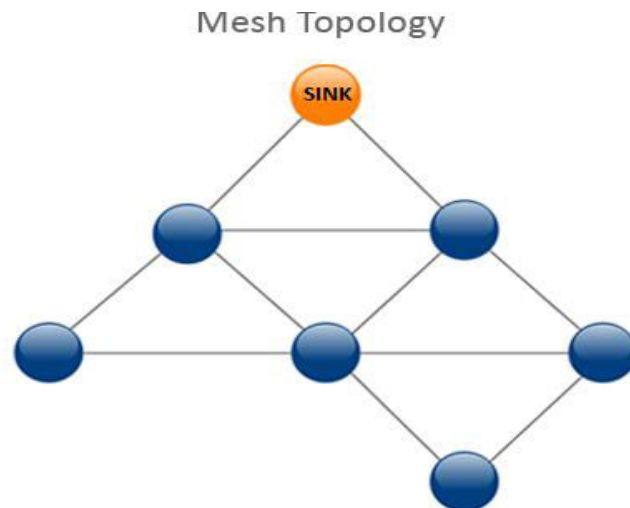


Figure 1.6 : Mesh topology

1.4.4. Circular Topology

In this topology, there is a circular sensing area and that the sensing area has a sink (at center). The sensor nodes sense the event of interest and transmit these data to the sink. The nodes are randomly deployed with uniform density all around the sink as shown in **Figure: 1.6**. Depending on the distance of a node from the sink and the transmission range of the nodes, data have to traverse single or multiple hops before being received by the sink. The circular web topology is easy to establish, easy to maintain, and more efficient. reduced. Circular topology of this routing algorithm has number of Tiers (Tier1, Tier2.). The node which is on the diagonal, follow its original path for communication. Each of these nodes has two possible paths for routing. Depending on the energy level of the path, it selects the path and forwards the packets. It is energy efficient, more packets received at sink. [5]

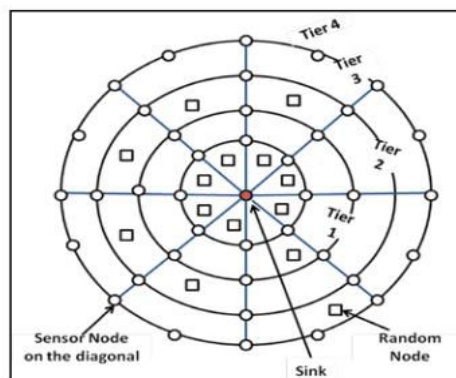


Figure 1.7 : Circular topology

1.5. Domains of wireless sensor network

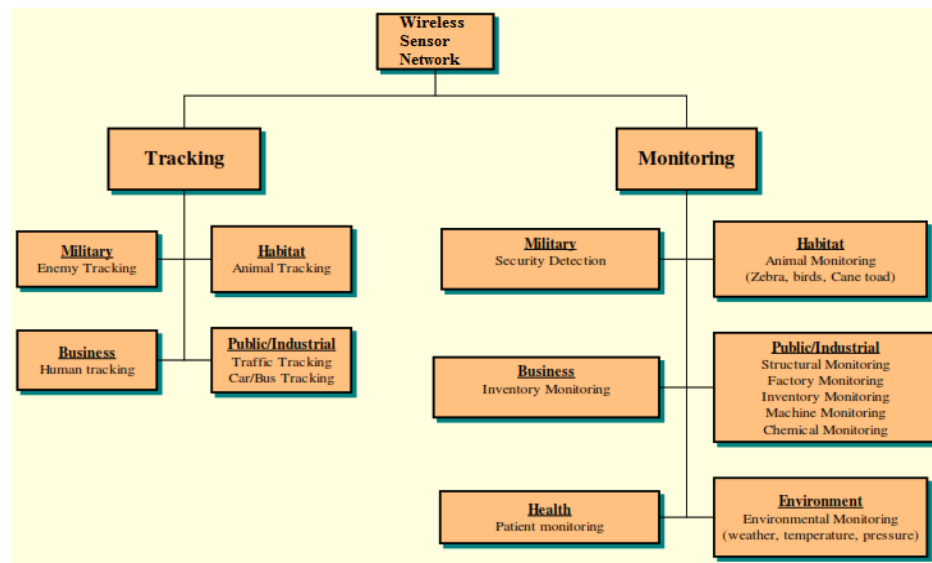


Figure 1.8: The application domains

1.5.1. Military Application

WSNs are becoming an integral part of military command, control, communication, and intelligence (C3I) systems [6]. Wireless sensors can be rapidly deployed in a battlefield or hostile region without any infrastructure. Due to the easiness of deployment, self-configurability, untended operation, and fault tolerance, sensor networks will play more important roles in future military C3I systems and make future wars more intelligent with less human involvement.

- **Battlefield Monitoring.** Sensors can be deployed in a battlefield to monitor the presence of forces and vehicles, and track their movements, enabling close surveillance of opposing forces.
- **Object Protection.** Sensor nodes can be deployed around sensitive objects, for example, atomic plants, strategic bridges, oil and gas pipelines, communication centers, and military headquarters, for the protection purpose.
- **Intelligent Guiding.** Sensors can be mounted on unmanned robotic vehicles, tanks, fighter planes, submarines, missiles, or torpedoes to guide them around obstacles to their targets and lead them to coordinate with one another to accomplish more effective attacks or defenses.

Figure 1.10 : Home control application

- Sensing applications embed intelligence to optimize consumption of natural resources.
- Sensing applications enable the installation, upgrading, and networking of a home control system without wires.
- Sensing applications enable one to configure and run multiple systems from a single remote control.
- Sensing applications support the straightforward installation of wireless sensors to monitor a wide variety of conditions.
- Sensing applications facilitate the reception of automatic notification upon detection of unusual events.

Body-worn medical sensors (e.g., heartbeat sensors) are also emerging. These are battery-operated devices with network beacons occurring either every few seconds that could be worn by home-resident elderly or people with other medical conditions. These sensors have two ongoing processes: heartbeat time logging and transmission of heart rate and other information (instantaneous and average heart rate, body temperature, and battery voltage) [8].

1.5.3. Health Care

The most of surveys are written about this domain like [19] and [9] WSNs can be used to monitor and track elders and patients for health care purposes, which can significantly relieve the severe shortage of health care personnel and reduce the health care expenditures in the current health care systems.

- **Behavior Monitoring.** Sensors can be deployed in a patient's home to monitor the behaviors of the patient. For example, it can alert doctors when the patient falls and requires immediate medical attention. It can monitor what a patient is doing and provide reminders or instructions over a television or radio.
- **Medical Monitoring.** Wearable sensors can be integrated into a wireless body area network (WBAN) to monitor vital signs, environmental parameters, and geographical locations, and thus allow long-term, noninvasive, and ambulatory monitoring of patients or elderly people with instantaneous alerts to health

care personal in case of emergency, immediate reports to users about their current health statuses, and real-time updates of users' medical records. [10]

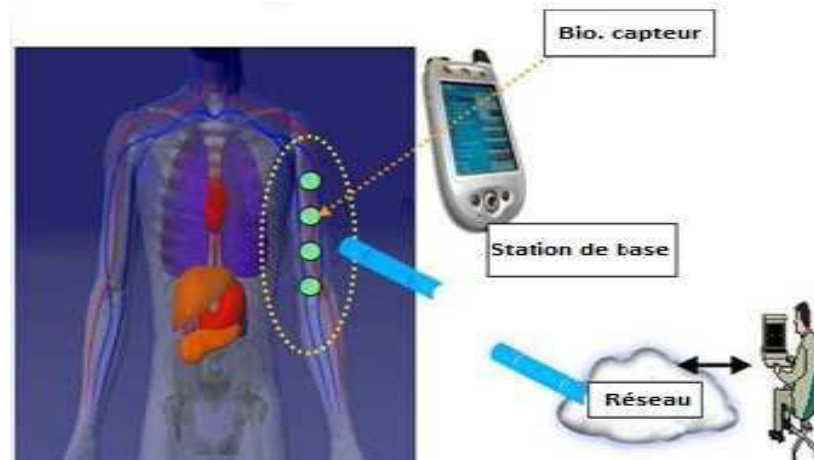


Figure 1.11 : Health-care application

1.6. Communication in WSN

When communications options and parameters are taken into account:

1.6.1. Mode Communication:

single-hop or multi-hop

- Single-hop: in that way all the sensors send the information collected directly to the BS (red circle in Figure 1.11) [11].
- Multi-hop: in that case the sensors send the data to a neighbor node (called aggregation node, light blue circle in Figure 1.11), and then those nodes collect the information and finally send them to the BS (Base-station) [12].

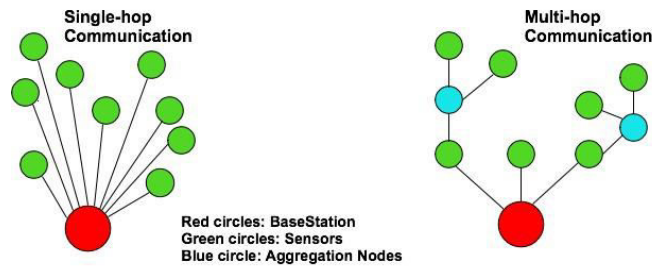


Figure 1.12 : Single-hop and Multi-hop

1.6.2. types of communication:

unicast, geocast, anycast, broadcast and multicast. There are many articles written about this point like [13] and [14].

Like types in wired network we have the same types for WSN and the same mean for each type.

Unicast: Unicast communication is used to send sensed information to a single node at destination.

Geocast: Geocast communication is used to deliver sensed data to one or more nodes lying in a specific area of the network and there are geographical restrictions in this communication rather than specific node ID.

Anycast: anycast communication when the source node distributed the data to any node in a particular network.

Broadcast: broadcast communication is used to send data sensed from node how sensed to all other node in deployment field.

Multicast: multicast when a single source node sends the packet to a group of nodes.

1.6.3. Frequency (channel):

In WSN, MAC protocols are having a single channel for communication. They are mainly focusing on energy efficiency and scalability and adaptability to changes. Some protocols like Z-MAC [23], Burst-MAC [24] still produces high throughput even if they have only single channel communication. Parallel transmissions over multiple channels can improve the throughput by eliminating the contention and interference on a single channel [15], and this discussion is the objective of chapter 02 we will be discussing about multichannel and classification of multichannel protocols.

1.7. Conclusion

After we have known some generalities about WSNs and styles of communication, we are going to take into account frequency element to study protocols of communication in WSNs in chapter 02.

CHAPTER 02

2. MULTICHANNEL COMMUNICATION

2.1. Introduction

In this chapter we will discuss about technology multifrequency and Its importance in communication in WSNs and how to reduce interferences. Channel assignment is one solution to alleviate and minimize interferences by using multiple channels. Hence, an interference model defines which set of links can be active (transmission/reception) simultaneously. This chapter discusses one of the most classification of multi-channel protocols.

2.2. Definition of multichannel

Multi-channel communication is attractive to wireless sensor networks (WSNs) as an effective approach to reducing interference and enhancing spatial reuse. Channel allocation significantly influences the performance of multi-channel WSNs. It is particularly important in WSNs employing TDMA protocols where interfering transmissions scheduled at the same time slot must be assigned different channels. It is, therefore, important to allocate the channels to reduce interference and increase the number of concurrent transmissions [16].

2.3. Benefits of multichannel communication

The benefits brought by multichannel communications can be summarized as follows [17]:

A climax accretion in parallel transmissions by Accommodating multiple channels to adjoining nodes. This will result an improvement in the network outcomes, many multichannel protocols assume the existence of a sink with multiple transceivers enabling simultaneous receptions from its children in the data gathering tree. Hence, multi-interface sinks increase parallel transmissions.

- enhance the network capacity, the latter is very limited in WSNs, and for this it must be effectively shared among the network nodes, to satisfy the application requirements.

- improve the delivery ratio of data, especially the high precedence data, such as alarms. WSN must guarantee that the high priority data reaches the sink in shortest possible time, otherwise this makes danger situations, for example an information as that the temperature value must not exceeds a given threshold, must be delivered in the possible fast time to the sink to prevent dangerous situations.

- improve the accuracy of monitoring by resulting a fresher collected data through minimizing the delay of gathering these data.

-increasing data rate; in crises conditions it is very important that the data rate must be continuously increased without interruption, such when alarms are triggered. New trends in WSN have directed the designer's consideration towards application with high data requirements.

-improve robustness especially when interference occurs. the multichannel protocols widen the chance to use multiple channels to prevent channels with high level of fuss, resulting that the chosen channels are more robust and clear.

A recent surveys classified the different channel assignment strategies in WSNs into three categories: centralized channel assignment, decentralized channel assignment and hybrid channel assignment. We will explain it below:

2.4. The centralized approach

The centralized ones require knowledge of the whole network's topology the channel and slot allocation for the whole network is managed by a central node responsible for planning all the transmissions [18]. a central node performs all the necessary computations. Therefore, all information related to network topology on each channel, conflicting nodes and routing graph should be forwarded to this entity. These solutions generally perform a centralized or hybrid channel assignment. Some studies aim at maximizing the throughput or minimizing the interferences. A centralized channel assignment can be envisioned for small topologies of WSNs (50 sensors) that do not exceed three hops [17].

Centralized channel assignment: The basic idea of Centralized channel assignment approaches is to cluster the nodes and each cluster only uses a single channel, which is different from the channels that are assigned to the other clusters that may cause interference. The main advantage of Centralized channel assignment approaches is the ease of implementation since the dynamics due to channel switching and variations in the network topology are not considered. However, Centralized channel assignment enforces the nodes to keep their interfaces on a particular channel leading to some drawbacks such as nonadaptive to dynamic network conditions and unable to communicate if transceivers of two neighboring nodes are Centralized on different frequencies. Vedantham et al. [21] came up with rather different idea from clustering, however with Centralized channel assignment. They introduced the concept of component-based channel assignment induced by a flow graph between sources and destinations. All links in the connected components are assigned a single channel and operate on the same channel throughout [20].

2.4.1. TMCP (Tree-based Multi-Channel Protocol):

In communication WSNs, most of data collection schemes proposed some tree structure connecting between the base-station and nodes, and forward the data along the tree, but this proposition with mono-channel transmission collision occurs in the tree and flow congestion nodes this problem or this collision reduce the performance of this network. for that, the researcher proposed protocol multichannel and based in tree schemes TMCP [34]. The main idea of protocol TMCP is separate the whole network into multiple sub-tree and assign channel for each sub-tree, then forwards the data flow to corresponding sub-tree as shown in **Figure 2.1**.

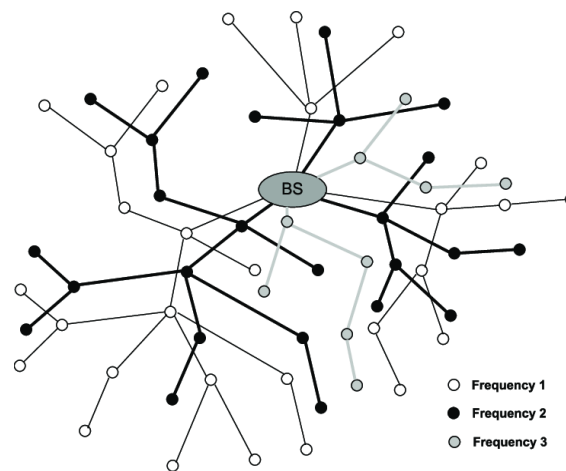


Figure 2.1: Frequency assignment in TMCP

The central node or the Sink share the network to other groups of subtrees with execute the PMIT algorithm. This algorithm first applies a Breadth-First search algorithm to build a tree rooted at the base station. There are two important properties of the fat tree. First, nodes keep their height and have multiple parents on the fat tree. Second, the fat tree is actually the shortest path tree, where branches from the base station to each node are paths with the least hop count, because we use a BFS strategy to build the tree.

After that its execute channel assignment for each level and process the nodes with fewer parents or in other words choose an optimal tree to add node .for choosing the tree .first the tree connects with the node and this node reduce the interference for this tree , in situation multiple trees tie ,selects the tree when having fewer parents .if the node is connected ,it chooses one of parents how has the least interference value among all possible parents within the tree selected. and when a node gets a channel, the algorithm ensures it connects to one tree rooted.

The protocol TMCP can greatly improve network throughput, while maintaining high packet delivery ratios and low delivery latency. Furthermore, we show that it outperforms other multi-channel protocols (e.g. protocol MMSN).

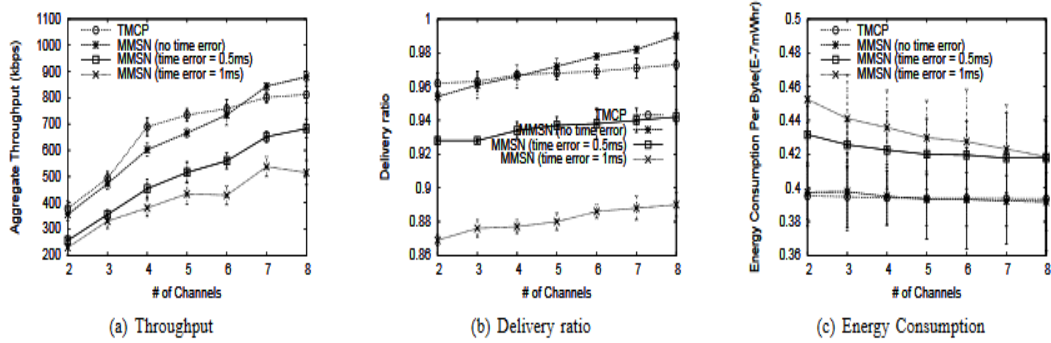


Figure 2.2: Comparison between TMCP and MMSN

2.4.2. Protocol MCRT (Multi-Channel Real-Time communication):

In WSNs many applications count on Information being sent in a timely manner, for example military application when the enemy threatens or Warning of natural disasters, it needs to notify authorities promptly upon the detection.

MCRT [35] protocol is specially designed for real-time communications in multichannel WSNs. MCRT is designed to achieve application specified end-to-end delays by using only a small number of orthogonal channels. MCRT achieve desired end-to-end communication delays and reduce power consumption at the same time, which are not addressed in existing multi-channel work. that utilizes both multiple channels and transmission power adaptation to achieve soft real-time guarantees in WSNs. MCRT features a flow-based channel allocation strategy that is designed based on the multichannel realities, In MCRT, channels are allocated to network partitions formed based on many-to-one data flows in a WSN. MCRT then merges multiple paths as data flows for improved fault tolerance and energy efficiency and allocates a different channel to each data flow to minimize the channel contention among different flows. After the network partitions are established, transmission power adaptation is used to achieve energy efficiency while forwarding each packet with real-time guarantees. In flow-based channel allocation strategy which is mainly motivated by two observations.

First, many of data in communication WSN compete for the only shared channel and thus result in degraded real-time performance, but if that each data uses a different channel. Second, dynamic channel switching is not good for node because it incurs his overhead and

this overhead impacts in switching delay and energy consumption, but It is best that the node does not need to switch the channel repeatedly.

In MCRT try to allocate channel for each data flow this allocation may be reduce interferences among data flow. A data flow is containing source node and destination node and the intermediate nodes forwarding the packet from source to destination. data packets are periodically sent from the source node to the destination in a data flow, but data packet may take different path, and each data use different channel and any nodes expect source can be allocated to at most one data flow. To build data flow must partition the network by searching for a set of disjoint paths from source nodes to the destination. In order for each data flow to meet the specified deadline, the worst-case end-to-end communication delay of each path needs to be smaller than the deadline. Then merge multiple paths to form a data flow so that the data flow can be resilient to node failures and can still achieve the desired real-time performance even when the network conditions (e.g., interference) change at runtime.

We have comparative between MCRT and node-based.

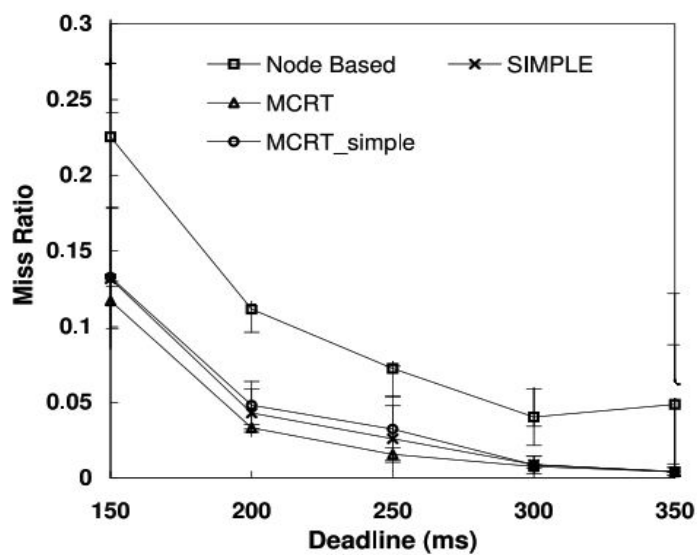


Figure 13.3: comparison between MCRT simple and MCRT and Node based by Deadline-based

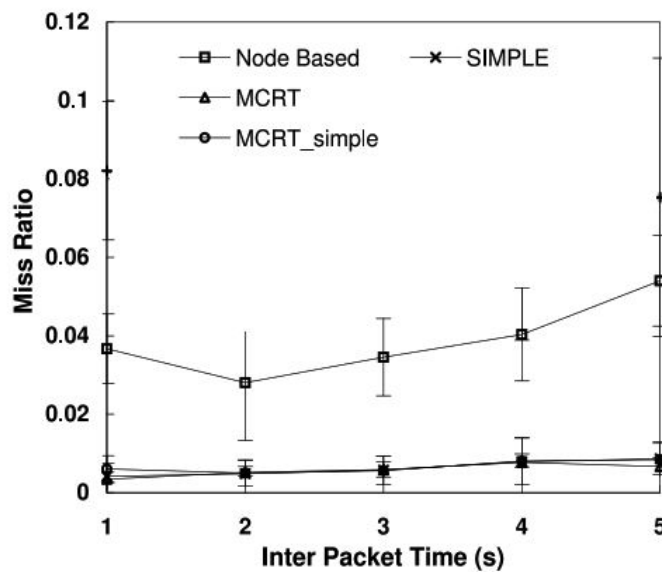


Figure 2.4: comparison between MCRT simple and MCRT and Node based by Inter packet time-based

Advantages

- improves the throughput while keeping high packet delivery ratio and low latency.

Disadvantages

- blocks the direct communications between nodes belonging to different sub-trees which is an inconvenient restriction.
- The difficulty to manage communications between sub-trees due to the use of different frequencies in a permanent manner.

2.5. Hybrid channel assignment:

Hybrid channel assignment: In these approaches, fixed channels are assigned either to the senders or receivers and the nodes can switch their interfaces on the selected channels to communicate with other nodes. the researchers proposed the use of graph-based approaches to solve channel assignment problem. An advantage of hybrid approaches over the centralized channel assignment is that nodes can switch to different channels to communicate with different neighbors such that partitions can be eliminated. On the other hand, with semi-decentralized channel assignment approaches a detailed coordination of channel switching is required between the senders and receivers in order to be on the same channel at the same

time. The problems that arise due to the channel switching are multi-channel hidden terminal problem, deafness problem, and broadcast support [20]. Many protocols are supported this approach like EM-MAC [38] and MMSN [39].

2.5.1. PROTOCOL EM-MAC

Each node in the Dynamic Multichannel Energy-Efficient MAC Protocol (EM-MAC) [38] uses a dynamic mechanism, based on channel conditions, to optimize all the channels on which it switches. With this mechanism, a node avoids choosing channels that are congested or degraded by interference caused by Wi-Fi devices or jamming attacks [22]. An EM-MAC node independently collects channel status information as a result of regular transmit-receive operations without additional power consumption. A node maintains for each channel a metronome "badness" non-negative. When an EM-MAC node wakes up on a channel to send a wake-up tag or a data packet, it proceeds to a Clear Evaluation Channel (CCA) to check the status of the channel before starting the transmission. If the channel is unoccupied, the node sends the packet and decreases the badness of this metric channel in 1 (the metric cannot be less than 0). Otherwise, the node performs CCA control again after a short random delay.

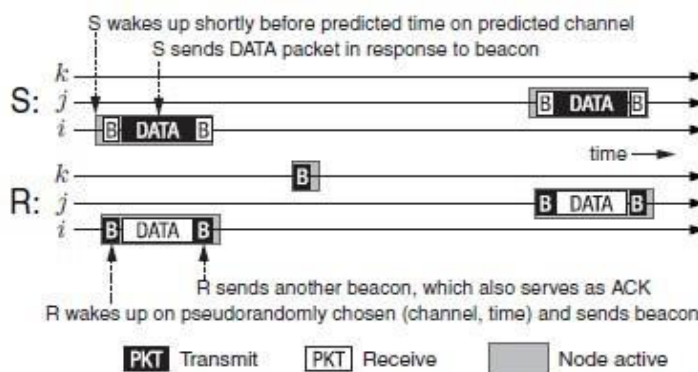


Figure 2.5: EM MAC communication process

If the channel is still busy, after three CCA checks, the node increases the badness of that metric channel by 2 and goes to sleep. In addition, after a node sends a wake-up tag, if the CCA result indicates that the channel is unoccupied, but the node does not receive a valid packet, the node assumes a collision has occurred and resolves the collision by informing the senders to retransmit packets using a back off window increases. On the basis of channel badness metrics, a node in EM-MAC selects the set of channels it passes between. Each node maintains its own list of channels that identifies the Badness status of each channel. When the metric is greater than a CBAD threshold, the channel will be added to the node's blacklist.

If all channels have a badness metric beyond CBAD, the least bad channel is removed from the blacklist.

A node switches between the channels according to the result achieved by the pseudo random generator. If the selected pseudo-randomness falls on a channel of the blacklist, the node remains on its current channel (used for its previous wake-up).

The results shown in Table 2 show that EM-MAC is more efficient compared to both Y-MAC and PW-MAC. The duty cycle of both Y-MAC and MAC-PW is more than 3 times higher than that of the EM-MAC as well as the Y-MAC distribution latency is more than 8 times higher than that of the EM-MAC.

Protocol	Sender Duty Cycle	Delivery Latency(ms)	PDR
EM-MAC	5.3%	611	100%
Y-MAC	32.8%	5130	100%
PW-MAC	19.8%	762	100%

Table 2.1 : Comparison of EM MAC versus Y-MAC and PW-MAC

2.5.2. Multi-Frequency Media Access Control protocol (MMSN)

Researchers are proposed MMSN [39] for raise a parallel transmission. this protocol has many channel assignment strategies which are: exclusive frequency, even-selection, eavesdropping, and implicit-consensus. In the exclusive frequency the number of channels must equal to or greater than number of nodes in 2 hops, in 2-hop neighborhood the nodes exchange their identities (IDs), each node chooses his channel according to order his ID among other IDs.

So, in 2-hop neighborhood the smallest ID choose the smallest channel among available channels. and then it sends the chosen frequency to its 2-hop neighbors.

In Figure :2.6, node 2 has the smallest Id within its two communication hops (in green oval). We suppose that the smallest available frequency is f_0 , thus node 2 broadcast in two communication hops that it allocates frequency f_0 , while node 4 have to wait for the

frequency allocation of node 2 and 3 to decides its frequency and broadcast its decision in two communication hops (the blue oval).

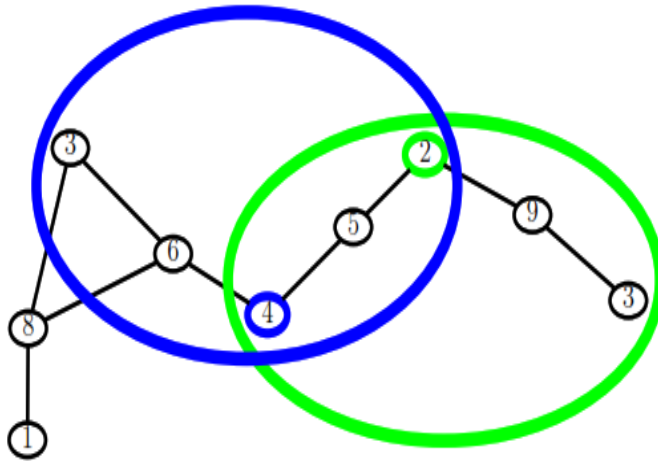


Figure 2.6: Channel allocation in MMSN MAC protocol.

In even-selection, the number of channels is smaller than the number of nodes within 2-hops. It is when all frequencies are already chosen in a 2-hops neighborhood, a node randomly chooses one of the least chosen frequencies. Hence, it does not ensure that nodes in any 2-hop neighborhood are assigned different frequencies. The eavesdropping, each node takes a random back-off during which it waits for its 1-hop neighbors to choose their frequencies. When its back-off expires, it randomly chooses one of the least chosen frequencies within one hop. This strategy has less communication overhead compared to the first two strategies, but it only collects frequencies information within 1-hop neighborhood and during a limited random time interval which results in more conflicts and more interferences. Finally, In the implicit-consensus strategy, nodes exchange their identities in their 2-hop neighborhood. For each frequency, each node calculates a random number for itself and a random number for each node in its 2-hop neighborhood using the same pseudo random number generator. A node wins current frequency if its random number is the highest among all the other random numbers. It then broadcasts its frequency to the 2-hop neighbors. This strategy guarantees smaller overhead but assumes a high number of available frequencies. As we know each node broadcast his channel to his neighbor,so, any node knows channels of her neighbors. To ensure efficient communication, the nodes synchronize for access to the medium using the

time frames. A time frame consists of a broadcast control period (T_{bc}) and a transmission period (T_{tran}). During the period T_{bc} , the nodes are competent for the same frequency (f_0 for example), whereas during the period T_{tran} , they are competent for the frequencies affected. Each node first checks the f_0 channel for transmitting or receiving a broadcast packet. If there is no broadcast packet, the node goes to the unicast packet transmission or reception operation using the assigned frequencies.

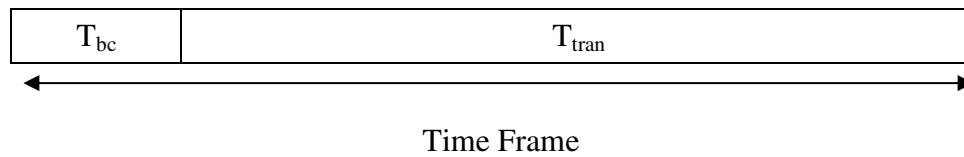


Figure 2.7: Time frame used by the MMSN protocol

Advantages

- Get good results in terms of delivery rate, productivity, channel access times and power. These results increase with an increase in the number of frequencies.

Disadvantages

- it induces high communication overhead due to the ID and frequency exchange between 2-hop neighbors.

2.6. Decentralized approach

the distributed ones, each node chooses its own communication channel and timeslot without the need of a central node. It needs only local knowledge from each node's neighbors. The distributed protocols are more adaptive to network changes and as a result are more suitable for WSNs [18]. the channel assignment decision is distributed among all the nodes. Therefore, distributed channel assignment involves communication and coordination among nodes/subtrees/clusters. Hyacinth [22], DMesh [23] are gateway-oriented channel assignment approaches where each node is responsible for assigning channels to its children. CoMTaC [24] deals with network topology changes when the channel assignment plan changes. Distributed channel assignment can be adopted in large and dense WSNs, because centralized solutions have scarce performances in multi-hop networks with a large number of sensors [17]. in the distributed. decentralized channel assignment approaches, every data transmission

takes place after a channel selection. The channel selection can be measurement based or status based. In measurement-based approaches, the communicating parties measure the Signal-to-Interference-plus-Noise Ratio (SINR) values on a channel before transmitting. In status-based approaches, nodes keep track of the status of the channels, such as busy or idle, according to the received control packets. Decentralized channel assignment approaches share the problems of Hybrid channel assignment approaches. Decentralized channel assignment is further classified into three categories based on the methods of coordination [20]:

➤ **Dedicated Control Channel:**

This approach requires dedicated control channel for the transmission of control packets [25, 26]. These control packets are used for the purpose of channel negotiation and notification. The method is simple, however reducing spectral efficiency from the use of one channel purely for the management purpose. It is also necessary that the device needs to have two radios so one can be tuned to listen to the control channel at all time while the other one is used for data communication. This leads to higher cost and complication on the end devices.

➤ **Split Phase or Time Division:**

This approach requires only one radio for each device. In this technique, the channel negotiation process is performed on a control channel however within a specified timeslot. The communication can then be carried out in the next timeslot (dedicated for data transmission) on the agreed channel. This agreed channel can also be the same as the control channel since the data transmission and control packet transmission are assigned in different time period. The method is based on time division approach to separate time into the control period and the communication period. In this type of methods, timing synchronization is necessary. Nevertheless, the approach benefits from the use of all available channels for data communication in the data transmission timeslots avoiding the single control channel bottleneck especially when number of available channels is low. Multi-Channel MAC (MMAC) [27], Multi-Channel Access Protocol (MAP) [28] and TMMAC [29] are examples of protocols that are based on time division access.

➤ **Frequency Hopping:**

This approach does not require any dedicated control channel or the channel negotiation process. Proposed in [30] and [31], the channel hopping approaches are used. Devices do not negotiate on the operating channel. On the other hand, they hop from one

frequency to another together using the known channel hopping sequence. As a result, only one radio is needed. However, timing synchronization becomes very curtail. Further adaptations to originally proposed idea is also presented in [32] and [33], where several hopping sequences are employed. The hopping patterns are previously set or generated randomly.

2.6.1. Protocol Y-MAC

Proposed Energy-Efficient Multi Channel MAC Protocol (Y-MAC) [36] for reduce latency, it is distributed TDMA-based and used a decentralized channel assignment. Y-MAC, this one gives better performance in terms of energy consumption. Y-MAC utilizes an access method which is time is divided into cycles. Each cycle is composed of a broadcast period and a unicast period as shown in Figure: 2.9. the broadcast period that uses the control channel for 3 slots to broadcast the control message and the unicast period that is used for the transmission or reception of the data. each node wakes up in order to exchange broadcast messages. Nodes exchange the time remaining in the current frame period in order to maintain synchronization. Y-MAC allows to join other nodes and assign timeslot a dynamic way.

Node in Y-MAC maintains a vector of slot allocation of its first hop neighbor including itself, where the byte at position i refers to the slot i .

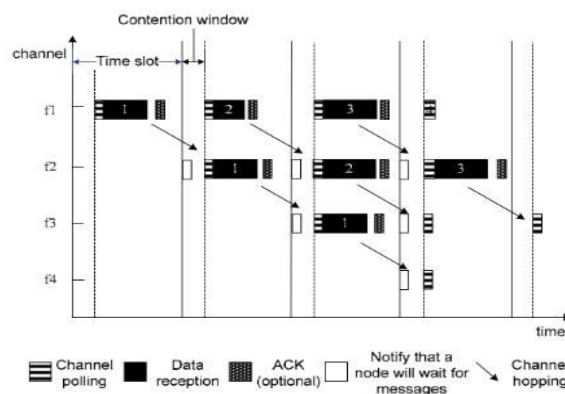


Figure 2.8: A light weight-channel hopping mechanism.

The mechanism of channel hopping in Y-MAC is illustrated in Fig.2.10. After that node receives a unicast message in the base channel (f1), it determines the channel of communication by using the hopping sequence generation algorithm [8].

Each node has a schedule of sending time with respect to neighbors with two jumps, which provides access without collision more but it generates more processing. Such a system is therefore able to reduce energy wastage by dodging as much as possible from contention and

collisions. However, all nodes must wake up at each time slot in order to check for incoming messages that are different depending on the period: if it is a broadcast period, the node synchronizes knowing the time remaining for the next time interval so for updating the slot allocation table. If it is a unicast period, the node wakes up at the end of the contention window to see if there is communication with a neighboring node, otherwise it goes into sleep mode to save energy and wake up periodically for receive messages.

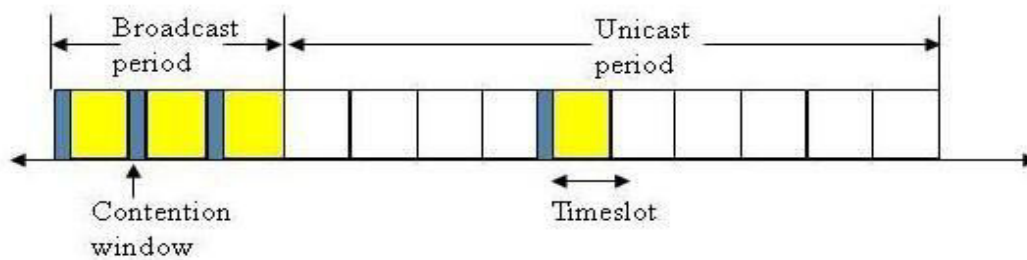


Figure 2.9: Y-MAC protocol architecture

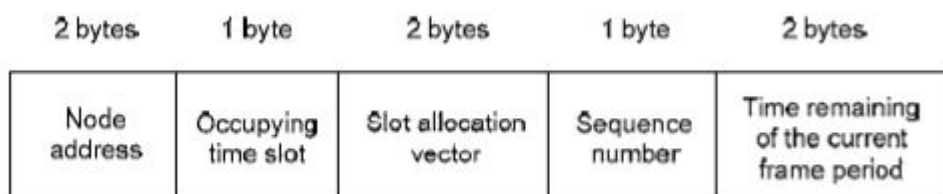


Figure 2.10: Control message in Y-MAC

2.6.2. Distributed Routing and Channel Selection (DRCS)

The DRCS [37] scheme distributes transmission with multiple channel for adapting the current consumption energy in the nodes so that their remaining lifetimes are balanced. This gives more time for lifetime of network. Receiver channel which is the channel of receiving all packet and transmit channel which is the channel of node transmit temporarily and which is channel of receiver channel for final destination. each node selects its receiver channel for enabling distribution. the listening of channel is between the node and its receiver but it is limited just neighboring transmissions on a node's receiver channel only. the choice of channel is dynamic for conserving the lifetime of node which is energy saving.

in DRCS, the channel selection depends on two stages, which are described below. We assume that all nodes broadcast periodic beacon messages, which include their node ID, their receiver channel, the ETX value, and their battery health-metrics.

In first stage : the nodes choose common channel for communication , after that each node choose a random backoff and select the channel which is the least used in neighborhood and it informs its neighbors via beacon packets ,If there is more than one channel less commonly used choose a random channel among the channels that make the tie when the tie is broken each node stores its neighbors as well as the neighbors' receiver channel information. After that the second stage begins.

The second stage: the nodes will be turned on their receiver channels and select dynamically a parent and then transmit channels depends on periodic assessments of the battery health and ETX values. For any channel c , each node calculates $H_c = \min \{H_i\} \forall i \in S_c$ where S_c is the set of neighbors that are in receiver channel c and H_i is the health metric of node i , for transmit to the base-station and we proposed the base-station is in common channel , all neighbors of base-station switch to the common default channel for transmitting DATA packets.

All other nodes choose a transmit channel c with a probability of H_c/H , where $H = \sum H_c \forall$ channel c in the node's neighborhood such that there is at least one neighbor that is in channel c , whose ETX is less than the node's ETX. The term H_c/H ensures that the receiver channel of the node with the worst health-metric is chosen with the lowest probability This mechanism minimizes the overhearing for the neighboring node that has the worst health-metric After choosing the transmit channel, a node chooses the parent among all its neighbors on c that has the best metric path to the sink. Nodes choose transmit channels as well as their parents in periodic intervals, called route-update intervals (RUI).

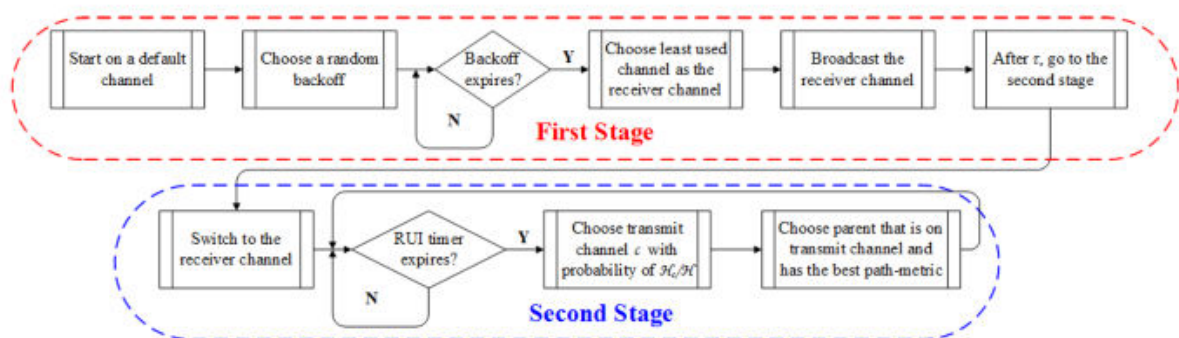


Figure 2.11: Conceptual diagram of DRCS.

Advantages

- A new node is always able to receive beacons from its neighbors and can connect to the network, irrespective of its initial choice of a default channel.
- Each node makes a long lifetime While maintaining its energy.

Disadvantages:

- need for synchronization between the nodes.

2.7. Conclusion:

After we saw classification of multichannel protocols and its advantages and disadvantages we will take them into consideration, in addition we take characteristics of some protocols. like TMCP is based on the distance and other protocol is based on energy and distance like DRCS protocol that is attached and we will implement both techniques to see the comparison.

CHAPTER 03

3. IMPLEMENTATION AND EXPERIMENTATION

3.1. Introduction

In this chapter we will explain the design and experimental setup, which aims to integrate the energy level in the communication nodes and choice of the shortest path to the Sink in the process of channel selection in order to maintain the node less energy as long as possible and the arrival of the package in the shortest possible time. That is why we choose the technology which is TMCP-based protocol (short path) and technology DCRS-based (energy and distance) protocol for implement the technics. Here's a step-by-step to the best solution.

3.2. Our Work:

3.2.1. General description

In order to improve communication techniques in wireless sensor networks, we wanted to study the comparison of two technologies: before that, the sender must select channel and use method Preferable Channel List after that use one of these technologies: First, a technology based on the node's energy, in order to preserve the life of the node and thus the life of the network because the death of the node changes the structure of the network, Cost more when each sender if it is going to send firstly check it who has from his neighbors the largest energy. Second, a technique based on the shortest path in order to reach packets in the shortest possible time to the node responsible on the network or responsible for the collection of information and packets. Which is each sender select the next destination, the next destination is the nearest neighbor to the Sink.

3.2.2. Scenario:

In this experiment, we will use simulator Jsensor as mentioned, and the number of nodes is not fixed, because in each test we will change number of nodes. And after running simulation all the nodes select channel by using method Channel_Affectation after that we will select the nodes which are the senders after that each sender uses the principal method for sending a message to the next destination use method Unicast_Send in which send message unicast to next destination , which will be the new sender and with the same method down to the base station , each node has energy 100 , for sending a message need 2 from energy , for receive a message need 1 from energy. And we have 8 channels.

3.2.3. Problematic:

This work relies on comparing two protocols of each protocol from a different classification. Protocol centralized (TMCP) but we use just his method-base (shortpath) and protocol Decentralized (DCRS) also we use just his method-base (energypath) in order to

show the disadvantages and advantages of each protocol. We have adopted in this simulation to several criteria which are:

- Dead nodes compared to the time (life time of network).
- energy consumption compared to the time.
- Packet Delivery Ratio: In this experiment, we calculate the ratio of the number of correctly received packets. compared to the number of transmitted packets.

3.2.4. Methods

Method Select Channel

Channel-list techniques require a control handshake before any data exchange in order to allow the sender to know the condition of all the channels at the receiver side. Then, the sender can choose the most suitable channel based on this information. Channel-list techniques are usually receiver-based; i.e., they attempt to select the best channel at the receiver side. The sender and receiver sense the carrier on all the data channels and build a list of channels available for transmission in their respective range. The set of available channels is known as Preferable Channel List (PCL).

Method shortpath-based

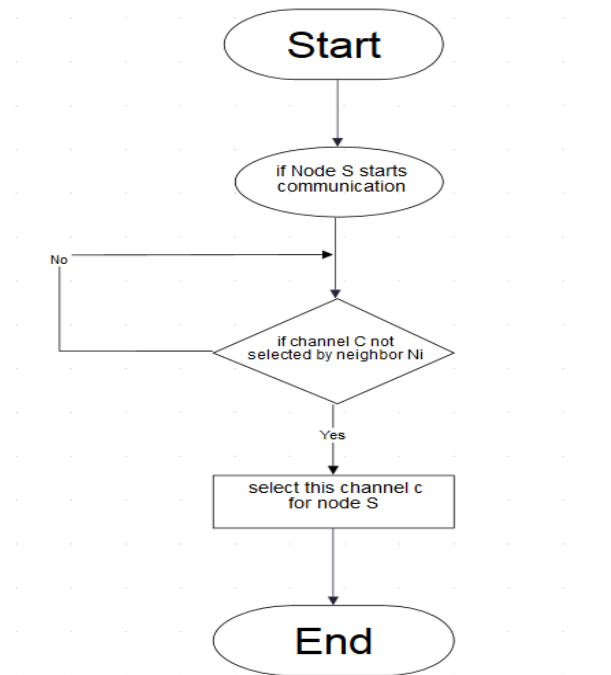
After selecting the sender channel carrier This method to find the closest neighbor to the last node. This takes the coordinates of neighbors and the last node and the calculation of the nearest node after finding the sender to send information to this node and in turn is the new sender and repeat the same way for the new sender until the destination the final packets are guaranteed to arrive at the shortest path to the final destination.

Method Energy-based

This method is similar to the previous method, but in this we rely on the energy allocated to each node so that at the beginning of the connection all nodes have the same energy, but when any node is sent, its energy decreases the power of the destination. This method works as follows: The sender selects the neighbor who has the greatest energy from the other neighbors and sends him information, of course his energy is depleted and the old destination becomes the new transmitter and this method is repeated to the final destination. This method is possible to take a longer path to reach the final destination.

3.2.5. Diagrams

Organigram

**Figure 3.1 Channel selection**

Scheme (Figure 3.1) represents tasks that can do the node in first communication in WSNs:

Firstly, the node while is connected with other nodes must select channel for communication but this must be not used or select by any neighbor of this node.

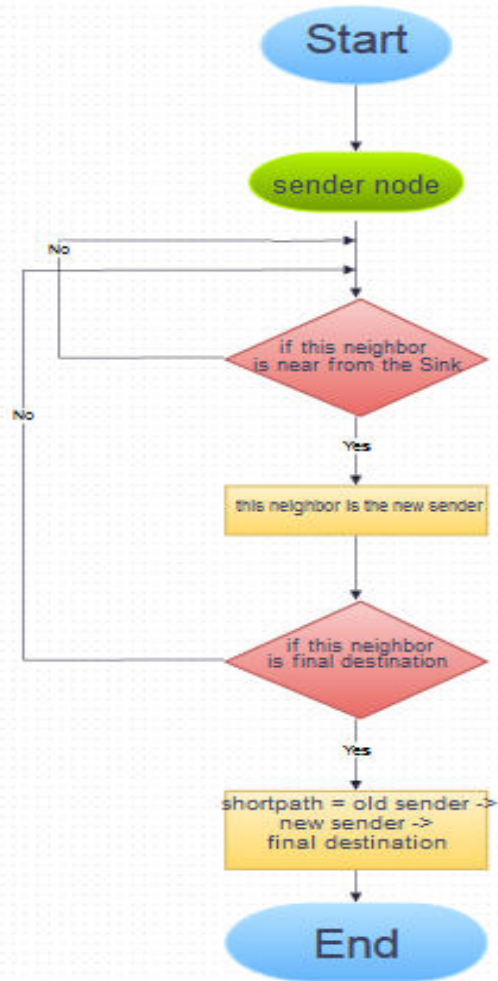


Figure 3.2: The shortest path selection

Figure 3.2 represents when the sender selects the short path first the sender chooses the neighbor which is near for the sink after select nearest neighbor, this latter will be the new sender Until we get there the sink or final destination. the short path is the list of nearest neighbors

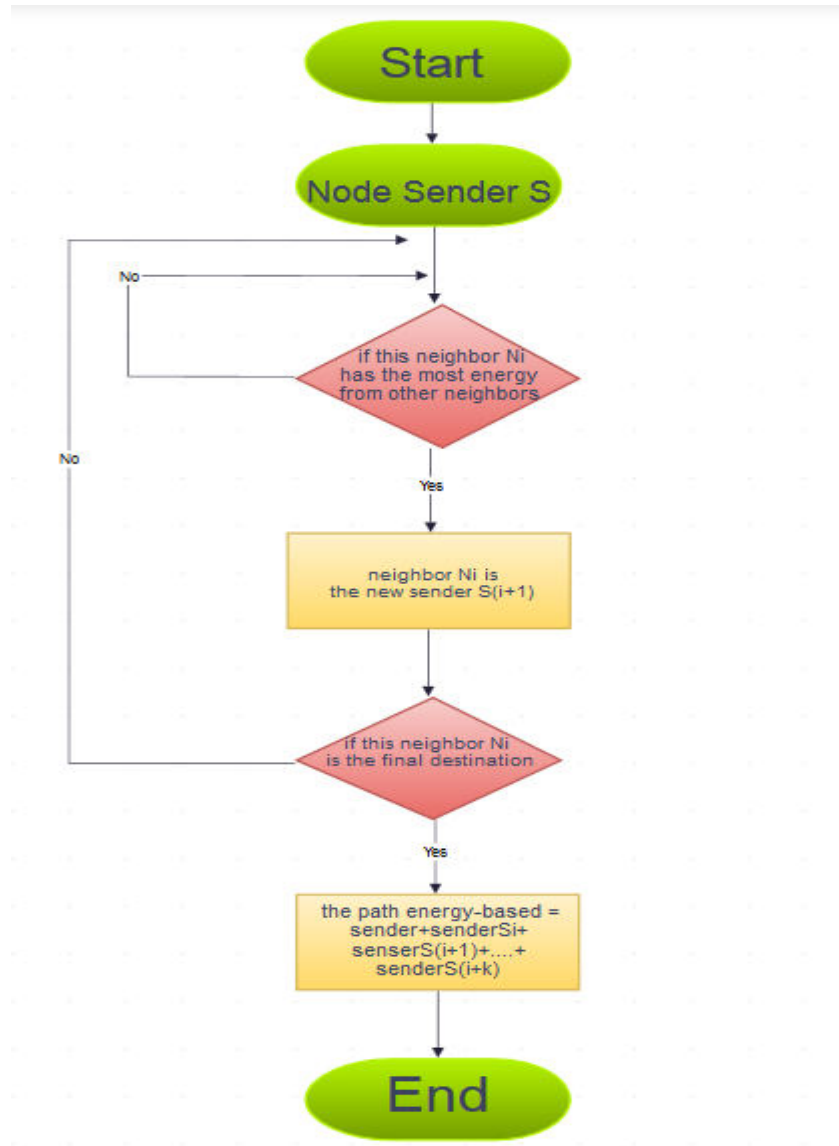


Figure 3.3 The path selection energy-based

Figure 3.3 represents same the **Figure 3.2** but this must be check it the node neighbor the most energy and send after that the neighbor most energy will be the new sender and repeat the same selection of neighbors we get there the sink, and the path is the list of neighbors which is has the most energy.

3.3. Implementation

Our study is based on a comparison of the two technologies mentioned above. We chose these two techniques because they complement each other. The short-circuit technology consumes a lot of energy because there is a possibility that two or more nodes are sent to the same destination, which leads to a lot of energy shortage, and as we mentioned, this affects the life time of the network. The second energy-based technology, if used alone, is likely to be the first destination Far from the final destination but with the characteristics of the first technique and the characteristics of the second technology, they create a new way to choose the destination closest to the final destination and at the same time have a great energy from other neighbors. To do this work we choose the simulator Jsensor [40] Among the existing simulation tools, which is an open source tool written in Java which has the advantage of already specialized in the study of WSNs. it allows the proposition of simulation models considering some embedded software components, such as, general data structures, inter-process communication mechanisms, and load balancing.

3.3.1. Simulator JSensor

Jsensor [40] is a sensor network simulator capable of running parallel simulations, at the present development stage suitable for shared-memory computer architectures. It is a tool that performs efficiently in multi-core architectures allowing faster simulations and/or scenarios where hundreds of thousands of sensors can be simulated in a single multi-core CPU.

JSensor allows synchronous and asynchronous parallel simulations. In both cases, a runtime class is defined considering methods to allow synchronous and asynchronous simulations. To implement these models, the JSensor provides a set of abstract classes where the user can extend and integrate into your project.

The abstract kernel classes of JSensor are:

- (i) Node class represents the sensor nodes. Every new type of node is created extending this class.
- (ii) Message class is used to implement the messages sent by the nodes during the simulation. In this class the message type and how it can be instantiated are defined.
- (iii) Fact class represents the events occurred in the environment.

The events are treated in different ways depending of simulation type. In synchronous simulation, for each round, the framework iterates over the events (also in parallel) updating

their current values and decreasing their remaining time. If the event time expires it is automatically and definitely removed from simulation. In asynchronous simulation, each event is associated with one or more AbstractFactEvent, class responsible to update the event values.

In addition, JSensor allows the specification of different models:

- (i) Nodes distribution specifies how the nodes are distributed in monitored area.
- (ii) Nodes connectivity allows the manipulation of nodes connectivity.
- (iii) Nodes mobility is considered only in synchronous simulations.

In each round, each node can move to a new position in the simulated area following the described model. In JSensor, a synchronous simulation has the execution flow based on rounds. In each round all nodes execute some predefined operations. During the parallel execution, the kernel divides the number of nodes by the lightweight processes (threads) created during the simulation. In general, we use data decomposition to ensure a synchronous, parallel, and scalable simulation. The kernel distributes all nodes and events among the threads. Then, each thread scans your subset of events and nodes updating their values.

3.4. Implantation of methods

Public static void Channel_affectation(Node I)

First find the neighbors of this node and return channel of each neighbor after that the channel which is not used return this channel for this node.

Public void unicast_send(FloodingNode sender, Message msg)

Each sender after select the next destination send message unicast for him .and decrease 2 from his energy and the next destination decrease 1 from his energy. For sending select the channel for sending message (out channel) and channel for receiving message (in channel).

Public FloodingNode energyPath()

For each node (sender) firstly return its neighbors if these neighbors is found so, for each neighbor return its energy of course in the beginning each node has energy, after return energy for each neighbor select the neighbor which has most energy .

Public static Node shortpath(Node node , int xdis, int ydis)

In the first return the neighbor if sender and make the coordinate of each neighbor and the coordinate of destination (xdis,ydis) after that calculate the neighbor near from the destination based by the coordinate .

```

//////////////////////////////// select channel //////////////////////////////////
public static void Channel_affectation(Node l) {
    int i;
    FloodingNode[] tngheibors = l.getNeighbours().getNodesList().toArray(new
    FloodingNode[0]);
    for (i = 1; i < ChannelNbrMax; i++) {
        if (l.getChannel() == 0){
            for (int j = 0; j < tngheibors.length; j++) {

                if (tngheibors[j].getChannel() == i) {
                    l.setChannel(i+1);
                    if(i<ChannelNbrMax){
                        i++;
                        j=0;
                    }
                } else {
                    l.setChannel(i);
                }
            }
        }
    }
}

////////////////////////////////

public void unicast_send(FloodingNode sender, Message msg) {

```

```
super.unicast_send(sender, msg);

FloodingMessage message = (FloodingMessage) msg;

FloodingNode nextSender = energyPath();

message.inChannel = nextSender.getChannel();

message.outChannel = sender.getChannel();

message.setMsg(message.getMsg().concat(ID + " - "));

sender.unicast(msg, nextSender);

////////////////////////////////////

public FloodingNode energyPath() {

//return the neighbor of this node

    Object[] tn = getNeighbours().getNodesList().toArray();

    // System.out.println(tn.length);

// the neighbor which has the most energy

    FloodingNode finaldE = null;

    FloodingNode n;

    int value;

////// if it exists neighbor

    if (tn.length > 0) {

//////make the value by energy of first neighbor

        n = (FloodingNode) tn[0];

        value = n.getEnergy();

        finaldE = n;

        for (int i = 0; i < tn.length; i++) {

            n = (FloodingNode) tn[i];
```

```
/////search the neighbor most energy

        if (n.getEnergy() > value) {

            value = n.getEnergy();

            finaldE = n;

        }

    }

}

return finaldE;

}

////////////////////////////////////method Shortpath////////////////////////////////////

public static Node shortpath(Node node, int xdd, int ydd) {

    // get neighbor of this node

    for (int i = 0; i < 1; i++) {

        ngh = node.getNeighbours();

        tnodes = ngh.getNodesList().toArray(new Node[0]);

    }

    // add the cordinate of each neighbor to array [][]

    for (int j = 0; j < tnodes.length; j++) {

        sizengheibour = node.getNeighbours().size();

        xg = tnodes[j].getPosition().getPosX();

        yg = tnodes[j].getPosition().getPosY();

        points[0][j] = xg;

        points[1][j] = yg;

    }

}
```

```
// method return the nearest from base-station (xdd,ydd)

FindNearestPoints fir = fd();

FindNearestPoints.dis(sizengheibour, xdd, ydd, points);

// find ID of the neareset

for (int i = 0; i < sizengheibour; i++) {

if (fir.getXg() == tnodes[i].getPosition().getPosX() && fir.getYg() ==
tnodes[i].getPosition().getPosY())

finald = tnodes[i];

}

return finald;

}
```

3.5. Simulation results

Test 1: comparison between two technics Shortpath and energy, number of nodes 50 node and number of senders 10 node.

Test 2: comparison between two technics Shortpath and energy, number of nodes 150 node and number of senders 30 node.

Test 3: comparison between two technics Shortpath and energy, number of nodes 400 node and number of senders 80 node.

Test 1:

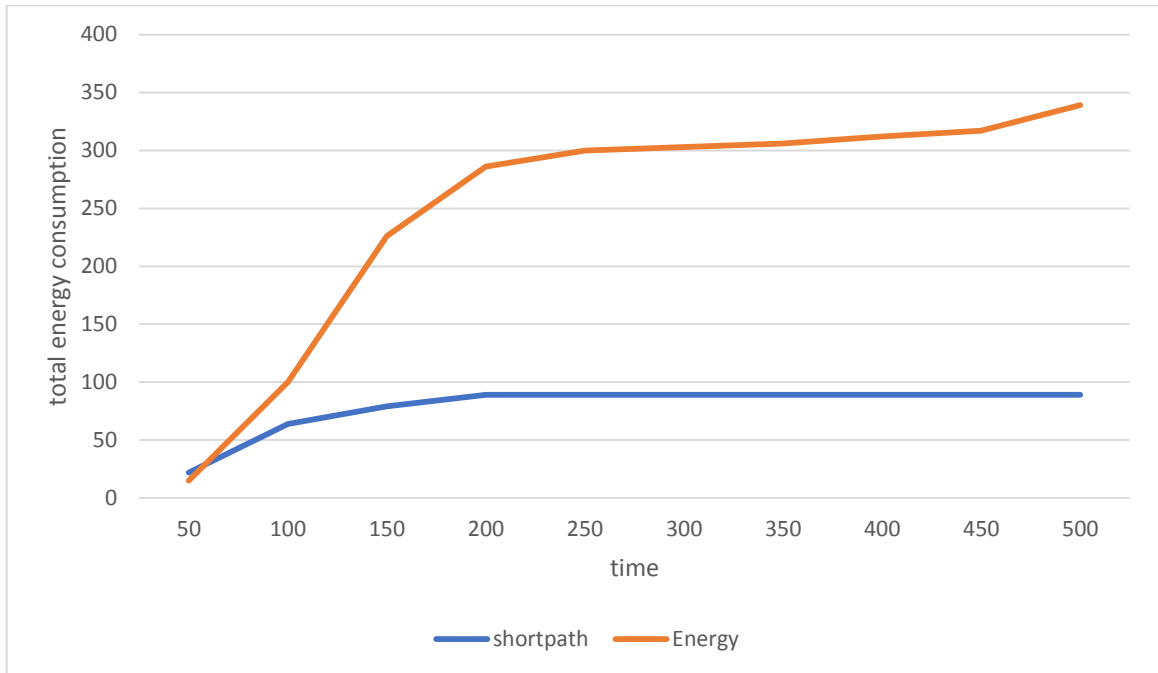


Figure 3.4. comparison between shortpath and energy saving by Total energy consumption

We see in figure 3.5 method energy need a lot of energy to final destination and when the time is increases the energy is increase because with energyPath method has big network. on other hand as we see the shortpath method less than method energy because shortpath choose the shortest path to final destination, so little network.

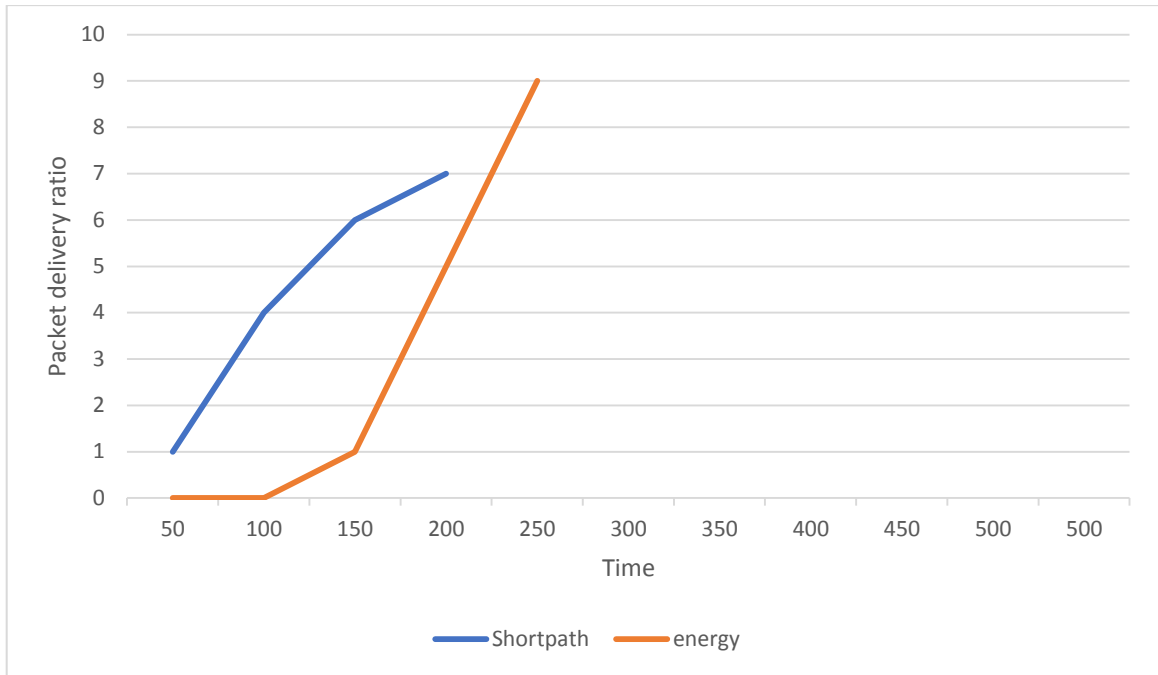


Figure 3.5: comparison between shortpath and energy saving by Packet delivery ratio test 1

In figure 3.6 we see method energy has more good results than method shortpath. Because energy the packets sends is the packets receives. In other hand shortpath delivery ratio equal 80%.

Test 2:

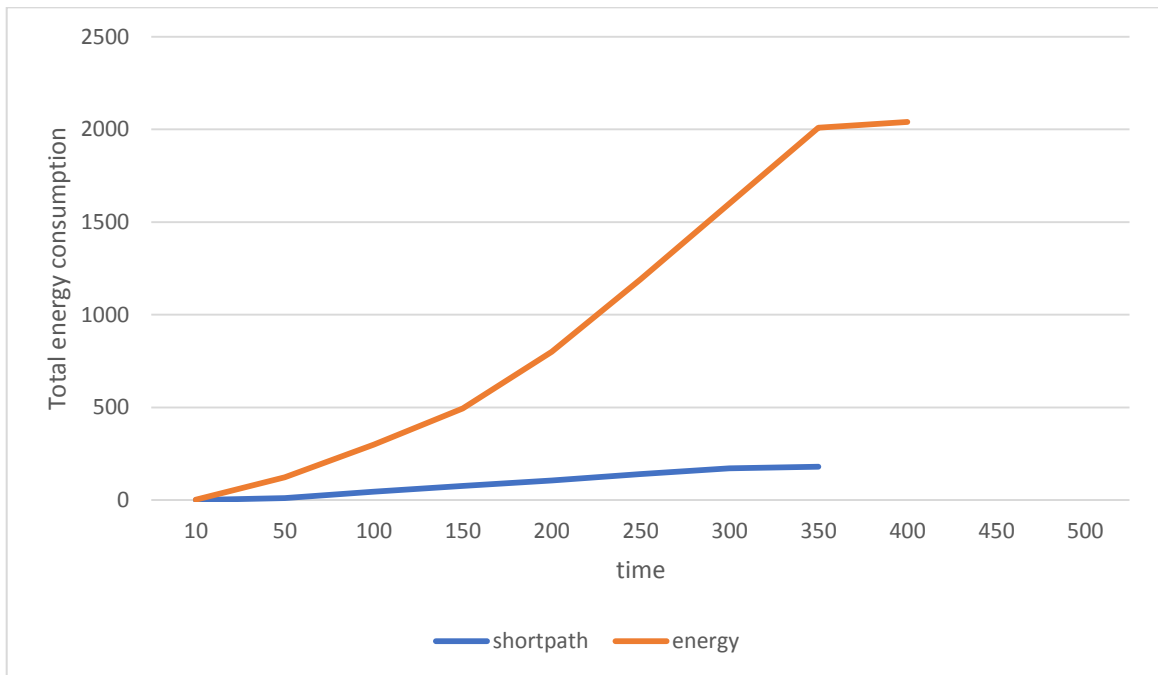


Figure 3.6: comparison between shortpath and energy saving by Total energy consumption.

Figure 3.7 presents total energy consumption we note method shortpath has less energy consumption like test 01 than method energy because as we see in figure 3.5 it has big network this is reason that led to superiority of method shortpath.

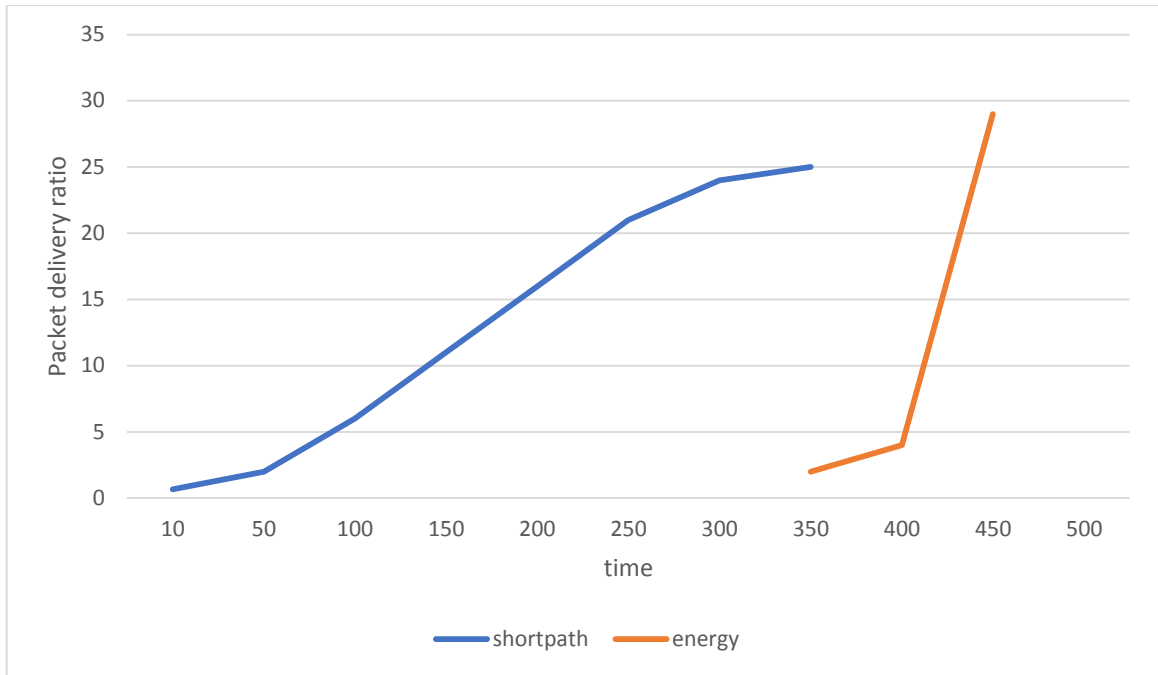


Figure 3.7: comparison between shortpath and energy saving by Packet delivery ratio.

Like figure 3.6 the same result and the same reason

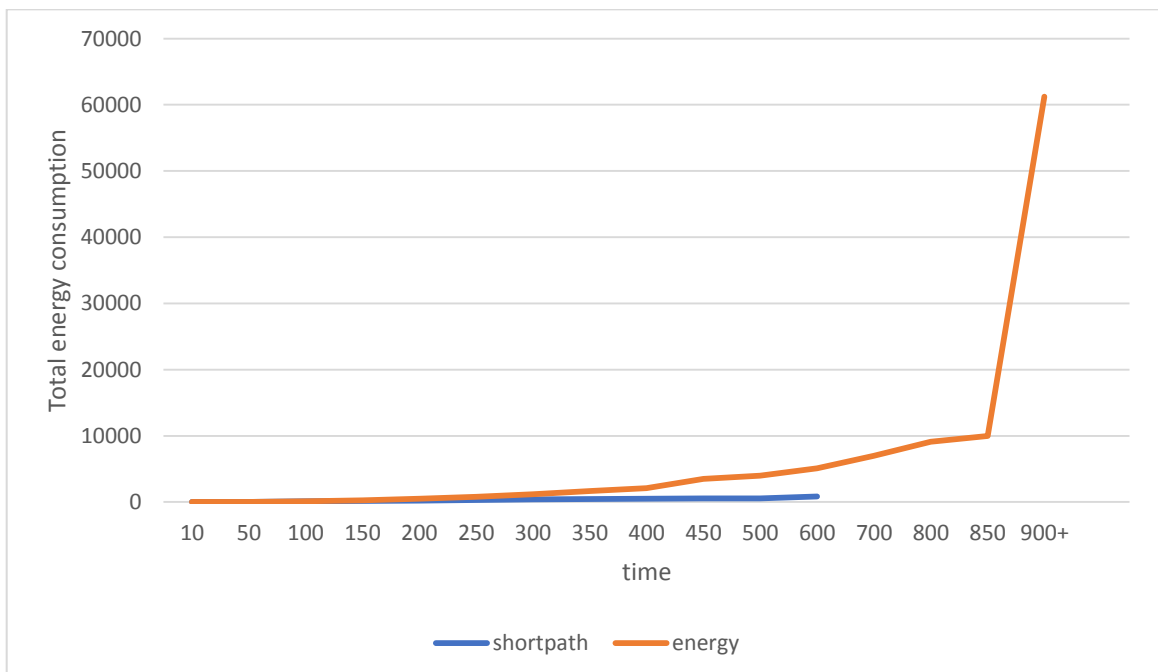


Figure 3.8: comparison between shortpath and energy saving by Total energy consumption.

Figure 3.9 after long time method shortpath and method energy close together after 600 ms energy method has more energy consumption like test 01 than method shortpath because in this test network has 400 nodes and if network increase energy consumption on energy method is increase.

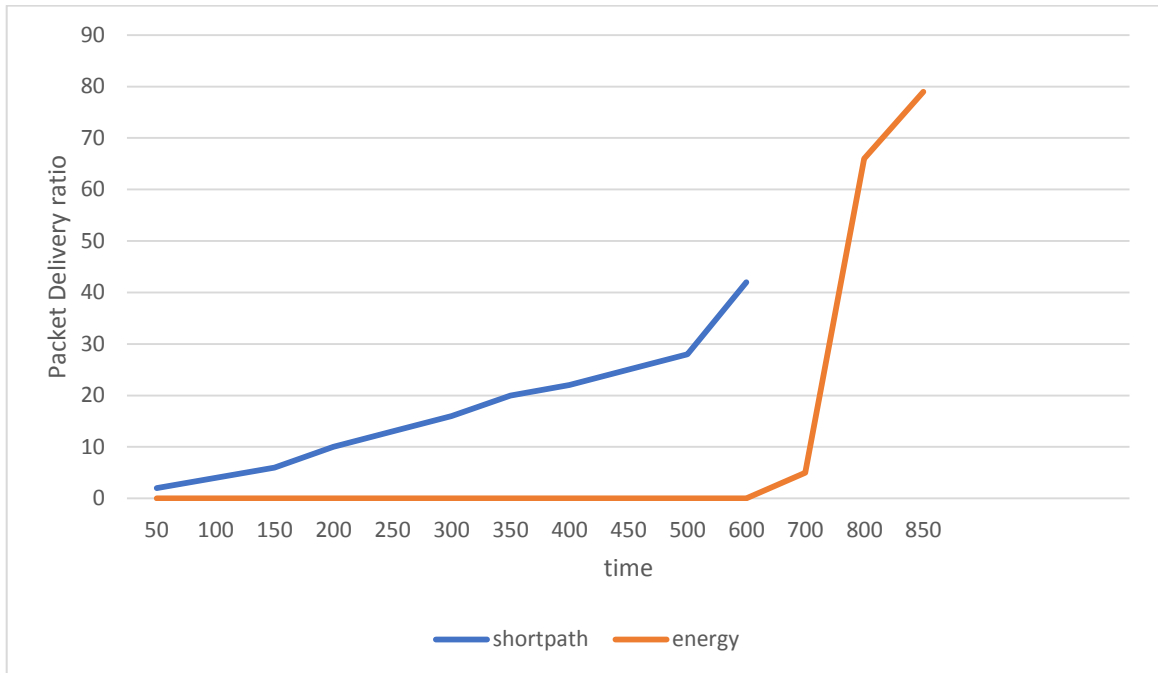


Figure 3.9: comparison between shortpath and energy method by Packet delivery ratio.

The same result of each test, energy method has 100% of Packet delivery ratio but shortpath has less than energy path.

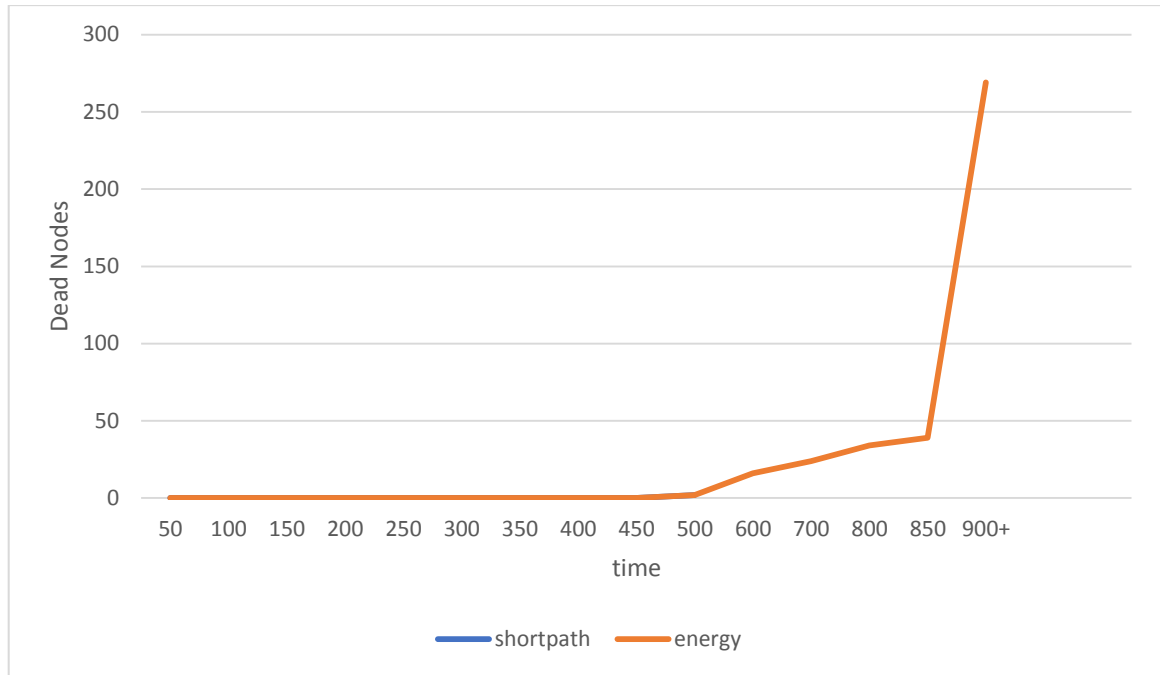


Figure 3.10: comparison between shortpath and energy method by Dead nodes.

This criterion we calculated just in this test because the network must be big 400 nodes for appearing dead nodes or life time network short path has 2 dead nodes but energyPath method has a lot of dead nodes because each sender has a large number of hops that's mean energy consumption but compared between energyPath and short path the dead nodes in energy path is not important in other side shortpath has dead nodes is important.

With shortpath:

- We can send the data with less energy.

With energy:

- Packet delivery ratio is in the most of the time equal 100%.

3.6. Conclusion:

After the simulation we found that the method of shortpath has a good performance in some criterion like energy consumption but the opposite has a bad side is a Packet delivery ratio the most packet sent do not arrive. on the contrary method of energy has a good performance a delivery packet but take a big energy for arrived messages to the base station.

GENERAL CONCLUSION

In this memory, we are interested in the study of WSNs, for its ease of publication and its emergence in several domains such as military fields and environmental fields. This was our study of communication within the network using multi-channel technology because of its importance in the wireless network. We articulate this memory into the three chapters:

the first chapter talked about the generalities about the WSNs and the most important domains as we talked about topologies.

The second chapter we have known the multi-channel technology and its importance in communication WSNs. As we explained one of the most important protocols of multichannel protocols and we have noticed that there are two important techniques in communication are shortpath and energy based on these techniques and the advantages and disadvantages of each technique.

These observations made us decide to make a comparison between the two technologies according to the time, Dead nodes packet delivery and energy consumption. Using the simulation.

We use Jsensor as a simulation tool. We found that each technique has a distinguishing feature from the other. Shortpath characterized by a small number of dead nodes and low energy consumption but the packet delivery is little that's mean a lot of messages do not arrive. Energy Also has the property of maintaining the network with a high energy consumption, a large number of dead nodes but a the most of messages are arrived because high Packet delivery ratio.

We proposed as future work to make hybrid between shortpath and energy for the test in a wider way.

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ملخص :

في شبكة الاستشعار اللاسلكية العديد من البروتوكولات التي تستعمل تقنية تعدد القنوات لتحقيق الاتصال الجيد بين العقد لكن هذا لا يكفي فمعظم التطبيقات التي تستعمل شبكة الاستشعار اللاسلكية تحتاج الى شبكة تتميز بخصائص مثل "عمر الحياة طويل" وهذا يحتاج الى دراسة الطاقة داخل هذه الشبكة كما تحتاج الى الخاصية "المسار الأقصر" لتوصيل المعلومات في اقل وقت ممكن لهذا عملنا مقارنة بين هاتين الخاصيتين او التقنيتين لمعرفة ايهما افضل باستعمال عدة معايير واستعملنا البرمجة والمحاكاة كوسيلة للمقارنة .

الكلمات المفتاحية : القنوات المتعددة ، الطاقة ، المسار الأقصر.

Abstract:

In WSNs there are a lot of protocols that use multichannel technique to achieve an effective communication between nodes, but this is not enough alone, most of the application that use WSNs need a network that is specific with characteristics such as long time and this requires to study the energy from within this network, as it needs shortpath option, to deliver information in the possible shortest time, for this we conducted a comparison between these two characteristics and techniques, to acknowledge the best using multiple standards. we used programming and simulation also as tools for this comparison.

Keywords: Multiple Channels, Power, Shortest Path.

Abstrait:

Dans les RCSF, de nombreux protocoles utilisent la technique multicanal pour obtenir une communication efficace entre les nœuds, mais cela ne suffit pas. La plupart des applications qui utilisent des RCSF ont besoin d'un réseau spécifique avec des caractéristiques telles que le temps long. étudier l'énergie à l'intérieur de ce réseau, car il a besoin de l'option shortpath, de livrer l'information dans les plus brefs délais, pour cela nous avons effectué une comparaison entre ces deux caractéristiques et techniques, de reconnaître le meilleur en utilisant plusieurs normes. Nous avons également utilisé la programmation et la simulation comme outils pour cette comparaison.

Mots-clés: multifréquence, énergie, plus court chemin.