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جـامـعـة الـشـرق الأوسـط
MIDDLE EAST UNIVERSITY

A COMPARATIVE STUDY OF TWO OBJECTIVE FUNCTIONS FOR ROUTING PROTOCOL IN WIRELESS SENSOR NETWORK

(RPL)

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Authorization

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Dedication

Every great success needs determination, hard work, confidence, and most importantly an unconditional trust from special people close to our hearts, whom we can find whenever we need especially in our hard times. I will always appreciate all what they have done for me, and I thank God for giving me the bless of having them in my life

I would like to proudly dedicate my thesis to my dear parents and my beloved friends for their endless love and for being a constant source of encouragement.

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List of Abbreviations

Abbreviations	Meanings
IETF	Internet Engineering Task Force
DODAG	Destination Oriented Directed Acyclic Graph
DIS	DODAG Information Solicitation
DIO	DODAG Information Object
DAO	Destination Advertisement Object
LLN	Low Power and Lossy Network
OF	Objective Function
RPL	Routing Protocol for LLN
WSN	Wireless Sensor Network
PDR	Packet Delivery Ratio
IOT	Internet of things
OF0	Objective Function Zero
EXT	Expected Transmission Count

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Abstract

With the development taking place in the twenty-first century, the concept of the Internet of Things has emerged, which is a new stage in the digital revolution that works to fully contribute to building a digital society by linking the Internet to things. . Where researchers work in various ways to make the most of Internet connectivity to things, for example health care. The Internet of Things depends on the wireless sensor network, which is a revolution in the field of wireless communications and embedded systems, which aims to monitor and control remotely through small wireless devices that sense the changes to be monitored in the sensors without the need for human intervention.Wireless sensors face many major problems, the most important of which are power consumption and packet connection. As there is more than one target function for dealing with information, the most important of which are OF0 and EXT, where a comparison will be made between them through a specific scenario in health care in order to reduce energy consumption and the percentage of packet delivery by cooja simulator. Where this simulation was carried out by applying twenty nodes distributed in random topology and network topology systems, and each of the nodes was divided into five sections based on the time interval and based on changes in network density, where network density was changed in two cases, the first at density 80% and the second at 100 % Where the results showed that the OF0 function is better when delivering packages and as it reduces energy consumption at 1.95 more than EXT.

Key words: objective function zero ,health care ,random toplogy ,graid topology

دراسه مقارنه بين وظيفتين الهدف لبرتوكول RPL في شبكه الاستشعار اللاسلكيه

أعداد

محمد صلاح موسى العسود

أشراف

دكتور بسام الشرجبي

مع التطور الحاصل في القرن الحادي والعشرين ، برز مفهوم إنترنت الأشياء ، وهي مرحلة جديدة في الثورة الرقمية تعمل على المساهمة الكاملة في بناء مجتمع رقمي عن طريق ربط الإنترنت بالأشياء. . حيث يعمل الباحثون بطرق مختلفة لتحقيق أقصى استفادة من اتصال الإنترنت بالأشياء ، على سبيل المثال ، الرعاية الصحية ..

يعتمد انترنت الاشياء على شبكه الاستشعار اللاسلكيه ،والتي تعد ثوره في مجال الاتصالات اللاسلكيه والانظمه المدمجه والتي تهدف إلى المراقبة والتحكم عن بُعد من خلال أجهزة لاسلكية صغيرة تشعر بالتغييرات التي يجب مراقبتها في المستشعرات دون الحاجة إلى تدخل بشري. تواجه شبكات أجهزة الاستشعار اللاسلكية العديد من المشكلات الرئيسية مثل استهلاك الطاقة ونسبة تسليم الحزمة لقد أجرى الباحثون العديد من الدراسات لمعالجة هذه التحديات باستخدام بروتوكول توجيه IPV6 لشبكه الطاقه المنخفضه والخساره (RPL) تعتمد RPL على وظيفه موضوعيه مختلفه تهدف الى تقليل استهلاك الطاقه ونسبه فقدان الحزم مثل OF0و EXT حسب تصميم الشبكه . في هذه الرسالة ، أجريت دراسة تجريبية لمقارنة OF0 و EXT في إطار سيناريو محدد في الرعاية الصحية لتحديد الوظيفة الموضوعية الأكثر فعالية لتصميم الشبكة ذات الصلة في الرعاية الصحية من حيث استهلاك الطاقة والنسبة المئوية لتسليم الحزمة.

صُممت التجارب على محاكي كوجا ، حيث يعتمد تصميم الشبكة على توزيع 20 عقدة في طوبولوجيا وأنظمة طبولوجيا الشبكة ، وتم تقسيم كل من العقد إلى خمسة أقسام بناءً على الفاصل الزمني وبناءً على التغييرات في كثافة الشبكة ، حيث كثافة الشبكة تم تغيير في حالتين ، الأولى بكثافة 80 ٪ والثانية بنسبة 100 ٪ حيث أظهرت النتائج أن وظيفة OF0 أفضل عند تسليم الطرود وأنها تقلل من استهلاك الطاقة عند 1.95 أكثر من .EXT

الكلمات المفتاحيه :وظيفه الهدف صفر ،الرعايه الصحيه ،طبلوجيا العشوائيه ،الطبلوجيا الشبكه

Chapter One

Introduction

Chapter One Introduction

1.1 Introduction

The increased use of information systems, the proliferation of technology that makes users more dependent on the computer and the digital network have all revealed new technologies in the world of computers including the Internet of Things (IoT) Recently, where IoT has become a potential future and a technology impact on human life, such as health care, logistics, home appliances and sensor wireless networks (WSN), Etc. WSN is a network of wireless sensor networks consisting of a set of sensors that are used in the transmission or monitoring of a specific physical or chemical phenomena without the need for human intervention. The WSN design is based on the application, and there are many routing algorithms and protocols that have been acquired through wireless sensor networks to deal with many challenges, such as a power consumption and loss of packets in any routing algorithm. The researchers have done many studies to tackle these challenges using IPv6 Routing Protocol for Low Power and Lossy Network (RPL) (Quan Le, Thu Ngo-Quynh, Thomaz, Magedanz 2014).in WSN the RPL is a protocol relies on different objective function.

RPL is a routing protocol for wireless networks with power consumption and packet loss. It is a protocol based on IEEE 8 0 2 .15. It has connections such as many to one, one to many, many to many, and supports individual messages, also creates, paths, network, Quickly and actively share topology. The protocol relies on two important components, specifically, a distance-vector (DV) and the source of the routing protocol that handles vectors from distances to other nodes in a network, it requires the router to inform neighbors of topology by changing periodically and calculating the direction and distance between the nodes and choosing the path of the least way between any two nodes. (OF0), (EXT). The way of the source routing protocol works to allow the packet sender to specify the path that the packet follows over the network in whole or in part. Allows node to discover all possible ways of the host.

1.2 Background of the study

It is important at the beginning to clarify the exact meaning of the common terms used in the field of the study are briefly defined as follows:

- Internet of Things (IOT):

The Internet of things refers to a type of network to connect anything with the Internet-based on stipulated protocols through information sensing equipment to conduct information exchange and communications in order to achieve smart recognitions, positioning, tracing, monitoring, and administration. (Keyur K Patel, Sunil M Patel,2016).

- Routing Protocol (RPL):

RPL is IPv6 Routing Protocol designed for Low Power and Lossy networks. RPL is a distance vector routing protocol that builds Directed Acyclic Graphs (DAGs). (AgnieszkBrachman,2013).

- Objective Function:

Is a selection path mechanism when choosing parent node by node underneath to form DODAG. (Nurrahmat Pradeska, Widyawan, Warsun Najib, Sri SungKus,2016).

- EXT:

EXT is directly proportional to the communication cost of the link between two nodes in terms of energy, particularly in Low Power networks. Designing a routing protocol considering EXT as an objective function can be achieved by first mathematically deriving EXT of a link in the network.

- OF0

An Objective Function defines how a RPL node selects and optimizes routes within a RPL Instance based on the information objects available.

1.3 Problem Statement

The ipv6 RPL is the standard routing protocol for WSN and IoT. WSN routing is a crucial factor influencing connectivity and performance of information exchange between the sensors different. The general performance of Low Power and Lossy Network LLN is highly dependent on the choice of routing protocol and quality of its implementation because they are very resource-constrained, such as power supply therefore, control traffic, power consumption, and packet delivery ratio plays a vital role in the performance of the routing protocol. Two objective function within RPL protocol EXT and OF0 is used determine route for packets within IoT networks. Nonetheless, the IoT network design and the spread of sensors or devices will have a major impact on which objective function to choose for routing the packets.

Therefore, a comparative study of using (EXT) and (OF0) to prove their effectiveness in reducing energy consumption and delivery of packages using simulator cooja with using a different network topology. The comparison will be based on a number of the objectives that mentioned above and to indicate which of these functions are efficient based on power consumption and packet delivery ratio.

1.4 Questions of the Study

This research is aimed to answer the following questions:

- Which objective function that fits IoT networks in terms of packet loss and power consumption?
- Which network design is the best fit for both objective function EXT and OF0?

1.5 Goal

The goal of this research is to demonstrate the efficiency of the RPL protocol by using EXT and OF0 as objective functions. To clarify the differences between EXT, OF0 and determine which is the best application scenario that best fit in term of reducing energy consumption and improvements in network access time and packet delivery ratio depending on the network design.

1.6 Motivation

There are many objective functions for RPL we need to conduct a wide comparison of these elements. So we can choose the best protocol for RPL. Then choose the best design for the IOT network, which allows to reducing the loss of energy and loss of packets. A comprehensive study of this subject will be carried out and a comparative comparison between (ETX) and

(OF0) will be made to compare these two functions from all aspects so that we can take the desired objectives.

1.7 Contribution and importance of research

The aim of this research is to study objective functions of RPL protocol in order to compare the energy consumption and the percentage of packet delivery for specific IoT network domain such as in healthcare. The research provides comparisons between functions and reveals the effectiveness of each of them will be comparisons in order to improve these techniques and development.

1.8 Scope of the Study

The scope of this study is inside the classification of the function RPL dependent on wireless sensor network. The work involves examining two functions in that RPL protocol and detecting their effectiveness in term power consumption and packet delivery ratio based on two IoT network topologies.

1.9 Limitations of the study

The study is comparative and limited to the use of IoT RPL objective function within healthcare application to choose the best function and the lowest power consumption and Package delivery ratio.

Chapter Two

Theoretical Background and Literature Review

Chapter Two

Theoretical Background and Literature Review

2.1Overview

This chapter covers the definition of RPL, WSN and IoT concept, objective function and highlights the differences among different objective function, power consumption, packet delivery ratio. Then, a literature survey of RPL variants and their functions and others on the power consumption, packet delivery ratio.

2.2 Introduction to Internet of Things

The Internet of Things is described as the next industrial revolution, as it will make it easier for people to live, travel, industry and other living things. Where the IOT is an evolving concept of the Internet so that all things in our lives possess the ability to connect to the Internet or to each other to send and receive data to perform specific jobs throughout the network where this concept enables an understanding between the devices associated with each other (via the Internet protocol) where it includes devices, tools and sensors where the advantage they provide is the lack of the need for the presence of the human element or its direct intervention at the scene. Where the sensors are used randomly or regularly in a specific geographical area.

2.3 WSN

wireless sensor network also called Low power and lossy network, which is a category of networks consist of devices that have sub-infrastructures for connections intended to control the physical conditions surrounding them in different locations. These devices are called nodes. This contract includes a power adapter, a small computer, and a transmitter and receiver. The network aims to reduce traffic and reduce energy consumption (Hazrat Ali ,2012).

WSNs typically employ Wireless Personal Area Network (WPAN) or Low Power Wide Area Network (LPWAN) standards for data transmission and analysis to the base station, these standards include Bluetooth, ZigBee, or IEEE802.15.4 No single connection solution is now suitable for all WSN. (ABID YAHYA &JOSEPH CHUMA 2017).

The WSN typically contains a set of sensors that are used to transmit or follow a significant physical or chemical phenomenon. Where the information about this phenomenon is transmitted wirelessly to the data processing center to take advantage of it and consists of a set of sensors that are connected wirelessly between these sensors and information is sent to the center for analysis as illustrated in Figure 2.1.

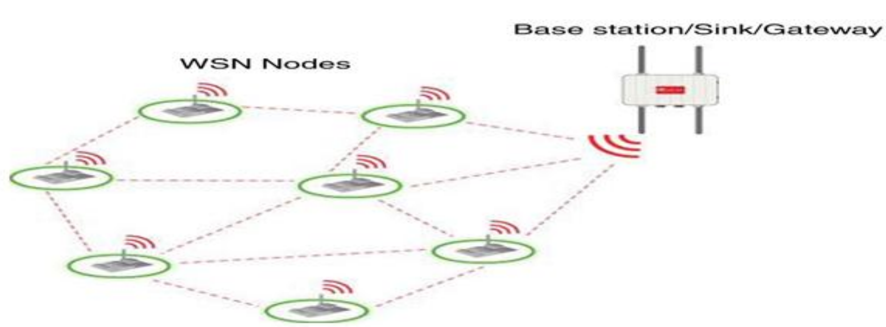


Figure 2.1 A typical WSN (Libelium,2016).

2.3.1 Network Topologies

Network topology refers to the physical or logical layout of a network. It defines the way different nodes are placed and interconnected with each other. Alternately, the network topology may describe how the data is transferred between these nodes. The two types of topology:

2.3.1.1 Random Topology

Random topology is a distribution node in random forms that allow nodes to reach the sink directly or contact each other in order to reach the sink, especial nodes in the edges. (Hussein Altwassi, Mamoun Qasem, Muneer Bani Yassein, 2015).

Figure 2.2 shows a random topology where 20 nodes were randomly distributed and the main node is in the middle and is distributed randomly in a way that ensures coverage of the desired area up to the edges.

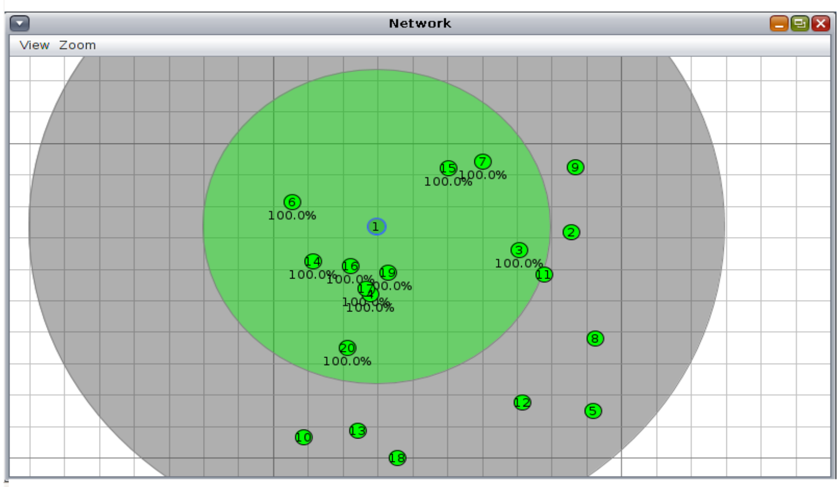


Figure 2.2 Random topology.

2.3.1.2 Grid Topology

In grid topology the distribution of nodes in forms that allow the nodes to communicate with each other in order to reach the sink, the special nodes at the edge, which contributes to the transfer of information between nodes faster, leading to a decrease in energy consumption. (Hussein Altwassi, Mamoun Qasem, Muneer Bani Yassein, 2015).

The grid topology typically it consists of a set of interconnected sensors and each sensor connected to another neighbor two, which allows the transfer of information between each as shown in Figure 2.3.

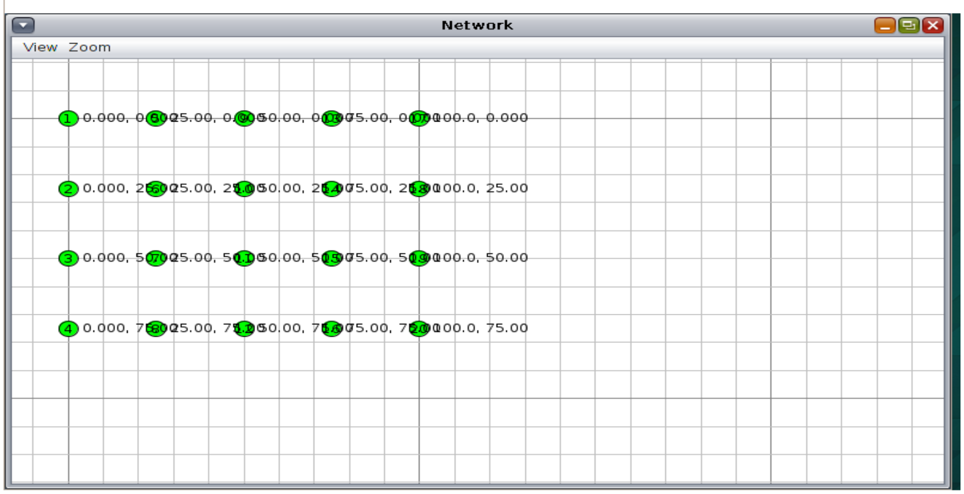


Figure 2.3 Grid Topology

‘

2.4 RPL

The RPL is the IPv6 routing protocol for low-power and lossy networks, standardized by IETF in 2012 as RFC6550. Specifically, RPL is designed to be a simple and inter-operable networking protocol for resource-constrained devices in industrial, home, and urban environments intended to support the vision of the Internet of Things with thousands of devices interconnected through multihop mesh networks. (Hyung-Sin &, Jeonggil K & David E.2017).

RPL supports multipoint-to-point, point-to-multipoint, and point-to-point traffic flows which correspond to upward, downward, and any-to-any traffic patterns, respectively. Typical application scenarios such as monitoring in LLNs require multipoint-to-point traffic flows from the sensing devices to the central control point. Applications such as actuation and selective sensor queries generate point-to-multipoint traffic flows which need downward routes. Since RPL is based on LLNs comprising IPv6 addressable nodes, we can envision diverse point-to-point IoT applications where a device interacts with another device within an LLN.(Chansook Lim,2019).

In addition to RPL creates a topology similar to a tree (DAG or directed acyclic graph). Each node within the network has an assigned rank (Rank), which increases as the teams move away from the root node (DODAG). The nodes resend packets using the lowest range as the route selection. As shown in Figure 2.4.

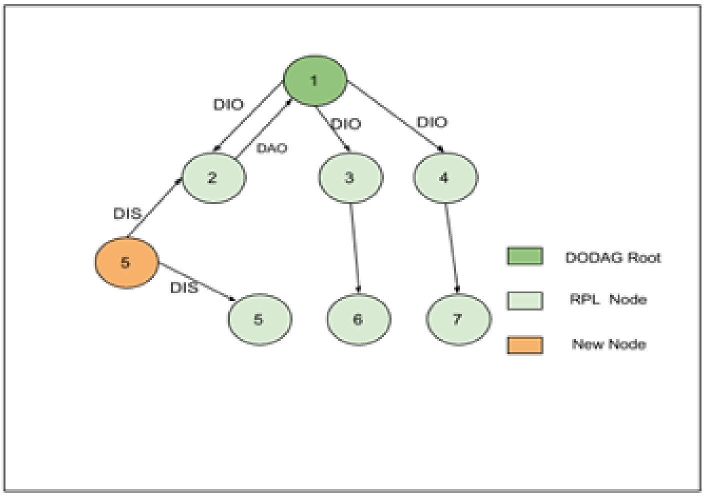


Figure 2.4 A Typical DODAG (Cisco Systems,2012)

There are three types of (DODAG) are as follows:

- DIS (information request DODAG).

Used to request information from nearby DODAG, similar to router request messages used to detect existing networks helping to reduce power consumption and find the shortest route between nodes. (J. Hui, R. Kelsey, P. Levis, Cisco Systems 2012).

- DIO (object of information of the DAG).

The message that shares information from DAG, sent in response to DIS messages, as well as used periodically to update nodes information on the network topology. (J. Hui, R. Kelsey, P. Levis, Cisco Systems 2012).

- DAO (object of update to the destination)

-Sent in the direction of the DODAG, it is a message sent by the teams to update the information of their "parent" nodes throughout the DAG. (J. Hui, R. Kelsey, P. Levis, Cisco Systems 2012).

2.5 Objective Functions

The Objective Function (OF) is used by RPL to specify how the routing metric and constraints should be used to reach specific objectives. For example, the OF may specify that the objective is to find the constrained shortest path where the constraint is related to the node power mode (T. Winter, P. Thubert, R. Alexander cisco system 2012).

2.5.1 Objective Function Zero (OF0)

Objective Function Zero is designed to find the nearest Grounded root. This can be achieved if the Rank of a node is very close to an abstract function of its distance to the root. This need is balanced with the other need of maintaining some path diversity, which may be achieved by increasing the Rank. In the absence of a Grounded root, inner connectivity within the LLN is still desirable and floating DAGs will form, rooted at the nodes with the highest administrative preference. (P. Thubert, Ed. Cisco Systems,2012).

2.5.2 Expected Transmission Count (ETX)

The ETX metric of a wireless link is the expected number of transmissions required to successfully transmit and acknowledge a packet on the link. The Routing Protocol for Low Power and Lossy Networks (RPL) allows the use of objective functions to construct routes that optimize or constrain a routing metric on the paths. This specification describes ETXOF, an objective function that minimizes ETX. The RPL path computation using ETXOF results in minimum-ETX paths from the nodes to the DAG roots, i.e., paths that minimize the number of packet transmissions for packet delivery from nodes in the network to the DAG root. (O.G. Gnawali, Stanford University,2010)

ETX can be considered as a link metric that predicts the number of retransmissions needed for a packet to be successfully received at the destination performs in finding the best path and predicting the number of retransmissions needed to receive the packet. Through the following equation (1), we can find the number of hops and find the best path,

2.5.3 Packet Delivery Ratio (PDR):

This metric is used to measure the total received packets at the root node compared with the total sent packets from clients. The higher PDR percentage of successfully delivered messages to the root node during the test, the higher routing protocol performance. (Shimaa A. Abdel Hakeem, Anar A. Hady, HyungWon,2019).

2.5.4 Power consumption

It’s known that IoT devices are limited in term of power or memory. So long lifetime requirement of different applications and limited energy storage capability of sensor nodes have led us to find out new horizons for reducing power consumption upon nodes. To increase the sensor node's lifetime, circuit and protocols have to be energy efficient so that they can make a priori reactions by estimating and predicting energy consumption.

(Sidra Aslam, Farrah Farooq, Shahzad Sarwar,2009).

Energy consumption is represented in the nodes, which is spent during the change of information in the network and the energy consumption of the node is calculated based on the energy consumed in the transmission and reception during transport. The main objective of RPL protocol is to reduce power consumption and reduce battery drain, thus reducing the consumption period.

2.6 Related works

This section provides a set of selected related works to the use OF0 and EXT objective functions of the RPL protocol with regards to the network design to enhance power consumption and packet loss. The related work arranged from the oldest to the newest

1-(N. Accettura, Grieco, Boggia, P. Camarda,2011) the authors conducted a survey the RPL functions were compared by the COOJA emulator. Where 100 nodes were put and after the comparison, where the stability of the percentage of energy consumption and that the rate of delivery of the package ratio compared to the number of transmissions initial packages.

2-(Hazrat Ali ،2012) the authors of this paper performed an evaluation on the performance of RPL protocol based on two objective functions, OF0 and ETX. The evaluation relies on, Latency, loss of energy, loss of beam, and this measurement was done using the Contiki environment. In an experiment for 80 nodes where OF0 includes the number of jumps and ETX to calculate the best tracks, DIO DOUBLING and DIO MINMAM INTERVAL provides a range of variable functions such as fast network convergence, energy efficiency, reduced costs, reduced access time, high PDR rate and after comparison, ETX is better than 0F0 due to convergence of network time, improved traffic and power consumption But the number of application messages is still high will be an attempt to compare to reduce them. As compared to this work in this thesis a comparison between OF0 and ETX based on the distribution of 20 nodes, where the the random topology and grid network topology. The network design will have based on network scenario a hospital ward.

3-(Mamoun Qasem, Hussien Altawssi, Muneer BaniYassien,Ahmed Al-Dubai,2015)

The authors conducted a comparative study based on two functions (OF0, MRHOF).

This simulation was conducted on 30 nodes and was distributed to random topologies and other GRIDs, and they were tested to show that the energy consumption rate was significantly reduced and also the package delivery rates and that ofs better than MRHOF The results revealed that MRHOF provides the best results compared with OF0 when compared to the delivery of packets and energy consumption, the comparison work was done in COOJA.

4-(Wail Mardini, BassamAl-Shargabi, MuneerBani Yassein, Amani Jamel Alkhatatbeh, Esraa Bani Abdurrahman,2017) In this study, two types of RPL were measured and compared on the basis of their functions. There are two types: the objective function 0 (OF0) and the lower rank with the function of the Horseradish Objective (MRHOF). In OF0, the original nodes will be chosen to achieve the minimum number of hops to the destination. On the other hand, MRHOF selects the parent node so that the expected transmission number (ETX) is proved to have been increased by increasing packet reliability.

5-(Wail Mardini, Maad Ebrahim, Mohammed Al-Rudaini,2017) In this paper, the researcher presented an analysis of the performance of the routing RBL, which is widely used in the protocol of wireless sensor networks, where two OF0 and MRHOF functions were analyzed using fixed topology and random mobile networks with 81 nodes and three transmitting bands 11,20,50 meters. Where this comparison was made based on average received beams, average lost packets and number of hops, the goal was to reduce power consumption and reduce lost packets.

6-(Aashima Bisen, Jimmy Matthew ,2018) The author of this paper, using functions such as the radio duty cycle, the number of hops and the power consumption of each contract, he made a comparison between 21 nodes and they were randomly distributed and as a result of that distribution all nodes were sent in an area of 200 m and DAG was used to send the packages in a way that ensures their final destination It was found that these jobs achieved a decrease in power consumption.

7- Banh, Mai, et al., evaluate the performance of RPL by using two objective functions and two RPL instances in the network layer. The comparison was made between single and multiple instances in term of three performance matrices: routing tree convergence, latency, and PDR. The simulations were made by using the Cooja simulator with two types of data: regular and critical data. The authors set the value of Successful Reception Ratio (RX) to three values: 70%, 85%, and 100%. Regarding the routing tree convergence metric, the results show that using multiple instance increase the routing tree convergence time in a comparison with a single instance, this because every node has to join the both DAGs and thus the convergence time need more time to complete the two DAGs construction. In other hands, by using multiple instance, the performance in term of latency and PDR is also better.

8 -Barceló, Marc, et al. create multiple RPL instances with a cooperative strategy between instances called (C-RPL) which organize RPL multiple instance to create energy efficient coalitions taking in account both the OF for each instance and other network characteristics. The main stone in C-RPL is what the authors called "collation", which consists of multiple instances with a collaborative relationship between its nodes to improve their utilities. The authors proposed a fairness analysis for networks with multiple instances to manage the trade-off between performance and power consumption. To evaluate C-RPL, the authors made a comparison between C-RPL and RPL with different traffic using Matlab. The comparison was made between four RPL versions: RPL, RPL version two (RPL II), C- RPL, C-RPL No Cooperation Game (C-RPL NCG). In general, the results show C-RPL create instances efficiently according to the objective functions and other network conditions. In term of power consumption, CRPL always trends to consume less power by adapting the number of created instances regarding network densities. Also, it provides more balanced energy consumptions and performance.

Table 2.1: Comparison between RPL Classifications

ID	Title	Yea r	The Main Goal	Strength point	Weakness point
1	Performance Analysis of the RPL Routing Protocol	2011	1. RPL can ensure a very fast network set- up thus allowing the development of advanced monitoring application also in critical conditions. 2. Decrease the protocol overhead.	1. RPL is a very powerful technique, granting a very fast network set-up and bounded communication delays. 2.Effectiveness can be further improved in terms of overhead,	1. Low data rates. 2. Limited energy reserves. 3. Link failures.
2	A Performance Evaluation of RPL in Contiki	2012	Evaluate the performance of the (RPL) with respect to different performance metrics	1. RPL to provide good energy efficiency. 2. lower Control Traffic overhead	1. Energy efficiency. 2. PDR and connectivity becomes more difficult.
3	Performance Evaluation of RPL Objective Functions	2015	Selects the ideal routes from a source to destination node based on certain metrics injected into the Objective Function (OF).	1. Great impact on the PDR and achieved saved energy levels in the given networks. 2. Indicated that the performance of RPL within light density networks for MRHOF can provide a better RPL behavior that OF0 could not provide.	1. Energy efficiency is only when RX 60%. 2. Ineffective in heavy networks.
4	Energy Saving in Modified RPL: An Experimental Study and Results	2017	Balancing energy consumption between sensor nodes within wireless sensor networks to try to extend the life of the network.	1. The distribution of energy consumption between nodes leads to extended network life. 2. Improved reliability increases packet delivery for WSN.	1. The expected number of transmitters leads to an unbalanced distribution of energy between the nodes. 2.Lack of interest in reliability mainly
5	Comprehensive Performance Analysis of RPL Objective Functions in IoT Networks.	2017	Comparing the two functions of OF0 and MRHOF in terms of average transmission, average package and the number of hops to choose the best of these functions based on reducing power	1. Using a fixed and random topology. 2.Make a comprehensive comparison of all objective function	1. Make improvements to deal with mobile- random 2. modifying the internal parent selection methods of the Objective Functions that may

			consumption and the number of hops		enhance the Convergence
6	Performance Evaluation of RPL Routing Protocol for Low Power Lossy Networks for IoT Environment	2018	The relationship between fixed and mobile nodes and checking the efficiency of the contract on a continuous basis, which guarantees the best methods between the contract and the maintenance of energy in a stable manner.	1. Applying metrics to all nodes periodically and examining two models to reduce energy consumption. 2.The results demonstrate that the utilization of energy is identified with the quantity of sink nodes	1. The increase in the number of nodes, which leads to an increase in the number of measures used in the evaluation. 2.Transferring the contract leads to consuming more energy than the fixed contract
7	Performance evaluation of multiple RPL routing tree instances for Internet of Things applications.	2015	using two objective functions and two RPL instances in the network layer.	1. best path is based on the value of the hop 2. are the two slandered objective functions in RPL. 3. selecting the possible parents' list and defining the priority	1. multi-objective metrics that the single routing metric 2. C-RPL and RPL with different traffic
8	Cooperative interaction among multiple RPL instances in wireless sensor networks.	2016	The main stone in C-RPL is what the authors called “collation”, which consists of multiple instances with a collaborative relationship between its nodes to improve their utilities. The authors proposed a fairness analysis for networks with multiple instances to manage the trade-off between performance and power consumption. To evaluate C-RPL, the authors made a comparison between C-RPL and RPL with different traffic using Matlab.	1. cooperative strategy between instances 2. create instances efficiently according to the objective functions and other network conditions 3. it provides more balanced energy consumptions and performance.	1. Collaborative relationship between its nodes to improve their utilities. 2. time in a comparison with a single instance

2.7 Summary

In this chapter, several studies that are related to RPL protocol for wsn were reviewed, described, analyzed, and summarized. This review included the advantages, limitations, objectives, and effectiveness of their protocol for WSN. In general, the existing approaches aim at either increasing the performance of the RPL or reducing power consumption. It is noted that it is possible to compare more than one function. One of the important functions of the routing protocol is to find the shortest possible ways between the contract and add improvements such as reducing energy consumption, reducing the loss of packets and increasing efficiency. In the transfer of the information, it will be studied and conducted in-depth to indicate which functions are more useful.

Chapter Three

Methodology and the Proposed Work

Chapter Three

Methodology and the Proposed Work

3.1 Overview

This chapter presents the proposed methodology; the organization of this chapter is as follows: Section 3.2 discus the importance of RPL protocol performance metrics of IoT-based healthcare monitoring systems. Section 3.3 presents and analyzes the comparative study of RPL protocol methodology and its implementation steps. Finally, Section 3.5 gives a summary of this chapter.

3.2 Introduction

This chapter provides the details of the steps performed to achieve the objectives of this thesis and answer the main research questions: "Which objective function that fits IoT networks in terms of packet loss and power consumption?" and" Which network design is the best fit for both objective functions EXT and OF0". Therefore, the IoT network design in healthcare is major challenge when implementing the RPL protocol regarding which objective function to be chosen. Sensors in IoT network in ICU have higher priorities and the packet loose in such network my result in major disaster to a patient. In order to determine which objective function is best fit for different scenarios of implementing RPL in IoT network within healthcare we will perform a comparison through OF0, EXT, these systems will be applied in a private hospital in Jordan as a case study using the structure and distribution of medical departments, through which we can determine the objective function that suits the Internet Things network in terms of energy consumption and packet loss, and which best and efficient network design for these functions will be performed by using this evaluation simulator Cooja.

3.3 Research Methodology

The methodology used in this thesis as illustrated in figure 3.1, consist of the following steps:

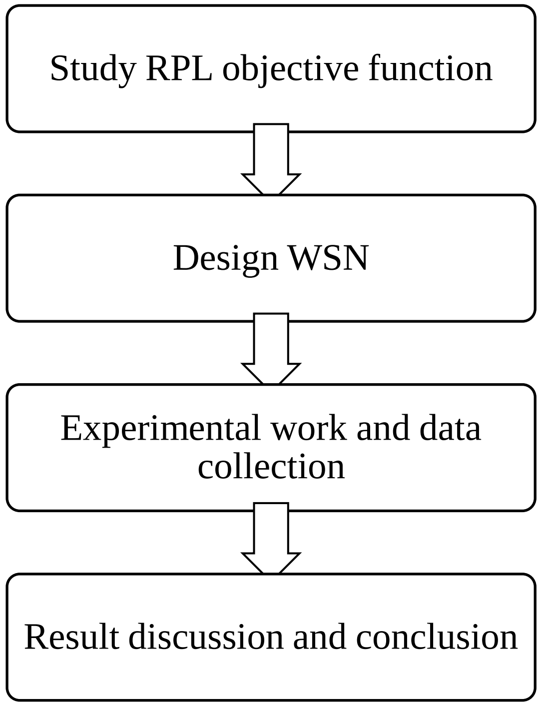


Figure 3.1 Research Methodology.

3.3.1 STUDY RPL OBJECTIVE FUNCTION

(RPL) is a measurement protocol for a wireless sensor network. Two functions are used in this command: ETX, OF0 where EXT is used to calculate the best path between nodes and OF0, the number of jumps. The objective of this assessment is to evaluate the performance of these functions through a scenario to evaluate power loss and packet loss. In this scenario, extending the efficiency of OF0, which is the number of jumps, that will take as many jumps from source to finish by determining the origin, and calculating the EXT in the best possible path because of specific criteria for this evaluation, such as energy consumption and packet loss, this comparison will be created in COOJA.

3.3.2 DESIGN WSN:

The network design scenarios will be implemented by the cooja Simulator. This network design will be implemented for one of the hospital floors where there are two different sections, namely the intensive care unit (ICU) wards and the ordinary patients (inpatients) wards where the intensive care section contains ten beds and the regular inpatients has twelve beds, where we need in the inpatients wards and the ICU wards on a set of sensors where the health status of each patient should be monitored as shown in Figure 3.2.

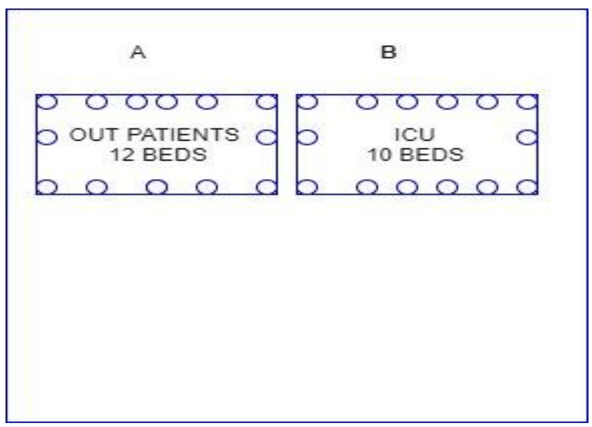


Figure 3.2. Internal departments of the hospital

So that we can record vital signs and record environmental factors such as temperature, humidity, pressure, etc., where section (B) is one of the most important sections and must be given high importance and taking vital signs continuously and that section (A) less important and take vital signs every time period of Time. Patients will be divided as follows:

- Very critical.
- Critical.
- Regular cases (residents).
- Environmental labels such as pressure and heat.

As this floor, where these departments have intensive care and inpatients, vital signs must be taken continuously and periodically and in five minutes for ordinary patients and an average of 10 seconds for very critical cases and 20 seconds for critical cases where the following table 3.1 indicates the periods of transmission and the size of packets sent.

Table 3.1 The proposed values for data traffic's sending interval and packet size.

Data Traffic Type	Sending Interval	Packet size
High-critical	Average of 10 seconds	16 bytes
Critical	Average of 20 seconds	16 bytes
Low-critical (periodic)	Every 5 minutes	48Bytes

- **Topologies and Simulation Setup**

The construction of the topology depends on the distribution of the partition as shown in Figure 2.3 and shown in the previous section. This section provides more details on the topology creation of this section and how different types of traffic can be expressed in practice using Cooja simulator. The process of constructing topology will depend on the distribution of random and grid topology. Each representative section has a different topology that corresponds to the number of beds in each medical wing. We assume that each patient residing in a single bed should be connected to two healthy medical devices to collect two types of vital signs. Regarding the number of sensors (nodes) responsible for collecting environmental standards, it is assumed that we will be equal to 20 distributed in the medical wings in each department. Whereas, EXT will be used for high-critical and critical data traffic functions and will use the of0 function for traffic.

So that we can make this experiment in the IOT healthcare network design using the RPL protocol using the cooja simulation and depending on specific as shown in the following table 3.2.

Table 3.2 simulation parameter

Parameter	Value
OF	OF0,EXT
Mote type	Sky mote
Transmission Ratio	100%
Transmission Range	100m
RX Ratio	80%-100%
Simulation time	900 second
Squared Area	1000 meters
Topology	Random, Grid

- **Random Topology**

Referring to the following figure 3.3, 20 nodes were randomly distributed and their source point was 50.50 this format was designed based on the COOJA Simulator.

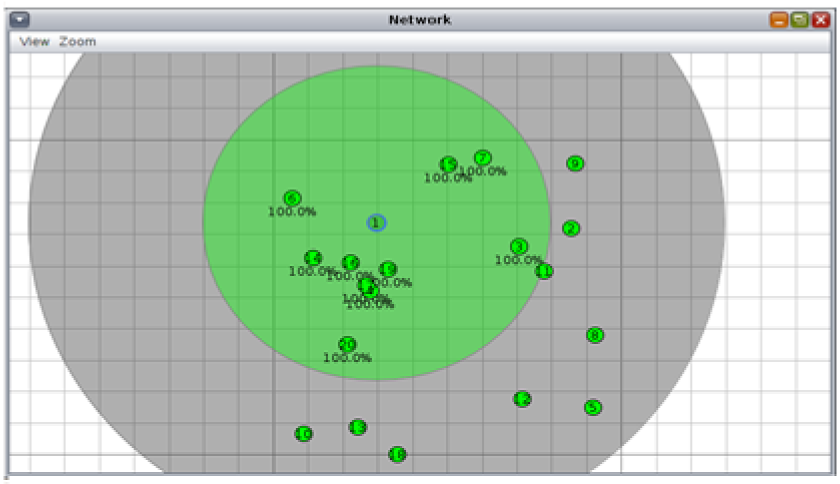


Figure 3.3 Random Topology

Grid Topology

The network topology shown in Figure 3‹4 was used where the nodes are allowed to communicate with each other in order to reach the sink.

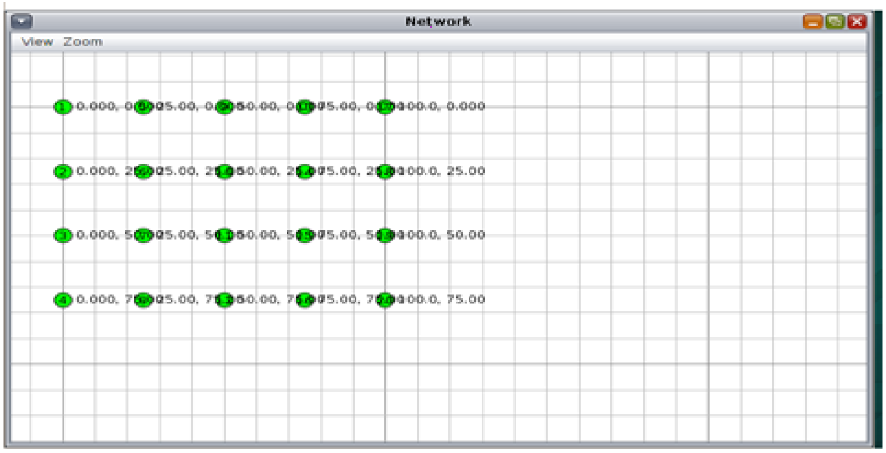


Figure 3.4 Grid Topology

3.3.3 Experimental work and data collection

In this step, the IoT network design scenarios will be implemented on cooja simulator to collect data about the use of two objective functions of RPL protocol with regards power consumption and packet delivery ratio in random and grid topologies to select the best path between IoT network nodes.

3.3.4 Result and discussion

Based on the collected data from experiments for the IoT network scenarios, an evaluation for two objective functions for IoT network scenario will be conducted with regards power consumption and packet delivery ratio along with the suitable IoT network topology.

3.3.5 Summary

In this chapter, the RPL protocol was used using the cooja simulator which relies on the Internet of things, where a specific scenario was set up in a hospital section. A number of sensors were distributed within this section to enable us to measure the environmental and biological factors of each patient, and a specific method of work method was followed:

1. Study RPL objective function
2. Design wsn
3. Experimental work and data collection
4. Result discussion and design wsn

In order to allow us to make a comparison and choose the best between the objective function available to us based on specific parameters through which the results will be extracted so that we can choose the appropriate job and thus we have achieved the goal.

Chapter Four

Implementation and Results

Chapter Four

Implementation and Results

4.1 Overview

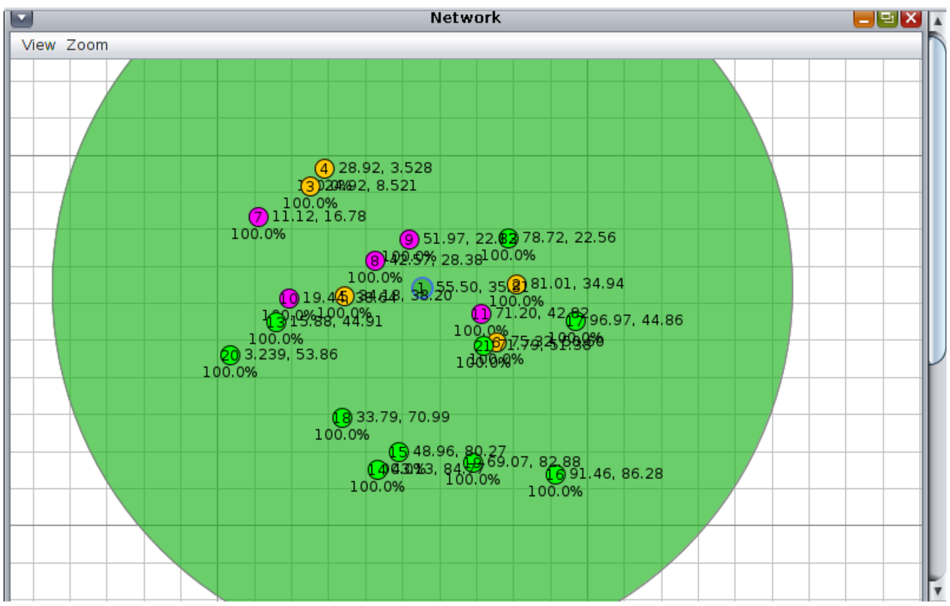
This chapter shows the experimental results of the proposed methodology OF RPL protocol. This chapter is sorted out as pursues: Section 4.2 gives an introduction to the investigations led. Section 4.3 talks about the implementation of subtleties. Section 4.4 presents the parameter settings for the proposed and compared approaches. Section 4.6 presents the results of the implementation and demonstrates the performance of the proposed RPL. At long last, Section 4.7 gives a summary for this chapter.

4.2 Introduction

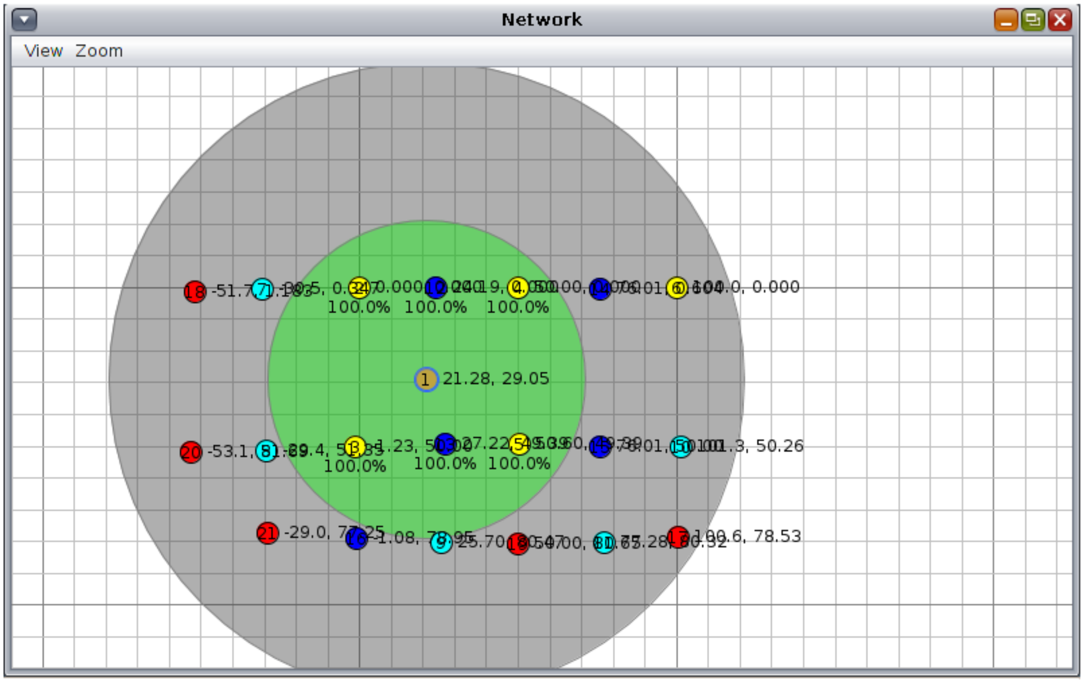
This section presents the experimental evaluation study of RPL using the data collected from the Cooja simulator. The objective of the experiments is to evaluate the two objective functions: OF0 and EXT, in terms of packet delivery ratio and power consumption. Experiments are performed with different numbers of nodes and different topologies such as random topology and grid topology and apply it to a specific scenario in order to check the effect of these factors on RPL performance. These factors will be analyzed based the experimental results obtained from the Cooja simulation. Therefore, new results have been observed in order to provide a comparison EXT and OF0.

4.3 RPL Performance implemntation rely on OF0

Experiments were placed under different network densities where (20 nodes) will be distributed, according to the time interval, so that each 5 nodes will be distributed using different times. Using random topology and grids therefore we will observe OF0 performance for different values of RX. We'll change the RX values (80 and 100%) and we'll investigate the RPL behavior in terms of delivery rate and power consumption. The result of this simulation is obtained from the OF0 installed nodes. The medium is extracted so that we can make a comparison as in the following figure 4-1 and figure 4-2



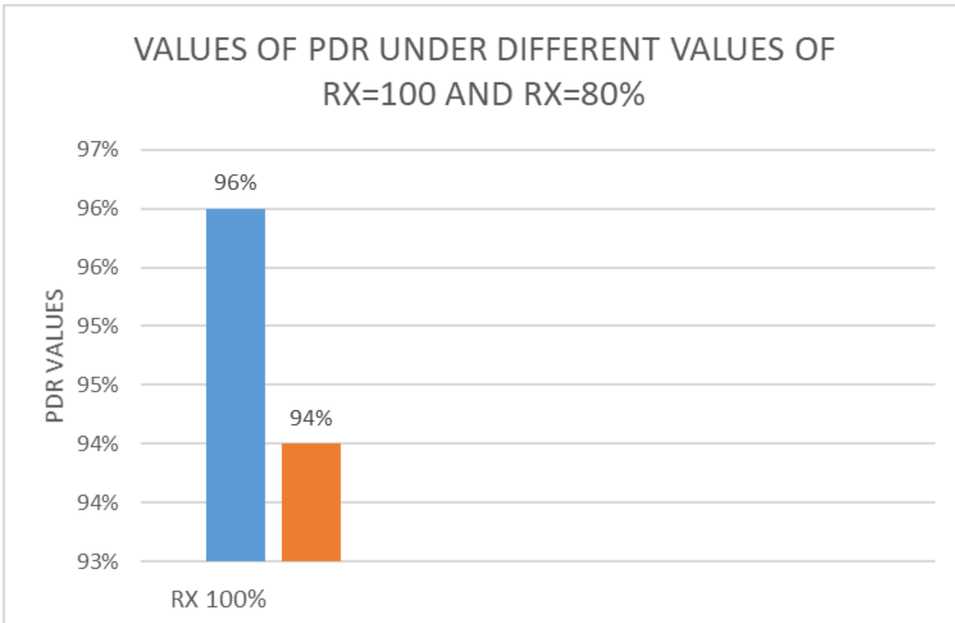
Figures 4-1 distributing 20 nodes in random topology



Figures 4-2 distributing 20 nodes in grid topology

4.3.1 paket delavery ration in random topology

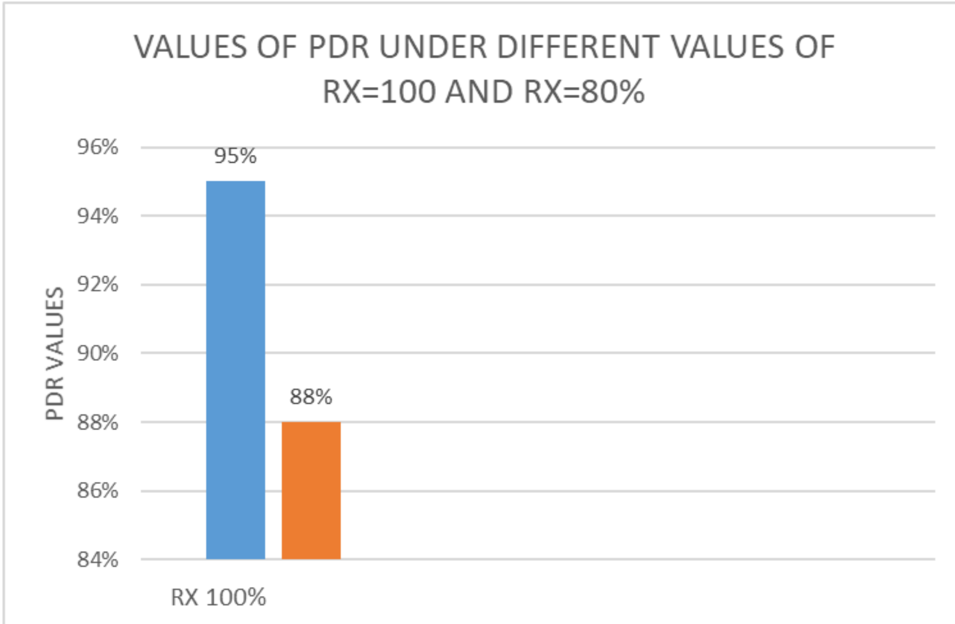
As shown in Figure 4-3, PDR behavior is presented based on the changes that occurred in RX, which were implemented in a random topology. Since it was compared when using RX 100 and 80% Whereas, the RX values were fixed at 100%, and the following results appeared, as the percentage of packet delivery reached 96% where the values of the PDR increase with increasing the value of RX. In the following figure 4-3, where the behavior of the PDR was presented based on the change in the value of RX where it was set at 80% and it was executed in random topology where comparisons were made based on the number of nodes and by sending different times where they were divided into four sections where we note that the value of PDR Change in random topology, where the rate is about 94, where delivery rates are good when using RX 80%, as they are sufficient to send messages.



Figures 4-3 PDR value when RX 100% and 80%

4.3.2 Packet delivery ratio in grid topology

As shows in Figure 4-4, the behavior of the PDR when applied to the network topology, as the value of the PDR is directly affected by the intensity of the network and when applying the density by 100% the value of the PDR was 95% where we note that the value has increased, leading to a good delivery rate based on the network topology. In the following figure, we note that the value of PDR decreases when applied in RX 80 where the rate is 88%



Figures 4-4 PDR value when RX ratio 100% and 80%

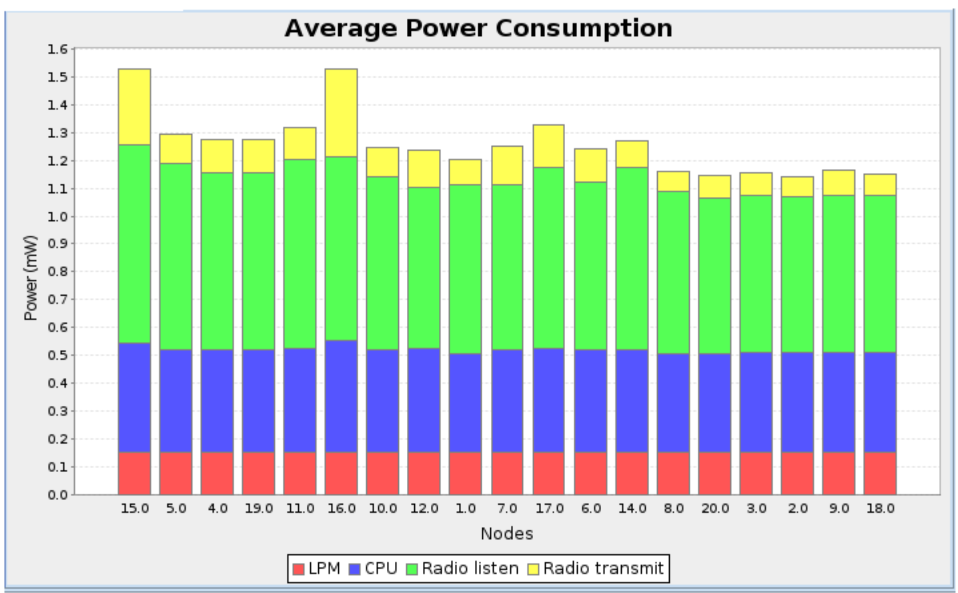
In summary, table 4-1 shows that the OFO give better result for packet delivery ratio compared to the grid topology.

TAPEL 4-1 RESULT FOR PDR WHEN RX 100%RX80%

PDR WHEN N=20	RANDOM TOPOLOGY	GRID TOPOLOGY
RX100%	96%	95%
RX80%	94%	88%

4.3.3 power consumption when RX ratio 100% in random topology

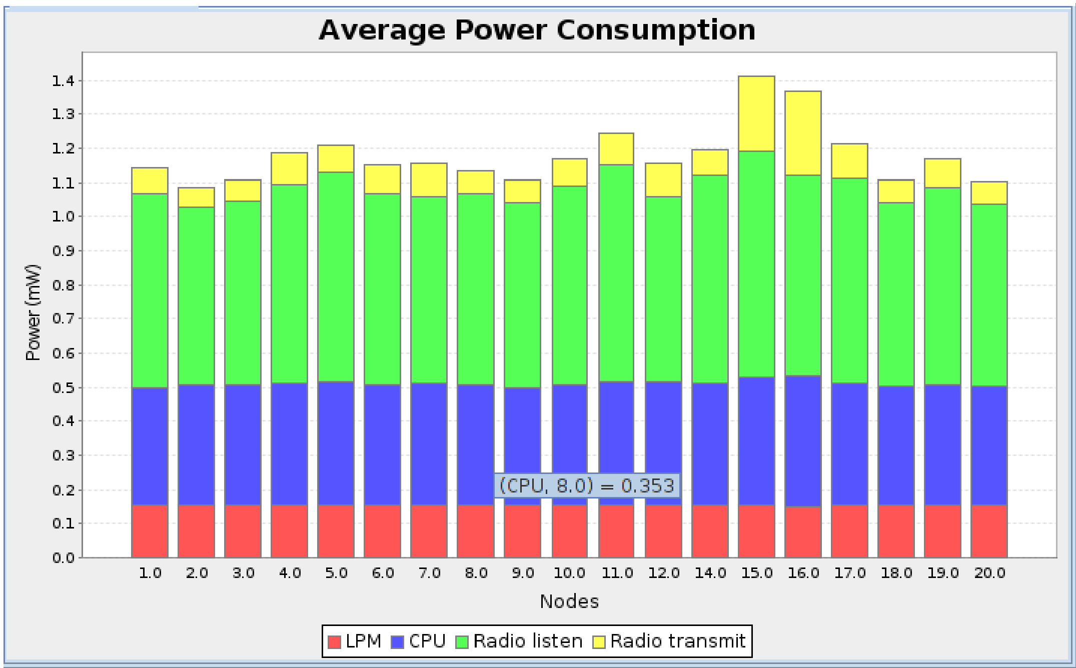
The following figure 4-5 shows the behavior of power consumption based on RX levels in random topology, as it has been observed that the values of power consumption have decreased, and the RX values have been increased as the average power consumption is good, and when the RX is equal to100% we get a result1.62.



Figures 4-5 power consumption when RX RATIO 100%

4.3.4 power consumption when RX ratio 80% in random topology

The following figure 4-6 provides an average RPL of the same rate of consumption for random topology, about 1.473% at RX equals 80%. The reason is that the RX value has not been detected yet 82%, which is enough to conserve energy.



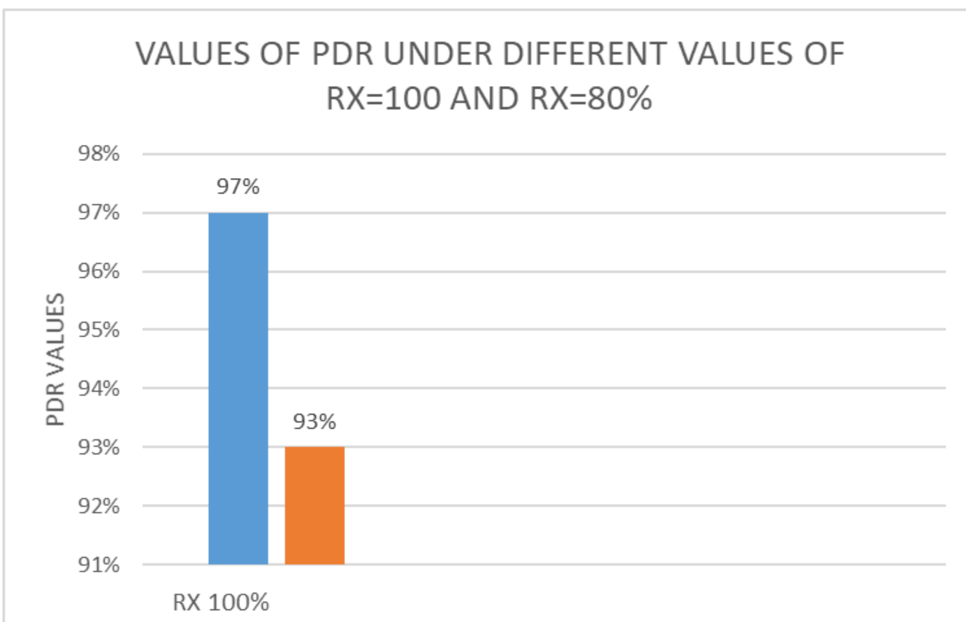
Figures 4-6 power consumption when RX RATIO 80%

4.4 RPL Performance implemntation rely ON EXT

We have set the experiments under different network densities (20, nodes) using Random and Grid topologies so to observe the performance of EXT for different values of RX. We vary the RX values (80, and 100%), A comparison will be made of the RBL behavior in terms of package delivery rate and power loss .

4.4.1 paket delivery ratio in random topolgy

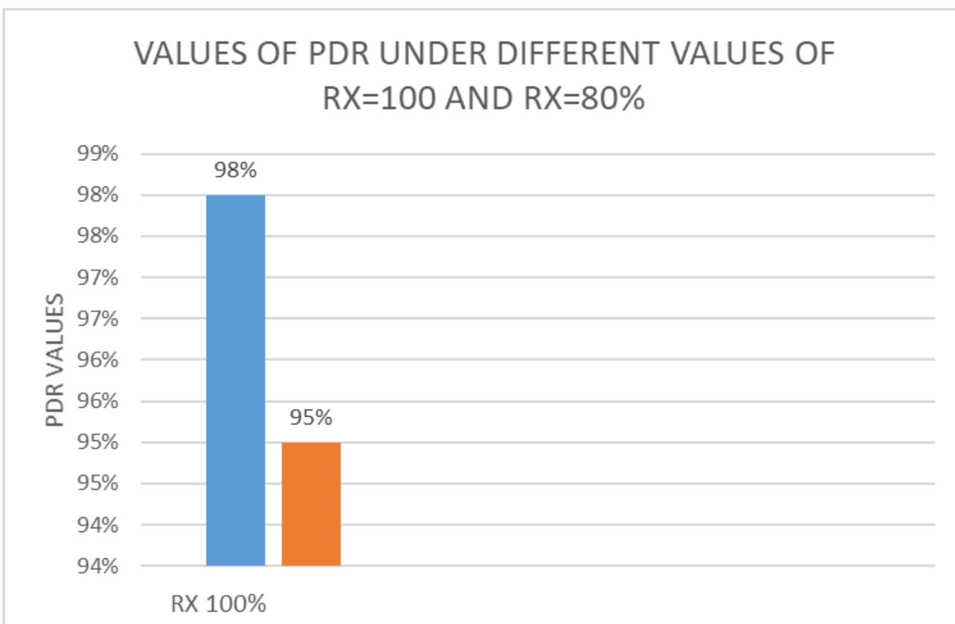
As illustrated in figure 4-7 PDR behavior based on RX in random topology, and we notice that PDR values increase when RX values increase. And that when performing the PDR simulation, the value reached 100% when the RX is greater than or equal to 80% and this means that we can use the value of RX 100% instead of 80% RBL provides an almost bad delivery rate (97%) The following graph shows 4-7 PDR behavior based on RX in random topology, and we notice that PDR values increase when RX values increase. And that when performing the PDR simulation, the value reached 100% when the RX is greater than or equal to 80% and this means that we can use the value of RX 100% instead of 80% RPL provides an almost bad delivery rate (93%) Where it was measured inside the random topology when it was RX = 80% where the result was 93% .



Figures 4- 7 PDR when RX ratio 100%and 80%

4.4.2 paket delivery ratio in grid topology

As illustrated Figure 4-8, the behavior of the PDR when applied to the network topology, as the value of the PDR is directly affected by the intensity of the network and when applying the density by 100% the value of the PDR was 98% where we note that the value increased, leading to a good delivery rate based on the grid topology. In the following figure, we note that the value of PDR decreases when applied in RX 80% compared when it was compared to where the percentage of packet delivery within it, depending on the grid topology, reached, where it decreased the packet delivery rate by three degrees at RX 100%.



Figures 4-8 PDR when RX ratio 100%and 80%

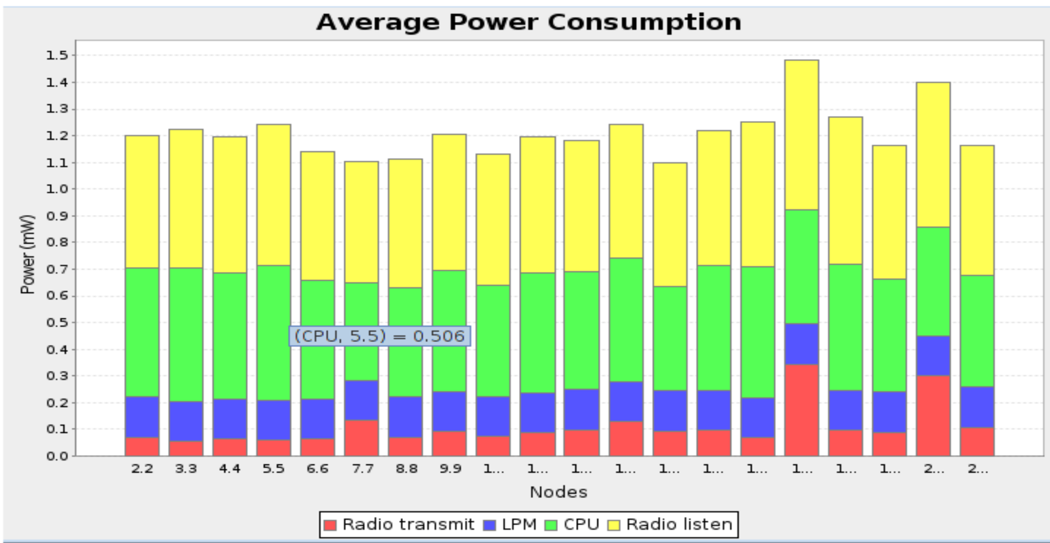
In summary, table 4-2 shows that the EXT give better result for packet delivery ratio compared to the grid topology.

TAPEL 4-2 result for PDR when RX 100%RX80%

PDR WHEN N=20	RANDOM TOPOLOGY	GRID TOPOLOGY
RX100%	97%	93%
RX80%	98%	95%

4.4.3 power consumption when RX ratio 100% in random topology

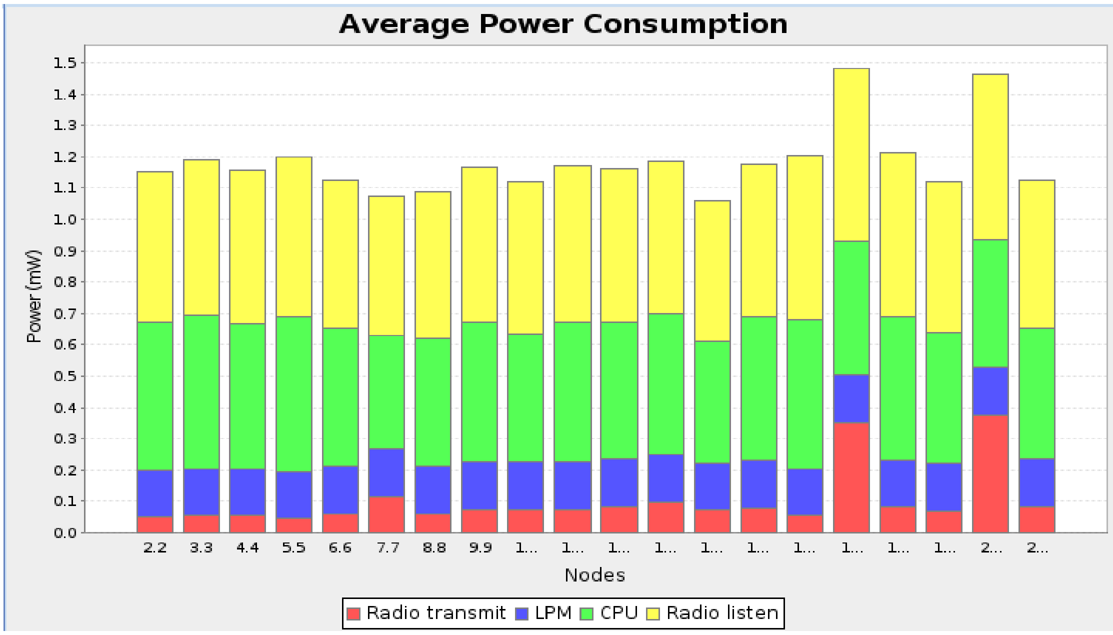
As illustrated in figure 4-9, where it shows the behavior of power consumption based on RX levels in random topology, as it has been observed that the values of power consumption have decreased, and the RX values have been increased as the average power consumption is good, and when the RX is equal to100% we get a result 1.302%



Figures 4-9 power consumption when RX RATIO 100%

4.4.5 Power Consumption when RX ratio 80% in random topology

The following figure 4-10 provides an average RPL of the same rate of consumption for random topology, about 1.11% at RX equals 80%. The reason is that the RX value has not been detected yet 82%, which is enough to conserve energy.



Figures 4-10 power consumption when RX RATIO 100%

4.5 Impact of RX on RPL performance reliance on OF0 and EXT.

By keeping the node packet reception ratio constant, a useful result of this simulation is achieved from the nodes that have installed OF0 or EXT by setting a fixed number of nodes, we can obtain topologies that have given us the chance to observe the OFs under different network densities. Therefore, we have thoroughly compared the main effects of using OF0 and EXT to evaluate the behaviour of RPLthrough computing the PDR and Power consumption for each of those topologies.

4.5.1 paket delavery ratio

the result in a random topology was used and found that the average packet delivery ratio of OF0 is approximately 0.96% and that the average packet delivery ratio of EXT is approximately 0.97%.and when we have used Grid topology to represent the average packet delivery ratio, and the results show similar behaviour, where average packet delivery ratio of OF0 is approximately 0.95% and the average packet delivery ratio of EXT is approximately 0.98%. By contrast, the PDR collection from the simulation results observed that the OF0 and EXT have given a good PDR where EXT outperforms OF0. This is due to a simple difference in the light density network that we used. In these results, we observed in the network configured by 20 nodes that the average PDR is best when the network density is for RX 100% using Random or Grid topology.

TAPEL 4-3 RESULT FOR PDR WHEN RX 100%RX80%

PDR WHEN N=20	RANDOM TOPOLOGY	GRID TOPOLOGY
RX 100%	96%	95%
RX 80%	94%	88%
RX 100%	97%	98%
RX 80%	98%	95%

4.5.2 power consumption

the results show that the average power consumption of OF0 is approximately 1.62% and the power consumption of EXT is approximately 1.30% when using Random topology. A similar average power consumption behavior of both OFs was achieved when we used Grid Topology and then the results show that the average power consumption of OF0 is approximately 1.47% and the power consumption of EXT is approximately 1.11% when using Random topology. A similar average power consumption behavior of both OFs was achieved when we used Grid topology and The average power consumption has a steady increase for both OFs when the network's light density is RX 80. Simulation results revealed that the OF0 consumes more power than EXT, and the average power consumption for both OFs is best when the network density is at 20 nodes. Moreover, we have found that the standards-based RPL produces similar behavior of PDR for both OFs in this light density network and that the average power consumption of OF0 outperforms EXT.

4.6 Summary

This chapter presents the implementation of the methodology that was previously developed where it was implemented to make a comparison between the functions of RPL PROTOCOL which are OF0, EXT in a specific scenario in the health care system where this comparison was implemented in the cooja simulator where the results showed that OF0 is better and saves energy consumption and maintains a rate Package delivery compared with EXT when applied with random and network topology.

Chapter Five

Conclusions and Future Work

Chapter Five

Conclusions and Future Work

5.1 Conclusion

In this thesis, we presented a comparison between the RPL functions in order to reduce the energy consumption and the percentage of packet delivery based on a specific scenario in the healthcare systems that was developed and was taken reading through random and network topology, where these experiments were conducted through a certain number of nodes with different network density Where results showed that the function OF0 is the best when delivering packages, as it reduces the rate of energy consumption at 1.95 more than EXT, which helps us in developing the healthcare system and reducing energy consumption directly in the nodes. which helps us in developing the healthcare system and reducing energy consumption directly in the nodes, in icu when PDR rate must be high, because if it low, patient may be high risk or death therefore when design IOT network in ICU we will configure IOT result to use OF0 And other patent use in icu EXT because delivery rate is low .

5.2 Future Work

The future and suggested works for the RPL protocol in this thesis are as follows:

1. Application of the protocol RPL multiple instances

2.Apply bottlenecks in the RPL protocol and apply it in the healthcare system

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