Table of Contents

[ **Steps of Master thesis** 1](#_Toc455361288)

[**1.** **Comparison of WSN hierarchical routing protocols according to energy efficiency heterogeneity levels** 2](#_Toc455361289)

[1.1. Abstract 2](#_Toc455361290)

[1.2. Studied protocols 2](#_Toc455361291)

[1.3. Simulation results 2](#_Toc455361292)

[1.4. Summary 2](#_Toc455361293)

[**2.** **Added value of research** 3](#_Toc455361294)

[2.1. Abstract 3](#_Toc455361295)

[2.2. Suggest a mathematical model 4](#_Toc455361296)

[2.3. Modify behavior of LEACH to include previous mathematical model. 5](#_Toc455361297)

[2.4. Comparison and evaluation of proposed algorithm with LEACH 5](#_Toc455361298)

[2.5. Summary of simulation results. 5](#_Toc455361299)

# **Steps of Master thesis**

I performed my master thesis in two parts:

**First part:** I studied hierarchical routing protocols in WSN, I focused mainly on three protocols which designed to cop to different levels of energy heterogeneity. Then i implemented them in MATLAB to simulate then evaluate their performance according to defined performance measures.

This part yields to my ***first paper*** which I published in IRECOS Journal.

**Second part:** from the previous study, I figured out a new mathematical model that saves more energy in some cases of nodes localization in homogeneous environment. Then I draw the flow chart that took into consideration the implementation of the new model. I implemented and tested the in MATLAB to simulate then evaluate their performance according to defined performance measures.

This part yields to my ***second paper*** which I published in Damascus Journal for engineering science.

Details about my two papers will be discussed below, but the simulation parameters and results is found in my papers.

# **Comparison of WSN hierarchical routing protocols according to energy efficiency heterogeneity levels**

## Abstract

*The hierarchical routing protocols of WSN depend on clustering algorithm to reduce energy consumption. Theses protocols can increase scalability and lifetime of the network. Energy-efficient clustering protocols should be designed for adapt to the characteristic of energy efficiency heterogeneity of wireless sensor networks.*

*In this paper, we evaluate hierarchical routing protocols by their sensitivity to energy heterogeneity and their effects on lifetime, number of cluster heads per rounds, performance, stability and instability period of the whole network.*

*The obtained simulation results show the comparison between three routing protocols designed to cop to different levels of energy heterogeneity. The first protocol (called LEACH) designed for homogeneous network, the second one (SEP) designed for tow-level heterogeneous networks and the third and last one (DEEC) designed for multi-level heterogeneous networks.*

*This paper shows which hierarchical routing protocol to use in sensor networks to cope with targeted performance measures taking into consideration application needs.*

## Studied protocols

I evaluated energy efficiency for hierarchical routing protocols by studying three protocols differing one from each other by heterogeneity level that we take it into account.

These protocols was: LEACH, SEP and DEEC.

I studied the mathematical model of energy consumption for each protocol and compared performance of the selected protocols based-on measures which are stability period, instability period, network lifetime, number of cluster heads per round and number of deed(or alive) nodes per round.

## Simulation results

I performed the comparison in three different types of environments, they are   
**1.2.1.** Homogeneous environment

**1.2.2.** 2-level Heterogeneous environment

**1.2.3.** n-level Heterogeneous environment

I discussed the suitable protocol for each case of environment type insight of each performance measure.

## Summary

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Homogenous** | **2-level**  **Heterogeneous** | **Multi-level**  **Heterogeneous** |
| **Stability period**  (crucial for many applications where the feedback from  the sensor network must be reliable ,so the longer value is preferred) | LEACH & DEEC yield to long measure value (**preferred**).  SEP yields to small measure value. | SEP has the greatest measure value (**preferred**).  LEACH & DEEC have the smallest measure value. | DEEC yields to the longest measure value (**preferred**).  LEACH yields to long measure value if there is a little bit difference between nodes’ energy.  SEP yields to the smallest measure value. |
| **Instability period**  the smaller value is the preferred value | LEACH & DEEC yield to small measure value (**preferred**).  SEP yields to long one. | LEACH & DEEC yields to long measure value.  SEP yields to small measure value (**preferred**). | DEEC yields to small measure value (**preferred**).  LEACH yields to small measure value if there is a little bit difference between nodes’ energy.  SEP yields to long measure value. |
| **Total throughput**  the longer value is preferred | SEP & DEEC have the largest throughput (**preferred**).  LEACH has the smallest throughput. | DEEC has the longest throughput (**preferred**).  SEP has less throughput comparing to DEEC.  LEACH has the smallest throughput. | SEP has the longest throughput (**preferred**).  DEEC has throughput less than SEP.  LEACH has the smallest throughput. |
| **Lifetime**  the longer value is preferred in the case of no need for reliability | LEACH & DEEC yield to small lifetime (**preferred if reliability not necessary**).  SEP yields to long lifetime. | LEACH & DEEC yield to long lifetime.  SEP yields to small lifetime (**preferred if reliability not necessary**). | DEEC yields to small measure value.  LEACH yields to long measure value if there is a little bit difference between nodes’ energy.  SEP yields to long measure value (**preferred if reliability not necessary**). |
| **No. Of CHs**  (optimal value is N\*) | In LEACH, it is centred around optimal value (**preferred**).  SEP, it isn’t centred around optimal value during instability period (long period).  DEEC, there is a variance in it. | In LEACH & SEP, it is centred around optimal value during stability period,  but in SEP, CHs percentage is centred around optimal value which is the optimal value. This percentage extends along the stability period which is the best measure value for SEP protocol  (**SEP preferred**).  DEEC, there is a variance in it. | In LEACH, it is centred around optimal value (**preferred**).  SEP, it isn’t centred around optimal value during instability period (long period).  DEEC, there is a variance in it. |

This study helps us to make decision which one fits to our application needs before deploying the sensors in the work field. For example many applications need reliability to insure the feedback from sensor nodes, some applications need to prolong the lifetime of sensor batteries because of difficulty of recharge or replace them.

# **Added value of research**

Propose a new routing protocol that take into consideration the distance between sensors and base station which I named it:

**Base-Station Distance Adaptive LEACH**

This work includes:

## Abstract

*For some applications, we need to deploy large number of sensors in working field to sense the environment and send collected data to a base-station for processing; these sensors depend on non-rechargeable batteries, so the routing protocols for such network needs to be efficient. LEACH is a hierarchical routing protocols which helps in saving energy in wireless sensor networks.*

*In this paper, we propose an algorithm that enhance LEACH (LEACH works efficiency in homogeneous networks) to be adapt with base-station distance, consequently, more energy saving for certain distances from base-station.*

*Enhanced LEACH depends on mathematical model that calculates an estimated average energy in each round as well as node’s remaining energy to ensure rotating cluster head role across all nodes, it also calculates base station distance from sensor node during election that LEACH doesn’t take into consideration.*

*The obtained simulation results show that proposed algorithm outperforms LEACH, it saves more energy than LEACH and increase network stability and reliability when base-station is inside working field and consume as much as energy in LEACH when base-station is outside work field.*

## Suggest a mathematical model

Total network energy

Estimated average energy

Where R is the number of maximum rounds of network operation

Consumed energy in each round

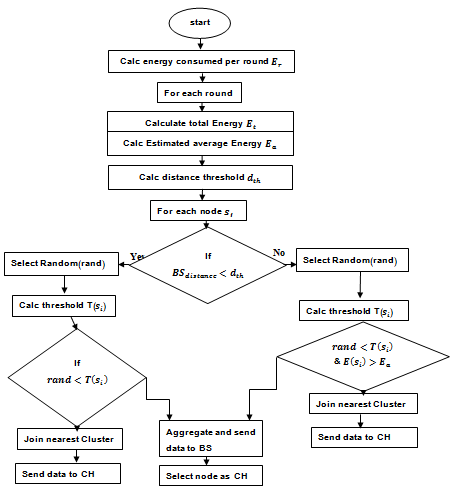
Where is communication energy, is aggregation energy, is the distance between CH and BS, is the distance between CH and member nodes.

Distance threshold

Where is amplifying energy in case of free space is lose, is amplifying energy in case of multipath space.

Distance between any sensor node and sink node calculated by:

## Modify behavior of LEACH to include previous mathematical model.



## Comparison and evaluation of proposed algorithm with LEACH

I evaluated proposed algorithm with LEACH depending on specific performance measures, which there are:

Stability period, instability period, network lifetime, number of cluster heads per round and

Number of dead (or alive) nodes per round.

We used MATLAB as simulator to compare proposed algorithm with LEACH.

## Summary of simulation results.

The proposed protocol outperforms LEACH when base-station is located inside working field, but it give results same as LEACH when base-station is located outside work field.

We conclude that the proposed protocol saves more energy, increases network stability period, consequently, increases reliability.