EFFICIENT POWER-AWARE DATA GATHERING IN WIRELESS SENSOR NETWORK (EPD)

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DEDICATION

They watched over us, their greatest dream to see us growing in front of their eyes, healthy, successful and living happily ever after, they participated in this whole life project until they made the best and the non-forgettable achievements came true, my adorable parents, to you both Mother and Father I dedicate you one of your successes, my Lovely Father my gorgeous mother, this is my gift to you today.

Walked with me along the road, step by step, hands were rolled over each other, every step of mine was matching his, worked as I worked to achieve this magnificent work, it is a must now to share him my thesis my success my happiness as I shared him already my whole life, I dedicate it to my Sweet Husband Luay.

Lived with me every moment of my bachelor study till the last day in master, she attended my lectures, she shared me many and big moments in my life, she is the most gorgeous, sweet, beautiful, well-raised, well mannered girl, I dedicate it to my daughter Shahd.

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Not to forget my soul mate my husband the one who didn't let any shortage of support weather Incorporeal or touchable to knock my doors, he played the supporter and the giver role, many thanks Luay.

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LIST OF ABBREVIATIONS

ACE	Algorithm of Cluster-Head Election
ACE-C	ACE by counting
ACE-L	ACE by Location
BS	Base Station
CH	Cluster head
CM	Clustering with Mobility
EB-PEGASIS	Energy-Efficient Power-Efficient Gathering in Sensor Information Systems
EECFP	An Energy Efficient Cluster Formation Protocol with Low Latency In Wireless Sensor Networks
EPD	Efficient Power-aware Data gathering
FLOC	Fast Local Clustering
LEACH	Low Energy Adaptive Clustering Hierarchy
Omnet++	Objective Modular Network Testbed in C++
PEGASIS	Power-Efficient Gathering in Sensor Information Systems
RDM	Random Direction Mobility model
RP	Real Power

RWM	Random Walk Mobility Model
SM	Simple Mobility Model
SOS	Self Organizing Sensor
WSNs	Wireless sensor networks

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ABSTRACT

In wireless sensor networks (WSN) , the sensor node resources are limited in terms of battery power, processing capability, wireless bandwidth, and storage space, so many routing protocols have been proposed for wireless sensor networks. The main goal of the routing protocols in wireless sensor networks is to find ways for improvement of energy efficiency and reliable transmission of sensed data to the sink and to increase the network lifetime.

In this thesis we proposed a new algorithm which we call an Efficient Power-aware Data gathering in Wireless sensor Network **(EPD)** that combines clustering in order to gather data in an energy efficient way, increase the network lifetime and increase the lifetime of important sensors which nearest to fixed point, **EPD** is proposed as modification to the Clustering with Mobility (CM) in Distributed clustering algorithms for data-gathering in WSN in it is threshold and, made a modification in the Algorithm of CH election by Location (ACE-L) .

The simulation results show clearly that EPD energy dissipation decreases in the network compared with Low Energy Adaptive Clustering Hierarchy (LEACH) and Clustering with Mobility (CM) by the modification done on the formula, simulation results show also that the saving in the power is 31% when using EPD , in other hand the saving in the power is 23% only when using LEACH.

EPD increases the system lifetime in percentage of 67% comparing with ACE-L. The deceases in energy dissipation and the increases in the lifetime leads to increase the performance of the network.

INTRODUCTION

1.Introduction

1.1 overview

Wireless communications offer organizations and users many benefits such as portability and flexibility,increased productivity, and lower installation costs ,Wireless Sensor Networks (WSNs) consist of a large number of intelligent sensor nodes with sensing, processing and wireless communicating capabilities, in order to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants, at different locations ,(Colette at el 2006).

Because of the strict energy limitation of sensor nodes, optimization of energy consumption is essential in all aspects of WSN, sensors in such environments are energy controlled and their batteries can not be recharged, later on, designing energy-aware algorithms becomes an important factor for extending the lifetime of sensors.

Therefore, energy management has become a challenge issue. The current interest in WSN has led to network protocols and algorithms. In section 1.3, we will mention some of these algorithms, (Abbasi at el 2007).

However, wireless sensor networks are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment, (Wang et al 2007)

1.2 Clustering in Wireless sensor network

In General, WSNs involve large number of sensors range in hundreds or even thousands.

Clustering is an effective mean for managing such high population of nodes, Clustering means that the nodes in the network will be partitioning into groups called clusters, shaping at the network a hierarchical organization. Each cluster includes a cluster head and some ordinary nodes. Each node belongs to one cluster only. In addition, a cluster is required to obey certain constraints that are used for network management, routing methods, resource allocation, etc.

Dividing the network into clusters gives the network the following advantages:

1- Clustering facilitates the reuse of resource, which can improve the system capacity. Members in a cluster can share the resource as software, memory space, printer, etc.

2- Clustering-based routing reduces the amount of routing information propagated in the network. Clustering can be used to reduce the amount of information that is used to store the network status. CH will collect the status of nodes in its cluster and build an overview of its cluster status, (Chunhung et. al 1997).

1.3 Proposed Clustering Algorithms

There are several requirements for a clustering algorithm in WSN.

- A clustering algorithm should be completely distributed because a centralized control manner is not practical in a large-scale sensor network.
- The CH should be well distributed throughout the monitoring area to make energy consumption well balanced among all sensor nodes.
- The clustering algorithm itself should be energy efficient.

A clustering algorithm needs to hold the heterogeneous energy situation, (Ming Liu 1 et. al 2009)

We will explain some of the famous Clustering algorithms, LEACH, FLOC, PEGASIS, and ACE-L.

1.3.1 Low Energy Adaptive Clustering Hierarchy (LEACH):

LEACH is one of the most popular clustering algorithms for WSNs, it is a communication protocol for microsensor networks. LEACH collects data from distributed micro-sensors and transmits it to a base station. in LEACH, some of the nodes elect themselves as CH's without any centralized control. each non-CH node determines its cluster by choosing the CH that can be reached using the least communication energy; these CH's collect sensor data from other nodes and transfer the aggregated data to the base station. since data transferring to the base station dissipate much energy, the nodes take turns with the transmission – the CH's "rotate", this rotation of CH's leads to a balanced energy consumption of all nodes and hence to a longer lifetime of the network,(Heinzelman et al 2000).

In LEACH The role of being a CH is rotated periodically among the nodes of the cluster in order to balance the load. The rotation is performed by getting each node to choose a random number called T which is the value between 0 and 1. A node becomes a CH for the current rotation round if the number is less than the threshold as shown in formula (1) :

$$T(n) = \begin{cases} \frac{p}{1-p(r \bmod \frac{1}{p})} & n \in G \\ 0 & n \notin G \end{cases} \qquad (1)$$

Where:

p : is the desired percentage of CH nodes in the sensor population.

R : is the current round number.

G : is the set of nodes that have not been CH's in the last 1/p rounds.

Since the decision to change the CH is probabilistic, there is a good chance that a node with very low energy gets selected as a CH. When this node dies, the whole cell becomes dysfunctional. Also, the CH is assumed to have a long communication range so that the data can reach the base-station from the CH directly, (Heinzelman et al 2000).

The operation of LEACH is broken up into rounds, where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.

1.3.1.1 Advertisement Phase

Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node _ choosing a random number between 0 and 1. If the number is less than a threshold T(n) which shows in formula (1), the node becomes a cluster-head for the current round, using this threshold which shown in formula 1, each node will be a cluster-head at some point within 1/P rounds. During round 0(r = 0), each node has a probability P of becoming a cluster-head. The nodes that are cluster-heads in round 0 cannot be cluster-heads for the next 1/P rounds. Thus the probability that the remaining nodes are cluster-heads must be increased, since there are fewer nodes that are eligible to become cluster-heads. After 1/P - 1 rounds, T =1 for any nodes that have not yet been cluster-heads, and after 1/P rounds, all nodes are once again eligible to become cluster-heads , and after 1/P rounds ,all nodes are once again eligible to become cluster-head , (Heinzelman et al 2000).

1.3.1.2 Cluster Set-Up Phase

After each node has decided to which cluster it belongs, it must inform the cluster-head node that it will be a member of the cluster. Each node transmits this information back to the cluster-head again using a CSMA MAC protocol. During this phase, all cluster-head nodes must keep their receivers on, (Heinzelman et al 2000).

1.3.1.3 Schedule Creation

The cluster-head node receives all the messages for nodes that would like to be included in the cluster. Based on the number of nodes in the cluster, the cluster-head node creates a TDMA schedule telling each node when it can transmit. This schedule is broadcast back to the nodes in the cluster, (Handy at el 2002).

1.3.1.4 Data Transmission

Assuming nodes always have data to send, they send it during their allocated transmission time to the cluster head. This transmission uses a minimal amount of energy (chosen based on the received strength of the cluster-head advertisement). The radio of each non-cluster-head node can be turned off until the node's allocated transmission time, thus minimizing energy dissipation in these nodes. The cluster-head node must keep its receiver on to receive all the data from the nodes in the cluster. When all the data has been received, the cluster head node performs signal processing functions to compress the data into a single signal. For example, if the data are audio or seismic signals, the cluster-head node can beam form the individual signals to generate a composite signal. This composite signal is sent to the base station. Since the base station is far away, this is a high-energy transmission. This is the steady-state operation of LEACH networks. After a certain time, which is determined a priori, the next round begins with each node determining if it should be a cluster-head for this round and advertising this information, (Heinzelman et al 2000).

1.3.2 Fast Local Clustering service (FLOC):

FLOC is a distributed technique that produces almost the same size as clusters with minimum over-lap. The supposed radio model classifies nodes based on their nearness to the CH into inner (i-band) and outer (o-band). i-band nodes will bear very little interference communicating with the CH, while message from o-band nodes may be lost. FLOC favours i-band membership in order to increase the strength of the intra-cluster traffic.

Figure [1.1] summarizes the FLOC algorithm. A node stays idle, and waits for random duration to receive an invitation from any possible CH. If there is no invitation, this node becomes a candidate CH then it broadcasts a candidacy message as shown in Figure [1.1]. Based on hearing the candidacy message a recipient node ''k'' that is already an i-band member of a cluster Ck, will reply to tell the candidate CH about such membership. The candidate CH will then realize the conflict and join Ck as an o-band node see (transition 3). If the candidate CH receives no conflict messages, it becomes a CH and starts inviting members to its cluster (transition 4). An idle node would join a cluster as an o-band node (transition5) if it does not receive an invitation from a closer CH (transition 2). That judgment can be changed, if the node later receives an invitation from a closer CH, (Demirbas et. al 2004).

FLOC constant time is O(1), It also exhibits self-healing capabilities since o-band nodes can switch to an i-band node in another cluster. In addition, new nodes can execute the algorithm and either joins one of the existing clusters or forms a new one that possibly would attract some of the current o-band nodes in neighbouring clusters, (Abbasi at el 2007).

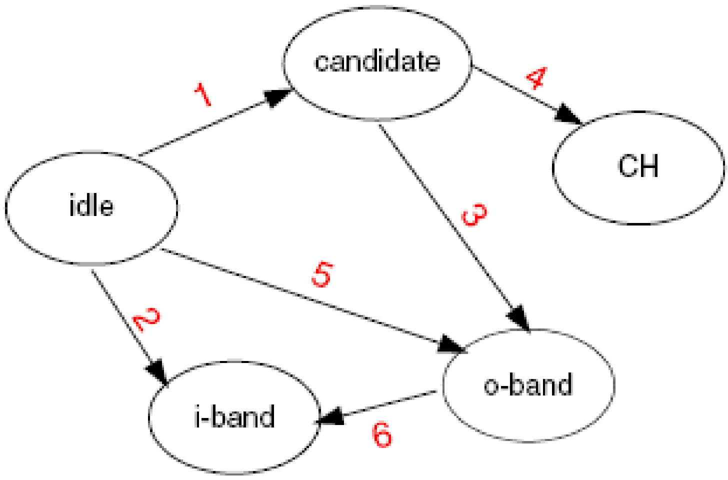

Figure [1.1] : State Transition for the FLOC Clustarting Algorithm.(Abbasi at el 2007)

1.3.3 Power-Efficient Gathering in Sensor Information Systems (PEGASIS):

In PEGASIS each node received from and transmit to close neighbors and take turns being the leader for transmission to the BS. This approach will distribute the energy load evenly among the sensor nodes in the network. First PEGASIS place the nodes randomly in the play field. The nodes will be organized to form a chain, which can either be accomplished by the sensor nodes themselves using a greedy algorithm starting from some node. Alternatively, the BS can compute this chain and broadcast it to all the sensor nodes. To construct the chain, we start with the furthest node from the BS. We begin with this node in order to make sure that nodes farther from the BS have close neighbors, the neighbor distances will increase gradually since nodes already on the chain cannot be revisited. Figure [1.2] which shows a sketch how PEGASIS work . When a node dies, the chain is reconstructed in the same manner to bypass the dead node, (Dechene at el 2003).

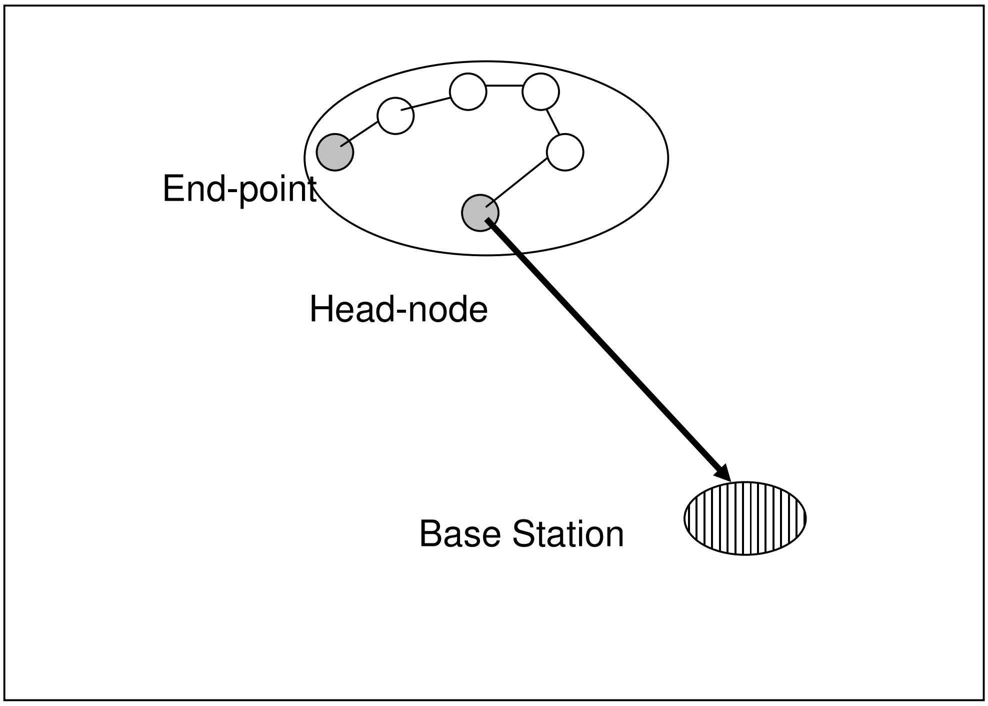

Figure [1.2] : Sketch how PEGASIS work

1.3.4 Algorithm of CH election by Location (ACE-L):

The ACE-L, Suppose the number of sensors in a mobile sensor network is N and the number the sensors from 0 to N−1. Each sensor hence can use the assigned number as a unique identifier (ID).

In the sensor network there are some fixed reference points in the area of the mobile sensor network, it considers to set the distance of a sensor node to a reference point as the metric of the delay time, which used when a sensor node contends a channel, sensor that is closest to the fixed point will be the CH. see Figre [1.3] show the algorithm of ACE-L, (Liua at el , 2007).

```
Algorithm of Cluster-head Election by Location
Input: C reference points
/* chb: cluster-headbeacon */
(1) decide the MRP and set distance to be the distance to the MRP
(2) if receive chb from other node u and have the same main MRP as node u then
    (2.1) cluster ←—— head true
    (2.2) exit
(3) else
    (3.1) delay time  ←——  distance
    (3.2) while (delay time decreases one) do
        (3.2.1) if receive chb from other node u and
                have the same MRP as node u then
              (3.2.1.1) cluster-head true
              (3.2.1.2) exit
              endif
        endwhile
    (3.3) transmit its chb
endif
End
```

Figure [1.3] : Algorithm of ACE-L . (Ming Liua et al 2007)

1.4 Thesis Organization:

This thesis contains five chapters outlined . Chapter One presents a brief introduction about wireless networks in general , and this Chapter explain the clustering and it's benefit for the network ,also we highlights some of clustering algorithm LEACH , FLOC , ACE-L, SOS and CM . Chapter Two presents the related work, which contains many of related algorithms.Chapter Three introduces the proposed Efficient Power-aware Data gathering in Wireless sensor Network (EPD), how it is work and it's properties, and the mechanism of EPD .in Chapter Four we present detailed description of simulation environment and the results obtained from the simulation. This chapter present an introduction to the Omnet++ network simulator. Finally Chapter Five: will conclude conclusion of this thesis and the future work.

RELATED WORK

2.Related work

Sensor networks are the key to gathering the information needed by smart environments, whether in buildings, utilities, industrial, home, shipboard, transportation systems automation, sensor network is required that is fast and easy to install and maintain.

There are many algorithms related to EPD, we will discuss five algorithms in details, Low Energy Adaptive Clustering Hierarchy with Deterministic CH Selection , Distributed clustering algorithms for data-gathering in wireless mobile sensor networks (CM), Self Organizing Sensor Networks Using Intelligent Clustering (SOS), Energy Efficient Cluster Formation Protocol with Low Latency in Wireless Sensor Networks (EECFP)and an Energy-Efficient PEGASIS-Based Enhanced Algorithm in Wireless (EB-PEGASIS).

2.1 Low Energy Adaptive Clustering Hierarchy with Deterministic CH Selection

LEACH collects data from distributed micro sensors and transmits it to a base station . In LEACH some of the nodes elect themselves as CH's.Since data transfers to the base station dissipate much energy, in this proposed protocol a modification of LEACH's CH selection algorithm took a place to reduce energy consumption**.**

In LEACH each single round is obvious that a stochastic cluster head selection will not automatically lead to minimum energy consumption during data transfer for a given set of nodes. All CH's can be located near the edges of the network or adjacent nodes can become CH's.

In these cases some nodes have to bridge long distances to reach a CH, looking at two or more rounds it could be assumed that a selection of favorable CH's results in an unfavorable cluster head selection in later rounds since LEACH tries to distribute energy consumption among all nodes. Figure [2.1] shows the bad scenario in LEACH, (Handy at el 2002).

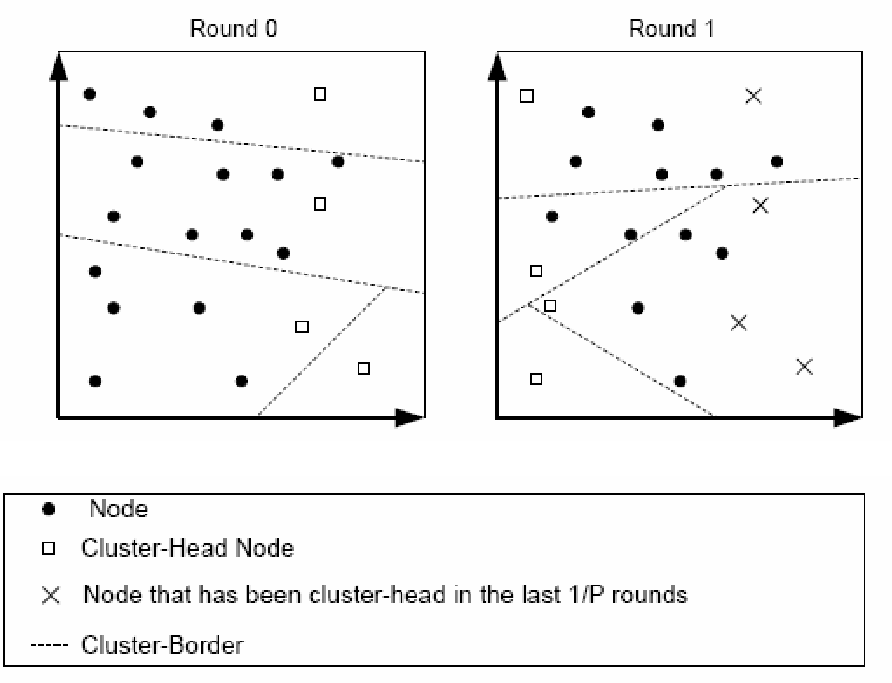

Figure [2.1] : Bad Scenario in LEACH. (Handy at el 2002)

It is necessary that all nodes stay alive as long as possible in some cases , since network quality decreases considerably as soon as one node dies. Scenarios for this case cause intrusion or fire detection. In these scenarios it is important to know when the first node dies.

In Low Energy Adaptive Clustering Hierarchy with Deterministic CH Selection they assumed that :

FND : First Node Dies

HNA : Half of the Nodes Alive

LND : Last Node Dies

The new metric *First Node Dies* (FND) denotes an estimated value for this event for a specific network configuration. Furthermore, sensors can be placed in proximity to each other. Thus, adjacent sensors could record related or identical data. Hence, the loss of a single or few nodes does not automatically diminish the quality of service of the network. In this case the new metric *Half of the Nodes Alive* (HNA) denotes an estimated value for the half-life period of a microsensor network. Finally, the metric *Last Node Dies* (LND) gives an estimated value for the overall lifetime of a microsensor network For a cluster-based,(Handy at el 2002).

2.2 Distributed clustering algorithms for data-gathering in wireless mobile sensor networks (CM):

Clustering in WSN one of the most issue and efficiency way to organize the network, there are two main subjects in any cluster algorithm, the CH election and cluster formation.

In CM they proposed Distributed clustering algorithms for data-gathering in wireless mobile sensor networks **(CM)** , they focus on these issue by propose two distributed algorithm for CH election among mobile sensors node take in consideration energy consumption and, They provide a mechanism to have a sensor node select a proper CH to join for cluster formation.

In LEACH the CH electing strategy based on the threshold which shown in formula(1) .

$$T(n) = \begin{cases} \frac{p}{1-p(r \bmod \frac{1}{p})} & n \in G \\ 0 & n \notin G \end{cases} \quad (1)$$

On the other hand, when using LEACH there are some problems, the difference in the number of the CH between the rounds might be huge, because in each round, this threshold is independent from the number of CH in previous round and it happens that there is no CH at all in some rounds.

In CM they made a modification of the threshold to solve these problems, so it became as shown in formula (2).

$$P_f(r) = \left(1 - \frac{P}{1 - P\left(r \bmod \frac{1}{P}\right)}\right)^{|G|} \quad (2)$$

We can conclude that, using such a threshold, there can be no CH elected in some rounds and the number of CH's elected in a round was related to the total number of CH's elected in the previous rounds. (Liua et al 2007).

They also proposed two distributed algorithms for CH election; the first one is to establish the CH's by counting, and the second was establishing the CH's by location.

In there work they used both ACE-L and ACE-C ,ACE-C only uses the ID of each sensor in WSN to decide the CH without considering the locations of sensor nodes, the elected CH's might be close to each other, the cluster sizes may be different among all the generated clusters. It turns out that some sensor nodes may consume a large amount of energy and the system lifetime therefore becomes short. Because of this, they used also ACE-L, which uses the locations to elect the CH's, hence, can avoid such a situation.

There proposed CM result show a better performance in terms of energy consumption; therefore, lead a longer system lifetime. The result also show that the maximum speed of a sensor node or the clustering factor increased, the system lifetime increased and indicate a better clustering factor which is from 0.75 to 0.9. (Ming Liua,,et al 2007).

Our proposed algorithm EDP will make modification in CM and ACE-L and we will discuses that in details in Chapter 3.

2.3 Self Organizing Sensor Networks Using Intelligent Clustering (SOS):

In this cluster algorithm, they mentioned the increasing of number of CH in the network. They tried to minimize the number of clusters leading to make all nodes belong to one cluster.

Minimizing the number of cluster heads would provide an efficient cover of the whole network and minimize the cluster overlaps; this will reduces the amount of channel contention between clusters and improves the efficiency of algorithms that executed at the level of the CH. Figure [2.2] show clustering in wireless sensor network, (Shin , et al 2006).

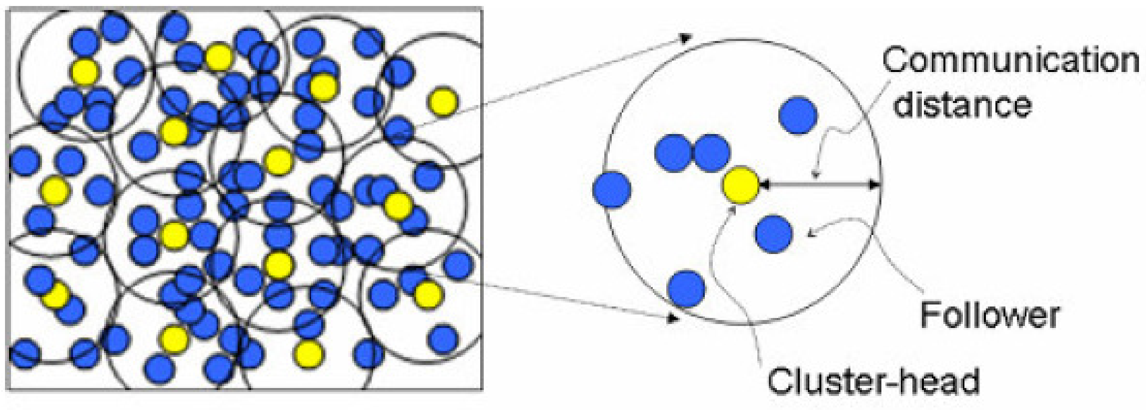

Figure [2.2] : Clustering in Wireless Sensor Network .(Shin , et al 2006)

The proposed SOS enter in many steps:

Step 1; the algorithm makes the centre node a cluster that has the maximum number of followers. they assume that there is a coordinator which controls globally in the entire network ,so it does not matter to locate the centre node during this step. In step 2; the algorithm includes the selected cluster head node and its followers to the clustered node set G. In step 3; SOS selects the node, which can communicate with a node in G and has the maximum number of followers, and makes a cluster with it as a cluster head, then include it and its follower to set G. Figure [2.3] illustrates step 3. A node 'a' is No node and node 'b' is the node which can communicate with the next cluster head node (that is, node 'c'), which has the maximum number of followers. Then it elects node 'c' as a next cluster head node and makes a cluster with it. The process is then repeated until all the nodes are cluster, (Shin , et al 2006).

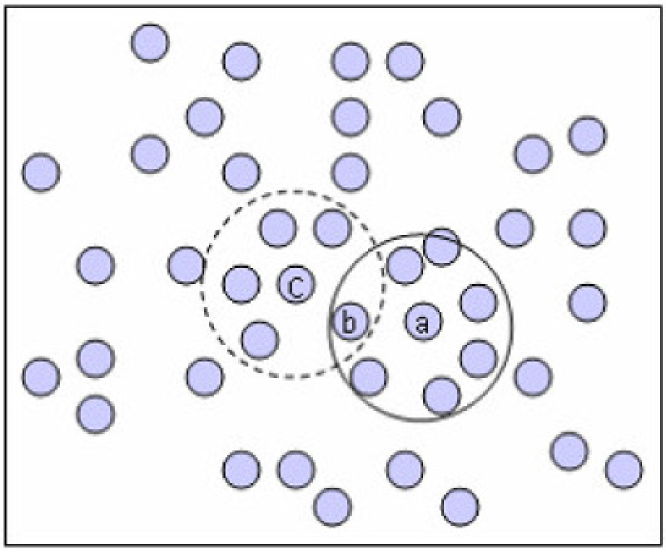

Figure [2.3] : Clustering example in SOS. (Shin , et al 2006)

Where :

A: node is No node

B: node is the node which can communicate with the next head node

C: node is which has the maximum number of followers

In SOS, they define tow concepts:

Super node: the node elected as a cluster head in first cluster, then to elected the new cluster head

Linked node: node that connected between tow clusters has a boundary location as *'b' in* Figure [2.3].

The clustering process using in this algorithm summarized as the following paragraph.

Every node that do not belong to any cluster waiting for ‘survey’ message send by super node, then these nodes check how many are not clustered nodes exist within the area of its communication range. If there are no existing nodes that can communicate with, then it reports it to their head and ends its algorithm. If some nodes exist, it send 'survey' message to every follower and waits for its 'report' messages. When every follower send reports , the node selects follower's ID, which has the biggest number of neighbours, and save that follower's ID then send a 'report' back to its head recursively, (Shin , et al 2006).

This works in a recursive way and every 'report' message arrives in super-node. If super-node get all report from every follower, then it selects a message contains the follower's id, which has the biggest number of neighbours, and broadcasts 'notify' message with that follower's ID to its followers. Every clustered nodes, which receive 'notify' message, compares 'notify.node_id' with saved id and if it is same, then it changes its status as 'linker' and set its next-head as saved node id, and send a 'notify' message to its next-head. If CH received a 'notify' message, then it compares ‘notify.node_id’ with stored ID and if it is same, then it broadcasts, otherwise it will just drop it. If the not clustered node received 'notify' message then it changes its status as CH and broadcasts a 'recruit' message to its followers to make a cluster with it. If super-head get every 'report' message with 'none' then it terminates its algorithm ,(Shin , et al 2006).

2.4 Energy Efficient Cluster Formation Protocol with Low Latency in Wireless Sensor Networks (EECFP):

EECFP is a protocol architecture for wireless micro sensor networks that achieves low energy dissipation and latency. The nodes in wireless sensor network can work together locally to reduce the data that needs to be transmitted to the end user remaining the reason that the data are correlated and the end user only requires a high level description of the events occurring in the environment the nodes are sensing. That lead to make clustering infrastructure to allows nodes that are close to share data, and send the data to a local CH, which is responsible for receiving all the data from nodes within the cluster to the end user.

Hence, a number of data signals are taken and the *actual* data (total number of bits) is reduced, while the *effective* data (information content) is maintained by the cluster head node, which must then send the aggregate data set to the end user , (Allirani at el 2009).

There might be no fixed infrastructure with a high energy node that can act as a cluster head in WSN, in case this position was fixed, the CH would quickly use up its limited energy and die, which ends the communication ability of the rest of the nodes in the cluster as well., EECFP includes rotation of this cluster head position among all the nodes in the network to evenly distribute the energy load. EECFP minimum overhead, in time and energy with the aim of rotating CH nodes and associated clusters, then the nodes must communicate their data to the CH node efficiently with respect to energy consumption.

To achieve their work, they assume a simple model where the radio dissipates *elec E* = 50 nJ / bit to run the transmitter or receiver circuitry and ϵ_{amp} = 100 pJ / bit / m2 for the transmit amplifier to achieve an acceptable E_b / No. Also they assumed an r^2 energy loss due to channel transmission. Thus, to transmit a k-bit message a distance d using their radio model, the radio shown in formula (3) :

$$E_{Tx}(k,d) = E_{Tx} - elec(k) + E_{Tx\text{-}amp}(k,d) \quad (3)$$

$$E_{Tx}(k,d) = E_{elec} * k + \epsilon_{amp} * k * d^2$$

and to receive this message, the radio expends as shown in formula (4) :

$$E_{Rx}(k,d) = E_{Rx-elec}(k)$$
$$E_{Rx}(k) = E_{elec} * k \quad (4)$$

They made the statement that the radio channel is symmetric such that the energy required to transmit a message from node A to node B is the same as the energy required to transmit a message from node B to node A for a given Signal to Noise Ratio.

Initially, the data sent to the base station by the nodes are sent to the CH's which in turn would consolidate the data and direct them towards the base station. Thus the data is primarily sent to the CH's. This can be performed by the nodes only when they posses a certain amount of energy that can be calculated with the support of radio model. Eventually the energy of the nodes goes down from their initial energies, (Allirani at el 2009).

All the energies of individual nodes are compared with each other. The top 5 nodes which have higher energies compared to others are elected as new CH's for the consecutive cycles. These steps repeated until all the energies of nodes are dried up which is known as death of nodes. The nodes which are alive after every round are calculated. Finally the graph between the numbers of nodes alive versus number of cycles is plotted.

They compare the performance of EECFP with LEACH and PEGASIS .the results show that this protocol achieves low energy dissipation and latency without sacrificing application specific quality. The simulation results demonstrate that, the EECFP attains an order of magnitude increase in system lifetime, (Allirani at el 2009).

2.5 An Energy-Efficient PEGASIS-Based Enhanced Algorithm in Wireless (EB-PEGASIS):

EB-PEGASIS a new proposed algorithm to overcome "long chain" in PEGASIS. And It save energy on sensors, and also balance the energy consumption of all sensor nodes, (Yueyang et al 2006).

An upstream node wants to search a node for communication. If the distance from closest node to the upstream node is longer than distance threshes it has a probability to construct a "long chain".

They assume the following symbols:

- *Sk(k=1,2,Λ,N) : N* nodes in network .
- *di,j* : is the distance between two node is,
- *h :* hop number of the the chain.
- *dp(p=1,2,Λ,h):* is distance of every segment of formed chain
- *daver :* is average distance of formed chain.
- *Dcomp :* is distance thresh.

Then they use formula (5) , (Yueyang et al 2006).

$$d_{aver} = \frac{\sum_{p=1}^{h} d_p}{h} \quad (5)$$

$$d_{comp} = a \times d_{aver}$$

They assume that we have node *Sm* chose *Sn* as downstream node. *Sm* informed *Sn* to join data chain and continue looking for other nodes to join data chain.

When *Sn* received the packet from *Sm*, it will compute *daver* formed the chain using the last formula.

dcomp, is a constant. Then, *Sn* sends chaining request to all other nodes, which did not join the chain yet. *Sn* will find a node that the distance between them *dn,j* is minimum. Then, node *Sn* chosenode *Sl* as its downstream node and inform node *Sl* to continue chaining operation. If *dn,l* > *dcompare*, it shows node *Sl* is far away from *Sn*.

When node *Sl* joins data chain through *Sn*, it will lead to "long chain". *Sl* will consume much energy in transmission. In other hands, *Sl* will look for a nearer node on the chain. If *Sl* can find a node that is closer to itself than *Sn*, *Sn* will be an end node of data chain. Thus, *Sl* join the data chain through the nearer node on the chain and continue to finish chaining operation. If *Sl* can not find a node that is closer to itself than *Sn*, the "long chain" can not avoid. Thus, *Sl* also join the data chain through *Sn* and continue to finish chaining operation, (Yueyang et al 2006).

When the chain is shaped, the end chain nodes begin to send data. Each node aggregates data from downstream node with its own data in order to come into being a new data packet.

Then, send the new data to upstream node. Every node on chain repeat the same operation till the data reaches to leader node. Then, leader node send aggregated node to BS.

The results show that EB-PEGASIS, can avoid "long chain" in chaining process through average distance of network. And it can guarantee approximately the same in consumed energy of sensor nodes, and increasing the lifetime of sensor networks. (Yueyang et al 2006).

PROPOSED ALGORITHM: EFFICIENT POWER-AWARE DATA GATHERING IN WIRELESS SENSOR NETWORK (EPD)

3. PROPOSED ALGORITHM:

EFFICIENT POWER-AWARE DATA GATHERING IN WIRELESS SENSOR NETWORK (EPD)

3.1 Introduction

In wireless sensor networks, the sensor node resources are limited in terms of battery power, processing capability, wireless bandwidth, and storage space, so energy consumed for communication and the limitation of power for sensor node consumption in wireless sensor network are an important problems when designing protocol, there are many proposed protocols for data gathering in wireless sensor network as we mentioned before in the related work in chapter two.

Clustering is an effective mean for managing such high population of nodes, clustering facilitates the reuse of resource, which can improve the system capacity other benefits of clustering members in a cluster can share the resource as software, printer, memory space, etc.

Clustering reduces the amount of routing information in the network. Clustering could be used to reduce the amount of information that is used to store in the network. CH will collect the status of nodes in its cluster, and build an overview of its cluster status then the CH send the gathered information from the sensors in its cluster and send it to base station , (Abbasi at el 2007).

3.2 Proposed Algorithm : Efficient Power-aware Data gathering in Wireless sensor Network (EPD)

In our proposed algorithm, we propose an Efficient Power-aware Data gathering in Wireless sensor Network **(EPD)** that combines clustering in order to gather data in an energy efficient way, increasing the network lifetime and increasing the important sensors lifetime.

In our thesis, the model sensor network has the following properties:

- The based station (BS) is fixed and located far away from the sensor nodes.
- All the sensor nodes are mobile, homogeneous, and power limited.
- Each sensor node is equipped with a Location Finding System, using in CM
- All sensor nodes are time-synchronized.

Fgure.[3.1] shows the components of this mobile sensor network which we use.

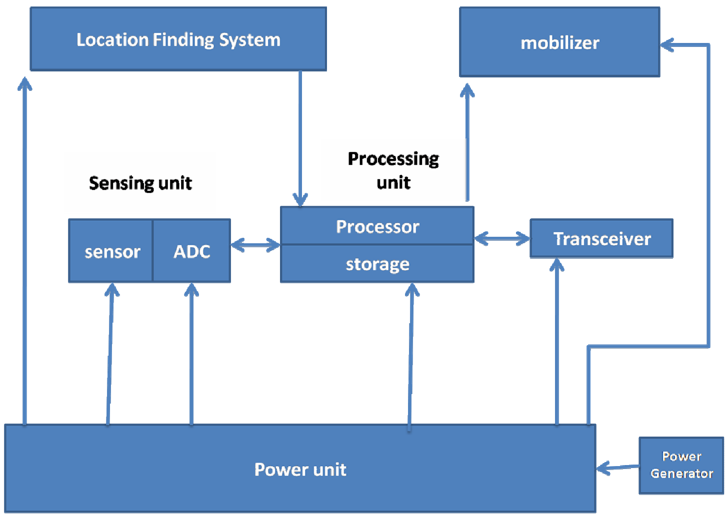

Figure [3.1] : Component of a Wireless Mobile Sensor Node

We used the same radio model used in CM, where the radio dissipates Eelec = 50 nJ/bit to run the transmitter or receiver circuitry and ϵ_{amp} = 100 pJ/bit/m2 for the transmitter amplifier. Using this radio model, the transmission cost and receiving cost for a l-bit message with a distance r are

- Transmission: ET x(l, r) = Eelec × l + _amp × l × r^2, and
- Receiving: ERx(l, r) = Eelec × l

Receiving is also a high cost operation, therefore, the number of receives and transmissions should be minimal.

In EPD we try to save consumed power in the wireless sensor network, in the other hand we achieve saving the energy in sensitive nodes located in important location -which is nearest to the fixed points - beside make efficient transmission of data to the base station, and that lead to maximized the lifetime of the network as possible.

The sensors that located nearest to the important location should not choose as a cluster head to save its power. We should decrease the probability of these sensor to become cluster head .The idea is to reduce the use of its energy by minimizes the job of these sensors to pass its data rather than collect it from members then pass it. Beside that, we took in consideration some of the factors that increase the lifetime without affecting our goal by making some modifications in existed protocols.

EPD is proposed as modification to the CM and made modification in the ACE-L algorithms .

3.3 Mechanism of EPD

We propose two methods to achieve our goals, the first one is the modification in the threshold using in CM, and the second one is the modification in the algorithm, which used in ACE-L which using to elect the CH based on the sensor location .

3.3.1 First part in EPD, the Modification in CM.

The first part in EPD is the modification in the threshold which using in CM, formula (6) shows EPD threshold.

$$P_f(r) = \left(1 - \frac{p}{1 - p\left(r \bmod \frac{1}{p}\right)}\right)^{|G|} + F \qquad (6)$$

Where :

r : is the number of rounds that have passed,

P : is the required percentage of CH's

F : biased factor; the percentage of the node to become CH depends on the node location and power

G : is the set of sensor nodes were not being a CH yet.

By using this threshold the number of CH's elected in a round is related to the total number of CH's elected in the previous rounds as they achieve in CM , but the new thing we propose is adding the biased factor "F" which means the percentage of the node to become CH depends on the node power and the node location ; distance between this node and the fixed point .

When adding the "F" we add the probability for each sensor to be CH depends on the distance of the fixed point , and its power. Since CH collects sensor data from other nodes and transfer the aggregated data to the base station, that dissipate much energy and give the CH more work than other sensors in the WSN, because of the additional works of CH "F" demonstrates the quality of the sensor node to nominated to be a CH; the node with more power and far away from the fixed point will have more percentage to become a CH .

In EPD, we added the "F" in the formula to improve the signal which goes through the sensor by decreasing the resistance to the signal which lead to decrease the noise and the losing in the power beside more stability to the signal, and saving the power in important sensors which located nearest of fixed point .

3.3.2 Second part in EPD, the Modification in ACE-L.

The second part of EPD is the modification which made in ACE-L algorithm, to achieve our proposed algorithm in choosing the CH depends on it location, EPD focuses in the location because EPD proposed that in the network we have an important fixed points such as, emergency room in a hospital or sensitive chemical labs or dangerous factory and others , so the sensor which nearest to the fixed reference point (F_x) must not chosen as a CH that will save its power which lead to longlife time for this sensor , so it will keep transmitting and sending information about this fixed point as longer as possible .

EPD protocol supposes that we have C clusters in each round, and we have C important regions, which include F_x, equal to clusters number C. These F_x will make affect to the propriety for a sensor to connect the channel and become CH. Each sensor node knows to which cluster it belongs and know it is nearness to F_x by the distance between them.

EPD assume that we have :

V : which means a virtual node

MSSv : Main Sensitive Sensor for v (the reference node closest to v)

MSS_d : Main Sensitive Sensor for any real node (d)

DT : Delay Time

Consider a node v, the reference node closest to v we will call it Main Sensitive Sensor for v (MSSv) belong to its cluster -for any real node the Main Sensitive Sensor will write as (MSS_d)-. In each round each node as v compute the delay time (DT), which uses as the priority to contend a channel, so the node which has the shortest DT will be chosen as CH , the DT in EPD depends on two things first, the distance between this node and the fixed point ,second the power of that sensor . To calculate DT, the sensor must calculate the following proposed factor in formula 7:

$$\text{factor} = \frac{\text{Power}}{\text{Max\_power}} + \frac{\text{Distance}}{\text{Max\_Distance}} \qquad (7)$$

Where :

Power : Real power (RP)

Distance : Real destination between the Fixed point and the tested sensor belong to that cluster.

Max_power : the initial power for the node .

Max_Distance : the maximum distance between the Fixed point and the tested sensor belong to that cluster constant for each cluster.

Next, subtract this factor from 2, which is the maximum number that factor could have.

DT = 2 – factor.

All sensors having the same MSS_d will contend a channel and the node with the largest supposed factor will be elected as a CH (the node with the shortest DT). Return to our node v, if v is the node with largest factor in its cluster, which means shortest DT, it will use the channel to broadcast a beacon of being a CH to other nodes. Otherwise, if v receives a beacon of being a CH from other node from the same cluster and during the delay time, v will stop and will not be a CH in this round.

Our propose algorithm EPD will be as follow in Figure [3.2] :

```
Algorithm of Cluster-head Election
Input: C Fixed Point (Fx)
/* chb: cluster-head beacon */
(1)  if receive chb from other node u and have the same MSSd
      (1.1) cluster-head  ←  true
      (1.2) exit
(2) else
     (2.1) delay time  ←  2-factor
     (2.2) while (delay time decreases one) do
          (2.2.1) if receive chb from other node u and have the same MSSd
            then
                  (2.2.1.1) cluster-head  ←  true
                  (2.2.1.2) exit
                  endif
          endwhile
    (2.3) transmit its chb
endif
End
```

Figure [3.2] : EPD algorithm for election a CH

Figure [3.2] displays the steps of our algorithm for sensor node v. In Step (1), *v* examines whether there is an elected CH that uses the same MSS_d. If there is, the algorithm stops. Otherwise moves to Step (2). In this step, a node v sets up its delay time according to our factor. Next as in Step (2), *v* again examines whether there is an elected CH uses the same MSS_d. If the delay time passes, sensor node v will obtain the channel successfully. So *v* know has the smallest DT (the largest factor) and will be a CH. Then it transmits the beacon of being a cluster head in this round.

Figure [3.3] shows ER diagram about the process of CH election in EPD in each round.

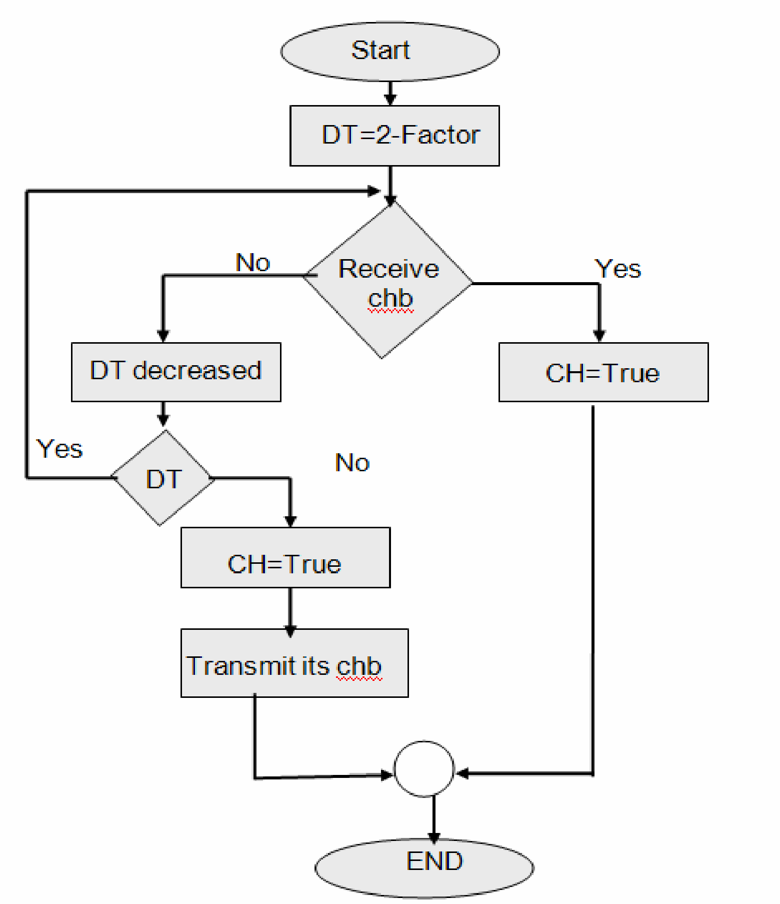

Figure 3. 3 ER diagram about the process of CH election in EPD

RESULTS AND ANALYSIS

4. RESULTS AND ANALYSIS

In this chapter, we will give an overview about the simulator used in our experiments, followed by the simulation results and their analysis. In this thesis, the Omnet++ was used to evaluate the performance of the EPD. Different performance metrics were used to compare EPD with the MC, LEACH and ACE-L and it will be described in the following sections.

4.1 Introduction to Omnet++

Omnet++ stands for Objective Modular Network Testbed in C++. It is a discrete event simulation tool designed to simulate computer networks, multi-processors and other distributed systems. Its applications can be extended for modelling other systems as well. It has become a popular network simulation tool in the scientific community as well as in industry over the years.

4.1.1 Components of Omnet++

- Simulation kernel library
- Compiler for the NED topology description language (nedc)
- Graphical network editor for NED files (GNED)
- GUI for simulation execution, links into simulation executable
- Command-line user interface for simulation execution
- Graphical output vector plotting tool

- Utilities (random number seed generation tool, makefile creation tool, etc.)
- Documentation, sample simulations, contributed material, etc.

4.1.2 Platforms of Omnet++

Omnet++ works well on multiple platforms. It was first developed on Linux. Omnet++ runs on most UNIX systems and Windows platforms (works best on NT4.0, W2K or XP).

Omnet++ is free for any non-profit use. The author must be contacted if it is used in a commercial project. The GNU General Public License can be chosen on Omnet++, (Bourgois et al 2001).

4.1.3 Organization of Network Simulation

Omnet++ follows a hierarchical module structure allowing for different levels of organization.

- **Physical Layer:**

1. Top-level network
2. Sub network (site)
3. LAN
4. node

- **Topology within a node**

1. OSI layers. The Data-Link, Network, Transport, Application layers are of greater importance.
2. Applications/protocols within a layer.

4.1.4 User interfaces

There are two user interfaces supported:

- Tkenv: Tk-based graphical, windowing user interface (X-Window, Win95, WinNT etc)
- Cmdenv: command-line user interface for batch execution

Simulation is tested and debugged under Tkenv, while the Cmdenv is used for actual simulation experiments since it supports batch execution. Figure 1 shows Example of a Tkenv User Interface in Omnet++.

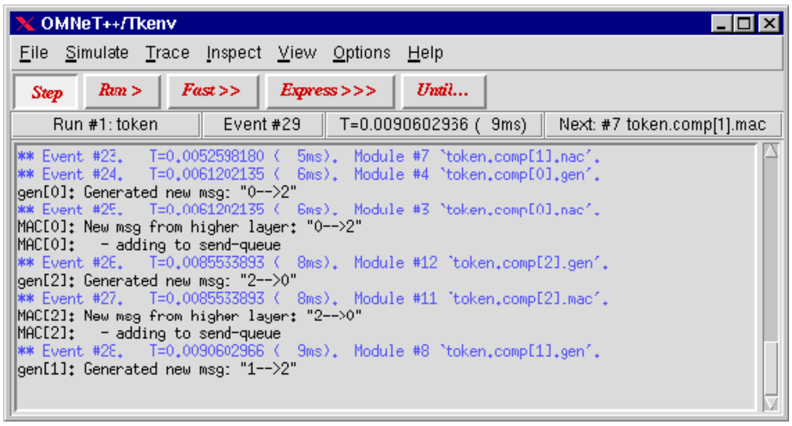

Figure [4.1] : Example of a Tkenv User Interface in Omnet++.

4.1.5 Expected Performance of Omnet++

One of the most important factors in any simulation is the programming language. The common languages used are C/C++ based. Omnet++ performance is of a particular interest since it reduces the overhead costs associated with GUI simulation library debugging and tracing. The drawback found in Omnet++ was its simulations were 1.3 slower than it C counterpart, (Bourgois et al 2001)

4.2 Simulation environment :

In the experiments we have conducted in this thesis, the simulation modelled a network of 100 mobile sensors placed randomly within a 155 X 155 meters, as we used also ring token topology network.

We have four to six clusters which equal to number of fixes reference point (F_x) Figure [4.2] shows the test network area as be in the simulation.

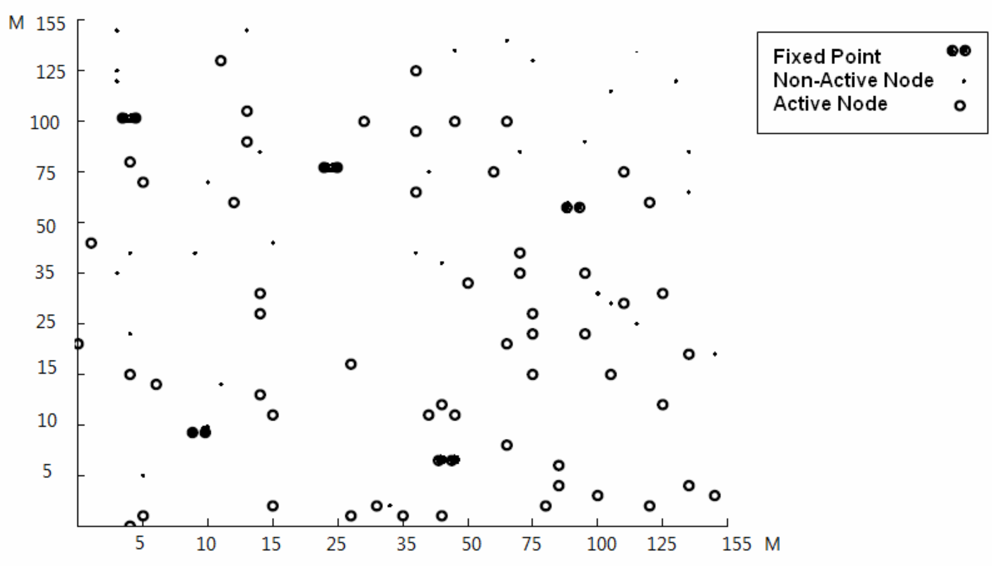

Figure [4.2] : Tested Area

We therefore select the following three mobility models to evaluate the proposed data-gathering protocols: we will use the Random Walk Mobility (RWM) model, Random Direction Mobility (RDM) model, and Simple Mobility (SM) model that using in CM.

Table [1]: show our simulation parameters used.

Items	**Values**
Network area	155 X 155
Base station location	(100,155)
Mobility models	SM , RWM , RDM
Number of sensors node	100
Speed of sensor node	0 – 1 m/s
Size of the packet (in round)	2000 bits
Period of each round	5 s
Transmission distance	<155 m
Transmission rate	> 1 M/s
Reference Points	(10,9), (40,50) ,(25,75) ,(4,100),(80,50)
ID's of sensor nodes	0 – 99
Expected number of cluster head	4 to 5

In this testing, we run each protocol 50 times and measure the round at which the first sensor node dies and the round at which the last sensor node dies. These proposed protocol perform better than LEACH, ACE-L and MC do and can make the network live longer and decreasing the consuming of the power in each sensor and that lead to increase the efficiency of the network.

Much more important and more suitable performance metrics for wireless networks are energy-efficiency and the network lifetime ,because of the redundancy and the application-level importance associated with the data generated by the network , also one of the most important issues in wireless sensor network is the limitation of power supply and the life time of the each sensors in the network, so we use the following performance metrics to compare the performance of EPD and MC, LEACH and ACE-L protocols.

- Network lifetime: is the total number of rounds which a wireless mobile sensor network experiences.
- Using power : sensor power needed to transmission and communication

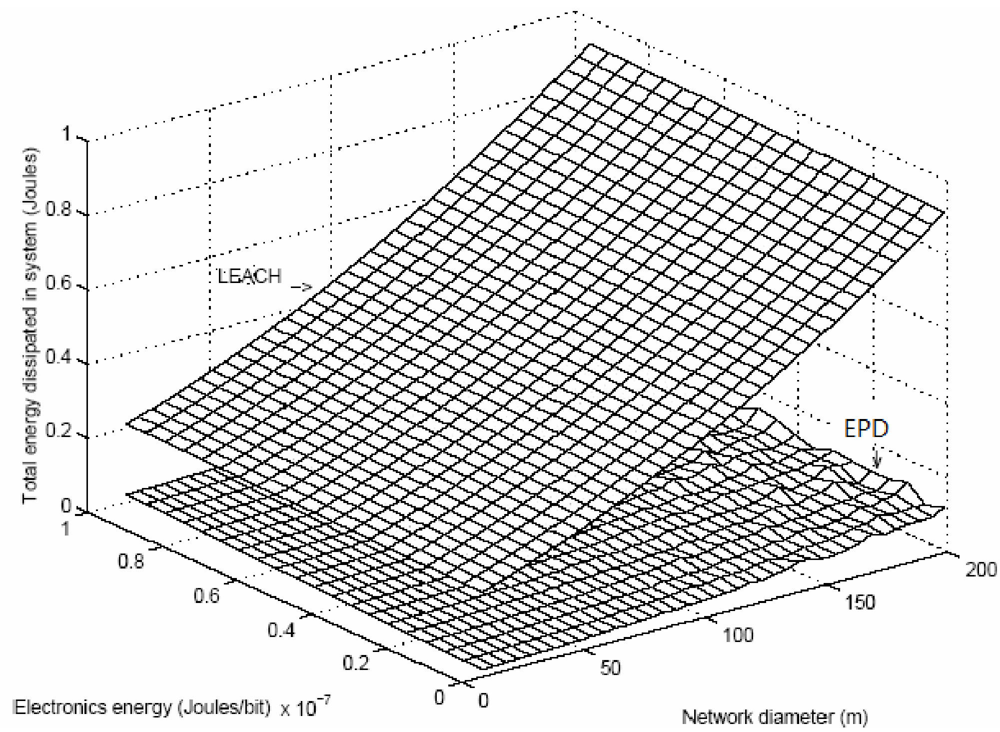

Figure [4.3] : Shows Comparing between EPD and LEACH in Energy Dissipated

Figure [4.3] shows the comparing between our protocol EPD and the LEACH in using the power for the network and the amount of energy dissipated using LEACH and EPD as the network diameter is increased and the electronics energy varies, and it shows clearly that EPD energy dissipated decreasing in the network comparing with LEACH, and This Figure shows the large energy savings achieved using EPD for most of the parameter space ,the saving in the power is 31% comparing with LEACH which it save 23% only , that is because in EPD all the sensors increase its power by using our threshold .

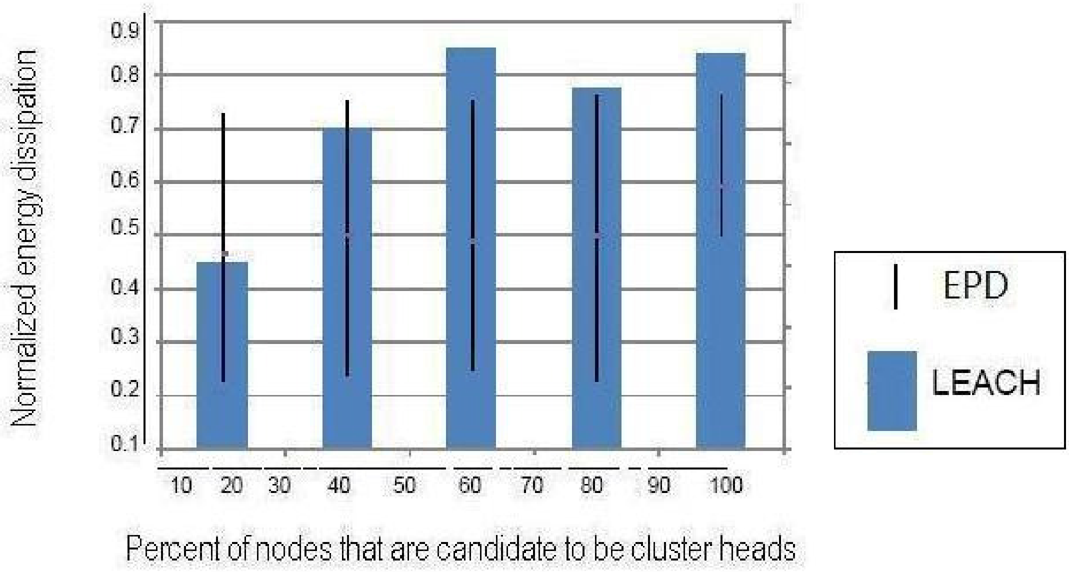

Figure [4.4] : shows the comparing between the LEACH and EPD in term of the normalized energy dissipation with the increasing of the nodes which candidate to be CH

In other, hand Figure [4.4] shows the comparing between the LEACH and EPD in term of the normalized energy dissipation with the increasing of the nodes which candidate to become CH , the Figure shows that EPD is more stable than LEACH despite the increasing of the nodes that are candidates to be a CH in the network.

The Figure shows also when using EPD all the nodes in the network will be candidate to be CH, this means that the energy dissipated is decreasing in the network comparing with LEACH, as shown in Figure [4.3], and that lead to increasing in the network power.

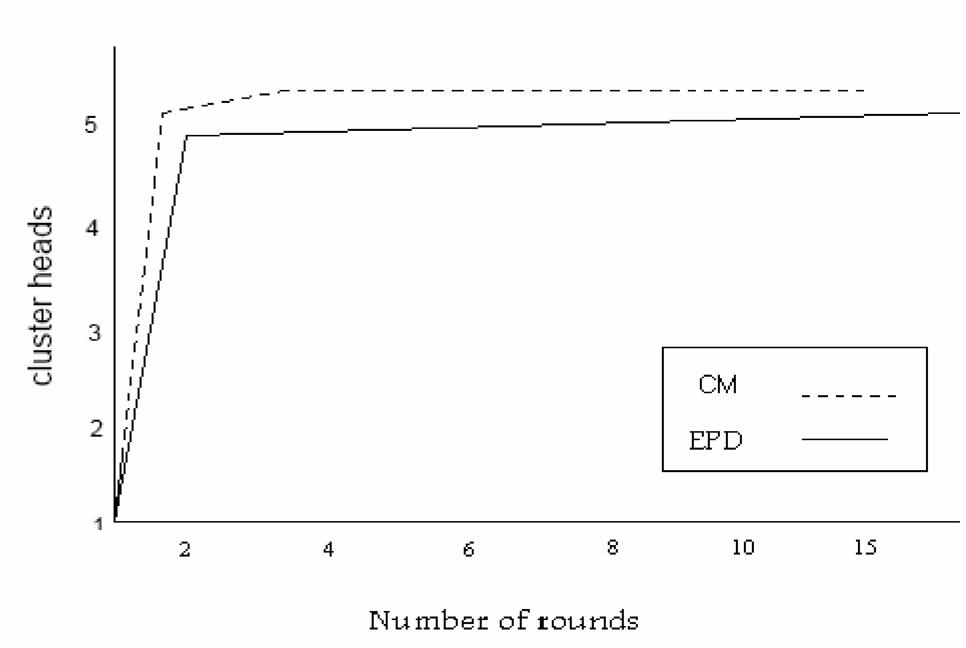

Figure [4.5] : Shows number of CH in each round for both LEACH and EPD for 50 nodes

Figure [4.5] shows that the approximate percentage of nodes that will be CH is 10 % nodes, where the total number of nodes in the experiment is 50.

Based on the EPD mechanism, protocols using our CH election algorithms, which are the modification of ACE-L algorithm, show that the positions of the CH's in each round far away from the fixed point in each cluster .

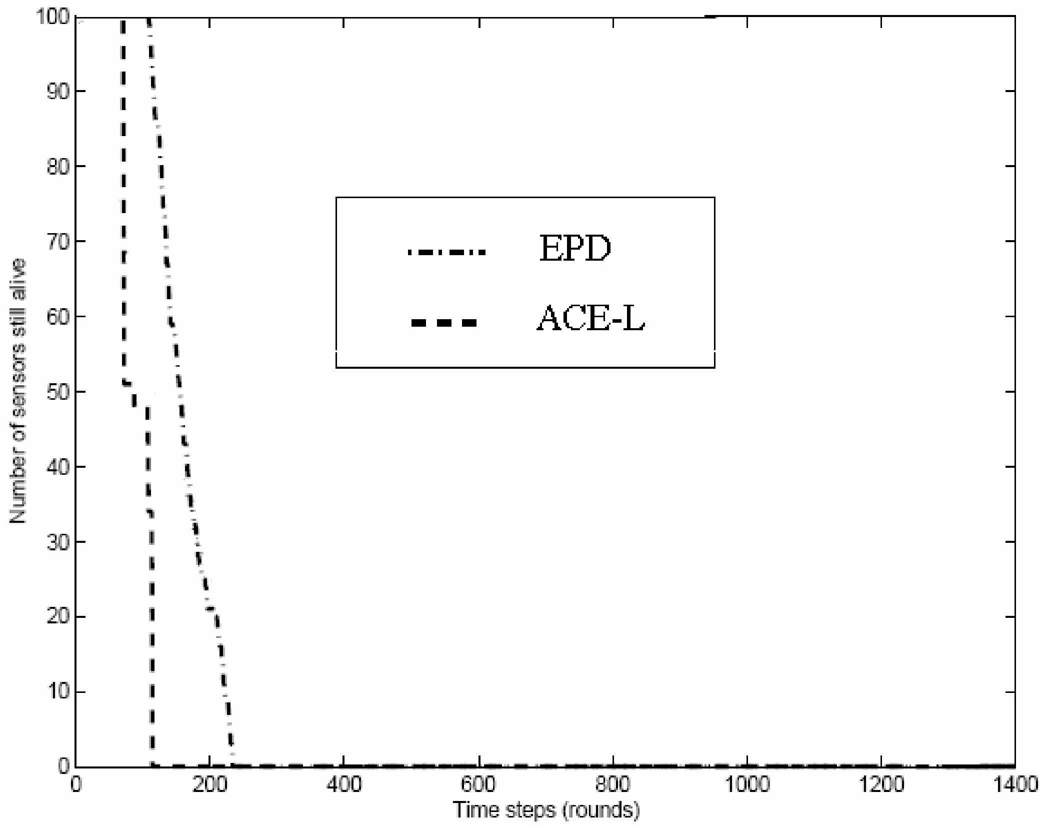

Figure [4.6] : Shows the Effect of EPD on the System Life Times Comparing with ACE-L

The EPD can further make the system live much longer by reaching to an equal number of CH's elected in each round and can improve our proposed idea in choosing the CH depends on its location. Figure [4.6] shows the effects of EPD on the system life times comparing with ACE-L, and this Figure prove that EPD can increase the net work lifetime in percentage 67%, using ACE-L lead the network to dead status after the round 100 as shown in Figure [4.6], and all the nodes in the network dead too,

On the other hand, at the end of round 100, the network still works and there are number of sensors still alive until 240 round when using EPD.

EPD algorithm in the second part uses the modification of the ACE-L to select the CH.

In such a case, some CH's will consume the energy dramatically due to a large cluster size and the cluster members need to consume more energy due to a long distance to the cluster heads. In our experiments, we further set the number of the reference points to be four and the reference points are located at the centre's of the sensing region. For five reference points, we added one reference at the centre of the sensing region.

In our experiments, the simulation shows that EPD algorithm save consumed energy in the wireless sensor network, as shown in Figure [4.3] and Figure [4.4]. On the other hand, we achieved saving the power in sensitive nodes located in important location, beside make efficient transmission of data to the base station, so lifetime of the network is maximized as possible as shown in Figure [4.6].

The sensors that located nearest to the important location must not choose as a cluster head to save its power. We must decrease the probability of being cluster head .The idea is to reduce the use of its energy by minimizing the job of these sensors to pass its data rather than collect it from members then pass it. Beside that, we took into consideration some of the factors that increase the lifetime without affecting our goal by making some modifications in existed protocols. Beside that, EPD proved the efficiency for all signals in the network, which lead to increase the performance to the network.

CONCLUSIONS
AND
FUTURE WORKS

5. Conclusions and future works conclusions

1.5 Conclusions

The simulation results show that we saved consumed energy in the wireless sensor network, and on the other hand we achieved saving the power in sensitive nodes located in important location nearest to the fixed reference points, beside make efficient transmission of data to the base station so the lifetime of the network is maximized, the sensors which located must not choose as a cluster head to save its power. The simulation results show that EPD. The saving in the power when using EPD is 31% comparing with LEACH which it save 23% only.

Our proposed algorithm added the "F" ;which mean CH probability depends on the node location and power , in the modification LEACH formula done by CM, we increased the quality of the sensor node to CH, on the other hand decreasing the power losing, and the modification done in ACE-L increasing the network lifetime along with time passing. Simulation result shows that EPD can increase the net work lifetime in percentage 67% . That leads to increasing the performance to the network. Table [2] shows Lifetimes using different amounts of initial energy for the sensors using EPD and ACE-L .

Table [2] shows Lifetimes using different amounts of initial energy for the sensors

Energy (J/node)	Protocol	Round first node dies	Round last node dies
0.25	EPD	50	111
	ACE-L	36	62
0.5	EPD	100	200
	ACE-L	17	100
1	EPD	200	455
	ACE-L	106	230

5.2 Future work:

In our proposed algorithm the network topology, which apply our EDP, was token ring topology, we hope to apply EPD in all network topologies.

We can work on this algorithm to reach the best result in the energy issues so we can decrease the dissipated power in all network ,and increase the power not only for the sensor which nominate to become CH but also all the sensors in WSN.

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جمع المعلومات في الشبكة الاسلكية اعتمادا على الطاقة المتوفرة للمجسّات الاسلكية

اعداد

أمل العودات

المشرف

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المشرف المشارك

الدكتور صالح الشرايعة

ملخص

في الشبكات الاسلكية، المجسات الاسلكية تمتاز بمحدودية حصولها على الطاقة من البطارية المزودة لها بالطاقة ،وايضا processing capability, wireless bandwidth وايضا اماكن التخزين فيها .لذلك تم اقتراح العديد من بروتوكولات التوجيه للشبكات الاسلكية .الهدف الرئيسي من هذه البروتوكولات هوايجاد طرق لتحسين اداء الطاقة و ضمان الموثوقية و الاستمرارية في التواصل اثناء استقبال المعلومات و ارسالها ، و ذلك الاطالة عمر الشبكة الاسلكية .

في هذه الرساله نقترح بروتوكول جديد لجمع المعلومات في الشبكة الاسلكية اعتمادا على الطاقة المتوفرة للمجسّات الاسلكية، و عمل المجموعات بطريقة تساعد على توفير الطاقة و زيادة عمر الشبكة الاسلكية ، اسم هذا البروتوكول (EPD) . يوجد مجسات ذات اهمية اكثر من غيرها في الشبكة ، تلك التي تقع في اماكن قريبة من نقاط ثابته تم تحديدها مسبقا ذات اهمية خاصة، نسعى لتوفير طاقتها و زيادة عمرها .

لقد تم التعديل على المعادلة المستخدمة في بالبروتوكولين CM و LEACH الخاصة بايجاد المجس المسؤول عن مجموعته ، كما و تم التعديل على الالوغوريثم المستخدم في البروتوكول ACE-L المعتمد على اختيار المجس المسؤول عن مجموعته اعتمادا على موقعة .

اثبتت النتائج ان البروتوكول المقترح حقق بوضوح توفير اكثر في الطاقة المستهلكه مقارنتها بالبروتوكولين CM و LEACH بحيث كانت نسبة التوفير بالطاقة هي ٣١% مقارنتها في LEACH الذي كانت نسبة توفيره هي فقط ٢٣ % .

كما و ان البروتوكول المقترح حقق زيادة في اطالة عمر الشبكة مقارنتها ACE-L بنسبة ٦٧% . التوفير الحاصل في الطاقة و تقليل الطاقة المهدورة و زيادة عمر الشبكة ادى بالنتيجة الى تحسين اداء الشبكة الاسلكية بشكل عام .