

ENERGY EFFICIENT CLUSTER HEAD SELECTION IN MOBILE WIRELESS SENSOR NETWORKS

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Abstract

In the era of New Generation Networks (NWGN) many emerging and future enable technologies accomplish the requirements of ubiquitous communication networks. Wireless Sensor Networks (WSNs) is a vital category of these state-of-the-art technologies, the enormous concerns of these networks are energy efficient and well-organized data aggregation. Cluster based routing in WSNs is an immense solution to enhance the energy efficiency of the nodes and resourceful data gathering. Many studies on network lifetime and data aggregation have been proposed by the Low Energy Adaptive Clustering Hierarchy (LEACH) scheme that allows the role of the cluster head rotated among the sensor nodes and attempts to distribute the energy usage through all the nodes. The lifetime of WSNs will be affected by the cluster head (CH) selection; this is because a CH consumes more power than a regular (non-CH) node. In this research study, an energy efficient cluster head selection in Mobile Wireless Sensor Networks is proposed, analysed and validated on the basis of residual energy and randomized selection of the node, who is not assigned as a cluster head in previous round. Moreover, the proposed approach shows the significant improvements when compared with LEACH and A Novel Application Specific Network Protocol for Wireless Sensor Networks (Hybrid Multi-hop LEACH) protocols in terms of energy consumption of sensor nodes, enhanced network lifetime and efficient data gathering due to less energy consumption during data transmission.

Keywords: Mobile wireless sensor networks, WSNs, Clustering protocol,
Routing protocol.

1. Introduction

Wireless Sensor Networks have low-cost computation, storage capacity and radio technologies that assemble economical micro-sensor nodes. Micro-sensor nodes are not powerful devices like macro-sensors but they provide fault-tolerant and high quality sensor networks by the deployment of hundreds and thousands of sensors within a network region. What is meant here, is that the electronics of sensing or detecting are capable of calculating the immediate conditions of the environment surrounding the sensor and eventually transforming them into an electronic signal and a message. In reaching the base station, the path by which a message should travel through the sensor node is determined by a mechanism known as routing protocol that will simultaneously and directly influence the energy efficiency of the WSNs [1 - 6].

In many research papers and projects it is explained that the hierarchical routing especially the clustering techniques make an immense enhancement on WSNs. These approaches are used to reduce the energy utilization and network performance when all the sensor nodes of the network are sending data to the base station or central collection centre. The core components of the cluster based WSNs are sensor nodes, clusters, cluster heads, base stations and end users (Fig. 1). The monitoring and controlling of each cluster is carried out by the CH which acts as a leader, the cluster heads have direct communication with the base station (BS) [7, 8].

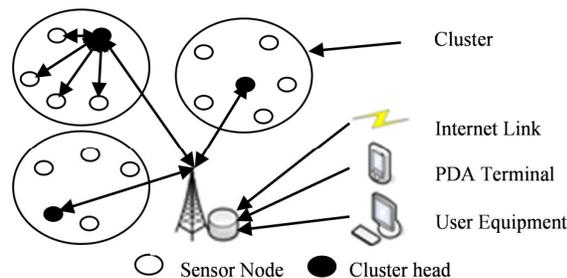


Fig. 1. Cluster Based Wireless Sensor Network.

Several clustering proposals have been reported in literatures that propose various strategies for selecting the cluster head and the rotation of its role. In order to get a global view of these strategies for choosing the cluster head, the following parameter needs to be considered.

- Who begins the selection of the cluster head?
- Which parameters determine a sensor node's role?
- Which sensor nodes will be chosen to be cluster heads?
- Is re-initiation of the cluster formation procedure required?
- Is there an even distribution of the chosen cluster heads?
- Is the creation of balanced clusters guaranteed?
- Which technique is appropriate in a large network, Single-hop or Multi-hop?

Data fusion protocols were designed for network configuration and collection of data from the desired environment. In each round data has collected from sensor nodes to CH and then transmitted towards the BS; an easy way to do that is

to combine (sum, average, min, max, count) data from different nodes. Round is defined as the process of collecting the data from the sensor nodes towards the base station, no matter how much time it takes.

Mobile devices are also the best approach to resolve the data gathering issues in an efficient way. There are a number of the existing WSN scenarios using mobile platforms, such as animal monitoring, traffic monitoring and battlefield surveillance applications. The Mobile Wireless Sensor Networks (mWSN) is a specified category of WSNs where mobility acts as a primary part in the application execution. In recent years, researchers and vendors have been entirely focused on to retain mobility in WSNs [9-11]. The presence of mobile sinks or agents is a novel and emerging concept in WSNs, and now, mobility in WSNs is regarded to be an advantage rather than a problem. The results have revealed the capability of mobility in improving the lifetime of networks and further enhancing the data reliability. Delay and latency problems also deal with specific situations in mobile WSNs; most of the essential features of mobile WSNs are the same as that of regular fixed WSNs [12-15].

Cluster head selection strategies

To compare the different strategies for cluster head selection, a wider comprehension is needed; these are their CSA (assistance considered in selecting the cluster heads), utilized parameters, required RC (re-clustering), required FC (formation of the cluster), even or fair DCHs (distribution of cluster heads) and BCC (balanced cluster creation)

- **Deterministic Schemes**

Sensor nodes in the range of communication first choose themselves as a cluster head after fulfilling the fixed node degree criterion. During each round, in order to make the decision of cluster head, hello messages are broadcast by all the sensor nodes to their neighbors; the first nodes to receive the pre-defined number of these messages declare themselves to be cluster head, and therefore, broadcast for a cluster setup. At least one cluster head is guaranteed to be present in a range of communication; this is achieved by the sensor nodes receiving the broadcast for setup from broadcasting again. The sensor nodes which have received the broadcast for setup then transmit joining requests to the cluster head which confirms the joining upon receiving the requests; it then prepares and distributes the time schedule to all its cluster members.

- **Base Station Assisted Schemes**

On the basis of the node deployment data, which is either collected from the sensor nodes or priori available, the base station performs cluster formation in the network and informs the nodes. The cluster heads are chosen by either the sensor nodes or the base station.

- **Fixed Parameter Probabilistic Schemes**

Cluster heads, in these schemes, are chosen for the beginning and following data collecting rounds by evaluating expressions involving probabilistic requirements, and by using parameters which are fixed such as the how many cluster heads there are and the round number.

- **Resource Adaptive Probabilistic Schemes**

In a resource adaptive scheme, data regarding the available resources of the nodes are considered, when making the selection for the cluster heads in each subsequent round. The threshold is calculated by the scheme taking into consideration the residual energy, energy consumed during present round and the average energy of the node as additional parameters; this causes the strategy for the selection of the cluster head to be energy adaptive.

- **Cluster Head Selection in Hybrid Clustering (Combined Metric) Schemes**

In literature on cluster based data collecting, a few hybrid methods have been proposed that combine clustering with, one or more of the other architectures; these hybrids have been reported to have more energy efficiency. This scheme adjusts the nodes and the threshold function, and the non cluster-heads select the optimal cluster-head by taking into consideration the comprehensive nodes' residual energy and how far the node is from the base-station.

This research work explains the energy efficient cluster head selection in mobile wireless sensor networks on the basis of residual energy and randomized selection of the node, who is not assigned as a cluster head in previous round. The objective of this research work is to minimize energy consumption during communication and maximize data gathering at the base station. Mobile Data Collector (MDC) based routing protocol using for communication from source to destination. MDC is moving in predefined trajectory from top to bottom in each corner of the network and transmit beacon message in every 5 sec for CH and BS to update the MDC location and residual energy. When CH received the beacon message from MDC, then CH measure the MDC's energy and selects the maximum residual energy MDC to deliver the sensed aggregated data towards the base station. The basic parameters of networks are: Fixed base station which is located far from the sensors, Homogenous and energy controlled sensor nodes and no high-energy nodes during the communication.

The rest of the paper organized as follows: Section 2 summarizes the related works of energy efficient cluster based routing protocols; Section 3 presents a critical evaluation of LEACH and Hybrid Multi-hop LEACH routing protocols; Section 4 describes proposed Energy Efficient Cluster Head Selection Scheme in a Mobile Wireless Sensor Networks; Section 5 explains the results and discussions and finally conclusion and future works presented in Section 6.

2. Related Works

The main purpose of an efficient cluster head selection in hierarchical routing is to maintain efficient energy utilization and data aggregation towards the sink. The clustering technique usually functions in regards to the energy maintained in the sensors which are near the cluster head. This section provides a brief introduction about cluster head selection schemes in different hierarchical cluster based routing protocols.

2.1. Low energy adaptive clustering hierarchy (LEACH)

Construction of the Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the first significant developments to conventional clustering approaches in WSNs as

shown in Fig. 2. The algorithm is self organized, employs a single hop approach and the data combination technique can decrease the rate of the data transfer.

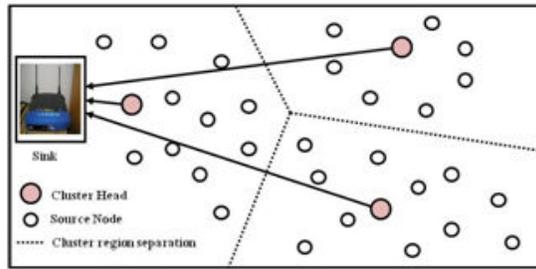


Fig. 2. Single Hop LEACH Routing Strategy.

It utilizes the randomized rotation of the local base stations (i.e., CHs) to evenly distribute the energy load among the sensors in the network. During the set-up phase, all nodes are organized into clusters through communicating with short messages and one node is selected as a cluster head according to cluster head selection algorithm. At the beginning of this phase, every node in the network must decide whether it will become a cluster head or not. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold $T(n)$, the node becomes a cluster head for the current round. The threshold $T(n)$ is set as:

$$T(n) = \begin{cases} \frac{P}{1 - P * (r \bmod \frac{1}{P})} \\ 0 \end{cases} \quad (1)$$

Every cluster head sets up a time division multiple access (TDMA) schedule for all the member nodes of its cluster. All the nodes broadcast short messages using the Carrier Sense Multiple Access (CSMA) MAC protocol, LEACH uses localized coordination to enable scalability and robustness for the dynamic network, and incorporates data fusion into the routing protocol [16].

2.2. Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN) and the Adaptive Sensitive Energy Efficient Sensor Network Protocol (APTEEN)

The threshold sensitive Energy Efficient sensor Network protocol (TEEN) is a cluster based hierarchical protocol [17] which is planned to be sensitive to unexpected modification in the perceived elements such as habitat monitoring and measuring of the temperature. For time-sensitive applications, responsiveness is an important parameter, where the network operates in a reactive mode. TEEN adopted a hierarchical approach with the use of a data-centric mechanism. The architecture of the sensor network in this protocol is based on a hierarchical grouping, where closer nodes form clusters and this is the second level process till the (sink) base station is accomplished.

Two thresholds transmit through the cluster head to the nodes after the creation of the clusters. These are the hard and soft thresholds characteristic. The smallest possible value of the hard threshold is to activate a sensor node to switch on its transmitter and transmit to the cluster head. Accordingly, the hard threshold allocates the nodes to broadcast simply when the attribute is detected within the specific region, which will reduce broadcasts, extensively. When a node detects a value equal to or greater than the hard threshold, it sends the data only when the value of that attribute changes by an amount equal to or above the soft threshold. Ultimately, the soft threshold is to further reduce the number of transmissions if there is a slight or no change in the perceived values. One can regulate the hard and soft thresholds to control the number of packet transmissions. The model is adopted from [17] as illustrated in Fig. 3.

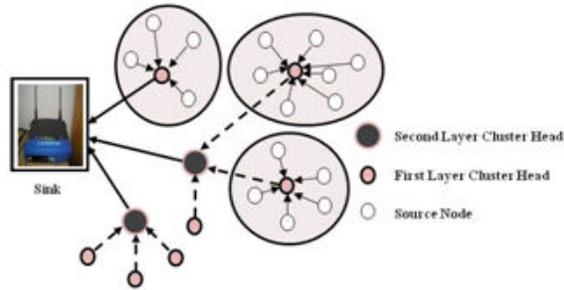


Fig. 3. TEEN and APTEEN Hierarchical Clustering.

The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [18] is a new version of TEEN; the main objectives is to capture both the regular collection of data and respond to critical events in time. The APTEEN architecture is similar as in TEEN. All nodes receive the attributes, threshold values and communication plan from the cluster heads, while the cluster is created around a base station. To save energy, data aggregation is the best method and is performed by the cluster heads. Three different query types use APTEEN: the chronological, analysis of the earlier period data values; one-time, take a picture of the network; and continuing to pursue a case for duration of time.

The simulation results of TEEN and APTEEN shows better than LEACH. APTEEN's performance is between TEEN and LEACH in terms of the lifetime of the network and energy consumption. TEEN offers the best performance since the number of the transmissions is reduced, but TEEN is not suitable for high-quality applications which require periodic reports while the user cannot obtain any data at all if the thresholds are not met. Moreover, the main disadvantages of both approaches are the complexity and overhead of the multiple cluster levels based on the implementation of the threshold functions and features according to the description of the query.

2.3. A novel application specific network protocol for wireless sensor networks

In many routing protocols for traditional MANETs such as DSDV and DSR used widely multi-hop routing strategy, these protocols employed one or more intermediate nodes from source to destination. Zhao et al. [19] proposed a novel self-organizing energy efficient Hybrid protocol based on LEACH that combines multiple-hop

routing strategy and cluster based architecture. Cluster heads act as backbone after the formation of clusters, every member node of cluster directly send the data to respective cluster head and then cluster head adopting multi-hop routing strategy to transmit the data towards the base station. Multi-hop routing strategy is an alternative of straight communication in order to reduce communication energy and distribute energy load evenly throughout the whole network.

Moreover, this protocol creates same suppositions as LEACH protocol almost the network model like CSMA MAC protocol utilizing to decrease the probability of collision at set-up phase. The node in the network is aware of its location, which is necessary for the multi-hop routing between cluster heads and can be achieved by Global Positioning System (GPS) technology. It employs randomized rotation of local base stations (i.e. CHs) to consistently allocate the load of energy between the sensors in the network. All nodes are managed within some clusters by the help of short message communication during the set-up phase and one node is selected as cluster head, according to cluster head selection algorithm same as LEACH protocol. At the start of set-up phase, each node in the network needs to select whether it will become a cluster head or not, this decision is made based on threshold value that is random number between 0 and 1. The node converts into cluster head for the current round if the value of number is less than the threshold.

Similar as LEACH, the steady-state of Hybrid routing protocol is made up of many frames where each member node occupies its own time slot to send its data to the cluster head. If a cluster head has the fused data to transmit to the BS, it will try to find a multi-hop route among all cluster heads to relay the data packet to the BS according to a routing algorithm as illustrated in Fig. 4. Since energy is quite precious in inaccessible sensor nodes for environment monitoring, the routing algorithm used here should be as simple as possible to prevent complexity of the protocol from rising too much. Therefore, the minimum transmission energy (MTE) [20, 21] routing is adopted as routing algorithm, which is a straightforward solution in the family of the multi-hop routing algorithms. The significant benefit of this proposed protocol is to reduce the transmission energy depletion that directly increases the overall network lifetime but network latency time and end-to-end delay is increased.

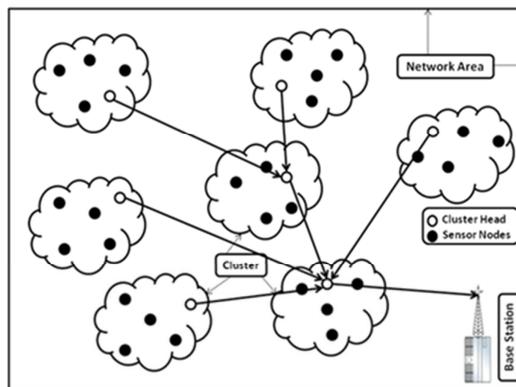


Fig. 4. Architectural View of Hybrid Multi-hop LEACH Protocol.

3. Critical Evaluation of LEACH and Hybrid Multi-hop LEACH

Since LEACH and Hybrid Multi-hop LEACH are described in literature survey which are the base starting points of this research work, this section cover the critical analysis of the design rules of these protocols.

3.1. Energy dissipation due to displacement

The foremost drawback of LEACH routing protocol is directly forwarding the aggregated and compacted data from all cluster heads to the base station, in this situation some of the cluster heads are far from the base station and other are closer to it because of all sensor nodes are ubiquitous in an enormous area. This has been huge effect in terms of communication energy depletion among the cluster heads towards the base station. Two types of radio communication energy depletion include transmitter/receiver electronics and transmit amplifier energy. Normally the energy of amplifier is essential for efficient communication that is much bigger than the energy of transmitter and receiver electronics and controls the energy depletion of communication. The minimum essential energy of amplifier is directly related to double the distance from source to preferred destination (E_{Tx-amp}/d^2) advising in free space model, so the energy depletion of communication significantly increases when the distance of communication rises. That is proved, the far cluster heads acquired much more energy to forward the data towards the base station than the other cluster heads those near the base station and the significance difference arises in energy dissipation among the sensor nodes those which are near and far from the base station after successful rounds of the network. In LEACH protocol all sensor nodes start with same energy level, the far nodes utilizes the energy before those closer the base station, so the overall effect the network divided in two sections by alive and lifeless nodes and the network performance declines.

3.2. Energy dissipation calculation in LEACH Protocol

First order radio model is the big achievement in the area of low energy radio networks; this model gives very simple equations for both transmitting and receiving data from one node to another node are given below in Eqs. (1) and (2).

$$E_{Tx}(l, d) = E_{Tx-elec}(l) + E_{Tx-amp}(l, d) \quad (1)$$

$$= \begin{cases} lE_{elec} + lE_{fs}d^2, & d < d_0 \\ lE_{elec} + lE_{fs}d^4, & d \geq d_0 \end{cases}$$

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec} \quad (2)$$

Transmission energy to transmit a message of l bits comprises radio electronics dissipation $E_{Tx-elec}(l)$ and amplifier dissipation $E_{Tx-amp}(l, d)$; d is the distance between transmitter and receiver. If d is less than a threshold d_0 , $E_{Tx-amp}(l, d) \propto d^2$ according to the free space model; otherwise $E_{Tx-amp}(l, d) \propto d^4$ is according to the multipath model. E_{elec} and E_{amp} are affected by many factors, LEACH protocol set as: $E_{elec} = 50$ nj/bit and $E_{amp} = 10$ pj/bit/m². Figure 5 explains the data transmission architectural view of LEACH protocol.

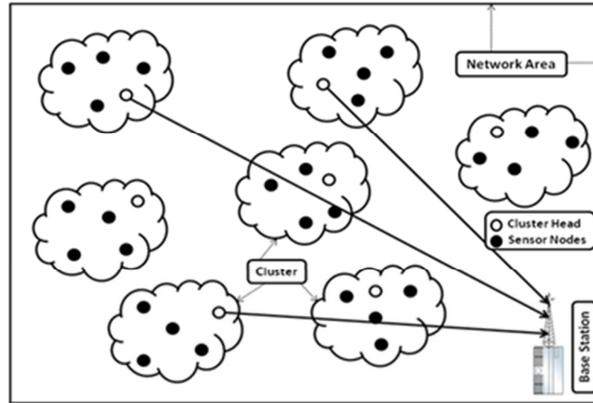


Fig. 5. Data Transmission in LEACH Protocol.

Therefore, for above given parameters it is clear that receiving and transmitting data is not a low cost operation. Energy dissipation of transmission and receiving analysis between nodes A and B are given below, suppose the packet size is 288 bits and distance d is approximately 30 meters.

$$\begin{aligned}
 \text{Energy dissipation to transmit per packet} &= lE_{elec} + lE_{amp}d^2 \\
 &= l(E_{elec} + E_{amp} * d^2) \\
 &= 288 (50 \text{ nj/bit} + 10 \text{ pj/bit/m}^2 * (30)^2) \\
 E_{Tx}(l, d) &= 16.9 \times 10^{-6} \text{ J}
 \end{aligned}$$

$$\begin{aligned}
 \text{Energy dissipation to receive per packet} &= lE_{elec} \\
 &= 288 * 50 \text{ nj/bit} \\
 E_{Rx}(l) &= 14.4 \times 10^{-6} \text{ J}
 \end{aligned}$$

3.3. Energy Dissipation Calculation in Hybrid Multi-hop LEACH Protocol

Energy dissipation of transmission and receiving analysis between nodes A and B in Hybrid Multi-hop LEACH, suppose the packet size is 288 bits and distance d is approximately 12 meters from cluster head to another cluster head. Figure 6 explains the data transmission architectural view of Hybrid Multi-hop LEACH protocol.

$$\begin{aligned}
 \text{Energy dissipation to transmit per packet} &= lE_{elec} + lE_{amp}d^2 \\
 &= l(E_{elec} + E_{amp} * d^2) \\
 &= 288 (50 \text{ nj/bit} + 10 \text{ pj/bit/m}^2 * (12)^2) \\
 E_{Tx}(l, d) &= 14.8 \times 10^{-6} \text{ J}
 \end{aligned}$$

$$\begin{aligned}
 \text{Energy dissipation to receive per packet} &= lE_{elec} \\
 &= 288 * 50 \text{ nj/bit} \\
 E_{Rx}(l) &= 14.4 \times 10^{-6} \text{ J}
 \end{aligned}$$

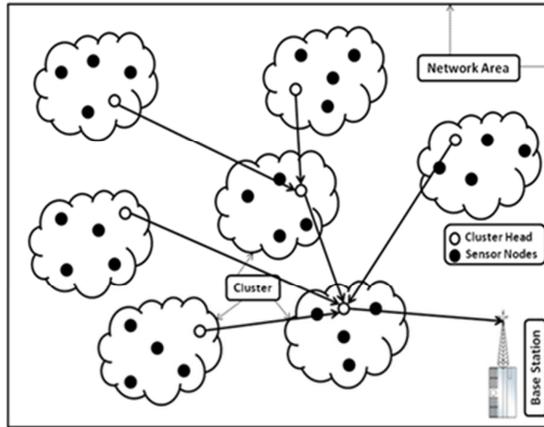


Fig. 6. Data Transmission in Hybrid Multi-hop LEACH Protocol.

4. Energy Efficient Cluster Head Selection Scheme in Mobile Wireless Sensor Networks

This protocol uses a three-tier network architecture and multi-hop routing communication for data aggregation and transmission from the sensor node to base station. It has been observed that this type of architecture enhances the network scalability for large scale environmental applications. Multi-hop routing communication is used to reduce the disruption of the channel area and provide prospective energy savings by the help of long and multi-hop communication from source to destination.

4.1. Energy model for data transmission

In recent years, a lot of research has been carried out in regards to low-energy propagation radio models. This proposed routing protocol employs a simple First Order Radio Model, where the transmitter and receiver dissipate E_{elec} 50 nj/bit and an transmit amplifier circuit at ϵ_{amp} 100 pj/bit/m² to achieve an acceptable E_b/N_o . The current state-of-the-art radio design, First Order Radio Model's parameters are slightly better than the other models.

Suppose r^2 is the energy loss within a channel transmission, when sending a k -bit message at a distance of d by the help of the radio model, the transmission end calculations are in Eqs. (3) and (4):

$$E_{Tx}(k, d) = E_{Tx-elec}(k) + E_{Tx-amp}(k, d)$$

$$E_{Tx}(k, d) = E_{elec} * k + \epsilon_{amp} * k * d^2 \tag{3}$$

And the receiving end calculations are:

$$E_{Rx}(k) = E_{Rx-elec}(k)$$

$$E_{Rx}(k) = E_{elec} * k \tag{4}$$

4.2. Inter and intra cluster communication

The end-to-end data transmission process of the proposed protocol is divided into many rounds with each round followed by a set-up phase and steady phase for cluster formation and data transfer, respectively, from the sensor nodes to MDC and then finally towards the base station. The operation time line of the LEACH protocol is shown in Fig. 7.

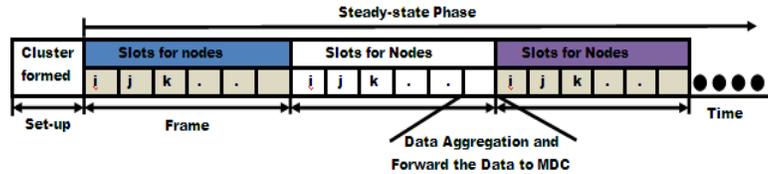


Fig. 7. LEACH Operation Time Line.

Set-up Phase and Cluster Head Selection: In the period of cluster formation, all nodes are autonomous, self-organized and arranged into clusters through short messages using the Carrier Sense Multiple Access (CSMA) protocol. Every node of the network has to make a decision to become a cluster head or not with the probability of P_i and the residual energy of node; P_i with the residual energy node in the proposed formula is calculated according to the LEACH algorithm as shown in Eq. (5).

$$P_i(t) = \begin{cases} (1 - (E_{con}/E_{Total})) * \frac{k}{N - k * (r \bmod \frac{N}{k})} \\ 0 \end{cases} \quad (5)$$

At the beginning of the set-up phase every node uses this formula to calculate the probability P_i check with the residual energy of node. The first part of Eq. (5) computes the residual energy of each sensor node; E_{con} and E_{total} are the consumed energy in each round and the total energy of the node respectively. The second part ensures that the expected number of cluster heads for every round is k ; this means that the whole network is divided into k clusters and N is the total number of nodes in the network. Every node has been elected once as a cluster head after N/k rounds on average and r shows the round number. Those nodes selected as a cluster head for the current round are not eligible to be selected as a cluster head for the next round.

Table 1 explains the analytical comparison results between the normal and proposed cluster head selection formula, if it is assumed that $E_{total} = 2J$, $k = 10$, $N = 100$ and $r = 1, 2, 3$ and 4 . All cluster heads in the network broadcast an announcement from all the nodes through the CSMA protocol, this message has some fields like cluster head node position and message type that indicate it is a short message. After time t_1 , nodes receive many announcement messages from different cluster heads, then the member node decides the closest cluster head on the basis of the signal strength of the packet announcement and picks the closest cluster head with the smallest distance.

Steady Phase: Figure 8 explains the steady phase flow transmission of proposed protocol; this phase uses multi-hop routing by the help of Mobile Data Collector for data transmission towards the base station. After the cluster formation, the cluster head sets up a Time Division Multiple Access (TDMA) schedule for every

node to send data to the cluster head. This scheduling is to avoid collisions and reduce the energy consumption between the data messages in the cluster and enables each member of the radio equipment to be off when not in use.

To reduce inter cluster interference every cluster uses a unique spreading code; when the node is selected as a cluster head it selects that unique code and informs all the member nodes within the cluster to transmit their data using this spreading code. In the data fusion mechanism towards the base station, the Mobile Data Collector transmits a beacon message for all the cluster heads to update their current position as illustrated in Fig. 9.

Table 1. Analytical Comparison Results.

r	E_{con}	Normal Formula	Proposed Formula
1	0.1	0.111	0.104
1	0.2	0.111	0.099
1	0.4	0.111	0.088
2	0.6	0.125	0.087
2	1.0	0.125	0.062
3	1.2	0.142	0.056
4	1.4	0.166	0.049

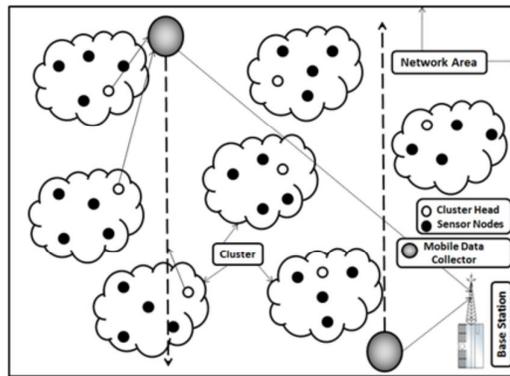


Fig. 8. Steady Phase Flow Transmission.

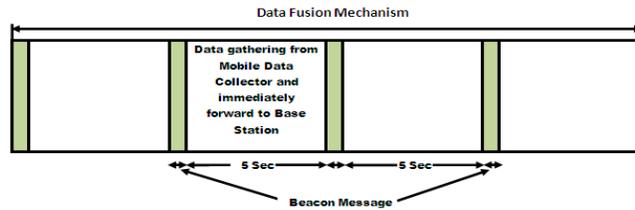


Fig. 9. MDC Beacon Message.

According to the inverse square law, the transmission energy is inversely proportional to the square of the distance, thus, sensor node A calculates the least distance by the squared distance function $S(M)$ to reach the base station through MDC.

$$S(M) = s_{A-M}^2 + s_{M-BS}^2 \quad (M \text{ denotes MDC})$$

Then, the least distance of them is taken in relation to the square of the distance from the head node A to BS.

$$\text{Min}(S(M)) < s^2_{A-BS}$$

Pseudo Code of the Proposed Protocol:

```

BEGIN
1. Identify the Probability ( $p_{set}$ ), number of nodes (s);
2.  $E_{init}(s) = E_0, s = 1, 2, 3, \dots, n$ ;

SET-UP PHASE
1. do { //repeat for r rounds
2.    $r \leftarrow \text{random}(0, 1)$ ;
3. if  $E_{res} >$  among all candidate CH &  $(E_{init}) > 0$  &  $\text{mod}(1/p_{opt}) \neq 0$  then
4.   compute T (s); //given by (1)
5.   if ( $r < T(s)$ ) then
6.     CH {s} = TRUE; //node "s" be a CH
7.   Else
8.     CH {s} = FALSE; //node "s" not be a CH
9.   End if
10. End if
11. if (CH {s} = TRUE) then
12.   BC (ADV)  $\leftarrow$  broadcast an advertisement message;
13.   Join (IDi); //non-cluster head node i join into the closest CH
14.   Cluster (c); //form a cluster c;
15. End if

STEADY PHASE (CH – MDC)
1. if (CH (s) = TRUE) then
2.   Receive (IDi, DataPCK) //receive data from members;
3.   Aggregate (IDi, DataPCK) //aggregate received data;
4.   Trans To MDC (IDi, DataPCK); //transmit received data;
5. Else
6.   if (My Time Slot = TRUE) then
7.     Trans To CH (IDi, DataPCK); //transmit sensed data;
8.   Else
9.     Sleep Mode (i) = TRUE; //node i at a sleep state
10.  End if
11. End if

STEADY PHASE (MDC – BS)
1. Receive (location update); //receive beacon message
2. if (CH (s) = TRUE) then
3.   dis = cal_dist (CH, MDC);
4.   after "t" Time
5.   if (CH.dis > dis)
6.     CH.dis = dis;
7.     CH.MDCID = MDC.ID
8.   Else
9.     CH.dis = CH.dis
10.    CH.MDCID = CH.MDCID
11.  End if
12. End if
13. Trans to MDC (CH.ID, DataPCK); //transmit data from CH
14. Else
15.   Update (X pos, Y pos) //coordinates of MDC
16.   message (ACK); // message to MDC
17. End Else

```

When a cluster head has received sufficient data from its members, then it will change the spreading code for MDC and return to receive the sensed data messages from its members after successful transmission. During the transmission from the cluster head to MDC, all the cluster heads broadcast the messages within the network through another assigned spreading code and CSMA/CA is employed as a MAC layer protocol to avoid possible collision between them. When MDC has received the data from any of the cluster head, then it will directly forward data towards the base station.

5. Results and Discussion

The network parameters of the simulation are explained in Table 2. The following performance metrics are measured: Energy consumption of the sensor node, Network lifetime, Traffic received at the base station, Channel Access Delay and End-to-End Delay; all were measured by computer simulation.

Table 2. Simulation Parameters.

Parameters	Values
Number of Nodes	Forty (40)
Simulation Area	1000×1000 (m)
Sensor Node Deployment	Random Deployment
Number of Cluster Head	Five (5)
Transmitter Electronics ($E_{TX-elec}$)	50 nj/bit
Receiver Electronics ($E_{RX-elec}$)	
Transmit Amplifier (ϵ_{amp})	100 pj/bit/m ²
Battery	Initial capacity is assumed to be constant
Data Rate	250 kbps
Packet size	288 bits/packet or 36 Bytes
Node Ground Speed	0.5 m/sec
MDC Beacon Message Rate	5 sec/message
Number of MDC's	2
MDC Velocity	0.054 m/sec
Round time	30 sec

Energy consumption of sensor nodes and network lifetime:

In Figs. 10, 11 and 12, the results shows energy consumption of sensor nodes after multiple simulations runs over LEACH, Hybrid Multi-hop LEACH and Energy Efficient Cluster Head Selection in Mobile Wireless Sensor Networks. As the energy limit of each node was fixed at 2j, the energy consumption of node 19 in the LEACH died after the simulation of 4 hours and in Hybrid Multi-hop LEACH routing protocol dissipates 1.6j, however in the proposed routing protocol it was still alive and consumed only 0.6j after the simulation of 5 hours. On the other hand, the energy consumption of nodes 24 and 36 also lived longer in proposed protocol: after 5 hours of simulation they consumed only 0.9j and 0.8j respectively.

Moreover 1.9j and 2j in LEACH and 1.6j and 1.5j of energy consumed in Hybrid Multi-hop LEACH routing protocols by node 24 and 36 after the simulation of only 5 hours. In these graphs, there is a significant difference in the energy consumption of the sensor nodes in the network, which directly impacts on the performance of the network or network lifetime.

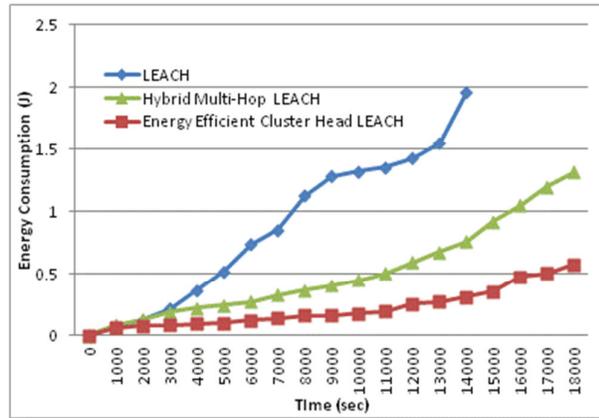


Fig. 10. Energy Consumption of Node 19.

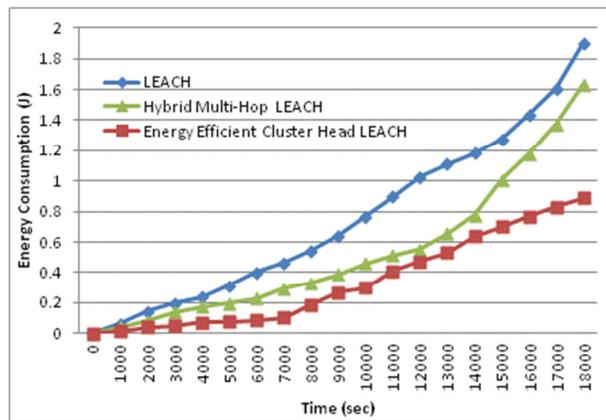


Fig. 11. Energy Consumption of Node 24.

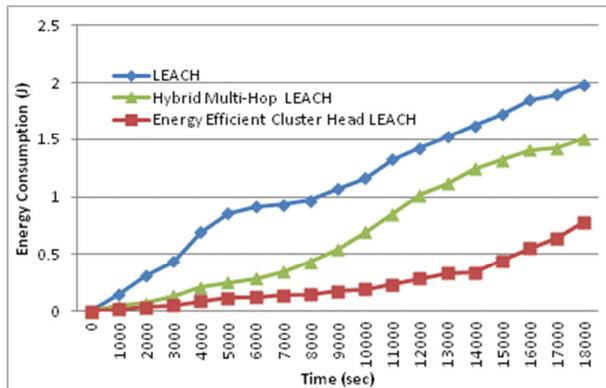


Fig. 12. Energy Consumption of Node 36.

The simulated result of Fig. 13 exposed the considerable variation in the network lifetime. Therefore, the energy efficient cluster head selection in an mWSN is better than the LEACH and Hybrid Multi-hop LEACH routing protocols in terms of the network lifetime because it stays active as a whole, longer and falls slightly faster. The sensor nodes in energy efficient cluster head selection in mWSN stays alive longer and generate packets higher than the LEACH and Hybrid Multi-hop LEACH routing protocols because sensor nodes are died earlier and not be able to generate more packets.

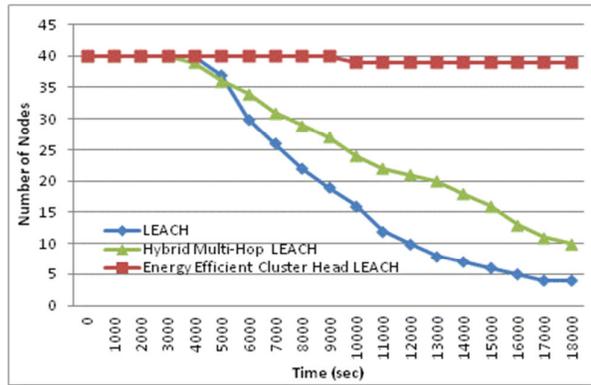


Fig. 13. Network Lifetime.

Figure 14 demonstrate the amount of traffic received at the base station over time in LEACH, Hybrid Multi-hop LEACH and energy efficient cluster head selection in mWSN routing protocols.

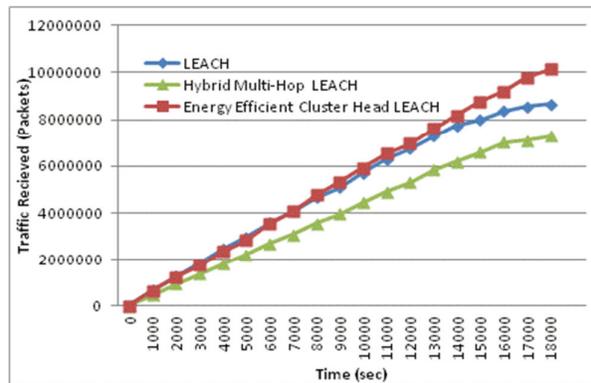


Fig. 14. Traffic Received.

The channel busyness or latency time of the data packet when it enters and leaves the network layer is measured by the channel access delay. The result shows that the channel access delay of energy efficient cluster head selection in mWSN is slightly higher than the LEACH and Hybrid Multi-hop LEACH routing protocols due to the increased traffic load between the sensor nodes to the base station by applying the MDC based multi-hop routing.

The main metric of the network latency is the End-to-End delay; it is defined as the time latency of the data packet, channel access delay and other potential delays from the source to destination.

Figures 15 and 16 explain the graph of the average channel access delay and End-to-End delay over time using LEACH, Hybrid Multi-hop LEACH and energy efficient cluster head selection in mWSN routing protocols. The End-to-End delay of energy efficient cluster head selection in mWSN routing protocol is higher than the LEACH and Hybrid Multi-hop LEACH routing protocols that is nearly same as channel access delay. The possible problems of end-to-end delay in proposed protocols are aggregated data packets taking multi-hops to reach the base station, node mobility, packet retransmission due to weak signal strengths between nodes, interference level along the route, connection tearing and making, and therefore both the routing scheme and the MAC layer scheduling scheme can affect end-to-end delay. Improving end-to-end delay through load balancing with multi-path routing, proactive routing strategy, routing and MAC layer scheduling, etc.

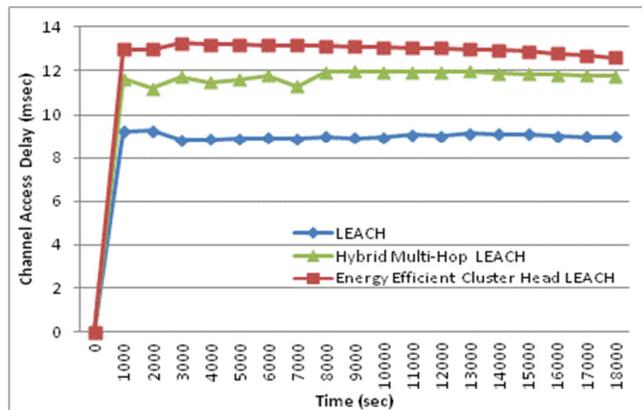


Fig. 15. Channel Access Delay.

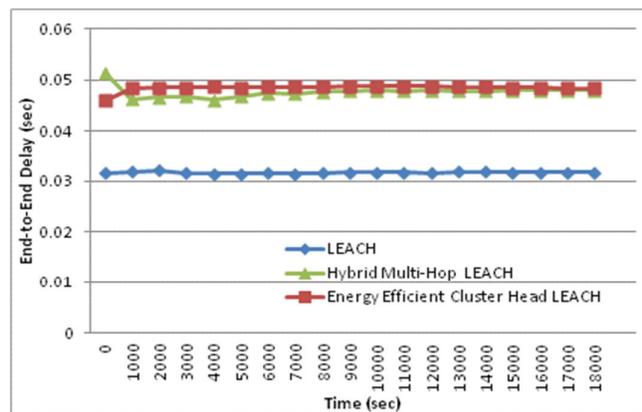


Fig. 16. End-to-End Delay.

6. Conclusions

This research work addresses the considerable comparison in single-hop and multi-hop routing protocols. According to aforementioned simulated results is the evidence for multi-hop energy efficient cluster head selection in mWSN routing protocol is better than single-hop LEACH and Hybrid Multi-hop LEACH routing protocol in terms of the energy consumption of sensor nodes, extensively improving the network lifetime, higher traffic received, trade off with the channel access and end-to-end delays. In our future work, we will enhance and validate the Mobile Data Collector based routing protocol by Multi-channel concept at the base station to directly allocate the channel for MDC's instead of single channel and also find the best approach to resolve channel access and end-to-end delays in Mobile Data Collector based routing protocol.

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