INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

A three-tier cluster-based routing protocol for mobile wireless sensor networks

Muhammad Arshad[1]*, **Ahmad Almufarreh**[1], **Muhammad Taha Jilani**[2], **Farhan A Siddiqui**[3]

1 Assistant Professor, Deanship of e-Learning and Information Technology, Jazan University, Jazan, 82812, Kingdom of Saudi Arabia. Tel.: 00-9665-373-66015
2 Associate Professor, College of Computer and Information Sciences, PAF-KIET, Karachi, 75190, Pakistan
3 Assistant Professor, Department of Computer Science, University of Karachi, Karachi, 75270, Pakistan

OPEN ACCESS

Received: 18-06-2020

Accepted: 12-08-2020

Published: 10-09-2020

Editor: Dr. Natarajan Gajendran

Citation: Arshad M, Almufarreh A, Jilani MT, Siddiqui FA (2020) A three-tier cluster-based routing protocol for mobile wireless sensor networks. Indian Journal of Science and Technology 13(33): 3409-3424. https://doi.org/10.17485/IJST/v13i33.951

*__Corresponding author__.

Tel: 00-9665-373-66015
msarshad@jazanu.edu.sa

Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Background/Objectives: Based on the recent advances in the area of wireless networking, computing, and storage devices, Wireless Sensor Networks (WSN) has emerged as an evolving and future-enabled technology in recent decades. The objective of the research work is to design, analyse, and evaluate the performance of A Three-Tier Cluster-Based Routing Protocol for Mobile Wireless Sensor Networks. **Methods/Statistical analysis**: The proposed protocol is based on autonomous sensor nodes, distributed techniques on cluster development; cluster heads collected at random, multi-hop routing method, and transferring the data towards the base station used by the assistance of MDC maximum residual energy LEACH. **Findings**: WSN is used globally in different forms of networking technologies; these systems come with the ability to be applied worldwide at an unrivaled scale and to add a consistent viewpoint to production. Routing protocols in these networks act as middleware, which is responsible for enhancing the network performance with less energy consumption and the cluster-based routing protocol is a massive solution to improve node's energy efficiency and reliability of data toward the base station. Moreover, the simulation results showed that the proposed protocol achieves not only better network lifetime and data reliability but also decreased energy dissipation of the sensor nodes when compared with prominent WSN cluster-based routing protocols. **Novelty/Applications:** The main outcomes of MDC maximum residual energy LEACH are: Minimize the energy consumption of sensor nodes, Enhance the overall network lifetime, Resolve communication (energy and routing) holes issues, Maintain data reliability, and finally reach tradeoff between energy efficiency and latency in terms of End-to-End and channel access delays. This proposed protocol has been substantially applicable in an extensive variety of environmental and civil surveillance applications.

Keywords: Wireless sensor network; mobile data collector; three-tier architecture; data gathering method; cluster-based routing

1 Introduction

Wireless Sensor Network is an evolving network with the number of sensor nodes in a region for the sensing and transmitting of data from a given area to the base station or sink node. The sensor node has minimal sensing, connectivity, and processing capability. A sensor may sense certain types of inputs from the physical world, such as temperature, illumination, air, sound, acceleration, moisture, proximity, or certain other phenomena [1,2].

Significant progress of WSN technology has occurred in recent years and is now widely used in military, intelligent, medical and surveillance applications. Data collection is the main activity in WSN and a growing number of researchers are paying attention to this. All nodes are fixed in a traditional data collection scheme in a position to collect data before being forwarded to the Sink by routing protocol [3]. The most demanding unresolved issues with this phase at the moment are:

- Energy and routing holes concern, where data streams adopt a multiple-for-one mode that exposes nodes or clusters to a higher traffic load near the Sink, resulting in premature energy depletion and creating energy and routing holes issues around the Sink.
- Overhead communication issue, the self-energy of the sensor nodes is restricted, the overhead is managed independently of the routing protocol algorithm and hence the implicit need to regulate the energy usage of the network nodes.

The nodes are powered by the battery in most WSN applications and are placed in an unattended or harsh environment. Battery replacement is difficult, or even impossible. If the node exhausts its resources, the node is deactivated. This will affect network service and break network to shorten the life of the network. Hence, network lifetime in WSNs is the essential predictor of network success. WSN's data-gathering algorithms will conserve resources and optimize network activity. The researchers have shown that the algorithm for collecting hierarchical data achieves exceptional success in extending network lifetime [4,5].

The architecture of the WSN is largely unstructured and consists of a series of homogenous or heterogeneous nodes, Data Collectors (DC), and a Base Station (BS). The BS is sometimes called Sink. Mobility can be integrated into all of those three elements. Sensor node mobility, Mobile Data Collectors (MDC), or Sink Nodes find it very difficult to handle network topology maintenance. When a node detects a change in the status of the environment it can recognize and take notice of the changes. The information collected is transmitted to the BS / Sink node through a single hop or multi-hop communications protocol [6].

Mobile WSN can be categorized into flat, two-tier or, three-tier hierarchical architecture: the network architecture involves a collection of heterogeneous tools for ad hoc connectivity with the flat or level-like. These devices are fixed or mobile, all within the same network they need to communicate. The Two-tier architecture is composed of a set of nodes in place and a set of mobile nodes. The moving nodes form an overlay network or play data mules' role in transferring data across the network. In the three-tier architecture, a set of fixed sensor nodes transmits data to a set of mobile devices, which then transmits data to one set of access points. The heterogeneous network is designed to span wide areas and to be compliant concurrently with many applications [7,8].

1.1 Techniques in mobile WSN data collection

Traditional WSN topologies consist of sensor nodes that are randomly deployed within a sensing network. Today the expansion of WSN attempts to apply mobile elements (ME) as relay agents in the collection and forwarding of data from sensor nodes to the sink. In order to fully understand the basic characteristics of wireless sensor networks with mobile elements (WSN-MEs), let us first implement the reference network topology, which is stated as per the MEs function [9,10] . Following are the major modules of WSN-MEs:

- Nodes or Regular sensor nodes are the sources of data. The main tasks of these nodes are to perform sensing and to relay or forward messages to the sensor network, depends on the methodology of communication implemented.
- Base Stations or Sink is the information destinations, which is responsible for collecting data that are detected directly (i.e. by visiting sensors and extracting data from each node) or indirectly (i.e. by transitional sensor nodes) by the sensor nodes. The sinks will use the information from various sensors separately or create it accessible to the users concerned through an Internet connection.
- Supportive special nodes are meant to serve a particular function, which is to act as transitional data accumulators or network gateways. They are not messaging sources or destinations but intended to exploit mobility in order to assist data collection or network connection [11] .

Various approaches for maximizing the versatility of data collection strategies for WSN have been suggested. These techniques are classified according to the features of the versatility of the sink and the methods of wireless data transmission: A Mobile Data Collector (MDC) functions as a mobile sink that independently meets all of the sensors in the network. Before the MDC visits the sensor-generated buffered data at source and the information is retrieved through a single hop transmission. The Mobile Base Station (MBS) is a mobile sink that, by transmission, changes the location. The sensors forward data without delay to MBS. The Rendezvous Solution is a hybrid WSN mobility system where sensor data is gathered at a given point near the mobile devices. Then, the mobile devices download the buffered data from appointed points [12,13].

The critical significance of the energy awareness of the WSN is network durability. Some reason has emerged, a number of accomplishments for the creation of the "intelligent" routing protocols in which their application will position the routing decision based on the energy level of the node [14] . Related to this, this further section will present all of the routing protocols by focusing on energy awareness based on several trades offs of certain design decisions. In addition, the following section will describe several latest and well-renowned WSN routing protocols including flat or data-centric routing techniques, hierarchical, and mobility-aware. Mobility-aware routing is still a moderately new concept in this case.

WSN Cluster Head Positioning Algorithm (CHP) [15] aims to find the best CH position for other nodes within the same cluster so that the contact path-loss of all SNs is minimized and the lifetime of the sensor nodes is thus increased. The proposed algorithm changes the CH position dynamically by leveraging CH nodes with mobility capabilities to allow them to travel to the appropriate locations. In addition, the proposed algorithm is used to modify multi-cluster CHs located on a spiral trajectory to preserve the multi-hop relation to the BS. The problem addressed by the authors here is about loading balancing and reducing the network's energy usage by initially splitting the network into subsections (zones) depending on the number of sensor nodes (SNs). All the nodes have to function for CH's position but only one at a specific round of clusters. The suggested algorithm uses a form of hybrid deployment for SNs, where the CHs nodes and BS are distributed along a spiral trajectory in predetermined positions to take advantage of convergence and connectivity.

A three-tiered [16] heterogeneous clustering routing protocol for wireless sensor networks is introduced to improve the network workflow. The suggested protocol uses threshold and energy considerations to select the most capable nodes as a cluster head (CH). CH's selection helps to improve the efficiency of the overall network process and improves network functionality. To select the CH from the different heterogeneous nodes, this protocol uses parameters such as energy (medium and residual), rounds, and the probability of CH. The sensors are grouped into three different node sets using their energies (low, medium, and high). The clustering method in the suggested methodology starts with random number generation within the range [0, 1]. The nodes that meet the threshold requirements get the function of the CH. The criterion is used for calculation of CH overall degrees of heterogeneity.

Unlike state-of-the-art methods, the author implements a Scalable and Energy-efficient routing protocol (SEEP) [17] . SEEP uses a multi-tiered clustering architecture to achieve a flexible and energy-intensive network. With the aid of the proposed sub-domain division algorithm, the network area in SEEP is divided into separate areas. The quantity of zones inside the network is reduced as the network size increases to eliminate long-distance interruption. In the proposed protocol, static and mobile scenarios were considered by incorporating the Random walk and Random waypoint model for node mobility in simulation to make it more realistic as the various IoT applications that are sponsored by WSN. SEEP was evaluated for multiple implementation scenarios, mobility models, and efficiency metrics, which primarily involves statistics relating to network lifespan and energy depletion.

The author in [18] suggested a bi-layered WSN architecture for the routing and recovery of complex clustering-based hole identification and coverage. The proposed work consists of four stages cluster forming, selection of the cluster head (CH), the discovery of the coverage void, and recovery and routing. The K-means algorithm is used to shape clusters. CH is selected by Determined Weight (DW) which determined by remaining energy, distance to the base station from the cluster. CH is chosen according to weight and Efficient Entropy Function utilizes for cluster maintenance (cluster splitting and merging). The identification and recovery of coverage hole after cluster forming was conducted for efficient packet transmission. Coverage holes happen at different places. The author describes the coverage hole at three locations: (1) Within the cluster, (2) Between the clusters, (3) and Network's Boundary. Used at four separate positions, the hole manager (HM) uses fuzzy logic (energy, stability) to figure out which node will recover the coverage hole. Multi-objective Emperor Penguin Optimization Algorithm (MO-EPO) chooses the optimal multi-hop path for transmission.

1.2 Energy-efficient communication protocol for wireless microsensor networks (LEACH)

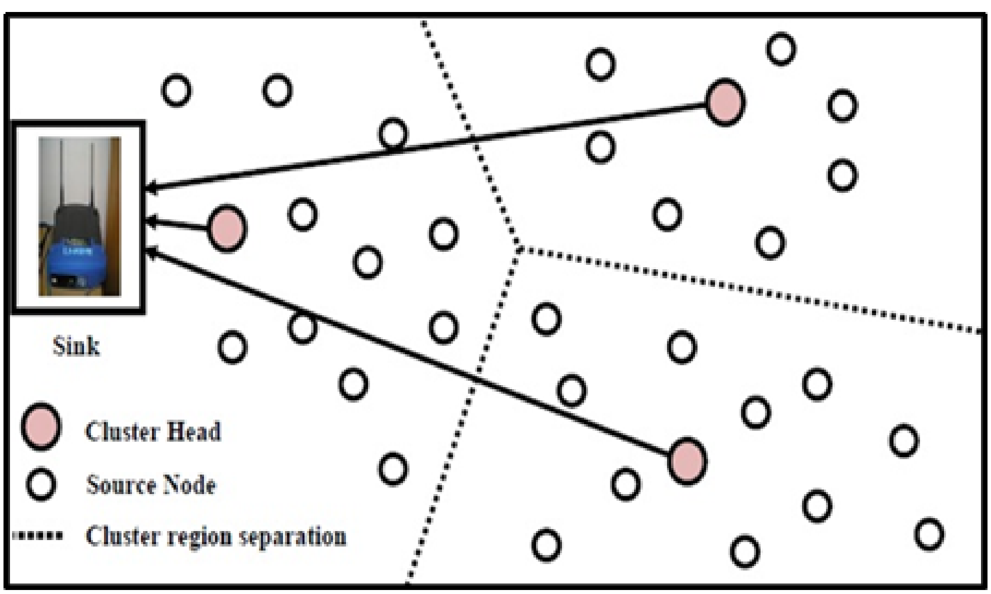

Fig 1. LEACH cluster configurations and transmission

The Low Energy Adaptive Clustering Hierarchy (LEACH)[19] is a revolutionary theoretical work on the topologies of hierarchical networks. For this purpose, LEACH should presume that homogeneous nodes are deployed as a platform, and the base station is unmoving. Therefore, in LEACH, nodes that are closer to a cluster head in nature will be grouped into a logically separate network using the self-configuration of the clusters, this implies that each of them is considered a single hop and kept at a distance from the cluster head. Meanwhile, the data messages at the head of the cluster will be aggregated in each cluster. Given that the cluster head is constantly one communication away from the sink node, the LEACH operation transmits the accumulated messages straight to the base station.

This transmission, in fact, might be considered a high-power one by which comparing it to the normal source-to-cluster head transmission, will consume more node energy factors. Figure 1 illustrates the mechanism of the LEACH proposed protocol in selecting and rotating the cluster head randomly to distribute aggregation and transfer load sink over the network.

1.3 Novel application specific network protocol for wireless sensor networks (Hybrid Multi-hop LEACH)

MANET old-fashioned routing protocols used one or even more entry-level nodes to transfer the data to the destination, such as DSR and DSDV, which utilized extensively multi-hop routing. The author of[20] suggested a new, LEACH-based energy-efficient hybrid protocol integrating multi-hop routing approach with cluster-based architecture. Cluster heads serve as the core component after cluster forming; each cluster leader node transfers the information immediately to the corresponding cluster head. Afterward cluster head decides to adopt a multi-hop routing approach for transmitting the data to the base station as a substitute to direct communication in exchange to minimize transmission burden and uniformly spread power consumption across the entire network.

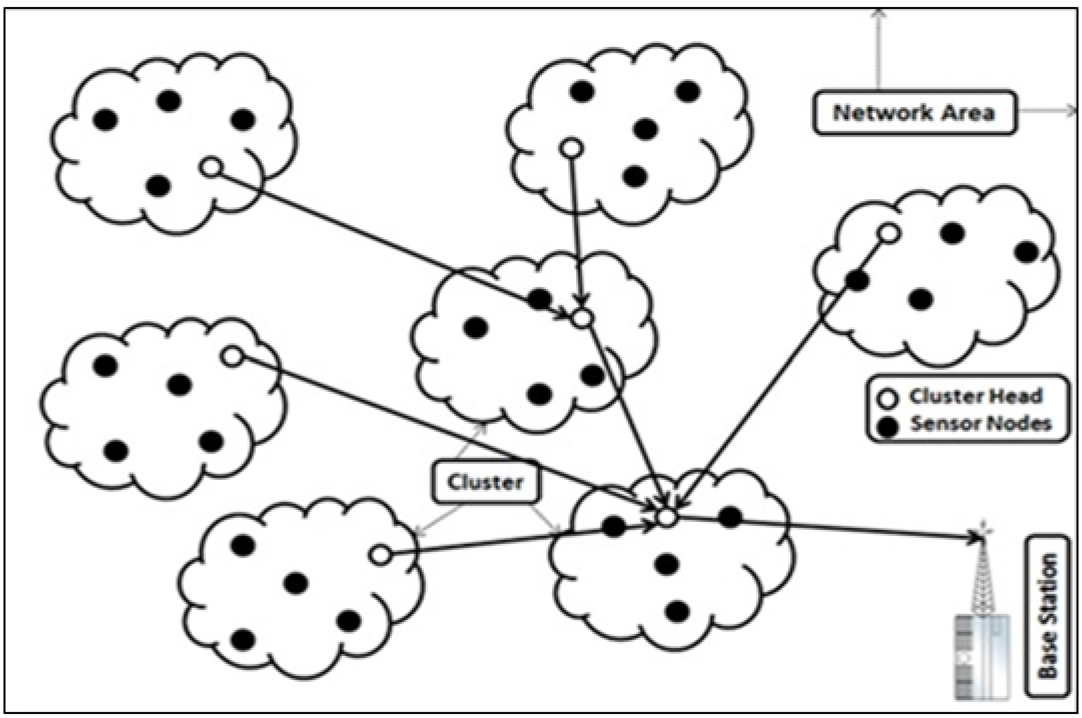

Fig 2. Hybrid multi-hop LEACH routing protocol

This protocol produces the same assumptions as almost the LEACH network model protocol, including the Carrier Sense Multiple Access (CSMA) MAC protocol used to decrease the likelihood of collision during the setup step. The node in the network is aware of its location, which is important for the multi-hop routing between cluster heads that can be carried out using the Global Positioning System (GPS). It uses a randomized rotation of local base stations (CHs) to ensure reliable distribution of the energy charge between the network sensors. During the setup process, all nodes are controlled in certain clusters with the help of short text messages and one node is chosen as a cluster head (CH) as per the CH selection algorithm identical to the LEACH protocol. At the start of the initialization cycle, each node within the network will choose whether or not it will become a cluster head, this choice is taken on the basis of a threshold value amongst 0 and 1. For the present round, the node transforms into a cluster head if the number sum is less than the threshold.

Compared to LEACH, the steady-state of the Hybrid routing protocol is made up of multiple frames in which each member node maintains its own time slot to pass their data to the cluster head. Once a CH has the data fused to send to the BS, it can seek to locate a multi-hop path through all cluster heads to relay the data packet to the BS using a routing algorithm as illustrated in [Figure 2]. As energy is very valuable to track the environment in unreachable sensor nodes, the routing protocol utilized here will be as simple as possible to avoid increasing the complication of the protocols. The routing of minimum transmission energy (MTE) [21,22] is thus implemented as a routing protocol which is a simple solution within the multi-hop routing algorithms family. The key advantage of this new protocol is to minimize the communication energy depletion, which significantly decreases the whole lifespan of the network but eliminates the duration of network congestion and end-to-end delay.

1.4 Mobile agent based LEACH

More energy is saving with LEACH which is Mobile Agent as illustrate in [Figure 3] because the redundant data is neglected and the data delivery to the base station is reliable. It has been proposed to use a clustering technique with a mobile agent in this protocol. In order to locally manage the mobile agent technical clustering is applied. Mobile agents can move between nodes in a sensor network, therefore, they are dynamic. They are also intelligent so they can share information. The average from the collection of data is calculated by the mobile agent, an increase in the redundancy of the sensor networks can be affected by the mobile agent. Alternative nodes can be located by the agent if any node should die. Reliable data is delivered by the mobile agents as they can determine which data are faulty [23] .

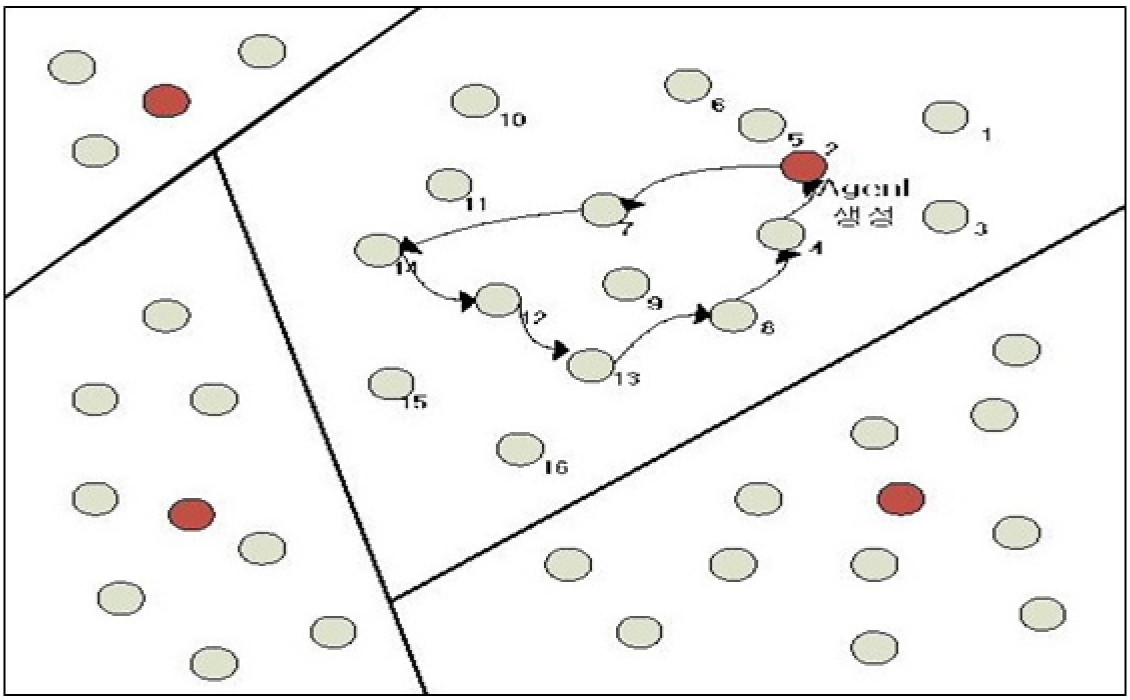

Fig 3. Mobile agent based LEACH architecture

Specific sensor nodes are able to distribute the spending energy to other sensor nodes according to the clustering technology and mobile agent. Moreover, because the mobile agent compares the new data with the existing data, more reliable data is collected by the head node. The sensing data can be filtered by the mobile agent; therefore, more accurate information can be received by the client. However, there is a need for the agent size to be minimized in order to save more energy. Moreover, the redundancy of the sensor networks can be creased by the agent.

This research study proposes a Mobile Data Collector maximum residual energy based clustering routing protocol for MWSN, combining cluster-based hierarchical architecture by utilizing a multi-hop routing approach from cluster heads to the base station through Mobile Data Collector (MDC) for inter-cluster communication. The main characteristics of the proposed protocol are: Cluster formation in MDC maximum residual energy LEACH is randomly distributed; self-configuring, scalable, transfers of data can be managed locally, and adopts MAC protocol for low energy consumption and perform different application data analysis, such as data compression or aggregation. The process of the MDC maximal residual energy LEAHC is allocated in time intervals where two phases form every time period: setup and steady state. Until node implementation, the above time period is calculated, clusters are established in the set-up phase and data transfer from cluster heads to MDC, and then in the steady-state phase to the BS. The MDC moves in a predefined trajectory from every corner of the network from top to bottom and transmits a beacon message for cluster head (CH) and the base station (BS) every 5 sec. When CH receives the beacon message from MDC, CH measures the MDC's energy and selects the MDC's maximum residual energy to transmit the sensed accumulated data to the base station.

The rest of the manuscript is structured as follows: Section 2 describes the problem statement of LEACH and Hybrid Multi-hop LEACH, section 3 present the proposed A Three-Tier Cluster-based Routing Protocol for Mobile Wireless Sensor Networks, section 4 describes the results and discussions and lastly the conclusion and future works are presented in section 5.

2 Problem statement of LEACH and hybrid multi-hop LEACH

Since LEACH and Hybrid Multi-hop LEACH are identified as the basic preliminary sources of this research work in the literature review, this section covers the detailed examination of the design rules of these protocols.

2.1 Energy dissipation in LEACH

The main disadvantage of the LEACH routing protocol is to forward the combined and compressed data directly from all cluster heads (CHs) to the base station, in this case, most of the CHs are very far away from the base station and some are nearer to it, as all the sensor nodes are pervasive in a huge area. In terms of connectivity energy depletion, this has become a major impact amongst the cluster heads to the base station. Dual different kinds of energy-depleting radio communication include transmitting amplifier energy and transmitter/receiver electronics. Generally, amplifier energy is necessary for effective communication and is far greater than electronic transceiver energy which limits the energy depletion of communication.

The amplifier's minimal critical energy is closely associated with doubling the distance from the source to the target destination (E_{Tx-amp} / d^2), providing advice in the free space model, so the energy depletion of communication increases significantly when the communication distance increases.

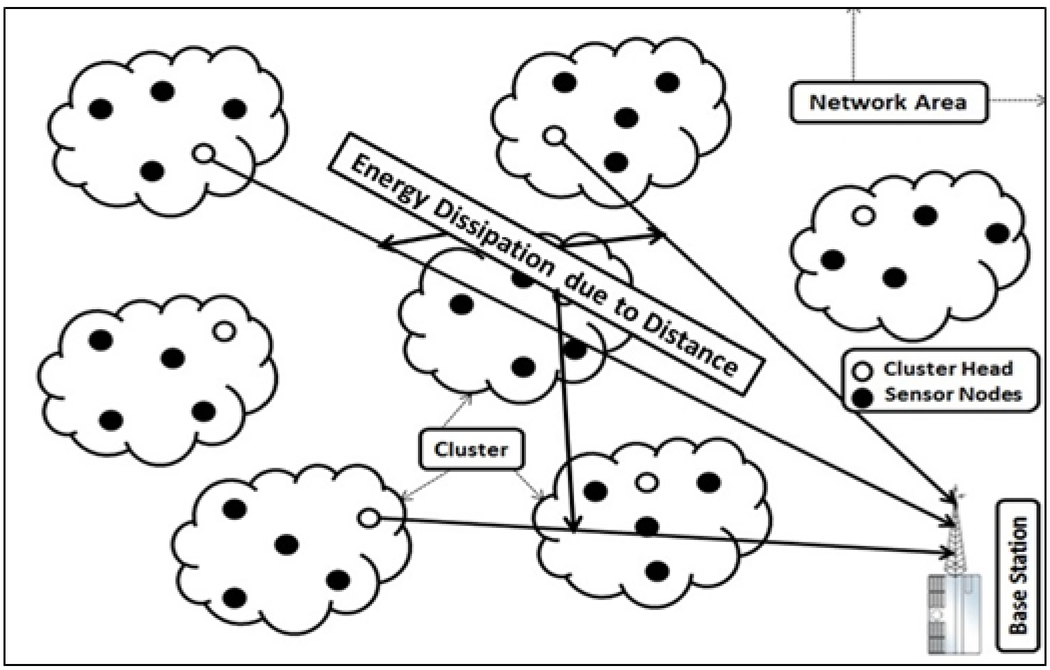

Fig 4. Energy dissipation in LEACH protocol

This proves that the faraway cluster head has gained much extra energy to transmit the data to the base station than the other cluster head near the base station. The significance variance arises in energy consumption amongst the sensor nodes those which are near and far the base station after successful rounds. In the LEACH protocol, all sensor nodes begin with the same level of energy, the faraway nodes use the energy before any of these nearer to the base station, thus reducing the total impact of the network performance and network also divided into two sections by live and dead nodes as illustrated in [Figure 4].

2.2 Communication holes in hybrid multi-hop LEACH

The entire network of Hybrid multi-hop LEACH protocol is dispersed into limited sections that are recognized as cluster and one node is chosen as a cluster head in every cluster involved in collecting and transferring collected data from its member nodes of the cluster to the next cluster head or direct base station. The disadvantage of this multi-hop routing protocol is facing routing and energy hole issues as cluster head near the base station transmitting heavy traffic load from other cluster heads in each round and relaying cluster head is dying due to energy depletion in the current round. This issue occurs another time in each round, as the topology of the network varies due to the mobility of sensor nodes and cluster heads in each round is distinct from the round before, so the ultimate result is the network lifespan of this multi-hop routing protocol does not last long and data stability at the base station is not adequate.

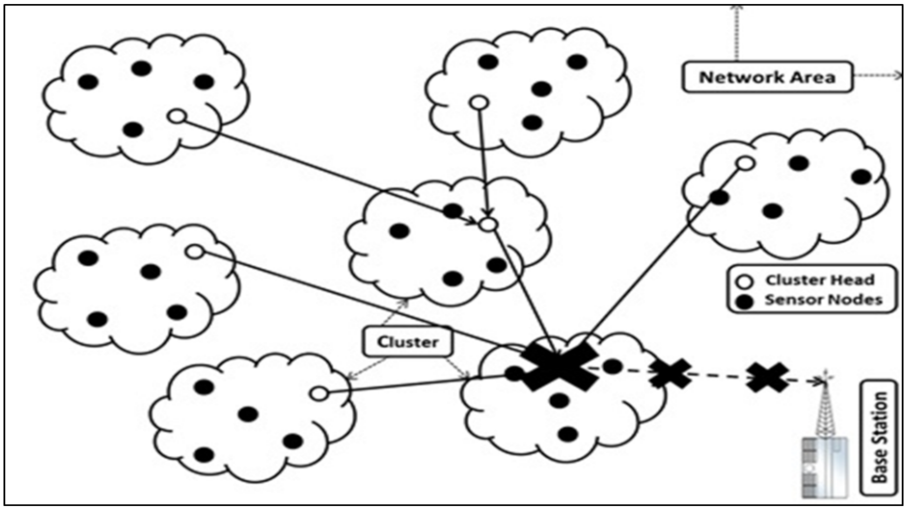

Fig 5. Communication holes problems in hybrid multi-hop LEACH protocol

Based on the energy hole issue in the LEACH protocol Hybrid Multi-hop, which has a significant effect on the routing process of the network. The routing direction from the cluster head to the base station seems to be no longer usable due to high data transmissions from other CH's and the energy is depleted instantaneously; this impact constantly reduces sensed and useful data as the final destination of the route is broken down as illustrated in [Figure 5]. The cumulative result is the number of nodes that are chosen as a cluster head in every round will die due to the issue of energy and routing hole, so the network is not able to survive for a prolonged period.

3 A three-tier cluster-based routing protocol for mobile wireless sensor networks

This protocol uses three-tier network architecture and multi-hop routing communication for the accumulation and transmitting data from the sensor node to the base station. [Figure 6] illustrated the topological structure of the MDC maximum residual energy LEACH routing protocol.

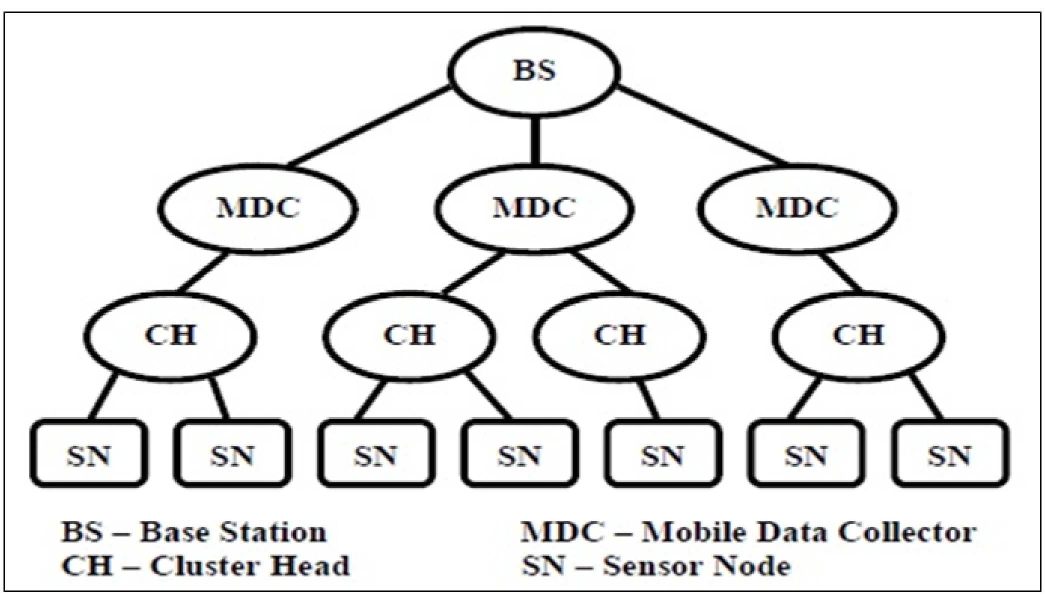

Fig 6. Topological hierarchy of proposed protocol

This style of architecture was observed to increase the scalability of networks and best design solutions for environmental applications. The communication in Multi-hop routing is used to minimize the conflict of the channel area and provide potential energy savings from source to destination through long and multi-hop communication.

3.1 Data-transmission energy model

A lot of work has been conducted in recent years in terms of low-energy radio propagation models. The LEACH maximum residual energy routing protocol based on MDC uses a simple First Order Radio Model where the transmitter and receiver dissipate E_{elec} 50 nj / bit and a transmitter amplifier circuit at ε_{amp} 100 pj / bit / m^2 in order to achieve an acceptable E_b / N_o. The new state-of-the-art radio model, First Order Radio Model's metrics are slightly higher than the other data transmission models. Table 1 has the parameters of the data-transmission energy model.

Suppose r^2 is the energy loss inside a channel transmission, the transmission end measurements are in both equations i.e. 1 and 2 when transmitting a k-bit message at a distance of d by means of the radio model, the transmission end calculations are in equation 1 and 2:

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

$$E_{Tx}\,(k,d) = E_{elec} * k + \varepsilon_{amp} * k * d^2 \tag{1}$$

And the receiving end calculations are:

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

$$E_{Rx}\,(k) = E_{elec} * k \tag{2}$$

Table 1. Parameters of the data-transmission energy model

Name	Parameter Description
E_{elec}	Constant energy consumption of transmitter and receiver electronics
ε_{amp}	Constant energy usage for a transmitter
k	Number of Bits per packet
d	Total Transmission Distance
r	Radius of communication
E_{Tx} (k,d)	Total energy consumed as a k bit packet is transmitted
E_{Rx} (k)	Total energy consumption to receive the packet k bit

3.2 Communication in inter and intra cluster

The end-to-end data transmission method of the MDC maximum residual energy routing protocol is split into multiple rounds, after every round followed by a set-up round and a steady round for cluster forming and data transmission, from the sensor nodes to MDC and eventually to the base station respectively. [Figure 7] illustrate the operation timeline of the MDC maximum residual energy routing protocol.

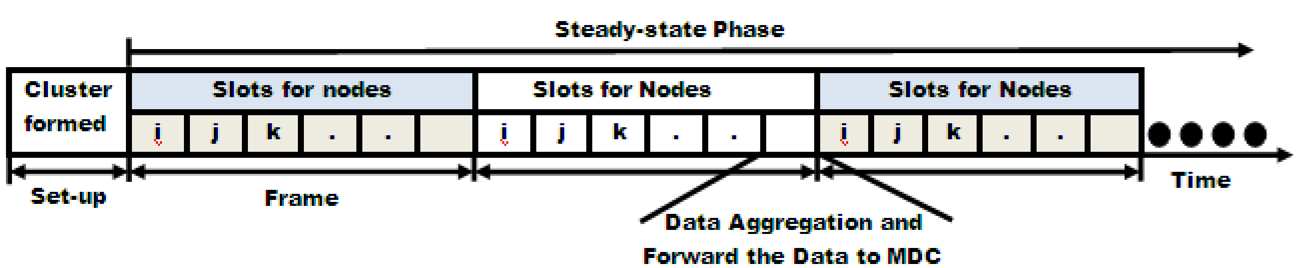

Fig 7. Communication operation timeline

3.3 Set-up phase and cluster head selection

All nodes are autonomous and grouped into clusters via simple messages using the Carrier Sense Multiple Access (CSMA) protocol during the cluster forming phase. Each node of the network must decide to become a cluster head or not with the likelihood of Pi, Pi is calculated according to the LEACH algorithm as illustrated in equation 3.

$$P_i(t) = \begin{cases} \dfrac{k}{N - k \cdot \left(rmo\, d \dfrac{N}{k} \right)} \\ 0 \end{cases} \tag{3}$$

Every node uses this formula at the beginning of the setup phase to calculate the Pi probability. This equation implies that the predicted number of CH is k for each round; this means that the entire network is divided into k clusters and N is the number of nodes in total. After N/k rounds on average, every node has been chosen as a CH once, and r indicates the round number.

For the current round, those nodes classified as CH do not qualify as CHs for the next round. All CHs in the network transmitted a brief broadcast message over the CSMA protocol for all nodes; this message includes the address of the CH node. After time t_1, the nodes receive multiple transmitted notifications from different CHs, and then a member node agrees on the closest CH based on the received signal intensity of the packet announcement and selects the nearest CH with the smallest distance.

3.4 Steady phase using by mobile data collector

CH determines the Time Division Multiple Access (TDMA) schedule for each node to transmit data to CH following the cluster creation. This plan is designed to prevent collisions and minimize energy usage between the cluster's data messages to allow each part of the radio equipment to be off while not in operation. To reduce inter-cluster interference, each cluster uses a unique spreading code, selecting that unique code while the node is chosen as a CH and informing all member nodes inside the cluster for data transmission using the spreading code assigned to it.

Once a CH has collected enough data from its cluster members, after positive transmission, it will update the spreading unique code for MDC, after successful collection of data, it finally returns to collect sensed data messages from its members again. All CHs send messages over the network via another delegated spreading code during communication from the cluster head to MDCs and CSMA/CA is used as a MAC layer protocol to prevent potential collisions between them. Upon receiving the data from any CH, MDCs must route the data directly and instantly to the base station using the MDC maximum residual energy LEACH routing protocol.

3.5 Characteristics of mobile data collector

Current routing protocols depend on a static configuration within the network of sensors and base stations. Certain areas of the network can become disconnected from its path to the sink; otherwise, the node may fail or travel beyond the full transmitting distance and static nodes cannot sense the data from sharp corners of the region of the network. Implementation within the network of mobile nodes and mobile data collectors is the feasible option for tracking or sensing data from the whole network and efficiently capturing it at the base station.

Besides the coverage area, another big problem impacting Wireless Sensor Networks (WSNs) lifespan comes from unbalanced energy usage across various areas of the network. This unbalanced use of energy is a direct consequence of providing a stationary sink: nodes close the sink are intensively used for relaying data to the sink by other nodes. A logical approach to such a problem is to have several mobile sink nodes (which we call data collectors) and to regularly adjust their positions such that the load is equally spread among all sensor nodes. The author argues in this study for the use of multiple mobile data collectors and proposes a scheme to place these data collectors in a way that balances energy expenditure and increases the network's lifetime. Using the probability density function, the node movement model may be a random movement sequence, and the mobile data collector uses a predefined trajectory to transmit the data to the base station. Mobile Data Collector may implement the closest to the sink as a reduction in traffic load at the cluster head, and knowledge of MDC location status is needed to successfully modify the behavior of the cluster heads routing protocol.

In [24], the authors found that up to 90 percent of the network's overall capacity can be lost when the whole network is prematurely destroyed. The cluster of similar size and multi-hop routing is the key cause of the energy hole problem, this can be overcome by using a mobile sink to collect data. If a single mobile sink is used to collect data, it has to traverse a whole distribution area that is not possible for large-scale WSN, meaning that many mobile sinks are used to gather energy-efficient data. The authors in [16] suggested the concept of using multiple mobile elements rather than one or a static drain, where multiple mobile elements are used to gather data when traveling on preset paths. Mobile elements should remain set for gathering data from sensor nodes at some stages. Another energy-efficient data collection with multiple mobile sinks using an artificial bee colony algorithm in large-scale WSN was proposed in [3]. The option of the cluster head is dependent upon the node's residual energy. This research focused on a large-scale and complex WSN that allows for a certain level of data latency by analyzing the mobile sink compromise from three components: maximizing data processing, reducing the length of the signal route, and optimizing network efficiency.

According to literature, the mobile sink or data collector is equipped with an unlimited energy source, a powerful CPU with large memory, a long-range transceiver, and a GPS device. Mobile Data collectors are not energy-constrained, as they can be recharged easily. The proposed MDC maximum residual energy LEACH protocol randomly selects the 30j MDC battery value which is more than enough for 1800 seconds of simulation period and supposed to be MDC rechargeable easily by the external source.

3.6 Maximum residual energy (RE of MDC)

Both MDCs relay a beacon message for all CHs in the data collection system toward the base station that includes their present position and residual level of energy. Once CH receives the beacon message from MDC, then CH checks the energy of the MDC and chooses that MDC who have maximum residual energy to transfer the data towards the base station in each round.

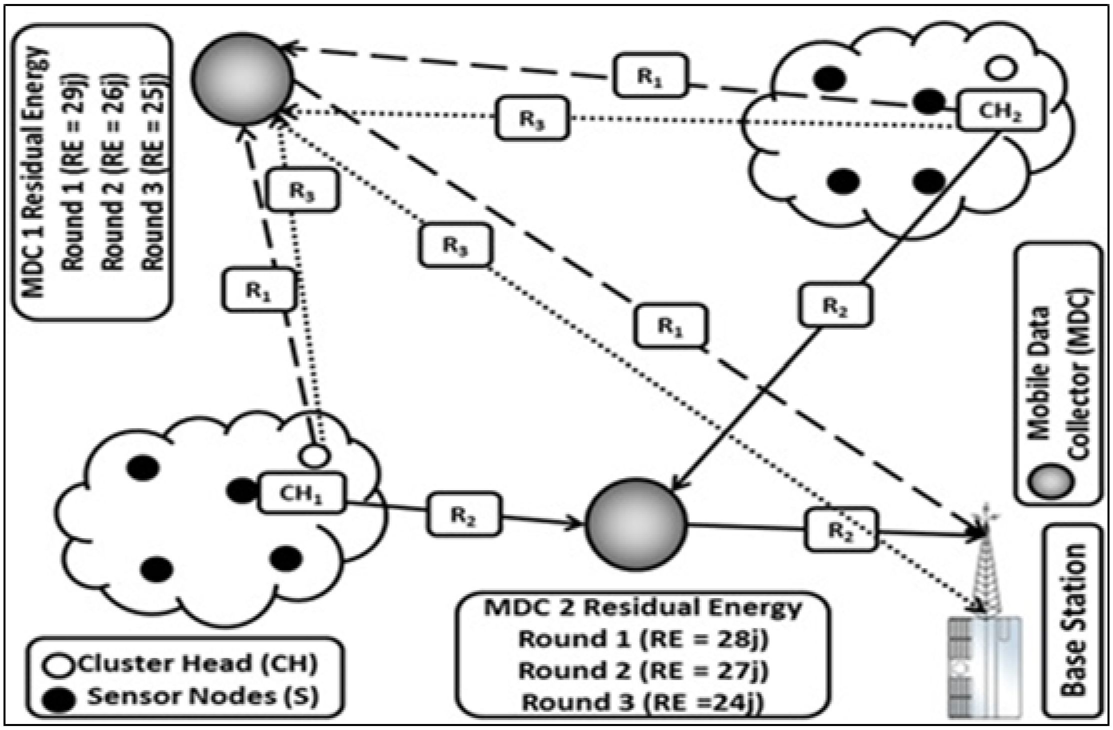

Fig 8. MDC maximum residual energy LEACH routing protocol

[Figure 8] illustrates the detailed data gathering mechanism by the approach of the maximum residual energy of MDC, in the existing round, the cluster head CH_1 and CH_2 receive the residual energy level from MDC 1 and MDC 2 that is 29j and 28j, respectively. Cluster head CH_1 and CH_2 select MDC 1 for transferring the collected data because the residual energy level of MDC 1 is higher than MDC 2. In the upcoming round, all the cluster heads once more receive residual energy information along with the MDC's current location by the beacon short message from a number of MDCs. At this round, the RE level of MDC 2 is 27j and MDC 1 is 26j, every cluster head selects MDC 2 as a relay node for transferring the data towards the base station. MDC 1 again selected as a relay agent towards the base station for data transmission in the subsequent round of the network because the RE levels of MDC 1 are 25j and MDC 2 is 24j in this round respectively. Table 2 illustrates the selection of the routing paths of every round.

Table 2. Selection of routing paths

Rounds	Available Routes	MDC's Residual Energy	Selected Route
R_1	MDC-1 and MDC-2 – Base Station	MDC-1 29j MDC-2 28j	CH_1 and CH_2 –> MDC 1 –> Base Station
R_2	MDC-1 and MDC-2 – Base Station	MDC-1 26j MDC-2 27j	CH_1 and CH_2 –> MDC 2 –> Base Station
R_3	MDC-1 and MDC-2 – Base Station	MDC-1 25j MDC-2 24j	CH_1 and CH_2 –> MDC 1 –> Base Station

The same protocol will be followed for data gathering inside the network at the base station until the residual energy of the sensor nodes and MDCs is available. This method explicitly preserves the energy level of the relay node that is MDC all over the network until the sensor nodes and MDCs are alive.

4 Results and Discussion

Table 3 illustrates the simulation's network parameters. LEACH, Hybrid multi-hop LEACH, and MDC maximum residual energy LEACH protocol simulation parameters are based on WSNs environmental applications. Measured performance metrics are the energy consumption of each sensor node, the lifetime of the network, the traffic received at the base station, the Packet Loss Ratio, the Channel Access Delay, and the End-to-End Delay.

Table 3. Simulation parameters

PARAMETRES	VALUES
For Sensor Node	
Number of Nodes	Forty (40
Number of Cluster Head	Five (5)
Sensor Node Deployment	Random Deployment
Simulation Area	1000 * 1000 (m)
Node Ground Speed	0.5 m/sec
Battery	Constant Initial capacity (5j)
For Network	
Transmitter Electronics ($E_{TX-elec}$) Receiver Electronics ($E_{RX-elec}$)	50 nj/bit
Transmit Amplifier (ε_{amp})	100 pj/bit/m^2
Packet size	288 bits/packet or 36 Bytes
Data Rate	250 kbps
Traffic Model	CBR traffic for periodic data generation
For Mobile Data Collector	
Number of MDC's	2
MDC Velocity	0.054 m/sec
MDC Battery	30j (Rechargeable)
MDC Beacon Message Rate	5 sec/message
Round time	30 sec

4.1 Simulation tool

Many simulation tools such as NS2, QualNet, Matlab, OMNeT++, and OPNET are using to simulate the WSNs environment. OPNET simulator is selected to simulate the proposed MDC maximum residual energy LEACH routing protocol. OPNET offers an interactive framework for distributed systems architecture and communication network design. Discrete representations of events are tested for the behavior and efficiency of modeled processes. OPNET offers graphical editors and a scalable, high-level, C / C++-based programming language for a development framework. Throughout this way, users can build comprehensive design models. In addition to some built-in application statistics, which are automatically obtained during simulation, users can also specify new application statistics which are calculated by the user-defined procedure. OPNET also offers a range of integrated post-simulation research tools; provides excellent features including data retrieval simulation and performance assessment.

4.2 Energy consumption of sensor nodes and network lifetime

Energy consumption in mobile and static WSN is the most noteworthy metrics, given that sensor nodes have limited battery power. A sensor node's energy consumption is equivalent to the total of dissipated energy in the states of sense, sleep, idle, overhearing, transmitting, and receiving. The emphasis of this research is on energy depletion during communication in both transmission and receiving. In addition, the energy dissipation of sensor nodes has a direct effect on network efficiency or network lifetime, more energy dissipation has less network lifetime and a smaller volume of energy dissipation has longer network lifetime.

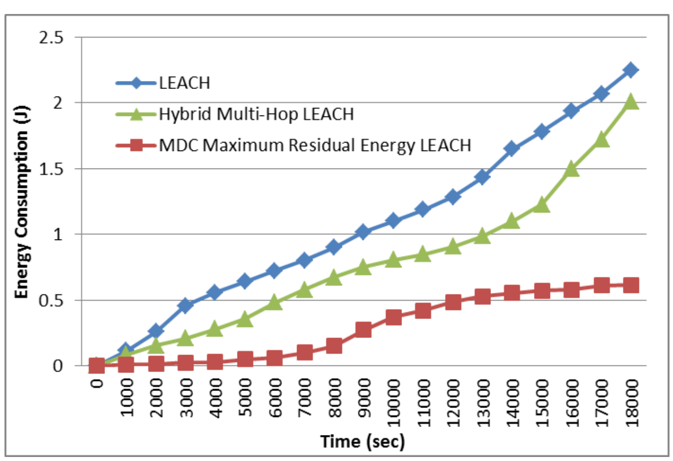

Fig 9. Energy consumption of node 19

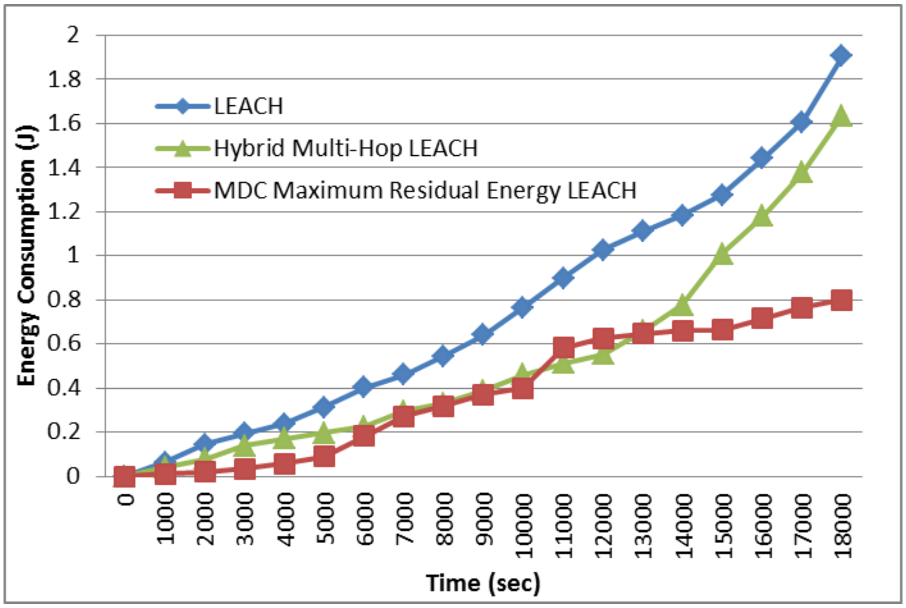

Fig 10. Energy consumption of node 25

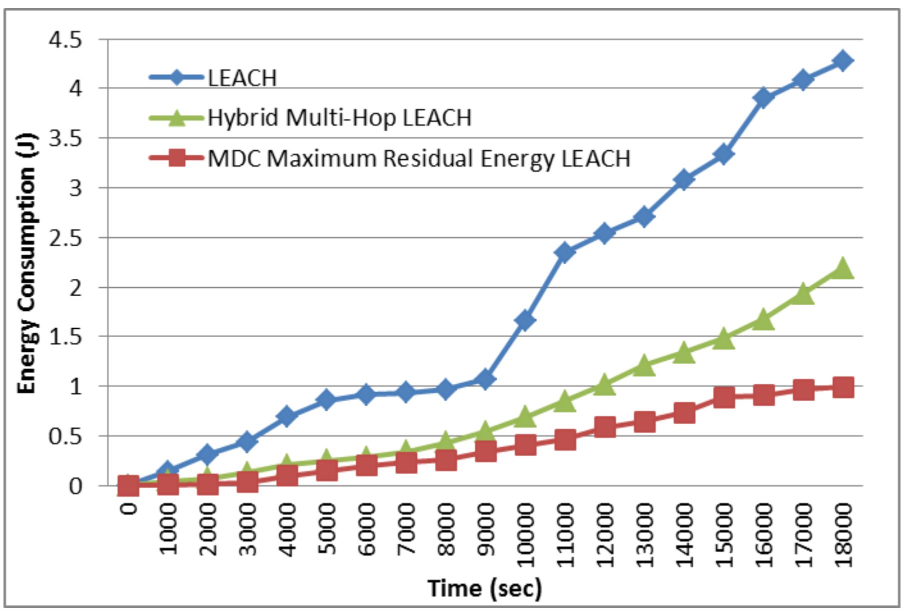

Fig 11. Energy consumption of node 36

The results of [Figures 9, 10 and 11] illustrate the consumed energy of the sensor nodes after numerous simulations run over LEACH, Hybrid Multi-hop LEACH, and the MDC maximum residual energy LEACH routing protocols. In the LEACH and Hybrid Multi-hop LEACH routing protocols, the energy utilization of node 19 is consumed 2.3j and 2.0j respectively, but in the MDC maximum residual energy LEACH routing protocol consumed just 0.6j after 5 hours simulation. Conversely, the energy utilization of nodes 25 and 36 in LEACH protocols is 1.9j and 4.3j, the energy consumption of nodes 25 and 36 in Hybrid Multi-hop LEACH is 1.6j and 2.1j, while MDC 's cumulative residual energy LEACH routing protocol absorbs 0.8j and 1.0j in nodes 25 and 36 after 5 hours simulation. The energy usage of the sensor nodes in the network according to these graphs is substantially different which directly affects the network lifetime and performance of the network.

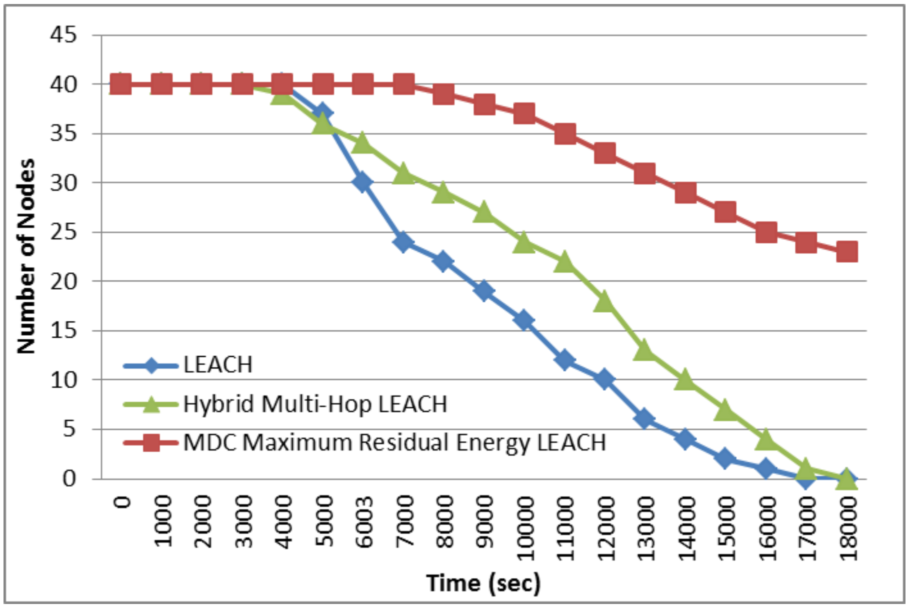

Fig 12. Network lifetime

The simulated results of [Figure 12] illustrate the considerable variation in the overall lifetime of the network. The MDC maximum residual energy LEACH routing protocol is, therefore, better than the single-hop LEACH and Hybrid Multi-hop LEACH routing protocols in terms of the lifespan of the network, as it remains operational as an entire, extended and declines somewhat lower.

4.3 Traffic received and packet loss ratio

The traffic received can be given as the received packets at the base station relative to the number of packets sent through all intermediate nodes. Received traffic is a significant parameter as it defines the performance of the routing protocol as well as the ability of the protocol to manage topological variations and faults within the networks.

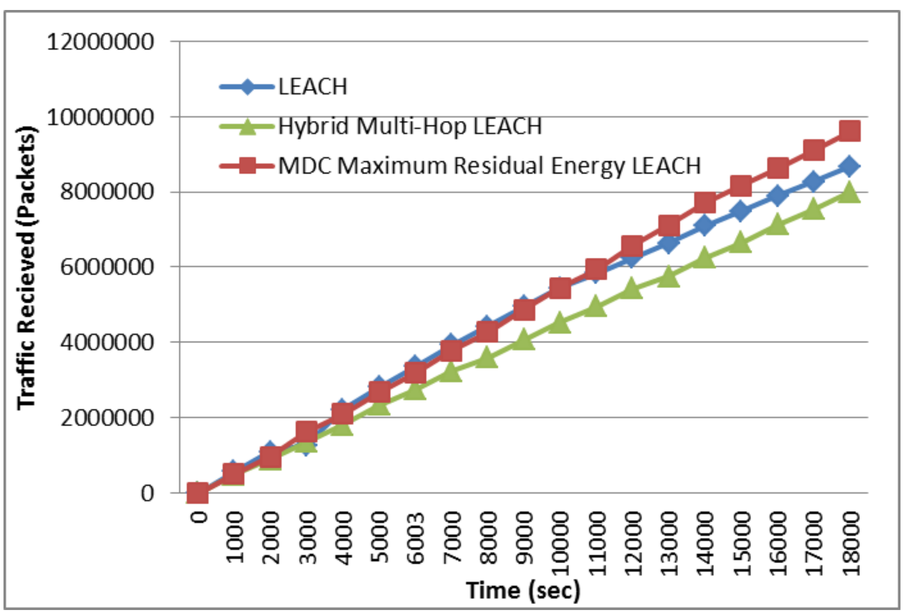

Fig 13. Traffic received

The packet loss ratio can be calculated as the proportion of the traffic received at the base station to the number of traffic sent from all source nodes. Packet loss ratio is an important statistic as it defines the routing protocol's message efficiency as well as the capacity of the protocol to manage topological shifts and errors within the networks.

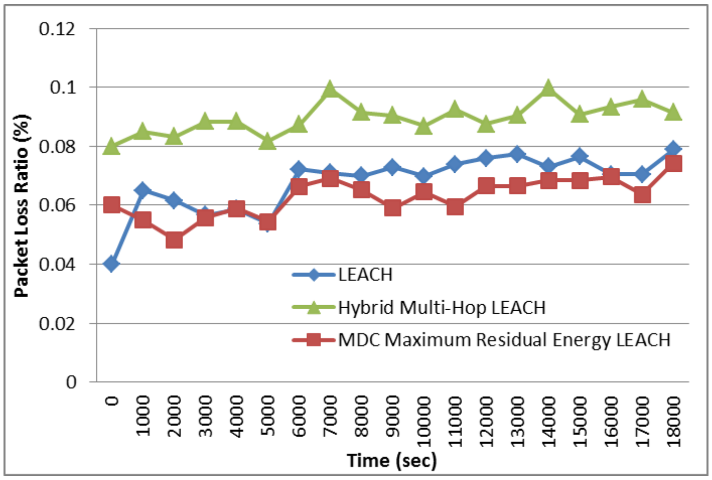

Fig 14. Packet loss ratio

Traffic received at the base station in MDC maximum residual energy LEACH routing protocol is 5-20 percent higher than LEACH and Hybrid multi-hop LEACH routing protocols because the sensor nodes in MDC maximum residual energy LEACH remain long to live and produce more data packets. MDC maximum residual energy LEACH has a smaller amount of packet loss ratio than LEACH and Hybrid multi-hop LEACH because it keeps away from the bad radio communication, packet collision, congestion, network node failures, and full memory capacity. [Figures 13 and 14] illustrates the traffic received and packet loss ratio in LEACH, Hybrid multi-hop LEACH, and MDC maximum residual energy LEACH routing protocols overtime at the base station.

4.4 Channel access and end-to-end delay

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 the MDC maximum residual energy LEACH routing protocol is slightly higher than the LEACH and Hybrid multi-hop LEACH routing protocols due to increased traffic load between sensor nodes to the base station by applying mobile data collector that is based on multi-hop routing strategy. The network latency's key metric is the End-to-End delay; it is characterized as data packet time latency, channel access delays from source to destination. [Figures 15 and 16] illustrate the channel access delay and End-to-End delay respectively over time using the LEACH, Hybrid multi-hop LEACH, and MDC maximum energy LEACH routing protocols.

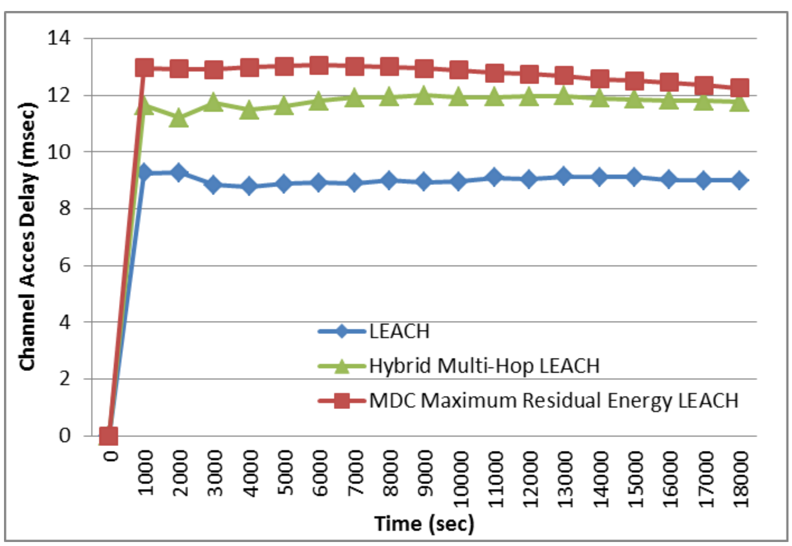

Fig 15. Channel access delay

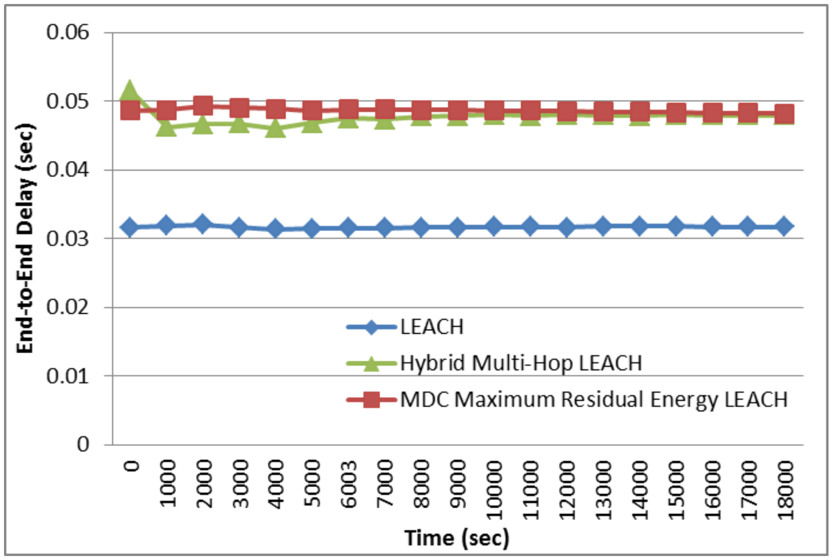

Fig 16. End-to-End delay

The End-to-End delay of the MDC maximum residual energy LEACH and Hybrid multi-hop LEACH routing protocol is higher than the LEACH routing protocol due to the aggregated data packets in the MDC based LEACH taking multi-hops to reach the base station which is nearly the same as with the channel access delay.

5 Conclusion and Future Work

To manage failures as well as topological changes (node mobility) within the network, the routing protocol is required, without using too much energy in the network as a whole to accommodate the changing network architecture. The design of a routing protocol based on MDC included a detailed understanding of the routing concepts of WSNs and the fundamental contributions to the field. Literature proves that a routing protocol contributes to the energy efficiency and data reliability of WSNs by limiting the number of message transmissions. This study addresses the considerable comparison in the single and multi-hop routing protocols for the cluster-based LEACH protocol. According to, comparison of the MDC maximum residual energy LEACH routing protocol gives better accuracy results than the LEACH and Hybrid Multi-hop LEACH routing protocols in terms of the energy consumption of the sensor nodes, improving the lifespan of the network, increased traffic received, less packet loss ratio and the trade-off with channel access and end-to-end delays. Possible future research areas and topics may include:

- Investigation of other mobility models such as random walk, random waypoint, and circular models with variable speed for mobile data collector movement based on specific applications in an attempt to verify the design of MDC maximum residual energy LEACH routing protocol.
- Current implementation of MDC maximum residual energy LEACH is based on the allocation of single channels at base station. By multi-channel definition at the base station, MDC maximal residual energy LEACH can strengthen and verify to directly distribute the channel to MDC's instead of a single channel.
- MDC maximum residual energy LEACH ensures the critical messages are transmitted successfully. In the routing layer, more research may provide information to connect important messages with corresponding ACK messages by means of a "conversation key." In this case, it may be the responsibility of the routing protocol to retransmit failed transmissions and dynamically discarded failed transmission links to future use.
- Develop and verify the MDC maximum residual energy LEACH routing protocol in future work by choosing another strategy at the physical layer by log-normal shadowing propagation model. Future work also includes implementing the system in a real environment, which will enable us to evaluate the practicality of the system and propose corrective measures to the proposed algorithm, particularly about the mobility aspect, which is a challenging problem, especially in rough terrain environments.

References

1) Sumathi J, Velusamy RL. A review on distributed cluster based routing approaches in mobile wireless sensor networks. *Journal of Ambient Intelligence and Humanized Computing*. 2020. Available from: https://dx.doi.org/10.1007/s12652-020-02088-7.
2) Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. A survey on sensor networks. *IEEE Communications Magazine*. 2002;40(8):102–114. Available from: https://dx.doi.org/10.1109/mcom.2002.1024422.

3) Vijayashree R, Dhas CSG. Energy efficient data collection with multiple mobile sink using artificial bee colony algorithm in large-scale WSN. *Automatika*. 2019;60(5):555–563. Available from: https://dx.doi.org/10.1080/00051144.2019.1666548.
4) Yue Y, Li J, Fan H, Qin Q. Optimization-Based Artificial Bee Colony Algorithm for Data Collection in Large-Scale Mobile Wireless Sensor Networks. *Journal of Sensors*. 2016;2016:1–12. Available from: https://dx.doi.org/10.1155/2016/7057490.
5) Fissaoui ME, Beni-Hssane A, Saadi M. Energy efficient and fault tolerant distributed algorithm for data aggregation in wireless sensor networks. *Journal of Ambient Intelligence and Humanized Computing*. 2019;10(2):569–578. Available from: https://dx.doi.org/10.1007/s12652-018-0704-8.
6) Sujeethnanda M, Kumar S, Ramamurthy G. Mobile wireless sensor networks: a cognitive approach. 2013;p. 491–518. Available from: https://doi.org/10.1201/b15425.
7) Siddiqui AF, Jibran R, Saeed M, Arshad M, Touheed N. Mobile Data Collector Routing Protocol Scheme for Scalable Dense Wireless Sensor Network to Optimize Node's Life. *International Journal of Advanced Computer Science and Applications*. 2018. Available from: https://dx.doi.org/10.14569/ijacsa.2018.090967.
8) Arshad M, Aalsalem MY, Farhan A, Siddqui. Energy Efficient Cluster Head Selection in Mobile Wireless Sensor Networks. *Journal of Engineering Science and Technology (JESTEC)*. 2014;9(6):728–746. Available from: http://jestec.taylors.edu.my/Vol%209%20Issue%206%20December%2014/Volume%20(9)%20Issue%20(6)%20728-746.pdf.
9) Farhan A, Siddiqui M, Saeed JR, Khan M, Arshad N, Touheed. WSN Multi-Tier MDC GRID based Routing Protocol to mitigate Financial Impact. *International Journal of Computer Science and Network Security (IJCSNS)*. 2017;17(11):20–27.
10) Gajbhiye P, Mahajan A. A survey of architecture and node deployment in Wireless Sensor Network. In: and others, editor. First International Conference on the Applications of Digital Information and Web Technologies (ICADIWT), Ostrava. 2008;p. 426–430. Available from: https://doi.org/10.1109/ICADIWT.2008.4664386.
11) Chen X, Yu P. Research on hierarchical mobile wireless sensor network architecture with mobile sensor nodes. In: 3rd International Conference on Biomedical Engineering and Informatics. 2010;p. 2863–2867. Available from: https://doi.org/10.1109/BMEI.2010.5639549.
12) Dhand G, Tyagi SS. Data Aggregation Techniques in WSN:Survey. *Procedia Computer Science*. 2016;92:378–384. Available from: https://dx.doi.org/10.1016/j.procs.2016.07.393.
13) Hadi K. Analysis of exploiting geographic routing for data aggregation in wireless sensor networks. *Procedia Computer Science*. 2019;151:439–446. Available from: https://doi.org/10.1016/j.procs.2019.04.060.
14) Munir SA, Ren B, Jiao W, Wang B, Xie D, Ma J. Mobile Wireless Sensor Network: Architecture and Enabling Technologies for Ubiquitous Computing. In: 21st International Conference on Advanced Information Networking and Applications Workshops (AINAW'07). 2007;p. 113–120. Available from: https://doi.org/10.1109/AINAW.2007.257.
15) Khalifeh A, Abid H, Darabkh KA. Optimal Cluster Head Positioning Algorithm for Wireless Sensor Networks. *Sensors*. 2020;20(13):3719–3719. Available from: https://dx.doi.org/10.3390/s20133719. doi:10.3390/s20133719.
16) Priyadarshi R, Rawat P, Nath V, Acharya B, Shylashree N. Three level heterogeneous clustering protocol for wireless sensor network. *Microsystem Technologies*;2020. Available from: https://doi.org/10.1007/s00542-020-04874-x.
17) Shukla A, Tripathi S. A multi-tier based clustering framework for scalable and energy efficient WSN-assisted IoT network. *Wireless Networks*. 2020;26(5):3471–3493. Available from: https://dx.doi.org/10.1007/s11276-020-02277-4.
18) Jain JK. A Coherent Approach for Dynamic Cluster-Based Routing and Coverage Hole Detection and Recovery in Bi-layered WSN-IoT. *Wireless Personal Communications*. 2020. Available from: https://doi.org/10.1007/s11277-020-07377-0.
19) Heinzelman WR, Chandrakasan A, Balakrishnan H. Energy-efficient communication protocol for wireless microsensor networks. In: Proceedings of the 33rd Annual Hawaii International Conference on System Sciences;vol. 10 of 2. 2000. Available from: https://doi.org/10.1109/HICSS.2000.926982.
20) Zhao J, Erdogan AT, Arslan T. A novel application specific network protocol for wireless sensor networks. In: IEEE International Symposium on Circuits and Systems. 2005;p. 5894–5897. Available from: https://doi.org/10.1109/ISCAS.2005.1465980.
21) Ettus M. System capacity, latency, and power consumption in multihop-routed SS-CDMA wireless networks. In: Proceedings of IEEE Radio and Wireless Conference. 1998. Available from: https://doi.org/10.1109/RAWCON.1998.709135.
22) Shepard TJ. A channel access scheme for large dense packet radio networks. In: ACM SIGCOMM Computer Communication Review;vol. 26. Association for Computing Machinery (ACM). 1996;p. 219–230. Available from: https://dx.doi.org/10.1145/248157.248176.
23) Hee-Jin J, Choon-Sung N, Yi-Seok J, Dong-Ryeol S. A Mobile Agent Based LEACH in Wireless Sensor Networks. In: Proceeding of 10th International Conference on Advanced Communication Technology. 2008;p. 75–78. Available from: https://doi.org/10.1109/ICACT.2008.4493715.
24) Gharaei N, Bakar KA, Hashim SM, Pourasl AH, Siraj M, Darwish T. An Energy-Efficient Mobile Sink-Based Unequal Clustering Mechanism for WSNs. *Sensors*. 2017;17:1858–1858. Available from: https://dx.doi.org/10.3390/s17081858.