Performance Analysis and Evaluation of a Multi-Hop Routing Protocol for Wireless Multimedia Sensor Networks

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ABSTRACT

Researchers in wireless multimedia sensor networks (WMSNs) are constantly interested in designing and developing energy-efficient routing protocols. Numerous clustering routing protocols have been developed in recent years to overcome the limitation of consuming less energy and prolong the lifetime of sensor nodes in homogeneous and heterogeneous WMSNs. Existing approaches depend on single-hope communication, in which sensor nodes consume more energy and die faster. Inter-communication nodes can play an important role in reducing energy by transmitting data in a multi-hope fashion to the sink. An energy-efficient multi-path clustering with load balancing routing protocol for wireless multimedia sensor networks (EEMCL) is proposed in this study. In this protocol, the main cluster heads (MCHs) are preselected in each network cluster and filled with more energy than normal sensor nodes. The two secondary cluster heads (SCHs) with the highest energy nodes will be selected by the main cluster head algorithm. Moreover, inter-cluster multi-hop routing with the help of MCHs can enhance the network lifetime when the sink is located at the corner of the sensing field. The simulation results verify that the proposed multi-hop technique provides better performance than existing LEACH, LEACH-C, SEEN, and IEE-LEACH routing protocols in scenario 1 and when compared with CPMA in scenario 2. The last node dead (LND) for the proposed protocol is at round 5721, 2225 for LEACH, 2300 for LEACH-C, 2900 for SEEN, and 3160 for IEE−LEACH in scenario 1, while in scenario 2, the LND for the proposed protocol is at round 3820 and 435 for the CPMA routing protocol.

Keywords: Wireless Multimedia Sensor Networks, Clustering, Energy-Efficient, Multi-Path Routing Protocol, Network Instability, Load Balancing

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1. INTRODUCTION

A wireless sensor network is proposed in this study consisting of numerous sensor nodes and a sink. These nodes are small, with limited energy, memory, and processing capabilities. A sensor node is composed of four main units: a power supply unit, processing unit, communication unit, and sensing unit. Optional equipment, including a mobility module or GPS location module, may also be supplied. Fig. 1 shows the basic sensor node architecture [1]. Due to advancements in microelectronics and wireless technology, as well as the development of low CMOS microphones and cameras, promising new wireless multimedia sensor networks (WMSNs) have been developed in recent years.

The availability of affordable equipment capable of detecting multimedia content from the physical environment, such as CMOS cameras and microphones, has promoted the advancement of WMSN to capture audio and video streams, still images, and scalar sensor data. WMSNs help to facilitate new applications for improving health, multimedia monitoring, traffic avoidance, and industrial process management. They also enhance current sensor network applications like monitoring home automation and environmental tracking [2].

In [3], the authors discuss the different features of WSNs and WMSNs. Many WMSN multimedia applications require the development of efficient protocols for transmitting multimedia to meet distinct QoS requirements. Multimedia data consumes more energy, quickly depleting batteries and making the node unusable, even in applications requiring relatively low detection. Every source sensor will transmit its data through the shortest path to the sink through single-path routing. A single-path node failure breaks demands by initiating a new path discovery operation to increase energy consumption. Node breakdown leads packets to be dropped and may result in a delay in delivering data to the sink in time, hence failing to meet the real-time needs of multimedia applications.

Alternative methodologies for decreasing the effects of node loss on performance are desired. Since multimedia data demands a high bandwidth and latency, multipath routing must be established for transmission. The alternative multi-path routing protocol can improve network throughput, working efficiency, minimize overlap across multi-path, and allow WMSN nodes to consume energy uniformly. Multi-path routing is generally used

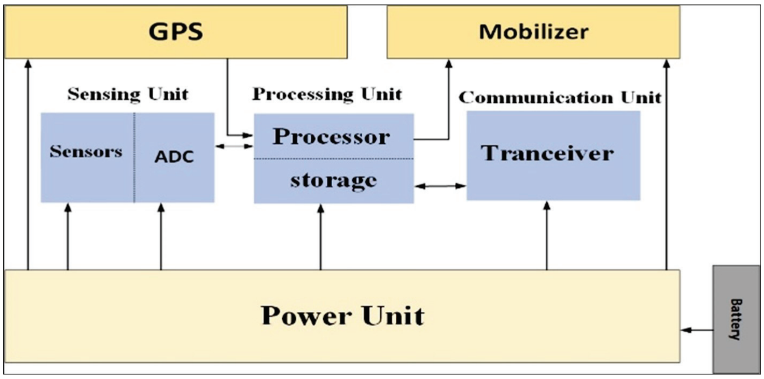


Fig. 1: *The architecture of a typical sensor.*

for load balancing or reliability purposes. Load balancing is performed by balancing energy use throughout the network's nodes, leading to an increase in the lifetime of the network. The lifetime of the sensor node relies on the batteries upon which the network's lifetime depends. The main issue in WSNs is that sensor nodes quickly deplete their energy. The maximum proportion of energy is consumed in the communication substation. As a result, energy-efficient methods need to be developed to prolong and increase the lifetime of sensor nodes [4–6]. It is essential to properly control resources in order to extend the lifetime of WSNs. Network challenges such as lifetime and the geographic coverage of energy efficiency must be taken into consideration while operating with WSNs [7–10].

While communications must be reliable and efficient, the main purpose of developing a routing protocol is to prolong the lifetimes of cluster members and cluster leaders. Energy-efficient clustering methods should consider the following points. Firstly, since it operates better in large-scale WSNs, the proposed algorithm should be distributed [11]. Secondly, cluster leaders should be deployed equally in the sensing field such that all sensor nodes can communicate with cluster leaders uniformly [12]. Thirdly, since cluster leaders and the sink consume the highest amount of energy during communication, it is recommended that this be kept to a minimum [13]. Fourthly, the cluster head selection methodology is inefficient in most hierarchical routing protocols. The total energy used to gather data from the sensor nodes differs between cluster leaders due to the number of members in each. Cluster members consume varied proportions of resources since the distance between cluster members and cluster leaders affects energy consumption. In most conventional WSN routing protocols, it has been discovered that if one problem is addressed, other problems are ignored, leading to a reduction in resource efficiency. To achieve optimum resource efficiency, all the parameters mentioned above should be considered when establishing a routing protocol to prolong the lifetime of the sensor nodes and reduce the energy consumed by sensor nodes.

This research proposes an energy-efficient multi-path clustering with a load balancing routing protocol for wireless multimedia sensor networks (EEMCL). The proposed protocol combines two main approaches: cluster-based routing and multi-path routing, to reduce energy consumption without affecting network performance. The sensor nodes in the network area consisting of normal nodes and the main cluster head are first distributed randomly into clusters, and the main cluster head for each cluster is then preselected with higher energy than normal sensor nodes. In each round, two secondary cluster head nodes (SCHs) are chosen by the main cluster heads based on distance and residual energy to aggregate and compress the data packets from normal nodes to the main cluster head. Finally, intra-cluster multi-path or single-path routing is formed based on distance and residual energy, with multi-path routing based on the remaining energy to send the detected data from the main cluster head to the sink, thereby improving the network lifetime.

The remainder of the paper is organized as follows. In Section 2, the related work is explained. In Section 3, the proposed routing protocol is described in detail. Section 4 shows the performance of the proposed protocol. Finally, Section 5 provides the conclusion.

2. RELATED WORK

Due to the complicated characteristics of WMSNs, several issues need to be resolved by researchers and technologists [14]. In recent years, a number of energy-efficient routing protocols have been suggested. The network is partitioned into multiple clusters in a cluster-based network, and the hierarchy of nodes established. Each cluster is managed by a cluster head (CH). The sensor nodes of each cluster gather data for transmission to the CH. The CH gathers data from sensor nodes in a particular cluster area, aggregates it, and sends it to the sink or the next hop using a predefined protocol.

The low-energy adaptive clustering hierarchy (LEACH) in [15] is a routing protocol that forms the cluster, enabling the energy to be evenly distributed throughout all sensor nodes in the network. Many clusters of sensor nodes are formed in the LEACH protocol, with one node identified as the cluster head and serving as a routing node for the other clusters. As in routing protocols, the cluster head is chosen first before the whole communication process starts, and the communication fails if the cluster head experiences any problems. As the fixed cluster head is trying to perform the routing duties for the whole cluster, the battery is likely to die faster than the other nodes in the cluster.

The LEACH protocol utilizes randomization, and the cluster head is chosen from a group of nodes. Since the cluster head is chosen from a group of nodes on a temporary basis, the protocol lasts longer because the batteries of a single node are not overloaded. The low-energy adaptive clustering hierarchy-centralized (LEACH-C) routing protocol in [16] utilizes the BS to generate clustering. Nodes transmit the level of energy and position information to the BS throughout the clustering process. Based on the energy needed for data transmission from the cluster nodes to cluster heads, the BS partitions the network into a set number of clusters and cluster heads. For data transfer, more energy-efficient clusters are established in LEACH-C. Additionally, the optimum number of cluster heads is estimated. On the other hand, the BS receives overhead.

MODLEACH is a modified variation of the LEACH protocol in [17]. An effective CH replacement mechanism has been established in MODLEACH with the setting of a predefined threshold value. If the existing battery capacity has sufficient energy, then it will operate the CHs in the next round. The CHs remain unchanged until their battery capacity falls below a certain level. Routing updated packets for new CHs saves energy by utilizing the CH selection mechanism known as a stable energy effectual network (SEEN), used in [18] as a hierarchical routing protocol for clustered networks with three energy levels of sensor nodes: normal, advanced, and super advance sensor nodes. The proposed protocol selects the CHs based on the residual node energy and the distance between nodes and the BS. The proposed method outperforms several existing heterogeneous sensor network protocols in terms of lifetime and system stability.

To decrease network energy, an improved energy-efficient LEACH (IEE-LEACH) routing protocol is proposed in [19]. The authors in [20] proposed a hierarchical multi-path routing protocol for wireless multimedia sensor networks (HMPR). In this protocol, the data is transmitted to the base station via resource-rich nodes selected as cluster heads. The main cluster heads aggregate the data before sending it on to the base station node to minimize transmission, thus ensuring network stability. To save energy while establishing a bounded delay and enhancing accuracy, transmission takes place one hop or multi-hop within the cluster. This ensures that the QoS requirements are met for both intra and inter-clusters. Another layer is needed to achieve optimal QoS when evaluating cluster heads routing to the base station.

The authors in [21] proposed efficient multi-path routing based on a genetic algorithm (EMRGA), in which clusters and a genetic algorithm are used to perform the multi-path-based protocol. The cluster usually consists of sensor nodes that are near to the event's position. The CH is the most powerful node in the cluster. Data is sent to the CH by the cluster members, which gather and subsequently transmit aggregate data to the base station. Since the CH consumes greater resources than the other nodes, all nodes act as CHs to save a single node from dying early. A genetic algorithm is used to search for multiple paths in data transmission. Based on the cost function, it selects the best route with the minimum energy consumption and the shortest travel distance.

The authors in [22] proposed an energy-efficient clustering routing protocol for wireless sensor networks based on the yellow saddle goatfish algorithm (YSGA), developed using a distinct energy-efficient clustered routing mechanism. The proposed protocol aims to increase the network lifetime by reducing energy consumption. The network is considered a base station with a collection of CHs in its cluster topology. The number of CHs and the optimal CHs are determined by the YSGA algorithm, whereas sensor nodes are assigned to the closest CH. The YSGA modifies the network's cluster design to retain optimal CH distribution while decreasing the communication distance. In comparison to typical clustering routing protocols, according to the experimental data, the created routing protocol utilizes limited energy, has a longer lifetime, and extends the network's stability period.

The initial energy of nodes, remaining energy of nodes, total energy of the network, and average energy of all nodes have all been considered in the proposed protocol. The node closest to the base station will be ignored from the cluster formation and be isolated. The energy consumption of single-hop and multi-hop paths was analyzed and compared using different metrics throughout the data transmission phase. The path conserving the minimum number of resources was mostly selected. The network lifetime was extended, and the communication costs minimized. On the other hand, the energy of the sensor node is not taken into consideration when choosing the CH. If a node's energy is very low, being selected as the CH will accelerate its death. Furthermore, the distance between the base station and sensor node is not considered.

3. PROPOSED PROTOCOL

The network model, consisting of two types of N sensor nodes, normal sensor nodes (NNs), and main cluster heads (MCHs), provides the operating environment for the development of the proposed routing protocol. Sensor nodes are distributed at random across the network where they are likely to be the most active in the communication process, while the sink is situated in the corner of the network field. The aim of this cluster-based multi-path routing protocol is to minimize energy consumption among clusters by establishing appropriately sized clusters, thus improving the total

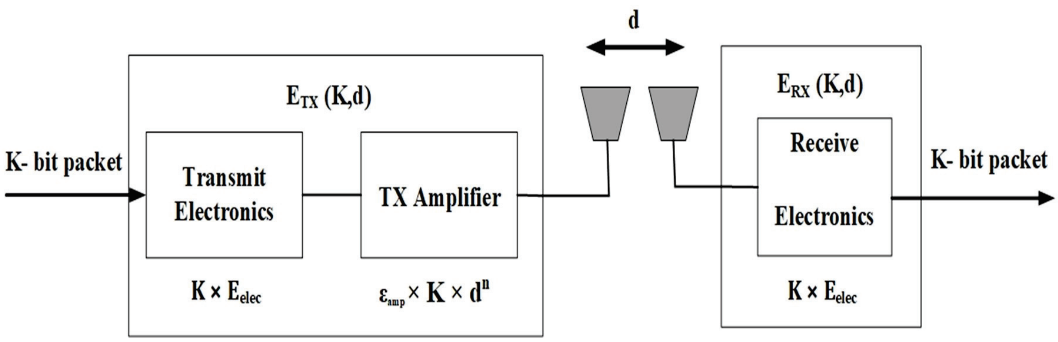


***Fig. 2**: Energy model.*

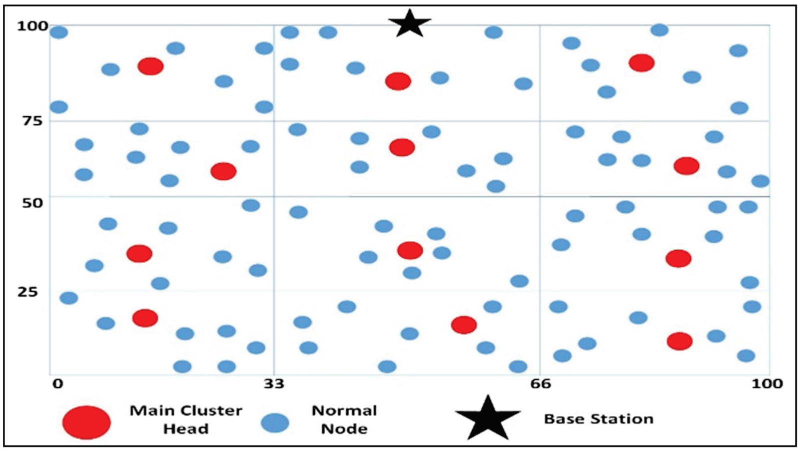


***Fig. 3**: Network model for the proposed protocol EEMCL in case the BS in the corner.*

network lifetime.

3.1 Energy Model

The energy consumption of the proposed protocol is based on the model given in the LEACH algorithm [15], as shown in Fig. 2. In this model, the proportion of energy consumed in the sending node for transmitting a K-bit data packet with the d distance (between both the transmitter and receiver nodes) is calculated using Eqs. (1) and (2).

$$E_{Tx}(k,d) = (k \times E_{elec}) + (k \times \varepsilon_{fs} \times d^2), \quad \text{if } d < d_o \tag{1}$$

$$E_{Tx}(k,d) = (k \times E_{elec}) + (k \times \varepsilon_{amp} \times d^4), \quad \text{if } d \geq d_o \tag{2}$$

where E_{elec} represents the energy expended by the electronic circuit during modulation or demodulation, ε_{fs} represents free space energy loss, ε_{amp} is the energy dissipated by the amplifier, and d_o is a threshold distance computed as $d_o = \sqrt{\varepsilon_{fs} / \varepsilon_{amp}}$. The amount of energy consumed by the receiving node when receiving a K-bit data packet is calculated using Eq. (3).

$$E_{Rx}(k) = k \times E_{elec} \tag{3}$$

If the distance between two nodes is less than d_o ($d < d_o$), energy consumption is calculated using Eq. (1); if the distance between two nodes is more than d_o ($d \geq d_o$), energy consumption is calculated using Eq. (2).

3.2 Network Model

In the proposed protocol EEMCL, the main cluster heads (MCHs) with more energy than normal sensor nodes (NNs) are preselected and deployed randomly in the square network, filed as shown in Fig. 3. The network model is single-hop and multi-hop in which the main cluster heads align with each other in a multi-path fashion until reaching the sink. In each round, the MCHs select two NNs in each cluster to be secondary cluster heads (SCHs) based on distance and the remaining energy. The reason for selecting two SCHs in each cluster is to aggregate and compose the data closest to the NNs. The SCHs then transmit the aggregated data to MCHs, which in turn transmit the data packet to the sink in a multi-path fashion. The following network assumptions are considered:

1. The MCH nodes have more energy than the NN nodes, and their batteries cannot be replaced or recharged.
2. All NNs nodes have the same connectivity, detection, and computational capabilities, and their batteries cannot be changed or recharged.
3. Sensor nodes are static and deployed at random

throughout the environment.
4. The sensor nodes continuously transmit data to the sink.
5. Only one stationary base station (or sink) is positioned in the corner of the sensing field and has a radio range that can supply sufficient energy to the whole field.
6. Every sensor node has a unique ID that identifies it from other nodes, assigned sequentially starting from (1), while the sink ID is (101).
7. All the channels available for use have the same bandwidth, which is equal to or more than the number of MCHs.

4. EEMCL ALGORITHM

It is a well-established fact that clustered protocols consume fewer resources than flat protocols. Generally, two different types of cluster head nodes (MCHs) and normal sensor nodes (NNs) exist in cluster-based protocol. MCHs require more energy than NNs. The general idea behind developing the network communication protocol is to manage energy among nodes in the cluster to increase its lifetime by promoting MCHs. The MCHs are preselected since they have more energy than NNs nodes, and two SCHs are then selected according to the distance and remaining energy in every round.

The topology of the proposed protocol consists of 12 clusters, each with one MCHs node and seven NNs nodes. Two normal nodes are then chosen to operate as SCHs to support MCHs via the NNs closer to SCHs than MCHs and transmit the data packet to one of the SCHs. The data packet from the SCHs to MCHs is then transmitted via the multi-path established from the MCHs to the sink. The four phases of the proposed EEMCL protocol consist of initialization, network clustering, cluster formation, and data transmission.

In the initialization phase, the sink sends a start message of 1 byte indicating its location to all sensor nodes. When all sensor nodes receive the message, each sends a hello message to the sink with its ID, location, and remaining sources of energy via the CSMA/CA protocol. The hello message is 2 bytes. During the in-network clustering phase, when the sink receives the hello message from all nodes, it determines the network's dimensions (X and Y) and the type of nodes in each cluster (MCHs or NNs) according to the node's energy level. The sink then divides the network area into four layers, each with three segments based on the location of each sensor node and the square cluster defined by the network designer. Eq. (4) shows the divided layers.

$$D_n = \frac{d_{\max} - d_{\min}}{4} \tag{4}$$

where D_n is the length of each layer, $d_{\max}$ is the distance of the farthest node from the sink and $d_{\min}$ is the distance of the closest node to the sink.

The sink then transmits a 2-byte message to all sensor nodes via the CSMA/CA protocol, including the ID layer, segment number, and MCHs ID for each cluster. When all nodes receive this message, they each keep track of the information on their neighboring clusters, including ID, layer ID, segment number, and MCHs. Each MCH transmits a message to all members of its cluster, informing them of its identity. Each MCH then generates a time-division multiple access (TDMA) frame based on the member. During the cluster formation phase, when a cluster member receives a message from an MCH, the NNs nodes respond with a message containing the energy level and distance from it. As soon as the MCHs receive this information, they begin picking two NN nodes to operate as SCHs, according to the distance and energy remaining in each round to exaggerate and compress the sensed information. The selection formula is as follows:

$$G_{sch(n)} = \frac{E_i - E_c}{D_{n-MCH}} \tag{5}$$

where E_i is the current energy of normal nodes, E_c is the energy consumed by normal nodes and D_{n-MCH} is the distance of normal nodes to MCHs. The larger two values of $G_{sch(n)}$ for node n are selected to be SCHs. Each MCH selects the two NNs nodes closest to it to act as SCHs in the first round and then compares the remaining energy of all its cluster members in subsequent rounds, selecting two NNs nodes with the highest remaining energy to act as SCHs. Two NNs nodes with a maximum $G_{sch(i)}$ announce themselves as SCHs. If the distance between NN nodes and MCHs is shorter than that between NN nodes and SCHs, they connect to MCHs and send sensing data; otherwise, they connect to the shortest distance between SCHs and send sensing data, and SCHs then transmit the aggregate data to MCHs using TDMA, as illustrated in Fig. 4.

This procedure is carried out in each round. The data transmission phase consists of two stages: intra-cluster and inter-cluster. NN nodes transmit the data packet to MCHs directly, either with one hop or two, through the SCHs. After aggregating and compressing the data, the SCHs then transfer it to the MCHs through TDMA intra-cluster communication. After the sensor readings in the inter-cluster have been aggregated in its MCHs, each MCH selects the best path to transmit the aggregated data to the sink in multi-hops, based on the energy remaining in the MCHs for the upper layer. This process is carried out using carrier-sense multiple access (CSMA), with each MCH having two channels, one for receiving and the other for transmitting data, to ensure non-interference. When the battery life of the MCH runs out before that of normal nodes, each cluster chooses one NN node with more energy remaining to operate as the MCH and then transmits the data packet to the sink in one hop or multiple hops to ensure a long network lifetime for all nodes. Fig. 5 shows the algorithm for the proposed protocol.

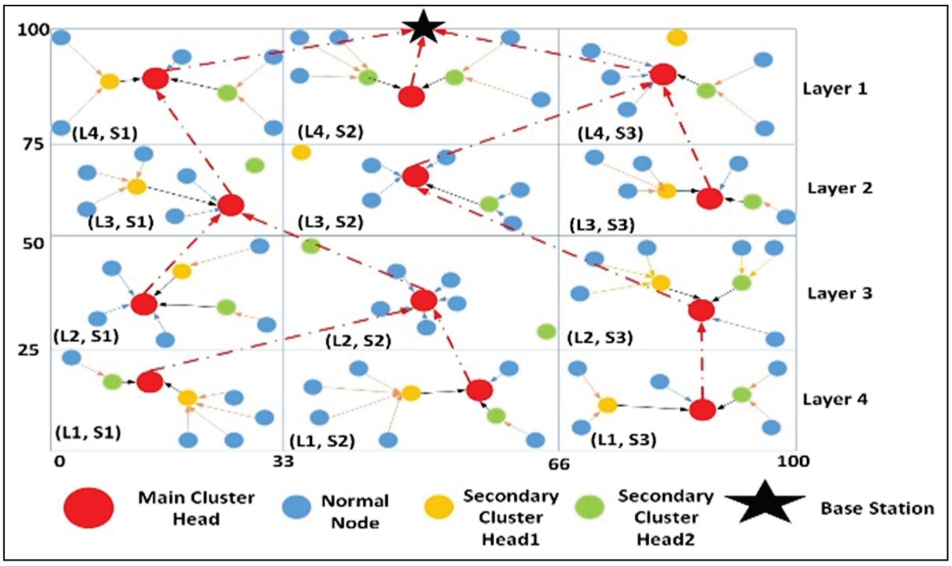


***Fig. 4**: Topology of the proposed protocol.*

***Table 1**: Simulation parameters.*

Parameters	Scenario 1	Scenario 2
Environment size	100 m × 100 m	200 m × 200 m
BS position	50, 100	100, 200
Number of normal nodes	88	88
Number of MCH nodes	12	12
Transmission range	100 m	200 m
MAC layer	IEEE 802.11b	IEEE 802.11b
Packet size	500 bytes	500 bytes
Control packet	25 bytes	25 bytes
Initial energy of the normal node (E_0)	1 J	1 J
Initial energy of the MCH node (E_0)	4 J	6 J
$E_{elec} = E_{bit}$	50 nJ/bit	50 nJ/bit
ε_{fs}	10 pJ/bit/m^2	10 pJ/bit/m^2
ε_{amp}	0.0013 pJ/bit/m^4	0.0013 pJ/bit/m^4
E_{DA}	5 nJ/bit	5 nJ/bit
d_o	87 m	87 m

5. SIMULATION RESULTS

In the simulation, a random network of nodes is placed in an area. Simulation is performed on MATLAB 2015b under two scenarios. To evaluate the performance of the proposed protocol EEMCL, it is compared with LEACH [15], LEACH–C [16], SEEN [18], and IEE–LEACH [19] in scenario 1 and CPMA [22] in scenario 2. It is assumed that 100 sensor nodes are randomly deployed over 100 m × 100 m and 200 m × 200 m area fields, respectively. The base station is located at 50 and 100 for scenario 1 and 100 and 200 for scenario 2. The initial energy of the normal sensor nodes is 1-joule and 4-joule for the MCH when the network area is 100 m × 100 m, and the initial energy of the normal sensor nodes is 1-joule and 6-joule for the MCH when the network area is 200 m × 200 m. The nodes are considered dead when their energy is equal to zero. Table 1 shows the simulation parameters used to evaluate the proposed protocol. The following metrics are used to compare and analyze the performance of the proposed protocol:

Stability Period: This is the time when the first sensor node in the network area fails to operate. The stability period is also known as the first node dead (FND).

Half Node Dead (HND): The time interval between the deaths of the first sensor node and half sensor node.

Instability Period: The time interval when the first and the last sensor nodes die. The instability period is also known as the last node dead (LND).

Number of Alive Nodes: This is the total number of sensor networks which have not consumed all their energy and are still operating.

Remaining Energy: This represents the total amount of energy available in all nodes during network operation.

Fig. 6 shows the network lifetime for the sensor nodes over the number of rounds in scenario 1. As can be

```
Begin
 1. Sink broadcasts the start message
 2. MCHs and NNs broadcast the message "x-position, y-position, node ID and residual
    energy"
 3. Sink divides the network files into four layers and three segments
 4. for i = 1 to NNs
        {Every NN in each cluster joins the MCHs}
        end
 5. for j = 1 to NNs
        {Every NN sends a message packet to the MCHs that joined its contained distance
         and residual energy}
        end
 6. MCHs in each cluster select two SCHs
 7. NNs find the shortest path to the MCHs or SCHs depending on the RSSI
        if (near to the MCHs)
            Joined to MCHs
        else (near to SCHs)
            Joined to SCHs
        end
 8. MCHs find the best path to the sink based on their residual energy for the upper layers
 9. for k = 1 to max cluster member
        {MCHs gives time slots to NNs}
        end
10. if (NNs has data)
        NN wake up at its time slot
        Send data
    else
        Turn off radio
    end
11. MCHs turn on radio multi-channel and receives data from the cluster members
12. MCHs transmit data to the upper MCHs
13. if (cluster member has no data)
        MCHs stay wake up
    else
        MCHs turn off radio
    end
14. Sink receives data
15. Return to step 5
End
```

***Fig. 5**: Pseudo code for the proposed protocol (EEMCL).*

observed, the EEMCL has a longer sensor node lifetime than LEACH, LEACH-C, SEEN, and IEE–LEACH. The first sensor node of the EEMCL dies after 1381 rounds, while the first sensor node of LEACH, LEACH-C, SEEN, and IEE–LEACH routing protocol dies after 1678 rounds, 1836 rounds, 2416 rounds, and 2636 rounds, respectively. This is because the MCHs near the sink at the corner deplete their batteries faster than other MCHs further away from the sink in which the data is transmitted through the multi-path.

Fig. 7 shows the FND, HND, and LND for all sensor nodes in scenario 1. As can be observed, at 1950 rounds, 2025 rounds, 2600 rounds, and 2800 rounds, half of the sensor nodes in LEACH, LEACH-C, SEEN, and IEE–LEACH, respectively die, while for the proposed EEMCL protocol, half the nodes are dead at around 3301. As can be observed, at 2225 rounds, 2300 rounds, 2900 rounds, and 3160 rounds, the last node dies in LEACH, LEACH-C, SEEN, and IEE–LEACH, while for the proposed EEMCL protocol, the last node dies at round 5721. This is because of the two SCHs selected to support the MCHs in aggerating the data from the normal nodes and the fact that the multi-path for transmitting data leads to load balancing for energy and maximizing the network lifetime.

Fig. 8 shows the average remaining energy of the NN nodes over the number of rounds in scenario 1. The NN nodes are considered to have initial energy of 1-joule; thus, the total energy for 88 NN nodes equates to 88-joules. The energy consumption of the EEMCL is less than that of LEACH, LEACH-C, SEEN, and IEE-LEACH routing protocols, as shown in Fig. 9. The EEMCL

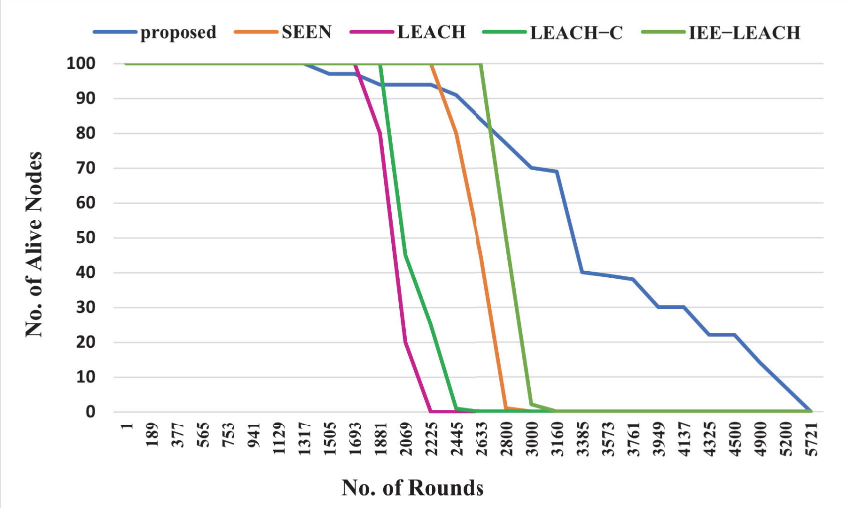
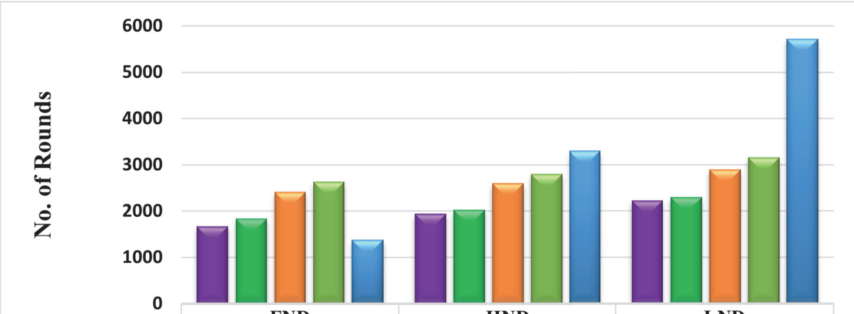


Fig. 6: *Number of alive nodes in scenario 1.*



	FND	HND	LND
LEACH	1678	1950	2225
LEACH−C	1836	2025	2300
SEEN	2416	2600	2900
IEE−LEACH	2636	2800	3160
proposed	1381	3301	5721

Fig. 7: *FND, HND, and LND results in scenario 1.*

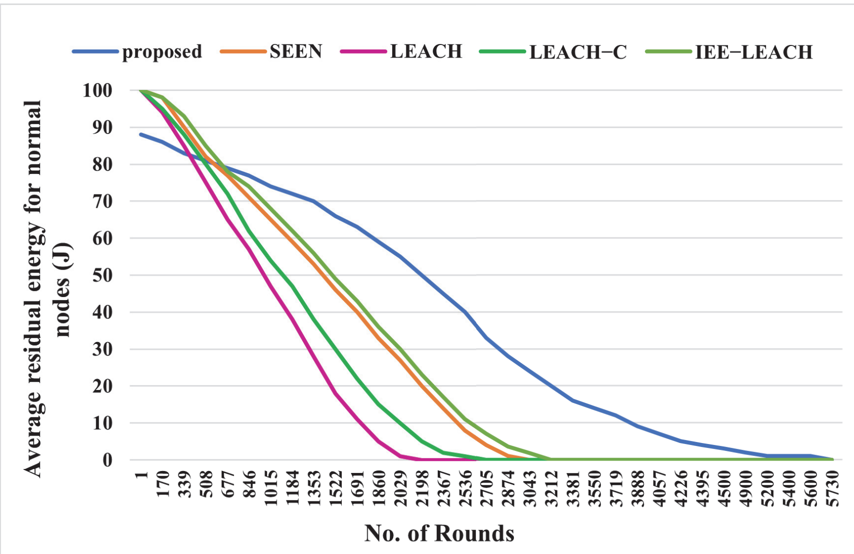


Fig. 8: *Energy consumption for normal nodes in scenario 1.*

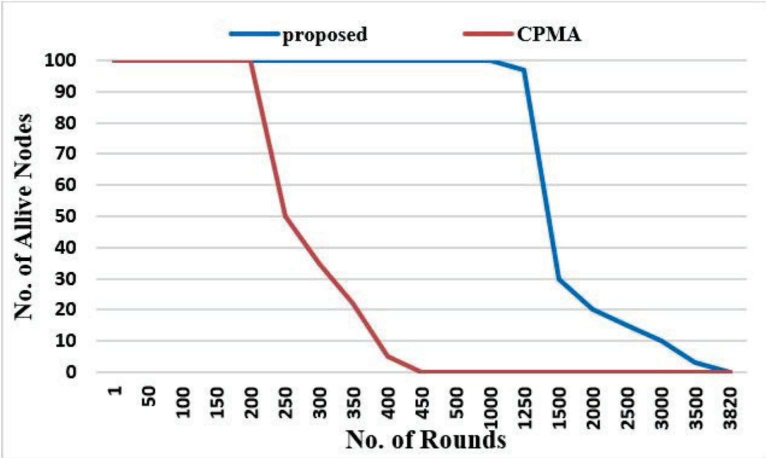


Fig. 9: Number of alive nodes in scenario 2.

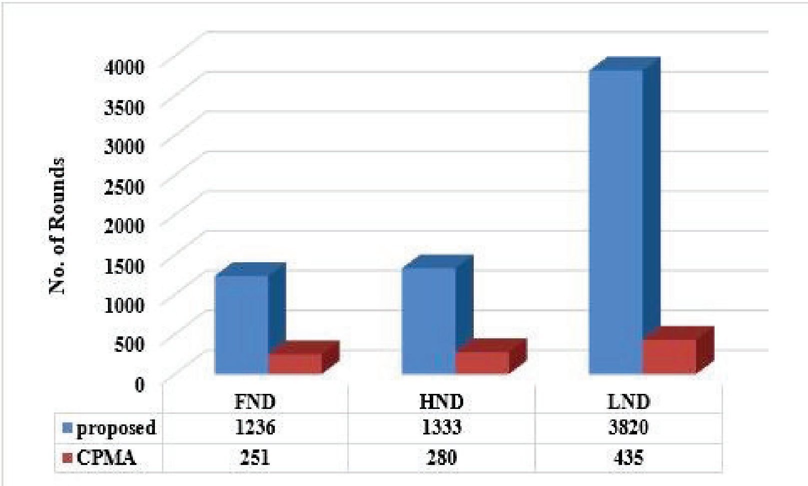


Fig. 10: FND, HND, and LND results in scenario 2.

performs better in terms of energy consumption over the rounds and outperforms the LEACH, LEACH-C, SEEN, and IEE–LEACH routing protocols.

The performance of the proposed EEMCL protocol in scenario 2 is compared with CPMA [23] in terms of the number of live nodes and network stability. The sensor nodes are randomly distributed, and the BS positioned at the corner of the 200 m × 200 m sensing field (100, 200). As shown in Fig. 9, the proposed EEMCL protocol presents a better performance compared to CPMA in terms of alive nodes. Fig. 10 shows that the LND for the EEMCL is around 3820, whereas, for the CPMA protocol, it is around 435. As a result, the proposed EEMCL protocol enhances the network lifetime in terms of the number of nodes still alive.

6. CONCLUSION

This paper proposes a cluster-based routing system called energy-efficient multi-path clustering with load balancing routing protocol for wireless multimedia sensor networks (EEMCL). When compared to the LEACH, LEACH-C, SEEN, and IEE-LEACH routing protocols in scenario 1 and the CPMA in scenario 2, the proposed protocol provides a much-enhanced network lifetime with greater efficiency. Various clustering routing mechanisms are investigated in this paper, which have shown a substantial improvement in power consumption for sensor networks in the past. The EEMCL, a clustering scheme in which the MCHs select two normal nodes to be SCHs to distribute the energy burden among the sensor nodes, is based on previous explanations in simulations of traditional protocols, such as LEACH, LEACH-C, SEEN, IEE-LEACH, and CPMA, demonstrating that these protocols may not be preferable for WMSNs. In this study, the methodology employed for the proposed EEMCL protocol extends the network lifetime. According to the simulation results, the proposed method provides additional improvements and can overcome the problems encountered with existing routing protocols. The MATLAB simulations indicate that the EEMCL can outperform the existing routing protocols LEACH, LEACH-C, SEEN, IEE–LEACH, and CPMA in terms of network lifetime, network instability, and energy consumption.

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