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Heterogeneous Multi-Clustered Energy Efficient Routing Protocol in Wireless Sensor Network

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***Abstract*—**The applications of Internet of things (IoT) devices and sensors are now increasing exponentially and it is achieving various status in industries. Wireless sensor networks (WSN) has become a prominent base for development of IoT and smart devices. Modern progressions in IoT bring out many benefits over traditional sensing devices and provided the researchers to develop a small, power efficient, low-cost, and multi-functional sensor devices. In this paper, we are presenting a heterogeneous multi-clustered energy efficient routing (HMCEER) protocol in Wireless Sensor Network with three levels of heterogeneity. HMCEER uses three energy levels to select cluster head in the wireless sensor network to improve network lifetime and through- put. The simulation result presents a significant improvement of network lifetime and throughput as compared to standard LEACH and LEACH based protocols.

***Keywords*—**WSN, LEACH, Energy Efficiency, Cluster, Sink Mobility, HMCEER
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I. INTRODUCTION

Wireless sensor network (WSN) is an active research field and its application sets are rapidly growing. Wireless sensor networks (WSNs) offer huge benefits as compared to that of wired sensor networks, for example, no cabling, high mobility, low installation cost and simple deployment [1]. WSN is advantageously deployed to bring up Internet of things (IoT) applications richer sensing and actuation capabilities [2], [3]. Basically, sensor network is a number of small sensor nodes deployed to cover a specific area to gather information using sensing capabilities and it is transferred to the base station (BS) as presented in Figure 1.

A radio communication system is needed for information transmission process which consists of the following:

- A processing unit having Digital to Analog Converter,
- A memory unit,
- Digital Signal Processing (DSP) unit which performs the data transmission process according to the system requirement.

The communication among nodes and node to base station is performed by using multi-hop or direct transmission, depending on the cluster location. In the multi-hop data transmission, nodes communicate with each other using minimal transmission power [4]. Since WSNs control mostly all aspects of mod- ern life, particularly after the progression of IoT technology, such taxonomy will provide readers with all the required information to start any real-life application considering all the application physical and logical requirements [5]. In fact, WSN solutions already cover a very broad range of applications, and research and technology advance continuously expand their application field.

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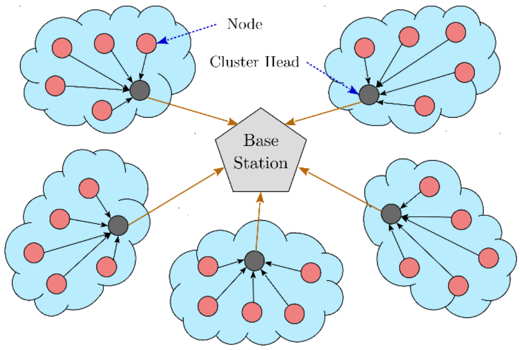

Fig 1: Basic WSN Working Model

This trend also increases their use in IoT applications for versatile low-cost data acquisition and actuation. The last years have shown us a wide range of Wireless Sensor Networks (WSNs), the application areas of WSN are military, environmental monitoring, agriculture, home appliances, industry automation and health monitoring [6].The sensor nodes are just dropped randomly to form ad hoc network where the nodes work automatically. The sensor nodes communicate in the peer-to-peer network and transfer the sensed data from one node to another. An in-built source of power supplies the energy required for the node to perform the programmed task [7]. Since the sensor nodes are low battery powered with the on-board power supply, the high energy consumption by the sensor nodes in performing its intended tasks is the main issue in WSN. Generally, the energy consumption in terms of data transmission is comparatively much higher than the data sensing and processing [8].

II. REVIEW OF LITERATURE

A large number of proposals in terms of distributed and centralized algorithms for clustering in WSNs can be found in the literature at present [9]. Clustering in WSN based on coverage area of network helps to achieve better energy efficiency [10]. The WSN area is split up into many clusters depending on some established characteristics. Only the CH (cluster head) node is able to communicate with the sink node, and hence, its role in WSN is significant [11], [12]. Ren *et al.* [13] furnished a unified framework of clustering approach in vehicular ad hoc networks, it includes neighbour sampling, back off-based cluster head selection and backup cluster head-based cluster maintenance schemes. Neighbour sampling scheme can filter out unstable neighbours in order to increase vehicle link stability. Back off-based cluster head selection scheme allows vehicles to make their own cluster head decisions in a distributed manner, which can reduce the clustering management overhead.

Yang *et al.* [14] studied how to improve the delay and throughput performance for delay-tolerant data collection applications in Wireless Sensor Networks with Mobile Sinks (WSN-MSs). They proposed a novel routing metric, contact- aware expected transmission count, based on queuing analysis theory to estimate the packet transmission delay over opportunistic links. By implementing the contact-aware expected transmission count in Tiny OS routing standard, they demonstrated that current contact-aware expected transmission count-based routing protocols for WSN with static sinks can be easily applied to WSN-MSs by using contact-aware expected transmission count. They also introduced a throughput-optimal data collection scheme, opportunistic backpressure collection, by integrating contact-aware expected transmission count into the Lyapunov optimization framework [15]. In contrast to current WSN-MS schemes, the opportunistic backpressure col- lection does not require any mobility prediction and performs well in large-scale sensor networks with multiple fast-moving sinks.

Nayak *et al.* [16] proposed formation of multiple chains protocol among sensor nodes which is found where every node is connected to one another to form a chain and the sink node is kept stationary. The network area is divided into several clusters based on its distance from sink node. Kulshrestha *et al.* [17] applied some intermediate procedure, several routes can be produced in order to transmit data so that waiting for a particular route is not required. The flat routing protocols used in WSN are not good for

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lifetime enhancement even though there is an appropriate criterion taking lesser time. But the multipath routing protocols are suitable for enhancing the lifetime of WSN.

Jafri *et al.* [18] introduced the mobility of the sink node in an improved version of PEGASIS-based IEEPB protocol, namely MIEEPB. The MIEEPB is based on the concepts of multi-clustering and multi-chain formation with introduction of sink node mobility. The mobility of the sink node affects the lifetime of the WSN to a large extent. In MIEEPB, a $100 \times 100\, m^2$ area of network was considered and divided equally into four different sections. Basumatary *et al.* [19] proposed a multi-clustered routing algorithm called as MERAM-C for WSN. By dividing the sensor nodes into several clusters through the application of clustering algorithm, each cluster has its own local base stations (cluster heads) to which they send their sensed data. The sink node having unlimited power source travels across the whole network area in a clockwise direction in a fixed trajectory, and it collects the aggregated data from CH nodes.

III. PROPOSED PROTOCOL

We propose a protocol heterogeneous multi-clustered energy efficient routing (HMCEER) for WSN in this paper. Each cluster has its own local base stations (cluster heads) to which they send their sensed data. The sink node having unlimited power source travels across the whole network area in a clockwise direction in a fixed trajectory, and it collects the aggregated data from CH nodes. To save battery power, basically the following four steps are followed:

A. Deployment of Sensor Node

To achieve efficient communication, random deployment of sensor nodes at fixed positions within the WSN area is adopted in the proposed multi-clustered algorithm. Every deployed sensor node is assumed to possess similar properties having limited and equal amount of battery power. There is an uninterrupted flow of information to the mobile sink node that moves continuously at various locations within the entire WSN area in each round.

B. Clustering

To create clusters, each node decides either to become a CH or to remains the normal node for the round. Based on a percentage suggested by the user, this decision of the sensor nodes is made. To become a CH, a number (say whose value is found between 0 and 1) is chosen at random by every sensor node. Then, (Threshold value) is calculated using the suggested percentage of becoming CH, and the current round. In real-time scenario, WSNs have more than two types of heterogeneity. Therefore, in TBEEDRA, we use the concept of three-level heterogeneity and characterize the nodes as: normal, intermediate and advanced. The probability for three types of nodes is given in equation below and is taken from the LEACH protocol

$$P_i = \begin{cases} \dfrac{P_{opt} E_i(r)}{\big(1 + m(a + m_0 b)\big) E_a(r)}, & \text{if } S_i \text{ is normal node,} \\ \dfrac{P_{opt}(1+a) E_i(r)}{\big(1 + m(a + m_0 b)\big) E_a(r)}, & \text{if } S_i \text{ is intermediate node} \\ \dfrac{P_{opt}(1+b) E_i(r)}{\big(1 + m(a + m_0 b)\big) E_a(r)}, & \text{if } S_i \text{ is advanced node} \end{cases} \quad \dots (1)$$

represents the list of nodes that were not CHs in the last 1 round. Every sensor node will utilize an equal amount of energy in order to become a CH.

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C. Energy Model

The radio/energy models [14] are used in this paper. The energy models are given in equation 2 to 6. To run the trans-receiver process, an amount of 50 nJ/bit (E_{elec}) energy is spent and 100 pJ/bit/m^2 ($Eamp$) energy for running transmitter amplifier. The following equations show the energy model:

$$E_{TRS}(k,d) = E_{TRS\_elec}(k) + \epsilon_{amp}(k,d) \quad \dots (2)$$

$$E_{TRS}(k,d) = E_{\text{elec}} \times (k) + \epsilon_{\text{amp}} \times k \times d^2 \quad \dots (3)$$

$$E_{RCV}(k) = E_{RCV\_elec}(k) \quad \dots (4)$$

$$E_{RCV}(k) = E_{elec} \times k \quad \dots (5)$$

$$d_0 = \sqrt{\frac{E_{fs}}{E_{mp}}} \quad \dots (6)$$

D. Mobility of BaseStation

We assumed that the sink node has unlimited power source to complete the programmed task. The performance of WSN is measured in round parameter. When the sensed data is sent to the CH from where it is collected by the sink node, it is considered as the completion of one round. The sink node moves continuously, starting from the location (20, 80) in a clockwise direction with a pre-defined fixed path. The sink node moves into forward, downward, backward and upward directions, respectively, to complete its data collection from the cluster head nodes. The pre-defined fixed path of the sink node continues till the simulation reaches to its last round. Figure 4 shows the movement of the sink node across the whole network are a with the above –mentioned pre-defined path during the simulation process. Here, all member nodes are represented by small circle symbols, CHs are represented by star symbols, and the large red circle represents the sink node. As we can see only the location of the sink node and the cluster heads are changed in every round, the coordinates of the other sensor nodes remain same.

E. Proposed Algorithm

The pseudo code of the proposed heterogeneous multi- clustered energy efficient routing (HMCEER) protocol is given below:

Algorithms 1

Deploy the sensor nodes randomly across the network area.
 for *all sensor nodes* **do**
  $i = 1$ to $n, S(i) = (X_i, Y_i)$
   Randomly establish the sensor nodes
  end

Elect the cluster heads (CHs) based on $T\ (n)$
Form the clusters, using elected CH
 for *every cluster* **do**
Transmit the sensed data to the CH
 CH forwards it to the sink node
 End

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Move the sink node to its next location

IV. SIMULATION AND RESULT

Figure 2 shows the comparison plot for dead nodes versus number of rounds in LEACH and MERAM−C. Figure 3 presents a plot for dead nodes *vs* number of rounds in proposed protocol HMCEER. The first node died at 1000^{th} round in LEACH, the first node died at 800^{th} round but in MERAM-C but in HMCEER, first node died after 3000^{th} round.

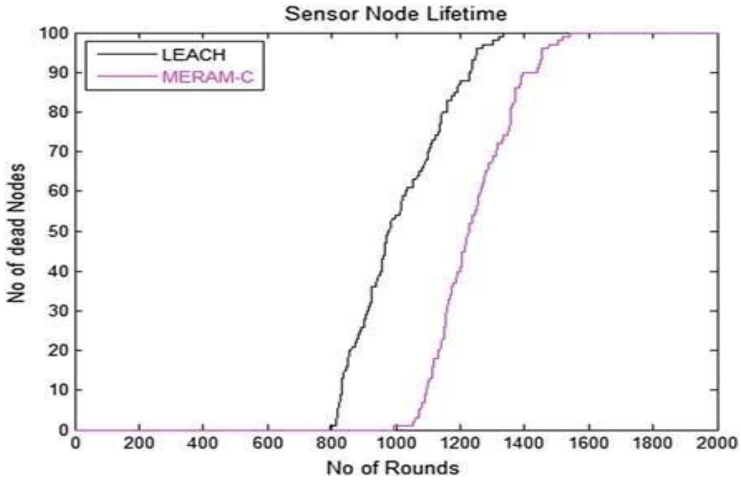

Fig. 2- Number of Dead Nodes in LEACH & MERAM−C Protocols

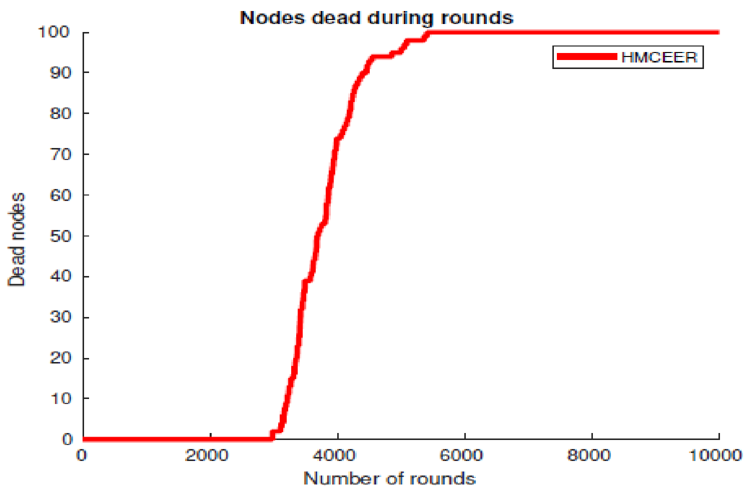

Fig. 3- Sensor Node Lifetime (Dead Nodes)

Figure shows the comparison plot for alive nodes versus number of rounds that each node completes before reaching to energy level zero. The lifetime of the network reached at 1300th rounds in LEACH, whereas in HMCEER the network lifetime reached at 1500th rounds. From the figures, it is shown that the lifetime of WSNs using the proposed HMCEER protocol is longer than using LEACH protocol.

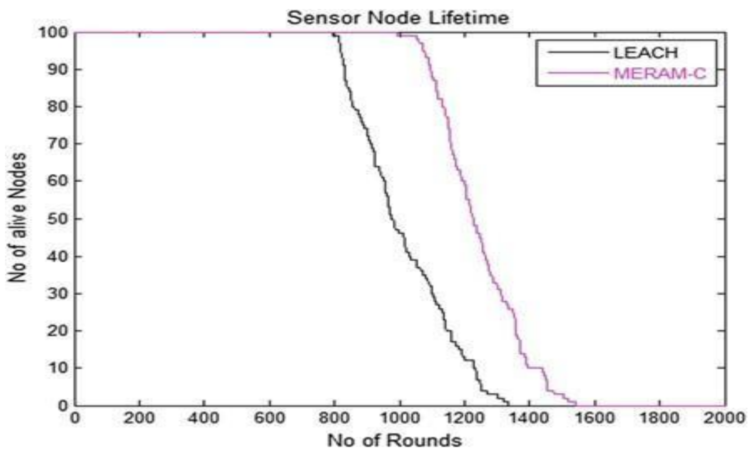

Fig. 4- WSN Lifetime in LEACH & MERAM−C Protocols

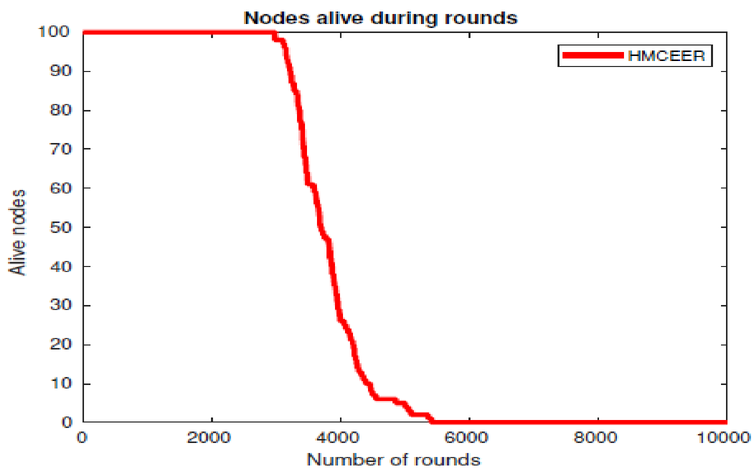

Fig. 5- Sensor Node Lifetime (Alive Nodes)

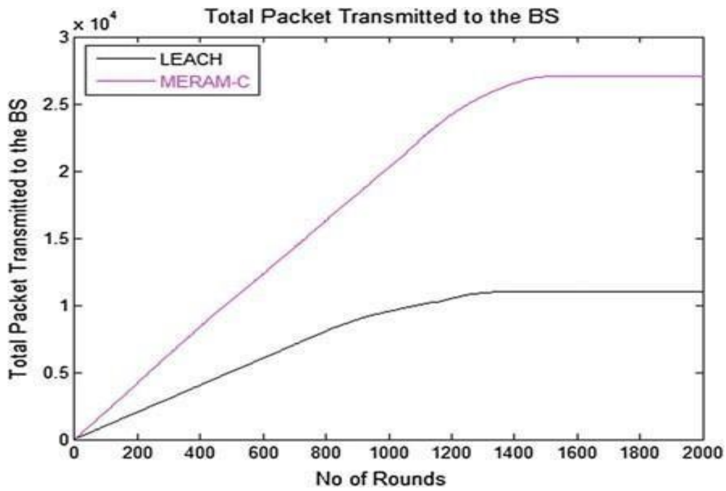

Fig. 6-Throughput in LEACH & MERAM-C Protocols

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Figure shows the comparison plot for packets sent to the base station versus number of rounds in the HMCEER, MERAM−C and LEACH protocols. The number of packets transmitted in the LEACH protocol was 10,967, whereas in HMCEER the number of packets transmitted was 27,090 which shows that the results of HMCEER are better than the LEACH protocol.

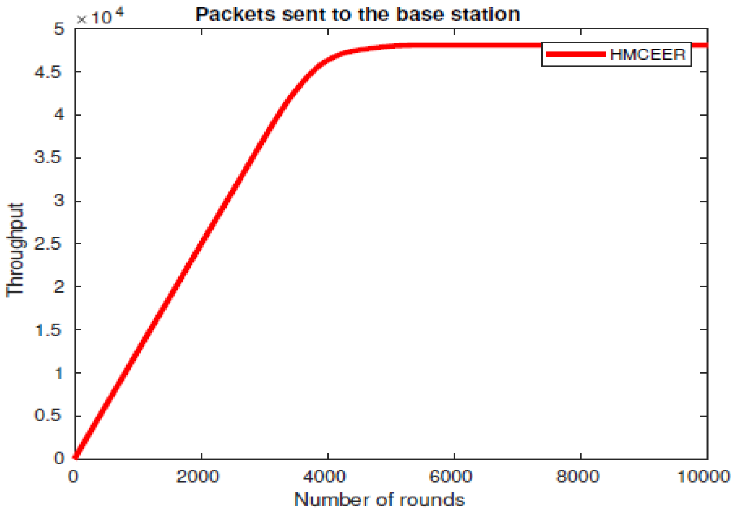

Fig. 7- Throughput (HMCEER)

V. CONCLUSION

In this paper, a heterogeneous multi-clustered energy efficient routing (HMCEER) protocol was proposed. It was also shown that the lifetime of the WSN using the proposed protocol (HMCEER) is longer than the lifetime of the WSN using the standard WSNLEACH protocol. It was also observed that the three level heterogeneity of nodes and mobility of base station not only decreases the load on the cluster head but also enhances the network lifetime. Further improvement can be done on the mobility pattern of the sink node considering larger network area for wireless sensor networks.

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