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HEOC: HIERARCHICAL AND ENERGY OPTIMIZED CLUSTERING BASED ROUTING APPROACH FOR WIRELESS SENSOR NETWORKS

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ABSTRACT

Of all technology trends occurring, perhaps one of the most prominent and popular domains is Wireless Sensor Network (WSN). The WSN has a vast range of applications such as disaster surveillance, structural health monitoring, agricultural control, biodiversity mapping and health care. The operation employs low-cost micro-sensors equipped with wireless interfaces for communication, thereby forming a sensor network. These sensors exhibit a constrained air due to their limited energy, storage capacity and battery life, making the design of an efficient routing scheme imperative yet tedious. This paper proposes Hierarchical and Energy Optimized Clustering based routing approach (HEOC) which ensures system's operation at minimal energy by multi - hop data traversal technique. The work refashions the existing model by selecting the most optimal cluster head for communication with sink. Simulation results prove that the proposed approach is effective in reducing the overall energy utilization and improves the lifespan of the sensor network as compared to other routing schemes.

Keywords: WSN- wireless sensor networks, hierarchical routing, energy optimized clustering.

1. INTRODUCTION

Recent progressions in semiconductor, networking and material science technologies are driving the ubiquitous deployment of large-scale wireless sensor networks (WSNs). Conjointly, these technologies have combined to enable a new generation of WSNs. These networks are application based which means different structure and requirements for every problem domain. The specification for every protocol change with the application with one common concern for network lifetime with energy serving as the leading element in its determination [1][2].Wireless sensor networks involve spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of an unattended environment and organizing the accumulated data at a central location, generally referred as a sink or a base station. These nodes are equipped with sensing, data processing, wireless communication and energy supply subsystems while the power and memory are highly constrained. These attributes further restraints the transmission range of the nodes, i.e. sensor can communicate only within a certain defined radius. Hence, it requires a suite of network protocols to implement network management and control functions. Primarily network routing protocols are categorized into three types, namely flat routing protocol, hierarchical routing protocols, and location-based routing protocol.

In this paper, we propose Hierarchical and Energy Optimized Clustering (HEOC) routing protocol to handle the problems encountered in a graceful and efficient tone without the degradation of resources through a hierarchical cluster based routing approach. The viewpoint behind the model above is that the nodes are randomly divided into clusters (based on the radio radius and the number of neighbors) that perform data dissemination through single hop or multi-hop communication. Every cluster would comprise a lead node known as the cluster head. The cluster head (CH) is responsible for accumulating data from all the sensor nodes in its cluster and then forwarding that data to the base station. In this context, the data transmission among the CHs is known as inter-cluster communication while the communication between the CH and its respective cluster members is referred to as intra-cluster communication. The remainder of the paper encompasses the following sections: Section I provide and insight into WSN domain, its constraints and approach preferred. Section II tours the origin and base of the proposed methodology with their observed disadvantages. Section III gives a vivid idea of the proposed algorithm followed by its assumptions and analysis. Section IV provides observed simulation result to hold the theory. This paper concludes in Section V followed by references used.

2. RELATED WORKS

We shall first explore few data dissemination/routing protocols developed in the recent past for wireless sensor networks. On account of different classification standards, routing protocols can be cataloged distinctly-

Based on the network structure

- Flat-based or Data-centric routing
- Hierarchical routing
- Location-based routing

Based on path establishment

- Table Driven or Proactive Protocols
- On-demand or Reactive Protocols

- Hybrid Protocols

Based on protocol operation

- Multipath based
- Query-based
- Negotiation-based
- QoS-based
- Coherent-based

This context emphasizes hierarchical routing protocols as the efficient way to reduce the energy dissipation within a cluster by performing data aggregation and fusion to lessen the number of messages addressed to the base-station. LEACH (Low Energy Adaptive Clustering Hierarchy) is the most prevalent and traditional cluster-based hierarchical routing protocol usually accepted in all its ramifications. LEACH algorithm is designed to organize nodes into clusters collection, each controlled by a CH. The CH implements the following tasks:

- Gathering and aggregating data from member cluster (intra-cluster communication)
- Communication between the CH's (inter-cluster communication)

The LEACH protocol operates in rounds, each consisting a setup phase and a steady-state phase [3] [4].

Setup phase: The network is separated into clusters, and each node decides whether to become a cluster head or not depending on a predefined criterion.

Steady-state phase: The CHs fuse the data gathered from their individual cluster member and forward it to the base station through single-hop communication. The election of CH is randomly rotated among the cluster nodes to ensure even energy load distribution between the sensor nodes in the network. This algorithm can hence reduce the volume of data directly transmitted to the base station while balancing the network load.Though significant, this protocol has several shortcomings. The CHs are unevenly distributed in the network. If they happen to be selected randomly only from a dense area, this may lead to more energy consumption during data transmission. Since the CHs are elected based on probability, it may lead to overhead and increase in network load.

Hybrid Energy Efficient Distributed Clustering (HEED) is an advanced design of the LEACH protocol in the manner of CH selection [5]. During each round, a CH is elected on account of the residual energy of each node and its proximity to other nodes in the cluster. Through iterations and competition, only one CH is chosen within a certain range. Hence, this protocol confirms uniform cluster head distribution across the network. Compared to LEACH, HEED ensures prolonged network lifetime and is useful for networks consisting of nodes with different initial energy. Nevertheless, LEACH and HEED consume more energy in the head nodes, which leads to abrupt deterioration of the CHs. Random selection of CHs would edge to higher communication overload, and periodic rotation of CHs would demand additional energy to rebuild clusters.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) is another enhancement of the LEACH protocol, which is a nearly optimal power-efficient chain-based routing scheme [6]. The aspect of cluster formation is sidestepped in PEGASIS. The greedy algorithm is used which implements chain formation among sensor nodes in the network. In this protocol, the $(i \bmod N)^{th}$ node is elected as a central node, only which communicates with the base station in round i, where i is the total number of rounds and N is the total number of nodes. Data accumulation begins at both endpoints of the chain and is fused on every transmission between the nodes until it reaches the central node. Thence, PEGASIS explains a distinct reduction in the total volume of data for transmission and brings about better performance than LEACH regarding network lifetime. Nonetheless, PEGASIS is not always accepted due to few drawbacks. This protocol assumes that all nodes have equal energy levels and shall perish at the same time. It would be inappropriate to select the chief node without considering its energy level. Since there would be only one central node communicating with the base station, it would be the bottleneck of the network causing delay. Redundant transmission of data may prevail as only the central node would participate in forwarding data to the base station.

Threshold Sensitive Energy Efficient Network (TEEN) is a distinct hierarchical routing protocol primarily designed for mission critical applications in reactive networks [7][8]. In this design, the base station and sensor nodes are assumed to have the same energy levels. Clustering in TEEN is similar to that of LEACH. The network comprises of simple nodes, first-level and second-level CHs. The data transmission continues to the second level cluster heads until the base station is grasped. This process takes place by addressing threshold values for the node members from the CHs. Elementally, TEEN defines two types of threshold values- hard threshold and soft threshold. The nodes depend on these values to for data transmission.

Hard Threshold- When the sensed value exceeds the given hard threshold value, the node switches its transceiver on and initiates the data transmission.

Soft Threshold- Unlike hard threshold, when minute changes are observed in the sensed attribute, the node initiates the data transmission by switching on the transceiver.

Therefore, sensor motes begin the data transmission when one of the following conditions are satisfied:

a. Sensed attribute > Hard Threshold
b. Sensed attribute ~ Hard Threshold >= Soft Threshold

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In Extending Lifetime of Cluster Head (ELCH) the CHs are chosen based on the neighbor node votes. This protocol has the self- configuration capability and hierarchical routing properties that consume low energy and thus to extend the life of the network, which combines the cluster approach [9][10]. During the first phase, clusters are generated after which CHs are selected from every cluster. This takes place through a voting mechanism between nodes and their neighbor sensors. Finally, the sensor node with the maximum number of votes acts as the CH. During the second phase, the nodes in the cluster forward data to the CH, which is further transmitted to the sink from the CHs. Once the clusters are formed, every cluster comprises a CH and its individual cluster members. The sensors located within a distance less than the radio radius form clusters together. After this, a time scheduling mechanism is introduced by the individual cluster members in every round. Every CH manages a table indicating the maximum power of each of cluster members which are updated at the end of every selection round. The data are transmitted directly from the cluster member to CH, which is further forward to the base station. This technique can result in minimum energy dissipation while maintaining a more balanced energy efficient network.

3. RADIO MODEL

In our algorithm, following properties were assumed about the network model:

- The network comprises N stationary and identical nodes.
- Nodes are randomly positioned in the network simulation area.
- Every node is the energy constrained with similar processing capabilities.
- The base station or sink is located far off from the topology constructed.
- All nodes have the same initial energy level in the network.

The sensor nodes used are energy constrained and perform data aggregation using different techniques to conserve energy. The energy needed for data transmission is dependent on the distance and the size if the data being transmitted. Similarly, even the energy required for receiving is dependent on the same factors. The equation for the above energy variables can be given as

$$Etransmission = (Eelec * K)\,(Eamp * K * d^2)$$
$$Ereceiving = Eelec * K$$

Where,

$Eelec$ = energy being dissipated to run the transmitter
$Eamp$ = energy dissipation of the transmit amplifier
K = length of the message in bits
d = distance between transmitter and receiver

4. HEOC

The major objective of the intended scheme lies in energy conservation and overhead control while transmitting data from the source node to sink through hierarchical cluster construction. In this approach, the ordinary nodes elect a deserved CH out of all the candidates. This protocol employs a combination of clustering along with the multi-hop architecture. Once the CHs are selected, it generates time schedules for every node in its cluster. The time slicing concept prevents overlapping and redundancy of data by fixation of data conveyance time slots for every node. Once all the data is aggregated at the CH, it is carried on with intercommunication among all CHs. By considering the location and energy of the CH, data aggregation takes place at the optimal CHs through multi-hop data forwarding techniques- multi-hop cluster and multi-hop node communications. These CHs (generally in the vicinity of the sink) further forward the fused data to the base-station. In this approach, Dijkstra’s algorithm is employed to transmit the data to the base station via the most optimum, i.e. the shortest path in the network. Along these lines, the proposed scheme aims to extend the lifetime of the network model by ensuring minimum delay and energy consumption with maximum achievable throughput.

The basic operation that follows the stated pattern of data transmission is illustrated below:

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Algorithm	
Step I	N sensor nodes are randomly distributed over the network area.
Step II	Let n_1, n_2, n_3……,$n_n$be the marking for the nodes.
Step III	Initially all nodes have same energy values assigned to them.
Step IV	Cluster formation performed with a suitable number of nodes in each assemblage.
Step V	Number of neighbors calculated for each node.
Step VI	Cluster Head selected.
Step VII	TDMA scheduling performed for each node within a cluster.
Step VIII	Intra - cluster communication between nodes and their respective cluster heads.
Step IX	Check if data is redundant. If yes, go to step VIII again Else proceed to step X.
Step X	Inter - cluster communication to select the CH with the shortest distance to sink.
Step XI	Optimal CH sends a unit of data to sink.
Step XII	Check if residual energy is above the threshold. If yes, go to step VI and repeat. Else end.

The operation could be explained in a more detailed fashion by splitting it into three phases, namely Initialization Phase, Election Phase and Data Transmission Phase.

Initialization phase: Initialization Phase is further composed of two phases: Random node deployment and Cluster formation. In the first phase, a certain number of nodes are taken as input and then plotted on the simulation area in a random fashion. An initial energy level is set for each node after the positioning.The second phase deals with cluster formation within the nodes. Cluster numbers are kept low to avoid overlaps. The cluster creation takes place based on the coordinates of the nodes in the simulation area to have a random distribution.A Simulated annealing algorithm is used as the base for the cluster formation. Small size cluster distribution proves more effective for energy conservation in wireless sensor networks.

Election phase: The election phase comprises both probability based as well as non-probability based CH selection. Once the nodes are randomly deployed in the sensor network and the clusters are formed, the next step deals with cluster head selection. In the first round, the degree of each node is calculated based on the sensor nodes proximity and range of transmission. The sensor with the highest degree is selected from the candidate set of nodes. This generates a broadcast of acknowledgment from the CH to all the nodes about the election result. The nodes, switch on their transmission power based on the received signal strength and the acknowledgment from the CH. This power can vary with every node adding to energy conservation. Once all the data from the nodes in a cluster gets aggregated at the cluster head, CH maintains a record of the node with highest remaining power. On the completion of round 1, the recorded node is elected as the new CH in the cluster and the same procedure is carried on for further iterations till the energy hits below the threshold value.

Data transmission phase: Data transmission phase encompasses both Intra and inter-cluster communication schemes. Intra-cluster communication occurs between the nodes and the CH. TDMA schedules are assigned to every node in which they send their data to the CH. The CH aggregates all the data sent to it.The inter-cluster communication deals with communication among the CHs to choose the most optimal CH which in turn further aggregate units of data and sends it to the base station. The CH changing with every round based on its residual energy for greater longevity. The network also takes care of the nodes excluded from the clusters using the multi-hop data forwarding technique. The nodes communicate to the nearest node in a linear chain path till its data reach nearest CH. Figure-1 illustrates the proposed system architecture.

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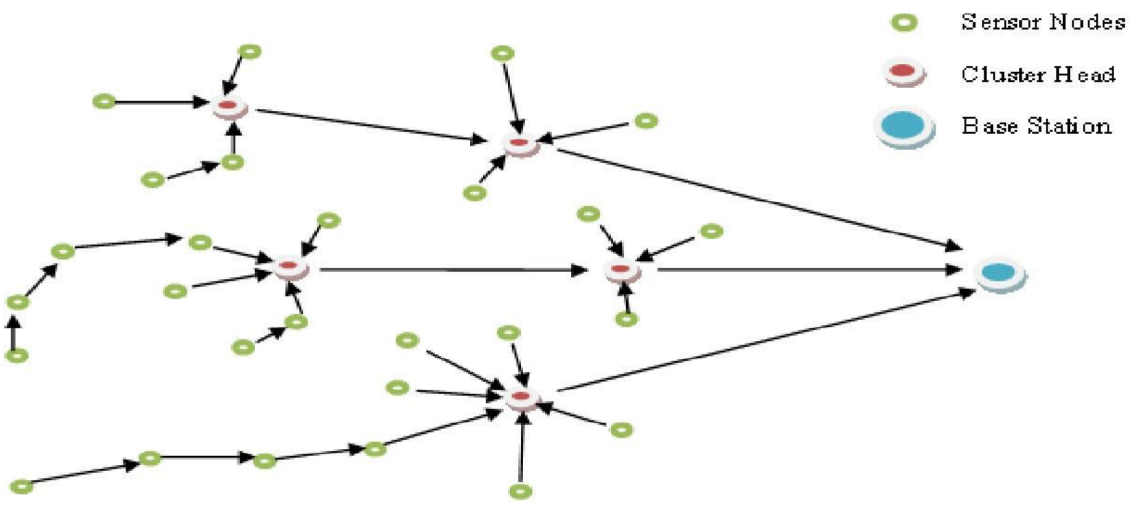

Figure-1. Hierarchical clustering.

5. SIMULATION RESULTS

Measures of "Packet Distribution", "Average Latency", and "Energy Dissipation" are considered to evaluate the proposed routing protocol. The simulation results of the projected algorithm are produced using NS-2 and compared with the performance of existing ELCH.

Table-1. Simulation parameters.

No.	Parameter	Specification
1	Network size	100 x 100 m^2
2	Number of sensors	100
3	Initial energy of each node	2J
4	Data packet size	150 bits
5	Transmitter Circuitry Dissipation	50nJ/bit
6	Amplitude Dissipation	100pJ/bit/m^2

Figure-2 shows the average energy dissipation noticed between transmitting and receiving of data packets. These simulation results confirm that HEOC has a much more beneficial energy disbursement curve with enhanced system lifetime when compared to ELCH. Since all the CHs in ELCH, transmit data directly to the base station, whereas HEOC uses simulated annealing and multi-hop data forwarding techniques for the data transmission.

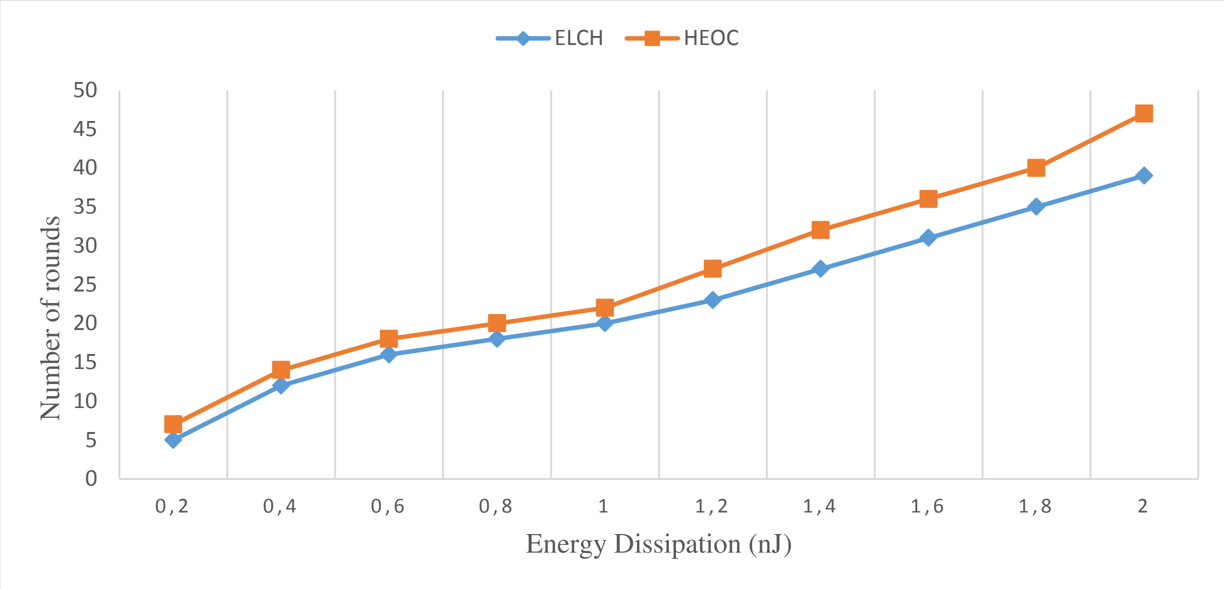

Figure-2. Energy dissipation.

Figure-3 represents the data packet delivery ratio between the HEOC and ELCH protocols. Expressly, the HEOC protocol is observed to process a greater number of successful packet deliveries hence increasing the packet delivery ratio to the number of nodes. Additionally, HEOC exhibits the rate of packet drops linearly with a comparatively low rate.

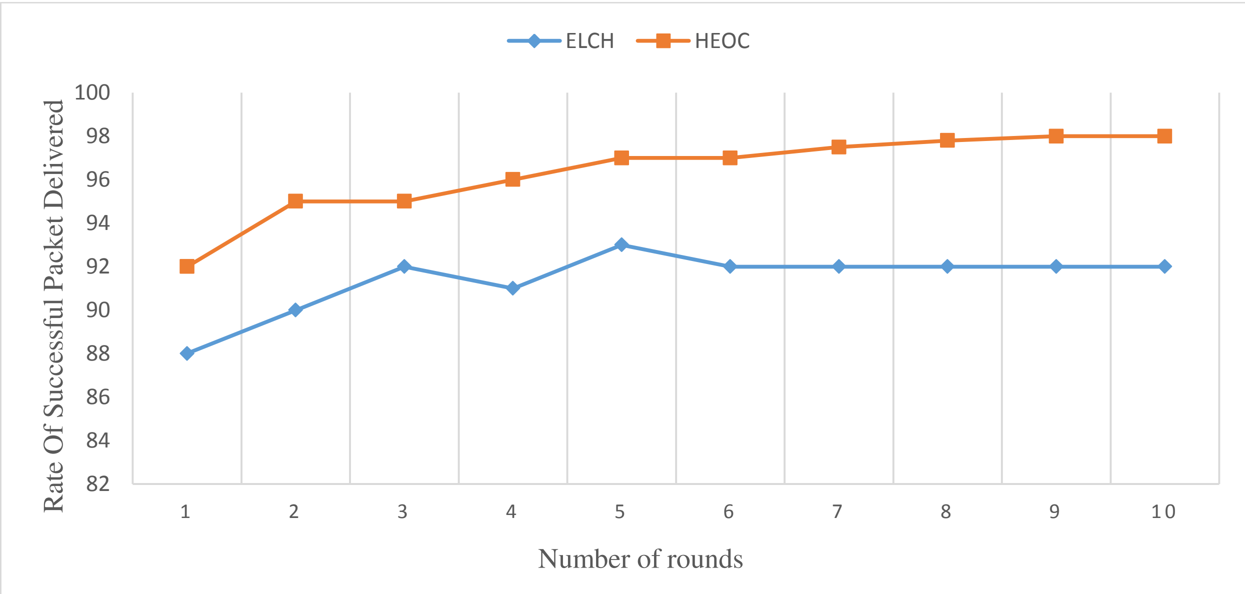

Figure-3. Packet delivery ratio.

Average Latency defines the period between the beginning of transmission and receipt of the first packet at the base station. Figure-4 represents the simulation results of average latency and average time delay for HEOC and ELCH. These simulations certify that the delay of ELCH escalates rapidly with time when correlated to HEOC. Since HEOC supports dynamic cluster configuration with cluster-head to cluster-head communication which enhances the throughput while minimizing the delay in transmission. Figure-4 shows an average delay in data transmission.

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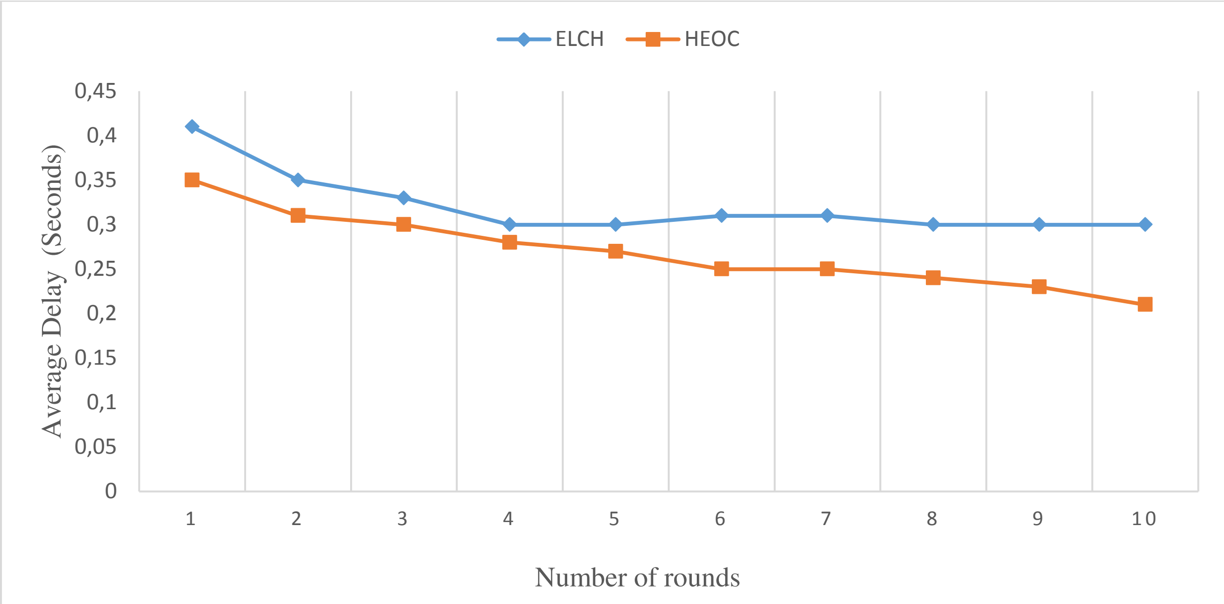

Figure-4. Average delay.

6. CONCLUSIONS

Recent years have eyeballed lots of consideration on routing in wireless sensor networks and introduced uncommon challenges compared to conventional data routing in wired networks. Wireless sensor networks markedly prolonged, playing a significant role for efficient data dissemination among sensor nodes.This paper targets on hierarchical routing in WSNs through the use of an enhanced routing protocol termed as Hierarchical Energy-Optimized Clustering Protocol (HEOC), which aims at the attainment of energy conservation through efficient routing. The proposed algorithm endorses an energy efficient routing technology for the nodes resting on the distance between the nodes and base station, the density of the node distribution, and residual energy of nodes. In our proposed algorithm,

- Network lifetime extended through the fair use of energy by selecting a node with maximum residual energy and least distance from the sink as the optimal cluster head.
- High packet delivery ratio (reducing the number of non-reaching nodes) has been achieved resulting in a minimum delay in delivering the packets.Acquiring a minimum amount of energy in each round to balance the energy consumption in the network.
- Distribution of cluster heads across the network results in low communication cost between the nodes. Despite the fact that there have been reams of attempts in addressing security and energy efficient routing, very few works are seemed to have benchmarked accompanied by various pitfalls. The performance of HEOC is assessed by simulation and compared to other clustering-based protocols (LEACH, HEED, and PEGASIS). The results prove that HEOC outperforms its comparatives by producing energy efficient results using a cluster-head to CH routing scheme to transfer fused data to the base-station. Therefore, it is concluded that HEOC provides an energy-aware hierarchical routing in wireless sensor networks suitable for a vast range of sensing applications.

REFERENCES

[1] Xuxun Liu. 2015. Atypical Hierarchical Routing Protocols for Wireless Sensor Networks: A Review. Proceedings of IEEE Sensors Journal. 15(10).

[2] SeemaBandyopadhyay and Edward J. Coyle. 2003. An Energy Efficient Hierarchical Clustering Algorithm for Wireless Sensor Networks. Proceedings of IEEE.

[3] W. Heinzelman, A. Chandrasekaran, H. Balakrishnan. 2000. Energy-Efficient Communication Protocol for Wireless Microsensor Networks. In: Proc.33rd Hawaii International Conference on System Sciences, HI, USA. 8: 110.

[4] W. Heinzelman, A. Chandrasekaran, H. Balakrishnan. 2002. An Application- Specific Protocol Architecture for Wireless Microsensor Networks. IEEE Trans. Wireless Commun. 1(4): 60-70.

[5] OssamaYounis and Sonia Fahmy. 2004. HEED: A Hybrid, Energy-Efficient, Distributed Clustering

Approach for Ad Hoc Sensor Networks. Proceedings of IEEE Transactions on Mobile Computing. 3(4).

[6] Lindesy and C.Raghavendra. 2002. PEGASIS: Power-Efficient Gathering in Sensor Information System. Proceedings of IEEE Aerospace Conference.

[7] A. Manjeshwar, D. Agrawal. 2001. TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks. In: Proc. 15th International Parallel and Distributed Processing Symposium (IPDPS'01) Workshops, USA, California. 2009-2015.

[8] Manjeshwar, D. Agrawal. 2002. APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks. In: Proc. International Parallel and Distributed Processing Symposium, Florida. pp. 195-202.

[9] Siva D. Muruganathan, Daniel C. F. Ma, Rolly I. Bhasin and Abraham O. Fapojuwo. 2005. A Centralized Energy-Efficient Routing Protocol for Wireless Sensor Networks. Proceedings of IEEE.

[10] J. Lotf, M. Bonab, S. Khorsandi. 2006. A Novel Cluster-based Routing Protocol with Extending Lifetime for Wireless Sensor Networks. In: Proceeding of 5th IFIP International Conference on Wireless and Optical Communications Networks (WOCN08), East Java Indonesia, Surabaya. pp. 1-5.