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Energy Efficient Routing Protocol For Homogeneous and Heterogeneous Wireless Sensor Networks

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ABSTRACT

Wireless sensor network is a collection of large number of sensor nodes. These sensor nodes have some constraint due to their limited energy, storage capacity and computing power. Cluster based routing is one of the key technique to conserve energy and increase network lifetime. This approach suits well for both homogeneous and heterogeneous sensor network. In homogeneous networks all the sensor nodes are identical in terms of battery energy and hardware complexity. On the other hand, heterogeneous sensor network consist of two or more types of nodes having different battery energy and functionality. An energy efficient clustering protocol which suits both for homogeneous and heterogeneous sensor network is proposed. The performance analysis of the proposed protocol is carried out using NS2. Simulation results show that heterogeneous sensor network outperforms homogeneous sensor network in terms of network lifetime, delay, residual energy, and throughput.

Keywords— *wireless sensor network, clustering, homogeneous, heterogeneous, energy efficiency, NS-2*

I. INTRODUCTION

Wireless sensor networks consist of number of sensors to monitor physical or environmental conditions. The WSN built of "nodes" from a few to several hundreds or even thousands, Where each node is connected to one (or sometimes several) sensors. These sensor nodes have to be designed in such a way that it should consume low energy in order to prolong the network lifetime. In the sensor node energy is consumed by data sensing, data processing and data transmission. The node almost spends upto 90% overall energy for communication. Normally two types of transmission protocols are used direct type and indirect type [4]. In the direct type protocol, all the nodes send the sensed data to the base station directly. Whereas in case of indirect type, the node send the sensed data to nearby node. Since the distance from the sending node to the forwarding node is shorter than the distance from the sending node to the base station. Energy consumption of the sending node can be reduced.

Clustering network normally classified as; homogeneous and heterogeneous sensor networks. In homogeneous network all the sensor nodes are identical in terms of battery energy and its main function is to gather the sensed data and sends it to the sink. Whereas a heterogeneous sensor network employs a range of different devices, which are able to cooperate in order to achieve a global goal by combining the individual capabilities of nodes [9]. There are two communication patterns used in WSN- single hop and multihop. Single hop provides a direct transmission of data from source to sink, where the furthest sensor nodes deplete their battery energy when compared to other nodes. In order to overcome this problem a multihop communication pattern is used.

The primary goal of heterogeneous network is to minimize energy consumption, reduce delay to provide long battery life. In this paper an energy efficient routing protocol is designed for both homogeneous and heterogeneous WSN and comparing them in order to obtain energy efficient network.

II. RELATED WORKS

Energy Efficient Homogeneous Vs Heterogeneous LEACH. by Neha Mehndiratta, Manju, Harish Bedi [1] describes the classification of sensor networks as a single hop homogeneous network, and a sensor network with two type of

nodes as a single hop heterogeneous network. They have compared heterogeneous network with homogeneous network. Here operation is performed in different phase: advertisement phase, cluster setup phase, schedule creation phase and data transmission phase. In homogeneous networks all the sensor nodes are identical in terms of battery energy and hardware complexity. On the other hand, in a heterogeneous sensor network, two or more different types of nodes with different battery energy and functionality are used. And proved that heterogeneous is more energy efficient than that of homogeneous only in terms of energy.

In HEED (Hybrid, Energy-Efficient Distributed) [2] clustering, periodical selection of cluster heads based on hybrid of residual energy and a secondary index called node proximity. Secondary index is used to break ties. HEED uses a combination strategy of energy and communication cost to generate CHs. Since the energy is non-uniform distributed among all nodes, it is approximately avoided that two nodes within each other's transmission range have the same probability to become CHs in HEED. But achieving global goals cannot always be guaranteed and energy consumption during the data transmission for far away cluster heads is significant.

A Cluster Based Routing Protocol For Prolonging The Network Lifetime In Heterogeneous Wireless Sensor Network[3] describes a cluster based routing protocol for heterogeneous WSN in order to minimize the energy consumption and increase the network survivability. By Comparing the heterogeneous LEACH protocol with this cluster based routing protocol under same simulation conditions and values, proves that the proposed model prolongs the life time of the network.

This paper "Improving lifetime in Heterogeneous Wireless Sensor Networks with the Energy-Efficient grouping Protocol [4] energy- efficient protocol with grouping is designed. The sensor nodes are divided into number of groups. It not only extends network lifetime but is also applicable for multilevel heterogeneous wireless sensor networks. Balanced energy-efficient grouping (BEEG) protocol for multi-level heterogeneous Wireless sensor networks is designed. Thus comparing this method with LEACH showing that the proposed method prolongs the stability period (the time interval before the first node dies).

DECS (Distributed energy cluster structure algorithm) [5] Scheme based on distance and residual energy. This protocol has been divided in two stages: initial stage and working stage. Cluster head election and TDMA slots are allotted by CH in initial stage. Cluster heads are elected based on high residual energy. In working stage, the adverse effect on the energy consumption of the cluster head is reduced resulting from non-uniform distribution of nodes in network and the direct communication between the base station and the cluster head is avoided. The algorithm balances the energy consumption, prolongs 31% of the lifetime, reduces 40% of the energy consumption and has a better performance than LEACH protocol

EEUC (Energy Efficient Unequal Clustering) [6] scheme is distance based scheme and it also required that every node has global identification such as its locations and distances to the base station. Hotspot is the main problem in WSNs because of multi hopping that occurs when CHs closer to the sink tend to die faster compared to another node in the WSNS, because they relay much more traffic than remote nodes. This algorithms partition all nodes into clusters of unequal size, and clusters closer to the sink have smaller sizes than those farther away from the sink. Thus cluster heads (CHs) closer to the sink can conserve some energy for the inter-cluster data forwarding. . However, the extra global data aggregation adds overheads to all sensors and deteriorates the network performance, especially for a multi-hop network.

III. ENERGY EFFICIENT ROUTING PROTOCOL

A. Clustering algorithm

Clustering is the process of organizing the network into connected groups of nodes with one node as cluster head (CH). This CH acts as the leader for that particular group, which collects the sensed data from the members of that group and transmits those data's to the sink.

B. Homogeneous Networks

In case of homogeneous all nodes are identical in terms of battery energy and hardware complexity.

Some features of homogeneous network:

- In case of identical nodes, main design objective is to maximize network lifetime and also all nodes expires at the same time, providing a very little residual energy left behind during the network expires.
- Since every node has capable of acting as CH, it is important for each node to have the hardware which is capable of performing long distance transmissions.

C. Heterogeneous Networks

It is of two or more types of nodes with different hardware and energy capabilities. In this paper two types of nodes are used: normal nodes and high energy nodes and high energy nodes acts as a cluster head.

Some of the salient features of heterogeneous networks are

- In case of predetermined cluster head nodes, the member nodes use a single hop communication to reach the cluster head nodes.
- Only the CH nodes are responsible for data transmission to sink all other nodes are designed with short range communication.

There are normally three types of resource heterogeneity in sensor nodes:

- Computational heterogeneity
- Link heterogeneity
- Energy heterogeneity

Computational Heterogeneity:

Nodes have more powerful microprocessor and more memory than the normal nodes. With the powerful computational resources, the heterogeneous nodes can provide complex data processing and longer term storage.

Link Heterogeneity:

Nodes has high-bandwidth and long-distance network transceiver than the normal nodes. It provides more reliable data transmission.

Energy Heterogeneity:

Nodes are line powered or its battery is replaceable.

In this paper, energy heterogeneity has been taken as a constrain. Routing protocol has been built to increase the life span of the network by ensuring a heterogeneous distribution of nodes in the clusters [19].

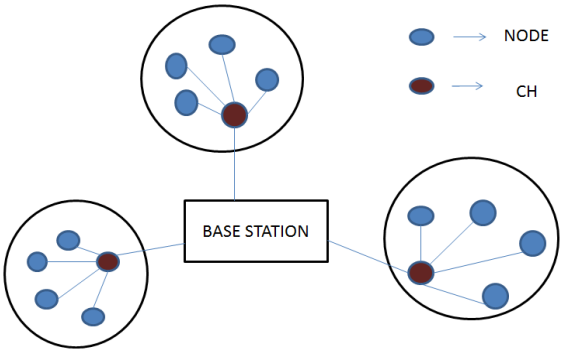

Fig.1. Proposed Structure

The routing infrastructure:

The core idea is to choose the cluster head based on the highest residual energy remaining in the nodes. This maximizes the network lifetime and the CH is choosed on random probability.

There are three phases of operation here, they are: Cluster head selection phase, Cluster formation phase and Data transmission phase

In Cluster Head Selection phase, the base station sends the notification to the sensor network about the cluster heads selected for that particular round, based on the residual energy remaining in each node. Next is the Cluster Formation phase, the selected CHs send advertisement messages to every node it can reach on the network. Based on the received signal strength of the advertisement, the nodes send join request to the CHs. The CH accepts the request and joins them as a cluster member. Thus several clusters are formed. The last phase is the Data Communication phase, in which the CH sends TDMA schedule to each of its member nodes. This TDMA schedule indicates when a node has to transmit its data to the CH in order to avoid collisions during transmission. The nodes can keep their radio turned off till their turn to transmit data arrives. This reduces the wastage of energy if radio maintained in ON state always. Each node transmits the sensed data along with the remaining or residual energy information to the CH. Then, the CH aggregates the data and energy information transmitted by each node and sends it to the base station or the sink node.

The cluster head nodes consume more energy than the member nodes because of its functionalities.

Consider E_m and E_h be the energy consumed by the member nodes and cluster head nodes. Let sensor node r has a residual energy $E_r(n)$ at the starting of round n and $E_r(n+1)$ at the next round n+1, then the equation becomes

$$E_r(n+1)=\begin{cases} E_r(n)-E_m \ , if\ it\ is\ member\ node \\ E_r(n)-E_h \ , if\ it\ is\ cluster\ head \end{cases} \quad (1)$$

Say if two nodes a and b have same have the same energy at the beginning of round n and n+α rounds.

$$|E_a(n+\alpha)-E_b(n+\alpha)|=|E_a(n)-E_b(n)|=0\leq (E_h-E_m) \quad (2)$$

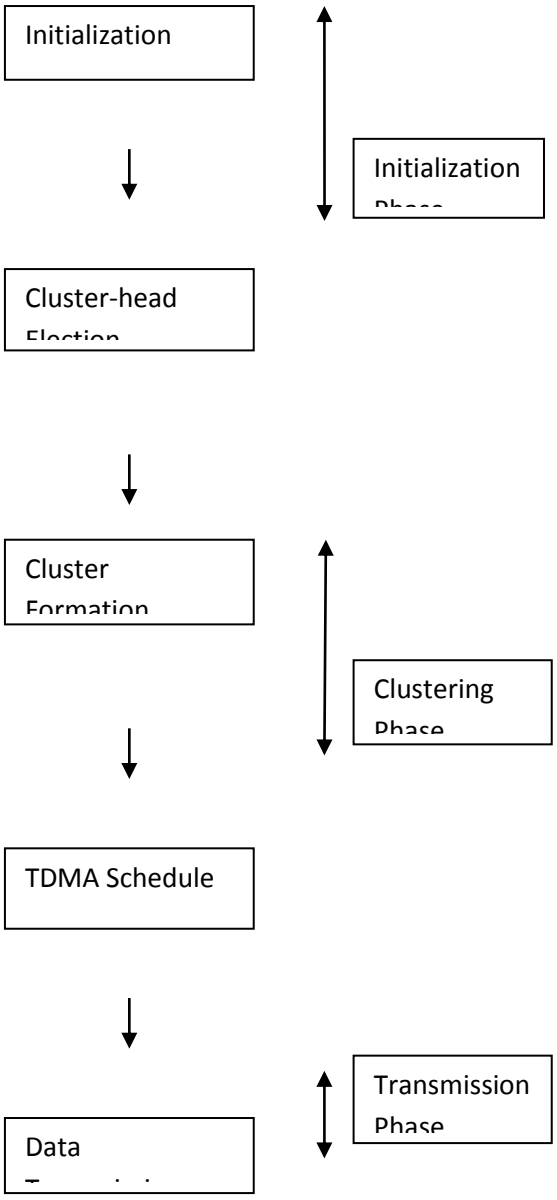

Fig.2. Proposed algorithm

IV. PERFORMANCE EVALUATION

The simulation was performed in NS2 and two scenarios were chosen :

Sparse Scenario: There were 16 random nodes deployed over 100m × 100m field.

Dense Scenario: There were 50 random nodes deployed over 100m × 100m field.

In this section, we provide an evaluation of the performance of both homogeneous and heterogeneous network. The performance metrics taken into account are energy efficiency, delay, throughput, overhead and residual energy.

The energy efficiency of the sensor nodes can be defined as the total energy consumed/total bits transmitted. Energy is the important resource of WSN nodes, and it determines the lifetime of WSNs.

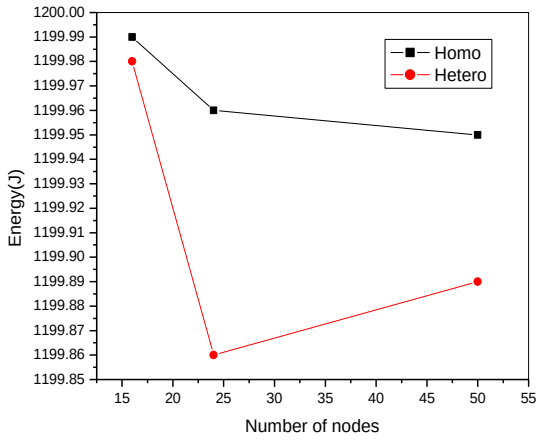

Fig.3. Number of nodes Vs. Energy.

Fig. 3 shows the energy comparison graph with number of nodes. The results show that the Heterogeneous network has least energy consumption than Homogeneous network.

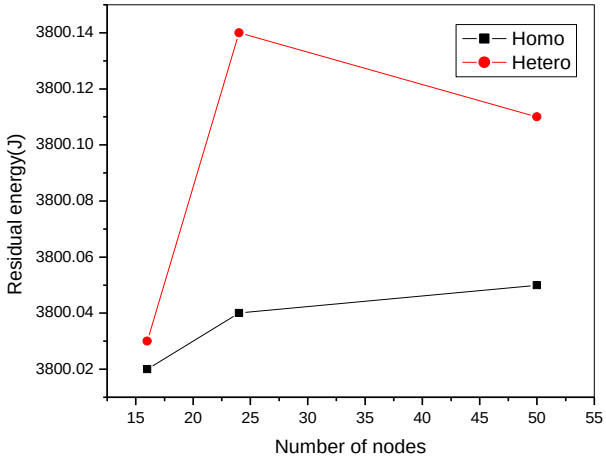

Fig.4. No of nodes Vs. Residual energy

Fig. 4 shows the comparison of No of nodes Vs Residual energy. Heterogeneous network has the high Residual energy. Residual energy is less in the case of Homogeneous network.

Packet delivery ratio is the ratio of number of packets received to the number of packets sent averaged over all the nodes.

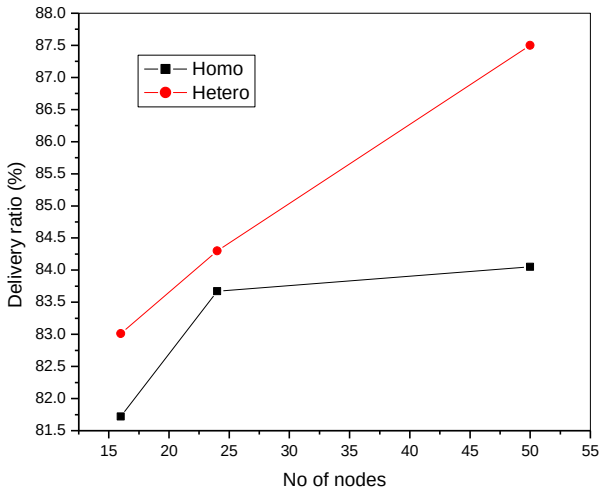

Fig.5. Number of nodes Vs. Delivery Ratio.

Fig. 5 shows the comparison of delivery ratio vs. number of nodes. From the results obtained, it has been shown that delivery ratio is very less in case of Homogeneous. Delivery ratio is high in case of Heterogeneous network.

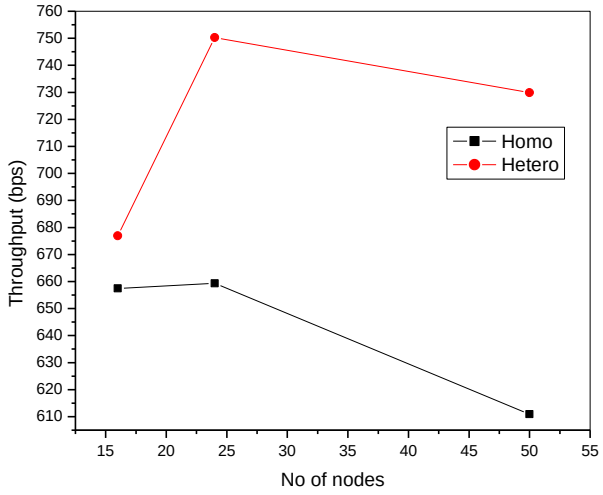

Fig.6. No of nodes Vs. Throughput.

Fig. 6 compares the No of nodes Vs Throughput.The result shows that the throughput is high in case of Heterogeneous network and less in Homogeneous network.

The average delay is the average time taken by the packets to reach the base station.

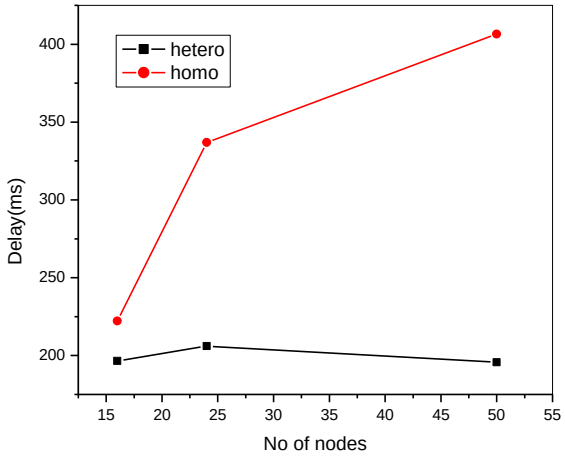

Fig.7. Number of nodes Vs. Delay.

Fig. 7 shows the comparison of delay with number of nodes. The delay is less in Heterogeneous network than that of the Homogeneous network.

V. CONCLUSION

In this paper, an efficient way of data routing for WSN has been proposed. Data routing is done using clustering mechanism in a established route with the help of CH nodes to reach the sink. Our proposed algorithm using clustering technique is extensively compared for both homogeneous and heterogeneous protocol regarding delivery ratio, delay, throughput, energy and residual energy. By using two levels of energy for the nodes to improve delivery rate, the obtained results clearly shows that our proposed algorithm outperformed the homogeneous algorithms for all evaluated scenarios. The performance of the clustering algorithms in saving energy for heterogeneous wireless sensor networks showed that energy efficient clustering protocols for heterogeneous WSN have better performance than energy efficient clustering protocols for homogeneous WSN in prolonging the network lifetime. Finally, the heterogeneous wireless sensor networks are more suitable for real time applications as compared to the homogeneous counterpart.

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