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Life Time Maximization in DOA Protocol for Mobile Ad-Hoc Networks

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***Abstract*— Energy efficient routing is the most important design criteria as mobile nodes are powered by batteries with limited capacity and that the power failure of a single mobile node not only affects the node itself but also its packet forwarding ability and hence the overall network lifetime. Energy consumption is directly proportional to the square of the distance among the nodes. It directly affects the lifetime of network and the problem becomes more serious as the size of the network increases. In order to minimize energy consumption and to increase lifetime of the network we propose an Energy Efficient DOA protocol (EEDOA) using HEF as a cluster-based scheme solution to this problem. This is done to make it suitable even for dynamic environment. The performance of other multicast routing protocols like AODV and DSR using HEF has been analyzed and then evaluated in terms of energy efficiency. Simulation results of the three protocols with HEF show that the performance of the protocols has been improved compared to the results without HEF on an average by 30 to 40 percent.**

***Keywords*— Clusters, Energy consumption, Life time, MANET, HEF.**

I. Introduction

Energy consumption is the most important factor to be considered to determine the lifetime of a Wireless Sensor Network. In Wireless Sensor Network all nodes are Sensor nodes which are battery-powered and so limited with very low energy resources. Hence energy optimization techniques are used to allow preservation of energy for an extended network life-time [1]. Energy saving protocols need to be addressed for clusters of communicating nodes in order to improved energy efficiency in the entire network. The life time of a sensor network can be increased to some extent if the application layer and the protocols are designed to be energy aware. The power consumption of the sensor nodes can also be reduced by developing strategies that support lower energy wastage [2]. High energy consumption in MANETs is due to the following reasons:

Distant receiver via multi-hop communication may lead to longer query latency period and causes higher energy consumption; When many clients frequently contact the database server, the server may become overloaded and so the server response time and as the size of the network increases i.e., when the number of nodes in the network increases, then due to multi-hop communication across the network, the network capacity will drop rapidly. Hence many packets may be dropped due to congestion.

Therefore to integrate MANETs with the Internet for database access, designing an efficient and effective mechanism is required. Sometimes mobile nodes may have inconsistent information due to discontinuous communication and therefore respond differently. As a result, to acquire necessary information becomes a challenging task to form clusters and to ensure their stability.

In this work we have implemented HEF algorithm in DOA protocol to improve energy efficiency and thereby extended the lifetime of the network. The rest of the paper proceeds as follows. In section 2 we discuss about some of the existing works on DOA and HEF in MANETs. Section 3 elaborates on the proposed work and the HEF algorithm, section 4 and 5 shows simulation environment, results and discussion for analysis. Section 6 summarizes the work and concludes the paper with an idea for future work.

II. Related Work

In this section we have undergone a literature survey on some existing works related to our research in energy efficiency in DOA protocol for MANETs. In [3], the authors had examined two routing protocols for mobile ad-hoc networks namely Destination Sequenced Distance Vector (DSDV) and the Ad-Hoc On-Demand Distance Vector routing (AODV) and proposed an algorithm to facilitate efficient routing of the packet and failure recovery mechanism.

In [4] the authors proposed a cooperative MIMO scheme that prolongs the network lifetime with 75% of nodes remaining alive when compared to LEACH protocol. This scheme extends High Energy First (HEF) clustering algorithm and enables multi-hop transmissions among the clusters. They proved by the simulation results that tremendous energy savings can be achieved by adopting hard network lifetime scheme among the clusters. The algorithm proved that the network lifetime can be efficiently prolonged by using fuzzy variables.

In [5], a clustering strategy using a new heuristic parameter that combine between energy, mobility and number of data to select the Cluster-Heads was proposed. This clustering strategy was compared with Lowest-ID Cluster Algorithm (*LID*) and the results showed that the algorithm improves system performance and increases its life. In [6], the Last cluster-head Change algorithm (*LLC*) was designed to minimize the change of cluster-head and to provide better stability in the composition of system. In [7], Trust-based clustering schemes have been combined with the existing clustering solutions to improve security. In [8] and [9], High-Connectivity Clustering (*HCC*) for the cluster-head election was designed based on the degree of connectivity i.e., the number of neighbors to the node instead of the identities of the node. In this work a node has been elected as a cluster head if it has the highest connectivity among all neighbors. The problem that occurred here is that it suffered from frequent changes of cluster-head.

The algorithms used in every work differed on the criterion of selection of cluster-head. Among these algorithms some are the Lowest-ID Cluster Algorithm (*LID*) [10]. In this algorithm, each mobile host in the network was given a unique *id*. The node that has the smallest *id* among all nodes shall be elected as the cluster-head. Every cluster consists of the cluster-head and its neighbors. This *LID* algorithm is simple and fast in generating a large number of clusters so that it can be adjustable to changes in the network topology.

In [11], the authors had proposed two clustering algorithms. The first approach was Distributed Clustering Algorithm (*DCA*) which was targeted to "quasi-static" where the movement of nodes must be "slow". In this method the node whose weight is the greatest among all its neighbors was elected as the cluster-head. The second algorithm was Mobility-Adaptive Clustering algorithm (*DMAC*) which was designed for mobility of networks. Here each node would react locally to all changes depending on the status of cluster-head. In both algorithms, different weights are assigned to the nodes and assumed that each node has knowledge of its weight.

In other works the authors had taken into account, data management in ad hoc networks. In [12], [13] and [14] methods of replication was adopted to improve availability of data and to facilitate the update and allocation of data. The authors in [15] have analyzed the performance of AODV and DSR routing protocols using fuzzy inference system. In order to further optimize the LEACH algorithm, an optimal energy efficient cluster-heads selection algorithm LEACH-G protocol has been used to calculate the optimal number of cluster heads first based on energy model for LEACH algorithm, and then move to LEACH-G algorithm for optimization of cluster heads [16]. In [17] and [18], a rigorous formulation using linear programming to capture the issue of power consumption more precisely was used. The objective of the method was to design the routing while maximizing the network lifetime. They used heuristic algorithms to solve the linear program approximately.In [19], a centralized algorithm was used to determine the maximum lifetime based on the Garg-Koenemann algorithm for multicommodity flow.

In [20] and [22] the authors had focused on the routing problem in MANET to maximize the lifetime of the network. They propose a distributed routing algorithm that provided an optimal and centralized solution with a asymptotically small relative error. Their approach depends on formulation of multi-commodity flow considering different power consumption models and bandwidth constraints. This algorithm is suitable for both static and slowly dynamic networks. In [21] the authors had proposed an efficient cluster head selection algorithm (ECHSA), for efficient selection of the cluster head in Mobile ad hoc networks. They compared the results with several other protocols like LEACH-C and proved perfection.

In [23], we have implemented HEF algorithm in AODV and DSR routing protocols and proved that energy efficiency has improved. In [24] we have used Exponential Weighted Moving Average (EWMA) algorithm to reduce the problem of position estimation error and also used Expectation Minimization (EM) algorithm to estimate the nearest neighbor selection to enhance the performance of DOA.

III. PROPOSED WORK

In mobile ad hoc network (MANET) cluster head selection is considered a gigantic challenge. Electing a specific node as a cluster head is very important at the same time a sophisticated job. Fig. 1 shows an example for arrangement of nodes in a wireless sensor network.

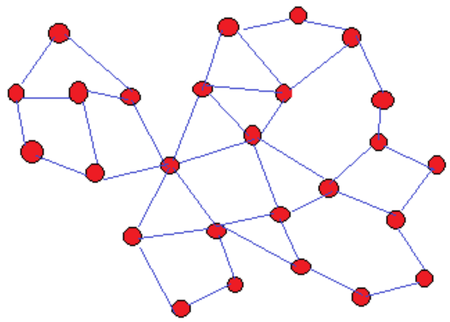

Fig. 1. An Example for Wireless Sensor Network

The cluster heads are the special nodes with higher energy. Usually the base station is considered as a cluster head which performs computational functions to reduce the number of transmissions to the base station so that energy can be saved. The advantage of clustering is that the latency can be minimized compared to flat base routing and flat based routing. Usually nodes that are very far from the base station lack the power to reach it. Hence Clustering based algorithms are the most efficient routing algorithms suitable for the WSNs.

The cluster heads that perform the function of transmitting the data to the base station usually consume more energy than the remaining nodes. Clustering schemes maintain the energy dissipation across the entire network to be balanced. Energy consumption in wireless networks is directly proportional to the square of the distance and since single hop communication is expensive in terms of energy consumption.

A. HEF Algorithm

HEF (High Energy First) is a centralized cluster selection algorithm which is used for electing the cluster head. This algorithm elects node with the highest residual energy to be the cluster head. Each round comprises of three phases namely: CHS Phase, CFM Phase, and DCM Phase [23].The steps involved in HEF algorithm are as follows:

1. The cluster head is selected based on the residual energy of each sensor node. The "setup" message is then sent with cluster ID to the cluster heads of other clusters.
2. The cluster head then broadcasts this "set up" message to all the neighbor nodes to make them join this group.
3. After receiving the set up message the regular nodes then send the "join" message to the corresponding cluster heads so that those regular nodes can also join this cluster.
4. Each cluster head then sends an acknowledgement and also the TDMA schedule to all the regular nodes.
5. The sensor nodes then perform tasks like sensing, processing and communication co- operatively at their individual clock cycle. The energy information is also transmitted during this cycle.
6. The cluster head also transmits all these information to the base station.

The cluster head's responsibility is to communicate with other nodes in its own cluster and also with the nodes of other clusters either directly or through the gateways. Communication is done in three steps. First, the cluster head receives the data from its members; second it compresses the data received, and then finally transmits them to the base station and other cluster heads. This is done for proper energy utilization and enhancement in the network lifetime [25] and [26]. Electing the best node as a cluster head is based on factors like location of the node with respect to other nodes, trust, mobility, energy and throughput of the node. Only one cluster head per cluster is selected during an election process, selection of multiple cluster heads within a single cluster may give rise to cluster reformation [27], [28] and [29].

B. Energy Consumption By A Regular Node

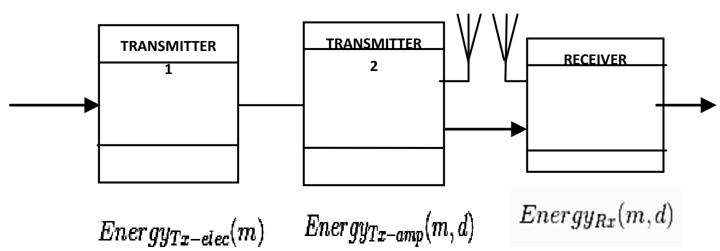

Fig.2. Energy model in wireless sensor network

The communication tasks contain two most important functions: transmitting and receiving.

$$Energy_{Comm} = Energy_{Tx} + Energy_{Rx} \quad (1)$$

Fig. 2 shows an example for energy model for radio propagation in wireless sensor network. This can be expressed by the following equations.

$$Energy_{Tx}(m,d) = Energy_{Tx-elec}(m) - Energy_{Tx-amp}(m,d) \quad (2)$$

$$Energy_{Rx}(m,d) = Energy_{Tx-elec}(m) \quad (3)$$

Thus the total energy consumption of Regular node is given by

$$Energy_{Total} = Energy_s + Energy_P + Energy_{Tx} + Energy_{Rx} \quad (4)$$

C . Energy Consumption for a Cluster Head

The cluster head node in every group senses environmental data and then aggregates its own data and data from sub-member nodes and sends to the base station. Let E_{da} denote the compressed energy consumption per bit.The total energy consumption for a cluster head is given by

$$Energy_{Total} = Energy_s + Energy_P + Energy_{Tx} + Energy_{Rx} + Energy_{da} \quad (5)$$

D. Energy Consumption per Round

Suppose there are K cluster heads, and (N-K) regular nodes alive in a round, then the energy consumption E is given by

$$E = \sum_{i=1}^{K} E\ Total + \sum_{i=1}^{M} \sum_{j=1}^{N-M} Erij \quad (6)$$

IV. SIMULATION ENVIRONMENT

Table 1 shows the simulation parameters used for analysis of the routing protocols DSR, AODV and DOA using HEF algorithm. The simulation has been carried out using NS-2 software.

Table 1.
Simulation Parameters

Simulator	ns 2.28
Routing Protocols	AODV,DSR,DOA
Radio Propagation model	Two ray ground
No. of mobile nodes	33
MAC layer protocol	IEEE 802.11
Maximum packets	50
Antenna model	Omni directional antenna
Channel Type	Wireless channel
X dimension	1800
Y dimension	700
Link layer type	LL

V. RESULTS AND DISCUSSION

In this section we have performed an analysis about the results obtained from simulation of AODV, DSR and DOA routing protocols using HEF algorithm. In all figures the curves in blue color indicates DOA, red for AODV and green indicates DSR protocol.

The parameters taken for performance analysis were packets received, Average Delay, throughput and Energy Consumption. All the four parameters were tested with respect to simulation time in seconds. The results obtained from simulation for various parameters are as follows.

A. Packets Received

The total number of packets received can be used to calculate the number of packets lost.

Packets received = Number of packets sent - Number of packets lost

Fig.3 refers to the graphs for Packets ReceivedVs Time obtained from simulation analysis for DOA over AODV and DSR protocols. DOA performs better than AODV and DSR as simulation time increases.

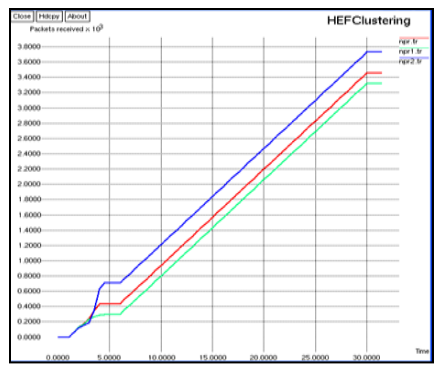

Fig.3. Packets Received Vs Time

Table 2.
Packets Received Vs Time

Packet Received vs Time (secs)			
Time	**DOA**	**AODV**	**DSR**
0	0	0	0
5	709	437	299
10	1210	938	800
15	1840	1568	1430
20	2470	2198	2060
25	3097	2828	2690
30	3727	3456	3320
Efficiency of DOA using HEF		DOA 14.5% efficient over AODV	DOA 23.2% efficient over DSR

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Table 2 shows the results obtained from simulation for packets received vs Time. It is observed that DOA with HEF performs better than DSR by 23% and by 15% over AODV.

B. Delay

Fig.4 refers to the graphs for Delay Vs Time obtained from simulation analysis for DOA over AODV and DSR protocols. DOA performs better than AODV and DSR using HEF as simulation time increases.

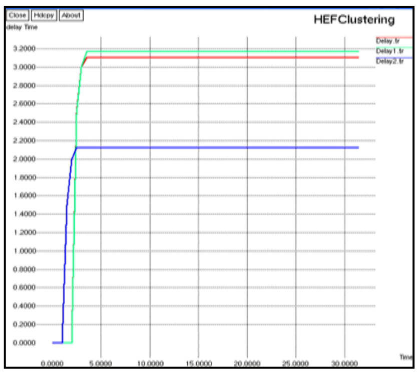

Fig.4. Delay Vs Time

Table 3.
Delay Vs Time

Delay (secs) vs Time (secs)			
Time	**DOA**	**AODV**	**DSR**
0	0 0	0 0	0 0
5	2.12	3.106	3.1659
10	2.12	3.106	3.1659
15	2.12	3.106	3.1659
20	2.12	3.106	3.1659
25	2.12	3.106	3.1659
30	2.12	3.106	3.1659
Efficiency of DOA using HEF		DOA 31.7% efficient over AODV	DOA 33.13% efficient over DSR

Table 3 shows the results obtained from simulation for Delay vs Time. It is observed that DOA with HEF performs better than DSR by 33.13% and by 31.7% over AODV.

C. Residual Energy

This is the energy remained in the node at any time, t. Fig.5 shows the simulation results for Residual energy Vs Time for the three DSR, AODV and DOA protocols.

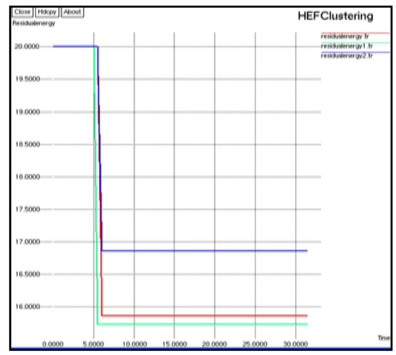

Fig. 5. Residual Energy Vs Time

Table 4.
Residual Energy Vs Time

Residual Energy (Joules) vs Time (secs)			
Time	**DOA**	**AODV**	**DSR**
0	20	20	20
5	20	20	20
10	16.86	15.86	15.73
15	16.86	15.86	15.73
20	16.86	15.86	15.73
25	16.86	15.86	15.73
30	16.86	15.86	15.73
Efficiency of DOA using HEF		4.19% improved over AODV	4.76% improved over DSR

Table 4 shows the results obtained from simulation for Throughput Vs Time. It is observed that DOA with HEF performs better than DSR by 4.76% and by 4.19% over AODV.

D. Throughput

Fig. 6 shows the simulation results of Throughput in DOA, AODV and DSR using HEF with respect to time. DOA produces better throughput than AODV and DSR.

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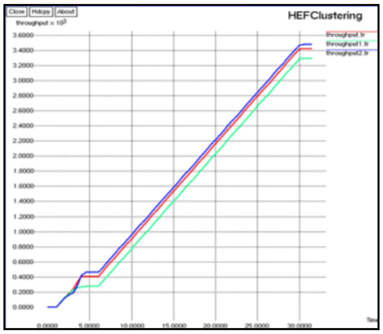

Fig.6. Throughput Vs Time

Table 5.
Throughput Vs Time

Throughput (Bytes) vs Time (secs)			
Time	**DOA**	**AODV**	**DOA**
0	0	0	0
5	459	406	274
10	960	907	775
15	1590	1537	1405
20	2220	2167	2035
25	2847	2797	2665
30	3478	3426	3296
Efficiency of DOA using HEF		2.8% improved over AODV	10% improved over DSR

Table 5 shows the results obtained from simulation for Throughput Vs Time. It is observed that DOA with HEF performs better than DSR by nearly 3% and by 10% over AODV.

VI. Conclusions And Future Work

Energy efficiency is in turn related to the problem of life time maximization. In this work we have presented an energy aware routing protocol DOA using High energy first clustering algorithm (HEF). This cluster head selection was based on residual energy level of the node. We have compared our results for DOA protocol with other routing protocols AODV and DSR and proved that DOA performs better in all cases taken for analysis. Thus HEF can be used for real time sensor network applications. In future the number of nodes and number of packets transmitted between the nodes can also be increased.

Some of the observations for conclusion are given below.

- HEF minimizes energy consumption of node by the concept of cluster head selection.
- The actual delay is less than the analytical worst case delay bound for which HEF is designed.
- DOA using HEF is energy efficient compared to other protocols AODV and DSR.

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