Modified OCABTR based Hierarchical Two Level Data Aggregation in Wireless Sensor Networks

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***Abstract*— In Wireless Sensor Network (WSN), it is necessary to optimize the energy of the sensor node. Each sensor node is equipped with a battery which is used for sensing and processing the data. Cluster based data aggregation and transmission reduce the communication overload by eliminating the redundant data transmission. In this paper, an energy efficient hierarchical data aggregation technique based on Optimized Cluster Algorithm Based on Target Routing (OCABTR) is proposed. In this approach, data aggregation is performed twice in order to reduce the data size so that network life time can be increased. Genetic algorithm is used for self-organizing the nodes into clusters based on the nodes sensing the similar targets and cluster head election is performed based on the cost and energy of the node. Low Energy Adaptive Clustering Hierarchy (LEACH) routing protocol is used. The proposed technique is simulated using Network Simulator and various performances have been studied.**

Keywords- Genetic Algorithm; Clustering; Data Aggregation; Energy Efficiency.

I. INTRODUCTION

Due to several advantages in the technology of Micro Electro Mechanical System (MEMS) and developments in wireless communication, wireless senor network has been emerged [1]. The wireless sensor network is an ad-hoc network which consists of light weighted wireless nodes called sensor nodes, deployed in physical or an environmental condition. These sensors are used to measure physical parameters such as sound, pressure, temperature, humidity etc. Sensors are equipped with a battery which is used to carry out the data processing and communication capabilities. Fig. 1 shows some of the applications of sensor networks. Sensor networks can be used for detecting animals in the forest and also used for surveillance mission in military applications. In hospitals, sensors are used for monitoring patients and it can also be used in home automation etc. The main advantage of sensor node is that, it can with stand in any harsh environment. Also due to high flexibility, compatibility and robustness, the sensor network is highly used in many applications.

A wireless sensor network consists of hundreds to thousands of sensor nodes that can be deployed in a particular region for sensing an event. These sensors can be manually placed in the sensing field or can be dropped by helicopter in the harsh or no man environment. Each sensor node is equipped with the elements like sensors to sense the target, on board radio for transmitting and receiving the sensed data, data processing unit for processing the sensed data, memory for storing the data and the board is equipped with a battery for performing all the above mentioned operations. Sensor nodes can be kept stationary or movable based on the application. Many algorithms have been developed to minimize the energy consumption in wireless sensor networks. The general method used to reduce the energy is to switch over the sensor node to sleep mode, once it senses an event. The energy consumption for a node, which is in transmit (or receive) mode is same as that of the node which is in an idle mode.

In WSN, there is a high probability that, more than one sensor node senses the same target results in data redundancies. If each sensor node transmits the sensed data directly to the Base Station (BS) without any control packets, there will be a lot of redundant data at the BS. This results in the wastage of energy, bandwidth, cost and also it leads to collision. To avoid the above difficulties, redundant data transmission should be eliminated. Data Aggregation (DA) is a technique to eliminate data redundancies. It is a method of correlating the sensed data into single data and transmitting it to the base station.

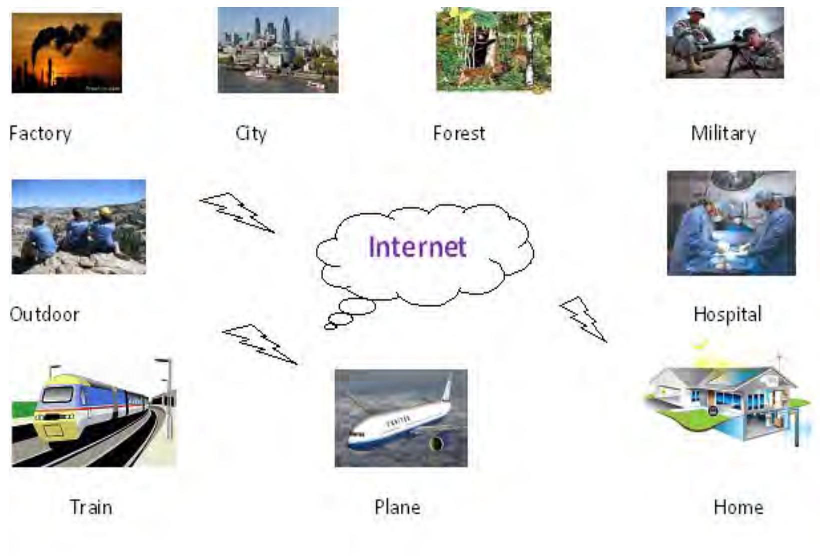

Fig 1. Applications of wireless sensor network.

Optimal Clustering Algorithm Based on Target Recognition (OCABTR) describes an optimized cluster formation based on the nodes sensing the similar target in order to reduce the communication cost. Data aggregation in wireless sensor network is a data transmission technique by which several packets from sensor nodes are combined into one [2]. Due to the reduction of data packets, energy consumption reduces; network lifetime increases and data transmission ratio gets improved [3].

In this paper, a Hierarchical Two level Data Aggregation based on OCABTR (HTLDA-OCABTR) is proposed. The sensor node sensing the similar targets are grouped into clusters. Communication cost and energy are also considered for forming a cluster. A node which is accessible to all other nodes in the cluster is elected as cluster head. Cluster head gathers the sensed data from the corresponding cluster nodes and aggregate it. Parent node of all cluster heads is called Head of Cluster Heads (HCH) which is elected that should be accessible to all the cluster heads. All cluster heads transmit the aggregated data into head of cluster head node for second level of data aggregation to reduce the data size. The reduced single data is alone transmitted to the base station, instead of sending all cluster heads data to the base station. By doing so communication overload and energy consumption can be further reduced and network life time can be increased.

This paper is organized as follows. The methods of data transmission in WSN is discussed in section II, concept of cluster forming using OCABTR in section III, proposed hierarchical two level data aggregation using OCABTR as HTLDA-OCABTR in section IV. Section V describes about simulation results and conclusion and future enhancement are discussed in section VI.

II. METHODS OF DATA TRANSMISSION

In WSN, each sensor node senses some data and the same are transmitted to the sink node or base station. The methods of transmitting the sensed data to the sink node or base station can be classified into three models namely one hop model, multi hop model and cluster hierarchical model [4].

A. *One hop model*

In one hop model as shown in fig. 2, all sensor nodes are attached to the base station directly. So each and every sensor node transmits the sensed data directly to the base station or sink node. There is only one hop between each source to destination in this model. The advantage of one hop model is less communication failure as all nodes are independent nodes. If any node becomes dead, data will be sensed by some other nodes and will be transmitted directly to the base station. The limitation of this model is higher energy consumption, as the sensed data has to travel a long distance to reach the base station.

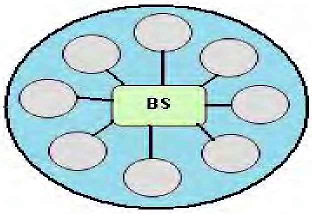

Fig 2. One Hop Model

B. Multi Hop Model

Fig. 3 shows multi hop model, in which sensor nodes are formed into groups by connecting the sensor nodes one after the other and finally to the base station. The sensed data is transmitted to the neighbor node and finally it reaches the destination or base station. This involves the data transmission taking multiple hops from source to destination. When compared to the one hop model, the energy consumption is far limited in multi hop model as the node transmits the sensed data only to its neighbor node. In case of failure in the node attached to the base station, the whole link of the node fails. But still, if a node attached directly to the base station fails, all the events can be sensed and transmitted to the base station by another set of nodes. This implies higher reliability in multi hop when compared to one hop model.

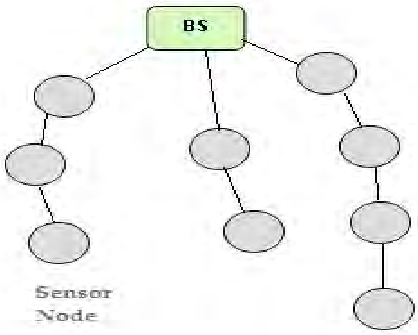

Fig 3. Multi Hop Model

C. Cluster Hierarchical Model

In Cluster based model shown in fig. 4, nodes are grouped together in the form of clusters and a Cluster Head (CH) is elected for each cluster, based on metrics like energy level, accessibility to all other nodes, node density etc. The nodes within the cluster are called Cluster Nodes (CNs) and head of the cluster is called Cluster Head (CH).

The sensed data from each cluster node is transmitted to its corresponding cluster head for aggregation. All cluster heads transmit the aggregated data to the base station. As the sensed data are aggregated into single data at the cluster level itself, communication overload reduces, hence lifetime of the node increases. As aggregated single data is only transmitted from each cluster; energy consumption in cluster hierarchical model is less when compare to one hop and multi hop model.

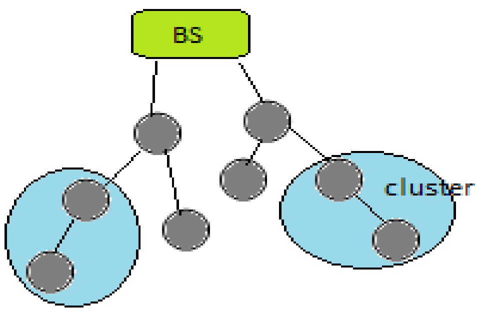

Fig 4. Cluster Hierarchical Model

III. OPTIMAL CLUSTER ALGORITHM BASED ON TARGET RECOGNITION (OCABTR)

In wireless sensor network, clustering is a method which reduces the energy consumption of a node and increases the network lifetime. It reduces the redundant data transmission, as the sensed data are aggregated and transmitted. LEACH is the first hierarchical cluster based routing protocol. It uses randomization of cluster head to balance the energy level of each sensor node in the network [3]. There are two phases in LEACH, first is set up phase and second is steady state phase. In the first phase, nodes are formed into clusters and in the second phase data are transmitted. Genetic algorithm is an Evolutionary Algorithm (EA), which generates an optimized solution for problems using techniques inspired by natural evolution such as inheritance, mutation, selection and crossover. Energy efficient clustering can be constructed using GA. C number of clusters can be formed using N number of sensor nodes. Nodes are formed into clusters based on the accessible range, energy level, cluster distance, distance between two clusters etc. The term chromosomes here can be assumed as total number of sensor nodes, each gene in the chromosomes represents single sensor node, it can be either a Cluster Node (CN) or Cluster Head (CH) [5] [6].

Optimal Clustering Algorithm Based on Target Recognition (OCABTR) is a technique which is used for periodically gathering the data in WSN [3]. The operation of OCABTR is as follows. Genetic algorithm is used for segregating the nodes which sense the similar targets. The nodes which sense the same target is formed into clusters. Based on the communication cost, energy level, and node densities are considered for electing the cluster head. LEACH is a cluster based routing protocol to transmit the sensed data from cluster node to cluster head. Once cluster head performs data aggregation, aggregated data is transmitted to the base station.

IV. PROPOSED ALGORITHM

The sensed data is directly transmitted to the base station in traditional one hop model. Energy consumption is higher in this model. Then multi hop model was introduced which uses hop by hop transmission to transmit the sensed data. Energy consumption in this multi hop model is slightly lesser when compared to one hop model. Then clustering model came into picture, in which a group of sensor nodes are formed into clusters. Each cluster has one Cluster Head (CH) and the members of the cluster are called Cluster Node (CN). The sensed data from each CN is transmitted to the corresponding CH. all CHs aggregate the corresponding CNs data and transmit to the base station.

A new approach called Hierarchical Two Level Data Aggregation based on OCABTR (HTLDA-OCABTR) is proposed. A centralized node is elected which is accessible to all cluster heads. This is a parent node for all cluster heads and can be named as Head of Cluster heads (HCH). The role of head of cluster head is to collect the aggregated data from all cluster heads. The collected cluster heads data are aggregated again by head of cluster head to narrow down the data size. The aggregated data from head of cluster head is transmitted to the base station. As the data size is reduced by performing total energy consumption is reduced and network life time is increased.

In the proposed Hierarchical Two Level Data Aggregation (HTLDA-OCABTR) algorithm, cluster is formed based on OCABTR. OCABTR uses genetic algorithm to form cluster and cluster head election takes place. Cluster heads do data aggregation operation and transmit the aggregated data to the head of cluster head to perform another level of data aggregation. Head of cluster head transmits the aggregated data to the base station.

For example, consider there are few sensors nodes for sensing the highest temperature in a particular region which is shown in fig 5. The sensed data from sensor nodes 2 and 3 are 36 and 32 respectively, from that highest temperature 36 is sent out. Node 5's data is 30 and that is compared with the existing result and highest temperature 36 is sent out. The same process is repeated for all sensed nodes and finally aggregated result is transmitted to the base station. In some cases more than one sensor sense same value, so while aggregating, such redundant values can be eliminated.

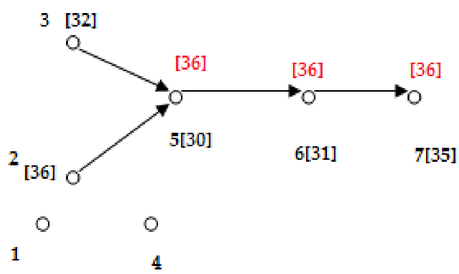

Fig 5. An example of Data Aggregation

A. One Level Data Aggregation based on OCABTR (OLDA-OCABTR):

Fig. 6 shows cluster formation based on OCABTR algorithm. OCABTR in which nodes are formed into clusters. This can be done by segregating the nodes in the sensing which senses the similar target using Genetic Algorithm. Cluster head is elected using GA based on the communication cost, energy level, and node densities. Due to segregation of nodes which senses the similar target communication overload can be reduced and network life time of a node can be increased. All sensor nodes transmit the sensed data to the cluster head. Cluster head aggregates the corresponding cluster nodes data into single data and transmits to the base station. This approach can be named is one level data aggregation based on OCABTR as OLDA-OCABTR.

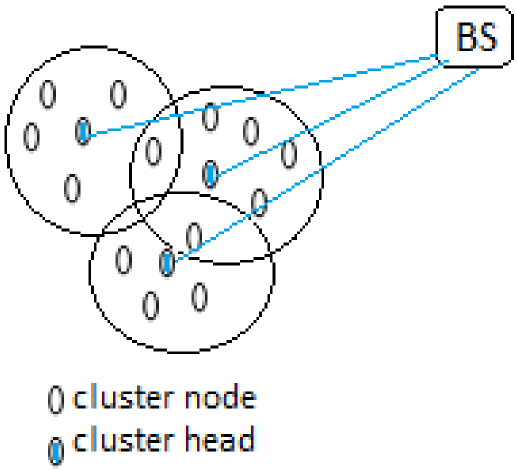

Fig 6. One Level Data Aggregation (OLDA)

B. Proposed Hierarchical Two Level Data Aggregation in based on OCABTR (HTLDA- OCABTR):

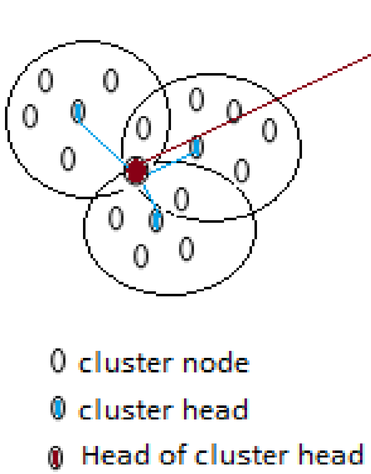

Fig 7. Hierarchical Two Level Data Aggregation (HTLDA)

In HTLDA-OCABTR, the concept of OCABTR is used to create a wireless sensor network scenario. Cluster is formed using genetic algorithm based on the nodes sensing the similar targets and cluster head is elected. For some applications, only exact value of sensed data is needed to take decision, so the sensed data can be still narrowed down based on the requirement. Fig. 7 indicates the two level data aggregation, in which Cluster Heads (CH) do first level of data aggregation and transmits the aggregated data to the Head of Cluster Head (HCH) instead of sending it to the BS. The HCH again performs data aggregation of all cluster heads data which is called second level of aggregation or Hierarchical Two Level Data Aggregation based on OCABTR (HTLDA

- OCABTR). Based on the applications, sensed data can be aggregated to single data and the same is transmitted from head of cluster head to the BS. As single data is being transmitted from sensing area to the BS energy consumption is can be reduced. Table I gives an overview of the proposed algorithm.

TABLE I PSEUDO CODE OF HTLDA-OCABTR

Start
Set initial network setup
Generate N no of nodes
Using GA form clusters (based on fitness)
Do cluster head election
Do cluster head of cluster head election
{
Sense
Transmit the sensed data to the cluster head
Perform one level data aggregation by cluster head
}
Transmit all cluster heads data to head of cluster head
{
Perform two level data aggregation by head of cluster head
}
Transmit head of cluster head data to the base station
End

V. SIMULATION AND RESULTS

Using NS-2 simulator, a wireless sensor network scenario is created with various number of nodes like 50, 75, 100 and 125. Table II shows few network parameters considered for designing the network. OCABTR uses genetic algorithm for cluster formation based on the metrics as like discussed earlier. For these various numbers of nodes, performances of packet delivery ratio, total energy consumption, throughput, end to end delay and control overheads are analyzed and discussed for both OLDA- OCABTR and proposed HTLDA-OCABTR.

TABLE II PARAMETERS CONSIDERED FOR SIMULATION

Parameter	**Value**
Sensing field size	100x100(m^2)
R_x threshold	3.652e-10
B.W	288000(bps)

TABLE III PACKET DELIVERY RATIO FOR DIFFERENT NUMBER OF NODES

No of nodes	**OLDA**	**HTLDA**	**Relative difference**
50	21.3552	37.1154	15.7602
75	41.7874	69.3110	27.5236
100	61.6959	99.7468	38.0509
125	57.0988	99.505	42.4062

Table III describes the packet delivery ratio for various numbers of nodes for both OLDA-OCABTR and proposed HTLDA-OCABTR. Let the number of packets received during the transmission be P_r and the number of packets transmitted be P_t, so the packet delivery ratio can be calculated using the formula (1):

$$\text{Packet Delivery Ratio} = \frac{Pr}{Pt} x100 \qquad (1)$$

Fig. 8 shows the packet delivery ratio for both OCABTR and proposed HTLDA-OCABTR. It can be observed that packet delivery ratio of proposed hierarchical HTLDA two level data aggregation algorithm is more when compared to one level OLDA data aggregation algorithm.

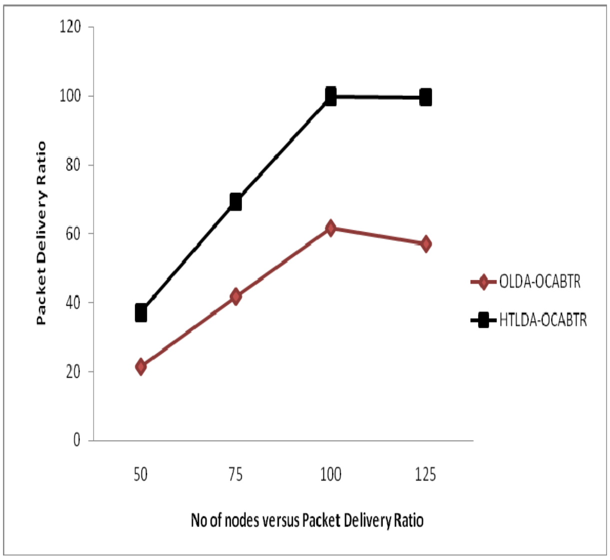

Fig 8. No of nodes versus packet delivery ratio

The relative difference between OLDA-OCABTR and HTLDA-OCABTR for nodes 50, 75, 100 and 125 are 15, 27, 38 and 42 respectively.

TABLE IV TOTAL ENERGY CONSUMED (JOULES) X10^3 FOR DIFFERENT NUMBER OF NODES

No of nodes	OLDA	HTLDA	Relative difference
50	223.401	216.975	6.42
75	368.824	361.402	7.42
100	489.854	487.579	2.27
125	608.781	605.956	2.82

Table IV gives the value of the total energy consumption for various numbers of nodes. Total energy consumed is the energy taken for transmitting the data from sensor nodes to base station. This can be calculated using the formula 2. Fig. 9 shows the energy consumption for various nodes in both OLDA-OCABTR and HLDTA OCABTR. Let an initial energy of the sensor node be $E_{initial}$, energy consumed for data transmission is $E_{consumed}$ and let the remaining energy be E_{remain}. So the total energy consumed for sensor nodes can be given in (2):

$$Econsumed = Einitial - Eremaining \qquad (2)$$

From Fig 9, it can be observed that the total energy consumed for HTLDA-OCABTR is slightly lesser when compared to OLDA-OCABTR. The relative differences between the energy for different number of nodes are 6.42, 7.42, 2.27 and 2.82 for the number of nodes like 50, 75, 100 and 125 respectively.

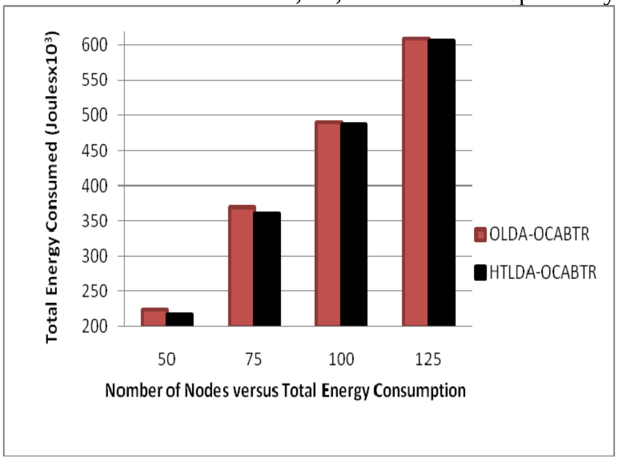

Fig 9. No of nodes versus Total Energy Consumption

TABLE V THROUGHPUT FOR DIFFERENT NUMBER OF NODES

No of nodes	OLDA	HTLDA	Relative difference
50	571.733	1338.13	0766.397
75	946.133	2301.87	1355.737
100	1778.40	2731.73	0953.330
125	1149.33	2787.20	1637.870

Table V gives the throughput value for both the existing and proposed algorithm. Throughput can be calculated using the formula:

$$Throughput = \frac{packet\ size \times Ptx \times 8}{Data\ Transmission\ Duration} \quad (3)$$

It can be seen that Throughput is high for the proposed HTLDA approach and the relative difference is given in the table. Fig 10 shows the comparative study between throughput of OLDA-OCABTR and the proposed HTLDA-OCABTR algorithm. The relative differences of throughput value between the two algorithms are 766, 1355, 953 and 1367 for the number of nodes like 50, 75, 100 and 125 respectively.

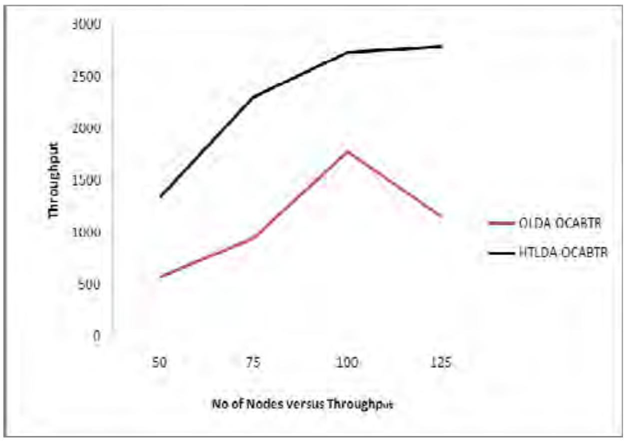

Fig 10. No of nodes versus Throughput

TABLE VI END TO END DELAY FOR DIFFERENT NUMBER OF NODES

No of nodes	OLDA	HTLDA	Relative difference
50	.295594	.11099	.1846
75	.278633	.142196	.1364
100	.313565	.141718	.1718
125	.586696	.138431	.4482

Table VI shows the values of end to end delay for both algorithm for various number of nodes. Let the receiving time for a data at the destination or base station be R_t and the starting or transmitting time be T_t. The end to end delay can be calculated as :

$$End\ to\ End\ Delay = \frac{Rt - Tt}{Total\ number\ of\ packets} \quad (4)$$

The relative difference value of end to end delay between the two algorithms are shown in fig 10. It can be seen that delay is almost same for both the algorithms. And delay is more for OLDA-OCABTR algorithm when compared to the proposed HTLDA-OCABTR algorithm. The relative difference are 0.18, 0.13, 0.17 and 0.44 for 50, 75, 100 and 125 respectively. This is clearly shown in fig 11.

Overhead data is a control data or control packets with the data packets that travels from source to destination. More number of control packets results in more energy consumption.

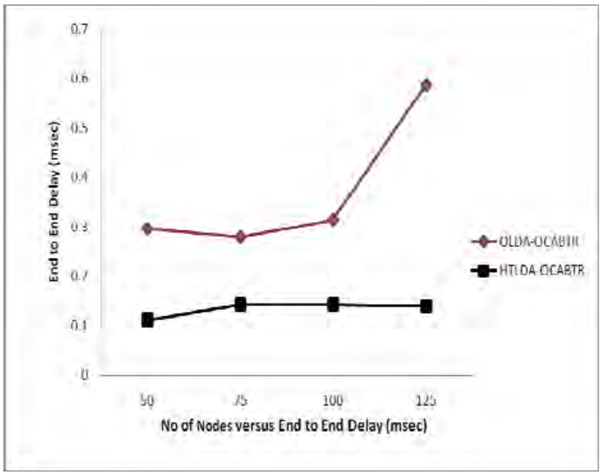

Fig 10. No of nodes versus End to End Delay

Table VII shows the number of control ovehead packets travelled from source to destination for various number of nodes for both the algorithms.

TABLE VII CONTROL OVERHEADS FOR DIFFERENT NUMBER OF NODES

No of nodes	OLDA	HTLDA	Relative difference
50	3357	2650	0707
75	5565	4559	1006
100	8061	7006	1005
125	10034	7895	2139

From the above table, number of control overheads is more in OLDA-OCABTR than HTLDA-OCABTR. If there is high number of control packets, delay will be more and energy consumption for a node will be high, so network life time is drastically reduced.

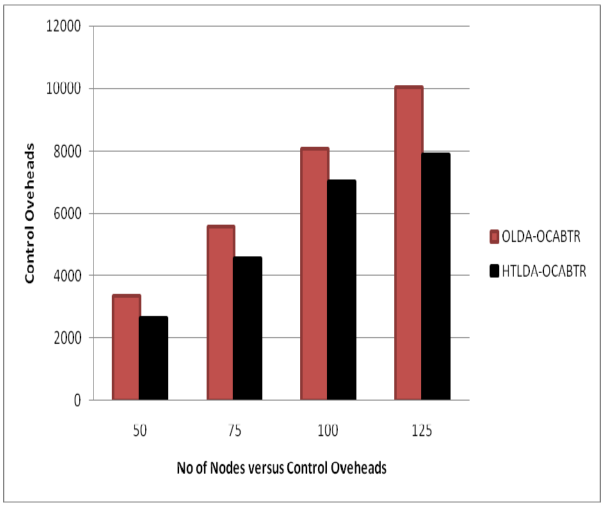

Fig 11. No of nodes versus Control Overheads

Fig. 11 shows the number of control packets that travels between source to destination in both algorithms. Number of control packets in OLDA-OCABTR is more than HTLDA-OCABTR.

VI. CONCLUSION

In the proposed HTLDA-OCABTR algorithm, two levels of data aggregation are performed to extend the network lifetime. A comparative study is made between OLDA-OCABTR and HTLDA-OCABTR and results are discussed. The result implies the performances of HTLDA-OCABTR which is better than OLDA-OCABTR algorithm. This work can be further motivated towards reducing the energy consumption by performing multiple hierarchical data aggregation. This in turn may increase the network lifetime.

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