SADA Data Aggregation and Delivery Protocol for Wireless Sensor Networks

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Abstract - The wireless sensor is deployed to sense large amount of data from the far places. With the large deployment of the sensor networks, it faces major issues like energy consumption, dynamic routing and security. The Energy efficient structure-free data aggregation and delivery (ESDAD) is the protocol which is hierarchal in nature. The base station localizes the position of each sensor node and defines level of each node for the data transmission. In the ESDAD protocol, the next hop node is selected on the basis of cost function for the data transmission. In this research work, improved in ESDAD protocol is proposed in which gateway nodes are deployed after each level for the data transmission. The sensor node will sense the information and transmit it to gateway node. The gateway node aggregates data to the base station and simulation results show that improved ESDAD protocol performs well in terms of energy consumption and number of throughput.

Keywords - Energy efficient Structure-free Data Aggregation and Delivery Protocol, Low-energy adaptive clustering hierarchy, Ant Colony Optimization, Particle Swarm optimization

I. INTRODUCTION

A network in which large number of self-directed, distributed, and low powered devices known as sensor nodes are deployed is known as wireless sensor network. The information related to the surroundings in which the network is deployed, is sensed, collected and then transmitted in order to be processed by concerned applications. There can be around hundreds to thousands of sensor nodes present within the network [1]. The information which is to be transmitted to the base station is passed through a data fusion mechanism first since there is limited power and the communication range is also less within these networks. With the help this, the accuracy of network increases and the overhead is minimized. Data fusion node is the node that performs data fusion in these scenarios. The maximum power within these networks is consumed during three main activities which are the sensing, computing as well performing of radio operations. However, amongst these three also, the energy consumed by radio operations is the highest [2]. Thus, the amount of time that is being consumed during the sensing and receiving of information is to be minimized as major objective within the energy efficient mechanisms. While receiving of information, higher power is consumed by nodes in comparison to when transmitting it. Most of the power of nodes is consumed when the channels need to be listened to in ideal manner and when overhearing the packets. Within WSNs, there are several routing protocols proposed amongst which Low Energy Adaptive Clustering Hierarchy (LEACH) and Power-efficient Gathering in Sensor Information Systems (PEGASIS) are the popular ones [3].

A Time-division Multiple Access (TDMA)-based MAC protocol for routing and energy consumption is known as Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. There increment of overall lifetime of these networks is the major objective of this protocol. LEACH helps in minimizing the energy consumption and generated and maintains the cluster heads within the networks [4]. There are two major phases which are repeated within the LEACH protocol. They are Set-up Phase and Steady Phase. The generation of clusters and then choosing cluster heads for them on the basis of highest energy remaining is known as set-up phase. The aggregation of data at the cluster heads and then transmitting it to the base station is done at steady phase that takes normally higher time than the previous phase [5].

II. RELATED WORK

Singh, *et.al* [6] proposed a novel LEACH protocol by utilizing hybrid ACO/PSO based routing which is known as NN-based RZ LEACH. This protocol is proposed for the mobile sink based wireless sensor networks. In order to identify the shortest route which can help in minimizing the energy being consumed by the networks, the hybrid ACO/PSO is applied. The CH selection process is enhanced with the help of NN approach. With the help of both of these enhancements, the overall lifetime of the network can be incremented. On the basis of several parameters such as first dead node, all dead nodes, energy left and the average energy left, the technique is evaluated. During the evaluations, the numbers of nodes are also changed within one specific region. In terms of minimization of energy and increasing the lifetime of the network, this technique has provided effective results as per the simulations. Kaddi, *et.al*[7] proposed novel routing protocol which is named as Kangaroo Method-based

(KMbased) adaptive routing protocol. The information is transmitted from cluster head nodes to the base station with the help of optimal path. The lifetime of the network is improved here due to the enhancement in its performance. As per the simulation results, it is seen in terms of energy consumption and lifetime of network, the proposed protocol provides enhanced results in comparison to the existing LEACH protocol. Ghosh, *et.al*[8]proposed LEACH-DS-ACO which is an enhancement of the genuine LEACH protocol. This protocol is proposed in order to increase the lifetime of WSNs. As, the number of active nodes present within a cluster is |DS| that is also a subset of cluster nodes, there is minimization of data latency. Within closer time duration, a node death is indicated by the results achieved through LEACH-DSACO. This results in providing better load balancing within the network. Due to a fixed base station, there are homogeneous and static nodes only involved here. The operation cost of the networks in minimized when a deterministic node distribution is called for within an application. Krishna, *et.al*[9]presented a study related to LEACH in order to provide vitality proficient grouping computation for the WSNS. Within the remote sensor systems, one of the commonly used group based structures is Low Energy Adaptive Clustering Hierarchy. A TDMA based MAC technique is utilized by this filter and the vitality utilization is adjusted as major objective through this filter. The results of various parameters such as the lifetime of network and the energy being consumed are calculated in NS2 tool within this paper such that the performance of proposed filter can be evaluated. Enhancement is seen within the results as per the simulations achieved. Kumar, *et.al* [10] presented in this study a routing protocol named as ENHANCEDLEACH. Numbers of connections within the cluster are utilized as per the proposed technique. A cluster head is chosen b each cluster and the information is passed on to the base station through this CH. The previously existing LEACH protocol and ENHANCED LEACH are compared within the simulations. Form the cluster, the base station is placed at equal distance and the clusters communicate directly with it. The force level of a chosen cluster is not included. Thus, through this mechanism, the lifetime of the network in increased in comparison to other protocols in terms of several parameters.

III. IMPROVED ENERGY EFFICIENT STRUCTURE-FREE DATA AGGREGATION AND DELIVERY (IESDAD) PROTOCOL

The IESDAD protocol is improved version of ESDAD protocol for the data aggregation in wireless sensor networks. In the ESDAD protocol, the logical topology is constructed for the data transmission. When the logical topological is constructed cluster heads are selected in the network. The cluster heads select its next hop in the step of judicial data transmission. In the IESDAD protocol, gateways are deployed after each hop to forward data to next hop. The cluster head select its nearest gateway using Euclidian distance. The cluster heads need not to next its next hop for the data transmission which reduce routing overhead and also improve network lifetime. IESDAD protocol works in three phases they are shown in Fig.1

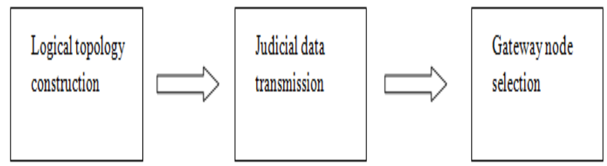


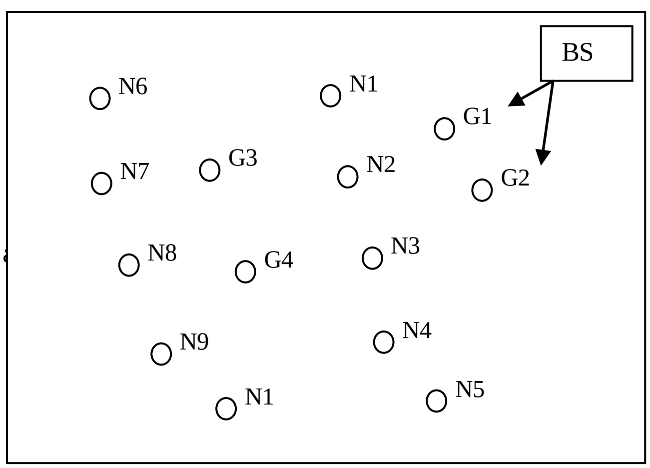
Fig.1 Phases of IESDAD

3.1. Logical topology construction

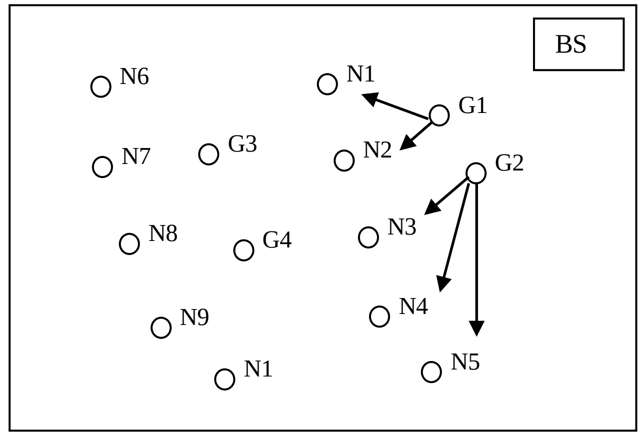
The problems that have been caused due to the redundant number of nodes and their deployment in dense manner can be minimized with the help of topology control. By utilizing the least power, the connectivity is preserved with the help of topology control. During the logical topology construction phase, the position of node itself, its neighboring nodes, as well as the base station is must. Once the sensors are deployed within an area, the BS initiates the logical topology construction phase. A “HELLO” message is broadcasted by BS in order to initiate the topology construction. When the logical topology construction process is to be carried, the “HELLO” message received by a node is transmitted further. In order to prevent collision amongst the peer nodes, the “HELLO” message is transmitted randomly by each node.

In order to reach towards the BS, the “HELLO” message includes within it the node ID, location information, energy level, buffer status as well as the hop-count *(hc).* hc=0 is the condition for the HELLO message that is broadcasted by the BS. The hc is set as one by the sensor node that hears the HELLO message that has been transmitted from the BS. *hc* is sent two by the sensor node that receives this HELLO message and similarly this continues. From the several received HELLO messages, the neighbor that has least hc value is chosen by the node. The *hc* of its own is set to minimum *hc+1* by the node itself. The first logical level is generated by gathering all the nodes that have *hc* one. Similarly, logical level two is generated by the nodes that have value of *hc* as two and the generation of levels similarly continues. Until all the nodes are included within a hierarchy or the logical topology is generated completely, this process continues. HELLO messages are broadcasted in order to identify their location after time out by the orphan nodes that are not involved within the logical topology. Once the HELLO message is received from neighborhood, the position and hc value is set by the orphan nodes [11].

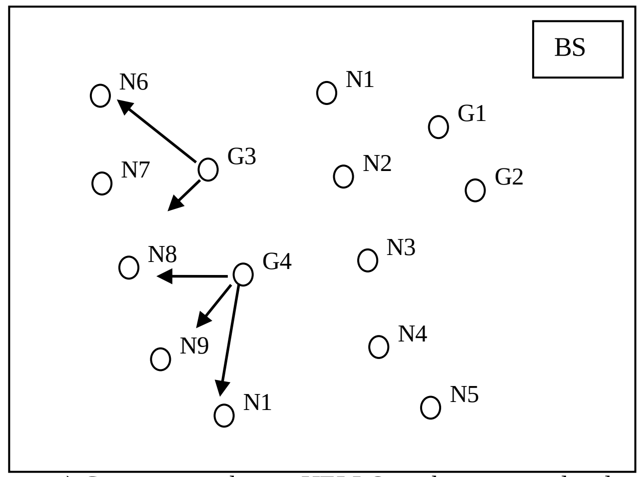
In this method, a structure free topology is included and no static structure in involved. The forwarding of data to certain level is decided by the nodes however the particular node to which the data is to be transferred is not decided. The complete details of the neighboring nodes are known by each node once the topology construction phase is completed. Only at the initial phase, the logical topology is constructed and unlike other structure based topology constructions, there is no need to reinitiate it. The neighborhood of the node is recognized by the initial topology construction phase. The topology of WSN keep changing when a node is dead, due to which is known as dynamic in nature. When the energy level of a network goes below certain threshold value, the topology construction phase is generated by the structure based topology control protocols. The energy consumption of the networks is increased due to this. The energy that is being spent on the topology generation is now saved due to the presence of structure-free data delivery technique within the proposed protocol. On the basis of cost function, new nodes are chosen for transmitting the data once the neighboring node of a particular node is dead. Thus, without reconstruction of topology, the topology changes can be handled by the proposed protocol. The logical topology construction within a sensing field is shown in Fig.2. The transmission of HELLO packet from base station is shown in Fig. 2(a). In the next figure 2(b), the HELLO packet is being transmitted by the gateway. Further, the packets are transmitted to next level by gateway as shown in Fig.2(c). Fig.2(d) shows the logical node hierarchy generated within this sensing area [11].



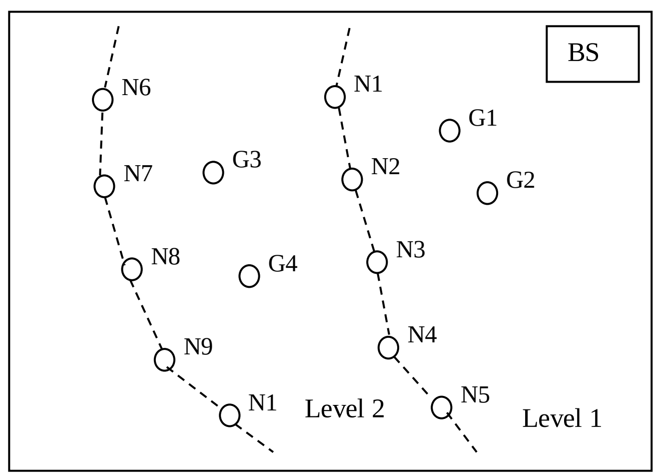
a) BS transmit HELLO packet to Gateway nodes



b) Gateways transmit HELLO packet



c) Gateways exchange HELLO packets to next level



d) Logical Node Hierarchy

Fig.2 Logical topology of nodes

3.2. Judicial data transmission

Large amount of co-related and redundant data is generated due to the dense deployment of sensor nodes within the sensing field. When the sensed data is selectively forwarded to the aggregation point, there is a possibility of reducing the energy consumption of WSN. The sensing reliability within the sensing fields is needed to be of different levels within several WSN applications. Different reliability weights $(w_j, 1 \leq j \leq n_s)$ are assigned in the sub-regions amongst which the numbers of sub-regions are denoted $by\ n_s$. The requirement of QoS is decided on the basis of weight factor that is assigned to sub-region. The delay and data delivery ratio of a particular region are two of the parameters which define QoS of a network. There are different sensing reliability requirements of the sensing field. An accurate scenario of the event can be generated when more amounts of data is gathered related to the event procedures. Thus, there is direct proportionality of the amount of data gathered and the reliability of event that is occurring [12]. On the basis of required level of reliability, the complete sensing zone is partitioned into sub-regions by the proposed method. On the basis of reliability requirement for a particular region, the number of sensors that can be allowed to transmit the sensed data is decided. There is a need to gather higher amount of data from the sensor nodes in comparison to lower reliability, in the event that is being performed for transmitting the sensed data. Thus, to achieve the required level of reliability within a sub-region, the data is transmitted by proposed protocol such that the energy can be conserved. If an event is occurring within the sensing radius, there is the possibility for sensor node to sense it. The reliability factor (r_f) is assigned by each sensor to the sensed data further. Using Eq 1:, the $(r_f)$of sensory data is calculated as:

$$r_f = \frac{d_{dense} - d_{Event-Sensor}}{100} \quad \text{---- (1)}$$

Here, the distance amongst the event and sensor node that is sensing it is denoted by$d_{Event-Sensor}$. The sensing radius of the sensor node is denoted byd_{dense}. The accuracy of nodes that are closer to the event is higher in comparison to the ones that are far from them [13]. However, the identification of radius of the affected region can be done with the help of nodes that are far from that particular node. The decision whether the data is to be transmitted or not on the basis of (r_f) is only made by the sensor node. In case of $r_f \geq tr_f$, the data is transmitted by the sensor node. for a node, the threshold reliability factor for an event is given by tr_f which can be computed as given below in Eq 2:

$$tr_f = \frac{100 - w_j}{100} \quad \text{---- (2)}$$

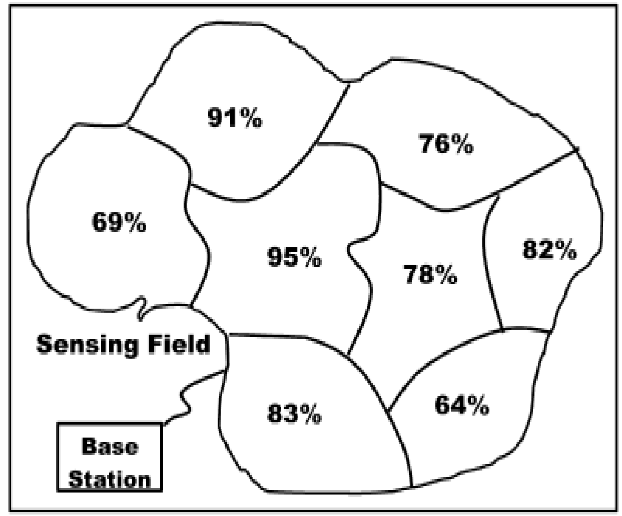


Fig.3 Sensing field with required different levels of sensing reliability

3.3. Gateway Node selection

In the last phase of the algorithm, the gateway nodes are deployed in the network. The gateway node depends upon the total number of nodes which is described by the Eq 3:

$$G_{nodes} = n/4 \quad \text{--- (3)}$$

Here, G stands for Gateway node. The total numbers of nodes are denoted by n. The gateway nodes are the forth part of the total nodes. The best node is selected from the all gateways nodes to send data to the base station. The distance between the base station and gateway node calculated with Eq 4:

$$\text{Distance} = \sqrt{(x(i) - x)^2 + (y(i) - y)^2} \quad \text{---(4)}$$

In order to transmit the packet of its own or for data aggregation towards the base station, the gateway node is chosen by the sensor node. The gateway is chosen sensibly in order to sense unique data by the sensor node. Within the structure-free aggregation and routing, the selection of nexthop is a major concern. On the basis of distance function, the gateway node is chosen within the proposed protocol. The distance calculation formula is given in the equation (6). Thesensor node which is nearest to the gateway node is selected as the data forwarding gateway.

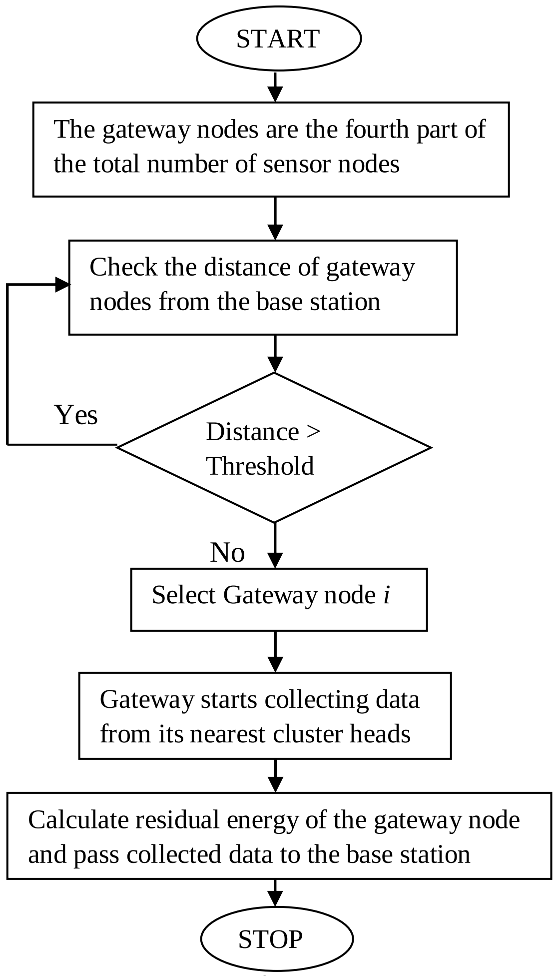


Figure.4 Flowchart of the gateway node

IV. PERFORMANCE EVALUATION

NS-2.35 simulation tool is used in order to evaluate the performance of proposed protocol. Comparisons are made amongst the existing structure-free data aggregation protocolssuch as Real-time data AGgregation (RAG)[15], and Structure-Free and Energy-Balanced data aggregation (SFEB) [16] within a multi-hop network and the proposed ESDAD protocol. The simulation parameters of the proposed protocol are summarized within Table I. Within the area of 500 X 500 m^2, there is random deployment of 400 sensor nodes within the network. Around 50 m of transmission range (dtran) is set for a sensor node along with 200 kbps of data rate. For sensor nodes, 50m is the sensing range set and the length of packet is up to 60bytes. 0.6 J (joules) of initial energy is provided for each sensor node. In order to transmit and receive a bit, 50 nJ/bit of energy is consumed. During sensing, around 0.083 J/s of energy is consumed along with 5 nJ/bit/signal of energy consumption during aggregation and 10 pJ/bit/m^2 of energy consumption during radio amplification. Within the sensing field, after every 3 seconds there is random generation of events. The aggregation of packets that include similar event id (EID) is done. Around 65 packets of buffer length is sent for each node. Sub-regions are created by dividing the complete sensing area randomly. Within every simulation, the sensing reliability is assigned randomly to each of the sub-region. For 35 seconds, the simulation is run around 25 times. For best possible results, the average value of runs is considered.

With respect to certain parameters like average energy consumption, miss ratio and end-to-end delay, the performance of proposed protocol is evaluated and compared with other existing protocols. In order to evaluate the performance of WSNs, the most important parameter to be considered is average energy consumption. The energy consumed while transmission of data is depicted through this parameter and through this, the life time of complete network is also predicted. The percentage of packets which are not delivered to the Base station within the time limit and discarded within the delay sensitive applications helps in computing miss ratio. In order to calculate the miss ratio, for for each generated packet the value of Time-To-Deadline (TTD) is set similarly as in RAG. Within the congested real time sensor network application, miss ratio is very important when a reliable event is to be reported. The time span from the generation of packet till its delivery to the destination is known as end-to-end delay which is very important within time bound data communication system to evaluate its performance.

TABLE I: Simulation Parameters

No.	Simulation Parameters	Value(s)
1	Area of sensor field	500 X 500 m^2
2	Number of sensor nodes	400
3	Packet length	60 bytes
4	Buffer length	65 packets
5	Initial node energy	70 J
6	Bandwidth	200 Kb/s
7	Sensing length	50 m
8	Radio range	40 m
9	Propagation model	Two ray
10	Eelec	50 nJ/bit
11	Esense	0.083 J/s
12	Eagg	5 nJ/bit/signal
13	Eamp	10 pJ/bit/m2

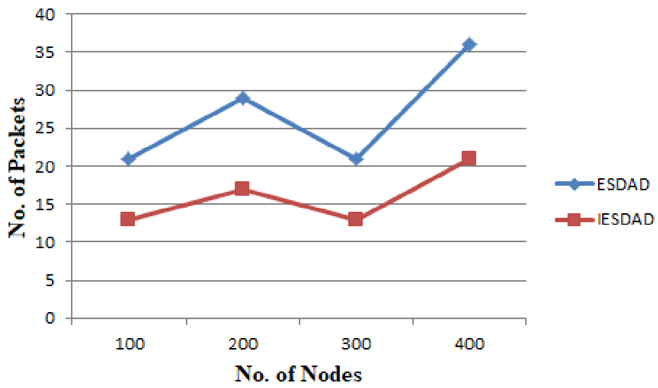


Fig.5 Energy Consumption Comparison

As shown in figure 3, the performance of ESDAD and IESDAD protocol is compared in terms of energy consumption. It is analyzed that energy consumption of IESDAD protocol is low as compared to ESDAD protocol

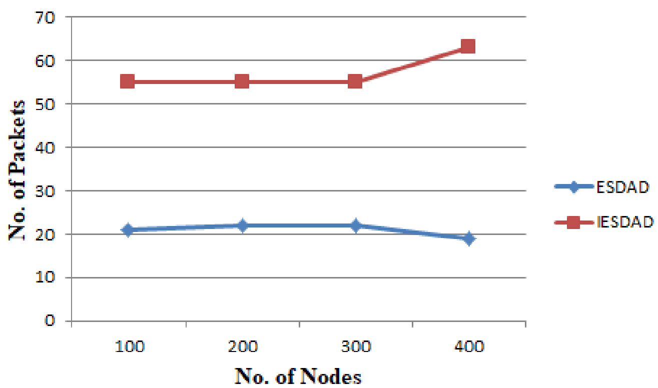


Fig .6 Throughput Comparison

As shown in figure 4, the ESDAD and IESDAD protocols are compared in terms of number of throughput. The throughput of the IESDAD protocol is high as compared to the ESDAD protocol.

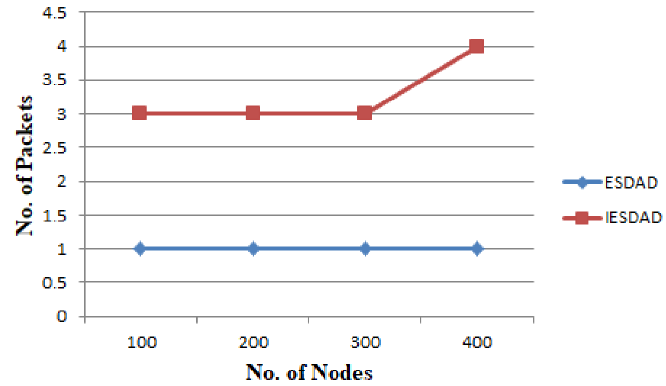


Fig.7 Lifetime comparison

As shown in figure 7, the ESDAD and IESDAD are compared in terms of network lifetime. It is analyzed that IESDAD protocol has higher lifetime as compared to ESDAD

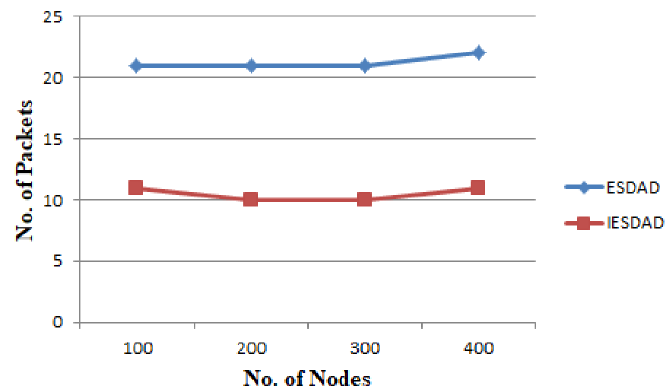


Fig.8 Packetloss comparison

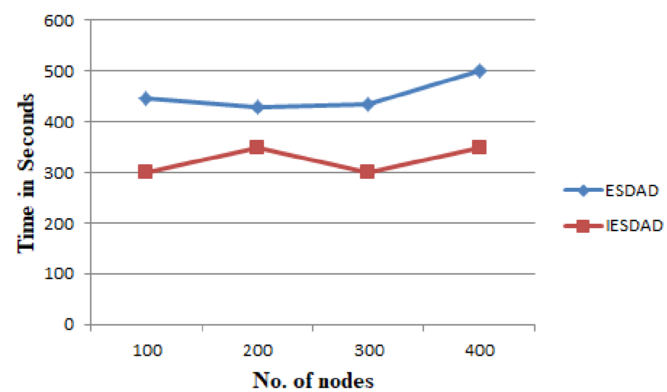


Fig.9 Delay comparison

As shown in figure 9, the delay of the ESDAD and IESDAD protocol is compared and it is analyzed that delay of IESDAD protocol is less as compared to ESDAD protocol

V. CONCLUSION

In this paper, it is concluded that wireless sensor network is the decentralized type of network. The energy consumption is the major issue due to far deployment and small size of the sensor nodes. The ESDAD protocol is the energy efficient protocol in which the sensor nodes can sense information and pass it to next hop node. The next hop node is selected on the basis of cost function. In this research work, gateway nodes are deployed in the network in which sensor nodes transmit data to gateway node. The gateway node then sends data to the base station. The simulation results show 15 to 20 percent improved in improved ESDAD protocol as compared to ESDAD protocol.

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