

April 2012

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Recommended Citation

Bhovi, Ajit K.; Sutagundar, A. V.; Manvi, S. S.; and Halakarnimath, B. S. (2012) "Tree Based Aggregation and Routing in WSN: A Multi-agent System Approach," *International Journal of Computer Science and Informatics*: Vol. 1 : Iss. 4 , Article 1.

Available at: <https://www.interscience.in/ijcsi/vol1/iss4/1>

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Tree Based Aggregation and Routing in WSN: A Multi-agent System Approach

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Abstract - In WSN one of the issues is to route the data from the sensor nodes to sink node. The tree-based approach provides an efficient solution for establishing the path and in network aggregation. Tree is nonlinear structures, which have hierarchical levels in terms of parent-child combination. In this work the tree is constructed using the software agents. The proposed scheme uses multiagent system that comprises of both static and mobile agents. On every sensor node of WSN agent platform is running that coordinates the agent communication. Tree Construction Agent (TCA) is mobile agent that is generated at the sink node. TCA uses the angle of constraint for the construction of the tree. In the proposed work along the tree in network aggregation is done that saves the energy and reduces the delay. Aggregation Agent (AA) gets the routing information and visits the nodes along the path (tree) for data aggregation based the correlation of the sensor node data. Finally the aggregation agent routes the aggregated data to the sink node.

Keywords - Tree, Correlation, Angle of constraint, Routing and aggregation.

I. INTRODUCTION

A Wireless Sensor Network (WSN) [1][2][3] comprises of a large number of nodes equipped with different sensor devices. Each sensor nodes consists of sensing module, tiny operating system, a transceiver, memory, processor and a small battery. WSN have been widely used in the fields of environmental monitoring, military applications, disaster management, etc. One of the major challenge in WSN is energy or power constraint regarding power resources and computational capacity.

Routing Algorithms [4] can be proactive, reactive, centralized, distributed, broadcast, etc. Routing means transferring the data from target to sink. The authors proposed different kinds of protocols [5], [6], [7], [8], [9], [10], [11] in this field.

A tree [12] is a nonlinear data structure, which is derived from real tree. A tree data structure is considerably more constrained in its variety than a real tree and is typically viewed upside down, with its root at the top and leaves on the bottom. A tree is usually accessed from its root, then down through its branches to the leaves. A tree may be described as a nonlinear

container of nodes. The nodes provide storage for contained objects as well as references to other nodes for connectivity. Nodes are connected by edges.

The next task is to aggregate [13] the data for increasing the life time of network. Data aggregation is method to combine the data coming from different sources by eliminating redundancy, minimizing the number of transmissions and thus saving energy. An aggregator can compute the sum, average, minimum or maximum of the data from different nodes and send the aggregation result to sink node through specified route.

Agent-based systems are more suitable for providing flexible and adaptable services in a distributed environment [14]. Agents are the autonomous programs located in environment, which perform dedicated tasks either by itself or interacting with other agents in the environment. Agent architectures are especially suitable for realizing frameworks for context-aware services as they satisfy the following properties: modularity, scalability, adaptability, and distributive. Mobile agent systems perform tasks by roaming in an environment and interacting with other mobile agents as well as the nodes in an environment. Mobile agents also aggregate

the data from all sensor nodes and help in routing the aggregated data to sink node.

In this paper we propose the tree based in network aggregation and routing algorithm using multiagent system. In tree based aggregation and routing first the tree is constructed by using certain parameters and then data is routed to sink from event generated area.

The rest of our paper is organized as: section 2 presents the proposed work, section 3 describes simulation and section 4 describes the simulation procedure and section 5 presents the conclusion of the proposed work.

II. PROPOSED WORK

This section presents the system environment, tree based aggregation and routing, proposed agency and agent interaction.

2.1. System Environment

In this work we propose the tree based aggregation and routing in WSN using multiagent system. In tree structure there is one parent node that has two child nodes. In tern the child node (parent node) have the two child nodes. This process of creating the tree structure continues in hierarchy. Figure 1 presents the system environment. In this work we consider 3 levels. In first level only sink node (SN) is present, in second level parent nodes are present like P1, P2, P3 ... Pn and in third level children nodes are present like C1, C2, C3... Cn. Children nodes are at lowest level just like leaves of real tree, parent node acts as branches of tree and sink node acts as root of the tree. The data is routed from lower level to higher level i.e. children nodes to sink node. The aggregation is done in the node where more than one node joins it.

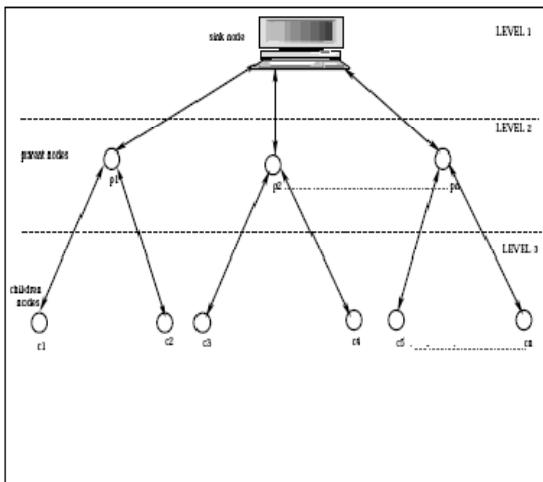


Fig. 1 : System Environment

2.2. Tree based aggregation and routing (TBAR)

This section presents the tree formation phase and data aggregation and routing.

2.2.1. Tree formation phase

- 1) Deploy sensor nodes manually in the grid from in a network environment.
- 2) Assume one node as sink node in network environment and it also called as 1st level node. It constructs the tree by taking angle of constraint (Φ) [15], [16]. Φ is calculated by sending sink id and sink location to one hop neighbor. Sink sends exchange message to find the one of neighbors. A sink message comprises of the sink node id and location information. Using the Φ sink node finds its children nodes. These set of nodes are called as parent nodes and also called as 2nd level nodes, which is shown in figure 2.

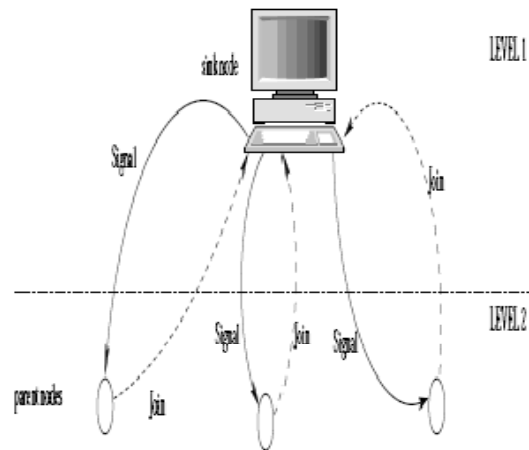


Fig. 2 : Joining of parent nodes to sink node

- 3) These parent nodes decrease Φ by α degree and again the process is repeated at every parent node. Some of the problems that are encountered during the tree construction are:

- Check whether they are already joined some node or no.
- Check whether it is a sink node.
- Check whether two parents have Common children.

If all conditions are satisfied then nodes sends their id and location to their respective parent node along with joining parent node which is shown in figure 3. The set of nodes that has joined the parent node are called as children nodes and also called as 3rd level nodes. This process is repeated until the entire network is covered.

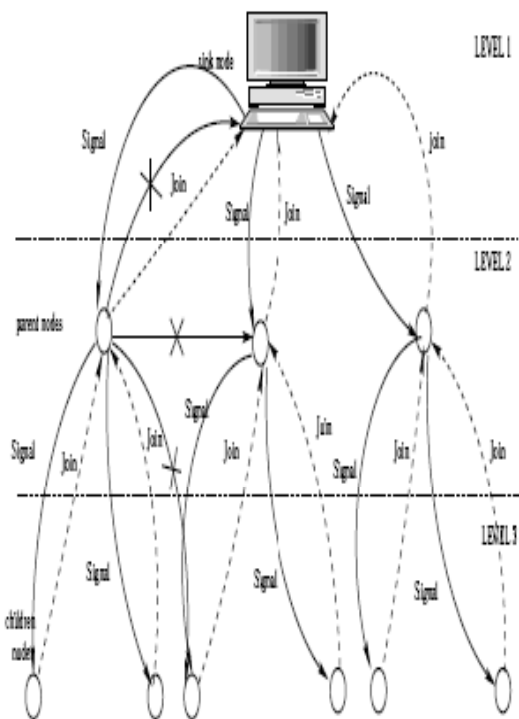


Fig. 3 : Joining of children nodes to their respective parent node

2.2.2. Data aggregation and routing

In this work we propose sink driven data aggregation and routing, whenever the user is interested in the data, user sends the request through the sink node.

- 1) Sensor nodes sense the target compares with the previous data, which is stored in node database. If there is deviation in sensed data with previous data sense data is updated in the database else the data is discarded from the node.
- 2) Whenever the nodes have data, nodes send the data to their parent node. In parent node the data is aggregated in order to eliminate the redundant data. Intern the aggregated data is sent to their parent node, which is shown in figure 4.

There are many methods to find angle of constraint like convex position estimation and semi definite programming. But in this work Semi definite programming (SPD) is used.

In SPD the angle is calculated by equation 1.

$$\Phi = \tan^{-1} \left[\frac{S(y) * n_1(y)}{S(x) * n_1(x)} \right] \quad (1)$$

Where, $s(x, y)$ is sink node location and $n(x, y)$ is node location.

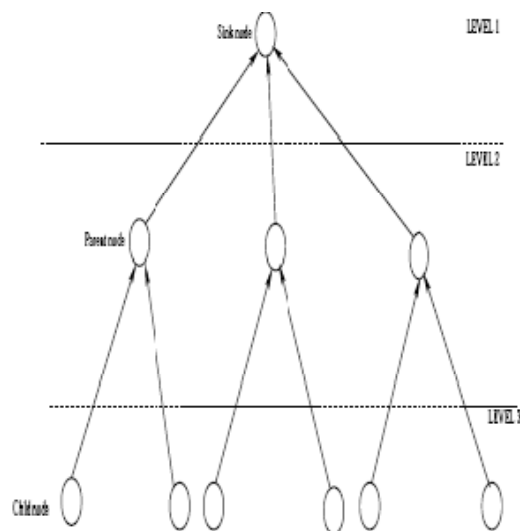


Fig. 4 : In network aggregation along the tree

2.3. Agencies

In this work, we propose multi agent system to minimize the energy loss, delay, and to increase network lifetime of WSN. We propose three agencies namely: Sink agency, Parent agency, and Node agency.

2.3.1. Sink agency

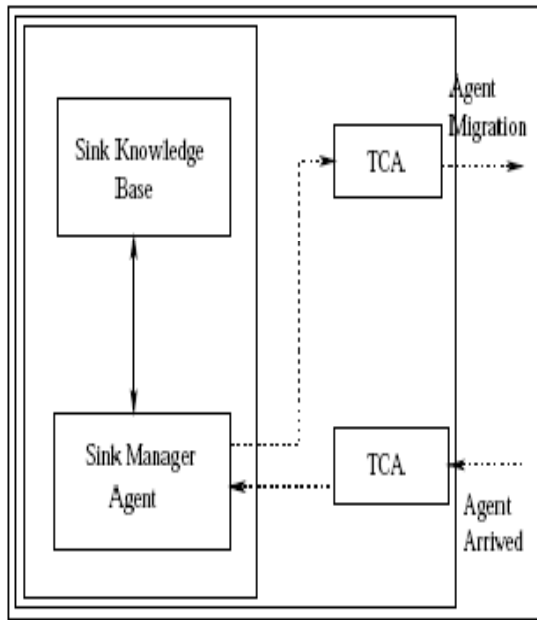
Sink agency comprises of one static agent; one mobile agent and a Sink Knowledge Base (SKB) for inter agent communication. Agents are Sink Manager Agent (SMA) and Tree Construction agent (TCA). The agency is depicted in figure 5.

Sink knowledge base (SKB): It is the knowledge base that consists of information like sink id, residual energy, neighboring node ids, neighboring node location information, angle at which the neighboring node are situated, and present children node. It is updated regularly by SMA if it finds any changes at the target.

Sink Manager Agent (SMA): It is static agent that resides in the sink node. It generates TCA that finds Φ_1 for sink node neighbors using equation 1 which will be updated to the SKB as $\Phi_1, \Phi_2 \dots \Phi_n$. It generates TCA that constructs tree; it gives Φ_1 to TCA and then TCA gets node information such as: node id, node location, residual energy and stores in SKB. It also trigger node to become parent node.

Tree Construction Agent (TCA): SMA generates the TCA which is mobile. SMA gives all information (i.e. sink id, Φ_1 and sink location) to TCA to constructs tree. TCA gets the tree member nodes information (i.e. their

id, location and residual energy) and stores it in the SKB. TCA decreases Φ by α degree at every level of the tree.



Sink Agency
TCA: Tree Construction Agent

Fig. 5: Sink agency

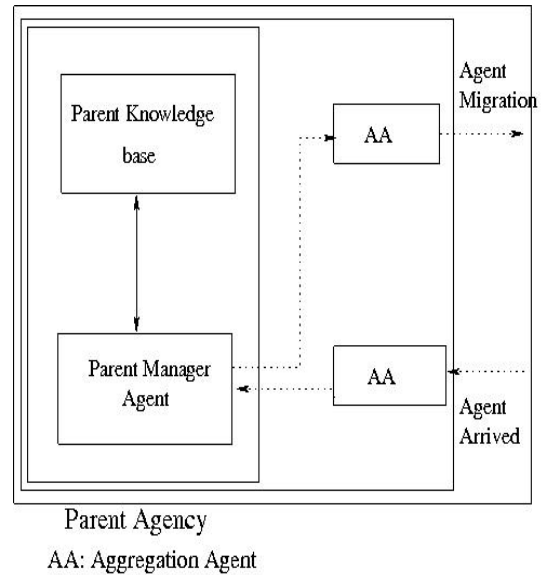
2. Parent agency

Parent agency comprises of static agent, mobile agent and a Parent Knowledge Base (PKB) for inter agent communication. Agents are Parent Manager Agent (PMA) and Aggregate agent (AA). The agency is depicted in figure 6.

Parent Knowledge Base (PKB): It is the knowledge base that consists of information like Parent id, residual Energy, parent location and joining node id. It is updated regularly by PMA if it finds any changes at the target.

Parent manager agent (PMA): It is the static agent that resides in the all the sensor nodes. SMA triggers the PMA when user request for data. PMA generates Aggregate Agent (AA) for aggregation and routing of data along the tree.

Aggregation agent (AA): It is a mobile agent generated by PMA to aggregate and route the data to sink node along the tree. When more than one children node is present then it aggregates the data by calculating the difference between them and route it to parent node and then to sink node.

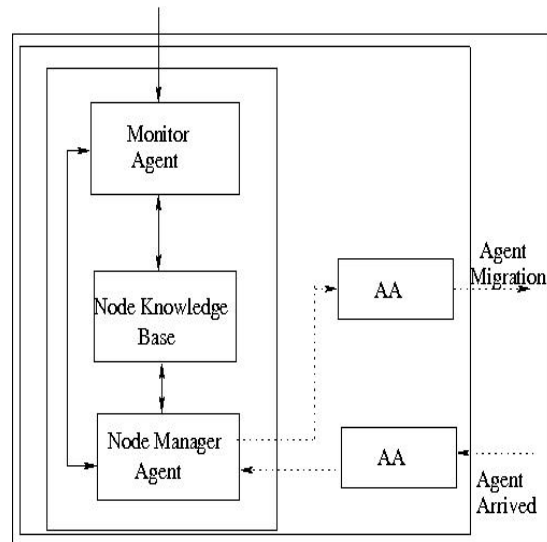


Parent Agency
AA: Aggregation Agent

Fig. 6 : Parent agency

2.3.2. Node agency

Node agency comprises of static agents, mobile agent and a Node Knowledge Base (NKB) for inter agent communication. Agents are Node Manager Agent (NMA), Monitoring agent (MA) and Aggregate agent (AA). The agency is depicted in figure 7.



Node Agency
AA: Aggregation Agent

Fig. 7: Node agency

Node knowledge base (NKB) : It is the knowledge base that consists of information like Node id, residual Energy, and node location. It is updated regularly by NMA if it finds any changes at the target. It also stores information like time of sensing, required power to transfer the data when user sends request.

Node manager agent (NMA) : It is a static agent that resides in all the nodes of WSN. It creates the monitoring agent. NMA makes the node to operate in sleeping and active mode. In sleeping mode, node will not transmit any information. It also monitors the battery life, if it is getting down then sends the status of the battery to its sink nodes. When user sends request, it gets active and by using AA it aggregates data and route the data from children node to parent node and then to sink node.

Monitoring agent (MA) : It is a static agent that resides in all sensor nodes. It monitors the information available such as signal strength, type of information present, and transmission power to transfer data to its parent node and updates the NKB periodically.

2.4. Agent interaction

Agent interaction diagram is as shown in figure 8, which provides a detailed view of the data aggregation and routing by agents in a distributed sensor network. The numbers shown on the directed arcs denotes the action number in the sequence of interactions that takes place.

- a. SMA generates TCA, which calculates the Φ_i of all its neighbor nodes by sending TCA, and then stored in SKB.
- b. SMA generates TCA and gives all necessary information like sink id, sink location, and one of the angles of constraint (Φ_1) to construct the tree. The nodes, which come in Φ_1 , send the joining signal to sink node with its id and location, then SKB is updated.
- c. TCA then decreases Φ by 5° and repeats the same process as in parent node and construct next level of the tree. The next level of nodes sends joining signal to their respective parent node, and then PKB is updated. This process continues till all nodes are covered in the network and then TCA dies.
- d. When user sends the request to sink node the SMA sends the request to parent node, then PMA generates AA. Data is gathered and aggregated by AA from nodes and routed to their respective parent node.
- e. AA aggregate and transfer the data to next higher level of parent node. This process is continued till data reaches sink node.

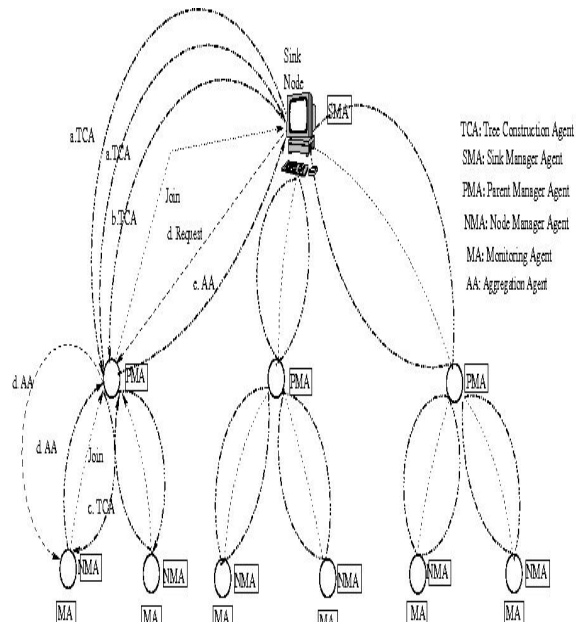


Fig. 8: Agent interaction

2.5. Algorithm

The algorithm comprises of three parts namely calculation of angle of constraint, tree construction, data transfer and aggregation.

Nomenclature:

- SN = Sink Node, PN = Parent Node.
- N = Total number of nodes.
- M = Number of levels.
- Φ = Angle of constraint.
- Φ_i = Angle of constraint of all neighbors, i = index.
- n_i = Node id, i = Index.
- m_j = level number, j = index.
- $n_{i(m+1)}$ = Parent node of n_i
- e_n = Elder node.
- e_n' = another elder node.
- D_i = Data of i^{th} node, i = index.
- D_a = Data from all nodes.
- D_{avg} = Average of data coming from lower level.

A. Calculation of angle of constraint

- **\\ SMA**
Generates TCA
Calculate Φ_i ;

SMA \rightarrow SKB;

End.

B. Tree construction

- **\\ SMA**
Generates TCA

If ($\Phi < \Phi_1$)

Then

n_i join SN;

End if

$\Phi = \Phi - 5$;

$M = 1$;

For $i = 1$ to N do

 If ($\Phi < \Phi_1$)

 Then

n_i join e_n ;

 Else

n_i join e_n' ;

 End if.

$\Phi = \Phi - 5$;

$M = M + 1$;

End for.

C. Data aggregation and routing

- **\\ When user sends request**

SMA (request) \rightarrow PMA

PMA generates AA

- **\\ AA (for aggregation)**

If ($D_1 - D_2 \leq 10$)

Then

 Send D_1 ;

Else

Then

D_{avg} ;

End if.

- **\\ AA (for routing)**

While ($n_j = SN$)

$n_i \rightarrow n_{i(m-1)}$;

End while.

III. RESULTS

We have simulated proposed scheme for various network scenarios using C programming language with a confidence interval of 95%. In this section performance parameters and result analysis are presented.

Simulation inputs for proposed scheme are as follows: $l = 500$ meters, $b = 500$ meters, $N = 20$ to 200 , propagation constant $\beta = 2.5$, communication range of the node $r_c = 300$ to 500 meters, Number of packets transmitted per second, $Trpkts = 256$ per second, $BW_{single_hop} = 5$ Mbps, Size of sensed data at each node $S_d = 5$ Kbytes, size of the processing code $S_{proc} = 3$ Kbytes.

Simulation procedure involves following steps.

1. Generate sensor network environment.
2. Sensor node gets the neighbor node information.
3. Apply the proposed scheme.
4. Compute performance parameters of the system

The following performance parameters are assessed.

IV. RESULTS

We present the results by considering the parameters like total energy consumption, total delay, and network lifetime.

A. Energy consumption

Energy is consumed for each data transfer to sink node from source. We observe from the figure 9 that the energy consumption increases as the number of nodes increases and the energy consumption decreases as data threshold increases. As data threshold increases the number of alive nodes gets decrease by this the total energy consumption decreases.

Sensor nodes require less energy to transmit data with aggregation as compared to without aggregation because data comes from different children node are aggregated by this data redundancy is removed in parent node and only one data is sent to next level; it is illustrated in figure 10. Trees are identified in terms of levels; the energy consumed by sensor nodes of each level is different. The energy consumed by nodes present in level 1 is lesser than level 2 and even lesser than level 3 because the distance of level 3 is greater than level 2 and even greater than level 1 from sink node; it is illustrated in figure 11.

By varying r_c , the communication range of a node, we can control the connectivity of the network. The larger r_c , the more strongly the network is connected

this will be decreasing the total energy consumption; it is illustrated in figure 12.

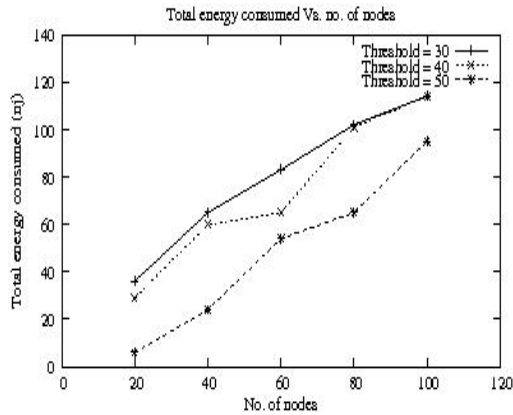


Fig. 9: Total energy consumed Vs. No. of nodes (with respect to data th)

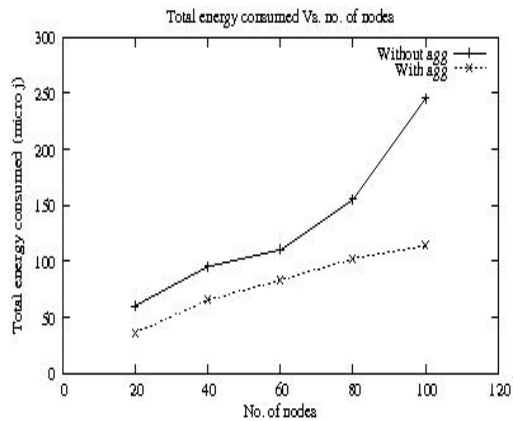


Fig. 10: Total energy consumed Vs. No. of nodes (by taking aggregation)

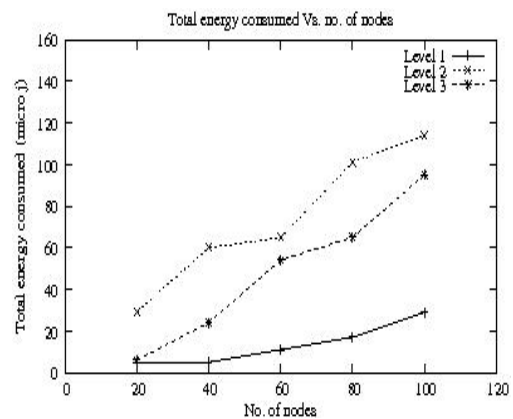


Fig. 11: Total energy consumed Vs. No. of nodes (by taking levels in consideration)

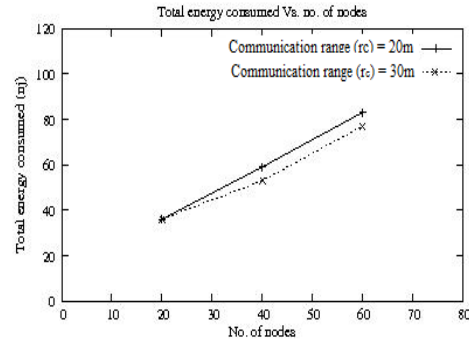


Fig. 12: Total energy consumed Vs. No. of nodes (by taking communication range)

B. Total delay

The delay is mainly depends on the distance of sensor node from sink node and data to be transferred. We observe from the figure 13 that the total delay increases as the number of nodes increases and the total delay decreases as data threshold increases.

Sensor nodes require less time to transmit data with aggregation as compared to without aggregation because data comes from different children node are aggregated by this data redundancy is removed in parent node and only one data is sent to next level; it is illustrated in figure 14. Trees are identified in terms of levels; the time taken by sensor nodes of each level is different. The time taken by nodes present in level 1 is lesser than level 2 and even lesser than level 3 because the distance of level 3 is greater than level 2 and even greater than level 1 from sink node; it is illustrated in figure 15.

By varying r_c , the communication range of a node, we can control the connectivity of the network. The larger r_c , the more strongly the network is connected this will be decreasing the total delay; it is illustrated in figure 16.

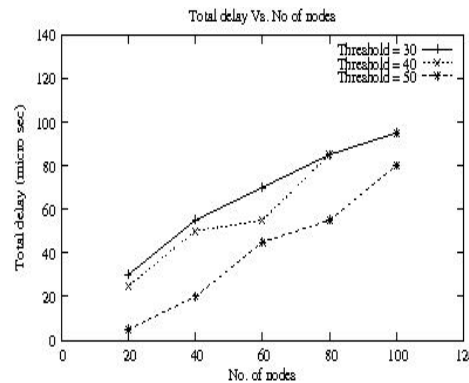


Fig. 13: Total delay Vs. No. of nodes (with respect to data threshold)

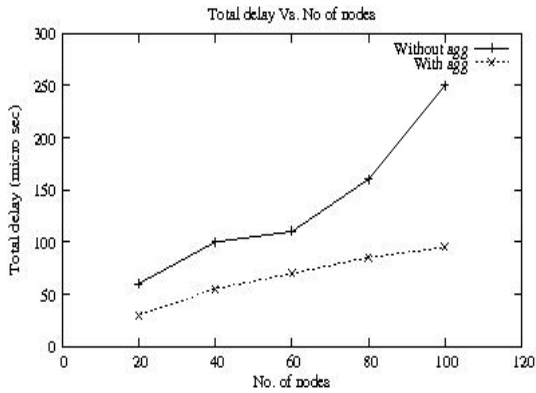


Fig. 14: Total delay Vs. No of nodes (by taking aggregation)

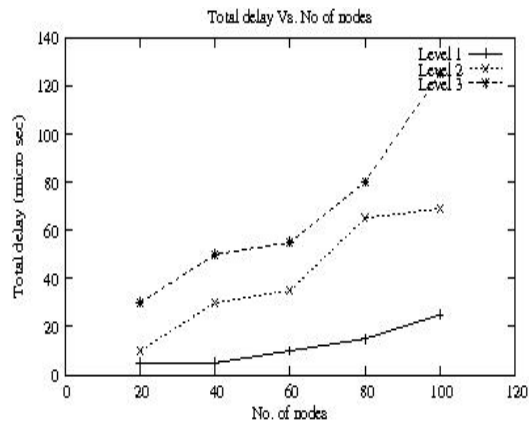


Fig. 15: Total delay Vs. No of nodes (by taking levels in consideration)

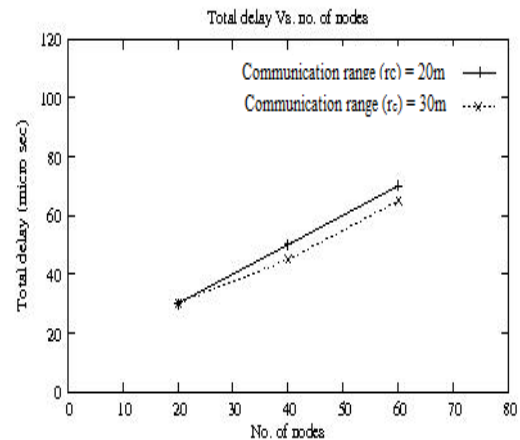


Fig. 16: Total delay Vs. No of nodes (by taking communication range)

C. Network lifetime

The life time of the sensor node mainly depends on the battery life time and its power. In our work we are considering the initial battery of sensor nodes is 5 Joules. For each data transfer the sensor node loses some energy. At some point of time the battery gets drained and there will be no energy in the battery to transfer and aggregate the data, that time is called as network lifetime of that node; it is illustrated in figure 17.

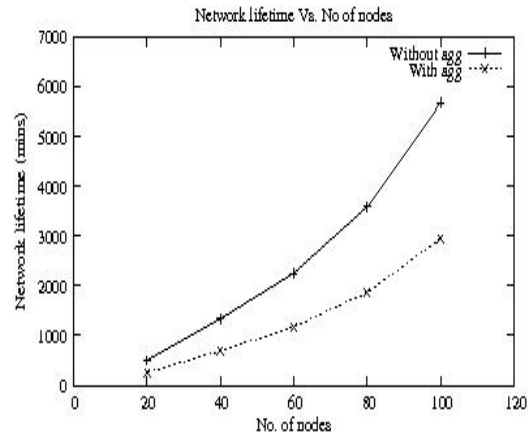


Fig. 17: Network lifetime Vs. No of nodes

VI. CONCLUSION

In this work the tree is constructed by using Φ and neighbor node information. The total energy consumption, total delay gets increases and prolongs the network lifetime as we increase number of nodes from this protocol. And also by increasing communication range and data threshold the total energy consumption and total delay get decrease. In this work we took agent in consideration this helps in reducing total energy consumption, total delay and increases network lifetime. As we are taking aggregation in consideration the data redundancy is reduced and took fewer amounts of energy and time as compared to without aggregation process, thus proposed scheme increases the network lifetime.

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