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Attribute and Energy Aware Tree Formation in Wireless Sensor Network

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ABSTRACT

Data Aggregation is a vital technology to save energy in Wireless Sensor Network (WSN). Data aggregation has been recognized as an competent method to reduce energy consumption by dropping the number of packets sent. For data aggregation solutions, different topologies are created to aggregate the data. For e.g. line, chain, cluster and tree. In this paper, our focus is on tree based data aggregation. There are different methods of tree formation for tree based data aggregation techniques. Most of them do data aggregation efficiently in homogeneous networks but not in heterogeneous networks. Many different applications can be deployed together in WSNs and packets generated by different applications have different attributes. These packets from different applications cannot be aggregated. To make data aggregation more efficient in heterogeneous networks, Attribute and Energy aware tree formation is introduced. In this routing approach, any node will select parent of same type and having higher residual energy and there are more chances of aggregation between same type of packets so that data aggregation can be efficient even in heterogeneous networks.

Keywords: Wireless Sensor Networks, Data Aggregation, Attribute Aware, Tree based Data Aggregation, Heterogeneous Networks

I. INTRODUCTION

A. Wireless Sensor Network

A Wireless Sensor Network is having a no. of wireless sensor nodes which form a sensor field and a sink node. These sensor nodes, having the abilities to sense their surroundings and perform some computation and communicate wirelessly [1].

There is a limitation of size and battery power, these devices typically have limited storage capacity, limited energy resources, and limited network bandwidth. Data propagates via wireless links in the network and wireless transmission is extremely expensive when compared to local processing of data.

Many different types of sensors available like thermal, visual, infrared, acoustic and they monitor a wide variety of environment conditions like humidity, temperature, lightning condition, pressure, soil makeup, noise levels and characteristics such as speed, direction, and size of an object. WSN applications are in many areas like emergence surveillance [2], environment monitoring [3], target tracking [4], military, health, home, space exploration, chemical processing, disaster relief, and other commercial areas [6].

B. Data Aggregation in Wireless Sensor Network

Data aggregation refers to acquiring data from the sensor nodes to the gateway node. Data aggregation reduces the power consumed during data transmission between the sensor nodes [7].

The sink node is secure as it has unlimited energy available and the sensor nodes are having limited energy and are unsecured. The sensory information collected by these nodes is sent to the Gateway node through Wireless hop by hop transmissions and it is aggregated at intermediate sensor nodes to conserve energy by using suitable aggregation function on the data received. The reduction in network traffic and energy consumption on sensor nodes is achieved by data aggregation as in [1, 9].

To make easy deployment it is required that sensor devices are inexpensive, small in size but having long lifetime. So, protocols for sensor networks need to be designed vigilantly and limited resources like energy, storage and computation should be used efficiently. The Data Aggregation in WSNs can be classified into five basic types: 1) Centralized Data Aggregation 2) Cluster Based Data Aggregation 3) Multipath Data Aggregation 4) Tree Based Data Aggregation 5) In Network Data Aggregation [12].

C. Tree based Data Aggregation

In the tree-based approach, aggregation is performed by constructing an aggregation tree as shown in Figure 1, which is mostly a minimum spanning tree, where root is the sink node and leaves are the source nodes.

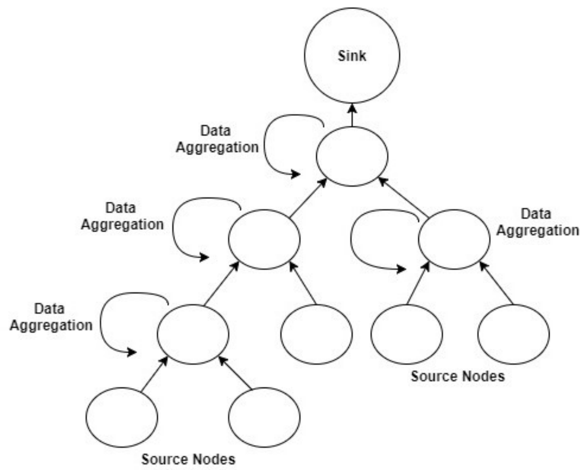


Figure 1. Tree based data aggregation

Each node has a parent node to forward its data. The data flow starts with leaves nodes up to the sink and the aggregation done by parent nodes [5].

Here Tree based data aggregation techniques are explored for further study and in tree based approach, most of the available techniques works with homogeneous networks only, which consists of only one type of sensor nodes. Research work has been started in attribute aware tree based approach for data aggregation in heterogeneous networks in wireless sensor networks [17].

II. MOTIVATION AND RELATED WORK

A. Motivation

In Wireless Sensor Networks, sensor nodes first collect the data, aggregate the data and then transmit it to the gateway node directly or indirectly with the help of other sensor nodes. Tree based data aggregation protocol works with homogeneous networks only while in real life, many times WSN is a heterogeneous network. Current schemes do not provide efficient data aggregation in heterogeneous environment. Here heterogeneous environment represent two or more application running on same network.

It is found that attribute aware aggregation is very much required for heterogeneous networks which should be explored more for research work. As here when there are two applications which are sensing different type of data are always finding the same path, which is statically predefined. In this case, if any node tries to select the parent node of its type then aggregation can be performed efficiently and overall network lifetime can be increased.

B. Related Work

The data sampled by the same type of sensors have more redundancy since the sensor nodes are usually quite dense in wireless sensor networks. To make data aggregation more efficient, the packets with the same attribute, defined as the identifier of different data sampled by different sensors, such as temperature sensors, humidity sensors, etc., should be grouped together [8].

Data aggregation is performed at intermediate nodes in tree-based routing protocols, and a brief representation of data is transmitted to the root node, i.e. sink. One of main tasks for tree-based scheme is to construct an energy efficient data aggregation tree. Since the tree constructed in advance is static, most tree-based schemes can only be suitable for applications in which source nodes are known.

In the following section, we focus on some of tree based routing protocols separately which works well in homogeneous networks by reviewing the main concepts and briefly commenting on the pros and cons of each scheme.

1) **TAG -** The Tiny Aggregation Approach: TAG [13] is a data-centric protocol. Tiny Aggregation algorithm uses the routing scheme which consists of two phases: 1) The distribution phase, where queries are scattered to the sensor nodes 2) The collection phase, where the aggregated sensor readings are routed up the aggregation tree. After the tree is constructed, the queries are sent along with the structure to all nodes in the network. TAG uses the selection and aggregation database query languages (SQL). During the data collection phase, because of the tree structure, each parent has to wait for data from all of its children before it send the aggregated data. TAG may be ineffective for dynamic topologies or link/device failures. As the topology changes, TAG has to rearrange the tree structure, that means it is expensive in terms of energy consumption. It only supports homogenous networks.

2) **EADAT -** Energy Aware Distributed Heuristic: EADAT is an energy-aware distributed heuristic algorithm [15] to construct Data Aggregation Tree in WSNs and also maintain it. In this approach, the node having higher residual energy level has the higher probability to become non-leaf and that is parent tree node, as the number of alive nodes are more the network lifetime. It does not supports aggregation for different type of sensor reading packets.

3) **PEDAP -** Power Efficient Data gathering and Aggregation Protocol: PEDAP [16] constructs a minimum spanning tree considering transmission overhead as the link cost, and thus each communication round consumes less energy. It is expensive to reconstruct the spanning tree for every communication round. Does not support aggregation in heterogeneous environments.

4) **ADA -** Attribute aware Data Aggregation scheme: Nearly all of the existing tree based data aggregation scheme work suitably in homogeneous environment but rarely considers the impact of diversity, including diverse sensors or different applications in the same WSN [16]. This scheme provides routing based on type or attribute of nodes.

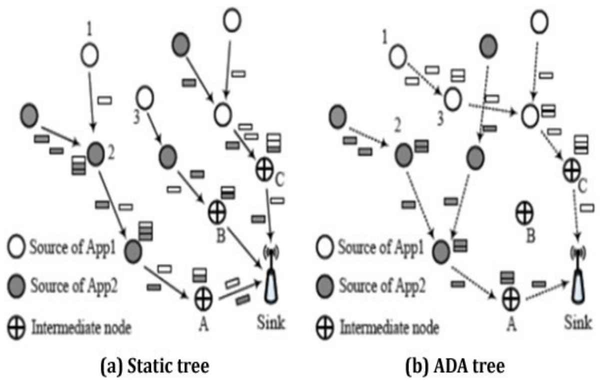


Figure 2. Basic idea of ADA scheme[17]

As shown in Figure 2, it illustrates a typical tree-based routing protocol consists of the shortest path tree rooted at the sink with metric such as hop-count. The static and predetermined routing protocol hardly adapts to heterogeneous environment. Routing in ADA improves aggregation efficiency even in heterogeneous environment. Here Energy of node is not considered while selecting parent for maintaining a tree.

III. IMPLEMENTATION AND RESULTS

A. Flow of work done

For research work, we developed two tree formation techniques for using as performance measures of data aggregation efficiency.

a) Shortest path tree : This scheme will select any parent node from all possible parent nodes which has one lesser level than its level in tree. So it is a static tree formation technique which takes in consideration only distance of parent node.

b)Attribute and Energy aware tree : This scheme will select any parent node of its similar type from all possible parent nodes which has one lesser level than its level in tree and it also considers residual energy while selecting parent node from all possible parent of similar types and which is enhanced ADA (Attribute and Energy aware Data Aggregation scheme).

This ADA program decides parents of each node and make tree based routing possible. ADA scheme gives text file as output which contains list of parent node for every node in network. And it is given to NS2 as input. So that NS2 routing protocol will know about parent node of every node and also children of every parent node and so that finally it works as a Tree based routing protocol.

There are some modification performed in DSR routing protocol so that it can be used as tree based routing protocol and also aggregation function is added in DSR routing protocol.

1)Flow Chart of Attribute and Energy aware Tree formation Scheme (ADA): In Figure 3, the flow chart of ADA program is shown.

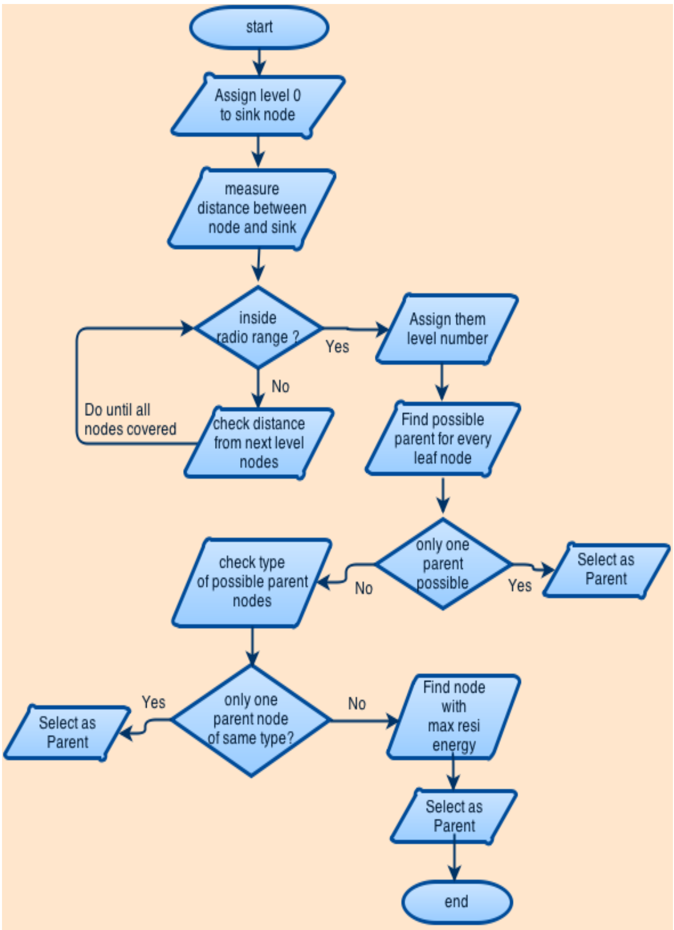
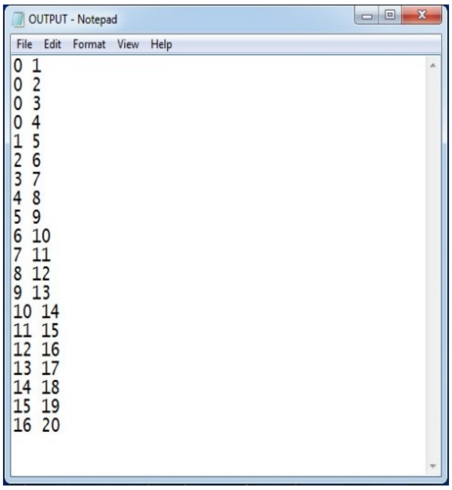


Figure 3. Flow chart of ADA program

2) Output of ADA program : Output Text file as shown in Figure 4 is given to NS2 as input. Here first column represents parent node id, second column represents child node id.




```
0 1
0 2
0 3
0 4
1 5
2 6
3 7
4 8
5 9
6 10
7 11
8 12
9 13
10 14
11 15
12 16
13 17
14 18
15 19
16 20
```

Figure 4. Output text file of ADA program

3) Implementation done in NS2: For generation of tree based topology for data aggregation, some changes are made in DSR routing protocol. Some functions added in DSR routing protocol. Output text file generated by ADA program is given to NS2 as input and this file has list of Parent nodes in first column and child nodes in second column.

Get Parent and child list for tree topology based routing and using this information every node will know if it is a parent node or not and every parent node will know list of all child nodes.

When node receive any packet and timer's current state is on then node does not forward that packet if it is of same type with first packet received, and it is of different type from first packet received then node will forward that packet. If any node receive more packets of same type then more aggregation is possible.

Using energy and attribute aware scheme there are more chances that same type of nodes are children of a single parent of same type and so that more data aggregation can be performed.

B. Simulation Results

All simulation results are observed considering the parameters shown in table I and II. Some source nodes starts initially and send packets to sink node and total max 1000 packets sent at the rate of 1 packet per seconds.

Table 1. simulation parameters

Parameter	Value
Number of Nodes	50, 100, 150, 200, 250, 300, 350, 400, 450
Simulation Time	1000 seconds
Simulation Area	1000 x 1000 meters
Radio Range	250 meters
MAC	802.11

Table 2. energy model parameters

Parameter	Value
Idle Power	0.843 W
Transmit Power	1.650W
Receive Power	1.40W
Radio Range	250 meters
Initial energy of nodes	140J
Packet Size	512 bytes
Idle Power	0.843 W

All graphs are generated for two tree formation schemes: 1) Shortest Path Tree and 2) Attribute and Energy aware Data Aggregation Tree, considering two types of application running in heterogeneous network.

1) Graph of No. of nodes Versus Aggregation Ratio: As shown in Figure 5, the X - axis of graph represents No. of nodes and Y - axis of graph represents Aggregation Ratio. As no. of nodes increases network become more dense and chances of aggregation are more in dense network.

Formula of Aggregation Ratio is as below: Aggregation Ratio = avg [(Total forwarded packets at node 1/ Total received packets at node 1) + (Total forwarded packets at node 2/ Total received packets at node 2)+..+ (Total forwarded packets at node n/ Total received packets at node n)]

So, as node density increases, Aggregation Ratio decreases which shows Aggregation is performed more efficiently. Graph shows Aggregation Ratio is lesser in ADA scheme with compare to SPT scheme. SPT has less chances of aggregation than ADA scheme.

In SPT scheme : There are less chance of Aggregation so that any node will forward more packets out of total received packets. It may send 7 out of 10.

In ADA scheme : There are more chance of Aggregation so that any node will forward less packets out of total received packets. It may send 4 out of 10.

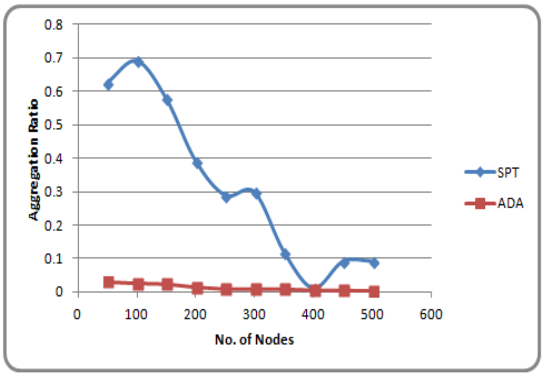


Figure 5. No. of nodes Versus Aggregation Ratio

From this graph, we can say ADA performs Aggregation efficiently than SPT scheme.

2) Graph of No. of nodes Versus PDR: As shown in Figure 6, X - axis represents No. of nodes and Y - axis represents Packet Delivery Ratio. As node density increases Packet Delivery Ratio decreases which shows Aggregation is performed more efficiently.

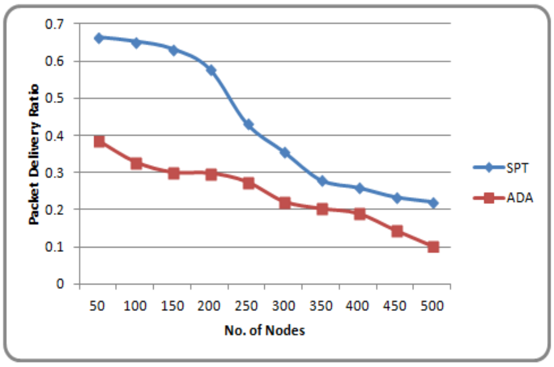


Figure 6. Graph of No. of nodes Versus PDR

Graph shows Packet Delivery Ratio is lesser in ADA scheme with compare to SPT scheme. So that in this scenario, we can say ADA performs Aggregation efficiently than SPT scheme in heterogeneous network.

3) Graph of No. of nodes Versus avg. Residual Energy: As shown in Figure 7, X - axis represents No. of nodes and Y - axis represents Avg. Residual Energy. As node density increases Avg. Residual energy decreases much slowly in case of ADA than that of case when SPT scheme.

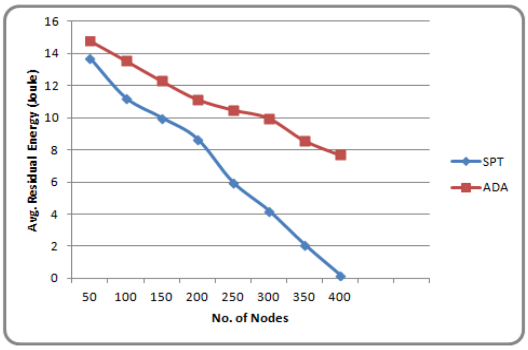


Figure 7. Graph of No. of Nodes Versus Avg. Residual Energy

So that in this scenario, less energy is used in ADA because it forwards less packets. In other way, we can say ADA performs Aggregation efficiently than SPT scheme. Thus, ADA scheme is Energy aware also.

4) Graph of No. of applications Versus Aggregation Ratio: As shown in Figure 8, X - axis represents No. of applications and Y - axis represents Aggregation Ratio.

Graph shows that aggregation efficiency decreases with increase in no. of application so ADA performance is vary with more no. of application. But it still performs better than SPT scheme in all ways ADA is better in heterogeneous networks. Here SPT increase aggregation ratio faster than ADA. This graph is for fixed number of nodes 200.

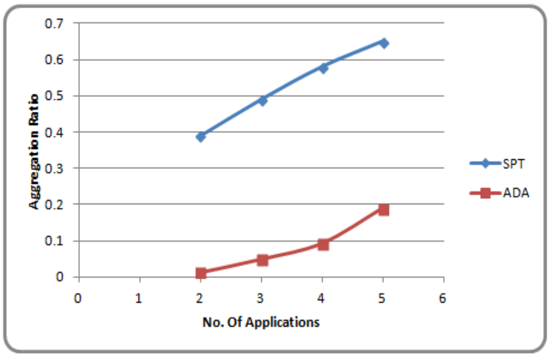


Figure 8. Graph of No. of applications Versus Aggregation Ratio

IV. CONCLUSION

ADA program is developed for tree formation which considers type of parent node and also residual energy while selection of parent which performs better in heterogeneous networks compare to other tree formation techniques like SPT (shortest path tree formation scheme). Performance comparison is done between SPT and ADA for parameters like Packet Delivery Ratio, Aggregation Ratio and Avg. Residual Energy Versus node density and Aggregation Ratio Versus No. of application. Results justify that ADA performs far better aggregation than SPT in all parameters. Overall residual energy is saved more in ADA scheme so that network lifetime is increased. Finally, it is observed that Attribute aware tree formation is an efficient method for data aggregation in all aspects for heterogeneous networks.

V. FUTURE WORK

ADA can perform better even if tree maintenance part is managed. If tree is maintained properly, no. of alive nodes can be more and network lifetime increases. If any parent node dies, all children of that node also become disconnected which make very poor performance of ADA. For that, if any node's energy go below pre defined threshold then it's children should select new parent so that they can continue sending data in the network and overall network lifetime can be increased.

ADA's performance can be measured in multiple sink scenario.

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