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MULTI HOP CLUSTER DESIGN IN WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensor networks (WSN) are the refined networks used to gather information from different environment factors. It is a promising technology which is composed of tiny sensing objects called sensors that are wirelessly distributed in the environment of interest in the form of clusters. Consumption of energy of sensor nodes depends on the size of the cluster and the amount of information send over the network. An inherent problem with the WSN is the consumption of battery power since when the cluster size is increased depending on application it is designed for, battery life of sensor nodes gets reduced with this extra consumption of energy due to the expanded size of the cluster. In this paper we examined different performance matrices of the WSN by increasing the size of cluster up to four hops and then compared the results with the network having a cluster with small number of hops.

KEY WORDS: *Cluster Scalability, Energy consumption, Multi hop Clustering, Wireless Sensor Networks.*

I. INTRODUCTION

Wireless sensor networks (WSNs) are the networks in which sensor nodes are scattered in a certain area and are used to observe particular events[1]. These sensor networks communicate through wireless channels. Usually these networks are installed in the regions which are not accessible like border areas. WSN is a special type of ad hoc networks[2], in which nodes are arranged in random fashion. Communication links among the nodes are wireless. Function of each node is to gather information from area of interest. Processing units are installed in the sensor nodes whose function is to process these information, and then communicate through wireless medium with other neighboring nodes or directly with base station (BS) in the network[3]. The function of BS is then to collect all data coming from scattered nodes over an area and to analyze this data to describe any conclusion about an event.

Problem with WSN is the limited amount of energy of the nodes[4], so if they are arranged once in an area it is then not possible to replace them or revitalize them. This is among the most important challenges in the design of WSNs[5].

Networks with static nodes are more common. In order to work under all the conditions satisfactorily, the nodes of WSN must have the capability of self-governing and the network itself has to be self-organizing. In WSN, the topology of the network is subject to change very frequently whenever any node suffers with malfunctioning.

In sensor networks, function of sensor nodes is to send their sensed data to clusterhead for further processing[6]. Since sensor nodes are large in number and they use to send data to a single clusterhead, this model give rise to uneven consumption of energy. When the size of a network is large there are high transmission losses, so in this case it is necessary to use multi-hop mode of communication to offset that transmission loss. But when node organization is based on clusters and they use multi hop mode of communication to send their collected data to clusterhead, the nodes which are located in proximity of a clusterhead will have to tolerate a load of large overhead packets. While in case of mobile nodes, this relaying load then uniformly distributed among the nodes due to the randomness, but mostly nodes are static. As a result the nodes in proximity to the clusterhead tolerate greater load and lose energy rapidly. Similarly if single hop mode of communication is used by the network, nodes near the clusterhead do not face greater energy burden but nodes located at a distance from the clusterhead have to send the data at high power, so they suffer with a quick energy drain condition[7]. The clusterheads themselves use large amount of energy to perform long range communication to the BS located far away.

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A. Communication Modes

In case of clustering two modes of communication are used through which data can be sent.

1) Single Hop Mode

In single hop mode of communication each node directly sends its data packets to the clusterhead as shown in Figure 1. Since there is point to point communication between the sensor nodes and the clusterhead, data should be send by one node in a one time. So the life span of the network suffers with a concave constraint in which the life of the network depends upon the life of the node dying the earliest. For example if in a network there are 100 node having different life times, the one with the smallest lifetime will be consider the overall lifetime of a network.

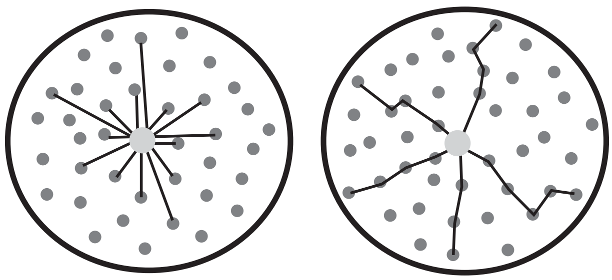

Figure 1: Communication Modes

2) Multi Hop Mode

In multi hop mode, data is not send directly by each sensor node to the clusterhead but it is first send to its neighbor node which then forward to either other node or directly to the clusterhead. We have the example of multi hop communication in a cluster. Lets consider a simple communication model in which each sensor node have a communication radius 'R' which is the distance of a sensor node from its neighbor node to communicate. Further assumption is that the node area of communication is much smaller than the cluster area. Otherwise the cluster will act as a single hop communication cluster. R should be sufficiently large for operation of multi hop communication so that the nodes connectivity is not disturbed.

II. PROBLEM OUTLINE

Sensor networks communicate through wireless channels. We consider that nodes are organized in cluster. As the network is of heterogeneous type, there are two types of nodes used in the network; cluster head nodes and sensor nodes. Sensor nodes can be arranged in cluster form. In cluster form these sensor nodes use two modes of communication to send their information to cluster heads. These modes are single hop mode and multi hop mode. When the size of a network is small, single hop mode of communication should be used but for large networks it is better to use multi hop mode of communication to avoid extra consumption of energy for sending data on long distances. Sensor nodes used in network has a sensing radius within which it can observe certain event. Multi hop mode of communication is used to increase the size of cluster but as we increase the size of cluster here we face the problem of decrement in energy level of each node as the time passes. So we need to maintain the energy of a system with increasing cluster size. Increase in cluster size automatically gives us extension in communication range. Beside that there are several other parameters like packet loss rate, delay, packet delivery rate etc which need not to be affected by increasing size of the cluster.

III. RELATED WORK

Lot of research work has been done in the field of WSNs to make this technology more scalable, energy efficient and robust.

A. WSN Models

Adeel *et.al.*[7] described different routing models used for WSN. According to authors there are three models in WSN including:

- Single Hop Model
- Multi Hop Model
- Cluster Based Model

One Hop Model

This is a simple model in which there is point to point communication between sensor node and BS.

Multi-Hop Model

In this model nodes send data to their neighbors which then forward data toward the BS. Multi-hop model is an energy efficient model of routing[6].

Cluster Based Model

In this model network is arranged into different clusters. Each cluster has two types of nodes, cluster head (CH) node and common nodes. The function of clusterhead is to gather information from common nodes, combine the gathered information and then collectively send this information to the BS.

Cluster routing is an energy efficient routing model as compared with direct routing and multihop routing. But there are some issues in cluster routing as well.

B. Leach

Clustering protocol called LEACH is studied in WSN by Heinzelman *et. al*[8]. In which he uses homogeneous scenario and nodes communicate with CH through single-hop mode of communication. The cluster heads combine the data being received, and then perform point-to-point transmission of this data to the base station located at a distance. Distributed algorithm for cluster head selection is used by other. Random rotation of clusterhead in LEACH algorithm makes it a uniform energy distribution approach.

C. Multi Hop Clustered WSNs

Bandyopadhyay *et al.*[9] have also studied clustering algorithm but as against the previous work they studied multi-hop mode of communication in clusters of WSNs. Nodes communicate with clusterhead not directly but through different level of node. The cluster heads collect data from these nodes, combine the collected data, and send it to a base station. For this case, in order to minimize total energy expenditure of the network the authors have developed a mathematical model which indicates CH densities in an area.

Some researchers[10], have studied the problem of designing a surveillance sensor network. In this approach two types of nodes are used by author. One type of nodes are cluster member nodes which are termed as sensor nodes and the other type of nodes are called clusterhead nodes. Clusterhead nodes are complex in terms of hardware and software. They also require higher battery energy than normal nodes. Sensor nodes communicate with clusterhead by using multi-hop mode of communication. The authors formulated an optimization problem to minimize the overall cost of the network and determine the optimum number of cluster heads and the battery energies of both types of nodes.

IV. EXPERIMENTAL SETUP

In our experimental setup we are using NS-2.34 as our simulation tool. The whole simulation process is done by varying different number of hops in a cluster. We then observed different parameters and their effect by changing number of hops in a cluster. The results from trace file is extracted by AWK file in terms of packet delivery fraction (PDF), Energy consumed and average End to End Delay in msec. The results are plotted with the help of MATLAB. Conclusion is based on these graphical results. The whole process is mentioned here.

A) Simulation Model

We are using NS-2.34 as our simulation tool. Because it is the most robust and widely accepted simulation tool for the wireless sensor networks. It supports various wireless sensor routing protocols including AODV (Adhoc On-demand Distance Vector) routing protocol, DSR (Dynamic Source Routing) protocol), DSDV (Destination Sequenced Distance Vector) routing protocol. We have used DSDV as routing protocol, omni antenna and radio propagation model is Two-ray ground.

B) Parameters for Simulation Scenario

These are general parameters for wireless sensor network (WSN) listed below.

1) Transport Protocol

TCP and UDP are the available transport layer protocol used by WSN that provide FTP and CBR traffic application.

2) Routing protocol

Destination-Sequenced Distance-Vector Routing (DSDV) is one of the proactive[11] protocol. Here routing massages are exchanged between nodes which are in the range of one another. Routing updates are either triggered or are send in the routine. It solves the problem of routing loop[12]. In the routine route updation scenario, it constantly updates its routing table, while routing triggered occurs whenever there is any change in network i.e. node removed or added. It is suitable for ad hoc and clustering based mobile wireless networks. As DSDV constantly updates its routing table even when the nodes are idle so it consumes more amount of battery energy.

3) Medium Access Control (MAC)Protocol

In 1997 the IEEE 802.11 standard was formulated as the first WLAN standard. This standard has been widely accepted for different environments and scenarios. The main characteristics of the IEEE 802.11 are its simplicity, scalability and robustness against failures due to its distributed nature. The following two network architecture modes have been defined for the IEEE802.11 standard:

PCF: The Point Coordination Function (PCF) mode uses the centralised approach in which a network access point controls all traffic in the network, including local traffic between wireless nodes in the network.

DCF: The Distributed Coordination Function (DCF) mode supports direct communication between wireless nodes. Each node gets an equal share of the channel through contention. It is clear that, for ad hoc networks, DCF mode is the one used.

4) Link Layer

NS-2 uses LL for default link layer parameter configuration.

5) Physical Layer

Two [9] configuration options are provided

One provide Lucent Physical Layer provide 914 MHz Lucent Wave LAN DSSS radio interface.

Second provide default frequency for simulating Mica2 sensor node.

6) Antenna

Sensor node Antenna parameter include antenna type e.g. Omni-directional antenna, antenna position, antenna hight etc.

7) Radio Propagation Model

Different propagation models are available for wireless network in NS-2 i.e. Free Space model, Shadowing model, Two Ray Ground model (default). We have used two ray ground propagation model in our work.

8) Interface Queue (IFQ)

Queue model provided in NS-2 are DropTail, DropTail/XCP, RED, RED / Pushback, RED / RIO, XCP.

9) IFQ Length

It is Queue buffer size in term of number of massages it can retain for a while default value is 50 massages

10) Scenario Size

It has two parameter X and Y which define two dimensional space in meter for network coverage.

11) Trace Options

Trace means kind of network information we need to evaluate for performance of the network .Trace file can store information about MAC trace, Routing trace and Agent trace by setting TRACE-MAC, ROUTE-TRACE, AGENT-TRACE set to option ‘ON’.

12) Simulation Time

Simulation start time, stop time can be set in second by the respective “Finish proc”.

V. EXPERIMENTAL DETAILS

Experimental details include different performance matrices and simulation parameters which are discussed below in detail.

A. Performance Matrices

Our performance matrices are for PDF (Packet Delivery Fraction), Packet Loss, Energy and Average End-to-End Delay across varying number of nodes per cluster.

PDF: The ratio of the data packets received by the destination to those transmitted by the traffic sources.

Energy: It includes all the energies consumed in packet transmission, packet reception and the total remaining energy.

Average End to End Delay: This includes all possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays, propagation and transfer times.

Packet Loss: Number of unsuccessful packets out of the total packets sent.

B. Simulation Parameters

In this work we simulated the network for five different scenarios. Each experiment is run a number of times depending upon the number of hops in the network. Initially the experiment was performed without hoping, then the number of hops were increased in each experiment upto 4-hops. The QOS parameters under consideration in this experiment were Energy, Packet loss, Delay, PDF. These parameters were observed in this experiment by varying the number of nodes per cluster. Different parameters for experiment are shown in the Table I.

VI. RESULTS

We obtained results for Delay, Packet Loss, PDF and Energy Consumed for different scenarios and plotted those results with the help of MATLAB which are shown and discussed in the following lines.

Table 1: Simulation Parameters for Experiment

Parameters	Values
WSN Model	Multi-hop Cluster Based
Routing Protocol	DSDV
Simulation Time	900seconds
Simulation Area	50x50m^2
Propagation Model	Two-Ray Ground Reflection
Channel Type	Wireless
Initial Energy (node)	10joul
Initial Energy (clusterhead)	100joul
Transmission Range (node)	50m
Transmission Range (clusterhead)	100m
Sensing Parameters	Temperature
Topology	Grid

1) Delay

Within multi-hop communication as we increase the number of nodes in a cluster delay is increased, it was observed that the cluster delay in 4-hops is more than 1 and 2-hops communication as shown in Figure. 2. This figure depicts the results obtained from the simulated network starting from 30 up to 50 nodes per cluster. But as nodes per cluster increases above 50, behaviour of delay for four hop communication mode and single or two hop communication mode become similar. It means that multi-hop communication mode is useful for cluster with greater number of node density rather than cluster with less number of nodes.

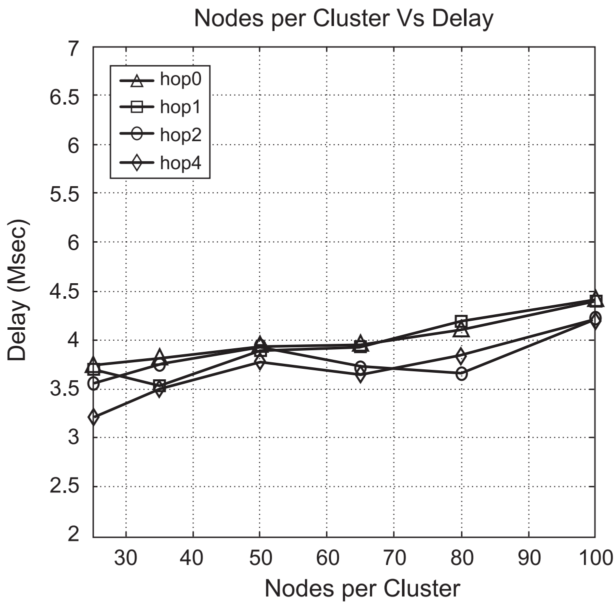

Figure 2: Nodes per Cluster vs Delay Graph

2) Packet Loss

Results for the packet loss occurring in the network can be observed from the graph shown in Figure. 3. When number of sensor nodes per cluster is less about 30 or 40, packet loss is greater for 4-hop communication mode as compared to 1 or 2-hop communication mode. But as cluster is going to be denser i.e. number of sensor nodes per cluster increases going above 50 up till 100 in our case, packet loss for four hop communication mode becomes less and starts increasing gradually compared to 1 or 2-hop communication mode. Another worth noting point is that the packet loss for same number of sensor nodes arranged without cluster is more than packet loss with multi-hop cluster communication mode. The reason is that without multi-hop cluster communication each sensor node needs to communicate directly with cluster head. As cluster size is greater than range of sensor node therefore most of the sensor node in such cluster can never communicate with cluster head directly due to its weak signal level at cluster head position. This loss can be minimized by selecting a central position for the cluster head where it is in the direct approach of the other nodes of the network.

3) Packet Dilevery Fraction (PDF)

Packet Delivery Fraction is the Goodput of the network. PDF is a parameter which is directly related to packet loss, If packet loss is higher, PDF will be smaller and vice versa. From the graph it can verified that Packet Delivery Fraction for cluster with less number of sensor nodes is comparably high for 1 or 2-hop communication mode than 4-hop communication mode. While for highly densor cluster Packet Delivery Fraction for 4-hop communication mode is better than one or two hop mode. (Figure 4)

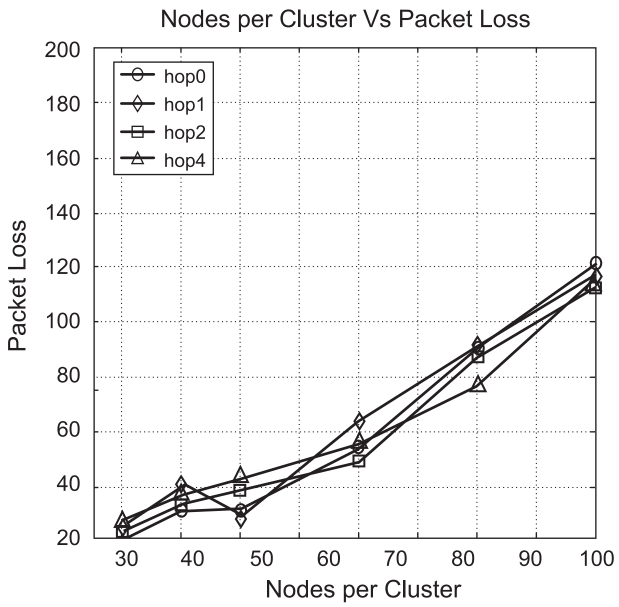

Figure 3: Nodes per Cluster vs Packet Loss Graph

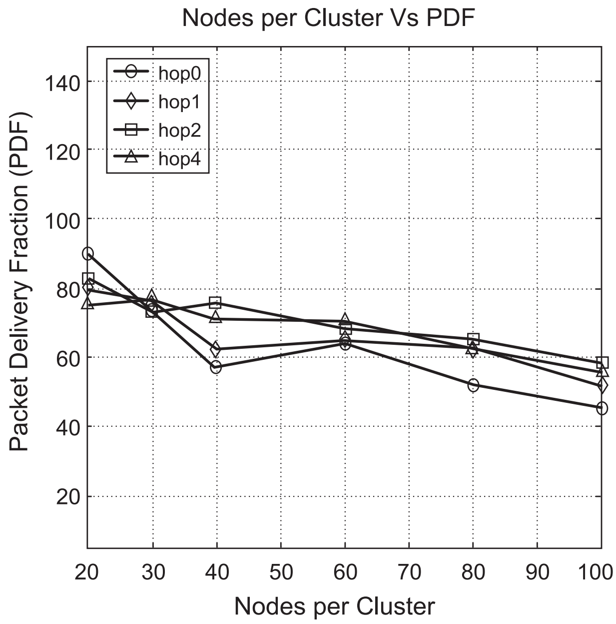

Figure 4: Nodes per Cluster vs PDF Graph

4) Energy

Energy is one of the most important factors in wireless sensor network because sensor nodes are provided with power sources that cannot be recharged. We observe from the graph that when there are less number of sensor nodes per cluster, energy consumed is almost equal for, 2or 4-hop mode of communication. As we increase sensor nodes per cluster energy consumption increases almost exponentially. For 4-hop mode of communication there is more overhead compared to 1 or 2-hop mode. Extra energy consumption is one of major drawback of multi-hop mode of communication. (Figure 5)

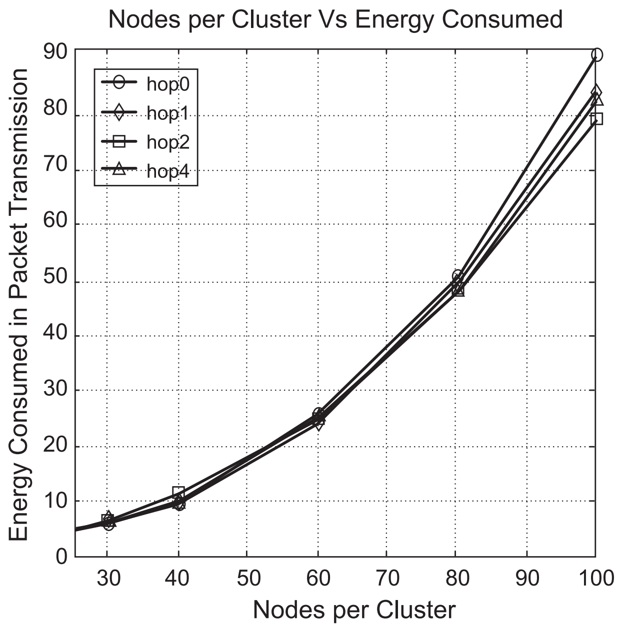

Figure 5: Nodes per Cluster vs Energy consumed in Packet Transmission Graph

VII. CONCLUSION

In order to make the network scalable we simulated the model for 4-hops in a cluster. We analyzed a number of parameters for 4-hop communication network. These parameters include delay, packet delivery ratio, packet loss and consumed energy. Simulation was carried-out for these parameters in NS2 environment. Results were plotted in graphical format using

MATLAB. The results show an initial improvement in the performance for less number of hops but as the number of hops starts increasing, there is a decline observed in the results. Tendency of the curves show that cluster of greater hops are better in terms of packet loss and packet delivery fraction but it are not suitable in terms of delay and energy.

VIII. FUTURE WORK

In order to make the network scalable network was simulated for four hops in a cluster. A number of different parameter were observed for these four parameters but more reliable results can be obtained by adding the following dimensions to the presented work.

1) Hardware Implementation

Currently simulation is done in NS-2 platform but more reliable results can be obtained by implementing the same network on a hardware test bed to obtain real-time results.

2) Network Size

The presented work has been tested on a network size of upto 100 nodes, but same results for larger network can improve the possibility of the implementation of the presented work in real-time scenarios.

3) Simulation Time

Simulation time of 900 seconds has been chosen for the presented work. But more effective results can be obtained if the simulation is run for a longer time.

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