Fundamentals of Cluster Based Routing

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Abstract – Remote Sensor Networks have pulled in the consideration of numerous specialists. Remote Sensor Networks are utilized for different applications, for example, living space observing, robotization, agribusiness, and security. Since various sensors are generally conveyed on remote and unavailable spots, the organization and upkeep ought to be simple and adaptable. Remote sensor organize comprises of huge number of little hubs. The hubs then sense natural changes and report them to different hubs over adaptable system engineering. Sensor hubs are incredible for sending in antagonistic situations or over vast topographical territories. The estimation of temperature and light by the utilization of Crossbow sensor pack in which there are diverse hubs/bits set at various areas. These hubs are having distinctive hub ID and they will detect the temperature and light of their encompassing area and send it to the base station hub which is associated through USB port to the PC by utilization of MoteView and MoteConfig environment. The information procurement board that we have utilized is MDA100CB (Mote Data Acquisition). The programming of the sensor hubs is finished by MoteConfig and live information is seen through MoteView environment. The hubs that we have utilized are MicaZ, the MDA100CB board is settled over these hubs by method for 51 input/yield pins. A vitality effective progressive group based steering convention for constant stream inquiries in WSN. We present an arrangement of group heads, head-set, for bunch based directing. The head-set individuals are in charge control and administration of the system. On pivot premise, a head-set part gets information from the neighboring hubs and transmits the amassed results to the inaccessible base station. For a given number of information gathering sensor hubs, the quantity of control and administration hubs can be efficiently acclimated to lessen the vitality utilization, which expands the system life. Hubs in a sensor system are seriously obliged by vitality, stockpiling limit and figuring power. To drag out the lifetime of the sensor hubs, outlining productive directing conventions is basic.

Index Terms – Remote Sensor, Routings.

1. INTRODUCTION

Hierarchical cluster-based routing scheme is suitable for habitat and environmental monitoring application. The routing scheme is based on the fact that the energy consumed to send a message to a distant node is far greater than the energy needed for a short range transmission. We extend the LEACH protocol by using a head-set instead of a cluster head. In other words, during each election, a head-set that consists of several nodes is selected. The member of a responsible for transmitting to the distant base station. At one time, only one member of the head-set is active and the remaining head-set members are in sleep mode. The task of transmission to the base is uniformly distributed among all the head-set members.

First, we describe a few terms that are used in defining our protocol. A cluster head is a sensor node that transmits an aggregated sensor data to the distant base station. Non-cluster head are sensor nodes that transmit the collected data to their cluster head. Each cluster has a head-set that consists of several virtual cluster heads; however, only one head-set member is active at one time. Iteration consists of two stages: an election phase and a data transfer phase. In an election phase, the head-sets are chosen for the pre-determined number of cluster. In the data transfer phase, the members of head-set transmit aggregated data to the base station. Each data transfer phase consists of several epochs. Each member of a head-set becomes a cluster head once during epochs. A round consists of several iterations. In one round, sensor node becomes a member of head-set for one time.

States of a sensor

The damaged or malfunction sensor states are not considered. Each sensor mode joins the network as a candidate. At the start of each iteration, a fixed number of sensor nodes are chosen as cluster heads; there chosen cluster head acquire the active state. By the end of election phase, a few nodes are selected as member of the head-sets; there nodes acquire associate state. At the end of an election phase, one member of a head-set is in active state and the remaining head-set member are in associate state.

In an epoch of a data transfer stage, the active sensor transmits a frame to the base station and goes into the passive associate state. Moreover, the associate, which is the next in the schedule to transmit to the base station, acquire the active state. During an epoch, the head-set members are distributed as follows; one member in active state, a few members are in associate state, and a few members are in passive associate state.

During the transmission of the last frame of an epoch, one member active and the remaining members are passive associates; there is no member in an associate state. Then, at the start ofthe next epoch, all the head-set member becomes associate and one of them is chosen to acquire the active state. At the end of iteration, all the head-set member acquire the non-candidate state. The member in non-candidate state are not eligible to become a member of head-set. At the start of new rounds, all non-candidate sensor nodes acquire candidate state; a new round starts when all nodes acquire non-candidate state.

Election Phase

In the proposed model, the number of clusters, k, are pre-determined for the wireless sensor network. At the start, a set of cluster heads are chosen on random basis. These cluster head send a short range advertisement broadcast message. The sensor nodes receive the advertisement and choose their cluster heads based on the signal strengths of the advertisement message. Each sensor nodes send an acknowledgement message to its cluster head. Moreover, for each iteration, the cluster heads choose a set of associate based on the signal analysis of the acknowledgments.

A head-set consists of a cluster head and the associate. The head-set, which is responsible to send messages to the base station, is chosen for one iteration of a round. In an epoch of an iteration, each member of the headset becomes a cluster head. All the head-set members share the same time slot to transmit their frames. Based on uniform rotation, a schedule is created for the head-set member for their frame transmission; only the active cluster head transmits a frame to the base station. Moreover, a schedule is created for the data acquisition and data transfer time intervals for the sensor nodes that are not members of the head-set.

Data Transfer Phase

Once clusters, head-sets, and TDMA-based schedules are formed, data transmission begins. The non-cluster head nodes collect the sensor data and transmit the data to the cluster head, in their allotted timer slots. The cluster-head node must keep its radio turned on to receive the data from the nodes in the cluster. The associate members of the head-set remains in the sleep mode and do mot receive any message. After, some pre-determined time interval, the next associate becomes a cluster head and the current cluster head becomes a passive head-set member. At the end of an epoch, all the head-set member have becomes a cluster head for once. There can be several epochs in iteration. At the end of iteration, the head-set members become non-candidate members and a new head-set is chosen for the next iteration. Finally, at the end of a round, all the nodes have becomes non-candidate members. At this stage, a new round is started and all the n members.

2. QUANTITATIVE ANALYSIS

In this section, we describe a radio communication model that is used in the quantitative analysis of our protocol. The energy dissipation, number of frames, time for message transfer, and the optimum number of cluster are analytically determined.

Radio Communication Model

We use a radio model, where for a shorter distance transmission, such as within clusters, the energy consumed by a transmit amplifier is proportional to r^2. For a longer distance transmission, such as from a cluster head to the base station, the energy consumed is proportional to r^4. Using given radio model, the energy consumed to transmit a 1-bit message for a longer distance, d, is given by:

$$E_T = lE_e + l\varepsilon_l d^4$$

Similarly, the energy consumer to transmit a 1-bit message for a shorter distance is given by:

$$E_T = lE_e + l\varepsilon_s d^2$$

Moreover, the energy consumed to receive the 1-bit message is given by:

$$E_R = lE_e + lE_{BF}$$

Equation 5.3 includes the cost of beam forming approach that reduces energy consumption. The constants used in the radio model are given in Table5.1.

Table- Sample parameter values of the communication model used in our quantitative analysis.

Description	Symbol	Value
Energy consumed by the amplifier to transmit at a shorter distance	€s	10Pj/bit/m^2
Energy consumed by the amplifier to transmit at a longer distance	$€_l$	0.0013 Pj/bit/m^4
Energy consumed in the electronics circuit to transmit or receive the signal	E_e	50nJ/bit
Energy consumed for beam forming	E_{BF}	50nJ/bit

Election Phase

For a sensor network of n nodes, the optimal number of cluster is given as k. all nodes are assumed to be at the same energy level at the beginning. The amount of consumed energy is same for all the clusters. At the start of the election phase, base station randomly selects a given number of cluster heads. First, the cluster heads broadcast message to the entire sensor in their neighborhood. Second, the sensor receives messages from one or more cluster heads and choose their cluster head using strength. Third, the sensors transmit their corresponding cluster heads. Fourth, the cluster heads receive message from their sensor nodes and remember their corresponding nodes. For each cluster, the corresponding cluster head chooses a set of m associates, based on signal analysis.

For uniformly distributed clusters, each cluster contains n/k nodes. Using Equation 5.2 and Equation 5.3, the energy consumed by a cluster head estimated as follows:

$$E_{CH-elec} = \{lE_e + l\mathcal{E}_s d^2\} + \{(\frac{n}{k} - 1)l(E_e + E_{BF})\} \quad (5.4)$$

The first part of Equation 5.4 represents the energy consumed to transmit the advertisement message; the energy consumption is base on a shorter distance energy dissipation model. The second part of Equation 5.4 represents the energy consumed to receive $(\frac{n}{k} - 1)$ message from the sensor nodes of the same cluster.

Using Equation 5.2 and Equation 5.3, the energy consumed by non-cluster head sensor nodes is estimated as follows:

$$E_{non-CH-elec} = \{klE_e + klE_{BF}\} + \{lE_e + l\mathcal{E}_s d^2\} \quad (5.5)$$

The first part of Equation 5.5 shows the energy consumed to receive message from k cluster heads; it is assumed that a sensor node receives message from all cluster heads. The second part of Equation 5.5 shows the energy consumed to transmit the decision to the corresponding cluster head.

Data Transfer Phase

During data transfer phase, the nodes transmit message to their cluster head and cluster heads transmit an aggregated message to a distant base station. The energy consumed by a cluster head is as follows:

$$E_{CH/frame} = \{lE_e + l\mathcal{E}_l d^4\} + \{(\frac{n}{k} - m)l\,(E_e + E_{BF})\} \quad (5.6)$$

The first part of Equation 5.6 shows the energy consumed to transmit a message to the distant base station. The second part of Equation 5.6 shows the energy consumed to receive message from the remaining $(\frac{n}{k} - m)$ nodes that are not part of the head-set.

The energy, Enon-CH/frame, consumed by a non-cluster head node to transmit sensor data to the cluster head is given below:

$$E_{non-CH/frame} = lE_e + l\mathcal{E}_s d^2 \quad (5.7)$$

For circular cluster with a uniform distribution of sensor node and a network diameter of M, the average value of d2 is given as: E [d2] $=\left(\frac{M2}{k2IIk}\right)$. Equation 5.7 can be simplified as follows:

$$E_{non-CH/frame} = lE_e + l\mathcal{E}_s\left(\frac{M2}{2IIk}\right) \quad (5.8)$$

In first iteration, Nf data frames are transmitted. The frames transmitted by each cluster are Nf/k frames are uniformly divided among n/k nodes of the cluster. Each cluster head frame transmission needs $(\frac{n}{k} - m)$ non-cluster head frames. For simplification of equations, the fraction f1 and f2 are given as below:

$$f_1 = (1 / (n/k-m=1))\,(1/k) \quad (5.9)$$

$$f_2 = ((n/k-m)/\,(n/k-m+1)(1/k)) \quad (5.10)$$

The energy consumption is data transfer states of each cluster are as follows:

$$E_{CH-data} = f_1 N_f E_{CH/frame} \quad (5.11)$$

$$E_{non-CH-data} = f_2 N_f E_{non-CH/frame} \quad (5.12)$$

3. RESULTS

1. The graph that shows the variation in optimum number of cluster with respect to the head-set size, where the base station is at distance=150m and the number of nodes n=1000.the head-set size can be varied between 1 and 6. As the graph shows, the head-set size cannot be greater than 6. Moreover, for a given head-set size, the maximum number of cluster can also be determined from the graph.

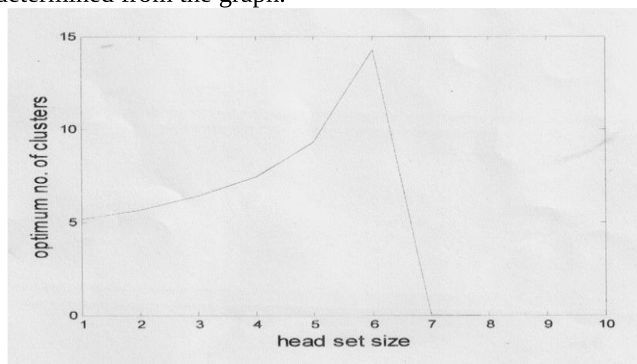

Figure 6.5 Optimum number of cluster Vs Head set size

2. Graph shows the variation in maximum cluster size with respect to distance from the base station and the head-set size. As the graph shows, bigger cluster size can be managed for larger value of head-set size. However, when the head-set size is small, only small number of cluster is possible. Moreover, when the distance from the base station is increased, more energy is spent for a distant transmission. As a result, for the same head-set size, the maximum number of clusters decreases when the distance to the base station increases.

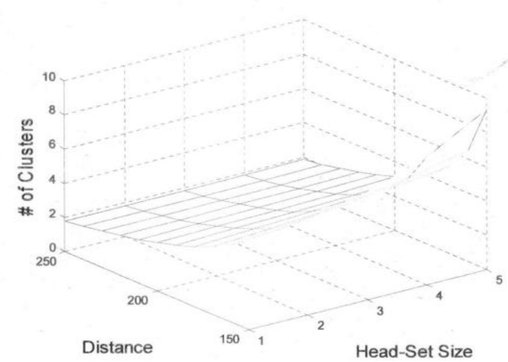

Figure 6.6 Variation in maximum cluster size with respect to distance from the base station and the head-set size.

3. Graph shows the energy consumption with respect to the number of clusters. As expected, the energy consumption is reduced when the number of cluster are increased. However, the rate of reduction in energy consumption is reduced for higher cluster sizes. Moreover, the energy consumption is lower when head-set size is 3 as compared to head-set size of 1.

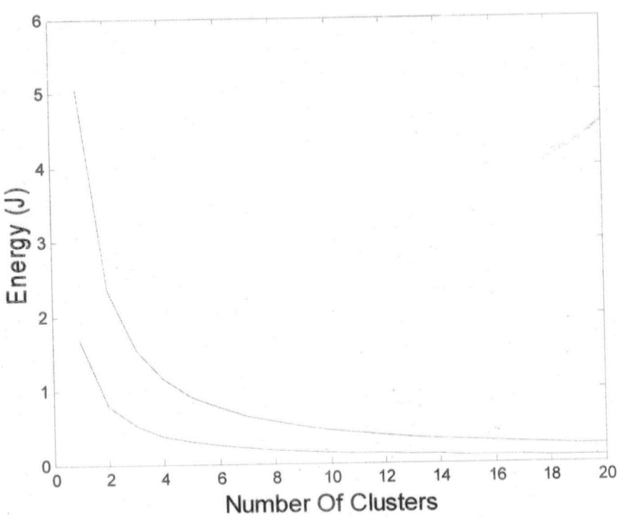

Figure 6.7 The energy consumption with respect to the number of clusters

4. Graph shoes the variation in the energy consumed per node with respect to the number of cluster and network diameter. The x-axis represents the number of cluster and the energy consumed in one round, respectively. In a round, the number of frames transmitted by one node is 20. The graphs show that energy consumption is reduced when the number of clusters is increased. For the simulated network of 1000 nodes, graphs shows that the optimum range of cluster lays between 20 and 60.

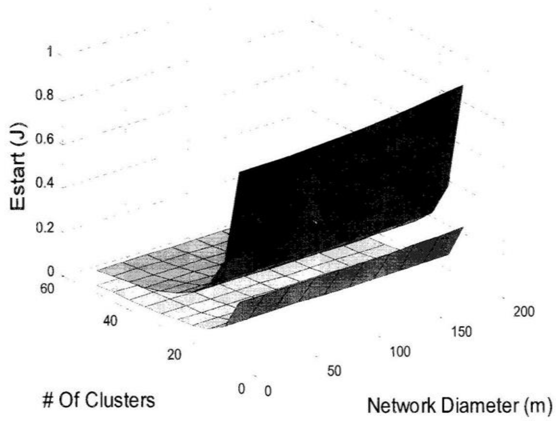

Figure 6.8 Energy consumed per round with respect to number of clusters

When the numbers of clusters are below the optimum range, for example 10, the data collection sensor node has to send data to the distant cluster heads. On the other hand, when the number of clusters is greater than optimum range, there will more transmission to the distant base station. Moreover, the energy consumption is lower for the higher head-set size. in the given graphs, the energy consumed is approximately three times less when headset size is 3 as compared to LEACH, where head-set size is1.

5. Graphs shows the variation in the energy consumed per round with respect the head-set size and network diameter. The x-axis, y-axis, and z-axis represent the network diameter, the head-set size, and the energy consumed in one round, respectively. The number of data frames in one iteration is No=10,000 and the number of clusters k=50. As expected, the graphs show that energy consumption is reduced when the head-set size is increased. Moreover, this protocol provides a more systematic approach of reducing the energy consumption. If more nodes are added in LEACH, all the nodes are treated alike and these extra nodes will also be used in collecting the sensor data. However, in our approach, the number of sensor nodes for data collection remains unchanged and the number of control and management nodes can be adjusted.

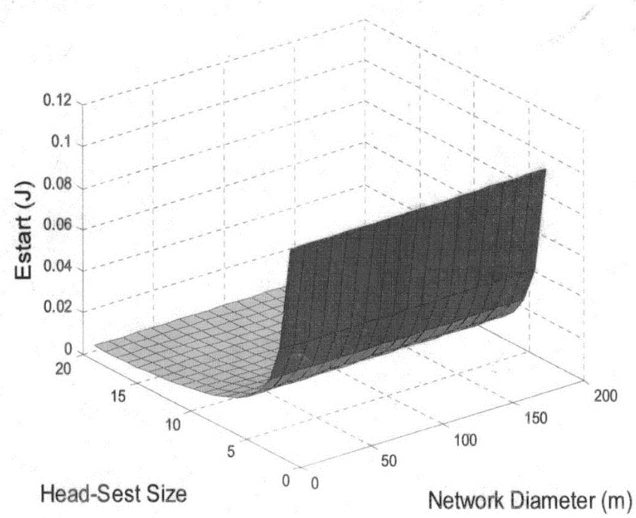

Figure 6.9 Energy consumed per round with respect to head-set size and network diameter.

6. In this section, average time to complete one iteration such that every node becomes a member of head-set is estimated. In other words, an average time for one iteration in each round is estimated. Moreover, frames transmitted are each iteration is also evaluated. The graph shows the variation in time to complete one iteration with respect to cluster diameter and head-set size. The x-axis, y-axis and x-axis represent the cluster diameter, head-set size, and time to

complete one iteration, respectively. The head-set size is given as a percentage of cluster size. The start energy, start is fixed for all the cases. The start energy can be used for the longest period of time when the head-set size is 50% of the cluster size. When the head-set size is less than 50% of the cluster size, there is less transmission in each iteration but there is more iteration to complete the round. However, when the head-set size is greater than 50% of the cluster size, there is more transmission in each iteration, although there is less iteration.

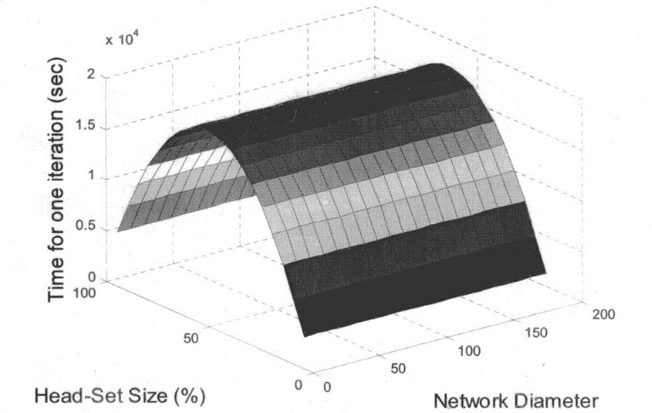

Figure 6.10 The time for iteration with respect to cluster diameter and the head-set size

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