Energy Efficient Adaptive Clustering for Heterogeneous Sensor Networks with power control

Sudarmani.R
Assistant Professor, Department of ECE
Avinashilingam Deemed University for Women
Coimbatore, Tamil Nadu, India.
sivasudar@yahoo.com

Dr. K.R. Shankar Kumar
Professor, Department of ECE
Sri Ramakrishna Engineering College
Coimbatore, Tamil Nadu, India.

Abstract—Wireless sensor networks are energy constraint battery powered sensing, computing and communication infrastructure. Sensor nodes are randomly deployed and organized as clusters, and each node is responsible for transmitting the data to its cluster head. Most of the existing sensor networks focus on homogeneous and most of the existing clustering algorithms can be applied only for homogeneous sensor networks in which the cluster heads are changed periodically. In this paper, to reduce power consumption of Sensor Networks, we have investigated Hierarchical Heterogeneous Sensor networks using Energy Efficient Adaptive Clustering algorithm (EEACA). The simulation results show that the consumed energy is less in the case of EEACA when compared AODV.

Keywords- *Heterogeneous sensor networks, sensor nodes, clustering, transmission power control.*

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of large number of nodes, having sensing, computation and wireless communication capabilities. They also collect information from the environment, where they deployed and reports to the remote base station. Usually, sensors in the network can only be equipped with a limited power. It is impossible to recharge the sensors battery power after they are scattered, deployment may be uniform or random. Therefore, the sensor networks depend mainly on the battery lifetime. The main factors of energy consumption of sensors are sensing, communication, and data processing. A sensor uses maximum energy for communication among the three factors. Its communication involves both data transmission and reception.

WSN have wide range of applications, such as environment monitoring, home and assisted living medical care, industrial automation and numerous military applications [1],[2]. Normally stationary sink is used in Wireless Sensor Networks and is more energy efficient when compared to the nodes present in the network. Each sensor node communicates wirelessly with a few other local nodes within its radio communication range. The existing homogeneous wireless sensor networks have sensors with equal capacity and hence they become application specific.

In this paper, heterogeneous sensor network is analyzed, which consists of different compositions of sensors with different capabilities such as collection of image, data, collection of audio signal etc. The clustering method is used for communication between nodes and sink, since it is energy efficient when compared to single and multi hop routing .In clustering, one of the sensors in the cluster will be elected as cluster head and the elected one is responsible for relaying data from each sensor to the remote receiver. In addition, data fusion and data compression can occur in the cluster head by considering the potential correlation among data from neighboring sensors. This clustering approach is preferred because it localizes traffic and can potentially be more scalable [3, 4, 5, and 6]. The network life time can be increased by reducing the energy consumption for communication and load balancing [7]. Many clustering algorithms have been discussed in [3, 7, 8, 9]. In this work, adaptive clustering with adaptive transmission power control in Heterogeneous Sensor Network is analyzed, the transmission power level determines the quality of the signal that could be received at the receiver, the range of a transmission and the magnitude of the interference that it creates for the other receivers. Power control affects the physical layer, the network layer - since the transmission range affects routing and the transport layer because interference causes congestion [10]. In sensor network, transmission power also determines the level of energy consumption. Therefore, power control problem has important cross-layer design issues affecting all layers of the protocol stack from physical to transport. In the clustering algorithm, we determine the transmission power level depending on the cluster coverage range and the number of nodes in a given cluster.

An Energy Efficient Adaptive Clustering Algorithm (EEACA) is implemented over HSN. In a typical clustering algorithm, a distributed leader election protocol is executed in each cluster. In HSN, cluster head nodes are fixed and uniformly distributed over the network area which decreases the time period of cluster formation phase. EEACA divides the nodes into cluster groups and the boundary of the clusters is adaptively changed according to the number of cluster members present in the group. Hence load balancing is achieved. HSN with EEACA, adaptive transmission power control over sensors are analyzed. The paper is organized as follows. In section II, related work is carried out, section III heterogeneous sensor network model is analyzed, section IV discusses Energy Efficient Adaptive Clustering Algorithm also HSN with ATPC system is discussed in section V, followed by section V explains about the Load Balanced HSN , section VII deals with the protocols used in our system, section VIII about the energy consumption analysis of our system. Finally, concluded with simulation and results.

II. HETEROGENEOUS SENSOR NETWORK MODEL

Heterogeneous sensor network (HSN) modeled by both Low (L) as well as High (H) Energy sensors [10] and are distributed uniformly and randomly in the environment. The powerful H sensors form clusters around them and act as cluster heads. The cluster formation is depicted in Fig.1, consists of L sensors, H sensors and the Base station (BS). H sensors provide longer transmission range, higher data rate than L sensors and also facilitates better protocols, algorithms, and secure schemes in sensor networks. As an efficient and robust cluster formation scheme is adopted in HSN the sensor nodes provide coverage of the region with a high probability [2]. Cluster heads are responsible for data aggregation and transmission of the aggregated data to a base station.

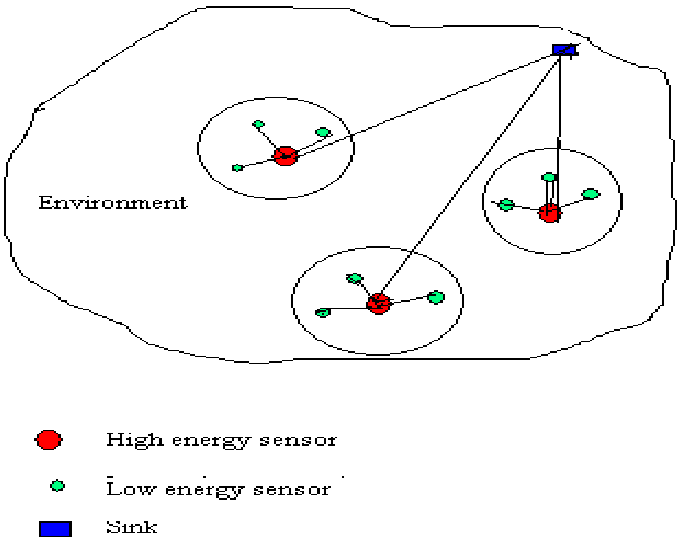

Figure 1.Hierarchical network model

III. ENERGY EFFICIENT ADAPTIVE CLUSTERING ALGORITHM

A. Node distribution in HSN

Sensor nodes in HSN are divided into clusters. Number of clusters in a network region is based on number of nodes and their distribution. Each cluster is a subset of nodes that can communicate with H sensor.

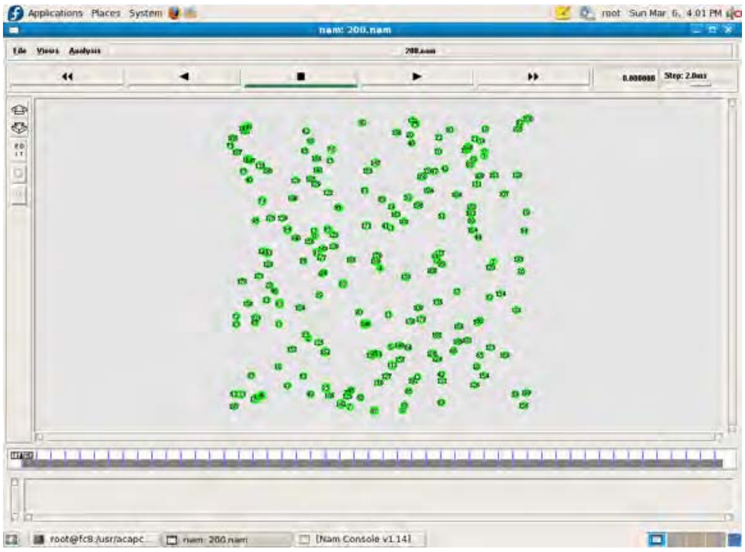

Figure 2. Node distribution in HSN

After the cluster partition, L sensors directly communicate with its H sensor. Each cluster has its own CH. All the cluster members transmit the data to its own CH. The CHs of each cluster communicate with the base station. The direct communication between the cluster members and base station is restricted because of its maximum power consumption during data communication. The network area is 500 x 500 with 25 cells, each cell in 100 x100 dimensions. Let R be the communication range of the sensor node and d is the uniform network node density. Number of nodes in a cluster will be total number of nodes divided by total number of cells in the network.

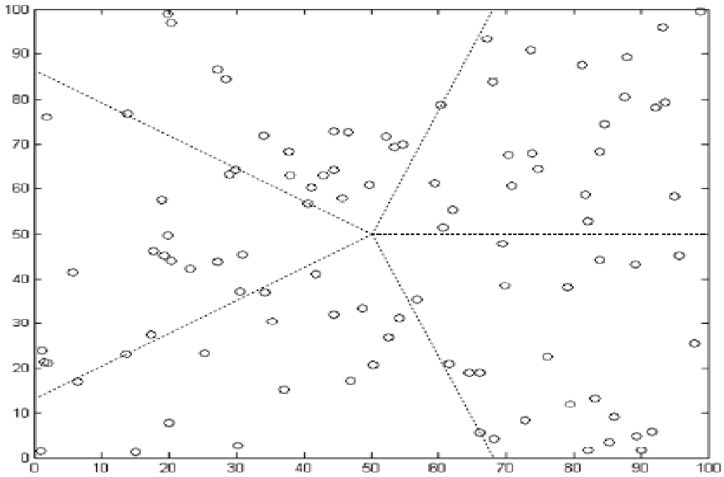

Figure 3. Clustering based on area partitioning

21	22	23	24	25
16	17	18	19	20
11	12	13	14	15
6	7	8	9	10
1	2	3	4	5

Figure 4. Cell Alignment in HSN

B. *Algorithm*

Step 1: To achieve the communication between the nodes, the position of the nodes should be known.
Grid size x=100, y=100.
Node position = 5y+x+1 (Here 5 represents rows)

Step 2: Next the adjacent cells should be known before performing merging and division of cells.
Column No.: cell no -1 and cell no +1.
Row No.: cell no -5 and cell no +5

Step 3: Cell merging and division are classified as
Horizontal merging
Vertical merging

If cell has lesser than 5 nodes, we prefer merging process. If cell has greater than 10 nodes, we prefer division process. The situation decides about horizontal or vertical process between the nodes.

Step 4: The cell position should be found because based on it merging and division process takes place.

Column-wise

1. If |mod 5| of cell no =0 ---- no right cells.
2. If |mod 5| of cell no is not equal to 0 then it has two sides(i.e left and right) else it has no left cell (ie cell no -1 should be 5 divisible)

Row-wise

1. If Q=0 ---- no bottom cells.
2. If Q= 4 ---- no top cells.
3. If 1 > Q < 4 ---- has both top & bottom cells.

Step 5: Rule for merging process

6	7	8	9	10
1	2	3	4	5

If the cell 2 has less nodes (< 5) ,then we merge the cell with another cell having less than 5 nodes. If it is merged with the cell having more nodes, consecutively it results in division. If cell 2 is merged with cell 3, it is horizontal merging. If the cell 2 is merged with cell 7, it is vertical merging. Every merged cell is allowed to have a single division, otherwise it is considered as exception case and kept as it is.

Step 6: Rule for division process

6	7	8	9	10
1	2	3	4	5

If the cell 2 has nodes more than 10 nodes, then we move for dividing the cells. The divided cell is allowed to merge with the adjacent cells having less nodes. If the cell 2 is divided vertically, then it is allowed to merge with cell 3 horizontally. If the cell 2 is divided horizontally, then it is allowed to merge with cell 7 horizontally. While dividing and merging, the cell area will undergo a size change and it should be updated.

Step 7: The cluster head (CH) will be selected for each cell. The node which is nearest to the centre of the cell is taken as CH, in order to have uniform power transmission between the cells. Distance between the cluster heads is about 125m (approx).

This results the CHs communication to base station rather than node communication. Node communication consumes more power since every node in the cell plays a role in data transmission. Thus we come out with CH communication to reduce the power during transmission which reflects in maximizing the sensor lifetime.

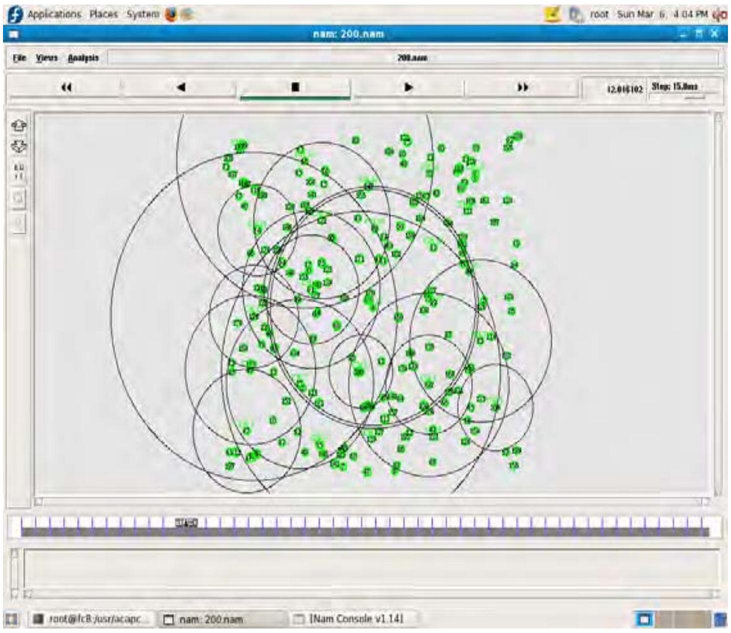

Figure 5. Cluster formation phase

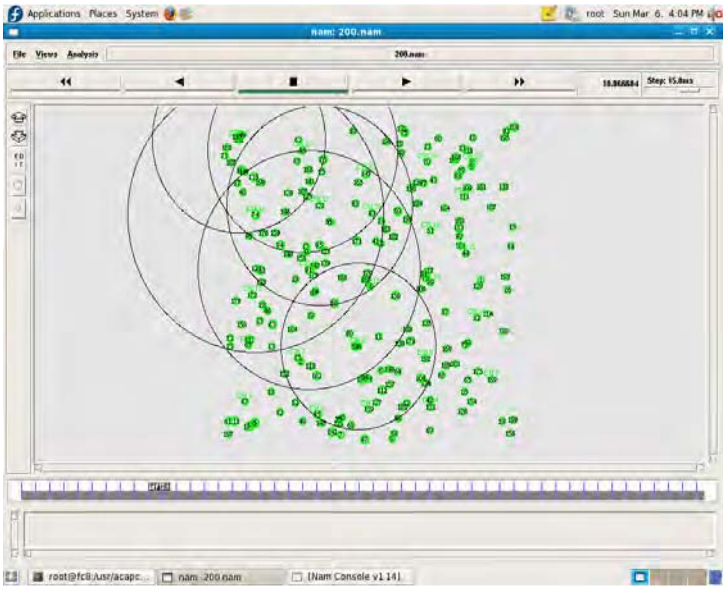

Figure 6. Communication between CH and sink

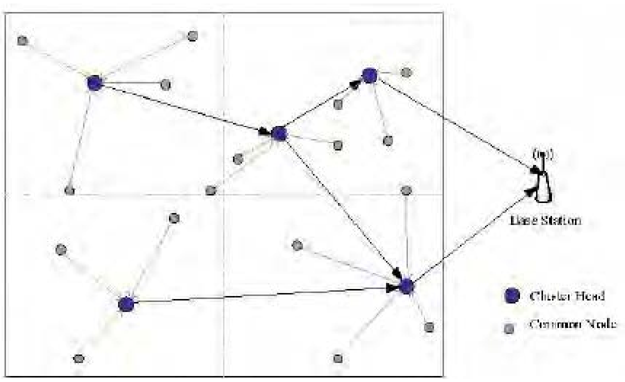

Figure 7. Cluster communication in EECA

C. Heterogeneous Sensor Nerwork with power control

In a hierarchical sensor network, the H nodes transmit hello packets to all the nodes and the nodes in turn acknowledge the receipt of it. Clusters are formed on the basis of shortest distance between H and L nodes. After the cluster formation, the L nodes reduce its transmission power level based on the distance to the corresponding H nodes.

The initial energy of the cluster head should be optimally shared between the two CH activities: intra-cluster management and inter cluster routing. The energy optimization and network life time are simultaneously done by adjusting the transmission power level of each L node, the adaptive transmission power level has taken from [9]. At the same time transmission range also reduced for L nodes.

D. Load balanced HSN with ATPC

The sensor network is denoted by undirected graph G (V, E), where V denotes the set of all nodes which includes H nodes and L nodes. In that 10% of nodes are H nodes. E denotes the set of links between any pair of nodes in the radio range R. The initial energy of L and H sensors are represented by E_{LEi} and E_{HEi} respectively. The H sensors are having high energy, that is $E_{HEi} > E_{LEi}$. The algorithm consists of two phases that are Cluster formation phase with Load balancing, data communication phase with transmission power control (ATPC).

E. Radio Model

The two ray ground propagation model is used for communication. The minimum transmission power of sending node Pmin is given by equation (1).

$$P_{min} = P_t \, P_{thr} / P_r \qquad (1)$$

P_{thr} is the minimal threshold power of received signal

F. Energy Model

Energy consumption in WSN is mainly divided into two parts, based on energy consumption for processing, computation and transmission of collected data.

The energy required for data transmission will be more compared to data collection. The power dissipation of radio module as:

$$E_{tx}(k,d) = E_{elc}(k) + E_{amp}(k,d) \qquad (2)$$
$$= k\,E_{elc} + k\,\varepsilon fr\, d^2 \text{ for } d \leq d0$$
$$= k\,E_{elc} + k\,\varepsilon amp\, d^4 \text{ for } d > d0$$
$$E_{rx}(k) = k\,E_{elc}, \qquad (3)$$

E_{elc} is the electronics energy. E_{amp} is the amplifier energy, depending on the distance to the receiver. As the distance between sources to sink plays a major role in energy consumption, the sensor nodes that transmit data over a long distance will drain energy soon. Reducing the node transmission radius will lead to less energy consumption [19].

G. Adaptive transmission power control phase

Let R be the initial transmission range of all nodes. Mapping table shows the distance between L and H nodes and the corresponding transmission power level [20].

TABLE I. VARIOUS TRANSMISSION RANGES AND CORRESPONDING POWER LEVELS

Pt(mW)	Transmission range(m)
282	250
36.6	150
7.25	100
3.5	80
1	40

IV. Energy Energy Consumption Analysis in HSN with EEACA

The overall system design problem involves determining the optimum number of cluster head nodes. The cluster is a circular region and the cluster head is located at the center of this region. The communication between nodes and node to base station takes place in a single hop. Propagation loss constant k , for communication within a cluster, and k_0 for communication between the H nodes and base station. Since the cluster head to base station communication is long range, it is likely that $k_0 > k$.

The exact values of k and k_0 depend on the environment in which the network operates. Each node directly transmits its packet to the cluster head as in Fig. 1. The communication area of each node is smaller than the total area of the cluster.

The total energy consumption of heterogeneous sensor networks is obtained by combining the energy consumed by cluster heads and non cluster heads. The total energy consumed by heterogeneous sensor networks [19] is given by

$$E_T = E_{HE} + E_{LE}\ E_T \quad (4)$$

$$E_{HE} = T(n_o / n_1(l_1 + E_f) + (l_2 + \mu_2 d^4)) \quad (5)$$

$$E_{LE} = T(l_1 + \mu_1 A^2 / n_1) \quad (6)$$

E_f is the computational energy spent on fusion of each packet

l_1 is the amount of energy spent in the transmitter electronics circuitry within a cluster

l_2 is the amount of energy spent in the transmitter electronics circuitry from the cluster head to the base station

μ_1 is the energy spent in the RF amplifier within the cluster

μ_2 is the energy spent in the RF amplifier from the cluster head to the base station

A is the radius of the region

T is the data gathering cycles

n_0 is the number of low energy nodes

n_1 is the number of high energy nodes

$\frac{A}{\sqrt{n_1}}$ is the radius of the cluster region

In this paper, the power control functionality is introduced based on the distance between L and H nodes. According to the distance between them, the L nodes reduce its transmission power adaptively. Hence, reduction in the power consumption takes place according to equation (4), at the same time network life increases compared with HSN.

V. Simulation Results

A. Simulation Environment

Network simulator ns-2 is used for simulation. Two ray ground reflection model is used and 100 nodes are uniformly spread in a square region with a dimension of 500m x 500m, out of which 10% are H nodes

B. Simulation Results

Figure.9 shows the residual energy of EEACA protocol over HSN, it is energy efficient. As the residual energy of HSN with ATPC is more compared to the HSN as shown in fig.10 , the life time of HSN with ATPC is longer compared to HSN. Simulation is carried out for calculating energy consumption by varying the number of L nodes. The plot of the number of L nodes Vs energy consumption is shown in fig. 11. It shows that the energy consumed by HSN with ATPC is less when compared to HSN.

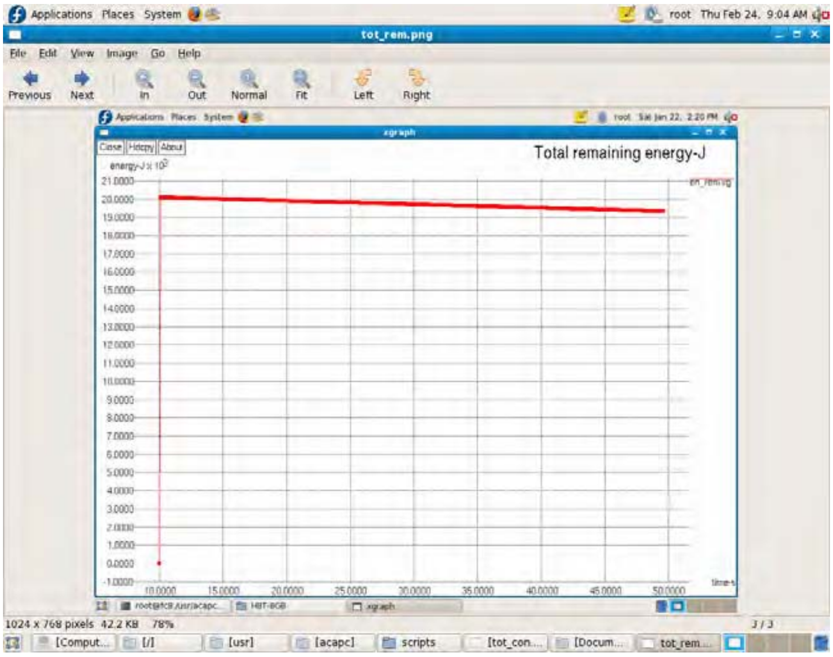

Figure 8. Total remaining energy of EEACA

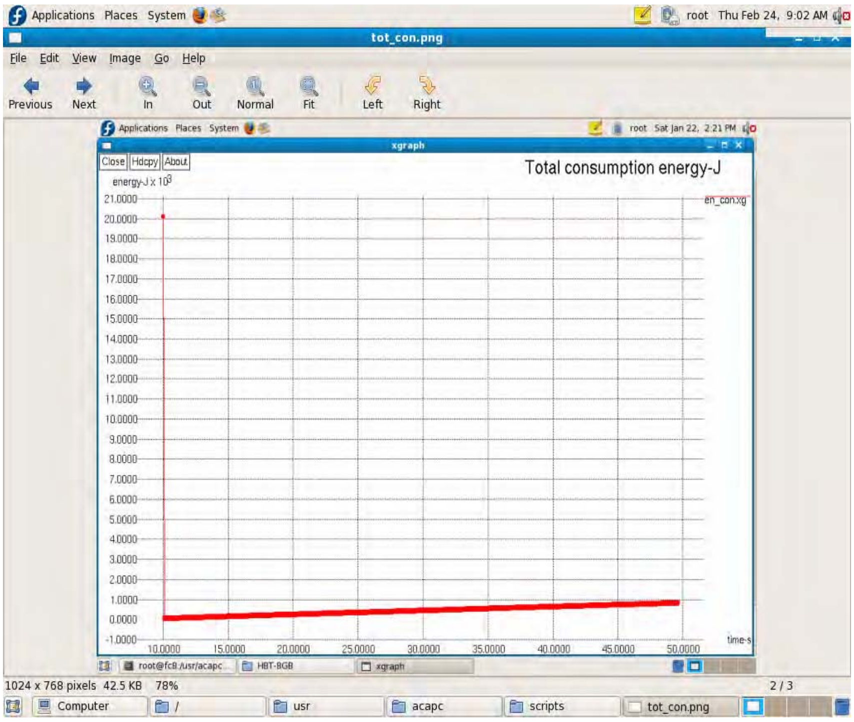

Figure 9. Total energy consumption of EEACA

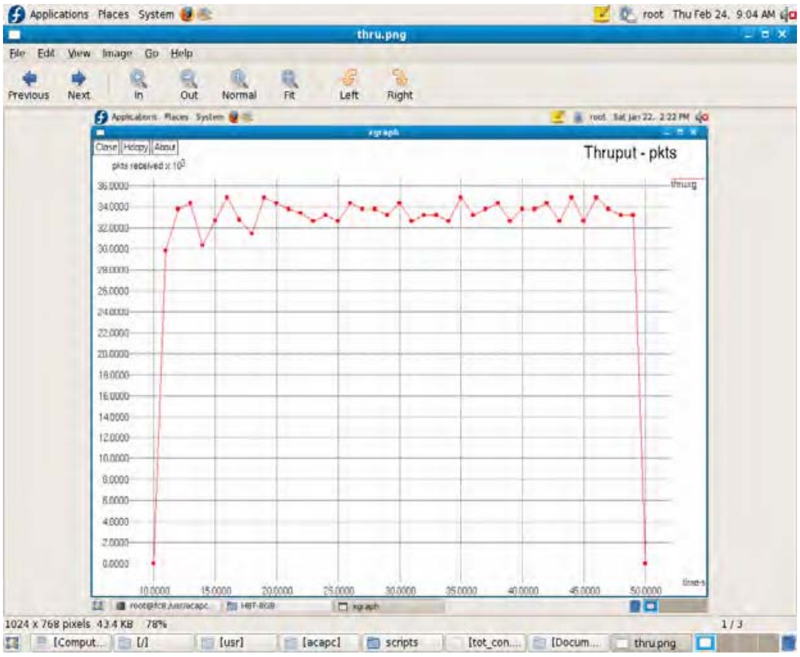

Figure 10. Throughput of EEACA

VI. SIMULATION RESULTS

Wireless Sensor Network are energy constraint, because after deployment battery of the node cannot be replaced. The EEACA protocol uses zones that are divided based on the location information of each sensor node. It is possible that the zone concept can adaptively construct clusters depending on the node density. In addition, this protocol dynamically controls the transmission power level according to the radius of cluster, so that it can avoid collision caused by interference of other clusters. In this paper, EEACA is implemented over Load balanced HSN. The results shows that EEACA protocol performs significantly better compared to other Routing protocols such as AODV. H sensors have longer transmission range, hence number of hops to reach receiver is reduced at the same time L sensors reduces its transmission range and thus energy optimization is obtained.

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AUTHORS PROFILE

R. Sudarmani is working as Assistant Professor in Avinashilingam Deemed University for Women, Coimbatore, India. She received her BE (ECE) degree from Bharathiar University, Coimbatore, in the year 1997 and ME (Applied Electronics) degree from Anna University, Chennai, in the year 2005. She has more than 10 years of teaching experience. She is presently pursuing her PhD programme in the area of Wireless Sensor Networks in Anna University, Coimbatore. Her current area of research is wireless sensor networks.

K.R. Shankar Kumar is working as Professor in Sri Ramakrishna Engineering College, Coimbatore, India. He received his BE (ECE) and ME (Applied Electronics) degrees from Coimbatore Institute of Technology, Coimbatore, and Anna University, Guindy, Chennai, respectively. He received PhD degree in Communication Engineering from Indian Institute of Science, Bangalore, in the area of CDMA, and received Swarna Jayanthi award from Government of India for his research. He has published 20 papers in National and International journals and currently guiding 15 research scholars. He is having more than 6 years of teaching and research experience. His current research interest is CDMA, OFDM and MIMO.