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Heterogeneous Energy Efficient Wireless Sensor Networks

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ABSTRACT

Wireless sensor networks consist of nodes that transmit aggregated data to the base station by sensing the environment. In this paper we have used LEACH protocol on heterogeneity basis in which some nodes have higher energy as compare to other nodes. The higher energy nodes works as cluster heads which passes the information to the base station. Thus the lifetime of the system increases as the nodes having higher energy will die later. This system also performs data compression that helps in compressing the useless information and finally desired information is achieved on the base station.

Optimal no. of cluster heads are approximately five which is observed after simulation and also the nodes would die after a long time that would help in increasing system lifetime and would make a system more energy efficient. This simulation shows that energy can be saved approximately double as compare to previous protocol.

1. INTRODUCTION

Wireless sensor networks (WSNs) uses nodes which contain memory and processors these nodes process the data and pass the collected information to the base station. Wireless sensor networks are used in various applications for example in vehicle tracking or in medical. The only problem faced by wireless sensor networks is limited energy of the nodes. This limited energy of the nodes limits the lifetime of the whole network. So in order to remove this problem we need efficient protocol which would help in increasing the lifetime of the network.

All the protocols that are designed and implemented in WSNs should provide some real-time support as they are applied in areas where data is sensed, processed and transmitted based on an event that leads to an immediate action. A protocol is said to have real-time support if and only if it is fast and reliable in its reactions to the changes occuring in the network. It should provide useful information to the base station or sink using the data that is collected among all the sensing nodes in the network. The delay in transmission of data to the sink from the sensing nodes should be short, which leads to a fast response. The basic communication types considered send periodic data or event-driven data to the base station or to the sink. The other major type extracts data from a particular location or specific nodes or set of nodes. Routing protocols must fulfill these requirements along with energy conservation and focus on Quality of Service (QoS) factors. Such requirements can be fulfilled using clustering protocols. In clustering protocol, nodes are organized into clusters that communicate with their cluster head and the cluster head transmit the data to the base station.

LEACH stands for low energy adaptive clustering hierarchy uses random distribution of energy to the nodes in which nodes forms a cluster randomly, nodes which have higher energy becomes cluster head and nodes which have lower energy gives the data to the cluster head after sensing the environment. These cluster head passes the collected data to the base station, it also performs data fusion which compresses the useless information and sends only desired amount of data which reduces amount of energy and thus increases the system lifetime. LEACH works according to homogeneous distribution of energy to the various nodes in the network. Due to which nodes those are cluster heads for a particular round die soon because of which the lifetime of the system reduces. This drawback is overcome by Heterogeneous LEACH protocol.

Heterogeneous LEACH works on the principle of heterogeneity. In homogeneous each node utilizes same amount of energy while in heterogeneous each node uses different amount of energy. In wireless sensor network when we add more number of nodes in the network then these nodes are introduced with higher energy as compare to the other nodes in the network. We add more number of nodes in the network because lifetime of sensor networks are generally short due to which we add more number of nodes in the network which is basically performed by the heterogeneous LEACH. This simulation is based on Heterogeneous protocol.

2. Homogeneous LEACH Protocol

LEACH uses random distribution of energy to the nodes in which nodes forms a cluster randomly, nodes which have higher energy becomes cluster head and nodes which have lower energy gives the data to the cluster head after sensing the environment. These cluster head passes the collected data to the base station,

LEACH protocol works on randomization. Thus each node decides itself that whether it has to be cluster head for this round or not on probability basis. Now each cluster head passes a message to the other nodes in the network. Each node decides itself to which cluster head it wants to belong by searching the minimum transmission distance. Which reduces the amount of energy as the nodes passes the data to the nearest possible node.

Energy saving also depends on the number of clusters in the network. If the number of clusters would be less then optimal number of clusters than non cluster head nodes will have to transmit the data on the longer distance which would increase the energy utilization also if the number of clusters would be more then the optimal number of clusters than more number of cluster heads will utilize more amount of energy as cluster heads work on higher energy as compare to non cluster nodes. Thus we need optimal number of clusters in the network which would help in saving overall energy of the network. LEACH works in three phases: advertisement phase, set up phase and steady state phase. In advertisement phase, advertisement is passed to all the nodes. In set up phase where each node chooses its nearest cluster head to become the part of the cluster. In order to become the part of the cluster, node transmits its request to the cluster head in form of a message which consist of id of node and id of cluster head. After this cluster head passes a TDMA (time divison multiple access) schedule to each node of the particular cluster and accordingly collect the data from the other nodes. In steady state phase data is transmitted to the base station. Data is send into frames and each node sends data once per frame as it works according to the TDMA Technique.

3. Heterogeneous LEACH Protocol

Heterogeneous LEACH works on the principle of heterogeneity. In homogeneous each node utilizes almost same amount of energy and we can not add additional nodes any time while in heterogeneous each node uses different amount of energy and we can add nodes any time. In wireless sensor network when we add more number of nodes in the network then these nodes are introduced with higher energy as compare to the other nodes in the network. We add more number of nodes in the network because lifetime of sensor networks are generally short due to which we add more number of nodes in the network which is basically performed by the heterogeneous LEACH. Heterogeneous LEACH also works in three phase advertisement phase, set up phase and steady state phase.

Advanced nodes which are denoted as 'm' and the additional energy factor between the advanced nodes and normal nodes is denoted by 'a'. So these advanced nodes get more chances to become cluster head thus overall energy of the network increases.

Suppose that E_0 is the initial energy of each normal sensor. The energy of each advanced node is then E_0 (1+a). The total (initial) energy of the new heterogeneous setting is equal to:

n . (1- m) E_0 + n . m . E_0 . (1 + a) = n . E_0 . (1 + a. m)
1

As a solution, assume heterogeneous LEACH Protocol, which is based on the initial energy of the nodes. This solution is more applicable as compared to any other solution which assumes that each node knows the total energy of the network and then adapts itself to become a cluster head according to its remaining energy.

4. Wireless Sensor Network Model:

There are three main components in a wireless sensor network; sensor nodes, sink and monitored events as shown in figure 1.

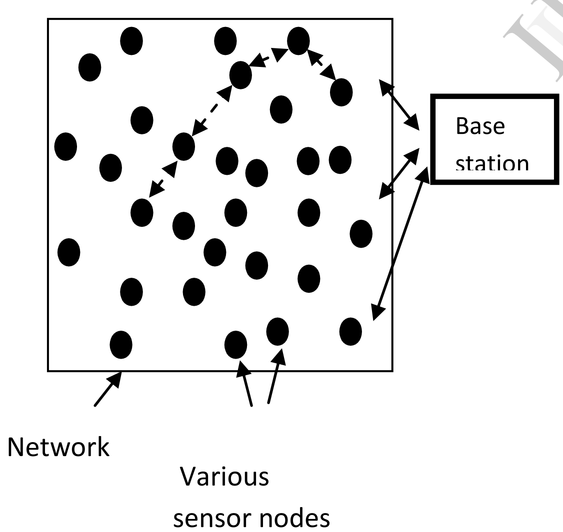

Figure 1: Wireless Sensor Network Model

With the help of this model following assumptions that are adopted as below:

1. *N* sensors are uniformly dispersed within a square field S. The BS is situated far away from the square field S.

2. All sensors and BS (Base station) are stationary after deployment. Each node knows the location of BS. Each sensor with enough energy can communicate with BS directly.

3. Sensors can use power control to vary the amount of transmit power depending on the distance to the receiver.

4. Communication is symmetric and a sensor can compute the approximate distance based on the received signal strength if the transmission power is known.

5. All sensors are location-unaware and are heterogeneous in terms of initial energy.

5. Channel Propagation Model in Wireless Sensor Networks

In wireless sensor networks channels are basically communication path between the transmitter and receiver. In a particular channel, the electromagnetic wave propagation can be modeled as a power law function of the distance between the transmitter and receiver.

We assume certain cross over distance (d_0) and now we will compare the distance between the transmitter and receiver with this cross over distance. If this distance is less than cross over distance then friss free space model is used which is based on d^2 attenuation and if the distance is more than the cross over distance then the two-ray ground propagation model is used which is based on d^4 attenuation. The cross over distance is defined as:

$$d_o = \frac{4\pi\sqrt{L}h_r h_t}{\lambda} \qquad 2$$

Where L ≥1 is the loss in the system which is not related to propagation, h_r is the height of the receiving antenna above ground, h_t is the height of the transmitting antenna above ground, and λ is the wave length of the carrier signal.

If the distance is less than d_o, the transmitted power is attenuated according to the Friss free space then the received power equation is given by:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2 L} \qquad 3$$

Where $P_r(d)$ is the received power where d is the distance between the transmitter and receiver, P_t is the transmitted power, G_t is the gain of the transmitting antenna, G_r is the gain of the receiving antenna, λ is the wave length of the carrier signal and L ≥1 is the losses in the network which is not related to propagation.

If the distance is greater than d_o then the transmitted power is attenuated according to the two-ray ground propagation equation given by:

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4} \qquad 4$$

Where $P_r(d)$ is the received power where d is the difference between transmitter and receiver,

P_t is the transmitted power, G_t is the gain of the transmitting antenna, G_r is the gain of the receiving antenna, h_r is the height of the receiving antenna above ground, and h_t is the height of the transmitting antenna above ground.

In order to calculate cross over distance we use an omni directional antenna with the following parameters: $G_t = G_r = 1$, $h_t = h_r = 1.5$m, L =1 (without loss), 914 MHz radios, and $\lambda = 3*10^8 / 914*10^6$ = 0:328m. Using the above parameters, we have: d_o = 86.2m and on putting d_o = 86.2m, equations becomes:

$$P_r = \begin{cases} 6.82 \times 10^{-4} \dfrac{P_t}{d^2} & : d < 86.2m \\ 2.25 \dfrac{P_t}{d^4} & : d \geq 86.2m \end{cases} \qquad 5$$

6. Radio Energy Model in Wireless Sensor Networks

Energy is utilized in transmitting and receiving of data from node to the base station. Radio energy is used for both transmission and reception. So radio energy model is used in which transmitter consumes energy via radio electronics and the power amplifier and receiver consumes energy via radio electronics.

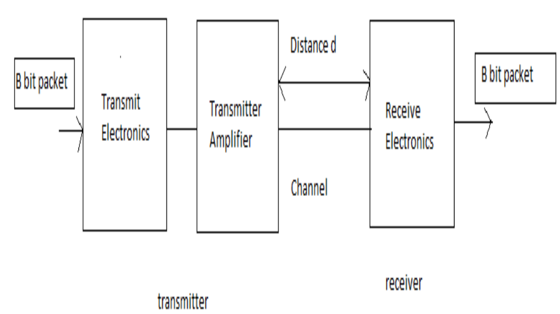

Figure 2: Radio energy model

Thus in order to transmit a B-bit message over a distance d, radio energy at the transmitter is given by:

$$E_{Tx}(B,d) = E_{Tx\_elec}(B) + E_{Tx\_amp}(B,d) \qquad 6$$

$$E_{Tx}(B,d) = \begin{cases} BE_{elec} + B\varepsilon_{friss\_amp} d^2 : d < d_o \\ BE_{elec} + B\varepsilon_{two\_ray\_amp} d^4 : d \geq d_o \end{cases} \quad 7$$

Now radio energy at the receiver is given by:

$$E_{Rx}(B) = E_{Rx\_elec}(B)$$

$$E_{Rx}(B) = BE_{elec} \quad 8$$

The energy utilized by a cluster during sending of the frame is:

$$E_{cluster} = E_{CH} + \frac{N}{n} E_{non\_CH} \quad 9$$

Where $E_{cluster}$ is the energy utilized by a cluster during sending of the frame, E_{CH} is the energy utilized by the cluster-head node during a single frame, E_{non_CH} is the energy utilized by a non cluster-head node during a single frame, N is the number of nodes distributed randomly in an M*M region, n is the expected number of clusters per round.

7. Optimum Number of Clusters in Heterogeneous LEACH Protocol

In heterogeneous LEACH, the cluster formation algorithm is used which makes sure that the expected number of clusters per round is n. We need to define optimum number of clusters so as to minimize utilization of energy in the network. We can assume there are N nodes distributed uniformly in an M*M region. If there are n clusters, we get average N/n nodes per cluster. Each and every cluster head in the network consumes energy in order to receive data from various other nodes and then finally to transmit the aggregate data to the base station. The distance between the cluster head node and base station is large. Therefore, the energy dissipated in the cluster-head node during a single frame is:

$$E_{CH} = BE_{elec}\frac{N}{n} + BE_{BF}\frac{N}{n} + B\varepsilon_{two\_ray\_amp} d^4_{to\_BS} \quad 10$$

where B is the number of bits in each data message and d_{to_BS} is the distance from the cluster-head node to the base station. Each non-cluster-head node transmits its data to the cluster-head once during a frame. Now the distance between the non-cluster-head node and its cluster-head is less than the cross-over distance, so the energy dissipation follows the Friss free-space model (e.g., d^2 power loss).Thus, the energy used in each non-cluster-head node is:

$$E_{non\_CH} = BE_{elec} + B\varepsilon_{friss\_amp} d^2_{to\_CH} \quad 11$$

The energy dissipated in a cluster during the frame is:

$$E_{cluster} = E_{CH} + \frac{N}{n} E_{non\_CH} \quad 12$$

Thus the total energy for the frame is:

$$E_{total} = nE_{cluster}$$

$$= B(E_{elec}N + E_{BF}N + n\varepsilon_{two\_ray\_amp} d^4_{to\_BS} + NE_{elec} + N\varepsilon_{friss\_amp}\frac{1}{2\pi}\frac{M^2}{n}) 13$$

The optimum number of clusters can be determined by setting the derivative of E_{total} with respect to n to zero:

$$\frac{dE_{total}}{dn} = 0$$

$$\varepsilon_{two\_ray\_amp} d^4_{to\_BS} = N \varepsilon_{friss\_amp} (\frac{1}{2\pi} \frac{M^2}{n^2_{opt}})$$

$$n_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}} \sqrt{\frac{\varepsilon_{friss\_amp}}{\varepsilon_{two\_ray\_amp}} \frac{M}{d^2_{to\_BS}}} \quad 14$$

In this work, N=100nodes, M=100m, ε_{friss_amp} =10pJ, $\varepsilon_{two\_ray\_amp}$ =0:0013pJ, and 75< d_{to_BS} <185, so the expected optimum number of clusters are:

$$1 < n_{opt} < 6 \quad 15$$

When there is only 1 cluster, the non-cluster-head nodes will have to transmit data very far to reach the cluster-head node, and when there are more than 5 clusters, there is not as much local data aggregation being performed.

8. Total Energy consumed per round

The total energy drained from each node per round depends on the average number of frames per round, $N_{frames/round}$, as follows:

$$E_{CH/round} = N_{frames/round} * E_{CH/frame}$$

$$E_{non\_CH/round} = N_{frames/round} * E_{non\_CH/frame} \quad 16$$

where $E_{CH/frame}$ is the energy to receive all signals from non-cluster-head nodes, the energy to aggregate the signals, and the energy to send the aggregate data to the base station which means total energy from cluster head to the base station, while $E_{non\_CH/frame}$ is the energy to send a data to the cluster-head.

Putting the values E_{elec} = 50 nJ/bit, E_{BF} = 5 nJ/bit, ε_{friss_amp} = 10 pJ/bit/m^2, $\varepsilon_{two\_ray\_amp}$ = 0.0013 pJ/bit/m^4, N = 100, M = 100 m, n = 5, B = 4000 bits and R_b = 1Mbps bits gives:

$$N_{frames/round} = \frac{E_{start}}{9mJ}$$

$$t_{msg} = 4ms$$

$$t_{frame} = 80ms$$

$$t_{round} = 0.08 \text{ seconds} * \frac{E_{start}}{9mJ}$$

Therefore, given the initial energy of the nodes, E_{start} the cluster-heads and associated clusters should be rotated approximately every 0.08* $\frac{E_{start}}{0.009}$ seconds.

9 Radio Parameters

In Wireless Sensor Networks simulations are made with MATLAB. According to these simulations, we have assumed network which consists of 100 nodes which are randomly distributed. The base station which is the destination and is far from the network and the closest distance which is taken is 75 meters from the nearest node. The bandwidth of the channel which is used to transmit the data is considered to be 1Mbps. The length of the data message is considered to be 500 bytes. The cross over distance which decides the attenuation of signal is considered to be 87m. The energy in order to aggregate the data is considered to be 5nJ/bit. Also the size of the network is 100*100 square of meters.

9.1 Simulation Results

Simulations are performed by considering the 100 node network. Number of clusters are compared with the average energy consumed per round.

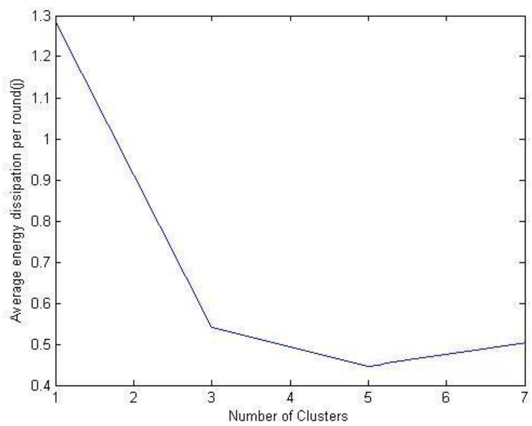

Figure 3: Average energy dissipation per round in LEACH versus the number of clusters.

Various nodes decide according to the probability that whether the particular node would become cluster head for this round or not.

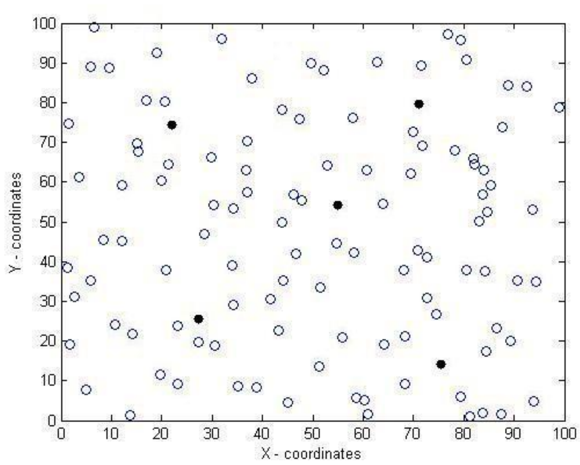

Figure 4: Cluster head nodes at time t.

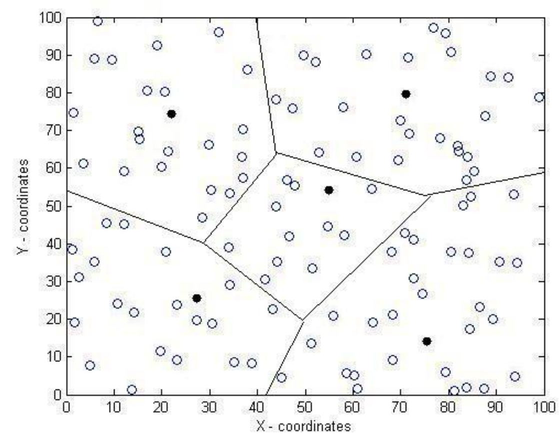

Figure 5: Cluster head nodes and cluster formation at time t.

9.2 Comparison between Direct Transmission and LEACH Protocol

Direct transmission consists of nodes which directly transmit the information to the clusters. While LEACH protocol works according to clusters. Figure 6 shows the average amount of energy consumption verses number of cluster heads in the complete network. This graph shows that LEACH achieves approximately 7 times reduction in energy compared to direct communication, when using optimal number of cluster-heads. The main energy saving of LEACH protocol is due to combining compression with the data routing. There is a trade-off between the quality of output and the amount of compression achieved. In this case, some data from the individual signals is lost, but this results in a reduction of the overall energy dissipation of the system.

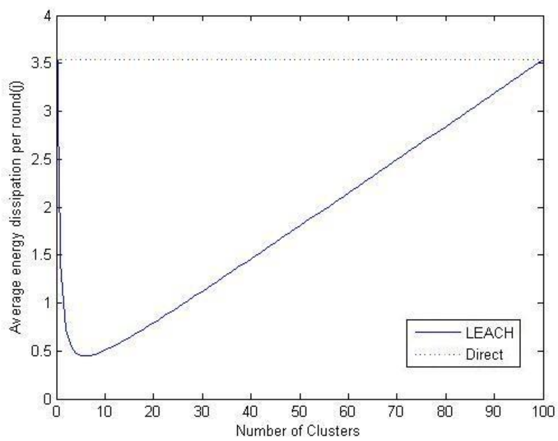

Figure 6: Average energy dissipation versus percentage of cluster head nodes.

9.3 Energy Dissipation Comparison of heterogeneous-LEACH and LEACH Protocols

We have discussed the energy consumption of various protocols related to LEACH protocol. But now the comparison is related to the heterogeneous LEACH. Now we will compare the performance of both protocols via graphs. As in LEACH, nodes transmit their data to the cluster head node during each frame of data transfer, and the cluster head aggregates the data and sends the resultant data to the BS. When the cluster head node's energy is depleted, the nodes in the cluster lose communication ability with the BS and are essentially "dead." Whereas, in hetero-LEACH protocol some of the nodes are of higher energy nodes (advanced nodes) that takes more time to get depleted, hence they hetero-LEACH protocol system has larger lifetime in comparison to LEACH.

The results of hetero-LEACH simulations are shown in Figure 7 and 8 for m = 0.1 and a=0.9 with initial energy 0.5J and 1J respectively.

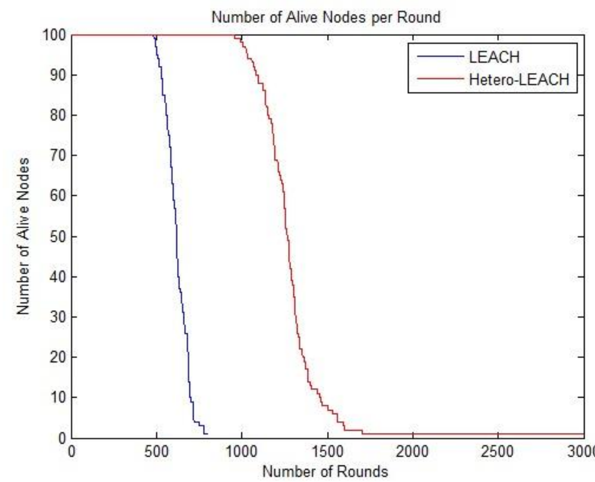

Figure 7: Number of alive nodes using LEACH in the presence of heterogeneity with advanced nodes m=0.1 and normal nodes a=0.9 with initial energy 0.5J.

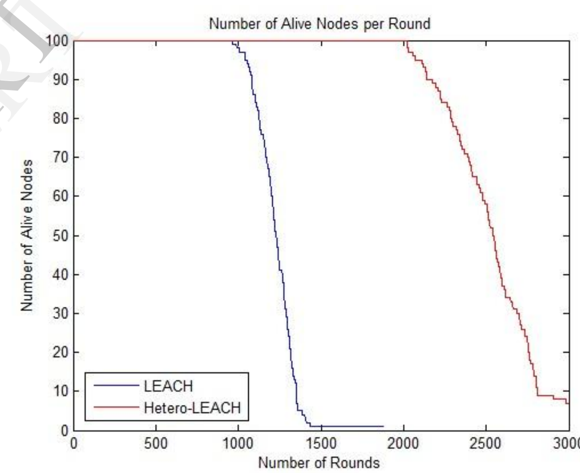

Figure 8: Number of alive nodes using LEACH in the presence of heterogeneity with advanced nodes m=0.1 and normal nodes a=0.9 with initial energy 1J.

We observe that LEACH takes some advantage of the presence of heterogeneity (advanced nodes), as the first node dies after a significantly higher number of rounds (i.e. longer stability period) compared to the homogeneous case (m = a= 0). The lifetime of the network is increased.

The simulations are performed to determine the number of rounds of communication when 1%, 20%, 50% and 100% of the nodes die using direct transmission, MTE, LEACH and heterogeneous LEACH with each node having the same initial energy level. Once a node dies it is considered dead for the rest of the simulation. The nodes begin to die at a more uniform rate after about 20% nodes die. This is because the distances between the nodes become greater, and nodes have to become leaders more often causing the energy to drain rapidly. As can be expected, the number of rounds doubles as the energy/node doubles for a given size of network. Figure 9 and 10 shows the number or rounds the complete sensor network take until 1%, 20%, 50%, and 100% nodes die with initial energy per node of 0.5J and 1J respectively for a 100m x 100m network. It is clear that as the initial energy of the sensor node decreases then the nodes drain out quickly and follows the inverse square law.

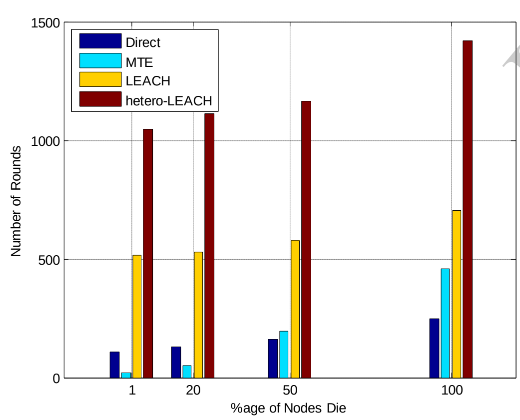

Figure 9: Performance results with initial energy 0.5J/node for a 100m x 100m network

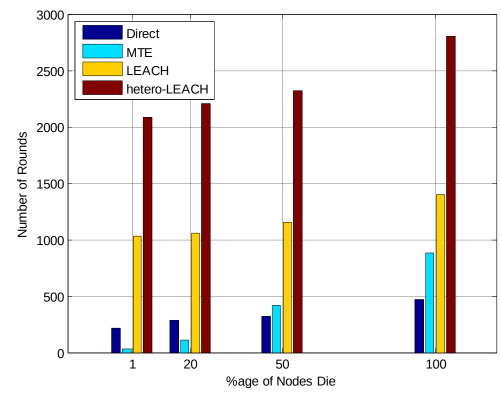

Figure 10: Performance results with initial energy 1J/node for a 100m x 100m network

The simulation shows that heterogeneous LEACH achieves:

- Approximately 2x the number of rounds decreases compared to direct transmission, when 1%, 20%, 50%, and 100% nodes die for a 100m x 100m network.
- Approximately 2x better than MTE for a 100m x 100m network.
- As the energy level doubles the number of rounds approximately doubles for all cases.
- Near optimal performance.

10 CONCLUSION

We have used clustering based algorithm in which load is equally distributed among the nodes. Heterogeneous protocol is used which uses additional nodes which are equipped in the network with higher energy these additional nodes becomes cluster heads and all other nodes becomes non cluster heads at any time. This protocol does not require any control information from the base station and distributes the energy in the network which is very effective in order to increase system lifetime. The Simulation results show that heterogeneous-LEACH is much more efficient in comparison to direct, MTE and LEACH routing protocol. Heterogeneous-LEACH achieves approximately 2x reduction in energy as compared with LEACH protocol. Thus heterogeneous type of protocol can be applied to various applications which needs energy savings and increased lifetime of the system. Based on these simulations heterogeneous

LEACH provides energy dissipation, quality of the network, and lifetime of the system.

REFERENCES

[1] A. Cerpa, J. Elson, D. Estrin, L. Girod, M. Hamilton and J. Zhao, (April 2001), " *Habitat monitoring: Application driver for wireless communications technology*", ACM SIGCOMM Workshop on Data Communications in Latin America and the Caribbean

[2] C. Schurgers and M.B. Srivastava,(2001) "*Energy efficient routing in wireless sensor networks",* in the MILCOM Proceedings on Communications for Network-Centric Operations: Creating the Information Force, McLean, VA.

[3] C. Li, M. Ye, G. Chen and J. Wu, (2005), "*An energy-efficient unequal clustering mechanism for wireless sensor networks"*, Proceedings of the 2nd IEEE International Conference on Mobile Ad-hoc and Sensor Systems.

[4] C. Merlin and W. Heinzelman, (November 2005), "*A Study of Safety Applications in Vehicular Networks,"* Proceedings of the IEEE International Workshop on Heterogeneous Multi-Hop Wireless and Mobile Networks.

[5] E. Woodrow and W. Heinzelman, (September 2002), "*SPIN-IT: A Data Centric Routing Protocol for Image Retrieval in Wireless Networks,"* Proc. International Conference on Image Processing (ICIP '02).

[6] M. Yebari, T. Addali, A.Z.Sadouq and M. Essaaidi, (January-june 2008), "*Energy conservation challenges in Communication Protocols for Wireless Sensors Networks: State-of-The-Art Study*", International journal on Information and Communication Technologies, Vol. 1, No. 1-2 , pp. 29-35.

[7] M. Perillo and W. Heinzelman, (2004), *"DAPR: a protocol for wireless sensor networks utilizing an application-based routing cost",* Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC'04).

[8] M. Qin and R. Zimmermann, (2007), "*An energy-efficient voting-based clustering algorithm for sensor networks"*, Journal of Universal Computer Science.

[9] M. J. Handy, M. Haase and D. Timmermann, (2002), "*Low energy clustering hierarchy with deterministic cluster head selection*", Proceedings of IEEE MWCN.

[10] Nitin Mittal, Davinder Pal Singh, R.S. Chauhan and Dr. Rajesh Goel, (September 11,2009), "*Optimal Energy Efficient Routing Protocol for WSN*", Proceeding of International conference on Emerging Trends in Electronics and Communications, pp-8.5.