AN ENHANCED 3-LEVEL HIERARCHICAL HETEROGENEOUS COMMUNICATION PROTOCOL FOR WIRELESS SENSOR NETWORKS

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Abstract— Wireless Sensor network consist of hundreds or thousands of wireless sensor nodes. Wireless Sensor network are use in Health and care monitoring, Environmental Monitoring, Military command control, Forecasting System, object tracking and detection, land slide detection and track monitoring. We have to increase its life time by reducing the energy consumption by design a low energy transmitting protocol. Low Energy Adaptive Clustering Hierarchy is energy efficient based routing protocol. It is homogenous system so we proposed a new routing protocol and data aggregation system known as leach heterogeneous system it increase the system life time. In our work we introduced an algorithm to increase the network life time more than residual protocol. In this, the cluster head is elected on the basis of residual energy of the node and the cluster. In this node behave like super nodes if its energy is high when it lowers down it behave like an advanced node and if it further down the normal node. In this we also show the life time of the wireless sensor network on the basis of first node dies half of the nodes dies and last node dies in graphs. In this work we also represent the numbers of packets transmit by the nodes in hetero-leach protocol and super hetero-leach protocol. Simulation results using MATLAB shows that the proposed advanced residual heterogeneous protocol appreciably reduces energy consumption and increase the total lifetime of the wireless sensor network compared to the residual heterogeneous low energy adaptive cluster hierarchical protocol and super hetero-leach protocol.

1. Introduction
The wireless sensor networks are small device which is sensed, computation and communication. Wireless communication made it possible to develop wireless sensor networks consisting of small devices called micro-sensors, which collect information from cooperating with each other. These tiny sensing devices are called nodes. A sensor is a device that shows a physical quantity from the environment to a quantitative measurement. Advancement in sensor technology, low-power radio frequency design made it possible to develop small, relatively inexpensive and low-power sensors, called micro sensors. Sensor nodes have a micro sensor like acoustic, image sensor capable of sensing some quantity of the environment, CPU (for data or signal processing from sensors), battery (for energy), memory (for data storage) and transceiver antenna (for receiving and sending signals or data). In military or surveillance applications sensor node size is very small. Its cost depends on various parameters like processing speed, transceiver, memory size and battery [1].

Figure 1: Sensor node architecture

For increasing the system lifetime we have to decrease energy usage by a node, resulting in a large increase in the overall value of the system of a small number of nodes does not affect the overall system performance. This requires that the nodes are able to communicate with each other even in the absence of an established network infrastructure. Some of the potential diverse applications of WSNs are as follows: habitat monitoring, military, physiological monitoring, precision agriculture, forest fire detection, nuclear, chemical and biological attack detection and transportation [2]. In this paper, we design a routing protocol that helps in low power consumption during the transmission of data to the base station.

In this paper, we are discussing about WSNs problem of maximizing network lifetime, data aggregation and existing protocols. We explain about the wireless networks, its characteristics and applications than related to past research work i.e which protocol is exist and how it works and represents various routing protocols for solving data aggregation problem and maximizing the network life time then briefly describes the system and energy model that has been considered in designing the protocol. After this a detailed description of the algorithm will be presented. Simulation is done with
the help of MATLAB software show that our protocol gives better life time than other.

2. Routing Protocol

In this section we describe the model of a wireless sensor network with nodes heterogeneous in their initial amount of energy. Let us assume the case where a percentage of the population of sensor nodes is equipped with more energy resources than the rest of the nodes. Let \( m \) be the fraction of the total number of nodes \( n \), which are equipped with few times more energy than the others. These powerful nodes are termed as advanced nodes, and the rest of the nodes as normal nodes. A heterogeneous LEACH [3] protocol is a modified LEACH protocol, which improves the stable region of the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes \( (m) \) and the additional energy factor between advanced and normal nodes \( (\alpha) \). Suppose that \( E_o \) is the initial energy of each normal sensor. The energy of each advanced node is then \( E_o (1+\alpha) \). The total (initial) energy of the new heterogeneous setting is equal to:

\[
n \cdot (1- m) \ E_o + n \cdot m \ . \ E_o \cdot (1 + \alpha) = n \cdot E_o \cdot (1 + \alpha \ . m)
\]

(1)

So, the total energy of the system is increased by a factor of \( 1+\alpha \cdot m \). The weighed probabilities for normal and advanced nodes are following [3]:

\[
p_{nrm} = \frac{p_{opt}}{1 + \alpha \cdot m}
\]

(2)

\[
p_{adv} = \frac{p_{opt}}{1 + \alpha \cdot m} \times (1 + \alpha)
\]

(3)

We define as \( T(s_{nrm}) \) the threshold for normal nodes, and \( T(s_{adv}) \) the threshold for advanced nodes.

Thus, for normal nodes, we have:

\[
T(s_{nrm}) = \begin{cases} 
\frac{p_{nrm}}{1 - p_{nrm} \cdot (r \ mod \ 1) / p_{nrm}} & \text{if } s_{nrm} \in G' \\
0 & \text{otherwise}
\end{cases}
\]

(4)

where \( r \) is the current round, \( G' \) is the set of normal nodes that have not become cluster heads within the last \( \frac{1}{p_{nrm}} \) rounds of the epoch, and \( T(s_{nrm}) \) is the threshold applied to a population of \( n \cdot (1 - m) \) normal nodes. This shows that each normal node will become a cluster head exactly once every \( \frac{1}{p_{nrm}} (1 + \alpha \cdot m) \) rounds per epoch, and that the average number of cluster heads that are normal nodes per round per epoch is equal to \( n \cdot (1 - m) \times p_{nrm} \). Similarly, for advanced nodes, we have:

\[
T(s_{adv}) = \begin{cases} 
\frac{p_{adv}}{1 - p_{adv} \cdot (r \ mod \ 1) / p_{adv}} & \text{if } s_{adv} \in G^* \\
0 & \text{otherwise}
\end{cases}
\]

(5)

where \( G^* \) is the set of advanced nodes that have not become cluster heads within the last \( \frac{1}{p_{adv}} \) rounds of the epoch, and \( T(s_{adv}) \) is the threshold applied to a population of \( n \cdot m \) (advanced) nodes. It shows that each advanced node will become a cluster head exactly once every \( \frac{1}{p_{adv}} (1 + \alpha \cdot m) \) round. Let us define this period as the sub - epoch. It is clear that each epoch (let us refer to this epoch as “heterogeneous epoch” in our heterogeneous setting) has \( 1+\alpha \) sub-epochs and as a result, each advanced node becomes a cluster head exactly \( 1+\alpha \) times within a heterogeneous epoch. The average number of cluster heads that are advanced nodes per round per heterogeneous epoch (and sub-epoch) is equal to \( n \cdot m \times p_{adv} \). Thus the average total number of cluster heads per round per heterogeneous epoch is given by

\[
n \cdot (1 - m) \times p_{nrm} + n \cdot m \times p_{adv} = n \times p_{opt}
\]

(6)

It is the desired number of cluster heads per round per epoch.

Hierarchical Heterogeneous LEACH protocol considers three types of nodes (i.e., normal, advanced and super) which have deployed in a harsh wireless environment where battery replacement is impossible. Nodes with higher battery energy are advanced and super nodes and the remaining nodes are normal nodes. Intuitively, advanced and super nodes have to become CHs more often than the normal nodes. The total initial energy of the new heterogeneous network setting is given by:

\[
n \times E_o \times ((1-m)+m \times (1+\alpha)\times m \times (1+\mu))
\]

\[
= n \times E_o \times (1+m \times (\alpha-\mu) \times (\alpha-\mu))
\]

(7)

The first improvement to the existing protocols is to increase the epoch of the sensor network in
proportion to the energy increment. If we set the same threshold value for advanced, super and normal nodes with the difference that each normal node $\xi \notin G$ becomes a CH once every $\left( \frac{1}{p_{\text{opt}}(t)} \right) \times \left( 1 + m \times (\alpha - m_b \times (\alpha - \mu)) \right)$ rounds per epoch, and each advanced and super node $\xi \notin G$ becomes a CH $\left( 1 + \alpha \right)$ and $\left( 1 + \mu \right)$ times every $\left( \frac{1}{p_{\text{opt}}(t)} \right) \times \left( 1 + m \times (\alpha - m_b \times (\alpha - \mu)) \right)$ rounds per epoch, there is no guarantee that number of CHs per round per epoch will be $p_{\text{opt}} \times \alpha$. This problem can be overcome by modifying the threshold equation. We assign a weight to the optimal probability $p_{\text{opt}}$. This weight should be equal to the initial energy of node divided by the initial energy of the normal node. Let us define $p_{\text{norm}}$, $p_{\text{adv}}$, and $p_{\text{sup}}$ are the weighted election probabilities for normal, advanced and super nodes.

There are $n \times \left( 1 + m \times (\alpha - m_b \times (\alpha - \mu)) \right)$ nodes which have energy equal to the initial energy of a normal node. In order to maintain the minimum energy consumption in every round within an epoch, the average number of CHs per round per epoch must be constant and equal to $p_{\text{opt}} \times \alpha$. In the heterogeneous scenario, the average number of CHs per round per epoch is equal to $\left( 1 + m \times (\alpha - m_b \times (\alpha - \mu)) \right) \times \alpha \times p_{\text{opt}}$ because each virtual node has same energy as of a normal node. Therefore, the weighed probabilities for all normal, advanced and super nodes are respectively given by following equations:

$$p_{\text{norm}} = \frac{p_{\text{opt}}}{\left( 1 + m \times (\alpha - m_b \times (\alpha - \mu)) \right)} \times \left( 1 + \alpha \right)$$

$$p_{\text{adv}} = \frac{p_{\text{opt}}}{\left( 1 + m \times (\alpha - m_b \times (\alpha - \mu)) \right)} \times \left( 1 + \alpha \right)$$

$$p_{\text{sup}} = \frac{p_{\text{opt}}}{\left( 1 + m \times (\alpha - m_b \times (\alpha - \mu)) \right)} \times \left( 1 + \mu \right)$$

An enhanced Hierarchical Leach Protocol In this, probability of becoming a cluster-head is based on the assumption that all nodes start with an equal amount of energy. If nodes begin with different amounts of energy, the nodes with more energy should be cluster-heads more often than the nodes with less energy, in order to ensure that all nodes die at approximately the same time. This can be achieved by setting the probability of becoming a cluster-head as a function of a node’s energy level relative to the aggregate energy of the cluster in the network [4], rather than purely as a function of the number of times the node has been cluster-head:

Probability of becoming cluster-head = Energy of the node/Energy of the cluster. This protocol is a modification in the basic LEACH protocol in terms of residual energy (ratio of energy in current round to total energy of the network) of nodes and is known as NEAP Protocol [5]. So residual energy will increase the overall energy of the network hence lifetime of the network will increase.

NEAP Protocol has changed the equation of the threshold value only to incorporate the residual energy in cluster head selection process as follows:

$$T(n) = \frac{p_{\text{norm}}}{} \frac{E_{\text{current}}}{E_{\text{max}}} \times \left( 1 - \frac{E_{\text{current}}}{E_{\text{max}}} \right)$$

where, $E_{\text{current}}$ is the current energy, $E_{\text{max}}$ the initial energy of the node. The other parameters have the same definitions as of LEACH.

We call the proposed protocol as Residual Energy Efficient Leach Protocol as modification in the basic LEACH protocol in terms of residual energy (ratio of energy in current round to total energy of the network). So residual energy will increase the overall energy of the network hence lifetime of the network will increase.

On receiving this message all member of the cluster will stop transmitting the data until next round begins.

The effect of heterogeneity in terms of residual energy can be applied to Hierarchical-Heterogeneous LEACH protocol and the protocol is termed as Residual Energy Efficient Hierarchical Leach Protocol. Thus, for normal nodes, advanced nodes and super nodes, we have:

$$T(s_{\text{norm}}) = \left\{ \begin{array}{ll}
\frac{p_{\text{norm}}}{E_{\text{max}}} & \text{if } s_{\text{norm}} \in G \\
0 & \text{otherwise}
\end{array} \right. \quad \text{(12)}$$

$$T(s_{\text{adv}}) = \left\{ \begin{array}{ll}
\frac{p_{\text{adv}}}{E_{\text{max}}} & \text{if } s_{\text{adv}} \in G \\
0 & \text{otherwise}
\end{array} \right. \quad \text{(13)}$$

$$T(s_{\text{sup}}) = \left\{ \begin{array}{ll}
\frac{p_{\text{sup}}}{E_{\text{max}}} & \text{if } s_{\text{sup}} \in G \\
0 & \text{otherwise}
\end{array} \right. \quad \text{(14)}$$

Further, we have an enhanced communication protocol; in this we use a algorithm to increase the network life. In this algorithm we have to change the type of every node after every round. We check the energy after each round if it is greater than a certain value then type of node is change if its energy becomes less than that value. Then we change the node type and its threshold value also. Simulation
work shows that it should increase the network lifetime.

3. Simulation Result and Analysis

(a) Radio Parameters

Wireless micro sensor network simulations using MATLAB are performed to determine the benefits of the different protocol architectures discussed in this thesis. For these experiments, the random 100-node network is used. The base station is placed 50 meters from the closest node, at a location (x=50, y=50). The bandwidth of the channel is set to 1Mbps, and the processing delay was 25 μs on the transmitting side and 25 μs on the receiving side. Each data message was 500 bytes long. The radio electronics energy is set to 50 nJ/bit and the radio transmitter energy is set to 10 pJ/bit/m² for distances less than \( d_0 = 87.2 \text{m} \) and 0.0013 pJ/bit/m⁵ for distances greater than \( d_0 = 87.2 \text{m} \). The energy for performing beam forming computations to aggregate data was set to 5 nJ/bit/signal. These parameters are summarized in Tables 1 and 2.

To evaluate the performance of various routing protocols, the simulations are performed in MATLAB using a random 100-node network. Figure 2 shows a random 100-node network. A set of nodes selects themselves cluster-head depending upon the energy left, the clusters within the specified sensing field. Therefore, (for \( P = 0.05 \) and the threshold given) at time \( t \), the random test network.

![Figure 2: Sensor Network](image)

We simulate the heterogeneous-LEACH and LEACH protocol, in the presence of heterogeneity in the initial energy of nodes to evaluate the behavior of both protocols in terms of the performance measures.

### Table 1: Radio parameters values

<table>
<thead>
<tr>
<th>Description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio electronics energy</td>
<td>( E_{\text{elec}} )</td>
<td>50 nJ/bit</td>
</tr>
<tr>
<td>Energy for beam forming</td>
<td>( E_{\text{BF}} )</td>
<td>5 nJ/bit</td>
</tr>
<tr>
<td>Bit-rate</td>
<td>( R_b )</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Antenna gain factor</td>
<td>( G, G )</td>
<td>1</td>
</tr>
<tr>
<td>Antenna height</td>
<td>( h_t, h_r )</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Signal Wavelength</td>
<td>( \Lambda )</td>
<td>0.325 m</td>
</tr>
<tr>
<td>Cross-over distance for Friss and two-ray ground attenuation models</td>
<td>( d_0 )</td>
<td>87.2 m</td>
</tr>
<tr>
<td>Radio amplifier energy</td>
<td>( \varepsilon_{\text{friss,amp}} )</td>
<td>10 pJ/bit/m²</td>
</tr>
<tr>
<td></td>
<td>( \varepsilon_{\text{two-ray,amp}} )</td>
<td>0.0013 pJ/bit/m⁵</td>
</tr>
</tbody>
</table>

### Table 2: Characteristics of Wireless Network

<table>
<thead>
<tr>
<th>Nodes</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network size</td>
<td>100m * 100m</td>
</tr>
<tr>
<td>Base station location</td>
<td>(50, 50)</td>
</tr>
<tr>
<td>Radio propagation speed</td>
<td>( 3 \times 10^8 \text{m/s} )</td>
</tr>
<tr>
<td>Processing delay</td>
<td>50 s</td>
</tr>
<tr>
<td>Radio speed</td>
<td>1 Mbps</td>
</tr>
<tr>
<td>Data size</td>
<td>500 bytes</td>
</tr>
</tbody>
</table>

For clustering, nodes are organized into cluster initially by the BS using the same method as in LEACH to ensure that good clusters are formed. These clusters and cluster heads remain fixed throughout the lifetime of the network. 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 the 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 the hetero-LEACH protocol system has a larger lifetime in comparison to LEACH protocol system.

Energy Dissipation Comparison of Hierarchical Hetero-LEACH, Hetero-LEACH and LEACH Protocols results of the experiments comparing LEACH, Hetero-LEACH and Hierarchical Hetero-LEACH in a three-node heterogeneous settings. The stable region of hetero-LEACH is extended compared with that of LEACH using \( m = 0.3 \) and \( a = 1 \) in a two-node setting. The unstable region of hetero-LEACH is also shorter than that of LEACH.

Figure 3 shows hierarchical Hetero-LEACH, LEACH and hetero-LEACH in the presence of energy heterogeneity. Similarly, the presence of hierarchical heterogeneity (advanced nodes and super nodes), as the first node dies after a significantly higher number of rounds (i.e. Longer stability period) compared to...
the heterogeneous case \((m_0 = 0.4 \text{ and } \beta = 2)\). The lifetime of the network is also increased.

![Figure 3: Number of alive nodes using LEACH in the presence of heterogeneity with advanced nodes \(m=0.3\) and normal nodes \(\alpha=1.0\) with initial energy 0.25J.](image)

(b) Energy Dissipation Comparison of various routing Protocols

The results of LEACH, hetero-LEACH, hierarchical hetero-LEACH, and residual hetero-LEACH simulations are shown in Figure 4 for \(m=0.3\) having \(\beta=2\) and \(m_0=0.4\) having \(\alpha=1\) with initial energy 0.25J. Similarly, the presence of hierarchical heterogeneity (advanced nodes and super nodes), as the first node dies after a significantly higher number of rounds (i.e. Longer stability period) compared to the heterogeneous case \((m=0.3 \text{ and } \alpha=1)\). The lifetime of the network is also increased. The simulation shows that residual Hierarchical-Hetero-LEACH achieves:

- Approximately 5x the number of rounds decreases compared to LEACH for a 100m x 100m network.
- Approximately 2x better than Hetero-LEACH for a 100m x 100m network. As the energy level doubles the number of rounds approximately doubles for all cases.

![Figure 4: Number of alive nodes using LEACH in the presence of heterogeneity with advanced nodes \(m=0.3\) having \(\alpha=1\) and hierarchical heterogeneity with super nodes \(m_0=0.4\) having \(\beta=2\) with initial energy 0.25J.](image)

When we further increase the energy then the size of the system is increased. So we add the advanced residual effect. We design an advanced residual heterogeneous protocol which further increases the life time of the system. The parameters are same but we use an algorithm to increase the life time of nodes. According to this algorithm, we change the type of node when its energy is reduced due to transmission of packets of data. This algorithm help in using the all residual energy present in the node. It also increases the lifetime of the wireless sensor networks and information send by the sensors is also increased. The advanced residual protocol life time is shown in the figure 5.

![Figure 5: Number of alive nodes using LEACH in the presence of heterogeneity with advanced nodes \(m=0.3\) having \(\alpha=1\) and hierarchical heterogeneity with super nodes \(m_0=0.4\) having \(\beta=2\) with initial energy 0.25J.](image)
energy 0.25J along with the advanced residual energy effect.

REFERENCES


