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Wireless Sensor Network for Forest Conservation using Energy Efficient Protocol

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Abstract: *One of the biggest threats to humanity and nature in recent times is the change in climate such as the Global warming that is caused by the excess emissions of carbon to the atmosphere. Apart from these there are also other notable climate changes that affect nature. The major cause for Global warming is deforestation even though factors such as industrial effluents, automobile exhaust also contribute a little to this catastrophe. Many serious measures have been taken by the Government of various countries to keep in control of the rustlers involved in Deforestation. Some of these methods include fixing of a large number of cameras in certain areas of the forest spread over a wide range, awareness programs including public awareness, automatic alarm testing, use of satellites to provide images of forests, etc. Some of the issues to be considered when implementing such schemes are hugs cost and power consumption. Also the lifetime of the materials and hardware used should be considered. In this paper, an efficient wireless sensor networking algorithm is proposed that can be used to prolong the life time of the network by using the Heterogeneous - Hybrid Energy Efficient Distributed Protocol (H-HEED).*

Keywords*:* Wireless Network, Sensor nodes, Network Lifetime, Sensors.

INTRODUCTION

The major cause for the global climatic changes in many areas is the deforestation and the release of a large amount of CO_2 into the atmosphere. Not just the CO_2 but other greenhouse gases have been sent into the atmosphere. Forests have been destroyed due to many reasons such as forest fire which is a natural cause. But apart from this other activities such as logging and land conversion for agriculture were also done. So to avoid global climate changes, the deforestation and degradation of forests should be reduced. Many statistics and survey have been conducted to record such destruction. The overall statistics results show that more than 15 million hectares of forests have been lost every year globally. Due to this every year more than 15% of greenhouse gases and CO_2 is emitted globally. Deforestation occurs mostly in the tropical regions where there are large forests and tons of trees. The record stands at 87% of global deforestation occurring in these tropical countries such as Brazil, Indonesia, etc. Carbon and CO_2 emission is more in these areas and more than 210 GT (Giga Tons) of carbon has been emitted. So there is a need to keep these activities under control for the wellbeing of our planet and ourselves.

One such solution to detect these problems is by using sensors and wireless detectors. A wireless sensor network (WSN) is used to sense and monitor both physical and environmental conditions by using various interconnected sensors. These sensors are spatially distributed over an area and contain autonomous sensors that coordinate with each other or send signals. The environmental conditions denote the various conditions of the atmosphere or environment such as the pressure, temperature, vibrations, sound, etc. Each node in the WSN is also equipped with a radio transmission device called the radio transceiver and other wireless communication devices to enable communication and signal transmission. A small microcontroller is embedded inside each node to control them and

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the nodes are running using an energy source such as a battery.

At first the development and implementation of the WSN was used for surveillance of battlefield during wars and for other military operations. Most of the military applications comprise of various sensors for various needs. But in recent time they are also being used in industrial areas and public areas as well. They include monitoring the industrial processes, healthcare, environment monitoring, traffic control, habitat monitoring, etc. Other than these sensors have been used in places such as in homes, offices, banks and also in other economical areas.

Many researches have been done in the WSN in recent times but most of them focused mainly on the internal issues such as the MAC, the routing protocols used for transmission, energy saving and other issues related to the lifetime of the nodes. In some areas research also focus on the architecture of the gateways that connect the WSN and the rest of the world. Here the lifetime of a node or the node's life time is an important factor and increasing the node's life time is a good research focus.

This can be done by using the Hybrid Energy Efficient Distributed (HEED) protocol as discussed in [4]. It is a clustering protocol that uses the available residual energy as the primary parameter and network topology features such as the distance to nearby nodes and node degree are used as the secondary parameters. The secondary parameters are used to break the ties between various candidate cluster heads during cluster selection for load balancing. Here all nodes in the WSN are taken to be homogeneous nodes where all the nodes contain the same initial energy.

In this paper, the study focuses on the impacts of heterogeneity in case of energy of the nodes. That is the impact of varying energies within the nodes should be studied. So an assumption is made where we take some percentage of the nodes to have more energy than the other nodes within the same network. As the lifetime of the WSN is limited it keeps degrading and the energy should be refilled by adding new nodes to the network. These nodes are added with more energies than the energies available in the nodes that are within the network. This way again the heterogeneity is preserved [15] and the study can be continued.

STATE-OF-ART IN FOREST MONITORING

Forest monitoring have been done to prevent deforestation and to sense any activities that will endanger the environment of the forest. Apart from forests, other areas of the planet have also been sensed for other activities. Remote sensing is an essential method that can make observations over a large area of the surface of the Earth more than possible by normal ground based observations. The remote sensing makes use of a large number of resources to accomplish this task. A number of cameras and multi-spectral scanners are used for capturing and sensing the places. RADARs are mounted over the air-borne and space-borne platforms. The remote sensing can take aerial photographs and satellite images as well and also yield LiDAR datasets. The data available from remote sensing varies in resolution and quality depending on the method that is used for image capturing. To capture images over a single province of a country or over a large geographical area, the aerial photography, satellite imaging, LiDAR are used and high resolution satellite sensors such as IKONOS and Quickbird are used. The regional datasets of specific regions are captured at regular intervals from satellites such as SPOT, Landsat, etc. and the lower resolution data are captured across the entire planet everyday using satellites like MODIS. By comparing and analyzing the image data with respect to the extent of the forest and its texture, it is possible to identify the areas of the forest that have been illegally poached or extinguished due to forest fire or other causes.

Another existing sensor and notification system is the Automatic Alarm System. The system provides an alarming mechanism to the main monitoring system by making use of various sensors and the MSP430 controller and the Chipcon CC2420. The system is embedded with the Zigbee protocol for operations. The major disadvantage in this system is that the lifetime of the sensors Is very short due to large power consumption.

NEED FOR HEED PROTOCOL

The remote sensing method explained above can cover over a large area of the planet or a forest alone specifically. Due to this the officials will not be able to identify the specific place where the forest poaching happened. The change in terrain and texture of the forests can be seen but not the exact location unless they can go and confirm. Also this method demands the use of a large amount of money for the RADARs and satellites. In case of the Automatic Alarm System as said before the power or energy consumption of the sensors is large and so the refilling of energy should be done often. So there is a need for increasing the lifetime of a sensor node.

This can be achieved by implementing clustering mechanism using the Hybrid Energy Efficient Distributed (HEED) protocol. Using this protocol, the exact locations of the poaching or any other activities in a forest can be identified by enhancing the lifetime of a sensor node in a cost effective manner. By improving the lifetime the sensors can be used for a longer duration that will help the system to identify specific areas. The proposed method requires a two-step simulation process; (1) the first step describes the formation of clusters using the HEED protocol and also explains about the heterogeneous HEED protocol (H-HEED protocol) and (2) the second step shows the performance of the performance of the H-HEED protocol obtained from the simulation and it is compared with the performance of the original HEED protocol.

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PROPOSED SYSTEM

The HEED Protocol

The HEED protocol is implemented in MATLAB by creating a simulation of sensor nodes connected in a WSN. Let us consider there are a total of N sensor nodes in the WSN and that they are dispersed in various locations randomly over a square region of 100*100 square meters. This is shown below in Figure 1 as simulated in MATLAB. Certain assumptions have been made for the clustering algorithm for the clustering of the given network model. The basic assumptions are:

1) The nodes in the WSN are quasi-stationary
2) The locations of all the nodes are not known.
3) All nodes are similar in characteristics such as processing, communication and performance.
4) The nodes are left unattended after they are deployed into the network.

The cluster heads are the center nodes for each of the clusters within the network and the selection of cluster heads are primarily defendant on the amount of energy left in each node, which is the residual energy of the nodes. Every time a node involves itself in activities such as sensing, processing or communication then a little bit of energy is consumed for such activities. So the consumed energy is kept noted for each activity and the residual energy or the remaining energy of each of the nodes is calculated based on this.

During the clustering process, sometimes there may be a tie between two cluster head when a sensor node falls within the range of both these cluster heads. In such cases a secondary parameter is used to identify the cluster head to which it should be assigned. This parameter is the intra cluster communication cost. The intra cluster communication cost is the energy needed or consumed when the node wants to communicate with other nodes in other clusters. The ties are broken and the node which yields less intra cluster communication cost is favoured. This intra cluster communication cost parameter (C) is a function two things: (1) the properties of the cluster such as cluster size and (2) the fact if varying power levels are permitted for intra cluster communication or not. This is the power level (P) used for the intra cluster communication.

If this power level is fixed for all the sensor nodes and the requirement is to distribute the load among various cluster heads then:

$$C \propto Node\ Degree$$

That is the cost is directly proportional to the Node Degree in this case. And if the power level is fixed for all nodes and the requirement is to create dense clusters then:

$$C \propto \frac{1}{Node\ Degree}$$

That is the cost is inversely proportional to the Node Degree. This means that a particular node will join a cluster head with minimal node degree if the priority is to maintain or distribute loads with all cluster heads and it will join a cluster head with maximal node degree if the priority is to create a dense cluster with more nodes.

Each of the nodes in the network performs a neighbor discovering phase where they detect their neighboring nodes and then broadcast their communication cost to them. This way the other nodes will know how much it costs to communicate with the other nodes. Similarly each of the nodes maintains a probability value for itself that say how much probability is there for that node to become a cluster center. The probability value CH_{prob} is given as below:

$$CH_{prob} = \max\left(C_{prob} * \left(\frac{E_{residual}}{E_{max}}\right), P_{min}\right) \quad (1)$$

Here,

C_{prob} – Initial percentage of cluster heads probability for the N nodes (set to 0.05)
E_{max} – Maximum energy of a node
$E_{residual}$ – Residual energy of a node
P_{min} – Threshold value for probability

The cluster head formation of the network in the MATLAB simulation is shown below in Figure 1.

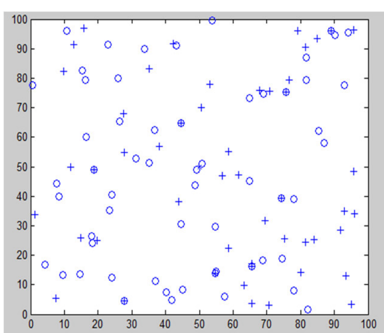

Figure 1. Cluster head formation in HEED network

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Heterogeneous HEED Protocol

The Heterogeneous HEED protocol or model uses varying energy levels for the nodes. The H-HEED protocol makes use of two or three types of nodes based on the needs and they are called the 2-level H-HEED protocol and the 3-level H-HEED protocol respectively. First let us take a look at the 2-level H-HEED protocol.

The 2-level Heterogeneous HEED protocol uses two types of sensor nodes in the network such as the (1) Normal nodes and (2) Advanced nodes. Consider a network that contains a total of N sensor nodes out of which the faction of advanced nodes is m. So the total number of advanced nodes is:

$$N_{adv} = N * m \quad (2)$$

The total fractions of number of normal nodes are given as $(1 - m)$ and the number of normal nodes is given as:

$$N_{norm} = N * (1 - m) \quad (3)$$

Let the initial energy of all the normal sensor nodes be E_{norm} and the initial energies of all the advanced nodes be kept higher than that of the normal nodes. The advanced nodes have α times more energy than the normal nodes. So the initial energies of the advanced nodes is given by:

$$E_{adv} = E_{norm} * (1 + \alpha) \quad (4)$$

The total initial energy of the whole network [9] combining the normal nodes and advanced nodes is then given as below:

$$E_{total} = (N_{norm} * E_{norm}) + (N_{adv} * E_{adv})$$
$$= [N * (1 - m) * E_{norm}] + [N * m * E_{norm} * (1 + \alpha)]$$
$$E_{total} = N * E_{norm} * (1 + \alpha * m) \quad (5)$$

From the above equation it is known that the 2-level H-HEED network has $(\alpha * m)$ time more energy than the normal HEED networks for the same number of sensor nodes. So the advanced nodes with higher energies can be used for special activities such as detecting specific locations of forest fire or forest poaching activities that will take more time than usual

The 3-level Heterogeneous HEED protocol uses three types of sensor nodes in the network such as the (1) Normal nodes, (2) Advanced nodes and (3) Super nodes. Same as in the 2-level H-HEED network consider a network that contains a total of N sensor nodes out of which the faction of advanced nodes and super nodes combined is m and the fraction of super nodes from this fraction m is m_0. So the total number of normal, advanced and super nodes is given as below:

$$N_{sup} = N_{norm} * m_0 \quad (6)$$
$$N_{adv} = N_{norm} * (1 - m_0) \quad (7)$$
$$N_{norm} = N * (1 - m) \quad (8)$$

Here also let the initial energies of the normal nodes be E_{norm} and the initial energies of the advanced and super nodes are higher than the normal nodes. Let the initial energy of the advanced nodes be α times more than the normal nodes and the initial energy of the super nodes be β times more than the normal nodes. Thus the initial energies of the advanced and super nodes are given as:

$$E_{adv} = E_{norm} * (1 + \alpha) \quad (9)$$
$$E_{sup} = E_{norm} * (1 + \beta) \quad (10)$$

The total initial energy of the whole network [13] [14] combining the normal nodes, advanced nodes and the super nodes is then given as below:

$$E_{total} = (N_{norm} * E_{norm}) + (N_{adv} * E_{adv}) + (N_{sup} * E_{sup})$$
$$= [N * (1 - m) * E_{norm}] + [N * m * (1 - m_0) * E_{norm} * (1 + \alpha)] + [N * m * m_0 * E_{norm}(1 + \beta)]$$
$$E_{total} = N * E_{norm} * [1 + m * (\alpha + m_0 * \beta)] \quad (11)$$

From the above equation it is seen that the 3-level H-HEED network has $(m * (\alpha + m_0 * \beta))$ time more energy than the normal HEED networks for the same number of sensor nodes.

In the multi-level Heterogeneous HEED protocol the initial energy value of each of the sensor nodes in the network is randomly distributed over the closed set range as given below:

$$[a_{min}, a_{max}] = [E_{norm}, E_{norm} * (1 + a_i)]$$

Here a_{min} and a_{max} are the upper bound and lower bound values of the range and they represent the minimal and maximal energies respectively. A node N_i is assigned with an initial energy that is a_i time higher than the normal initial energy E_{norm} and it is given as below:

$$E_i = E_{norm} + (1 + a_i) \quad (12)$$

The total initial energy of the whole network [11] is then given as below:

$$E_{total} = \sum_{i=1}^{N} E_{norm} * (1 + a_i)$$
$$= E_{norm} * (N + \sum_{i=1}^{N} a_i) \quad (13)$$

During the cluster formation phase each node has its own maximum energy level value defined by E_{max} and this is only in cases of heterogeneity HEED networks.

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SIMILATION RESULTS

The simulation is done using the MATLAB environment. A heterogeneous sensor network is considered with a total of $N = 100$ sensor nodes that are randomly distributed over the square area of 100*100 square meters. The base station of the whole network is assumed to be positioned in the center of the square area at position $(50,50)$. Initially the parameter values for the cluster head probabilities are set as below:

$$P_{min} = 0.0001$$
$$C_{prob} = 0.05$$

The energy consumed for transmitting message from or to the radio should also be calculated during the simulation. The energy consumed by the radio for transmitting a $k - bit$ message over a total distance of D is given as below:

$$E_{Tx}(k,D) = E_{Tx-elec}(k) + E_{Tx-amp}(k,D) \quad (14)$$

$$E_{Tx-amp}(k,D) = \begin{cases} kE_{fs}D^2 \\ kE_{mp}D^4 \end{cases} \quad (15)$$

$$E_{Tx-elec}(k) = kE_{elec} \quad (16)$$

Similarly the energy consumed by the radio to receive a message of $k - bit$ over a total distance of D is given as below:

$$E_{Rx}(k) = E_{Rx-elec}(k) = kE_{elec} \quad (17)$$

Here,

E_{elec} – Electronics energy

$E_{fs}D^2$ *and* $E_{mp}D^4$ – Amplification energies

The electronics energy constitutes to the energy consumption activities such as the coding and decoding of messages, modulation, filtering, sending and receiving signals, etc. The amplification energy constitutes to factors such as the distance of transmission and the error rate of the message that is transmitted. Apart from these the other external factors such as noise are ignored.

In the simulation process the various parameters such as the number of sensor nodes and their initial energies are defined at the start. The parameters for the different types of HEED protocol that is used for the experimentation is as below in Table 1:

TABLE 1
PARAMETERS FOR EXPERIMENTATION

Protocol	Parameters
HEED	$N = 100$, $P_{min} = 0.0001$, $C_{prob} = 0.05$
2-level H-HEED	$m = 0.25$, $N_{adv} = 25$, $N_{norm} = 75$, $E_{norm} = 100\%$, $\alpha = 1.25$, $E_{adv} = 125\%$
3-level H-HEED	$m = 0.30$, $m_0 = 0.4$, $N_{norm} = 70$, $N_{adv} = 18$, $N_{sup} = 12$, $E_{norm} = 100\%$, $\alpha = 1.25$, $\beta = 2.5$, $E_{adv} = 125\%$, $E_{sup} = 250\%$
Multi-level H-HEED	$a_{min} = 0.25$, $a_{max} = 2.5$

The simulation is executed in MATLAB for the designed HEED network by using 100 sensor nodes in the 100*100 square meters area. During the simulation each of these nodes form clusters by implementing the above discussed 4 types of HEED protocols and finally a comparison is made between these algorithms. At the time of simulation after forming clusters the sensor nodes keep communicating with each other and also send data packets to the base station (located in the center) about the various sensing activities. The energies of the nodes are consumed over the round and after the normal nodes lose their energy completely then they are refilled again to start the next round. At the start of next round again the nodes are cluster with new cluster heads. The performance of the HEED protocol is tested by taking three analyses as given below:

1) By calculating the number of alive nodes at each round.
2) The total remaining energy in each round.
3) The number of packets sent to the base station in each round.

Figure 2 below shows the comparison of the number of alive nodes at each round. In case of HEED since all the nodes are normal they die fast after consuming the energy. But in case of the 2-level and 3-level H-HEED networks the advanced and super nodes live for longer duration of time and so such nodes stay alive even after the round completes. In the multi-level H-HEED the sensor nodes die at random time due to their random energies. On average the multi-level H-HEED provides good performance here.

Figure 3 below shows the total amount of energy remaining after the end of each round. This is the sum of residual energies of all the nodes in the network except the base station. If the residual energy or remaining energy is high then after the sensing round is over this

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energy can be used to send many data packets to the base station as review of the sensing. From the figure it is seen that the 3-level H-HEED and the multi-level H-HEED networks have more residual energy lef.t compared to that of the normal HEED and 2-level H-HEED networks. This way the forest poaching and sudden forest fires can be alerted to nearby base stations easily and faster by using the residual energy left after sensing.

Figure 4 below shows the total number of packets sent to the base station at each round. The performance is said to be high if the number of packets is also high since more packets means more reports and sensing information have been shared. This depends directly on the residual energy left because nods having more residual energy have higher probability to become the cluster head and more energy will help the nodes to send more packets. From the figure it is clear that the 3-level H-HEED and the multi-level H-HEED networks have a really high packet delivery ration compared with the other two methods.

By comparing all the results from above it is evident that the multi-level H-HEED protocol and the 3-level H-HEED protocols are more efficient and can be used for the sensing of activities and forest poaching in various areas. This way the energy consumption is reduced and the overall lifetime of the sensor nodes are increased so they can keep sensing for more information and can send more amounts of data packets and reports back to the base station or the officials.

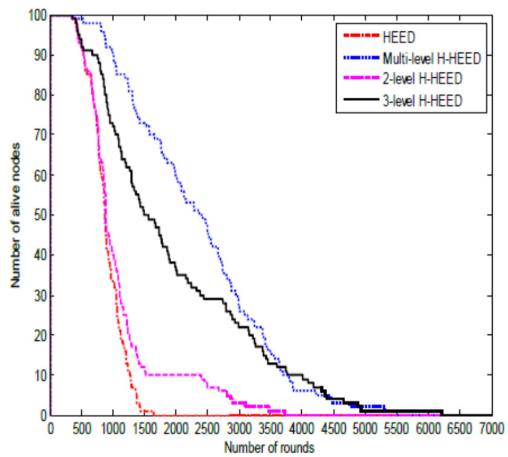

Figure 2. Comparison of number of nodes alive at each round in HEED networks

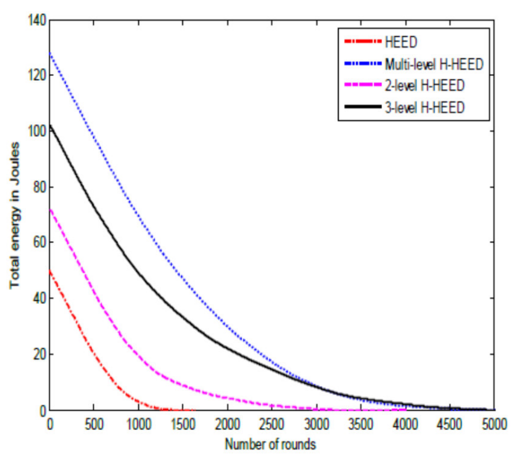

Figure 3. Comparison of total remaining energy at each round in HEED networks

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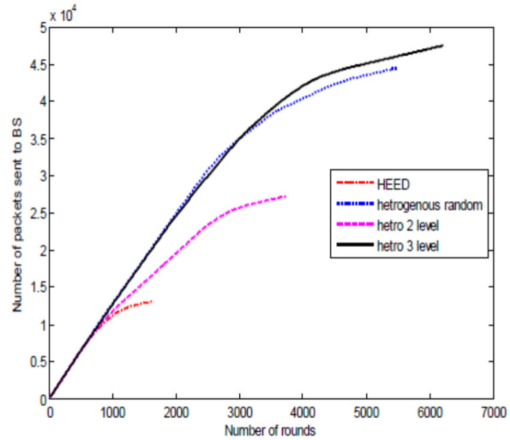

Figure 4. Comparison of number of packets sent to base station in HEED networks

CONCLUSIION

The lifetime of a sensor node is an important factor in any WSN. By increasing the lifetime it is possible to achieve many tasks in sensing and monitoring. In this paper the lifetime of sensor nodes are increased by implementing the heterogeneous HEED protocol or the H-HEED protocol. Different levels of heterogeneity were used in the proposed system such as the 2-level, 3-level and multi-level in terms of the energy of the sensor nodes. By improving the lifetime of the sensor nodes, the officials and the government were able to monitor the poaching activities and other activities in the forest easily.

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