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Reconnaissance of Hierarchical Routing Protocols of WSNs

Jaipreet Kaur
M.Tech Scholar, Computer Science & Engineering
Global Institutes of Management and Emerging Technology
Amritsar, Punjab, India

Dr. Rajiv Mahajan
Professor, Computer Science & Engineering Dept.
Global Institutes of Management and Emerging Technology
Amritsar, Punjab, India

Abstract- This paper has focused on the analysis of diverse hierarchical routing protocols of wireless sensor networks. The main subject of matter in case of wireless sensor networks is their short lifespan. Different protocols for the purpose of grouping the nodes and routing the data to base station are followed in order to maximize the lifespan of the WSNs. The main focus of this paper is to examin diverse protocols of WSNs and scrutinize them.

Keywords- WSN, Hierarchal routing, LEACH, pLEACH, HEER, GROUP, HEED, AEEC and TEEN.

I. INTRODUCTION

A wireless sensor network (WSN) consists of contigiously dispersed autonomous sensors to witness physical or conservational circumstances and to accommodatingly pass the detected data through the network to a main position [2] known as sink. The WSN is made of a number of nodes, where each node is connected to one (or various) sensors. The price of sensor node range from a little to hundreds of dollars, subject to the complexity of the sensor nodes. Size and rate limitations of sensor nodes result in equal limitations on resources like energy, speed and communications bandwidth. The sensor network nodes have some parts like a radio transceiver, a microcontroller, an electronic circuit, a battery and external memory.

The main function of a WSN is that the sensor nodes sense the data and then guide it to the base station or sink. The nodes interconnect wirelessly. WSN is the most significant technology of 21st century that has been beneficial in medical treatments, military observation, environment recognition, home monitoring and preventing natural disasters.

Some features of the wireless sensor networks are capacity to handle the node failures, capability to repel tough environmental situations, gullibility to huge scale of organization and usage is easy.

There are many aids of wireless sensor networks like low price and minute size. The lone source of power in WSN is batteries and changing them and that too on several nodes is a tough task, so the core research area in the WSNs is maximizing the lifetime of the network. Many routing protocols has been proposed for this purpose. We have analyse dsome of them in this paper.

II. WSN ROUTING PROTOCOLS

To maximize the lifespan of a wireless sensor network different protocols are followed. In this paper we will scrutinize various routing protocols. Routing in WSNs is very difficult owing to the large number of nodes that make it impossible to figure out a global addressing scheme and also as WSNs demand the movement of data perceived from different sensor nodes towards the base station. Another reason is the restriction of energy and memory and the redundancy of the data sensed among the nodes.

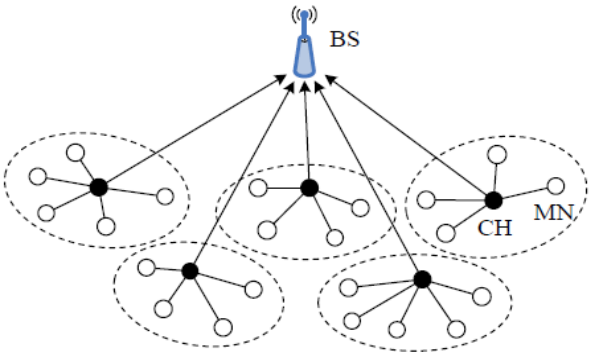

Figure 1: Clustering & Routing [1]

So, because of these reasons there is a need of routing in WSNs. Clustering also plays an important part in the WSNs. It groups the sensor nodes into clusters and allocate a cluster head to every clusters thus formed. The major benefits of clustering and routing in WSNs are:

1. It reduces the energy consumption.
2. The number of transmissions of the data from nodes to the sink also minimizes.

So combination of both the clustering and routing is known as the hierarchical routing.
Some of the hierarchical routing protocols for WSNs that we are going to scrutinize in this paper are: are: LEACH, PEGASIS, HEER, TSEP, pLEACH, EECS, HEED, and GROUP.

A. LEACH [2]

Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is the conservative grouping and communication protocol widely used in WSNs. It is centred on the small energy depletion routing algorithm for WSN. In LEACH, nodes are chosen as cluster heads randomly and in circular order to stabilize power ingestion of each node. LEACH operates in two phases which are as follows:

i. Setup Phase

Every single round initiates with a set-up phase where the clusters are formed. All through the set-up phase, all nodes attempts to become a cluster head as per the probability model. For choosing a cluster head, each node produces a random number between 0 and 1. If the δ is less than the threshold [2] *T (n),* the node is choosen as a cluster head for present round, the threshold is as follows:

$$T(n) = \begin{cases} \dfrac{p}{1 - p \ mod \left[\frac{1}{p}\right]} & n \in G \\ 0 & otherwise \end{cases}$$

Where *n* as the total number of sensor nodes in the network, *p* is the number of cluster head nodes for each round, *r* as the number of the current round, and *G* is the set of nodes that have not been selected as cluster heads in the last *n/p* rounds. The nodes elected as cluster heads send a message to the neighboring nodes to join them to create clusters. When the nodes reply to the message numerous clusters are created in the WSN.

ii. Steady Phase

In this phase the nodes send the data to the cluster head that further send the data to the base station or the sink. One round completes when the sensed data is received by the base station and then the next round initiates.

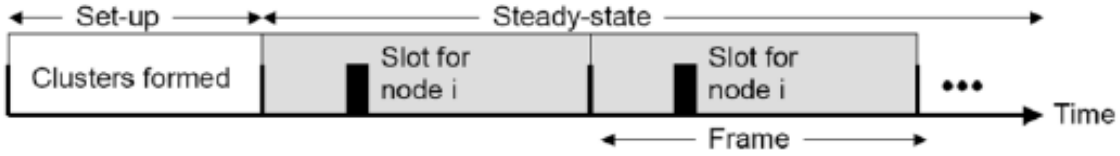

Figure 2: LEACH [2]

LEACH has some limitations like:

1. Choice of cluster heads is done randomly
2. Nodes have similar initial energy
3. Nodes with low energy are selected as the cluster heads

B. pLEACH [3]

In pLEACH or partition based LEACH is an enhanced form of LEACH protocol which splits the complete network into several sectors and then executes the cluster head selection. The pLEACH algorithm comprises of two phases and they are as follows:

i. Partition Phase

In pLEACH best number of cluster heads are calculated by the base station and network is partitioned into sector.

ii. Cluster formation Phase

At the beginning of the phase, nodes send their initial energy and location to the sink. The node having the highest energy in every sector is elected as the cluster head of that particular sector by the sink. If two nodes have same energy then the node with smallest ID is selected as the cluster head. When the cluster are formed then the data is transmitted. After the transmission is done the sink calculates the remaining energy of all the nodes for the next round.

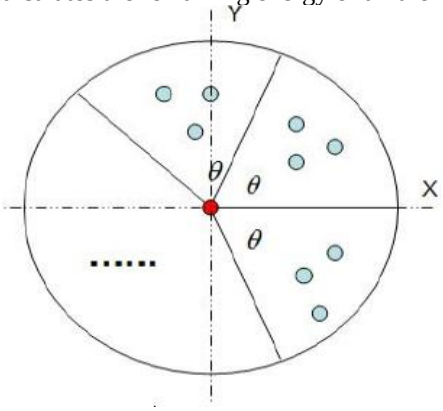

Figure 3: Partition of the network [3]

pLEACH have few benefits which are

1. In the whole network there is an even distribution of the cluster heads.
2. Energy dissipation is reduced
3. Lifespan of the network increases.

C. GROUP

In In GROUP [9], a chain is formed, but all nodes are not allowed to become the leader to transmit the data to the base station. The network lifespan is improved by letting distinct nodes to transfer data uneven number of times to the base station depending on the nodes remaining energy and position. Genetic Algorithms are followed in GROUP protocol.
Genetic Algorithm [12] is mainly a probabilistic investigation algorithm grounded on the codes and idea of natural selection and evolution. The GROUP protocol is executed according to the following steps:

i. Initialization

Initialize an unequal population of n chromosomes.

ii. Selection

Selection is the process in which two chromosomes are selected out of the total population of n chromosomes. These two chromosomes will breed that will produce children.

iii. Generation

A new population is generated by the processes known as crossover and mutation. Crossover is the assemblage of the two parent chromosomes to generate a child and mutation brings some variation in the next generation so that there is some dissimilarity among the chromosomes in new population.

iv. Leader Selection

After making the chain, the node with highest value of remaining energy will be the head that will transmit the data to the base station.

D. TEEN

TEEN [6] (Threshold sensitive Energy Efficient sensor Network protocol) is aimed to make the WSN a reactive network. In TEEN, whenever a cluster head is selected, the cluster-head send to its members a hard threshold and a soft threshold.
Hard Threshold is a value for the detected feature. It is the complete value of the feature past which the node detecting the value will switch on its transmitter and send to its CH.
Soft Threshold is the minute change in the detected feature that activates the node and the node switches its transmitter on to transmit data.
The hard threshold decreases the number of transmissions by permitting the nodes to transmit data only when the detected feature is in the array of interest. The soft threshold also decreases the number of transmissions by removing the transmissions that may occur after a change in the detected feature.

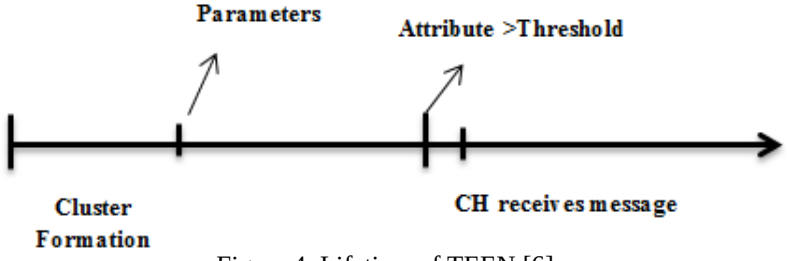

Figure 4: Lifetime of TEEN [6]

The main characteristics of TEEN are:

1. Important data is transmitted promptly.
2. A lot of energy is saved as data is not transmitted continuously.
3. Whenever a new cluster head is selected all the attributes are broadcasted with new values. So, if there is a need then the user can change their values.

The main disadvantage of TEEN is that if the thresholds are not touched then the nodes will never transmit the data and the user will not get any output from the network.

E. HEER

In In HEER [10] (Hybrid Energy Efficient Reactive) protocol cluster head (CH) is elected on the base of the ratio of remaining energy of node and average energy of the whole network. To further save the energy, Hard Threshold (HT) and Soft Threshold (ST) are also used just like the TEEN protocol.
HEER is also a reactive protocol where all the nodes make use of the starting and remaining energies to choose a CH. The probability [5] of a node becoming the cluster head is for normal nodes:

$$P = P_{opt} E_i(r)/(1 + am)E(r)$$

And for the advanced nodes

$$P = (1 + a)P_{opt} E_i(r)/(1 + am)E(r)$$

Where *a* and *m* are variables that control the percentage of advanced and normal nodes in the heterogeneous network, $E_i(r)$ is the initial energy of node and $E(r)$ is the residual energy.

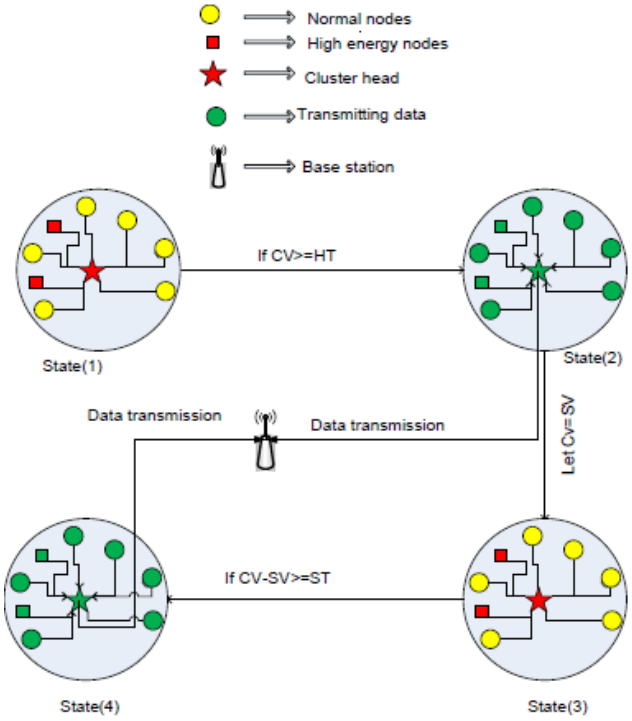

Figure 4: Data sensing and transmission [10]

When clusters are made, the CH transmits two threshold values, i.e. HT and ST. If a constraint from the attributes set touches HT value then node turns on its transmitter and transfers data. The Current Value (CV) [10], is the value on which first transmission takes place, is kept in a variable called Sensed Value (SV). This decreases the number of transmissions. The nodes will again transmit the only when

$$CV - SV = ST$$

So, HEER lessens the number of transmissions to that further reduces the energy depletion and increase the lifespan of the network.

F. HEED

HEED [7] (Hybrid Energy-Efficient Distributed clustering) from time to time picks cluster heads on the basis to remaining energy of node and node distance to its neighbours. To rise the lifespan of a WSN, the inter cluster communication cost is also taken care of.

Before beginning the HEED protocol, a probability [7] of becoming the cluster head is fixed

$$CH_{prob} = C_{prob} \frac{E_{resi}}{E_{max}}$$

Where C_{prob} is the percentage of cluster heads among *n* nodes, E_{resi} is the residual energy and E_{max} is the maximum energy. Several iterations are involved in the clustering process and during these iterations, a set of yet to become cluster head nodes is formed and selection of the cluster head is done on the basis of low communication cost. If a node is elected as a cluster head, it sends a message involving of node ID & its selection status.In HEED, a node is considered as dead if it has lost 99.9% of its starting energy.

G. AEEC

AEEC [17] is a unique adaptive, dispersed, energy effective clustering protocol used for heterogeneous networks. AEEC autonomously chooses cluster heads by checking the node energy comparative to the energy of whole network. It does not involve the overall information of whole network in every round. AEEC lengthens the network lifetime of sensor network and increases the efficiency and throughput of the network.

AEEC is just like LEACH, but the difference being that here the data transmission between cluster head and base station is done directly or in a single-hop. The execution AEEC protocol happens in 4 steps.

i. Preliminary Phase

In the preliminary phase the network is organized and all the nodes pass their starting energy message to the sink. Similarly each node can also calculate the total energy of the network and transmit it to all the nodes. As AEEC is uded for heterogeneous network so in this case there will be some advanced nodes having higher starting energy than the other normal nodes.

So the energy [17] of the normal node is E_o and for the advanced nodes is $E_o(1+\alpha_{max})$ where α is the boost for the advanced nodes.
The total energy of the whole network is:

$$E_{total} = E_o(N + \sum_{i=1}^{N} \alpha_i)$$

Where N is the number of nodes in the sensor network.

ii. Selection phase

A number of cluster heads are chosen in the selection phase. The nodes with the higher energy are selected as the cluster heads over the others. Nodes that become cluster heads transmit the ch_ad message to the neighboring nodes with the value of their current energy.

iii. Clustering phase

The nodes receive the ch_Ad message and clusters are formed on the basis of the threshold function [17]

$$T(s_i(r)) = \begin{cases} \dfrac{P_i(r)}{1 - P_i(r)\left(r \bmod \frac{1}{P_i(r)}\right)}, if s_i(r) \in G \\ 0, \quad otherwise \end{cases}$$

Where *r* is the current round number. *P* is the probability of the cluster heads, *G* and is the set of nodes that have not yet become cluster heads for the last 1/*p* rounds.
The probability of a node to become a cluster head is set as:

$$P_i(r) = min\left\{\frac{E_i(r)}{E_{total}(r)}k, 1\right\}$$

iv. Communication Phase

This is the phase where data transmission takes place. The nodes transmit data to their cluster heads and the cluster heads transmit the aggregated data to the BS.
In this way the whole round completes and next one starts.
AEEC is an improved version of the LEACH protocol.

H. TSEP

Threshold sensitive Stable Election Protocol [8] is reactive routing protocol which is also used for the heterogeneous sensor networks. In TSEP has 3 levels of heterogeneity is taken that is nodes are namely- usual, intermediary and advanced. The energy [8] of usual nodes will be E_0, for the advance nodes E_{ADV} and for the intermediary nodes be E_{INT}.

$$E_{ADV} = E_0(1+a)$$
$$E_{INT} = E_0(1+a/2)$$

Where a is surplus energy.
To become a cluster head in TSEP each node generate a number between 0 and 1 and if this number is less than the threshold then it becomes the cluster head. The threshold [8] for different nodes is given as,
for usual nodes

$$T_{NR} = {}^{P_{NR}}\Big/_{1 - P_{NR}\left[r, mod\frac{1}{P_{NR}}\right]}$$

For advanced nodes,

$$T_{ADV} = {}^{P_{ADV}}\Big/_{1 - P_{ADV}\left[r, mod\frac{1}{P_{ADV}}\right]}$$

For intermediary nodes,

$$T_{INT} = {}^{P_{INT}}\Big/_{1 - P_{INT}\left[r, mod\frac{1}{P_{INT}}\right]}$$

Energy dissipation is very low due to the heterogeneity of nodes. When clusters are formed then the CHs broadcast two values hard threshold and soft threshold. Hard Threshold (HT) is a complete value of sensed attribute after which node will start transmitting data. Soft Threshold (ST) is the minimum sensed value at which the nodes transmit the data. After the broadcasting of HT and ST nodes start detecting the data constantly. First time the data is transmitted when parameters reaches hard threshold value. This sensed value is saved in internal variable called Sensed Value (SV). Afterwards, nodes will transmit data if difference of currently sensed value and the value of SV is equivalent to or greater than soft threshold. So, by using the hard threshold, number of data transmissions is reduced and further transmissions are decreased by soft threshold.
The main advantages of TSEP are:

1. It is very useful for time critical applications as it transmit the time critical data to the user.
2. Energy depletion of the nodes is quite less due to the thresholds.

3. The network executes very efficiently and for longer lifetime.
4. Energy dissipation is greatly reduced due to the energy heterogeneity in the nodes.

But the only limitation of this protocol is that if the particular threshold is not attained than user won't get any data from the network.

III. CONCLUSION AND FUTURE SCOPE

Wireless sensor networks are being used for many applications but there only problem is its low battery life. Many protocols are established from time to time to extend its lifespan.

In this paper, various protocols have been discussed. The working of these protocols and their benefits are scrutinized. LEACH is the basic protocol that randomly executes while some protocols like HEED and HEER are reactive in nature and follows a suitable mechanism. In addition GROUP protocol has also been discussed that follows genetic algorithm to elongate the life of a wireless sensor network. WSNs is a very important technology that can be used in every field and in future sensors will almost be used everywhere from homes to offices to military fields.

So lifetime of WSN is a serious issue and in future energy harvesting concepts can be used to solve this issue. By using energy harvesting nodes [16], the WSN would never terminate thus increasing the capacity of a WSN.

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