International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 14 Issue 2 –APRIL 2015

Energy Efficient Cluster Based Routing Protocol for WSNs

NAVEEN KUMAR P, SUMANTH A V, ANIL KUMAR D S, SUJANA C V
VIII Semester, BE Students, Department of Electronics and Communication Engineering
Bahubali College of Engineering, Shravanabelegola, India
naveenkumarp61@gmail.com, sumanthv25@gmail.com, anilgowda293@gmail.com, sujanacv58@gmail.com

Abstract–Wireless Sensor Networks (WSNs) are the networks of sensing devices called motes, which are connected without any sought of wires. The sensed information will be communicated to the destination, the Base Station (BS). In order to communicate the information from nodes to the BS, node has to have a communication unit and it requires a power supply unit to drive it. The prominent issue in any WSN is the power consumption. Node consumes a large amount of power for transmission of information as well as during the selection of cluster head in cluster based networks. In certain applications recharging or replacement of batteries at sensor nodes will be very difficult, like in remote areas or in military applications where human intervention is difficult. Keeping this as our target, we are working on the existing cluster based routing protocol- LEACH and designing a novel algorithm which can minimize the overall power consumption for communication in the network, especially during the selection of cluster head and routing a path from node to BS, thus confirming uniform load amongst nodes which will result in getting an improved energy efficient network compared to the existing protocols. In turn it also enhances the life time for WSNs. Results are to be simulated and verified using NS-2.

***Key words*—Energy efficient routing, LEACH, routing protocol, cluster head (CH).**

I. INTRODUCTION

Wireless Sensor Networks (WSN) are networks of sensing devices called sensors, connected without any wires or cables. *Sensor nodes* (sometimes called as node) are said to be the most importantelementarypart of a WSN. The function of the node in to sense the temperature or moisture or pressure or all any other real time data, based on specific applications. The information sensed by a node is to be guided to the Base Station (BS). Normally, a nodeconsists of four blocks,namely, a sensing unit, a processing unit, a power unit, and the transceiver. Sensing unit senses the real time data, the sensed data is further processed in the processing unit. At last the processed information will be directedtowards the BS, to drive all these three units it is so necessary to have an energy source, which is been provided by the power unit. Node consumes a large amount of power for transmission and little during receiving. In many applications, recharging or replacement of batteries at sensor nodes will be very difficult, like in remote areas or in military applications where human intervention is challenging. The system is said to beenergy efficient, if and only if, it transmit or receive the signal/data consuming least amount of power. In order to make the system efficient, it is mandatory to care about the reliable path between nodes and the BS, through which the actual communication takes place. And also it is necessary to provide a secure environment for communication. The method of finding a route (path) is acknowledged as *routing*.The routing can be done considering few parameters and specifying applications, it is been donebased on:

A. Time driven:Here, the sensed data to be sent to the BSfrequently, irrespective of the change in situations or conditions. A perfect illustrationof time driven application is a GPS network.

B. Event driven: Connection between the BS and node is accomplished, only if there is anabrupt change or a rapid variation to the normal conditions. We can say, landslide detection and forest fire detection are the best examples for this kind.

*C. Query based:*This method of routing is useful in security based applications, where the nodes shouldrespond to the BS by sending the sensed information, whenever the BSdemands.

Sideways with the above mentioned methods,a combination of two or more methodscan also be taken at a time for better communication i.e., *Hybrid*.

The routing systems are divided into several protocols as follows:

*A. Hierarchical routing:*In this specific type, a huge network may be divided into numerous smaller networks, which may be further subdivided into tiny networks, forming a *hierarchy*. The communication between nodes andBS is been achieved after passing many stages in a hierarchical manner.

*B. Flat routing:*The sharing of information between any two nodes which is in turn connected, no need of formation any cluster or segments between them. Here, Node-to-Node communication is possible.

*C. Location based:*This routing technique works on the basis of position information. Here, each node has the ability to determine its own location, and also the location of the BS. Storing this information helps in computing an efficient path between the nodes and the BS.

Eventhough, the field of WSN vast, providing platform for numerous applications, there are few issues with it, mostly the power consumption and the network lifetime.

*A. Power Consumption:*As the sensor node senses the data and directs it to the respective heads or the BS, subjected to the type of routing.In general scenarios, the power required to transmit the information is comparatively higher than the power utilized for the sensing of the information. Higher consumption of energy will leading tolesseningthe*network life time*.

B. Network Life Time: The number of survived nodes arguments the living nodes with respect to the time. Time duration between the start of the simulation and the instant at which the first dead node appears in a network is said to be as the *life time of the network*.

The rest of the paper is organized as follows: A brief explanation on the LEACH protocol is given in the section II. Works done to analyzethe LEACH protocol is presented in section III. Section IV gives an insight into the future works and finally section V gives the concluding remarks.

II. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

In order to overcome the challenges and drawbacks of the energy constraints of the network, an optimal algorithm should be designed in such way that it should be resulting in the most energy efficient and least power consuming network. In this order, when we go finding energy efficient routing protocols we get the best of this kind, called the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol.

LEACH is the most popular and important Cluster based Hierarchal routing algorithm, especially designed to get energy efficient system. It works on the concept of grouping the nodes into several groups called *clusters* and guided by a leader node called the *Cluster Head (CH)*.

The most advantageous thing in LEACH is that, one node that had been CH cannot become CH for p rounds. Means, every node will have $\frac{1}{p}$ probability of becoming a CH in every round.

At the initial (set-up-phase) state, all nodes in the network choose a random number between 0 and 1. If the number chosen by the node is less than a threshold *T(n)*, then the node with least values shall become a CH for that newer round. The threshold can be calculatedusing the expression shown bellow:

$$T(n) = \begin{cases} \dfrac{p}{1 - p * (r \bmod 1/p)} & if\ n \in G, \\ 0 & Otherwise \end{cases}$$

Here,*p*is the desirable percentage of CHs in the network, *r* being the count number of the present round and the G is the set of nodes that have not been CH in the last l/p rounds.

Once the CH is made, every CH will broadcast a message called BEACON to all the neighboring nodes. The nodes which respond to the message sent by the CH, by sending HELLO message to the CH, will be added under the respective CH to form a cluster. The newly joined nodes will be working in group under the corresponding CH till the next round of selection of CH takes place.

Right after all the set-up is done, the node starts sensing the real time information and the data sensed by every node will be sent to particular CH, where the CH aggregates the data and sends the combined information to the BS. By doing this, wasting of energy for transmitting the redundant information by the nodes can be avoided, as well as the power consumption at each node for transmission between the node and BS for exchange of information will be made complete nil. The formation of hierarchy, results in minimizing the energy usage and improved network life time, this also supports the replacement of dead nodes in certain applications where humans can change the batteries. This feature helps in maintaining balance in the network.

III. RESULTS AND ANALYSIS

The key drawback of LEACH protocol is, it is not suitable for larger networks, as it uses single-hop routing, where every node should send the data to CH and then to the BS. Even though LEACH suits best for the stationary node application, it lags in using it for the mobile node applications as the nodes will be keep moving and it could not send the information to the respective CH once it goes away from the corresponding cluster. Here in the LEACH, equal priority is given to both nearest and the farthest nodes to the BS, we know that, to send any data from a far distance the CH(node) will require a huge amount of power but in case of the nearer CH(node) where the power required is very less, this end up in non-uniformity in energy drain between the nodes.

Keeping in mind that to overcome the limitations of LEACH and to design a perfect energy efficient algorithm we made a detailed study on the existing LEACH protocol. Outcome of our study has been obtained in the form of plots and we got ideas to make some major changes in the LEACH to improve the energy efficiency so as to reduce the power consumption which would in turn resultsin enhanced network lifetime.

Here are few basic parameters to be known well, to analyze the simulation results, they are as follows:

A. Number of nodes

The total number of active nodes considered in a network at the start of simulation is taken as the*Number of Nodes*. Here, if there were n number of nodes in a network, it is mandatory to consider n+1 number of nodes to be considered, as the extra one node acts as BS.

B.Initial Energy

Every node in the network has a power source to drive the remaining units in the node, the power at the node initial stage or before the start of simulation is said to be as the *Initial energy*. The energy is considered in terms of *Joules.*

C. Number of Clusters

The cluster formation is a unique characteristic of LEACH protocol, the number of cluster directly mean the number of CHs required to be selected for every round of operation.

D. Cluster Changing Time

The CHs will be rotating within the network and it is very necessary to mention the time duration for any round, till a node will be a CH and the next CH to be selected in the CH selection process.

E. Spreading Factor

Spreading factor deals with the distribution of arrangement of the sensors and how it is been spread throughout the area. The network lifetime is inter related to the change in spreading factor, as the spreading factor increases the life time of the network decreases due to the more consumption of power as the data gathering capacity is directly proportional to the spreading factor.

F. Packet Size

The combination of the sensed data and the header is said to be a packet, and the size is called as Packet Size. In this case the size of packet considered is 525 Bytes, where 25 Bytes represent the header and the remaining 500 Bytes is the sensed data.

G.Threshold

Threshold is intensity, after crossing the limit of threshold itself the actual operation starts. Thresholds are of three types:

a. RXThresh

It is the reception threshold, if and only if the received signal strength is greater than this value, then the signal will be received.

b. CSThresh

It is the carrier sensing threshold, the packet is been sensed only if the received signal strength is larger than this value.

c. CPThresh

It is called as the capture phenomenon, it is mostly useful in decoding the information and avoiding collision between two packets received at the same instant from different sources.

The basic conditions take are as follows:

- Size of field: 1000X1000
- Position of BS: (50, 175)
- Number of Nodes: 100
- Initial Energy at Nodes: 2 Joules
- Packet Size: 525Bytes
- Number of clusters: 5
- Spreading Factor: 8
- Threshold:
  - RXThresh: $6e^{-9}$
  - CSThresh: $1e^{-9}$
- Clusters Changing Time: 20 Sec
- Simulation Stops at: 3600Secor

The graphs have been plotted for the obtained numerical values for the respective simulation time, interval of 50 second is been of difference 50seconds is considered in order make the plotting easier and for better understanding. The simulation starts at the 0^{th} second and stops at 494^{th} second.

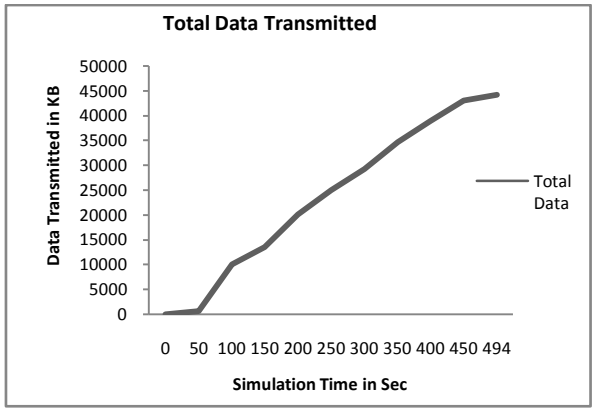

Fig. 1: Total Data Transmitted as the Function of Simulation Time

As from figure 1 it is so clear that the data transmission starts along with the star of simulation, it increases rapidly till the nodes start to die, once the most number of nodes fail, the curve or the data starts to be pointing at the constant level. Here, at the end of simulation at 494 seconds, the nodes in network had sent the data of44146 Bytes to the BS.

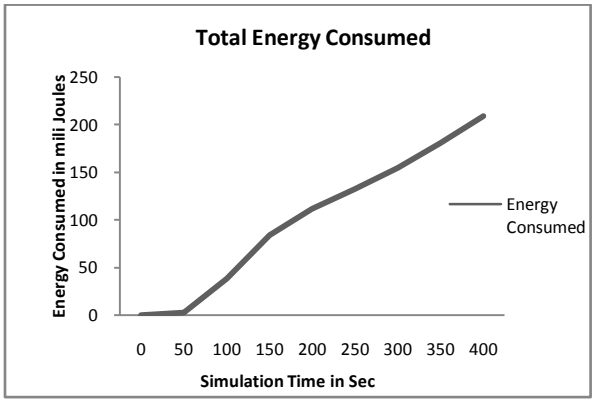

Fig. 2: Total Energy Consumed as the Function of Simulation Time

By viewing the figure 2, one can easily catch the response of Energy consumed with respect to change in time. As well known,node requires a huge amount of energy for the transmission of the sensed data,when compared to other activities in the network, in the same way it is proven that more the data transmission,higher the power consumption. It will sure lead to the draining up of the power source or the battery, at last resulting in death of node. In this situation, total consumption of energy increases as the time varies transmitting a large amount of data to BS.At the end of simulation the total power consumed by the network was 327.825mJ.

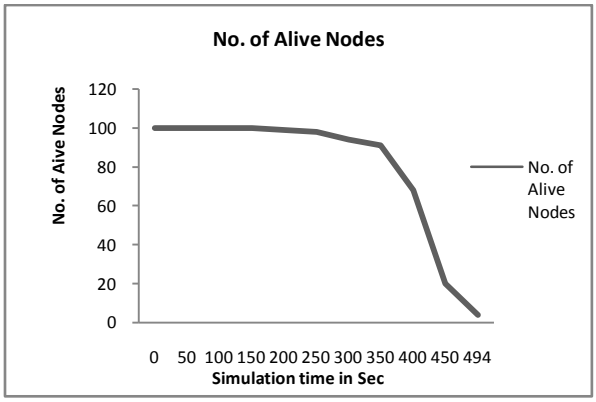

Fig. 3: Number of alive nodes as the Function of Simulation Time

From the graphs shown above, figure 3, at the initial state the response curve is constant and there were no dead nodes till the 150th second of start of simulation, when the first node appears to be dead and later the plot shows rapid decrement due to the massive failing of nodes because of the drying of power source.At the end of simulation there were only four alive nodes.

IV. FUTURE WORK AND CONCLUSION

The works yet to be done are, to change the parameters in the CH selection process, in order to get the threshold value as least as possible. This can result in an energy efficient protocol, an improvement of LEACH protocol. Improving all the available routing protocols can help in getting an efficient system and also a high secured environment, which is in turn reduce the maintenance cost i.e. for replacement of batteries.

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