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Energy-Efficient Routing Protocol for Wireless Sensor Networks Using Efficient Data Replication and Load Balancing

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ABSTRACT

Wireless sensor networks are comprised of thousands of battery powered sensor nodes. Because of limited energy source, economic utilization of energy is a critical issue in wireless sensor networks. Clustering techniques are used to reduce the energy consumption by the sensor nodes. In this work we introduce a new technique, data replication which can improve the energy efficiency and balance the load in the cluster.

Keywords:- Wireless sensor network, Clustering, LEACH, HEED, SEP

I. INTRODUCTION

Wireless Sensor Networks (WSNs) [1, 2] generally have a large number of sensor nodes and base stations. Because of their numerous applications like process management, health care monitoring, forest fire detection, etc. they are an interesting field of research. There is also a possibility to integrate them into more complex network systems. Sensor nodes can be assumed as a small computer which consists of components: processing unit, a communication device (radio transceivers) a power source battery. Communication in WSNs occurs in different ways which depends on the application. Generally, in WSNs there are three main types of communication:

Clock Driven**:** In clock driven, sensors gather data constantly and communicate periodically.

Event Driven: In event driven, communication can be triggered by occurrence or non-occurrence of a particular event.

Query Driven: In query driven WSN, communication occurs in response to a query.

Wireless sensor network have a very broad area. So now days it is very frequently used in various applications. WSN are very efficient but still some issues are related with it. These issues or problems are: energy efficiency, node life, load balancing in clusters, coverage problems, security issues, location of sensor devices, congestion in network, and load balancing in sensor network. These problems are very necessary to resolve in wireless sensor networks for making better communication. There are various methods proposed by researchers and still going search on these issues. Wireless sensor networks present vast challenges in terms of implementation. There are several key attributes like cost of nested clustering, selection of cluster heads and sub cluster heads, synchronization, data aggregation, quality of services which are important in WSNs

II. CLUSTERING

The sensor networks are divided into small unit is called as clustering and process known as clustering process [3,4]. The main reason behind the implementation of the clustering approach is to improve the energy efficiency and scalability of the network.

Cluster is a group of sensor nodes in which one node will act as a cluster head (CH) and remaining nodes act as member nodes. Clustering helps to reduce the number of exchanged communication messages in wireless sensor network which reduces the consumption of battery power of individual sensor nodes.

The selection of cluster head is depending on the distance and energy level of the node. Its main objective is to make only the cluster head which can communicate with the base station so that the remaining node can be put to a sleep state.

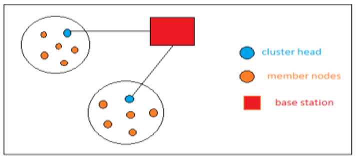

Fig.1.Cluster Formation

The cluster formation process leads to a two-level hierarchy where the CH nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes periodically transmit data to the corresponding CH nodes. The CH nodes aggregate the data and transmit them to the base station either directly or through the clustering technique. All the time CH nodes send data to higher distances than the common nodes, which they naturally spends energy at higher rates.

A common solution for balancing the energy consumption among all the network nodes is to periodically re-elect new CHs. For this the CH role is rotated among all the nodes over time in each cluster. Two of the most early and common classifications of Clustering Protocols are

1. Homogeneous or heterogeneous networks: based on the characteristics and functionality of the sensors in the cluster
2. Centralized or distributed clustering algorithms: based on the method used to form the cluster.

In this paper a new clustering protocol for heterogeneous wireless sensor networks is introduced. In which, some nodes can communicate directly with base station and some use clustering technique.

III. RELATED WORK

One of the most popular clustering protocol proposed for WSNs was LEACH [5, 6]. LEACH is a distributed and one hop clustering algorithm. In which each clustering cycle consists of two stages that is forming phase and data communicating phase. Its main objective is to improve the lifetime of wireless sensor networks and to reduce the energy consumption in the network nodes.

In LEACH, clusters are formed by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. All nodes can get a chance to become cluster head to balance the energy in each sensor node. Initially a node decides to be a CH with a probability "*p*" and broadcasts its decision. After its election, each CH broadcasts an advertisement message to the other nodes and each one of the other non-CH nodes determines a cluster to which they belong to, by choosing the CH that can be reached using the least communication energy message.

In general the election of cluster head depends on the selected threshold T (n) as follows,

$$T(n) = \begin{cases} \dfrac{p}{1 - p\left(r \bmod \dfrac{1}{p}\right)} & if\ n \in G \\ 0 & otherwise \end{cases}$$

Where p is the percent of cluster head nodes in all nodes, n is the token of the node, and r is the number of rounds for the election, r mod (1/p) is the number of nodes elected as cluster head in a cycle, and G is the set of nodes not elected as a cluster head, while each node is elected as the cluster head with the same probability.

Another improved and very popular protocol is HEED [7]. HEED is a hierarchical, distributed, energy efficient clustering protocol in which a single-hop communication pattern is retained within each cluster, whereas multi-hop communication is allowed among CHs and the BS. HEED overcomes the shortcomings of LEACH. The selections of CH nodes are based on, residual energy and intra-cluster communication cost. Residual energy of each node is used for the initial set of CHs. The intra-cluster communication cost reflects the node degree and is used by the nodes in deciding to join a cluster or not. In HEED, each node is mapped to exactly one cluster and can directly communicate with its CH and energy consumption is not assumed to be uniform for all the nodes.

At the beginning, the algorithm sets an initial percentage of CHs among all sensors. This percentage value, C_{prob} , is used to limit the initial CHs announcements to the other sensors. Each sensor sets its probability of becoming a CH and its probability can be given as $CHprob = Cprob * E_{residual}/E_{max}$, here $E_{residual}$ is the current energy in the sensor, and E_{max} is the maximum energy, which corresponds to a fully charged battery. CH_{prob} is not allowed to fall below a certain threshold p_{min}, which is selected to be inversely proportional to E_{max}.

LCA (link cluster algorithm) is the oldest clustering algorithms developed for wired sensor networks, but later also developed for wireless sensor networks [8]. In LCA, each node has a unique ID number and selection of CHs depends on the node has highest ID number in the cluster.

LCA used TDMA frame for communication between the nodes, where each frame has a slot for each network or node in the network to communicate. This means that LCA is only applicable for small networks. And for longer network LCA impose greater communication delay.

WCA [9] is a classical algorithm based on node degree and the number of single-hop neighbours. The elections of cluster head depend upon the factors of node degree, send-receive energy and residual energy. Means the cluster size is limited in order to save energy. The communication consumes large amounts of energy when the cluster size is too large. The WCA clustering algorithm is more comprehensive than the previously proposed algorithms, and some experiments show that the performance is more superior. The main drawback of WCA is that it needs to obtain the weight of the each node and require each node to save all the information of nodes before initializing the network, for that excessive amount of computing and communications require, which may cause excessive consumption of energy in the clustering directly. The process of aggregating and forwarding may cause a overhead and which may also give rise to excessive energy consumption and rapid death of cluster head node.

Most of the early routing protocols proposed for wireless sensor networks do not consider heterogeneity in the network and therefore are not able to take advantage of the heterogeneity present in the network. This heterogeneity may present in network either from very start of the network or may occur as a result of network operations as network evolves in time. SEP [10] judiciously consumes extra energy from the nodes having high energy and increase the stability period and life time of the network.

IV. PROPOSED PROTOCOL

Here a new Clustering protocol for Multi-level heterogeneous wireless sensor networks is presented. In this protocol, some nodes can transmit data directly to the base station while some can use clustering technique to send the data to the base station. The proposed protocol aims to conserve energy by keeping three key design factors into consideration: (1) the optimal distance up to which a node can directly send the data to base station, (2) electing an appropriate node as cluster head and (3) limiting the number of clusters in the network.

***Network deployment model*:** We portioned the network is into three zones:

a) α-nodes
b) β-nodes
c) ω-nodes

α-nodes have the highest energy among all the nodes, β-nodes have energy less than α-nodes but greater than ω-nodes and ω-nodes are normal nodes. We assume that a small fraction of total nodes are α- or β-nodes while most of the nodes are ω-node.

Cluster Head Selection: Let us assume that A is fraction of total nodes that are α-nodes and B is the fraction of total nodes that are β-nodes. The energy of a α-node is α times higher than a ω node while the energy of a β-node is β time higher than a ω node. If initial energy of a ω-node is E0 then total energy of all the nodes will be:

$$E_{total} = N(1 - A - B)E_0 + N.A.E_0(1+\alpha) + N.B.E_0(1+\beta)$$

$$= N.E_0(1 + A.\alpha + B.\beta)$$

Optimal probability of cluster head selection in case of homogeneous network can be calculated as:

$$P_{opt} = \frac{k_{opt}}{N}$$

Where N is total number of nodes in network and Kopt is optimal number of cluster heads , can be calculated as

$$K_{opt} = \sqrt{N/2\pi}\ M/d^{2\ to}BS\ \sqrt{\varepsilon_{fs}/\varepsilon_{mp}}$$

Where N is total number of nodes in network, M is the area, $d^{2\ to}$ BS is the average distance between a cluster head and base station, ε_{fs} is free space co-efficient, ε_{mp} is multi path co-efficient.

Now optimal probability of a node to be cluster head on the basis of residual energy can be calculated as:

$$(P_\omega)_i = \frac{P_{opt}\,E_i(r)}{(1+A\alpha+B\beta)\bar{E}(r)}$$

$$(P_\beta)_i = \frac{(1+\beta)P_{opt}\,E_i(r)}{(1+A\alpha+B\beta)\bar{E}(r)}$$

$$(P_\beta)_i = \frac{(1+\beta)P_{opt}\,E_i(r)}{(1+A\alpha+B\beta)\bar{E}(r)}$$

Here $E_i(r)$ is residual energy of ith node in rth round and $\bar{E}(r)$ is the average energy in the rth round.

Depending on the weighted probabilities the threshold values can be calculated as follows

$$T_\omega = \begin{cases} \dfrac{P_\omega}{1-P_\omega\left(1-r \bmod \frac{1}{P_\omega}\right)} & \text{if } \omega \in G'' \\ 0 & \text{otherwise} \end{cases}$$

$$T_\beta = \begin{cases} \dfrac{P_\beta}{1-P_\beta\left(1-r \bmod \frac{1}{P_\beta}\right)} & \text{if } \beta \in G' \\ 0 & \text{otherwise} \end{cases}$$

$$T_\alpha = \begin{cases} \dfrac{P_\alpha}{1-P_\alpha\left(1-r \bmod \frac{1}{P_\alpha}\right)} & \text{if } \omega \in G \\ 0 & \text{otherwise} \end{cases}$$

Where G, G' and G'' are the sets of α, β, ω-nodes that have not been the cluster head in last epoch respectively. Each node generates a number in interval [0, 1] randomly. If this random number is less then corresponding threshold the node will become cluster head.

Data replication: Once the cluster head is selected, the cluster head broadcasts an advertisement message to all the nodes. A node that receives such message decides on the basis of received signal strength that to which cluster head it will associate for the current round. The selection of cluster head rotated periodically and after each selection CH broadcasts an advertisement message to all the nodes. During advertisement cluster head consumes lots of energy. This may degrade networks efficiency. But this energy can be saving by reducing the number of advertisement. After the selection of cluster head when it broadcasts an advertisement message to all the nodes it must add the information at the same time about future node or next node in that advertisement message. The message is equally distributed to nodes which balance the load of the cluster. When next node will become the cluster head, it's no need to broadcast its advertisement message to all the nodes. Nodes previously know about the next cluster head. .

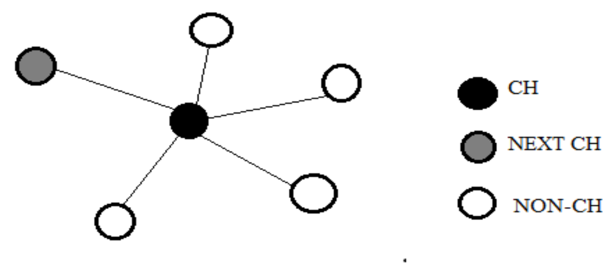

Fig.2. Data Replication

In the above figure, CH broadcasts an advertisement message to all the nodes which also contains the information about the next CH node. When the energy of running CH is over, then the node which is next to become CH, starts communicating with other nodes. The other non-CH nodes previously know about their next CH as the previous CH broadcasted the information about the next CH. And that's why; it's no need to broadcast again the advertisement message to all the nodes.

***Data Transmission*:** we use two techniques for data transmission:

a) Single-hop direct transmission
b) Multi-hop transmission
   In single hop transmission a node n near the base station will directly send the data to base station if

$$d_{n\ to\ BS} < {d_0}/{k'}$$

and

Residual energy $E_n(r) \geq \bar{E}(r)$

Here $d_{n\ to\ BS}$ is distance between nth node and base station; k' is a parameter which is used to control the single hop transmissions; $E_n(r)$ is residual energy of nth node in rth round; $\bar{E}(r)$ is average energy of whole network in rth round.

In Multi-hop transmission we used Dijkastra's shortest path algorithm to find the shortest route from a cluster head to base station through other cluster heads. For this we used the distance of nodes from each other and base station as weights.

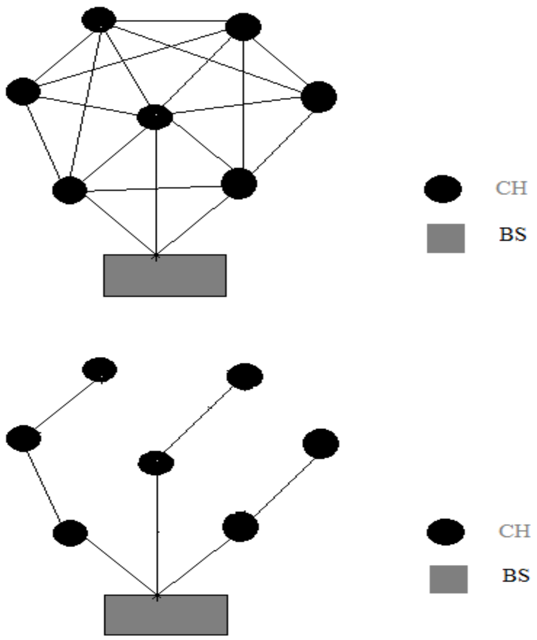

Fig.3. Formation of inter cluster communication

Above figures shows the formation of inter cluster communication using dijkastra's algorithm. But there may be possibility of bottleneck problem if the load on one cluster head is very heavy. This can be reduced by increasing the number of edges, in which each node consists of two or more edges through which they can communicate with BS.

V. CONCLUSION AND FUTURE SCOPE

In this paper we studied all pre-existing protocols which are used in WSNs. In this work we describe a hybrid cluster head selection protocol in detail that use the heterogeneity in sensor node for an intelligent deployment of nodes in the network and use the residual energy of nodes in particular data transmission round to weight the optimal probability of cluster head selection. We also describe an efficient Data Replication which can balance the load of the cluster and reduce the consumption of energy by broadcasting the information of next CH. There is no need to broadcast itself whenever a node becomes a CH.

In future we can extend the protocol to work with a mobile base station. Also we can put some constant value of p (percentage of cluster head nodes in all nodes) for a given rotation or a specific period of time.

REFERENCES

[1] K. Sohrabi et al., "Protocols for self-organization of a wireless sensor network, *IEEE Personal Communications"*, 7(5), 16–27, 2000.

[2] G. Gupta and M. Younis, "Load-balanced clustering in wireless sensor networks", in *Proceedings of the International Conference on Communication (ICC 2003)*, Anchorage, AK, May 2003.

[3] A. A. Abbasi and M. Younis, "A survey on clustering algorithms for wireless sensor networks", *Computer Communications*, 30, 2826–2841, 2007.

[4] R. Min et al., "Low power wireless sensor networks", in Proceedings of International Conference on VLSI Design, Bangalore, India, January 2001.

[5] W. P. Chen, J. C. Hou, and L. Sha, "Dynamic clustering for acoustic target tracking in wireless sensor networks", in 11th IEEE International Conference on Network Protocols (ICNP'03), pp. 284–294, 2003.

[6] W. R. Heinzelman, A.P. Chandrakasan, and H. Balakrishnan, "Energy efficient communication protocol for wireless micro sensor networks", in Proceedings of the 33rd Hawaaian Interantional Conference on System Sciences, January 2000.

[7] O. Younis and S. Fahmy, "HEED: A hybrid, energy-efficient, distributed clustering approach for Ad Hoc sensor networks", IEEE Transactions on Mobile Computing, 3(4), 366–379, 2004.

[8] D. J. Baker and A. Ephremides, "The architectural organization of a mobile radio network via a distributed algorithm", IEEE Transactions on Communications, 29(11), 1694–1701, 1981.

[9] M. Chatterjee, S.K. Das, and D. Turgut, "WCA: A weighted clustering algorithm for mobile ad hoc networks", Clustering Computing, 5, 193–204, 2002.

[10] G. Smaragdakis, I. Matta & A. Bestavros, "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks", in Proceedings of Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004), 2004.

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