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Energy Efficient Routing Protocol for Wireless Sensor Networks

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***Abstract*— The wide utilization of Wireless Sensor Networks (WSNs) is obstructed by the severely limited energy constraints of the individual sensor nodes. This is the reason why a large part of the research in WSNs focuses on the development of energy efficient routing protocols. WSN consisting of a large number of sensor nodes is effective for gathering data in a variety of environments. In this paper new energy efficient clustering algorithm is proposed for effectively selection of CH and data gathering scheme for Wireless sensor networks. The clustering algorithm mainly consist of two phase, first is Selection of cluster head which elect the cluster head for data aggregation and second is Data Transmission Phase which used to effectively route the gathered dada from cluster head to base station. The simulation result shows that the proposed algorithm scheme significantly reduce energy consumption and increases the lifetime of sensor network compared to other routing protocols. The simulation is done using NS-2 simulator.**

***Keywords*—Wireless sensor networks (WSNs), energy efficiency, network lifetime, scalability, clustering algorithm, hierarchy.**

I. INTRODUCTION

Recent technological advances have enabled the inexpensive mass production of sensor nodes, which, despite their relatively small size, have particularly advanced sensing, processing and communication capabilities. A WSN consists of spatially distributed sensor nodes, which are interconnected without the use of any wires [1]. In a WSN, sensor nodes sense the environment and use their communication components in order to transmit the sensed data over wireless channels to other nodes and to a designated sink point, referred to as the Base Station (BS) [2]. BS collects the data transmitted to it in order to act either as a supervisory control processor or as an access point for a human interface or even as a gateway to other networks [3]. The figure 1 shows the basic scenario of wireless sensor network. Data gathering is a common but critical operation in many applications of WSNs, where data aggregation and hierarchical mechanism are commonly used techniques. Data aggregation can eliminate the data redundancy and reduce the communication load [4].

Hierarchical (clustering) mechanisms are especially effective in increasing network scalability and reducing data latency, which have been extensively exploited [5].

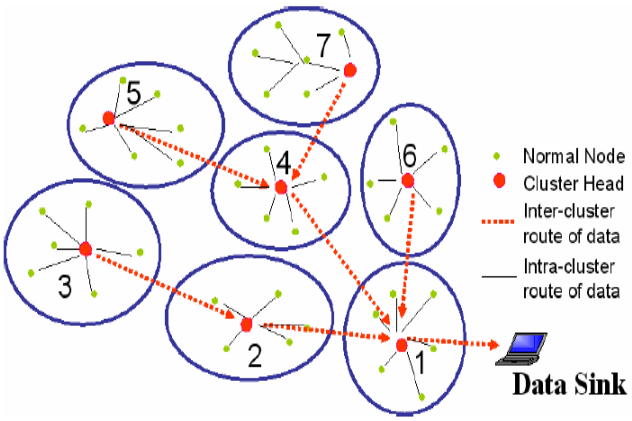

Fig. 1 Basic scenario of wireless sensor network [2]

II. PROBLEM STATEMENT

Sensor network has primary role to sense and forward resultant data to destination or base station BS. Routing plays a key role to identify path and transfer data in energy constraint sensor network. Initially routs defined by the nodes then nodes become able to send or receive the data by using those routing paths. In case if sensed data is available to some segments of network but network not able to transfer it to the destination due to the energy deplete of sensor nodes for some segments. Properly utilization of node energy and improve the network lifetime is major problem in WSN.

III. RELATED METHODS

There exists a considerable research effort for the development of routing protocols in WSNs. The development of these protocols is based on the particular application needs and the architecture of the network. However, there are several factors that should be taken into consideration when developing routing protocols for WSNs. Energy efficiency is the most important among these factors, since it directly

affects the lifetime of the network. There have been a few efforts in the literature pursuing energy efficiency in WSNs.

Heinzelman, et al. [6] introduced a hierarchical clustering algorithm for sensor networks, known as Low-Energy Adaptive Clustering Hierarchy (LEACH). LEACH is a cluster-based protocol that applies randomized rotation of the cluster heads to distribute the energy load evenly among the sensor nodes in the network [6]. The operation of LEACH is organized in rounds, each consisting of a set-up phase and a steady-state phase. During the set-up phase, the network is separated into clusters, each with a randomly selected cluster head from nodes in a cluster. During the steady-state phase, the cluster heads gather data from nodes within their clusters respectively, and fuse the data before forwarding them directly to the sink [6]. LEACH provides sensor networks with many good features, such as clustering-based, localized coordination and randomized rotation of cluster-heads, but expends much energy in cluster heads when directly forwarding data packets to the sink [6]

Lindsey et al. [7] presented an enhanced LEACH protocol. The protocol, Power Efficient Gathering in Sensor Information Systems (PEGASIS), assumes that all nodes have location information about all other nodes, and that each can send data directly to the base station [7]. Hence, the chain of PEGASIS is constructed easily using a greedy algorithm based on LEACH. Each node transmits to and receives from only one of its neighbors. In each round, nodes take turns to be the leader on the chain path to send the aggregated data to the sink [7]. To locate the closest neighbor node in PEGASIS, each node adopts the signal strength to measure the distance of all neighbor nodes. However, the global information of the network known by each sensor node does not scale well and is not easy to obtain. Since a sensor network generates too much data for the end-user to process, it has to aggregate the data [7]

Energy consumption is one of the most important criterions for the development of autonomous sensor network nodes. To improve efficiency all the sensor network nodes designs used duty cycling techniques which means unused nodes go to sleep mode with periodic wake up to save power [8]. Battery replacement is not an option for networks with thousands of physically embedded nodes used in technologies to save power such as power-aware computing, energy-aware software or power management radios [8].

TEEN protocol adopts the same clustering model used by LEACH, a cluster node in TEEN sends threshold value to its members for reducing delay of transmission [9]. Power Efficient Data Gathering and Aggregation in Wireless Sensor Networks (PEDAP) [10] is based on a minimum spanning tree. PEDAP assumes that the sink knows the locations of all nodes, and that the routing information is calculated by Prim's algorithm with the sink as the root[10]. PEDAP prolongs the lifetime of the last node in the system while providing a good lifetime for the first node. Additionally, sensor nodes transmit the sensed data to the sink via the previously constructed routing path to produce a minimum energy consuming system [11]. Nevertheless, the intermediate nodes consume energy quickly. In the Hierarchy-Based Any cast Routing (HAR) Protocol for Wireless Sensor Networks [12], the sink constructs a hierarchical tree by sending packets (such as CREQ, CREP, CACP, PREQ) to discover each node's own child nodes in turn. HAR avoids both flooding and periodic updating of routing information, but needs to reconstruct the tree when nodes fail or new nodes are added [12]. The drawback of HAR is that it sends and receives too many packets in the network, expending much energy. The Yu and Song [13] proposed an Energy-Efficient Chain-Based routing protocol (EECB) that is an improvement over PEGASIS.

IV. ENERGY EFFICIENT ROUTING PROTOCOL

Energy Efficient Routing Protocol is to generate clusters for randomly deployed sensor nodes, where each cluster is managed by a set of associate's nodes called a head-set. First step in this method is to setup the cluster and form hierarchical clustering model. In this selection of most efficient node becomes cluster head (CH) in each cluster using election algorithm [2]. The election algorithm after a specific number of transmissions, a set of new clusters is formed. The clusters are maintained for a short duration called round. A round consists of a selection of cluster head and data transmission phase. In a selection of cluster head is also based on the energy parameter and distance from base station. In data transmission phase, the cluster heads transmits the data to base stations (BS) periodically and spontaneously. In EERP clustering is one of the key processes to perform routing. Clustering includes partitioning stage and choosing cluster head using election algorithm called selection of cluster head.

A. Selection of cluster head

During an selection of cluster in each cluster, the election of cluster head among fellow nodes for a cycle is based on battery power which needs to be broadcast among others and the distance from the BS [3]. This information advertises initially to compare the amount of energy stored in each node and the energy efficient node elected as cluster head (CH). Once the cluster heads are formed other nodes goes to sleep, as they do not take part in routing and required to conserve energy. This method use sleep and wake-up algorithm to decide the mode of the nodes and using this method each node goes to sleep and wake-up when required [5]. After one round if required election process elect new CH in each cluster. Usually the battery power consumed with transmission but it can save energy once it goes to sleep mode. After data transmission if required the new cluster is formed and election process takes place accordingly.

B. Data Transmission Phase

The member nodes transmit data to their CHs and the CHs transmit aggregated data to the base station (BS). First,

member nodes transmit data to neighbors. Second, neighbor transmits data to cluster head. Third, CH transmits the aggregated data to BS. Fourth, CH checks the remaining energy and sends it to neighbors. Once the required energy calculated is higher than remaining energy it will call for election process and the CH removes itself from head-set. Fifth, the outgoing CH informs the new CH and sends all it message so that the new CH can continue the process and the remaining head-set members update it accordingly[5].

C. Architecture of wireless sensor nodes

The sensor nodes are small devices that consist of four basic components 1) sensing subsystem, 2) processing subsystem, 3) wireless communication subsystem 4) energy supply subsystem. The sensor nodes have limited battery power, communication range and memory etc. [2]. WSN are characterized with denser levels of sensor node deployment, higher unreliability of sensor nodes and several power, computation and memory constraints [2]. Due to severe energy constraints of large number of densely deployed sensor nodes, it requires a suite of network protocols to implement various network control and management functions such as synchronization, node localization and network security [4]

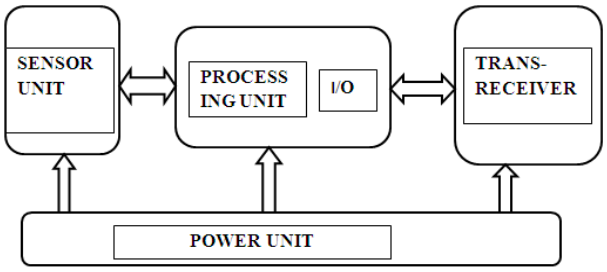

Fig. 2 Architecture of sensor node

The energy dissipated during data transmission was calculated using the following formula:

$$E_{TX} = E_{elect} * k + \xi_{fs} * k * d^2, \quad (1)$$

And the energy dissipated during data transmission was calculated using the following formula:

$$E_{RX} = E_{elect} * k \quad (2)$$

where E_{TX} is the amount of energy consumed by each node, E_{RX} is the amount of energy for receiving k bit packet, E_{elect} is the energy dissipated, ξ_{fs} is the free space propagation, d is the transmission distance and k is message length calculated as:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_2)^2} \quad (3)$$

where (x_1, y_1) and (x_2, y_2) are the coordinates of reference nodes.

V. ENERGY STEPS TO IMPLEMENT THE PROTOCOL

Step 1: Assumption when nodes are places

With the nodes being deployed, some assumptions were made concerning the node features and these are as follows:

- All nodes are homogeneous in nature.
- All nodes start with the same initial energy.
- The base station is situated at the (0, 0) origin of the area space.
- Clusters and nodes are static.
- Normal nodes transmit data directly to their respective cluster heads within a particular cluster.

Step 2: Parameter for simulation

The following parameter are used in simulation which given in below table.

TABLE 1.

THE PARAMETERS USED IN THE SIMULATION

Parameter	**Value**	**Parameter**	**Value**
Size of target area	500 x 500 m^2	Data packet size	512 bytes
Initial no. of sensor nodes	100	Max no. of nodes	1000
Initial energy	1J	Max no. of Rounds	1000
Transmitting and Receiving Energy	50 nJ/bit	E_{elec}	50 nJ/bit

Step 3: Deployment of wireless sensor nodes

The numbers of sensor node are randomly placed in given area. Initial energy of each node is 1J.

Step 4: Formation of cluster

Given area is divided into number of small region called clusters. Each cluster contain number of sensor nodes.

Step 5: Selection of cluster Heads in each cluster

The election of a CH among the fellow nodes for a cycle is based on battery power and the distance from the sink of each node.

Step 6: data send from non cluster head to cluster head

The sensor nodes has send the data to their respective cluster head within cluster is called as inter-cluster communication

Step 7: Path selection

According to shortest path selection method, the path is build from cluster head to the base station.

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_2)^2} \quad (4)$$

where (x1, y1) and (x2, y2) are the coordinates of reference nodes.

Step 8: Data transmission

The member nodes transmit data to their CHs and the CHs transmit aggregated data to the base station (BS).

Step 9: Update energy of each node

The transmission depends on the energy of the node and distance between CH and BS. After each round energy level of each node is changes. Due to this after each round calculate energy of each node and reform the cluster head.

VI. PERFORMANCE EVALUTION

In this section the different parameter is evaluated and compared with the existing routing measure system lifetime, energy consumption ration, packet delivery ration and latency of each protocol. The simulation is done using NS-2 software. The definitions of different parameter are given below.

1) *Packet Delivery Ratio (PDR):* It is the ratio between the number of data packets received and sent.
2) *Energy consumption:* The metric gives the energy consumption of nodes in the event area for transmitting a data packet to sink.
3) *Average Energy:* The metric gives the average of energy of all nodes at the end of simulation.
4) *Average delay:* The average end-to-end delay observed between transmitting a data packet and receiving it at the destination.
5) *Network lifetime:* This metric gives the time of the first node running out of its energy.

In below figure 3, the average energy dissipation is calculated according to the number of rounds. Compare the system with existing system. Hence EERP protocol total energy is used up to the 550 rounds.

In figure 4, the delay is calculated according to the number of rounds. It is end-to-end delay observed between transmitting a data packet and receiving it at the destination.

Figure 5 shows the comparison of system life-time of different routing protocols. Here count the alive nodes according to the number rounds. This defines after 500 rounds of packet delivery 50% of the nodes are still alive which is better than other routing protocols. EEHCR has better system life-time also when compared with LEACH, PEGASIS, TEEN and HAR.

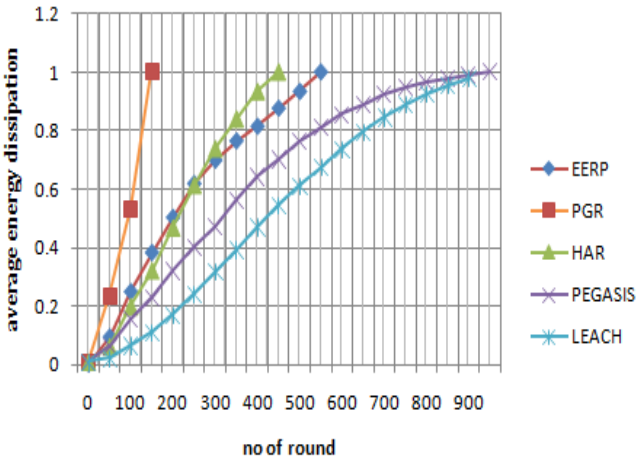

Fig. 3 Average Energy dissipation of different protocols

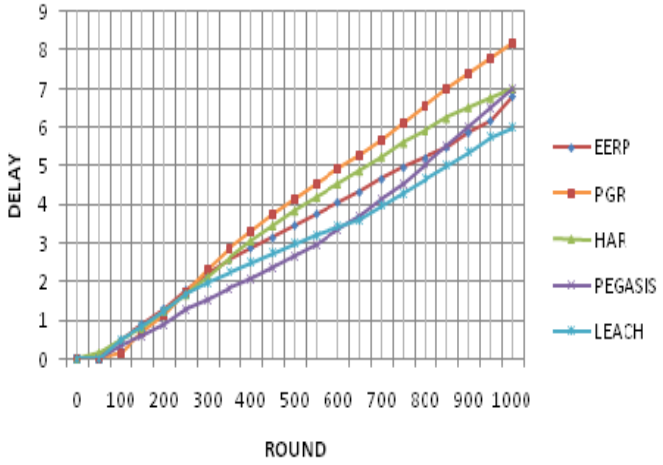

Fig. 4 Average Delay of different protocols

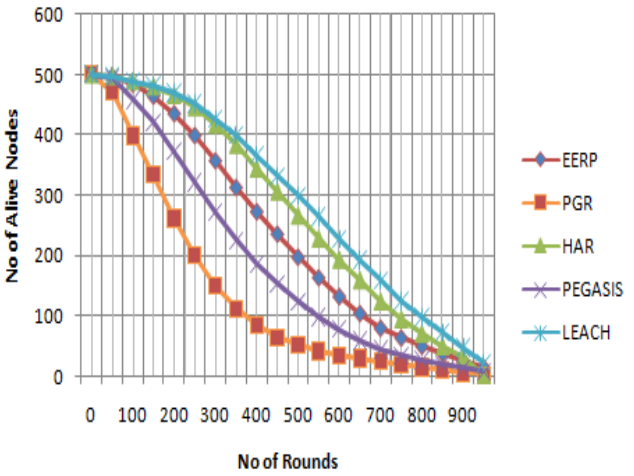

Fig. 5 Network lifetime of different protocols

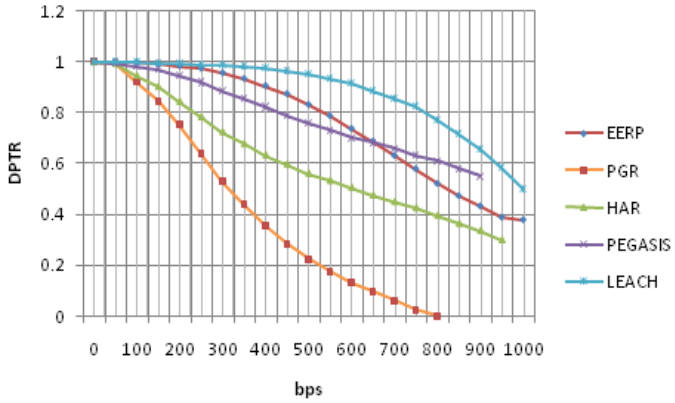

Fig. 6(a) Performance comparison for packet delivery ratio of protocols

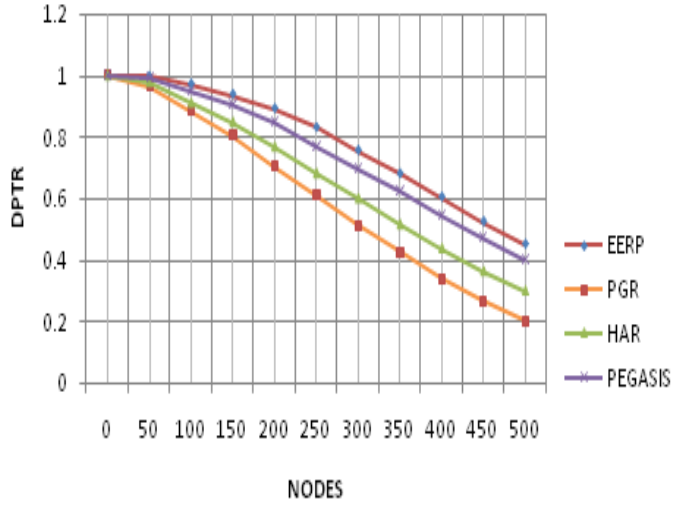

Fig. 6(b) Data Packet Delivery Ratio of different protocols

Figure 6 shows data packet delivery ratio with increasing number of rounds and transmission rate. The proposed protocol exhibits the rate of packet drops linearly with comparatively low rate.

VII. CONCLUSION

It is clear from the simulation results that EERP is balanced protocols which can have better the throughput. The network must be energy efficient, stable, and have a long lifetime. This EERP protocol improves the cluster head selection process and solves the problem of node isolation also showed how it provides the solution against the dynamic natures of WSN.

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