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Power Aware Cluster Based Routing With Sleep Scheduling in WSN (PACBR)

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Abstract: ***Wireless Sensor Networks (WSN) is an emerging technology in today's world. A WSN consist of thousands of sensor nodes it will perform sensing, computation and communication. Most of the sensor nodes are powered by batteries so there is a need of an energy efficient routing scheme in WSN. Many cluster based routing algorithms have been developed based on energy efficiency. In this paper, we propose a power aware cluster based routing with sleep scheduling in WSN for prolonging the sensor network lifetime. Here Cluster Head(CH) is selected based on number of neighboring nodes and the remaining residual energy of sensor node. In order to prolong network lifetime we are also using Sleep Scheduling in WSN. Most of the nodes are kept to sleep state to conserve energy and sleep scheduling will increase network lifespan. Evaluation of the system is done with Network Simulator-2 (NS-2). We are also comparing proposed system with system without sleep scheduling. The simulation results shows that the proposed approach prolongs the network lifetime and balancing the energy consumption among the nodes of the cluster.***

Keywords: WSNs, Cluster head node, residual energy, sleep scheduling.

1. Introduction

Recent technological advances in wireless communication, micro-electro-mechanical system (MEMS) technologies and digital electronics over the past few decades have enabled the development of wireless sensor network (WSN). Actually these sensors are small, with limited processing power and resources. Sensor nodes can able to sense the physical quantity in the environment and then perform local computations on the sensed data [1].

WSN are usually used in areas where human access is limited and it is powered by batteries. Replacement of batteries or recharging is not possible once they are deployed. So there is a need of an energy efficient routing in WSN. A typical sensor network contain 1000's of sensor nodes if these sensors are managed directly by Base Station (BS) then the network becomes less efficient. So clustering has been introduced by researchers.

The basic operation in sensor network is the systematic gathering of sensory data and then forwarding the aggregated data to the base station. Since the sensor nodes are highly energy-constrained, communication between the base station and the sensors must be carried out in an energy-efficient manner.

Routing in wireless sensor networks is a very challenging task due to several unique characteristics that distinguish them from other communication networks such as ad-hoc networks etc. Sensor nodes in sensor networks operate under several basic constraints [1], [2]. Some of these are mentioned below.

- Sensor nodes are highly energy constrained.
- Sensor nodes may fail at any moment.
- Communication bandwidth available for sensor node is limited.

The resource constrained nature of sensor nodes is a main challenge to the design of WSNs. Therefore, there is a need of more efficient use of scarce resources at individual sensor nodes. Clustering is an effective way to minimize the energy consumption in WSN. Objectives of clustering are to minimize the total transmission by performing aggregation function and reducing number of nodes taking part in transmission. The sensor nodes can be grouped to clusters and each cluster is managed by a special node called cluster head (CH). The CH is responsible for coordinating the data transmission activities of all sensors in its cluster. Data transmission to the base station is also performed by the CH. Clustering approach in WSN is shown in the Figure 1.

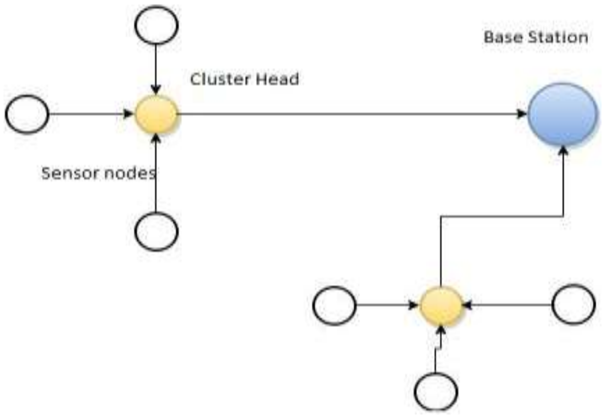

Figure 1: Clustering approach in WSN

Clustering schemes will reduce communication overheads and allow efficient resource allocations thus decreasing the overall energy consumption and reducing the interferences among sensor nodes. A large number of clusters will bottleneck the area with small size clusters and a very small number of clusters will drain the cluster head with large amount of messages transmitted from cluster members [2].

In this paper, a power aware cluster based routing protocol is proposed which falls under cluster based hierarchical model. So a new cluster head selection algorithm has been designed. The amount of energy consumption for communication in WSN is highest, so a sleep scheduling scheme is also introduced to preserve energy [3]. Every cluster head will manage communication time schedule of its cluster members. In every cycle, cluster head will assign communication time slots to every cluster member according to their needs. This allows sensor nodes to identify when to wake up and send the sensed data to the cluster head so that energy can be saved and this approach gives an extended network life time. This Sleeping techniques can be used to reduce energy consumption in sensor nodes.

The rest of the paper is organized as follows. Section 2 summarizes related work. Proposed algorithm for energy efficient routing in WSN is discussed in Section 3. Section 4 provides simulation results and performance evaluation of the protocol. Section 5 concludes the paper with an outline of future scope of this work.

2. RELATED WORK

Recently many researchers have proposed different energy efficient clustering algorithms for WSN. Heinzelman et al. introduced a hierarchical clustering algorithm for sensor networks, called low energy adaptive clustering hierarchy (LEACH [4]). LEACH is the first energy efficient routing protocol for hierarchical clustering. Network is divided into clusters to minimize energy dissipation. Each cluster has same number of nodes and one of the node is selected as Cluster Head (CH). LEACH uses a probabilistic function for selecting the cluster head which ensures every node with a cluster head role.

Heinzelman et al. proposed LEACH-C which is a modified version of leach protocol [5]. It is more suitable for increasing network lifetime. A central algorithm is used to form the clusters and may produce better clusters by dispersing the cluster head nodes throughout the network. This is the basis of LEACH-C. During the set up phase, nodes send their location and remaining energy level to BS or sink. After that sink runs a central cluster formation algorithm and forms cluster for that phase. In each round clusters are formed by sink. Steady phase of LEACH-C is identical to LEACH. This protocol distributes CH's throughout the network based on node's energy and location. Hence produce effective results.

O Younis, S Fahmy proposed Hybrid, Energy-Efficient Distributed Clustering (HEED) protocol in 2004 [6]. HEED was designed to select different CH's in a field according to the amount of energy ie, distributed in relation to a neighboring node. Periodic re-clustering will helps to select CH nodes based on higher residual energy. Clustering plays a dominant role in delaying first node death while aggregation plays a dominant role in delaying last node death. In each cluster one node acts as CH which is in charge of coordinating with other CH's. In HEED a node initially set its probability to become CH according to its residual energy. When there is no CH's announcement, a node selects itself with the probability it has or alternatively doubles its probability for next round. A node stops this process one iteration after its probability reaches the value of one.

G Ahmed et al. proposed an Energy-Efficient Cluster Based Data Aggregation, ECBDA [7] protocol. Here one node is selected as a CH by using its residual energy and the communication cost factor. If the residual energy is less than the required threshold value, a new cluster head is elected from the same cluster.

Most of the protocols proposed so far only consider residual energy for cluster head selection but there are other metrics like distance to aggregation point, node reliability, mobility [8] etc are also very crucial in order to maximize network life time.

3. Proposed System

In the proposed Cluster Based Power Aware Routing Protocol, CH is selected based on remaining residual energy of sensor nodes along with number of sensor nodes having more number of neighboring sensor nodes [9]. Sleep Scheduling is also used to reduce energy consumption by making some nodes to active/inactive nodes [3]. Currently communicating nodes are in active state and remaining nodes are put to sleep state. Also in order to reduce energy consumption by the nodes which are not capable of transmitting data or to communicate with in the cluster to the cluster head a sleep/wake scheduling technique is implemented in the network. By using sleep/wake scheduling process, it is possible to conserve energy in the network. This is possible by dividing the nodes of a cluster into active nodes and the inactive nodes. The active nodes are the nodes which are having high energy. They are capable of communicating with the cluster head. The inactive nodes are the nodes which are having low energy and are not capable of communicating with the cluster head. These inactive nodes are put to the sleep mode. And the remaining nodes are kept in the wake up mode which is capable of communicating to the cluster head. Through this way it is possible to conserve the network energy and life time. Proposed system can be divided into following processes flooding and topology discovery [10], cluster formation, CH selection [11], Data Transmission, Power saving schedule [3], New CH selection.

3.1 Flooding and topology discovery

Flooding is an important concept in communication for Wireless Sensor Networks (WSN). It is used whenever there is any change in network. Each and every node broadcasts the flooding packets to its one hop neighbors. By listening to the communication channel a node can understand the presence of other nodes within its direct range. Topology discovery is shown in the Figure 2.

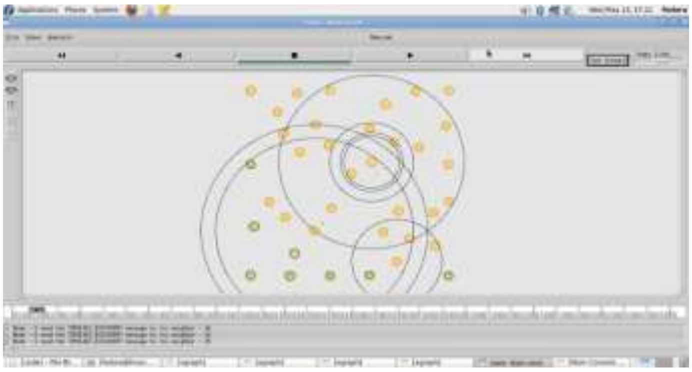

Figure 2: Topology Discovery

3.2. Cluster Formation

Depending on the density and geographical layout of the network, Sink node virtually divides the network into different clusters

3.3. Cluster Head (CH) Selection

After topology discovery, each and every node calculate its neighboring nodes distance by using Euclidean formulae, then Cluster Head (CH) is selected based on nodes having highest residual energy and more number of neighboring nodes. Then the current CH sends CHADV message to its cluster members declaring their presence as CH. Once the clusters are formed, CH will assign a time slot to each and every node so that sensor nodes can only able to communicate in its allocated time slot and the remaining nodes will be in the sleep state. Figure 3 shows CHADV message passing to cluster member.

Figure 3: CHADV message passing to cluster members

3.4. Data Transmission

Cluster members will send sensed data to CH and then CH will perform data aggregation and send the collected data to sink node. Only nodes that have any data to communicate will be in active state and remaining nodes will be in sleep state. Data transmission happens in two different patterns. One is inside cluster and the other is from the CH to the sink. In this protocol, multi-hop data transmission may occur even inside a cluster *(at the maximum two hop)* based on the distance of an ordinary node and the CH. This decision is made by the CH based on the topology of the cluster received from the sink. Again data transmission between a CH and the sink may be single-hop or multi-hop based on the corresponding distances. This is decided by the sink (and informed to the CH) and based on the relative distances among the CH's. Figure 4 shows data transfer from sensor node to a CH and Figure 5 shows data transfer from CH to Sink.

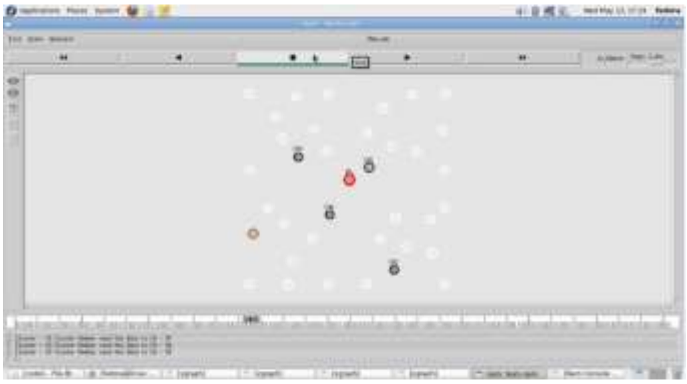

Figure 4: Data transfer by node 30 to CH 4

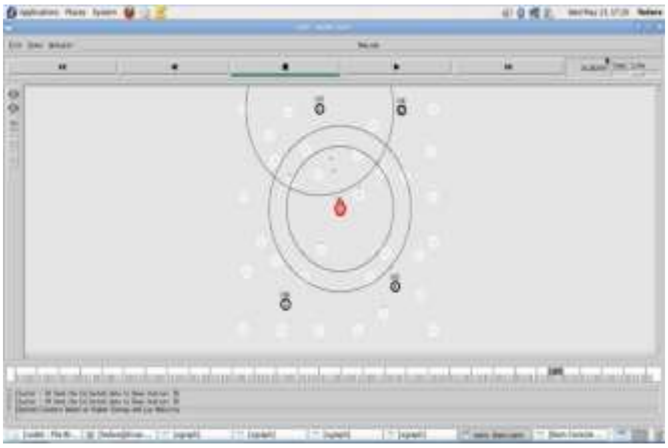

Figure 5: Forwarding data from CH 3 to Sink

3.5. Power Saving Schedule

For transmitting data to the base station**,** the cluster members will first transmit the data to respective cluster heads. The data transmission is the most energy consuming task in the operation of WSN. So if the number of transmissions is reduced, it saves a considerable amount of energy.

In this paper the power saving is achieved using a sleep and active scheduling of the member nodes in each cluster. For this the randomly deployed node positions are considered. Only nodes that have any data to communicate will be in active state remaining nodes will be in sleep state

A sensor node can have following four states- *Sensing*, *Receiving*, *Sending* and *Sleeping*. Moreover, we assume that sensor nodes are deployed densely so it is possible to make some sensor nodes sleep without leaving any geographic region unattended or un-sensed. Since the CH has knowledge about relative geographic locations of the members of its cluster *(which is obtainable from the base station),* the CH now makes the sleep schedules for some of the nodes inside its cluster. And possibly *(based on the relative geographic location of the members of its cluster)* every node inside a cluster gets a *sleeping* time slot. This saves lots of energy inside a cluster as a whole. Whenever a node is not in *sleeping* state it does anyone of the following three tasks at any point in time- sensing, receiving, and sending. And moreover, in this type of WSN system, sensing is a continuous activity.

Again the CH makes a schedule for all other sensor nodes inside its cluster which are not in *sleeping* state. And the CH keeps on changing these two schedules (*sleeping* and *transmition/sending*) among its cluster members after a certain time interval. This time interval can be fixed by the user (at the BS).

3.6 New CH Selection

Energy of CH's nodes will drain faster than other sensor nodes so in each round a new CH should be selected. When energy of current CH goes beyond a threshold value then the current CH will send CH_Die packet message to its one Hop neighbors. Upon receiving CH_Die packet, sensor nodes are aware about low energy of current CH. Then sensor nodes will stop transmission to the current CH and then a new CH is selected based on following criteria:

(a) A node has not become a CH for the past rounds.

(b) The factor (ECurrent)/ (EMax) should be nearest to one. (ECurrent=current of the node and EMax=initial energy level of the node)

(c) The most preferred next CH is the node nearest to the existing CH

4. Simulation Results and Analysis

We carry out simulation in ns2 for evaluating the proposed routing protocol .In order to make a comparison of test results proposed PACBR with sleep scheduling are consistent with simulation without sleep scheduling. The comparison between Cluster based routing protocol with and without Sleep Scheduling is performed over the common factors like throughput, packet drop, packet delivery ratio and energy consumption in the network over different simulation time. The simulation program has been written in C++. The specific parameter values for the simulation is showed in Table 1.

Table 1: Main Simulation parameters for the simulation

Parameters and Models	*Value*
Number of Sensor Nodes	37
Location of Sink Node	221.65,238.66
Sensor Node Deployment	Random Deployment
Sensor ID	0-36
Number of cluster heads	10% of total sensor nodes
Data Packet Size	5000 bit
Radio Model	Two-Ray Ground model
Interface Queue Type	CMUPriQueue
Interface Queue length	500
Idle Power	2.2 mW
Rx Power	4.8 mW
Tx Power	5.5 mW
Sleep Power	0.0015 mW
Initial Energy	200 J

Figure 6 shows the average energy expenditure (*i.e., average energy consumption per node, Joule*) under the influence of the proposed PACBR with sleep scheduling protocol and the same under without sleep scheduling protocol. It is observed that the proposed protocol has less energy expenditure per node in comparison to that against protocol without sleep scheduling.

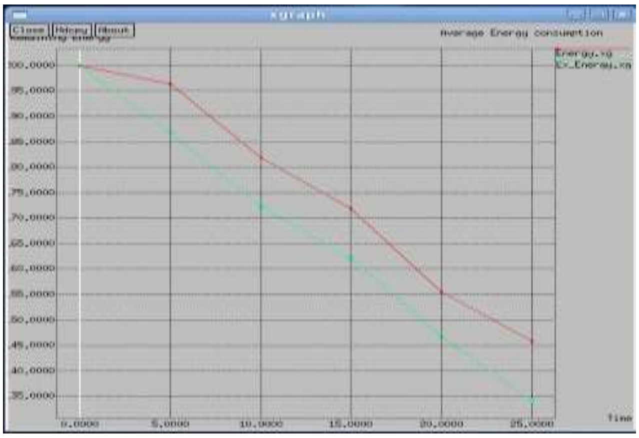

Figure 6: Average energy consumption for proposed protocol and protocol without sleep scheduling.

Figure 7 shows the packet delivery ratio for the proposed PACBR with sleep scheduling protocol and the same under without sleep scheduling protocol. It is noticed that the proposed method achieves higher and more stable packet delivery ratios than protocol without sleep scheduling.

Figure 7: Packet delivery ratio for proposed protocol and protocol without sleep scheduling.

Figure 8 shows the packet drop under the influence of the proposed PACBR with sleep scheduling protocol and the same under without sleep scheduling protocol. It is observed that the proposed protocol has less packet drop in the network in comparison to that without sleep scheduling.

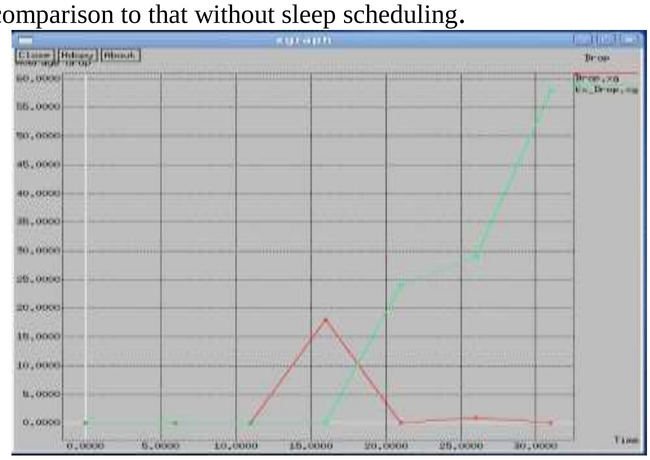

Figure 8 : Packet drop for proposed protocol and protocol without sleep scheduling

Figure 9 shows the Throughput of the network under the influence of the proposed PACBR with sleep scheduling protocol and the same under without sleep scheduling protocol. It is observed that the proposed protocol has better throughput in the network in comparison to that without sleep scheduling.

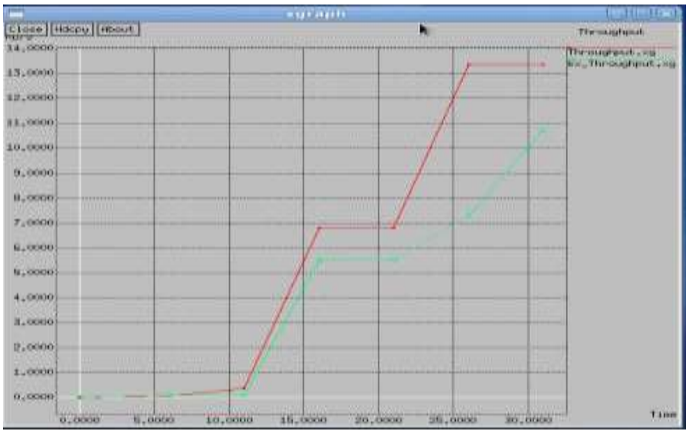

Figure 9: Throughput of the network for proposed protocol and protocol without sleep scheduling

4. Conclusion and Future Work

In this paper, a power aware cluster based routing with sleep scheduling in WSN has been proposed. The performance of the proposed protocol is compared with protocol without sleep scheduling through simulation experiments in ns-2. It is observed that the proposed protocol outperforms protocol without sleep scheduling under all circumstances considered during the simulation. As a future scope of this work, the protocol can be enhanced for dealing with mobility of nodes..

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