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Prolonging Network Lifetime Using Cluster Based Routing Protocol in Heterogeneous Wireless Sensor Networks

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Abstract—Wireless Sensor Networks (WSNs) are combination of a low cost and low power sensor nodes capable of sensing physical or environmental conditions as temperature, sound, pressure. Energy balancing for nodes is an important factor in Heterogeneous Wireless Sensor Networks for better efficient system. Many routing Protocols have been designed for WSNs where energy consumption is an essential design issue. Routing Protocols for WSN can be classified as Heuristic, Weighted, Hierarchical and Grid Based. In this Paper, we have proposed Cluster Based Routing Protocol for Heterogeneous WSNs in order to minimize energy consumption and prolonging network lifetime. Cluster Based Routing Protocol is active branch of routing technology among others and proven to be more effective than LEACH and PEGASIS. In this paper, We discuss Cluster Based Routing Protocol along with LEACH and PEGASIS.

Keywords—Heterogeneous Wireless Sensor Network, Sensor nodes, Cluster head, LEACH , PEGASIS and Cluster Based Routing Protocol .

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consists of small size sensors. These sensors equipped with limited battery power and are responsible for wireless communications [1]. Wireless sensor networks are evolving to be an important enabling technology due to the increasing capability to sense, process and communicate their information at low cost [3]. WSNs are divided into two classes: structured and unstructured. In structured, all or some of sensor nodes are deployed in pre-planned manner at fixed locations. The advantage of Structured WSNs is lower maintenance and management costs. In unstructured WSNs consists of dense collection of sensor nodes, which are randomly placed into field [4] When WSN is deployed in sensing field, sensor nodes will be responsible for sensing physical and environmental conditions [5]..

Clustering Algorithms for Wireless Sensor Networks (WSNs) consists of mainly following components [6]:

- Sensor Node: A sensor node is the main component of a WSN. Sensor nodes performs multiple roles in a network, such as sensing, data storage, data routing and data processing.
- Clusters: Clusters are the basic unit for WSNs. It is required that WSNs should be divided into clusters to simplify tasks such a communication.
- Cluster heads: Cluster heads are the leader of a cluster. They are required to organize various activities in the cluster. These include data-aggregation and organizing the communication schedule of a cluster. They sends useful data to base station.
- Base Station: The base station(BS) is at the heart of the Hierarchical Wireless Sensor Network (HWSN). It provides the communication link between the sensor network and the end-user.
- End User: It is the last component of Network. End user may be civil, governmental, commercial or industrial entity. The data in a sensor network can be used for a wide-range of applications. Therefore, a particular application may make use of the network data over the internet, using a PDA, or even a desktop computer. In a queried sensor network (where the required data is gathered from a query sent through the network). This query is generated by the end user.
- . Limited Energy: Wireless sensor nodes are ”off-grid”, meaning that they have limited energy storage and the efficient use of this energy will be vital in determining the range of suitable applications for these networks. The limited energy in sensor nodes must be consumed with proper clustering algorithm which can reduce the overall energy usage in a network.
- Network Lifetime: The energy limitation on nodes results in a limited network lifespan for nodes in a network. Proper clustering algorithm should attempt to reduce the energy usage, and also increases overall network lifetime.
- Limited Abilities: The small physical size and small amount of stored energy in a sensor node limits many of the abilities of nodes in terms of processing and communication abilities. If good clustering algorithm is used it can be able to provide better abilities.

Figure below shows architecture of WSN [6].

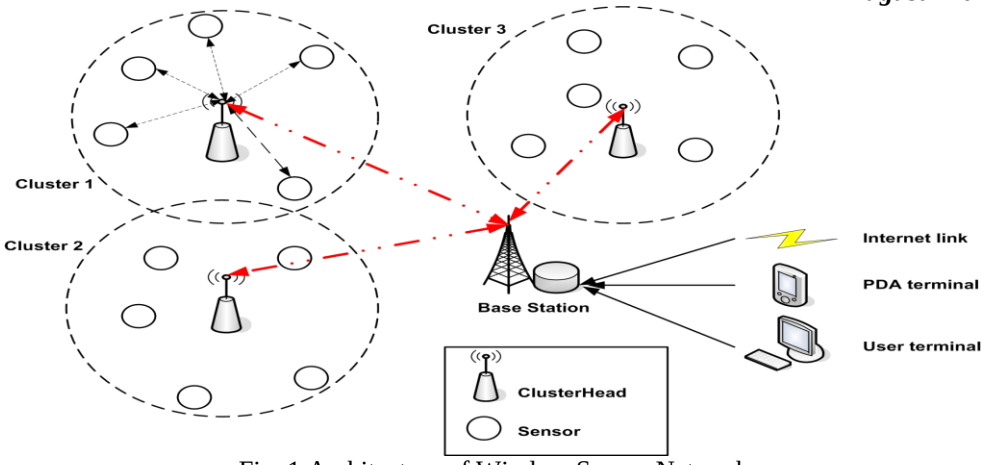

Fig. 1 Architecture of Wireless Sensor Network

II. HOMOGENEOUS AND HETEROGENEOUS SENSOR NETWORKS

Homogeneous Wireless Sensor Networks (H0WSNs): A Homogeneous Wireless Sensor Networks is a combination of sensors having the same capabilities in terms of energy, storage, processing, and communication capabilities so that they achieve a desired goal. Such type of Wireless Sensor network called Homogeneous Wireless sensor network [7].
Heterogeneous Wireless Sensor Networks (HTWSNs): A Heterogeneous Wireless sensor network is the combination of different sensors having different capabilities in terms of energy, storage, processing, and communication capabilities to work such that they achieve a desired goal. Such type of Wireless sensor network called Heterogeneous Wireless sensor network [7].

A. Heterogeneous Wireless Sensor Networks Design

1) Basic LEACH: Low-Energy Adaptive Clustering Hierarchy (or LEACH) was one of the first major improvements on conventional clustering approaches in wireless sensor networks. LEACH divides network into several clusters of sensors and provide routing and data dissemination more scalable [2]. .LEACH includes distributed cluster formation. In this a randomized rotation of the cluster head's role is allowed for reducing energy consumption within a cluster and to distribute the energy load evenly among the sensors in the network. In this protocol cluster formation will done in set-up phase and data transfer in steady-state phase. Each node elects itself as Cluster Head at the beginning of round *r+1* with probability *Pi(t) and* ***k*** is the number of clusters.

$$\sum_{i=1}^{N} P_i(t)*1=k \qquad ....(1)$$

In setup phase some part of node p, elect themselves as cluster heads. A sensor node selects a random number r, between 0 and 1. If number is less than threshold value T(n), the node becomes a cluster head for the current round. The threshold value is calculated based on an equation which include the of the node's required percentage to become a cluster head, the current round, and the set of nodes which are not selected as a cluster heads in the last (1/p) rounds, denoted by G This is given by

$$T(n)=p/1-p(r \bmod(1/p)) \qquad \text{if } n \in G \qquad ....(2)$$

Where G is the set of nodes. Those nodes here are elected as cluster head which requires the least energy consumption for communicating within the cluster i.e. the nodes with largest node degree. After each set-up of cluster head a TDMA schedule is transmitted to the nodes so as to facilitate every node in the cluster to transmit data in the corresponding time slot. When clusters are being created each node decides whether it become a cluster head or not for the current round. This decision is based on required percentage of clusters for the network and number of times the node has become cluster head [7].

2) PEGASIS: Power-Efficient GAthering in Sensor Information Systems (or PEGASIS) is a data-gathering algorithm that establishes the concept that energy savings can result from nodes not directly forming clusters. The algorithm presents the idea that if nodes form a chain from source to sink, only 1 node in any given transmission time-frame will be transmitting to the base station. Data-fusion occurs at every node in the sensor network allowing for all relevant information to permeate across the network. In addition, the average transmission range required by a node to relay information can be much less than in LEACH, resulting in an energy improvement versus the hierarchial clustering approach[8].

3) CBRP: Clustering Based Routing Protocol is a LEACH based routing protocol designed for prolonging network lifetime. In this Scheme, cluster based routing protocol based upon the LEACH algorithm, residual energy of sensor nodes is considered to avoid unbalanced energy consumption of the sensor node and to extend the overall network lifetime without performance degradation [9]. To increase the lifetime of network, the proposed algorithm uses a probability function. Equation (3) shows computation of the threshold value for a cluster head selection [1].

$$T(n)=P_t\, E_{res.}/P_t(r \bmod 1)\_\ E_{max} \quad \text{if } n \in G \qquad .....(3)$$
$$\text{Otherwise } 0$$

Where,
Pt: the desired percentage of cluster heads,
r: current round number
G: the set of nodes that have not been cluster-heads in the last 1/ Pt rounds,
Eres: current residual energy of node Emax: maximum residual energy of entire network

B. New Clustering Based Routing Protocol

The proposed algorithm works in round. Each round has three phases:

1) Set-up phase,
2) Steady state phase
3) Pre-setup phase

The algorithm works as follows:

In the set-up phase: Each node generates a random probability (p) at the beginning of a new round and computes the threshold value (T(n)) with the use of equation (3). If r=1 (i.e. the first round), let $Emax$ of all nodes be 1. In case of P < Pt, the node is selected as a cluster head. A selected cluster head broadcasts an advertisement message over neighbor nodes. The neighbor nodes collect advertised message during a given time interval and then send a "join REQ" message to the nearest cluster head. The cluster head receives the "join-REQ" message and builds a cluster member list schedule. The member node receives and save the message for data transfer [1].
In the steady-state phase: After the cluster selection process completes, each member sends data and its residual energy information to the cluster head. Cluster head maintains the received information of member nodes [1].
In the pre-setup phase: Before the last frame of a round completes, the cluster head sends the maximum residual energy value of nodes, belonging to its own cluster, to the BS. BS collects all the values, finds maximum residual energy value ($Emax$) of the network, and sends $Emax$ back to cluster heads. The cluster head broadcasts $Emax$ over cluster nodes. Each node save the value of $Emax$ for the next computation of T (n) and the current round is terminated [1].

III. RELATED WORK

Analysis of clustering protocol for System Optimization in Heterogeneous Sensor Network: Optimization of Wireless sensor network, means to develop a system in that way so that its throughput and life time of the system will increased. For optimization of system various parameters are used i.e. energy efficiency, routing, data aggregation and load balancing. In this paper they focus on energy efficiency and load balancing in heterogeneous wireless sensor network. They analyze clustering protocol Low energy adaptive clustering hierarchy (LEACH) and Hybrid energy efficient distributed clustering (HEED) how they effectively work for system optimization.

Hierarchical cluster based routing protocol with high throughput for Wireless Sensor Networks: Hierarchical routing having cluster based topology is a very efficient approach for improving throughput. Wireless Sensor Networks (WSNs) are distributed networks consisting of various sensors deployed randomly in an area. Sensors operate on limited battery-power. The goal of WSN is to improve network lifetime and reliability with improved throughput. Limited energy resource is the main driving factor behind increasing the throughput. LEACH is one of the eminent hierarchical routing protocol in WSN. In this paper, an improvement of LEACH has been suggested. In our proposed algorithm, we adopt static clustering with dynamic selection of clusterheads within each cluster. It prevents random and concentrated selection of clusterheads. A negligible increase in energy leads to prominent improvement in the throughput. The protocol has been simulated in Castalia-3.2 and results show improvement in throughput when compared to LEACH and LCTS protocol.

A Survey of Clustering Algorithms for Wireless Sensor Networks: In this paper,they examine proposed clustering algorithms for Wireless Sensor Networks briefly discuss the operations of these algorithms, as well as comparisons on the performance between the various schemes. Specifically,performance in terms of the power and quality aspects of these schemes is examined. Also improvements to be made for future proposed clustering schemes are discussed. This paper should provide the reader with a basis for research in clustering schemes for Wireless Sensor Networks.

A Study of Power and Energy Efficient Clustering Protocols in Wireless Sensor Network: Clustering plays a vital role in any wireless sensor network (WSN). By adapting clustering in WSN the performance of the WSN can be improved. Performance is related to amount of power and energy consumed in any WSN. These two parameters are interlinked with the lifetime of the WSN. If a WSN consumes less power means, the energy stored in the sensor node (SN) has been maintained for longer time. Clusters create hierarchical WSN, which incorporate efficient utilization of limited resources of sensor nodes thus extends network life time. The energy that is stored in the battery of the SN decreases when more amount of power is consumed by the SN. So care has to be taken by considering these parameters while designing the WSN. In this paper, power and energy efficient clustering protocols are discussed.

IV. RESULTS

A. Simulation Parameters

Table 1 shows parameters we have used for implementing our algorithms.

TABLE 1
SIMULATION PARAMETERS

Parameters	Values
Area	100 m
Nodes	100
Trnsmission Energy	50*0.000000001
Reception Energy	50*0.000000001
Free Space Energy	10*0.000000000001
Multipath Loss	0.0013*0.000000000001
Data Aggregiation Energy	5*0.000000001

B. Simulation Results

1) Network Lifetime with LEACH: As dead nodes are the main reason for short lifespan of network, here we observe number of dead nodes with LEACH algorithm.

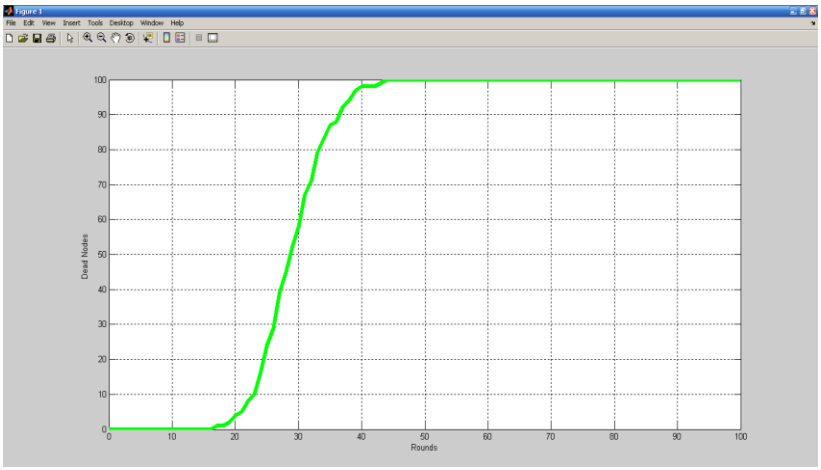

Fig. 2 Network performance with LEACH

Table 2
Network lifetime with LEACH

No. Of Rounds	No. Of dead nodes
10	0
20	5
30	58
40	98
50	100
60	100
70	100
80	100
90	100
100	100

2) Network Lifetime with PEGASIS: Here we observe network lifetime by assuming number of dead nodes with PEGASIS algorithm.

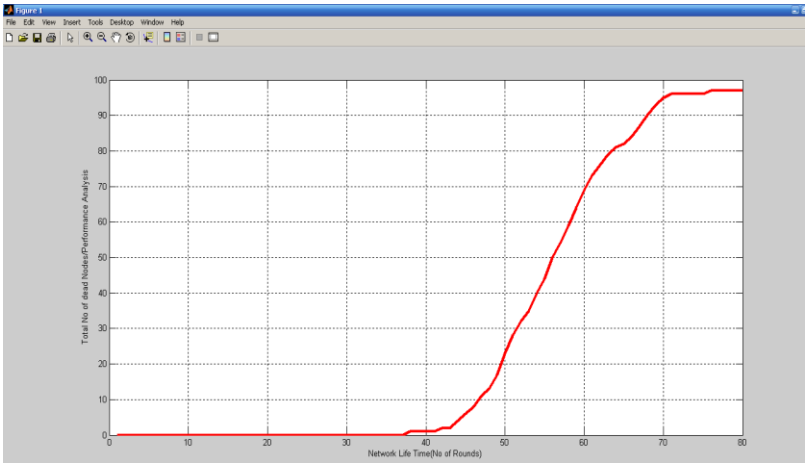

Fig. 3 Network performance with PEGASIS

Table 3
Network lifetime with PEGASIS

No. Of Rounds	No. Of dead nodes
10	0
20	0
30	0
40	2
50	22
60	70
70	95
80	98
90	100
100	100

3) Network Lifetime with CBRP:As network lifetime depends upon life of nodes, here we observe lifetime of network by assuming no of dead nodes with CBRP algorithm.

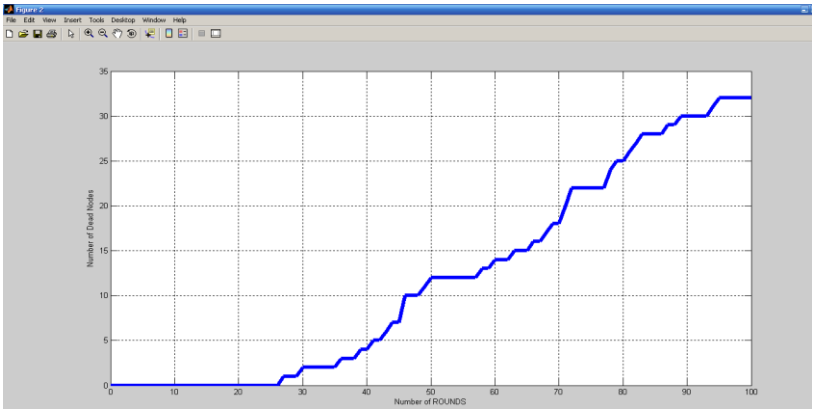

Fig. 4 Network performance with CBRP

Table 4
Network lifetime with CBRP

No. Of Rounds	No. Of dead nodes
10	0
20	0
30	1
40	4
50	12
60	14
70	18
80	25
90	30
100	32

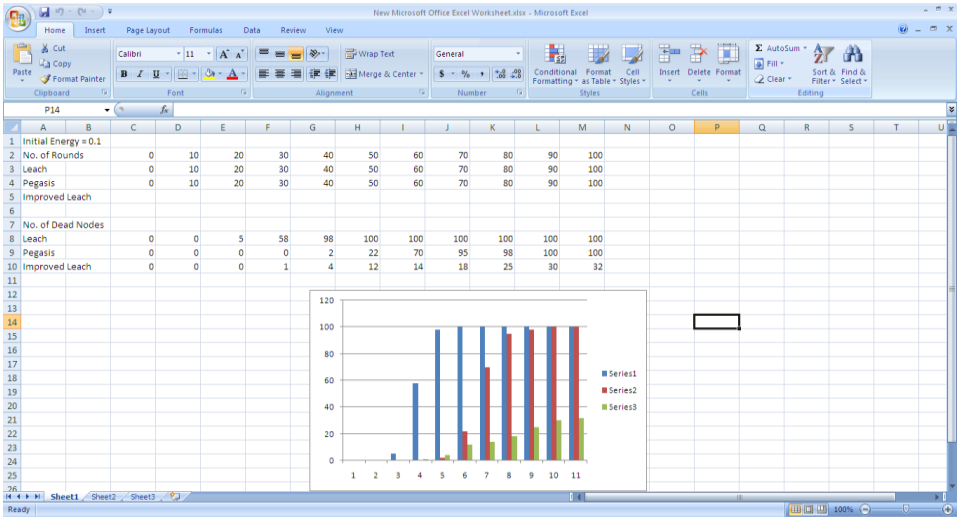

Fig. 5 Network Lifetime with LEACH, PEGASIS & CBRP

V. CONCLUSION

In this paper, we have implemented and observe results of Cluster Based Routing Protocol which considers residual energy of nodes to extend the overall network lifespan. We have compared the LEACH and PEGASIS algorithms with our proposed CBRP. We have considered various parameters such as transmission energy, reception energy and multipath loss. The resuts of simulations show that CBRP prolongs overall lifetime of system.

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