Network Architecture Design for Wireless Sensor Nodes

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Abstract: *Wireless Sensor Networks (WSNs) provide a new paradigm for sensing and disseminating information from various environments, with the potential to serve many and diverse applications. Current WSNs typically communicate directly with a centralized controller or satellite. On the other hand, a smart WSN consists of a number of sensors spread across a geographical area; each sensor has wireless communication capability and sufficient intelligence for signal processing and networking of the data. The key challenge in setting up and proper operation of WSN is to increase the life span of the network by optimizing the energy consumption. A sensor node is battery-operated. Thus; lifetime of a sensor node depends unequivocally on the battery life time, particularly where no power source recharging is conceivable in a few requisitions situations. Since the principle goals of sensor nodes are sensing/gathering events, information handling, and information transmission through routing; then the force asset might be separated among these three operations (sensing, computation, and communications).On the other hand; lifetime of a sensor node plays a key role on energy effectiveness and strength of sensor node. Therefore; numerous investigates are concentrating on planning power-aware protocols and calculations for WSNs with the objective of minimization of vitality use.*

Keywords: WSN, CH selection, leach

1. Introduction

The structures of WSNs are tightly application-dependent, and many services are also dependent on application semantics (e.g. application-specific data processing combined with data routing). Wireless sensor networks is an intelligent distributed sensor system providing a wide range of applications in both military as well as civilian domains connected via wireless links. Wireless Sensor Networks (WSN) has emerged as the first real application of the ubiquitous computing. Sensor networks bridge the gap between the physical and computational world by providing reliable, scalable, fault tolerant and accurate monitoring of the physical phenomenon. Wireless sensor networks support multichip communication i.e. each sensor node forwards its sensed information to a neighborhood node that is near to sink. This process increases the communication overhead on these nodes as a consequence these nodes will die quickly as compared to other nodes resulting in overall failure of the system. Clustering would be an enhancement over aforementioned technique. Clustering is the process in which highly dense WSNs are divided into several small groups of sensor nodes, one node among the cluster members acts as a leader called cluster head. These cluster head nodes are responsible for enhancing energy efficiency of system through a process called data aggregation. The primary goal of data aggregation methods is to eradicate superfluous data transmission and hence improving the lifespan of sensor networks. There are several issues associated with the procedure of clustering a WSN. First is, the number of clusters ought to be formed that may optimize performance of the system. Second might be how numerous nodes ought to be taken into a solitary cluster. Third essential issue may be the selection process of cluster-head inside a cluster [3]

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including figures and tables [1]. In addition, designate one author as the "corresponding author". This is the author to whom proofs of the paper will be sent. Proofs are sent to the corresponding author only [2].
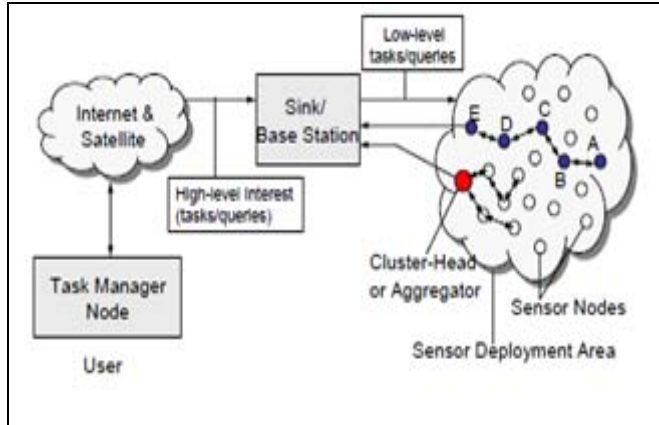
2. Wireless Sensor Networks

A WSN is a collection of millimeter-scale, self-contained, micro-electro-mechanical devices. These tiny devices have sensors, computational processing ability (i.e.CPU power), Wireless receiver and transmitter technology and a power supply. In a WSN a large number of sensor nodes usually span a physical geographic area. Typical WSNs communicate directly with a centralized controller or a satellite, thus communication between the sensor and controllers is based on a single hop. In future, a WSN could be a collection of autonomous nodes or terminals that communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralized manner by forming an ad hoc network. Such WSNs could change their topology dynamically when connectivity among the nodes varies with time due to node mobility. But current, real-world deployment usually consists of stationary sensor nodes. WSNs are intelligent compared with traditional sensors, and some WSNs are designed to use in-network processing, where sensed data can be gathered and transformed to more abstract and aggregated high-level data before transmission. The combination of processing power, storage and wireless communication also means that data can be assimilated and disseminated using smart algorithms. The vast number of sensor nodes planned for many applications also implies a major portion of these networks would have to acquire self organization capability. Intuitively, a denser infrastructure would create a more effective sensor network. It can provide higher accuracy and has more energy available for aggregation. If not properly handled, a denser network

can also lead to collisions during transmission, and network congestion. This will no doubt increase latency and reduce efficiency in terms of energy consumption. One distinguishing characteristic of WSNs is their lack of strong boundaries between sensing, communication and computation. Unlike the Internet, where data generation is mostly the province of end points, in sensor networks every node is both a router and a data source.

Figure 1: WSN Overview

3. Related Work

Wireless Sensor Networks are generally divided into a number of small groups called clusters based on explicit demands of the application. Each cluster has a leader node known as Cluster Head (CH) Node and a number of Member Nodes. Selection of cluster head is generally based on energy level of nodes. Several researchers had worked on energy efficiency problem in WSNs. The typical energy efficient cluster based routings protocols in WSNs include Low-energy Adaptive Clustering Hierarchy (LEACH) [4], Threshold sensitive Energy Efficient sensor Network protocol (TEEN) [5],], Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [6],The Adaptive Threshold sensitive Energy Efficient sensor Network protocol (APTEEN) [7],Hybrid Energy-Efficient Distributed clustering (HEED) [8],Algorithm for Cluster Establishment (ACE) [9],Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC) [10],LEACH (TL-LEACH) [11],Unequal Clustering Size (UCS) model [12],Energy Efficient Clustering Scheme (EECS) [13],Energy-Efficient Uneven Clustering (EEUC) algorithm [14] etc. Furthermore several energy efficient clustering architecture for heterogeneous wireless sensor network are also present in the literature including Distributed Energy Efficient Clustering (DEEC) [15], Developed DEEC [16], Stable election protocol (SEP) and Modified Stable Election Protocol(mSEP)[18] which are proven to provide energy efficiency.The aforementioned schemes uses random deployment of sensor nodes whereas performance of these schemes can be elevated through intelligent sensor nodes deployment and wise cluster head election strategies. In this context this paper proposes intelligent sensor node deployment and cluster head election protocol, in our proposed scheme we have divided sensor field to several regions and cluster formation as well as cluster head election

is done separately for respective regions. Rest of this paper is arranged as follows:

3.1 Network Model

Let us consider an of A meter squares where sensor nodes are randomly deployed to monitor environment. The ith sensor node is represented as S_i and so on. The network model considered is shown in figure below:

3.1.1 Network Assumptions
- Base station is deployed out of sensing field, both base station and sensor nodes are stationary after deployment.
- An additional node called as Network agent is deployed in the center of sensing field, it is assumed that network agent have unlimited resources.
- Each sensor node is associated with an ID and all sensor node considered to be homogeneous in resources.
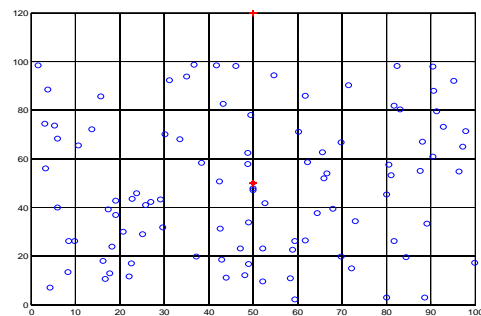
Figure 1: Network Model (Base Station (50,120), Network Agent (50, 50))

3.1.2 Network Energy Consumption Model
Consider the radio energy dissipation model as given in figure-2.
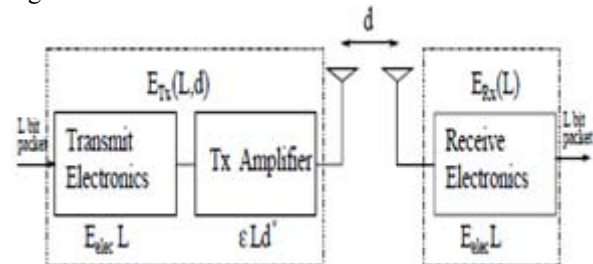
Figure 2: Radio Energy Dissipation Model

The energy spend by the radio to achieve satisfactory Signal-to-Noise Ratio while transmitting L-data bits over a distance D is given by-

$$E_{T_x}(l,d) = \begin{cases} L.E_{elect} + L.\epsilon_{fs}.d^2 & if\ d < d_0 \\ L.E_{elect} + L.\epsilon_{mp}.d^4 & if\ d \geq d_0 \end{cases} \quad (1)$$

Here E_{elect} is the energy dissipation per bit of transmitter or the receiver circuit, ϵ_{fs} and ϵ_{mp} depend on the transmitter amplifier model, and d is the distance between the transmitter and the receiver.Putting d=d_0 in equation-1 we get:

$$d_0 = \sqrt{\frac{\epsilon_{fs}}{\epsilon_{mp}}}$$

Hence the energy expended by the receiver to receive L-bit message is given by:

$$E_{R_x} = L.E_{elect}$$

Assuming the field area to be 100×100 square meters and 100 nodes are uniformly distributed over the field. For sake of simplicity assume that sink node is located at (50, 120) position and no node is situated farther than d_0 from sink node. Therefore the energy dissipation of clusterhead node during a round is given by:

$$E_{CH} = L.E_{elect}\left(\frac{100*}{k} - 1\right) + L.E_{DA}\frac{100*}{k} + L.E_{elect} + L.\epsilon_{fs}.d_{toBS}^2 \quad (2)$$

Here k is number of clusters, E_{DA} is data aggregation cost, d_{toBS} is distance between clusterhead and sink. Energy dissipation of a normal node (non-CH) is given by:

$$E_{nonCH} = L.E_{elect} + L.\epsilon_{fs}.d_{toCH}^2 \quad (3)$$

Where d_{toCH} is distance between normal node and its cluster head. From equations (2, 3) the energy dissipation of a cluster can be given as:

$$E_{cluster} \approx E_{CH} + \frac{100*}{k}E_{nonCH}$$

And total Energy dissipation of network is given by:

$$E_{T\_d} = L.\left(2nE_{elect} + nE_{DA} + \epsilon_{fs}\left(k.d_{toBS}^2 + n\frac{M^2}{2.\pi.k}\right)\right) \quad (4)$$

And also the optimal probability of a node to be elected as cluster head is given by:

$$p = \frac{k}{n} \quad (5)$$

4. Proposed Algorithm

This section presents our proposed our proposed agent based energy efficient clustering architecture. Consider sensor nodes always have data to send, to reduce communication overhead data fusion is done. In order to improve network performance, network agent is deployed in the field. Network agents are responsible for collecting data from base station, aggregating the data and to transmit the aggregated data to base station. In this way cluster head nodes are made free from data aggregation task and network performance can be improved.

A. Initial Phase
Let us consider that sensor field contains homogeneous sensor nodes that are distributed randomly over the area. Initially base station broadcasts HELLO messages, and network nodes forward their location in response to the message. The BS calculates the distance of each nodeand save all information of the sensor nodes into the node data table. The node data table consists of distinctive nodeID, residual energy of node, location of node and its distance to the BS and gateway node.

B. Setup Phase
In setup phase, network field is divide into four logical regions based on the location of sensor nodes. No design

region-one use direct communication and transmit their data directly to BS as the distance of these nodes from BSis very short. Similarly nodes near gateway form region-two and send their data directly to gateway which aggregates data and forward to BS. These two regions are referred to asnon-clustered regions. All the nodes away from the gateway node and BS are divided into two equal half regions. We call them clustered regions. Sensor nodes in each clustered region organize themselves into small groups known as clusters.

C. CH Selection
Initially BS divides the network into regions. CHs are elected in each region separately. Sensor nodes are elected to be cluster-heads in a particular round based on a probability function p and broadcast their status to all the sensor nodes belonging to network. Based on minimum energy requirement for transmission each sensor node decides to which cluster it desires to join. As cluster-head receives data from all cluster members it will perform data aggregation and forwards aggregated data to base station. In cluster creation process, based on a priori determined percentage each node is elected as cluster head in a particular round.

Each node n selects a random number between 0 and 1 and this number is then compared with threshold $T(n)$ and based on this decision of election of cluster head is done. Threshold value $T(n)$ is calculated for each round from the formula given in equation 1.

Table 1: Simulation Parameters

Network Operation	Energy Dissipation
Transmitter/Receiver	E_{elect}=50nJ/bit
Data Aggregation	E_{DA}=5nJ/bit/report
Transmit Amplifier if $d_{toBS} \leq d0$	ϵ_{fs}= 10pJ/bit/m2
Transmit Amplifier if $d_{toBS} \geq d0$	ϵ_{mp}=0.0013pJ/bit/m4

$$T(n) = \begin{cases} \frac{P}{1 - P*\left(r \bmod \frac{1}{P}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (6)$$

Here P being percentage of cluster heads r is present round and G is set of nodes that have not been elected as cluster head in last $\frac{1}{P}$ rounds. This threshold T is utilized to elect a node as cluster head within $\frac{1}{P}$ rounds. In the starting of rounds $(r = 0)$, every node has a probability of being cluster head, nodes elected as cluster head in current rounds cannot be elected as cluster heads for $\frac{1}{P}$ rounds.

D. Scheduling
When all the sensor nodes are structured into clusters, each CH creates TDMA based time slots for its member nodes. All the associated nodes transmit their sensed data to CH in its own scheduled time slot. Otherwise nodes switch to idle mode. Nodes turn on their transmitters at time of

transmission. Hence, energy dissipation of individual sensor node decreases.

Steady-State Phase
In steady state phase, all sensor nodes transmit their sensed data to CH. The CH collects data from member nodes, aggregates and forwards to gateway node. Gateway node receives data from CHs, aggregates and forwards to BS.

Experimental Setup
To evaluate the performance of our proposed clustering architecture, MATLAB based model has been developed and simulated with network parameters and sensor node parameters given in table-1 & 2 respectively.
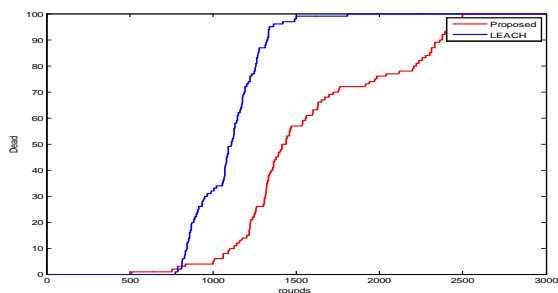
Table 2: Energy Dissipation of Wireless Sensor Networks

Field Dimension	100x100
Number of Nodes	100
Election Probability	0.1
Heterogeneity Percentage	0.1, 0.2
a	2, 3
Number of Rounds	30000

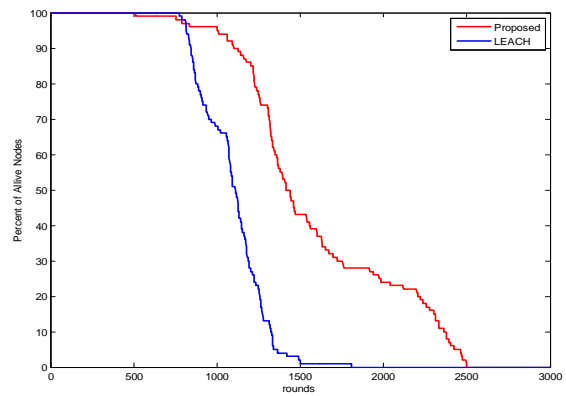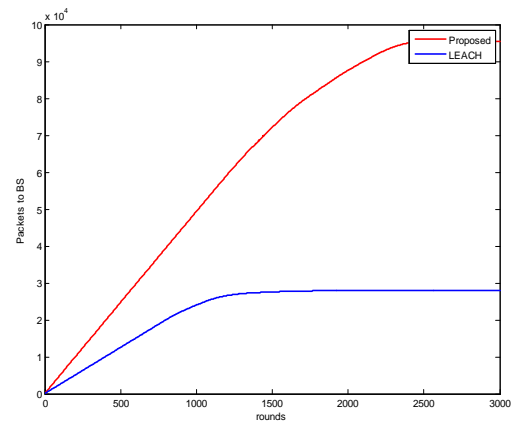# 5. Simulation Result
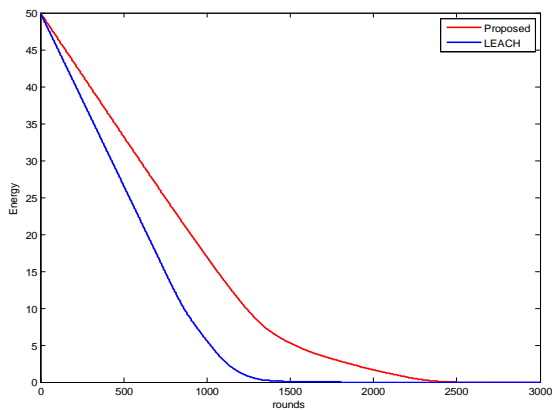
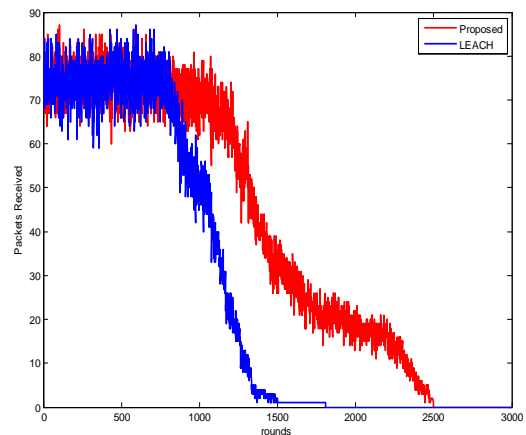**Figure 3:** Dead Nodes Comparison LEACH vs. Proposed

Figure 4: Alive Nodes Comparison LEACH vs. Proposed

Figure 5: Remaining Energy Comparison LEACH vs. Proposed

Figure 6: Packets to BS LEACH vs. Proposed

Figure 7: Packets Received LEACH vs. Proposed

6. Conclusion

Wireless Sensor has attracted considerable amount of interest in researchers for past few decades. The focus was to enhance the performance and lifetime and stability of the system. In this paper we propose an intelligent agent based clustering algorithm to enhance network lifetime and provide a stable clusterhead selection criteria. Simulation results show that proposed scheme provides batter network lifetime and throughput than conventional leach based algorithm for homogeneous wireless sensor networks.

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