A Novel Energy Aware Routing Protocol in WSN

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Abstract— Wireless sensor networks (WSNs) are energy and bandwidth constrained.
Therefore routing protocols have to be designed as to increase the network lifetime. Accordingly it has been realized that conventional protocols of direct transmission, multihop routing etc.may not are optimal for sensor networks. So we present a low energy adaptive clustering hierarchy (LEACH) a clustering based protocol which utilizes randomized rotation of cluster heads to evenly distribute the energy load among the sensors in the network. In this paper we simulate the LEACH protocol for a sensor field & verify energy savings achieved by LEACH.

Keywords-Cluster head, LEACH, Energy model, Radio Signal Strength Indicator (RSSI)

I. INTRODUCTION

WSN ha s a good application prospect in the field of military, disaster relief, medical health, intelligent home & ecological environment protection because of their(WSN) small volume low cost & strong ability to acquire information. These applications have made WSN to become the focus of research in wireless communication networks. Commonly a designer uses a routing protocol to transfer data so the performances of routing protocols are closely related to network performance.

Many routing protocols have been recently researched & they can be divided into two categories flat protocol & hierarchical protocols. Common flat protocols include i) Flooding ii) Gossiping iii) SPIN iv) DD(Directed Diffusion).Usually a flat routing protocol requires maintaining a larger routing table & taking larger memory space which limit its application in large scale network on the other hand hierarchical protocols can resolve these problems to a certain extend by selecting some head nodes which can manage& control their neighbor so as to coordinate their work (a head node & some member nodes under its control for a cluster. LEACH is a mature clustering algorithm from which many similar algorithms have been evolved such as TEEN & PEGASIS.

This paper is organized as follows: Section II discusses the related work followed by the principle & flow of the LEACH algorithm. In section IV the simulation framework is presented in detail. The results which highlights the power saving & hence increase in network lifetime are discussed in section IV.Finally we analyze the scope for future work.

II. RELATED WORK

The growing interest in WSN and the continued emergence of new architectural techniques have inspired efforts to design communication protocols which are energy aware and energy efficient. Sensor networks can be classified by considering several architectural factors such as network dynamics & data delivery model such classification is helpful for the designer to select the appropriate infrastructure for the application.

The design of data collection systems must satisfy the following: first an observer must be able to communicate with the network in order to retrieve data second once a query has been formulated by the observer it must be communicated to the network & send to the appropriate nodes. Finally once all the sensors nodes involved in the query have been reached the query must be executed in such a way that the observer retrieves the requested information.

The collection of data from the sensors to the base station requires in most cases the establishment of a routing structure. The radio range of sensors is limited& therefore the data from distinct sensors to the base station must be relayed by intermediate sensors. The transmission of data using multiple relay node is called as multihop routing. The other relevant routing concepts which are being researched are as under:

(a) Data Centric Paradigm:

At the conceptual level one of the fundamental differences between WSN & other networks is that the routing & querying techniques can be made more efficient if the communication is based directly on application specific data content instead of the traditional IP style addressing.(21) This focus on data content is referred to as data centric paradigm(28).whose main characteristic is the routing based on attributes.

(b) Energy Efficiency & Aggregation Services:

Energy consumption depends on the amount & type of activities performed by sensor nodes. In order to more precisely control energy consumption sensor nodes are usually designed so that their components can be powered on &off. The current consumption is lowest in the standby

mode so a simple solution to save energy & extend the lifetime of a sensor node is to operate the node with periodic switching between standby & active nodes.

(c) S-MAC Protocol.

The medium access decision within a dense network composed of nodes with low duty cycles is a hard problem that must be solved in an energy efficient manner. The S-MAC protocol achieves energy efficiency by reducing potential energy wastes.

III PRINCIPLE AND FLOW OF LEACH ALGORITHM

The application that the typical WSN's support is the monitoring of a remote environment since individual nodes data are often correlated in the network the end user does not require all the(redundant data) rather the end user needs a high level function of the data that describes the event occurring in the environment since the correlation is the strongest between data signals from nodes located close to each other a clustering infrastructure is suitable for this purpose & is the basis for Leach.

This allows all data from nodes within the cluster to be processed locally, reducing the data set that needs to be transmitted to the end user. In particular data aggregation techniques can be used to combine several correlated data signals into a smaller set of information that maintains the effective data of the original signal.

For the development of leach we made some assumptions about the sensor nodes & the underlined network model as under:

- We assume that all nodes can transmit enough power to reach the BS(base station) if needed.
- The nodes can use power control to vary the amount of power.
- Each node has the computational power to support different MAC protocols &performs signal processing function.
- For the network, we use a model were nodes always have data to send to the end user & nodes located close to each other have correlated data.

In LEACH the nodes organize themselves into local clusters with one node acting as the cluster head all non cluster head nodes transmit their data to the cluster head. While the cluster head nodes receives data from all the cluster members it performs signal processing functions on the data(e.g. data aggregation) & transmits data to the remote BS. Therefore being a cluster head node is much more energy intensive then being a non-cluster head node. If the cluster heads were chosen 'a priori' and fixed throughout the system lifetime these nodes would quickly use up their limited energy. Once the cluster head runs out of energy it is no longer operational & all the nodes that belong to the cluster loose communication ability. Thus, LEACH incorporates randomized rotation of the high energy cluster head position among the sensors to avoid draining the battery of any one sensor in the network. In this way the energy load o f being a cluster head is evenly distributed among the nodes.

The operation of LEACH is divided into rounds. Each round begins with a set-up phase when clusters are organized, followed by a steady state phase when data are transferred from the nodes to the cluster head & on to the BS shown in fig 1.

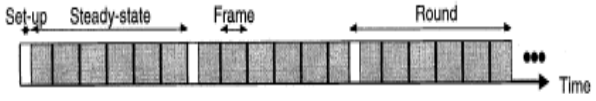

Fig. 1. Time line showing LEACH operation. Adaptive clusters are formed during the set-up phase and data transfers occur during the steady-state phase.

Next we describe the cluster head selection, distributed cluster formation algorithms & steady state operation of LEACH.

IV SIMULATION FRAMEWORK

As explained above the LEACH protocol is divided into two main phases: setup phase and steady phase. Each sensor node generates a random number between 0 and 1 and then compares it with a given threshold T(n). If the number is less than the latter then establish the node as a cluster head node. T(n) is calculated by the following formula:

$$T(n)=\begin{cases}\dfrac{P}{1-P*(r \bmod \frac{1}{P})} & \text{if } n \in G \\ 0 & \text{otherwize}\end{cases} \quad (1)$$

In the formula (1), P is the probability of a node becoming a head node, r is the current round number, and G is the set of nodes that did not become head nodes in this round.

To ensure that all nodes are cluster heads the same no. of times requires each node to be a cluster head once in N/k rounds on average. Where k is the number of clusters. If $C_i(t)$ is the indicator function determining whether or not node I as been a cluster head in the most recent round (r/mod N/k) rounds (i.e .$C_i(t)$ =0 if node i has been a cluster head and one otherwise) then each node should choose to become a cluster head at round r with probability:

$P_i(t) = \{k/N-k*(r \bmod N/k) \quad C_{i(t)}$
$=1\ 0 \quad C_{i(t)} =1$

Therefore only nodes that have not been cluster heads recently & which presumable have more energy available then nodes that have recently performed. This energy intensive function may become cluster heads at round r+1.

A node will broadcast to all its neighbors after it becomes a head node and all member nodes answer back to their determined head node according to the received signal strength. After the cluster is built up, the head node then

allocates the slots for each member's data transmission in TDMA mode. While in read phase, member nodes transfer the data gathered to their head node and each head node then forward the data to sink nodes after fusion. This is the steady phase which lasts for a certain time; network will enter the set up phase to rebuilt cluster, which is the next round of the network. So the perpetuating cycle. The flow graph of LEACH is given below.

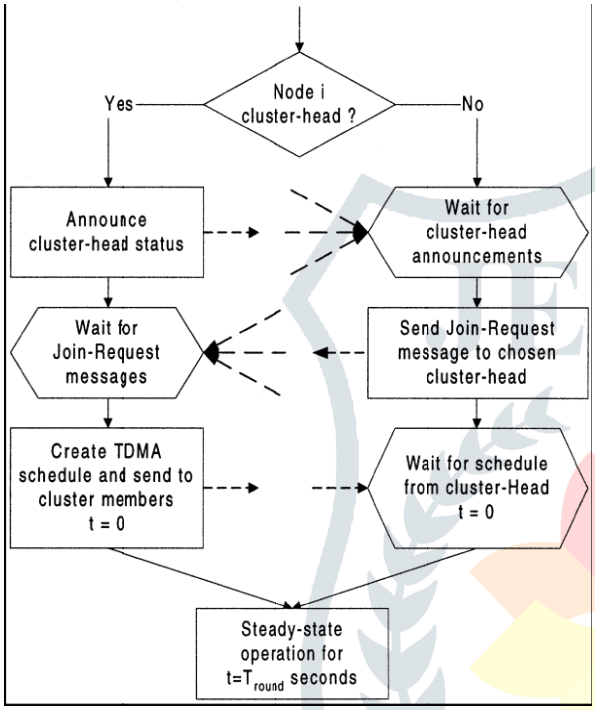

Fig. 2. Flowchart of the distributed cluster formation algorithm for LEACH.

A *Simulation process*

(i) General steps of NS-2.We will adopt Network Simulator (NS-2) developed by UC Berkeley to simulate the behavior of LEACH. NS-2 is a powerful network simulation tool which is developed with C++ and OTCL language. The whole simulation process consists of the following steps (1)

Preparation of the required components; (2) Test of components; (3) Preparation of Octl script file; (4) Execute the script file; (5) analyze the trace file.

(ii) Simulation Process LEACH. The simulation is of completed through the following stages:

(a) Platform and wireless energy consumption model.

We simulate the UNIX OS through the Ubuntu environment. We then construct the energy consumption model as follow:

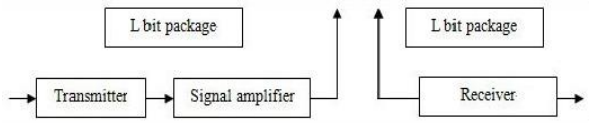

Fig.3 Wireless communication energy consumption model

In this model, energy consumed when transmitting l bits can be calculated as follow:

$$E_{Tx}(l,d)=\begin{cases} E_{elect}\times l+\varepsilon_{fs}\times l\times d^2, d<d_0 \\ E_{elect}\times l+\varepsilon_{amp}\times l\times d^4, d>d0 \end{cases} \quad (2)$$

In (2), $d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{amp}}}$, and energy consumed by receiving l bit can be calculate as $E_{Rx}=E_{elec}\times l$. All parameters required by the model are list in Table 1.

Table 1 Parameters for the model

Energy loss in	Value
Transmission energy E_{elec}	50nJ/bit
Power amplify energy loss in free space ε_{fs}	10pJ/(bit/m^2)
Multi-path fading loss in power amplifier ε_{amp}	0.0015pJ/(bit/m^4)
Threshold of transmission distance d_0	100m

If energy consumed in data fusion is $E_{DA}=5nJ/bit/signal$, energy consumed by member node in transmit l bit to the head node can be calculated as:

$$E_{non-CH}=l\times E_{elec}+l\times\varepsilon_{amp}\times d_{to-CH}^n,$$

And we can also calculate the energy consumed by the head node in transmitting data to the sink node:

$$E_{CH}=l\times E_{elec}\times(\frac{N}{K}-1)+l\times E_{DA}\times(\frac{N}{K})+l\times E_{elec}+l\times\varepsilon_{amp}\times d_{to-\sin k}^n$$

(b) Generation of scene file. There are two methods to get scene file for simulation. One is use the file 100nodes.txt directly which can be located in the directory "ns-2.27/mit/uAMPS/sims", the other is the execution of "ns genscen" after entering the directory "ns-2.27/mit/uAMPS/sims" to generate a file named new100nodes.txt. Both files contain100 nodes spread to the whole scene at random. We use the 100nodes.txt directly and the figure 4 shows the distribution of 100 nodes.

(c)Other parameters. Before starting simulation, we may the following assumptions:

1) 100 nodes are spread in a 100X100 space and the sink node is fixed at point (150, 80) and all nodes are static.

2) All nodes share a 1Mbps wireless chann l in their emission radius; all packets have a fixed length for 2000 bits. Both transfer delay and receive delay are 25μs.
3) Initial energy of each node is 5J.

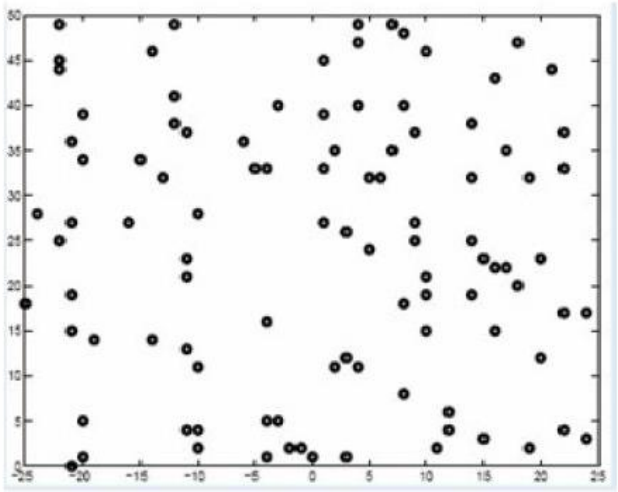

Fig. 4 100 nodes spread in the scene at random.

V. RESULTS AND ANALYSIS

For even moderately-sized networks with tens of nodes, it is extremely difficult to analytically model the interactions between all the nodes. Therefore, we used the network simulator ns to evaluate LEACH and compare it to other protocols.

A. Advantages of LEACH.

LEACH selects head node randomly in a circular fashion, makes the energy load are uniformly distribute to each sensor node, so as to reduce the network energy consumption and improve the overall survival time of the network. The result of simulation shows that compared to general flat multi-hop routing protocols and static hierarchal algorithms, LEACH can extend the lifetime of the whole network by 15%. We list the main contributions of the algorithm below:

1) Before the data is transmitted to the sink node, each cluster head node runs a data fusion algorithm to reduce the amount of the data to be transmitted, thus reduces energy consumption.
2) A MAC mechanism based on TDMA/CDMA is adopted to reduce collision.

3) The dynamic adaptive head node election strategy adopted by LEACH ensures that energy distribution is balanced.

B. Disadvantages.

Compared to most flat routing protocols LEACH has a good performance in increasing network lifetime. However it has some disadvantage in clustering, communication between clusters and data fusion:
1) The random selection of cluster head nodes raises some issues: some CHs may be too far from the BS causing more loss of energy; CHs may aggregate too many child-nodes leading to fast decline in energy.

2) One assumption of LEACH is that all nodes can communicate with its head node and the sink node. But when the distance between a head node and the sink node is very large, the head node will die rapidly and that cluster. So we can conclude that this algorithm is not applicable in large area monitoring.

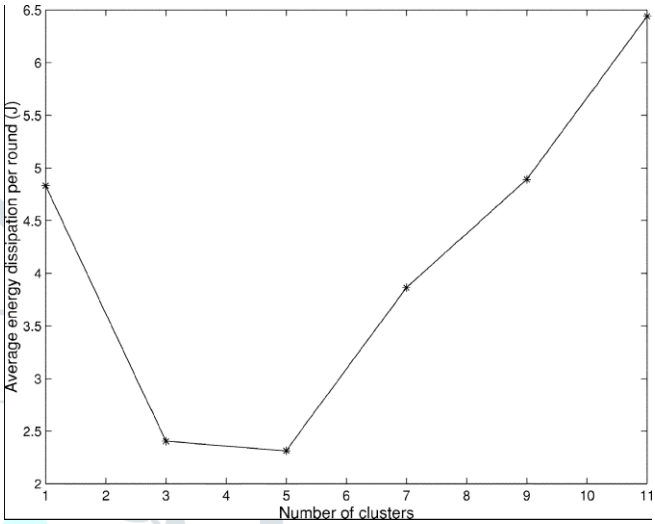

Fig. 5. Average energy dissipated per round in LEACH as the number of clusters is varied between 1 and 11. This graph shows that LEACH is most energy efficient when there are between 3 and 5 clusters in the 100-node network, as predicted by the analysis.

VI. CONCLUSION

When designing protocol architectures for wireless sensor networks, it is important to consider the function of the application, the need for ease of deployment, and the severe energy constraints of the nodes. These features led to the design LEACH, a protocol architecture where computation is performed locally to reduce the amount of transmitted data, network configuration and operation is done using local control, and media access control (MAC) and routing protoc ls enable low-energy networking. Results from our experiments show that LEACH provides the high performance needed under the tight constraints of the wireless channel.

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