Distance Energy Efficient Protocol for Wireless Sensor Network

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Abstract
The wireless sensors networks consume energy in both sensing the data & transmitting the sensed data. The wireless sensor networks have to monitor the data in the remote areas where the human existence is not possible so energy efficient protocols are required which can minimized the energy consumption & increase the lifetime of the network. In this paper we have discussed about the low energy adaptive clustering hierarchy (LEACH) protocol, NEAP protocol and DEEP protocol with the concept of distance factor b/w base station (sink) and nodes. Our result shows that the LEACH using the concept of residual energy and distance between the base station and nodes can improve the lifetime of the network.

Keywords
Wireless Sensor Network, LEACH, NEAP, DEEP

I. Introduction
Recent advances in wireless communication made it possible to develop Wireless Sensor Networks (WSN) consisting of small devices called micro-sensors, which collect information by cooperating with each other. These small sensing devices are called nodes. A sensor is any device that maps the physical quantity from the environment to a quantitative measurement. advance in the sensor technology, low-power analog and digital electronics and low-power Radio Frequency (RF) design have enabled the development of small, relatively inexpensive and Low power sensors, called micro sensors. Sensor nodes consist of a micro sensor module (e.g. acoustic, seismic, image sensor etc.) capable of sensing some quantity about the environment, CPU for data/ signal processing from sensors, memory for data storage, battery for energy, and transceiver for receiving and sending signals or data from one node to another. The size of each sensor node varies with applications. For example, in some military or surveillance applications it might be microscopically small. Its cost depends on its parameters like memory size, processing speed and battery [7]. The typical architecture of the sensor node is shown in Figure 1.

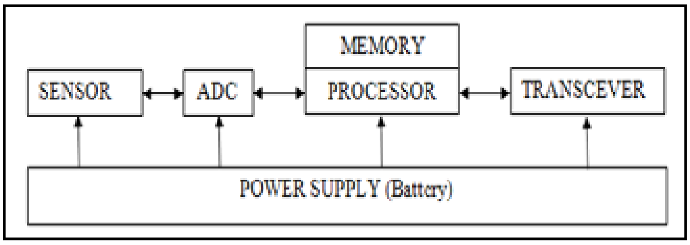

Fig. 1:

This paper build on the work described in [1] giving the detailed description of LEACH, an application-specific protocol for wireless sensor networks & also the work described in [3] giving the description of NEAP. In this paper we propose & evaluate the concept of residual energy with the distance factor b/w the sink and nodes.

II. Related Work
Routing in wireless sensor networks is different than routing in other networks due to the nature and objectives of the sensor networks. The most important characteristic in a routing protocol for a sensor network are energy-efficiency and awareness. Multi-hopping is widely used in There are three types of routing protocols for wireless sensor networks; flat-based, hierarchical and location based. Most of the protocols for wireless sensor networks are not fault tolerant such as HEED [5], PEGASIS [4], SPIN [6] & LEACH [1]. LEACH is a self-organizing, adaptive clustering protocol that uses randomization to distribute the energy load evenly among the sensors in the network [7].

A. Low-Energy Adaptive Clustering Hierarchy (LEACH)
In LEACH, the nodes organize themselves into local clusters, with one node acting as the local base station or cluster-head. LEACH includes randomized rotation of the high-energy cluster-head position such that it rotates among the various sensors in order to not drain the battery of a single sensor. In addition, LEACH performs local data fusion to "compress" the amount of data being sent from the clusters to the base station, further reducing energy dissipation and enhancing system lifetime [1].

1. LEACH Algorithm Details
The operation of LEACH is broken up into rounds [7], where each round begins with a set-up phase, when the clusters are organized, followed by a steady-state phase, when data transfers to the base station occur. In order to minimize overhead, the steady-state phase is long compared to the set-up phase.
Advertisement phase : Initially, when clusters are being created, each node decides whether or not to become a cluster-head for the current round. This decision is based on the suggested percentage of cluster heads for the network (determined a priori) and the number of times the node has been a cluster-head so far. This decision is made by the node n choosing a random number between 0 and 1. If the number is less than a threshold T (n), the node becomes a cluster-head for the current round. The threshold [21] is set as:

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

Where P = the desired percentage of cluster heads, r = the current round, and G is the set of nodes that have not been cluster-heads in the last 1/ P rounds. Using this threshold, each node will be a cluster-head at some point within 1/ P rounds. The nodes that are cluster-heads in round 0 cannot be cluster heads for the next 1/ P rounds. Each node that has elected itself a cluster-head for the current round broadcasts an advertisement message to the rest of the nodes. The non-cluster-head nodes must keep receivers on during this phase of set-up to hear the advertisements of all the cluster-head nodes. After this phase is complete, each non-cluster-head node decides the cluster which it will belong for this round. This decision is based the received signal strength of the advertisement.

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(i). Cluster Set-up Phase

After each node has decided to which cluster it belongs, it must inform the cluster head node that it will be a member of the cluster. Each node transmits a join-request message back to the chosen cluster head using a non-persistent CSMA MAC protocol. The cluster head node sets up a TDMA schedule and transmits this schedule to the nodes in the cluster.

(ii). Steady State Phase

The steady-state operation is broken into frames, where nodes send their data to the cluster head at most once per frame during their allocated transmission slot [1]. The duration of each slot in which a node transmits data is constant, so the time to send a frame of data depends on the number of nodes in the cluster. The cluster head must be awake to receive all the data from the nodes in the cluster. Once the cluster head receives all the data, it performs data aggregation to enhance the common signal and reduce the uncorrelated noise among the signals.

B. NEAP Protocol

In LEACH [1, 7], probability of becoming a cluster-head is based on the assumption that all nodes start with an equal amount of energy, and that all nodes have data to send during each frame. If nodes begin with different amounts of energy, the nodes with more energy should be cluster-heads more often than the nodes with less energy, in order to ensure that all nodes die at approximately the same time. This can be achieved by setting the probability of becoming a cluster-head as a function of a node's energy level relative to the aggregate energy of the cluster in the network [2], rather than purely as a function of the number of times the node has been cluster-head:

Probability of becoming cluster head= Energy of node/ Energy of cluster

Deterministic cluster head selection introduces the heterogeneity to LEACH in terms of residual energy [3]. It considers the residual energies of the sensor nodes in order to manage rational power consumption throughout the network. It follows the underlying mechanism of LEACH exactly. It has changed the equation of the threshold value only to incorporate the residual energy in cluster head selection process [8] as follows:

$$T(n)_{new} = \frac{p}{1-p(r \bmod \frac{1}{p})}\frac{E_{current}}{E_{\max}}$$

where, E current is the current energy, E max the initial energy of the node. After a significant amount of time of operation, the residual energies of the sensors would become very low and then this threshold value will be very low. This can result in a situation where all the live sensors are one member cluster head. In this case the energy consumption rate will be very high. To break this stuck condition another modified equation of the threshold value [8] given by:

$$T(n)_{new} = \frac{p}{1-p(r \bmod \frac{1}{p})}\left[\frac{E_{current}}{E_{\max}} + (r_s div \frac{1}{p})\left(1-\frac{E_{current}}{E_{\max}}\right)\right]$$

Where p = the desired percentage of cluster heads (i.e. 5% as suggested by LEACH), r = the current round, and G is the set of nodes that have not been cluster-heads in the last 1/p rounds, r_s = number of consecutive rounds in which a node has not been cluster head.

So in the round zero each node's probability to become cluster-head can be re-written as:

T (n) = p; since for r = 0, r mod 1/p=0

But during other than first round the cluster-head is selected based on the residual energy left in node. Actually during Data Transmission phase of each round every member sends data along with information regarding its residual energy to their cluster-head and based on the information the cluster-head decides which node will become the future cluster head. This is done by calculating the probability of becoming cluster head as a function of node energy divided by total energy of the cluster.

$T(n) =$ Energy of node/Total energy of the cluster

The above calculated probability is conveyed by each cluster-head to their cluster members after completion of Data Transmission phase. So that when the next round will start each node can decide whether they can become the cluster-head by comparing their T(n) with selected random number(0 to 1). if T(n) < random number(0 to 1) then the node becomes cluster head for this round else not.

III Distance Energy Efficient Protocol

The randomization of electing cluster-head nodes can distribute the load among the network; it suffers from the following drawbacks-

- It assumes that the energy of all the nodes is same and remains so with time.
- The election of cluster-head nodes ignores the residual energy information about the nodes and this will easily result in the cluster head nodes disable.
- It ignores the distance factor between the nodes and the base station

Since LEACH has many drawbacks, many researchers have tried to make this protocol performs better by improving cluster head selection algorithm by several parameters.

LEACH's stochastic cluster head selection algorithm is extended by adjusting the threshold T(n) , NEAP [3] Protocol, as follows:

$$T(n) = \frac{p}{1-p(r \bmod \frac{1}{p})}\frac{E_{current}}{E_{\max}}$$

Where $E_{current}$ is the remaining energy of the sensor nodes and E_{max} is the initial energy of the node before transmission.

As an improvement in LEACH's algorithm and NEAP algorithm, the threshold value of the node can be extended by adjusting the threshold T(n) by considering residual energy of the nodes, distance between the nodes and the base station and the number of consecutive rounds in which a node has not been a cluster head as parameters as follows:

$$T(n)_{new} = \frac{p}{1-p(r \bmod \frac{1}{p})}\frac{E_{current}}{E_{\max}}\frac{D_{avg}}{D_{\text{sink}}}$$

Where D_{avg} is the average distance of the farthest node from all other nodes, and D_{sink} is the distance from node i to base station.

After a significant amount of time of operation, the residual energies of the sensors would become very low and then this threshold value will be very low. This can result in a situation where all the live sensors are one member cluster head. In this case the energy consumption rate will be very high. To break this stuck condition another modified equation of the threshold value is given by:

$$T(n)_{new} = \frac{p}{1-p(r \bmod \frac{1}{p})} \frac{D_{avg}}{D_{sink}} \left[\frac{E_{current}}{E_{max}} + (r_s div \frac{1}{p})\left(1 - \frac{E_{current}}{E_{max}}\right) \right]$$

Where p = the desired percentage of cluster heads, r = the current round, and G is the set of nodes that have not been cluster-heads in the last 1/p rounds, r_s = number of consecutive rounds in which a node has not been cluster head.

VI Stimulation Results

In this work, a simple model shown in fig. 3. [8] is used where the transmitter dissipates energy to run the radio electronics and the power amplifier and the receiver dissipates energy to run the radio electronics. The power attenuation is dependent on the distance between the transmitter and receiver. For relatively short distances, the propagation loss can be modeled as inversely proportional to d2, whereas for longer distances, the propagation loss can be modeled as inversely proportional to d4. Power control can be used to invert this loss by setting the power amplifier to ensure a certain power at the receiver. Thus, to transmit a k-bit message a distance d, the radio expends:

$$E_{Tx}(k,d) = E_{Tx\_elec}(k) + E_{Tx\_amp}(k,d)$$

$$E_{Tx}(k,d) = \begin{cases} kE_{elec} + \varepsilon_{friss\_amp}\, d^2 : d < d_0 \\ kE_{elec} + k\,\varepsilon_{two\_ray\_amp}\, d^4 : d < d_0 \end{cases}$$

And to receive this message, the radio expends:
$E_{Rx}(k) = k\,E_{Rx\_elec}$
as shown in fig.

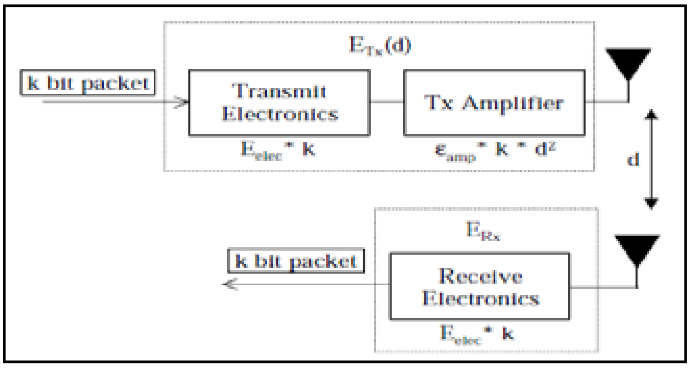

Fig. 2: First Order Radio Energy Dissipation Model

The electronics energy, E_{elec} depends on factors such as the digital coding, modulation, and filtering of the signal before it is sent to the transmit amplifier. In this thesis, the energy dissipated per bit in the transceiver electronics to be set as: E_{elec} = 50 nJ / bit for a 1Mbps transceiver [7]. This means the radio electronics dissipates 50mW when in operation (either transmit or receiver). The parameters ε_{friss_amp} and $\varepsilon_{two\_ray\_amp}$ will depend on the required receiver sensitivity and the receiver noise figure, as the transmit power needs to be adjusted so that the power at the receiver is above a certain threshold. These are the radio energy parameters [8] that will be used for the simulations.

ε_{friss_amp} =10 pj/bit/m^2

$\varepsilon_{two\_ray\_amp}$ =0.0013 pJ / bit/ m^4

Table 1: Radio Energy Parameters

Parameters	Values
No. of nodes	100
Network size	100*100
Initial energy of nodes	1 joule
Data packet	6400

Comparison of DEEP and LEACH protocol

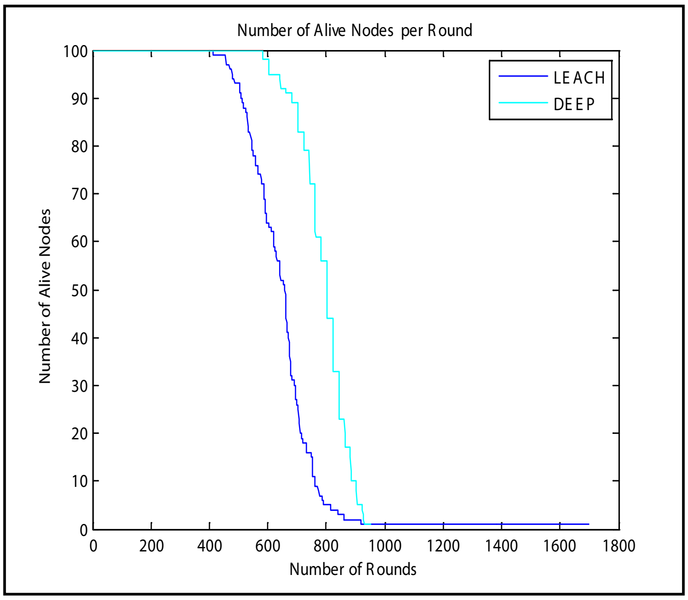

Fig. 3: Nodes Alive with the Energy 0.5 J

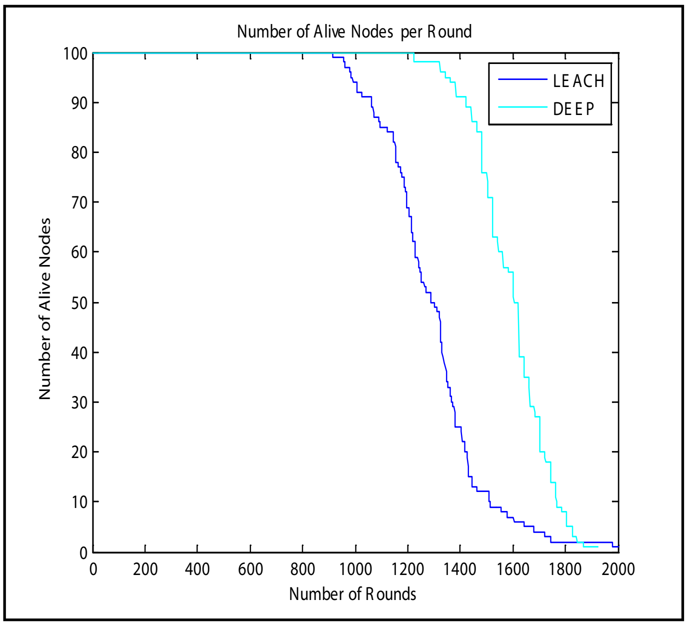

Fig. 4: Nodes Alive with the Energy 1 J

Regarding the network life time, there are following regulations are considered. When a node's energy is less than 0, we say that node is dead. When surviving nodes with in network are less than 10, i.e. 90 nodes are dead; we consider that network is out of work. In this paper matrix approach is used to define the network life time. FND- first node dies, this matrix define the time during which first node of the network is dead. HNA- half nodes alive, this matrix define the time during which half of the nodes of network alive and half are dead. LND- last node dies, this matrix defines the time during which last node of the network is dead.

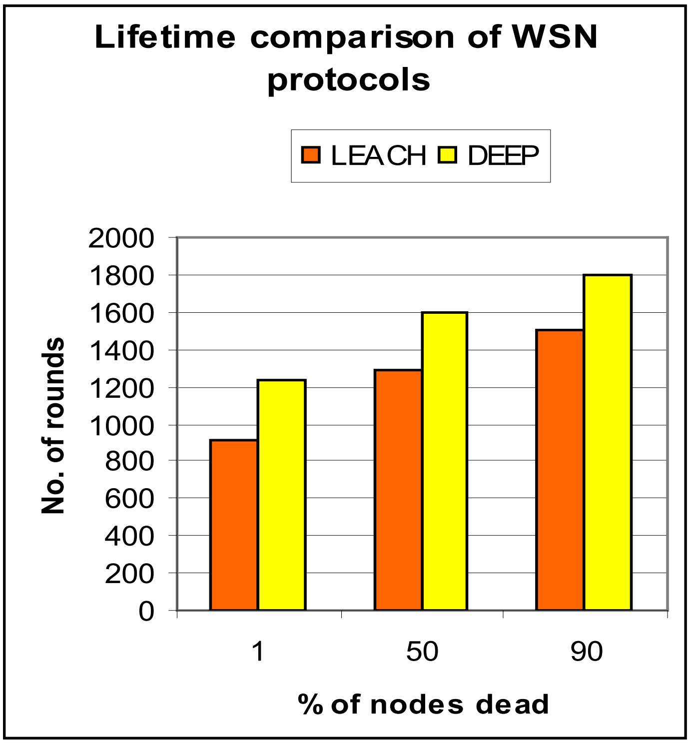

Fig. 5: Lifetime Comparison of WSN Protocols

VI. Conclusion

In wireless sensor networks the energy conservation is the main concern as the simulation result for the lifetime comparison of various routing protocols shows that DEEP achieves: Increase in network life time by 20% than LEACH protocol. So DEEP Protocol is energy efficient protocol which increases network life time so names as Distance Energy Efficient Protocol for Wireless sensor networks which provides the near optimal performance as required.

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