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An Energy Efficiency Routing Algorithm for increasing area and frequency of Wireless Sensor Networks

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Abstract— The key challenge in wireless sensor network protocol design is to provide energy efficient communication, as most of the nodes in sensor networks have limited battery power and it is not feasible to recharge or replace the batteries. There are so many levels of power consumption in sensor networks like as: idle listening, retransmissions resulting from collisions, control packet overhead, unnecessarily high transmitting power and sub-optimal utilization of the available resources. By definition, sensor nodes are deployed in an ad hoc fashion, with individual nodes remaining largely inactive for long periods of time. In order to minimize power consumed during idle listening, some nodes, which can be considered redundant, can be put to sleep. Therefore, the energy of the nodes and the network needs to be conserved. The idea is sensor nodes dynamically create on-off schedules such that the nodes will be awake only when they are needed. This also limits the collisions; therefore, the energy consumed during retransmissions can be saved. Although, it seems best way to limit consumed energy and the main consideration should be energy efficiency, the other Quality of Service (QoS) issues have to be considered. The key design considerations for duty cycle control protocol design are scheduling and routing. The research through this paper will be focused on routing protocol for modern high speed integrated wireless sensor networks.

Keywords— Wireless sensor network, Routing protocol, energy efficient, network Lifetime.

1. Introduction

Over the recent years, the continued advances in micro-sensor technology have resulted in the development of small, low cost and low power sensing devices with computational "sensing" and communication capabilities. These advances make economically possible the deployment of large numbers of nodes to form a wireless sensor network (WSN) that can monitor a one or more parameters. Because of these advancements, modern WSNs offer significant advantages, such as these are easier, faster and cheaper to deploy than wired networks; and have a large coverage area and longer range. Another feature of these networks is that these are mostly unattended to, and can be self-configuring or self-organizing. In terms of construction, a typical wireless sensor network may comprise of hundreds or thousands of nodes that can be densely deployed in a large geographical area. These sensors measure ambient conditions/desired parameters in the environment surrounding them and then transform these data into electric signals which can be processed to reveal some characteristics about phenomena located in the area around these sensors [1].Therefore, one can get the information about the area which is far away from them.

Wireless sensor networks is build up of products integrating sensors, embedded techniques and distributed information processing, and communication techniques. An example of wireless sensor network is shown in Figure 1 and the functional component of a typical wireless sensor of WSN is given in Figure 2

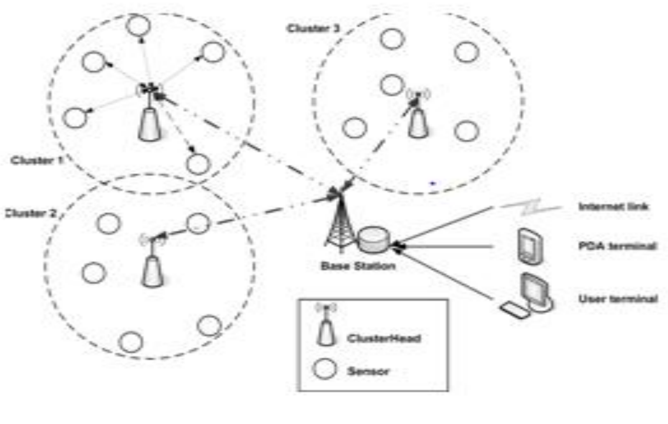


Figure 1: wireless sensor network architecture [1].

As shown in Figure 2, in a typical wireless sensor system, the transducer unit senses and gives the electrical analog signal, A/D convertor converts the sensed analog signal to digital signal, control unit receives digital input from the sensing unit and perform protocol operation, the radio unit transmits the packet over wireless link and the battery is the power source of the entire device [1]. The control unit can function at micro-watts, while the radio transmissions typically require energy in milli-watts to even watts depending upon the transmission power.

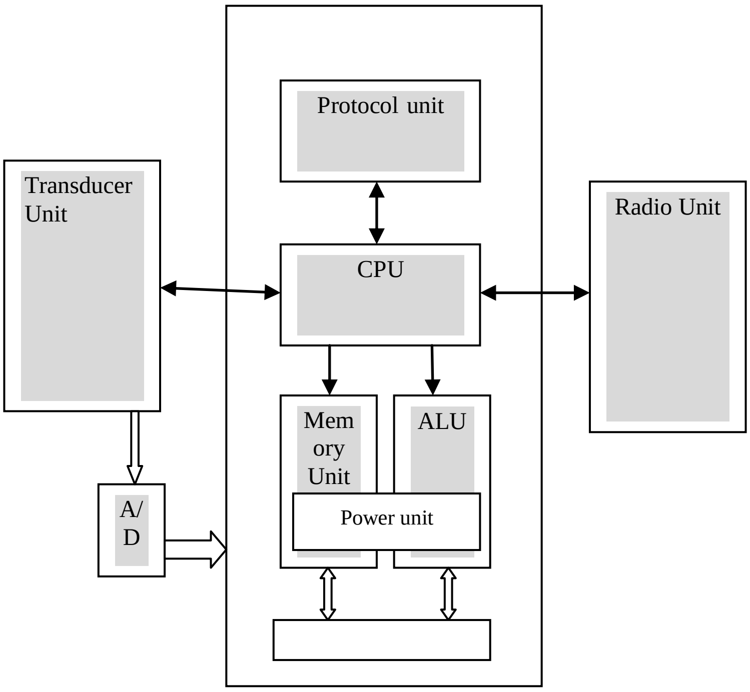


Figure 2: Functional components of a typical WSN.

2. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY PROTOCOL (LEACH)

Low Energy Adaptive Clustering Hierarchy (LEACH) is a TDMA-based MAC protocol which is integrated with clustering and a simple routing protocol in wireless sensor networks [11]. LEACH is a distributed clustering protocol which utilizes randomized rotation of local CHs to evenly distribute energy utilization between the nodes of WSNs. The goal of LEACH is to provide data aggregation for sensor networks while providing energy efficient communication that does not predictably deplete some nodes more than others.

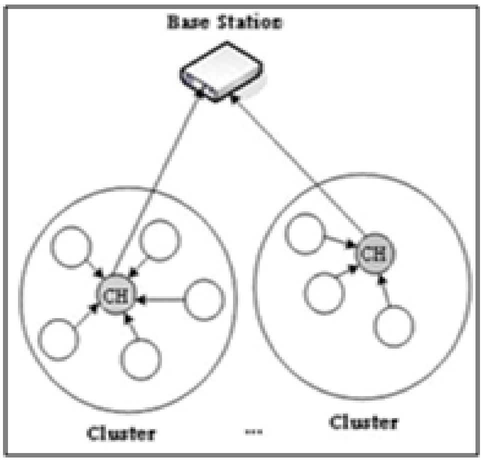


Figure 3: LEACH protocol [12].

According to the Figure 3, the LEACH is a hierarchical protocol in which most nodes transmit to cluster heads, and the cluster heads aggregate and compress the data and forward it to the base station. Each node uses a stochastic algorithm at each round to determine whether it will become a cluster head in this round. LEACH assumes that each node has a radio powerful enough to directly reach the base station or the nearest cluster head, but that using this radio at full power all the time would waste energy [11, 12].The principle of LEACH protocols is shown in Figure 4.

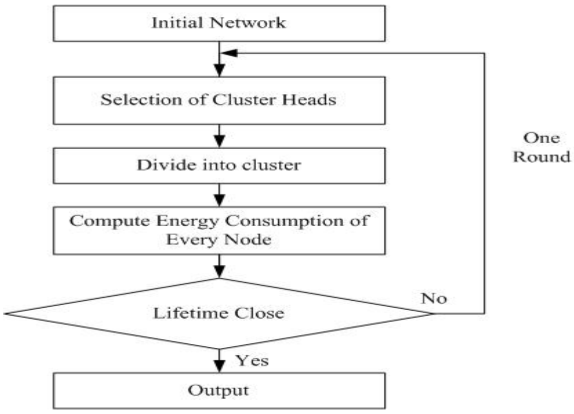


Figure 4: Flowchart of LEACH protocol [11]

The whole operation of the LEACH protocol is divided into rounds. Each round consists of:

a) Set-up phase in which cluster head selection and formation is done.

b) Steady state phase for data transmission.

A sensor node chooses a random number, r between 0 and 1. If this random number is less than a threshold value T(n), the node becomes a cluster head for the current round. This threshold value is calculated using:

$$T(n) = \begin{cases} \frac{p}{(1 - p(r \bmod (1/p)))}, & if\ n \in G \\ 0, & otherwise \end{cases} \quad \text{.............} \quad (1.1)$$

Where,

p = predetermined fraction of nodes that elect themselves as CHs.

G = the set of nodes that have not been selected as a cluster-head in the last (1/p) rounds.

r = number of current round.

3. WIRELESS SENSOR NETWORKS ROUTING PROTOCOLS

Routing technique determine the specific choice of route. Most routing technique for WSN depends on location information of sensor nodes for estimation of distance between two specific nodes to deduce energy consumption. For example, to sense a known region, through the use of location sensor, a specified query can be sent to that known region and this will significantly reduce transmitted data compare to a broadcast request being sent to the entire network sensor protocol for information via negotiation [13, 14].

- **HIERARCHICAL PROTOCOLS:** Hierarchical protocols have been proposed in order to meet the energy efficiency and scalability requirement of the WSNs. The main issue is forming sub network clusters, encouraging multi hop transmission and enabling data fusion [16].

4. PROPOSED PROTOCOL

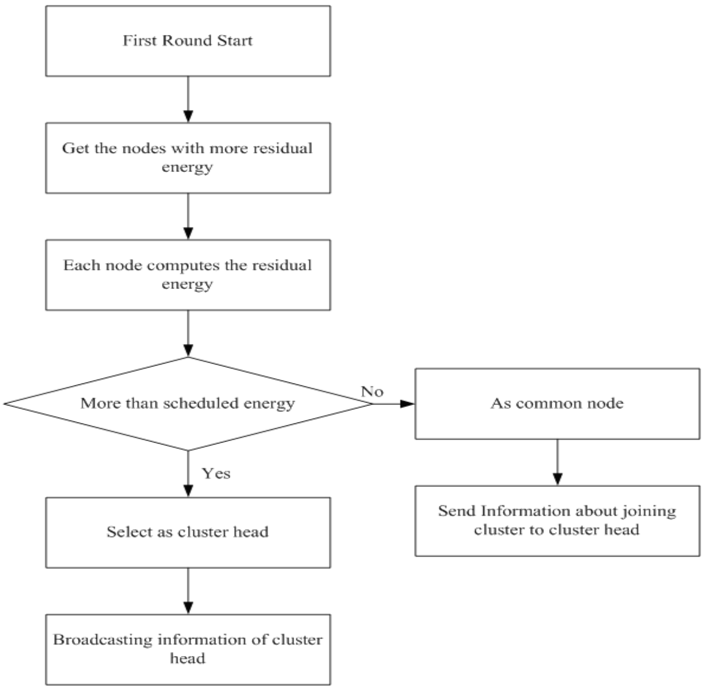


Figure 5: Flow chart of energy modified LEACH proposed protocol [11].

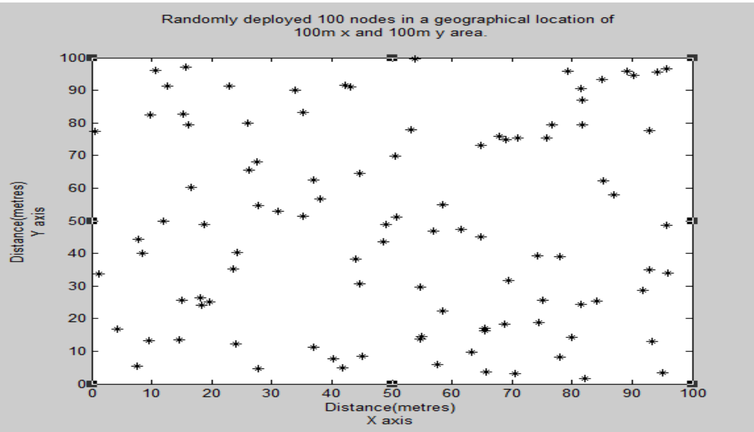
5. SIMULATION & RESULTS

The key parameters taken are mentioned in Table 1.The key parameters to evaluate the efficiency of these algorithms are: time (in terms of rounds) till the nodes are alive; time (number of rounds) when all the nodes are dead, number of cluster heads, packets sent during the lifetime and the overall network lifetime.

Table 1:Initial parameters of implementing the LEACH protocol.

Parameter	Value
Area	100m x 100m y
No of Nodes	100/200/300/400/500
Rounds	1000/2000/3000/4000/5000
Energy required in sending or receiving 1bit: Elect	50nJ/bit
The amount of data sent by nodes each time: k	200bit.
The initial energy of every node: E	0.5J
Energy consumed in every bit data fusion: EDA	50pJ/bit

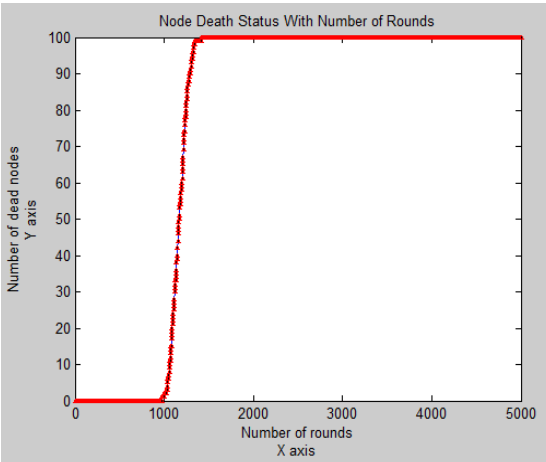
In the simulation model, the nodes are randomly deployed within a space region, as shown in Figure 6. It is to be noted that the distance on X and Y coordinates in Figure 6 is in meters, and the number of nodes and area size can be changed and these values are taken randomly for illustration purposes only. The developed Matlab based algorithm is also checked for other values of number of nodes and area size.



* Base station

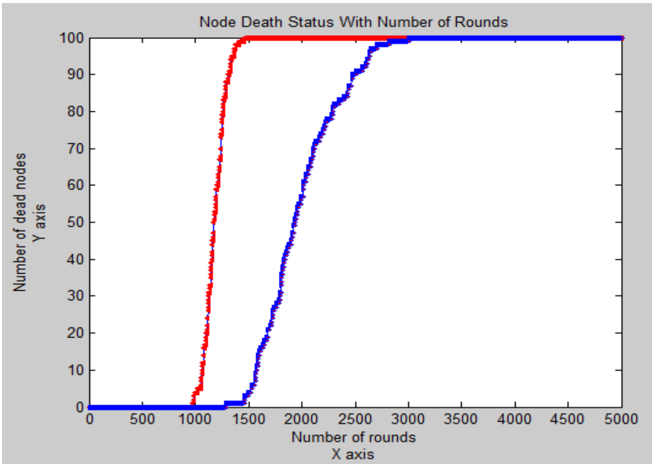
Figure 6: An example of randomly deployed 100 nodes in a geographical location of 100m x and 100m y area.

- DEAD NODES: *



---------- LEACH

Figure 7: Showing the number of dead nodes vs number of rounds in a network with 100 nodes, 100m x and 100m y area. using the LEACH protocol.



--------- LEACH
--------- PROPOSE MODEL

Figure 8: Showing the number of dead nodes vs number of rounds in a network with 100 nodes, 100m x and 100m y area.

All nodes are alive till the 1000th round approx. After the 1000th rounds, the nodes started dying very quickly in the cluster and all the nodes died at approximately 1500th rounds. After the 1500th rounds, there is no data transfer because all the nodes are dead.

- ALIVE NODES:

Comparison between LEACH and modified LEACH protocol (Propose model).

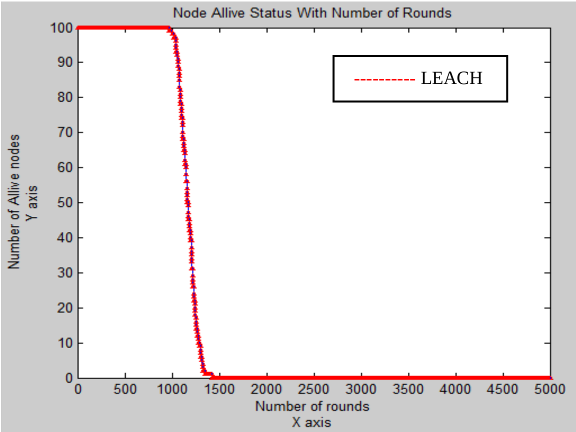


Figure 9: Showing the number of alive nodes vs. number of rounds in a network using the LEACH protocol. The number of nodes is 100

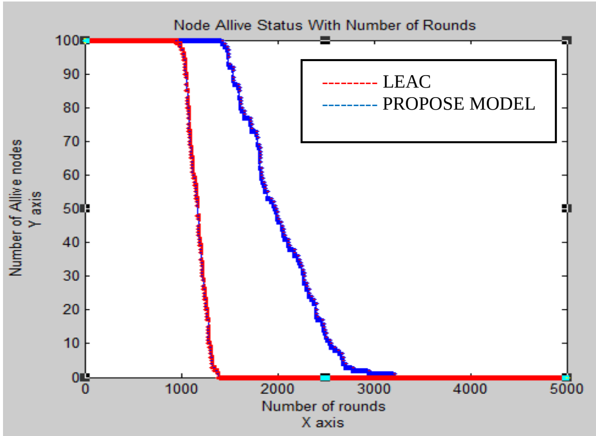


Figure 10: Showing the number of alive nodes vs Number of rounds in a network with 100 nodes, 100m x and 100m y area.

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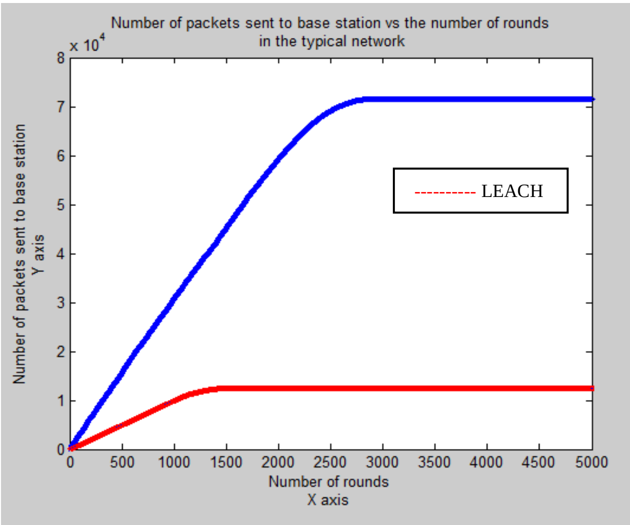

Figure 11: Accumulated number of packets sent to base station vs the number of rounds in the typical network with 100 nodes, 100m x and 100m y area.

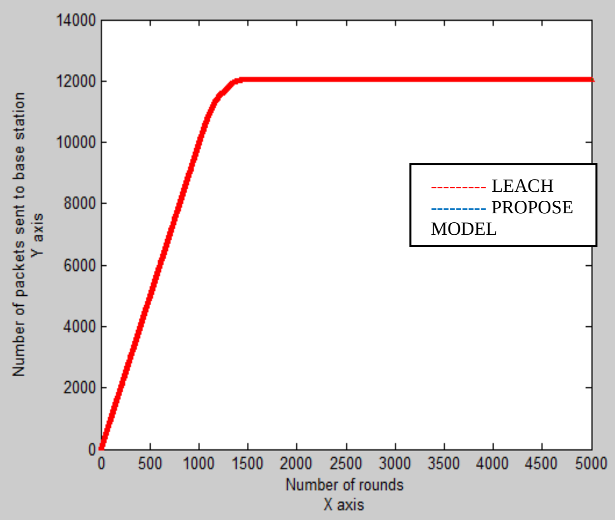

Figure 12: Accumulated number of packets sent to base station vs the number of rounds in the typical network with 100 nodes, 100m x and 100m y area.

From Figures 7 & 8, the nodes started dying approximately around 1500 rounds; whereas the entire network dies (when all the nodes are dead) at around 3100 rounds approximately. This is considerably higher than the corresponding value of 1000th round mentioned for LEACH protocol. Therefore, the modified LEACH protocol is better than the LEACH protocol. The results for the accumulative number of packets transmitted to base station and the number of selected cluster heads during the lifetime of network is shown in Figures 11 & 12. From Figures 11 & 12, the number of packets sent till network breakdown is approximately 70,000; which is much higher than the corresponding value of approximately 12,000 for the LEACH protocol.

6. CONCLUSIONS

Over the last decade, wireless sensor networks have become very popular. This is because of their low cost, less power requirement, performance and high potential application areas. Although a significant work has been done in relation with wireless sensor networks; yet, there are many challenges in WSN to be addressed. For example, increasing the lifetime of wireless sensor networks is a critical issue because of the limited energy resources. Therefore, this paper focuses on developing an algorithm for increasing the lifetime of the wireless sensor network. More specifically, it focuses on LEACH protocol as its basis. It is because, the cluster head generation algorithm with the original LEACH clustering protocol can cause unbalanced distribution of cluster heads, which often leads to redundant cluster heads in a small region and thus cause the significant loss of energy. To solve this problem, an algorithm for the cluster head selection is proposed in this paper.

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