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Energy Aware Leach Protocol for Wireless Sensor Networks

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Abstract: *-Wireless Sensor Networks (WSN's) consist of small devices, which have a battery, a sensor, a central processing unit and a radio transmitter component. One of the limitations of wireless sensor nodes is their natural partial energy resource. Refreshing or exchanging the sensors battery may be inconvenient, or even difficult in some monitoring atmospheres. Thus the key challenge in the scheme of wireless sensor network protocols is how to make the most of the network lifetime, which is limited by the battery energy in sensor nodes, while provided that the application requirement. Moreover, maximizing the lifespan of the sensor node, it is better to allocate the energy degenerate through the wireless sensor network in order to minimize the conservation and maximize the general system performance. The main objective of this paper is to develop an Energy Aware LEACH for providing energy efficiency, longer lifetime, and faster data delivery for heterogeneous WSNs.*

Keywords: WSN, Energy Efficiency, LEACH, Network Lifetime

1. INTRODUCTION

Wireless Sensor Network (WSN) due to its potentially large application area emerged as a premier research topic. WSN consists of thousands tiny nodes which individually has limited capabilities but collectively they can form a very useful network for various applications like disaster management, forest fire detection, vehicle tracking, habitat monitoring etc. Usually the WSN once deployed, works in an unattended manner and each sensor node has limited battery capacity. So after each operation a node comes closer to death which finally brings the whole WSN's operation to a halt. So energy is the main constraint for any application using WSN. In a large scale WSN the nodes which are nearer to sink are always used for forwarding packet from all other distant nodes. Due to this, the nodes which are nearer to sink are out of energy very soon and an energy hole is created near the sink and the sink becomes unreachable, while maximum nodes in the network are still alive [1]. Sensor node are closely organized in wireless sensor network that means physical atmosphere would produce very similar data in close by sensor node and transmit the type of data is more or less redundant. If sensor nodes of same application and at minimum distance between them alternatively perform data collecting, processing and communication then we can able to transmit information to the base station for longer time. Thus network lifetime will be improved. In a WSN, sink is usually a powerful device and it fails very rarely. But due to energy constraint and some other issues node failures are common in WSN. Though, for densely deployed WSN a single node failure does not have much significance, yet when some individual node failures create an energy hole then it affects the performance of the WSN and sometime it stops the operation of the WSN. We want to monitor the power consumption by the nodes for increasing the life time of WSN. Currently, energy awareness and efficiency is the most important metric in the design of an algorithm for data collection, processing and communication. This growing development of WSN leads to the design of many new routing protocols. Energy reduction of nodes can interrupt communication and in an inferior quality case, it could cause the network separating which lead the break of monitoring. Unlike ad-hoc networks, refreshing or exchanging the sensors battery may be difficult, or even difficult in some monitoring environments. Thus the key challenge in the scheme of wireless sensor network protocols is how to make the most of the network lifetime, which is limited by battery energy in sensor nodes, while provided that the application requirement. The network lifetime is a strictly application specific metric in sensor network performance and depends on many parameters: the topology of the sensor network [2], the data aggregation regime in the network (raw data transmission or processed data transmission, periodic or event triggered data gathering); the channel access (MAC) schemes; the routing protocols; and the energy model for transmission (based on the channel model). Our proposed protocol is designed in a way that it extended the lifetime of the sensor networks by balancing the energy depletion of the nodes. It makes the high remaining energy node to become a cluster-head. The nodes are used to gather the energy information of the adjacent sensor nodes and then choose the cluster-heads.

2. LITERATURE REVIEW

Grouping sensor nodes into clusters has been widely pursued by the research community in order to achieve the network scalability objective. Every cluster would have a leader, often referred to as the cluster-head (CH). Although many clustering algorithms have been proposed in the literature for ad-hoc networks and sensor networks [3] - [6], the objective

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was mainly to generate stable clusters in environments with mobile nodes. Many of such techniques care mostly about node reach ability and route stability, without much concern about critical design goals of WSNs such as network longevity and coverage.

LEACH is one of the most popular clustering algorithms for WSNs [7]. Its clusters based on the traditional signal strength and use the CH nodes as routers to the base-station. All the data processing such as data fusion and aggregation are local to the cluster. LEACH forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control.

Youssef et al. [8] proposed MOCA, a randomized, distributed Multi-hop Overlapping Clustering Algorithm for organizing the sensors into overlapping clusters. The goal of the clustering process is to ensure that each node is either a CH or within k hops from at least one CH, where k is a preset cluster radius.

The QoS-based energy-efficient sensor routing (Quest) protocol [9] defines the application specific, near-optimal sensory-routes by adjusting the multiple QoS parameters (end-to-end delay and bandwidth requirements) and energy depletion, based on the Multi-Objective Genetic Algorithm (MOGA). The Quest protocol is accomplished of determining the set of QoS based or adjacent optimal paths even with loose the network information.

An energy efficient and QoS aware multipath based routing (EQSR) [10] has been proposed by oath man et al., which provides service differentiation by giving real-time traffic absolute preferential treatment over the non-real-time traffic. EQSR uses the multi-path paradigm together with a Forward Error Correction (FEC) technique to recover from node failures without invoking network-wide flooding for path-discovery. The EQSR protocol uses residual energy, available buffer size and the signal-to-noise ratio to predict the next hop through the paths construction phase. EQSR splits up the transmitted message into a number of segments of equal size, adds correction codes and then simultaneously transmits it over multiple paths to raise the probability that a critical portion of the packet is established at the destination without suffering extreme delay. The EQSR protocol handles both real-time and non-real-time traffic efficiently. It does so by employing a queuing model that provides service differentiation.

Singh et al. [11] proposed homogeneous clustering algorithm for wireless sensor network that saves power and prolongs network life. The life time of the network is improved by certifying a homogeneous distribution of nodes in the clusters. A new cluster head is selected on the basis of the residual energy of existing cluster heads, holdback value, and nearest hop distance of the node. The homogeneous algorithm makes sure that every node is either a cluster head or a member of one of the clusters in the wireless sensor network. In the proposed clustering algorithm the cluster members are homogeneously spread and thus the life of the network is longer. Further, in the proposed protocol, only cluster heads broadcast cluster formation message and not the every node. Hence, it prolongs the life of the sensor networks. The importance of this method is to increase the life span of the network by confirming a homogeneous delivery of nodes in the clusters so that there is not too much getting and spreading overhead on a Cluster Head.

Sharma et al. [12] proposed Leach- heterogeneous system in the specific clustering of the complete network, which is energy efficient routing method for WSN's and associated it normal Leach-Homogeneous system. Simulation results using MATLAB shows that the proposed Leach-heterogeneous system meaningfully reduces the energy consumption and improves the total lifetime of the wireless sensor network.

Min et al. proposed an Energy Efficient, Fault Tolerant Routing LEACH (EF-LEACH) Protocol for Wireless Sensor Networks [13] to diagnose faults and perform appropriate measures to recover sensor network from failures. It maintains the connectivity of the network and the reliability of data transfer even when a node in the network runs out of energy. Simulation results show that EF-LEACH protocol is more energy efficient in terms of network lifetime and throughput than the existing LEACH protocol. In hostile environments, unpredicted failure of CH may divider the network or degrades application performance; therefore, CH node fault discovery is very important. If CH_{alive} is equal to 1 and $CH_{Isalive}$ is equal to 0, it flags this CH as a dead node and distributes the information to the rest of the network and CH fault retrieval process is introduced.

3. PROPOSED ALGORITHM

The main objective of our proposed algorithm is to develop an Energy Aware LEACH for providing energy efficiency, longer lifetime, and faster data delivery for WSNs which are mainly used for those areas where nodes remaining largely inactive for long periods of time, but then becoming suddenly active when something is detected. LEACH is clustering based protocol in which nodes arrange in a local area called clusters. After every round, a new cluster head is selected to balance energy load. Every new round consists of Set-up phase followed by Steady-state phase. Some sensor nodes independently elect themselves as CHs without any negotiation to other nodes. CHs elect themselves on basis suggested percentage P and their previous record as a CH. In Set-up phase, clusters are formed based on some threshold value which is given as below [14]:

$$\boldsymbol{Threshold(n) = \frac{p}{1 - p \times rmod(1/p)}}$$

Based on received signal strength of sensor nodes in a cluster, cluster head will form a TDMA schedule and each node is supposed to transmit within their allotted slot. After collecting data from all cluster-members, CH aggregates the data and then data to BS. But there are some problems associated with LEACH. Though cluster head selection procedure ensures that all nodes would get an equal chance to become cluster head but energy factor is not considered while selecting cluster head. After a time period, it is likely that a node with low energy may get selected as cluster head. Another issue is that different cluster head elected would have different distance to base station, so their energy needs would also be different. In addition, in large network that CH which is located at more distance from BS has to adopt multipath path which consumes high energy. Moreover, energy demands for intra cluster communication are less than

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inter cluster communication. LEACH is completely dependent on cluster head for transmission and aggregation of data and a compromised cluster head would drop packets and may not perform task assigned to it thus making an unsecure network. Thus it is very important to choose a suitable CH.

In Energy aware LEACH (EA-LEACH), we have considered a heterogeneous network in which all the nodes don't have same energy. Some of the nodes, say m% of total nodes n, has α times more energy than the other nodes. Let us assume that the total number of nodes is n & m fraction of the nodes has α time more energy than the other nodes. They are known as advanced nodes.

Number of normal nodes = (1-m) x n

Initial Energy of each normal node = E_{ini}

Number of advanced nodes = m x n

Initial Energy of each advanced node = E_{ini} x (1 + α)

Hence the total energy of the network =

$$((1-m) \times n) \times E_{ini} + (m \times n) \times (E_{ini} \times (1 + \alpha))$$

During set-up phase, cluster heads are selected. We have assumed that BS has unlimited source of energy and it is free from any kind of attack. Nodes will be selected as cluster head based on threshold value given in equation below:

$$Threshold(n) = \frac{p}{1 - p * rmod(\frac{1}{p})} \sqrt{\frac{E_{res}}{E_{ini}}} \quad n \in G$$

Where p is the desired percentage of cluster heads, G is set of nodes that have not been elected as cluster-heads in the last 1/p rounds and r is the current round, E_{res} is residual energy of node and E_{ini} is initial energy of node. After this phase, nodes has list of all eligible cluster head members.

Every node produces random number between 0 and 1 and the node announces itself as CH if this number is less than threshold value. The value of threshold is set to zero for the node that have been already acted as CH so that this node doesn't get selected as CH again. The detailed flowchart of EA-LEACH is given in Figure 2.

Elected cluster head will find all its neighboring cluster head and all information such as ID neighbor node, residual energy of CH, distance, how many times node is elected as cluster head in the past in the form of a table. Now cluster head will examine whether neighbor is nearest neighbor or not by calculating distance between cluster heads using signal strength. If number of nearest neighbor are greater than 0 then cluster head will calculate suitability factor associated with every nearest neighbor cluster head as below. Since energy is an important constraint so we have chosen higher weight for E_{res}. Cluster head with highest suitability value is selected as new cluster head and will broadcast this information to other nodes. Packet forwarding behavior is calculated by the ratio of packets received to packets sent to BS.

4. SIMULATION RESULT

The proposed algorithm EA-LEACH has been designed in MATLAB [15]. It is considered that 100 nodes are randomly distributed over area of 1000×1000 m^2. Firstly basic LEACH is implemented. Sensor nodes send data to CH, CH after aggregating the data from cluster members further route it to BS. Hence, proposed scheme is energy efficient, so network lifetime is improved with this scheme. In addition, CH with better suitability factor is selected, so probability of packets drop ratio is decreased. Evaluation is done based upon following metrics:

- Network lifetime
- Packets to BS
- PDR

Simulator parameters are mentioned in table 1.

Table 1: Simulation Parameters

Network parameters	Values
Network Size	1000X1000m^2
Number of nodes	100
Number of rounds	100, 300
Packet Size	1000 bits
Routing Protocol	LEACH
Initial battery power of node	0.5 J/node
Energy to run transmitter and receiver	50 nJ/bit
Data aggregation energy	5 nJ/bit
Amplification Energy (Cluster to BS)	Efs =10pJ/bit/m^2
Amplification Energy (Intra Cluster Comm.)	Efs/10 = Efs_1

Figure 1 shows random distribution of sensor nodes in an area of 1000*1000m^2 units and LEACH protocol is used for routing. Normal nodes are represented with a blue circle, advanced nodes with + and dead nodes with red diamond. Nodes that are selected as cluster head are represented with asterisk. With implementation of EA-LEACH, suitability factor of node is calculated and CH is selected based upon this suitability factor represented by asterisk so there is less but highly suitable CH selected in EA-LEACH.

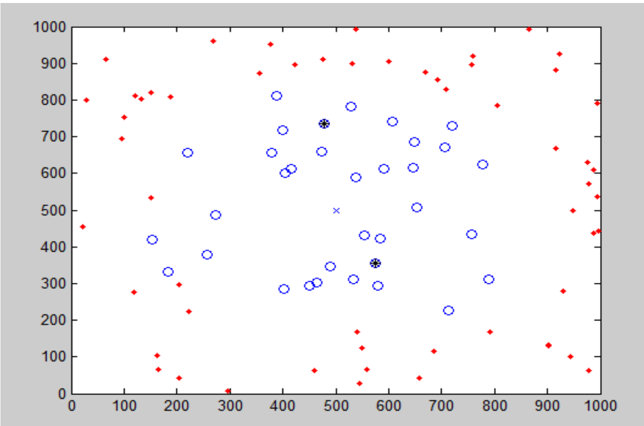

Figure 1: CH selection in EA-LEACH

$$(SuitabilityFactor)_{CH} = 0.5 * \left(\frac{E_{res}}{E_{ini}}\right)_{CH} + 0.3 * (Packet\ forwarding\ \text{behavior})_{CH} - 0.2 * \left(\frac{Dist_{CH\rightarrow BS}}{AD_{CH\rightarrow BS}}\right)_{CH}$$

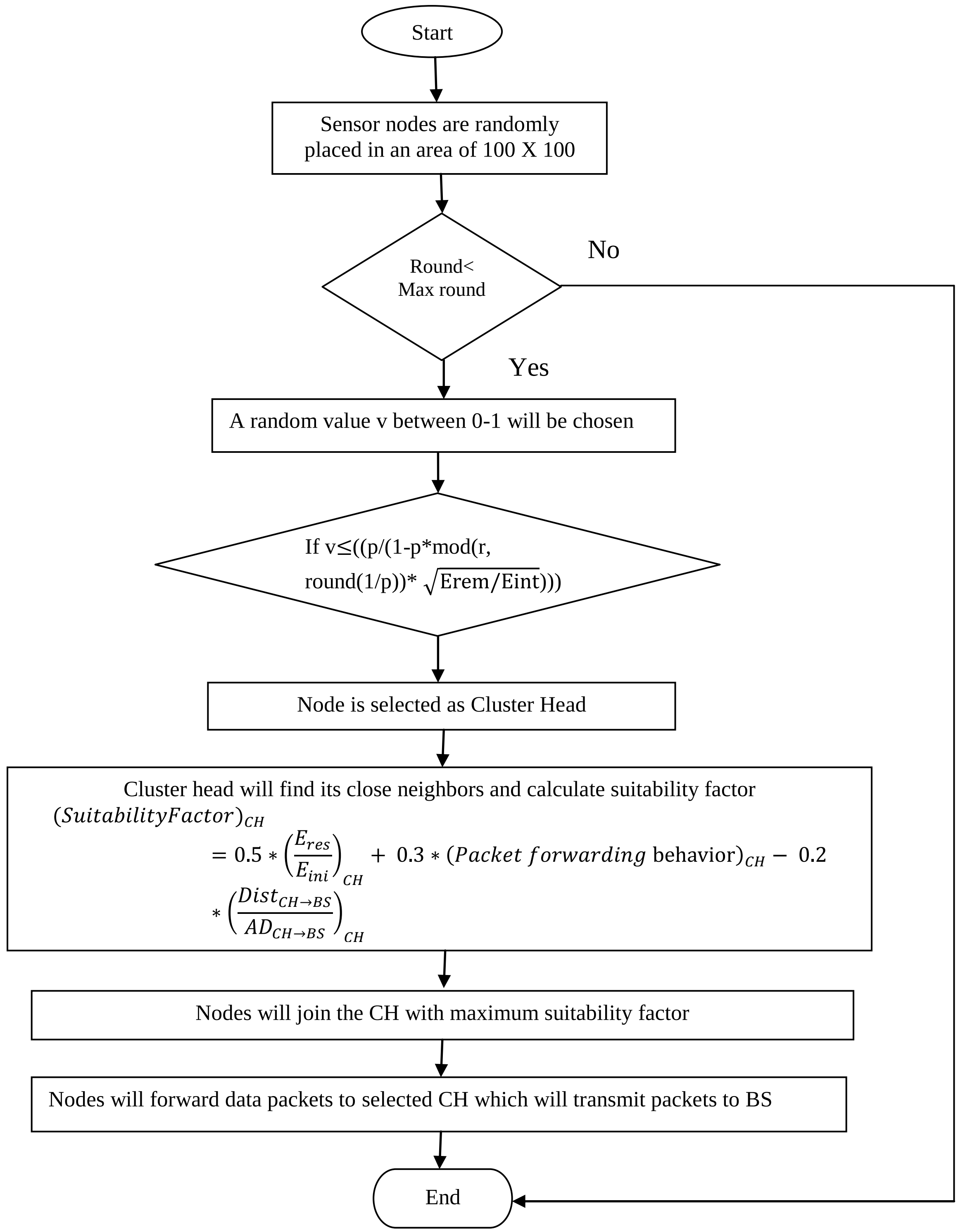

Figure 2: Flowchart of Proposed EA-LEACH in WSN

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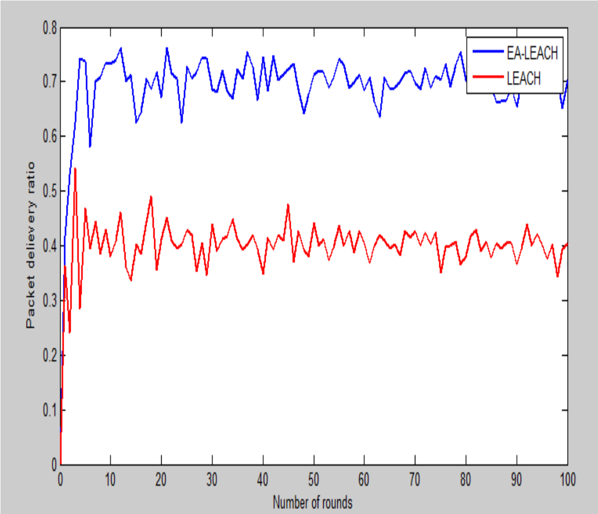

Figure 3: PDR vs Number of round

Packet delivery ratio is defined as packets received by base station to packets sent to BS. As it is clear in Figure 3 that PDR is high algorithm for proposed EA-LEACH with an average value of 0.78 as number of rounds increases from 1 to 100 as compared to LEACH where average PDR is 0.45.

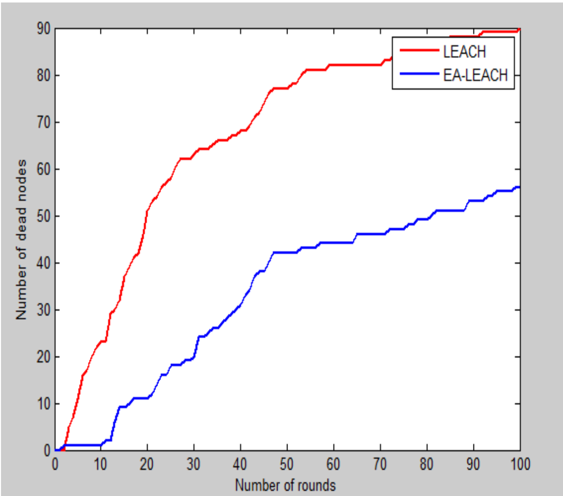

Figure 4: Network lifetime comparison

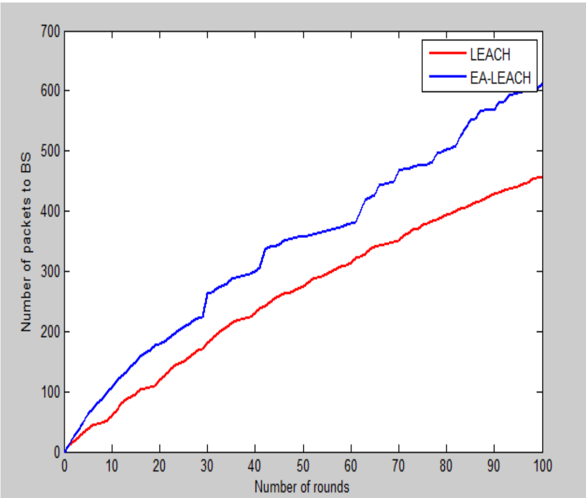

Figure 5: Packets sent to BS vs Number of rounds

Figure 4 signifies network lifetime comparison for 100 rounds. It has been shown in Figure4 that at 10th round, number of dead nodes in LEACH is 12 whereas in EA-LEACH is 8. As number of rounds increases to 100, number of dead nodes decrease from 82 to 58 in EA-LEACH.

Figure 5 depicts number of packets sent to BS and it is clear that more number of packets is sent for EA-LEACH as network lifetime is increased.

5. CONCLUSION

Wireless Sensor Networks (WSN's) contains large number of small and low cost sensor nodes powered by lesser non rechargeable batteries and equipped with various sensing devices. In order to provide reasonable energy consumption and to improve the network lifetime for WSNs, energy aware LEACH (EA-LEACH) protocol is proposed. In the proposed algorithm, new cluster head is selected on the basis of suitability factor which is calculated on the basis of residual energy, past packet forwarding behavior and distance between cluster head and base station. The simulation results proved that proposed scheme is energy efficient and improves network lifetime. In addition, CH with better suitability factor is selected, so packet delivery ratio is increased from an average value of 0.45 to 0.78.

In future, we plan to extend our proposed design by incorporating the mobility and autonomic fault management aspect in the context of network management system. We are also interested to deal with energy efficiency at MAC layer that includes the effects of antenna orientation with respect to human body.

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