ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 9, September 2015

Improved EF-Leach Routing Protocol To Extend Network Lifetime

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Abstract: Implementing energy-efficient and fault tolerant routing protocols for Wireless Sensor Networks (WSNs) applications such as, seismic monitoring, battlefield surveillance and civil structural health monitoring is a great challenge due to the continuous change of the network topology. Moreover sensor nodes are prone to energy drainage and failure in WSNs because of harsh environment. Therefore, energy-efficient and fault tolerant are essential issues for WSNs. Low-Energy Adaptive Clustering Hierarchy (LEACH) protocol is one of the efficient and important protocols for routing in WSN, which maintains balanced energy consumption. ; EF-LEACH proposes vital solutions to some shortcomings of the pure LEACH. EF-LEACH provides network fault tolerant and achieves reliability and quality of service. But EF-LEACH is suffers with low energy, delay and low network lifetime. So in this paper we modified the EF-LEACH by adding two cluster heads in each cluster. The proposed approach will improve the network life as never the cluster head will die. As a cluster head will die it will be replaced by its secondary cluster head.

Keywords: Clustering, LEACH, Energy Efficient and fault-tolerant LEACH (EF-LEACH) protocol, two cluster heads, Wireless Sensor Network.

I. INTRODUCTION

WSNs are generally cluster based networks that use data fusion and hierarchy to reduce energy consumption and delay. The main design goal of wireless sensor networks is to transmit data to the desired location by increasing the lifetime of the network and by employing energy efficient routing protocols. Mostly, sensor nodes are organized into clusters where data collected by sensor nodes is sent to cluster head (CH), which is elected by BS. CH processes this data and sends it to the BS.

Clustering is an effective way for improving the energy efficiency and prolonging the network lifetime of WSNs. If there is CH failure in network accidentally, it may lead to connectivity and data loss within cluster.

It also disconnects cluster members from rest of the network. So, it is important to detect and recover the CH failure to maintain normal operation of cluster and network as a whole [2].

We proposed fault recovery protocol based on LEACH protocol for WSNs. To solve the above mentioned challenges, that offer efficient fault recovery mechanisms to make the network fault-tolerant.

II. RELATED WORK

We have already existing fault recovery approaches for WSNs, which are vary in forms of architectures, protocols, detection algorithm or detection decision fusion algorithm etc [3]. Several works has been done on fault tolerance over many clustering algorithms.

One of the fault tolerance approaches has been discussed in [4]. Here also the research work is done on LEACH. Here fault recovery is suggested in two ways: inter-cluster recovery & intra cluster recovery.

Another existing fault tolerance approach is a Dynamical Jumping Real-time Fault-tolerant Routing Protocol (DMRF) which is discussed in [5].

"When there is node failure in the wireless sensor network, then there is a chance of occurrence of network congestion or void region. Then the transmission mode will turn to jumping transmission mode. It leads to reduced transmission delay and guarantees the data packet to be sent to its desired destination within the time limit" [5]. Each node can dynamically adjust the jumping probabilities to increase the ratio of complete data transmission by using feedback mechanism. The DMRF mechanism results in reduced effect of failure nodes, congestion and void region, transmission delay, number of control packets and higher ratio of successful transmission.

One more fault tolerant work is discussed in [6]. Basically, WSNs faces resource constraints, high failure rates and fault caused by wireless channels & wireless sensor nodes. It increases the reliability & robustness of the network by adding a backup path for every node on a main path of data delivery. When a node gets failure it immediately applies its backup path as the main path for data delivery of next incoming packets. This protocol reduces the number of dropped data packets and increases robustness of the entire network by maintaining the data packet transmission even in presence of faults.

One more protocol is Energy Efficient and fault tolerant LEACH (EF-LEACH) protocol, which is very efficient protocol for detecting and recovering the failure head nodes in leach protocol. It maintains the connectivity of the network and the reliability of data transfer even when a node in the network runs out of energy.

DOI 10.17148/IJARCCE.2015.4989

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ISSN (Print) 2319-5940

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Whenever cluster head at any of the levels fails accidently, the recovery algorithm is called up and new cluster head takes the responsibility for the rest of the round. Therefore the disconnection of the cluster at that level from the rest of the network does not take place.

III.LEACH (LOW - ENERGY ADAPTIVE CLUSTERING HIERARCHY) PROTOCOL

LEACH (low-energy adaptive clustering hierarchy) is well known clustering based protocol in WSN. LEACH is a significant protocol that utilizes randomized rotation of local cluster base stations (cluster-heads) to evenly distribute the energy load among the sensors in the network [7].

In LEACH protocol all cluster members transmit the sensed data to cluster heads, and each cluster head aggregate and compress the data and forward it to the base station. The operation of LEACH protocol is done in terms of rounds. The implementation process of LEACH includes many rounds. Each round consists of the Setup Phase and the Steady State Phase:

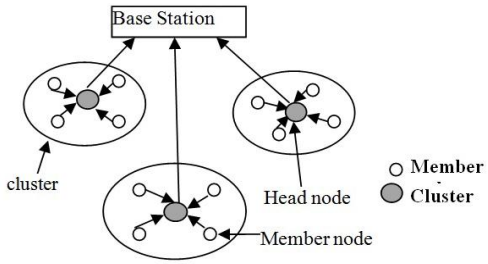

Fig 1: LEACH Architecture

A. Setup Phase

The setup phase starts with the self-election of nodes to cluster heads. CHs selection is made based on an elective percentage of deployed nodes can become CH, also by considering a factor that so far how many times an individual node performed the role of CH. Every individual node from the group of deployed nodes chooses a random number between *0* and *1*, if the selected number is less than a set threshold *T (i),* the sensor node can become a CH for the current round.

Where *T (i)* is calculated as,

$$T(i) = \left\{ \frac{p}{(1-p*(r \bmod \left(\frac{1}{p}\right))} \right\} \quad \text{if i€G}$$

$$=0 \qquad \text{otherwise}$$

Where,

p : Probability of node becoming CH.

r : Round Index

G: Set of nodes not perform as CHs in last *1/p* rounds.

The selected CH informs their neighbourhood with an advertisement packet. Non cluster-head nodes decide their cluster for current round by choosing the CH that requires minimum communication energy, based on the received signal strength of the advertisement from each CH. After the selection each non-CH informs the CH by transmitting a join request message (*Join-REQ*) back to the CH. Then the CH node sets up and broadcast a *TDMA* schedule to all member non-CH nodes.

B. Steady-State phase

During the steady state phase, the data collected by the individual sensors will be given to the CHs during TDMA schedule. The Steady Sate Phase is broken into many frames, in which nodes can send their data to the CH at most once per timeslot. CH sends the aggregated data to BS in single hop manner. During transmission of data from CHs to BS the cluster members are in sleep state. So the energy consumption at this stage reduces. But the CH will be active stage during the entire round of operation.

The BS receives the aggregated data sent by cluster-heads, leading to energy conservation. After a certain period, the network returns into the setup phase again and enters another round for selecting new CH.

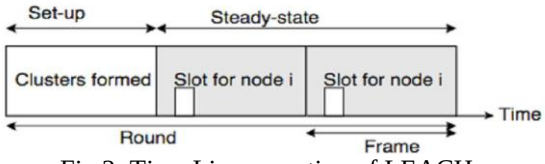

Fig 2: Time Line operation of LEACH

Each cluster communicates using different CDMA codes to reduce interference from nodes belonging to other clusters. However, the heavy tasks executing on CH can lead to too much energy consumption. The CH failure causes the connectivity and data loss within cluster. It also disconnects cluster members from rest of the network. Hence, it is crucial to detect and recover the CH failure to maintain normal operation of cluster and network as a whole.

IV. EF –LEACH PROTOCAL

In this section, we discussed the Energy efficient, Fault Tolerant LEACH (EFLEACH) Protocol for WSNs, which is already existed for fault tolerance purpose. The phases for EF-LEACH protocol are explained here.

A.Cluster Formation and Cluster Head Selection Phase

In this phase, the clusters are formed based on the minimum distance factor and CHs are elected based on highest energy. After electing, the CHs advertise their selection to all cluster member nodes. After receiving advertisement packets, then all nodes choose their nearest CH based on the received signal strength. The CHs then assign a TDMA schedule means time slots for their cluster members.

B.Data Transmission Phase

The second phase, data transmission phase, all sensor nodes sense the environment and send data to the cluster head. CHs receive all the data, and then aggregate it and send it to the Base-Station.

C.Fault Detection Phase

The third phase is the fault detection phase. In hostile environments, unexpected failure of CH may partition the network or degrade application performance; therefore, CH node fault detection is very important. If CH is not sending desired data or any data to neither BS nor cluster

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International Journal of Advanced Research in Computer and Communication Engineering
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members within a given interval time, it flags this CH as a dead node and disseminates this information to the rest of the network and CH fault recovery process is initiated.

D.Fault Recovery Phase

In the final phase, after a CH fault is detected, fault recovery process starts immediately.

V. PROPOSED SCHEME

In our new version of EF-LEACH protocol, the cluster contains; primary CH (responsible only for sending data that is received from the cluster members to the BS), secondary CH (the node that will become a CH of the cluster in case of CH dies) for backup purpose, cluster nodes (gathering data from environment and send it to the CH). In the previous leach, the CH always on receives data from cluster members, aggregate these data and then send it to the BS that might be located far away from it. The CH performs its operation of receiving, sending and overhearing. Due to this the CH will die earlier than the other nodes in the cluster. When the CH die, the cluster will become useless and disconnected, so the data gathered by cluster nodes will never reach the base station.

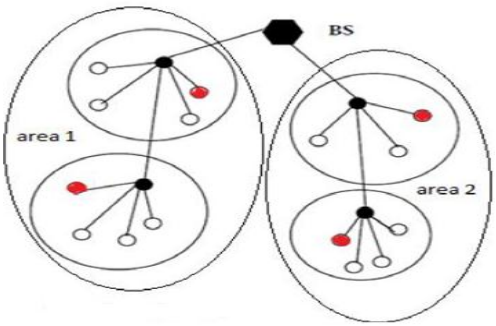

Fig 3: Improved EF-LEACH

In improved EF-LEACH protocol, besides having a primary CH in the cluster, there is one more CH. Secondary CH called as a vice-CH that takes the role of the CH when the CH dies. Primary CH gathers the data from all of is cluster members. Vice-CH also do the same work as primary CH done, but does not send the reply or acknowledgement to the cluster members. But primary CH sends the reply to nodes.

Whenever there is a failure or running out of energy of CH in the round of operation the protocol, the secondary CH takes the responsibility of primary CH. By doing this cluster nodes data will always reach the BS; no need to elect a new CH each time the CH dies. This will extend the overall network life time.

The process of cluster head selection criteria is different. It is on the basis of three factors i.e. Minimum distance, maximum residual energy, and minimum energy. Based on received signal strength, each non-cluster head node determine its cluster head, greater the signal strength means shorter the distance between them and if distance is small then for the transmission less energy is required .The proposed approach will improve the network life as never the cluster head will die. As a cluster head will die it will be replaced by it's vice Cluster head.

VI. SIMULATION RESULTS

Mat lab software MATLAB (matrix laboratory), a computing environment and fourth-generation programming language has been used to simulate the result. The result refers to the measurement of life time, throughput, and energy consumption. Life time of network is related to no. of alive nodes, throughput is rate of packet transmission and how long time cluster of nodes is formed in network. System which is proposed here gives good output in all three parameters.

To validate the performance of modified EF-LEACH protocol, we simulate the protocol and utilize a network with 100 nodes randomly deployed. The initial power of all nodes is considered to be 2J and maximum number of rounds is 2500.

We measure the performance of modified EF-LEACH protocol and compare with existing EF-LEACH protocols in terms of energy consumptions, throughput, and network lifetime. Figure 3 illustrates that the network energy consumptions of MODEF-LEACH protocol is much less than that of EF-LEACH protocol. Hence, the network lifetime MODEF-LEACH is more than LEACH protocol (Figure 5).

Energy Consumption for MODEF-LEACH and EF-LEACH:

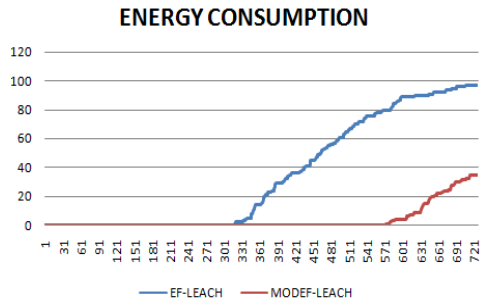

Fig 4: Energy Consumption

Throughput for EF-LEACH and EF-LEACH

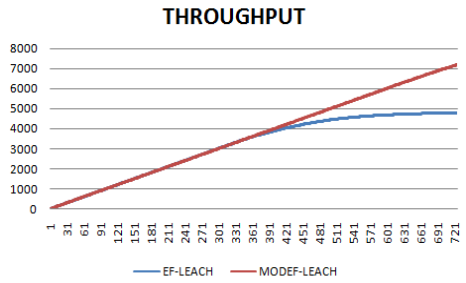

Fig 5: Throughput

Lifetime for MODEF-LEACH and EF-LEACH:

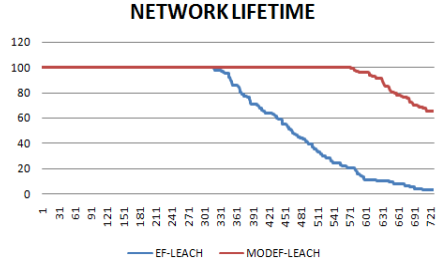

Fig.6 Lifetime

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ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
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VII. CONCLUSION & FUTURE WORK

A wireless sensor network contains several numbers of small, low cost, low energy and multifunctional sensor nodes where each sensor node has very low battery life. Different energy efficient algorithms have been implemented for this. This paper proposes a modified version of EF- LEACH protocol called MODEF-LEACH protocol. From the simulation results, we can draw a number of conclusions:

1) There is less energy consumption,
2) Network lifetime is enhanced,
3) Packet transmission to base station occurs frequently,
4) Even in last round clustering process is going take place.

Therefore, the proposed clustering approach is more energy efficient and hence effective in prolonging the network life time compared to the original version of EF-LEACH protocol.

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.

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