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Lack of Power Avoidance: A Fault Classification Based Fault Tolerant Framework Solution for Lifetime Enhancement and Reliable Communication in Wireless Sensor Networks

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Abstract: Clustering provides an effective way to improve the lifetime in Wireless Sensor Network (WSN) environment. Clustering protocols in WSN requires optimal grouping for cluster heads which further leads to inter cluster communication in reliable manner. In this study, Lack of Power Avoidance (LoPA) protocol is proposed and evaluated. By using heuristic algorithms, LoPA considers heterogeneous clustering and controls the network parameters significant in low power applications. Reduction in energy consumption using this algorithm is obtained by the use of fault classification methods. Inter cluster communication is made reliable by using conditional utilization of energy of the nodes in various model of operation. Simulation results indicate that the protocol can efficiently decrease the dead speed of the nodes and prolong the network lifetime.

Key words: Wireless sensor network, fault tolerance, life time, LEACH, voronoi diagram

INTRODUCTION

A Wireless Sensor Network (WSN) is a self-organized network that has a collection of numerous sensor nodes which are haphazardly distributed in a sensor field. WSN is recently coming up as a premier technology due to its usefulness in wild life monitoring, military and health applications (Ruan and Sun, 2011). Various characteristic issues which influence the performance of a sensor network are fault-tolerance, scalability, operating environment and topology (Chu *et al*., 2011). Wireless sensor network are resource scavenging in nature (Liang *et al*., 2011). The communication architectures in WSN in general based on layering and clustering concepts. Clustering provides a mean of achieving enhanced lifetime (Akyildiz *et al*., 2002). Past literature in fault tolerant and energy aware frameworks (Saleh *et al*., 2006) produced good results in terms of throughput and end to end delay measurement. But lack in prolonging the lifetime. This may be due to Loss of Data Avoidance (LoDA) and Lack of Power Avoidance (LoPA) (Dhulipala *et al*., 2010). When the lifetime enhancement of the network of sensor nodes is concerned, it is important to develop heuristic approaches for power and energy calculations. Heuristic approach in this regard could be reasonably a good solution.

Many clustering protocols or algorithms have been proposed for WSNs in recent years. The Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm, which is based on gradient cluster, plays a great role in reducing the energy consumption of the nodes and enhancing the network lifetime (Yang and Zhang, 2009; Xin *et al*., 2008; Wang *et al*., 2011). However, owing to selecting the cluster heads stochastically in disregard of the size of clusters and the residual energy of nodes and adopting the one-hop forwarding model in inter-cluster communication, it cannot guarantee the even energy dissipation of the network (Koushanfar *et al*., 2004; Paradis and Han, 2007). A further improvement of this algorithm known as LEACH-C is proposed (Saleh *et al*., 2006), in which the cluster formation is done using a centralized mechanism by the BS. Results analyzed (Saleh *et al*., 2006) have shown that the overall performance of LEACH-C is better than LEACH due to improved cluster formation by the BS. A new application of the Particle Swarm Optimization (PSO) algorithm to the problem of clustering nodes (Gao *et al*., 2009). The number of nodes and candidate cluster-heads in each cluster are equalized in the algorithm, with the objective of minimizing the energy expended by the nodes while maximizing the total data gathered. However, no comparison with other benchmark clustering protocols in terms of energy efficiency has been addressed. An energy-aware clustering for WSNs using PSO algorithm, which is implemented at the BS, is proposed in energy aware fault tolerant management framework

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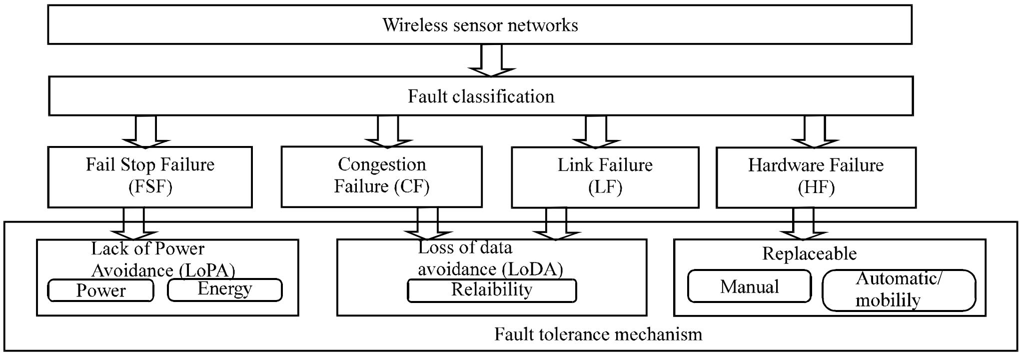

Fig. 1: Fault classification based Fault Tolerant Framework for WSN

(Dhulipala *et al*., 2010). The cost function is defined with the objective of simultaneously minimizing the intra-cluster distance and optimizing the energy consumption of the network. Compared with LEACH and LEACH-C, the protocol can achieve better network lifetime and data delivery at the BS. However, owing to adopting the one-hop routing in inter-cluster communication, the protocol may cause unbalanced energy dissipation of the network, especially when the BS is outside of the network. That is, the cluster heads farther away from the BS are prone to consume more energy to transmit data to the BS and die quickly (Guo *et al*., 2011). The Unequal Clustering Size (UCS) clustering algorithm balances the energy dissipation through controlling the size of the cluster (Jiang *et al*., 2010) and this scheme can prolong the network lifetime.

Energy-balanced unequal clustering (EBUC) routing protocol for periodical environment monitoring applications in WSNs (Jiang *et al*., 2010) concentrating on the lifetime enhancement of the network of nodes. It organizes the network via unequal clustering and multihop routing. By using Particle Swarm Optimization (PSO-C) algorithm. The WSN should also be Fault tolerant and reliable in case of environmental monitoring. Thus the cluster heads of the particular cluster will consume lower energy during the intra-cluster data processing and can preserve some more energy for the inter-cluster relay traffic. It also acts as a Fault tolerant network as proposed in Fault classification based Fault Tolerant Framework beneath. Simulation results show that LoPA saves the energy awareness of the individual nodes and balances the energy consumption over the entire network and enhances the network lifetime.

Fault classification based Fault Tolerant Framework for WSN: In this study we proposed a fault classification based fault tolerant framework for WSN which is simulated with a unequal clustering of sensor nodes as shown in Fig. 1.

In Wireless sensor networks, fault-tolerant and energy efficiency are two important factors. Some link failure may happen during data transmission and some threat can come from compromised nodes, which might relay incorrect information (packet) to the next node during routing. Energy is the major concern in networks. The energy may gets wasted due to collisions, unnecessary traffic, long idle time etc., In WSN, generally we classify the possible fault as power lagging (fail-stop), congestion, link and hardware failures (Koushanfar *et al*., 2004). The failures are totally differ from each other; it won't affect or interfere with each other. But it will affect the performance and functions of the nodes. The first failure can occur due to power lagging of the nodes. Second, congestion may occur due to large number of nodes present in the network that nodes transition from power saving state to active state (Paradis and Han, 2007). The collisions are high, when large amount of packets during transmission from source to sink. Link failure is the third one, the result is data loss. It breaks the fine communicated environment or network and causing changes in topology. The final is hardware failure; it may be predicted or unpredicted one. The solution is replacement. Replace the node by manual or automatic depend upon the application or the requirement of the user.

Lack of power avoidance (LoPA): We analyse two mechanisms Lack of Power Avoidance (LoPA) and Loss of Data Avoidance (LoDA) as shown in Fig. 1. These two algorithms the simulation results of these algorithms proved good in reliable communication. LoPA fully concentrate on power energy and reliability the nodes (De Cicco *et al*., 2008). But this gives the reliable and secured packet routing to the end user. The fault tolerates mechanisms handles three types of failure in wireless network. When fault occur, it deviate the network from the normal flow (Jiang *et al*., 2010). To tolerate/recover the fault, come back into the communication to an original

```
Initialize: Main parameters
P← Power; t←Time; E←Energy
Begin process
 GET : t
 E = (P/t);
 Consideration: Ti =(((Ei/ti))>xi&&?A!=0)
 /* CONDITION STARTS */
 If (E≥T1)
 Node: "Sink";
 If (E≥T2)
 Node: "Operational Sensor";
 Else If (E≥T3)
          Begin branch
          GET: A←FS; B←S_S; C←T_S
           Compare→ BIG {A , B , C....N}v nodes
            SET: N = Number of Nodes/*node
settings*/
           If (BIG≥E)
           Node: "Route";
           Else
           Node: "All Nodes are L_E";
          End branch
 Else
 Node: "Lacking Strength"; /* condition ends */
End process
```

Fig. 2: Pseudo code for LoPA

one. LoPA, check the battery level of the sensor and act accordingly. The faults are mainly worsened by the multihop communication nature of the network. Single node or link failure leads to miss behaviour or missing reports to the destination/nearby nodes. The fail-stop failure occurred due to power lagging.

Pseudo code for LoPA algorithm is shown in Fig. 2. The main parameters are power (P), time (t) and energy (E) are to be initialized. The process of operation starts, vary the time with constant power. We assume that each sensor nodes knows the percentage of remaining power level of its battery. Consider the threshold value into three different conditions like 75% (T_1), 50% (T_2) and 25% (T_3) of power is indicated in Fig. 4. Check the battery level of the node under three boundary conditions. If the energy level is higher or equal to 75% of threshold value (T_1), then the sensor is act like a sink. It directly routing the packets successfully. Else check the next to this, if the condition is satisfied ($E = T_2$), the sensor cannot be a sink. It acts an operational sensor that participates in any communication or sensing activity. While the same condition checking has continued till the packets sending successfully or reaches to the destination. But the last condition takes more time for its operation. If the above two conditions are not satisfied, we consider that the node is having low battery level. First examine the battery level of all sensor nodes and compare the node's energy level with another one. We assume that each cluster having only four nodes. Let F_S, S_S and T_S be the energy level of the first sensor, second sensor and third sensor nodes. Finalize the higher energy node (BIG) that should be greater than the previous. If yes, packets are routed through this higher node. If not, we assume that all nodes having lower energy (L_E) or otherwise it gives the default output "Lacking Strength" "Lacking Strength"- it loses all power to routing the packets. The main aim of this LOPA is routing the packets successfully, avoid packet loss, improve the reliability of communication and increase throughput of the sensor node (Yen *et al*., 1998; Campanoni and Fornaciari, 2007; Polastre *et al*., 2004).

Preliminaries of the network model and simulation parameters

- All sensors are deployed in the region of interest
- All nodes are energy constrained.
- The nodes are either a cluster head or ordinary head
- All nodes are static in nature

Radio energy model: The energy model for the sensors is based on the radio model (Jiang *et al*., 2010).The radio model equation is given by:

$$E_{tx}(k,d) = E_{elec}k+E_{fs}\,kd^2\ d<d_0 \quad (1)$$

$$E_{tx}(k,d) = E_{elec}k+E_{mp}kd^4;\ d>d_0 \quad (2)$$

$$E_{rx}(k) = E_{elec}k \quad (3)$$

Where:

K : No. of bits

D : Distance

E_{elec} : Energy dissipated per bit to run the transmitter or the receiver circuit

E_{rx} : Energy dissipated during receiving data

E_{fs}(pJ/(bit-$^{m-2}$)), E_{mp}(pJ/(bit-m^{-2})) : Energy dissipated per bit to run the transmit amplifier based on the distance between the transmitter and receiver.

The simulation parameters for the evaluation of the LoPA algorithm shown in Table 1. Terrain dimensions for the evaluation are fixed as 500×500 m^2 and network sized is 200 nodes. Base station for the clustering environment located at 250×750 m^2. The experiment is conducted with energy considerations as shown in Table 1.

Table 1: Simulation results and network parameters

Parameters	Value
Network size	500×500 m^2
Number of nodes	200
Base station location	250×750 m
E_{elec}	50 nj/bit
E_{fs}	10 pj/bit-m^2
Initial energy	0.5 Joule
Probability of becoming a cluster head	0.1
Data message size	2000 bytes
Header bytes	50 bytes

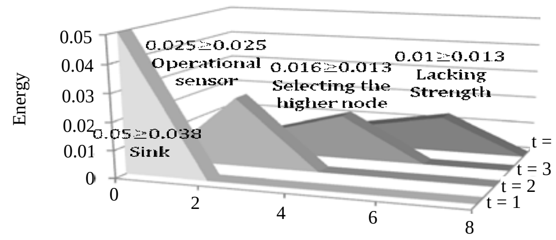

Fig. 3: LoPA conditional utilization of energy

RESULTS AND ANALYSIS

The scenario of the network model is simulated by considering the conditional utilization of the energy as shown in the Fig. 3. The graph in Fig. 4 takes time along X-axis as a measure of simulation specification and energy in Joules for performance evaluation along Y-axis.

Figure 3 explains that decreasing amount of node's energy by the variation of time period of the node's performance. The operation of the nodes differs from the battery level of the sensor. This condition depends completely on the transmission and reception of the sensor's activity i.e., by checking the condition with threshold values. The sensor drops its energy after a long life time as a result the node reaches the state of death.

Energy decaying process as the variation of nodes alive and dead condition analysis starts is depicted in the Fig. 4. It also represents the characteristics of battery which $V_0 \rightarrow V_1$ for setting the threshold T_1, $V_1 \rightarrow V_2$ for setting threshold T_2 and $V_2 \rightarrow V_3$ for setting threshold T_3.

The lifetime of the battery is represented as the equation:

$$F(x) = a_1 \sin(b_1 x + c_1) + a_2 \sin(b_2 x + c_2) \quad (4)$$

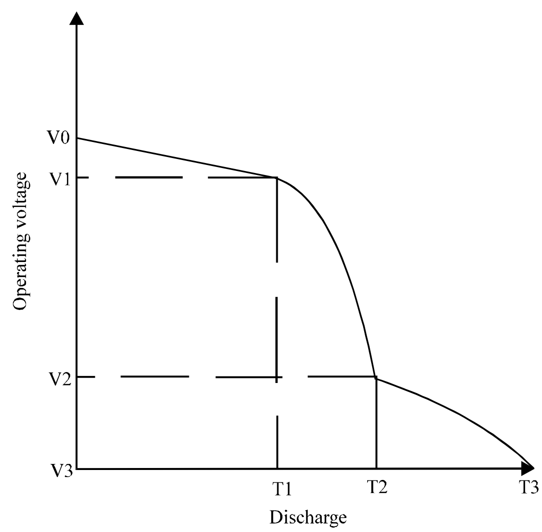

Fig. 4: Energy variations based on threshold

Deployment and evaluation of performance of LoPA: The random deployment of sensor nodes in the terrain considered influences the sensor network performance in terms of Quality of Service (QoS) metrics. Figure 5 shows the random deployment scenario of sensor nodes set for this experiment.

Voronoi diagram represents the points that are connected in a region having common boundary. Voronoi diagram helps in solving numerous geometric problems. The common boundary of two Voronoi regions is called as Voronoi edge, The Voronoi edges are called as Voronoi vertices. Voronoi diagram represents the clustering environment of the proposed algorithm. The Voronoi diagram representing the networking scenario as shown in Fig. 6.

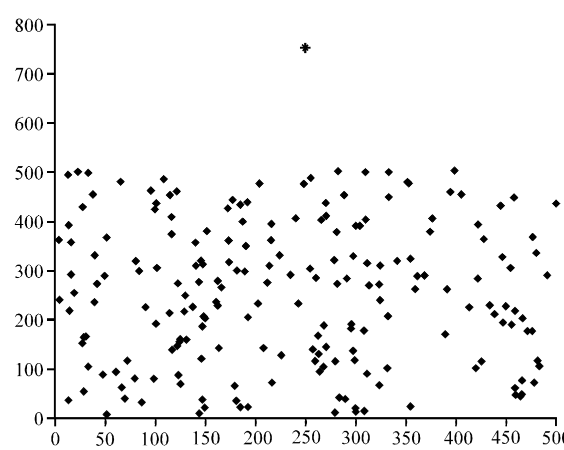

Fig. 5: Random deployment scenario of sensor nodes

Performance evaluation of the proposed algorithm is done using MATLAB protocol, LEACH, PSO-C, LoPA and their performance are being compared. Initially 200 nodes we randomly deployed in 500×500 m^2 terrain. The data message size was 2000 bytes with 50 packet header. The energy efficiency of the three algorithms with respect to network lifetime is examined.

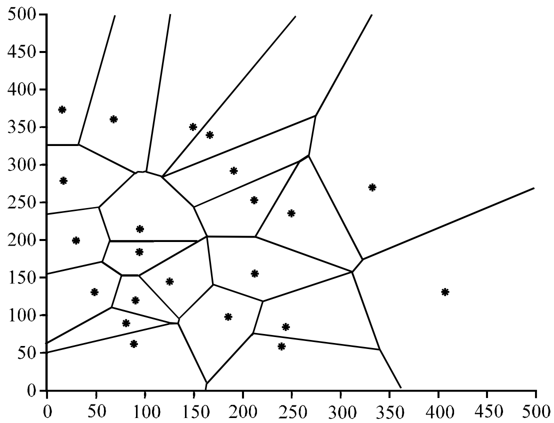

Fig. 6: Voronoi diagram for network model

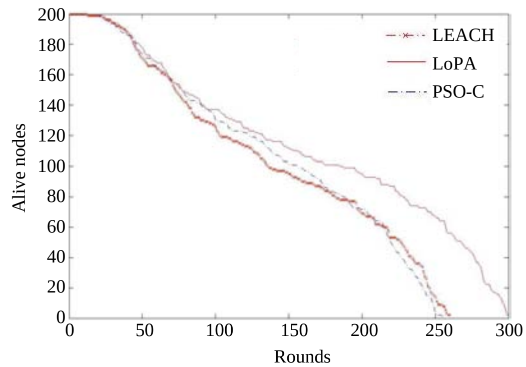

Fig. 7: Alive nodes (vs) simulation rounds

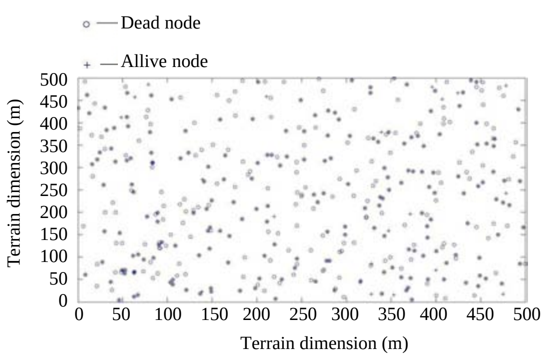

Fig. 8: Distribution of dead nodes and alive nodes

Figure 7 illustrates the improved network lifetime with the fault tolerant ability in case of LOPA-LEACH over the other two algorithms. The hotspots problem can be avoided causing a reliable communication to the network.

The dead nodes are equally distributed in terrain dimension so that the network life time is increased as shown in Fig. 8. The load on the network is equally distributed which avoids overloading of nodes near the base station. The dead nodes in other two algorithms are concentrated in particular region of terrain due to unequal load balancing strategy.

CONCLUSION

In this study, we have presented the results obtained for Lack of Power Avoidance (LoPA) using the heuristic algorithmic concept of fault classification based fault tolerant framework. The heuristic algorithm introduced in this paper could perform better compared to earlier works in reliable energy aware communication in WSN such as LEACH and PSO-C. It is found from our simulation experiments that the number of alive nodes is good over dead nodes. This situation can better prolong the lifetime of sensor nodes leading to reliable inter cluster communication. Our future work (in progress) aims at scalability and trustworthy issues for reliable communication in WSN and also to provide detail of the real time implementation.

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