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Efficient Utilization of Energy using Fault Tolerant and Mobility Aware Routing Protocol for Mobile Wireless Sensor Network

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***Abstract*-- Fault Tolerance is becoming an important aspect to achieve reliability in Wireless Sensor Network (WSN), and also to use the energy efficiently as WSN are resource constrained. Designing energy efficient and reliable routing protocols for mobility centric applications such as wildlife monitoring, search and rescue, health monitoring and battlefield surveillance is a great challenge due to the frequent change of network topology. The proposed protocol is hierarchical and cluster based. Also mobility management is performed by using an update slot. Simulation results show that the proposed protocol outperforms in terms of communication energy, throughput, node death rate, delay, etc.**

Keywords – Mobile Wireless sensor networks; Cluster; Energy efficiency; Reliability; Mobility.

I.INTRODUCTION

Recently, Wireless Sensor Network has become an important area of research, as it has attracted a great deal of research interest because of its unique features. WSN consist of connected wireless sensor nodes that have the ability to sense, process and store environmental information and also communicating with other nodes. Initially sensor network were designed keeping static sensor nodes, due to recent advancement in technologies some applications require network with mobile nodes. Such applications include wildlife monitoring, search and rescue, battlefield surveillance, habitat monitoring, etc. these applications requires fault tolerance due to the frequent change in topology.

Fault Tolerance, if we look at the words fault and tolerance, we can define the word fault as a malfunction or deviation from expected performance and tolerance as the capacity for enduring with some faults. Fault Tolerance is the understanding that we will always have faults (or the possibility for faults) in our system and that we have to design the system in such a way that it will be tolerant of those faults i.e. the system should compensate for the faults and continue to function. Thus fault tolerance increases the reliability and availability of the system. The best approach for fault tolerance is multipath routing.

Mobility in WSN can increase its capability to handle coverage and connectivity. Mobility Management of mobile sensors is to deploy sensor to organize a WSN, so that the coverage and connectivity can be achieved. Mobility Management in turn reflects reliability of WSN such a way that the sensors are monitored and managed so that no information is lost.

II.RELATED WORKS

In WSN, Routing is an important task. Routing in WSN is very challenging. The challenging factors and design issues that affect routing process in WSNs are node distribution, energy consumption, data reporting model, fault tolerance, scalability, connectivity, coverage, quality of service, etc. depending on the network structure routing in WSN can be classified into flat-based routing, hierarchical routing and location-based routing. Flat routing protocols are Sensor Protocol for Information Via Negotiation (SPIN), Directed Diffusion, Rumor Routing, Minimum Cost Forwarding Algorithm (MCFA), Gradient Based Routing (GBR), COUGAR, etc. In hierarchical routing protocols nodes play different roles. This concept is utilized to perform energy-efficient routing. In this architecture, lower energy nodes are used to perform the sensing in the target area, while the high energy nodes are used to process and send the information to the destination. Hierarchical routing requires cluster formation. Hierarchical routing protocols are Low Energy Adaptive Clustering Hierarchy (LEACH) [1] this protocol was designed keeping static sensors in mind. Power Efficient Gathering in Sensor Information System (PEGASIS) [2] a chain-based protocol. It introduces excessive delay for distant node in the chain. Threshold-sensitive energy-efficient sensor network (TEEN) [3], adaptive TEEN [4] and hybrid energy-efficient distributed clustering are some examples of energy-efficient and hierarchical routing protocol for WSN. However, all these protocols consider static WSN only.

Moreover, the protocol does not consider mobility of the sensor nodes and the BS. The modified LEACH (MLEACH) is an extension of the LEACH protocol, which can handle mobility of sensor nodes. However, M-LEACH, again, does not consider mobility in the BS. LEACH is also enhanced in order to support mobile sensor nodes. Node mobility in the WSN is supported by adding membership declaration to the LEACH protocol. It declares the membership of a cluster as they move and assures whether sensor nodes are able to communicate with a specific CH node. This version also does not support mobility in the BS.

Low Energy Adaptive Clustering Protocol (LEACH) is for homogeneous networks, where every node has the same energy initially. During the cluster formation phase of LEACH, clusters are formed and a node A is chosen as a cluster head (CH) if a arbitrary number (between 0 and 1) chosen by A is less than the threshold value. In steady state, each non-CH node sends data at its allocated time slot to CH that will aggregate and send data to base station (BS).

A cluster formation is set up in every round, which is not energy efficient. LEACH also does not support mobility. LEACH-Mobile (LEACH-M) [1] is an enhancement of LEACH routing protocol and has the setup phase as that of LEACH. CH sends data request packet to the member node m at its allocated time slot that ensures the communication of the node m with CH even if m is in motion. For this purpose, CH, n waits two time slots of two consecutive frames to decide whether the node m has moved. The node m does not send any data at its allocated time slot to n until it receives Data-Request from n. If the node m does not receive any Data Request at the beginning of a time slot from n then m goes to the sleep mode and waits for the Data-Request from n until the next frame. If m does not receive the Data Request in the next frame it requests for a JOIN-ACK message to join a new cluster in its vicinity of m. Similarly, if the CH does not receive data from m in two consecutive frames CH removes the time slot of m considering that m has moved. CHs are assumed stationary. Hence, LEACH-M is not efficient in terms of energy consumption and data delivery rate because a number of packets are lost if the CH keeps moving before selecting a new CH.

To mitigate this problem, LEACH-Mobile-Enhanced (LEACH-ME) was proposed, where a node with the lowest mobility is selected as CH. Mobility factor is measured based on the number nodes movement outside of a cluster. Exactly, mobility factor is calculated in an extra time slot of a frame by multiplying node’s velocity with the time needed to move a node from one position to another. In steady phase, a non-CH node m might not receive data request packet from CH due to the mobility of m to a new location. In this case, if CH does not receive any acknowledgement from m in two time slots in consecutive frames, CH assumes that m has moved and deletes the time slot of m.

Cluster Based Routing protocol for Mobile Nodes in WSN (CBR Mobile-WSN) [5] reduce the energy consumption and packets loss rate of LEACH-M. Each CH keeps some free time slots for incoming mobile nodes from other clusters to join its cluster. If CH does not receive data from a non-CH node m even after sending a data request, the CH discards the membership of m, at the end of the frame. Consequently, if the node m does not receive Data Request message from its CH, m tries to join in a new cluster to avoid packets loss. In another scenario, if m moves and does not receive any Data Request message from CH, m sends its data to the free CH to avoid packet loss. Then m sends a registration message to CH of a nearby cluster. Moreover, each sensor node m wakes up one time slot before its scheduled time slot to whether a time slot has really been assigned to it. If m has not been assigned any time slot it goes back to the sleep mode. This phenomenon reduces energy consumption of CBR-Mobile.

Energy- Efficient and Reliable Routing (E2R2) protocol [9] was proposed to provide an energy efficiency and reliability through the use of Deputy Cluster Head (DCH). This protocol takes into account the mobility of the sensor nodes while routing decisions are made. DCH is used to increase the lifetime of the network. This protocol also makes use of cluster head (CH) panel which also increase the lifetime of the network. Moreover, this protocol ensures reliability in terms of packet delivery at the BS through which the throughput can be increased. But this protocol also has extra timeslot for a new node.

III. PROPOSED WORK

In this section, the working principle of the proposed Fault Tolerant and Mobility Aware Routing Protocol for Mobile WSN. The various phases of the proposed work is analyzed in detail.

1. *Cluster Formation and Cluster Head Selection*

In this proposed approach, the clustering is done at the base station during the first round and it is not done after every round. After n number of rounds, clustering is being done. After clustering, base station determines the appropriate cluster head for each cluster, so during the first round base station selects node near to centre of the cluster as cluster head. Base Station also determines the primary path and secondary path for the cluster heads to follow to route the data to base station. If the Cluster Head on primary path fails, the secondary path is being followed by the cluster heads and in this way fault tolerance is achieved during routing between cluster heads. After cluster head selection, base station broadcasts the information about the selected cluster heads and primary and secondary path.

After every round the cluster head selects the new cluster head for next round until clustering is done. So for that, node with less distance and mobility and remaining energy greater than the threshold energy which determines the minimum energy required to be a cluster head is selected as cluster head for the next round. And these cluster heads broadcast its position to base station and base station creates primary and secondary path for it and broadcast the paths to cluster heads.

So after n number of rounds, the clustering setup is done and now base station made new clusters and assign cluster head which is determined on the basis of its relative position and the energy left. During clustering the cluster area is determined by the base station and base station broadcasts it to the nodes in the network and nodes accordingly join the cluster area in which it is present. So the cluster sizes are different based on the distance of the cluster. The clusters which are nearer to the Base Station are smaller in cluster size as compared to the clusters located far from the base station. As the clusters near to the base station have to forward the data of another clusters that are located far in a multi hop way, so these cluster consumes more energy as compared to the cluster that are located.

So to balance the energy consumption in different clusters we consider less number of mobile nodes present in cluster near to the base station. So it will have to receive data from less number of nodes to forward it to the base station and its make network balanced in terms of energy consumption.

2. *Scheduling Phase*

The mobile node sends registration message to the cluster head in its cluster and then cluster head make TDMA schedule for them and broadcast this schedule to mobile nodes in the cluster and also let them know about the event to be sensed and then data transmission phase starts.

In TDMA schedule there is an update slot at the end for mobile nodes to join the cluster or to send message to Cluster Head to tell about its presence in cluster i.e. IN_CLUSTER message. In data transmission phase, nodes send their data according to the time slot assigned to it in a TDMA schedule along with the mobility information of that node. If the node does not have the data to send it can send the special packet to cluster head. And to check the node mobility two cases are there:

1. If any mobile node does not receive an acknowledgement from its cluster head, it localize itself with the procedure described in [10] and if its current position is within the cluster then it wakes during update slot and send IN_CLUSTER message to cluster head. If the mobile node receives a keep message from cluster head then it send data according to previous time schedule or else it send join request to join new cluster head.
2. If cluster head does not receive data or special packet, then cluster head marked that node as check node. And if cluster head receive IN_CLUSTER message from that node in update slot then cluster head keeps the time slot for that node else it will assign that slot to the node that moves inside the cluster.

3. Data Transmission Phase

In data transmission phase it is done in rounds and every round have certain number of frames in which data is being forwarded to base station. At the end of each frame there is an UPDATE slot which is used for mobility management. Clustering is not done after every round but after N rounds. After every round the new cluster head is being selected by the previous cluster head for that cluster on the basis of less mobility and energy left that should be above the threshold energy i.e. the minimum energy required to become the cluster head for the next round. Cluster Head election is done by the Base Station during first round and after every clustering phase. During every intermediate round previous cluster head selects the new cluster head based on low or no mobility and distance. If two nodes are with low mobility, the one with less distance to center of cluster is elected as Cluster Head.

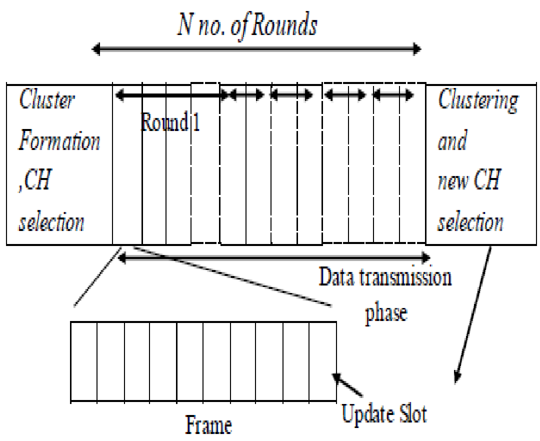

Fig. 1.Setup and Data Transmission Phase

In fig. 1, the data transmission in rounds has been described. Initially cluster formation and cluster head selection is done in setup phase and then data transmission phase starts. In data transmission phase it is done in rounds and every round have certain number of frames in which data is being forwarded to base station. At the end of each frame there is an UPDATE slot which is used for mobility management.

Clustering is not done after every round but after N rounds. After every round the new cluster head is being selected by the previous cluster head for that cluster on the basis of less mobility and energy left that should be above the threshold energy i.e. the minimum energy required to become the cluster head for the next round.

4. Mobility Management Phase

To detect cluster head failure during data transmission from cluster members to cluster head, if cluster member does not receive acknowledgement from cluster head and node location is within the cluster then node again send IN_CLUSTER message to cluster head in update slot if again node does not receive reply form cluster head, node informs base station about no response from cluster head. Now Base Station check the cluster head status, if it get failed then it inform node for reelection of cluster head otherwise inform node to send Join request. In this way fault tolerance is achieved during data transmission from cluster members to cluster head. As the node moves out of cluster it need to update its location through mobile anchor nodes

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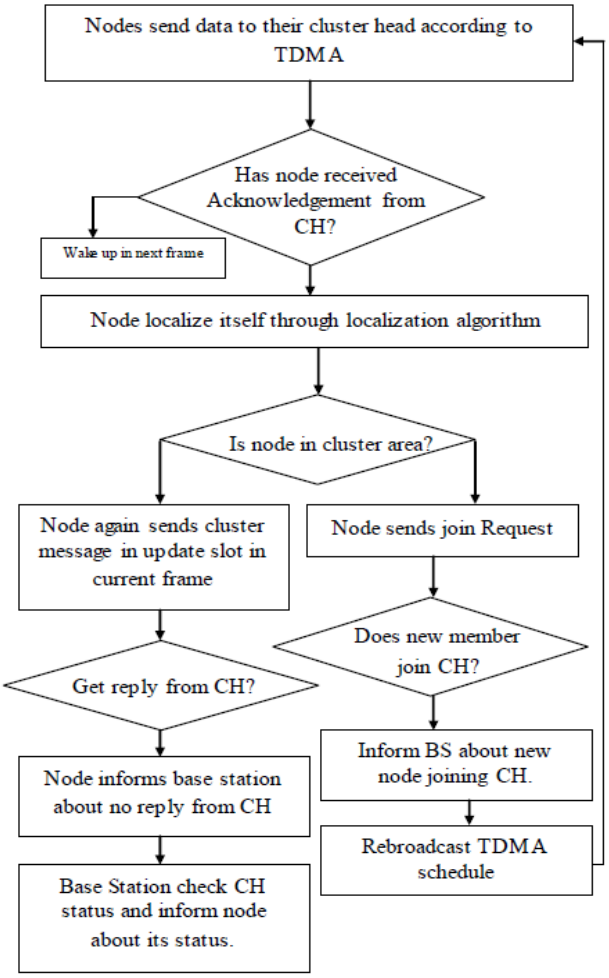

Fig. 2.Mobility Management during data transfer.

Base Station also broadcast the primary and secondary path for cluster heads to follow to forward data to base station. So for this Base Station determine primary and secondary path by dividing cluster heads in three levels labeled as level 0, 1, 2 based on maximum Receive Signal Strength Indicator(RSSI) from these cluster heads as in Fig 3. Then Cluster head in Level 2 forwards its data to nearest cluster head in level 1 and level 1 forward the aggregated date to nearest cluster head present in level 0. Finally Cluster Head in level 0 forward the aggregated data to the base station. So for this Cluster Head follows primary paths, if any node on primary path fails then cluster heads follow secondary path to forward the data to Base Station.

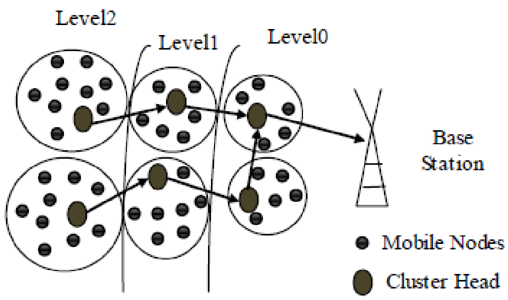

Fig. 3.Showing Cluster head distribution in levels

IV. SIMULATION RESULTS

The performance of the proposed routing protocol is verified through simulation experiments. The parameters used for the comparison of existing protocol with the proposed protocol are energy level, throughput versus network size and node death rate. the simulation is done by using MATLAB version R 2014a.

TABLE I. Simulation Parameters and their values

Parameter	Value
Network size	100 X 100 meter
Number of nodes Maximum	200
Number of clusters Maximum	16
Base station position	90 X 170
Number of Rounds	50

Users are allowed to input the number of nodes, cluster, rounds, and cluster formation phases in the simulator.

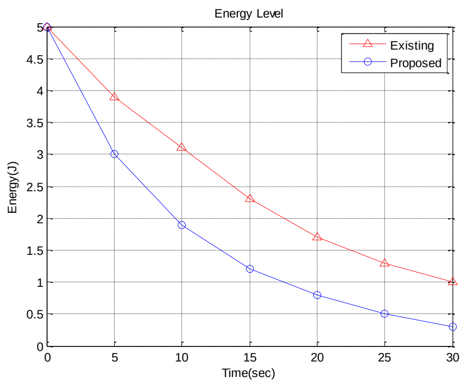

Fig.4. Energy level

Fig.4 depicts the behavior of the proposed protocol in terms of energy level. It is the average energy spent on communication in the network over a period of time. It is clear that the energy spent is low for the proposed system than in the existing system.

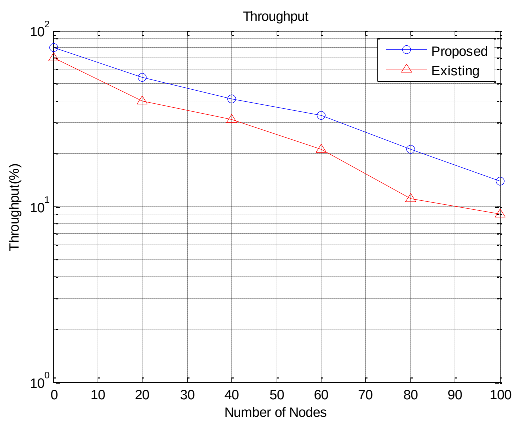

Fig. 5. Throughput versus network size

Fig.5. shows that the throughput with respect to the network size is high when compared to the existing protocol. This states that the number of packets delivered successfully is more in FTCP-MWSN protocol

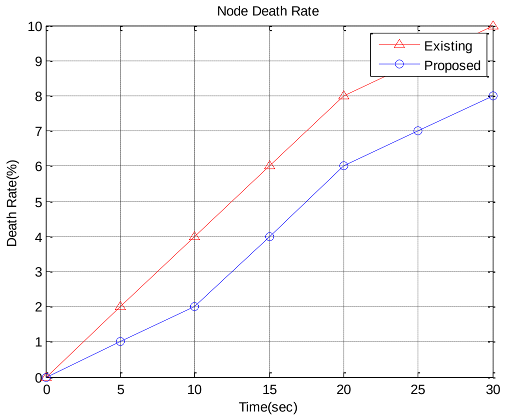

Fig. 6. Node Death Rate

Fig.6 depicts the number of nodes that died at different time intervals over the entire simulation time. It is clear that the proposed protocol increases the lifetime of the network.

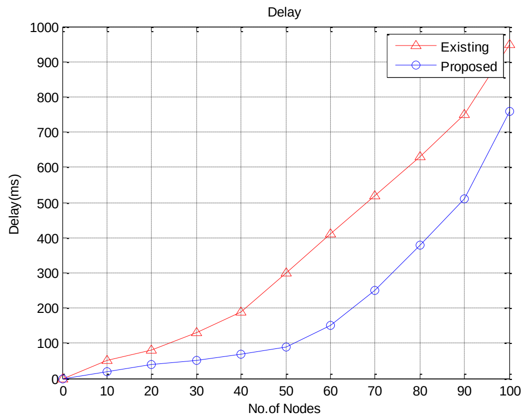

Fig. 7. Delay

Fig. 7. shows that the delay is low compared to existing protocol.

V. CONCLUSION

In this work, a fault tolerant and mobility aware routing protocol that supports mobility in Wireless Sensor Network (WSN) is proposed. This protocol makes use of special packets, which are sent by non cluster head (non-CH) nodes to CH when non-CH nodes have no sensed data to send, to detect mobility and failure of nodes. Simulation results show that the proposed protocol is more energy efficient in terms of network lifetime than the existing E^2R^2 routing protocol. Moreover, this can detect the failure of sensor nodes and reduce delay.

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