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Conference Paper · June 2011

DOI: 10.1109/icc.2011.5962583 · Source: DBLP

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This full text paper was peer reviewed at the direction of IEEE Communications Society subject matter experts for publication in the IEEE ICC 2011 proceedings

Energy Efficient and Fault Tolerant Routing Protocol for Mobile Sensor Network

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Abstract – **Designing energy efficient and reliable routing protocols for mobility centric Wireless Sensor Networks (WSN) applications such as wildlife monitoring, battlefield surveillance and health monitoring is a great challenge due to the frequent change of the network topology. Existing cluster-based routing protocols such for LEACH-Mobile, LEACH-Mobile-Enhanced, and CBR-Mobile that are designed for mobile sensor network consider only the energy efficiency of sensor nodes. Moreover, these protocols allocate extra timeslots using TDMA scheme to accommodate nodes that enter a cluster due to mobility and thus, increase the end-to-end data transmission delay. In this paper, we propose a Fault Tolerant Clustering Protocol for Mobile WSN (FTCP-MWSN) that is not only energy efficient but also reliable. Moreover, FTCP-MWSN does not require any extra timeslot for calculating the mobility of sensor nodes and thus, provides faster data delivery to base station (BS). Simulation results show the FTCP-MWSN protocol has more network lifetime and reliability than the existing LEACH-Mobile and LEACH-Mobile-Enhanced protocols**.

Keywords – *Mobile Wireless Sensor Network, Fault Tolerance, Cluster-based Routing Protocol, Mobile Sensor Node, and Mobility Factor etc.*

I. INTRODUCTION

Designing energy efficient routing protocols for resource constrained WSNs is highly important. Clustering-based routing protocols are considered as more energy efficient since in these protocols, cluster head (CH) produce limited useful information from a large amount of raw sensed data by member nodes in a cluster and transmit this precise useful information to the base station (BS) of a network that consumes less energy [1, 4]. Most clustering protocols of WSN in the literature are designed for static sensor nodes and thus, not suitable for WSN applications that require mobile sensor nodes such for habitat monitoring, wildlife monitoring, and heath. Low Energy Adaptive Clustering Protocol (LEACH) [2] is a standard clustering protocol of WSN. LEACH is enhanced as LEACH-Mobile [3], LEACH-Mobile-Enhancement [7], and Cluster Based Routing protocol for Mobile Nodes in Wireless Sensor Network (CBR Mobile-WSN) [1] to support mobility of sensor nodes. These protocols assume that if a non-CH sensor node does not receive a data request packet from CH, or CH does not receive data from a non-CH node after sending data request packet, the non-CH node has moved from its previous location. Then, the moved non-CH node tries to find a new CH node or cluster. The CH also discards the non-CH node from its allocated timeslot and allocates this free timeslot to a new mobile member node of the cluster. But this scenario may arise not only for mobility but also for the failure of a CH or non-CH cluster member. Thus these protocols cannot detect the failure of sensor nodes. Moreover, these protocols initiate a cluster formation phase at every round, where a round comprises a number of cluster formations and steady phases. This is also not considered as energy efficient since a large number of messages are transmitted to and from a cluster. To alleviate these problems, we propose a Fault Tolerant Clustering Protocol for Mobile WSN (FTCP-MWSN). In this protocol, a special packet is sent by a non-CH node if it has no sensed data to send to the CH at its allocated timeslot and thus, saves energy by not sending data at every timeslot. At the end of a round, a node with the least mobility is selected as a new CH. The mobility of a node is the ratio of the number movements of a node inside and outside of its cluster. Moreover, if CH does not receive data from a node x at its allocated timeslot the CH deletes x from the member list, discards the timeslot of x and also notifies BS the ID of x. If x moves to a new cluster it sends a join request to the CH of this new cluster. If CH accepts the join request it sends the ID of x to BS. Thus, if BS receives the ID of node x in two consecutive frames, BS assumes that node x has moved. Otherwise, node x is considered as a failed node.

The remainder of this paper is organized as follows. Section II presents some existing mobile clustering protocols of WSN. Section III presents the working principle of FTCP-MWSN protocol with pseudo-code. In Section IV, the performance of FTCP-MWSN protocol is analyzed and evaluated through computer simulation in terms of network lifetime, and end-to-end delay. Section V concludes the paper with some future research directions.

II. RELATED WORKS

Low Energy Adaptive Clustering Protocol (LEACH) [4] works well for homogeneous networks, where every node has the same initial energy. In the cluster formation phase of LEACH, clusters are formed and a node A is selected as a cluster head (CH) if a random number (between 0 and 1) chosen by A is less than a threshold value. In steady state, each non-CH node sends data at its allocated timeslot to CH that aggregates and sends data to base station (BS). A cluster formation is initiated in every round, which is not energy efficient. Moreover, occasionally all CHs exist in a close area and thus, non-CH nodes require more energy to communicate CHs. LEACH also does not support mobility. Thus, the work done by Do-Seong Kim D.S and Chung Y.J. [3] propose LEACH-Mobile (LEACH-M) routing protocol that has the setup phase as the LEACH. CH sends data request packet to the member node x at its allocated timeslot that ensures the communication of the node x with CH even if x is in motion. For this purpose, CH, y waits two timeslots of two consecutive frames to decide whether the node x has moved. The node x does not send any data at its allocated timeslot to y until it receives Data-Request from y. If the node x does not receive any Data Request at the beginning of a timeslot from y then x goes to the sleep mode and waits for the Data-Request from *y* until the next frame. If *x* does not receive the Data Request in the next frame it requests for a JOIN-ACK message to join in a new cluster in its vicinity of *x*. Similarly, if the CH does not receive data from *x* in two consecutive frames CH removes the timeslot of *x* considering that *x* has moved. However, LEACH-M assumes that the CHs are stationary. Hence, LEACH-M is not efficient in terms of energy consumptions and data delivery rate because a large number of packets are lost if the CH keeps moving before selecting a new CH. To alleviate this problem, Kumar G.S. et al. propose LEACH-Mobile-Enhanced (LEACH-ME) [7, 8], where a node with the lowest mobility factor is selected as CH Mobility factor is calculated based on the number nodes movement outside of a cluster. More elaborately, mobility factor is calculated in an extra timeslot of a frame by multiplying node's velocity with the time required to move a node from a position to another. In steady phase, a non-CH node *x* might not receive data request packet from CH due to the mobility of *x* to a new location. In this case, if CH does not receive any acknowledgement from *x* in two timeslots in consecutive frames, CH assumes that *x* has moved and deletes the timeslot of *x*. However, LEACH-M consumes much energy for determining mobility factor of each node in extra slots. The work done by Samer A.B. Awwad et al. proposes [1] Cluster Based Routing protocol for Mobile Nodes in WSN (CBR Mobile-WSN) that reduce the energy consumptions and packets loss rate of LEACH-M. Each CH keeps some free timeslots for incoming mobile nodes from other clusters to join its cluster. If CH does not receive data from a non-CH node *x* after sending a data request, he CH discards the membership of *x*, at the end of the frame. Consequently, if the node *x* does not receive Data Request message from its CH, *x* tries to join in a new cluster to avoid packets loss. In another scenario, if *x* moves and does not receive Data Request message from CH, *x* sends its data to the free CH to avoid packet loss. Then *x* sends a registration message to CH of a nearby cluster. Moreover, each sensor node *x* wakes up one timeslot before its scheduled timeslot to whether a timeslot has really been assigned to it. It *x* has not been assigned any timeslot it goes back to the sleep mode. This phenomenon reduces energy consumptions of CBR-Mobile.

III. PROPOSED MOBILE ROUTING PROTOCOL

In this section, we present the working principle of the proposed Fault Tolerant Clustering Protocol for Mobile WSN (FTCP-MWSN) with Pseudo-code.

A. Working Principle

The FTCP-MWSN protocol works into the following phases.

1. *Cluster Formation and Cluster Head Selection*

Base station (BS) forms clusters based on the geographical locations of sensors and selects cluster heads (CHs) based on the residual energy and position of the sensors. Since all nodes have the same initial energy CH is selected based on a random number (between 0 and 1) and CH probability, which is similar to the method used in the LEACH protocol [2, 4]. Once CHs are selected they broadcast their positions and IDs. A node *x* is assigned to a cluster if the CH of that cluster is at the minimum distance with *x*. The node *x* then sends a registration message to the CH with its ID and current location. CHs send cluster information to BS for centralized control and operations. We assume that each CH that is selected at the beginning of a round is static until a new CH is selected in the next round based on the mobility factor of nodes. After a number of rounds a new cluster formation and CH selection phase is initiated to balance the network energy consumptions. Once the network operation starts and nodes move at a fixed (low) velocity, each node keeps track of the number of movements inside and outside of its current cluster based on which node's mobility is calculated at each round.

2. *Steady Phase*

In the steady phase, CHs assign timeslots to the member nodes using TDMA scheme. Member nodes of a cluster transmit data, receive acknowledgements from the CH, and count their movements inside and outside of the cluster at their allocated timeslot. Thus, no extra timeslot is required to calculate nodes mobility. We also assume that all nodes are homogeneous in terms of mobility and so, while a node moves out of a cluster there is a high probability of another node entering into that cluster. However, if a node moves into a new cluster and sends JOIN-REQUEST message to CH, the CH does not allocate the node a timeslot until any timeslot becomes free for moving a node out of this cluster.

CH subscribes to each node *x* for some events of interest such as "notify if the temperature exceeds 70 degree". Whenever the node *x* sense the subscribed events at its allocated timeslot, the node *x* sends data packet to CH. In case of no such sensed event of interest, the node *x* sends a small sized special packet to notify CH that it is still alive or within the communication range of CH (i.e., it has not moved). After receiving the data or special packet CH replies to *x* with an ACK packet. If a CH does not receive any data or special packet from *x* at its allocated timeslot the CH assumes that the node *x* either has moved out of the cluster or failed. Then CH deletes the node *x* from its members list and also the timeslot allocated to *x*. CH also notifies BS the ID of *x*. On the other hand, whenever *x* does not receive any ACK packet from CH, *x* assumes that it is no longer attached to its CH due to mobility. Then *x* broadcasts a JOIN-REQUEST packet and the CHs that are within the communication range of *x* and also have free timeslot replies *x* with an ACK-JOIN packet. Then *x* registers to the cluster of the CH from which *x* receives the ACK-JOIN packet with the highest signal strength (i.e., the CH which is at the shortest distance). This new CH of *x* then allocates a timeslot for *x* and notifies BS. If the ID of this new cluster member *x* does not match with the ID of the sensor node which was reported to BS either as moved or died at the previous frame, BS identifies the node *x* as failed because if it is not dead it obviously sends JOIN-REQUEST and later, BS knows the ID of this node. Figure 1 illustrates the working principle of different phases of FTCP-MWSN protocol.

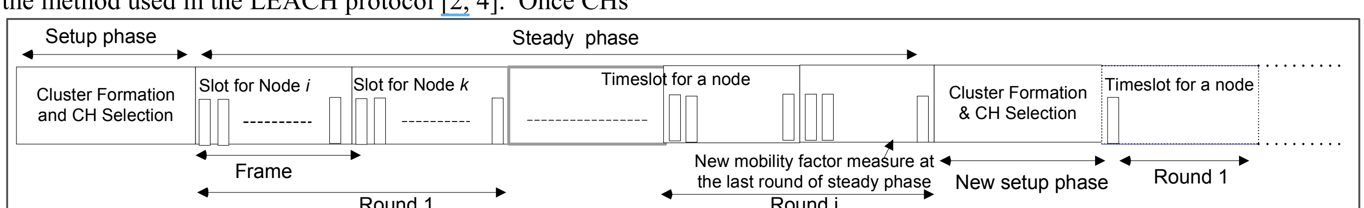

Figure 1: Different Phases of FTCP-MWSN protocol

3. *Nodes Mobility Determination*

The node with the lowest mobility factor in a cluster is selected as a CH if its residual energy is above a threshold value. The mobility factor is determined as the probability of a node to move into a different cluster during the steady period and is calculated as the ratio of the number of times a node enters different clusters to the number of times a node changes positions within a cluster. Hence, the least number of times a node enters other clusters it will have the least mobility factor. Each node keeps track of the current time of the beginning of its allocated timeslot in two consecutive frames. Let the current time at the beginning of a timeslot is t_1. Since the node can move, it estimates the distance d it has travelled at the beginning of timeslot t_2 in the next frame as

$$d = \left| t_2 - t_1 \right| \times velocity \qquad (1)$$

If $d > 0$ and the node does not receive any ACK from its CH then it broadcasts a JOIN-REQUEST message that represents nodes mobility into a different cluster. Otherwise, the node counts its movement as within its own cluster. Then each node x measures its mobility as

$$mobility_x = \frac{CountMoveOutOfCluster_x}{CountMoveInsideCluster_x} \qquad (2)$$

B. *FTCP-MWSN Algorithms*

The pseudo-code of the FTCP-MWSN protocol, based on the working principle, is presented as follows.

Initial State (Cluster formation, Initial CH selection)

BS broadcasts *ID*, *Position*, *Initial Energy* and *CH probability* of each node to the network
BS assigns *ClusterArea, NoOfClusters* and *ClusterID*
for *i* ← 1 to *NoOfNodes* **do //Assign node to a cluster**
  for each *cluster j* **do**
    if *Position*[*Node*[*i*]]∈ *ClusterArea*[*ClusterID*[*j*]] **then**
      Node[*i*] ← *ClusterID*[*j*]
    end if
  end for
end for

for each *node j* in a *cluster i* **do //initial CH selection**
  CHProbNode[*i*][*j*] ← *random*(0,1)
  if *CHProbNode*[*i*][*j*] <= *CH Probability* **then**
    CH[*i*] ← *Node* [*j*]
    CH[i] subscribes events to *Nodes*[*j*] of *Cluster*[*i*]
  end if
end for

Steady State (TDMA, Mobility Calculation, new CH selection, Data/Special packet sending)

for each *frame f* in each *round r* **do**
  for each *node j* of a *Cluster k* ← *t* (a time slot) **do**
    if (*node*[*k*][*j*] has an sensed event) **then**
      node[*k*][*j*] sends data to CH
      Calculates *DataEnergyConsumption*[*k*][*j*]
      Calculate *ReceiveEnergy* of *CH*[*k*]
      CH sends ACK to node[*k*][*j*]
    else //send special packet for mobility & fault tolerance
      node[*k*][*j*] sends a *special* packet to CH
      Calculate *SpecialEnergyConsumption*[*k*][*j*]
      Calculate *ReceiveEnergy* of *CH*[*k*]
      CH sends ACK to node[*k*][*j*]
    end if
    if *node*[*k*][*j*]] moves inside *Cluster k* **then**
      ++CountMoveInsideCluster[*node*[*k*][*j*]]
    end if
    if CH not receive data/special from *node*[*k*][*j*] **then**
      delete *node*[*k*][*j*] & timeslot of *node*[*k*][*j*]
      notify BS about *node*[*k*][*j*] sending MOVED-NODE
    else if *node*[*k*][*j*] not receive ACK from CH **then**
      Broadcast JOIN-REQUEST
      CH within shortest communication range replies with ACK-JOIN & notify BS the ID of *node*[*k*][*j*] using NEW-NODE
    end if
    if BS receives NEW-NODE & MOVED-NODE for *node*[*k*][*j*] in two consecutive frames **then**
      mark *node*[*k*][*j*] as a moved-node
      ++CountMoveOutsideCluster[*node*[*k*][*j*]]
    else if CH receives NEW-NODE or MOVED-NODE
      mark *node*[*k*][*j*] as failed **//fault tolerance**
    end if
  end for //each node
  CH[*k*]aggregates Data and Sends to BS
  CHEnergyConsumption[*k*] for aggregating, sending to BS
end frame
CH[*k*] selects new CH with least mobility calculated as

$$Mobility[node[k][j]] = \frac{CountOutsideCluster[node[k][j]]}{CountInsideCluster[node[k][j]]}$$

Calculate *CHEnergyConsumption*[*k*] for new CH Selection
Calculate number of frames for the next round as

$$NoOfFrames = \left\lceil \frac{PrevNoOfFrames}{PrevNetEnergy} \times CurrentNetEnergy \right\rceil$$

end for //round

Iterate **steady state** for a certain number of rounds and then go back to cluster formation and CH selection based on nodes mobility factor as shown in the steady state.

C. *Major Differences with Existing Approaches*

Setup phase is initiated after a certain number of rounds in FTCP-MWSN protocol, whereas in LEACH-M, LEACH-M, setup phase is initiated at every round. Since setup phase consumes much energy for a large number of control message transmissions, the proposed FTCP-MWSN protocol is expected to be more energy efficient. Moreover, in LEACH-M and LEACH-ME, CH sends DATA-REQUEST to nodes and nodes also send data packets at every timeslot. In FTCP-MWSN protocol, events are subscribed to sensors and when these events occur sensor nodes send data packets; otherwise, sensors send small sized special packets, which consume much less energy as compared to large data packets. Thus, FTCP-MWSN is considered to be more energy efficient.

To achieve reliability or detect the failure of nodes, CH sends the ID of the sensor nodes to BS, which has been moved out of the cluster and also the ID of the node which sends JOIN-REQUEST packet. Though these data transmissions are not required in existing protocols, FTCP-MWSN achieves reliability at the cost of these extra messages transmissions. In LEACH-ME, CH allocates an extra timeslot during when the mobility of each member node is measured by broadcasting messages among sensor nodes. This results an extra processing overhead, a large number of message transmissions, and thus, more end-to-end delay. In FTCP-MWSN protocol, no extra timeslot is needed to calculate the nodes mobility. On the other hand, in LEACH-M, a node requires timeslots in two consecutive frames to determine whether it has moved and then requests for join the new cluster. This results more packet losses, which is not the case for the FTCP-MWSN protocol since a node does not wait timeslots in two consecutive frames to know whether it is still in the same cluster or has moved. Moreover, in FTCP-MWSN protocol, the number of frames that constitutes a round is not fixed. CH determines the number of frames at the beginning of each round based on the residual energy of network. Table I presents the comparison of FTCP-MWSN protocol with LEACH-M and LEACH-ME on some important features.

Table I. Comparison of FTCP-MWSN, LEACH-M &LEACH-ME

Features	Routing Protocols		
	LEACH -M	**LEACH - ME**	**FTCP-MWSN**
CH subscribes for events to member nodes	X	X	√
Member nodes send special packets to CH if they do not have any subscribed event to notify	X	X	√
Setup is initiated at every round	√	√	X
Extra timeslot is required to calculate mobility of nodes	X	√	X
Fault tolerance	X	X	√
Each node updates information and calculates mobility factor at timeslot of the last round of steady phase	X	X	√
Extra timeslot is used in a frame	X	√	X
Number of frames in a round is determined at the end of round	X	X	√

IV. EXPERIMENTAL DESIGN

The following subsections present mathematical analysis, simulation setup, and results with performance analysis.

A. *Performance Analysis*

The energy consumptions of a node for sending data packet of size n_{data} bytes to Cluster Head (CH) at the distance d is

$$E_{data}(n_{data}, d) = n_{data}(E_{elec} + d^2 \varepsilon_{elec}) \quad (3)$$

Similarly, energy consumptions of a node for sending a special packet of size n_{spec} bytes to CH at the distance d is

$$E_{spec}(n_{spec}, d) = n_{spec}(E_{elec} + d^2 \varepsilon_{elec}) \quad (4)$$

In Equations (3) and (4), E_{elec} represents the energy consumptions of radio for driving the transmitter (50 nJoule/bit) and ε_{elec} represents the transmitter amplifiers energy dissipation (100 pJoule/bit/m^2). We assume that the probabilities of a node to send data and special packet are P_{data} and P_{spec} respectively. Hence, the total energy consumptions of a node considering that each node either sends the subscribed data packet or special packet is

$$E_{TX-FTMWSN} = P_{data} \times E_{data}(n_{data}, d) + P_{spec} \times E_{spec}(n_{spec}, d)$$

$$= P_{data} \times n_{data}(E_{elec} + d^2 \varepsilon_{elec}) + P_{spec} \times n_{spec}(E_{elec} + d^2 \varepsilon_{elec})$$

$$= (P_{data} \times n_{data} + P_{spec} \times n_{spec})(E_{elec} + d^2 \varepsilon_{elec}) \quad (5)$$

As the size of the special packet (n_{spec}) is much smaller than that of the data packet (n_{data}), we assume that

$$n_{data} = k \times n_{spec} \text{ where, } k \geq 2 \text{ is a constant} \quad (6)$$

In simulation, we assume the value of k is at least 32. Moreover, P_{data} and P_{spec} are equally likely to occur.

Hence, $P_{data} \times n_{data} + P_{spec} \times n_{spec} < n_{data}$ (7)

Now from Equation 5 we find

$$E_{TX-FTMWSN} < n_{data}(E_{elec} + d^2 \varepsilon_{elec})$$

$$\Rightarrow E_{TX(FT-MWSN)} < E_{TX(LEACH-M)} \quad (8)$$

From Equation 8 we find that the transmission energy consumptions of a node in the FTCP-MWSN protocol are less than that of the LEACH-M protocol. Similarly, the receiving energy consumptions of FTCP-MWSN protocol will be less than that of LEACH-M protocol. Now, we assume that n_{active} bytes are transmitted in the active slot for each node to measure the mobility in LEACH-ME protocol. Thus the transmitted energy consumptions for each node in LEACH-ME is

$$E_{TX-(LEACH-ME)} = n_{data}(E_{elec} + d^2 \varepsilon_{elec}) + n_{active}(E_{elec} + d^2 \varepsilon_{elec})$$

$$\Rightarrow E_{TX-(LEACH-ME)} = E_{TX-(LEACH-M)} + n_{active}(E_{elec} + d^2 \varepsilon_{elec})$$

$$\Rightarrow V = E_{TX-(LEACH-ME)} > E_{TX-(LEACH-M)}$$

$$\therefore E_{TX-(LEACH-ME)} > E_{TX-(FT-MWSN)} \quad (9)$$

From Equation 9 we find that the transmission energy consumptions of a node in the proposed FTCP-MWSN protocol are less than that of the LEACH-ME protocol. From this analysis, we can conclude that the proposed FTCP-MWSN protocol is more energy efficient than that of the existing LEACH-M and LEACH-ME protocols. Moreover, FTCP-MWSN protocol provides fault tolerance by using small sized special packets.

B. *Simulation Setup*

We simulate the performance of FTCP-MWSN protocol using *C* programming language. We use randomly connected Unit Disk Graphs (UDGs) on an area of 100 *m* X 100 *m* as a basis of our simulation model. The co-ordinate of BS is assumed to be at 90X170. Table II shows the network parameters and their respective values.

Table II. 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
Data Packet size	512 Bytes
Special packet size	32 Bytes
Energy consumption for sending data packets	50 pJoule
Energy consumption in free space/air	0.01 pJoule
Initial node energy	2 Joule
Cluster head probability	3%
Aggregated packet size	2048 Bytes
Nodes Velocity	0.01meter/sec
Sensors Communication Range	25 meters

Users are allowed to input the number of nodes, clusters, rounds, and cluster formation phases in our simulator. For networks with a fixed number of clusters and nodes, we change the number of rounds at different runs of the simulation.

C. *Simulation Results*

We measure the performance of FTCP-MWSN protocol and compare with existing LEACH-M and LEACH-ME protocols in terms of energy consumptions, end-to-end delay, and number of communications. Figure 2 illustrates that the network energy consumptions of FTCP-MWSN protocol is much less than that of LEACH-M and LEACH-ME protocols. Hence, the network lifetime FTCP-MWSN is more than LEACH-M and LEACH-ME protocols (Figure 3). Number of communications that take place in FTCP-MWSN protocol is also less than the other two protocols as shown in Figure 4.

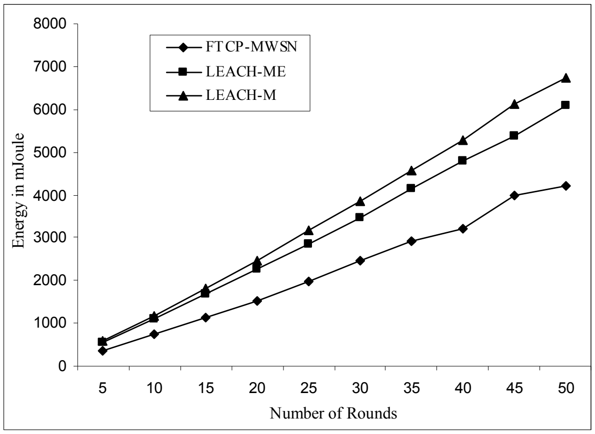

Figure 2: Comparison of Energy Consumptions of the Networks

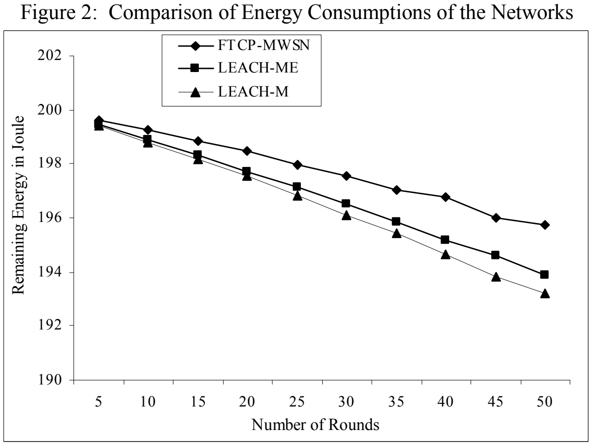

Figure 3: Comparison of Network Lifetime

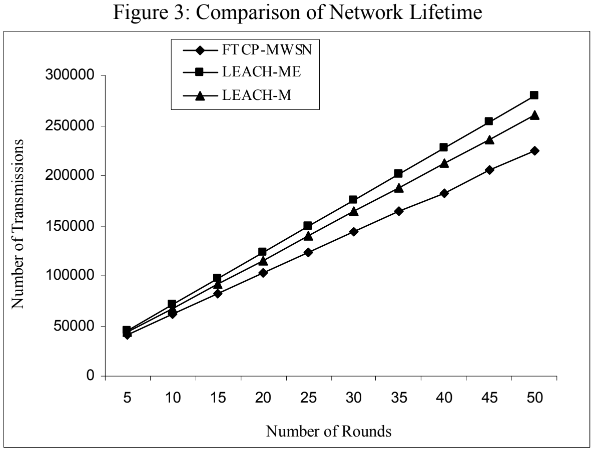

Figure 4: Comparison of Number of Communications

Though Figure 5 demonstrates that the end-to-end delay of FTCP-MWSN is slightly lower than other two protocols, statistical analysis (student's *t*-test at 95% confidence interval) reveals that all these three protocols are same in terms of end-to-end delay. One of the possible explanations is that though we are expecting that mobility of each node are equally likely (if a node *x* enters a new cluster, another node exits that cluster so that *x* has no delay to be allocated a timeslot), in reality this is not the case.

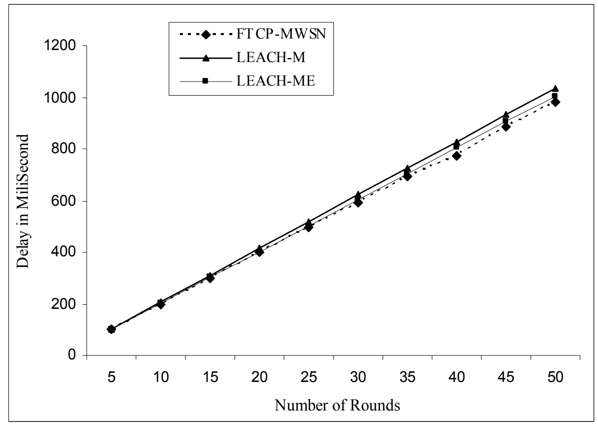

Figure 5: End-to-End Delay of the Networks

V. CONCLUSION AND FUTURE WORKS

In this paper, we propose a fault tolerant and energy efficient clustering routing protocol (FTCP-MWSN) that supports mobility in Wireless Sensor Network (WSN). This protocol uses special packets, which are sent by non cluster head (non-CH) sensor nodes to CH when non-CH nodes have no sensed events to send, to detect mobility and failure of nodes. Simulation results show that FTCP-MWSN protocol is more energy efficient in terms of network lifetime than the existing LEACH-M and LEACH-ME protocols. Moreover, FTCP-MWSN can detect the failure of sensor nodes. Though our analysis reveal that the FTCP-MWSN protocol should have less end-to-end network delay than LEACH-M and LEACH-ME simulations results and statistical analysis demonstrate them same in terms of end-to-end delay. Hence, we aim to consider other factors such as variable length timeslots to reduce the end-to-end delay of FTCP-MWSN protocol as a future work. Moreover, we expect to evaluate the performance of the FTCP-MWSN protocol in terms of energy efficiency, end-to-end delay by varying the velocity of sensor nodes.

REFERENCES

[1] S. A. B. Awwad, C. K. Ng, N. K. Noordin and M. F. A. Rasid, "Cluster based routing protocol for mobile nodes in wireless sensor network," in *Collaborative Technologies and Systems, 2009. CTS '09. International Symposium on,* 2009, pp. 233-241.

[2] F. Bajaber and I. Awan, "Dynamic/Static Clustering Protocol for Wireless Sensor Network," *Computer Modeling and Simulation, 2008. EMS '08. Second UKSIM European Symposium on,* pp. 524-529, 2008.

[3] Do-Seong Kim, Yeong-Jee Chung, "Self-Organization Routing Protocol Supporting Mobile Nodes for Wireless Sensor Network", Proceedings of the First International Multi-Symposiums on Computer and Computational Sciences (IMSCCS'06), 2006

[4] A. Durresia, V. Paruchuri and L. Barolli, "Clustering protocol for sensor networks," *Advanced Information Networking and Applications, 2006. AINA 2006. 20th International Conference on,* vol. 2, pp. 5 pp., 2006.

[5] Feilong Tang, M. Guo, Minglu Li, Zhijun Wang and Zixue Cheng, "Scalable and Secure Routing for Large-Scale Sensor Networks," *Embedded and Ubiquitous Computing, 2008. EUC '08. IEEE/IFIP International Conference on,* vol. 2, pp. 300-305, 2008.

[6] Jieun Cho and Jongwon Choe, "A cluster-based routing protocol for supporting mobile sinks in sensor network," in *Information Networking, 2008. ICOIN 2008. International Conference on,* 2008, pp. 1-5.

[7] G. S. Kumar, M. V. Vinu Paul, G. Athithan and K. P. Jacob, "Routing protocol enhancement for handling node mobility in wireless sensor networks," in *TENCON 2008 - 2008 IEEE Region 10 Conf,* 2008, pp. 1-6.

[8] T. P. Lambrou and C. G. Panayiotou, "A survey on routing techniques supporting mobility in sensor networks," in *Mobile Ad-Hoc and Sensor Network. MSN '09. 5th International Conference on,* 2009, pp. 78-85.