IJARCCE
International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 12, December 2016
ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

Energy Efficient Fault Tolerable Routing Protocol for Wireless Sensor Networks

Ajay Singh[1], Ankit Tripathi[2], and Bharti Chourasiya[3]

[1,2,3]Department of Electronics and Communication Engineering, SCOPE College of Engineering, Bhopal

***Abstract*— Wireless sensor networks provide a significant contribution to the emerging field such as ubiquitous computing and ambient intelligence. Due to the inherent property of WSN, it is most vulnerable for reliability. In literature, most of the authors concern about network longevity and ignore fault tolerance. In this dissertation, we present an energy-efficient fault tolerable routing protocol (EEFT) mechanism for WSN. The major novelty of this work is that sensor nodes can send their data to alternate path during a fault. The energy efficient can be achieves using clustering protocol for routing. The subordinate for each cluster help to tolerate faults occurred in the proximity. The cluster head nodes in proximity propagate aggregated data to base station. The simulation results show that the proposed approach yields better performance than the existing methods. It has observed that the proposed protocol EEFT has better energy utilization than existing EE-LEACH and FTREEP protocols. The EEFT protocol also has better packet delivery ratio than FTEERP; it increased up to 53.60%.**

***Index Terms*— Energy efficiency; wireless sensor network; cluster head selection; fault tolerance.**

I. INTRODUCTION

A Wireless sensor network is a complex system consists a number of small wireless sensor nodes and a base station (BS). Sensor node consists of sensor, processor, memory, RF transceiver (radio), peripherals, and power supply unit (battery) [1]. These sensor nodes are spread over an area of interest and connected in an ad-hoc manner for event detection and collect data for various ambient conditions. The WSN has many applications like disaster management such as earthquake monitoring, tsunami warning, pipeline monitoring systems and flood forecasting. The self-organization, rapid deployment and fault tolerance characteristics of wireless sensor networks make them a very promising sensing technique for military applications [2]. Since WSN has limited resources due to the limited size of the node, either changing or recharging batteries are not feasible. The failure of a single node can prostrate the entire system hence system become unreliable. Data reliability is most important in many critical applications but due to the environmental obstacle and failure of network connection also reduces data reliability. Hence optimized routing with reliable data dissemination can be considered as a very challenging problem in wireless sensor network. This problem imposes many challenges to the researchers for developing energy-efficient fault tolerable protocols.

The routing protocols in sensor networks are classified into three categories: data centric protocols, location based protocols, and hierarchical protocols. This paper considers the hierarchical protocols which deal with organizing network into a two tiers. In this paper, a fault tolerable energy efficient routing protocol is proposed which provides an energy efficient network retain a long time with data dissemination reliability. In this approach, two leaders are selected for fault handling and data transmission. It has been observed that the proposed approach minimizes the missing data between cluster head and its members. It also saves a lot of energy by reducing retransmission and increase stability period of the sensor network.

This paper is organized as follows: Section II presents the related work. Section III consists the network and radio energy model. Section IV presents the proposed EEFT technique in detail. Section V contains simulation setup and results. Section VI concludes with future enhancement of this work.

II. RELATED WORK

A lot of research have been carried out in the area of energy-efficient and fault tolerable routing in sensor networks, which are mainly focused on enhancing the network lifetime.

Low Energy Adaptive Clustering Hierarchy (LEACH) proposed in [3] is the first and most popular hierarchical routing protocols designed to aggregate and disseminate data to the base station for network lifetime enhancement. LEACH obtains energy efficiency by partitioning the nodes into clusters.

Younis [4] presents a protocol, HEED (Hybrid Energy-Efficient Distributed clustering), that periodically selects cluster heads according to their residual energy. The authors do not make any assumptions about the presence of infrastructure or node capabilities, other than the availability of multiple power levels in sensor nodes. However, the proposed algorithms support only for building a two-level hierarchy and lack for multilevel hierarchies.

Karaboga et al. formulated an energy-balanced routing protocol for data gathering. Enhanced mechanisms were used to identify and eliminate the loops [5]. Dervis et al. utilized an artificial bee colony algorithm for energy-efficient clustering. The artificial bee colony algorithm was used to prolong the lifetime of the sensor nodes and the network [6]. Yuea et al. discussed the balanced cluster-based data aggregation algorithm. The sensor network was divided into rectangular grids. For each grid, the cluster head was elected to manage the nodes and balance the load among the sensors [7].

Rout et al. introduced an adaptive data aggregation mechanism based on network coding. Here, the group of nodes acts as network coder nodes and the remaining nodes were used for relaying purpose. The network coder nodes were sometimes

DOI 10.17148/IJARCCE.2016.51208

used as aggregation points based on the measure of the data correlation [8].

Arumugam et al. in [9] proposed an energy-efficient LEACH (EE-LEACH) Protocol for data gathering. It offers an energy-efficient routing in WSN based on the effective data ensemble and optimal clustering. In this system, a cluster head is selected for each cluster to minimize the energy dissipation of the sensor nodes and to optimize the resource utilization. The energy-efficient routing can be obtained by nodes which have the maximum residual energy. Hence, the highest residual energy nodes are selected to forward the data to BS. It helps to provide better packet delivery ratio with lesser energy utilization. The experimental results show that the proposed EE-LEACH yields better performance than the existing energy-balanced routing protocol (EBRP) and LEACH Protocol regarding better packet delivery ratio, lesser end-to-end delay and energy consumption.

Bagci et al. [10] introduced a distributed fault-tolerant topology control algorithm, called the Disjoint Path Vector (DPV), for heterogeneous wireless sensor networks composed of a vast number of sensor nodes with limited energy and computing capability and several nodes with unlimited energy resources (called super-node). The DPV algorithm addresses the k-degree topology control problem where the primary objective is to assign each sensors transmission range such that each has at least k-vertex-disjoint paths to super nodes, and the total power consumption is minimum. The resulting topologies are tolerant to node failures in the worst case. Authors prove the correctness of proposed approach by showing that topologies generated by DPV are guaranteed to satisfy k-vertex super node connectivity.

Hezaveh et al. [11] proposed a Fault-Tolerant and Energy-Aware Mechanism (FTEAM), which prolongs the lifetime of WSNs. This mechanism can be applied to cluster based WSN protocols. The main idea behind the FTEAM is to identify overlapped nodes and configure the most powerful ones to the sleep mode to save their energy for the purpose of replacing a failed Cluster Head (CH) with them. FTEAM not only provides fault tolerant sensor nodes but also tackles the problem of emerging dead area in the network.

Ahmed in [12] considers a problem of connections and vulnerability to frequent node/ link failures in multi-hop wireless sensors networks. The author proposed a new fault-tolerant routing and energy-efficient protocol that modifies the conventional DSR protocol. The protocol tries to find two routing paths (if they exist) from the source to the destination node, considering the present energy levels at intermediate nodes in the path. Results show that the proposed protocol achieves better packet delivery ratio and network throughput as compared to conventional DSR.

Sharma et al. in [13], proposed an algorithm for the wireless sensor network that works on both the major issues, cluster formation based on the energy of cluster heads and fault tolerance of the wireless sensor network. It recovers the matter of cluster head failure. the sensor nodes select efficient or proper cluster head considering a function which primarily consists of residual energy of the CH, based on the distance of cluster head to sensor node and the distance of cluster head to base station. Algorithm works upon two critical parameters first is cluster formation, and another one is fault tolerance. In the first phase i.e. cluster formation, it also takes cares about uncovered sensor nodes or in other words, those sensor nodes which are not covered by cluster head due to some long distance issue, and it also works on the issue of cluster head failure. To tolerate the failure, it avoids reclustering or also avoids the redundant deployment of cluster heads.

Yin et al. in [14], study the fault tolerant topology design problem for an Energy-harvesting Heterogeneous WSN (EHWSN). EHWSN contains a large number of energy harvesting sensor nodes and a few resource-rich nodes (called super-node). The topology design problem aims to build a sparse time evolving topology which not only maintains the connectivity from sensor nodes to super-nodes but also can survive with k-1 node failures. This time-evolving structure can be used for deciding which subset of sensors need to be awake and assigning their transmission ranges. Authors first define the fault-tolerant topology problem in an EHWSN modeled by a space-time graph G, which aims to find a k-connected space-time graph H (a subgraph of G), such that Hs cost is minimized. After that, six heuristics which can significantly reduce the total cost of network topology while preserving the k-connectivity over time is computed.

Kshirsagar et al. in [15] addressed the problem of link failure due to the inability of the nodes in the WSN and with the aim of providing robust solutions to satisfy the QoS-based based end-to-end requirements of communication networks. In this paper, authors propose the new solution by modifying the existing extended fully distributed cluster-based routing algorithm (EFDCB). In this, the faulty nodes or nodes that are more prone to failure in every cluster of the network get identified by exchanging data and mutually testing among neighbor nodes. When nodes establish a path between source and destination, these faulty nodes get excluded in the path selection process, and more stable, less prone to failure path is formed.

Nitesh et al. in [16], proposed an energy efficient distributed algorithm for clustering, called EEFCA, which is also faulted tolerant in nature. The algorithm is based on a range of parameters such as the residual energy of RNs, various distance parameters of RNs and cluster cardinality.

Peng et al. in [17], proposed three network evolution models for generating fault-tolerant and energy-efficient large-scale peer-to-peer wireless sensor networks (WSNs) based on complex networks theory. Being scale-free is one of the intrinsic features of complex networks based evolution models that generates fault-tolerant topologies. In this work, authors argue that fault-tolerant topologies are not necessarily energy efficient. The three proposed energy-aware evolution models are energy-aware common neighbors (ECN), energy-aware large degree promoted (ELDP) and energy-aware large degree demoted (ELDD). ECN considers neighborhood overlap, whereas ELDP and ELDD consider topological overlap for node attachment. The ELDP model promotes the establishment of links to nodes to a large degree, whereas the ELDD model denotes this strategy.

We studied various routing and fault tolerance algorithms;

DOI 10.17148/IJARCCE.2016.51208

the parameter authors took for cluster heads selection are energy, density, distance and location of sensor nodes. There are few algorithms which use one of the parameters for cluster head selection. They do not take many parameters for cluster head selection. The fault tolerance algorithm considers the faulty node and connections between node to node, leader to the base station, leader to another leader. We need such approaches which optimize the path between the node to the head so that reliability of data dissemination increases.

III. NETWORK AND RADIO ENERGY MODEL

In this section assumption about the networks and parameter used in energy, consumption model is described.

A. *Network Model*

The following assumptions on the EEFT are made.

- Sensor nodes and base station are static.
- The base station does not limit by energy.
- Sensor nodes do not become aware of their geographic location.
- Sensor nodes know the relative position of the base station in the field.
- The distributions of sensor nodes are random over the sensing area.
- The sensor nodes are densely deployed in the sensing area. This dense deployment of sensor network achieving Quality of Service.
- Sensor nodes are homogeneous in energy level.
- Sensor nodes can measure the current energy level.

B. *Radio Energy Model*

According to the radio energy dissipation model [18] , to attain an acceptable Signal-to-Noise Ratio (SNR) for transmitting an l -bit message over distance d, the energy consumption by the radio is given by:

$$E_{TX}(l,d) = \begin{cases} lE_{ele} + l\epsilon_{fs}d^2 & if \quad d \leq d_0 \\ lE_{ele} + l\epsilon_{mp}d^4 & if \quad d > d_0 \end{cases} \tag{1}$$

Where E_{ele} is the energy dissipated per bit to run the transmitter or the receiver circuit. ϵ_{fs} and ϵ_{mp} depend on the transmitter amplifier model. d is the distance between the transmitter and the receiver. By equating the two expressions at $d = d_0$, we have $d_0 = \sqrt{\epsilon_{fs}/\epsilon_{mp}}$. To receive an l -bit message the radio expends $E_{RX} = l * E_{ele}$.

The energy dissipated in the non-cluster head node during a round is given by the following formula

$$E_{NCH} = (lE_{elec} + l\epsilon_{fs}d^2_{(NCH-CH)}) \tag{2}$$

Thus, the energy dissipated in the cluster head node during a round is given by the following formula:

$$\begin{aligned} E_{CH} = lE_{elec}N_{mem} + lE_{DA}(N_{mem}+1) \\ + lE_{elec} + 1\epsilon_{mp}d^4_{(CH-BS)} \end{aligned} \tag{3}$$

Where N_{mem} is the number of members in a cluster, d_{CH-BS} is the distance between the cluster head and base station, $lE_{elec}N_{mem}$ is the power that N_{mem} cluster member consume when each of them send data to the cluster head, and $lE_{DA}N_{mem}$ is the power consume by cluster head for data aggregation, when it receives l length data from its cluster member.

IV. PROPOSED METHOD - EEFT

In the FTEER, routing process accomplish in 2 stages, it requires $2 * T_{max}$ (T_{max} is the time require for clustering). In the first step, sensor nodes select a leader called cluster head according to the probabilistic threshold. At the end of the first step, all the cluster heads are selected, and formation of the cluster is accomplished. In the second step, sub-cluster head (sub-CH) selection process starts where all the cluster heads pick a new subordinate from remaining energy and region density. After the completion of the second step sub-cluster head also receive data from cluster members and verify the reception of data to cluster head if data is not received by cluster head then sub-cluster head send missing data to base station. After verification, cluster head sends aggregated data to the base station. It extends the time interval before the first node deceased and preserved the reliability of the network. It is essential for many applications where reliability about feedback needed.

A. *Cluster head selection*

The first stage includes cluster head selection as well cluster formation process. In the cluster head selection procedure, each sensor node chooses a random number between 0 and 1 separately. If this number is lower than the calculated threshold $T(i)$ for node i, then the sensor node i become a cluster head. The threshold $T(i)$ is given by

$$T(i) = \begin{cases} \frac{p}{1-p\times mod(r,round(\frac{1}{p}))} \times \frac{E_r}{E_I} & if \quad i \in G \\ 0 & otherwise \end{cases} \tag{4}$$

where P is the desired percentage of cluster heads, r is current round, and G is the set of nodes that have not been CH in the last $1/P$ rounds. E_r is the remaining energy of sensor node, E_I is the initial energy of sensor node

B. *Cluster formation*

In the process of cluster formation, each cluster heads broadcast a join message within the sensing field. On reception of join message each non-cluster head sensor node decides to join the cluster head, if more than one join messages are received then sensor node join nearest cluster head. After a constant time, interval cluster head received join request messages from non-cluster head sensor nodes. It creates a TDMA schedule for data transmission within the cluster and sends to its cluster members.

TABLE I
SIMULATION PARAMETERS

Parameters	Values
Area	$100 \times 100\ meter^2$
Base station position	$(100m, 100m)$
Total sensor nodes (n)	100
Initial energy	0.5 J
Predefined threshold (p)	0.05
Transmitter/Receiver electronics (E_{elec})	50 nj/bit
Data aggregation (E_{DA})	5 nJ/bit/report
Reference distance (d_0)	87 meters
Transmit amplifier (ϵ_{fs})	10 pJ/bit/m^2
Transmit amplifier (ϵ_{mp})	0.0013 pJ/bit/m^4
Message size (l)	4000 bits

C. Sub-cluster head selection

The second stage consists sub-cluster head selection process and data verification process. In the sub-cluster head selection process each cluster head selects a sub-CH by remaining energy and region density with a random number. Each sensor node in cluster send a $T_s ub$ to the cluster head.

$$T_{sub} = E_r \times N_{rp} \tag{5}$$

Where $N_r p$ is the number of messages received by neighboring nodes.

The sensor node is selected as gateway node which has highest T_{new}. Cluster head selects a node as sub-CH which has highest T_{sub}. The cluster head sends a message within the cluster to inform about the sub-CH. Each cluster members save sub-CH as the second parent node.

D. Data verification and data dissemination

After the sub-cluster head selection, each sensor node in the cluster sends sense data to cluster head and sub-CH. Periodically sub-CH send information about received packet to the respective cluster head. Cluster head verifies sub-CH information to own received data. The missing data can be recovered by merging these data. After verification, cluster head sends aggregated data to base station. The EEFT process summarized in Fig. 1.

V. RESULTS AND PERFORMANCE ANALYSIS

In this section the performance of the proposed EEFT technique is evaluated and compared with the existing distributed cluster head scheduling EE-LEACH [9] and FTREEP [12] Protocol. There are 100 sensor nodes deployed in the 100 100 m^2 area. The efficiency of the proposed system is evaluated based on the following criteria: average energy utilization and packet delivery ratio. Table I presents the parameters used in the simulation.

Fig. 1 shows that the number of nodes alive over the rounds. It is observed that the FTEER uniformly distribute the energy uses which increases stability period of the network. It is also seen from Fig 1 that the network lifetime of FTEER is about 2000 rounds.

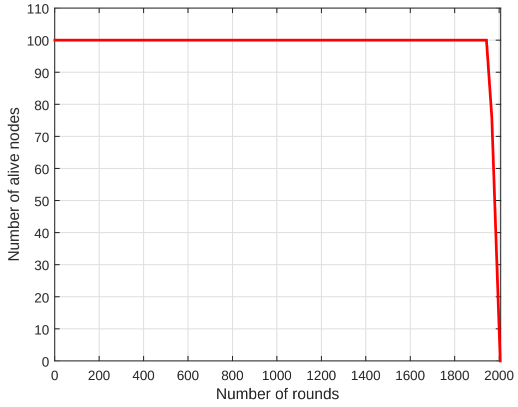
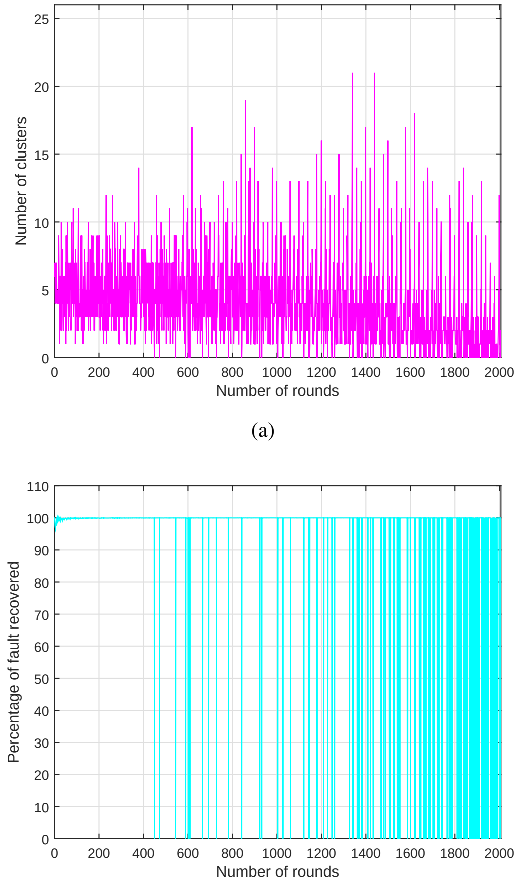


Fig. 1. Number of alive nodes over rounds



(a)

(b)

Fig. 2. Cluster formation and fault recovery

Here the analysis is made on cluster formation and fault recovery. Fig. 2(a) shows that the number of clusters formed in a round up to 21 clusters. Fig. 2(b) shows that the faults recovered using EEFT is up to 100

It has been observed from the graph that energy consumption is stable in both protocols. Fig. 3 shows that the total energy required for network operation is also almost constant over time. The proposed EEFT has less energy consumption

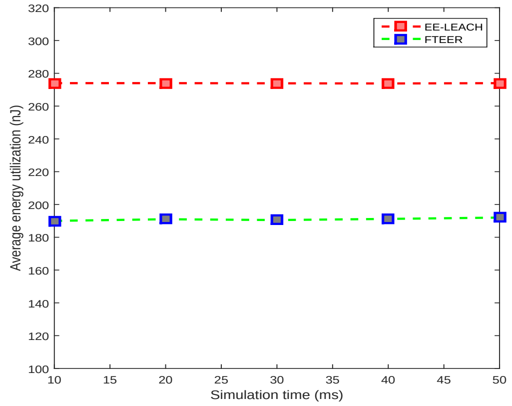


Fig. 3. Energy consumption over the time

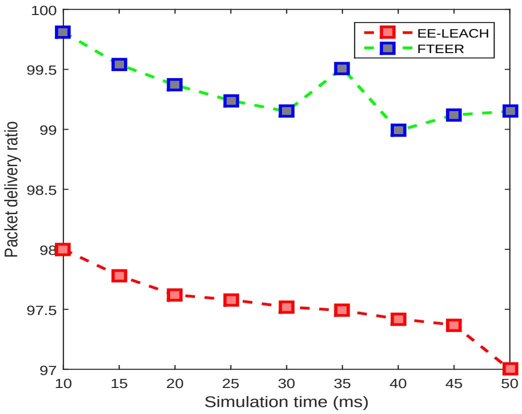


Fig. 4. Packet delivery ratio over the time

than EE-LEACH protocol [9] because of better faults tolerance. Fig. 3 shows the simulation result for $n = 100$, initial energy of a node is $2J$, base station placed at $(110m, 45m)$ and packet length is 4000 bits for this simulation [9].

Fig. 4 shows the packet delivery ratio decreases with increasing time. The proposed approach has better packet delivery ratio than the EE-LEACH protocol because FTEER recovered missing data. The EEFT ensures that the data reliability using the sub-cluster head. In this 50 sensor nodes are distributed in $2000 \times 2000\ m^2$ area of sensing field arumugam2015ee.

Fig. 5 shows the packet delivery ratio decreases with increasing time. The proposed approach has better packet delivery ratio than the FTREEP [12] protocol because EEFT has better fault tolerance.

VI. CONCLUSION

In this paper, a new energy efficient fault tolerable routing protocol has been proposed which is based on clustering approach. It improves the stability period of the sensor network with packet delivery ratio. A subordinate of the cluster has been chosen for data recovery which is based on the remaining energy of the sensor node and node density. Simulation results show that EEFT approach has better energy utilization and

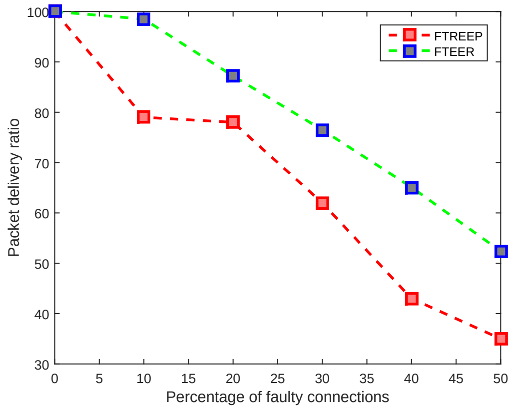


Fig. 5. Faulty connection vs. packet delivery ratio

packet delivery ratio than existing technique EE-LEACH. It is also found that EEFT recovered packet up to 100 in the faulty network than FTREEP method. In future, we extend EEFT protocol for inter-cluster communication with different parameters for clustering.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," *Communications magazine, IEEE*, vol. 40, no. 8, pp. 102–114, 2002.

[2] Z. Zhang, M. Ma, and Y. Yang, "Energy-efficient multihop polling in clusters of two-layered heterogeneous sensor networks," *Computers, IEEE Transactions on*, vol. 57, no. 2, pp. 231–245, 2008.

[3] M. Handy, M. Haase, and D. Timmermann, "Low energy adaptive clustering hierarchy with deterministic cluster-head selection," in *Mobile and Wireless Communications Network, 2002. 4th International Workshop on*, pp. 368–372, IEEE, 2002.

[4] O. Younis and S. Fahmy, "Heed: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks," *Mobile Computing, IEEE Transactions on*, vol. 3, no. 4, pp. 366–379, 2004.

[5] F. Ren, J. Zhang, T. He, C. Lin, and S. K. Ren, "Ebrp: energy-balanced routing protocol for data gathering in wireless sensor networks," *Parallel and Distributed Systems, IEEE Transactions on*, vol. 22, no. 12, pp. 2108–2125, 2011.

[6] D. Karaboga, S. Okdem, and C. Ozturk, "Cluster based wireless sensor network routing using artificial bee colony algorithm," *Wireless Networks*, vol. 18, no. 7, pp. 847–860, 2012.

[7] J. Yuea, W. Zhang, W. Xiao, D. Tang, and J. Tang, "Energy efficient and balanced cluster-based data aggregation algorithm for wireless sensor networks," *Procedia Engineering*, vol. 29, pp. 2009–2015, 2012.

[8] R. R. Rout and S. K. Ghosh, "Adaptive data aggregation and energy efficiency using network coding in a clustered wireless sensor network: an analytical approach," *Computer Communications*, vol. 40, pp. 65–75, 2014.

[9] G. S. Arumugam and T. Ponnuchamy, "Ee-leach: development of energy-efficient leach protocol for data gathering in wsn," *EURASIP Journal on Wireless Communications and Networking*, vol. 2015, no. 1, pp. 1–9, 2015.

[10] H. Bagci, I. Korpeoglu, and A. Yazıcı, "A distributed fault-tolerant topology control algorithm for heterogeneous wireless sensor networks," *IEEE Transactions on Parallel and Distributed Systems*, vol. 26, no. 4, pp. 914–923, 2015.

[11] M. Hezaveh, Z. Shirmohammdi, N. Rohbani, and S. G. Miremadi, "A fault-tolerant and energy-aware mechanism for cluster-based routing algorithm of wsns," in *2015 IFIP/IEEE International Symposium on Integrated Network Management (IM)*, pp. 659–664, IEEE, 2015.

[12] R. E. Ahmed, "A fault-tolerant, energy-efficient routing protocol for wireless sensor networks," in *Information and Communication Technology Research (ICTRC), 2015 International Conference on*, pp. 175–178, IEEE, 2015.

DOI 10.17148/IJARCCE.2016.51208

[13] I. K. Sharma and B. Singh, "Energy efficient fault tolerant and clustering algorithm using alternative backup set for wireless sensor network," in *Computer Engineering and Applications (ICACEA), 2015 International Conference on Advances in*, pp. 649–653, IEEE, 2015.

[14] Z. Yin, F. Li, M. Shen, and Y. Wang, "Fault-tolerant topology for energy-harvesting heterogeneous wireless sensor networks," in *2015 IEEE International Conference on Communications (ICC)*, pp. 6761–6766, IEEE, 2015.

[15] R. V. Kshirsagar and A. B. Jirapure, "A fault tolerant approach to extend network life time of wireless sensor network," in *Advances in Computing, Communications and Informatics (ICACCI), 2015 International Conference on*, pp. 993–998, IEEE, 2015.

[16] K. Nitesh, M. Azharuddin, and P. K. Jana, "Energy efficient fault-tolerant clustering algorithm for wireless sensor networks," in *Green Computing and Internet of Things (ICGCIoT), 2015 International Conference on*, pp. 234–239, IEEE, 2015.

[17] H. Peng, S. Si, M. K. Awad, N. Cheng, H. Zhou, X. Shen, and H. Zhao, "Energy-efficient and fault-tolerant evolution models for large-scale wireless sensor networks: A complex networks-based approach," in *2015 IEEE Global Communications Conference (GLOBECOM)*, pp. 1–6, IEEE, 2015.

[18] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *Wireless Communications, IEEE Transactions on*, vol. 1, no. 4, pp. 660–670, 2002.

DOI 10.17148/IJARCCE.2016.51208