

EEZC: Energy Efficient Zone based Clustering protocol for Heterogeneous Wireless Sensor Networks

Wided Abidi¹, Hamadi Lirathni², Tahar Ezzedine³

^{1,2,3} University of Tunis El Manar (UTM), National Engineering School of Tunis (ENIT), Communications Systems Laboratory (SysCom)

Abstract— Wireless sensors networks (WSNs) are composed of a number of sensor nodes which are limited energy resources. Therefore, the major challenge for WSNs is how to minimize the energy consumption and prolong the network lifetime. Hence, the selection of the adequate Cluster Head (CH) is essential. In this paper, we propose a new protocol that divides the network area to zones, assigns the different types of nodes to each zone. Then our proposed protocol selects CHs basing on the residual energy of the nodes and without penalizing nodes that have the highest energy level. Our simulation results are compared with some famous and recent protocols like Stable Election protocol (SEP), Zone-based stable election protocol-enhanced (Z-SEP-E) and other recent protocols. This comparison has demonstrated that our proposed protocol outperforms these protocols in term of increasing the stability period, saving the energy and prolonging the lifetime of network.

Index Terms— Energy efficiency, Clustering, Heterogeneous, Sensor node, Network Lifetime, Wireless Sensor Networks, Zone

1 INTRODUCTION

Nowadays, wireless sensor networks (WSNs) become essential for our daily life. Thus, they are used in several areas [1] such as smart cities, smart environment, e-health, etc. In WSN, sensor nodes are powered by batteries which are, in the most of time, difficult to recharge or replace it. Hence, the key issue of this technology is how to reduce the energy consumption of the sensor nodes and increase the lifetime of the network [2, 3, 4]. Several routing protocols have been developed [5, 6] to achieve the energy efficiency of the network for homogeneous and heterogeneous wireless sensor networks. Heterogeneous wireless sensor networks (HWSN) are very much useful in real deployments because they are more close to the real life situations [7, 8] than homogeneous WSN. In addition, after many researches in routing protocols for WSNs, hierarchal and clustering algorithms show that they are effective in term of saving energy consumption of the network and increasing the network lifetime. In this way, many clustering algorithms for HWSN [9, 10, 11], where sensor nodes are collected into groups, are proposed. Each group is called cluster and contains a cluster head (CH) and sensor members. Thus, only CH is allowed to communicate with the base station (BS). The main issue of clustering is how to elect the CH in order to limit the energy dissipation in the network.

This paper proposes an energy efficient zone based clustering protocol for heterogeneous wireless sensor networks (EEZC). Our proposed protocol aims to prolong the lifetime of the network and to reduce the energy consumption of nodes. To achieve this goal, EEZC divides the HWSN area into rectangular zones. Then, it assigns the different nodes type to zones. Furthermore, EEZC gives a new threshold for selecting CH nodes in each zone based on the remaining energy of the node. Finally, clusters are formed; member nodes send the data to CHs; CHs aggregate the collected data and transmit it

to the base station.

The remainder of this paper is organized as follows. Section 2 presents the related works. Section 3 provides the description of the system model used. In section 4, the proposed protocol is described in detail. Simulation results are presented and discussed in section 5. Finally, we conclude in section 6.

2 RELATED WORK

In [12], authors introduced the heterogeneity by developing the Stable Election protocol (SEP) which is based on two levels of heterogeneity. In SEP protocol, sensor nodes are divided into advanced nodes and normal nodes. The advanced nodes represent an m fraction of the total number of nodes 'n' in the network and are provided with an additional energy 'a' compared to normal nodes. So the initial energy for normal nodes is E_0 and for advanced nodes is $E_0 \cdot (1+a)$. Like Leach protocol, CHs election in SEP is done randomly on the basis of thresholds of each type of node. Nodes sense data and transmit it to associated CH which convey it to BS.

Distributed energy efficient Clustering (DEEC) had been elaborated in [13] for heterogeneous wireless sensor networks. In DEEC, the probability to select cluster head is based on ratio of residual energy and average energy of the network. The rotating epoch for each node depends on its initial and residual energy. The advanced nodes which have the highest initial energy have more chance to become CHs than the normal nodes which have the lowest initial energy. Hence, DEEC protocol can increase the lifetime of the network but it has a major shortcoming: it penalizes the advanced nodes when their remaining energy decrease up to the order of the normal nodes which leads to the death of these advanced nodes quickly.

In [14], authors presented a new protocol named Devel-

oped Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous WSN. Like DEEC protocol, the selection of CH in DDEEC depends on the remaining energy of the node. In this case, the advanced nodes have more chance to become CH than normal nodes which penalizes the advanced nodes and they die quickly. To overcome this shortcoming, DDEEC gives more chance to the advanced nodes to be CH only for the first transmission rounds. Then, when the energy of advanced nodes decreases, they will have the same probability as the normal nodes to be CH.

Enhanced Distributed Energy Efficient Clustering (EDEEC) had been proposed in [15]. EDEEC is based on DEEC protocol and it has increased the heterogeneity level to three. In fact, authors have added a new type of nodes known as super nodes and have more energy than advanced and normal nodes.

The researchers in [16, 17] introduced an enhanced DDEEC protocol called Enhanced Developed Distributed Energy-Efficient Clustering for Heterogeneous Wireless Sensor Networks (EDDEEC). It has three level of energy heterogeneity. For the CH selection process, EDDEEC provided a new probability function which give more chance to the super nodes and advanced nodes to become CH. Then, after some time, all nodes in the network will have the same chance to be CH. Simulation results show that EDDEEC beats DEEC, DDEEC and EDEEC in term of prolonging network lifetime and reducing the energy consumption of the network.

Zonal-Stable Election Protocol (Z-SEP) had been proposed in [18]. It is a clustering algorithm based on dividing the network to zone for heterogeneous wireless sensor networks. Z-SEP considers two types of nodes: advanced and normal nodes. The advanced nodes which have the highest initial energy are located at corners far from the base station. However, the normal nodes which have the lowest initial energy are placed in the middle near to BS. In this case, normal nodes transmit directly their data to BS and advanced nodes use the transmission via CH.

Zone-based stable election protocol-enhanced (ZSEP-E) had been in proposed [19]. This protocol makes a partition of the network into zones and three level of heterogeneity energy is adopted. In fact, advanced nodes are located in the furthest zones of the BS. The normal and intermediate nodes are deployed in the nearest zone to the BS. Besides, the CH selection process is based on the residual energy of the node and is done in each zone separately. Comparing to Z-SEP [18], Simulation results show that the stability period is increased and the network lifetime is enhanced.

In [20], authors proposed a Multi-zonal approach Clustering based on Stable Election Protocol (MZ-SEP) for heterogeneous WSN. This new protocol is based on SEP protocol and it divides the network area to multiple triangle zones. Furthermore, MZ-SEP proposes an optimized CH repartition in the network. The simulation results show that the proposed MZ-SEP protocol outperforms SEP protocol by increasing the stability period and the lifetime of the network.

Zone Based Heterogeneous Clustering Protocol (ZBHCP) had been introduced in [21]. ZBHCP divides the network area into four equal rectangular zones where the number of de-

ployed nodes in each zone is the same. This protocol focus on the intra-cluster and inter-cluster communication distance and select each cluster head from the respective zone by comparing its residual energy to the other zone nodes.

A modified version of SEP protocol called M-SEP had been presented in [22]. M-SEP is based on SEP protocol [12] while introducing the concept of multilevel power transmission which increases the network lifetime. In fact, M-SEP considers the different types of transmission in the network such as transmission intra-cluster, inter-cluster and between CHs and BS and allocates the appropriate energy to each type. Hence, the multilevel concept will limit the packets drop, collision and improve the energy efficiency of the network. Simulation results confirm the concept of the proposed protocol.

The researchers in [23] proposed an improved routing protocol for heterogeneous WSNs. This protocol uses two types of nodes (advanced and normal nodes) with different energy level. First, it divides the network area to regions with fixed size and deploys each type of nodes to appropriate region. Then, it applies the dynamic clustering to the advanced nodes which are in the farthest zones but normal nodes send data directly to the BS by choosing the optimal route. And finally, in order to limit the overhead and congestion problems, this protocol introduces the state transmission concept. Simulations results show the efficiency of the proposed protocol comparing to M-SEP protocol [22].

3 SYSTEM MODEL

3.1 Heterogeneous Network Model

We consider an heterogeneous wireless sensor network with three levels of energy heterogeneity. Hence, we have three types of node: super, advanced and normal nodes. Each type of node has its own initial energy. The normal nodes have E_0 as initial energy. The super nodes, of fraction m_1 , have higher energy than all other nodes and is given by $E_{sup} = E_0 (1+\alpha)$, where α times more energy than other nodes. The energy of the advanced nodes, of fraction m_0 , is between the energy of normal and super nodes and is given by $E_{adv} = E_0 (1+\beta)$. Since n is the total number of nodes in the network, nm_1 , nm_0 and $n^*(1-m_0-m_1)$ are respectively the number of super, advanced and normal nodes.

The total energy of super nodes is expressed as:

$$E_{suptot} = nm_1 E_0 (1+\alpha) \quad (1)$$

The total energy of advanced nodes can be given by:

$$E_{advtot} = nm_0 E_0 (1+\beta) \quad (2)$$

The total energy of normal nodes is calculated by:

$$E_{nmtot} = n (1-m_0-m_1) E_0 \quad (3)$$

The total initial energy of the network can be written as follows:

$$E_{tot} = E_{suptot} + E_{advtot} + E_{nmtot} \quad (4)$$

$$E_{tot} = nE_0 (1+m_0\beta + m_1\alpha)$$

3.2 Energy Consumption Model

In our research, we have used the same energy model as the traditional LEACH [24], as shown in figure 1.

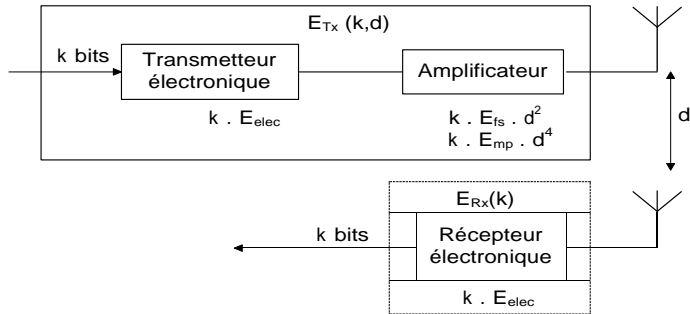


Fig. 1. The radio energy consumption model.

Note that, E_{elec} is the energy consumption per bit for running transmitter or receiver circuitry, k is the number of bits, ϵ_{fs} and ϵ_{mp} are proportional constant of the energy consumption for the transmit amplifier in free space channel model ($\epsilon_{fs} \cdot k \cdot d^2$ power loss) and multipath fading channel model ($\epsilon_{mp} \cdot k \cdot d^4$ power loss), respectively and d is the distance between transmitter and receiver.

Thus we can deduce the energy consumed to transmit k bits along a distance d through a free space channel model is:

$$(5)$$

Or multipath fading channel is:

$$(6)$$

And the energy to receive these bits is:

$$(7)$$

4 THE PROPOSED PROTOCOL: EEZC

In this section, we present our proposed protocol EEZC in detail. Our protocol relies essentially on two axes: the deployment by zone of the heterogeneous sensor nodes in the network area and the selection of the cluster heads for each zone.

4.1 Node Deployment by Zones

In EEZC, we have divided the network area to three zones to provide efficient coverage over the entire field, as shown in figure 2. The division of zones is based on the distance between the deployed nodes and the base station, the availability of the heterogeneous nodes according to their remaining energy and power transmission. In fact, the energy consumption increases when the distance to BS increases. Thus, regions far from the BS require more energy to transmit the data than other regions. Hence, the normal nodes which have the lowest initial energy are placed in the closest region to the BS and the region is called Reg-1. The super nodes are placed in the middle and the region is called Reg-2. Finally, the advanced nodes are placed in the outermost region which is called Reg-3. We have deployed the super nodes which have the highest energy in the middle zone to ensure the multi-hop transmission be-

tween the CHs of the Reg-3 and the base station. Then the normal nodes (Reg-1) are deployed close to BS to transmit their data directly to the BS. Finally, super and advanced nodes, deployed respectively in Reg-2 and Reg-3, transmit their data via CHs.

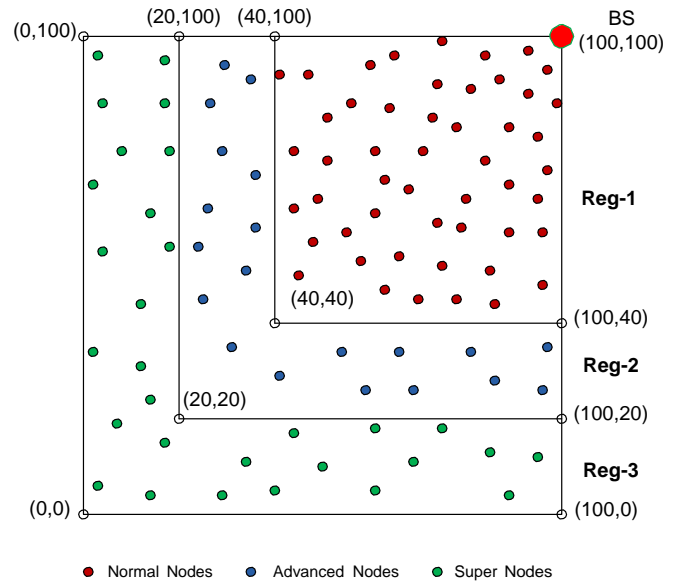


Fig. 2. The proposed network architecture.

4.2 CH selection algorithm

Our protocol EEZC includes the residual energy of the node and the average energy of the network to select the CHs for each zone. All regions (Reg-1, Reg-2 and Reg-3) are concerned by the CHs selection. The main steps are described in the flowchart of our proposed protocol in figure 4. Our algorithm operates in round. In every round, each sensor node chooses a random number between 0 and 1. If this number is less than the thresholds: T_{nrm} for normal nodes, T_{adv} for advanced nodes and T_{sup} for super nodes and expressed respectively in equations (8), (9) and (10) the node becomes a CH.

$$\text{---} \quad \text{---} \quad (8)$$

$$\text{---} \quad \text{---} \quad (9)$$

$$\text{---} \quad \text{---} \quad (10)$$

Note that G_{nrm} , G_{adv} and G_{sup} are the set of normal nodes, advanced nodes and set of super nodes that has not become CHs in

the past respectively. p_{nm} , p_{adv} and p_{sup} are the probabilities of becoming CH for advanced and super nodes respectively and are given by equation (11), (12) and (13):

$$\text{_____} \quad (11)$$

$$\text{_____} \quad (12)$$

$$\text{_____} \quad (13)$$

Where, p_{opt} is the optimal probability of each node to become CH, E_a the average energy of the network and $E(i)$ is the residual energy of the node i .

After CH election phase, each CH in each zone broadcasts advertising messages to the remaining nodes, inside the zone, inviting it to choose which of the CHs they will join and finally, clusters are created for the current round. The choice of remaining sensor nodes will depends on the signal strength of the received broadcasting messages.

Cluster setup phase: Each remaining node communicates its decision to the chosen CH node that it will be belong to the cluster. To receive this information, all CHs keep their receivers on during this phase. Based on the number of nodes in the cluster, the CH creates a time division multiple access (TDMA) schedule and informs other sensor nodes when it can transmit. Steady-state phase: In this phase, transmission data starts. Sensor nodes send their data in their own time slot and their radio can be turned off. CHs must keep their radio on to receive all data from nodes. CHs aggregate data and send it to the base station. We must note that the CHs of the Reg-3 work in multi-hop technique between each other. In fact, CHs of the Reg-3 collect and aggregate data from their members then they send it to CHs of the Reg-2. And finally, CHs of the Reg-2 perform the aggregation tasks and send data to BS.

5 SIMULATION RESULTS AND DISCUSSION

We have implemented our proposed protocol EECZ using MATLAB. As shown in figure 3, we consider an heterogeneous WSN consisting of 100 nodes deployed in 100x100 network field. Sensor nodes are deployed by zones depending in their energy. The base station is located at point (100, 100) and appears in black point in the figure. Normal nodes are in red, the super nodes are in green and the advanced nodes are in blue. The rest of used parameters are listed in table 1.

TABLE 1

Parameters System.

Parameters	Values
P_{opt}	0.1
E_0	0.5J
Transmission/ Reception energy per bit E_{elec}	50 nJ/bit
Transmitter Amplifier energy dissipation free Space	10 pJ/bit/m ²
Transmitter Amplifier energy dissipation multipath	0.0013 pJ/bit/m ⁴

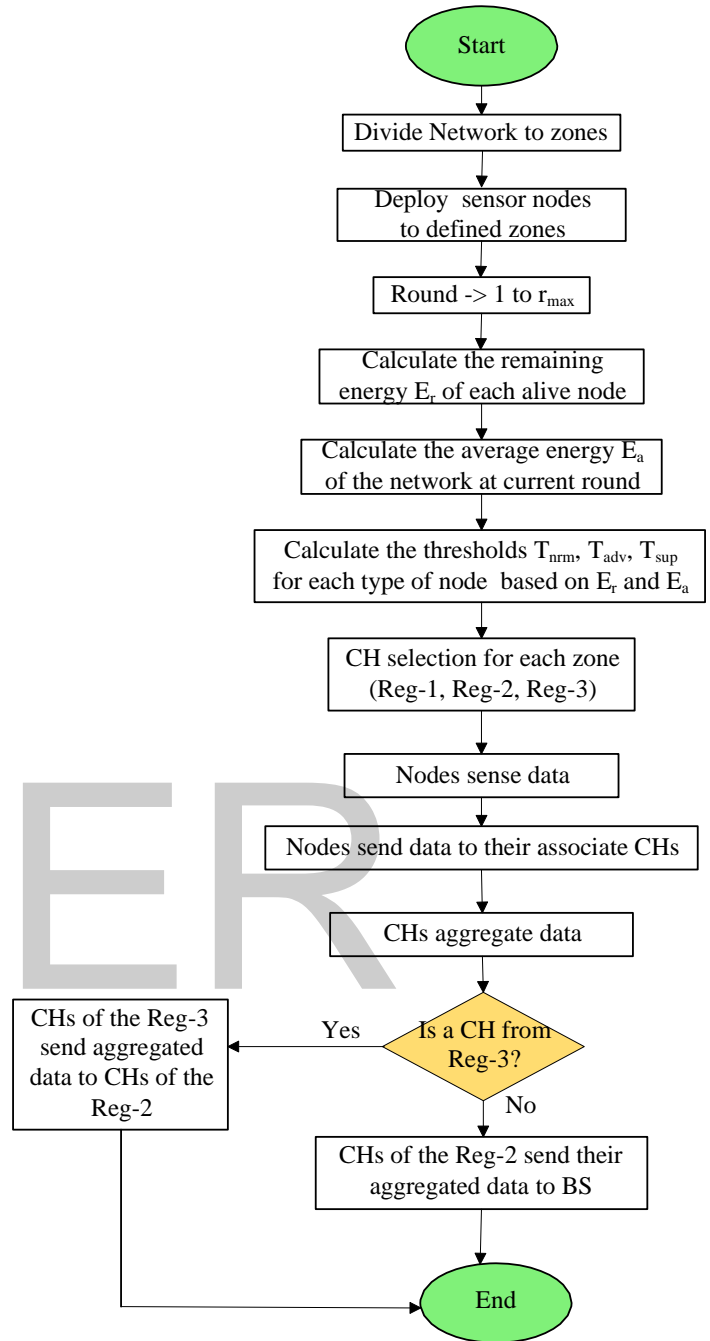


Fig. 3. Flowchart of the proposed protocol: EECZ.

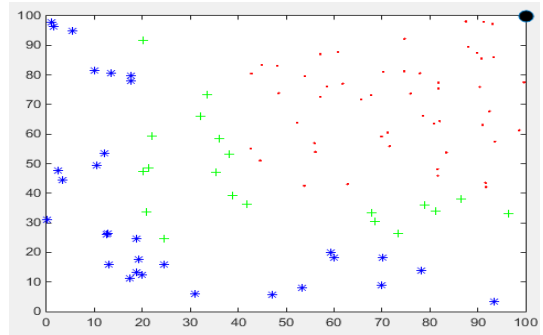


Fig.4. Initial distribution of WSN nodes.

5.1 Performance Metrics

- Stability Period: is the time interval from the start of network operation until the death of the first sensor node.
- Network lifetime: is the time interval from the start of operation (of the sensor network) until the death of the last alive node.
- Number of dead nodes per round.
- Number of packets sent to BS: The throughput
- FND and LND: are respectively the first dead node and the last dead node.

5.2 Simulation Results

To illustrate the performance of our proposed protocol EEZC, we have compared our simulation results with SEP [12], Z-SEP [18], Z-SEP-E [19], ZBHCP [21] and the improved routing protocol [23] for heterogeneous WSNs protocols.

We consider a network with $m_0=0.3$, $m_1=0.2$, $\alpha=3$, $\beta=\alpha/2$. The sensor nodes are deployed by zone as follows: 28 normal nodes with initial energy E_0 are deployed in Reg-1, 48 advanced nodes with $E_{adv}=1.5 \cdot E_0$ are deployed in Reg-2 and finally, 24 super nodes with $E_{sup}=2 \cdot E_0$ are deployed in Reg-3.

The figure 5 shows the number of dead nodes per round for each protocol. We can see clearly that our protocol beats the other protocols. Furthermore, the table 2 represents the FND and LDN for SEP, Z-SEP, Z-SEP-E, ZBHCP, the improved routing protocol and EEZC. The first dead node is at 971th round for SEP, 1546th for Z-SEP, 1450th round for Z-SEP-E, 1500th round for ZBHCP and 1610th round for the improved routing protocol while in our proposed protocol EEZC, the first node dies at 1861th round.

The figure 6 describes the number of packets sent to the BS per round. The throughput of our proposed protocol is far better than the rest of the protocols.

The figure 7 represents the stability period of SEP, Z-SEP, Z-SEP-E, ZBHCP, the improved routing protocol and EEZC. When comparing these results, we can note that the stability period of our proposed protocol EEZC is longer than SEP, Z-SEP, Z-SEP-E, ZBHCP and the improved routing protocol. Therefore, our protocol outperforms the other protocols in terms of stability period.

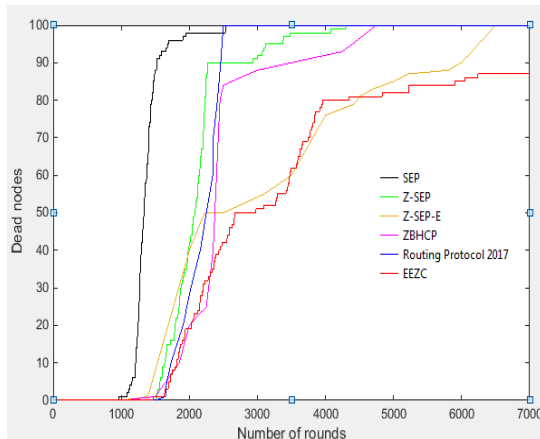


Fig. 5. Number of dead nodes per round.

TABLE 2.

FND and LDN for all Protocols

Algorithms	FND	LDN
SEP	971	2482
Z-SEP	1546	4219
Z-SEP-E	1450	6200
ZBHCP	1500	4800
routing protocol 2017	1610	2500
EECZ	1861	9552

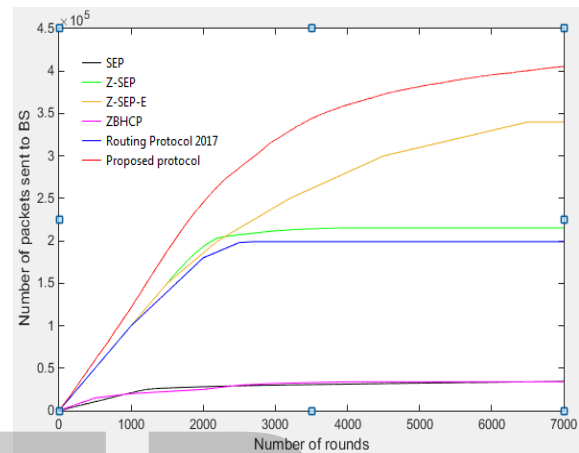


Fig. 6. Throughput of the protocols.

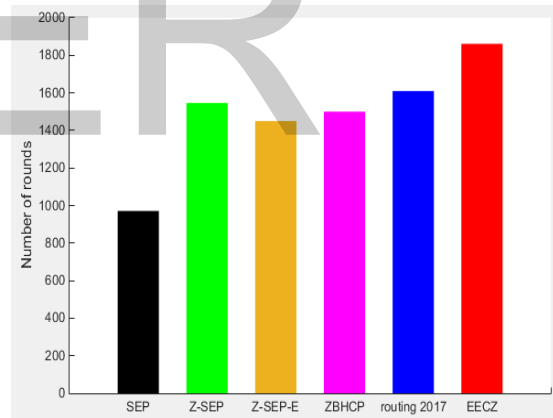


Fig.7. Stability period of protocols in rounds.

Figure 8 shows the network lifetime of our proposed protocol as well as SEP, Z-SEP, Z-SEP-E, ZBHCP and the improved routing protocol. For the SEP protocol, the LDN is at 2482th round while for Z-SEP, Z-SEP-E, ZBHCP and the improved routing protocol, the last node dies at the 4219th, 6200th, 4800th and 2500th round respectively. However, the LDN for our protocol EEZC is at 9552th round. These results indicate that the network lifetime using our protocol is prolonged comparing to SEP, Z-SEP, Z-SEP-E, ZBHCP and the improved routing protocol.

5 CONCLUSION

In this paper, we have proposed a new clustering protocol

EECZ which is based on dividing the heterogeneous WSN area to zones. Then, our protocol assigns the different nodes type to zones. The CH selection is done for each zone separately and based on the remaining energy of the node. The simulation results show that the stability period of EECZ is prolonged by 47,82% than SEP, 16,93% than Z-SEP, 22,08% than Z-SEP-E, 19,4% than ZBHCP and 13,49% than the improved routing protocol. In addition, the network lifetime of EECZ is increased by 74,01% than SEP, 55,83% than Z-SEP, 35,09% than Z-SEP-E, 49,75% than ZBHCP and 73,83% than the improved routing protocol. All these results confirm that our proposed protocol EECZ outperforms the other protocols in term of reducing the energy consumption of the network and prolonging the network lifetime.

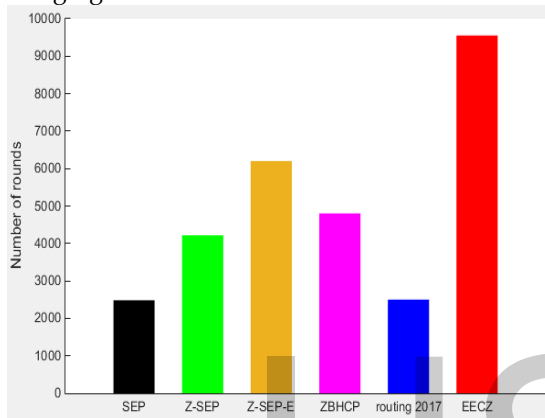


Fig. 8. Network lifetime of protocols in rounds.

REFERENCES

- [1] C. BURATIL, A. CONTI, D. DARDARI, R. VERDONE, "An Overview on Wireless Sensor Networks Technology and Evolution," *Sensors Journal*, 2009, vol.9, p. 6869-6896. DOI: 10.3390/s90906869
- [2] F. CHEN, L. GUO, C. CHEN, "A Survey on Energy Management in the Wireless Sensor Networks," In the Proceedings of the International Conference on Mechanical and Electronics Engineering, The Bangkok (Thailand), 2012, vol. 3, p. 60-66. DOI: 10.1016/j.jeri.2012.09.01
- [3] S. TARANNUM, "Energy Conservation Challenges in Wireless Sensor Networks: A Comprehensive Study," *Wireless Sensor Network*, 2010, vol. 2, p. 483-491. DOI: 10.4236/wsn.2010.26060
- [4] S. SHARMA, R. K. BANSAL, S. BANSAL, "Issues and Challenges in Wireless Sensor Networks," In Proceedings of the IEEE International Conference on Machine Intelligence Research and Advancement (ICMIRA). The Katra (India), 2013, p.58-62. DOI: 10.1109/ICMIRA.2013.18
- [5] G. ANASTASII, M. CONTI, M. DI FRANCESCO, A. Passarella, "Energy conservation in wireless sensor networks: A survey," *Ad Hoc Networks Journal*, 2008, vol. 7, issue 3, p. 537-568. DOI: 10.1016/j.adhoc.2008.06.003
- [6] S. K. SINGH, M. P. SINGH, D. K. SINGH, "Routing protocols in wireless sensor networks-A survey", *International Journal of Computer Science & Engineering Survey (IJCSSES)*, 2010, vol. 1, no. 2. DOI: 10.5121/ijcses.2010.1206
- [7] M. YARVIS, N. KUSHALNAGAR, H. SINGH, et al, "Exploiting Heterogeneity in Sensor Networks," In Proceedings IEEE 24th Annual Joint Conference of the IEEE Computer and Communications Societies. The Miami, FL (USA), Mars 2005, vol. 2, p. 878-890. DOI: 10.1109/INFCOM.2005.1498318
- [8] V. MHATRE, C. ROSENBERG, "Homogeneous vs. heterogeneous clustered networks: a comparative study," In Proceedings IEEE International Conference on Communications (ICC). The Paris (France), 2004, vol. 6, p. 3646-3651. DOI: 10.1109/ICC.2004.1313223
- [9] G. HAN, X. JIANG, A. QIAN, et al, "A Comparative Study of Routing Protocols of Heterogeneous Wireless Sensor Networks," *The Scientific World Journal*, 2014, vol. 2014, Article ID 415415, 11 pages, DOI: 10.1155/2014/415415
- [10] V. KATYAR, N. CHAND, S. SONI, "A Survey on clustering algorithms for heterogeneous wireless sensor networks," *International Journal of Advanced Networking and Applications*, 2011 vol. 02, issue: 04, p. 745-754.
- [11] S. CHABRA, D. SINGH, "Cluster head selection mechanisms in homogeneous and heterogeneous WSNs: A Survey," *International Journal of Computer Science & Engineering Technology*, 2014; vol. 5, no. 6, 654-658. ISSN : 2229-3345
- [12] G. SMARAGDAKIS, I. MATTA, A. BESTAVROS, "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks," In Proceedings of the Second International Workshop on Sensor and Actor Network Protocols and Applications (SANPA). The Boston, Massachusetts (USA), 2004, p. 1-11.
- [13] L. QING, Q. ZHU, M. WANG, "Design of a distributed energy efficient clustering algorithm for heterogeneous wireless sensor networks," *ELSEVIER, Computer Communications*, 2006, vol. 29, issue: 12, p. 2230- 2237. DOI: 10.1016/j.comcom.2006.02.017
- [14] B. ELBHIRI, R. SAADANE, S. EL FKIHI, D. ABOUTAJDINE, "Developed Distributed Energy-Efficient Clustering (DDEEC) for heterogeneous wireless sensor networks," In the Proceedings of the 5th International Symposium on I/V Communications and Mobile Network (ISVC). Rabat (Morocco) , 2010, p. 1-4. DOI: 10.1109/ISVC.2010.5656252
- [15] P. SAINI, A. K. SHARMA, "E-DEEC- Enhanced Distributed Energy Efficient Clustering Scheme for heterogeneous WSN," In the Proceedings of the 1st International Conference on Parallel, Distributed and Grid Computing (PDGC). The Solan (India), 2010, p. 205-210. DOI: 10.1109/PDGC.2010.5679898
- [16] N. JAVAID, T. N. QURESHI, A. H. KHAN, et al, "EDDEEC: Enhanced developed distributed energy efficient clustering for heterogeneous wireless sensor networks," In the Proceedings of the International Workshop on Body Area Sensor Networks (BASNET) Science. The Nova Scotia (Canada), 2013, vol. 19, p. 914-919. DOI: 10.1016/j.procs.2013.06.125
- [17] N. JAVAID, M. B. RASHEED, M. IMRAN, et al, "An energy-efficient distributed clustering algorithm for heterogeneous WSNs," *EURASIP Journal on Wireless Communications and Networking*, 2015. DOI: 10.1186/s13638-015-0376-4
- [18] S.FAISAL, N. JAVAID, A. JAVAID, et al, « Z-SEP: zonal-stable election protocol for wireless sensor networks," *Journal of Basic and Applied Scientific Research (JBASR)*, 2013.
- [19] S.A.S.A. MARY, J. B. GNANADURAI, "A zone-based clustering protocol for wireless sensor networks," In the Proceedings of the 9th International Conference on Computer Engineering and Applications. Dubai, Feb 2015, p. 151-161. ISBN: 978-1-61804-276-7
- [20] A. MAHBOUB, E. EN-NAIMI, M. ARIOUA, et al, "Multi-zonal approach Clustering based on Stable Election Protocol in Heterogeneous Wireless Sensor Networks," In the Proceedings of the 4th IEEE International Colloquium on Information Science and Technology (CiSt). The Tangier (Morocco), 2016, p. 912-917. DOI: 10.1109/CIST.2016.7805018
- [21] S. HASSAN, M. S. NISAR, H. JIANG, "Energy Preservation in Heterogeneous Wireless Sensor Networks through Zone Partitioning," *Indonesian Journal of Electrical Engineering and Computer Science*, May 2016, vol. 2, no. 2, p.390-395. DOI: 10.11591/ijeecs.v2.i2.pp390-395
- [22] T. JINPA, B. V. R. REDDY, "M-SEP: A Variant of SEP for WSN. In Intelligent Systems Technologies and Applications," *Advances in Intelligent Systems and Computing*, Springer, Cham, 2016, vol 385, p. 45-56. DOI: 10.1007/978-3-

319-23258-4_5

- [23] L. ZHAO, N. CHEN, "An Improved Zone-Based Routing Protocol for Heterogeneous Wireless Sensor Networks," Journal of information Processing Systems, June 2017, vol113, No.3, p. 500-517. DOI:103745/JIPS.03.0072
- [24] W. B. Heinzelman, A. Chandrakasan, H. Balakrishnan, "Energy-efficient communication protocol for wireless microsensor networks;" In Proceedings of the 33rd Annual Hawaii International Conference on System Sciences (HICSS). The Maui, Hawaii, (USA), 2000, p. 1-10, vol. 8. DOI: 10.1109/HICSS.2000.926982

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