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Progressive energy efficient least edge computation (P-ELEC) routing protocol in wireless sensor networks

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A B S T R A C T

The energy of nodes in Wireless Sensor Networks (WSNs) is usually limited, which has to be consumed economically in order to prolong the lifetime of the network. The imbalanced use degrades the sensor node energy quickly and leads to sensor voids, which further cause the routing hole problem. The routing hole problem ultimately affects network performance. To solve the routing hole problem, an Energy Efficient Least Edge Computation routing protocol (ELEC) is proposed in the literature. The simulation results show that ELEC achieves nearly double network lifetime by equal energy consumption in various parts of the network as compared to other existing routing techniques such as GRACE, LEACH, and AODV-EHA. This work presents a progressive Energy Efficient Least Edge Computation (P-ELEC) routing protocol, where a cluster head percentage is incremented periodically. Incrementing the cluster head minimizes the workload of each cluster head, and in turn, enhances the lifetime of the network. The simulation result shows the prolongation of a lifetime under various scenarios and modes of operation.

1. Introduction

Due to the vast applications, the Wireless Sensor Network (WSNs) has witnessed notable considerations in recent research and development (Alemdar and Ersoy, 2010; Abdulkarem et al., 2020). The energy of the nodes is usually limited, which has to be consumed economically in order to prolong the lifetime of the network, otherwise leads to sensor voids (Fu et al., 2020). The sensor void caused by the degradation of energy is a major issue in WSNs. A sensor node, which is unable to disseminate the packets, is known as a void or hole. The void sensor is highly utilizing the energy, which leads to the routing hole problem in WSNs (Mohemed et al., 2017; Saranya et al., 2018). Hence the efficient use of energy among sensors is one of the fundamental research themes. Cluster based routing protocol is the energy efficient routing technique in WSNs (Deepa and Latha 2019; Thangaramya et al., 2019). Many multi-hop cluster-based routing protocols are present in literature (Zen and Ur-Rahman, 2017; Behera et al., 2019; Maitra et al., 2019), but energy unaware path selection caused routing hole problem as shown in Fig. 1 (Biswas et al., 2019). For balance energy consumption, many routing techniques are proposed by many authors (Khari, 2018; Yue and He, 2018; Bhushan and Sahoo, 2019).

To minimize the energy consumption and enhance the network lifetime through a load balancing among sensor nodes, a grid based routing technique is in Kareem and Jameel (2018). The evaluation proves that the proposed technique enhances the stability and energy efficiency as compared to the CFDASC algorithm in terms of network stability and load balancing of the entire network. The distributed Unequal Clustering Algorithm (DUCA) is proposed in Gowda and Subramanya (2019). The proposed DUCA technique makes the cluster size small near to base station because the workload of these CHs is more. The simulation result shows that the DUCA algorithm improves the lifetime by balancing the energy loads among the sensor nodes as compare to the LEACH protocol.

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Cluster based routing leads to non-uniform energy consumption among sensor nodes and cluster heads. The CH near to base station has more energy consumption due to the larger load. Many-to-one data routing pattern results in quicker loss and destruction of energy resource of the CH's near the sink; this is referred to as a routing hole problem. The CH's are unable to forward a packet toward the sink. Because neighbor CH depletes their energy faster and dies out due to uneven workload. As a result of this problem, the network will be partitioned, and the WSN will not be able to accomplish its designated critical function, as shown in Fig. 1. Once the hole is formed, the network operation of the remaining system is useless because data can no longer be transferred to the base station.

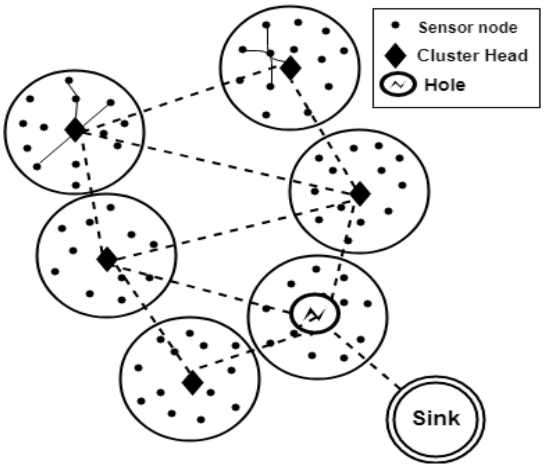

Fig. 1: Routing hole in multi-hop cluster based WSN

To balance the energy consumption, it is very crucial to balance the workload among the sensor nodes and CH. To reduce the routing hole problem, the energy consumption of sensor nodes should be balanced, which demands to balanced workload among the different parts of the network. Therefore, the density of CH's among different parts of the network should be uniform. To deal with imbalanced energy consumption and to overcome the routing hole problem, a novel energy efficient least edge computation routing protocol (ELEC) is proposed by authors in Sama et al. (2019). The simulation results show the enhanced performance of ELEC as compared to other existing routing techniques such as GRACE, LEACH, and AODV-EHA. The proposed paper presents Progressive-ELEC (P-ELEC), the further evaluation of ELEC routing protocol. In P-ELEC, a cluster head percentage is incremented periodically, which minimizes the workload of each cluster head and, in turn, enhances the lifetime of the network. The proposed routing strategy proves that if the increment of CH's percentage is uniform at different parts of the network, then it is possible to balance the energy consumption in the network and prolong the network lifetime.

The simulation result shows the prolongation of a lifetime under various scenarios and modes of operation. The organization of the remaining paper is shown in Fig. 2.

2. Cluster based routing protocols

The proposed research focused concern is the routing hole problem; therefore on the analysis of routing hole problem, energy efficient utilization, and lifetime enhancement strategies, literature will be briefly presented in this section (Rahman et al., 2013; Zen and Ur-Rahman 2017; Wang et al., 2019). It is proven from the research that communication is the major reason for energy exhaustion. To minimize the communication energy consumption clustering technique considers that only cluster heads (CH) will forward the aggregated data sink. The issue in cluster based routing is, the CH have to handle the load as head and also forward the packets to the next CH. To balance the workload of CHs, a modified Mutual Exclusive Distributive Clustering (MEDC) protocol is presented in Chugh and Panda (2018). Proposed work balanced the workload of cluster heads and enhanced the network lifespan.

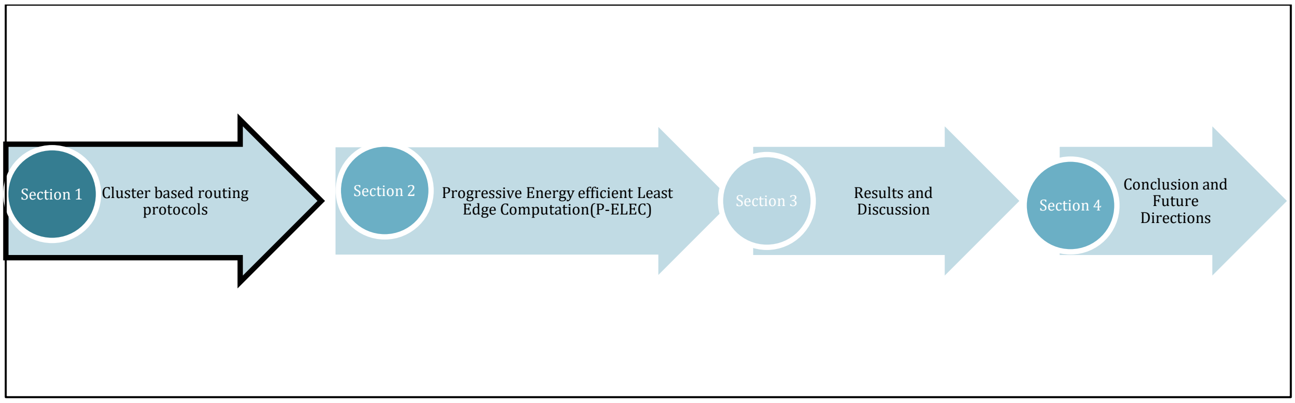

Fig. 2: Paper organization

For the balanced energy consumption and enhanced network lifetime, an Energy Balanced Distributed Clustering Protocol (EBDCP) is proposed in Chowdhury and Giri (2019) through an efficient elected clustering technique with the support of a mobile base station. EBDCP ensures to forward the packets to the sink within the tour limit. The proposed work enhanced the network performance in terms of energy utilization, overhead, remaining energy, and network lifetime. A novel Mobile Energy

Aware Cluster Based Multi-hop (MEACBM) routing protocol is presented by Toor and Jain (2019) which elects sensor node highest energy as a cluster head. After the distribution of sensor nodes and the selection of clusters, the whole network is spat into zones, and inside each zone, a mobile sensor node is deployed, which behaves as Mobile Data Collector (MDC) for gathering data from CHs. Results from the simulation show the enhancement of network performance in terms of network lifetime, throughput, security, and a number of critical nodes. But the proposed MEACBM routing protocol increases the overhead due to the mobility of sensor nodes.

To best fit the specific application, it is very important to select the most relevant routing protocol. A more suitable, appropriate, valid, and consistent clustering technique is proposed, which is adaptable and improves the lifespan of the network as compared to the existing routing protocol, LEACH (Jain and Thakur, 2019). Wang et al. (2019) proposed a Compressive Sensing-based clustering technique to minimize the power exhaustion and mitigate the hole problem. The technique rotates the roles between the Cluster Head (CH) and Backup Cluster Head (BCH), furthermore presents an Energy-Efficient Compressive Sensing-based clustering Routing (EECSR). The extensive simulation experiment shows the improved energy utilization and enhanced network lifetime of WSNs. Many of the routing strategies mitigate the routing-hole problem with the additional cost or leads to other problems. The routing hole problem has been minimized by various perceptive routing strategies without even energy utilization in a network taking into account. Efficient energy consumption has been accomplished by sharing the load, energy efficient deployment techniques, and power balancing routing protocols, but still requires to take into account the energy aware path selection routing protocol.

With the consideration of issues in literature, energy efficient least edge computation (ELEC) routing protocol is proposed which uses energy aware path selection for intra-cluster multi hop routing in wireless sensor networks. The results show the improvement of ELEC, which achieves nearly double network lifetime by equal energy depletion in different parts of the network.

3. Progressive-energy efficient least edge computation (P-ELEC) routing protocol

In our previous work, an energy efficient least edge computation (ELEC) routing protocol in WSN is proposed to reduce the routing hole problem. A reactive routing algorithm ELEC creates the local route table whenever an event occurs. The sensor nodes close to the event detect and transmit it to the CH via single or multi-hop clustering depending on the distance. If the sensor nodes are distant from the CH, then they will send the data through multi-hop clustering; otherwise, the data are sent directly to the CH through a single hop. After data collection, the CH forwards the data to the BS via multi-hop. Then, the source CH selects the next hop CH with minimum values of edge count, energy level, and link weight.

Further evaluation of ELEC is proposed, where a cluster head percentage is incremented periodically. Incrementing the cluster head minimizes the workload of each cluster head and, in turn, enhances the lifetime of the network. The simulation shows the results taken in a variety of scenarios and methods of operation.

3.1. ELEC routing network model

Homogenous sensor nodes are deployed randomly in the wireless sensor network area. The area is divided into the cluster, and each cluster is controlled by one cluster head (CH). The sensor nodes will send the sensor data to the cluster head via single-hop or multi-hop, depending on the distance of CH from nodes. If the CH is far away, then sensor nodes will send the packets via multi-hop; otherwise, they will forward the sensor data directly to CH via single-hop. After the collection and aggregation of receiving packets, the CH will forward the data to the sink via multi-hop. The proposed protocol follows the same routing algorithm as ELEC, which considers the edge count, energy level, and link cost for the next hop neighbor selection. Route processing in the ELEC algorithm is illustrated in Fig. 3.

3.2. Theorem

The proposed theorem is to proof of that if we increase the CH percentage, this will enhance the performance of the network. To reduce the routing hole problem, the energy consumption of sensor nodes should be balanced. And for balanced energy consumption its necessary to balance the workload among the different parts of the network. Therefore the density of CH's among different parts of the network should be the same. The proposed theorem proof that if the increment of CH's percentage is equal at different parts of the network, then it is possible to balance the energy consumption in the network and prolong the network lifetime.

3.3. Theorem to proof PELEC

Suppose network lifetime of *ith* and *(i+1)th* clusters are equal

$$\epsilon M_i / E_i = \epsilon M_{i+1} / E_{i+1} \qquad 1 \le i \le Cl$$

where Cl is the outer cluster.

Therefore,

$$M_i E_{i+1} = M_{i+1} E_i \tag{1}$$

The number of sensors in each cluster can find by the following equation

$M_i = 2\pi \mathrm{r_i}/\mathrm{C_r}$

$$2\pi r_i/_{\mathrm{C_r}} \text{ x } E_{i+1} = 2\pi r_{i+1}/_{\mathrm{C_r}} \text{ x } E_i \quad (2)$$

As the outer cluster only generate and forward its own packets, so the total energy consumed by the outer cluster E_{Cl} is equal to

$$E_{Cl} = M_{Cl} K e_1 \quad (3)$$

Putting the value of M_{Cl} in Eq. 3

$$E_{Cl} = \left(2\pi r_{Cl}/_{\mathrm{C_r}}\right) \text{ x } K \text{ x } e_1$$

The ith cluster generates and sends its own packets as well as forwards and receives the packets from the outer cluster, so the total energy consumed by ith cluster E_i is equal to

$$E_i = K\left(2\pi r_i/_{\mathrm{C_r}} \text{ x } e_1 + \sum_{j=i+1}^{Cl} 2\pi r_j/_{\mathrm{C_r}} (e_1 + e_2)\right) \quad (4)$$

where, K is a bit rate, e_1 is sending energy, e_2 is receiving energy, E_{Cl} is the total energy of the outer cluster, r_{Cl} is the radius of the outer cluster, $\mathrm{C_r}$ is communication range and r_i is the radius of the ith cluster

$$E_{i+1} = K\left(2\pi r_{i+1}/_{\mathrm{C_r}} \text{ x } e_1 + \sum_{j=i+2}^{Cl} 2\pi r_j/_{\mathrm{C_r}} (e_1 + e_2)\right) \quad (5)$$

Putting the values of E_i and E_{i+1} in Eq. 2

$$2\pi r_i/_{\mathrm{C_r}} \text{ x } K\left(2\pi r_{i+1}/_{\mathrm{C_r}} \text{ x } e_1 + \sum_{j=i+2}^{Cl} 2\pi r_j/_{\mathrm{C_r}} (e_1 + e_2)\right) = 2\pi r_{i+1}/_{\mathrm{C_r}} \text{ x } K\left(2\pi r_i/_{\mathrm{C_r}} \text{ x } e_1 + \sum_{j=i+1}^{Cl} 2\pi r_j/_{\mathrm{C_r}} (e_1 + e_2)\right)$$

$$2\pi r_i/_{\mathrm{C_r}} \text{ x } 2\pi r_{i+1}/_{\mathrm{C_r}} \text{ x } e_1 + 2\pi r_i/_{\mathrm{C_r}} \text{ x} \sum_{j=i+2}^{Cl} 2\pi r_j/_{\mathrm{C_r}} (e_1 + e_2) = 2\pi r_{i+1}/_{\mathrm{C_r}} \text{ x } 2\pi r_i/_{\mathrm{C_r}} \text{ x } e_1 + 2\pi r_{i+1}/_{\mathrm{C_r}} \sum_{j=i+1}^{Cl} 2\pi r_j/_{\mathrm{C_r}} (e_1 + e_2)$$

$$\frac{2\pi r_i/_{\mathrm{C_r}}}{2\pi r_{i+1}/_{\mathrm{C_r}}} = \frac{\sum_{j=i+1}^{Cl} 2\pi r_j/_{\mathrm{C_r}}}{\sum_{j=i+2}^{Cl} 2\pi r_j/_{\mathrm{C_r}}} \quad (6)$$

Let Z is the total number of CH's in the network

$$\mathrm{Z} = \sum_{i=1}^{Cl} \frac{2\pi r_i}{\mathrm{C_r}}$$

$$\mathrm{Z} = \sum_{j=1}^{i} \frac{2\pi r_j}{\mathrm{C_r}} + \sum_{\mathrm{j=i+1}}^{Cl} 2\pi \mathrm{r_j}/_{\mathrm{C_r}}$$

Then

$$\mathrm{Z} - \sum_{j=1}^{i} \frac{2\pi r_j}{\mathrm{C_r}} = \sum_{\mathrm{j=i+1}}^{Cl} 2\pi \mathrm{r_j}/_{\mathrm{C_r}}$$

Similarly

$$\mathrm{Z} - \sum_{j=1}^{i+1} \frac{2\pi r_j}{\mathrm{C_r}} = \sum_{\mathrm{j=i+2}}^{Cl} 2\pi \mathrm{r_j}/_{\mathrm{C_r}}$$

By equal ratio theorem

$$\left(w/_x = y/_z = w+y/_{x+z}\right)$$

Eq. 6 becomes

$$= \frac{\left(Z - \sum_{j=1}^{i} 2\pi r_j/_{\mathrm{C_r}}\right) + 2\pi r_i/_{\mathrm{C_r}}}{\left(Z - \sum_{j=1}^{i+1} 2\pi r_j/_{\mathrm{C_r}}\right) + 2\pi r_{i+1}/_{\mathrm{C_r}}}$$

$$= \frac{Z - \sum_{j=1}^{i} 2\pi r_j/_{\mathrm{C_r}} + 2\pi r_i/_{\mathrm{C_r}}}{Z - \sum_{j=1}^{i+1} 2\pi r_j/_{\mathrm{C_r}} + 2\pi r_{i+1}/_{\mathrm{C_r}}}$$

$$= \frac{Z - \sum_{j=1}^{i-1} 2\pi r_j/_{\mathrm{C_r}}}{Z - \sum_{j=1}^{i} 2\pi r_j/_{\mathrm{C_r}}}$$

$$= \frac{2\pi r_{i-1}/_{\mathrm{C_r}}}{2\pi r_i/_{\mathrm{C_r}}}$$

$$\frac{2\pi r_i/_{\mathrm{C_r}}}{2\pi r_{i+1}/_{\mathrm{C_r}}} = \frac{2\pi r_{i-1}/_{\mathrm{C_r}}}{2\pi r_i/_{\mathrm{C_r}}}$$

$$Den_i/_{Den_{i+1}} = Den_{i-1}/_{Den_i}$$

The lifetime of the network is:

$$T = \frac{\epsilon M}{E},$$

where, M is the entire quantity of sensor nodes in a network; E is the entire energy of the network, and ϵ is the initial power of the sensor node.

This expression in Eq. 7 shows that the density (Den) proportion of the CH's in the ith and (i+1)th clusters is identical to the density proportion of the CH's in the (i-1)th and the ith clusters, so the network lifespan of the two adjoining clusters will be equal. This shows that optimum energy consumption is achievable.

4. Results and discussion

In this study, an effort is made to evaluate the performance of incremental cluster heads routing protocol by answering the following questions:

- How much the increment of cluster head percentage avoids the routing hole problem in the wireless sensor network?
- How much the increment of cluster head percentage affects the lifetime of the network?

4.1. Performance metrics

For assessing the performance of the proposed routing protocol, the network lifetime is used as a performance metric. It is clear that goodness and badness of routing strategies depend on the working life of the network, i.e., a lifetime. The simulation results of the proposed strategy are shown in Figs. 4-15.

Fig. 3: Route processing of ELEC algorithm

4.2. Network lifetime

The lifetime of a WSN is one of the important issues in WSN. To improve the lifetime of a network, an energy-efficient routing protocol strategy is needed. Depends on the network application, the network lifetime definition appears in different forms throughout existing research.

a) Lifetime of a network means how much time the sensor network is in an operational state.
b) The time until a fixed number of nodes depletes its energy (Filipe et al., 2004).
c) The time when an interesting area is no longer sensed by any node (Karl and Willig, 2007).

The proposed work considers the three definitions of network lifetime.

a) 1st CH node failure: According to this definition, the lifetime of the network is the time until the first CH fails or runs out of energy.
b) 10% node failure: According to this, the lifetime is the time until 10% of the total CH depletes its energy.
c) Last packet received: When the last packet was received at the base station from any CH.

4.3. Network lifetime (1st CH node failure)

Here the lifetime of a network is evaluated according to the 1st definition of a lifetime. With the increase in CH percentage, i.e., 10%, 20%, 30%, 40%, and 50% for power multipliers 1, 5, 8, and 10, the lifetime is maximized as shown in Figs. 4-15.

The results in Fig. 4 show that the network lifetime depends on the number of CH's in a network. It can be seen that for 0% CH, the network lifetime for different CH range multiplier (communication range of CH) is up to 300 seconds. At 10 percent CH, multiplier 1 to 8, there is no noticeable change in the lifetime, but the perceptible change at multiplier 9 and 10, i.e., 500 seconds, can be observed. At 50 percent CH of sensor nodes, multiplier 1, 2, 3 still there is no enhancement in the network lifetime, while it is 400 to 1100 seconds with multiplier 4, 5, 6, 7, 8, respectively, and noticeable improvement can be observed at multiplier 9 and 10, i.e.,1400 seconds. It can observe that at 40% and 50%, the lifetime is the same. That's why there is no need to evaluate 60%, and no difference can see in range multipliers 9 and 10. That's why it is better to consider the range multiplier 9 as optimal.

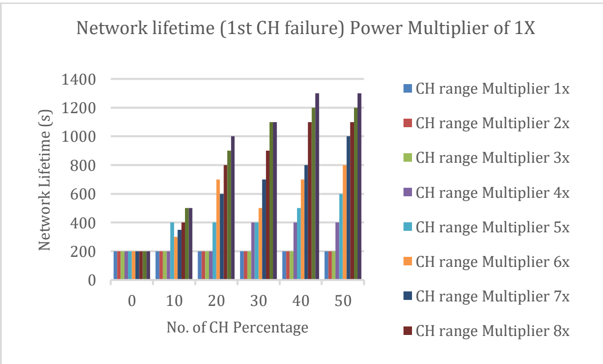

Fig. 4: Network lifetime (1st CH failure) PM=1

The results in Fig. 5 show that the network lifetime depends on the number of CH's in a network. It can be seen that for 0% CH, the network lifetime for different CH range multipliers is up to 300 seconds. At 40 percent CH, multiplier 1 to 5, there is no noticeable change in the lifetime, but the perceptible change at multiplier 5 to 10, i.e., 800 seconds, can be seen. At 50 percent CH of sensor nodes, multiplier 1, 2, 3 still there is no enhancement in the network lifetime, while it is 500 to 800 seconds with multiplier 4 to 10.

In Fig. 6, the power multiplier for all cluster head is taken as 8. The network lifetime at 0% CH for range multiplier's 1 to10 is the same, i.e., 300 seconds. At 10 percent CH, multiplier 1 to 5, there is no noticeable improvement in the network lifetime, but the little change at multiplier 9 and 10, i.e., 500 seconds, can be noticed. At 50 percent CH of sensor nodes, multiplier 1, 2 still there is no enhancement in the network lifetime, while it is 500 to 1200 seconds at with multiplier 3 to 8. The better enhancement can be seen in CH range multiplier 9 and 10, i.e., 1300, and both are the same; therefore, the CH range multiplier 9 can be considered as optimal.

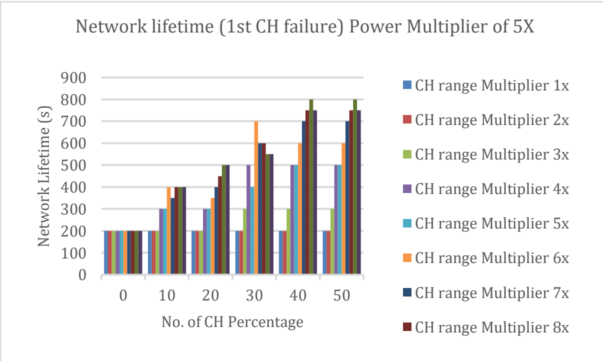

Fig. 5: Network lifetime (1st CH failure) PM=5

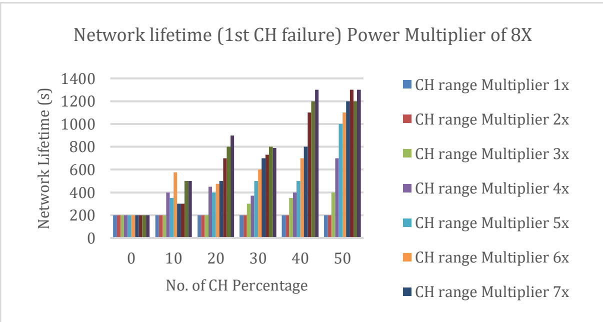

Fig. 6: Network lifetime (1st CH failure) PM=8

To evaluate the lifetime of the network here, the energy for all CH is considering power multiplier 10, as shown in Fig. 7. The lifetime of the network for CH range multiplier 1 to 10, at 0% CH is the same, i.e., 300 seconds. At 10 percent CH, little improvement in a lifetime can be observed, i.e., 500 seconds. At 50 percent CH of sensor nodes, multiplier 1, 2, 3 still there is no enhancement in the network lifetime, while it is 500 to 1200 seconds with multiplier 4, 5, 6 respectively, and noticeable improvement can be observed at multiplier 7 to 10, i.e., 1500 seconds.

4.4. Network lifetime (10% CH node failure)

The network performance is assessed according to the second definition of a lifetime, i.e., 10% CH failure. Impact of incremental CH percentage on the network lifetime with a CH range multiplier from 1 to 10, for different power multipliers 1, 5, 8, 10 are shown in Figs. 8, 9, 10, and 11, respectively.

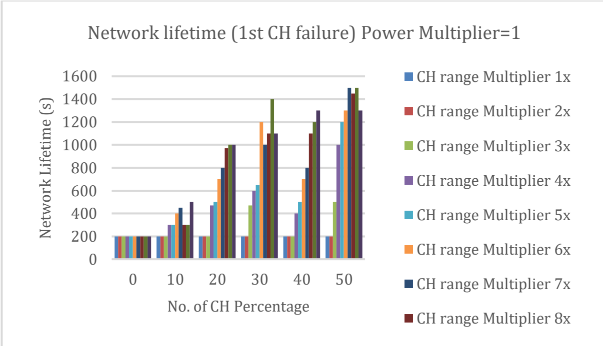

Fig. 7: Network lifetime (1st CH failure) PM=10

The results in Fig. 8 shows that the network lifetime depends on the number of CH's in a network. It can be seen that for 0% CH, the network lifetime for different CH range multiplier (communication range of CH) is up to 500 seconds. At 10 percent CH, range multiplier 1 to 4, there is no noticeable change in the lifetime, and little increase of lifetime can be noticed at multiplier 5 to 8, but the perceptible change at multiplier 9 and 10, i.e., 800 seconds, can be observed. At 50 percent CH of sensor nodes, multiplier 1and 2 still there is no enhancement in the network lifetime, while it is 700 to 3000 seconds with multiplier 3, 4, 5, 6, 7, 8, respectively, and noticeable improvement can be observed at multiplier 9 and 10, i.e., 4000 seconds. It can observe that at 40% and 50%, the lifetime is the same. That's why there is no need to evaluate 60%, and no difference can see in range multipliers 9 and 10. That's why it is better to consider the range multiplier 9 as optimal.

The lifetime at 0% CH for all power multiplier is the same, i.e., 500 seconds. It can be observed that life is increased with the increase in CH percentage, i.e., 10%, 20%, 30%, 40%, and 50% for power multipliers 1, 5, 8, and 10.

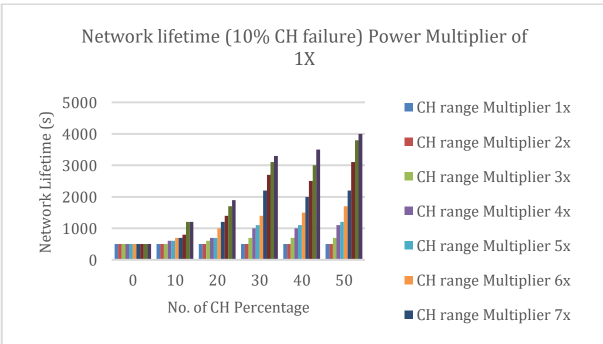

Fig. 8: Network lifetime (10% CH failure) PM=1

Fig. 9 shows the impact of incremental CH percentage on the network lifetime with a CH range multiplier from 1 to 10 with the power multiplier 5. At 0% CH, the network lifetime for different CH range multipliers is up to 500 seconds. At 40 percent CH, multiplier 1 to 4, there is no noticeable change in the lifetime, but the perceptible change at multiplier 5 to 10, i.e., 1000 seconds, can be seen. At 50 percent

CH of sensor nodes, multiplier 1, 2, 3 still there is no enhancement in the network lifetime, while it is 1000 to 2000 seconds increment with multiplier 4 to 10.

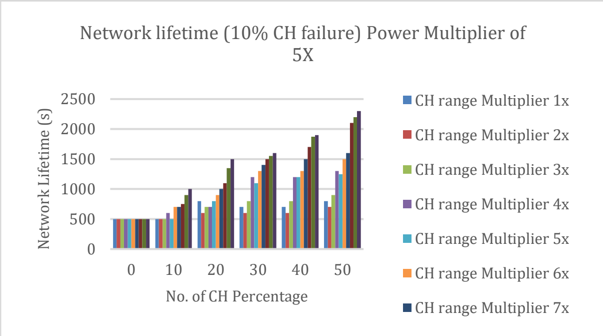

Fig. 9: Network lifetime (10% CH failure) PM=5

Fig. 10 shows the impact of incremental CH percentage on the network lifetime for the power multiplier 8 with a CH range multiplier from 1 to 10. At 0% CH, the network lifetime for different CH range multipliers is up to 500 seconds. At 40 percent CH, multiplier 1 to 3, there is no noticeable change in the lifetime, but the perceptible increase at multiplier 4 to 10, i.e., 3000 seconds, can be seen. At 50 percent CH of sensor nodes, multiplier 1, 2, 3 still there is no enhancement in the network lifetime, while it is 1000 to 3000 seconds increment with multiplier 4 to 10.

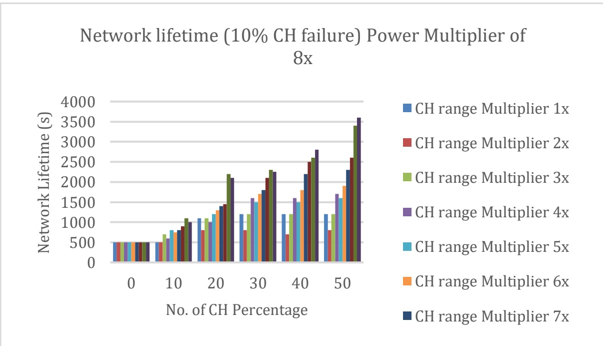

Fig. 10: Network lifetime (10% CH failure) PM=8

Fig. 11 shows the impact of incremental CH percentage on the network lifetime for the power multiplier 10 with a CH range multiplier from 1 to 10. At 0% CH, the network lifetime for different CH range multipliers is up to 500 seconds. At 50 percent CH of sensor nodes, multiplier 1 and 2 still there is no enhancement in the network lifetime, while it is 2000 to 4000 seconds increment with multiplier 4 to 10.

4.5. Network lifetime (Last packet received)

The network performance is assessed according to the third definition of a lifetime, i.e., the last packet received. Impact of incremental CH percentage on the network lifetime with a CH range multiplier from 1 to 10, for different power multipliers 1, 5, 8, 10 are shown in Figs. 12, 13, 14, and 15, respectively.

The lifetime at 0% CH for all power multiplier is the same, i.e., 500 seconds. It can be observed that lifetime increases with the increase in CH percentage, i.e., 10%, 20%, 30%, 40%, and 50% for power multipliers 1, 5, 8, and 10.

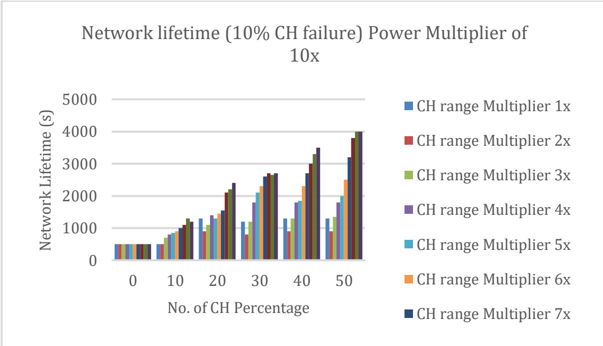

Fig. 11: Network lifetime (10% CH failure) PM=10

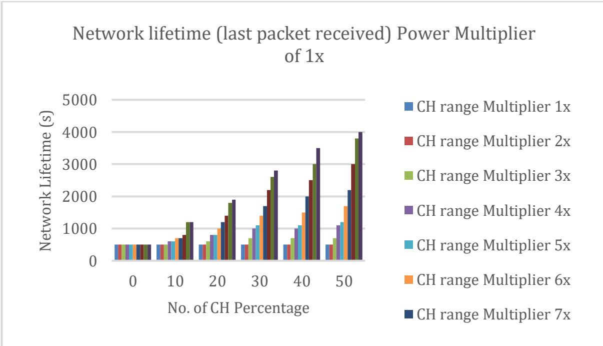

Fig. 12: Network lifetime (last packet received) PM=1

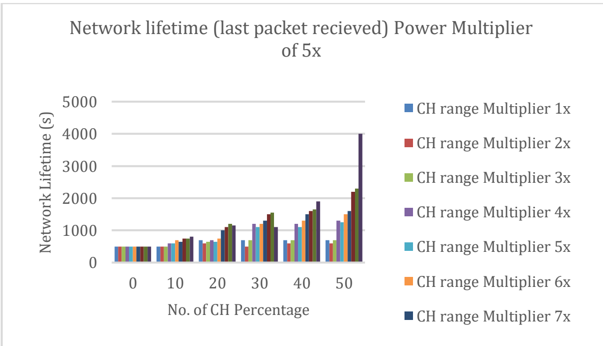

Fig. 13: Network lifetime (last packet received) PM=5

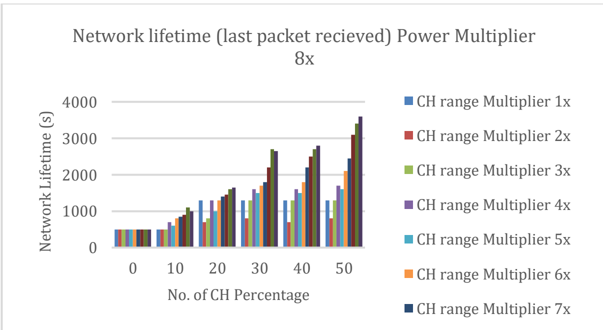

Fig. 14: Network lifetime (last packet received) PM=8

5. Conclusion

Many researchers are making efforts to explore sensor networks. The network lifespan depends on the energy level. The imbalanced use degrades the sensor node energy quickly and leads to sensor voids, which further cause the routing hole problem. The routing hole problem ultimately affects network performance. To solve the routing hole problem, an Energy Efficient Least Edge Computation routing protocol (ELEC) is proposed in the literature. The simulation results show that ELEC achieves nearly double network lifetime by equal energy consumption in various parts of the network as compared to other existing routing techniques such as GRACE, LEACH, and AODV-EHA. The proposed paper presents progressive Energy Efficient Least Edge Computation (P-ELEC) routing protocol, where a cluster head percentage is incremented periodically.

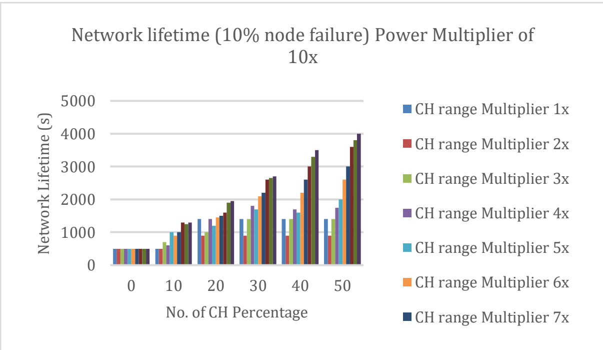

Fig. 15: Network lifetime (last packet received) PM=10

The simulation result shows the prolongation of a lifetime under various scenarios and modes of operation. In all of the above-mentioned results at 0% CH's there is no enhancement in the lifetime for different power multiplier, which proves that the cluster based routing has a high impact on the prolongation of network lifetime. Incrementing the CH's minimizes the workload of each cluster head and in-turn enhances the lifetime of the network.

The dense deployment of CHs in the proposed work shows the enhanced lifetime of the network. But a larger number of CHs leads to redundant data transmission to the sink. To avoid redundant data transmission due to the dense deployment of CHs, the sleep and awake strategy can be implemented in the future.

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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