Progressive Energy Efficient Least Edge Computation (P-ELEC) Routing Protocol in WSN

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Abstract
The energy of nodes in Wireless Sensor Network (WSNs) is usually limited which has to be consumed economically in order to prolong the lifetime of the network. The imbalanced use degrade the sensor node energy quickly and leads to sensor voids which further cause the routing hole problem. The routing hole problem ultimately effect the network performance. To solve the routing hole problem an Energy efficient Least Edge Computation routing protocol (ELEC) is proposed in 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. Proposed paper presents progressive Energy efficient Least Edge Computation (P-ELEC) routing protocol, where a cluster head percentage is incremented periodically. Incrementing the cluster head minimizes workload of each cluster head and in-turn enhances the lifetime of the network. Simulation result shows prolongation of lifetime under various scenarios and modes of operation.

Keywords
Wireless Sensor Network, Routing Protocol, Routing Hole problem, Cluster Based Routing, ELEC routing protocol

1. Introduction

Due to the vast applications, the Wireless Sensor Network (WSNs) has witnessed notable considerations in recent research and development [1]. 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. The sensor void caused by degradation of energy, is major issue in WSNs. A sensor node, which is unable to disseminate the packets, is known as void or hole. The void sensor are highly utilizing the energy, which leads to routing hole problem in WSNs[2, 3]. 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[4]. Many multi-hop cluster based routing protocols are present in literature[5-7], but energy unaware path selection caused routing hole problem as shown in Fig. 1 [8]. For balance energy consumption many routing techniques are proposed by authors [9-11].

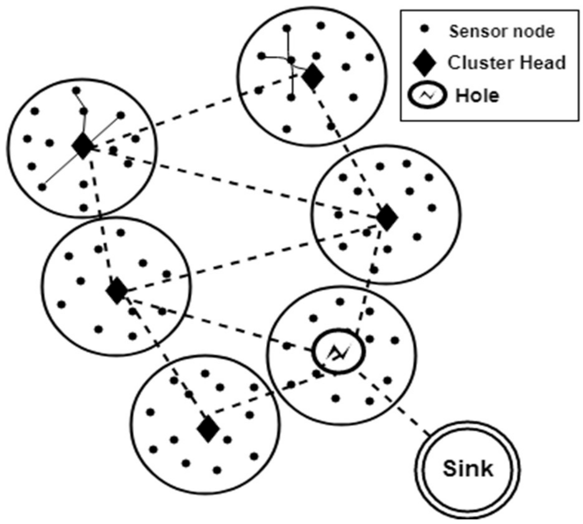

Figure 1 Routing hole in Multi-hop Cluster Based WSN

To minimize the energy consumption and enhance the network lifetime through a load balancing among sensor nodes a grid based routing technique is presented by author in [12]. The evaluation prove that proposed technique enhance the stability and energy efficiency as compared to CFDASC algorithm in terms of network stability and load balancing of the entire network. Cluster based routing leads to non-uniform energy consumption among sensor nodes and cluster heads. The CH near to base station have more energy consumption due to larger load. To balance the energy consumption, it is very crucial to work load among the sensor nodes and CH. To deal with imbalanced energy consumption a Distributed Unequal Clustering Algorithm (DUCA), is proposed [13]. The proposed DUCA technique make the cluster size small near to base station, because the work load of these CHs is more. The simulation result shows that the DUCA algorithm improve the lifetime by balancing the energy loads among the sensor nodes as compare to LEACH protocol.

To overcome the routing hole problem a novel energy efficient least edge computation routing protocol (ELEC) is proposed by authors in [14]. The simulation results show the enhanced performance of ELEC as

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compared to other existing routing techniques such as GRACE, LEACH and AODV-EHA. 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. Simulation result shows prolongation of lifetime under various scenarios and modes of operation. The organization of remaining paper is shown in Fig. 2.

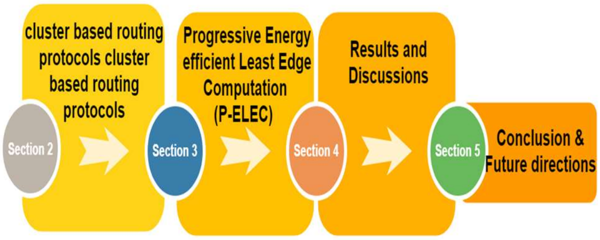

Fig. 2 Paper Organization

2. Cluster Based Routing Protocols

Proposed research focused concern is routing hole problem therefore on the analysis of routing hole problem, energy efficient utilization and lifetime enhancement strategies, a literature will be briefly presents in this section [5, 15, 16]. It is proven from the research that communication is the major reason of energy exhaustion. To minimize 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 next CH. To balance the workload of CHs a modified Mutual Exclusive Distributive Clustering (MEDC) protocol is presented in [17]. Proposed work balanced the work load of cluster heads and enhance the network lifespan.

For the balanced energy consumption and enhanced network lifetime an Energy Balanced Distributed Clustering Protocol (EBDCP) is proposed in [18] through efficient elected clustering technique with the support of a mobile base station. EBDCP insures 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 presents by authors in [19] which elects sensor node highest energy as a cluster heads. After the distribution of sensor nodes and selection of clusters, the whole network is spited into zones and inside each zone a mobile sensor node is deployed which behave as Mobile Data Collector (MDC) for gathering data from CHs. Results from simulation shows the enhancement of network performance in terms of network lifetime, throughput, security and number of critical nodes. But the proposed MEACBM routing protocol increases the overhead due to 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 compare to existing routing protocol, LEACH[20]. Authors proposed a Compressive Sensing-based clustering technique to minimize the power exhaustion and mitigate the hole problem in [16]. The technique rotate 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 the even energy utilization in a network taking into account. An efficient energy consumption has been accomplished by sharing the load, energy efficient deployment techniques and power balancing routing protocols, but still requires to take in 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 will send the data through multi-hop clustering; otherwise, the data are sent directly to the CH through 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.

A further evaluation of ELEC is proposed, where a cluster head percentage is incremented periodically.

Incrementing the cluster head minimizes workload of each cluster head and in turn enhances the lifetime of the network. Simulation show the results taken in variety of scenarios and methods of operation.

3.1 ELEC routing Network Model:

Homogenous sensor nodes are deployed randomly in wireless sensor network area. The area is divided into cluster and each cluster is control by one cluster head (CH). The sensor nodes will send the sense 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 will forward the sense data directly to CH via single-hop. After the collection and aggregation of receiving packets the CH will forward the data to sink via multi-hop. The proposed protocol follow the same routing algorithm like ELEC, which considers the edge count, energy level and link cost for the next hop neighbor selection. Route processing in ELEC algorithm is illustrated in Fig. 3.

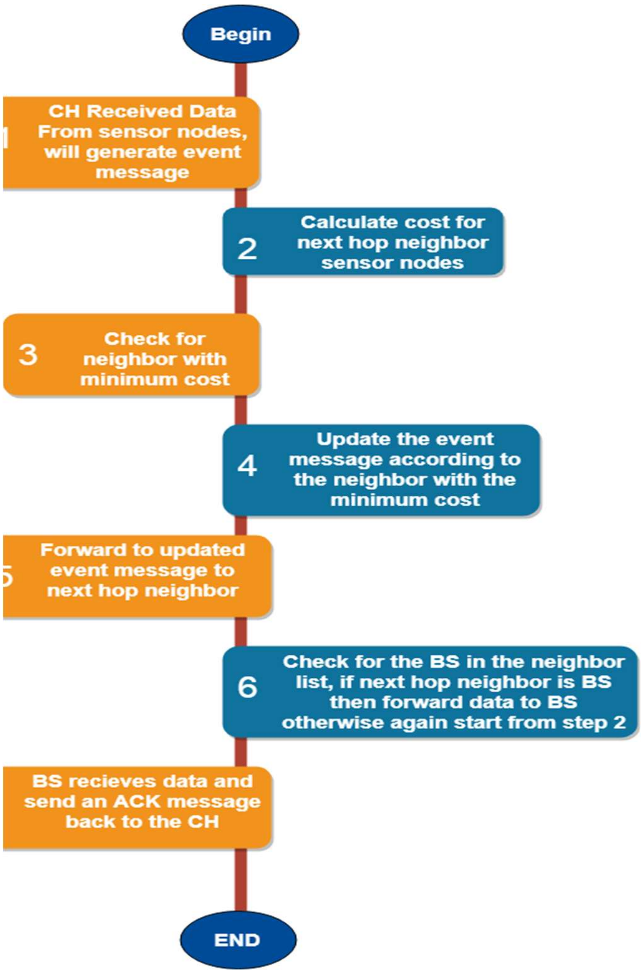

Figure 3 Route processing of ELEC algorithm

3.2 Theorem:

The proposed theorem is to proof of that if we increase the CH percentage, this will enhance the performance of 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 work load among the different parts of network, therefore the density of CH's among at different parts of network should be 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.

The lifetime of the network $T = {\epsilon M}/{E}$

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.

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

$$\epsilon M_i / E_i = \epsilon M_{i+1} / E_{i+1} \qquad 1 \le i \le Cl \qquad \text{Where Cl is outer cluster}$$

Therefore, $M_i E_{i+1} = M_{i+1} E_i$ (1)

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

$$M_i = 2\pi r_i / C_r$$

$$2\pi r_i / C_r \times E_{i+1} = 2\pi r_{i+1} / C_r \times E_i \quad (2)$$

As the outer cluster only generate and forward its own packets so the total energy consumed by 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)

$$E_{Cl} = \left(2\pi r_{Cl} / C_r\right) \times K \times e_1$$

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

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

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

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

Putting the values of E_i and E_{i+1} in eq(2)

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

$$2\pi r_i / C_r \times 2\pi r_{i+1} / C_r \times e_1 + 2\pi r_i / C_r \times \sum_{j=i+2}^{Cl} 2\pi r_j / C_r \,(e_1 + e_2) = 2\pi r_{i+1} / C_r \times 2\pi r_i / C_r \times e_1 + 2\pi r_{i+1} / C_r \sum_{j=i+1}^{Cl} 2\pi r_j / C_r \,(e_1 + e_2)$$

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

Let Z is the total number of CH's in the network $Z = \sum_{i=1}^{Cl} \frac{2\pi r_i}{C_r}$

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

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

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

By equal ratio theorem $(w/x = y/z = w+y / x+z)$ eq(6) become

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

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

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

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

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

$$Den_i / Den_{i+1} = Den_{i-1} / Den_i \quad (7)$$

Figure 4 Theorem to proof PELEC

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 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. lifetime. The simulation results of the proposed strategy are shown in figures.

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 operational state.
b) The time until a fixed number of nodes depletes its energy [21].
c) The time when an interested area is no longer sensed by any node [22].

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 received at 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 lifetime. With the increase in CH percentage, i.e. 10%, 20%, 30%, 40% and 50% for power multiplier 1, 5, 8 and 10 the lifetime is maximized as shown in figures.

4..3.1 Network lifetime (1st CH node failure) for CH power multiplier 1

The results in Fig 5 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 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 same that's way, no need to evaluate 60%, and no difference can see in range multiplier 9 and 10 that's why it is better to consider the range multiplier 9 as optimal.

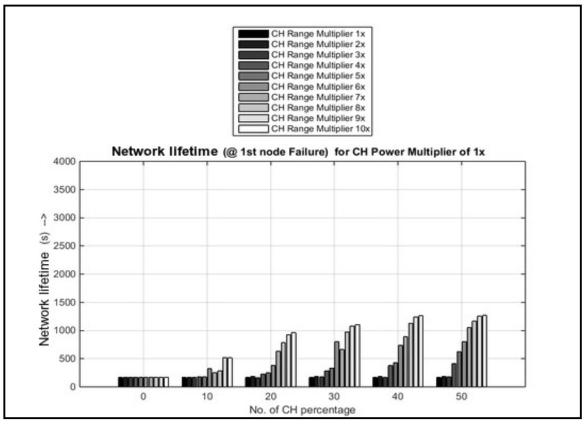

Figure 5 Network lifetime (1st CH failure) PM=1

4..3.2 Network lifetime(1st CH node failure) for CH power multiplier 5

The results shown in Fig. 6 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's 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.

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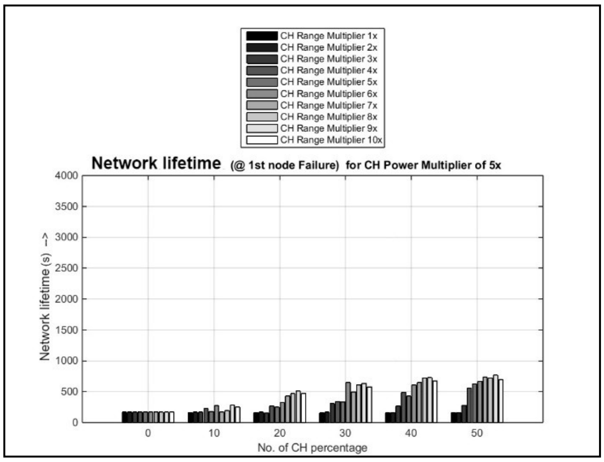

Figure 6. Network lifetime (1st CH failure) PM=5

4..3.3 Network lifetime (1st CH node failure) for CH power multiplier 8

In the Fig. 7 the power multiplier for all cluster head is taken as 8. The network lifetime at 0% CH for range multiplier's 1 to10 is 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 same therefore the CH range multiplier 9 can be considers as optimal.

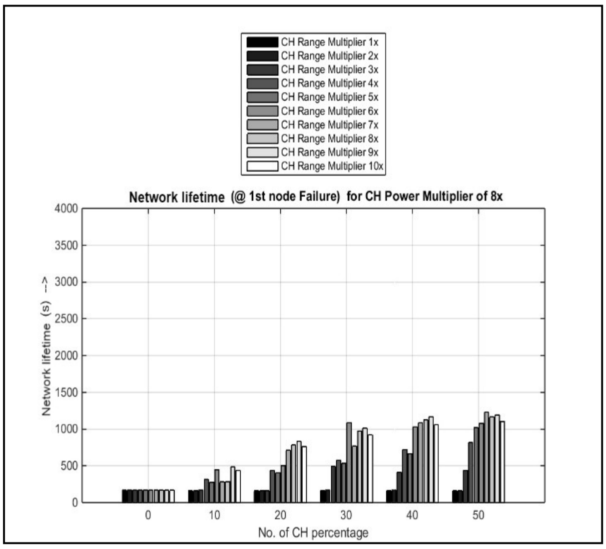

Figure 7. Network lifetime (1st CH failure) PM=8

4..3.4 Network lifetime(1st CH node failure) for CH power multiplier 10

To evaluate the lifetime of the network here the energy for all CH is considering power multiplier 10 as shown in Fig. 8. The lifetime of network for CH range multiplier 1 to 10, at 0% CH is same i.e. 300 seconds. At 10 percent CH, little improvement in lifetime can be observe 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.

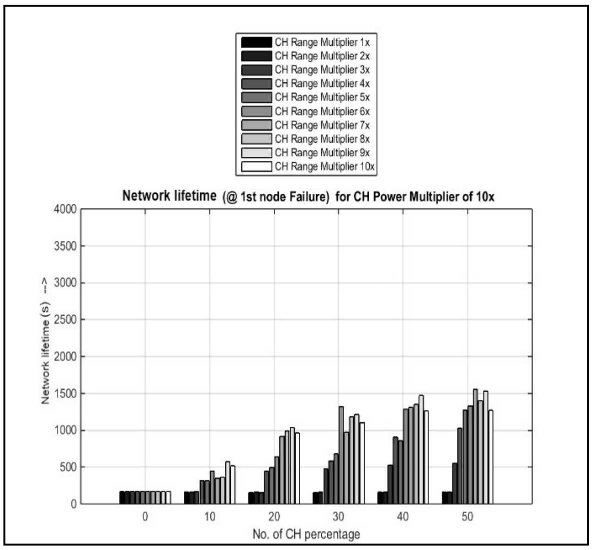

Figure 8 Network lifetime (1st CH failure) PM=10

4.4 Network lifetime (10% CH node failure)

The network performance is assessed according to the second definition of 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 Figures 9, 10, 11 and 12 respectively.

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

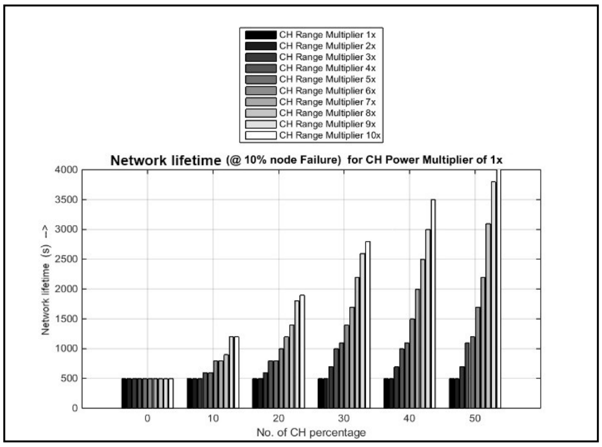

Figure 9 Network lifetime (10% CH failure) PM=1

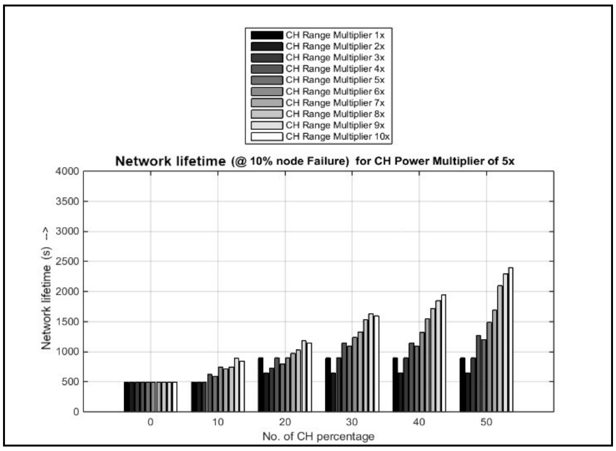

Figure 10 Network lifetime (10% CH failure) PM=5

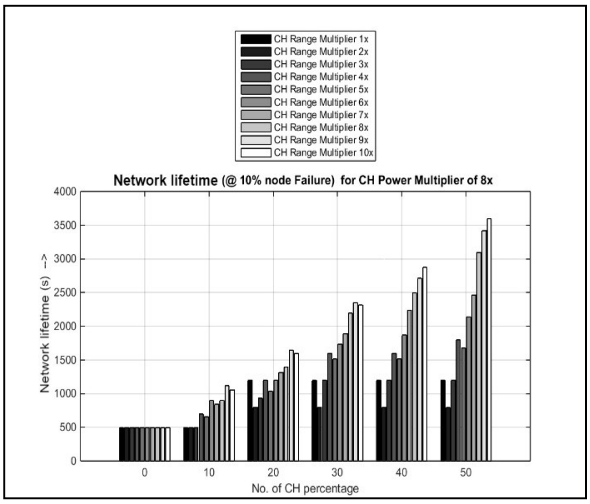

Figure 11 Network lifetime (10% CH failure) PM=8

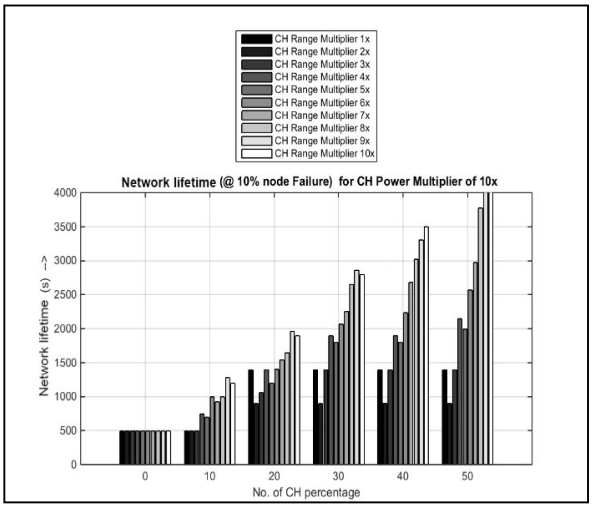

Figure 12 Network lifetime (10% CH failure) PM=10

4.5 Network lifetime (Last packet received)

The network performance is assessed according to the third definition of lifetime i.e. 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 Figures 13, 14, 15 and 16 respectively.

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

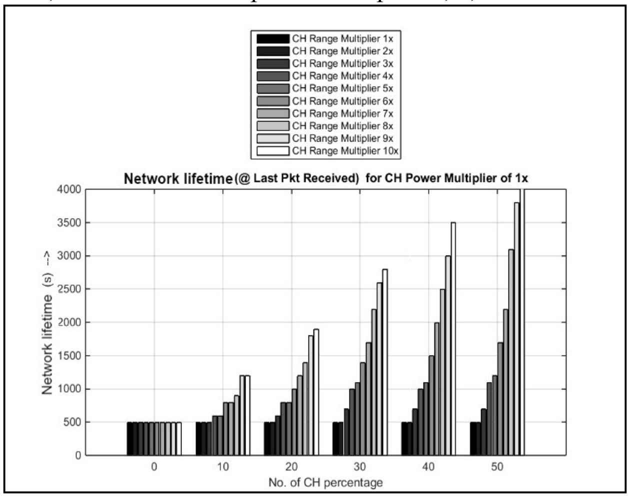

Figure 13 Network lifetime (last packet received) PM=1

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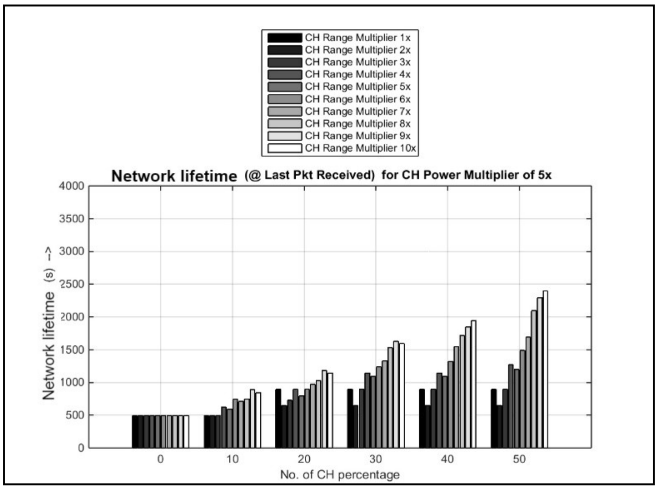

Figure 14 Network lifetime (last packet received) PM=5

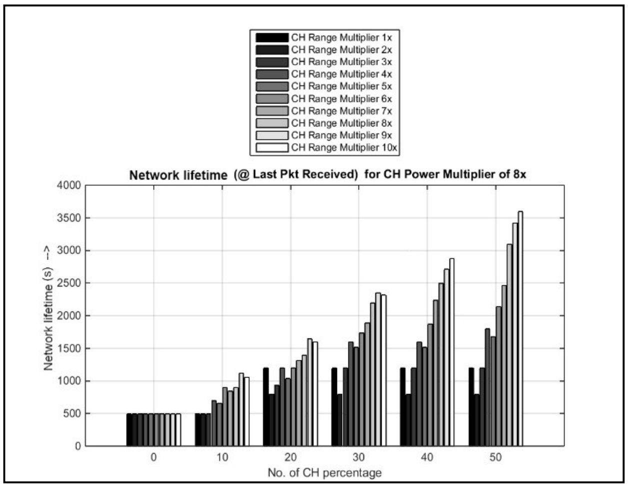

Figure 15 Network lifetime (last packet received) PM=8

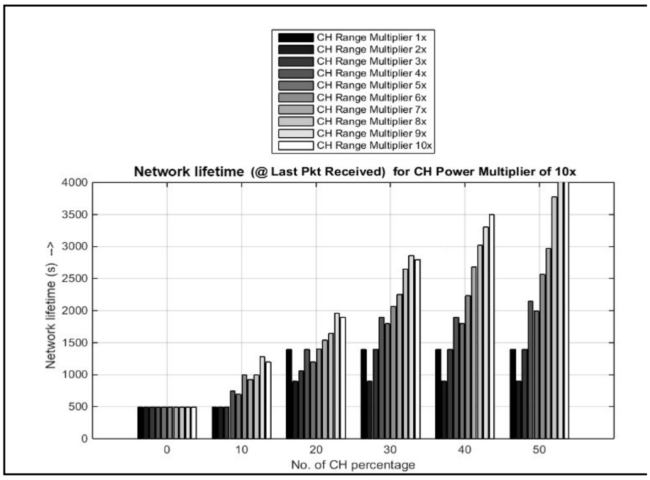

Figure 16 Network lifetime (last packet received) PM=10

5. Conclusion

Many researches are doing efforts for exploring sensor networks. Network lifespan depends on energy level. The imbalanced use degrade the sensor node energy quickly and leads to sensor voids which further cause the routing hole problem. The routing hole problem ultimately effect the network performance. To solve the routing hole problem an Energy efficient Least Edge Computation routing protocol (ELEC) is proposed in 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. Proposed paper presents progressive Energy efficient Least Edge Computation (P-ELEC) routing protocol, where a cluster head percentage is incremented periodically. Incrementing the cluster head minimizes workload of each cluster head and in-turn enhances the lifetime of the network. Simulation result shows prolongation of lifetime under various scenarios and modes of operation.

Dense deployment of CHs in the proposed work, shows the enhanced lifetime of network. But 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 implement in future.

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