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Novel Energy Efficient Protocols for Gaussian & Uniform Distributed Heterogeneous WSNs

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ABSTRACT

Network lifetime is a serious problem in the design of wireless sensor networks (WSNs). Prolonged network lifetime is desired characteristics of WSNs. Gaussian distributed heterogeneous WSNs can fulfill such requirement and are widely deployed in realistic scenarios. In addition, the presence of some heterogeneous sensor nodes leads to performance enhancement in terms of intrusion detection probability, network lifetime, nonstop delay and throughput. In this paper, we have proposed novel routing-chains protocols for Gaussian and uniformly distributed heterogeneous sensor networks. Proposed protocols, lifetime enhancement in Gaussian distributed heterogeneous sensor network (GHetLESN) and lifetime enhancement in uniformly distributed heterogeneous sensor network (UHetLESN) have been compared with existing energy efficient chain formation (EECF) protocol. We have also presented the results that how much percentage of heterogeneity of total nodes will provide good impact on network lifetime. By experimentation, it is shown that proposed protocols GHetLESN provides 4.76 times enhancement in network lifetime compared to existing protocol EECF and UHetLESN provides 1.78 times enhancement in network lifetime compared to EECF.

Keywords: Gaussian and uniform node deployment, chain formation, energy efficient routing, GHetLESN, UHetLESN.

1 Introduction

In the design of wireless sensor networks (WSNs), lifetime is a serious problem [1, 2]. Many factors influence the network lifetime, which include network architecture and protocol, lifetime definition, data collection initiation, energy consumption model and channel characteristics. This makes the lifetime analysis of networks a difficult task [3]. This paper deals with the minimization of energy consumption by using an efficient routing protocol and appropriate node deployment which improves the lifetime of the network. Efficient power gathering in sensor information systems (PEGASIS) [4] and energy efficient chain formation (EECF) [5] are the two important link formation techniques. Overhead delay is reduced in EECF algorithm by streamlining message flow over a strip-tree chain formed throughout the network [6, 4]. For

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a uniformly distributed network, the EECF protocol relays the aggregated message stream to the BS using only a single node. By reducing the number of nodes operation during one round, energy savings can be achieved, which in turn results in the usage of energy for data aggregation per message per node. In tree formation scheme delay is introduced till the final message reaches the destination node i.e., base station (BS) as one single chain passing over all nodes in the network. In our protocol, by allowing multiple chains to be formed to the BS, the delay can be reduced. The coverage is not deterministic to an extent as it is dependent on the placement of nodes, which is selected to be random. There are three kind of heterogeneity in WSNs [7, 8], link, computational and energy heterogeneity. Computational heterogeneity means some of the nodes have powerful processor, large memory. Link heterogeneity, in this some of the sensor nodes have highly reliable communication links. Energy heterogeneity, in this some of sensor nodes have more energy resources or battery. Energy heterogeneity play great role in sensor networks because computational and link heterogeneity will take more energy resources. In WSNs Heterogeneity provides enhancement in expressions of response time, lifetime and reliability of link [9,14]. In the absence of energy heterogeneity, computational and link heterogeneity will affect the sensor network unconstructively consequential in a decrease of the network lifetime. In this paper, we are assuming a claasical sensing model of sensor node [19-20].

The major contributions of the paper are summarized as follows:

- Development of lifetime enhancement protocol for Gaussian distributed heterogeneous sensor networks i.e. GHetLESN.
- Development of lifetime enhancement protocol for uniformly distributed heterogeneous sensor networks i.e. UHetLESN.
- Dependence of network lifetime on percentage of heterogeneous and start nodes of total nodes in sensing field
- Providing MATLAB programming and demonstrating the effectiveness of GHetLESN and UHetLESN protocols over existing protocol EECF [5] based on network lifetime.

In our knowledge, there is no published work providing these protocols and energy model of sensor nodes. The subsequent sections of this paper are structured as follows: We explain the network model that is used in this work with some background information in section 2. Section 3, discusses a review of related works with chain formation algorithms. Section 4 shows, proposed protocols GHetLESN and UHetLESN. Results and analysis are presents section 5. Section 6 concludes the paper along with the direction of future work.

2 Preliminaries and Network Model

This section describes the model of heterogeneous WSNs, In which sensor node following Gaussian & uniform random distribution. We consider stationary heterogenous WSNs with the omni- directional transceiver. Sensor nodes follow classical sensing model to sense the information. Important network characteristics are listed below that influence the network lifetime along with network assumptions[23, 21].

2.1 Network Architecture :

It provides an idea about how the sensor nodes should inform their collected data to the BS. In the literature three types of network architecture have considered: cluster ad- hoc, flat ad-hoc and sensor network with mobile access (SENMA).

2.2 Data Collection Initiation:

In clock-driven WSNs, sensor nodes transmit and aggregate data at fixed time intervals. In demand-driven or event-driven WSNs, data aggregation are triggered by an event of interest from the BS.

2.3 Energy Consumption Model:

Sensor node energy consumption model plays a great role for analysis of network lifetime.

2.4 Lifetime Definition:

It is defined as time duration from the deployment of sensor nodes to the instant when the network is nonfunctional.

2.5 Network Assumptions

The following are the assumptions used in proposed protocols [10].

- BS is located at the center of the sensing field
- Some of the sensor nodes are heterogeneous and they are stationary after deployment.
- Nodes follow Gaussian and uniform random distribution
- The mean of Gaussian distribution is zero
- Nodes are location aware, i.e. it has GPS facility

3 Related Work

Se-Jung Lim et. al [5] have proposed an energy efficient chain formation (EECF) method for resolving uneven energy consumption concern due to long distance communication of few sensor nodes in Efficient power gathering in sensor information systems (PEGASIS) by the help of greedy algorithm. EECF [5] protocol uses the Buttenfield strip tree geometry to form a chain. From the beginning of the initial round, the start node and end node decide upon, for the chain, by using the coordinates of the two nodes, the anchor length (straight line distance between the nodes) is calculated. "root node" is selected based on the perpendicular distance from the anchor length, the node which is having the longest perpendicular distance from the anchor length is chosen as the root node and the process is repeated recursively with each root node as the end node for a fixed count. The chain formations, then starts as a strip tree and all nodes are included in a single chain. The advantage of this algorithm is, throughout the network it reduces overhead delay by streamlining message flow over a strip-tree chain formed. This protocol simulated for a uniformly distributed network and consists of a single end node to relay the aggregated message stream to the Base Station (BS). In sensing field start and end node connected by a straight line. Furthest node from the sink is start node, and a node with longer communication distance from this start node becomes the end node. Which is shown in Figure 1.

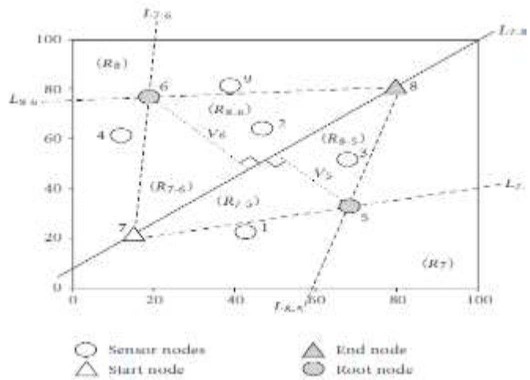

Figure 1: How the sensing field is divided (100m × 100 m) [5].

When the nodes 7 and 8 are the start and end node and location of the sink is (50, 300) respectively. The sensing field is partitioned into two groups by a straight line (L7-8) that joints nodes 7 (x7, y7) and 8 (x8, y8) [5]. Wang et al. state that if it starts inside the network area and is near to the target uniform random WSNs is not able to detect moving intruder. Differentiated detection capabilities at different locations will be provided by Gaussian-distributed WSNs. Performance comparison has been done by the authors between Gaussian-distributed WSNs and uniformly distributed WSNs. This work mathematically formulates detection probability and provides instructions to select an suitable deployment strategy and to determine significant network parameters [11]. Zhinua et al. stated that due to uniform deployment the nodes those are closer to a BS carrying heavy traffic loads via multi-hop transmission create a problem of uneven energy consumption and energy holes in many-to-one sensor network. This outcomes in energy depletion within the area at an increased rate and finally it produces to energy holes around the BS. Such hot-spots found are more likely to happen nearer to the BS instead of any other geographical area enclosed by the network [12].

4 Proposed Protocols

In this paper, we have proposed two protocols: lifetime enhancement of Gaussian distributed heterogeneous sensor network (GHetLESN) and lifetime enhancement of uniformly distributed heterogeneous sensor network (UHetLESN). Figure2 shows the sensor nodes deployment, which is following Gaussian random distributions over the sensing field. Mathematical representation of probability density functions of normal distributions given below [9]:

$$f(x)=\frac{1}{\sqrt{2\pi}\sigma}\exp\left[\frac{-(x-\bar{x})^2}{2\sigma^2}\right]\ (-\infty < x < \infty) \tag{1}$$

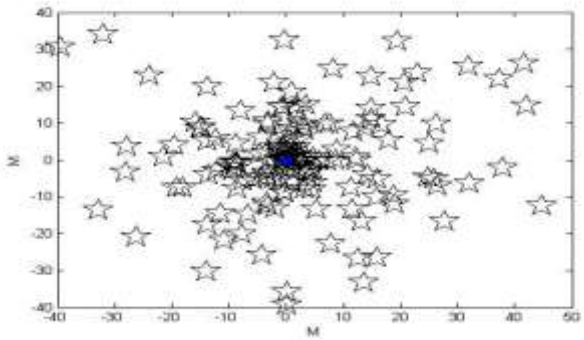

Figure 2: Gaussian distributed Sensor networks

Where $\bar{x}$ and σ^2 are the mean and variances respectively. The shape of density function is as shown in the Figure 3.

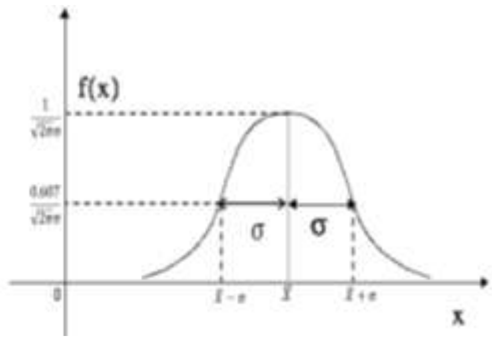

Figure 3: Normal Probability density function

If we considering mean $\bar{x}$ =0 and variance σ^2 =1, we obtain standard Gaussian distribution curve:

$$f(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2}x^2\right) \qquad (-\infty < x < \infty) \tag{2}$$

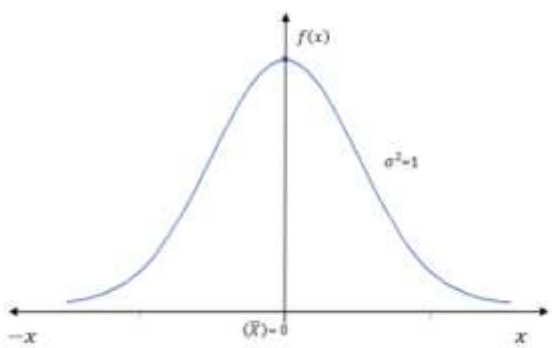

Figure4: Standard Gaussian distribution curve

For the probability density function in two dimensional Gaussian distribution in which a sensor node resides at point (x, y) with respect to the deployment point (x_0, y_0) [9,13] is denoted by Eq.3.

$$f_i(x,y) = \frac{1}{2\pi\sigma_x\sigma_y} e^{-\left(\frac{(x-x_0)^2}{2\sigma_0 x^2} + \frac{(y-y_0)^2}{2\sigma_0 y^2}\right)} \tag{3}$$

Where σ_x and σ_y are standard deviation to x and y co-ordinate

Deployment of sensor nodes affects the energy consumption of WSNs along with individual nodes because the distance between nodes and BS is different due to different node position. Random deployment of sensor in WSNs is frequently adopted due to following advantages: Its easy scalability, fast deployment, fault tolerant and it can be applied in a human-inaccessible and hostile region. Therefore, there are two types of node deployment uniform random node deployment and Gaussian random node deployment.

Heterogeneous WSNs means some of the nodes having more energy compare to other nodes

4.1 Lifetime enhancement of Gaussian distributed heterogeneous sensor network (GHetLESN) protocol:

Working of proposed algorithm GHetLESN with justifications are given below:

4.1.1 Sensor node deployment follows a heterogeneous Gaussian distribution

We emphasize that the heterogeneous Gaussian random distribution is more appropriate to most of the applications compared to uniform and random distribution for information collection purposes.

- Realistic events occurrence are usually follow heterogeneous Gaussian distribution rather than random and uniform in an random environment.
- The high density region provides robustness to network failure which is desirable.

4.1.2 Heterogeneous sensor network instead of the homogenous sensor network used in EECF

In EECF protocol nodes are homogeneous in nature, but in this paper we are introducing heterogeneity and for analysis purposes: Sensor nodes inside twenty percent of the sensing radius are assigned double initial energy as compared to remaining sensor nodes. We have chosen heterogeneous nodes near to BS in order to avoid hot spot near BS. In multi-hop communication, sensor nodes near to BS have to receive the data from the other nodes and transmit the same to BS, whereas nodes away from BS have to just collect data and pass it to nearest node hence, they require less energy comparatively.

4.1.3 Formation of multiple start nodes to form multiple chains

The EECF produces high delay due to single chain formation. The delay can be reduced by consideration of simultaneous multiple. All nodes may not be included in one round of chains, but over succeeding rounds, most of the sensor nodes will be able to transmit their collected data to the BS.

4.1.4 Root node formation based on shortest perpendicular distance to the BS

The justification behind this step is to form straight chains from the end node to start node. Using Buttenfield recursive tree traversal algorithm, two branches are formed.

4.1.5 Start nodes rotated along the edge nodes for each successive round.

Start nodes for all chains are always considered among the sensor node which are far away from the BS. Roles of start node rotation are performed between sensor nodes that have earlier been start nodes and the nearest edge sensor nodes that have not considered in chain formation. Figure8 represents flow chart of GHetLESN protocol along with the modified buttenfield algorithm

4.2 Lifetime enhancement of uniform and random distributed heterogeneous Sensor Network (UHetLESN) Protocol:

Working of this protocol is same as GHetLESN protocol. Only difference is deployments of the nodes are uniform and random.

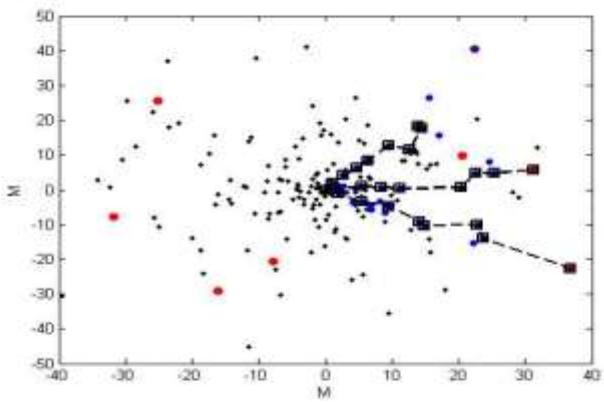

Figure 5: Start nodes formation, candidate nodes are represented by blue, start nodes are represented by red nodes and normal nodes are represented by black in heterogeneous networks

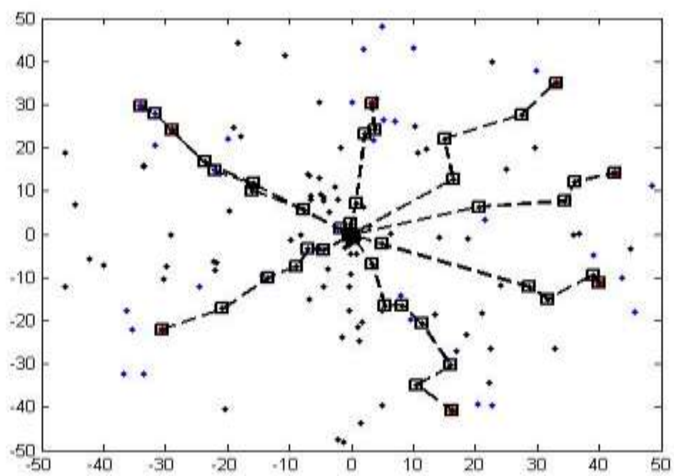

Figure 6: In uniform and random distributed heterogeneous GauassianWSNs, final formation of chains after one round

Figure 5 represents Start nodes initial formation of nodes, candidate nodes are represented by blue, start nodes are represented by red nodes and normal nodes are represented by black in heterogeneous networks. Figure6 represents Figure6: Uniform and random distributed heterogeneous WSNs, final formation of chains after one round and Figure7 shows a Gaussian Distributed heterogeneous WSNs, final formation of chains after one round.

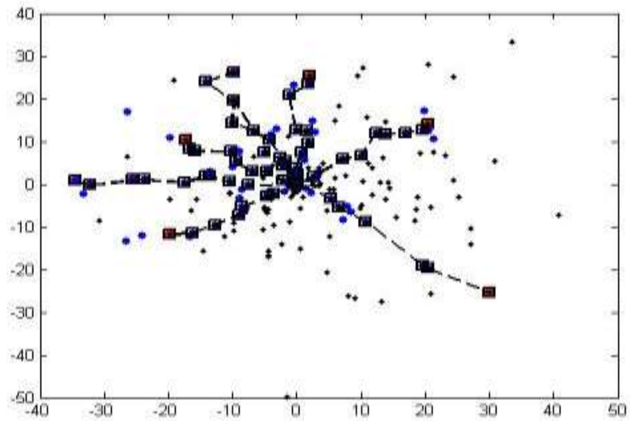

Figure 7: Gaussian Distributed heterogeneous WSNs, final formation of chains after one round.

5 Network Lifetime Analysis of GHetLESN and UHetLESN Protocols by Existing Criterions

This section describe the existing criterions to analyze performances of proposed protocols GHetLESN and UHetLESN are general formula of a lifetime [23],Time to First Fail (TTFF) [24] and ONP method [24].

5.1 General Formula for Network Lifetime

Expected lifetime of the network E [T], is expected amount of time until the network dies.Total non-rechargeable initial energy μ_0 for WSNs, is given by [23]

$$E[T] = \frac{\mu_o - E[E_{WE}]}{P_C + \mu E[E_{RE}]} \tag{4}$$

Where $E[E_{WE}]$ is the expected exhausted energy in the network when it dies, $E[E_{RE}]$is the expected informative energy consumed by all sensors when they are randomnly distributed, P_C is the continuous power consumption, μ is the number of data aggregation per unit time.

Proof: Eq. 4 is derived on the basis of strong law of large numbers.Assume that to record the network lifetime T we perform M independently and identically distributed trials on the same WSN, the wasted energy E_{WE} , and the energy consumption in each data collection E_j . Total energy consumed during the whole lifetime for the r-th trial can express (1 ≤ r ≤ M), as [23].

$$\mu_0 - E_{WE}^{(r)} = P_C T^{(r)} + \sum_{i=1}^{N^{(r)}} E_j^{(r)} \tag{5}$$

Where N (p) is the number of data aggregation during the r-th trial. For a M trials summing Eq. 5 and dividing both sides by M, we get

$$\mu_O - \frac{1}{M}\sum_{r=1}^{M} E_{WE}^{(r)} = \frac{1}{M}\sum_{r=1}^{M} L^{(r)}\left[P_C + \left(\frac{\sum_{r=1}^{M} N^{(r)}}{\sum_{r=1}^{M} L^{(r)}}\right)\times\left(\frac{\sum_{r=1}^{M}\sum_{j=1}^{N^{(r)}} E_i^{(r)}}{\sum_{r=1}^{M} N^{(r)}}\right)\right] \quad (6)$$

Strong law of large numbers (SLLN): let $Y_1, Y_2, Y_3, Y_4 ...$ be pair wise independent identical distributed random variables with $E|Y_j| < \infty$.

If $E|Y_i| = \mu$ and $S_n = Y_1 + Y_2 + Y_3 + ...Y_n$ then $\frac{S_n}{n} \to \mu$ as $n \to \infty$

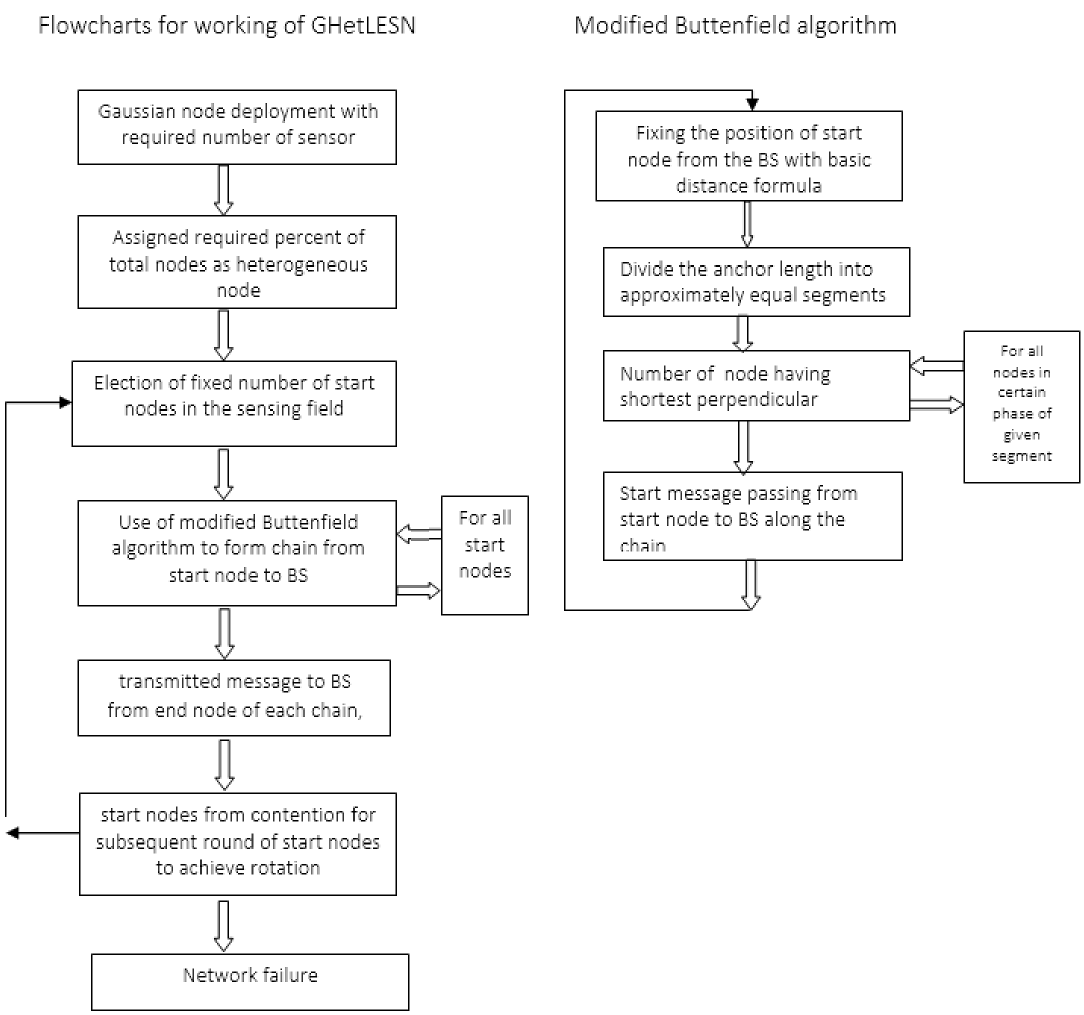

Figure 8: Flow chart of GHetLESN protocol and Modified Buttenfield algorithm

Using Strong law of large numbers is the average sensor reporting rate.

$$\lim_{M \to \infty} \frac{\sum_{r=1}^{M} N^{(r)}}{\sum_{r=1}^{M} L^{(r)}} = \mu \quad (7)$$

Next, we will derive that

$$E[E_{RE}] \stackrel{\Delta}{=} E_j\{E[E_j]\} = \lim_{M \to \infty} \frac{\sum_{r=1}^{M} \sum_{j=1}^{N^{(r)}} E_j^{(r)}}{\sum_{r=1}^{M} N^{(r)}} \quad (8)$$

Where $E_j\{\ \}$, $E[E_j]$ are respectably the expectation and average reporting energy consumed in over the randomly chosen data collection index *j*. For *j*-th data collection The average reporting energy consumed can be written as [23].

$$E[E_j] = \lim_{M \to \infty} \frac{\sum_{r=1}^{M} E_j^{(r)} Y_j(j)}{D_j} \quad 1 \le j \le R \quad (9)$$

Where $Y_r(j) = 1$ for $1 \le i \le N^{(r)}$ and 0 otherwise, $D_i = \sum_{r=1}^{M} Y_r(j)$ is the total number of the happening of the *j*-th data aggregation among the *M* trials, and $R = \max\{N(r)\}$ is the maximum number of data aggregation during the whole network lifetime. The probability that the randomly chosen data aggregation happen to be the *j*-th data collection is given by

$$r_j = \lim_{M \to \infty} \frac{D_j}{\sum_{r=1}^{M} N^{(r)}} \quad 1 \le j \le R \quad (10)$$

Taking expected value of Eq. 9 over the randomly chosen data aggregation index *j*, we will get the average reporting energy spend in a randomly chosen data aggregation as given in Eq. 23. To take account of the energy consumed in maintenance of network, we will get the following equation

$$E[T] = \frac{\mu_O - E[E_{WE}]}{P_C + \mu E[E_{RE}] + \mu E[E_{main}]} \quad (11)$$

Where $E[E_{main}]$ is the expected energy spend in a randomly chosen for maintenance of network, without loss of generality, number of data aggregations per unit time $\mu = 1$. Constant power consumption over the whole network $P_c = 0$. Substituting all value we will get Eq. 12 for sensor networks in which all sensor nodes have same capicity.

$$E_{HomogenousNetwork}[T] = \frac{NE_0 - E[E_{WE}]}{E[E_{RE}]} \quad (12)$$

Table 1: Expected Energy values for homogeneous sensor

No of Trails	Reporting Energy per Node, $E[E_r]$ (J)	Wasted Energy per Node, $E[E_w]$(J)	Life Time of the Network(S)
1	0.1719	0.8281	14,304
2	0.1720	0.8280	14,294
3	0.2713	0.7827	11,325
4	0.2352	0.7648	10,467
5	0.1548	0.8452	15,875
6	0.1122	0.8878	12,886
7	0.2113	0.7887	11,643
8	0.1355	0.8645	12,133
9	0.0790	0.9210	13,740
10	0.2648	0.7352	9,300

Eq. 12 is applicable to homogeneous network with *N* homogeneous sensors in the sensing field, each with non-rechargeable battery of value E_0 called initial energy. Let us consider number of homogeneous sensor nodes (N) =50. Initial energy of each sensor node is $E_0 = 1J$. Radius of sensing area= 50. Since, the node deployment in current network setting is completely random, data is collected for 10 trails and then average lifetime is calculated from tabulated values. Table 1 shows resultant average lifetime for homogeneous network, $E_1[T]$=13,003(Sec).The above obtained analysis is applicable to homogeneous network. But, in our scenario all the sensor nodes doesn't have equal initial energy. Sensor nodes inside the particular defined boundary are assigned double initial energy when compared to those out of the boundary. Hence, Eq.12 can be modified as follows:

$$E_{HET}[T] = \frac{(k_1 E_1 + k_2 2E_1) - E[E_{WE}]}{E[E_{RE}]} \tag{13}$$

Where k_1 is number of sensor nodes having E_1 initial energy and remaining sensor nodes having twice of E_1 . Figure 3 shows that average lifetime for heterogeneous network, $E_1[T]$=13,946 sec. It can be observed that average lifetime of heterogeneous network is greater than that of homogeneous network. Wasted energy is nothing but the amount of initial energy left with sensor nodes after network failure. More wasted energy implies remaining energy of the network is more. If we want to deploy the network again less energy is to be given to batteries. Hence, it is another advantage of heterogeneous network when compared to homogeneous network using Gaussian distribution.

Table 2: Expected Energy values for heterogeneous sensor network

No of Trails	Initial Energy of the Network $k_1 * 2E_1 + k_2 * E_1$ (J)	Reporting Energy per Node $E[E_{RE}]$ (J)	Wasted Energy per Node $E[E_{WE}]$ (J)	Life Time of the Network(S)
1	30(2)+20(1)=80	0.4231	1.1769	9,315
2	28(2)+22(1)=78	0.4410	1.1190	8,715
3	32(2)+18(1)=82	0.2598	1.308	15,513
4	30(2)+20(1)=80	0.3188	1.2812	12,347
5	31(2)+19(1)=81	0.2666	1.3534	14,936
6	37(2)+13(1)=77	0.1652	1.5748	25,857
7	36(2)+14(1)=86	0.3265	1.3935	12,958

5.2 Time to First Fail (TTFF)

It is the generally used algorithm to discuss performances of protocols in communication. This is the criterion used in GHetLESN and UHetLESN protocols. In this we have calculated the number of rounds (i.e., lifetime of the network) when first node dies It is the lifetime measure which provides the number of communicating events achieved before any sensor nodes in the sensing field runs out of its battery energy [24].

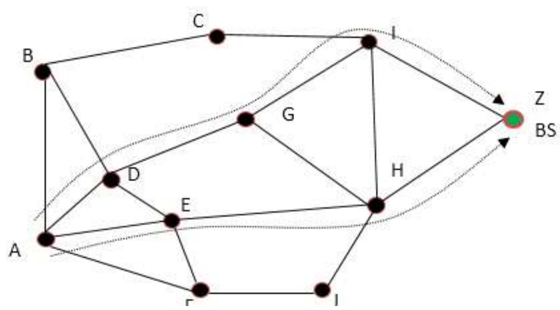

Figure 9: A WSN structure with 10 nodes and a BS, and two different paths between node A and BS: {A, E, H, Z} and {A, D, G, I, Z}.

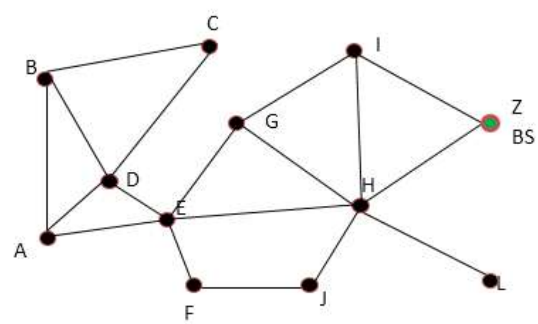

Figure10: WSN structure with 11 sensors and a BS. Node E failure will partition the network; node L failure will not. Node L seems to be less Important

In Figure 9, when node A detects an information, proposed protocol will try to alternate paths used to route information towards BS. For example, using paths {A, E, H, Z} and {A, D, G, I, Z}, this will allocate consumption of energy along paths, resulting into a better lifetime of the network. It is mandatory to consider, that some of the nodes are "more important" than other nodes existing in networks. For example, in Figure 10, if node E exhausts its battery energy, this will resulting in partition the network, avoiding nodes A, B, C and D to communicate with the BS even if they still have some energy. On the other hand, node L failure will not stop other nodes work correctly. So that the first failure does not always mean network partitioning. In our applications, it is desire that all the sensors nodes have to be alive, this measure is appropriate, else we should use another definition of lifetime [24].

5.3 Operative Nodes Percentage (ONP)

A node which either does not have enough battery to work properly, or cannot communicate with the BS is called an inoperative node. On other side, a node works properly and can converse with the BS [24] is called an operative node. percentage of operative nodes as time goes by is called operative node percentage criterion (ONP). If the probability of sensors are more inoperative, this may resulting to partitioning the network. Thus, even if a sensor is on condition, it shall be measured as useless if it cannot communicate with the BS. For example in Figure 13, if node E runs out of its battery energy, we have to consider nodes A,B, C and D has being inoperative nodes, even if they still have energy. They can not communicate with BS because the network is partitioned, so if an event occurs near them (A, B, C, D), they will not be able to inform the BS. That's why we do not add up the average number of alive nodes as in [6], but the average number of operative nodes.

Here we consider the threshold energy as 0.7 J. If the node battery energy goes below the threshold it is assumed to be non-operative node. 50 nodes are deployed in circular sensing field with radius 50m. Since, nodes are randomly deployed, the values change every time we simulate the program. Hence, we go with m-trails and take average of these values. The remaining number of nodes for uniform and Gaussian node deployment as tabulated below: The table 3 gives number of alive nodes out of 50 nodes by 10 trails. The average alive nodes will be 26. Hence, 26 nodes are alive out of 50 nodes deployed in the field. Similarly, these values are calculated for different network settings.

Table 3: Number of alive nodes for different network settings

No of Trails	GHeN	GHoN	UHeN	UHoN
1	19	11	24	14
2	24	14	21	13
3	32	14	19	17
4	16	25	28	14
5	31	17	20	16
6	27	15	16	20
7	31	13	27	12
8	23	25	27	20
9	37	15	25	13
10	24	26	31	11

Table 4: Percentage of alive nodes in different network settings

Network	Average operative node Remaining	Percentage of operative nodes remaining
GHeN	26	52%
GHoN	17	34%
UHeN	24	47.6%
UHoN	15	30%

From Table 2 & Table 3, we can say that heterogeneous network has more number of operative nodes remaining when compared that of homogeneous. And Gaussian node deployment has more number of operative nodes remaining when to uniform node deployment. Hence, provided more network lifetime.

6 Results and Analysis of GHetLESN and UHetLESN Protocols:

Table 5: Simulation Parameters [13]

Parameters	Value
Initial energy of each sensor	1-2 J
Energy required to run the transmitter circuitry ($E_{tx}elect$)per bit	50 nJ/bit
Energy required to run the receiver circuitry ($E_{rx}elect$) per bit	50nJ/bit
Multipath amplification coefficient (ε_{amp})	100 pJ/bit/m^2
Message length (L)	2000 bits
Path loss exponent (n)	2

In the proposed protocols, all the nodes do not expend energy in all rounds of message passing and hence network lifetime is increased. Network lifetime decreases for excessive increase in number of nodes. This is explained by lifetime definition chosen i.e. the number of nodes counted till any one sensor node dies out. The fringe nodes are definitely expected to die first, and are not proportionally compensated by increase in node density as many nodes are near to BS. Due to the deployment of a Gaussian network, chain formation is fairly uniform. There won't be significant effect in chain structure by dying of nodes near the BS due to presence of several adjacent nodes to take place in the chain. Figure11 shows graph of the network lifetime Vs radius of sensing field for different node density in GHetLESN protocol. Which show that for a node density 50, GHetLESN protocol provides better network lifetime compare to other node density. Figure12 shows graph of the network lifetime Vs number of node for different sensing radius in GHetLESN protocol. Which show that for a radius values 50, GHetLESN protocol provides better network lifetime in compare to other radius value. Figure13 shows graph of the network lifetime Vs number of node for sensing radius R=50 m for different proposed protocol like GHetLESN, GHomLESN, UHetLESN, GHomLESN. After analysizing it shows that radius value R= 50 in GHetLESN protocol provides better network lifetime in compare to other proposed protocal. Figure14 shows graph of the network lifetime Vs radius of sensing field for different proposed protocol like GHetLESN, GHomLESN, UHetLESN, GHomLESN. After analysizing it shows that for a node density N= 50 in GHetLESN protocol provides better network lifetime in compare to other proposed protocal. Figure15 shows graph of the network lifetime Vs number of node for different proposed protocol like GHetLESN, UHetLESN, EECF. After analysizing it shows proposed protocol GHetLESN provides better network lifetime in compare to other proposed protocal. Figure16 and 17 shows the network lifetime vs percentage of start nodes and heterogeneous nodes for different sensing area. If we select start nodes, which is 10% of the total nodes, the circular sensing field provides highest network lifetime. For 20% and above the number of start nodes, all kinds of sensing fields provide almost same network lifetime. If we select heterogeneous nodes, which is 10% of the total nodes, the network lifetime in all types of sensing field will be same. For 50% of heterogeneous node rectangular kind of sensing field has highest network lifetime. Table 7 shows the abbreviations used in this paper. Table 6 shows comparison of percentage improvement in Network lifetime (Sec) of different protocols.

7 Conclusion

Proposed GHetLESN and UHetLESN protocol are novel chain formation protocols which enhanced the network lifetime of WSNs as compared to existing protocol EECF [5]. GHetLESN is an energy efficient protocol which can be used for many realistic applications. Results of this paper are summarized as follow:

- Proposed protocol GHetLESN provides 4.76 times improvement in network lifetime compare to existing protocol EECF[5]
- Proposed protocol UHetLESN provides 1.78 time improvement in network lifetime compare to EECF[5].
- Different existing criterions of networks lifetime shows that the proposed algorithms GHetLESN and UHetLESN are better as compared to EECF [5].
- Selecting 10% start nodes of the total nodes deployed in the sensing field, the circular sensing field provides highest network lifetime compared to square and rectangular sensing field.
- Selecting 10% heterogeneous nodes of the total nodes deployed in sensing field, the network lifetime in all types of sensing field (circular, square and rectangular) will be same. For 50% of heterogeneous node rectangular sensing field has highest network lifetime.

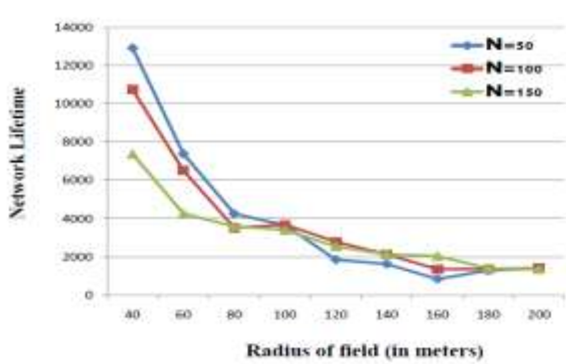

Figure11: Network lifetime (Sec) Vs radius of sensing field for different node density in GHetLESN protocol

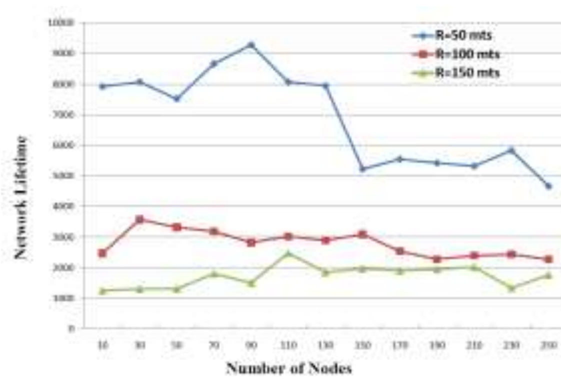

Figure12: Network lifetime (Sec) Vs node density for different sensing radius in GHetLESN protocol

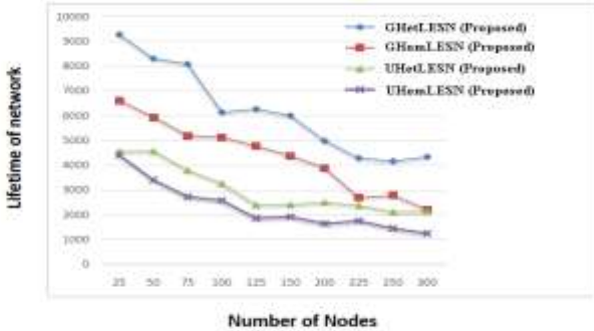

Figure13: Network lifetime (Sec) Vs node density (R=50 m)

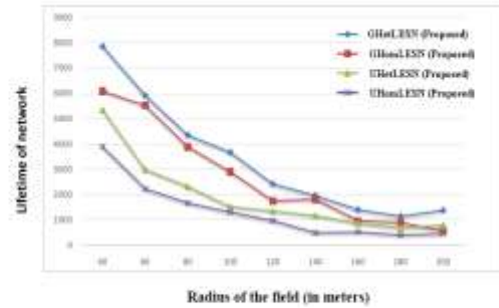

Figure 14: Network lifetime (Sec) vs. Radius of field (N=50)

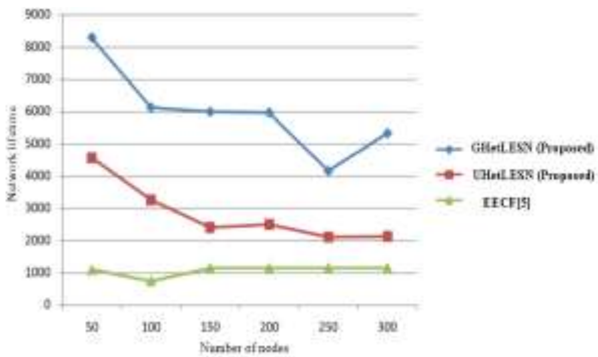

Figure 15: Network lifetime (Sec) vs. no. of nodes of various protocols

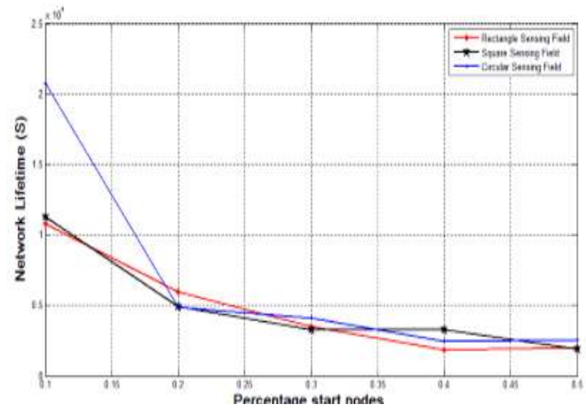

Figure16: Network lifetime (Sec) vs percentage start node for different type of sensing field

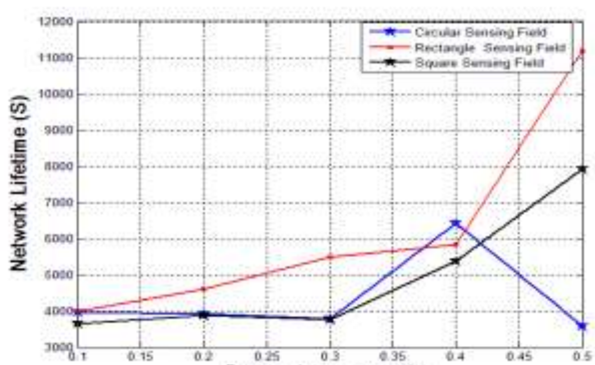

Figure17: Network lifetime (Sec) vs percentage heterogeneous node for different type of sensing field

Table 6: Comparison of Percentage improvement in Network lifetime (Sec) of different protocols

Number of nodes	Percentage improvement in Lifetime		
	GHetLESN vs. EECF[5]	UHetLESN) vs. EECF[5]	GHetLESN vs. UHetLESN
50	730	356	81
100	546	244	87
150	422	109	139
200	420	98	149
250	262	83	159

Table 7: Abbreviations

GHeN	Gaussian node deployment with Heterogeneity
GHoN	Gaussian node deployment with Homogeneity
UHeN	Uniform node deployment with Heterogeneity
UHoN	Uniform node deployment with Homogeneity
BS	Base Station
WSNs	Wireless Sensor Networks
GHetLESN	Network Lifetime Enhancement in Gaussian heterogeneous sensor
UHetLESN	Network Lifetime Enhancement in uniform and random heterogeneous sensor networks
GHomLESN	Network Lifetime Enhancement in Gaussian homogeneous sensor networks
UHomLESN	Network Lifetime Enhancement in uniform and random homogeneous sensor networks
ONP	Operative nodes percentage
TTFF	Time to first fail

SCOPE FOR FUTURE RESEARCH

The following are the possible research areas identified, which is not being considered in this work

1. Applicability of GHetLESN in presence of noise, fading by using efficient clustering techniques [15-16] [22].
2. Analysis of proposed protocol GHetLESN with packet collision avoidance techniques [17-18].
3. Applying GHetLESN protocol for other sensing field models like rectangular, hexagonal or any other irregular shape.

4. The proposed models can provide very good results in term of network lifetime and intrusion detection by using different sensing models: Tunable sensing model and Tunable Multilevel sensing model [19].
5. The proposed model with the mobility of node can be considered as future work [20].

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