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A survey on successors of LEACH protocol and base station mobility pattern on WSN lifespan

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ABSTRACT

Wireless Sensor Network (WSN) is a network consisting of a large number of low energy sensor nodes. The main objective in WSN is the maximization of network lifespan through efficient utilization of energy. Low Energy Clustering Hierarchy Protocol (LEACH) is a protocol which balances the energy consumption all the sensor nodes in a sensor network. Recent variants of LEACH are Fixed LEACH and N-LEACH clustering routing protocol. Static Base station balances energy consumed in data relaying to extend the network lifespan. Base Station (BS) mobility increase the sensor lifespan even further in certain network configurations. Furthermore, utilization of multiple mobile BSs extends WSN lifespan still further as compared to single BS case. It has been observed by researchers that optimal mobility patterns of multiple mobile BSs can be employed for achieving the maximum lifespan in WSNs. In recent literature, four representative patterns Grid, Random, Spiral, and Gaussian). It has been developing a novel Mixed Integer Programming (MIP) framework to characterize network lifespan under different mobility patterns for multiple mobile B.S.

Keywords— *WSN, Sensor nodes, LEACH protocol, Cluster head selection, Lifespan, Mobile Base Station, Multiple Base Station, Sink mobility, Mixed Integer Programming (MIP), Energy efficiency*

1. INTRODUCTION

Wireless Sensor Network (WSN) is a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. One of the most important design criteria in WSN is to maximize the network lifespan by minimizing the energy consumption as it is not practical to change the batteries of the sensor node in the field.

Low Energy Adaptive Clustering Hierarchy (LEACH) is a part of Wireless sensor network, LEACH can be divide into two phase setup phase and steady phase. Setup phase makes cluster formation and selects the cluster head. Steady state phase, cluster nodes send their data to the cluster head and the member sensor in each cluster can communicate only cluster head. It can describe the type of LEACH, Fixed-LEACH is homogenous where cluster head is fixed. N-LEACH is heterogeneous where cluster head is not fixed. It compares the performance of LEACH. It can study several algorithms to describe the type of LEACH.

It has been found that in WSNs, the location of the base station affects the network lifespan directly (single-hop) or indirectly (multi-hop). In single hop which is far away from the BS use to consume more energy than the nodes which are closer to BS V scenario between sensor nodes and BS, nodes and rapidly get depleted of energy. On the other hand, in multi-hop scenario, where the data packet is conveyed to the base station via multiple intermediate sensor nodes acting as relays, the sensor nodes closer to the base station are encumbrance with the task of relaying the data coming from farther nodes in addition to transmitting their own generated data. It can study a novel Mixed Integer Programing (MIP) frame work capable of jointly capturing the essence of data flows, energy dissipation and multiple B.S nobilities .it can study the vary pattern of base station mobility, analyze a wide range of possible campaigner.

The rest of the paper is organized as follow: Define LEACH phase, type and describe the N-LEACH Algorithm in Section-II. It can define Base station, energy model, a mathematical programming framework for maximizing network lifespan of WSN with single/multiple static Base station and Base station mobility pattern for Random, Grid, spiral and Gaussian configuration are elaborated and compare the performance of single and multiple base station in Section III. In last Section IV define conclusion.

2. OBJECTIVES OF LEACH AND ITS VARIANTS

LEACH (Low Energy Adaptive Clustering Hierarchy) is a routing protocol for WSN. It can be divided into the following two phases. Set-up phase makes clusters and selects the cluster head in equation (1). Cluster is an important method to extend the lifespan in WSN. It involves grouping of sensor nodes into cluster and election Cluster Heads (CHs) for all cluster [1].

$$Th_n = \begin{cases} \frac{p}{1-p.\left(r.mode\frac{1}{p}\right)} & if\ n\ in\ G \\ 0 & otherwise \end{cases} \quad (1)$$

Where: Th_n is a value of Threshold, n is a random number 0 and 1, r is a current round, P is the cluster head probability and G is the set of nodes that weren't clustered –head the previous rounds.

Steady Phase, cluster nodes transmit their data to the cluster head via a single hop transmission. Cluster head aggregates all the collected information and forward to the base station either directly (single hop) or indirectly (multi hop).

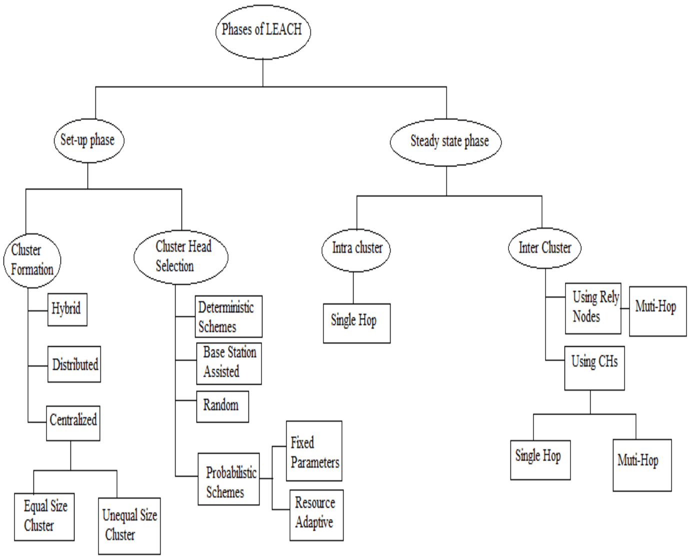

Fig. 1: Phase of LEACH [1]

3. FIXED LEACH VS. N-LEACH

LEACH was the first protocol to balance the energy consumption among nodes, there is basically two types of LEACH (Fixed LEACH and N-LEACH). The number of cluster heads is fixed in Fixed LEACH but N-LEACH, cluster heads are not fixed due to random selection.

Fixed LEACH is used heterogeneous network so it can provide different initial energy among all nodes but N-LEACH is using homogenous network so it can provide the same initial energy to all nodes.

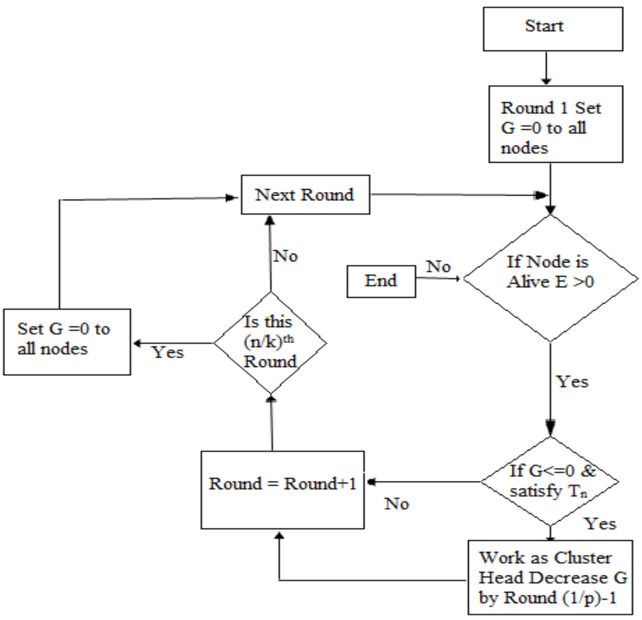

Fig. 2: Fixed LEACH Algorithm flow chart [1]

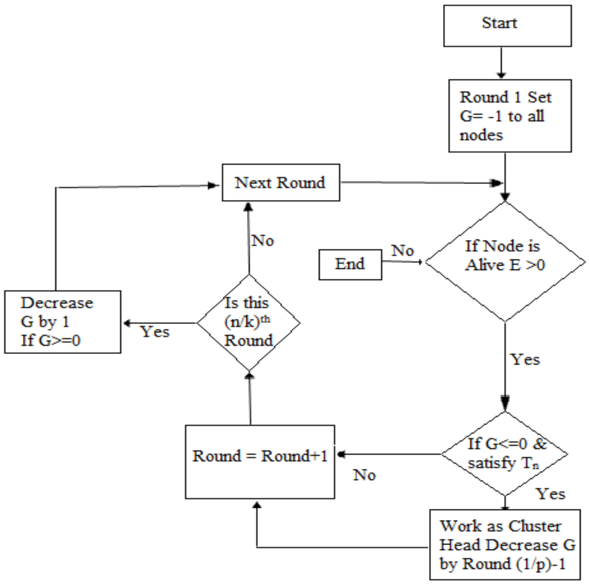

Fig. 3: N-LEACH Algorithm flow chart [1]

4. CLUSTER SELECTION ALGORITHM

Several surveys have been studying [1] that N-LEACH is a modified version of the Fixed LEACH figure (2). It can describe the modified version of LEACH. There are the following step to describe the algorithm of N-LEACH in figure (3):

Step 1: In the first round of data transmission G (set of the node that wasn't cluster heads the previous nodes) is set to be -1 for all nodes.

Step 2: Operation for the era is performed after every n/k (average number of supported nodes by cluster head) round. The value of G is reduced by one to all the nodes which are having G≥0.

Step 3: All the nodes which are having G<0 are eligible to become cluster head.

Step 4: Now the nodes will become cluster head choosing a threshold Th_n (Equation 1) between 0 and 1.

Step 5: If nodes become a cluster head, it supports N (number of nodes). If $N>N_{ave}$, this node loose a large amount of energy (where $N_{ave}= n/k$). If $N<N_{ave}$, this node become a cluster head and save some initial energy compare to another node.

It has been added (k/n)*N to G when node become cluster head. Thus the value of G proportional to N. if a node supports a large number of nodes then this will lose their eligibility criterion for next few n/k rounds, therefore it will become cluster head unless G≤0 or G< N_{ave} remains eligible node become cluster head. According to the Cluster head selection algorithm figure (2), Cluster Head selection is improved by 5% in fixed LEACH. In figure (3), Cluster head selection is improved by 12% in N- LEACH. So N-LEACH performance is better than Fixed LEACH.

5. BASE STATION

A Base Station (BS) connected the sensor network to another network. It consists of a processor, Energy model, and antenna and USB interface board. It is preprogrammed with low-energy mesh networking software for communication with WSN. Generally base station are analysis in static nature but literary survey [2] they are analyses to be mobile to collect the data from sensor node, some sensor nodes is near to the Base Station (BS) which consumes the more energy drain their batteries and dies earlier sensor node this problem known as Hot-spot problem, but faraway sensor node consumes less energy.

Therefore repositioning the base station helps to solve the Hot-spot problem in WSN which improved the lifespan of network, data delivery, throughput, load balancing and area coverage [2]. In this Literature survey [3] it has been a focus on four mobility pattern (Random, Spiral, Grid and Gaussian) in term of the WSN lifespan under static/mobile and single/multiple base station scenarios [3].

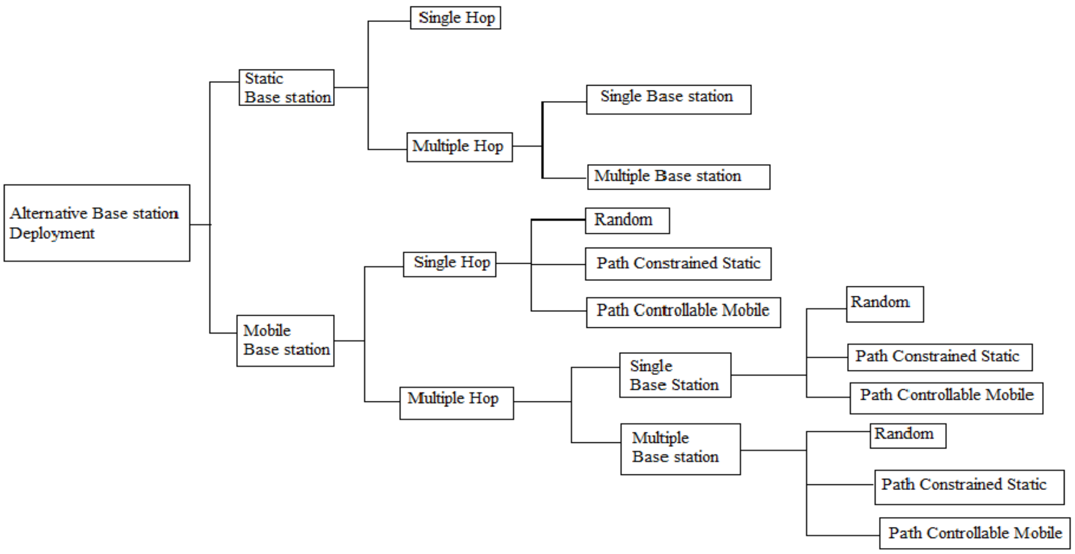

Fig. 4: Alternative Base station deployment [4]

Figure 4 is a flow chart of base station deployment alternative for WSN. Single Hop BS collects the data without relying on relay nodes when the sensor node is within its transmission range but Data relying is possible in Multiple-hop.

Energy Model, to utilize the Mica2 sensor nodes communicate energy dissipation characteristics which consist of an Atmel Atmega 128L processor and Chipcon CC1000 radio transmitter/receiver IC. There are 26 different energy levels to adjust the output power of the CC1000 radio transmitter. Table 1, power level represented by l, $E_{tx}(l)$ represents energy dissipation for transmission (per bit) at power level l. $R_{max}(l)$ represents the maximum transmission range at power level l. The optimum power level for node-i to node-j to transmit over a distance d_{ij} (l_{ij}^{opt}) is given [3]:

$$l_{ij}^{opt} = \arg \min_{l \in s_l, d_{ij} < R_{\max}(l)} \left[E_{tx}(l)\right] \quad (2)$$

Table 1: Maximum Transmission Range $R_{max}(l)$ in Meters and The Energy Dissipation $E_{tx}(l)$ in µJ/bit for each discrete Energy Level-*l* for Mica2Motes [3].

l	$E_{tx}(l)$	$R_{max}(l)$	l	$E_{tx}(l)$	$R_{max}(l)$
1	0.672	19.30	14	0.844	41.19
2	0.688	20.46	15	0.867	43.67
3	0.703	21.69	16	1.078	46.29
4	0.706	22..69	17	1.133	49.07
5	0.711	24.38	18	1.135	52.01
6	0.724	25.84	19	1.180	55.13
7	0.727	27.39	20	1.234	58.44
8	0.742	29.03	21	1.313	61.95
9	0.758	30.78	22	1.344	65.67
10	0.773	32.62	23	1.445	69.61
11	0.789	34.58	24	1.500	73.79
12	0.813	36.66	25	1.664	78.22
13	0.818	38.86	26(l_{max})	1.984	82.92

Mobile BS is two types, Single Hop and Multiple Hop. This subpart of mobile BS can be divided into three part. The first part, Random means the trajectory of the BS is not based on a specific pattern. The second part, Path Constrained Static means trajectory depends on a BS that must follow a specific path imposed as an external factor. The third part, Path Controllable Mobile trajectory gives a lot of room for the decision maker to steer the BS through an area of interest to optimize an objective function [3].

Table 1 show the Maximum Transmission Range $R_{max}(l)$ in Meters and The Energy Dissipation $E_{tx}(l)$ in µJ/bit for each discrete Energy Level-*l* for Mica2Motes [3].

6. MIP (MIXED INTEGRATED PROGRAM)

To maximize the WSN lifespan (L_{rnd}) which define the total number of the round until the first sensor node consumes their battery and dies. It can be seen that all node dissipate their energies in a balanced manner to maximize the lifespan. It has been studied [] that sensor node in the network operates altogether to avoid the premature death sensor nodes due to over utilization of energy, so it can use the MIP model, which provides the optimal result by using global network information.

The arcs (A) are the directed communication links, between the nodes represented by an ordered set of arcs (A= {(i, j): i ∈ W, j∈ V-i}). But the definition of A implies that no node sends data to itself. t have been defined a set of arc (A_k={(i,j):i∈W, j∈W, j∈U_k}) for each set U_k to ensure that all sensor data terminate at virtual base station-k when it is active [3].

Equation 3, states that all flow is non-negative. Equation 4 is used to balance the incoming and outgoing flow for each sensor node-i. When the virtual base station-k is active. It ensures that the sum of data incoming to sensor node-i(from all the other sensor nodes) add the data generated by node-I equals to the sum of data flowing out of sensor node-I to the rest of the network (Either virtual base station-k or other sensor nodes acting as relays). All data terminates at the virtual base station-k. The total number of rounds that the virtual base station-k is active, denoted by N^k_{LFT} and the total number of data packets generated by node-i destined for the virtual base station-k is given by $s_iN^k_{LFT}$. Equation 5 provides the total energy consumed by each sensor node for data transmission and reception (e_i).

$$f_{ij}^{k} \geq 0 \forall (i,j) \in A \forall k \in Y \tag{3}$$

$$\sum_{(i,j)\in A_k} f_{ij}^{k} - \sum_{(j,i)\in A_k} f_{ji}^{k} = s_i D_{rnd}^{k} \forall i \in W \forall k \in Y \tag{4}$$

$$D_p \sum_{k\in Y}\left[\sum_{(i,j)\in A_k} f_{ij}^{k} E_{tx}\left(l_{ij}^{opt}\right) + E_{rx} \sum_{(j,i)\in A_k} f_{ji}^{k}\right] = e_i \forall i \in W \tag{5}$$

$$e_i \leq battery \forall i \in W \tag{6}$$

$$f_{ij}^{k} = 0 if d_{ij} > P_{\max}(l_{\max}) \forall (i,j) \in A \forall k \in Y \tag{7}$$

$$\sum_{k\in Y} D_{rnd}^{k} = D_{rnd} \forall k \in Y \tag{8}$$

$$D_p\left[\sum_{(i,j)\in A_k} f_{ij}^{k} + \sum_{(j,i)\in A_k} f_{ji}^{k} + \sum_{(j,m)\in A_k} f_{jm}^{k} I_{jm}^{i}\right] \leq D_{rnd}^{k} T_{rnd} \eta \forall i \in V \forall k \in Y \tag{9}$$

Equation 6 applies an upper limit on the energy used as each sensor node, any sensor node-I can dissipate at most battery amount of energy. Equation 7 provides limit the maximum transmission range of each node, where P_{max} (l_{max}) is the maximum transmission range possible. Equation 8 defines the total lifespan of the network. Equation 9 presents the constraint for the bandwidth. For each node which is a member of U_k the aggregate amount of interfering flows, incoming flows and outgoing flows in upper bounded as the product of total active duration of the virtual base station-k and the channel bandwidth(ɳ), where ɳ= 38.4kbps for Mica2 motes(table 1)

Table 2: Variable used in Expression [3]

Variable	Description
N	Number of nodes
Ny	Number of virtual base stations
W	Set of sensor nodes
Z	Set of the selected virtual base station
Y	Set of the virtual base station
A	Set of arcs
A_k	Set of arcs for each set of U_k
U_k	W U Base station k
U	Set of all nodes (V=W U Y)
s_i	Generated data at node i (packet/ round)
e_i	Consume battery energy at node-i
d_{ij}	Distance between node-i to node-j
$P_{max}(l)$	Maximum transmission distance for power level '*l*'
Battery	Initial energy store in sensor nodes(the equivalent of two AA batteries 25.0kJ)
D_p	Data packet size
E_{rx}	Energy consumption for reception
D_{LFT}	Total network lifetime
D^k_{LFT}	Dwelling time at virtual base station-k
ɳ	Channel bandwidth
I^i_{jm}	Interference function for node-i
f^k_{ij}	Total number of a data packet transmitted from node-i to node-j
N_w	Number of sensor nodes

6.1 Mobility patterns

It has been studying that Base station mobility pattern to analyze a wide range of possible campaigner. There are four mobility patterns which are random, grid, spiral and Gaussian mobility patterns [2] [3].

6.2 Random mobility model

To repositioning the static base station in an alternative manner known as random mobility pattern. The uniformly random distribution of the set Y throughout the network area.

6.3 Grid mobility model

To improve version of Random mobility, it is set alternative view of two dimensions regular sampling of sensing domain. Where Y set in a vertical grid.

6.4 Spiral mobility model

A non-regular sampling of sensing domain called spiral mobility where a set of positions (Y) lies on point in spiral trajectory over sensing domain which is placed at the network's geometrical center (i.e., center of gravity).Equation (10) and (11) generate the spiral shape and adjust the scale and density of the spiral curve by using the parameter *K* and σ. Where scaling of the spiral curve adjust by scaling factor (*K*) and limit of spiral curve adjust by interval parameter (σ).

$$x(\sigma) = e^{k\sigma}\cos(\sigma) \tag{10}$$

$$y(\sigma) = e^{k\sigma}\sin(\sigma) \tag{11}$$

6.5 Gaussian mobility model

The optimal Gaussian mobility is a non-uniform distribution function like the spiral mobility model. The base station mobility is determined candidate positions by using a Gaussian distribution. By changing the standard deviation of the distribution average proximity of the candidate bases stations to the center of the network is determined. Randomly generated candidate positions located outside the sensing domain are discarded and randomly regenerated.

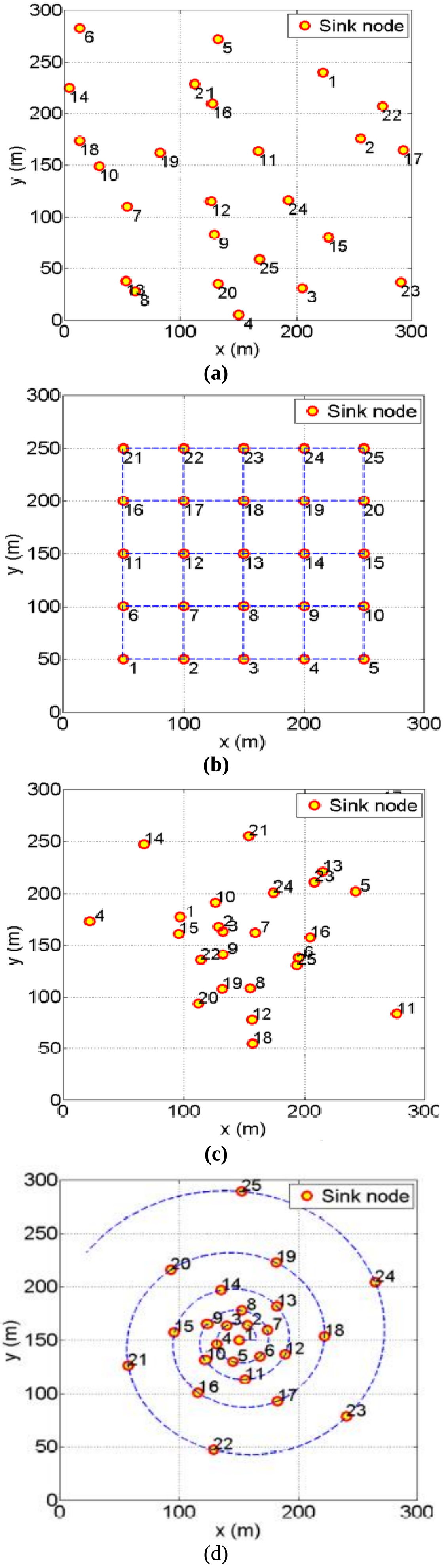

Fig. 5: Base station positing for the (a) Random, (b) Grid, (c) Spiral and (d) Gaussian [3]

7. SINGLE BASE STATION VERSUS MULTIPLE BASE STATION [4]

Single Base Station (BS) the longest network lifespan is obtain by spiral mobility, but multiple BS case, the longest network lifespan is obtained by Grid mobility pattern. The lowest performance improvement is obtained as Spiral mobility for multiple BS.

In single BS, Random mobility pattern exhibits medium lifespan improvements in comparison to Grid and Spiral mobility patterns but multiple BS, network lifespan of Grid mobility can be 25% and 23% more than network lifespan of Random mobility and Spiral mobility. Network lifespan obtained by using Spiral mobility can be 17% and 22% more than the network lifespan obtained by using Grid mobility and Random mobility for single mobile BS.

Single BS is found an optimal nearby position to collect data from sensor nodes in a way that maximum the WSN lifespan but multiple BS Grid-based positioning of the BS distributed the BS regularly around the network.

Single BS, a non-uniform centripetal mobility pattern performances better and for multiple BS a spatially homogenous mobility pattern generates a better network lifespan. Multiple BS has product 20-22 times longest lifespan than single BS configuration.

8. CONCLUSION

The paper present a LEACH and Base station mobility pattern to improve the network lifespan.

Section I: LEACH, it has been described as the phase and type of LEACH. According to figure (2) and (3) describe the LEACH algorithm and cluster head selection is improved by 12% to N-LEACH and 5% to Fixed LEACH.

Section II: Base station mobility pattern describe the four type of mobility pattern (Random, Spiral, Grid and Gaussian) and mixed integer programming (MIP) to achieve the optimal network lifespan. It has been compared to the performance of multiple mobiles and static base station under a similar configuration.

In the single Base station, the longest network lifespan is obtained by Spiral mobility pattern yet multiple base station, the longest lifespans obtained by Grid mobility pattern.

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