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Residual Energy in Corona-based Deployment Strategies in Wireless Sensor Network

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Abstract— **Wireless sensor networks (WSNs) are getting in a wide range of applications, such as mart homes, military surveillance, habitat monitoring, and precision agriculture. Sensor node placement is the most challenging problem in wireless sensor network due to the limited battery power. For critical applications, sensor node placement in efficient way is necessary to monitor the event precisely, which alternatively achieve balance energy depletion and extend the network lifetime. In multi-hop transmission, nodes lies in sink vicinity have heavier traffic loads which deplete their energy quickly; this leads to energy holes around the sink, which ends network lifetime. However, most of sensor nodes have enough residual energy in network. This paper presents corona based sensor node deployment strategies and their effect on residual energy has been showed. Simulation result shows residual energy of each corona during network lifetime.**

Keywords—**Corona-based Wireless Sensor Network, Engineered Gaussian deployment, Energy hole problem, Arithmetic and Geometric proportions.**

I. Introduction

Wireless Sensors Network (WSNs) has broadened their applications by recent advancement and are used for many civil and military applications [1-3], such as, forests, habitat monitoring, farmlands, target tracking, environmental surveillance, smart homes industrial applications Sensor Node placement have an important role in the success of WSNs which are known by deployment of the network.

Network lifetime is the most important challenge which is based on sensor node's battery. Once the sensor node is placed then it is impossible to replace the battery. Those nodes which have heavier traffic will deplete their energy earlier but the remaining will have enough energy. Once the energy of some nodes finished then the network will stop functioning and will not forwards the data towards the sink. Although most of the sensor nodes still retain significant amounts of energy. This leads to the energy hole problem in wireless sensor network due to unbalanced energy consumption [4], which split the network into two sub graph.

In corona based engineered Gaussian deployment strategy using arithmetic and geometric proportion, the residual energy of the network is minimized in which the number of nodes is placed in different fashion. This technique also maximize network lifetime but balance energy depletion cannot be achieved by simply increasing sink neighboring nodes. Because if we only increase sink neighboring nodes then neighbor to neighbor nodes early diminish their energy while sink neighbor nodes have enough residual energy. To overcome this problem Gaussian deployment strategies in which the network is divided in coronas and number of nodes decreases from inner to outer corona with arithmetic and geometric proportions is proposed and the residual energy has been analyzed on multiple experiment.

The main aim of this paper is to minimize the residual energy of the network using minimum number of nodes to achieve maximum coverage. Due to these factors, the sensor nodes are deployed using four different strategies with the same number of sensor nodes and analyze its impact on the residual energy of WSNs.

II. Related Work

The analysis of network residual energy and the occurrences of energy hole problem will briefly discuss in this section. The authors examine the complex network properties introduced by the graphs that represent WSNs, and proposed the use of a new centrality measure called Sink Betweenness. They use this metric to elaborate a new data-collection algorithm able to mitigate the energy hole problem by evenly balancing the relay load, and thus, reducing the network residual energy [5-7].

The author in [8] discussed the theoretical aspects of the network load and the node density. They proved the accessibility condition to satisfy that all the working sensors deplete their energy with the same ratio. To achieve balanced energy depletion per node they proposed an algorithm for density control with the concept of equivalent sensing radius. To minimize the repetition of identical messages a new pixel-based transmission mechanism is adopted. To balance the energy consumption and enhance the network lifetime, nodes are activated with non-uniform distribution on different energy layers. Simulation results show the effectiveness of their algorithm. For the avoidance of energy holes in a wireless sensor network the authors proposed several design criteria with uniform node deployment [9]. To construct a hierarchical network structure, heterogeneous deployment use two types of sensors, low energy sensors and high energy sensors. But, this approach raises the deployment and implementation complexity [10].

Sensor nodes near to sink are involved in more data forwarding that’s the way there should have a high density of sensor nodes. The authors address the problem of movement-assisted sensor positioning (MSP) to achieve theoretical sensor densities with the objective to minimize sensor movement and increase the network lifetime. Their proposed solutions are: an integer-programming formulation, a localized matching method, and a distributed corona-radius scanning algorithm [11]. To solve energy hole problem, the authors proposed a strategy which is based on the non-uniform distribution of the sensor nodes in the sensing field. In this strategy the sensing area is divided into multiple regions and place more nodes in the regions near to the sink node to balance the energy consumption [12, 13].

For alleviating power consumption an N-policy M/G/1 queue has been reported in [14]. In this scheme, a queue threshold N is specified for the concept of queued wake up. The threshold is used to control the latency delay for the buffered data packets and the number of times the data radio is turned on. In the queued wakeup scheme when the queue holds N packets, the sensor node triggers its data radio, conducts the process of medium-contention and sends the queued packets in a burst.

To maximize network lifetime the authors proposed an in-network data aggregation scheme in [15]. Each node multiplies its reading with a random coefficient and sends results to the next hop to calculate weighted sum of all messages. Instead of individual node reading the base station will receive weighted sum and restore the original data. Energy consumption of all sensor nodes is same because each node to calculate the weighted sum only perform one addition and one multiplication.

In a wireless sensor network the sensor node deployment is one of the key problems for researchers. The authors in [16] proposed particle swarm optimization concept for efficient deployment of sensor nodes. Simulation results show that particle swarm optimization reduces the network energy consumption and increase the whole coverage ratio.

In [17] the authors proposed two random deployment strategies for avoiding energy hole problem. First, the lifetime-oriented deployment strategy is proposed to prolong the network lifetime by achieving balanced energy consumption of relay nodes (RNs) and second the hybrid deployment concern with connectivity. Both the strategies provides guidelines for better deployment of sensor nodes and Relay nodes in heterogeneous WSN.

III. Methodology

Engineered Corona-based Sensor Node Deployment Strategies using Arithmetic and Geometric Proportion

In corona based networks, the sensor nodes are deployed in a circular fashion with a static sink located in the center. The sensors are homogenous and each of them uses the same sensing range and communication range. The sensor nodes are distributed in the coronas and each of the corona's sensor nodes can communicate with its neighbouring corona's nodes directly through one hop. The sensor nodes are deployed through four different methods using arithmetic and geometric proportions and assess their impact on residual energy. The main purpose here is to investigate the optimal strategies for corona-based network deployment with full and limited control over the positioning of network nodes as shown in Figure 1.

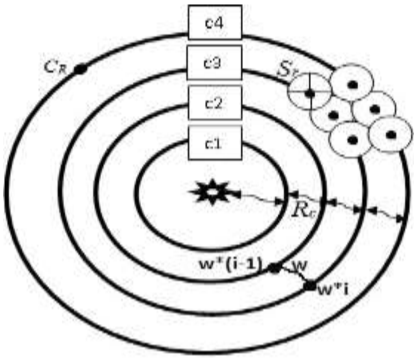

Figure 1: Corona based deployment strategy

a. Engineered-uniform Corona-based Deployment Strategy

In this strategy, the same number of nodes has been deployed in all the four coronas. This type of deployment can be employed when a large sensing area needs to be covered with a limited number of sensor nodes.

b. Engineered-Gaussian Corona-based Deployment Strategy with an Arithmetic Proportion

In this strategy, the sensor nodes are distributed in such a way that the density of the sensor nodes decreases from the inner to the outer coronas with an arithmetic proportion. The density of the sensor nodes in the first corona is higher than the other coronas. This strategy is beneficial in scenarios where all the nodes are similar in power and processing capabilities.

c. Engineered-Gaussian Corona-based Deployment Strategy with Geometric Proportion of ratio 2

In this strategy, the sensor nodes are distributed in the engineered-Gaussian fashion such that, the density of the sensor nodes decreases from the inner to the outer coronas with the geometric proportion of ratio 2.

d. Engineered-Gaussian Corona-based Deployment Strategy with Geometric Proportion of ratio 3

In this strategy, the sensor nodes are distributed in the engineered-Gaussian fashion, such that the density of the sensor nodes decreases from the inner to the outer coronas with an inverse geometric proportion of ratio 3. This shows the sparse placement of nodes away from the sink, whereas those closer to the sink are dense and congested.

IV. Performance Analysis and Simulation Results

In this section, the performance analysis of the corona based deployment strategies of WSNs is evaluated and compared with the following.

i. Random uniform deployment strategy [18-20]
ii. Engineered uniform deployment strategy [18, 21-23]
iii. Random Gaussian deployment strategy [20]

Simulation results demonstrate that the proper placement of sensor nodes guaranteed coverage, connectivity, enhanced lifetime, data delivery and most importantly minimize residual energy of the sensor node in WSNs. Simulations have been performed on homogeneous nodes, random uniform traffic, and stationary sink at the center of topology. The simulated networks were deployed in a geographical area of 1000x1000 m^2. The area was divided into four coronas. The number of sensor nodes in the network was kept at 120 and their transmission range to 150 meters. The initial energy assigned to each node was 1 Joule, whereas the energy consumption during transmission was set to be 10 milli Joule (See Table 1). The total number of sensor nodes distributed in four coronas C_1, C_2, C_3, C_4 are given in Table 2. Our proposed deployment strategies are compared with the existing topologies in a literature in context of residual energy as shown in Table 3.

TABLE 1: SIMULATION PARAMETERS

Parameters	**Values**
Area	1000*1000 m^2
No of source Node	120
Transmission Range (maximum)	150 m
Initial Node Energy	1 Joule
Energy Consumption (during Transmission)	10 mili Joule
Energy Consumption (during receiving)	0.1 mJ
Total Number of Coronas	4

TABLE 2: Sensor node deployment using arithmetic and geometric proportion

Parameters	**Values**			
	Uniform Distribution	**AP (d = 14)**	**GP (ratio 2)**	**GP (ratio 3)**
Total No of SN	**120**	**120**	**120**	**120**
i. SN in C-1	30	51	64	81
ii. SN in C-2	30	37	32	27
ii. SN in C-3	30	23	16	9
iv. SN in C-4	30	9	8	3

a) Average Residual Energy per Corona of Engineered Corona-based Deployment Strategy

i) Engineered-uniform

The average residual energy of each corona during network lifetime at first node failure is presented here first. The sensor nodes were distributed in four coronas uniformly i.e. C_1, C_2, C_3, and C_4 are 30, 30, 30, and 30 respectively. The average residual energy of first corona, C_1 = 4% therefore 4/100 x 30 = 1.2 Joules. The average residual energy of second corona, C_2 = 28% therefore 28/100 x 30 = 8.4 Joules. The average residual energy of third corona, C_3 = 51% therefore 51/100 x 30 = 15.2 Joules and the average residual energy of fourth corona, C_4 = 78% therefore 78/100 x 30 = 23.4 Joules. The total residual energy therefore becomes = 1.2 + 8.4 + 15.2 + 23.4 = 48.2 Joules. The total energy assigned to the network at start-up was 120 Joules. At the end of the simulation, 40.16% of the total energy are left unused as shown in Figure 2.

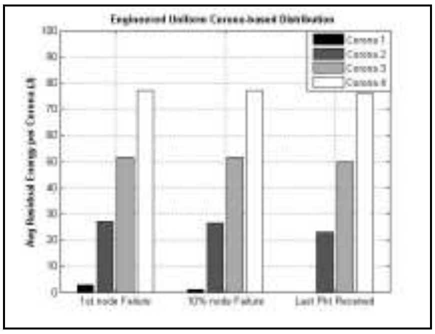

Figure 2: Average residual energy per corona of engineered-uniform deployment strategy

ii) Engineered-Gaussian with an Arithmetic Proportion:

The average residual energy of each corona during network lifetime at first node failure is present here first. The sensor nodes were distributed in four coronas i.e. C_1, C_2, C_3, and C_4 are 51, 37, 23, and 9 respectively. The average residual energy of first corona, C_1 = 2% therefore 2/100 x 51 = 1.02 Joules. The average residual energy of second corona, C_2 = 23% therefore 23/100 x 37 = 8.5 Joules. The average residual energy of third corona, C_3 = 44% therefore 44/100 x 23 = 10.12 Joules and the average residual energy of fourth corona, C_4 = 60% therefore 60/100 x 9 = 5.4 Joules. The total residual energy becomes 1.02 + 8.5 + 10.12 + 5.4 = 25.04 Joules. The total energy assigned to the network at start-up was 120 Joules. The total residual energy = 1.02 + 8.5 + 10.12 + 5.4 = 25.04 Joules. At the end of the simulation, 20.86 % of the total energy are left unused as shown in Figure 3.

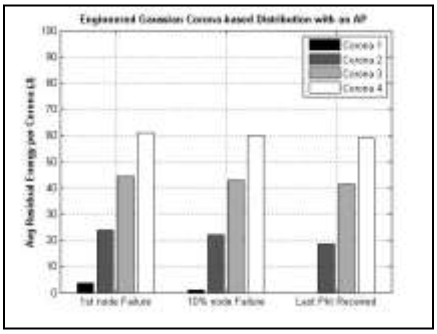

Figure 3: Average residual energy per corona of engineered-Gaussian with an arithmetic distribution

iii) Engineered-Gaussian with Geometric Proportion of ratio 2

The average residual energy of each corona during network lifetime at first node failure is present here first. The sensor nodes were distributed in four coronas i.e. C_1, C_2, C_3, and C_4 are 64, 32, 16, and 8 respectively. The average residual energy of first corona, C_1 = 8% therefore 8/100 x 64 = 5.12 Joules. The average residual energy of second corona, C_2 = 13% therefore 13/100 x 32 = 4.16 Joules. The average residual energy of third corona, C_3 = 27% therefore 27/100 x 16 = 4.32 Joules and the average residual energy of fourth corona, C_4 = 52% therefore 52/100 x 8 = 4.16 Joules. The total residual energy = 5.12+4.16+4.32+4.16 = 17.76 Joules. The total energy assigned to the network at start-up was 120 Joules. At the end of the simulation, 14.8% of the total energy are left unused as shown in Figure 4.

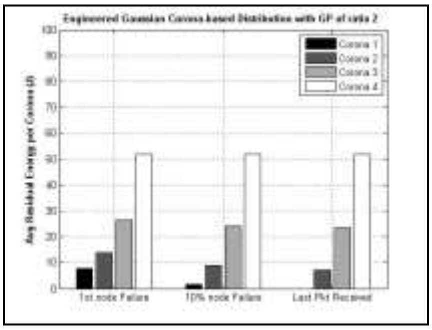

Figure 4: Average residual energy per corona of engineered-Gaussian distribution with geometric distribution of ratio 2

iv) Engineered-Gaussian with Geometric Proportion of ratio 3

The average residual energy of each corona during network lifetime at first node failure is present here first. The sensor nodes were distributed in four coronas i.e. C_1, C_2, C_3, and C_4 are 81, 27, 9, and 3 respectively. The average residual energy of first corona, C_1 = 28% therefore 28/100 x 81 = 22.68 Joules. The average residual energy of second corona, C_2 = 30% therefore 30/100 x 27 = 8.1 Joules. The average residual energy of third corona, C_3 = 35% therefore 35/100 x 9 = 3.15 Joules and the average residual energy of fourth corona, C_4 = 51% therefore 51/100 x 3 = 1.53 Joules. The total residual energy = 22.68 + 8.1 + 3.15 + 1.5 = 35.43 Joules. The total energy assigned to the network at start-up was 120 Joules. At the end of the simulation, 29.52 % of the total energy are left unused.

The average residual energy of each corona during network lifetime at last packet received is present. The sensor nodes were distributed in four coronas i.e. C_1, C_2, C_3, and C_4 are 81, 27, 9, and 3 respectively. The average residual energy of first corona, C_1 = 0% therefore 0 Joules. The average residual energy of second corona, C_2 = 5% therefore 5/100 x 27 = 1.35 Joules. The average residual energy of third corona, C_3 = 21% therefore 21/100 x 9 = 1.89 Joules and the average residual energy of fourth corona, C_4 = 51% therefore 51/100 x 3 = 1.5 Joules. The total residual energy becomes, 0 + 1.35 + 1.89 + 1.5 = 4.74 Joules. The total energy assigned to the network at start-up was 120 Joules. At the end of the simulation, 3.95% of the total energy are left unused as shown in Figure 5.

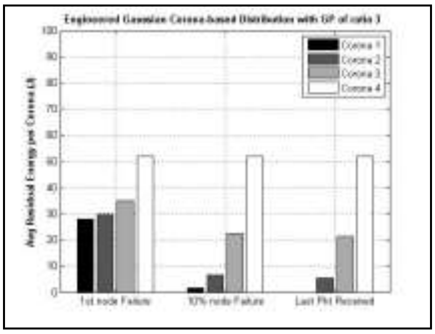

Figure 1: Average residual energy per corona of engineered-Gaussian distribution with geometric distribution of ratio 3

TABLE 3: Comparative analysis with the existing Deployment Strategies

Research Publication	**Deployment Strategies**	**Network Residual Energy during network lifetime @ First Node Failure**
[18-20]	Random-uniform	90%
[18, 21-23]	Non-corona based Engineered-uniform	79%
[24-27]	Minimum Sensor Node for full coverage (Grid)	74%
[28]	Random using GRACE	70%

Deployment Strategies	**Network Residual Energy per Corona of Engineered Corona-based Deployment Strategy**				**Total Residual Energy during Network Lifetime @ first Node failure**
	C-1	**C-2**	**C-3**	**C-4**	
Engineered-uniform	4%	28%	51%	78%	40.16%
CSDS using AP	2%	23%	44%	60%	20.86%
CSDS using GP of Ratio 2	8%	13%	52%	14.8 %	14.8%
CSDS using GP of Ratio 3	28%	30%	35%	51%	29.52%

V. Conclusions and Future Work

Corona based deployment strategies in wireless sensor network can affect the overall performance of wireless sensor network. Improper placement of sensor node can disconnect the network and much residual energy can be wasted during the network lifetime. An optimum sensor deployment strategy is one that minimizes the residual energy of the network. The main factor for minimizing the residual energy of the network as to deploy more nodes at sink locality, rather than other performance factors such as increased energy level and transmission range of all the sensor nodes.

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