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Analysis of Deployment Strategies in Wireless Sensor Network (WSN)

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***Abstract*— The field of wireless networking is experiencing a tremendous growth. With the advancement of wireless communication technologies, Wireless Sensor networks (WSNs) have become useful for many applications. A sensor is a device which allows "sensing" of the environment. It is usually small and resource constrained. A sensor network is composed of large number of sensor nodes. In a wireless sensor network, if the sensors are deployed uniformly across the network, they experience different traffic intensities, thereby, different energy depletion rates depending on their locations. Usually, the sensors near the sink tend to deplete their energy sooner; when enough of them exhaust their energy, they leave holes in the network, causing the remaining nodes to be disconnected from the sink. To avoid energy holes and for achieving maximum lifetime this paper proposes : First deploy the sensors in network and then compute the traffic load and energy consumption in different regions of the network and then propose a energy consumption model for accurate energy hole avoidance. Based on energy consumption model is used for the deployment strategy which ensures a guaranteed FDT and ADT of the network with minimum number of sensors.**

Keywords*— Wireless sensor network, Energy-hole, Node deployment, Network lifetime, Adjustable transmission range.

I. INTRODUCTION

In wireless sensor networks, the sink is the gathering centre of sensory data. As energy consumption for data transmission is an exponential function of the communication distance between sender and receptor according to the energy consumption model, multi-hop communication strategy is considered to be efficient in energy conservation for data gathering.

Energy hole: Wireless sensor network playing many important roles in many of the applications like in agricultural applications, video surveillance applications, military applications, and the only one important criterion is the deployment strategies for these different applications. Sensors close to the sink tend to loss their energy faster than other sensors because they have to relay data for a large number of sensors and thus run out of batteries very quickly. This area is known as the hotspots. Nodes in the hotspots die much faster than other sensors because of higher energy dissipation rate. This phenomenon is referred to as energy-hole. When energy-hole present in the network, the traffic flow will be switched to other alive sensors in the network, which leads to the expansion of the energy-hole region. This phenomenon is referred to as funnelling effect. At last, the entire network is subject to premature death because it is separated by the energy-hole. When network is out of function, some sensors in the network still have energy up to some initial energy. Energy hole forms in the hotspot region, which is also called as the weakness of the network; it can be avoided by deploying additional nodes in this area. This is called the non-uniform node distribution strategy.

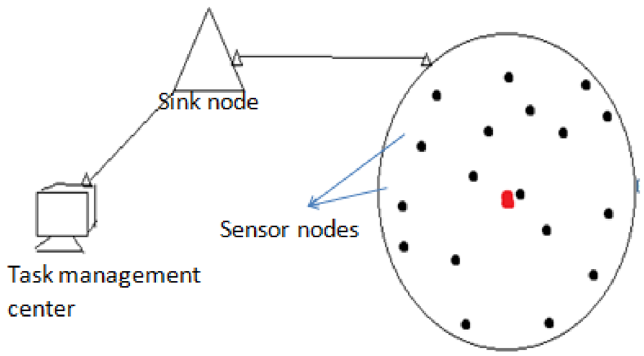

Fig 1: Sensor Network

To avoid energy holes and to achieve maximum lifetime this paper proposes three interventions: (A) The node density in different areas of the network should be a continuous varying function of the distance from the sink in order to achieve an balanced energy consumption among all nodes in the network, (B) if there are insufficient nodes to achieve a balanced energy consumption in the whole network, then to achieve the required lifetime threshold T with minimum number of nodes in the network proposed node deployment strategy can be used; and (C) if there are sufficient nodes in the network to ensure the network connectivity and coverage with the node density of s, then algorithm is designed to identify the optimal transmission radius r and the corresponding achievable maximum network lifetime. Conclusions are verified by using extensive simulation results. By avoiding energy holes, the quality of service is improved.

II. RELATED WORK

Although there are number of proposed node deployment strategies, their common goal is only to balance the overall energy consumption. In mission-critical applications, however, a guaranteed life time T of the network is usually required, which is not considered in previous research.

Sensor placement problem has been addressed in many network applications. The problem of sensor placement for steady state filtering & smoothing is considered. By verifying sensor locations, different solutions are obtained. Matrix equations are derived that relate individual changes in sensor locations [5].

Propose two algorithms to optimize sensor placement with a minimum number of sensors for effective coverage and surveillance purposes under the constraint of probabilistic sensor detections and terrain properties [6].

Address the sensor placement problem for complete coverage under the constraint of cost limitation. The grid based placement scenario is adopted and the sensor placement problem formulated as a combination optimization problem for minimizing the maximum distance error in a sensor field under the constraints [7].

Jointly optimize sensor placement and transmission structure in a one-dimensional data-gathering WSN, where a given number of nodes need to be placed in a field such that the sensed data can be reconstructed at a sink within specified distortion bounds. This approach aims at minimizing the total power consumption under distortion constraints [8]. Address the optimal sensor placement to ensure connected coverage in WSNs. Sensor placement schemes that maximize network lifetime have also been addressed for different WSNs [9].

The optimal placement and role assignment algorithm can be used to maximize the lifetime of a WSN which consists of sensors and relay nodes. Systematic collection of information from an area of interest then transmitting this to a base station. Nodes are allowed to perform in-network data aggregation [10]. Proposed "Energy provisioning for wireless sensor network by considering two-tier wireless sensor network and studied the joint problem of energy provisioning and relay node placement for upper tier aggregation and forwarding nodes to increase network lifetime"[11].

All sensor nodes [12] generate CBR (Constant Bit Rate) data and send them to single sink via multi-hop transmissions. Sensor nodes sitting around the sink need to relay more traffic and suffer much faster energy consumption rates (ECR), In this paper present a mathematical model and characterize the energy hole problem. Using this model, investigating the effectiveness of some existing approaches towards mitigating this problem in a formal manner. And simulation results are used to validate this analysis.

"Constrained multivariable nonlinear programming problems[13] to determine both the locations of the sensor nodes and data transmission pattern. The two objectives studied in the paper are to maximize the network lifetime and to minimize the application-specific total cost, given a finite number of sensor/aggregation nodes in a region with certain coverage requirement. It includes study of a linear network, and find optimal placement strategies numerically. Through numerical results, showing that the optimal node placement strategies provide significant benefit over a commonly used uniform placement scheme". Deployment guidelines for achieving maximum lifetime and avoiding energy holes in wireless sensor network [4]" address the balanced energy consumption in wireless sensor network with adjustable transmission ranges to achieve required minimum lifetime.

It is noticed that cluster-based networks can achieve higher energy efficiency than flat network [5]. HEED [8] and UCR [7] hierarchical structures of the sensor networks are constructed and clustering schemes are proposed aiming at balanced energy depletion among all nodes. LEACH employs clusters head rotation to balance the energy depletion.

III. SYSTEM DESIGN

A. System Architecture

System architecture is the conceptual design that defines the behaviour and structure of a system. Description about system architecture defines system's formal description, and planned in a way that supports structural properties of a system. It defines components of a system and provides a plan for developing the system, that will work together to implement the overall system. The System architecture is shown in fig 1.

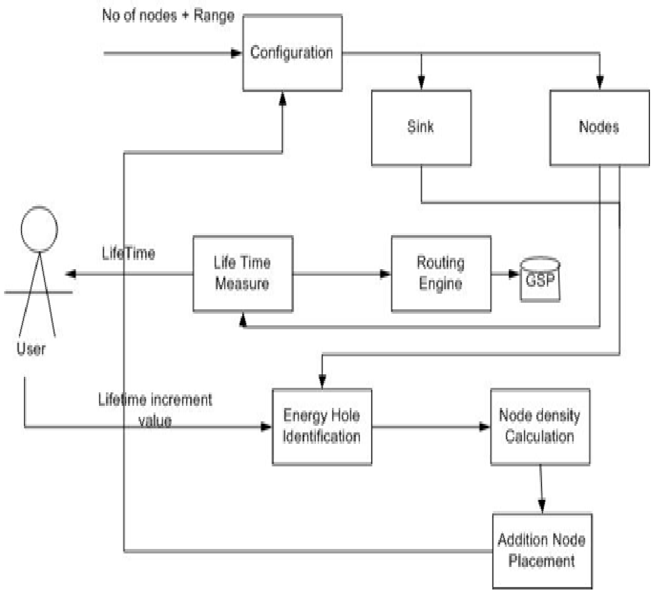

Fig 2: System Architecture

The modules explained are as follows.

Configuration, Sink, Nodes, Routing Engine, Life Time Measure, GSP, Energy Hole Identification, Node Density Calculation, Addition Node Placement.

Number of nodes and ranges are configured to the sink and nodes. Calculate the life time measures from the node and user access the lifetime achieved by the node. Routing engine finds the geographic selection path. User increments the lifetime value to the energy hole. The energy holes are identified by the nodes and calculate the node density. Addition node placements are configured to the sink and nodes.

B. Traffic Load

Assume the single sink node S is located in the centre. Divide the whole area into M concentric bands with a step size of r meters. As in Figure 2, ring 0 is the small circle with radius r meters, and ring 1 is the shaded band with radius 2r meters. Since a greedy shortest hop routing policy is assumed to be in use, data packets from outer area hop from ring to ring towards the sink node S. Note that here we assume a packet can traverse each ring using only one hop transmission, although in reality a packet may be transmitted more than one time within the territory of a single ring.

The nodes around the sink have to relay more traffic compared to nodes that are farther away from the sink. Let us do a few calculations to analyze the details. p = N/ A_{net} is the node density, and b is the per node bit-rate. Note that any data traffic generated from the outer rings has to reach a node in ring 0 first, and then the node in ring 0 relay the data to the base station. Besides this relaying traffic, a node in ring 0 also needs to transmit its own sensed data. So, the per node traffic load in ring 0 is:

$$Load_{ring\ 0} = \frac{\text{Total traffic in the network}}{\text{Number of nodes in ring 0}} = \frac{p(Mr)^2 b}{p \pi r^2} \qquad \text{Equation (1)}$$

C. Network Model

All sensor nodes are deployed in the circular network with R as the radius and the red node as the sink. Assume the minimum node density ensuring network connectivity and coverage to be s which is also called working node density. Denote the network node density as ρ and if ρ≤τ all nodes work concurrently and if ρ >τ a corresponding node density control strategy is used so that the density of nodes working is τ. And in each round of data collection every sensor generates a packet and sends it to the sink.

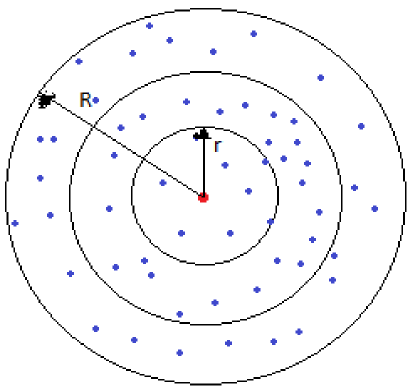

Fig 3: Network Model

Each packet is forwarded to the sink using greedy strategy with multi-hop transmission. The effective network lifetime is the number of rounds of data collection. The radius of sensor node transmission is denoted with r. The transmission power of node is adjustable, that is the node can adjust its transmission power according to the distance between it and the receiver. Range of communication is the distance between the sender and the receiver, which is usually not larger than r as nodes are randomly deployed. Network is devided into no of regions say R1,R2,R3……Rn where all regions consist of some number of nodes

R1={n1,n2,….nn},

R2={n1,n2,…..nm}………

Rn={n1,n2,……np}

And A={R1,R2,….Rn} where A represents deployment area which is having regions called as R1,R2,…Rn.

If A is exponentially distributed, the values will be in the form of the set {1,2,4,8,16,32,64….} it means that increasing the no of nodes exponentially in the particular area.

If A is uniformlly distributed, the values will be in the form of the set {4,8,12,12,12,8} it mean that nodes are deployed uniformally in the particular area.

If A is normal distribution, then values will be in the form of the set {4,8,12,16,12,8,4} it mean that nodes are deployed normally in the particular area.

If A is random distribution, then nodes are deployed randomly in the network. And finally comparing the these all deployment strategies.

IV. IMPLEMENTATION

Three modules are used for implementation

A) Deployment
B) Simulation
C) Results.

A. Deployment

Deployment of sensors in different patterns (random, exponential, uniform, normal order) in the sensor network is achieved. Inputs are:

- No of nodes as the user wants to enter.
- Range of the network.
- Initial energy of sensor node.
- Energy of sink sensor node.
- FDT (First node Die Time).
- ADT (All node Die Time)

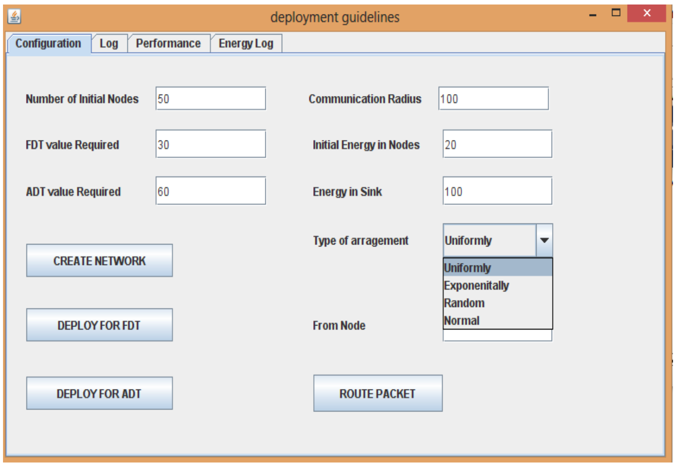

Fig 4: Network Configuration

After deploying the sensors, need to calculate region of sensor node by using some distance formula from each sensor node to the sink node.

FDT: Suppose that the required minimum FDT is T, then lifetime of each sensor node is no less than T if the energy consumption of each node in the network is no longer than threshold energy. To ensure that the energy consumption of each node is equal or less than threshold energy, deploy additional nodes in the area where per-node energy consumption is grater than threshold energy.

ADT: The node with minimal lifetime is the node which dies first and its position is exactly where energy hole begins. The energy hole keeps extending with more and more nodes running out of energy. When the width of the energy hole grater than the transmission radius , the network is separated and reaches its ADT

Based on the energy consumption model, proceed to propose the deployment strategy which ensures a guaranteed FDT and ADT of the network with the minimum number of sensors.

B) Simulation: In this module log information is to be maintained.

- Energy loss for transmitting packets from each sensor node to the sink node.
- Energy loss for receiving packets.
- Path status of sensor node to sink node.
- Maintenance of normal log status

C) Results: Deployment of sensors randomly, uniformly, exponentially, and normally is achieved in the network. Fig 5 shows the random deployment of sensors in the network.

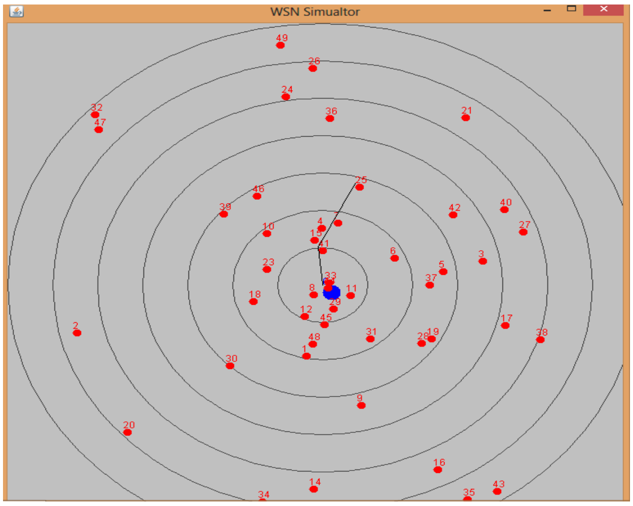

Fig 5: Random Deployment of Sensors

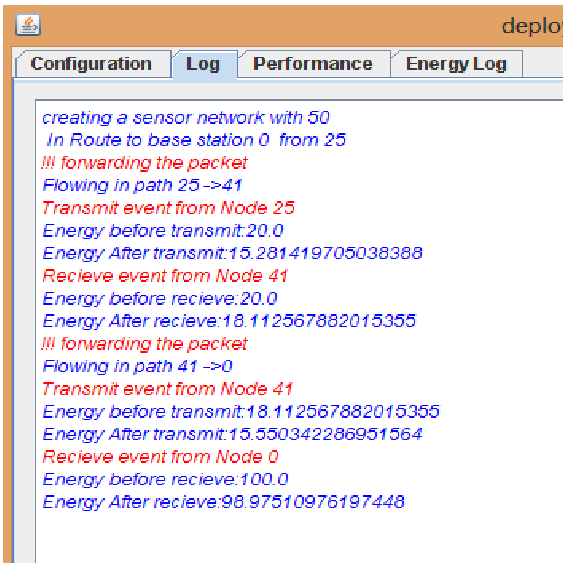

Fig 6: Log status

Deployment of new nodes in the network is achieved when energy exceeds threshold energy of the network. It is calculated for both FDT and ADT.

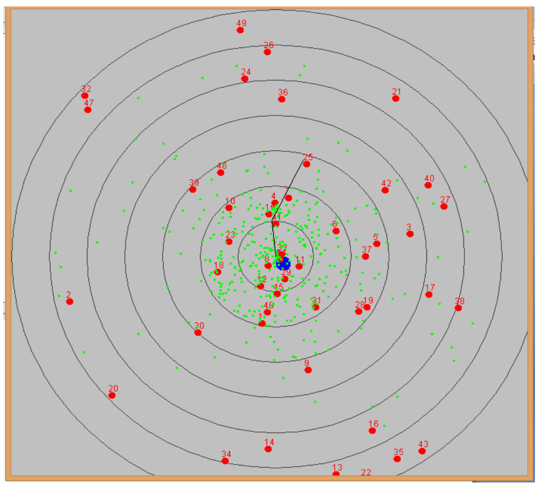

Fig 7:New node deployment in the sensor network

Comparison with ring based deployment: This method involves divide the network into several rings having the same width r. And the area closer to the sink is deployed with higher node density while the node density in area far away from the sink is smaller. But the node density in the same ring is uniform.This method is ring based deployment. Another difference is computation of node density in each ring based on assumption that all deployed nodes work at the same time. While in this proposed method assumption is based on the fact that density of all working nodes should be τ. In ring based deployment network, the energy consumption in the same ring is not balanced although nodes are uniformly deployed in the same ring.

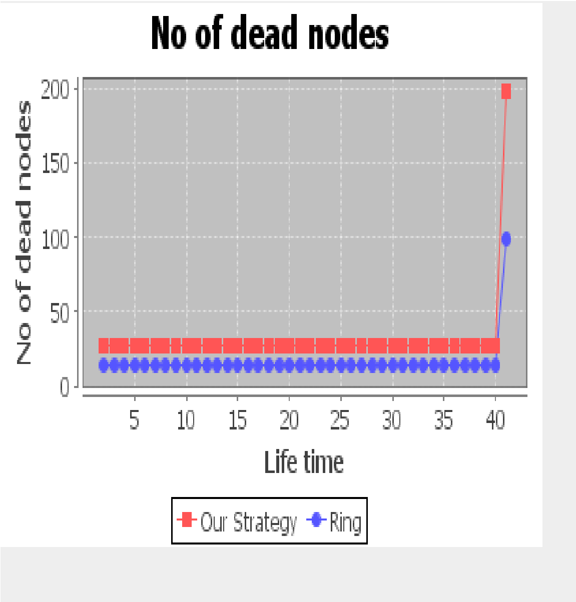

Fig 8: No of Nodes vs Lifetime(sec)

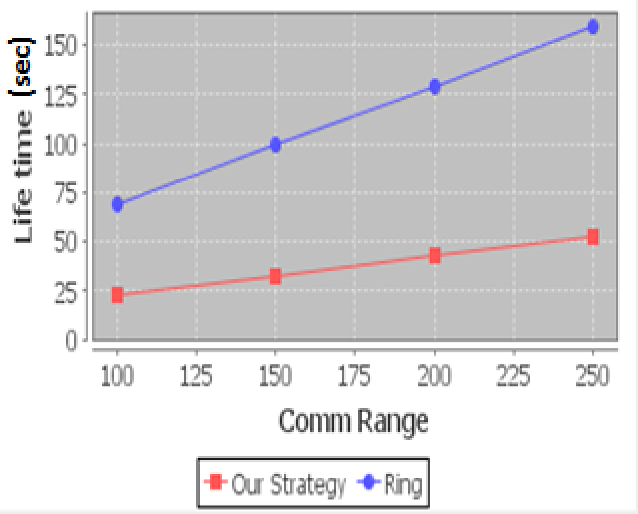

Fig 9:Life Time Graph

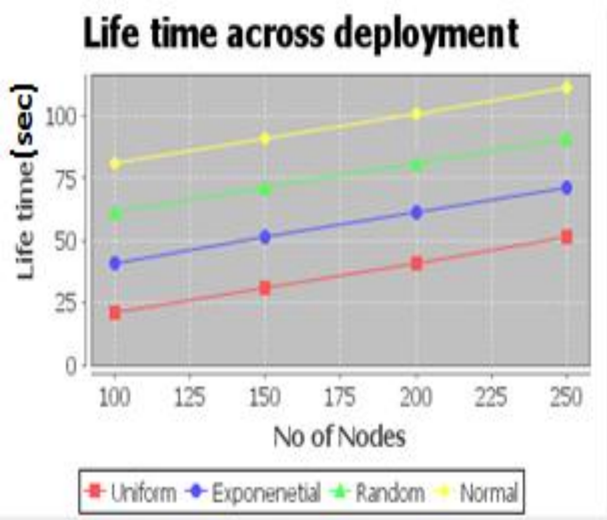

Fig 10: Comparison Graph of Lifetime(sec) vs No of Nodes

Fig shows the comparison between different deployment patterns. Comparison is made for the nodes 100,150,200, and 250. Normal deployment strategy having the maximum lifetime compared to other deployment strategies.

V. CONCLUSIONS

Computation of the data load of sensor nodes and the energy consumption in different regions of network through some theorotical analysis of network parameters. And analysis of different deployment strategies using random, normal, exponential, uniform forms. Based on this, accurately identification of the hotspot and the energy-hole regions and further derivation of the deployment strategy to avoid energy holes. This deployment strategy achieves balanced energy consumption among all nodes in the network.

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