Chapter 3

3.1 Introduction

In recent year’s utilization of WSN has expanded in various applications, for example natural life woods observing, disaster administration, space investigation, industry mechanization, secure establishment, border protection and battle field surveillance. The interest for such application is to utilize sensors of miniaturized size. WSN is a rising innovation, which has extraordinary creation for different minimal effort applications both for public and military. The advances in recent innovation have lead to the improvement of remote sensor nodes. A WSN, which throughout the years is utilized for military application to industry, family, medicinal and etc. The deployment example of sensor nodes in WSN is constantly irregular for application ranging from smaller to larger level. Such procedure will prompt insufficient use of the network like less nodes are situated at far separation and thick nodes are situated at some reason and some part of the locale may be without the observation of any node, where the networks do expend extra energy or even may not exchange the information. The remote sensor communication innovation permits irregular participation of sensor nodes with specific applications to take part in the network, which brings about the greater part of the uncovered simulation area, where less nodes are situated at far separations. The disadvantage of such network would be, extra energy is spent by the nodes situated in an example of thick area, utilizing more number of nodes for a littler separation of communication in a region with less number of nodes, extra energy is again spent by the source node so as to transmit a packet to neighbors there by transmitting a packet to reach the destination and calling it as Three Issue Placement Problem (TIPP). The proposed work is planned to create Energy Efficient Node Placement Algorithm (EENPA) keeping in mind the end goal to put the sensor nodes proficiently in simulated range, where every one of the nodes are similarly situated on an radial path to cover most extreme zone at equidistance and is expected to add to the improved network by effective arrangement of nodes in circle and grid design, which we call it as consistency of nodes to be compared with irregular positioning of nodes. Every node is in optimized positions at uniform separation with neighbors, trailed by running an energy effective routing calculation that spares an extra energy further to give integration administration by uniting every one of the nodes in the network. The aggregate energy devoured by every node of optimized position when contrasted with irregular situation of nodes is less by having equivalent weight on less nodes of far area, having appropriated the nodes in entire of the
reenactment territory. There by finding the network lifetime which additionally turns out to be productive when contrasted with irregular arrangement of nodes, henceforth expanding the network lifetime as well. Recreation results are compared with the random position of nodes. The leftover energy of a network, lifetime of a network, energy utilization of a network demonstrates a definite change for uniform network as that of with the irregular network. Simulation is been done in a Qualnet 6.1 test system and C++, results are obtained keeping pace with irregular arrangement of nodes with EENPA calculation.

Sensor networks are not quite the same as different remote networks because of the quantity of impediments like battery power, node densities, node arrangement, security issues, transmission capacity, colossal information volume and etc. WSN's use an expansive number of militarized sensor nodes with detecting, handling and remote imparting capacities to execute the said undertakings in the detection region. Recent studies have demonstrated that the overwhelming quantity of energy utilization is more between node communication and ordinarily less for computation. In this manner, so as to enhance the operational lifetime of the network and to meet the application particular lifetime necessities, it is vital to develop new energy effective and correspondence protocols. Information usually spares energy limit and decreases data transfer capacity use. This additionally prompts a general enhanced adaptability of the framework. Diminishment in the measure of information to be conveyed additionally enhances the reliable quality of the framework by lessening the measure of movement offered to the network. It can be for instance, the moment when the first sensor passes on, a rate of sensors death, the network allotments or loss of coverage happens. Since the WSN nodes are ordinarily battery prepared, effective techniques that enhance energy effectiveness to draw out the network lifetime are exceedingly needed. A few techniques have been given to increase the lifetime of network. Clearly, if a few nodes results in substantially more energy consumption in the predefined period than different nodes, they will run out energy before and abbreviate the lifetime of the entire network. Additionally, less energy expense of all nodes in the predefined positions, the more saving of energy to network survive. As a rule to extend out the lifetime, we ought to adjust the energy expense of every node and lessen the measure of energy expense of all nodes in a predefined period.

The arrangement of sensor nodes and access points in WSN can be static or dynamic. Sensor nodes are set near to a specific application or close to it. Nodes might self arrange into groups of distinctive size and diverse sorts of nodes to complete an assignment issued by the client. These node positions are predefined therefore, they fit for
many applications. Sensor network considered with expansive number of nodes is separated into clusters and inside of a group there are a few number of nodes, the benefit of WSN is that as opposed to sending individual information from of every node, joined result from every one of the nodes from each of the cluster can be sent to the base station, therefore lessening the energy consumed by every node. WSN's are intended to work on a little battery capacity say 100 nJ. A node quits working out when it comes up short on energy and accordingly we consider that WSN may be physically harmed, if numerous sensors debilitate their battery power which is as good as energy debilitate. The lifetime of WSN is for the most part effected by node position, example of topology, routing convention. One of the real challenge and test in WSN's is to put the remote sensor nodes in indicated field of a recreation range. Node position by enhancement can enhance the energy utilization and network lifetime. Node placement is a prime concern as many applications of WSN demands for longer life over the years.

A lot of work has been tended to this issue to accomplish three unique objectives, minimizing aggregate energy utilization, adjusting energy utilization and expanding network lifetime that is based on Sensor Nodes (SN) arrangement and information transmission, node position is concerned with how to place nodes in a WSN such that they can cover the assigned region effectively. Information transmission is to plan information accumulation conspires that can meet the focused on advancement objective on energy utilization. Sensor node positioning directly influences the execution of information transmission in WSN.

In numerous situations, the positions of SN’s are difficult to change once conveyed. Because of the successful scope by sending SN’s with specific topology designs. Consider an observed sensation where hundreds or a huge number of sensors may be conveyed. The sensor nodes in WSN are energy obliged devices that it is unfeasible for periodical recharge or substitution of batteries. The battery has extremely constrained lifetime, hence adds to the issues of limited correspondence and registering abilities. Consequently, the sensors should be outlined as cheap, low power and very energy productive. In the meantime, they ought to be productive as far as transmitted power and coding so as to decrease any superfluous additional transmission power and to enhance the general network execution.

The exceptional component of sensor nodes is its multifunctionality which comprises of signal handling and remote correspondence abilities, detecting unit and power unit. Sensor nodes actualize direct reckonings by utilizing the preparing capacities to process information and after that transmit only the obliged information. Thus, energy
constructive is one of the real issues in WSNs. Therefore, node arrangement in network is basic issues in remote sensor networks. Although numerous applications expect an irregular placement, such dissemination is not ideal and can bring about superfluous loss of energy, hence reducing network lifetime. Expecting that the ability to control the beginning deployment of sensor nodes exists, it is attractive to locate the ideal arrangement that can give adequate scope while minimizing the energy use needed for the network. Apart from scope, it is basic that the sensor nodes be collected such that information correspondence ways exist to take into consideration consistent assembling and reporting of detected data. Furthermore, some redundancy in these information ways is a desirable goal, since it imparts adaptation to non-critical failure to the network.

It is considered that placement strategy is going to be an important strategy for WSN, since effective utilization of the network can be done by having controlled placement of nodes, where the node positions are known which when compared with the random placement technique, where sometimes nodes are placed in a such a way that it is nearly far from the region to reach the neighboring nodes, thus leading to ineffective utilization of such nodes in the network. The deployment of sensors can be static or a random but yet a fast response. For example in a military application, it is difficult to reach the specified areas so as to practically place the sensors, in that case sensors are randomly thrown from an area above the ground, another case would be the scenario of an agricultural application which requires structured monitoring, where sensors are uniformly distributed to receive the data at regular intervals. WSN can be treated as distribution of nodes for a particular task.

It is always referred by most of the researchers that WSN uses maximum communication energy for communication, which intently can be considered as, sensor node can be made to use minimum energy to reach the neighbors thus trying to save the energy consumed. This technique can be very effective utilization to save the energy during sleep, idle and receive mode and there is always a chance of death of node and hence the network should sustain itself to the current load or sometimes entry of new node into the network where WSN should withstand the changes for the newer nodes providing scalability. As the sensor nodes are battery powered optimized positions along with the routing protocols to be designed for sensors so as to consume minimal energy extending the network lifetime, while guaranteeing good performance overall. As the placement of node is an important phenomenon, if done efficiently followed by energy routing protocol, such network can greatly enhance the network lifetime.
There are various techniques to deploy the nodes to replace the random deployment. Nodes can be deployed in square pattern creating grids, hexagonal patterns, triangular or a circular pattern. Most of the techniques that use the node placement pattern are complex leaving behind non-inclusion of relay nodes or additional power nodes. We consider the drawback of WSN with placement strategy and place uniform nodes without addition of any relay nodes. The nodes are placed on different pattern and run with the routing algorithm to transmit the data. Simulation is carried in a Qualnet 6.1 simulator which tries to give a behavior of a network in a real time to calculate for various performance parameters of the network, since we are working with energy, the status of every node after the simulation in terms of energy and lifetime is noted for grid, circular, random pattern of deployed nodes. The proposed work is intended to concentrate on the different placement of nodes like random, circular and grid based scenario of a network that is fundamentally worked out to save the energy devoured by the network comparable to sensor nodes and to build the network lifetime.

Proposed EENPA calculations considers energy based deployment technique to minimize out energy utilization by considering a circular and grid pattern of nodes to convey them in a simulation area and furthermore lifetime oriented strategy, that primarily concentrates more on lifetime of a nodes which specifically expands the lifetime of a network. As the data gathered by every one of the nodes is to be sent to BS which is called as sink node. It is obliged to have an adequate energy for every node. An efficient sensor location algorithm gives us the minimum intersection of sensor's range and expands the aggregate zone secured by sensors.

3.2 Relay Node Placement Algorithm

Node placement is a technique to place the nodes effectively in a simulation area so as to conserve the minimum energy from each node that is intended for transmission of packets or a data. Most of the network considers a communication by deploying the nodes randomly. When the nodes are deployed randomly, there are three issues that mainly are, some nodes are densely deployed at particular region while the other region has got fewer nodes located at farer distances and leaving region will not at all be with the single coverage of node.

The drawbacks of such random node deployment is that nodes with dense location, where routing is to take place. All the hops between source and destination in a region of dense location of nodes take part in routing leading to additional utilization of energy from each node, where as in the case of nodes at far location, additional energy is
again spent in transmitting the data to neighbors as well to the destination located at far distances. On a similar way it is difficult to manage the routing in a region where no nodes are located leading in all the three case, an uneven distribution of energy source and node deployment. As a prototype model we have simulated the proposed work in Qualnet 6.1 simulator and figure 3.1 shows the random deployment of sensor nodes.

Figure 3.2 shows the circular deployment of nodes which provides mainly two objectives. First one is, careful node placement can be a very effective optimization means for achieving the desired design goals and is classified as static approaches. On the other hand, some schemes have advocated dynamic adjustment of node location, since the optimality of the initial positions may become void during the operation of the network depending on the network state and various external factors, we categorize the placement strategies into static and dynamic depending on whether the optimization is performed at the time of deployment or while the network is operational, this approach considers positions of node metrics that are independent of the network state or assume a fixed network operation pattern that stays unchanged throughout the lifetime of the network. Careful node placement can be a very effective optimization means for achieving the desired design goals and thus classifying them as static approaches.

As indicated in figure 3.1 which consider a situation of running an AODV routing protocol utilizing Qualnet simulator 6.1 system.

![Figure 3.1: Random deployments of sensor nodes](image)
Despite the fact that the region considered for simulation is quite larger of 100 × 100 m, nodes are hardly distributed in a region of 50 × 50 m, in random node distribution. The random deployment pattern indicates that nodes are densely deployed in one
particular area, leaving behind most of the region uncovered. The proposed model considers a pattern of node distribution in a circular pattern in such a way that base station is located at the center surrounding a first layer of 8 sensor nodes covering equal area on a circle, followed by covering rest of the area on same pattern of deploying the nodes on a circular area so as to cover the complete simulation area with each layer adding another of 8 nodes where each layer is spatially separated by a distance of $1 \, m$. The advantage of optimized placement of node is that maximum area is covered and burden on nodes is reduced followed by increasing the network lifetime.

Figure 3.3 shows the grid placed node with the Qualnet 6.1 simulator scenario. It is said to be uniformity as we know where the positions of nodes are. Grid pattern also resembles to square pattern distribution but for the simulation hence forth it is taken with grid pattern of equidistance nodes, so as to consider any of the node within total simulation area and not by dividing it.

### 3.3 Implementation

The implementation for node deployment and best routing analysis is done in this section. We have considered three different node deployments for our experimentation and results. The figure 3.4 shows the uneven distribution of nodes calling it as random deployment of nodes. Node placement is a technique to place the nodes effectively in a simulation area so as to consume the minimum energy from each node that is intended for transmission of packets or a data. The present research is on deployment of wireless sensor nodes that are mainly concentrated in the static and the dynamic manner. In static deployment nodes are fixed, whereas in dynamic deployment of nodes, the nodes are mobile. For the discussion we have classified the static deployment into non deterministic (random) and deterministic deployment.

Randomized sensor placement often becomes the only option for WSN. Consider an example, in applications of WSN’s in reconnaissance missions during combat, disaster recovery and forest fire detection. It is widely expected that sensors will be dropped by helicopter, grenade launchers or clustered objectives. Such means of deployment lead to random spreading of sensors with node density being controlled to some extent.

As with most of the research that have been carried out, communication network of WSN is always considered deploying the nodes with randomness. The randomness is a function to deploy the nodes randomly leading uneven or unequal distribution of nodes. When such network with the nodes that are deployed randomly is considered for the simulation, there are three issues that mainly arise, some nodes are densely deployed at
particular region while the other region is distributed with only fewer nodes located at farer distances and leaving region will not at all be with the single coverage of node.

The drawbacks of such random node deployment is that nodes with dense location, where routing is to take place, additional hops between source and destination in a region of dense location of nodes take part in routing leading to additional utilization of energy from each node, where as in the case of nodes at far location, additional energy again is to be spent in transmitting the data to neighbors located at far distance as well to the destination which is located at quite far distances. On a similar way it is difficult to manage the routing in a region where no nodes are located leading in all the three case, an uneven distribution of energy source and node deployment.

We have considered the other method of simulation using computer graphics and c simulation. In this case we have arranged the sensor nodes in all three patterns considering $x$ and $y$ axis, the first case is shown in figure 3.4. It shows the probability of random deployment of sensor node network, the node pattern is set in a simulation environment.

![Figure 3.4: Random placements of sensor nodes](image)

The random function distributes the nodes close to each other for example node ID 25, 30, 85, 79, 55, 48 are all closely located and node 77, 86 are located at a such far distance that they may not be in a communication range leading to loss of data transfer or finding more additional neighbors or energy to complete the routing. Such drawback can be overcome by placing the nodes uniformly in a simulation area which we call it as deterministic node deployment.
In Deterministic Sensor Placement Schemes (DSPS), the nodes are placed to meet a percentage of the desired execution targets. Likewise, coverage of the observed region can be guaranteed through careful arranging of node densities and fields of perspective. In this way the network topology can be established at the setup time. DSPS are common in specific applications like room temperature checking, therapeutic applications, submerged acoustics, imaging and feature sensors among others. In our proposed work we have considered two diverse uniform models grid and circular arrangement of nodes, which are compared with random deployment topology.

Figure 3.5: Grid placement of sensor nodes

Figure 3.5 demonstrates the arrangement of nodes in grid way, the same reenactment area as that of random network is considered with 100 nodes and every one of the nodes are held at a uniform separation. Experiencing the vast majority of the research papers, where for any application, nodes are simply conveyed haphazardly or randomly. The primary intention of the work is to give optimized positions for the nodes expressing that the nodes are intended to work from the defined position till the node dies, in this manner the designed algorithm will at first fix the position of nodes then go for the routing. Enhanced placement can certainly prompts powerful usage of network like routing, energy, coordination between the nodes to give expanded network lifetime.
Figure 3.6: Circular placement of sensor nodes

Figure 3.6 shows the circular deployment of nodes which provides mainly two objectives. First one is, careful node placement can be a very effective optimization means for achieving the desired design goals and is classified as static approaches. On the other hand, some schemes have advocated dynamic adjustment of node location, since the optimality of the initial positions may become void during the operation of the network depending on the network state and various external factors, we categorize the placement strategies into static and dynamic depending on whether the optimization is performed at the time of deployment or while the network is operational, this approach considers positions of node metrics that are independent of the network state or assume a fixed network operation pattern that stays unchanged throughout the lifetime of the network.

To do the routing be it for all the 3 distinctive node topology, considering a simple shortest path from a set of multipath via source and destination, the area considered for reenactment is $100 \times 100 \ m$, as shown in figure 3.4. Nodes that are deployed only cover an area of $50 \times 50 \ m$. The arbitrary arrangement of node as an example demonstrates that nodes are thickly conveyed in one specific range, deserting a large portion of the locale uncovered. The proposed model considers an example of node circulation in grid and circular pattern of nodes in a manner that for the network it is with node at regular intervals and circular, base station is situated at the centre encompassing a first layer of 8 sensor nodes covering equivalent territory on a circle, trailed by covering rest of the range on same pattern of deploying nodes on a circular zone in order to cover the complete simulation region with nodes being increased at an order of 8 for every circular path. The
advantage of optimized placement of node is that most extreme zone is covered and load on nodes is diminished trailed by expanding the network lifetime.

3.4 Analytical Model

The WSN which utilizes a strategy for arbitrary deployment of nodes can ordinarily be supplanted by uniform circulation of nodes, be it regarding grid or circular example for arrangement of nodes. The work for the most part focuses on running a recreation utilizing uniform node arrangement topology as a part of a network, which is worked for decreasing the general energy devoured by the network further expanding the network lifetime.

Work is done considering three distinctive network topology in which sensor nodes are set at diverse positions, the routing is held at distinctive moment in the network taking into account with which the energy utilization can be found. The proposed work is considering an irregular distribution of sensor network, as the name proposes randomness. The nodes are put at un-equivalent separation at diverse positions as demonstrated in figure 3.4. The nodes do not exhibit optimized location with haphazardness in x and y positions, i.e. the two unique nodes are never at equidistance. Energy consumption depends on the distance the data is been transmitted to reach the destination, this is a critical thought for WSN. Illustrations for uniform network (Grid and Circular) are indicated in figure 3.5 and 3.6. Here the node topology is at uniform separation framing a grid and circular design. The network is characterized in (100 × 100 m) separation. Every node is set at a uniform separation of 1 m, considering the aggregate number of nodes to be 100. Taking note of that network is versatile to appropriate nodes at an equivalent separation and varying the nodes through 0 to 99. The neighbor of any node can be at a separation of just 1 m, which we call it as a uniform example of nodes. Let "n" be aggregate number of nodes in a network picking "n" equivalent to 100, then the aggregate number of grids "k" that can be needed, can be found by the accompanying mathematical statement for grid based topology:

\[ k = \sqrt{n-1} \]  \hspace{1cm} (3.1)

Where ‘k’ be a number of grids

Let ‘d’ be the distance of separation between two sensor nodes in a network and ‘R’ be the radius with which, all the sensor nodes are situated. The sensing range \( R_{\text{sense}} \) for a particular network is given by,
The above concept is based on the fact that nodes are predetermined. This result in many usages, particularly when the node is replicated of energy, a particular node can easily be found and substituted. Hence the Node Location ‘NL’ of every node in a network is given by,

\[ NL = (R_{\text{sense}}, \alpha) \]  

\( \alpha \) - is in the range 0 to 360° with \( \alpha \) varying 10° for every node.

Once the node location of every node is found, they are placed in a regular grid pattern, by this method a WSN in a grid pattern is created, which is called uniform distribution of nodes. As stated the node location, it is not just that nodes are simply placed as a grid pattern but an equation is been given mentioning the position of node which we call it as an optimized position of every node, which also holds good for circular placement of node topology. Another methodology for uniform node distribution can be a circular pattern of sensor nodes. The WSN in circular node placement topology is as shown in figure 3.6. For simplicity circular deployment pattern of nodes is defined using circles and number of nodes increasing on each circle present at different radii has two types of communication. The data can be transmitted on a trajectory path or on circular path i.e. routing can go in both the paths depending on which the distance is shorter. Distance between the nodes for either of the methods is going to be varied. The trajectory method on trajectory path follows a distance of 1 m, between the neighbors, where the distance between the neighboring nodes are different for different circles in a circular pattern. For the first circle it can be 0.39 m, where 8 nodes are placed, for the second circle it is 1.56 m, by placing 16 nodes and for the third circle it can be 3.51 m, for the fourth circle it can be 6.24 m. These distances can rather be called as ‘Sectorial Separation’ which is given by,

\[ \text{sector} = \left( \frac{1}{2} \times \theta \times \left( \frac{\pi}{180°} \right) \times r^2 \right) \]  

\( r \) = a radius of a circle  
\( \theta \) = an angular difference between the nodes.

With the uniform grid distribution pattern, node location is aware for each node and is not a random. Node locations are predefined, where every node is placed on these locations, hence node location \( NL_o \) for circular deployment can be:
\[ NL_\alpha = F(\alpha_i) r \]  

\[ F(\alpha_i) = \frac{2\sqrt{3} \sin \frac{\alpha}{2}}{\alpha} \]  

The \( \alpha \) is in the range of 0 to 360°

\( F(\alpha_i) \) = Position for every node.

After the nodes are deployed on a circle, routing is done by any of the method, where routing is on a trajectory path or it is on a circular path and sometimes both. Definiteness can occur as the nodes are with uniformity. After the variety of patterns is set, every node is allocated with energy, traffic density, neighbor information along with their energy. That is every node is allocated with say 50 J of initial energy \( E_{ini} \). The instant of time at which node transmits data, there is a reduction from its total energy of a node that depends on the distance and traffic it carries on the path of its routing.

Once the network is set up, information as packets can be sent from source to the destination. One general technique that we take after for 3 different networks node deployment is that, source and destination are picked on the edges and with same positions then the routing is done. For the routing strategy we use multipath based routing, where various routes from source and destination have been picked. Path taking into account separation, neighbor and traffic has been chosen for routing. When the routing happens, the energy devoured by the network nodes is discovered, that is identified with the network lifetime, the general energy expended from a specific way between source and destination is given by "\( E_{total} \)"

\[ E_{total} = \sum_{i=1}^{s} E_i \]  

\( i \) = be the number of neighbors, \( s \) = total number of nodes, where \( E_i \) is given by,

\[ E_i = \sum_{j=1}^{n'} \sum_{k=1}^{i_j} e_k \]  

\( e_k \) - The energy consumption over the way of routing where data is sent

\( n' \) - The total number of nodes in the way

\( i_j \) - Number of hops

Therefore \( e_k \) is given by

\[ e_k = e_{tx} + e_{rec} + E_{res} \]  

\( e_{tx} \) and \( e_{rec} \) are transmission and reception energy constants for every hop, the mathematical model which is been developed to find out the energy consumption \( E_{res} \) by the nodes during the routing using variety of placement pattern of nodes.
As said all the nodes are initially assigned with 50 \( J \) of energy say \( E_{ini} \) which we call it as initial energy of a network \( (E_{ini}) \). A sensor consumes \( E_{sur} = 50 \) \( nJ \) for transmitting unit of data and \( k = 100 \) \( pJ/\text{bit/m}^2 \) for the transmitting amplifier. So the energy consumption of sensor node in order to be active in the network is given by ‘\( E_{sur} \)’

\[
E_{sur} = E_{ene}
\]

(3.10)

The energy utilized depends on the number of bits sent and hence if sensor node transmits \( K \) bits, then the actual energy consumed in order to be active in the network is given by ‘\( E_s(Actual) \)’

\[
E_s(Actual) = K \times E_{ene}
\]

(3.11)

At the destination nodes will get packets, practically obtained packets are less than whatever packet sent. Hence energy consumed for receiving packets ‘\( E_r(Actual) \)’, which is lesser than \( E_s(Actual) \).

\[
E_r(Actual) = (T_p - P_l) = E_s(Actual)
\]

(3.12)

Where \( T_p \) is the energy due to transmission and \( P_l \) is the energy lost due to packet loss. Energy consumption for sensor \( S_i \) in sending a unit of data packet to neighboring nodes ‘\( E_{nr} \)’ is given by:

\[
E_{nr} = \sum_{n=0}^{m} E_{r(Actual)} + n_n E_{l} d_{tr}^2
\]

(3.13)

Where \( n_n \) is the number of neighbors, \( E_{l} \) is the energy of each node and \( d_{tr} \) is the energy distance of each neighbor from source node.

The neighboring node is with the burden to send the data to the destination node, the energy consumption of it turns out to be an important factor, which is calculated as ‘\( E_r \)’

\[
E_r = E_{r(Actual)} + E_{l} d_{tr}^2
\]

(3.14)

\( E_{l} \) = Energy consumed by neighbor of destine node.

Total energy consumed in network ‘\( E_t \)’

\[
E_t = E_{nr} + E_r
\]

(3.15)

If there are ‘\( n_2 \)’ no of sensor nodes in a target area which are active and sending data, then total energy is,

\[
E_{tot} = n_2 E_t
\]

(3.16)

Residual energy for the sensor node is given by ‘\( E_{res} \)’

\[
E_{res} = E_{ini} - E_{tot}
\]

(3.17)
**Lifetime Definition**

Considering each node has the same initial battery energy $E_{ini}$, the lifetime $T_i$ of node $S_i$ is defined as the expected time for the battery energy to be exhausted, given by

$$T(n) = \frac{e_i}{E_{ini}} \times 100$$  \hspace{1cm} (3.18)

Where, $n$ = number of sensor node taken with 0 to 100 to get the numerical in percentage.

Depending upon energy model calculation, simulation is been carried and comparative results are obtained for the pattern of nodes. Trajectory based node placement definitely reduces the energy compared to random distribution of nodes as shown with the below graphs.

### 3.5 Simulation

The simulation is done in two parts, initially with the Qualnet 6.1 simulator followed by simulation with C++ and their respective results are obtained which are as discussed. In Qualnet 6.1 simulator AODV routing protocol is used to carry out routing in three node placement topology methods. In circular pattern the radial path routing and trajectory path routing is carried out. The simulation outcome for energy utilization of nodes, leftover energy of a node and total network energy lifetime are measured and compared for other patterns. After a few rounds of routing packets through AODV, simulation results show that energy utilization for circular method is absolutely effective and less as compared with grid and random pattern of sensor nodes. The calculations are carried to save the energy of a network, covering most extreme range with expansion in lifetime of a network. Results acquired are plotted for irregular, grid and circular modes on different parameters. Simulation inputs for first part simulated with Qualnet 6.1 with number of nodes 99 and AODV is the routing protocol.

The other part of the simulation is carried out in OpenSuse stage utilizing gcc C++. In the simulation model we consider "n" number of nodes such that "n" can be in the scope of 00 to 99, in the region of length "L" and breadth "B". The execution parameter like battery life of every node which differ more than a discretionary scope of qualities is considered. In the geographical region of simulation "n" nodes are put in $L*B$ square meter field considering 3 unique topologies (Random, Circular and Grid position of nodes). Every node transmits “P” packets at different times during simulation and their transmission reach are "R" meters. For the simulation source and destination is selected by user. All the nodes are initially assigned with same amount of energy. Depending upon
the battery life and range of transmission we find out the neighbors of each node. Utilizing neighbor and separation is a path to locate the shortest path. The transmission energy is calculated using mathematical model, thus finding the leftover energy of the network after the routing takes place. The wireless sensor network is considered to be static, following inputs are considered for simulation. Number of nodes = 100, initial energy of every node is 50 J, $E_{ele} = 50$ nJ/bit/edge separation, radio scattering of transmitter and receiver $E_{amp} = 100$ pJ/bit/m$^2$, communication range = 20 units. Simulation is to produce WSN topology, by applying routing convention calculation to every topology, then ascertaining the energy, lifetime, hops that are execution parameters of the network.

The Performance parameters measured are as follows.

- **Number of hops**: It is the number of hops (nodes) required to transmit data from source to destination
- **Consumed Energy**: The amount of energy that is consumed after the routing that takes place from source to destination for data transfer
- **Network Lifetime**: It is total network lifetime that remains after the complete iteration of routing.

The result of simulation demonstrates that, initial deployment of node topology is considered by placing node on a uniform path, the energy consumption of each node and total network energy consumption is considered and compared with the random node placement pattern. The result shown proves that energy consumption is definitely less with grid and circular deployment having distributed the node in whole of the simulation area, whereas random placement tries to cover only half of the simulation area, following which the algorithm tries to save the energy consumed by the network, covering maximum area with increase in lifetime of network.

### 3.6 Results and Discussion

Graphs are plotted for WSN using Qualnet 6.1 simulator that are explained briefly in following section. Figure 3.7 gives the total residual energy remained by circular, grid and random node deployment topology, it is noted from the simulation that the amount of energy remained for the pattern with circle is more that is done for 5 rounds of routing with small amount of data transmitted, similarly when routing is done for thousands of rounds to transmit the complete data, a considerable energy can be saved.
Figure 3.7: Residual energy for three pattern of deployed nodes

Figure 3.8 shows the transmitting energy of nodes from source node for three pattern of nodes placed, since the nodes are with equidistance hence they consume equal and minimal energy for proposed algorithm. Random deployed nodes consumes more energy as compared with grid and circular pattern.

Figure 3.8: Energy consumed in transmit mode for three pattern of deployed nodes
Figure 3.9: Energy consumed in receive mode for three pattern of nodes

Figure 3.9 shows the amount of energy consumed by a node in a receive mode, for three pattern of nodes, the calculation justifies to use a minimum energy for circular pattern, because of its positioning and random deployed nodes again do consume additional energy that will be directly affecting the lifetime of a network.

Figure 3.10: Energy consumed in ideal mode for three pattern of deployed nodes

Figure 3.10 gives the ideal energy consumed for three pattern of deployed nodes. Efficiency of the network can always be enhanced by making use of minimal amount of
energy during the ideal mode of nodes. Since nodes with proper positions need not have a
dynamism during the non transmission thus increasing the energy factor.

![Route discovery time for three pattern of deployed nodes](image)

**Figure 3.11: Route discovery time for three pattern of deployed nodes**

The next part of simulation carried out using ‘c’ shows the results as discussed.
Figure 3.11 gives an interesting feature from the simulation and finds the route discovery
time between source and destination nodes, from the plotted graph, it is clear that the total
time to discover the route for circular pattern of nodes is less compared with two
deployed patterns, which again relays on placement of nodes that is relating with its
neighbours. Thus the simulation concludes that the WSN with circular placement of
nodes proves to be efficient for routing. Figure 3.12 shows number of intermediate nodes
or hops that are utilized to transmit the information between two neighbors, the outcomes
demonstrates the definiteness of the node position as the grid and circular deployed
network nodes use greatest correspondence radius for discovering the following hops.
The number of hops needed to reach the destination in uniform network is most likely
less as contrasted with irregular network as with the simulation results. Figure 3.13 gives
the sum of remaining energy spared by the grid, circular and random network based
topologies that are ascertained after the routing is been completed. It is indicated from
figure 3.13 that random network expends the most elevated sum energy for the routing.
Figure 3.12: Intermediate nodes for three pattern routing

![Intermediate nodes in routing Vs Number of nodes](image)

Figure 3.13: Residual energy of network for three patterns of nodes

![Residual energy of network in joules Vs Number of nodes](image)

Figure 3.13: Residual energy of network for three patterns of nodes

Figure 3.14 gives the network lifetime that identifies with utilization of a network from the devoured energy. From the graph we can infer that random based topology network lifetime is less contrasted with other two topologies. For applications with the large number of data and with distant transmission our scheme works more efficient in energy saving and network lifetime.
Figure 3.14: Percentage of network lifetime for three patterns of nodes
3.7 Summary

The work is carried to simulate the sensor network, to differentiate the conduct of network under distinctive situations. Routing protocol is carried for running random, grid and circular based network for distinctive rounds. Taking into account the analytical and simulation results, it is demonstrated that random organization has little scope territory with more number of nodes sent with un-equivalent separations prompting more energy usage to decrease in general network lifetime. Grid and circular deploying network has large scope with less number of nodes deployed at equivalent separations. Subsequently energy usage will be less with expansion in network lifetime. The proposed model infers that energy can be effectively used in WSN’s with the grid and circular node organization. Work is carried out to run the calculation till the energy is efficiently used. Distinctive routing protocols can be considered to check the maintainability of the network. The proposed model concludes that energy can be efficiently utilized in WSN’s with the grid and circular node deployment. Different placement patterns can be considered to check the sustainability of the network.