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Steering Technique-Based Detection and Optimization of Overlapping Coverage in Wireless Sensor Networks

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Abstract

A wireless sensor network (WSN) is a collection of autonomous sensors and networks. The performance of WSN depends on the nature of the sensors and their deployment. Deploying many sensors in a typical region requires a high level of energy consumption for the same data range, due to overlapping. The detection and optimisation of overlapping coverage are the major problems in WSN. This paper focuses on the detection improvement and optimization of overlapping nodes. In this paper, a steering technique is proposed that contains six phases for the detection and minimization of the overlapping nodes of sensors containing adjustable radii. The area of a redundant node is also adjusted to overlap, and the rest of the redundant nodes are turned off. The radius of nodes is enhanced using two steps: (1) these nodes tend to enlarge their radius up to a threshold value, and (2) with the help of the Venn diagram and set theory, the nodes double their radius so that overlapping and intersections can be avoided. Finally, it is found that some nodes that were not overlapping are now left, and the network's lifetime has increased.

Keywords: *Wireless sensor network, Overlapping coverage, Steering technique, Redundant nodes*

1. Introduction

In wireless sensor networks (WSNs), the detection of a sensor's scope might be in units or variables as addressed in [1]. It is well-known that the region detected by sensors is called the coverage area of the sensor networks. It is important to acquire the maximum coverage area of WSNs utilizing accessible sensors. The deployment of the sensors is carried out in two different ways: The first way is deterministic deployment and the second way is random deployment [2]. The detection of at least two sensors is covered with one another then the nodes are called excess nodes otherwise called sensor nodes. To plot nodes utilizing an arbitrary arrangement strategy, the quantities of excess nodes might be found in the system. To make the system vitality and effective, which is a parameter of system quality of service (QoS) [3], a few nodes that share a typical inclusion territory can be killed. These outcomes are in a diminished inclusion territory with a similar number of nodes which is likewise a parameter of QoS. As the lifetime of the sensors is not long, WSN covers the greatest territory with a smaller number of nodes that have similar art gallery issues [4]. This issue is to decide the number of onlookers important to cover a workmanship exhibition. The craftsmanship display issue expresses that each purpose of a workmanship exhibition must be seen by no less than one eyewitness. Inclusion issues in sensor systems can be ordered into three expansive sorts: (1) region inclusion, (2) target inclusion, and (3) break inclusion [5]. In region inclusion, all focus inside the system is checked by the sensors themselves. In target inclusion, a lot of discrete target zones are secured by sensors. The objective of the break inclusion is to limit the number of revealed targets. In this paper, this study has proposed an area-aware coverage (AAC) that considers Venn chart and sets hypotheses to recognize and limit covering inclusion zones in WSN utilizing six stages. This study thought about the range of a sensor variable and movable and along these lines the methodology is material in condition containing nodes with both unit and non-unit sweep. AAC covers more territory with a smaller number of nodes with less covered inclusion. In doing so, this study additionally expanded the system lifetime by sparing the intensity of sensors. This study proposed a systematic model dependent on the six periods of AAC and recreations with irregular organization setups. The outcomes demonstrated that the inclusion region in the arrangement has been expanded with a smaller number of nodes. The results likewise demonstrated that the covering inclusion zone in the arrangement has been diminished generously.

2. Literature review

Limiting energy utilization and dragging out the framework lifetime is a significant issue for wireless ad hoc networks. There are a few different ways for the topology to control the overlapping coverage in WSNs. In [6], sensors that have an adjustable sensing range are used. With the help of the approach mentioned in [6], they minimize the overlap area but they noted the focus of the blind point. The blind point is the point where a hole is created in the topology and the data starvation acts. The problem of set covers in target coverage is addressed in [2]. For this, they have used a distributed optimum algorithm for target coverage. But the used algorithm is based on greedy search optimal analysis. In which a node is assumed to be common greed which takes the shortest minimum path to every other node. By which, the shortest distance to the target is considered. In [2], the obstacles in the sensing range are considered. For this, they use designing localized algorithms for barrier coverage. The approach is based on the search scheduling algorithm. In [4], the node placement for connected coverage in sensor networks is addressed and notices the issue of the ideal node situation for guaranteeing associated coverage in sensor systems by considering two diverse functional situations. In the main situation, a specific district (or a lot of areas) is to be given associated coverage, while in the second case, a given arrangement of n focuses is to be secured and associated. In [5], the focus is on the use of sensor systems for the interruption location problem and related issues of target arrangement and tracking. The methodology relies on a robust, distributed, remote system of modular, asset-poor sensors integrated into freely interpretable sensor exhibits that perform in situ discovery, estimation, pressure, and exfiltration. In [7], it is also addressed as a productive technique to broaden the sensor arrangement and operational time by sorting out the sensors into a maximal number of disjoint sets that are activated progressively.

3. Coverage in wireless sensor networks

Coverage is an essential parameter in wireless sensor networks that measures how a target field can observe the entire area. Sensors are of various kinds: (a) Uni-directional, (b) multi-directional, (c) Omni-directional.

- Coverage of every sensor is controlled by the sort of detecting.

- The sensor situation is in-deterministic.
- The sensor anyway is not dynamic enough to expect a deterministic position to accept the greatest coverage.

3.1 Sensing models

Wireless sensor network (WSN) nodes, by and large, have generally extraordinary hypothetical and physical qualities. Subsequently, various models of shifting multifaceted nature can be developed depending on application needs and the workplace. Interestingly, most detecting gadget models share two actualities in like manner:

1) Sensing capacity decreases as separation increments.
2) Due to decreasing impacts of clamor rushes in estimations, detecting capacity can improve as the allocated detecting time (presentation) increments.

Accept sensor S_i is conveyed at point $(x_i\ , y_i)$. The study indicates the Euclidean separation among S_n and Q as $deg(S_i\ , Q)$, i.e., $deg(S_n\ , Q) = \sqrt{(x_i - x)^2 + (y_i - y)^2}$. Equation (1) characterizes the general reasonableness $S(S_n\ , Q)$ of S_i at a self-assertive point P as

$$S(S_n\ , Q) = \lambda \tag{1}$$

$[deg(S_n\ , Q)]K$, where $deg(S_n\ , Q)$ is the Euclidean separation between the sensor S_i and the point P, and limitations λ and K are sensor innovation subordinate parameters. The less $deg(S_n\ , Q)$ is, the more grounded the detecting capacity will be. Clearly, the denominator cannot be zero in Eq. (1). Henceforth, a shared factor can alter $[deg(S_n\ , (Q + \delta)]K$ so that Eq. (1) is significant, where δ is bigger than 0, however, unbounded near zero.

3.2 Detection and optimization of overlapping coverage area

This study proposed area-aware coverage (AAC) that considers the detecting and transmission scope of sensor nodes movable and utilizes six stages to distinguish and limit overlapping coverage area. This study additionally limited the nearness of excess nodes and nodes with the least coverage in any given area by turning them off and keeping a little subset of nodes alive. These nodes increment their range in two stages the nodes increment their span up to limit esteem and after that copy current sweep abstaining from overlapping or crossing point utilizing Venn diagrams and set theory. Accordingly, a huge measure of the intensity of nodes is spared and the system lifetime is expanded. The systematic model and reproduction of the methodology demonstrated that the methodology accomplishes the most extreme coverage area with the least number of nodes with the least overlapping area among them.

3.3 Proposed steering calculation

In our methodology, every sensor node is locally aware of its coverage area. This awareness of the self-coverage of the area is called area-aware coverage. So as to do that, the study needs to pursue six stages as

Phase 1: Turn off redundant nodes from the network.
Phase 2: Minimize the common coverage area.
Phase 3: Turn off the node with a negligible radius.
Phase 4: Turn off the duplicate node.
Phase 5: Increase the radius of each node.
Phase 6: Turn on the sleeping node.

Phase 1: The primary errand of this stage is to kill the repetitive nodes from the system. This study made sense of repetitive nodes by checking two conditions. On the off chance that a node fulfills the conditions, at that point this study call the node excess and this study turn it off. Give us a chance to have three nodes in the system which are characterized as$A$,B and C, individually.

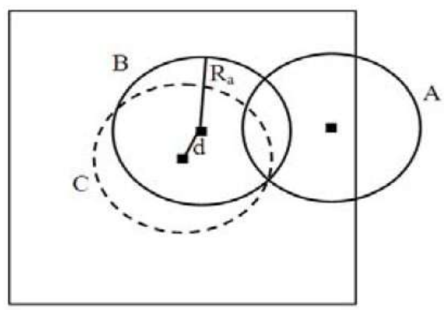

Figure 1: Network topology with redundant nodes where the reference node remains turned on.

The main condition is-if the separation between two nodes is not exactly or equivalent to 30 percent of the range of the reference node, at that point, the reference node stays on and the other node is killed. Let, node a be the reference node. In the first place, the study must discover nodes that converge with A. To discover the met nodes, a square is envisioned over the reference node A. The separation between the focal point of node An and any edge of the square is twice the span of the reference node A. At that point, the study must check all other node positions relating to the square. If any node lies in the square, at that point, there is a high likelihood that the reference node A crosses it. From Figure 1, the study locates that relating to the reference node A, the met nodes are B and C. At that point, the study looks at the separation and span of A, C, and A, B. In Fig, if the separation between A and C is under 30 percent of the span of node A, the study turns off C.

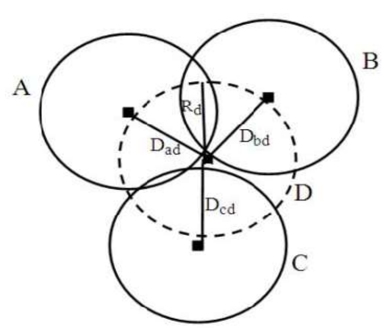

Figure 2: Network topology where the reference node is turned off.

The second condition is-reference node is killed if the separation between two nodes is not exactly or equivalent to 30 percent of the span of the reference node and if the number of met nodes is more prominent than or equivalent to two. Let, there are four nodes A, B, C, and D in the system, where, the node D is the reference node as shown in Figure 2. For this situation, the number of converged pairs are $A - D$, $B - D$, and $C - D$. On the off chance that separations between these sets (D_{ad}, D_{bd}, and D_{cd}) are under 30 percent of the sweep at that point reference node D is turned off.

Phase 2: In this phase, nodes decrease the common coverage area. In our approach, each node has information about the number of intersected nodes with it. The reference node calculates its common coverage area (e.g., overlapped area) with intersected nodes and minimizes its radius up to this overlapped area in Figure 3.

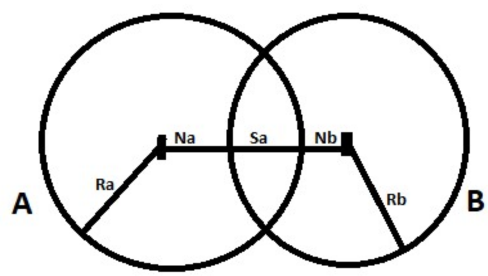

Figure 3: Two nodes with overlapping coverage.

Nodes calculate their overlapped area using (1).
R_a =Radius of A
R_b = Radius of B
D= Distance between A and B
N_a= Part of radius R_a which is not shared with R_b
  = D-R_b
N_b= Part of radius R_b which is not shared with R_a
  = D-R_a
S_a= Overlapped area between A and B
  = D-(N_a+N_b)

Phase 3: In this stage, the study turns off the nodes that have a radius not exactly or equivalent to a threshold radius. In our methodology, the study takes the estimation of threshold radius as 30 percent of the first radius. For instance, if the first radius of a node is 8, at that point, the threshold radius is 0.24.

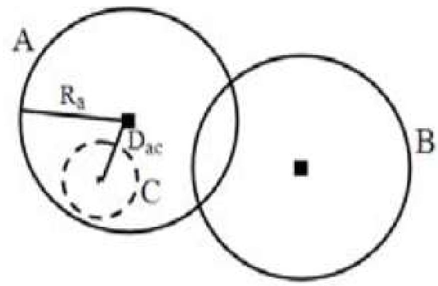

Figure 4: Turning off duplicate nodes.

Phase 4: In this stage, the study takes out copy nodes. The study consider node A will be a copy of node B, if node A is plotted into the sensing radius of node B. For instance, if the radius of node A is Ra, the distance between A and B is Dab, and on the off chance that Dab is less than or equal to Ra, at that point node B is turned off (Figure 4).

Phase 5: In phase 5, the study increases the radius of nodes in two stages. In the initial step, the radius of all nodes will increase up to an edge radius which is 25 percent of the current radius (Figure 5).

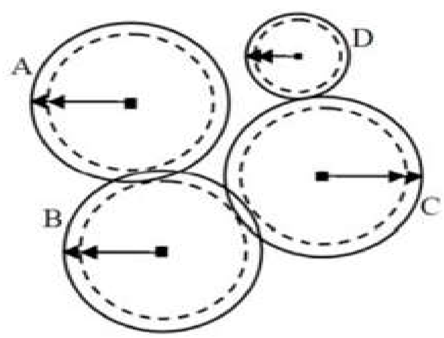

Figure 5: Increasing radius by all nodes up to a threshold value.

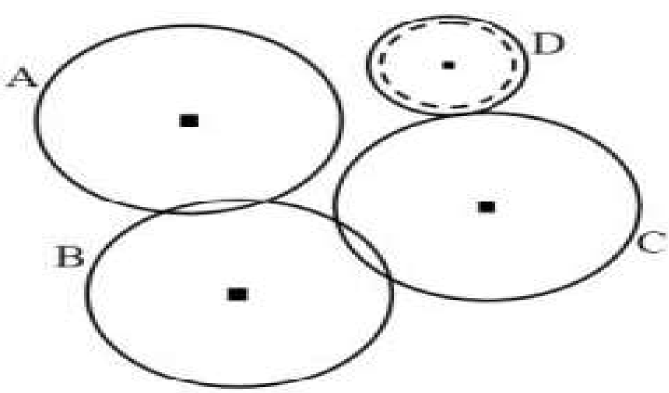

Figure 6: Increasing radius by the nodes up to the periphery of other nodes

The second step is to increase the radii of the nodes until they converge with the outskirts of different nodes (figure 6).

Phase 6: The study at first set the existence time for all nodes. At the point when the existence time of a node completes, a dozing node, which is turned off amid phases 1 to 5, should be turned on. The study turn on the node that is the closest to the node whose lifetime will be done. The study compute lifetime as (Initial radius*initial lifetime)/current radius.

3.3 Proposed pseudo-code of steering techniques for the above phases:

Input: A sensor network with a set of redundant sensors having an equal radius and overlapped coverage area.

Output: A sensor network with a set of the minimum number of sensors with variable radius and maximum coverage area.

```
BEGIN
FOR every node _$ in the network
DO
IF(D(Xi,Yi) <=ri *0.3) THEN
Turn off node with radius ri
        END IF
END FOR
FOR every node N* in the network
DO
IF (D(Xi,Yi) <=ri *1.3) THEN
Count intersected node, intersected ++
END IF
IF(intersect >=2) THEN
turn off node with radius ri
END IF
END FOR
FOR 0 TO number of intersected nodes
Common length = min (c1, c2, c3,…….ck)
ri = ri- common length
END FOR
FOR every node N* in the network
DO
IF (ri<= initial radius *0.3) THEN
turn off node with radius _&
END IF
END FOR
FOR every node N* in the network
DO
```

IF D(X_i, Y_i) <= r_i THEN
turn off node with radius r_i
END IF
END FOR
FOR every node N* in the network
DO
r_i+= initial radius*0.25
END FOR
FOR every non-intersected node
DO
r_i++
END FOR
FOR every node N* in the network
DO
IF (lifetime=0) then
turn on nearest neighbor node
END IF
END FOR
END

4. Simulation and experimental results

Steering techniques is the method to calculate the movement of any object. In terms of circular objects, the study compares two radii with one other in the reference of a threshold. In our problem, the study uses this approach for comparing the 30% of radius of nodes with the threshold distance between them.

Table 1: Parameter setups.

Number of Nodes in Initial Network	Random
Node Deployment over Network Area	Random
Node Radius	4 units
Initial Network Size	100 m ×100 m
Final Network Size	100 m ×100 m

In Table 1, the study takes the random no. of nodes deployed by randomly exploiting deployment in the area (100 ×100) meter^2.

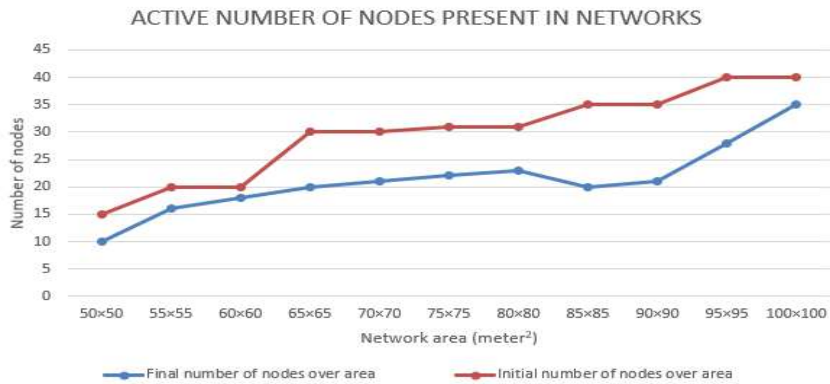

Figure 7: Number of active nodes present in the network

In Figure7, the study compared the initial number of nodes and the final number of nodes for different network areas. The study sees that for any network area, the number of nodes to cover any area has been increased significantly.

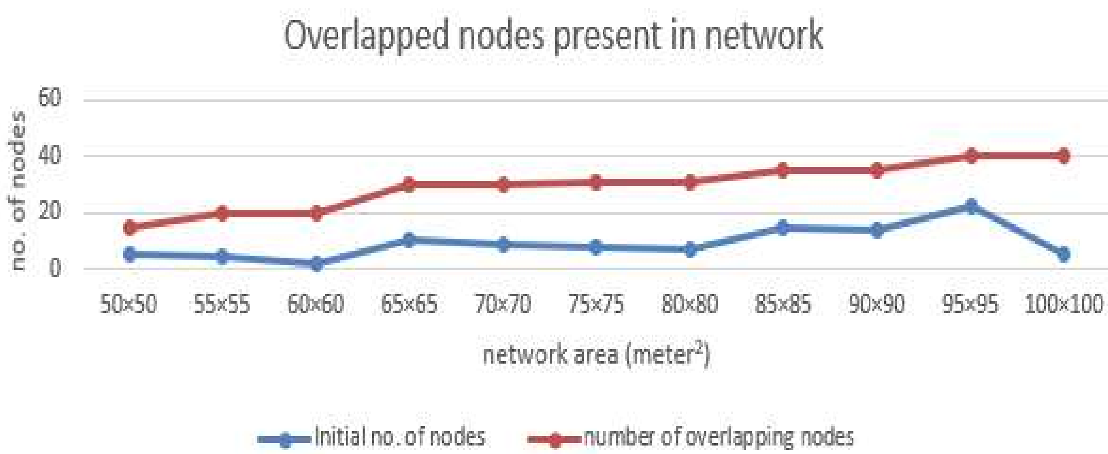

Figure 8: Number of overlapped nodes present in the initial and final network

In figure 8, the study plots the reverse graph of figure7, to show the initial number of nodes and number of overlapping nodes present in the network.

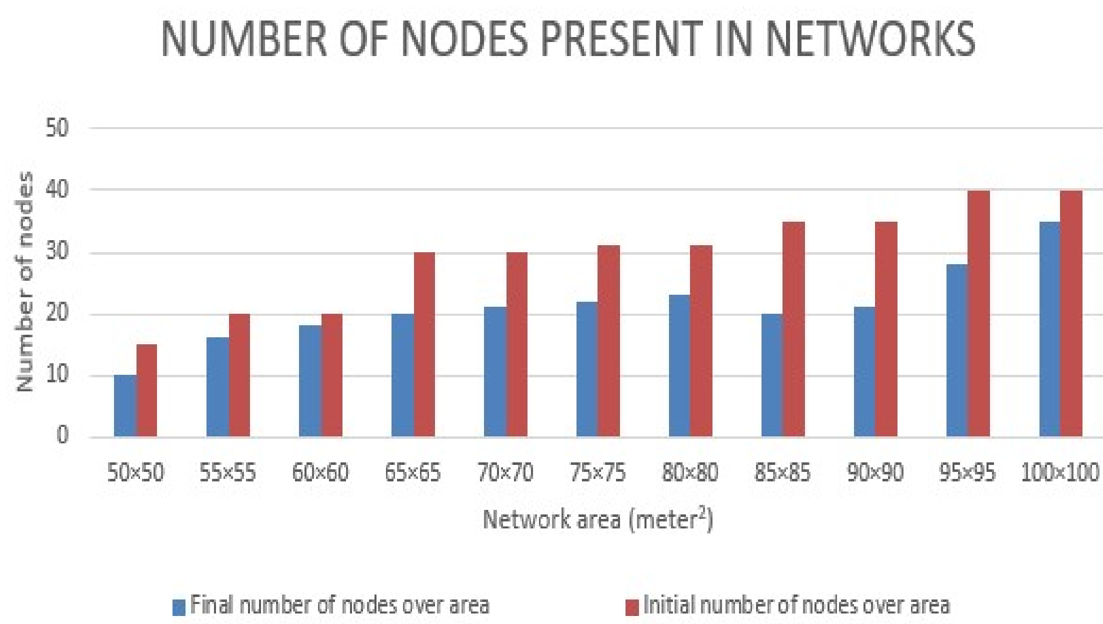

Figure 9: Number of nodes present in the initial and final network

In figure 9, the study sees the percentage of reduction of nodes for the given network areas. With our approach, the study reduced the number of nodes by taking the initial number of nodes and the final number of nodes for different network areas.

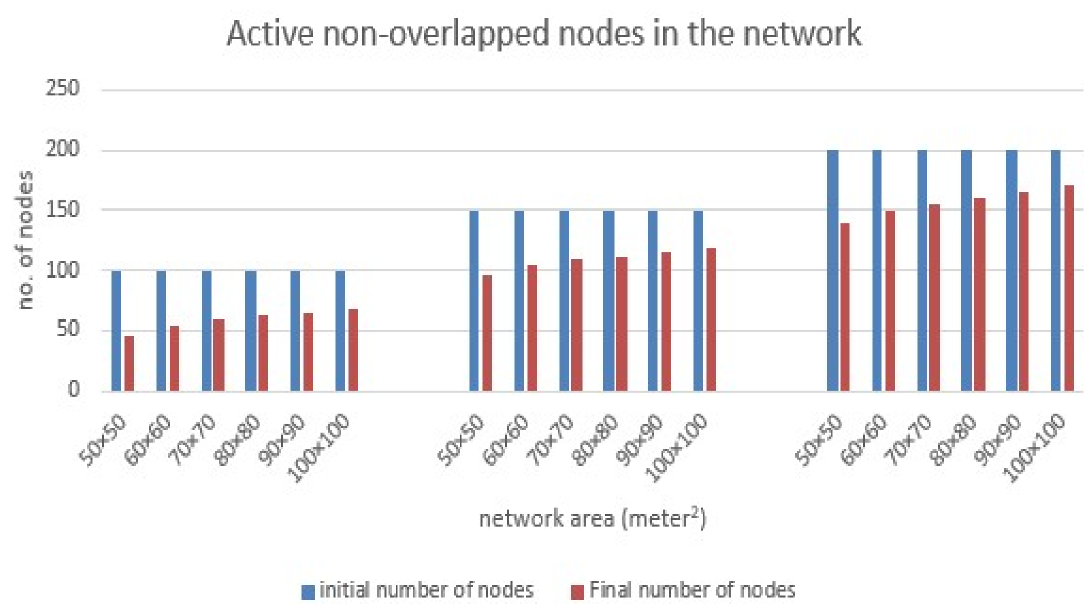

Figure 10: Active non-overlapped nodes in the network

In Figure 10, the study compared the initial number of nodes and the final number of nodes for different network areas. The study sees that for any network area, the number of nodes to cover any area has increased significantly.

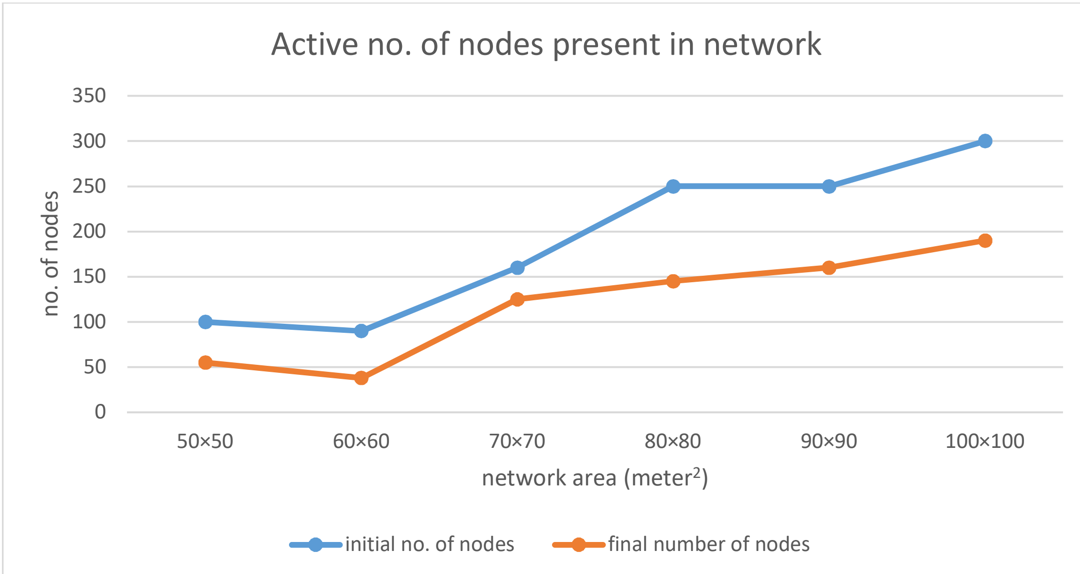

Figure 11: Number of active nodes present in the network

In figure 11, the study compared the initial number of nodes and final number of nodes for different network areas. The study sees that for any network area, the number of nodes to cover any area has different data.

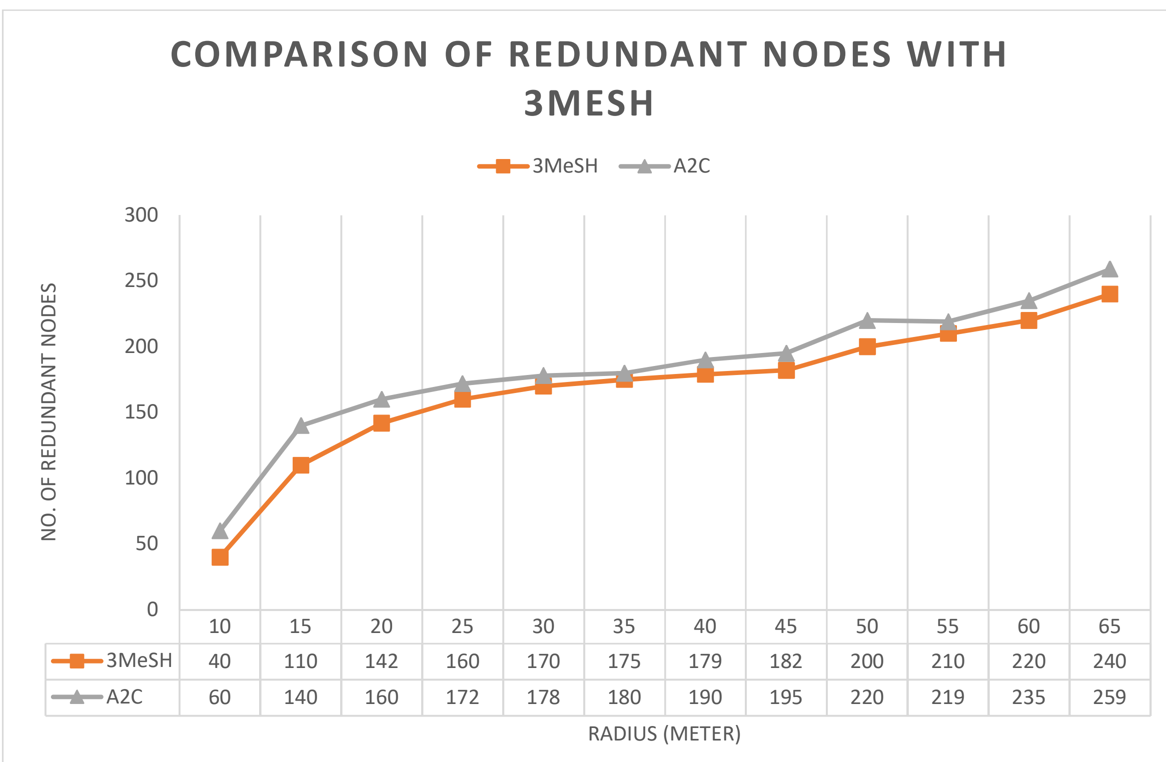

Figure 12: Comparison of redundant nodes with 3MeSH

In figure 12, the study calculated the number of redundant nodes in each network area 100m×100m of 500 nodes with respect to the variable radius and compared the result with 3MeSH. Results showed that A2C requires a much smaller number of active nodes to cover a given area. By analyzing the result, the study finds more redundant nodes.

5. Conclusion and future work

The six-phase approach, named area-aware coverage (AAC) decreases the overlapping coverage in wireless sensor networks with sensor nodes of variable radius. The study devised an analytical model based on the algorithm of the approach and showed that the study reduced the overlapping coverage in WSN significantly. The study also simulated AAC and the performance analysis showed that AAC reduces 52 percent of nodes to cover any given network area. AAC also increases the network coverage area by 23 percent. In a WSN using AAC, the study compared the number of active nodes present with another approach named 3MeSH and the result showed that our approach covers the same network area with a smaller number of nodes.

Conflict of Interest

The authors declare no conflict of interest.

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