Research on connectivity to Localized Area Coverage algorithm in wireless Sensor Networks

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Abstract

In wireless sensor networks, the area coverage sensing technology is one of the key foundation technologies. It is concerned about how to prolong the network lifetime based on meeting user sensing demands. Among the study of area coverage sensing technology, localized area coverage algorithm is gradually attracting wide attention for its less traffic and lower single-node computation. At present, the existing localized area coverage algorithms mainly depend on connectivity critical condition proposed by Xing. This condition is concerned about how to improve the perceived quality to coverage full area, ignores further studying for the network node connectivity. So, this connectivity condition is from the perspective of single node connectivity, resulting in limited conditions for algorithm application. For above issues, firstly, the coverage node set connectivity is introduced for localized area coverage algorithm in this paper. Secondly, the loose connectivity critical condition to ensure coverage and connectivity is re-analyzed from the perspective of network connectivity. Finally, a circle intersection localized coverage algorithm under different conditions to maintain connectivity is designed, to extend the application scene. Simulation results show that the algorithm, under different conditions, can maintain network node connectivity on the basis of ensuring full area coverage.

Keywords: Wireless Sensor Networks, Localized Area Coverage algorithm, Connectivity

1. Introduction

Because a single sensor node has limited perception ability in wireless sensor networks, the technology which effectively organizes node collaboration and realizes expected perception demands is called coverage control technology [1-3]. It is the basic technology of wireless sensor networks, and directly reflects quality of service of the aware of the environmental [4-6]. Because of limited energy of single sensor node, how to saving energy and prolong the network lifetime at the same time of meeting user sense demand is the key point of wireless sensor networks coverage control technology design. For the wild scenes, special environment like desert or battlefield, way of randomly spreading redundant nodes in designated area is often applied for initial deployment [8-10]. Therefore, when area coverage algorithm is being designed, both of the realization of full area coverage by wireless sensor networks, which avoids appearance of coverage holes and ensures perception service quality, and extension of network lifetime as far as possible by sleep schedule, making use of redundancy characteristic of sensor nodes, are expected. At present, localized area coverage algorithm is becoming the first choice of area coverage algorithm, for its advance of small traffic and low single–node computation, adaptation to dynamic change of network topology and rather expansion ability [11, 13].

In addition, wireless sensor networks not only need to sense outside environmental data, but also to pass on these data to users through base station, ensuring of network nodes connectivity is a key problem, which could not be ignored. Therefore, when the coverage algorithm is being designed, problem of active node set connectivity should also be considered beside user perception demands and network lifetime. However, because of critical condition of coverage and connectivity proposed by Xing et al [15], further study on connectivity problem is ignored, leading to local area coverage algorithm over relying on proposed critical condition. Because this critical condition is the connectivity conclusion attained from the view of single node, so restriction of the condition is rather strict aiming at area coverage algorithm, the application of the algorithm is greatly constrained.
Therefore, aiming at local area coverage algorithm shortcoming in term of connectivity problems, this paper analyzes loose critical condition suitable for local area coverage to maintain connectivity, standing on the view of the overall network, and designs a circle intersection local area coverage algorithm under different conditions, making connectivity in the situation of ensuring area overall coverage.

In this paper, the related work of existing local area coverage algorithm and connectivity is introduced in section 2; in section 3, connectivity problem in existing local area coverage algorithm is analyzed and loose critical condition to ensure coverage and connectivity is analyzed; in section 4, aiming at different situations, a circle intersection local area coverage algorithm which maintains node connectivity is designed; in section 5, performance of the algorithm is analyzed by simulation experiment; in the last section, the conclusion of this paper is given.

2. Related Work

At present, Antoine Gallais et al hold that if only cross-point in a circle can be covered by other circles, this circle can be covered by neighbor circles according to circle intersections coverage theory in computational geometry. Thus, a low-cost communications localized area coverage algorithm based on simultaneous network is proposed [7]. In this algorithm, nodes can send different message according to different needs (withdraw message, activate message etc.) to adapt to situation in which actual channel is not reliable. The three algorithms mentioned above can be judged by computational geometry according to circle coverage method and can realize full covered area and avoid phenomenon of coverage holes. But, they don't give concrete handling ways to connectivity problem. Jean Carle et al describe how to realize area coverage in the situation where node radio radius equals to sense radius [12]. The paper brings out connectivity problem of network nodes and gives a dominating set algorithm by using surface coverage relay. However, this algorithm only studies situation that node radio radius equals to sense radius.

Xing et al, aiming at coverage and connectivity problem, propose a theorem, which relates coverage with connectivity [15]. That is, if the node radio radius is at least twice the sense radius, complete coverage of a convex area implies connectivity among the active set of nodes. Introduction to this theorem constructs a bridge between node coverage and connectivity problem, solving the restriction of connectivity problem in the process of coverage. However, this critical condition stands from the view of single node and thinks as long as the node is connected with all neighbor nodes, network connection of overall area will be led inevitably. It overlooks the situation where area network connection will not necessarily make connection between single node and all neighbor nodes. So, restriction of the condition is rather strict aiming at area coverage algorithm.

Through analysis of related work mentioned above, we can see that existing local area coverage algorithm either only studies special situation, such as node radio radius equals to sense radius, or totally relies on connectivity critical condition proposed by Xing et al. Therefore, this paper firstly analyzes the connectivity problems of the existing localized area coverage algorithms; Secondly, it introduces a new loose critical condition suitable for localized area coverage algorithm. At last, aiming at different situations, a circle intersection localized area coverage algorithm which maintains connectivity is proposed.

3. The Connectivity Problem of Localized Area Coverage Algorithm

3.1. The Analysis of Localized Area Coverage Algorithm Connectivity Problem

At present, what is broadly concerned by localized area coverage algorithm is how to prolong network lifetime on the basis of ensuring user perception demands. The main problem to be solved is how to ensure area overall coverage to avoid the appearance of coverage hole phenomenon; at the same time, active node is as less as possible, making more nodes sleep and prolong time of network existence. However, wireless sensor network not only need to sense environmental data, but also to pass on these data to users through base station. So, ensuring of network node’s connectivity is a key problem, which could not be ignored. Therefore, when the coverage algorithm is being designed,
problem of active node set connectivity should also be considered beside user perception demands and network lifetime.

Xing et al, aiming at coverage and connectivity problem, propose a theorem, which relates coverage with connectivity [15]. That is, if the node radio radius is at least twice the sense radius, complete coverage of a convex area implies connectivity among the active set of nodes. Introduction to this theorem constructs a bridge between node coverage and connectivity problem, solving the restriction of connectivity problem in the process of coverage. Therefore, when studying area coverage, people almost do not consider connectivity problem any more and instead take critical condition proposed by Xing et al as the algorithm’s supposed condition.

However, the critical condition must be node radio radius is larger than two times of sense radius. Otherwise, when node radio radius is smaller than two times of sense radius, this theorem couldn’t ensure node connectivity. For example, deployment 50 nodes in the rectangular area [0:50, 0:50], and node sense radius equals to radio radius. The circle intersection local area coverage algorithm based on time round (CILAC) is taken to realize area coverage control, which is the improvement algorithm of document [7]. The implementation result of algorithm is shown in figure 1. In figure 1 (a), active node set realizes area overall coverage. However, it can be seen from figure 1 (b), that nodes within node set can not realize overall connection between each other and the existing situation of isolated node and isolated sub-node set will inevitably lead to part of the area sense data unable to be sent out, resulting in actual coverage holes.

The reason which leads to the result mentioned above is that, connectivity between active nodes is not considered when implementing coverage judgment. Figure 2 points out problem of connection between neighbor nodes when node 1 is covered by active neighbor nodes. Among this, figure 2 (a) shows the situation in which node radio radius equals to sense radius; figure 2 (b) shows the situation in which node radio radius is larger than sense radius but smaller than two times of sense radius. Solid line circle is taken to represent node sense range and dotted circle is taken to represent node radio range. It can be known from the figure that sense range of node 1 can be totally covered by active neighbor nodes. So, node 1 can go to sleep, but these active neighbor nodes can’t connect and communicate with each other. This kind of non-connection problem caused by single node coverage judgment can lead to the appearance of isolated node and isolated sub-node set, as is shown in figure 1 (b).

![Figure 1. Active node set coverage and connection](image)

![Figure 2. Connectivity between active neighbor nodes](image)
Therefore, it can be known from analysis mentioned above that when the node is implementing coverage judgment, because connectivity problem between neighbor nodes is ignored, non-connection phenomenon of active node set can thus occur. However, aiming at single node, its neighbor nodes, which are not connected can also in the overall network change into connected. Thus, finding critical condition suitable for local area algorithm coverage and connectivity problem is the main work of next section.

3.2. The Analysis of Localized Area Coverage Algorithm Connectivity Problem

3.2.1. Defects of Existing Connectivity Critical Condition in the Face of Local Area Coverage Algorithm

The critical condition proposed by Xing et al, that is, if the node radio radius is at least twice the sense radius, area complete coverage implies connectivity among the active set of nodes, is the conclusion drawn from situation of single node coverage critical condition, as is shown in figure3 (a). The sense circle of node 1 is covered by its neighbor node set. The solid line circle is taken to represent node sense circle, whose radius is node sense radius. In situation of this critical condition, neighbor node set of node 1 consist of two parts: node 2 and nodes distributed on the circle whose centre is node 2 and radius is two times of the node sense radius. So, the distance of node 2 and other neighbor nodes is two times of the node sense radius. When distance between the other neighbor nodes and node 2 is larger than two times of the node sense radius, then coverage holes will be produced in sense circle of node 1. When distance between the other neighbor nodes and node 2 is smaller than two times of the node sense radius, then number of neighbor nodes taking part in coverage can be gradually decreased.

(a) Connectivity Condition Proposed by Xing  （b）Defects of Condition Proposed by Xing

(c) Loose Critical Condition

Figure 3. Shown of Connectivity Critical Condition

The critical condition proposed by Xing et al is the conclusion drawn from the angle of single node, which deems that as long as there is connection between a node and all its neighbor nodes, network connection of overall area is necessarily led. However, this restricted condition has defects, or when non-connection between certain node and its neighbor nodes exists, in the overall area network, node which is not connected can also be re-connected because of connection of its follow-up node, resulting in node set connection of overall area, as is shown in figure3 (b). Node 1 is covered by node 2,3,4,5. Among them, node 2 is not connected with node 3. Therefore, it can be judged from node 1 that node 2,3,4,5 constitute a non-connection node set. However, through nodes 4, 5, we can see that node set constituted by node 2, 3, 4, 5 is a connection node set. It can be seen from this that, overall coverage formed through this situation can still keep connectivity. Because of Xing et al haven’t considered...
situation mentioned above, critical condition being proposed is rather strict and leads to great restriction of coverage algorithm realization. Thus, we need again aim at area coverage problem and consider its connectivity condition.

3.2.2. Loose Critical Condition for Local Area Coverage Algorithm Connectivity

It can be known from above section that problem of area coverage connectivity is just to also be able to maintain node set connectivity in the situation where area is covered by node set. Restricted condition of its connectivity is always lower than critical condition proposed by Xing et al. When connectivity problem is considered, it should not be restricted in the view of one single node, but to be considered in the view of overall network connectivity. Therefore, we proposes loose critical condition of area overall coverage and overall connection for local area coverage algorithm.

Theorem 1: For localized area coverage algorithm, randomly uniform deployment nodes in a designated convex area, if the node radio radius is over $1.2$ times of its sense radius, that is, , active node set, which can realize overall area coverage can also be similarly considered as connection node set.

[Proof] According to computer geometry theory, when area is filled with regular hexagon, number of figures which are needed is the smallest [14]. Therefore, in a designated convex area, if nodes are deployed as regular hexagon, number of sensor nodes which are needed is the smallest, as is shown in figure 3 (c). Node connection lines construct equilateral triangle, and the distance from each node to center of equilateral triangle is $r$. It can be known that the equilateral triangle side length is $r_s$, that is, distance between nodes is $r_s$. For localized area coverage algorithm, randomly uniform deployment nodes in a designated convex area, the number of active nodes produced by the algorithm is larger than the number of nodes deployed as regular hexagon. So, the distance between nodes is usually smaller than $r_s$.

If the node is covered by neighbor node set, which is shown by node1 in figure 3 (c), it can go to sleep. Each distance between its neighbor nodes is $r$. So, standing on the view of the overall network, if only the node radio radius is over $1.2$ times of its sense radius, that is, , neighbor nodes is connected with each other, leading to the connection of the overall area.

Therefore, if the node radio radius is over $1.2$ times of its sense radius, that is, , active node set, which can realize overall area coverage can also be similarly considered as connection node set.

### Table 1. Active node set connectivity distribution

<table>
<thead>
<tr>
<th>N</th>
<th>Re=Rs</th>
<th>Re=1.2Rs</th>
<th>Re=$\sqrt{2}$ Rs</th>
<th>Re=$\sqrt{3}$ Rs</th>
<th>Re=2Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>21%</td>
<td>60%</td>
<td>85%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>100</td>
<td>36%</td>
<td>71%</td>
<td>90%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>150</td>
<td>72%</td>
<td>92%</td>
<td>96%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>200</td>
<td>89%</td>
<td>90%</td>
<td>96%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>250</td>
<td>93%</td>
<td>96%</td>
<td>97%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>300</td>
<td>95%</td>
<td>96%</td>
<td>98%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

We further test and verify the theorem through simulation, in a [0:50, 0:50] rectangular area, deploy redundant nodes in a random uniform way, node sense radius is 10m. Separately in the situation where node radio radius is $r$, $1.2r$, $\sqrt{2}r$, $\sqrt{3}r$, $2r$, and deploy node number is 50, 100, 150, 200, 250, 300, implement circle intersection localized area coverage algorithm, judging active node set connectivity attained in each round. Because node production possesses randomness, Monte Carlo method is used to obtain average value, whose result is shown in table 1.

When local area coverage algorithm is implemented, active node set attained in each round can be connected and can also be not connected. Thus, data in table 1 are ratio of rounds in which node set keep connectivity and total round number in the instance of certain radio radius and network node density, in the situation where area overall coverage is ensured. For example, when node radio radius equals to sense radius and node number is 200, implement circle intersection local area coverage algorithm, ratio of round number in which active nodes set is connected and total round number is 89% in the situation, in the situation where area overall coverage is ensured, or in the situation of ensuring overall coverage, probability of attaining active node set which is not connected is 11%. It can be known from table 1 that active node set connectivity is related with network node density and ratio of node radio radius and...
sense radius. In the situation of designated network node density, with the gradual increase of node radio radius, active node set connectivity also continuously strengthened.

It can be known from table 1 that when node radio radius is larger than equals to times of sense radius, active node set which realizes overall coverage in the area can still keep connectivity. Therefore, effectiveness of theorem is tested and verified through simulation experiment.

4. Circle Intersection Local Area Coverage Algorithm Ensuring Connectivity

As mentioned above, loose critical condition maintaining overall coverage and overall connection in local area coverage algorithm application scene is discussed and it is indicated that in the situation where randomly uniform redundant nodes are deployed, if node radio radius is over times of node sense radius, active node set which can realize area overall coverage is also connected.

Therefore, if node radio radius is smaller than times of node sense radius, how to ensure active node set connectivity becomes key of this section discussion. We plan to take the way of searching for connected coverage set to solve this problem.

4.1. Construction of Connected Coverage Node Set

4.1.1 Definition and symbolic representation

Use \( V, E \) to show state of deployed nodes in the designated area. \( V \) shows sensor node set deployed in the area, and \( E \) shows link set keeping communication between any two nodes. \( r_c \) shows node radio radius, \( r_s \) shows node sense radius, \( Q \) shows monitor area, and \( X \) shows point in the area, that is, \( x \in Q \), \( d(x, y) \) shows distance between two point \( x, y \).

Definition 1: Node sense circle, that is, circle with node as its center, and node sense radius as its radius is called node sense circle, which represents node sense range and is shown by sign \( S(u) \).

\[
S(u) = \{x \mid d(x, u) \leq r_s, x \in Q, u \in V\}
\]

Definition 2: Neighbor node set of node \( u \) is shown by \( N_u \). It is set consist of nodes, from which distance to node \( u \) is smaller than or equals to node radio radius, that is,

\[
N_u = \{v \mid v \in V, d(u, v) \leq r_c\}
\]

Definition 3: if node sense circle is covered by sense area formed by neighbor node set, it is called that the node is covered by neighbor node set.

Definition 4: Coverage node set. Coverage node set of node \( u \) is shown by \( G_u \), and consists of neighbor nodes covering node \( u \). That is,

\[
G_u = \{v \mid v \in N_u, S(v) \cap S(u) \neq \emptyset\}, \text{And } S(u) \subseteq S(G_u)
\]

\( S(G_u) \) shows sense area jointly formed by all nodes in coverage node set \( G_u \).

Definition 5: Connected coverage node set. If any two nodes in coverage node set of node \( u \) are connected, then the node set is called connected coverage node set of node \( u \), which is shown by \( C_u \).

\[
C_u = \{v \mid v \in G_u, \forall w \in G_u, \exists L = e_{wv} = e_{v0} e_{k_1} ... e_{k_m} e_{wv}, e_{wv}, e_{v0}, e_{k_1}, ... e_{k_m} \in E\}
\]

4.1.2 Searching for connected coverage set

If node communication radius is smaller than times of sense radius, we use the way of judging whether coverage node set is connected coverage set to maintain connectivity of active node set in the area. If known the coverage node set \( G_u \), steps in constructing its connected coverage set node set \( C_u \) is as follows:

1) For known coverage node set \( G_u \) of node \( u \), initialize connected coverage node set \( C_u \), that is, random select one node from \( G_u \) and add it into \( C_u \);
2) For each node in \( C_u \), search its neighbor node in \( G_u \) and add them into \( C_u \);
3) Repeatedly implement 2) until each node in \( C_u \) is traversed once.

If constructed connected coverage node set \( C_u \) equals to \( G_u \), it indicates that node \( u \) can be covered by its active neighbor node set and this node set is also connected and node \( u \) can go to sleep; or node \( u \) should keep active state.
4.2. Localized Area Coverage Algorithm Based on Connected Coverage Node Set (CCS-CILAC)

Circle intersection local area coverage algorithm based on connected coverage node set, CCS-CILAC, is improvement to circle intersection local area coverage algorithm. Selection of active node set is realized on the basis of time round mechanism. Whole operation stage of network is divided into several “round”. Each round is subdivided into two phases, that is, active nodes set selection phase and running phase. In active nodes set selection phase, all nodes based on intersections coverage determination regulation judge their own state, forming active node set of the round. In running phase, nodes of active node set are responsible for data monitoring and transmission.

In active node set selection stage, each node is randomly woken up. After node is woken up, it will in a certain period of time receive state information sent by active neighbor nodes, which mainly contains <location, node present state>. Node uses coverage judgment algorithm based on circle intersection according to received state information of neighbor nodes to judge whether it is covered by active neighbor node set. If coverage condition is satisfied, it shows there is a coverage node set Gu, which covers this node. Thus, the node goes on judging whether nodes in the coverage node set are connected, that is, whether existing connected coverage node set Cu. When the condition is satisfied, it shows that this node is covered by connected neighbor node and this node can go to sleep; or, the node will be in active state and broadcast state message around, in order that surrounding neighbors can receive. When node energy is exhausted, node dies.

Description of CCS-CILAC is as follows:

Algorithm CCS-CILAC for each Node q
Begin
Do while Node u is not Dead
  Set Node wait wake time Tawake for Node u;
  DO while Tawake is not Expire
    // Node carry out random sleep time
  End while;
  Set Awake state for node u;
  Set Node receive message time TNRT for Node u;
  Do while TNRT is not Expire
    Receive state message sent by active neighbor Node v;
    Nu= Nu +\{v\};
  End while;
  Carry out Circle Intersection point coverage Decision-making method;
  If Node u is covered by Nu Then
    Gu= Nu;
    Build up Connected coverage Set Cu;
    If Cu = Gu Then
      Set sleep time Tsleep and sleep state for Node u;
      Do while Tsleep is not Expire
        // Node u go to sleep until current round end;
      End while;
    Else // Gu is not connected
      Set Active state to Node u;
      Broadcasting node u state message;
      Node u on duty until the current Round end;
    Endif
  Else // Node u is not covered by Nu
    Set Active state to Node u;
    Broadcasting node u state message;
    Node u on duty until the current Round end;
  Endif
End while; //Round loop end
End.
5. Performance Analysis

It can be known from table 1 that, if node radio radius is larger than times of node sense radius, network connectivity can be maintained in the situation of ensuring area overall coverage utilizing circle intersection local area coverage algorithm CILAC. Thus, the experiment implementing simulation analysis aiming at the situation of node radio radius is smaller than times of node sense radius.

In order to facilitate the analysis of algorithm function, this paper carries out with simulation comparison between local area coverage algorithm based on connected coverage node set (CCS-CILAC) and existing circle intersection local area coverage algorithm CILAC, separately aiming at different scenes. Suppose in a 50m*50m rectangular area, randomly uniform deployment 200 nodes, whose sense radius is 10m. In order to facilitate comparison with simulation result, node lifetime is set as 10 time units. In each round a node in active state consumes one time unit of battery energy and nodes in sleep state consumes no energy.

**Scene 1**: in the situation where network node number is 200 and node radio radius equals to sense radius, function comparison between local area coverage algorithm based on connected coverage node set (CCS-CILAC) and circle intersection local area coverage algorithm CILAC is analyzed.

Simulation result is shown as figure 4, in the situation where user sense demand is set to be larger than 98% of area coverage degree, network lifetime of CCS-CILAC algorithm is 24 and network lifetime of CILAC algorithm is 26. Main reason for CCS-CILAC algorithm lifetime shortening compared with CILAC algorithm lifetime is that in order to maintain active node set connectivity, increasing of node number in some round may be led, as is shown in figure 4(b), resulting in lifetime shortening. However, it can be known from table 1 that CILAC algorithm makes probability of active node set maintaining of connectivity in each round be only 75%, while it can be known from simulation that CCS-CILAC algorithm makes 100%.

**Scene 2**: If there are 200 network nodes and in the situation where relationships between node radio radius and sense radius are separately 1:1, 1.2:1, $\sqrt{2}$ :1, $\sqrt{3}$ :1, 2 :1 implement simulation comparison between CCS-CILAC algorithm and CILAC algorithm.
Simulation result is shown as table2 and it can be known from data in the table that, (1) CCS-CILAC algorithm solves problem of not being able to ensure node set connectivity in each round in CILAC algorithm; (2) In order to ensure connectivity, active node number of CCS-CILAC algorithm in each round is led to be larger than CILAC algorithm, which is similar to figure 4(b) and thus phenomenon of network lifetime is shortening occurs, that is, compared with CILAC algorithm, CCS-CILAC algorithm through shortening network lifetime ensures network connectivity; (3) In the process of increasing ratio of node radio radius and sense radius, network connectivity probability led by CILAC algorithm is also continuously increasing. Therefore, It need to be considered to keep balance between network lifetime and connectivity.

Scene3: If relationship between node radio radius and sense radius is fixed to 1:1, separately in the situation of having 50、100、150、200、250、300 network nodes, that is, different network node density, implement simulation comparison between CCS-CILAC algorithm and CILAC algorithm.

<table>
<thead>
<tr>
<th>N</th>
<th>Re=Rs</th>
<th>Re=1.2Rs</th>
<th>Re=$\sqrt{2}$ Rs</th>
<th>Re=$\sqrt{3}$ Rs</th>
<th>Re=2Rs</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCS-CILAC</td>
<td>24</td>
<td>26</td>
<td>32</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>Lifetime</td>
<td>26</td>
<td>27</td>
<td>32</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>CCS-CILAC</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Connection</td>
<td>75%</td>
<td>90%</td>
<td>96%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>CCS-CILAC</td>
<td>70.48</td>
<td>57.15</td>
<td>47.2</td>
<td>37.9</td>
<td>35.6</td>
</tr>
<tr>
<td>Active node number</td>
<td>69.4</td>
<td>56.69</td>
<td>46.9</td>
<td>37.6</td>
<td>35.5</td>
</tr>
</tbody>
</table>

Figure 5. Network lifetime based on different node density
In different network node density, network lifetime of CCS-CILAC algorithm and CILAC algorithm are shown in figure 5. It can be known from the figure that, with the continuous increasing of network node density, node redundancy can lead to difference between two algorithm lifetimes become larger. So, to high density network, whether use CCS-CILAC algorithm need to be considered, so as to keep balance between network lifetime and connectivity.

6. Conclusion

This paper firstly introduce connectivity problem existing in localized area coverage algorithm and aiming at defects existing in critical condition proposed by Xing et al, from the angle of overall network connectivity, brings out loose critical condition which is suitable for localized area coverage algorithm and maintains overall connection. At last, aiming at different situations, a circle intersection local area coverage algorithm maintaining connection is designed. Simulation experiment shows, this can maintain network node connectivity on the basis of ensuring overall area coverage.

7. Acknowledgments

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8. References


