An EAOW algorithm to optimize the throughput in ad-hoc network in emergency communication environment

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Abstract. For improving the throughput of wireless ad-hoc networks in emergency communication environments, this paper proposes an enhanced adaptive on-demand weighted clustering algorithm. The clustering algorithm is very important in heterogeneous wireless ad-hoc networks, but the widely used AOW algorithm has certain limitations. Combined with the emergency communication environment, this article first analyzes the importance of clustering algorithm in improving network throughput, and secondly introduces and analyzes the two shortcomings of the AOW algorithm. On this basis, an enhanced adaptive on-demand weighted clustering algorithm (EAOW) is proposed. In the EAOW algorithm, each weight factor is dimensionlessly processed, and the properties of the nodes are added to the heterogeneous network. The simulation results show that compared with the AOW algorithm, the EAOW algorithm has an obvious progress in the number of cluster heads and the network throughput.

1. introduction

In an emergency environment, communication will be interrupted due to various objective factors, thus losing contact with the outside world directly. Wireless ad-hoc network communication technology has the basic characteristics of independent infrastructure, self-organization, self-healing and strong invulnerability[1]. Even in the complex and chaotic disaster environment, it can recover the emergency communication system in the disaster area at the first time, which lays a solid foundation for the later rescue work. Throughput refers to the average throughput rate that each node can actually transmit, when the number of nodes is small and the network obtains a certain degree of connectivity, the throughput rate of per user will increase monotonically, but after this stage, as the number of nodes increases, the throughput rate of per user begins to decrease[2]. As shown in Figure 1.
Wireless self-organizing network can be divided into plane structure and hierarchical structure[3]. The plane structure is simple, which saves computational overhead. However, when the network scale is large, the number of nodes will increase, and it is possible that most of the bandwidth will be occupied by the routing overhead, and the node throughput will be greatly reduced[4]. The hierarchical network can solve this problem[5], because it adopts clustering algorithm. The clustering algorithm is used to divide the network scale into multiple nodes. The nodes are divided into cluster heads and cluster members[6]. The cluster head is responsible for managing the cluster. The internal node can learn the relevant information of a node through the cluster head. The nodes in the cluster do not need to understand the topology of the entire network, which saves part of the routing overhead[7], and the total number of nodes will be reduced, thereby indirectly increasing the throughput of wireless ad-hoc networks.

In this paper, we designed a new EAOW (Enhanced AOW) algorithm based on the adaptive weighted clustering algorithm (AOW). The algorithm adopts a hierarchical network structure. Through this algorithm, we can select a reasonable cluster head and optimize the number of cluster heads in wireless ad-hoc network, thus indirectly improving the throughput of wireless ad-hoc network.

2. AOW algorithm

The AOW algorithm uses the idea of combined weighting. In the process of electing cluster heads, four factors including the number of neighbor nodes $D_i$, mobility $M_i$, energy $E_i$, and power $P_i$ are considered comprehensively, and the weight formula is used to calculate the node’s final weight, as in formula (1), selects the node with the smallest weight among the nodes to assume the position of cluster head. Among them, $w_m + w_D + w_p + w_E = 1$ must be satisfied[8].

$$W_i = w_m M_i + w_D D_i + w_p P_i + w_E E_i$$

(1)

This algorithm not only makes the election cluster head more reasonable, but also enhances the applicability of the network. If the node has strong mobility, the weight of mobility can be increased. If the node is very sensitive to energy, the energy weight can be adjusted, which has strong flexibility[9,10,11].

Through the analysis of the AOW algorithm, combined with the emergency environment, the AOW algorithm has the following defects:

1) In the clustering process, the attributes of all nodes in the network are the same, but in the emergency communication environment, the network is heterogeneous. Air units such as drones, ground units such as vehicles, walkietalkies, and various portable communication devices have different attributes and information processing capabilities. Therefore, these factors need to be considered in the selection process of the cluster head.
2) In the process of calculating the total weight, the units of the number of neighbor nodes, mobility, energy, and power are not the same. Such a combination of weights will be poor, resulting in unreasonable selection of cluster heads. Therefore, dimensionless processing is required for improvement.

3. EAOW algorithm

3.1. Determination of weight

Aiming at the shortcomings in the AOW algorithm, we improve the weight formula in formula (2).

\[ W_i = w_1 M_i + w_2 D_i + w_3 P_i + w_4 E_i + w_5 / P_{ro} \]  

In the formula, \( w_1 + w_2 + w_3 + w_4 + w_5 = 1 \), the values of these five weighting coefficients are determined by the specific environment. Among them, \( P_{ro} \) refers to the attributes of nodes. According to the information processing capabilities of different nodes in the emergency communication environment, they are divided into three levels, the highest is three, the lowest is one, and the corresponding values are 1, 2, 3[12].

Perform dimensionless processing on the rest of the weighting factors, and the calculation formula is shown in formula (3).

\[
\begin{align*}
M_i' &= \frac{\log_{10}(M_i)}{\log_{10}(M_{\text{max}})} \\
D_i' &= \frac{\log_{10}(D_i)}{\log_{10}(D_{\text{max}})} \\
P_i' &= \frac{\log_{10}(P_i)}{\log_{10}(P_{\text{max}})} \\
E_i' &= \frac{\log_{10}(E_i)}{\log_{10}(E_{\text{max}})}
\end{align*}
\]  

\( M_i' \) represents the moving speed of node i, and \( M_{\text{max}} \) represents the maximum moving speed of all nodes. \( D_i' \) represents the node degree of node i, that is, the number of neighbor nodes of node i, and \( D_{\text{max}} \) represents the maximum degree of all nodes. \( P_i' \) is the sum of the distances from node i to its neighboring nodes, and \( P_{\text{max}} \) represents the maximum transmit power of all nodes. Substitute \( E_i' \) represents the energy consumption value of node i, and \( E_{\text{max}} \) represents the maximum energy consumption value of all nodes.

3.2. The selection process of cluster head

Since the EAOW algorithm has been improved on the basis of the AOW algorithm, the algorithm flow should also be distinguished from the AOW algorithm in details. Figure 2 shows the flow chart of the EAOW algorithm.
Figure 2 EAOW algorithm flow chart

1) Randomly assign attributes to nodes, the value is 1, 2 or 3.
2) Each node periodically sends "Hello" messages to obtain the number of neighbor nodes $D_i$.
3) Calculate the sum of the distances from node $i$ to all its 1-hop neighbor nodes as its power $P_i$.
4) Calculate $M_i$ based on the moving speed of the node.
5) Determine the energy consumption $E_i$ of the node according to the time when the node acts as the cluster head.
6) De-dimensionalize the values of the above four indexes: node degree, power, moving speed, and energy consumption.
7) Use the weight formula to calculate the weight of the node.
8) Select a node with the minimum weight between neighbor nodes. If a different node has the same total weight, the node having the smallest ID is used as the cluster head [13]. A node selected as a cluster head declares its identity by broadcasts the head message of the cluster. The adjacent node receiving the cluster head message becomes a member node of the cluster head. According to whether the nodes that have entered the cluster can enter other clusters, the structure can be divided into overlapping clusters and non-overlapping clusters[14]. This article examines non-overlapping clusters, that is, nodes that have entered the cluster no longer participate in the clustering.
9) Repeat 1-8 until all nodes belong to a certain cluster or serve as cluster heads, and the cluster head election ends.

Through the above process, the EAOW algorithm successfully divides the self-organizing network into several non-overlapping clusters.

3.3. Experimental simulation and analysis
In this section, we will verify the AOW algorithm and EAOW algorithm through simulation. In this simulation, 10 ~ 150 nodes were randomly distributed within the range of 1000 (m) * 1000 (m), and the node transmission range was set to 150 (m) ~ 1000 (m). Table 1 shows the network simulation parameter settings.

| parameter       | description                        | expectation          |
|-----------------|------------------------------------|----------------------|
| range           | Area (length * width)              | 1000*1000            |
| node_number     | Number of mobile nodes (network size) | 15-150               |
| simu_time       | Simulation duration                | 300s                 |
| Tn              | “hello” packet message cycle       | 2.0s                 |
| H_E_waste       | Cluster head energy loss           | 0.03%                |
| O_E_waste       | Ordinary node energy loss          | 0.01%                |
| Vmax            | Maximum moving speed               | 800km/h              |
| tx_range        | Wireless transmission distance     | 150-1000m            |

Figure 3 shows the relationship between the number of cluster heads and the total number of nodes. It shows that the number of cluster heads increases dynamically as the number of nodes in the network increases. The number of cluster heads generated by the proposed algorithm EAOW is small.
Fig. 4 shows how the number of cluster heads varies depending on the transmission distance. This graph shows that the number of cluster heads decreases with increasing transmission distance. In the extreme case, if the communication distance is less than 100, each node is considered to be single and can be cluster personally. In this case, the number of cluster heads is approximately equal to the total number of nodes. When the communication distance is 1000 or more, all the nodes can be connected to each other, so that only one cluster head exists. Furthermore, compared with the AOW algorithm, the EAOW shows that the cluster heads are less efficient and the spectral resources can be effectively saved.

![Figure 4](image1)

Figure 4 Number of cluster heads with different communication distance.

Figure 5 shows the throughput corresponding to different numbers of nodes in the AOW algorithm and the EAOW algorithm. It can be seen that compared to the AOW algorithm, the EAOW algorithm has a higher throughput at different numbers of nodes. This proves that our improved algorithm has a better effect in optimizing the throughput of the self-organizing network.

![Figure 5](image2)

Figure 5 the throughput of different numbers of nodes

4. Conclusion
This paper not only considers different weight factors, but also carries out dimensionless processing. At the same time, different attributes are assigned to nodes according to their information processing ability. Simulation results show that our proposed algorithm EAOW provides better performance than AOW in cluster heads election and network throughput.

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