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A Weight-based Clustering Routing Algorithm for Ad Hoc Networks

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***Abstract*—Clustering routing algorithm is an important part of network layer in Ad Hoc networks. Its main goal is to find an optimal multicast tree which can satisfy QoS constraints, the network can not only meet the QoS requirements of data services, but also improve the efficiency of limited network resources. WCRA(Weight-based Clustering Routing Algorithm), a clustering routing algorithm, is designed in this paper. It adopts the combination weighting method, and the cluster topology is flexible. If the clustering strategy is changed properly, the correlated cluster or uncorrelated cluster can be constructed quickly. It can also adjust itself according to the actual application, improve the fairness of node competition and optimize the cluster structure. Experiments show that it can significantly improve the transmission rate of mobile network nodes, enhance the stability of the network, and provide an application basis for QoS services in Ad Hoc networks.**

Keywords: Clustering algorithm; Ad Hoc Network; Node; Routing

Ⅰ. INTRODUCTION

Wireless mobile Ad Hoc network is a distributed network system without central control equipment. Every mobile node is both host and router. So far, the clustering routing algorithm has been researched a lot, and researcher had made many achievements.

CEDAR[1] is a clustered routing algorithm based on QoS. Its goal is to establish a virtual core structure for reliable routing information dissemination. The core area of CEDAR(Core Extraction Distributed Ad Hoc Routing Algorithm) is composed of core nodes. Any normal node must choose a core node as its manager. Each node performs periodic information exchange to determine and update the core area, trying to ensure the minimum number of nodes in the core area, and the core node selects an available path to cache in the routing table by broadcasting locally to neighboring nodes. The propagation distance of the state information depends on the bandwidth of the stability of the link. A stable link and sufficient bandwidth will enable more information to be found in the route search message. The advantages of CEDAR are mainly reflected in the discovery and maintenance of routes in the core area. When the scale of the network increases, the control overhead does not increase much, which is conducive to supporting the transmission of multimedia service streams.

ZHLS[2] is another layer-based routing protocol. ZHLS(Zone Based Hierarchical Link State Routing) defines two topological structures: node-level and interval-level. It contains two types of routing control messages: out-of-area messages and intra-area messages. Messages outside the zone are broadcast on the entire network to connect and communicate between the zones; messages within the zone are only broadcast within the zone, connecting nodes within the zone. Since it is only broadcast within the zone, it will not be affected by the movement of nodes in the zone. District-level status information has an impact.

All these classic algorithms have different degrees of limitations: some are only suitable for small-scale Ad Hoc networks with flat structure type; while some are only suitable for large-scale networks with hierarchical topology type; some never get the optimal problem solution in the formation of multicast trees, etc[3-4]. In this paper, a weight-based efficient clustering routing algorithm named WCRA (Weight-based Clustering Routing Algorithm) for Ad Hoc network is proposed. Simulation results show that its efficiency has been improved greatly.

In the rest of this paper, we first research on mathematical model in section II. Then, WCRA algorithm is analyzed in section III. The experiments and analysis are shown in section IV. At last, we offer conclusions in Section VI.

Ⅱ. WCRA ALGORITHM

WCRA is an efficient clustering algorithm based on weights for Ad Hoc network proposed in this paper.

A. Mathematical model

Suppose that some properties of Ad Hoc networks, such as processing power, wireless link stability, available bandwidth, and battery residual energy, can be represented by functions $f_1(x)$, $f_2(x)$, … , $f_n(x)$. Then the composite function of the attributes of node $n_i \in V$ can be expressed as equation (1)

$$H(i) = \lambda_1 f_1(x) + \lambda_2 f_2(x) + \cdots + \lambda_n f_n(x) \quad (1)$$

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Where λ_i is the weighting factor of the corresponding attribute. By taking different values of λ_i, we can simulate different application environment of Ad Hoc network. Using the normalized calculation method, the conditional constraint degree R_i of node $n_i \in V$ can be obtained, as shown in formula (2).

$$R_i = |H(i)|, 1 \le i \le n \qquad (2)$$

The physical meaning of R_i is the communication capability of node n_i, and $0 \le R_i \le 1$. At the same time, it can be divided into four levels, representing four different communication states and capabilities, as shown in formula (3).

$$T_i = \begin{cases} 0, & 0 \le R_i < 0.25 \\ 1, & 2.5 \le R_i < 0.5 \\ 2, & 0.5 \le R_i < 0.75 \\ 3, & 0.75 \le R_i \le 1 \end{cases} \qquad (3)$$

T_i=0 indicates that the communication capability of node n_i is weak; T_i=1 indicates that the communication capability is general; T_i=2 indicates that the communication capability is strong, and n_i can be used as a candidate node for the cluster head; T_i=3 indicates that the communication capability of the node is very strong and can be selected as cluster head.

B. Cluster head selection

WCRA algorithm uses four conditions to calculate the weight of nodes when selecting cluster head[5-7]. They are: the sum of the distance between the node and its neighbors, the deviation of the node degree and the residual energy of the node. As shown in Formula (4) .

$$W_i = \lambda_1 E_i + \lambda_2 M_i + \lambda_3 D_i + \lambda_4 \Delta_i \qquad (4)$$

Where, W_i represents the weight of the node; λ_1、λ_2、λ_3、λ_4 respectively represent the coefficient of each weight, its size varies with different application environments, and is a system parameter; E_i represents the initial energy of the node; D_i is the sum of the distances between node n_i and each neighbor node; Δ_i is the absolute value of the difference between node n_i and the best node degree; M_i is the relative movement characteristic value of the node. Assuming that the mobility of node n_j relative to node n_i is $M_j(i)$, then its value can be calculated by formula (5).

$$M_j(i) = 10\log\frac{New\_Power}{Old\_Power} \qquad (5)$$

Where, *New_Power* is the strength of the wireless signal received by node n_j from node n_i, *Old_Power* is the intensity of the signal from n_i to n_j at the previous moment. If $M_j(i)$<0, it means that node n_j has left the communication range of node n_i, otherwise they are getting closer. The relative mobility of node n_i can be expressed by equation (6).

$$M_i = \frac{\sum_{j=1}^{k} |M_i(j)|}{k} \qquad (6)$$

Where, k indicates that node n_i has k neighbor nodes. The larger the M_i is, the stronger the mobility of node n_i is, and vice versa.

The WCRA algorithm calculates the weight of candidate cluster head node according to equation (4). The node with the lowest weight will be selected as cluster head.

C. cluster size

If a cluster head manages more member nodes, it will consume its remaining energy too quickly and lead to the death of the cluster head, while the election of new cluster heads increases the control overhead of the network and initiates the re-run of the routing algorithm; in addition, too many cluster members will also cause congestion in the network. However, if there are too few member nodes in a cluster, it will lead to a waste of network resources. The following is an analysis of how the WCRA algorithm determines the number of member nodes in a cluster.

Assuming that in Ad Hoc network $G = \{V, E\}$, $n_i \in V$, where $i = 1, 2, \cdots, N$, BW is the total bandwidth of the wireless channel, then the maximum traffic *Flow* of each network node can be expressed as equation (7).

$$Flow = \frac{BW}{\sqrt{N}} \qquad (7)$$

The cluster heads will form an upper layer backbone network among themselves, and each cluster head will have to communicate with both intra-cluster nodes and other cluster heads, so it must initiate multi-frequency communication with both inter-cluster and intra-cluster traffic.

Assuming that the number of member nodes in each cluster is the same, and there are m members in each cluster, there are N/m cluster heads. If the intra-cluster bandwidth is BW_1 and the inter-cluster bandwidth is BW_2, the traffic of each cluster member node can be expressed by equation (8), and the traffic on the cluster head can be expressed by equation (9).

$$Flow_{member} = \frac{BW_1}{\sqrt{\frac{N}{m}}} \qquad (8)$$

$$Flow_{cluster} = \frac{BW_2}{\sqrt{m}} \quad (9)$$

The cluster head itself is also a member node in the cluster, so equation (10) holds.

$$\frac{m-1}{m} Flow_{member} \le Flow_{cluster} \quad 10)$$

The following analysis finds a value of m that maximizes $(m\text{-}1)/m\times Flow_{member}$, which is the optimal value for the number of cluster members determined by the WCRA algorithm.

Assuming that $m = m'$ is the value we need to solve, the upper limit of $(m\text{-}1)/m\times Flow_{member}$ can be expressed by equation (11).

$$F_{up\_member} = \frac{m'-1}{m'}\sqrt{\frac{8}{\pi}\frac{BW_1}{\Delta}}\sqrt{\frac{N}{m'}} \quad (11)$$

The upper limit of $Flow_{cluster}$ can be expressed by formula (12).

$$F_{up\_cluster} = \sqrt{\frac{8}{\pi}\frac{BW_2}{\Delta}}\sqrt{m'} \quad (12)$$

Obviously, if $F_{up\_member}=F_{up\_cluster}$, then equation (13) holds.

$$\frac{m'-1}{m'}\sqrt{\frac{8}{\pi}\frac{BW_1}{\Delta}}\sqrt{\frac{N}{m'}} = \sqrt{\frac{8}{\pi}\frac{BW_2}{\Delta}}\sqrt{m'} \quad (13)$$

From formula (13), formula (14) can be derived

$$m' = \frac{BW_1}{BW_2}\sqrt{N} + 1 \quad (14)$$

According to equation (14), the performance of the network can be optimized when the number of member nodes in the cluster is m'.

III. SIMULATION AND ANALYSIS

To evaluate WCRA and compare it to existing algorithm, simulations are performed. A Mobility Framework for NS2[8-9], a discrete event simulator written in C++, is used as a tool. the scene is 2000m×2500m, the number of nodes are respectively 50, 100, 150, 200, 250, 300, 350 and 400 in scene, and they are randomly distributed;

Fig. 1 shows data delivery rate is rapidly increased while the number of nodes is less than 200, but it is slowly decreased while the number of nodes is more than 200. That is because some paths will become longer if there are more nodes in network, more and more packets are dropped in process of transmission, then the two data delivery rates are decreased. With the increase of number of nodes, the network topologies become more and more complex. The packet delivery rate of WCRA is obviously higher than the other two algorithms by about 15%.

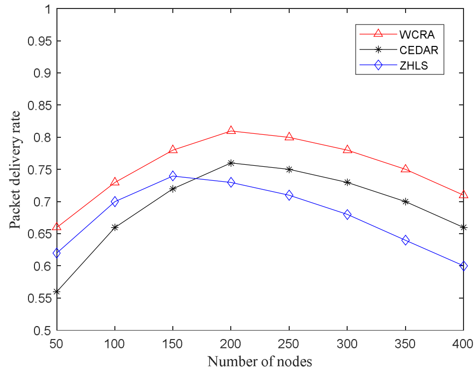

Fig. 1 Packet delivery rate

Fig. 2 shows the relationship between network lifetime and the number of nodes. With the increase of number of nodes, the network lifetime both incline slowly. That is because more nodes, more complicated topology and more data forwarded, which make load increase rapidly and residual energy is run out in a short time. Thus, network lifetime is declining. The network lifetime of WCRA is apparently longer than that of the other two algorithms in case of the same number of nodes.

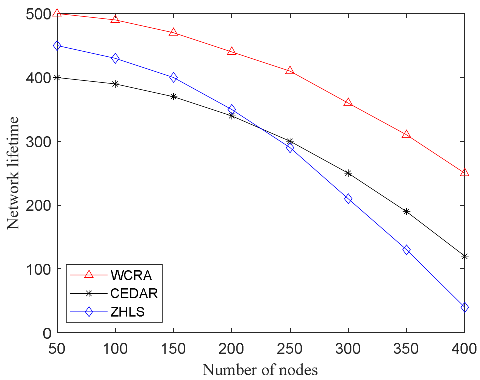

Fig. 2 Network lifetime

Ⅳ. CONCLUSION

This paper designs a clustering routing algorithm WCRA, which adopts a combined weighting method, and the determination of cluster topology is flexible. As long as the clustering strategy is appropriately changed, relevant or unrelated clusters can be constructed quickly. It can also make adaptive adjustments according to actual applications, improve the fairness of node competition, and optimize the clustering structure. Experiments show that it can significantly increase the transmission rate of mobile network nodes, enhance the stability of the network, and provide an application basis for QoS services in Ad Hoc networks.

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References

[1] Xiaojie Liu; Ulrich Speidel. RAODV Routing Protocol for Congestion Detection and Relief in Ad Hoc Wireless Networks. International Journal of Interdisciplinary Telecommunications and Networking, v 13, n 4, p 21-34, October 1, 2021.

[2] Sarao, Pushpender. Ad Hoc On-Demand Multipath Distance Vector Based Routing in Ad-Hoc Networks. Wireless Personal Communications, v 114, n 4, p 2933-2953, October 1, 2020.

[3] Wu, Huazhu; Guo, Wenyou. Study on the routing algorithm of airport navigation lighting system based on mobile wireless ad hoc network. Journal of Computational Methods in Sciences and Engineering, v 20, n 4, p 1085-1096, 2020.

[4] Basomingera, Robert; Choi, Young-June. Learning from routing information for detecting routing misbehavior in ad hoc networks. Sensors (Switzerland), v 20, n 21, p 1-22, November 1, 2020.

[5] Vinayagam, J.K.; Balaswamy, C.H. Cross-layered-based adaptive secured routing and data transmission in MANET. International Journal of Mobile Network Design and Innovation, v 9, n 1, p 37-45, 2019.

[6] Sekar, P. Chandra; Mangalam, H. A power aware mechanism for energy efficient routing in MANET. International Journal of Networking and Virtual Organisations, v 21, n 1, p 3-18, 2019.

[7] Osman, M.; Syed-Yusof, S.. A survey of clustering algorithms for cognitive radio ad hoc networks. Wireless Networks, v 24, n 5, p 1451-1475, July 1, 2018.

[8] Marchang, Jims; Douglas, Roderick. Dynamic Neighbour Aware Power-controlled MAC for Multi-hop Ad-hoc networks. Ad Hoc Networks, v 75-76, p 119-134, June - July 2018.

[9] Shengli, Mao. Research on the application of NS2 network simulation based on clustering algorithm. Open Automation and Control Systems Journal, v 7, n 1, p 1210-1215, September 14, 2015.