A Kind of Improved Congestion-Adaptive Ad-Hoc On-demand Distance Vector Routing Protocol

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ABSTRACT

The Ad Hoc networks are more likely to be congested and paths are easy to fail because of the dynamic change of network topology and limited processing capability of the nodes. In order to solve these problems, this paper proposes the Improved Congestion-Adaptive Ad-Hoc On-demand Distance Vector routing protocol (ICA-AODV). It presents a new method to calculate the node stability and establish a stable route by considering the calculation results. And it also uses congestion trend to calculate the congestion value of one node by cross-layer design. When judging out some nodes have congested by the cross-layer module, it establishes a bypass and split the data for achieving congestion adaptability. The simulation results show that the new ICA-AODV can improve the reliability and robustness of an Ad Hoc network.

INTRODUCTION

There are many routing protocols for Ad Hoc networks\[1\]. The Ad-Hoc On-Demand Distance Vector Routing Protocol\[2\](AODV) not only has low overhead but also can save network resources and adapt to the dynamic change of network topology. The principle of stable route mechanism is to establish stable paths by considering nodes stability. It can reduce the probability of routing failure. For example, the AODV-L\[3\] used movement information including highway mobility model to improve the routing reliability. For congestion control, the A-SCP\[4\] proposed a self congestion prediction algorithm for congestion prediction and modified AODV with SCP to alleviate congestion and improve routing efficiency.
In order to improve network performance, this paper proposed the Improved Congestion-Adaptive AODV Routing Protocol. This protocol can not only establish stable paths for connections, but also improve the reliability of the networks.

**DESCRIPTION OF ICA-AODV PROTOCOL**

**Node Comprehensive Stable Degree**

Ad Hoc networks can be abstracted as a directed graph model G(V,E), where V denotes the set of nodes and E denotes the set of links between nodes. And nodes u,v \(\in V\), then (u,v) represents a link between nodes u and v. According to the number of neighbor nodes, we can define the connectivity of node u by using Eq. 1.

\[
C(u) = \left| \{v \in N : (u,v) \in E\} \right|
\]

(1)

The given equation can reflect the connection state of node u. The value of \(C(u)\) is larger, the better connectivity of the node.

Node stability can be reflected by the node movement with respect to its previous position. The displacement and transmission range decide the stability. A node is said to be stable if its movement is within given range. If a node with transmission range r moves from position \((x_0,y_0)\) to \((x_t,y_t)\) in a period of time. The displacement of the node u movement within time t can be measured by Eq. 2 and the self stability \(S_s(t)\) can be estimated as given in Eq. 3. \(S_s(t)\) varies in the range 0 to 1.

\[
d'_s = \sqrt{(x_t - x_u)^2 + (y_t - y_u)^2}
\]

(2)

\[
S_s(t) = \begin{cases} 
1 - \frac{d'_s}{r/2} & 0 \leq d'_s < r/2 \\
0 & \text{others}
\end{cases}
\]

(3)

Base on the connectivity and self stability, the node comprehensive stability at time t can be calculated by Eq. 4.

\[
C_s(t) = \omega \times \frac{1}{C(u)} \sum_{i=1}^{C(u)} S'_s(t) + (1 - \omega) \times C_s(t-1)
\]

(4)

\(\omega\) is the weighting factor (lies between 0 and 1), \(C_s(t-1)\) is the recent neighbor node stability, \(S'_s(t)\) is the self stability of neighbor node i. This evaluation can be helpful to select nodes with higher comprehensive stable degree so that the selected path would maintain a longer duration.

**Node Congestion Value**

According to the length of buffer queue, MAC layer’s input and output rates, this paper presents the definition of congestion trend to calculate the node congestion value.
The node $u$ congestion trend can be calculated by Eq. 5. $Q$ is the maximal length of buffer queue and $q$ is the instantaneous length of queue. $R_{\text{in}}(u)$ and $R_{\text{out}}(u)$ are the input and output rates respectively. $C_T(u)$ can not only detect the degree of congestion, but also predict the change trend of congestion.

The node periodically detects its congestion trend to calculate its congestion value. The detecting cycle is $T$. After a detecting cycle, the number of packets in a node buffer and congestion value can be calculated by Eq. 6 and Eq. 7 respectively.

$$C_T(u) = \begin{cases} 0 & R_{\text{in}}(u) \leq R_{\text{out}}(u) \\ \frac{R_{\text{in}}(u) - R_{\text{out}}(u)}{Q - q} & R_{\text{in}}(u) > R_{\text{out}}(u) \end{cases}$$

(5)

The $C_T(u)$ varies in the range 0 to 1. The value of $C_T(u)$ is smaller, the congestion level of the node is lower. This paper set two thresholds to divide the congestion into three levels. They are non-congestion, slight-congestion and sever-congestion.

**Cross-Layer Design**

In Ad Hoc networks, the route selection of the routing protocol at the network layer directly affects the competition for the wireless channel between nodes at the MAC layer. Conversely, the competition also causes the routing protocol to be updated. But in traditional network architecture, the network layer can’t learn lower layers state. So this paper proposed the cross-layer design and the information can be interacted between each layer. This paper used the ECLAIR[5] structure and amends it to adapt to this design. It has two modules. The interfaces are responsible for interaction between the protocol layer and cross-layer module. The cross-layer module is responsible for calculating congestion value to implement the optimization function.

**Traffic Splitting and Congestion-Adaptive**

The principle of ICA-AODV is shown in Figure 1. The source node S established a primary route(S-F-A-E-B-D) to destination node D by judging out all the intermediate nodes are non-congestion and satisfy the stability conditions. In the process of communication, node E become congested. So it informed the upstream node A and then node A established a bypass(A-C-B) to ease the primary route’s congestion condition.

![Figure 1. Principle of ICA-AODV.](image-url)
Now that the bypass has been found, data packets coming to this node are not necessarily spread over the bypass and the primary link. Indeed, as long as the next primary node is non-congestion, there are no packet is forwarded on the bypass. The bypass can be used immediately if the next primary node becomes severe congestion.

In order to achieve congestion control, the probability of splitting is modified periodically based on the congestion status. To keep the protocol overhead small, ICA-AODV tries to minimize the use of multiple paths. If the next primary node and bypass are both sever-congested, ICA-AODV has to find another bypass.

**SIMULATION**

In the simulation, there are four simulation performances: packet delivery rate, normalized routing overhead, average end-to-end delay and routing discovery frequency.

In Figure 2, it showed that the packet delivery rate of ICA-AODV protocol is higher than AODV and it can be increased by 8%. This is because the ICA-AODV protocol has the ability of adapting to network congestion.

As shown in Figure 3, the normalized routing overhead of ICA-AODV protocol is higher than AODV when packet rate is slow. This is because AODV tries to establish a new route by broadcasting a route request when link fails. But ICA-AODV tries to make use of an available bypass and minimize the use of multiple paths. Overall, the ICA-AODV has the lower normalized routing overhead.

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In Figure 4, it is shown that the average end-to-end delay of ICA-AODV protocol is lower than AODV protocol and it can be reduced by 9%, because ICA-AODV splits the data between primary route and bypass.

![Figure 4. Average end-to-end delay of different protocols.](image)

As shown in Figure 5, the routing discovery rate of ICA-AODV protocol is obviously lower than other two protocols because ICA-AODV uses the stable route mechanisms and the congestion adaptive mechanisms. Comparing with AODV, routing discovery rate can be reduced by 8%.

![Figure 5. Routing discovery frequency of different protocols.](image)

SUMMARY

In this paper, the improved congestion-adaptive Ad-Hoc on-demand distance vector routing protocol (ICA-AODV) was designed to resolve the problems of reliability and routing failure. By using the stable route and congestion adaptive mechanism, ICA-AODV can improve the reliability and robustness of the networks.

REFERENCES

1. Wang, Fei, et al. "COSR: A Reputation-Based Secure Route Protocol in MANET." EURASIP Journal on Wireless Communications and Networking 2010.1(2009): 1-10.
2. Perkins, Charles E., and E.M. Royer. The Ad Hoc on-demand distance-vector protocol. Ad hoc networking. Addison-Wesley Longman Publishing Co. Inc. 2001.
3. He, Yang, W. Xu, and X. Lin. "A Stable Routing Protocol for Highway Mobility over Vehicular Ad-Hoc Networks." Vehicular Technology Conference IEEE, 2015.
4. Kamatam, Govardhan Reddy, P.V.S. Srinivas, and K.C. Sekhariah. "Self congestion prediction algorithm for efficient routing in Mobile Ad-Hoc Network." International Conference on Control, Instrumentation, Communication and Computational Technologies 2014: 745-750.

5. Raisinghani, Vijay T., and S. Iyer. "ECLAIR: An Efficient Cross Layer Architecture for Wireless Protocol Stacks." World Wireless Congress Sf(2004): 2004.