A Reliable and Adaptive AODV Protocol based on Cognitive Routing for Ad Hoc Networks

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***Abstract*— Ad hoc network is one sort of multi-hop, self-organization and dynamically changing network. The Ad hoc On-Demand Distance Vector (AODV) protocol is an on-demand protocol specialized for mobile ad hoc network. Future network should have cognitive characters and the collection of elements that make up the network observes network conditions and then, using prior knowledge gained from previous interactions with the network, plans, decides and acts on this information. This document is devoted to the development of cognitive routing techniques for Ad hoc network in order to improve reliability and efficiency of AODV protocol. We propose an idea called "first fast second reliable (FFSR)" which ensures data packages could be transferred in the shortest and the most reliable mode. The proposed routing metrics base on the cognition of each node and all nodes in cognitive Ad hoc networks collect message about the whole networks periodically. Preliminary simulations were provided and the result shows the performance enhancements of the AODV in cognitive Ad hoc networks.**

***Keywords*— Ad hoc networks, cognitive routing, routing switch, AODV, reliability, adaptability**

I. Introduction

With the rapid growth of wireless technologies, the task of providing efficient connectivity is still a challenge. Since almost wireless network poses many problems, including limited bandwidth, coping with bandwidth fluctuations, and lost or corrupted data, lots of studies have been done and many solutions proposed. Here, we wish to find a reliable and adaptive route mechanism based the cognitive capability in future cognitive Ad hoc networks.

Cognitive network is a network with a cognitive process that can perceive current network conditions, and then plan, decide and act on those conditions [1]. The network can learn from these adaptations and use them to make future decisions, all while taking into account end-to-end goals. Cognition could be used to improve resource management, Quality of Service (QoS), security, access control, and many other network goals. In a cognitive network any node can, in a standalone fashion, make decisions about how to react to a given situation or a collective decision can be taken by multiple nodes. This paper is to investigate a new cognitive routing metrics by exploiting the cognitive capability of the nodes.

An ad-hoc network is a good model to investigate cognitive routing metrics in cognitive networks. Ad-hoc networks are the wireless networks consisted of some mobile nodes. They are self-organized, dynamically changing and multi-hop networks. There are no fixed devices to route packets, and each device in ad-hoc networks is required to act as a router and forward packets to their destination [2]. In ad-hoc networks, each node moves irregularly in order that the topology of network also changes frequently. Therefore routing protocol is a challenging issue in dynamic environment.

Many routing protocols have been proposed in order to achieve better routing performance in ad-hoc networks [3]. These routing protocols may generally be categorized as table-driven routing protocols and on-demand routing protocols. Table-driven routing protocols maintain a table at each node that contains up-to-date routing information of all nodes. DSDV (Destination-Sequenced Distance-Vector Routing Protocol) is one of table-driven routing protocols. On-demand routing protocols, which are called reactive protocols, create routes only when they are desired by the source node [4]. Two examples of these protocols are DSR (Dynamic Source Routing) and AODV (Ad-Hoc On-Demand Distance Vector Routing). One of the primary differences between DSR and AODV is that AODV does not perform source routing [5]. The AODV on-demand approach minimizes routing table information. However, this potentially leads to a large number of route requests being generated. So it is necessary to improve the AODV performance.

This research is organized as follows: Section II summarizes a brief overview of AODV. Then Section III describes the optimization AODV. The simulation environment and results are evaluated in section IV. Finally, the conclusions are given in the last section.

II. Ad hoc On-Demand Distance Vector

The Ad hoc On-Demand Distance Vector (AODV) protocol is one of common routing algorithms in ad hoc Networks. It is designed to enable dynamic, self-starting, multi-hop routing between participating mobile nodes to establish and maintain an ad hoc network [6]. AODV protocol allows mobile nodes to obtain routes quickly to new destinations, and does not require nodes to maintain routes to destinations that are not in active communication. AODV protocol allows mobile nodes to respond to link breakages and changes in network topology in a timely manner. One distinguishing feature of AODV protocol is that it uses a destination sequence number for each route entry. Expiry timers are used to keep the route entries fresh.

Route Request (RREQ), Route Reply (RREP), and Route Error (RERR) packets are three kinds of message types defined by AODV. RREQs are used to establish a route to a destination. RREPs are used to respond to route requests. RERRs are used to inform the affected nodes when a link breakage has occurred.

When a source node wants to send a data packet to a destination, it initiates a route discovery process to obtain such a route and disseminates a RREQ. This can happen if the destination is previously unknown to the node, or if a previously valid route is marked as an invalid route. Once another node receives a RREQ for the first time, it initiates the creation of temporary route entry for the reverse path to the source. And a node, which has a route entry of the destination node or which itself is the destination, then returns a RREP to the source along the temporary reverse path [7]. The path is built before if either it is itself the destination, or it has an active route to the destination. Otherwise, it rebroadcasts the received RREQ to its neighboring nodes. When the RREP arrives at source, the route between source and destination is built up.

In AODV, the nodes in the active routes periodically broadcast hello message to their neighboring nodes in order to announce their connectedness. Local repair mechanism will be started to try to repair the link, when a nod detects a link break while data is being transmitted and the destination is no farther than MAX_REPAIR_TTL hops away. If local repair is unsuccessful, the node will send a RERR to all upstream nodes using this broken route. The nodes that receive the RERR will repeat this procedure. Eventually, the traffic source receives it and restarts route discovery procedure if there are still packets to be sent to the target. AODV is one of the leading ad hoc network routing protocols. But, it potentially leads to a large number of route control packets being generated.

III. An Optimized AODV Protocol

Because the topological structure of Ad hoc network has dynamic characteristics, a link failure is inevitable. In accordance with the AODV protocol, the link failure will cause the source node to start a new route discovery process again [8]. However frequent route discovery process will cost a large amount of network resources and reduce network performance. So excessive route discovery is the main reason why AODV is the high routing overhead and low efficiency, as in [9].

Ideally, we hope to find a route which is the shortest path route and at the same time which is also the most reliable route, as in [10]. However, because of the complexity of the real situation, we hardly find such an absolutely ideal route. To resolve this problem, this paper proposes a "first fast second reliable (FFSR)" cognitive routing policy taking into account the characteristics of an ad hoc network. That means that we firstly ensure data packages could be transferred through the shortest path route in order to complete the data transfer tasks in the shortest possible time. If this link is broken, local repair is firstly started. If local repair is failed, the source node immediately uses the backup reliable route instead of a new route discover process in order to ensure the data transfer tasks completed in the reliable mode.

This optimized AODV protocol based on the cognitive capacity of every mobile node in ad hoc networks. Every node with the cognitive capacity can know the number of neighboring nodes in order to implement this optimized AODV protocol, as in [11], [12].

The optimized AODV protocol has the function of adaptive selection of the paths and the switch between main route and backup route [13]. It could improve the scalability and reduce cost so that AODV protocol may satisfy the requirement of the dynamic network environment. This will reduce the burden of network caused by a new route discovery process and improve network resource utilization.

Specific approach is as follows:

1. A new field named Number (all-neighbor) is added after a RREQ, which is used to record the sum of all neighboring nodes in a whole link. When intermediate nodes receive RREQ messages it adds the number of its current neighboring nodes to the field Number (all-neighbor). When RREQ messages arrival at the destination node, the value of the field Number (all-neighbor) is the number of all neighboring nodes in the whole link.
2. This algorithm don't allow intermediate nodes return RREP messages even if they get the information of the destination node in their local route table, and must continue to transfer the RREQ messages along the path known until reaching the destination node. This strategy could avoid the returned RREP messages which don`t contain enough information to accurate, and ensure that the destination node knows the whole network information along the link well to make a wise decision.
3. The destination node is allowed to receive more than one RREQ message, and calculates every RREQ message.

a) When the destination node receives the first RREQ message, it reads hop count N and the neighbor number of all nodes in this link Number (all-neighbor), and calculates the average neighbors of every node, which is Number (all-neighbor)/N. Then the destination node records hop count N of this link and the average neighbors of every node Number (all-neighbor)/N. After that the destination node does not immediately return the RREP message, but has to wait a short time. During this time, if no other RREQ messages arrived, the destination node stops waiting, and returns the RREP message. But if there are other RREQ messages arrived during this time, the destination node calculates as before, finds and records the minimum hop count and the maximum average neighbors of every node in different links. Finally the destination node returns the RREP messages which have the minimum hop count or the maximum average neighbors of every node.

b) If the destination node received other RREQ messages later, it reads and calculates in the same manner, and gets their hop counts N and the average neighbors of every node. Then the destination node compares them with the records. If it is found that a new path, which has a smaller hop count N or a larger average neighbors of every node, the minimum hop count and the maximum average neighbors of every node saved in the destination node will be updated, at the same time the sequence number will be increased to marker this new route, the reverse path will be updated and new RREP message will be returned.

c) When the source node receives the RREP message from the destination node, a route with the minimum hop count is established between source and destination. And data transmission stage can be started. The route with the largest average neighbors will be stored. When a new RREP message returns to inform the source node to update the route, it will switch to a new route or stored the new route.

d) If an intermediate node in active minimum hop count route moves and link breaks, local repair stage will be started firstly. If local repair successes, data packets will continue to route along the link repaired. If local repair fails, the source node directly selects a reliable route which is stored instead of the failed route. That avoids source node to initiate route discovery process again which may causes more burden on the network.

e) If the reliable route breaks before the transmission of data passages completes, local repair stage is started. Because it is a reliable route with the maximum average number of neighboring nodes. Therefore, it is ensure that there are the enough neighboring nodes around the broken node to replace it. So it ensures the highest success rate of local repair and reduces the cost of new route discovery.

IV. Simulation and Results

A. Simulation Model

The NS2 network simulator is used to implement our mechanism and create simulation model to compare it with AODV protocol [14]. We simulated an Ad Hoc network comprised of some mobile nodes in a 1000m×1000m area. The number of nodes is between 10 and 100. During the simulation, nodes move freely towards a random spot with a random speed which is distributed between 0 and maximum speed within this area. And the maximum speed values 5m/s, 10m/s, 15m/s and 20m/s. The simulation time is 300 seconds. The nodes which produce or receive the CBR data flow are selected randomly from all nodes. And CBR packet size is fixed at 512 bytes.

B. Simulation Results and Analysis

To estimate the reliable of optimized AODV protocol, we choose the following two key parameters:

- The Frequency of REQUEST: this denotes the frequency of route discovery. It means each CBR data packet received successfully needs the number of REQUEST packets.
- Normalized load: this denotes the AODV control packets used by every data packet.

The experiment varies the maximum velocity (5, 10, 15 and 20m/s) and the number of nodes (10, 20, 30, 40, 50, 60, 70, 80, 90, and 100). Each result is an average of data from 10 times experiment results.

Figure 1 shows that the frequency of REQUEST in optimized AODV is less than AODV. It means that optimized AODV costs less network resources. Because of the increasing numbers of nodes, we can find a backup route which is more reliable.

Figure 2 shows that in different speed, the frequency of REQUEST in optimized AODV is also less than AODV. At high mobility, linking is broken frequently. But of the new cognitive routing metrics, the performance of the optimized AODV is better than AODV.

The normalized load is presented in Figure 3. With the number of nodes increasing, the normalized load is increasing. We can see the new cognitive routing metrics has less control packets than AODV. When linking is broken, source node don`t send RERR because it has a backup route. Then the route can use backup route resulting in less number of route discoveries.

As Figure 4 shows, the normalized load in optimized AODV is less than AODV. The main reason is that the frequency of route broken is increasing as the speed of nodes increasing. So it needs more route control packets. Because we have store the most reliable route, so we need less route control packets.

Packet delivery ratio and end-to-end latency in the optimized AODV don`t descend obviously compared with the basic AODV. But the frequency of REQUEST and the normalized load are optimized evidently. So the performance of the optimized AODV in Cognitive ad hoc networks is better than AODV.

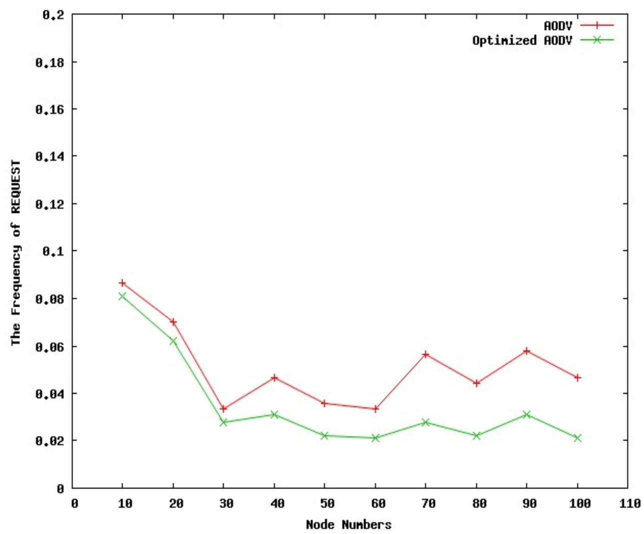

Figure 1. The Frequency of REQUEST vs Node Numbers

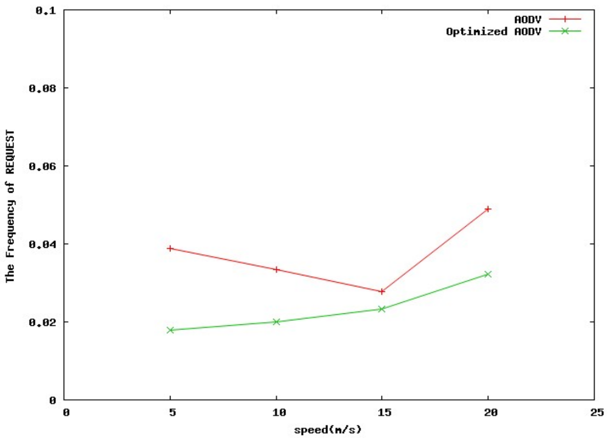

Figure 2. The Frequency of REQUEST vs Speed

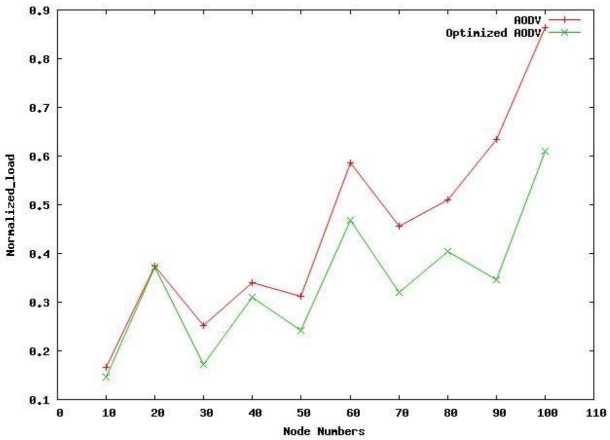

Figure 3. The Normalized Load vs Node Numbers

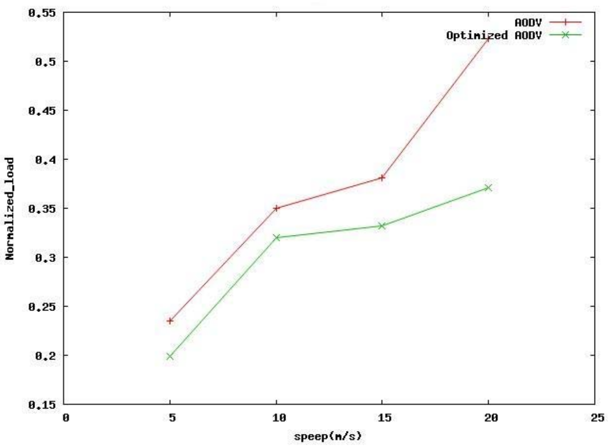

Figure 4. The Normalized Load vs Speed

V. CONCLUSIONS

This paper proposes an optimized AODV protocol based on a cognitive routing metric in which we first find the shortest route and backup the most reliable route. Two kinds of different routing mechanism are used in one protocol and we name the proposed protocol "first fast second reliable (FFSR)". The routing mechanism of the protocol bases on the cognitive capacity of nodes in cognitive networks. According to the result of simulation, this optimized AODV reduces the times of route discovery and the cost of route. And the reliability and adaptability of route is improved. However, there are still some points to be improved and they will be completed later.

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