Design and Implementation of the MANET and Internet Interconnection Based on AODV

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***Abstract*—In this paper, we present a solution of dynamic Ad-Hoc gateway to meet the urgent needs of interconnecting MANET to Internet. Comparing with the common fixed gateways, we integrate AODV with Mobile IP, eliminate the broadcast of Mobile IP by carrying the information in existing AODV messages so improve the performance remarkably. In this paper, we give the system's architecture design and its functional entities' module implementation. Finally, a simulation result is shown to evaluate the performance.**

Keywords-MANET; AODV; dynamic gateway;interconnect

I. INTRODUCTION

A mobile ad-hoc network (MANET) is a set of nodes which are self-configured and organized dynamically. Each node could move independently in MANET and each node is also could be a router. MANET routing protocols such as AODV [1], DSR [2], OLSR [3] are used to detect and maintain the route between the nodes. Ad Hoc network is an independent mobile network. Any two nodes in the network can communicate with each other freely. But in practical application some mobile nodes need to access Internet resources. The independent Ad Hoc network can not meet such demand. Only by interconnecting between Ad Hoc network and Internet, we can exert the potential of Ad Hoc network.

The mobile Ad hoc network (MANET) and Internet use the different routing methods. If we want to achieve the seamless interconnection between them, we should need a special gateway between the Ad hoc network and the Internet. In this paper we give a solution of ad-hoc dynamic gateway based on Ad hoc On-Demand Distance Vector (AODV) and mobile IP to solve this problem. In this solution we focus on how to modify the AODV protocol and Mobile IP to support interconnection with the Internet.

The rest of this paper is organized as follows:

Section II gives introduction to Ad-Hoc Routing protocol and mobile IP. Section III designs and implements the dynamic gateway. Section IV shows the performance evaluation results. Section V draws conclusions.

II. RELATED WORKS

A. Overview of Ad-Hoc Routing protocol

There are many Ad-Hoc routing protocols, according to the routing strategy they can be categorized as table-driven and on-demand shown as fig.1:

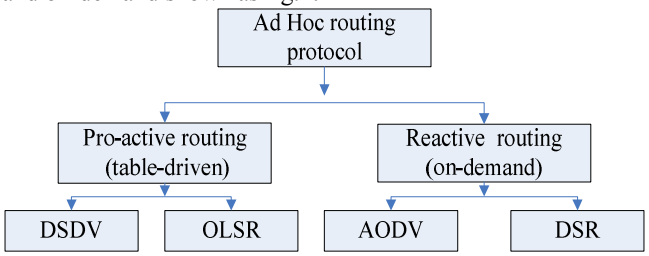

Figure 1. Ad-Hoc protocol

In this article we choose the on-demand protocol because it has the following advantages:

- Less traffic during route maintenance.
- Fast reaction on restructuring and failures.

AODV is a typical on-demand routing protocol. The mobile node only has the route what it needs. Consequently, the node maintains a routing table which contains route entries only to destinations it is currently communicating with. Each route entry contains same fields such as Destination IP Address, Next Hop, Hop Count and Lifetime. AODV guarantees loop-free routes by using sequence numbers that indicate how fresh a route is.

- Route Discovery

When a route is needed, a node broadcasts a route request (RREQ) message and sets a timer to wait for the reception of a route reply (RREP) [1]. If the source does not receive any RREP before the RREQ timer expires, it broadcasts a new RREQ with an increased time to live (TTL) value.

- Route Maintenance

When an active link breaks, the node broadcasts a route error (RERR) message that contains the IP address of each destination that has become unreachable. The routing table will delete this route entry which contains this destination.

B. The use of mobile IP in this article

Mobile IP [6] allows mobile nodes to have seamless access to the Internet while roaming between different networks.

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In this article we use the mobile IP to fulfill the Internet connectivity. We integrate Mobile IP with AODV and eliminate the broadcast of Mobile IP by carrying the information in existing AODV messages. As the result, the traffic generated by mobile IP reduced greatly.

III. DYNAMIC GATEWAY DESIGN AND IMPLEMENTATION

In traditional AODV don't have the concept of the gateway. We will add gateway function by amending AODV control messages. Then we will introduce in detail.

A. Data Structure

First of all, AODV protocol introduces several tables which are used to store the related gateway information. Detailed introduction is shown as follows.

- Gateway table

Each MANET node maintains a gateway table which records the gateway information. There is an item in the table recording which gateway we have registered with. When the MANET nodes hope to register with the gateway, they will inquiry the gateway table to select a suitable gateway.

- Node table

Each gateway node needs to maintain a node table to record the current active nodes in the Ad Hoc network. AODV protocol don't maintain the entire network topology, we must judge the routing request (RREQ)where it wants to go through the gateway. If it wants to communicate with Internet, the gateway will make a RREP to the source node to set up gateway routing. Then the data packets will be sent to gateway which will transmit this data to internet by mobile IP. If it wants to communicate with the node which locates in the MANET, the gateway node will forward the RREQ to neighbors.

The remaining data structures such as routing tables has been achieved by traditional AODV protocol. Here will not describe in detail.

B. The change of the gateway messagess

Traditional gateway messages are broadcasted through the mobile IP. In our subject we do not use the gateway messages which are broadcasted by mobile IP. Because AODV protocol broadcast the HELLO message periodically, it can instead of mobile IP broadcasting news to avoid redundant messages. If we want to use the HELLO message to complete this function, we must alter the HELLO message. Many existing methods add a flag for AODV control messages to determine whether it comes from gateway. But in my issue, we amend the reserved bits. And the length of control messages don't increase.

Fig.2 and Fig.3 describe the format for the pre-HELLO message and the modified HELLO message respectively.

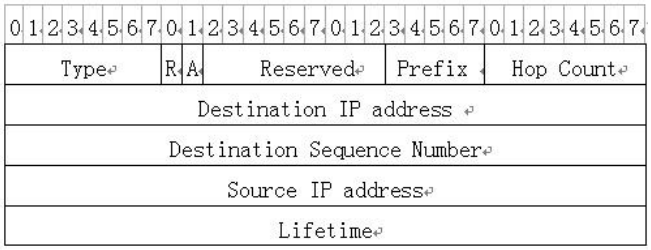

Figure 2. pre- HELLO message

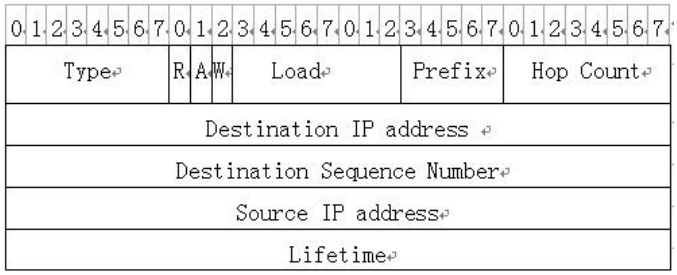

Figure 3. revised HELLO message

We use the first bit (W) of reserved bits as a flag to determine whether it comes from the gateway (if the w is 1,it is from gateway else from ordinary node). And the last 8 bits is load. The load is the selection standard of optimal gateway.

The other AODV control messages such as RREQ, RREP also have been amended like HELLO message to propagate gateway information.

C. gateway discovery and selection based on AODV

In this issue we want to realize the dynamic gateway, that is, each node can be used as gateway and that can also be used as an ordinary node. Firstly, in our subject, we add the network card detection module to judge the node being a gateway node or an ordinary node. When they find the node has internet access (through the card detection module), the node think that it is the gateway, and it will send the control messages which has been shown in Fig.3. Else, it will send the original control message as shown in Fig.2.

When the ordinary node receives the control messages which contain the gateway signs, they will add a routing entry which will be marked gateway in routing table, and add this entry into the gateway table simultaneously . Because every route exist short time in AODV protocol, when route has expired, the ordinary AODV protocol directly delete this route. But in my algorithms, if the route is gateway route, we are sending the RREQ of the destination address 255.255.255.255 to ensure the gateway existence in our routing table except the gateway break. If the node receives the RREP with the destination 255.255.255.255, it will add this route entry in the routing table and gateway table. If the node does not receive the control message with the gateway signs 20 second, it will broadcast the RREQ with destination address 255.255.255.255 to search gateway.

We use the AODV protocol control information (such as HELLO messages or RREQ message) to carry the load and

TTL value. The node selects the best gateway to register according to load and TTL.

We use the formula to select optimal gateway.

$$M=0.8*\alpha+0.2*\beta \quad (1)$$

The TTL (α) is the distance. The number of nodes which have registered at the gateway is called the LOAD (β).

We can select the optimal gateway according to the formula above.

D. Implementation for mobile IP

There are two main solutions for the connection of MANET and Internet. One is mobile IP, the other is NAT. We use the mobile IP to realize the dynamic gateway. In the Ad Hoc network, each node has the IP address. They do not occupy Internet IP resources, but some of the private network segment of the IP address. These nodes want to visit the Internet must through the gateway to communicate with Internet. In order to finish the gateway function, we choose the mobile IP to transfer the data packets.

When the mobile IP and AODV have launched simultaneously, we need to switch off mobile IP gateway search function. Because we can use the AODV control messages to complete the function of search gateway, it will reduce the network overhead.

E. Combination use of AODV and mobile IP procedure

In order to implement the connection with MANET and Internet, we need the AODV procedures and mobile IP procedures running simultaneously. So the two procedures required to deliver the optimal gateway address and the number of gateway load. MANET nodes receive control message with gateway sign, based on the above Gateway optimal formula which have been introduced to choose the best gateway.

Why the two procedures should transfer the gateway address, the reason is to finish the registered function of mobile IP. That is, select the optimal gateway through AODV procedure, then transfer this address to mobile IP registered module, and send the corresponding registered messages to gateway.

In this issue, we use one of the many process communication methods, semaphore + document, which are used to transfer the address and load.

F. Switching and load balancing problem

MANET networks are changing any time. If a better gateway for a node appears in the MANET which will lead to switch question. The node will send cancel message to the gateway which has been registered currently. This not only can balance the load of the gateway, but also can reduce the hops to destination host.

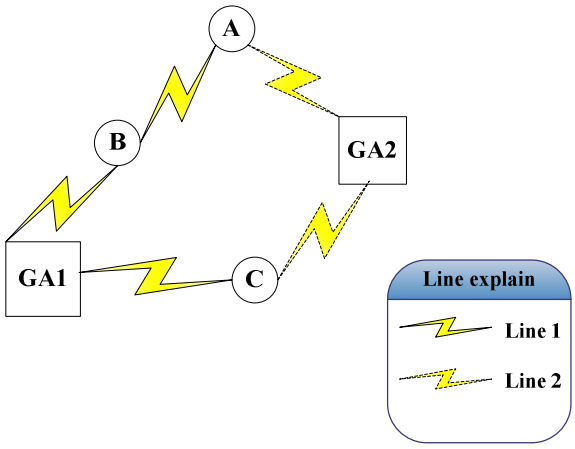

Figure 4. Switch

Examples of switching process:

In the Fig. 4 A, B, GA1 and GA2 are the nodes in the MANET. The GA1 and GA2 are gateways, C is home agent (HA) of A.

Process 1: When GA2 does not exist in the entire network, if A and C want to communications, the route is A-> B-> GA1-> C.

Process 2: When GA2 adds into the network, because GA2 jump from A only 1 hop, GA2 will be the best gateway for A according to formula. Then A will choose GA2 to register and cancel the registration with GA1 simultaneously. At last the route is A->GA2-> C.

IV. Environment And Running Process

A. Experiment Environment

In my environment there are three notebook PC as MN or HA and two PC as GA (gateway) as shown in Fig. 5.

MN1, MN2, GA1 and GA2 are ad hoc nodes .The have the private network address (192.168.0.*) in ad hoc network. Gateway node (GA1 and GA2) has an Ethernet interface. All nodes in ad hoc subnet access the internet through gateway interface. Their IP are 59.64.132.32 (GA1) and 59.64.132.45 (GA2). When the source nodes know the gateway IP then they can communicate with the internet.

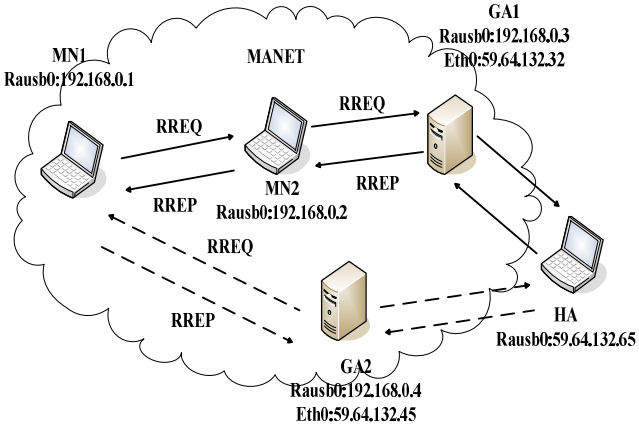

Figure 5. environment

B. *Running process of AODV and mobile IP*

Firstly, in our network don't have GA2.The running process will be described as follows.

1) When MN1 wants to communicate with HA, it will inquire the routing table then they will find that have no route to the HA. Then it sends the RREQ to search the route to HA. The message will be broadcasted in the Ad hoc network.

2) When MN2 node receives the RREQ, it will analyze Destination IP Address field value of RREQ which is not its IP address. Then MN2 broadcasts the RREQ to the GA1, and to set up the reverse route to MN1.

3) When GA1 node receives the RREQ, it will analyze Destination IP Address field values of RREQ which is not its address field. Because GA1 is also the gateway in MANET, it will search the node table which has been mentioned above. But node table does not have this address, then the GA1 will reply a special RREP to MN1. RREP will follow the reverse route back to MN1. Then MN1 sends the data packages through MN2, GA1 to HA.

4) In the process of sending data, GA2 joins in the network. GA2 is the optimal Gateway for MN1 by calculating the M value .Then MN1 SendS cancel registration messages to GA1 and sends the registration message to GA2 simultaneously. In the process of sending data, we will find the route from MN1->MN2->GA1-> HA to MN1-> GA2-> HA.

V. SIMULATIONS

To evaluate the proposed approach, we have implemented a prototype in the Network Simulator to compare the overhead of mobile IP over original AODV and the mobile IP over our modified AODV. We research the topology, a 30 node network over a 1200mx1200m square area .The simulation time is 100s.

With the changes in different conditions, the following figures can show the differences among original AODV over mobile IP, modified AODV over mobile IP.

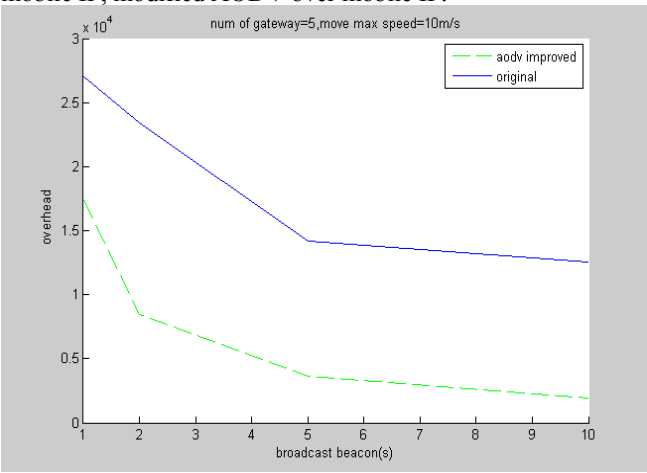

Figure 6. Overhead by varying Beacon Intervals

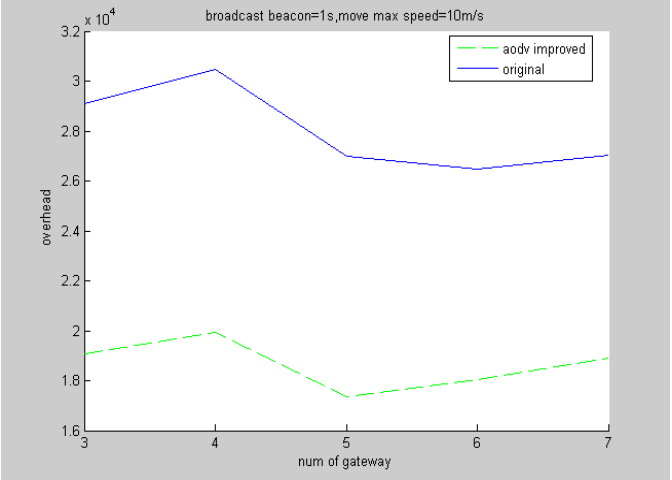

Figure 7. Overhead by varying mum of gateway

Fig.6, Fig.7 contrast the overhead among the pure and improved protocols. We can draw a conclusion that the overhead of modified protocol has been reduced greatly than the pure protocol.

VI. CONCLUSION

This paper presents a method for MANET access to the Internet through dynamic gateways based on AODV and mobile IP. The gateway discovery, gateway selection, data transmission and gateway switch procedures are introduced. The solution also has been implemented and evaluated in Network Simulator. The solution could reduce the network overhead and make modification to AODV to improve the performance greatly and complete the gateway discovery and so on.

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