IMPLEMENTATION OF GEOCAST-ENHANCED AODVbis ROUTING PROTOCOL IN MANET

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ABSTRACT

Mobile Ad Hoc Network (MANET) represents a complex distributed system that enables seamless internetwork in areas with no pre-existing communications infrastructure. Far less effort has been done on the real-world basis, with intensive evaluations through simulations. This paper outlines our experiences with the implementation of MANET testbed based on geocast-enhanced AODV-bis module. AODV-bis is an improved design of MANET routing protocol, from the lessons learned beyond the Experimental RFC AODV effort. The main goal of our research is to develop and verify the practicality of AODV-bis (Ad-hoc On-Demand Distance Vector-bis) routing protocol, featuring path accumulation. To enhance AODV-bis, location information is utilized during route discovery to limit forwarding zone by geocasting. It can be done with only little modification of packet format. We found that AODV-bis, compared to AODV, is a more powerful routing protocol especially in disseminating route information. Its overall performance is further improved with the aid of geocasting.

1. INTRODUCTION

The novel MANET is a collection of mobile computing devices that communicate via wireless links, without the aid of infrastructures. Its topology changes unpredictably and nodes are free to join or leave arbitrarily. Unlike Wireless LAN, MANET, as illustrated in Figure 1, does not rely on centralized administration and the control of the network is distributed among the nodes. Each node may function as a router to assist others searching for route. The applications of self-organized MANET are vast. It can be used in emergency services, conferencing and instantaneous classroom, home or community networking and battlefield communications.

An adaptive and robust routing protocol is necessary to cope with the dynamic nature of MANET. Classical routing protocols that were designed for static, wired environment can no longer [1] apply to MANETs due to node mobility and the fluctuating wireless channel. Consider the fact that mobile devices have limited power and radio transmission consumes extra energy, the activity of the radio interface should be limited. Regular sending and maintenance of topology updates by proactive routing consume large power and memory. They also tend to increase congestion and must be avoided. On-demand routing protocol eliminates redundant route table, resulting in lower traffic congestion. With less frequent control packets, processing requirements are reduced. As such, reactive protocols are more suitable for small low-power units with high mobility in MANET.

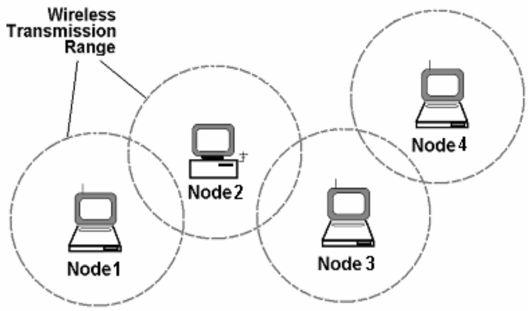

Fig. 1 *Mobile Ad hoc Network (MANET)*

Over the past several years, more than 50 MANET routing protocols have been proposed. However, many of them are evaluated on the basis of simulation results. In reality, connectivity and performance of MANETs are affected by several factors [1] and simulations cannot account for all of them. Moreover, simulation often makes many assumptions that are restricted to the expertise level of the researcher. Such limitations [2], therefore, motivate us to implement and evaluate ad hoc routing protocol in a real wireless MANET testbed.

The rest of this paper is organized as follows. Overview of AODVbis routing protocol is briefly discussed in Section 2 followed by geocast enhancement in Section 3. Next, we outline our implementation experiences of MANET testbed based on AODVbis routing protocol and its findings in Section 4. Finally, concluding remarks are made in Section 5.

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2. AODV-bis ROUTING PROTOCOL

AODV [3] has been promoted to Experimental RFC of IETF MANET charter [4] since July 2003. AODVjr [5] effort investigated an approach to simplify the overall AODV design. It is done in simulation, and has proved that for networks of limited size, reliable communications can be managed by implementing only a very limited number of AODV features. Thus, AODV-bis was proposed as MANET WG Internet draft [6] in October 2003. Many features are no longer mandated in AODV-bis compared to AODV, several redundant protocol semantics. These modifications are important especially for resource-limited mobile computing devices such as wearable computers.

AODV-bis incorporates new performance enhancements and simplifies the requirements for implementations based on experiences gained during the development of AODV. The modularity of AODV-bis aids IETF MANET WG's effort towards the convergence and standardization of MANET routing protocols. Three defined packet types are Route Request (RREQ), Route Reply (RREP) and the optional Route Error (RERR).

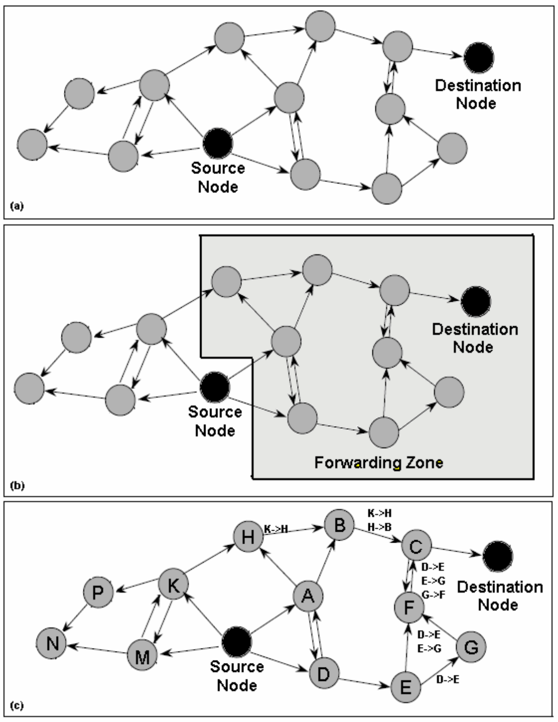

Fig. 2 (a) RREQ Broadcast. (b) Geocast-Enhanced Route Discovery. (c) Path Accumulation Feature.

AODV-bis is enhanced with the Path Accumulation (PA) feature (Figure 2(c)) with which the path from either the routing table or control packet may be used to route an RREP back to the requesting node during route discovery. This is an added advantage especially for nodes with limited resource since they can opt not to record the route during RREQ flooding. Instead, route information can be obtained directly from RREP packet. In addition, PA enables dissemination of route information during route discovery. Whenever a node receives an RREQ, it might update its route table for every path node listed in Accumulation Path List (APL). Consequently, the number of route discovery and broadcast messages is decreased. This is critical when the traffic internal to MANET is high. The PA feature is the preliminary attempt to converge AODV with Dynamic Source Routing (DSR) [7] before standardizing the ad hoc routing protocol.

In contrast to AODV, beaconing in AODV-bis is invoked only when the node is participating in the routing of data packet. This prevents an inactive node from continuously beaconing *HELLO* messages to its neighbor(s), resulting in the waste of resource and possibly traffic congestion. Precursor Lists feature is removed with the introduction of PA in AODV-bis since route updates can be done on each path node appended in RREQ and RREP. In addition, expanding ring search deployed by AODV has been proved [8] to cause the highest latency. Other major differences between AODV-bis and its previous versions can be found in the improved version of AODV-bis I-D [6]. It is important to develop and thus study the performance of AODV-bis to determine the essential features of routing protocol required by MANET devices with limited resources.

3. GEOCAST ENHANCEMENT

As illustrated in Figure 2(a), RREQ is broadcasted to all reachable neighbors in both AODV and AODV-bis. According to IEEE 802.11, each receiving nodes must process every single broadcast message it receives. Frequent broadcast causes network congestion, possibly broadcast storm, and degrades the performance of routing protocol. This is proved by several performance observations [8] that the number of RREQ in the network increases linearly with the node population. The ratio of control packet over data packet even reaches 5000 in one of the experiments.

As such, we suggest utilizing geocast mechanism to enhance AODV-bis. Geocasting defines request zones based on the expected location of the destination node during route discovery. By restricting the forwarding area to request zone, routing overhead in MANETs is reduced significantly especially in a dense network. Position information can be obtained from any location detection tool. In Figure 2(b), RREQs are forwarded only to the request zone. Simulation work [9] has proved that with the aid of position information, saving of wireless bandwidth could be achieved since RREQ is only sent to a restricted search area.

To enhance our AODV-bis routing module, a GPS-free location tracking tool is installed in each participating node of the testbed. First route discovery is carried out as described in the I-D [6]. Once the route to destination is found, the distance between source and destination is calculated based on the signal strength by the location monitoring tool. In case of link breakage, subsequent route search is initiated based on geocasting. According to Figure 3, RREQ will only be forwarded by neighbors who have shorter distance to reach the destination node compared to the distance between source and destination (e.g. DIST(ad) < DIST(sd)). To enable geocasting in AODV-bis, packet format modification is required by adding *Distance* field in RREQ message.

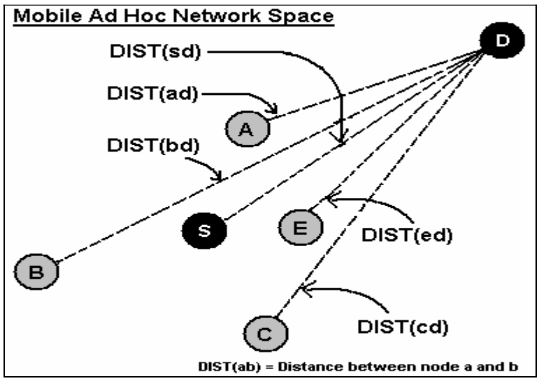

Fig. 3 *Location-Aided Route Discovery*

Geocasting reduces routing overhead due to regular broadcast of RREQs. As node position is utilized only in the route discovery phase of AODV-bis, we avoid the waste of a large portion of wireless bandwidth caused by periodic updates of routing tables in pure geographical forwarding (considered as a proactive routing protocol).

4. DEVELOPMENT AND IMPLEMENTATION

4.1. Testbed setup

AODV-bis protocol is essentially a network protocol. It is implemented within IP so that IP applications can be supported transparently. All AODV-bis packets are sent to port 654 using User Datagram Protocol (UDP).

A multi-hop MANET testbed has been set up and verified successfully based on AODV-bis. Both laptops and PDAs that build the testbed are configured to run in ad-hoc mode, Wi-Fi capable, and conform to IEEE802.11b. Laptops and PDAs run on Linux RedHat and Familiar [10], which is based on Linux kernel respectively. Linux is chosen as our developing platform due to its openness that provides access to the network protocol stack freely. AODV-bis routing daemon and the GPS-free location monitoring tool run in kernel and user space respectively.

Our AODV-bis routing module is developed as a Loadable Kernel Module (LKM) by using C language in the kernel space. It does not only [11] save memory and ease configurations, but most importantly, it avoids the costly kernel-to-user crossing for store-and-forward and improves overall efficiency. Delay caused by the crossings degrades the performance of the on-demand routing algorithm, which already has higher latency over proactive routing protocol during route establishment. Netfilter is used in our code to capture incoming and outgoing packets into AODV-bis functions.

4.2. Experimental testing and findings

Figure 4 illustrates the logical view of the experimental 7-hop MANET testbed. The developed routing module has been tested to verify the operation of AODV-bis with the aid of MACKill [12] tool. MACKill is used to filter packets by MAC addresses of nodes we wish to block at link layer. This enables testing and debugging tasks to be done in a close physical distance to each other. Initially, all nodes are inactive after AODV-bis routing module is invoked. There is no communications (no beaconing) among them. During the test, node A sends a *PING* to H, whose route is unknown to A. Output handler detects the unknown destination IP and invokes AODV-bis module to create and broadcast RREQs to its neighbor.

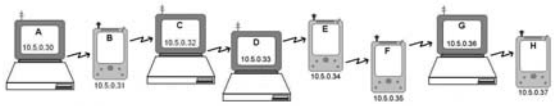

Fig. 4 *Logical View of 7-hop MANET Testbed*

The outcome is reflected on the log messages generated by A, in Figure 5. Node A's sequence number, which is introduced to ensure loop-freedom, is incremented once a *PING* is sent. This could be noticed from the log of Figure 6. When B gets the RREQ and has no route to H, it appends itself in the RREQ's Accumulated Path List (APL) and forwards the packet to its neighbors. At the same time, it updates its route table and starts beaconing *HELLO* messages until the node becomes inactive. The same happens in all participating nodes. They update their route table by adding the corresponding route information. When C receives the forwarded RREQ from B and if the route to node H is unknown, it appends itself in APL and forwards it. Otherwise, C generates and unicasts an intermediate RREP towards originator A. In the experiment, we set the Destination flag (D-flag) of RREQ. Thus, the latter case does not apply. The same process is carried out in Node D to G. Finally, the intended destination node H generates and unicasts RREP towards A, via the path recorded in APL, when it receives the forwarded RREQ from G.

Once A receives the forwarded RREP from B, it updates its route table by creating a new route entry for each corresponding APL node, resulting in the route table shown in Figure 6. Also, note that all path nodes to reach Node H are recorded in the route table. Now onwards, any data packet destined for H can be routed through Node A as long as the route is active.

Compared with AODV, AODV-bis is a more powerful routing protocol especially in route dissemination. Running similar test as described above but based on AODV produces little route knowledge for each MANET node. According to Figure7, each participating node knows the route to reach any node in the testbed with the path accumulation feature in AODV-bis. However, AODV node only has the route knowledge of its neighbor, packet originator and destination. It must run route discovery if it intends to reach other node, resulting in higher processing time, network load and consequently performance degradation.

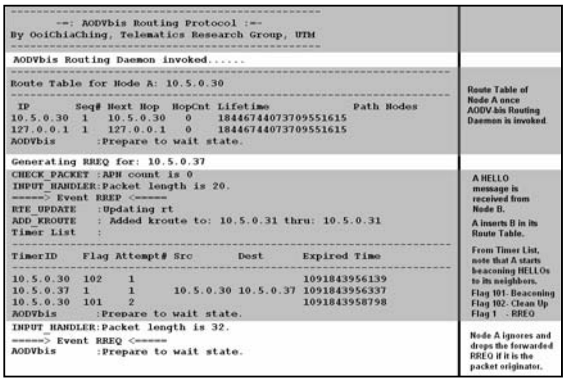

Fig. 5 *Log messages of Node A: HELLO invocation*

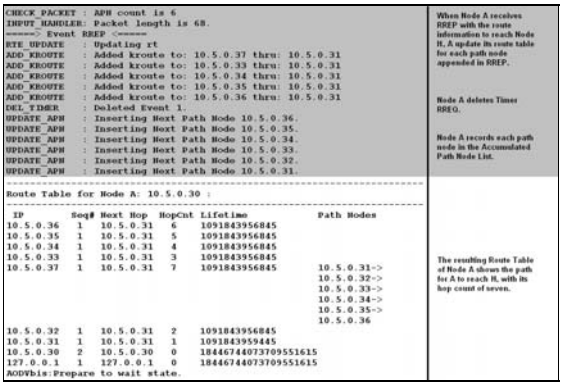

Fig 6 *Log messages of Node A: Route Table with Accumulated Path Nodes*

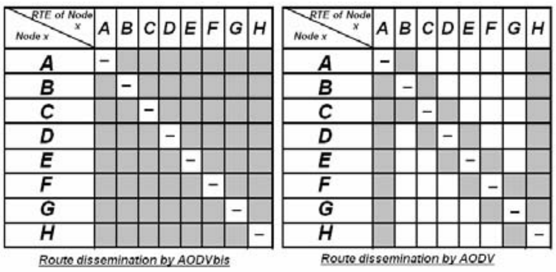

Fig. 7 *Comparison of Route Disseminations*

Geocasting feature is tested and verified on the same testbed. AODVbis retrieves distance value from distance table generated and updated regularly by GPS-free tracking program. As described in section 3, subsequent route discoveries replace broadcast with geocast mechanism, leading to RREQ flooding in a limited forwarding zone, as shown in Figure 3. Number of RREQs forwarded in MANET is reduced significantly especially in dense network, resulting in less routing load. Consequently, the cooperation of PA and geocasting with AODV-bis improve its overall performance with lower control overhead.

5. CONCLUSION

MANET technology has been receiving increasing attention among researchers in recent years. This paper details the implementation of AODV-bis that makes use of advantages from both on-demand and distance vector characteristics. Compared to AODV, the modularity of AODV-bis helps IETF MANET WG's effort towards convergence and standardization of MANET routing protocol. While PA feature is designed to increase route dissemination, geocast enhancement further decreases the number of broadcast within MANET. Position-based RREQ forwarding prevents the messages from flooding the whole network, leading to significant message savings. Consequently, the overall performance of AODV-bis routing protocol is improved.

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