Dynamic Agent Advertisement of Mobile IP to Provide Connectivity between Ad Hoc Networks and Internet*

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Abstract. Although the Ad Hoc On-Demand Routing Protocol (AODV) is well designed for the ad hoc network, it does not deal with Internet connectivity. While some of solutions are proposed for integrating the ad hoc networks with global Internet, there are some limitations and drawbacks. In this paper, we propose the dynamic agent advertisement to reduce the control packets overhead and the power consumption due to a redundant packet processing. We use ns2 to compare the proposed approach with the existing solutions in terms of the overhead and throughput for packet transmission.

1 Introduction

In recent, the proliferation of mobile communications and multimedia services has made mobility support on the Internet an important issue. This trend has led to the introduction of new protocols to Internet. In this paper, we examine a recently Ad Hoc On-Demand Routing Protocol (AODV) and the Mobile IPv4 (MIP) standard from the perspective of Internet connectivity over wireless environments [1,2].

MIP, supporting a macro-mobility at network layer, is the oldest and probably the most widely known mobility management proposal. The MIP allows the mobile node to move around the world with Internet connectivity. The AODV is generally viewed as a stand-alone network, where communication is only supported between nodes in the specific ad hoc network. The lack of connectivity to the wired infrastructure enables simple management and deployment, but limits the applicability of ad hoc network to scenarios that require connectivity outside the ad hoc network.

From the view point of Internet mobility, some of MIP-based proposals for providing Internet connectivity in ad hoc environments are proposed. The challenge to enable such support stems from the need to provide good connectivity

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in a dynamic, resource poor (i.e. limited power and bandwidth) environment[3]. However, the proposed solutions have several drawbacks over integrating environments. In this paper, we propose the dynamic agent advertisement to provide good connectivity with reduced overhead and to achieve good performance when mobile nodes move a new subnet. In our approach, we suggest the mobility agent located at boundary between ad hoc network and fixed network advertises its information to ad hoc network with two different lifetimes and two different advertisement scopes. The proposed approach combines the advantages of both MIP and AODV. The remainder of this paper is organized as following. Section II examines the tradeoffs between using advertisement and solicitations. In Section III, we describe our protocol and optimizations. The performance of our approach is detailed in Section IV and Section V concludes the paper.

2 Related Works

2.1 Connectivity for Mobile Ad Hoc Networks

There are several researches on extending MIP capabilities to an ad hoc network for supporting global roaming and Internet connectivity. These approaches are broadly divided into three classes in aspects of movement detection and finding mobility agent.

- First one mainly depends on the periodic advertisements from mobility agents (called as gateway): This approach provides good connectivity, but imposes a high overhead, especially when not all the nodes in the ad hoc network require Internet connectivity.
- Second one primarily uses solicitation method: such approaches have the overhead of maintaining connectivity to external traffic patterns but negatively impact the mechanisms necessary for MIP such as agent discovery and movement detection.
- The hybrid approaches utilize solicitation and advertisement signaling between a MANET node and the gateway. It still has traffic overhead and delay for registration.

Although the existing solutions provide Internet access for ad hoc networks, the solutions continue to suffer from several drawbacks as specified following. The most significant of which is high overhead of foreign agent advertisement messages (flooding). MIP relies on link-layer broadcasts to provide foreign agent information to interested nodes. However, these broadcasts can prove to be extremely expensive in a ad hoc network where a broadcast translates to the packet being flooded throughout the network. To reduce the flooding of advertisements, some schemes increase the beacon interval (i.e. the interval between successive advertisement floods). However, these increased interval cause to degrade the handoff performance of MIP due to delayed movement detection. Second, some protocols have an overhead for route maintenance. If not all the nodes in ad hoc

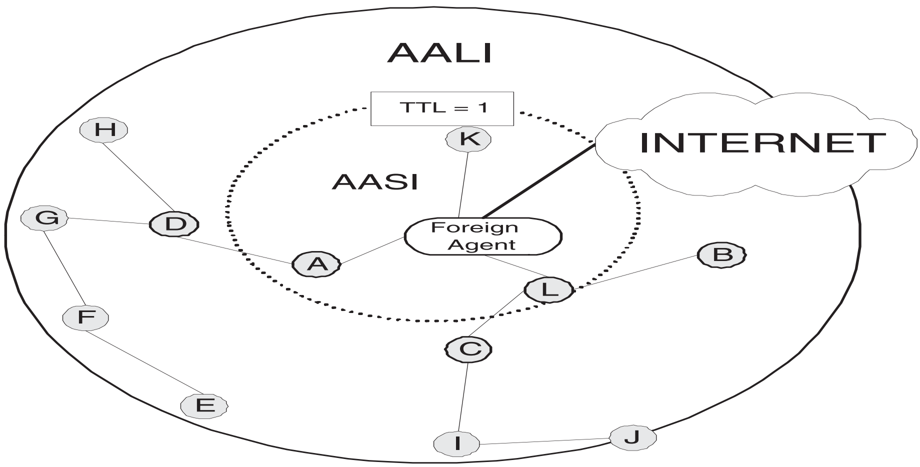

Fig. 1. Two types of agent advertisement

network require connectivity, the AODV's route maintenance can have a negative on the AODV due to excessive flooding overhead. Third, it is not useful that Agent advertisements set up reverse routes to the mobile node over frequently moving.

3 Dynamic Agent Advertisements

In this paper, we propose on demand Internet connectivity in ad hoc environments for achieving low handoff delay and low burden. The proposed approach is based on MIP for connecting an ad hoc network, in which AODV is used, to the Internet. While the purpose of the registration process in MIP is to update the binding information between the home address of mobile node and its current care-of address, the aim of AODV is to inform MIP in the mobile node, with having active route, of changing subnets (or a new AODV network). The proposed approach uses two kinds of advertisement in foreign agent so that the AODV's scarce resources are not further burdened with MIP overhead and the required information is received on demand.

- Agent Advertisement message with Short beacon Interval (AASI): All values in this message are identical to agent advertisement message in MIP (its advertisement scope is limited to one hop from mobility agent).
- Agent Advertisement message with Long beacon Interval (AALI): The message is identical to agent advertisement message of MIP, except with longer registration lifetime and larger time-to-live value (i.e. registration lifetime is over 300sec and TTL is set to 200).

In fig 1, the proposed model consists of three components: the foreign agent, inner nodes, and outer nodes. The foreign agent is responsible for routing packets between the ad hoc network and the Internet. While AASIs are periodically flooded within one hop from the foreign agent, AALIs are broadcasted through the whole ad hoc network. All nodes within one hop from foreign agent are notated as inner nodes (e.g. A, K, L in fig 1), and all nodes outside one hop range from foreign agent are depicted as outer nodes (e.g. B, C, D, etc in fig 1). In this paper, we assume that nodes in an ad hoc network that want Internet access use their home address for all communication and register with a foreign agent.

3.1 Agent Discovery

In the traditional MIP the movement detection is accomplished by receiving agent advertisement. Unfortunately none of the move detection methods provided MIP is suitable because of the on demand property and the multihop nature of ad hoc networks [6][7]. In this paper, the mobile node can find out a new mobility agent with one of following three methods.

- If the mobile node has one more active route, it can identify a new mobility agent with the extended RREP (e-RREP, Section 3.5).
- If the mobile node is located within one hop from a foreign agent, it can detect a new mobility agent by receiving AASI.
- If the mobile node has no active route, it can identify a new mobility agent with unicast solicitation message.

The movement detection in the proposed approach is archived by using routing update events and the extension of RREP.

When the event which the route for the destination is updated is occurred, the AODV compares the existing mobility agent (or gateway) with a fresh mobility agent included in the received RREP (e-RREP).

If the mobile node receives a new e-RREP including the different mobility agent information with the existing mobility agent, it first determines the hop count of the new e-RREP is smaller than the hop count for the existing mobility agent. If the hop count of the new e-RREP is smaller than the existing hop count, it immediately updates its mobility agent. Otherwise, it must wait some period. It updates the mobility agent if it does not receive another e-RREP message during waiting time. The mobile node without ongoing communication, it is valid that the mobile node is non-sensitive to the handoff delay. In this paper, the mobile node which has no active route finds out a new mobility agent with the unicast agent solicitation. If the mobile node is stayed in one hop from mobility agent, it can detect its movement with AASI. This procedure is the same as in that of the traditional MIP.

3.2 Registration

Once a node has recognized that a new mobility agent is available in a new ad hoc network, a node should register with a home agent via the new mobility agent. The registration procedure is almost the same as in the traditional MIP, except that the registration request may have to traverse multiple hops before reaching the foreign agent (and vice versa for the registration reply). A mobile node generates Registration Request message with the same method in standard MIP[1]. The foreign agent and home agent process the registration message as specified in [1] by recording the new care-of address for the mobile node. The foreign agent can utilize the AODV route discovery procedure to rediscover a route to the mobile node for delivering the Registration Reply message to the mobile node.

3.3 Routing

A mobile node does not initially know whether the destination node is within the ad hoc network, or whether it is reachable through the foreign agent. It therefore creates e-RREQ packet and broadcasts this packet to the whole ad hoc network.

This e-RREQ packet can be replied by one more nodes among three components:

- If an intermediate node receiving the e-RREQ have a valid route to the destination, it returns an e-RREP message including mobility agent information to the originator.
- If a mobility agent receives the e-RREQ, it first checks its visitor entry for the destination. If such an entry does not exist, it returns an e-RREP message with a large hop count to the originator (i.e. 200). That is, the mobility agent replies with a proxy ARP to the originator.
- If the destination node within an ad hoc network receives the e-RREQ packet, it replies an e-RREP packet including agent's information to the source.

If the destination exists within the ad hoc network, an e-RREP can be returned by both a mobility agent and the destination node (or an intermediate node which have a valid route to the destination node). In this case, if the mobile node receives e-RREP with large hop count from the mobility agent, it must store this route but wait some period because it is possible for the mobile node to receive an e-RREP from the foreign agent before it receives a route reply from the destination node (or a intermediate node) within the ad hoc network. Therefore, the mobile node should retain this route, and utilize it only after it has concluded that the destination is not located in the ad hoc network. Otherwise the mobile node receives a e-RREP from the destination, it can transmit data packets to that destination.

3.4 Operations for Ad Hoc Mobile Node

In this paper, mobile nodes in ad hoc network are divided into inner nodes and outer nodes. While AASI is only broadcasted to inner nodes, AALI is advertised

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<tr><td colspan="8">Type</td><td>R</td><td>A</td><td>G</td><td colspan="8">Reserved</td><td colspan="5">Prefix Sz</td><td colspan="8">Hop Count</td></tr>
<tr><td colspan="32">Destination IP address</td></tr>
<tr><td colspan="32">Destination Sequence Number</td></tr>
<tr><td colspan="32">Originator IP address</td></tr>
<tr><td colspan="32">Lifetime</td></tr>
<tr><td colspan="16">(maximum) Registration Lifetime</td><td colspan="16">Sequence Number</td></tr>
<tr><td colspan="32">Mobility Agent's address</td></tr>
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Fig. 2. Extension of Route Reply Message

to both inner nodes and outer nodes. When a mobile node receives an AALI, it records the IP address of the foreign agent, together with the sequence number of the Agent Advertisement, in its foreign agents list. It then assigns long registration lifetime to that entry. That is, outer node should not change this entry until it receives another agent advertisement from a new foreign agent or a Router Error (RERR) message from any inner node. Since an AASI is broadcasted within one hop from the foreign agent by the foreign agent, outer nodes can not maintain foreign agent information timely fashion. For solving this limitation, inner nodes are responsible for monitoring and detecting the reachability of the foreign agent. If an inner node does not receive an agent advertisement within an advertised lifetime of AASI, it sends unicast-solicitation to foreign agent. If an inner node can not receive any agent advertisements after broadcasting three successive solicitations, it must broadcast Route Error message for foreign agent in the whole ad hoc network. If an inner node moves outer range of mobility agent, it will receive an unicasted agent advertisement with long lifetime from mobility agent.

3.5 New Message Types

When an intermediate node or a mobility agent receives e-RREQ, it must reply with e-RREP including mobility agent information. Fig 2 shows the extension of RREP specified in the standard AODV. Unless otherwise noted, the parameter values for the standard AODV are the same as those suggested in [2]. We extend the RREQ message and the RREP message for showing which it can support the proposed algorithm or not. For RREQ message, we add the 'C' bit in reserved filed in the traditional AODV standard for showing that a node supports the extensions for the Internet Connectivity. For the RREP message, we add the 'G'

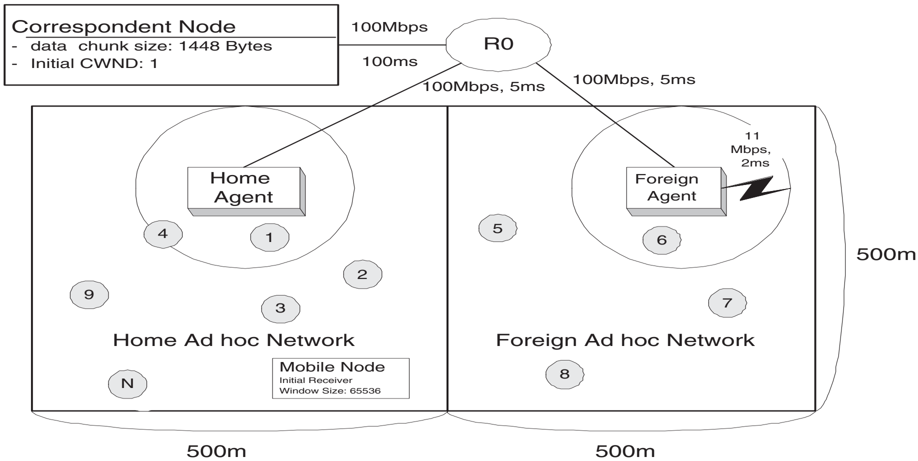


Fig. 3. Simulation Topology

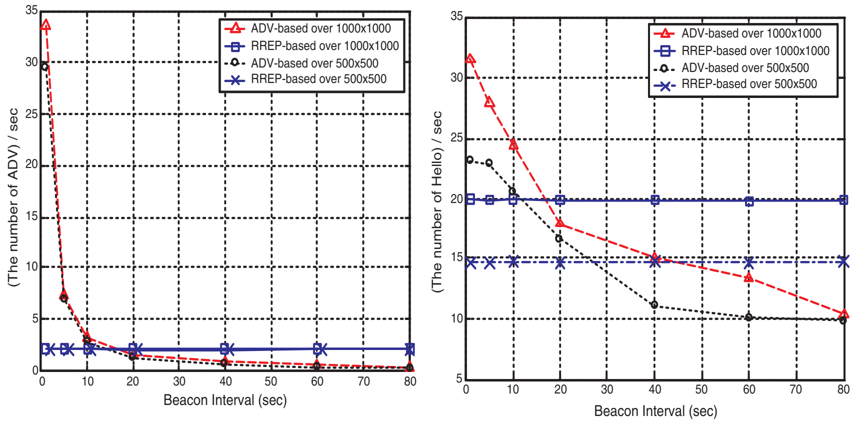
bit in reserved field in the standard AODV for indicating the RREP includes information of a new mobility agent and extend the message to include mobility agent information(see shaded portion of fig 2). The mobile node in ad hoc network can detect the subnet changing based this information.

4 Performance Evaluations

In this section we present a summary of our simulation results. The protocol is implemented in the NS-2 simulator with mobility extensions[4]. For generating random scenario, we use CMU's node-movement generator included in ns-2 2.1b9a. Unless otherwise noted, parameter values for MIP and AODV are the same as those suggested in [1,2], respectively.

4.1 Simulation Model

There are home agent and foreign agent running both AODV and MIP. There is one correspondent node on the wired network connected to both wireless domains through R0. Fig 3 illustrates this network configuration. There are three constant bit rate (CBR) traffic sources distributed randomly within each ad hoc network. The destination of each of the data sessions is the correspondent node in the wired network. The CBR data packets are 120 bytes and the sending rate is 66 packets per second. All mobile nodes move according to the random waypoint mobility model [5]. The Mobile node speeds are randomly distributed between zero and twenty milliseconds. The pause time is consistently 10 seconds. For our proposed approach, we assume that AASI is broadcasted with one second of interval and AALI is flooded with 180 seconds of interval.



(a) MIP overhead

(b) AODV overhead

Fig. 4. Mobile IP overhead and AODV overhead

4.2 Simulation Results

Fig 4(a) shows the difference in MIP overhead between the broadcast and the proposed approaches. Control packets may not be consuming large amount of bandwidth, but they may be too much to interfere with the transmissions. The MIP overhead is calculated with the number of advertisements per second and is counted on a per-hop basis, meaning that a packet that travels five hops is counted five times.

For the advertisement based approach (ADV-based), the number of beacon message is flooded within the whole network decreases as the beacon interval increases. In the ADV-based approach, two mobility agents flood each network periodically with their agent advertisements. According to the Fig 4(a), the MIP overhead of the ADV-based approach is sharply decreased at 5s and the number of advertisement per sec is one at 40s interval. The MIP overhead of the proposed approach is almost fixed to 2.1 packets per second because it limits the scope of flooding to one hop. Fig 4(b) shows the AODV overhead for each approach. In this simulation, we assume just six traffic source within the whole network and the interval for hello message is one second. If the number of active route rises, the AODV overhead simultaneously increases. For the ADV-based approach, the short beacon intervals cause the more redundant active route due to agent advertisement and result in increasing the AODV overhead (that is, all nodes in ad hoc network don't want to Internet connection). This also contributes to the degradation of throughput. The AODV overhead of our proposed approach is about 20 messages per second because its hello message overhead depends on the number of inner node and is independent of the beacon interval. Fig 5(a) illustrates the disruption time due to the handoff. To show distinct results, we assume the network partition (10m) between home ad hoc network and foreign

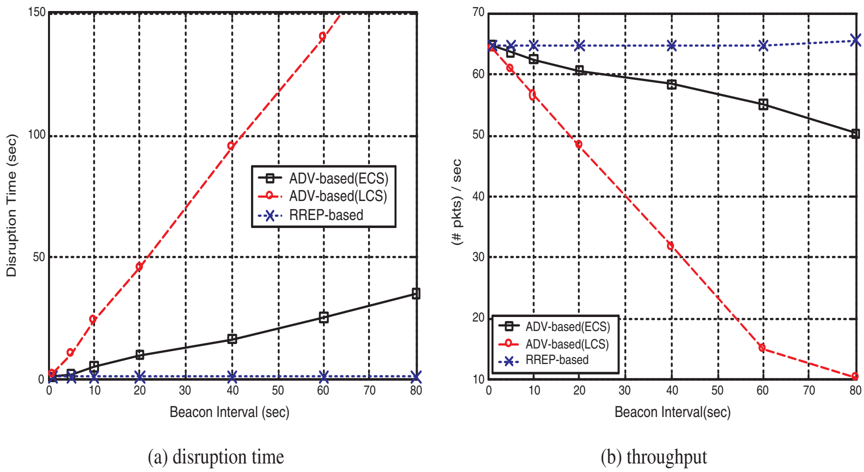


Fig. 5. Disruption Time due and Throughput at handoff

ad hoc network. Because the move detection methods provided by MIP highly affects the throughput. we compare the proposed RREP-based approach with the two basic solutions proposed in MIP.

- Lazy Cell Switching(LCS) is that a node registers its location with home agent as soon as it detects the unreachability to foreign agent. Other method proposed in MIP is Eager Cell Switching (ECS).
- ECS is that it assumes movement along a straight line and detects its movement as soon as a new agent advertisement.

The disruption time of LCS sharply rises as the beacon interval increases because of its waiting period. For example, an agent advertisement beacon period of 5 seconds results in an agent advertisement lifetime of 15 seconds. In worst case a node would wait 15 seconds. The increment of ECS is slower than that of LCS because it detects its movement on receiving a new agent advertisement. In the contrast, the proposed approach is fixed low disruption time because it is independent of the beacon interval. Fig 5(b) demonstrates the UDP throughput at receiver side for each method. Throughput is calculated such that, it is the number of the successfully received packet within the period, which starts when a source opens a communication, and which ends when the simulation stops. For both ECS and LCS method, While the movement detection time increases as the beacon interval increases, their performance is degraded as the beacon interval increases. However, the proposed approach is not depends on the beacon interval and its movement detection is determined by the routing update delay of AODV.

5 Conclusion

MIP and AODV protocols in a MANET can work together to support Internet mobility. In this paper, we propose dynamic agent advertisement of MIP to provide a good connectivity between ad hoc networks and global Internet while keeping flooding overhead costs low. Regarding MIP in mobile ad hoc networks, our proposal includes a new movement detection scheme using routing protocol. The proposed approach can support faster handoff than the movement detection of MIP because it detects its movement as soon as the route destined to the destination is updated. For network overhead, because the dynamic agent advertisement limit the periodical advertisement to one hop, it archives provide internet connectivity with lower burden than the overhead of the advertisement based approach. However, the proposed approach has some limitations when all nodes want to connect Internet or when the route of a node is changed frequently. This limitations is caused by the overhead per RREP because the frequent route change increases the number of RREP. Through the simulation results, we can see that the proposed approach achieve the best throughput for all case by using optimized route and eliminating the spurious packet transmissions. We believe that the work presented here is an important step towards supporting the connectivity between ad hoc networks and Internet.

Acknowledgements

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