An Analysis of Internet Integrated Mobile Adhoc Networks

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Abstract: **Mobile Ad Hoc Networking (MANET) is an emerging technology that supports self-organizing mobile networking infrastructures. MANETs can be extended by connecting with some other wired or wireless networks like Internet. As users wants freedom to the use of mobile devices, in home location as well as in roaming. The Mobile IP protocol has been developed as a solution for allowing users to roam outside of their home networks, while still retaining network connectivity. A number of technical challenges are faced today due to the heterogeneous, dynamic nature of MANET. This paper analyzes the issues in the connectivity of Internet with the Mobile Adhoc Network.**

I INTRODUCTION

In recent years there has been a rapid growth in mobile communication. Mobile Adhoc NETworks (MANETs) are very popular solution in the situation where network infrastructure is not available. Mobile Ad hoc Network are autonomously structured multi-hop wireless links in peer to peer fashion without aid of any infrastructure network. Due to lack of infrastructure support, each node in network act as router, coordinating to forward data packets to other nodes. Rapid progress in portable computer technologies allows MANET to be used in number of areas such as military application, industrial and commercial areas.

A mobile ad hoc network is a network formed and functioning without any established infrastructure or centralized administration and consists of mobile nodes that use a wireless interface to communicate with each other. These mobile nodes serve as both hosts and routers so they can forward packets on behalf of each other. Hence, the mobile nodes are able to communicate beyond their transmission range by supporting multi hop communication.

Since there may be multiple hops to the gateways, an unsolicited gateway change at an intermediate node may break the source node's return traffic flow, because it will not be triggered to re-register with the Mobile IP foreign agent at the new gateway. Another problem is related to addressing. Consider an ad hoc network where the IP addresses of nodes are strictly used as identifiers without any prefix semantics. This might be the case if visiting nodes use their home addresses in a foreign ad hoc network where one or more Mobile IP foreign agent gateways hide these *alien* prefixes behind one or more care-of-addresses. With such a mix of addresses and the combination of reactive routing there is a resolution problem [1]. A node cannot assume that a packet should be forwarded to a gateway just because there is a default route and no other matching host route in its routing table. It must first flood the network with a route resolution request to eliminate the possibility that there is a node in the ad hoc network with the destination address of the target. Furthermore, if the path to the gateway is multiple hops, this resolution problem will re-occur at each intermediate node, unless the source node can somehow delegate its information about the destination to other nodes in the network.

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II MOBILE ADHOC NETWORKS (MANETs)

Mobile Ad hoc networks are ideal in situations where installing an infrastructure is not possible because the infrastructure is too expensive or too vulnerable. However, MANETs are limited by intermittent network connections, restricted power supplies, and limited computing resources. These restrictions raise several new challenges for data access applications with the respects of data availability and access efficiency. In ad hoc networks, mobile nodes communicate with each other using multihop wireless links. Due to a lack of infrastructure support, each node acts as a router, forwarding data packets for other nodes.

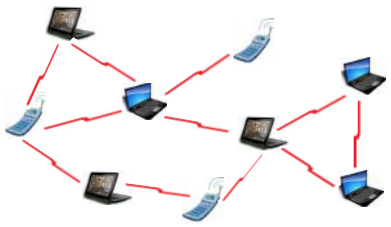

Fig. 1: A Typical Mobile Adhoc Network.

MANET is primarily focused on developing routing protocols to increase connectivity among MTs in a constantly varying topology. Due to the users' interests in accessing the Internet, it is an important requirement to consider the integration of MANET with the Internet. Thus, to put the MANET technology into the context of real life, we consider an *Internet based* MANET, called IMANET [2], [3], [4], [5], and investigate the problem of information search and access under this environment. Under IMANET, we assume that some of the MTs are connected to the

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Internet or wired private networks [2]. Thus, an MT may access Internet information via direct connection or via relays from other MTs. However, an IMANET has several constraints. First, not all the MTs can access the Internet. Second, due to MTs' mobility, a set of MTs can be separated from the rest of the MTs and get disconnected from the Internet. Finally, an MT requiring multi-hop relay to access the Internet may incur longer access latency than those which have direct access to the Internet.

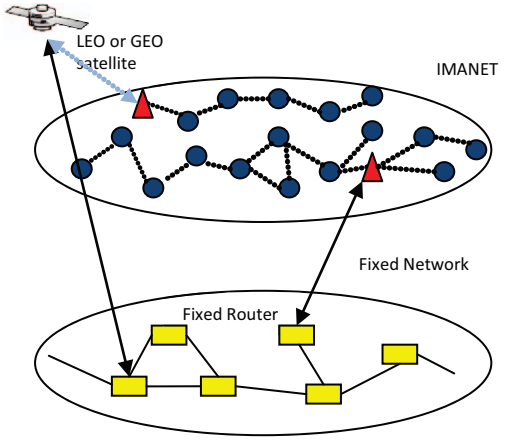

Fig. 2: A system model of IMANET.

III ON DEMAND ROUTING PROTOCOLS AND MOBILE IP

In this section, we examine the solutions proposed for the integration of Mobile IP and ad hoc networks.

The Mobile IP [7] protocol provides transparent routing of IP datagrams to mobile nodes in the Internet, enabling users to maintain connections as they roam in different networks. Gateways, called foreign agents periodically broadcast *Agent Advertisements* to advertise their presence to visiting mobile nodes. The functions of mobile IP are:

1. **Mobile node:** A host that changes its point of attachment from one network or subnetwork to another.
2. **Home agent:** A router on a mobile node's home network that maintains location information for the mobile node and tunnel packets to the node while the node is away from its home network.
3. **Foreign agent:** A router on the mobile nodes visited (foreign) network. The foreign agent cooperates with the mobile node's home agent to deliver packets to the mobile node.

Alternatively, mobile nodes may actively solicit foreign agents, causing foreign agents to respond with advertisements unicast to the node. On receiving an advertisement, a mobile node registers with their home network by sending a *Registration Request*, and the registration expires after a *registration lifetime*. The mobile node must re-register with the home network before the lifetime expires. The mobile node acquires a *care-of address* that is valid on the foreign network. This care-of address may be that of the foreign agent, in which case the foreign agent serves as the point of contact for the mobile node, or may be obtained by the mobile node by other means. Datagrams are tunnelled by the home network to the care-of address of the mobile node. Mobile IP relies on proactive mechanisms such as the broadcasting of advertisements and solicitations for agent discovery, movement detection and reachability of the mobile node. In mobile ad hoc networks (MANETs), on-demand routing protocols have been proposed to provide connectivity within the network. *Route Request* (RREQ) messages are broadcast when a mobile node requires a route. The destination or intermediate nodes that know a fresh enough route to the destination, respond with *Route Reply* (RREP) messages, effectively setting up the route.

This reactive approach provides good connectivity within the MANET while reducing the overhead costs when the network is idle. The basic design of Mobile IP and on-demand routing protocols makes integration difficult. Adjusting Mobile IP to operate in an on-demand fashion will cause nodes to have less up-to-date information about foreign agents, causing poor handoffs and bad connectivity. On the other hand, a pure proactive approach, used by Mobile IP, results in excessive control overhead. Furthermore, nodes those do not require Internet connectivity are unnecessarily burdened with the traffic imposed by repeated flooding.

IV CARE-OF ADDRESSES

There are two ways in which mobile nodes running Mobile IP can acquire care-of addresses. In the first method, a foreign agent must be available on the foreign network. This agent advertises one or more care-of addresses in its Agent Advertisements. Mobile nodes can then use one of those care-of addresses to obtain Interne connectivity.

The other method for a mobile node to obtain Internet connectivity is to acquire a *co-located* care-of address. This type of care-of address is used when a foreign agent is not available on the network. At minimum, a gateway between the wired and wireless networks must be configured to advertise network prefixes that are routable on the given network. When such a gateway is available, mobile nodes can use the advertised prefix to configure their own care-of addresses.

To obtain a unique care-of address, a mobile node must select a unique identifier to append to the advertised network prefix. A mobile node does not necessarily know the care-of addresses of the other mobile nodes within the wireless network. Hence, it must perform *duplicate address detection* to ensure that its selected address is unique. The following method is based on that described in [15].

When a node requires a unique IP address, it first selects a random host ID from the range 2048- $(2^{(32-n)}-1)$, where n is the number of significant bits in the advertised network prefix. The node then appends that host ID to the prefix

advertised by the Internet gateway. This is the IP address for which it performs duplicate address detection. The node then selects a random, temporary host ID in the range 0–2047 and appends this value to the advertised network prefix.

This ID serves as a source IP address for the short period while the node performs duplicate address detection. The node creates an Address Request (AREQ) by placing its randomly selected source IP address, as well as its temporary IP address, in the AREQ and broadcasting this request to its neighbors.

When a mobile node receives an AREQ message, it creates a *reverse route* entry for the node indicated by the temporary IP address in the AREQ. The node then checks whether its own IP address matches the requested address in the AREQ. If the node's IP address does not match the requested address, it rebroadcasts the packet to its neighbors.

On the other hand, if the node has the same IP address as that requested by the AREQ, then the source node is requesting an IP address that is already in use. In this case, the node with the duplicate IP address creates an Address Reply (AREP) packet. It places the requested IP address in this message, and unicasts this packet to the node that requested the address. The reverse route that was created by the AREQ broadcast is used to route the AREP back to the source node.

When a node originates an AREQ, it sets a timer to wait for the reception of an AREP message. If no AREP is returned for the selected address within a timeout period, the node retries the AREQ up to some maximum number of times. If, after all retries, no AREP is received, the node assumes that the address is not already in use and that the address can safely be taken for its own.

On the other hand, if the node does receive an AREP within the discovery period, and if the requested IP address included in the AREP matches the address it was requesting, then this indicates that another node within the ad hoc network is currently using that IP address. In this case, the node randomly picks another host ID from the same 2048-($2^{(32-n)}$ -1) range and begins the duplicate address detection again.

V INTERNET CONNECTIVITY TO MANET

The Mobile IP and AODV networking protocols can work together to create an environment where multihop wireless paths exist between mobile nodes and foreign agents. These paths eliminate dead zones and extend the coverage range of the foreign agents. To obtain care-of addresses the Mobile IP protocol is used and hence Internet connectivity, through a multihop path to a foreign agent.

A. Proactive and Reactive Approaches

A proactive approach to providing Internet connectivity to a MANET relies on ensuring that all nodes are registered with a foreign agent at all times. Mobile IP relies on link layer broadcasts to provide foreign agent information to interested nodes. However, these broadcasts can prove to be extremely expensive in a MANET where a broadcast translates to the packet being flooded throughout the network. Some of the solutions proposed for interconnecting MANETs to wired infrastructure also rely on this periodic flooding [13], [10] and [11]. [13] uses a proactive routing protocol to maintain connectivity within the MANET. The other approaches rely on on-demand routing in the MANET to maintain connectivity information. To reduce the flooding of advertisements, these schemes increase the *beacon interval* (i.e. the interval between successive advertisement floods).

In a purely reactive approach, mobile nodes obtain foreign agent information by sending out agent solicitations only when data needs to be sent to a node outside the MANET. To limit the flooding of these solicitations, solicitations may be piggybacked on RREQ messages [14], or an expanding ring search may also be used [15]. Although [10] is essentially a proactive approach with periodic flooding, intermediate nodes are allowed to reply with a route to the foreign agent, which reduces overhead.

An ideal solution should provide Internet access to MANETs while attempting to balance the proactive and reactive approaches. There are many benefits to a hybrid approach. A proactive solution allows mobile nodes to find the foreign agent closest to them and enables better handoffs, which in turn leads to lower delay. Periodic registrations in such a proactive scheme help foreign agents track the mobility of the mobile node. However, if not all the nodes in the MANET require connectivity, the repeated broadcasting of agent advertisements and solicitations can have a negative impact on the MANET due to excessive flooding overhead. A hybrid approach combines the advantages of both approaches so that the required information is received in a timely fashion and the MANET's scarce resources are not further burdened with Mobile IP overhead.

B. Route Discovery

Route discovery mechanism is used by a mobile node to find whether the node lies in the MANET or on the wired Internet, similar to mechanisms used in [10], [11]. A route discovery is initiated for the node. If a mobile node responds with a RREP message then the node lies in the MANET. Otherwise if a foreign agent receives the request and finds that it does not have an explicit route entry for the node the foreign agent sends back a special route reply (FA-RREP [11]). If no route reply is received, other than from the foreign agent, the node is assumed not to lie in the MANET.

The packets to destinations on the Internet are encapsulated and routed to the foreign agent that the mobile node is currently registered with, which then forwards to the destination using standard IP forwarding. Packets destined for the mobile node arriving from nodes on the Internet is tunneled from the home network to the foreign agent, which

decapsulates them and forwards them to the mobile node using the ad hoc routing protocol.

C. Agent Advertisement

Foreign agents periodically advertise their presence through Agent Advertisement messages. When a mobile node receives an Agent Advertisement, 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 that entry a lifetime. Recording this information serves the dual purpose of tracking the foreign agents from which the mobile node has received Agent Advertisements as well as preventing reprocessing of duplicate Agent Advertisements. If the mobile node later receives the advertisement as it is rebroadcast by the node's neighbors, the mobile checks the foreign agent IP address and advertisement sequence number and does not reprocess the packet. When a node receives duplicate Agent Advertisement messages, it discards the duplicates.

Mobile nodes also use the Agent Advertisement to update their route information to the foreign agent. If the mobile's route to the foreign agent has expired, or if this Agent Advertisement has arrived along a shorter path than the recorded route, the mobile node updates its route information for that foreign agent to indicate the new path.

After processing the Agent Advertisement, the mobile node rebroadcasts the packet on its interfaces. This allows mobile nodes that are not within direct transmission of the foreign agent to receive the Agent Advertisements. Mobile nodes randomize their rebroadcasting of the Agent Advertisement message so that synchronization and subsequent collisions with other nodes' rebroadcasts can be avoided.

D. Registration

For the internet connectivity, a node must register with the foreign agent. After receiving an Agent Advertisement, to register with the foreign agent, a node creates the registration request. The node places its home address, home agent address, and care-of address into the Registration Request and then unicasts the message to the foreign agent. In the event that the mobile node's route to the foreign agent has become invalid, the node can initiate a route discovery procedure to find a new route to the foreign agent.

The foreign agent and home agent process the Registration Request as specified in [12] by recording the new care-of address for the mobile node. When the FA receives the Registration Reply from the HA, the FA unicasts this reply along the (possibly multi-hop) path back to the mobile node. Upon reception of the Registration Reply, if the foreign agent's route to the mobile node has timed out or been invalidated, the foreign agent can utilize the AODV route-discovery procedure to rediscover a route to the mobile node. To maintain the registration, the mobile node must re-register before the lifetime expires.

VI CONCLUSION

For allowing Internet connectivity Mobile IP and on-demand routing protocols in a MANET can work together to set up multihop paths to a foreign agent in the network. AODV is utilized for the discovery and maintenance of routes within the ad hoc network, while Mobile IP is used for care-of address assignment and registration with the home agent. When a foreign agent is not available, duplicate address detection can be used for a mobile node to obtain a co-located care-of address that is unique within the ad hoc cloud.

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