Integrating Mobile Ad Hoc Network into Mobile IPv6 Network

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Abstract. In the future more and more devices connected to the Internet will be wireless. Wireless networks can be classified into two types of networks: network with infrastructure (i.e. networks with base stations, gateway and routing support), which is called Mobile IP, and network without infrastructure which is called ad hoc networks. Mobile IP tries to solve the problem of how a mobile node may roam from its network to foreign network and still maintain connectivity to the Internet. Ad hoc network tries to solve the problem if the infrastructure is not available or inconvenient for its use such as in rural environments. Integrating ad hoc into Mobile IP provide new feature for Mobile ad hoc network such as Internet connectivity, streamline communication with another network. This paper presents the development of a test bed for integrating Mobile Ad hoc NETwork (MANET) into Mobile IPv6.

1 Introduction

The Internet Protocol (IP) that is currently used is called IPv4. IPv4 was designed in January 1980 and since its inception, there have been many requests for more addresses and enhanced capabilities due to the phenomenal growth of the Internet. Therefore**,** IPv6 was developed in 1992. Major changes in IPv6 are the redesign of the header, including the increase of address size from 32 bits to 128 bits. Besides the larger address space IPv6 also provides other new features such as address auto configuration, enhanced mobility support and IP Security (IPSec) integrated into the standard IPv6 protocol stack [3,6,15]. Just having more addresses does not solve the problem of mobility. Because part of the IP address is used for routing purposes, it must be topologically correct. This is where Mobile IP comes in.

Wireless networks are classified into two modes: Infrastructure mode and ad-hoc mode. To provide mobility in infrastructure mode, Mobile IP is sufficient but with ad-hoc mode both the ad-hoc routing protocols as well as the Mobile IP is necessary. The Mobile IP tries to solve the problem of how a mobile node may roam from its network to foreign network and still maintain connectivity to the Internet [1]. Mobile IPv6 has more features compared to Mobile IPv4 such as route optimization and Dynamic Home Agent Address Discovery (DHAAD). Ad hoc network tries to

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solve the problem if the infrastructure is not available or inconvenient for its use such as in rural environments [7]. Ad hoc networks can be subdivided into two classes: static and mobile [4]. In this paper we will use Mobile ad hoc networks (MANETs).

Integrating MANET with Mobile IPv6 network will extend the capabilities of Mobile IPv6 to MANET which will introduces fast agent discovery, increases cell coverage of access points, monitoring system provision and extend connectivity to other networks or to Internet [1,10,11].

The rest of this paper is organized as follows: Section 2 presents related work in integration of MANET with Mobile IPv6 network. The implementation of our proposal will be described in Section 3 followed by Section 4, which will conclude the paper.

2 Related Work

There are many methods of integrating MANET with Mobile IPv4. The main difference is the routing protocol used in MANET and access point of MANET. One of the method of Integrating Mobile IPv4 with Ad hoc networks [9] is using the Destination-Sequenced Distance Vector (DSDV) routing protocol in the ad hoc network. It extends access to multiple nodes in MANET to create an environment that supports both macro and micro mobility. Another method is MIPMANET: Mobile IPv4 for Mobile Ad hoc Networks [10]. It uses Mobile IP Foreign Agent (FA) as access point to the internet. If any node wants Internet access, it registers in the FA and use its home address for communication. The Ad hoc On-demand Distance Vector (AODV) routing protocol is used to deliver packets between nodes and FA in the ad hoc network. It provides algorithm MIPMANT Cell Switch (MMCS) to determine when mobile node should register with a new FA. Another method of integration is Ad hoc Network and IP Network Capabilities for Mobile Host [13]. It uses AODV as the routing protocol in the ad hoc network and Mobile IPv4 in outside traffic network. It uses Multihomed mobile IPv4 so that any mobile node can register with multiple FAs simultaneously. This connectivity with multiple gateways will enhance performance and reliability. All these methods use mobile IPv4 and they depend of FA. Mobile IPv6, however, does not define foreign agents. To be able to reach the Internet, mobile nodes using Mobile IPv6 need an Internet Gateway.

3 Implementation

Four personal computers identified as HA, MN, CN and Gateway had been configured with IPv6 based on the Linux operating system as shown in Fig .1. Mobile IPv6 which is a distribution from Helsinki University of been setup in all MANET nodes [14]. Kernel AODV is a loadable kernel module Technology had been setup in HA, MN and CN. Kernel AODV which is a distribution from National Institute of Standards and Technology in US had for Linux. It implements AODV routing between computers equipped with WLAN devices.

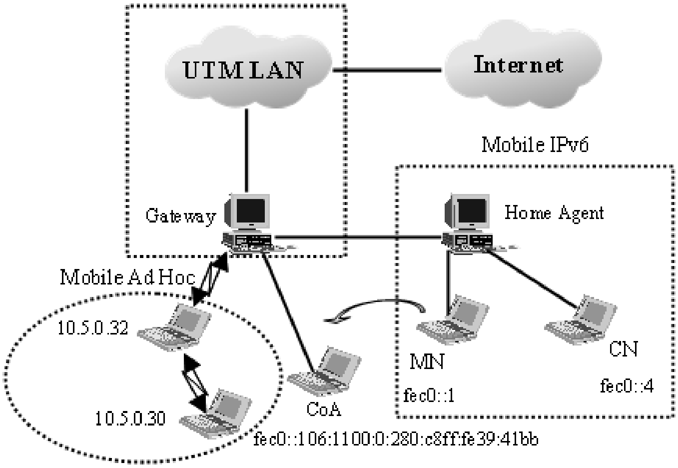

Fig. 1. Network Architecture

```
[root@localhost root]# /etc/rc.d/init.d/./mobile-ip6 restart
Stopping Mobile IPv6:                              [ OK ]
Starting Mobile IPv6:                              [ OK ]
```

Fig. 2. Start Mobile IPv6

NAT-PT has been setup in the gateway to establish communication links between IPv4 (MANET) network and IPv6 (Mobile IPv6) network [5]. The NAT-PT Linux gateway has three Ethernet ports and one WLAN as shown in Fig. 1. All HA, MN and CN are started by running the program as shown in Fig. 2.

3.1 Communication Between MN and CN

When MN starts its Mobile IPv6 program in home network, it sends multicast message (router solicitation) to all routers until HA send router advertisement as shown in Fig. 3. Then, MN will be assigned an address (fec0::280:c8ff:fe39:41bb/64). This will inform MN that it is in the home network. When MN moves to a foreign network, it attaches itself to the gateway, which advertises router advertisement periodically as shown in Fig. 4. After MN receives router advertisement from the gateway, it gets a CoA address (fec0::106:1100:0:280:c8ff:fe39:41bb /64). MN will send a BU to HA and CN. MN will register all sending BU in the BU list as shown in Fig. 4.

```
[root@localhost root]# tcpdump
tcpdump: listening on eth0
18:37:49.565538 fe80::280:c8ff:fe39:41bb > ff02::2: icmp6: router solicitation
18:37:50.671973 fe80::280:adff:fe81:1abc > ff02::1: icmp6: router advertisement
```

Fig. 3. Router Solicitations and Router Advertisements

```
[root@localhost root]#mipdiag -l
Mobile IPv6 Binding update list
Recipient CN: fec0::2
BINDING home address: fec0::1 care-of
address: fec0:106:1100:0:280:c8ff:fe39:41bb
      expires: 202 sequence: 1 state: 1
      delay: 1 max delay 256 callback time: 155

Recipient CN: fec0::4
BINDING home address: fec0::1 care-of
address: fec0:106:1100:0:280:c8ff:fe39:41bb
      expires: 329 sequence: 0 state: 1
      delay: 1 max delay 256 callback time: 329
```

Fig. 4. Mobile IPv6 Binding update list in MN

```
[root@localhost root]# mipdiag -c
Mobile IPv6 Binding cache in CN
Home Address Care-of Address                    Lifetime  Type
fec0::1    fec0:106:1100:0:280:c8ff:fe39:41bb  174       1
Mobile IPv6 Binding cache in HA
Home Address Care-of Address                    Lifetime  Type
fec0::1    fec0:106:1100:0:280:c8ff:fe39:41bb  916       2
```

Fig. 5. Mobile IPv6 Binding cache in CN and HA

HA and CN will keep the BU for a certain time (lifetime) in the Binding cache as shown in Fig. 5. Beyond the stipulated lifetime, if no update of BU is received then this shows that MN is unreachable. BU in HA, CN and in MN will be deleted once MN returns home.

3.2 Communication Between MN and MANET Node

Kernel AODV provides route table for all MANET nodes in the MANET coverage area as shown in Fig. 6. It also supports multihop connectivity between MANET nodes. This gateway has a pool of IPv4 address including IPv4 subnet 10.5.0/24. When MN attaches itself to the gateway, it gets a CoA of (fec0:106:1100:0:280:c8ff:fe39 :41bb/64). If MN wants to communicate with MANET node (10.5.0.30), MN creates a packet with the Source Address, SA=fec0:106:1100:0:280:c8ff:fe39:41bb and destination address, DA= PREFIX: 10.5.0.30. The PREFIX is static and any packet originating from an IPv6 node destined to the IPv4 network will contain that PREFIX as a part of the IPv6 destination address.

NAT-PT will translate the IP header including the source and destination address. After translation, the source address will be a one pool address (say 10.5.0.33) and the destination address is 10.5.0.30. The NAT-PT will retain the mapping between 10.5.0.33 and fec0:106:1100:0:280:c8ff: fe39: 41bb until the end of the session. In case of a reverse trip, source address will be 10.5.0.30 and the destination address will be 10.5.0.33. NAT-PT will change the source address to

PREFIX: 10.5.0.30 and destination address to fec0: 106: 1100:0: 280: c8ff: fe39: 41bb. The communication will continue as shown in Fig. 7 and Fig. 8.

```
[root@localhost root]#cat /proc/aodv/route_table

Route Table
-------------------------------------------------
  IP    | Seq |Hop Count| Next Hop
-------------------------------------------------
10.5.0.33  1    1     10.5.0.33  Valid  sec/msec: 2/892 0
10.5.0.30  1    0     10.5.0.30  Valid  sec/msec: 197610239/239 1
127.0.0.1  1    0     127.0.0.1  Valid  sec/msec: 197610239/239 1
```

Fig. 6. Routing Table in gateway

```
[root@localhost root]#ping 10.5.0.33
PING 10.5.0.33 (10.5.0.33) from 10.5.0.30 : 56(84) bytes of data.
64 bytes from 10.5.0.33: icmp_seq=1 ttl=64 time=4.84 ms
64 bytes from 10.5.0.33: icmp_seq=1 ttl=63 time=149 ms (DUP!)
64 bytes from 10.5.0.33: icmp_seq=2 ttl=64 time=4.20 ms
64 bytes from 10.5.0.33: icmp_seq=2 ttl=63 time=5.22 ms (DUP!)
```

Fig. 7. Ping one pool address in Ad hoc node

```
localhost root]#tcpdump
tcpdump: listening on eth0
13:01:02.963824 fe80::2e0:7dff:fec7:7450 > fec0:106:1100:0:280:c8ff:fe39:41bb: icmp6:
neighbor sol: who has fec0:106:1100:0:280:c8ff:fe39:41bb
13:01:02.963908 fec0:106:1100:0:280:c8ff:fe39:41bb > fe80::2e0:7dff:fec7:7450: icmp6:
neighbor adv: tgt is fec0:106:1100:0:280:c8ff:fe39:41bb
13:01:03.079703 ::10.5.0.30 > fec0:106:1100:0:280:c8ff:fe39:41bb: icmp6: echo request
13:01:03.079800 fec0:106:1100:0:280:c8ff:fe39:41bb > ::10.5.0.30: icmp6: echo reply
```

Fig. 8. MN receives ping request from gateway

4 Conclusion

This paper has presented a mechanism for integrating MANET with Mobile IPv6. The IPv6 is based on Linux operating system. Mobile IPv6 test bed with MN, HA and CN functions has been successfully setup and configured in a wired LAN environment. MANET software has been successfully setup and configured in gateway by using Universal Serial Port (USB) Wireless Local Area Network (WLAN) card. However, this Mobile IPv6 test bed is limited to Linux platform because it works under the kernel level of Linux operating system.

NAT-PT software has been successfully setup and configured in the gateway which allows communication between MANET (IPv4) network and mobile IPv6 network.

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