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Comparison of Mobility Management in MobileIPv4 & MobileIPv6 Networks

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Abstract:Mobile IPv6 is the next generation protocol and in the near future, routers are going to become more faster and new technologies are going to reduce the Internet delay (delay incurred in transmitting packets from one network to another).It overcomes the problems of Current Mobile IPv4, which is the most promising solution formobility management in the Internet.In this paper, we present performance evaluation of Mobile IPv4 and Mobile IPv6 usingvarious parameters such as *handoff latency*, *Throughput*, *packet end-to-end delay*, and *packet delivery ratio*. The study was carried out using an open source Network Simulator NS-2 to study and analyse the behaviour of Mobile IPv4 and Mobile IPv6 protocols.

Keywords - Mobile IPv4, Mobile IPv6, Protocol performance, Handoff Latency, Network Simulation

1. Introduction

Internet has become global computer network that can be accessed by anyone all over the world easily. Every year, Internet grows in speed, capacity, data traffic, makes the connection to the Internet very important for a lot of people. The Transmission Control Protocol (TCP) is a predominant protocol in the Internet service. The TCP/IP protocol was originally designed for fixed Internet without mobility in mind. The increasing need of anywhere and everywhere connectivity had made people to start think how to be connected regardless their position, including in mobile condition. Many researchers have come to the conclusion that IP is the correct layer to implement the basic mobility support. The greatest challenge for supporting mobility at IP layer is handling address changes. In other words, it is required to keep uninterrupted connections among nodes when they change their IP addresses during the movement. Mobile IP has been designed within the IETF to serve the needs of the growing population of mobile computer users who wish to connect to the Internet and maintain communications as they move from place to place.Mobile IPv4 (MIPv4) (Perkins and Myles, 1994) is a popular mobility protocol used in the current IP4 networks.

In MIPv4, the MN obtains a new IP address from a foreign router (foreign agent (FA)) in the visited network or through some external assignment mechanism and registers with the FA. To maintain continuous connectivity, the MN needs toupdate its location with its home agent (HA) whenever itmoves to a new subnet so that the HA can forward thepackets. But MIPv4 is not a good solution for users with highmobility: it suffers from extra-delays due to the routing ofeach packet through the HA (triangular routing), lack ofaddresses and high signalling load. IPv4 will not be able toprovide the functionality required by the mobile wirelessinformation services which will follow the 3rd generation(3G) IP-based services of today. Accordingto that the next generation IPv6 networks are emerging, Mobile IPv6 (MIPv6) is designed for dealing with mobility support and overcoming some problems of MIPv4. The integration of mobile cell-phones with Internet based multimedia services is inevitable. The sheer number of potential users of such services within business, industry and the private sector will force a move to the next generation version of IP (IPv6).Companies and countries in the process of building packet-based network infrastructures toprovide these services will want to invest in IPv6 rather than IPv4. IPv6 will provide the basis for flexible, scalable, efficient, and manageable solutions to the problems presented by 3G systems. Under mobile internet environment, MIPv6 deployment is delayed rather thanMIPv4.Inorder to apply Mobile IP in current internet environment, the performance of MIPv4 and

MIPv6 networks is evaluatedand compared in this paper by simulation studies using NS-2.

2. Internet Protocol Overview

The Internet protocol (IP) provides an unreliable, connectionless delivery mechanism. It defines the basic unit of data transfer through the TCP/IP Internet. Also, IP performs the routing function, choosing a path for data transmission. IP includes the rules for the unreliable data delivery: how hosts and routers process packets, how and when error messages should be generated, and which condition packets can be discarded.

IP is responsible from internetwork; interconnects multiple networks (sub networks) into the internet. Getting the packets from the source and deliver them to the destination, this require the pre knowledge about the network topology, the choice of the suitable path, and the avoidance of congestion, this can be done using IP addressing scheme. IPv4 addresses are 32 bits long, and IPv6 addresses are 128 bits long, some part is reserved for the current IPv4 addresses, and the other part is reserved for the link local addresses, which are not routable and unique on the link. These help nodes on the same link in one local network to communicate using their link local addresses without the needs for routers. Nodes know each other, the local routers and the network prefix using neighbour discovery protocol, which will be used by the MIP protocol as well, as will be shown next section. The IPv6 neighbour discovery protocol is a much improved version of two IPv4 protocols, the address resolution protocol (ARP) and the ICMP router discovery protocol.

The main features of IPv6 are:

- The Hierarchical addresses, to reduce the routing table size in the memory.
- The simple header, for more fast forwarding and routing process.
- Security improvement, including the availability of authentication and encryption.
- The dynamic assignment of addresses.

2.1. MobileIPv4

The IETF designed a solution for Internet mobility officially called “IP mobility support” and popularly named mobile IP (MIP). The general characteristics include: transparency to application and transport layer protocols, interoperability with IPv4 (using the same addressing scheme), scalability and security.

In Mobile IPv4, IP addresses are 32-bit long integers and are represented in a dotted decimal format (e.g., 197.128.55.44). IP version 4 assumes that a node's IP address uniquely identifies the node's point of attachment on the Internet. Therefore, a node must be located on the network indicated by its IP address in order to receive datagrams destined to it; otherwise, datagrams destined to the node would be undeliverable.

2.1.1. Entities and Terminologies:

There are some basic entities and terminologies for mobile IP which is given below.

Mobile Node (MN) - A Node moving from one network to another network, with permanent Home Address.

Correspondent Node (CN): Any Mobile or wired node which communicates with MN is called CN.

Home Network: The network in which MN is present and connected to internet before any Movement is the home network.

Foreign Network: The network in which the MN is entering after leaving its home network is foreign network. Foreign network is any network other than home network.

Home Agent (HA) - A router on a mobile node's home network which tunnels datagrams for delivery to the mobile node when it is away from home, and maintains current location information for the mobile Terminal.

Foreign Agent (FA) - Router in foreign network that provides CoA and tunneling with HA and forward the packets to MT.

Home Agent (HoA): This is the IP address of the MN. HoA is fixed and it does not change even the MN moves to the foreign network. Home address is used to send and receive packets when a MN is Present in its home network.

Care-of Address (CoA): When a MN moves from its home network to any other network that is called foreign network, a new IP address is assigned to MN which is called Care-of address or CoA.

2.1.2.Mobile IPv4 architecture and operations

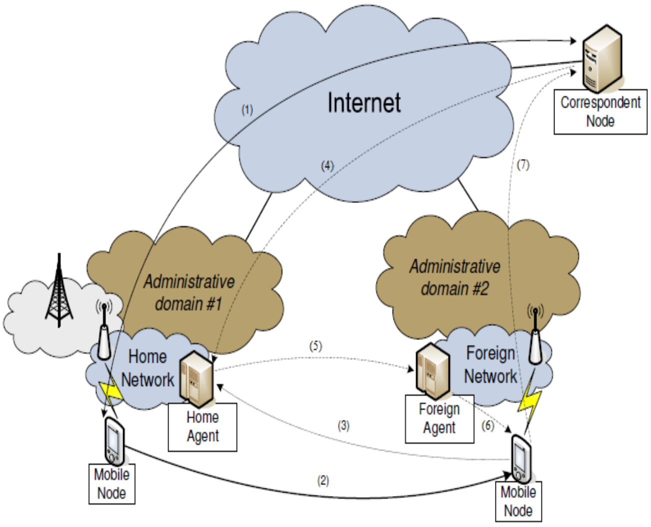

Fig.1.Mobile IPv4 architecture and operations

MIPv4, illustrated in Fig.1, preserves the IP address originally assigned to the MN in its home network(HN), so called *home address*, as an unique MN's identifier, to ensure application transparency. (1)As long as the MN stays in the HN, it is treated as any other fixed node of that network, thus notrequiring any kind of mobility support.(2)Whenever the MN moves out of the HN and gains the access to a foreign network (FN), it obtains a *care-of address (CoA)*. The CoA can be acquired either from agent advertisements sent by a *foreign agent (FA)* (a so-called foreign agent CoA; this is the preferred method and all further considerations presented here scope around this option) or by some external assignment mechanism such as DHCP (a co-located CoA; the FA functionality is not needed).(3)This CoA serves to capture the location of the MN in the FN, and such a location update must be communicated by sending a registration request message to a dedicated entity in the HN called *home agent (HA*. The HA maintains an up-to-date list of the mobility bindings (i.e., pairs of MN's home address and its current CoA) and confirms any recently made change with a registration reply message sent to the MN. An important security consideration is that both registration messages (from MN and from HA) must be authenticated to prevent packet hijacking. (4) HA intercepts any packet arriving at the HN, e.g., using Proxy Address Resolution Protocol (ARP).(5)HA forwards the intercepted packets to the MN at its current CoA using *IP tunneling*.The IP encapsulation is removed at the FA.(6)FA then delivers the packet to the MN.(7) However, in the opposite direction, the MN sends packets to the CN they are diverted along a direct path through FA to CN.

This delivery process is known as *triangular routing*. Triangle Routing means that the data takes a longer path to arrive to its destination. Thus the triangle routing causes a problem since it delays the delivery of the Datagram and places an unnecessary load on networks and routers.

2.2. Mobile IPv6 architecture and operations

The functionality of the MIPv6 is presented in Fig. 2,(1) No mobility support is needed aslong as the MN stays in the HN. (2)Once the MN moves out from the HN to a FN, it can obtainits CoA via either *stateful* (as in case of MIP), i.e., DHCP for IPv6 (DHCPv6) or*stateless address auto-Configuration* procedure. (3)(4)Newly obtainedCoA must be registered at HA (3) and CN using *binding update* messages. Both HA and CNmust maintain the list of the current MN's bindings. (5)As soon as the MN's bindings are updated, the packets can be routed directly from the CN to the MN's CoA and similarly in the oppositedirection, so that the triangular routing is avoided. In case the communication between CN andMN is established when the latter is already in the FN, the first packets from the CN are tunnelled via the HA to the CoA, like in MIP, until the binding update process is completed.

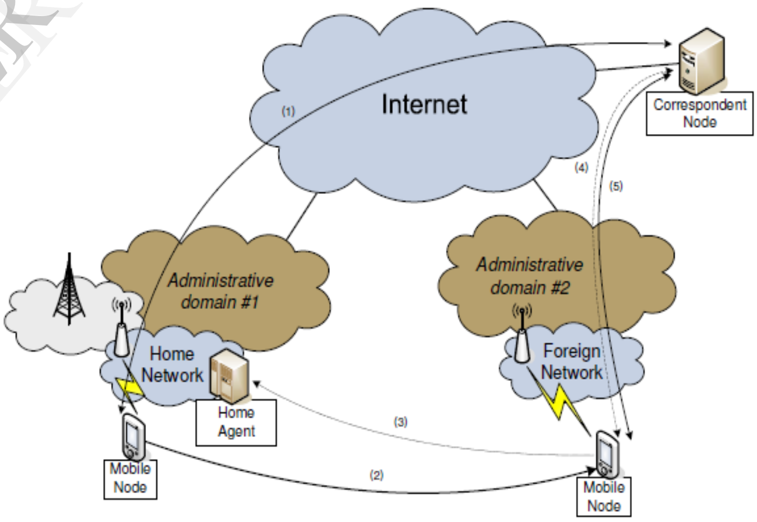

Fig2.Mobile IPv6 architecture and operations

Mobile IPv6 uses route optimization which allows the shortest path to be used and eliminates the congestion at the mobile node's home agent and home link. Thus the data packets are sent directly from CN to the MN's foreign location. If the CN is not IPv6 compatible, the data transfer will resemble the delivery method of mobile IPv4 since the data transfer is done via HA. However the HA intercepts the data packets and tunnels them using IPv6-over-IPv6 tunnelling to the mobile node's care-of address. In mobile IPv6 the data packets include a new routing extension header that contains the mobile node's home address.

Comparison of Mobile IPv6 and Mobile IPv4

Mobile IPv4 (MIPv4) and Mobile IPv6 (MIPv6) protocols share similar ideas, but their implementations are somewhat different. IP mobility is also specified for IPv4, but IPv6 provides more enhanced support for it.
The major differences between MIPv4 and MIPv6 are as follows:

- The address space of MIPv6 is bigger than that of MIPv4. IPv6 header is divided into optional extension headers. This makes the IPv6 base header smaller and more efficient for routers to route. The introduction of extension headers makes it possible to supply more information to the participants without disturbing parts of the system with information that they do not need.

- IPv6 address auto configuration simplifies the care of address assignment for the mobile node. It also eases the address management in a large network infrastructure. To obtain a care of address, the MN can use either stateful or stateless address auto configuration. In the stateful address auto configuration, the MN obtains a care of address from a DHCPv6 (Dynamic Host Configuration Protocol for IPv6) server. In the stateless address auto configuration, the MN extracts the network prefixes from the Router Advertisements, i.e. equivalent to Agent Advertisements in MIPv4, and adds a unique interface identifier to form a care of address.
- In MIPv6 an Advertisement Interval option on Router Advertisements is defined, that allows a Mobile Node to decide for itself how many Router Advertisements (Agent Advertisements) it is tolerating to miss before declaring its current router unreachable.
- Route Optimization feature to avoid triangle routing problem is built in as a fundamental part of the MIPv6 protocol. In MIPv4 this feature is being added on as an optional set of extensions that may not be supported by all IP nodes.
- In MIPv6 the functionality of the Foreign Agents can be accomplished by IPv6 enhanced features, such as Neighbour Discovery and Address Auto configuration. Therefore, there may be no need to deploy Foreign Agents in MIPv6.
- The Mobile IPv6, unlike Mobile IPv4, uses IPsec for all security requirements such as sender authentication, data integrity protection, and replay protection for Binding Updates. In MIPv4, the Security requirements are provided by its own security mechanisms for each function based on statically configured mobility security associations.
- MIPv6 and IPv6 use the source routing feature which is the insertion of routing information into a datagram by the source node. This feature makes it possible for the CN to send packets to the MN while it is away from its Home network using an IPv6 Routing header rather than IP encapsulation, whereas MIPv4 must use encapsulation for all packets. However, in Mobile IPv6 the Home Agents are allowed to use encapsulation for tunnelling. This is required, during the initiation phase of the binding update procedure.

3. Simulation and Result Analysis

3.1. Mobility Support in Network Simulator (NS2)

The Network Simulation 2 (NS2.33) has been used for the running the simulation of MIPv4 and NS2.33 extension MOBIWAN has been used to run the simulation of MIPv6.Regarding the current MIP architecture in *ns-2* , it is contributed by both CMU's MonarchGroup and SUN Microsystem Inc.. Monarch group extended the mobility support in *ns-2* while SUN introduced the mobile IP into *ns-2*. But, since the original CMU wireless model only allows simulation of wireless LANs and ad-hoc networks, the wired-cum-wireless feature was then developed in order to use the wireless model for simulations using both wired and wireless node. Also, SUN's Mobile IP was integrated into the wireless model, although it was originally designed for wired nodes. MHs could interact with base stations that were connected to wired nodes, to bring together wired and wireless topologies, Destination-Sequenced Distance-Vector (DSDV) routing protocol is used for this purpose.

The typical Mobile IP scenario consists of Home-Agents (HA), Foreign-Agents (FA) and Mobile-Hosts (MH). In the current *ns-2* system, HA and FA are basically the same kind of node - **Base-Station Node** in the *ns-2* system and they use the same Agent –**MIPBSAgent**to handle the packets. Since the HA and FA play the role to interconnect the wired and wireless nodes, they are implemented as Hybrid nodes of both wired nodes and wireless nodes.

In MOBIWAN extension, In order to support functionality of Mobile IPv6, the header size was modified ,Router Advertisements and Solicitations between BSs and MHs, encapsulation and decapsulation at all nodes, like modifications were made. The MNs rely on Class Mobile Node as contributed by CMU. For Base Station, the ad-hoc routing Agent is replaced by the Network Agent. As for CNs, we make use of Class Node.

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3.2. Simulation Scenario

The simulation scenario constructed(Fig.3) with hierarchical topology of one mobile host (MH), one correspondent host and one wired node and In case of MIPv4 the BS1 acts as HA, BS2 as FA, BS3 as FA1, BS4 as FA2 ,whereas In MIPv6 the BS2,BS3,BS4 acts as foreign links(because MIPv6 doesn't have concept of FA). During simulation, an MH travels randomly between one base station ranges to another base station range with variable speed.

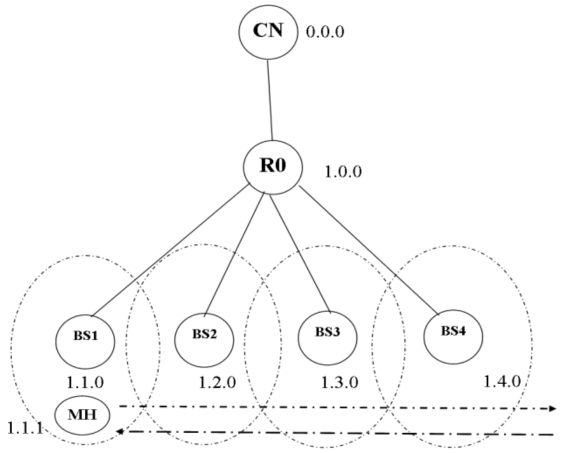


Fig3.Simulation Topology

I have used the following Simulation Environments (Hardware &Software):

CPU : Intel core i5 @ 2.27 GHz
RAM : 2 GB
Operating system : Fedora 13 i386
Simulation Tools :NS 2.33, Mobiwan extension for NS 2.33(for Mipv6 Simulation)

In the simulation, some important simulation parameters are listed as following:
Topology : Hierarchical
Topography : 800m X 800m
Wired Link Bandwidth : 100Mbps
Wireless Link Bandwidth : 100Mbps
Wired Link Delay : 2ms
Wireless Link Delay : 2ms
Wireless Protocol : 802.11
Traffic Type : TCP
Application : FTP

3.2.1. Simulation Results and Analysis:

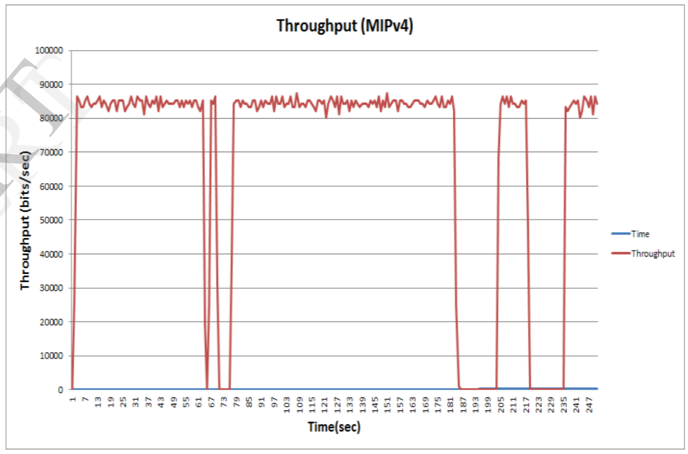
The Network Simulation 2 (NS2.33) has been used for the running the simulation of MIPv4 and NS2.33 extension MOBIWAN has been used to run the simulation of MIPv6.After running the simulation for both MIPv4 and MIPv6, simulation events were generated in the trace file (.tr).The trace files were analysed using the result analysis scripts (any scripting language).In this study AWK scripts were used for analysis.

The parameters such as the following are used for the comparison of the both protocols

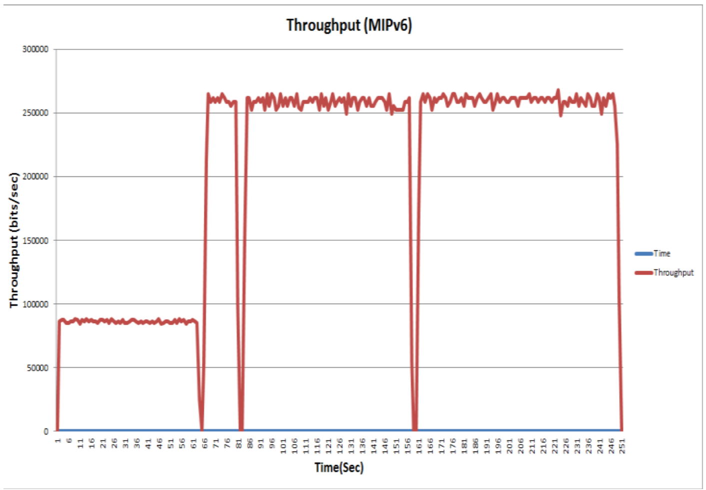
- Throughput
- Handover Latency
- Average End-to-End Delay
- Packet Delivery Ratio

1. Throughput

The Throughput is one of the performance metrics to evaluate the performance of Mobile IP Protocol. Generally it is defined as the amount of data processed in a specified amount of time. From the trace file generated by running the simulation the throughput values were captured and plotted graph with the values of "*Throughput of receiving bits Variation with Simulation Time*" as shown in the Graph.1 and Graph.2



Graph1. Throughput of MIPv4



Graph2. Throughput of MIPv6

Each packet generated by a source is routed to the destination via a sequence of intermediate nodes. From Graph1 and Graph.2, *it can be observed that the throughput of receiving packets in Mobile IPv6 is approximately 268128 bits/sec (*33516 bytes/sec), whereas for mipv4 is 87360bits/sec (10920 bytes/sec).*The throughput of mobile IPv6 is* obviously high compared to that of Mobile IPv4*; throughput has the* direct proportional relationship with handover latency. During the handover period the throughput falls to zero and reaches to maximum when handover finishes. After the handover process the mobile node attains high signal strength level so the throughput reaches maximum when compared to its previous throughput level.

Protocol	Max. Throughput (bytes/sec)
MIPv4	10920
MIPv6	33516

Table1: Throughput of MIPv4 &MIPv6

2. Handover Latency

The process of where the MN moves away from the range of the HA and enters into the range of Base Station or foreign agent(FA) is called Handover. The time taken to acquire Care of Address (CoA) from new BS or FA and registering to Home agent (HA) of Mobile Node is termed as Handover Latency.

By referring to the Graphs1&2 we can also observe the handover latency of MIPv4 and MIPv6.

Handover latency of MIPv4:

From Graph1, The X-axis represents the Simulation Time in seconds and the Y-axis represents number of TCP packets transferred. During the simulation time of 64 seconds the connection breaks between Mobile Node and Home Network and the connection re-establishes at 65 seconds with another Base Station (i.e., FA). So, here *handover latency is One second*.

Again Mobile Node leaves the present FA at 70 seconds and connects with new FA at 76 seconds and resulting in *handover latency of 6 seconds.* Third Handoff occurs at 185 seconds and connection reestablishment takes place at 203 seconds. So, here *handover latency is 18 seconds.* Fourth handoff occurs at 220 seconds and connection reestablishment takes place at 237seconds. So, here *handover latency is 16 seconds.*

Handover latency of MIPv6:

From Fig2, The X-axis represents the Simulation Time in seconds and the Y-axis represents number of TCP packets transferred. During the simulation time of 64 seconds the connection breaks between Mobile Node and Home Network and the connection re-establishes at 65 seconds with another Base Station. So, here *handover latency is One second*.

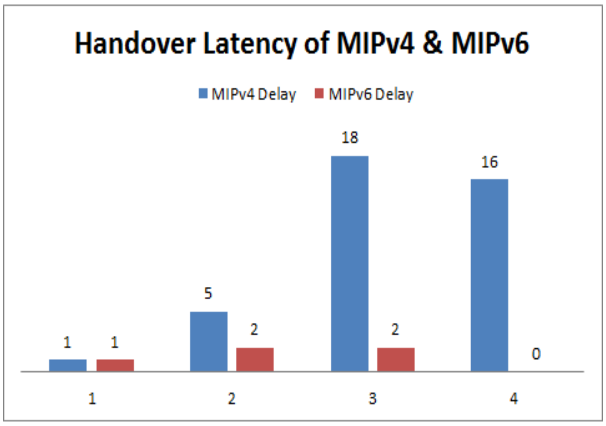
Again Mobile Node leaves the present BS at 81 seconds and connects with new BS at 83 seconds and resulting in *handover latency of 2 seconds.*

Third Handoff occurs at 158 seconds and connection reestablishment takes place at 163 seconds. So, here *handover latency is 2 seconds.* Fourth handoff occurs at 250 seconds and continues up to end of the simulation time (250seconds) Total delay= 1 second

Handover No	MIPv4 Delay	MIPv6 Delay
1	1	1
2	5	2
3	18	2
4	16	0

Table2.Handover Latency of MIPv4 &MIPv6

Total Handoff Latency of MIPv4= 1+5+18+16=40 sec
Total Handoff Latency of MIPv6=1+2+2+0=5 sec



Graph3: Handover Latency of MIPv4&MIPv6

From the various handover delay values of MIPv4 and MIPv6, it is concluded that the handover latency of MIPv6 is very shorter than that of MIPv4 handover latency. This is mainly due to the route optimization mechanism of MIPv6. Hence shorter handover latency gives better protocol performance.

3. Average End to End Delay

The End-to-End delay is the sum of the delays experienced at each hop on the way to the destination of each packet. If this value is lesser, then the packets will be delivered faster from source to destination. The average End-to-End delay is computed as below,

$$\text{Average End to End Delay} = \frac{\text{Sum of End to End delays of all packets}}{\text{Total No.of Received Packets}}$$

The following is the experimental values

Protocol	Average End to End Delay(seconds)
MIPv4	23.6109
MIPv6	8.7785

Table3.Average End to End delay of MIPv4 and MIPv6

The average End-to-End delay of MIPv6 is less than that of MIPv4. This is because of there is no foreign agent functions and route optimization procedure in MIPv6 operations. And therefore, home agent directly sends the data packets to the mobile node when binding updates obtained from correspondent host. The decrease in end-to-end delay is due to the low handoff latency by localizing the location update messages up to the mobile agents. Thus decreases the handoff latency, results lower end to end delay in MIPv6.

4. Packet Delivery Ratio (PDR)

The Packet Delivery Ratio is the ratio of received packets to sent packets. The PDR is computed as below,

The following is the experimental values

$$\text{Packet Delivery Ratio (\%)} = \frac{\text{Total No.of received packets} - \text{Total No.of Dropped Packets}}{\text{Total No.of sent Packets}} \times 100$$

Protocol	Packet Delivery Ratio (%)	No.of Packets Lost
MIPv4	97.8551	68
MIPv6	97.9191	13

Table4. PDR & Packet Loss of MIPv4&MIPv6

The PDR of MIPv6 is 0.064% more than that of MIPv4.However, in both the cases of MIPv4 and MIPv6 the delivery ratio is almost same. Also, the packets are delivered faster in MIPv6 when compared to MIPv4 as explained in average End to End delay.

Incase of Packet Loss the MIPv6 has the lowest no.of packet loss when compared to MIPv6 is due to lower handover Latency of MIPv6.In case of MIPv4 ,the higher is the Handover Latency ,so there occurs large no.of packet loss. Packet loss is not only affected by handover latency but also signal fading, noise like characteristics. Again these lost packets are retransmitted in case if we use TCP traffic. That's why the PDR performance is almost same in both MIPv4 and MIPv6.

4. Conclusion:

Mobile IP is a protocol developed by the IETF Group, which provides mobility support to wireless Internet users. In this master thesis, the Mobile IPv4 and Mobile IPv6 protocols are evaluated and their performances are presented. Simulation results and performance analysis are carried out by using NS-2. From the results analysis, MIPv6 shows very much improved performance than that of MIPv4 network in terms of *Throughput, Handover Latency, Average End-to-End Delay and Packet Delivery Ratio and dropped packets.*MIPv6 has very less Handover Latency in comparison with MIPv4. In MIPv6, the Mobile Host obtains care of address through either stateful (obtains a care of address from a DHCPv6) or stateless address auto configuration (MH extracts the network prefixes from the Router Advertisementsand adds a unique interface identifier to form a care of address). This binding update process reduces the Handover Latency. Due to lower Handover latency the Packet losses are also minimized in MIPv6 in comparison with MIPv4.Finally from the analysis in this thesis it is concluded that MIPv6 is the most preferred Protocol for Time sensitive applications.

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