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NIA based Mobility Management Technique for Seamless Roaming in Heterogeneous Networks

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Abstract

Heterogeneous networks are composed of different access technology together to provide Always Best Connected services in anywhere at any time. In such environment mobility is the major issue. Existing mobility support protocols like MIPv6, HMIPv6 and FMIPv6 are performing low during vertical handoff process. To improve QoS performances and to interconnect different networks, an agent called NIA (network interworking agent) and multiple IGMA (interworking gateway mobility agent) has been deployed. The UDP and TCP simulation results are obtained using NS2 environment and compared with an existing macro mobility protocols.

Keywords*: macro mobility protocols, NIA, handoff latency, interworking mobility support and handoff management*

1. Introduction

The fourth generation (4G) is considered as a heterogeneous environment which integrate a multitude of radio access technologies (RAT's) such as wireless technologies (802.11a, 802.11b, 802.15, 802.16, *etc.*) and cellular networks (GPRS, UMTS, HSDPA, LTE, etc.). The evolution of these technologies urged the operators to design and to make the mobile devices with several interfaces. With the variety of wireless interfaces, the users are able to benefit simultaneously from these networks and they can also use various services offered by each type of access network. The most important aim in heterogeneous networks is to ensure ubiquitous access for the end users, under the principle "Always Best Connected" (ABC) [1] . The design and development of heterogeneous wireless networks will provide seamless intersystem roaming across heterogeneous wireless access networks.

Mobility management is the essential technology that supports roaming users with mobile terminals to enjoy their services in progress through wireless networks. Mobility management techniques in heterogeneous wireless networks have been focused in [2]. Several protocols are proposed for NG all-IP-based wireless systems. These solutions try to support mobility from different layers of the TCP/IP protocol stack reference model. Traditional mobility management is mainly limited to terminal mobility that enables a mobile terminal (MT) to continue an ongoing call with its correspondent host (CH) or initiate/receive a call regardless of its point of network attachment.MIP and its variants have been designed for low-level mobility. In MIPv4 [3], triangular routing is used and the MH updates it's binding (Home Address, Care of Address) in the HA. If route optimization (MIPv4-RO)[4] is used, the MH also informs the CH of the binding updates. Alternatively, the HA may update the MH's binding in the CH [5]. MIPv6 [6] has integrated the route optimization concept, whereby the MH automatically sends the binding updates to CH and HA. As both MIPv4 and MIPv6 are

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macro (inter-domain) mobility protocols, micro (intra-domain) mobility schemes, such as Cellular IP, HAWAII and Hierarchical MIP, have been proposed to handle local terminal mobility. A MIP variant [7] may deal with mode handoff by using the FA as a gateway between the infrastructure networks and ad hoc networks.

The existing macro mobility protocols and architectures address various minimizing schemes with lack of performances in latency. These schemes have certain deficiencies and there is no one scheme that provides a complete solution to vertical handoff problem or macro mobility issues. To address this issue a novel NIA based vertical handoff architecture for seamless mobility is proposed. In this architecture vertical handoff execution has been carried out by NIA based seamless integrated architecture.

The rest of this paper is organized as follows. The NIA based seamless vertical handoff architecture (SVHA) is presented in section 2. Signaling flow operation of SVHA is presented in section 3. We present a detailed description of SVHA in section 4, followed by UDP and TCP performance analysis in section 5. Finally the advantages of our proposed architecture are summarized in section 6.

2. Seamless Vertical Handoff Architecture

A new macro mobility management architecture known as NIA based Seamless vertical handoff mobility Architecture as shown in figure 1 for next generation wireless IP network is proposed, which performs fast handoff, supports large-scale mobility and power consumption in IP based mobile network for real-time packet communication in a commercial heterogeneous environment. The NIA based seamless vertical handoff architecture has been developed on top of seamless handoff architecture for micro mobility management [8]. The proposed architecture is used to re-establish the communication link quickly and to minimize the handoff latency that occurs during mobile IP handovers. In this scheme, two different scenarios are proposed to handle macro mobility between networks. The first scenario is handles the handover between cellular to WLAN. The second scenario handles the handover between WLAN to Wi-Fi networks. Macro mobility handover supports the handovers between two adjacent domains. The reason for having several subnets is to deploy the network over a wide area to keep the mobile user in the same network as long as possible. The novelty of the scheme is to retransmit the buffered packets during macro mobility handover between networks and several multiple Interworking gateway mobility agents' protocol extensions have been proposed to avoid potential bottlenecks in single inter working gateway mobility agent configurations. Such multiple mobility agents' schemes allow the use of dynamic load balancing policies and power consumption to further improve the overall performance. The performance of the proposed architecture is compared with existing macro mobility protocols such as MIPv6, HMIPv6 and FMIPv6. From the simulation results, it is observed that in the proposed architecture the handoff latency due to binding updates is reduced because of localizing the binding updates with NIA and Interworking gateway (IG) deployment [9] and thereby reducing the probability of the packet loss during handoff.

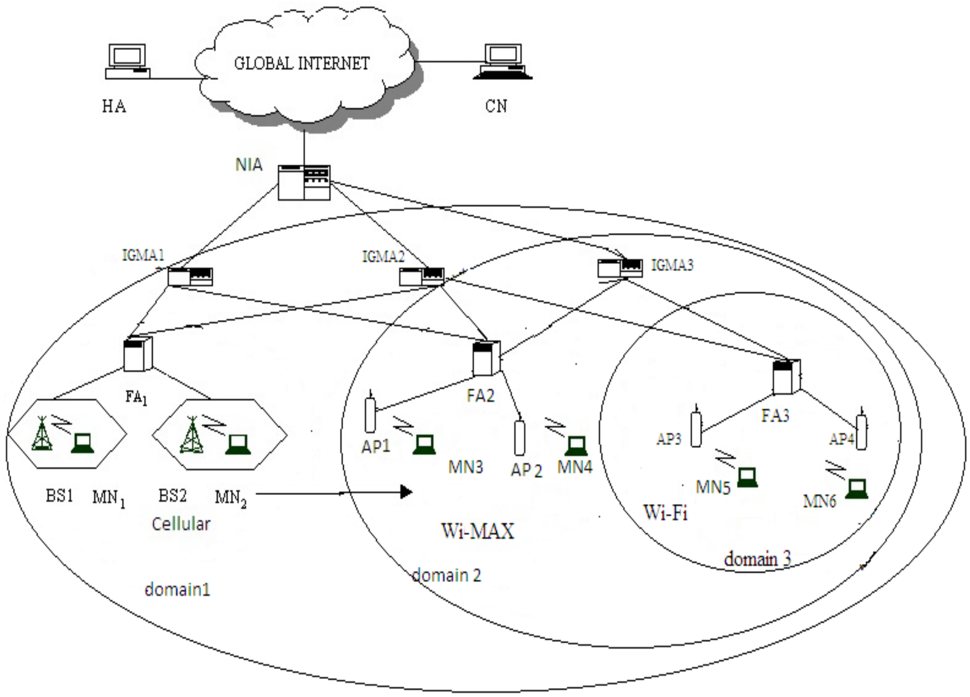

Figure 1. Seamless Vertical Handoff Architecture

2.1. Description

The access network is divided into several networks depending on its geographical location. We assume that each network has at least one FA server and each FA server must be associated with all IGMA (interworking gateway mobility agent) in that domain. The serving FA dynamically assigns the MN, an IGMA during the network specific registration process with NIA. When an MN enters into the domain for the first time, it performs an inter domain registration by sending the registration request to the FA in that network, first obtaining a NCOA (network care of address) which serves as an ICOA(interworking care of address) for that MN. The serving FA assigns the MN a designated IGMA. Once the mobile node receives the reply from the foreign agent, it sends a registration request to the assigned integrated gateway mobility agent; the binding update contains the mobile nodes home IP address, network care- of address, network domain lifetime (Ld) and lifetime of the mobile in the network (Lm).

When the IGMA receives the binding update, it creates a cache entry for the mobile node and it includes the care-of address of the IGMA mobility agent in the inter domain location update reply. After receiving the reply from the IGMA, the mobile node sends a binding update to NIA. The NIA adds the DCOA (domain care of address) to this binding update and sends the reply to MN. Subsequently the MN is responsible for generating a global location update to the necessary remote node such as HA. The acknowledgement from the home agent is routed to the mobile node through the NIA agent, IGMA mobility agent and the foreign agent in the network. Note that the NIA is used only during inter domain roaming. Once the MN moves into a new domain, the NIA is no longer involved. Hence, the load on NIA is minimal. The signaling flow, when the mobile node moves into a new network domain, is illustrated in Figure 2.

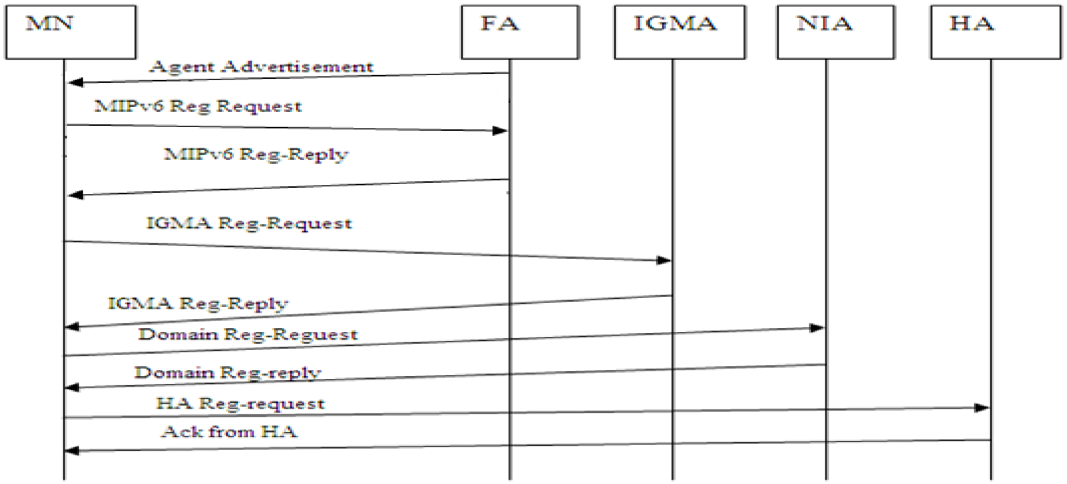

Figure 2. Signaling Flow during Inter Domain Handoff

The Seamless Vertical Handoff Architecture (SVHA) requires communication between the NIA, IGMA and the associated FAs. This correspondence may take place through non-standard protocols that are compatible with the existing telecommunication infrastructure. In the SVHA operation, the HA will tunnel all the packets received from CNs to the NIA by using the DCOA. The NIA will send control messages through the correctly associated IGMA and FA to the MNs. As long as the MN is under the control of a single IGMA, the MN does not transmit any location update to the HA. This architecture ensures that the localization of the entire inter domain mobility updates message between the network domain. When a mobile node moves from one domain to another, it performs domain specific registration with the new foreign agent in the visited network domain. Since the mobile node indicates that it has a valid registration, the foreign agent will not assign a new interworking gateway agent. By this mechanism, we have localized the binding updates to the interworking agent and this reduces the internet delay associated with the handoff and hence reduces the risk of higher probability of loss in binding update messages.

3. The Vertical Handoff Procedure

In Seamless Vertical Handoff Architecture, the handoff will takes place when the MN moves from one network to another network. SVHA handoff procedure is fuzzy based initiation and decision [10] based on the network layer 2 trigger to the MN that indicating an impending changes in connectivity. To minimize service interruption during vertical handoff process, SVHA requires the MN to generate a beacon message to the IGMA serving the MN. After reception of beacon message, IGMA multicast all inbound packet to the new and old FA. The FA buffers such arriving packets in the individual MN buffer, thus minimizing the loss of routed packets during the handoff execution.

When the MN subsequently performs a subnet level configuration with FA_2, the FA_2 can immediately forward all such buffered packets over the wireless interface, without waiting for the IGMA to receive the corresponding inter domain location updates. When the MN obtains the new ICOA, then it sends the binding update to the serving IGMA. The IGMA will redirect packets to the MN’s new ICOA only after receiving this message. The motion of the MN between different networks between domains will be transparent to the NIA. As long as the MN mobility is within a domain, the MN does not transmit any location updates to the

HA. By localizing the binding update between the network domains Interworking Agent, we are able to significantly reduce the frequency of global updates. Furthermore, the frequency of horizontal handoff within a small region is always larger than that of an inter domain handoff. We are able to significantly reduce the occurrence of large latency in global location updates, higher probability of loss of binding update message and loss of routed packets.

The handoff disruption time is defined as the interval between first detection of network movement and the first data packet to reach the MN at its new location. It is the sum of three terms: discovery period, establishment time and completion time [11-12].

Discovery period (T_d): The time for a mobile node to discover that it has moved to a new BS or foreign agent coverage area. This period of time includes the time to receive a new agent advertisement after crossing a cell boundary. In mobile IPv6, this period includes the time for the MN to realize that it has changed the subnet based on the subnet ID matching.

Establishment time (T_C): The time to complete an MIPv6 registration or to establish the new route to the mobile node.

Completion time: The time to receive the first forwarded IP packet after the new path has been established. In all the cases, it is assumed that the MN is roaming outside its home network and is receiving downlink traffic only.

Internet Delay (D_Int): The Internet delay is the delay that an IP packet experiences when traveling through the Internet across several routers. This delay will affect the overall end-to-end delay for communication between a remote correspondent host in the Internet and a mobile host or between two different mobile hosts that are in two different networks. This Internet delay is a component of the end-to-end delay and entails the propagation delay, the queuing delays and transmission delays. The Internet delay can be simulated by a sum of two functions, of which one is constant and the other is a random variable output with an Erlang distribution [13].

The average vertical handoff time of the proposed Seamless Handoff Architecture is very less and the link establishment time is very short as compared with MIP variants since the deployment of NIA in the architecture. The link establishment time depends on the following parameters:

B_w - Bandwidth of the wired backbone
B_{wl} - Bandwidth of the wireless link
L_w - Latency of the wired link (includes propagation delay and link layer delay)
L_{wl} - Latency of the wireless link (propagation delay + Link layer delay)
R_d - Router or Agent route lookup delay + packet processing delay (at the IP layer)
d_{x-y} - Average number of subnet between x and y
S - Size of Average number of subnet between x and y
D_Int - Average overall delay that a packet encounters while traveling across the wide area Internet

The transmission delay (S, d_{x-y}) of a message of size S sent from x (an MN always) to y (BS or AP) in a network consisting of the wireless and wired links is given by,

Total transmission delay = (Wireless link transmission delay from MN to BS) + (The number of hops x wired link transmission delay) + (The number of routing nodes x processing delay of the mobile node)

$$T (s, d_{x-y}) = (S/ B_{wl} + L_{wl}) + d_{x-y} * (S/ B_w + L_w) + (d_{x-y} + 1) * R_d$$

In Mobile IPv6, the average link establishment time tc includes two way transmission delay for wired and wireless link and it is given by ,

$t_{c,\,MIP} = 2(S/\ B_{wl} + L_{wl}) + 2d_{MN\text{-}HA}\ x\ (S/\ B_{w} + L_{w}) + 2(d_{MN\text{-}HA}+1) * R_{d} + 2\ D\_Int$

Here, $d_{MN\text{-}HA}$ denotes the number of hops between MN and HA. When the HA is located outside the network visited, D_Int, will be the predominant term. In seamless vertical handoff architecture, there is a nominal internet delay, because the binding updates are localized between MN and IGMA. Therefore, the average link establishment time during cellular-WLAN for seamless handoff architecture is given by,

$t_{c} = 2(S/\ B_{wl} + L_{wl}) + 2d_{MN\text{-}IGMA} * (S/\ B_{w} + L_{w}) + 2(d_{MN\text{-}IGMA} + 1) * R_{d}$

It is important to note the number of hops between domain $d_{MN\text{-}IGMA}$ in the above equation is very less. As a result, the average link establishment time in SVHA is very less compared to that of Mobile IPv6.

4. Simulation Tool and Environment

The simulation code used for the experiments was designed on top of INRIA/Motorola MIPv6 [Mobiwan] code for *ns-2.1b7a* [Network Simulator (ns)] implementation. We have extended the code with four main modules: MIPv6, Hierarchical Mobile IPv6, and Fast Handovers for Mobile IPv6 and SVHA. The simulator ns-2.1b7a has been modified to incorporate the SVHA. The ns-2 is an object-oriented simulator, written in C++, with an OTcl, which is the command and configuration interface for the simulator. The ns-2 tool is accompanied by separate tool, the Network Animator (NAM), for visualization of the simulation. The simulation environments and the parameters are shown in Table 1 and 2.

Table 1. Simulation Parameters

Topology	Hierarchical
Topography	1500m X 1500m
Wired Link Bandwidth	10Mbps
Wireless Link Bandwidth	2Mbps
Wired Link Delay	2ms
Wireless Link Delay	2ms
Wireless Protocol	802.11
Router Discovery	500ms
Binding Update delay	140ms
Delay through Internet	20ms
NIA − IGMA delay	20ms
DAD time	1000 ms
L2 packet size	18270 bits
Overlap of coverage area	30m
CBR Traffic: packet Size	210 bytes
CBR Traffic: packet interval	10ms
TCP packet size	1460 bytes
Application	CBR, FTP
TCP window size	20

Table 2. Simulation Environments

Processor	450 MHz, PIII
Hard Disk	20GB
RAM	128 SDRAM
Operating System	Red Hat Linux 7.2

The simulations of SVHA protocol are performed using the network topology, as shown in Figure 3. In this topology, the R_0 acts as a NIA , the R1,R2 and R3 act as mobility agents $IGMA_1$ $IGMA_2$ and $IGMA_3$, respectively, and the R4 , R5 and R6 act as foreign agents FA_1 ,FA_2 and FA_3, respectively, and from BS1 to BS2 act as a base station and from AP1 to AP4 act as a Access points. Mobile node connects to the access point (AP) using the ns-2 CSMA/CA wireless link model where each BS and AP is operates on a different frequency band. Simulation results are obtained using a single mobile node, continuously moving between BSs and AP at a speed that could be varied. Such a movement pattern ensures that the MN always goes through the maximum overlapping region between three radio interfaces. Nodes are modeled without constraints on switching capacity or message processing speed. During simulation, an MN travels periodically between neighboring access point with variable speed. The overlap coverage region between the access points is 30m. All the base stations are placed on a straight line.

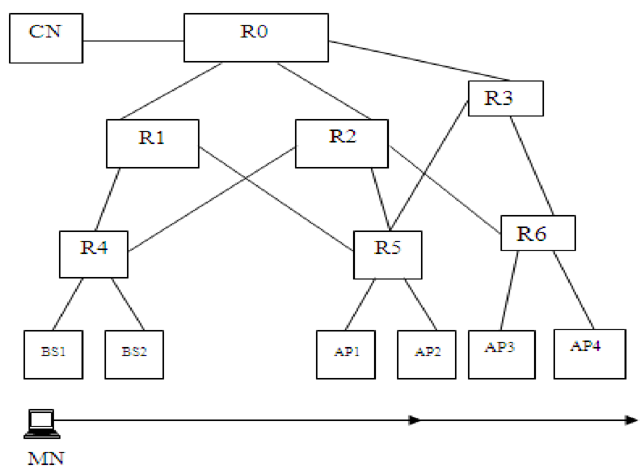

Figure 3. SVHA Simulation Topology

5. Simulation Results

The UDP probing traffic is directed from correspondent node to mobile node, with a packet inter arrival time of 10ms and a packet size of 210 bytes. During simulation, an MN travels periodically from BSs to APs. A single simulation run is 75 seconds in duration.

Transmission Control Protocol is known to suffer from performance degradation in mobile wireless environments. This is because such environments are prone to packet losses due to high bit error rates and mobility induced disconnections. TCP interprets packet losses as an indication of congestion and inappropriately invokes congestion control mechanisms, leading to degraded performance. After disconnection and upon subsequent reconnection, the MN sends three duplicate acknowledgements (dupacks) to the fixed host (FH). These dupacks cause the TCP sender at the FH to immediately enter the fast recovery phase, instead of waiting for its retransmission timer to expire. Thus this approach reduces the “idle period” of the TCP sender after the connection is re-established. However, the TCP sender at FH also reduces its slow start threshold (ssthresh) and congestion window (cwnd) parameters when it enters fast recovery phase. This side effect in turn reduces the throughput of the connection. Since many network applications are built on top of TCP, and will continue to be in the foreseeable future, it is important to improve its performance in wireless networks without any modifications to the fixed hosts. This is the only way by which mobile devices communicating on wireless links can seamlessly integrate with the rest of the access networks.

5.1. UDP Results

5.1.1. Vertical Handoff Latency: Handoff time can be defined as the time between receptions of the last packet through the old access point till reception of the first packet through the new access point. The simulation for handoff latency during vertical handoff for MIPv6, HMIPv6, FMIPv6 and SVHA protocols are plotted in Figure 4. During the simulation the MN is allowed to travel from BS1 to AP4. The crossover distance is 1, 2, 3, 4 and 5 hops when the mobile node moves between BS1-BS2, BS2-AP1, AP1-AP2, AP2-AP3 and AP3-AP4 respectively, for SVHA topology. It is observed that the handoff latency increases with increase in crossover distance for MIPV6 and FMIPv6 protocols when the MN moves between BS1-BS2, BS2-AP1, AP1-AP2 , AP2-AP3 and AP3-AP4.The handoff latency for SVHA is constant for all the crossover distance. The main reason for constant handoff latency is the number of hops from the MN to the crossover node which remains the same. The handoff latency is low in SVHA when compared to other protocols. This decrease in handoff latency is due to the fact that the binding updates are sent only up to the IG mobility agent in SVHA.

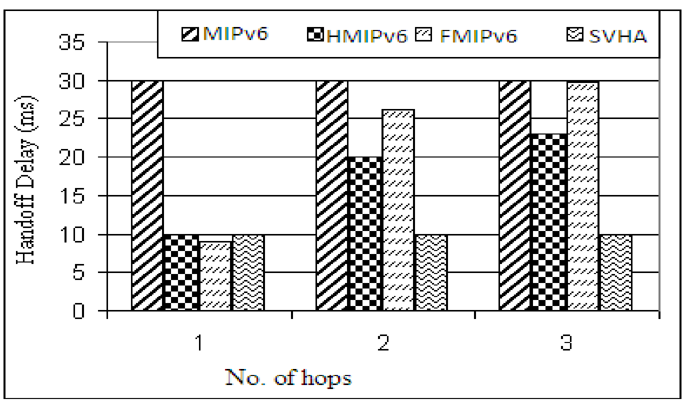

Figure 4. Vertical Handoff Latency

5.1.2. Packet Loss Ratio with Variable Mobile Speed: In this case, the simulation results are obtained using a single mobile node, continuously moving between base stations with variable speed. The UDP packet loss ratio with variable speed of the MN is plotted in Figure 5 for SVHA, MIPv6**,** HMIPv6 and FMIPv6 protocols. When the speed of MN increases, the frequency of handoff gets increased and as a result the packet loss ratio also gets increased. This phenomenon is observed from Figure 5 for SVHA and other macro mobility protocols. It is further observed that the UDP packet loss ratio is low in SVHA than in any other macro mobility protocols. This is because of the presence of low handoff latency in Seamless Vertical Handoff Architecture.

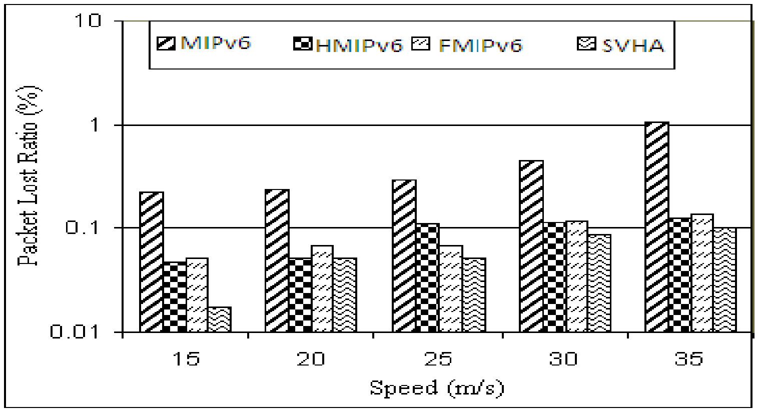

Figure 5. Packet Loss Ratio with Variable Mobile Speed

5.2. TCP Results

5.2.1. Throughput with Variable Mobile Speed: In this case, the simulation results are obtained using a single mobile node, continuously moving between base stations and access point with variable speed. The TCP throughput with variable speed of the MN is plotted in Figure 6 for SVHA, MIPv6, HMIPv6 and FMIPv6 protocols. When the speed of MN increases, the frequency of handoff gets increased and as a result the packet loss also gets increased. This phenomenon is observed from Figure 6 for SVHA and other macro mobility protocols. It is further observed that the SVHA provides better throughput performance when compared to other macro mobility protocols. This is because of the presence of low handoff latency in NIA based Seamless vertical Handoff Architecture.

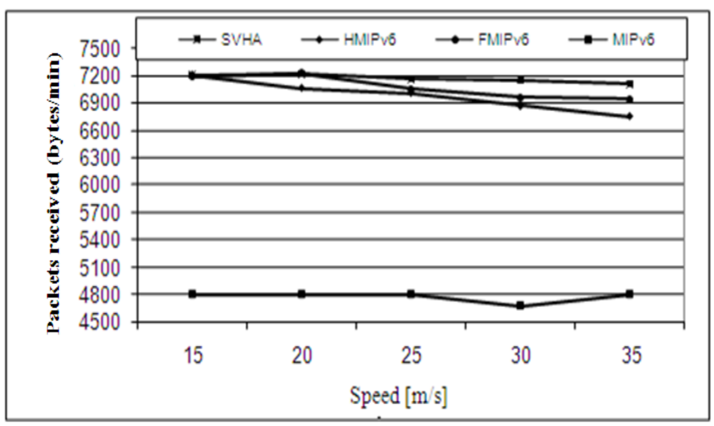

Figure 6. Throughput vs Speed

5.2.2. End to End Delay: The simulation results of maximum, minimum and average end-to-end delay of TCP packets for MIPv6, FMIPV6, HMIPV6 macro mobility protocols and SVHA are plotted in Figure 7. During simulation mobile node is allowed to move between the base stations and access point BS1-AP4 in hierarchical and SVHA topologies. From Figure 7 it is observed that the average end-to-end delay is the lowest for SVHA protocol when compared to the other macro mobility protocols whereas maximum delay is the highest for HMIPv6.

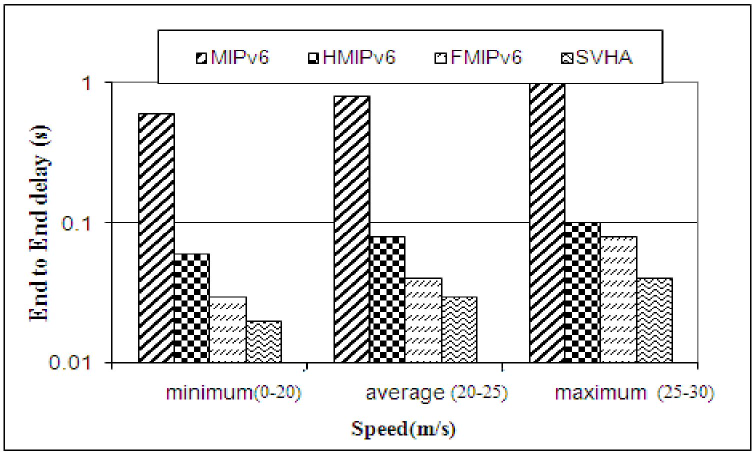

Figure 7. End to End Delay

6. Conclusion

In this paper, a new NIA based SVHA network architecture is proposed and the performance results are presented and it is compared with the existing macro mobility protocols in hierarchical topology, which reduces the latency due to binding updates and also reduces the packet loss due to handoff. The concept of localizing the binding update also has an important impact on the time to complete network registration with NIA. Since the distance traveled by the binding updates during inter-network movement is small, time taken to complete the registration is reduced as minimum as possible. The simulation results shows that the best performance is achieved in SVHA and it provides significant improvement in vertical handover performance, UDP packet loss and TCP throughput when compared to other macro mobility protocols.

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