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Influence of Topology on Micro Mobility Protocols for Wireless Networks

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Abstract: The support for IP-based real-time services in the next-generation mobile systems requires the coupling of mobility with quality of service. Currently, Mobile IP is the most promising solution for mobility management in the Internet. Several IP micro mobility approaches have been proposed to enhance the performance of Mobile IP which supports seamless mobility, minimum packet loss, limited handoff latency, scalability and robustness. But, most of the researches on micro mobility protocols were focused on networks with tree topology, which suffers from severe limited flexibility and scalability problem. This study investigates the influence of different topologies on the performance of the protocols namely, HMIP, HAWAII and Cellular IP. Simulation results presented in this paper are based on the Columbia IP Micro-mobility Software (CIMS).

Key words: Seamless mobility, micro mobility protocols, network topology, protocol performance

INTRODUCTION

Wireless access to the internet may outstrip all other forms of access in the near future. It is likely that mobile users will expect similar levels of service quality as wire line users. Such a vision presents a number of technical challenges for Mobile IP (Perkins, 2002) in terms of performance and scalability. Recently, a number of micro mobility protocols have been developed by the IETF Mobile IP working Group that addresses some of these issues. Micro mobility protocols are designed for environments where Mobile Node (MN) change their point of attachment to the network so frequently that the basic Mobile IP protocol tunneling mechanism (Johnson and Perkins, 2004) introduces network overhead in terms of increased delay, packet loss and signaling. Micro mobility protocols aim to handle local movement (e.g., within a domain) of MN without interaction with the Mobile IP enabled Internet. This has the benefit of reducing delay and packet loss during handoff and eliminating registration between MN and possibly distant Home Agents (HAs) when MN remains inside their local coverage areas. Eliminating registration in this manner reduces the signaling load experienced by the core network in support of mobility.

This study deals with micro mobility protocols namely Hierarchical Mobile IP (HMIP), Handoff-Aware Wireless Access Internet Infrastructure (HAWAII) and Cellular IP (CIP) (Sun *et al*., 2002). In HMIP the encapsulated traffic from a HA is delivered to the root FA. Each FA on the tree decapsulates and then reencapsulates data packets as they are forwarded down the tree of FA toward the MN's point of attachment. As a MN moves between different access points, location updates are made at the optimal point on the tree, tunneling traffic to the new access point. In HAWAII, MN retains their network address while moving within a domain. The HA and any corresponding hosts are unaware of the hosts mobility within this domain. Routes to the MN are established by specialized path setup schemes that update the forwarding tables with host-based entries in selected routers in that domain. Cellular IP inherit cellular principles for micro-mobility management such as passive connectivity, paging and fast handoff control. The location-tracking scheme imposes neither traffic nor processing load on global network as long as host is idle. The distributed location management and routing algorithms of Cellular IP lead to simple and low cost implementation of Internet host mobility requiring no new packet formats, encapsulations or address space allocation beyond what is present in IP.

For reasons of robustness against link failures, flexibility, scalability and load balancing, there is always a growing need to understand the performance of micro mobility protocols under the various network topologies (Sun *et al*., 2005; Hu *et al*., 2005). In this research, we study the behavior of TCP sources in a mobile environment using HMIP, CIP and HAWAII in tree, partial mesh and random topologies.

MICRO MOBILITY SOLUTIONS

Micro mobility solutions are presented for the intra-domain mobility management to implement a fast and seamless handoff and minimized control traffic overhead. Three main proposals are discussed in here, i.e.,

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HMIP, Cellular IP and HAWAII and it can be noted that none of these suggestions are trying to replace the Mobile IP. Instead, they are enhancements to the basic Mobile IP with the micro mobility management capability (Campbell *et al*., 2002). There are still many other micro mobility proposals existing, e.g., the Intra-Domain Mobility Management Protocol (Misra *et al*., 2000), Edge Mobility Architecture (Neill, 2000), Hierarchical Mobile IPv6 (Soliman, 2001).

Hierarchical mobile IP: HMIP (Akyildiz *et al*., 1999) the proposal from Ericsson and Nokia as illustrated in Fig. 1 the Fas in a domain are organized into a hierarchical tree-like structure to handle the MN's local registration. The basic idea of hierarchical structure of visited networks is that, the MN's HA needs not to be informed of every movement that the MN performs inside the foreign network domain. The root of the hierarchy (FA$_1$) is a special kind of FA called Gateway FA (GFA). An FA's agent advertisement is extended to include in the CoA field the IP addresses of FAs from the FA itself through all the ancestor FAs until the GFA (Fig. 1 FA$_4$, FA$_3$, FA$_1$). The MN's registration is then processed by all the FAs (updating the maintained visitor list entry) on the uplink path ended by the GFA and finally the HA stores the GFA's IP address as the current CoA of the MN. Through this mechanism, the location information is managed in a distributed mode.

When an incoming packet (from the HA or any Correspondent Node (CN)) arrives at the GFA, the downlink path is formed by searching the visitor list for a corresponding entry by each FA on the path. Each of the FA then re-tunnels (decapsulating and reencapsulating) the packet to its next lower-level FA and the packet are forwarded down the tree of FAs toward the MN's point of attachment. As a handoff occurs, the MN first finds the Closest Common Ancestor (CCA) by comparing the new CoA vector with the old one and choosing the lowest-level FA that appears in both CoA vectors. The MN then regionally registers this movement to the CCA and leaves all the higher-level FAs unaffected. In Fig. 1, when the MN moves from FA$_4$ to FA$_5$, the FA$_2$ is the CCA. When moving from FA$_5$ to FA$_6$, the FA$_1$ is the CCA. Typically only two levels of the hierarchy are considered: at the top level there is one or several GFAs and at the lower level all FAs are connected to the corresponding GFA. If there is a hierarchy of FAs between the GFA and the MN's current FA, the FA must support the smooth handover routing optimization.

HAWAII protocol: HAWAII a domain-based approach was proposed to the IETF in by researchers from Lucent Bell Labs (Ramjee *et al*., 2002). HAWAII is responsible for the intra-domain mobility limited to an administrative domain of an access network while Mobile IP handles the inter-domain mobility. In HAWAII a hierarchy based on domains is used like depicted in Fig. 2. The gateway into each domain is called *domain root router*. Further a HAWAII domain comprises several routers and base stations running the HAWAII protocol, as well as MN. A MN in a HAWAII environment runs a standard Mobile IP protocol engine with Network Access Identifier (NAI), route optimization and challenge/response extensions. HAWAII intends not to cause great modifications to the Mobile IP protocol engine running on a MN to prevent MN from having two protocol stacks implemented. The processing of Mobile IP messages is split in two sections. The first one reaches from the MN to the base station and the second one from the base station to the Mobile IP HA of the MN. Handover in HAWAII will take place, when the MN's next hop IP node changes. For describing re-establishments of routes after intra-domain movements a crossover router has to be defined. This is the one closest

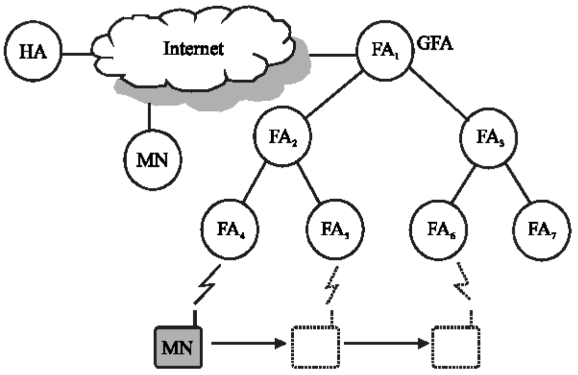

Fig. 1: Hierarchical mobile IP

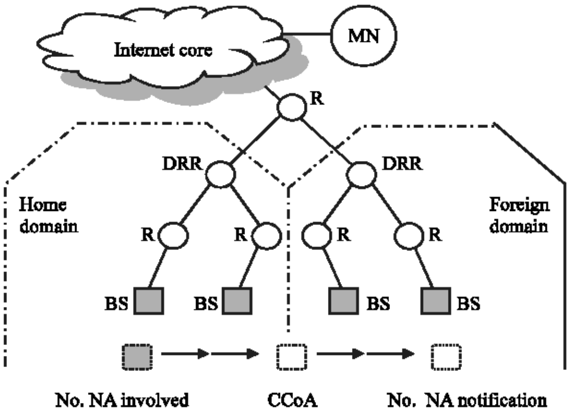

Fig. 2: HAWAII network architecture

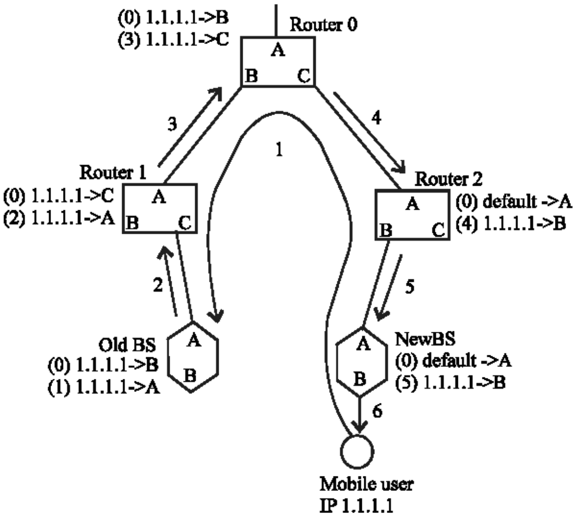

Fig. 3: Multistream forwarding scheme

to the MN at the intersection between the path from the domain root router to the old base station and the path from the old base station to the new base station. There are two different path setup schemes for updating routing information are forwarding path setup scheme and non-forwarding path setup scheme. One for networks with MN that can only maintain connection to one base station (e.g., TDMA networks) and the other one for networks with MN that can be connected to two or more base stations simultaneously like in CDMA networks.

Multistream forwarding path setup scheme as depicted in Fig. 3, in case of a handover, the new base station then sends a HAWAII path setup update message directly to the old base station which address was transmitted by the MN. The old base station performs a table look-up for a route to the new base station and determines the next hop router. It adds a routing table entry for the MN pointing to that next hop router and forwards the path setup update message. From now on the old base station forwards all data packets for the concerned MN to the new base station according to the new forwarding entry. The next hop router performs similar actions and in that way the packet is forwarded up to the cross-over router which then forwards the path setup update message completely to the new base station and sends a Mobile IP registration reply to the MN.

In Unicast non-forwarding path setup scheme as depicted in Fig. 4 the data packets are diverted at the cross-over router from that time on, when the path setup update message first passes the cross-over router. In this path setup scheme the old base station does not forward any packets to the new base station. On receiving a Mobile IP registration request, the new base station adds a forwarding entry for the MN pointing to the interface on which the registration request was received. Then it looks for a path to the old base station and sends a path setup update message on the determined interface. The next router performs similar actions and forwards the message, too.

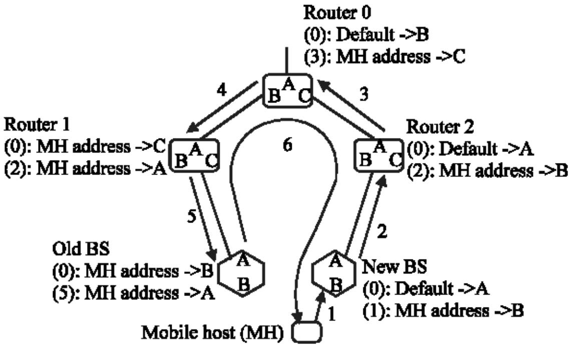

Fig. 4: Unicast non-forwarding scheme

Cellular IP protocol: Cellular IP (Valko, 1999) is a proposal to the IETF made by researchers from Columbia University and Ericsson. Besides the Mobile IP protocol engine, Cellular IP MNs have to run a special Cellular IP protocol that controls the micro-mobility support. In Cellular IP, location management and handoff support are integrated with routing. To minimize control messaging, regular data packets transmitted by MN are used to refresh host location information. Uplink packets are routed from a MN to the gateway on a hop-by-hop basis. All intermediate base stations cache the path taken by these packets. To route downlink packets addressed to a MN, the path used by recently transmitted packets from the MN is reversed. When the MN has no data to transmit, it sends small, special IP packets toward the gateway to maintain its downlink routing state. Following the principle of passive connectivity, MN that have not received packets for some period of time allow their downlink routes to be cleared from the cache as dictated by a soft state timer. Paging is used to route packets to idle MN in a Cellular IP access network s illustrated in Fig. 5. Cellular IP supports two types of handoff mechanisms: hard handoff, semi-soft handoff. Former for networks with MNs that can only be connected to one base station and the latter for MNs that can be simultaneously connected to two base stations at the same time.

Hard handoff (HHO): In Cellular IP a MN initiates a handoff (based on signal strength measurements) by sending a route update packet to the new base station.

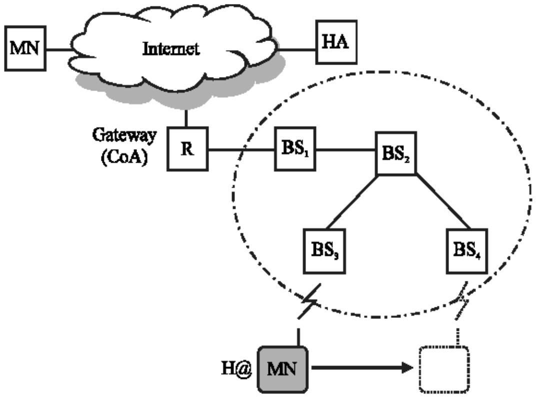

Fig. 5: Cellular IP access network

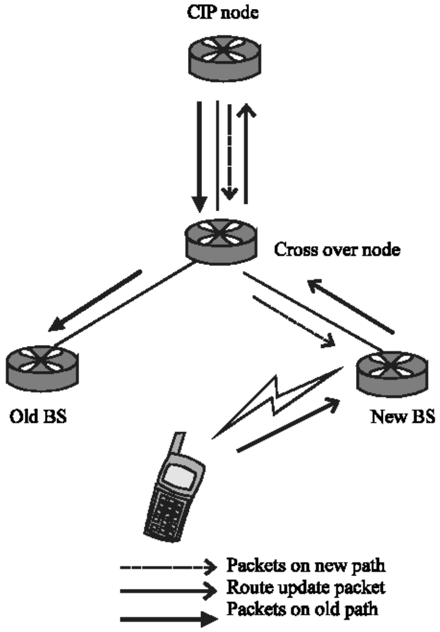

Fig. 6: CIP hard handoff

This packet travels as in Fig. 6 Handoff in Cellular IP takes hop-by-hop manner from the base station to the gateway router and reconfigures the route cache entries in the Cellular IP nodes along its way. The wireless interface of a MN changes from one base station to another at once. Data packets arriving at the cross-over node before the route cache entry is changed are misdirected and will be lost since the MN is already attached to the new base station

Semi-soft handoff (SSHO): The MN switches to the new base station, transmits a semisoft packet with a flag indicating a semi-soft handoff while listening to the old base station as shown in Fig. 7. The semisoft packet reconfigures the route caches on the way to the gateway

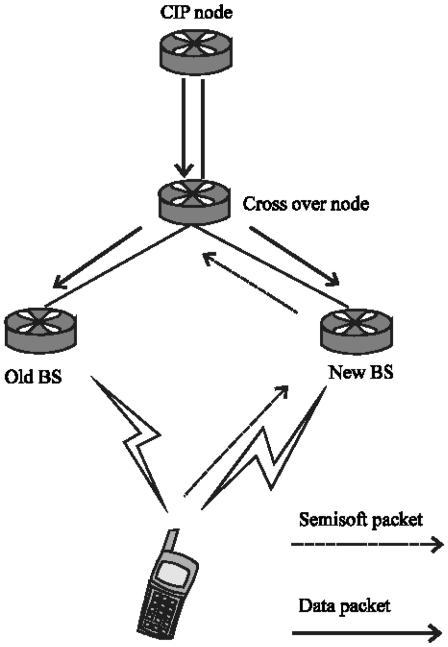

Fig. 7: CIP semisoft handoff

router and adds an entry to the cache of the crossover node. Downlink packets for the MN are duplicated in the crossover node and sent along paths, the new one and the old one. After a semi-soft delay, the MN performs a regular handoff. It migrates to the new base station and sends another route update packet to complete the handoff. This last packet stops the crossover node duplicating packets. The semi-soft delay is a fixed amount of time that is proportional to the mobile-to-gateway round-trip delay. If the path to the new base station is shorter than to the old one, some packets may not reach the MN. To overcome this problem, packets sent along the new path need to be delayed. A delay device mechanism, located at the crossover node, should provide sufficient delay to compensate for the time difference between the packets traveling on the old and new paths.

SIMULATION MODEL

For the simulation, we use the micro mobility protocols implementation, which was implemented in Columbia IP micro mobility software (CIMS) (http://cometColumbia.edu/micromobility;http:/www.isi.edu/nsnam/ns). It supports micro mobility protocols such as Hawaii, Cellular IP and HMIP for the ns-2 network simulator based on the version 2.1b6. The simulations are performed for an IP domain with a single gateway and a tree, partial mesh and three random network topologies varying the parameters like handover delay, packet loss etc. The partial mesh topology consists of the tree structure with the additional mesh links while the random topology is formed by the mesh one with no or extra uplinks. In Random 1 topology, there exists only one path from CN to MN. In Random 2 and 3 topologies, there exists more than one active path to the BS while Random 2 uses less number of links. In simulation model the C_i and BS_i represent Routers and Base Stations (BSs) and C_0 is the Domain Root Router (DRR) and Gateway in case of HAWAII and CIP, respectively. Here each wired connection is modeled as 10 Mbps duplex link with 2 ms delay. MN connects to the access point (BSs) using the ns-2 carrier sense multiple accesses with collision voidance (CSMA/CA) wireless link model where each BS operates on a different frequency band.

Simulation results are obtained using a single MN, continuously moving between BSs at a speed that could be varied. During simulation, a MN travels periodically between neighboring access point with a speed of 30 m sec^{-1}. The overlap coverage region between the access points is 30 m. During such a simulation, MN has to perform three handover to move from BS_1 to BS_4 as shown in Fig. 8-12. The loss of packets due to the failure of underlying mobility detection scheme is not considered and simulations were set up such that mobility detection always succeeded when the MN moved from one BS to another because the goal of our simulation is to evaluate and compare the influence of topology on these protocols. For traffic flow, FTP source with TCP agent is used and it has a packet size of 552 bytes.

PERFORMANCE EVALUATION

Performance metrics: The following metrics for evaluation and comparison of micro mobility protocols.

- Handoff delay is defined as the difference between the time at which the mobile node received the last packet from the old BS and the first packet from the new BS.
- Signaling cost is defined as number of signaling packets that are generated in a network which includes the location update cost and packet delivery cost.
- End to End delay is defined as the sum of the delays experienced at each hop on the way to the destination.
- Throughput is the measure of number of bytes received by a MN over a specified period of time.

Simulation results and discussion: Simulation is conducted for HMIP, HAWAII using UNF, MSF scheme and HH, SS handoff schemes for Cellular IP, over five topologies taking into account of various factors that affect the performance of the protocols. The simulation network with wired link delay of 2 ms accommodates TCP traffic. TCP probing traffic is directed from Correspondent

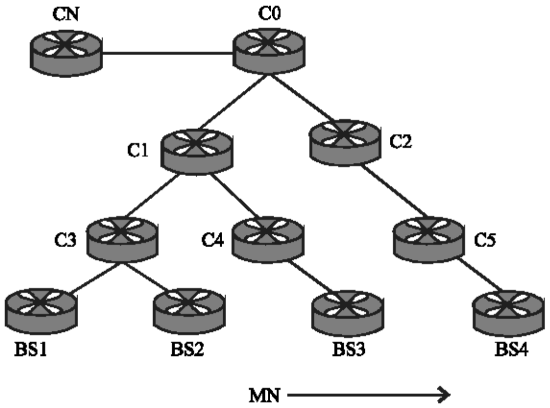

Fig. 8: Tree topology

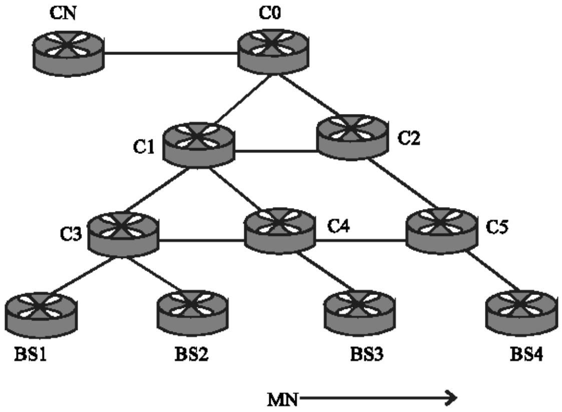

Fig. 9: Partial mesh topology

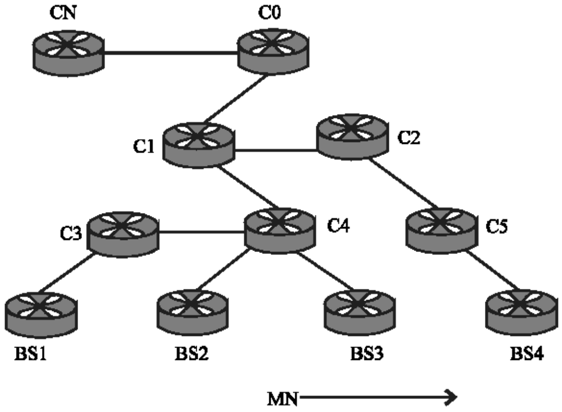

Fig. 10: Random topology 1

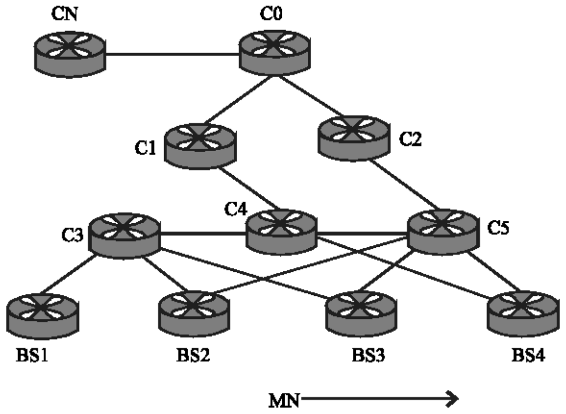

Fig. 11: Random topology 2

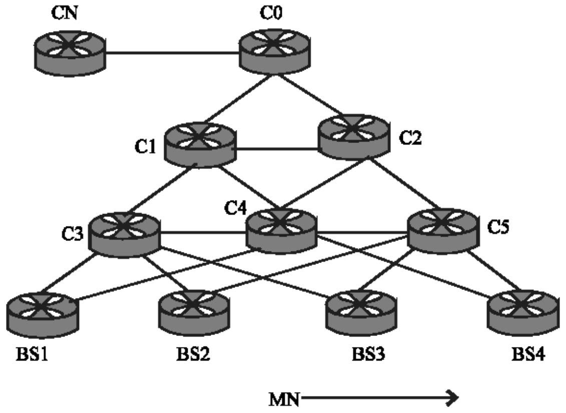

Fig. 12: Random topology 3

Node to MN, with a packet size of 552 bytes. A single simulation run is 30 sec in duration. While calculating Handoff delay, the MN is allowed to travel back and forth between the base stations BS1-BS2, BS2-BS3 and BS3-BS4 with the speed of 30 m sec^{-1}.

HMIP

Effect on handoff delay: One of the important performance measures of wireless networks is the delay experienced to deliver a packet from an old base access point to current point of attachment of MN. Handoff delay depends on number of links present in the path between old and new base station. During the simulation as the MN moves from BS1 to BS4, handoff delay increases which can be clearly observed from Fig. 13. For the scenario of BS1-BS2 handoff, except random 1 topology, all are providing low handoff delay. The reason is, only in the Random1 topology the number of links present in the path between old and new BS is high compared to others. In the similar manner, during the handoffs at BS2-BS3 and BS3-BS4, Tree topology provides higher delay than others.

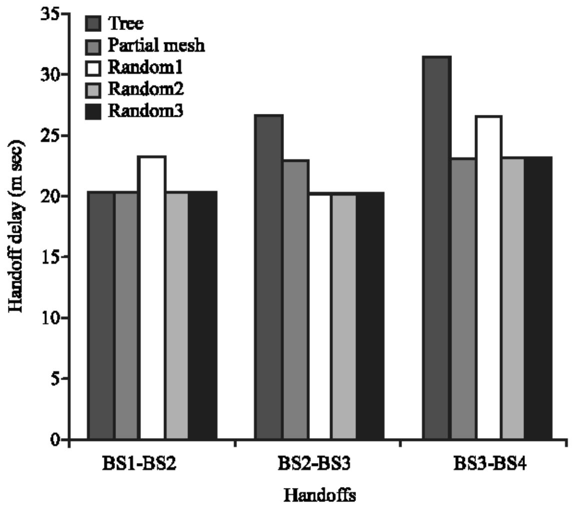

Fig. 13: Effect on HMIP handoff delay

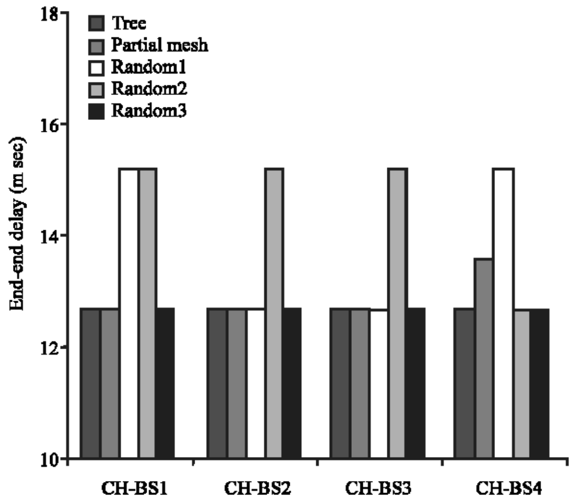

Fig. 14: Effect on HMIP End-End delay

Effect on End-End delay: Each packet generated by a source is routed to the destination via a sequence of intermediate nodes. Figure 14 shows the end to end delay involved in proposed topologies with respect to BS, through which the MN receives packet while it travels from BS$_1$-BS$_4$ End-End delay can be obtained using the time, at which the source has sent one packet and at which it has reached the destination. For the tree and random3 topology taken, irrespective of the BS to which MN has connected, the End-End delay is same. The reason is that the number of hops involved in reaching the MN from the correspondent node is same. Depending on the number of links present in the active path of communication between CN and MN and their link delay, End-End delay varies and topologies having lesser intermediate nodes reach the MN with less delay.

Variation of throughput with link delay: Throughput is a factor which depends on number of packets received by the MN successfully. More the link delay, more the packet loss and thereby throughput degrades for higher link delays as shown in Fig. 15. Random 1 and Random 2 topology suffers more degradation of throughput than others because of high delay involved in the handoff at BS3-BS4. Tree and Partial Mesh topology provides same throughput for all link delays. It is the Random 3 topology which works better than others because of its lower handoff delay.

Variation of throughput with speed: The speed with which the MN moves is an important factor that influences the throughput. From the No. of packets received, packet size and the simulation time, throughput is obtained. For the simulation setup described above, each increment in the speed of MN will make the number of handoffs to increase. From Fig. 16, it is clear that throughput degrades for more number of handoffs i.e., greater the speed, lesser the throughput. Throughput of Random 3 topology is superior to others for all speeds since it provides lower handoff delay.

Variation of signaling cost with speed: Signaling Cost includes all the TCP packets involved in acknowledgments and retransmission signaling and also the packets involved in Handoff process. It is clear from Fig. 17 that, Tree and Partial Mesh topology generates more signaling packets as it achieves all the three cross over distances. The difference in signaling cost occurs when the speed is more.

HAWAII

Effect on handoff delay: In HAWAII, Handoff Delay is the time between transmission of HAWAII path setup update message from the new BS and reception of the Mobile IP Registration Reply at the MN. The handoff delay depends on the crossover distance, which is a measure of distance required by the MN to reach the crossover router in terms of hops. When MN is allowed to travel between the base stations BS1-BS2, BS2-BS3 and BS3-BS4, the cross over distances achieved are 1, 2 and 3, respectively. As the crossover distance increases, handoff delay increases which can be clearly observed from Fig. 18. During the BS1-BS2 handoff, Random 1 topology provides more delay because the cross over distance involved is more. Similarly, Tree topology provides more handoff delay at BS2-BS3 and BS3-BS4 handoff scenarios. Because of extra mesh and random links, Partial mesh, random 2 and random 3 topologies provide less Handoff delay. Compared to the UNF scheme MSF has higher handoff delay.

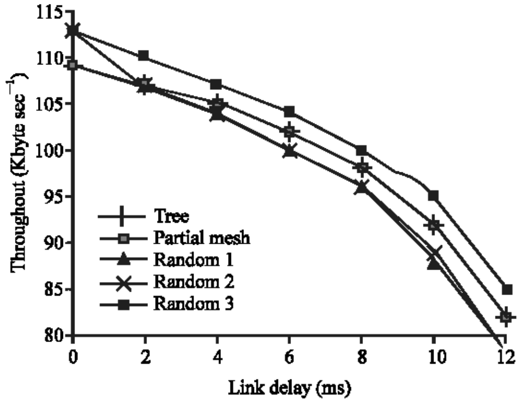

Fig. 15: Variation of HMIP throughput with link delay

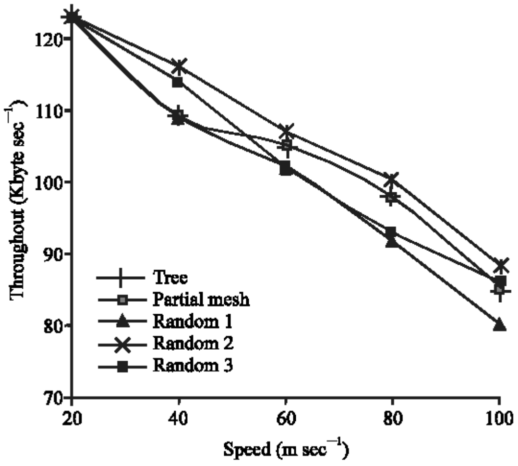

Fig. 16: Variation of HMIP throughput with speed

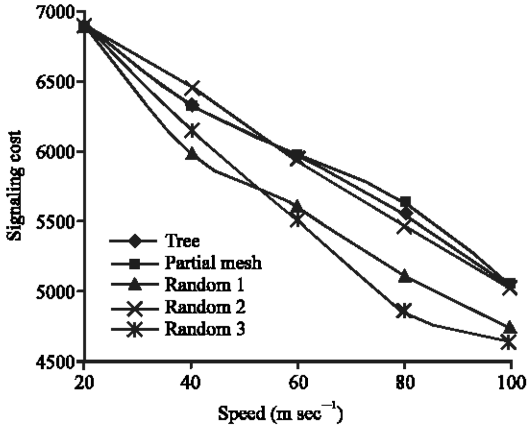

Fig. 17: Variation of HMIP signaling cost with speed

Effect on end-end delay: Each packet generated by a source is routed to the destination via a sequence of intermediate nodes. Figure 19 shows the end to end delay

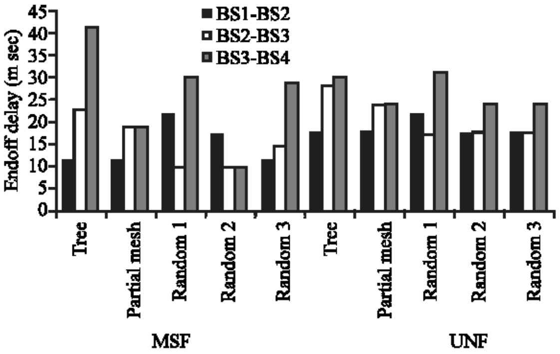

Fig. 18: Effect on Hawaii handoff delay

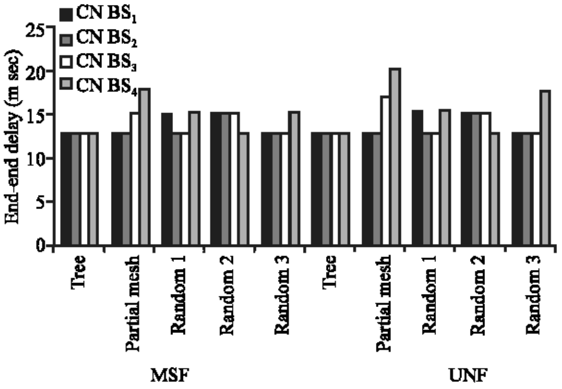

Fig. 19: Effect on Hawaii end to end delay

involved in MSF scheme of proposed topologies with respect to BS_i, through which the MN receives packet while it travels from BS_1-BS_4. For the tree topology considered, irrespective of the BS to which MN has connected, the End-End delay is same. The reason is the number of hops involved in reaching the MN from the Correspondent Node is same. Depending on the number of links present in the active path of communication between CN and MN and their link delay, End-End delay varies. Topology having lesser intermediate nodes to reach the MN provides lesser delay and the End-End delay of both the schemes are same.

Variation of throughput with link delay: Link latency or delay is the parameter which affects number of packet loss in the network. Higher the delay, higher the packet loss. This result in poor throughput as the delay involved increases. Because of the delay involved in each handoff, the throughput will keep on fall for all the topologies as shown in the Fig. 20. But random1 topology alone suffers from more degradation of throughput than others because of high delay involved in the handoff at BS3-BS4.

Variation of throughput with speed: The speed with which the MN moves is an important factor that influences the throughput From the no. of packets received, Packet size and the simulation time, throughput is obtained. For the simulation setup described above, each increment in the speed of MN will make the number of handoffs to increase. From the Fig. 21, it is clear that throughput degrades for more number of handoffs i.e., for higher MN speed, packet loss is higher. For both schemes, throughput of all the three random topology is superior to others for speed up to 80 m sec^{-1}. After that tree topology performs better.

Variation of signaling cost with speed: When the MN is made to move with various speeds, MN suffers more handoffs through out the simulation duration. Control packets used for acknowledgment, retransmissions and handoff process affects the signaling cost. It is clear from Fig. 22 that, tree topology generates more signaling packets as it achieves all the three cross over distances. The difference in signaling cost occurs when the speed is more. Compared to UNF scheme MSF provides less signaling cost.

Cellular IP

Effect on handoff delay: The delay between BS1-BS2 is same for all topologies since the cross over distance remains the same. As the crossover distance increases, handoff delay increases for Tree topology, which can be clearly observed from Fig. 23. Random 2 shows a constant handoff delay between all the base stations. SS provides less handoff delay then HH scheme.

Effect on End-End delay: For Tree, Partial Mesh and Random 3 topologies, the number of hops involved in reaching the MN from the Correspondent Node is same. So from Fig. 24 End-End delay involved in the delivery of packets through BS_1 is same for three cases. When considering BS2 and BS3, the end-end delay involved is more for random 2 and random 3 scenarios, respectively. Because of additional mesh and random links, the old path is maintained while the new path is setup for new base station. Partial Mesh, Random 1 and Random 3 involve more number of hops for a packet to reach MN through BS4 and for both schemes delay is same.

Variation of throughput with link delay: When delay is increased, the time taken by the packets to reach BS increases, by that time MN moves out of the coverage of that particular BS. When a handoff occurs the time taken by the route update packets to reach the Gateway increases. This results in poor throughput, as the delay

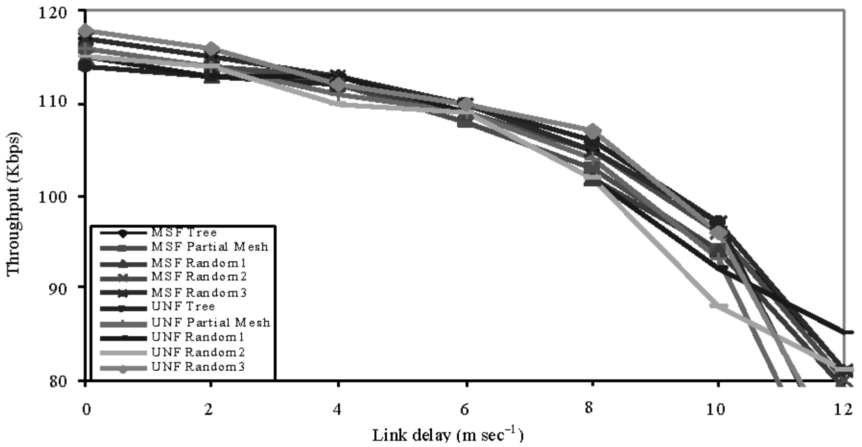

Fig. 20: Variation of hawaii throughput with link delay

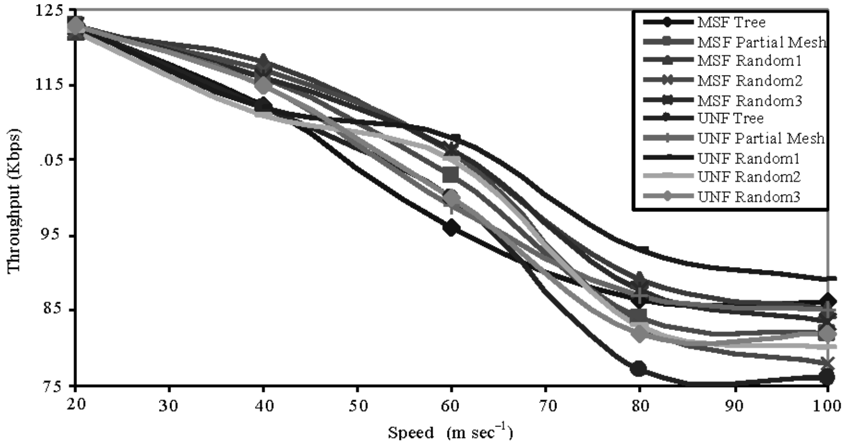

Fig. 21: Variation of hawaii throughput with speed

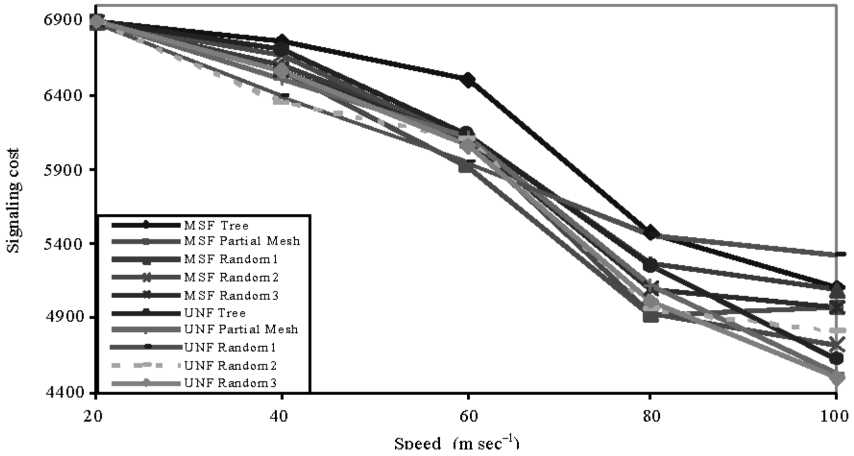

Fig. 22: Variation of hawaii signaling cost with speed

involved is keeps on increasing. Also, the Paging packets take more time to find the path to new BS. These are the two reasons that cause packet loss to increase as the link delay increases. Because of the delay involved in each handoff, the throughput will degrade for all the topologies as shown in the Fig. 25. In HH scheme, Random 2 topology suffers more degradation of throughput. Tree and Random 3 shows better performance since the number of hops involved for a packet to reach destination is less. The performance of SS scheme is better for all topologies.

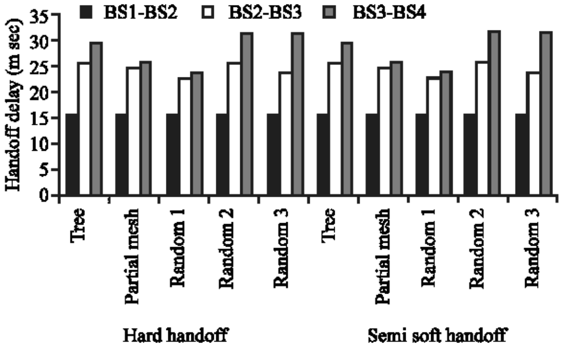

Fig. 23: Effect of CIP handoff delay

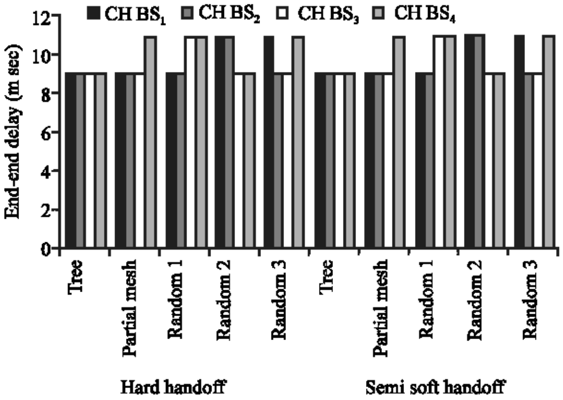

Fig. 24: Effect of CIP and end to end delay

Variation of throughput with speed: As illustrated in the Fig. 26, for both schemes higher the speed of the MN, greater the packet loss. Hence, as the speed increases the handoff frequency increases which lead to packet loss indirectly decreasing the throughput. However it is observed that Partial Mesh and Random 3 topologies have throughput more compared to the tree topology. The performance of Random 2 topology is very less for both the schemes.

Variation of signaling cost with speed: The speed of MN is increased in steps of 20 m sec^{-1}. Obviously, the handoffs will be more. Hence the number of control packets needed increase. In both schemes, for Tree, Partial Mesh and Random 3 topologies the signaling cost remained nearly same. Since there is only one active path in Random 1 Topology, there is more number of retransmissions and acknowledgment packets as in Fig. 27. Hence the signaling cost is more for Random 1 topology for both schemes.

Comparison: Table 1 shows the comparison of HMIP, CIP and HAWAII protocols for the five topologies using four

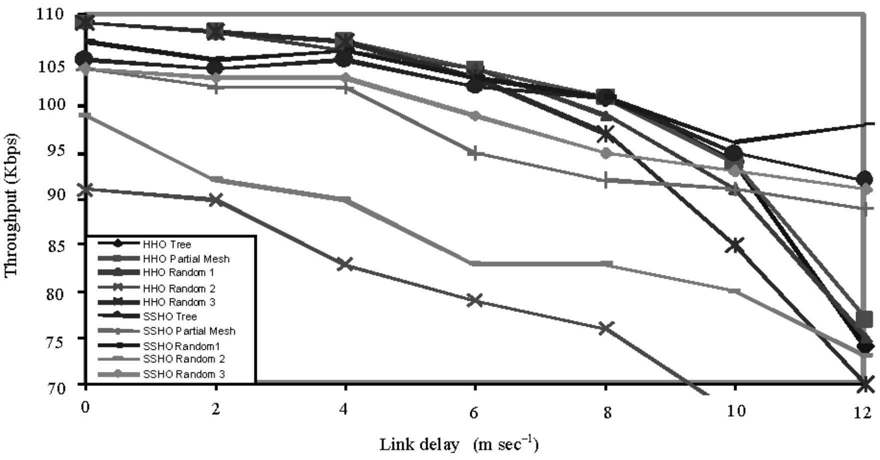

Fig. 25: Variation of CIP throughput with link delay

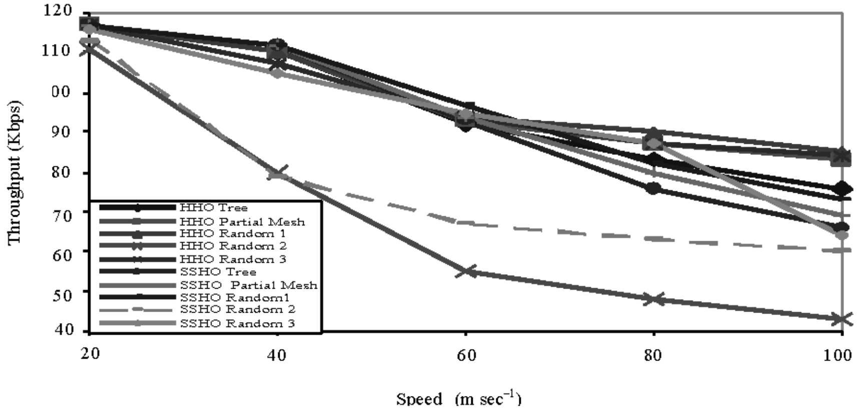

Fig. 26: Variation of CIP throughput with speed

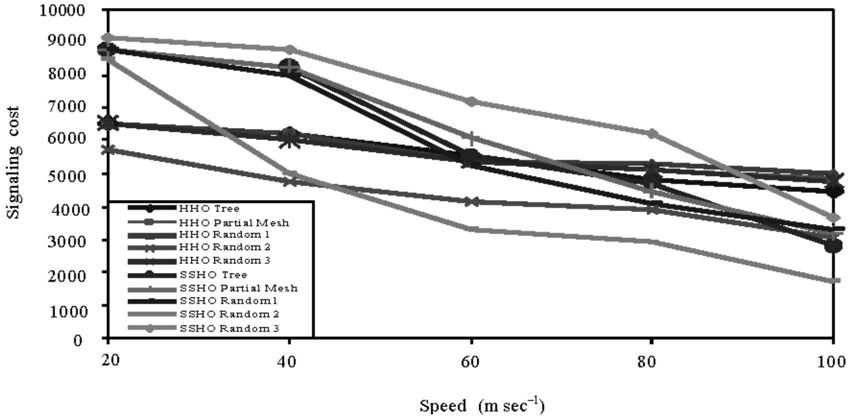

Fig. 27: Variation of CIP signaling cost with speed

Table 1: Comparison of micro mobility protocols using TCP traffic

			HAWAII		CIP	
Topology	Parameters	HMIP	UNF	MSF	HH	SS
Tree	Handoff delay	H	H	H	H	VL
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	M	M	M	M	M
	Throughput	H	M	L	L	L
Partial mesh	Handoff delay	M	M	L	M	M
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	M	M	M	M	M
	Throughput	H	M	M	L	VL
Random 1	Handoff delay	H	M	M	M	M
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	M	M	L	M	H
	Throughput	L	H	H	VL	M
Random 2	Handoff delay	M	M	L	L	L
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	M	M	VL	L	M
	Throughput	M	M	L	L	VL
Random 3	Handoff delay	M	M	L	M	L
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	VL	M	L	M	M
	Throughput	H	H	M	L	VL

H: High; M: Medium; L: Low; VL: Very Low

performance metrics with TCP traffic. For Tree topology, HMIP shows better throughput where as CIP shows better handoff delay. Considering Partial Mesh topology throughput of HMIP and HAWAII is better than CIP. In Random 1 topology, the performance of HAWAII is better. HAWAII and HMIP shows better throughput and CIP shows better handoff delay for Random 2 topology. All the protocols show better throughput and moderate hand off delay for Random 3 topology. Similar to TCP performance analysis, simulation is conducted using UDP traffic. UDP is used for applications that require multicast or broadcast transmissions, since these are not supported by TCP. UDP probing traffic is directed from CN to MN with a packet inter arrival rate of 10ms and a packet size of 210 bytes. The simulation results for UDP traffic are presented in Table 2.

Table 2: Comparison of micro mobility protocols using UDP traffic

			HAWAII		CIP	
Topology	Parameters	HMIP	UNF	MSF	HH	SS
Tree	Handoff delay	H	H	H	H	H
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	VL	VL	L	M	H
	Throughput	VL	M	H	VL	L
Partial Mesh	Handoff delay	H	VL	VL	H	H
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	VL	VL	L	M	H
	Throughput	VL	H	H	VL	L
Random 1	Handoff delay	H	M	M	H	H
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	VL	VL	L	M	H
	Throughput	VL	M	H	VL	L
Random 2	Handoff delay	H	VL	VL	L	L
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	VL	VL	L	M	H
	Throughput	VL	H	H	VL	L
Random 3	Handoff delay	M	VL	VL	L	L
	End to end delay	VL	VL	VL	VL	VL
	Signaling cost	VL	VL	L	M	H
	Throughput	VL	H	H	VL	L

H: High; M: Medium; L: Low; VL: Very Low

CONCLUSIONS

This study has presented the effect of five different topologies on the metrics: Handoff Delay, End-End delay, Throughput and Signaling Cost, with respect to speed and Link delay in HMIP, HAWAII and CIP protocols. From the simulation results it is concluded that, for the networks with stringent demand on throughput, random 3 topology suits well. Random 2 topology performs well for networks where low handoff delay is of concern. For networks that require moderate throughput and handoff delay, partial mesh topology is the best choice. Based on the performance results, it is observed that selecting the appropriate micro mobility protocol for the given network environment and topology is more important than the small difference found in terms of user perceived handoff quality.

REFERENCES

Akyildiz, I. *et al*., 1999. Mobility management in next-generation wireless systems. Proceedings of the IEEE, 87: 1347-1384.

Campbell, A.T. *et al*., 2002. Comparison of IP micromobility protocols. IEEE Wireless Commun., 9: 72-82.

Hu, B. *et al*., 2005. Local route optimization in Hierarchical mobile IPv6 networks from topologies perspective. IEEE Proceedings of ISCIT, pp: 787-790.

Johnson, D.B. and C. Perkins, 2004. Mobility support in IPv6. IETF RFC 3775.

Misra, A. *et al*., 2000. IDMP: An intra-domain mobility management protocol using mobility agents. Draft-misra-mobileip-idmp-00, Work in Progress.

Neill, A.O., 2000. Edge mobility architecture. Internet Draft, draft- oneill-ema- 02.

Perkins, C., 2002. IP mobility support. IETF RFC 3344. IBM Watson Research Center.

Ramjee, R. *et al*., 2002. HAWAII: A domain-based approach for supporting mobility in wide-area wireless networks. IEEE/ACM Trans. Networking, 10: 396- 410.

Soliman, H., 2001. Hierarchical Mobile IPv6 (HMIPv6). draft-ietfmobileip-hmipv6-04, Work in Progress.

Sun, J.Z. *et al*., 2002. Mobility management techniques for the next generation wireless networks. Machine Vision and Media Processing Unit, University of Oulu, Finland.

Valko, A., 1999. Cellular IP: A new approach to internet host mobility. ACM SIGCOMM Com. Commun. Rev., 29: 50-65.