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Seamless Handoff Architecture: A Micromobility Management for Next Generation Wireless IP Networks

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Abstract: Mobile IP can provide macromobility instead of the original IP existing communication. Mobile IP hosts are able to retain all existing communication, send and receive information while moving, despite their current point of attachment of Internet. Since the original mobile IP does not consider micromobility, it cannot avoid handoff latency. The latency causes packet loss or large variations of the packets delivery time. This study, proposed a mechanism to perform fast handoff in IP-based mobile networks for real time packet communication in a commercial cellular environment. Present proposal 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 mechanisms are proposed to handle micromobility and macromobility. The micromobility handover handles the movements within the same domain. Macromobility handover supports 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 novelties of the scheme is to retransmit the buffered packets during micromobility handover and several multiple mobility agents protocols extensions have been proposed to avoid potential bottlenecks in single mobility agent configurations. Such multiple mobility agents schemes allow the use of dynamic load balancing policies to further improve the overall performance. Load balancing action consists of data flows being redirected to vacant servers (mobility agent) rather than packets being dequeued and moved among servers. The entire scheme is performed within the proposed hierarchical topology named as Seamless Handoff Architecture (SHA) based on next-generation IP networks in which both micromobility and macromobility handovers are analyzed. The architecture and simulation results presented in this study are based on the network simulator (ns-2). The performance of the proposed architecture is compared with hierarchical mobile IP micromobility protocol. From the results, it is observed that, in the proposed architecture the handoff latency due to binding updates is reduced because of localizing the binding updates and thereby reducing the probability of the packet loss during handoff.

Key words: Mobile IP, micromobility, mobile host, care of address, SHA

INTRODUCTION

In recent years, there has been an increasing demand for providing data access in mobile networks. This development is undoubtedly the result of the success of the Internet together with the widespread use of the 2G mobile networks and has resulted in the specification and standardization of such mechanisms as the GPRS for enhancing the data traffic capabilities of the 2G systems. Provision of data access for users has also been a major driver for the specification of the 3G networks. At the same time, smaller scale wireless solutions intended for the provision of fast data access in a very limited area have become increasingly important. These mechanisms include most notably the wireless LAN systems based on the IEEE 802 series and ETSI Hyper LAN standards as well as the Bluetooth mechanism. All of these solutions can be utilized to provide fast IP access at a lower price per bit than the 2G or 3G systems, but on the other hand they are extremely limited in the geographical scalability.

This study utilizes the mobile Ipv4 protocol as the mechanism for providing mobility in a multi-access environment. For managing mobility on the level of the global Internet, mobile IP offers a practical solution. However, frequent handoffs inside a relatively small geographic area tend to generate a remarkable amount of signaling overhead due to required control messages between a mobile host and Home Agent (HA). Additionally, the need for obtaining a new Care-of-Address (CoA) and notifying it to a possibly distant home agent results in latency and disruption to user

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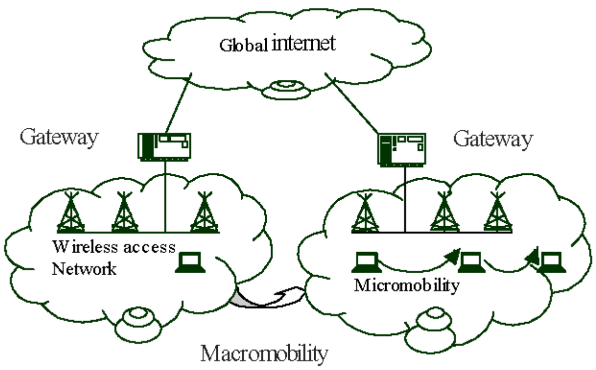

Fig. 1: Micro and macromobility

traffic during every handoff. Smooth, fast and transparent handoffs are impossible to do with the present basic mobile IP. If a large number of mobile hosts quickly migrate between foreign networks, mobile IP will turn out to be a weakly scalable solution for mobility management[1,2].

A number of micromobility protocols have been discussed in the IETF mobile IP working group. Micromobility protocols are designed for environment where mobile hosts change their point of attachment to the network so frequently. Micromobility protocols aim to handle local movement (e.g., within a domain) of mobile hosts without interaction with the mobile IP enabled Internet. This has the benefit of reducing delay and packet loss during handoff and eliminating registration between Mobile Hosts (MH) and possibly distant home agents when mobile host remain inside their local coverage areas. Eliminating registration in this manner reduces signaling load experienced by the core network in support of mobility. To minimize poor performance during handoff, micromobility protocols support fast, seamless, local mobility.

As the numbers of wireless users grow so will the signaling overhead associated with mobility management. In cellular networks registration and paging techniques are used to minimize the signaling overhead and optimize mobility management performance. Mobile IP supports registration but not paging. To minimize signaling overhead and optimize mobility management performance, micromobility protocols support paging.

Implementing hierarchy into the mobility management scheme is proposed as a remedy for the scalability problem. The current convention is to classify mobility management into two hierarchical levels. Figure 1 presents a network architecture, where two separate wireless access networks are connected through gateways to the global Internet. Macromobility is involved when a mobile host migrates from one such domain into another, while movements inside a single wireless access network are considered to represent micromobility. Micromobility should be transparent to the other parts of the network[3].

In recent years, there has been much interest in developing efficient IP-based micromobility management schemes to handle mobility within a domain in next-generation wireless networks. Such schemes are essential to achieve seamless integration of cellular network with existing IP-based data networks, popularly known as the Internet. In recent literature, several solutions have been proposed to support mobility in future wireless IP networks[4-6]. These mechanisms have been evaluated previously[7-10]. One of the challenges to keep connection with the Internet as the mobile user is roaming is to provide multiple real time services while achieving a high QoS support. Although the mobile IP protocol is suited for macromobility as it is, it fails to support micromobility efficiently[11]. Mobile IP requires the mobile host to register with the home agent and the Correspondent Host (CH) when it changes its point of attachment in the Internet. Mobile IP supports registration but not paging. Therefore, this causes mobile IP to incur long delay in the registration process and add signaling traffic to the backbone network when the home agent and correspondent host are far away from the mobile host.

In order to minimize the handoff latency and the signaling overhead present in the mobile IP, a new hierarchical SHA and load balancing policy is proposed, load balancing actions consist of data flows being redirected to vacant servers (mobility agent), rather than packets being dequened and moved among servers and fast handoff scheme to further improve the overall performance. This study, present a performance comparison of SHA with Hierarchical Mobile IP (HMIP) protocol. UDP probing traffic we used between the corresponding host, mobile hosts and count the number of packet lost during handoff, the number of packet loss as a function of speed and handoff latency during handoff is measured. The network simulator is used to evaluate the performance of the proposed architecture and it is compared with hierarchical mobile IP micromobility protocol. The results show the best performance is achieved in SHA and it provides significant improvement in handover performance and UDP packet loss when compared to hierarchical mobile IP protocol.

Hierarchical mobile IP: The hierarchical mobile IP protocol[12] from Ericsson and Nokia employs a hierarchy of Foreign Agents (FAs) to locally handle mobile IP registration. In this protocol, the mobile host sends mobile IP registration message (with appropriate extension) to update their respective location information. Registration messages establish tunnels between neighboring FAs along the path from the mobile host to a Gateway FA (GFA). Packets addressed to the mobile host travel in this network of tunnels, which can be viewed as separate routing network overlay on top of IP. The use of tunnel makes it possible to employ the protocols in an IP network that carries non-mobile traffic as well. Typically one level of hierarchy is considered where all FAs are connected to the GFA. In this case, direct tunnel connects the GFA to FAs that are located at access points. Paging extensions for hierarchical mobile IP[13] allow idle mobile nodes to operate in a power saving mode while located within a paging area. The location of mobile host is known by home agents and is represented by paging areas. After receiving a packet addressed to a mobile host located in a foreign network, the HA tunnels the packet to the paging FA, which then pages the mobile host to reestablish a path toward the current point of attachment. The paging system uses specific communication time slots in a paging area.

Seamless Handoff Architecture (SHA): In recent years, there has been much interest in developing new network architecture and efficient IP based micromobility scheme to enable efficient handling of mobile nodes in a domain. The developers of new architectures and protocols need to consider some of the key features desired in the networks such as latency associated with handoff, reduced packet loss during handoff, paging support and effective load balancing.

The proposed SHA is based on the observation that current IP mobility schemes have a subnet and finer granularity of location resolution and mostly no scope for the transmission of location updates. Cellular IP[14], for example, proposes a base station level (layer 2) granularity similar to cellular networks. The current subnet-based FA scheme in mobile IP, on the other hand, leads to change in care-of addresses at every subnet transition. A new network architecture was proposed which would achieve reduced latency due to localized binding updates and hence reduce the probability of packet loss during handoff. The SHA has a Gateway Agent (GA), Mobility Agent (MA) and a Foreign Agent (FA) (Fig. 2). The mobility agent is similar to Mobile Anchor Point (MAP) but the difference is that it is located at a higher level in the network hierarchy and maintains a cache entry for each mobile node assigned to it. In the SHA, the transmission of global updates is necessary only when the mobile node registers for the first time in the domain. The binding updates generated when a Mobile Node (MN) moves from one foreign agent to another, are

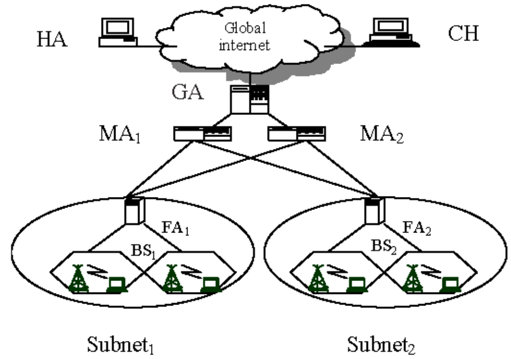

Fig. 2: Seamless handoff architecture

designed to travel upto the mobility agent. Since no existing work gives any ideas about the concept of load balancing, we have developed a separate load-balancing scheme for the SHA have developed. The load-balancing scheme eliminates the overloading of any particular mobility agent. By reducing the frequency of global update messages, the SHA overcomes several drawbacks of existing protocols, such as large latencies in location updates, higher likelihood of loss of binding update messages and loss of in-flight packets and thus provides better intradomain mobility support.

Before presenting the architectural and operational details of the proposed protocol, let us define the various elements of our architecture and describe their role in an SHA based mobility management solution.

Elements of Seamless Handoff Architecture (SHA): Most of the operational elements of the SHA architecture have functionality similar to those specified in mobile IP, with or without route optimization. For example, our definition of HA, CN, Home Network (HN), Foreign Network (FN) and Care-of Address (CoA) are identical to the conventional mobile IP definition[1]. The SHA architecture, however, requires some additional functionality in existing elements as well as an extra element, namely the MA and GA.

Gateway agent: It is an Internet host, which provides a more persistent Domain Care of Address (DCoA) for the mobile host than currently provided by the FA. All incoming packets and out going packets are routed via the GA, which act as a proxy point of attachment for the MH in the FN.

Mobility agent: A mobility agent serves as a link between the foreign agent in the subnet and the gateway agent. It creates a cache entry for the mobile node that sends binding updates to it during domain registration. It assigns mobility agent CoA and forwards the data gram to the MN via FA.

Foreign agent: Every subnet consists of at least one foreign agent; which is present on the MN's visited subnet and provides configurable parameter to the MN. In general it assigns two addresses to the MN: a Subnet Care of Address (SCoA) and Mobility Agent Care of Address (MCoA) provided if the mobile node enters the domain for the first time. If the mobile node indicates that it has already obtained a valid registration then the foreign agent will not assign a new mobility agent.

Mobile node: It is a host that changes its point of attachment from one network or sub network to another. The mobile node changes its subnet address without changing its Mobility Agent Care of Address (MCoA). The MN in the SHA has three addresses viz., the Subnet Care-of Address (SCoA), Mobility Agent Care of Address (MCoA) and the Domain Care of Address (DCoA).

Description of the seamless handoff architecture: The proposed Seamless Handoff Architecture is shown in Fig. 2. The foreign network is divided into several subnets depending on its geographical location. It is assumed that each subnet has at least one FA server: each FA servers must be associated with all MA in that domain. The serving FA dynamically assign the MN an MA during the subnet specific registration process. A load-balancing algorithm as explained in the following section can perform the assignment. In such a scenario, MNs in a single subnet may assign to different MAs. For example MN_1 in subnet 1 is associated with MA_1, while MN_2 in the same subnet may be associated with MA_2. An FA will periodically broadcast the agent advertisement containing the domain identifier to advertise its present. The MN can determine whether it is in a new subnet or in a new domain by listening to the agent advertisement. When a MN enters into the domain for the first time, it performs an interdomain registration by sending the registration request to the FA in that subnet, it first obtains a SCoA which serve as a LoCA for that MN. The serving FA assigns the MN a designated MA. Once the mobile node receives the reply from the foreign agent it sends a registration request to the assigned mobility agent, the binding update contains the mobile nodes home IP address, subnet care of address, domain lifetime (Ld) and lifetime of the mobile in subnet (Lm). When the mobility agent receives the binding update, it creates a cache entry for the mobile node and it includes the care of address of the mobility agent in the interdomain location update reply. After receiving the reply from MA the mobile node sends a binding update to GA. The GA adds the DCoA 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 for example HA. The acknowledgment from the home agent is routed to the mobile node through the gateway agent, mobility agent and the foreign agent in the subnet. The signaling flow when the mobile node moves into a new domain is illustrated in Fig. 3.

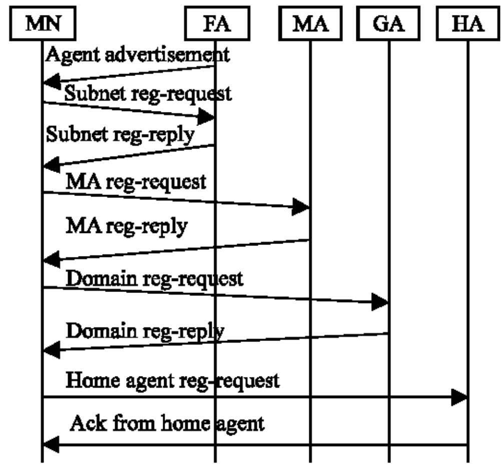

Fig. 3: Signaling flow during interdomain movement in SHA

In the Seamless Handoff Architecture, a MN will be assigned three care-of addresses:

- A domain care-of address from the public address space which act as a global care-of address for a MN and it is unchanged as long as the mobile node stays with in a specific domain. This is typically address associated with GA.
- A mobility agent care-of address of a MN is for roaming in a domain. The MA can handle M subnet. This address will not change every time when the mobile nodes change the subnet with the M subnet.
- A subnet care-of address of a MN is for roaming in a particular subnet. This may have only a local scope and it can be an address of the FA. This address changes every time the mobile node changes its foreign subnet.

When an MN enters a new domain, it will register the DCoA with the HA during the initial location update process. As long as the mobile node roams within this domain, all future correspondence from the CNs will be directed towards the DCoA. The MN gets a new local care-of address every time it changes subnets. This address is obtained from the FA server using conventional mobile IP techniques. In general, the GA and MA associated with a specific mobile will remain unchanged unless the association expires. The SHA requires communication between the GA, MA and the associated FAs. This correspondence may take place through non-standard protocols that are compatible with the existing telecommunication infrastructure. In the SHA operation, the HA will tunnel all the packets received from CNs to the GA by using the DcoA. The GA will send packet through the correctly associated MA and FA to the MNs. As long as the MN is under the control of a single MA, the MN does not transmit any location update to the HA. This architecture ensures that the localization of the entire intra domain mobility updates message within the domain. When a mobile node moves from one subnet to another, it performs subnet specific registration with the new foreign agent in the visited subnet. Since the mobile node indicates that it has a valid registration, the foreign agent will not assign a new mobility agent. By this mechanism, the binding updates to the mobility agent have been localized and this reduces the latencies associated with the handoff and hence reduces the risk of higher probability of loss in binding update messages.

The handoff procedure: In Seamless Handoff Architecture, the handoff will take place when the MN moves from one subnet to another subnet. SHA handoff procedure is based on the assumption that network layer 2 trigger will be available to either the MN or the old base station indicating an imminent change in connectivity. This study explains the handoff procedure with the help of Fig. 2 which shows the MN moving from $subnet_1$ (BS_1) to the $subnet_2$ (BS_2). To minimize service interruption during handoff process SHA requires either the MN or the old FA to generate a beacon message to the MA serving the MN. After the reception of this beacon message, the MA multicast all the inbound packet to the new and old FA. The FAs buffers such arriving packets in the individual MN buffer, thus minimizing the loss of in-flight packets during the handoff transient.

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 MA to receive the corresponding intradomain location updates. When the MN obtains the new SCoA, then it sends the binding update to the serving MA. The MA will redirect packets to the MN's new SCoA only after receiving this message. The motion of the MN between different subnet inside a domain will be transparent to the GA. As long as the MN mobility is with in a domain, the MN does not transmit any location updates to the HA. The signaling flow during intradomain movements is illustrated in Fig. 4.

By localizing the binding update within the domain gateway agent, we are able to significantly reduce the frequency of global updates furthermore, since the frequency of subnet handoff within a small region is always larger than that of an interdomain handoff. We are able to considerably reduce the occurrence of large latency in global location updates, higher like hood of loss of binding updates message and loss of in-flight packets. Additionally, since the SCoA have no global visibility, this provides the security for the mobile user to move within a domain and also permits the use of private addressing schemes to handle intradomain mobility, thus enhancing the scalability of the mobility management scheme.

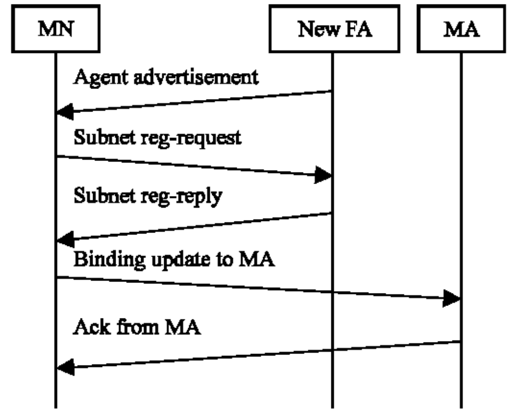

Fig. 4: Signaling flow during intradomain movement in SHA

Load balancing: Here, this study presents a separate load-balancing scheme that is used in this proposal. The number of mobile node that registers with a foreign agent cannot be approximated. Since present architecture proposes the use of N mobility agents for M subnets and all the N mobility agents are connected to the M subnets. A mobile node registering in any of these M subnets can be assigned any of the N mobility agents. After the initial intradomain registration process, SHA allows the MN to retain its GA address i.e. DCoA as long as it stays within the same domain. From Fig. 2, consider whenever the MN changes the subnets within the domain; it performs a new subnet specific registration with the new FA. Since the MN indicates that it has valid registration, the FA does not allocate it a new mobility agent. If the mobile node does not have a valid registration, then the foreign agent assigns the mobile node with a new mobility agent. Referring to the load-balancing table, which is present in the foreign agent, performs the assigning of the mobility agent.

The load-balancing concept is explained as follows: assume a mobile node that enters a new domain and

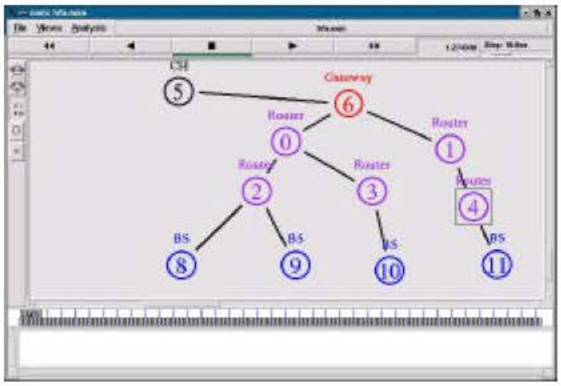

Fig. 5: Network animator display for HMIP

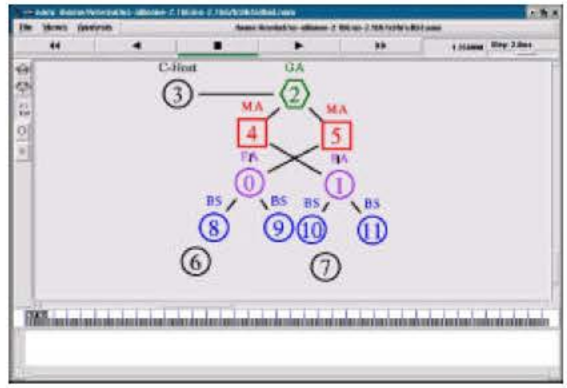

Fig. 6: Network animator display of SHA architecture

registers with FA1, the FA1 assigns MA1 to the mobile node. Once a mobility agent is assigned, the mobile node sends binding updates to the mobility agent through the Foreign Agent. On receiving the binding updates from the mobile node the mobility agents sends a beacon signal to all the foreign agents that are connected to it. Hence the number of MN in MA1 will be incremented by 1 in the entire load balancing tables in the foreign agents. Now if another mobile node sends the registration request to the FA1, by referring to its load balance table the FA1 will assign MA2. Whenever the mobile node moves from one subnet to another the cache entries in the mobility agent is refreshed. The load balancing concept defined for the SHA, overcomes the problem that exist in many network architecture at present, which is load balancing.

Simulation model: Here the simulation model and the performance of SHA protocol with respect the handoff latency and the number of UDP packet lost during handoff is presented and it is compared with the hierarchical mobile IP protocol. The network animator of the SHA and the hierarchical topology is shown in Fig. 5 and 6. The simulation study presented in this study uses the CIMS[15], which represent a micromobility extension of the ns-2 network simulator based on version 2.1b6[16]. The simulation models are briefly described in the following:

All simulations are performed using SHA and hierarchical topology. In hierarchical topology, the node 6 acts as a Gateway Foreign Agent, where as all the base station (BS_8-BS_{11}) act as mobility unaware routers. Since the topology considered represents the home network of the mobile hosts, the packets arrive from a CH without encapsulation. In SHA architecture, the node 2 acts as a gateway foreign agent, node 6 and 7 are Mobile Host, MA_1 and MA_2 act as mobility agents; FA_1 and FA_2 act as foreign agents and from BS_8 to BS_{11} act as a base station.

Here each wired communication is modeled as 10 Mb s^{-1} duplex link with 2 ms delay. Mobile host connects to the base station using ns-2 carrier sense multiple access with collision avoidance wireless link model, where as each base station operate on a different frequency band. Simulation results are obtained using a single mobile host, continuously moving between base stations at a speed that could be varied. Such a movement pattern ensures that mobile host always goes through the maximum overlapping region between the two-radio cells. Nodes are modeled without constraints on switching capacity or message processing speed. The simulation network accommodates UDP traffic. UDP probing traffic is directed from Correspondent Host (CH) to mobile host, with a packet interarrival time of 10 ms and a packet size of 210 bytes. During simulation, a MH travels periodically between neighboring access point. During such a simulation, MH has to perform four handovers to move from BS_8 to BS_{11} as shown in Fig. 5. The distance between two adjacent access routers is 200 m, with a cell overlap of 30 m. All the base stations are placed on a straight line.

Performance evaluation: First simulation results for the packet loss due to the basic number of handoff in SHA and hierarchical micromobility protocol for hierarchical topology is presented.

UDP packet loss due to handoff: To obtain these results, the mobile node is allowed to move between base stations. During simulation, a MH travels periodically between neighboring access points with a constant speed of 20 m s^{-1} and the UDP probing traffics transmitted between the CH and MH. The simulation result for UDP download during handoff is plotted in Fig. 7. It the shows comparison of UDP packet loss in SHA architecture and HMIP protocol in hierarchical topology. It is clear from the Fig. 7 that the number of packet loss increases with

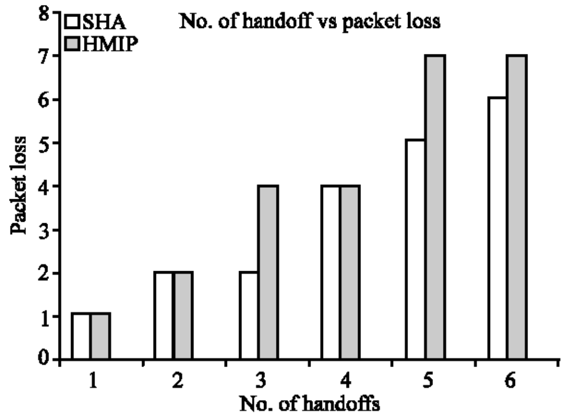

Fig. 7: UDP packet loss versus number of handoff

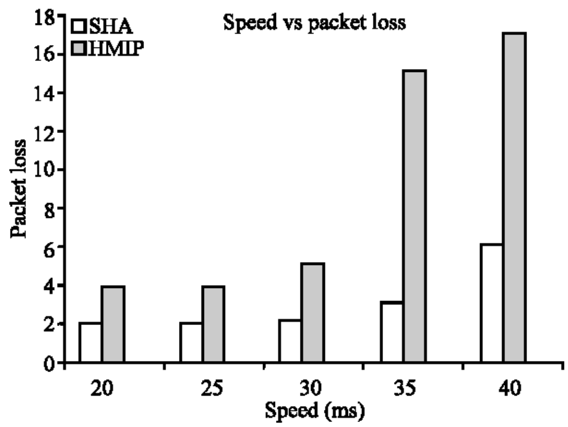

Fig. 8: UDP packet loss versus variable speed of MH

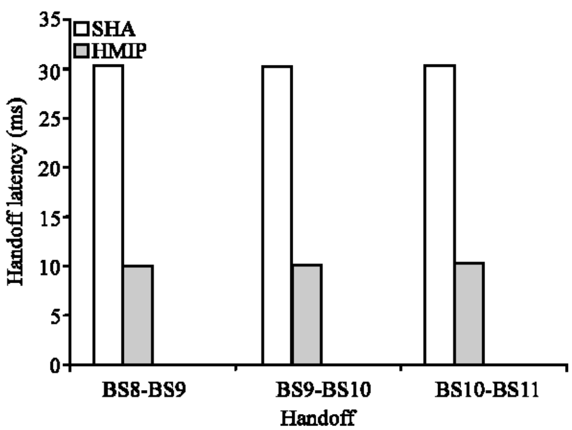

Fig. 9: Handoff latency versus handoff

increasing handoff frequency for both SHA and HMIP in hierarchical topology but it is lower in SHA when compared to the HMIP protocol. This is because of the low handoff latency.

UDP packet loss performance with variable mobile speed: In this case, the simulation results are obtained using a single mobile host, continuously moving between base stations with variable speed and UDP packet loss performance is plotted in Fig. 8 for both the SHA and HMIP protocol. It is observed that as the speed of MH increases, the frequency of handoff gets increased and as a result the packet loss also gets increased. It is further observed that the UDP packet loss is low in SHA when compared to HMIP. This is because of the presence of low handoff latency in SHA.

Handoff latency: One of the important performance measures of mobile IP networks is the delay experienced to deliver a packet from an old base access point to current point of attachment of MH. In IP-based micromobility management, handoffs involve redirecting IP packet flow to the MN's current point of attachment. The goal of any IP-based handoff scheme must be to minimize packet loss and 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 results for handoff latency for SHA and HMIP protocol are plotted in Fig. 9. During the simulation, the MH is allowed to travel from the BS_8 to BS_{11}. The handoff latency for nth handoff is constant for both architectures because the number of hierarchy levels remains the same. Since the distance traveled by the binding updates during inter-subnet movements is small, the time taken to complete the registration reduces. The handoff latency is low in SHA when compared to the HMIP protocol. This decrease in handoff latency is due to the fact that the binding updates are sent only upto the mobility agent in SHA where as in case of HMIP they are sent to the gateway agent.

CONCLUSION

In this study, a new Seamless Handoff Architecture is proposed and the performance results are presented and it is compared with the existing hierarchical mobile IP protocol in hierarchical topology, which reduces the latency due to binding updates and also reduces the packet loss due to handoff. Localizing the binding update reduces the handoff latency and this is done in the "Seamless Handoff Architecture". Since the handoff latency is reduced the possible packet loss that might happen due to handoff is also reduced. The global updates are sent only during domain registration to the concerned home agent. The concept of localizing the binding update also has an effect on the time to complete subnet registration. Since the distance traveled by the binding updates during inter-subnet movement is small, time taken to complete the registration is reduced to the minimum possible. Load balancing is one of the serious drawbacks in most of the current network architectures. The efficiency of architecture relies on how the load is balanced in the domain. By designing a suitable load-balancing concept for the SHA we have overcome the drawbacks. The results show that the best performance is achieved in SHA and it provides significant improvement in handover performance and UDP packet loss when compared to hierarchical mobile IP protocol.

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