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Simultaneous Mobility in MPLS

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Abstract: The movement of a mobile device is likely during its communication with other mobile or stationary nodes. This movement results in what is known as the mobility problem. The general mobility problem has been addressed by the Mobile Internet Protocol (MIP). However this solution only takes care of the scenario where there is only one mobile node communicating with a stationary node. Simultaneous Mobility Problem arises when both the communicating nodes in a network are mobile, a scenario not dealt with by the basic mobility protocols. When both communicating nodes move and update each other with their latest locations, the updates can be lost as a result of their simultaneous movement. Thus the communicating nodes are not able to find the current location of each other. Solutions for Simultaneous Mobility solutions have been discussed previously. In this paper we propose a solution to the problem of Simultaneous Mobility in a Multi Protocol Label Switching domain.

Keywords: Mobile IP, MPLS, Simultaneous Mobility

1. INTRODUCTION

In the general Mobility framework, the Mobile Node (MN) is often considered to be the only one node that can change its location. Thus the Mobility protocol focuses on maintaining the connections of this MN. However, the correspondent node (CN) can also be mobile and move while MN and CN are communicating with each other. When both the communication devices move simultaneously, mobility signaling like Binding Updates can be lost resulting in the Simultaneous Mobility Problem [1].

This problem is prevalent in Mobile Internet Protocol version 6 (MIPv6) where Route Optimization is used. Some signals are exchanged directly between the MN and the CN during the route optimization process in MIPv6. Thus, when the MN and CN both move, these signals can be lost resulting in a break in communication. This leaves the two communicating nodes with no idea as to where their respective correspondent node is currently located. Route Optimization messages reach the previous location of the CN. An update from CN to MN containing its new location is sent to the previous address of MN. As a result updates from both sides are lost resulting in what is known as the Simultaneous Mobility Problem.

None of the MIPv6 and its counterparts specifies a solution for this problem. Many of these proposals address fast handover issues with a good degree of success; however they lack Quality of Service (QoS) support and gradual deployment. [2]. A significant number of Internet Service Providers and network operators are migrating towards Multi Protocol Label Switching (MPLS) [3] as the transport option for IP services. MPLS provides notable benefits like QoS, Traffic Engineering (TE) and support of advanced IP services like differentiated services (DiffServ) [4,5]. Many MPLS based micro-mobility schemes have been proposed [6,7,8,9]. Our aim is to study the Simultaneous Mobility Problem in an MPLS domain.

Section 2 discusses the basic MIPv6 along with Route Optimization that lead to the Simultaneous Mobility Problem. Section 3 explains in detail the Simultaneous Mobility problem in MIPv6 domain. The proposed solutions to the Simultaneous Mobility Problem are looked into in Section 4. Integration of Mobile IP and MPLS is reviewed in Section 5. Solution to Simultaneous Mobility Problem in MPLS domain is proposed in Section 6. The paper ends with conclusions and future work in Section 7.

2. MOBILITY IN INTERNET PROTOCOL VERSION 6 (MIPv6)

Internet Protocol version 6 (IPv6) introduced additional features to overcome the problems in Internet Protocol version 4 (IPv4). This gave MIPv6 advantages over Mobile Internet Protocol version 4 (MIPv4) [10]. Route Optimization that was introduced later in MIPv4 became a part of MIPv6 specification with all nodes expected to support it. Also, in case of MIPv6 there is no concept of a foreign agent; the mobile node is a direct point of communication with the home agent (HA). Mobile IPv6 uses two IP addresses per node. One is the

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home address; the address a mobile node has in its home network. This address is fixed. The other address is the Care-of-Address (CoA); the address a mobile node has in the foreign network. The Care-of-Address changes as the mobile node moves from one network to another [11]. A home address and a care-of address pair is known as binding. This binding is valid only for a particular interval and needs to be refreshed periodically. The mobile node has the responsibility to update the HA with its new CoA [11-13]. Once this update is received, packets are tunneled to the CoA, leading to triangular routing. This procedure is shown in Fig.1.

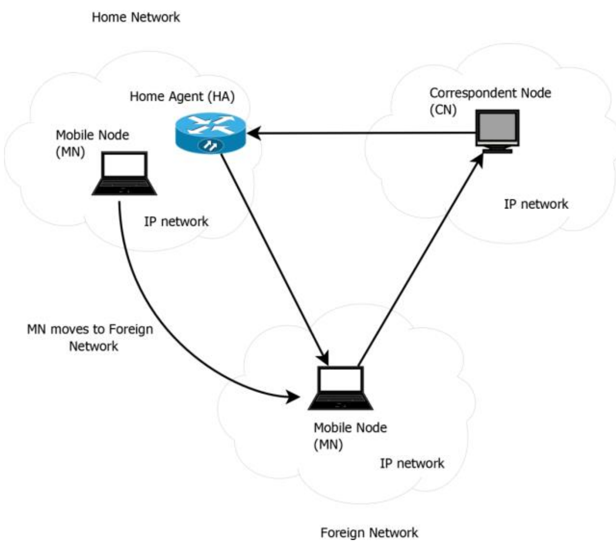

Figure1. Triangular Routing in MIPv6

The updates to the HA and the CN are sent through notifications that were introduced in MIPv6. Three new notifications namely Binding Update (BU), Binding Acknowledgement (BA) and Binding Request (BR) can be used. The CoA is communicated using these notification procedures. The MN sends a Binding Update to a correspondent node (CN) and the CN replies with a BA. Once the latest address of the MN has been communicated through these notification procedures, the CN can send packets directly to MN without HA in the communication line [14]. This procedure is known as Route Optimization and is supported in Mobile IPv6. Route Optimization removes the dependence on the home network [12]. Route Optimization is depicted in Fig. 2.

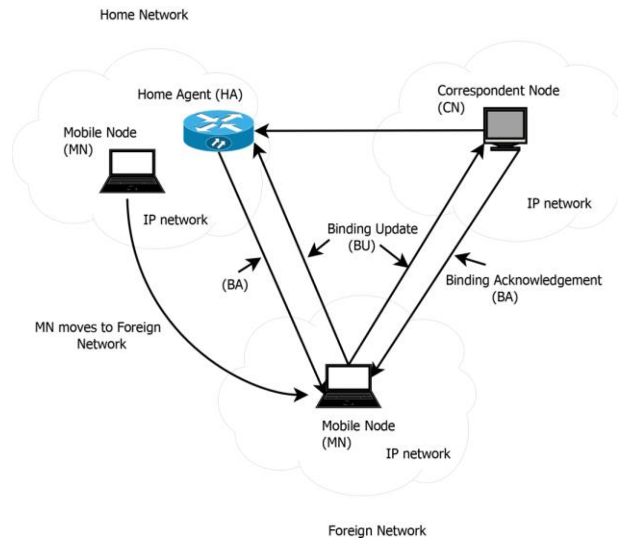

Figure 2. Route Optimization in MIPv6

When a MN receives a packet which is routed through HA, it understands that the CN is not aware of its CoA. It exchanges control messages followed by Binding Update and Binding Acknowledgement notifications with the CN after which the CN can communicate directly with the MN. Internet Protocol Security (IPSec) headers play their role in securing this communication [12]. When the CN sends packets to the CoA of the MN, it does it with a routing header that contains the original address of the MN. This routing header with the MN's home address makes sure that the exact socket of communication is selected. It also helps in swapping the CoA with the MN's original address so that at the higher level the connections are maintained [12][15].

Route Optimization uses Return Routability Procedure [15]. Two checks are involved in the Return Routability. This is done to ensure that there is a node to which packets can be sent to and accepted from. The Home Address check and the Care of Address check consist of messages that are sent to the Home Agent and the CN respectively. Return routability procedure starts with the MN sending two messages to the CN. These are the Care-of Test Init (CTI) message and a Home Test Init (HTI) message that are sent in parallel. The Care-of Test Init message is sent directly where as the Home Test Init message is sent to the CN via the Home Agent of the MN. The CN replies with the Care-of Test (CT) sent directly to the MN and Home Test (HT) sent indirectly via the HA of the MN to the MN. The MN calculates a binding management key from these replies [15]. Using this key, the MN authenticates a Binding Update (BU) message and sends it to the CN along with its Care-of Address. The CN verifies this message and sends back an acknowledgement known as the Binding Acknowledgement (BA). The signals exchanged are shown in Fig. 3 [12].

The Binding Management key is calculated from a number sent back to the MN by the CN to ensure security of the control messages [12][16]. An expedited return routability procedure can be used for deriving the key by re-using a recent token with a new token received from the CN [17]. This makes the whole process faster because sending the HTI and HT messages via the Home Agent may take considerably longer time than exchanging the tokens directly between the MN and the CN [12].

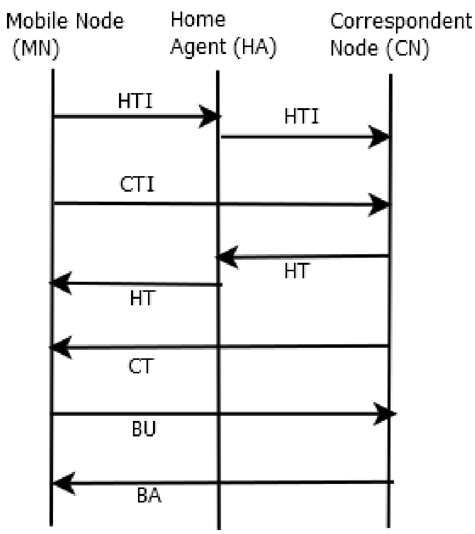

Figure 3. Return Routability Procedure

3. SIMULTANEOUS MOBILITY IN MIPV6

When a MN and a mobile CN actively exchange data, they are said to be in a communication session. A communication session is said to be in a normal state if the data from MN reaches the CN and vice versa [18]. If the data does not reach any of the two mobile hosts communicating with each other, they are said to be in a interrupted state [18].Simultaneous Mobility takes place when both the MN and the CN move during the course of communication resulting in an interrupted state that results in the loss of updates and signals exchanged between the two mobile hosts. This causes communication to break resulting in additional disruption to the disturbance otherwise caused by handoff in the actual mobility problem.

Simultaneous Mobility Problem will not arise in case of Mobile Internet Protocol version 4 (MIPv4) as mobile nodes communicate via the stationary home agent. This is true even if the correspondent node is mobile; in which case it will have its own home agent that is stationary. MIPv6 introduces route optimization to solve the problem of triangular routing. However as part of route optimization, MN and CN exchange binding updates directly with each other. Before exchanging Binding Updates the MN and CN exchange Care-of Test Init (CTI) message and a Home Test Init (HTI) message as part of the route optimization process as discussed in the previous section. The time period during which these CTI and HTI messages are sent and CT and HT replies are received creates a time frame during which movement of either MN or CN is possible. This results in MIPv6 being more prone to the Simultaneous Mobility Problem.

As described earlier, CTI and HTI messages are sent to the CN followed by a Binding Update (BU) from MN to CN as shown in Fig.4. There are two possibilities. CN can move before receiving CTI and HTI or after receiving these messages. If CN moves before receiving CTI and HTI, then the return routability procedure does not start at all, implying that the BU will never be sent from MN to CN. This is shown in Fig. 4. A and B are two nodes that have an ongoing communication. Both move pretty much simultaneously. A sends its CTI and HTI messages to B's old address and B sends its CTI and HTI messages to A's old address. As a result the messages from both sides are lost. This results in break of communication. If CN moves after receiving CTI and HTI and before receiving the BU, BU will be lost. This is shown in Fig.5.

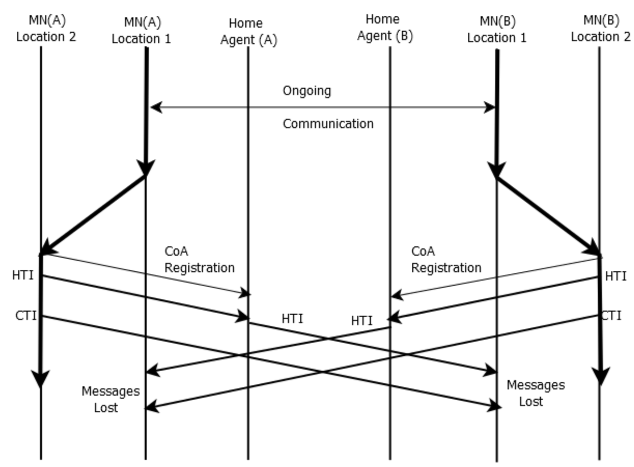

Figure 4. CTI and HTI lost during Simultaneous Mobility of Nodes A and B [1]

4. SOLUTION TO SIMULTANEOUS MOBILITY PROBLEM IN MIPV6

Simultaneous movement causes signals to be lost, be it CTI, HTI or the BU. Different kinds of solutions to Simultaneous Mobility problem in MIPv6 have been suggested in [19], [20] and [21].

Paper [19] discusses two approaches to solve the problem. The first approach introduces two proxies namely stationary binding update proxy and stationary location proxy.

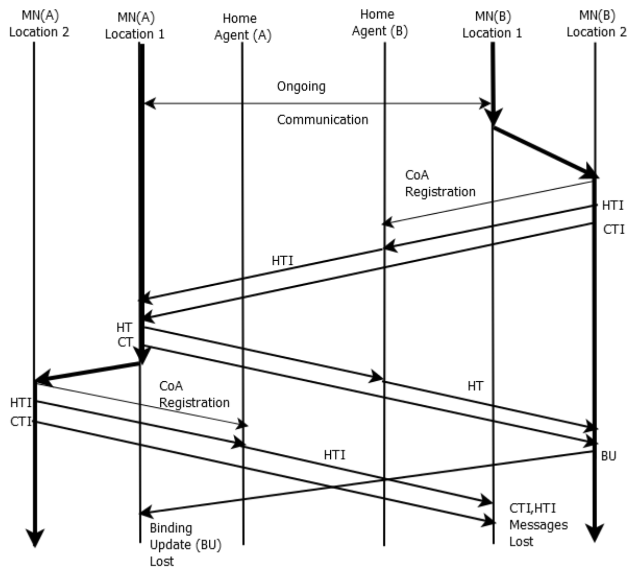

Figure 5. Binding Update lost during Simultaneous Mobility of Nodes A and B [1]

These proxies are present at both mobile nodes. The stationary binding update proxy obtains the latest location of the MN's correspondent nodes. The stationary location proxy maintains the latest location of the MN. Thus stationary binding update proxy of MN obtains the latest location of the MN's correspondent node from the stationary location proxy of the CN. And the stationary binding update proxy of the CN obtains the latest location of the MN from the stationary location proxy of the MN. These proxies are incorporated into existing network elements and are stationary as opposed to the MN and can be reachable at all times.

However some additional modifications to MIPv6 are needed to use these two proxies. When node A sends a return routability message or a Binding Update to the node B through its home agent, the home agent not only forwards this message to B but also maintains a copy of this message for a time period of T_h. This is indicated by Step 1 and Step 2 in Fig. 6. A's home agent then queries B's home agent for new address of B. B's Home Agent is also B's stationary location proxy. This is shown in Step 3. B's home agent sends the latest address of B to A's home agent and waits for a short time period T_b. If during this time period B registers a new care of address with its home agent, then this home agent sends the latest address of B to A's home agent. When Step 4 takes place, it is followed by Step 5 and Step 6 indicated with dashed line in the Fig.4. T_h and T_b are to be appropriately selected so that we can account the signaling and computational delays. T_h has to be greater than T_b so that when B's home agent informs A's home agent about B's new care of address, A still has the return routability message or the Binding Update to send to B's new address.

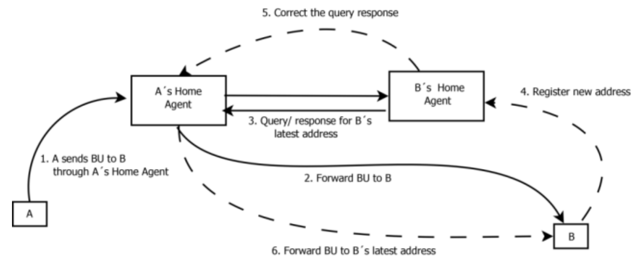

Figure 6. Preventing Simultaneous Mobility in MIPv6 using sender side and receiver side mechanisms [20]

The second solution discussed in Paper [19] is smart forwarding by signaling to the Home Agent. A's home agent does not need to be a *stationary binding update proxy*. A sends all control messages like *care of test init*, *home test init* and binding updates to B's home agent instead of B's care of address as shown in Step 1 of Fig. 5. B's home agent then takes care of forwarding the control signals to B's current location in Step 2 of Fig. 7. If B moves during this time interval, then the control signals might get lost. This solution stores the control messages for a time period of T_b along with the identity of the node B. These signals are discarded after this time period is over. If during this time period B's home agent receives a binding update from B designating its new care of address, then it checks if there are any control messages stored for this MN in its temporary storage. If messages are there they are forwarded to B. this is shown in Step 3 and 4 of Fig. 7.

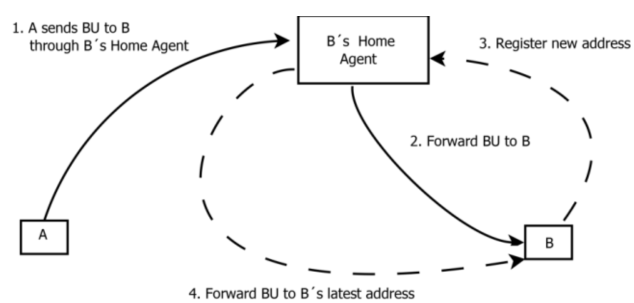

Figure 7. Preventing Simultaneous Mobility in MIPv6 using only receiver side mechanisms [20]

The time period T_b for which the control messages are stored should be long enough to accommodate the time B takes to move and obtain a new care of address plus the two way latency period from B's home agent to B for appropriate signals to be exchanged. This temporary storage and re-forwarding is a change in the home agent only. It can solve the simultaneous mobility problem even if this solution is implemented on one side only. The side it will be implemented (suppose B) will always receive the updates from the other side (A) and will have the current location of A. B can then resend its BU to A so that A gets to know the latest address of B.

On the MN side, the *home test init*, the *care of test init* and the binding updates are not sent to the care of address of the CN anymore. They are now sent to the home agent of CN. As evaluated in Paper [20], the second solution is the best as it requires least modification to the existing MIPv6 protocol. The Home Agent just has to be a more pro-active forwarding location proxy which is a very slight modification from its role of a forwarding location proxy. This is not very contradicting to its existing functionality. Similarly on the MN side only a slight modification is required by sending messages directly to the Home Agent of the CN. Fig. 8 and Fig. 9 depict the resolution of the problem shown in Fig. 4 and Fig. 5 respectively. The CTI and HTI messages are forwarded by the respective HAs to the new locations of A and B and are depicted in red color (1-4 in Fig. 8 and 1-3 in Fig. 9).

For MIPv6 this paper [20] proposes three solutions. The first solution proposes a forwarding proxy in the previous network. Normally a foreign agent could be made a forwarding proxy for the previous network. However, as there are no foreign agents in MIPv6, a router in the previous network will have to be transformed into a forwarding proxy and that would incur a significant change to the existing architecture. The second solution proposes both sender side and receiver side mechanisms as covered in the first solution proposed by paper [19]. The third solution proposed is the same as the second solution proposed in paper [19]. This paper also proposes solutions for other Mobility protocols like MIP-LR (Mobile IP with Location Registers) and SIP (Session Initiation Protocol) which is beyond the scope of this paper.

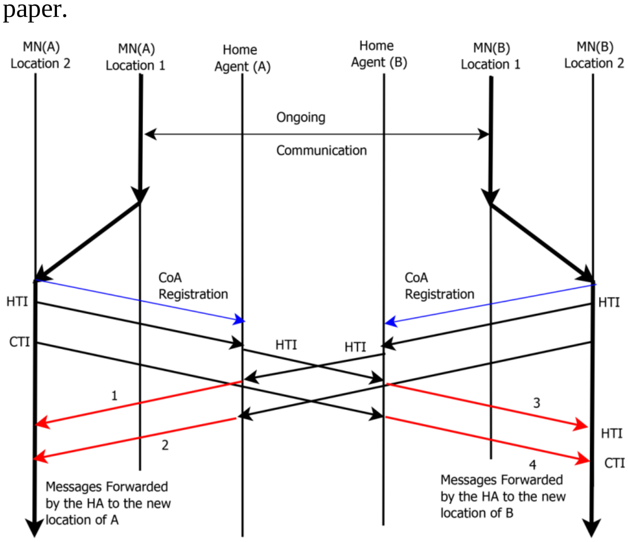

Figure 8. CTI and HTI messages forwarded by the respective Home Agents to the new locations of the Mobile Nodes A and B

Paper [21] introduces a multi-binding MIPv6 scheme and claims to make only a little modification to the existing standard protocol. In this scheme the Home Agent forwards the packets to all the available Care of Address of the MN. It does this by setting the S bit in the Binding Update to 1.

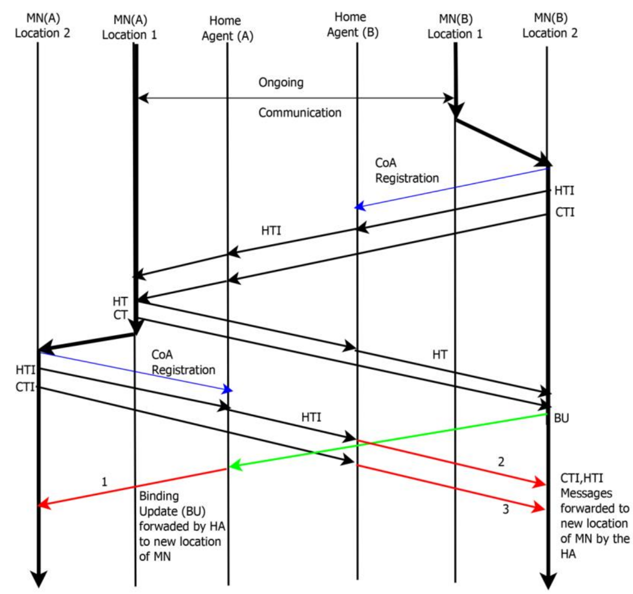

Figure 9. BU, CTI and HTI messages forwarded by the respective Home Agents to the new locations of the Mobile Nodes A and B

The value 1 of S bit indicates that the MN has requested the HA to bind MN's home address with multiple care of addresses. The cares of addresses to be bound are put in the extended option of the Binding Update. It also modifies a data structure called (*add struct in6_addr hashlist coa*) used by MN and HA. MN's home address corresponds to several care of addresses in the binding list maintained by the HA. MN is also supposed to keep all the valid care of addresses. Once a MN 'A' moves to a new network and configures a care of address it sends a modified BU to the HA. The HA maintains a binding relationship of this MNs home address and multi care of addresses. If the CN 'B' is also mobile all the return routability messages are sent to B's home agent.

There are two possible cases that can arise. If B moves during A's return routability procedure, B checks in its care of address table to see if it has an address that matches to the current visited subnet's prefix. If that is the case, the home registration can be postponed since HA will send the messages to all the care of addresses in its table. Else, it registers with the HA and the new care of address becomes the first in the address in BU. MN A will send its *home test init* and *care of test init* to B's Home Agent, and B's home agent will forward it to all the care of addresses simultaneously. Each copy is kept for a period of T_b as proposed in paper [19].

As a result, if MN B moves after A sends its return routability messages, the time period T_b will take care of this movement. Paper [21] scheme works to solve simultaneous mobility problem when a MN switches frequently between known networks. In that case if the MN moves back to a visited foreign network, it can use the previously received care of address and avoid delay to get new care of address and save time to complete home registration. However the disadvantage is the HA sending multiple copies that will increase the handling cost of the HA and the network load. It will not be advantageous if the MN's movement area has no regional feature.

5. Mobile IP in MPLS Domain

Mobile IP is not designed to support fast handoff in handoff-sensitive environments [22]. A lot of control traffic is produced inside the local domain that increases handoff delay and the risk of packet loss. Many protocols have been discussed that integrate Mobile IP within the MPLS domain. A study of around twenty one such protocols was conducted and it was noticed that the protocols proposed generally fall into three categories. The first category 'C0' is simple MPLS implementations of Mobile IP protocol with no intermediate agents. The updates go all the way to the home agent for every MN movement. Within the categories discussed the protocols are subdivided static (S-LSP) or dynamic LSP (D-LSP) based protocols. A sequence of Label Switched Routers (LSRs) in MPLS network forms a path known as the Label Switched Path (LSP) [3]. Protocol discussed in papers [23-26] fall in this category and found to be mostly dynamic LSP based.

The second category 'C1', are hierarchical protocols where a gateway agent is introduced in the hierarchy. This agent reduces the distance the updates have to travel from MN on changing location. The updates go up to the hierarchical agent instead of going all the way up to the HA. Only when the MN goes into the domain of another hierarchical agent is the HA notified. The protocols in this category are in some cases further divided into static or dynamic LSP based protocols and designated by S-LSP and D-LSP respectively. This classification depends on the presence of static or dynamic LSPs. Protocols discussed in papers [27-37] are category C1 protocols with all of them being D-LSP based. Protocol [27] also has the option of having a static LSP set up.

The third category 'C2', are the protocols where there are more than one hierarchy levels. There are either multiple level agents or a gateway agent and paging areas. Changes within the paging areas causes updates to the paging server only. Changes outside the paging area lead to updates being sent to the gateway agent. Only when the gateway agent domain is changed by the MN, updates have to be sent to the HA. Protocols discussed in papers [38-43] fall into this category with [38-40] being S-LSP based and [41-43] being D-LSP based.

We are proposing a protocol that takes care of simultaneous mobility in MPLS domain. Simultaneous Mobility arises because of Route Optimization between the MN and its communicating node. To understand Simultaneous Mobility in the MPLS domain, we will take the basic architecture in 'C0'category protocol and propose our solution accordingly.

We consider the Integration of mobile IP and multi-protocol label switching as the base case for discussion of the problem of simultaneous mobility in MPLS domain. This is discussed in [23]. The registration process and datagram delivery for this integrated protocol is shown in Fig. 10.

The Foreign Agent is a Label Switched Router (LSR), serving as an edge access router that connects to the MN. Since we are dealing with an MPLS network, the end of the LSP should be a Label Edge Router (LER). In our case we call the access router at the end of the LSP to the MN as the Foreign Agent (FA). This is where the LSP will terminate and the wireless network starts. After this point packets are delivered using the IP protocol. Groups of packets forwarded along the same path and treated in a similar fashion with regards to forwarding treatment belong to the same Forward Equivalence Class (FEC) in MPLS. FEC is therefore a subset of packets that are all treated in the same way by the router and are mapped to a label [44].

The HA delivers the packet destined for MN to the MN through the LSP set up between HA and FA. This implies that there is triangular routing being implemented as all the data that the CN sends has to pass via the HA. Triangular Routing can be removed by sending the Route Optimization messages as discussed to the CN followed by a BU to indicate the current location of the MN. This will be followed by a LSP set up between CN and MN by way of exchanging Label Request and Label Mapping messages. Such an LSP is set up between CN and MN in Fig. 11 indicated with the blue color. When MN moves from FA2 to FA3, again Route Optimization is to be performed.

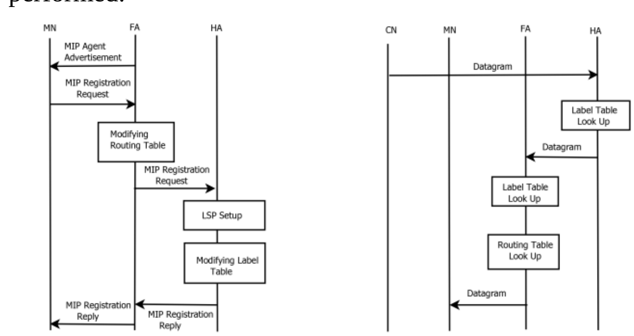

Figure 10. Registration Procedure and Datagram Delivery [23]

This integrated protocol does not discuss route optimization which is the main requirement for simultaneous mobility to arise. Route Optimization in this protocol is discussed in [45].

Route Optimization can be implemented by using Path Changing message. A path changing message is a Label Distribution Protocol (LDP) message with two FEC components. In our case, one is the MN home address and the other is the CoA of the FA. The FA initiates the route optimization and sends a Path Changing message towards the CN when a new MN registers at the FA. Each LSR then forwards this Path Changing Message hop by hop according to IP routing. Any LSR receiving the Path Changing Message gets the MNs home address and the CoA. The label table at the particular LSR is searched for an entry for MNs Home Address. If there is no such entry it indicates that the particular LSR was not there in the original LSP from CN to MN when MN was in its home network. The message is therefore forwarded using hop by hop routing towards the CN. If an entry was there for the MNs home address in the label table, then a special label request message is sent back to the FA with two FECs. First one is the CoA of the FA and the other is the home address of the MN. Thus, this LSR is actually a cross over LSR (COLSR) between the previous path from MN at home network and CN and the new path from MN at the foreign network to the CN.

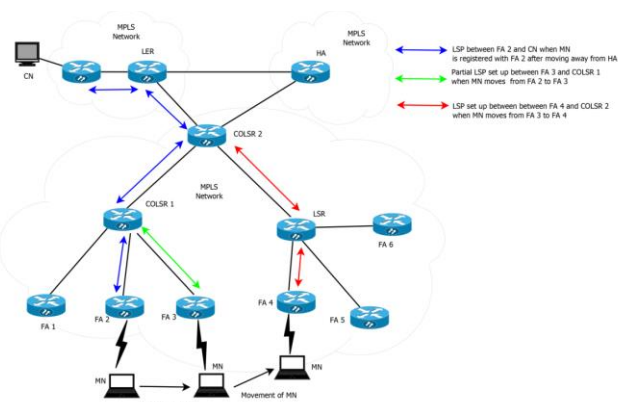

Figure 11. LSP set up between the CN and the MN on MNs movement from one domain to another.

This is shown in Fig. 11 where COLSR 1 is the cross over LSR when MN moves from FA2 to FA3. The special label message is sent hop by hop to the FA. This message passes through intermediate LSRs that note the two FECs in the message. When the message reaches FA, it sends a label mapping message back to the LSR that sent the special label request (COLSR 1). When this label mapping is received at the COLSR, the LSP from COLSR to FA (FA3 in this case) is established. This is indicated by green in Fig. 11. The Blue LSP is the LSP between CN and MN when MN was in the domain of FA2. COLSR 1 changes it label table and binds the CoA with a new label. Meanwhile the FA also modifies its label table and binds the MN home address with a new label value. The FEC entry for this new label is the MN home address.

Once Route Optimization is finished, and FA3 receives the packet from the CN via the newly set LSP, the old LSP between the COLSR 1 and HA should be deleted. This means the blue LSP from COLSR 1 to FA2 will be deleted. Similarly when the MN moves from the domain of FA3 to the domain of FA4, the red LSP is set up with the COLSR 2. The old LSP from COLSR 2 to COLSR1 to FA3 is then deleted.

6. SIMULTANEOUS MOBILITY IN MPLS DOMAIN

To study the Simultaneous Mobility problem, we first study the basic case of Simultaneous Mobility in the MPLS domain where control messages are lost when both the communicating nodes move simultaneously. The study is done on category ‘C0’ protocols with no intermediate agents between the MN and it’s HA. We have divided this into two parts based on if the LSP used is static or dynamic. Section 6.1and 6.2 discuss the case of static and dynamic LSPs for category ‘C0’ protocols. Section 6.3 discusses the case of Label Request and Label Mappings being lost as a result of movement of one node or both nodes simultaneously.

A. Simultaneous Mobility for C0 Static LSP Protocols

Dynamic LSPs between the communicating nodes need to be created after every movement of the MN by exchange of Label Requests and Label Reply or Path Changing Messages. This takes some time and as a result communication cannot start even if both the parties are aware of the each other’s newly acquired location. To resolve this problem, we can create and overlay mesh network of LSPs so that as soon as the communicating nodes get to know each other’s current location, they can straight away start exchanging data using one of the pre-existing LSPs set up on their path to each other. These static LSPs need to be configured initially and can be used as per requirement. In an environment where there are many mobile nodes that keep changing locations, a static LSP set up will save considerable time. In the static LSP set up, the update process will be carried out for the simple case of mobility as well as simultaneous mobility using receiver side mechanisms. The new locations will be exchanged and then a pre-existing static LSP between the two new locations will be used for communication process. The control messages that have to be communicated between the two MNs can also be sent via static LSPs that are reserved especially for control messages. This will help in giving priority to the control messages through traffic engineered LSPs. This will help decrease the time span during which the two MNs are unaware about each other’s latest location.

B. Simultaneous Mobility in Category C0 Dynamic LSP Protocols

In case of simultaneous mobility, the receiver side mechanism employed resolves the problem of loss of CTI, HTI or BU's as all control messages are sent via the Home Agent of the receiver. The HA is responsible to forward these messages to the current location of the MN. When a mobile CN and MN are communicating over a LSP, a change in the location of either MN or CN requires a new LSP set up. Since Route Optimization is being used, the original LSP that existed between the CN and MN need not necessarily go via the Home Agent of either of the two. The LSP is created dynamically upon exchange of Label Request and Label Reply messages between CN and MN.

When there is movement of either or both the communicating nodes, LSPs have to be set up again. Before the LSP can be set up, both the communicating nodes should know the current location of each other. This is done via sending the control messages through the Home Agent of the receiver. Once the control messages reach their destination as shown in Fig. 8 and Fig. 9, a LSP set up procedure is started. To save time on the LSP set up, we can use the approach discussed above and stated in [45]. This approach re-uses previous LSP path set up between the two communicating nodes by using Path Changing messages as discussed in section 5.

A series of simultaneous movement of A and B are indicated in Fig. 12. When MNs A and B are in their Home Networks, a green LSP is set up as a result of Route Optimization. First A moves into a foreign network (Move I) and re-establishes the LSP using Path Changing message. For this movement the COLSR is HA-B. An LSP shown in orange is set up between the new CoA of A (FA 1) and HA-B and it continues with the old green LSP from HA-B to B. The old LSP from previous position of A (FA 10) to HA- B is deleted.

Then MN A moves again (Move II) and while it is moving and updating its location with its HA and CN (B), B also moves (Move III). Once new location messages are exchanged using server side mechanisms, A and B both initiate Route Optimized LSP path set up using either the normal Label Request and Label Mapping message or by using Path Changing Messages. LSR 1 becomes the COLSR for the Path Changing message from A. For the Path Changing message from B, LSR1 again becomes the COLSR as the Path Changing Message is directed towards A hop by hop by the LSR using IP routing. As a result no LSP segment from the previous LSP between A and B is used and a completely new LSP (from FA2 to LSR 1, from LSR 1 to LSR 3 and from LSR 3 to FA6) is created. This newly set up LSP is shown in blue in Fig.12.

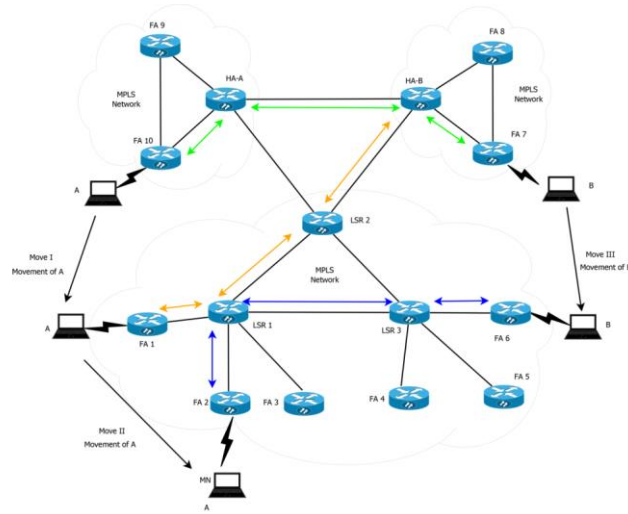

Figure 12. LSP change when Mobile Nodes A and B move simultaneously

A simple label request and label reply can also be used between A and B to set up a shortest path LSP between the two communicating nodes after they have exchanged control messages from their new locations. If there is no Cross over LSR between the two nodes, then the Path Changing message or a Label Request/ Mapping message will yield the same result. Path changing message will be useful only when there is a cross over LSR between the two communicating parties.

C. Mobility during the exchange of Label Request and Label Mapping for LSP path set up for C0-D-LSP Protocols.

In case of dynamic LSPs, the control messages can be exchanged using normal IP forwarding or defining and reserving some static LSPs for the purpose of control messages only. Once the control messages are exchanged for the case of simultaneous mobility or otherwise, dynamic LSPs need to be set up to resume communication between the two MNs. Setting up a dynamic LSP between the two MNs after they have exchanged their latest location information is a simple process where one node sends a Label Request message and gets a Label Reply/ Mapping from the other node. As soon as the Label Reply/Mapping is received on the other side, a LSP is set up between the two nodes. We already discussed above how Path Changing message can help us find a cross over LSR (COLSR) that helps in partially rebuilding the LSP between the two communicating nodes.

We will study the case where there is movement when Label Request and Label Reply / Mapping are being exchanged. There are three cases that arise for the same:

Case I: Mobility of one node or Simultaneous Mobility of both nodes happens before Label Request and Label Mapping are exchanged.

Case II: Mobility of one node or Simultaneous Mobility of both nodes happens while Label Request and Label Mapping are exchanged.

Case III: Mobility of one node or Simultaneous Mobility of both nodes happens after Label Request and Label Mapping is exchanged.

If MNs move simultaneously before any of the Label Request or Label Mapping messages are exchanged (Case I), then it is the simple case of Simultaneous Mobility and can be resolved using receiver side mechanisms as discussed in Section 6.1. The solution for Case III, i.e when Simultaneous Mobility happens after Label Request and Label Mappings are exchanged will be discussed after discussing Case II in detail.

We first make a list of all the possible scenarios that can arise for Case II as a result of mobility during the exchange of Label Request and Label Mapping messages. Let A and B be two MNs communicating with each other. In the past, A and B have both moved, either one at a time or both together, and therefore they must have exchanged their latest locations with each other using the receiver side mechanisms for simultaneous mobility. They are now starting the process of setting up a dynamic LSP for communication purposes when the following cases arise:

a. A sends a Label Request to B and B replies with a Label Mapping and B subsequently moves to a new network.

b. A sends a Label Request to B and B moves to a new network before or after receiving the Label Request from A (without replying with a Label Mapping message).

c. A sends a Label Request to B and B replies with a Label Mapping. A receives the Label Mapping and then moves to a new network.

d. A sends a Label Request to B and B replies with a Label Mapping. A moves to a new network without receiving the Label Mapping.

e. A sends a Label Request to B and B moves to a new network without receiving the Label Request. A also meanwhile moves to a new network. (Case of Simultaneous Mobility)

f. A sends a Label Request to B and B replies with a Label Mapping. B subsequently moves to a new network. A receives the Label Mapping and then moves to a new network. (Case of Simultaneous Mobility)

Cases (a) and (b) are shown in Fig. 13, cases (c) and (d) in Fig.14 and case (e) and case (f) for simultaneous mobility in Fig. 15.

The cases can be dealt in different ways. The first way is the simplest of all in which the control messages are exchanged again by the MN from the new location. To ensure the case of simultaneous mobility doesn't arise, the control messages are always sent using receiver side mechanisms as explained earlier. This will ensure the MNs get to know the latest location of each other after which they can initiate the process of setting up a dynamic LSP. However, in case (a), case (c) and case (f), the Label Request and Label Mapping has already been exchanged and received at both ends. This implies the LSP is already set up and therefore going for a new LSP set up preceded by exchange of control messages will be time consuming and cause more delay. Case (a), case (c) and case (f) will be therefore dealt with separately. We will first discuss the simple solution to case (b), case (d) and case (e).

Case (b) and case (d) are simple mobility cases where Label Request or Label Mapping is lost instead of control messages. This should initiate a mobility procedure where control messages are exchanged again using receiver side mechanisms to ensure the case of simultaneous mobility is also taken care of. This sending of control messages including CTI, HTI and BU will ensure the MNs know the latest location of each other before exchanging Label Request and Label Mapping again. The receiver side mechanism used will take care of Case (e) as well.

To handle Case (a), case (c) and case (f) we use the **Forwarding Chain Mechanism or the FC-Micro Mobile MPLS** that is based on the forwarding chain concept [42]. This is a pointer forwarding technique in a MPLS network. Although it is a 'C2' category protocol, we can use the forwarding chain concept in our solution.

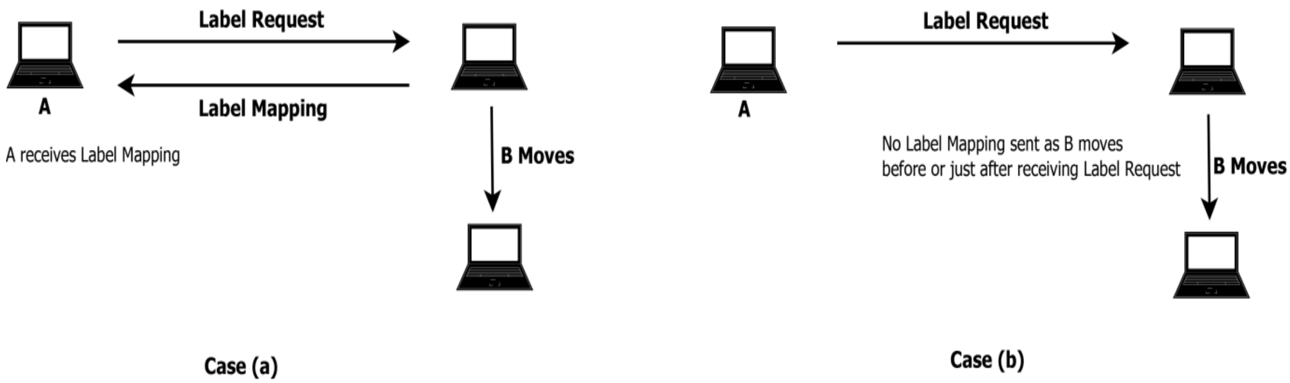

Figure 13. (a) Movement of B after sending Label Mapping. (b) Movement of B without sending Label Mapping.

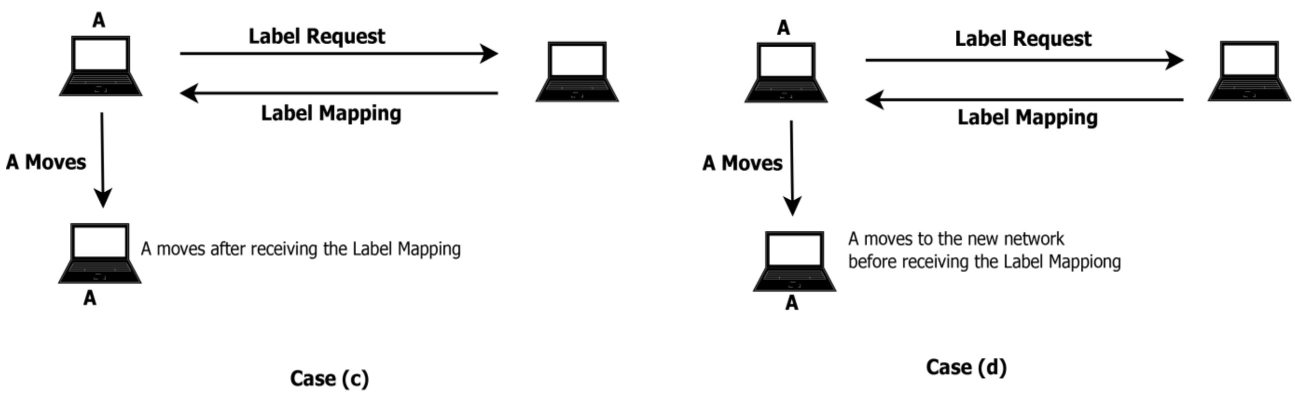

Figure 14. Movement of A after receiving Label Mapping. (b) Movement of A without receiving Label Mapping from B.

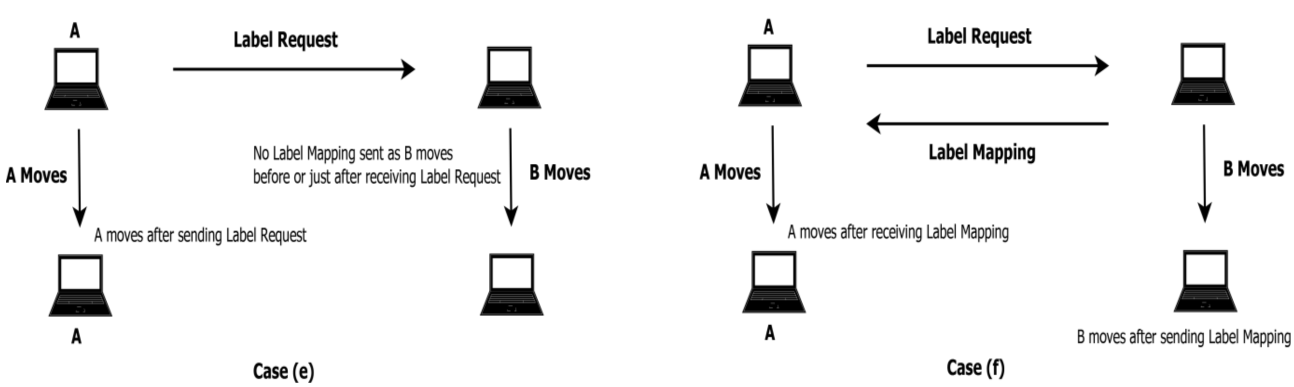

Figure 15. (e) Movement of A after sending Label Request and movement of B without sending Label Mapping. (f) Movement of A after receiving Label Mapping and Movement of B after sending back Label Mapping. (e) and (f) are both cases of Simultaneous Mobility.

In this mechanism, each time a MN moves to a new subnet it registers with the old FA instead of the Label Edge Router Gateway (LERG). LERG is an agent in the foreign network under whose domain the MN moves. As long as the MN is in the domain of the LERG, it has to update the LERG. Once it moves out into the domain of a new LERG, it has to update it's HA. In this particular mechanism the MN is made to update the old FA instead of the LERG. The LSP between LERG and old FA that was already there when MN was under old FA, is extended to the new FA. The old FA is the master FA for the MN at that time. This LSP extension continues until this forwarding chain reaches some threshold value that is defined previously. The MN keeps a buffer containing the IP addresses of the visited FAs. When the threshold of the forwarding chain is reached, MN registers to the LERG and deletes all addresses in its buffer. The current FA then becomes the new Master FA for the MN and the process continues like that. The benefit is using the existing path and just extending the path between the FAs. Resource reservation cost is reduced as a result. This mechanism can cause the creation of loops of the FAs the MN visits. Since the MN has an entry for the IP addresses of the FAs visited by it, a re-entry into the same FA region means the IP address is present in its binding cache. The loop can be detected easily and deleted by putting null in the out port and out label entries of that particular FA. This means that the LSP that was extended earlier now ends at this FA.

Applying this to our scenario, we see that there is no LERG in our network. The updates about the MN go all the way to the MNs HA. Also, we are dealing with the LSP between the two communicating MNs after route optimization. We introduce a change in our normal protocol by making the MN update its previous FA as well as it's HA about its movement to the new location. This helps us in extending the LSP that was set up between A and B prior to movement of either of them. Once the MN updates its old FA, the old FA extends the LSP that has just been created between the MNs towards the new FA. Thus in case of (a) when A receives the Label Mapping, the LSP between A and B is already set up. The old FA of B extends this LSP to the new FA of B and thereby helps in resuming communication at the earliest. The threshold on the number of times the LSP can be extended can be set and master FA updated as stated in protocol [42]. Case (c) is also dealt similarly with the LSP being extended between the old FA of A and the new FA of A. The threshold and the change of master FA is again taken care of using the protocol given in [42]. Case (f) is a combination of Case (a) and Case (c). The Label Request is sent by A and received by B. B has replied back with a Label Mapping and it has been duly received at A. As soon as B sends back Label Mapping and A receives Label Mapping, both move simultaneously. Since at this point of time the LSP between A and B is already set up, the LSP can be extended at both A's and B's end. Thus the LSP will be extended from the old FA of A to new FA of A. Also, the LSP will be extended from old FA of B to new FA of B. Meanwhile the packets destined to A from B and vice versa can be buffered at the old FA till the LSP extension is done. After this, the packets are forwarded to the new location.

Both the MNs meanwhile have sent their location update to their respective HA's on movement. MN would have also sent their control messages including the BU to all its CNs by way of receiver side mechanisms. The communication continues using the extended LSP for either or both of the MNs. Once the MNs are aware of each other's latest locations, the MNs can simultaneously start building another LSP directly between themselves by way of exchanging Label Request and Label Mapping messages. Once this LSP is set up and is gauged to be optimal, all communication should proceed through that.

7. Conclusion and Future Work

The paper specifically deals with the problem of simultaneous mobility in the MPLS domain. The protocol overview discussed in Section 3 suggests that MPLS improves the QoS of services in the Mobility framework. Many of these protocols support their claims using mathematical models or simulation studies. In our suggested protocol we have taken into consideration two scenarios in the MPLS domain. In the first scenario we work on the simultaneous mobility problem in an MPLS domain where static LSPs are used. This approach has an advantage because if LSPs are established prior to MNs actual movement to a new access point, the packet forwarding will be faster and as such there will be less drop and delay during handover. For the case of using dynamic LSPs in the MPLS domain we have used the concept of forwarding chains. Forwarding chains further improve handover as packets continue to flow along the previous path with only a LSP path extension from previous access router to the new access router. This has been used in our dynamic LSP solution to the simultaneous mobility problem during the exchange of Label Request and Label Mapping messages.

Many versions of MIPv6 and integrated protocols with MPLS do not give a solution to the problem of simultaneous mobility that can arise with the increasing number of MNs. This paper has given a solution to the problem of Simultaneous Mobility in the MPLS domain. A lot of years have been spent in the study of the integration of Mobile IP and MPLS without a definitive standard in place. From the literature survey of a combination of these integrated protocols, it is clear that MPLS improves the QoS of services in the Mobility. The work presented here is restricted to category 'C0'protocols and can be extended to other categories as well. Our future works aims at setting up mobility in MPLS domain and working out the solution presented here for solving the problem of simultaneous mobility in the MPLS domain. The results will be compared with the case of simultaneous mobility outside the MPLS domain to see the level of improvement based on various parameters.

REFERENCES

[1] Wong, K., Dutta, A., Young, K., Shulzrinne, H., " Managing simultaneous mobility of IP hosts," Proceedings of MILCOM 2003, vol. 22, pp. 785–790 (2003).

[2] Chiussi, F.M.; Khotimsky, D.A.; Krishnan, S., "A network architecture for MPLS-based micro-mobility," Wireless Communications and Networking Conference, 2002. WCNC2002. 2002 IEEE , vol.2, no., pp.549,555 vol.2, Mar 2002.

[3] E. Rosen, A. Viswanathan, R. Callon, "Multiprotocol Label Switching Architecture,"IETF RFC 3031, Jan2001.

[4] X. Xiao, A. Hannan, B. Bailey, L.M. Ni, Traffic engineering with MPLS in the Internet, 2000.

[5] D. Awduche, J. Malcolm, J. Agogbua, M. O'Dell, J. McManus, Requirements for traffic engineering over MPLS, RFC 2702, September 1999.

[6] Tubtim Sanguanwong thong and Priwit Chumchu "Design and Implementation of Micro-Mobile MPLS for NS-2" Proceedings of the 3rd International Conference on Performance Evaluation Methodologies and Tools, 2008.

[7] R. Langar, G. L. Grand, and S. Tohme, "Micro Mobile MPLS in next generation wireless access networks," Proceedings` 9th CDMA International Conference (CIC), 2004.

[8] R. Langar, S. Tohme, and N. Bouabdllah, "Mobility management support and performance analysis for wireless MPLS networks" International Journal of Network Management, 2006.

[9] V. Vassiliou, H. L., D. Barlow, J. Sokol, and H.-P. Huth, "M-MPLS: Micromobility enabled Multiprotocol Label Switching," IEEE International Conference on Communication (ICC), 2003.

[10] Jorn Hanskaar and Trond Almar Lunde, "Mobility in IPv6".

[11] Rachid Ait Yaiz and Osman Öztürk, "Mobility in IPv6".

[12] Shaima Qureshi, Ajaz H. Mir, "Mobility Management in Next Generation Networks: Analysis of Handover in Micro and Macro Mobility Protocols", Paper published in International Journal of Computing and Network Technology. Volume 2, Number 3, September 2014.

[13] IPv6 and Multicast Routing, SOI ASIA Operators Workshop.

[14] R.Koodli, "IP Address Location Privacy and Mobile IPv6: Problem Statement ," IETF Request for Comments 4882, May 2007.

[15] Pekka Nikander, Jari Arkko, Tuomas Aura, Gabriel Montenegro, " Mobile IP version 6 (MIPv6) route optimization security design".

[16] Guang Xiaoming, Wu Jing., " Mobile IP Analysis", China Data Communications, 2003(11).

[17] D. Johnson, C. E. Perkins, and J. Arkko, "Mobility Support in IPv6," IETF Request for Comments 3775, June 2004.

[18] K. Wong, A. Dutta and H. Schulzrinne, "Simultaneous Mobility Problem Statement," IETF Internet draft, Feb. 2008.

[19] Wong, K.D.; Dutta, A., "Simultaneous mobility in MIPv6," Electro Information Technology, 2005 IEEE International Conference on , vol., no., pp.5 pp.,5, 22-25 May 2005.

[20] K. D. Wong, A. Dutta, H. Schulzrinne, and K. Young, "Simultaneous mobility: analytical framework, theorems and solutions," ACM Wireless Communications and Mobile Computing, vol. 7, no. 5, June 2007, pp.623-642.

[21] Qiang Liu; Shaomei Li; Hongyong He; Binqiang Wang, "A Multi-binding Solution for Simultaneous Mobility of MIPv6," Service-Oriented System Engineering, 2006. SOSE '06. Second IEEE International Workshop , vol., no., pp.143,146, Oct. 2006.

[22] Bernd Gloss and Christian Hauser, "The IP Micro Mobility Approach " in: Proc of the EUNICE 2000 (September 2000).

[23] Zhong Ren; Chen-Khong Tham; Chun-Choong Foo; Chi-Chung Ko, "Integration of mobile IP and multi-protocol label switching," Communications, 2001. ICC 2001. IEEE International Conference on , vol.7, no., pp.2123,2127 vol.7, 2001.

[24] Berzin, O.; Daryoush, A., "Mobility label based network: Support for mobility using MPLS and Multi- Protocol BGP," Radio and Wireless Symposium, 2008 IEEE , vol., no., pp.511,514, 22-24 Jan. 2008.

[25] Francesco Palmieri," An MPLS-based architecture for scalable QoS and traffic engineering in converged multiservice mobile IP networks", Computer Networks, Volume 47, Issue 2, 4 February 2005, Pages 257-269, ISSN 1389-1286.

[26] Inwhee Joe; Hyojin Lee, "GM-MPLS: Group-based Mobile MPLS for mobility management in wired/wireless networks," Networked Computing (INC), 2010 6th International Conference on , vol., no., pp.1,6, 11-13 May 2010.

[27] Heechang Kim; Wong, K.-S.D.; Wai Chen; Chi Leung Lau, "Mobility-aware MPLS in IP-based wireless access networks," Global Telecommunications Conference, 2001. GLOBECOM '01. IEEE , vol.6, no., pp.3444,3448 vol.6, 2001.

[28] Tingzhou Yang; Makrakis, D., "Hierarchical mobile MPLS: supporting delay sensitive applications over wireless Internet," Info-tech and Info-net, 2001. Proceedings. ICII 2001 - Beijing. 2001 International Conferences on , vol.2, no., pp.453,458 vol.2, 2001.

[29] Adibi, S.; Naserian, M.; Erfani, S., "Mobile-IP MPLS-based networks," Electrical and Computer Engineering, 2005. Canadian Conference on , vol., no., pp.168,171, 1-4 May 2005.

[30] R. Langar, G. Le Grand, S. Tohme, "Micro Mobile MPLS: A Solutionfor Micro-Mobility Management in Next Generation Networks", 12th IEEE MASCOTS 2004, Volendam, The Netherlands, October 2004.

[31] Boeringer, Rene; Saeed, Ahmad; Diab, Ali; Mitschele-Thiel, Andreas; Schneider, Matthias, "I-MPLS: A Transparent Micro-Mobility-enabled MPLS Framework," Wireless Conference 2005 - Next Generation Wireless and Mobile Communications and Services (European Wireless), 11th European , vol., no., pp.1,9, 10-13 April 2005.

[32] Diab, A.; Boringer, R.; Mitschele-Thiel, A., "Optimized I-MPLS: A Fast and Transparent Micro-Mobility-Enabled MPLS Framework," Wireless Communication Systems, 2006. ISWCS '06. 3rd International Symposium on , vol., no., pp.113,117, 6-8 Sept. 2006.

[33] V. Vassiliou, H. L., D. Barlow, J. Sokol, and H.-P. Huth, "M-MPLS: Micromobility enabled Multiprotocol Label Switching," IEEE International Conference on Communication (ICC), 2003.

[34] Hairong Zhou; Chihsiang Yeh; Mouftah, H.T., "DHMM: A QoS Capable Micro-Mobility Management Protocol for Next Generation All-IP Wireless Networks," Global Telecommunications Conference, 2007. GLOBECOM '07. IEEE , vol., no., pp.4989,4993, 26-30 Nov. 2007.

[35] Shengling Wang; Yong Cui; Das, S.; Mingwei Xu, "Optimized Mobile MPLS," Communications Workshops, 2008. ICC Workshops '08. IEEE International Conference on , vol., no., pp.441,445, 19-23 May 2008.

[36] Polvichai, S.; Chumchu, P., "Mobile MPLS with route optimization: The proposed protocol and simulation study," Computer Science and Software Engineering (JCSSE), 2011 Eighth International Joint Conference on , vol., no., pp.34,39, 11-13 May 2011.

[37] Tingzhou Yang; Yixin Dong; Bin Zhou; Makrakis, D., "Profile-based mobile MPLS protocol," Electrical and Computer Engineering, 2002. IEEE CCECE 2002. Canadian Conference on , vol.3, no., pp.1352,1356 vol.3, 2002.

[38] Kaiduan Xie; Wong, V.W.S.; Leung, V.C.M., "Support of micro-mobility in MPLS-based wireless access networks," Wireless Communications and Networking, 2003. WCNC 2003. 2003 IEEE , vol.2, no., pp.1242,1247 vol.2, 20-20 March 2003.

[39] Chiussi, F.M.; Khotimsky, D.A.; Krishnan, S., "A network architecture for MPLS-based micro-mobility," Wireless Communications and Networking Conference, 2002. WCNC2002. 2002 IEEE , vol.2, no., pp.549,555 vol.2, Mar 2002.

[40] Hui Wang; Zhengkun Mi, "A new QoS-aware MPLS-based micro-mobility management technology," Wireless, Mobile and Multimedia Networks, 2006 IET International Conference on , vol., no., pp.1,4, 6-9 Nov. 2006.

[41] Sethom, K.; Afifi, H.; Ameur, W.B., "M&M's: an MPLS micro-mobility solution," Wireless Communication Systems, 2004, 1st International Symposium on , vol., no., pp.334,337, 20-22 Sept. 2004.

[42] Langar, R.; Bouabdallah, N.; Boutaba, R., "A Comprehensive Analysis of Mobility Management in MPLS-Based Wireless Access Networks," Networking, IEEE/ACM Transactions on , vol.16, no.4, pp.918,931, Aug. 2008.

[43] Tai Won Um; Jun Kyun Choi, "A study on path re-routing algorithms at the MPLS-based hierarchical mobile IP network," TENCON 2001. Proceedings of IEEE Region 10 International Conference on Electrical and Electronic Technology , vol.2, no., pp.691,697 vol.2, 2001.

[44] Artan Halimi, Brikena Statovci-Halimi, "Overview on MPLS Virtual Private Networks", Photonic Network Communications, May 2002, Volume 4, Issue 2, pp 115-131.

[45] Abdul Sakib Mondal. Mobile IP: Present State and Future. Series in Computer Science. 2006 Wittmann, R.

[46] Ulrike Meyer and Hannes Tschofenig, Georgios Karagiannis, "On the Security of the Mobile IP Protocol Family", University of Twente Publications, Proceedings of 1st IEEE Workshop on Enabling the Furture Service Oriented Internet, Workshop of GLOBECOM 2007, 26-30 Nov 2007.

[47] Mahajan A. & Wild B., "Route Optimizations in Mobile IP". Retrieved on 30 November 2008.

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