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Study of Basic Mobile Internet Protocols (MIP) in Multi Protocol Label Switching (MPLS) Domain

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Abstract: Multi Protocol Label Switching (MPLS) technology is being largely deployed in the Internet backbone to support traffic engineering and provide Quality of Service (QoS) requirements. Mobile Internet Protocol (MIP) is a protocol that allows users to move along with their devices without disrupting ongoing communications. Mobile IP in its basic form does not support traffic engineering. Integrating MPLS with Mobile IP can help in providing Quality of Service within the mobility framework. In this paper we survey various protocols that propose basic Mobility within a MPLS domain without having any hierarchy points. The protocols are compared based on their features and architectural framework.

Keywords: Mobile MPLS, MPLS, MIP, MIPv6

1. INTRODUCTION

Electronic gadgets have become smaller and more affordable and as such their usage is increasing tremendously. These devices are mobile and as such need special protocols to cater to their connectivity needs. Mobile Internet Protocol (MIP) has been designed to cater to mobile devices and to create an expanded address space for identifying such devices. The Internet Protocol (IP) address of a mobile node (MN) changes when it moves from one network to another. This change of network has to be done without affecting the ongoing sessions and maintaining. For higher level protocols like Transport Control Protocol (TCP), any change in the IP address or port numbers is harmful to the ongoing sessions as it breaks the stability of the session and goes against the concept of allowing mobility in IP. Mobility supported protocol should not have to worry about this break in the connection. In mobility, when a mobile device shifts its link-layer point of attachment to the Internet, it should not change its original IP address, i.e. the home address of the MN. A MN must also be able to communicate with other nodes that do not implement these mobility functions [1,2].

As the MNs are not connected via physical connections they generally tend to have lower bandwidth and higher error rates. Battery consumption of mobile devices should also be minimized. The number of messages required for the administration of such MNs in a mobility management framework also needs to be minimized. These messages should also be reduced in size to avoid burdening the network with such exchange of signals [3]. Mobile Internet Protocol version 4 (MIPv4) introduced agents in the home and foreign networks that helped in transparent movement of the mobile devices between networks. The transfer is done in such a way that the higher transport layers receive the original IP address of the MN, retaining the connection channel [4]. Thus the session continues even if the network location changes for a MN.

Mobility protocols can be global or local. Global mobility protocols are also termed as the macro mobility protocols [5]. MIPv4 and Mobile Internet Protocol version 6 (MIPv6) are both macro mobility protocols. Macro mobility Management Protocol is a mobility protocol that maintains session continuity when a MN moves from one network to another causing change in its network topology [6]. The global, end-to end routing of packets is changed during mobility to maintain session continuity. Mobile IP is not designed to support fast handoff in handoff-sensitive environments as it produces a lot of control traffic inside the local domain that increases handoff delay and the risk of packet loss. There is significant signaling overhead, handover latency, and

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transient packet loss and are jointly known as fast handover issues. For each handover, signaling has to take place between mobile host and its home agent, which takes time and adds to the network load. The signaling load is proportional to the number of users and their level of mobility [7]. These generate the need for micro-mobility schemes that can satisfactorily handle localized movement without any support from wide-area protocols. A number of micro-mobility schemes like Cellular IP, Hawaii, Hierarchical Mobile IP, Intra Domain Mobility Management Protocol (IDMP), Edge Mobility Architecture etc have been proposed over the last couple of years, an overview of which can be found in [8].

While many of micro mobility proposals address fast handover issues with a good degree of success, they lack flexibility, Quality of Service (QoS) support and gradual deployment. [9]. A significant number of Internet Service Providers and network operators are migrating towards Multi Protocol Label Switching (MPLS) [10] 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) [11,12].Traffic Engineering is a process of controlling traffic flows through a network to optimize resource utilization and network performance. However, it is generally more suitable for macro mobility where scalability is a main issue, whereas in micro mobile MPLS, mobility is the main area of concern [13]. Many MPLS based micro-mobility schemes have been proposed [14-17]. MPLS faces complexity issues as its domain routers have to run different routing algorithms for giving the best QoS paths. DiffServ and IntServ have also been investigated in the mobility framework. Paper [18] investigates the effect of handoff on quality of mobile nodes in DiffServ network.

In the following sections, Section 2 and Section 3 we will discuss Mobility IP in general and Mobile IPv6 in particular, followed by an introduction to MPLS. Section 4 will discuss in detail the basic Mobility management protocols proposed for the MPLS domain. This paper deals exclusively with only those protocols that do not use any hierarchy points in their architecture. Hierarchy points improve performance as the updates have to travel to the nearest hierarchy point as opposed to the home agent that can be far away. The scope of this paper is limited to basic mobility architecture protocols. The paper will compare the protocols discussed in Section 4. Section 5 will conclude the paper.

2. MOBILE INTERNET PROTOCOL

A collection of fixed and mobile network components belonging to one operational domain and providing access to the internet is known as an access network [6]. Once a MN moves to another network and the movement is detected, it is followed by a tie up with an agent in the foreign network known as the foreign agent (FA) and acquiring of a new IP address known as the Care-of-Address (CoA). The FA helps the MN to inform its Home Agent (HA) about its new location and serves as an intermediary by accepting packets from HA and forwarding them to MN. Home Agent (HA) helps in maintaining the connection and makes the network switch transparent to the communicating entities. The entity or node communicating with the MN is known as the Correspondent Node (CN). The reply to the CN is send directly from the MN, which leads to triangular routing [19].

Movement has to be identified when a node changes its network. A delay occurs when a node moves from one network to another. Thus the whole procedure of movement and address configuration should be aimed to minimize delays and help in the smooth functioning of the mobility protocol [1]. The delays comprise handover which is basically a process of terminating the existing connections and setting up new IP connections. The total delay caused is the handover latency [20][21].

Messages that report the new position of the mobile node to the home network must be authenticated in order to protect them against remote redirection attacks [2]. MIPv6 has advantages over MIPv4 because of the additional features available in IPv6 [22]. MIPv6 also has the additional advantage of having a large pool of IP addresses available to it because of the 128 bit address space of IPv6. IPv6 also known as the Next Generation Network (NGN) has security features that give MIPv6 advantage over MIPv4.

Route Optimization is a part of MIPv6 specification; all IPv6 nodes are expected to support it. The other difference is the absence of a foreign agent; the mobile node is a direct point of communication with the home agent. Mobile IPv6 uses two IP addresses per node. One is the home address; the address a mobile node has in its home network. This address is fixed and anyone on the internet can communicate with this node through this address. The other address is the Care-of-Address; the address a mobile node has in the foreign network. It changes as the mobile node moves from one network to another [23]. 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. It is the responsibility of the mobile node to update the

HA with its new CoA [19] [20] [23]. Once this update is received, packets are tunneled to the care of address. This tunneling leads to triangular routing as shown in Fig. 1. No foreign agent is present in this case.

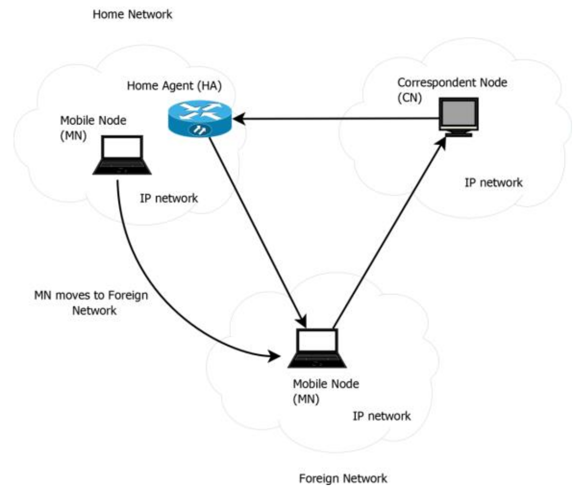

Figure 1. Triangular Routing in MIPv6

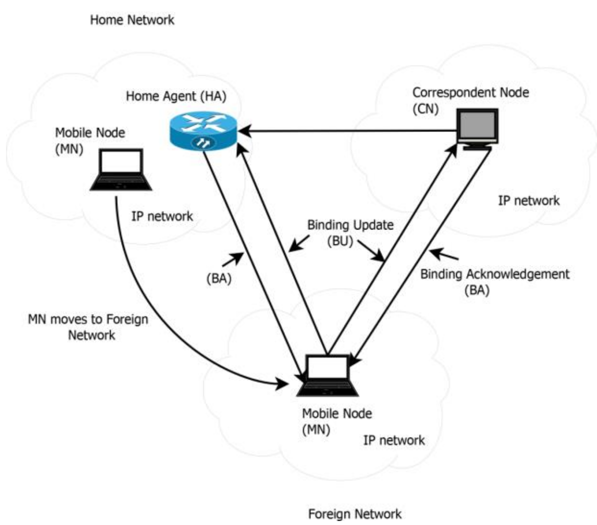

Figure 2. Route Optimization in MIPv6

The updates to the HA and the CN are sent through notifications. In IPv6 there are three new procedures known as the Binding Update, Binding Acknowledgement and Binding Request [24]. The CoA is communicated using these notification procedures. The MN can send a Binding Update to a correspondent and later the correspondent can send packets directly to MN, without having HA as an intermediate [24]. This is done using Route Optimization supported in Mobile IPv6. Fig. 2 depicts the notification procedures in Route Optimization. The CN sends packets to the CoA with a routing header. This routing header with the MN's home address ensures 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. Route Optimization uses Return Routability Procedure [4]. The communication is carried out using ICMP (Internet Control Message Protocol) version 6 (ICMPv6). MIPv6 supports mobility without having to worry about the presence of agents in other networks. Also, the inbuilt Route Optimization feature removes the dependence on the home network.

3. Multi Protocol Label Switching (MPLS)

Multi Protocol Label Switching (MPLS) [25-27] is a technology for the next-generation packet networks. Need for high speed packet switching, forwarding and large scalability requirements gave rise to the need for such a technology. This helps Internet Service Providers (ISPs) to offer several services on the single network architecture [28]. It came into existence to improve forwarding speed of routers. MPLS is also helpful at providing: Traffic Engineering, Virtual Private Networks (VPN) and routing performance at low cost and with minimum configuration overhead [29-31]. MPLS can provide QoS guarantees [32-33] with ability of one-to-many connection. It solves the problem of performance bottleneck due to longest prefix match in IP networks. Excessive overhead of network management in IP is also reduced. Problems with overlay models like IP over ATM (Asynchronous Time-Division Multiplexing) are also resolved. MPLS is viewed by some as one of the most important network developments of the 1990's [34]. MPLS allows routing with QoS restrictions, using signaling protocols like Constraint Based Routing over Label Distribution Protocol (CR-LDP) or Reservation Protocol (RSVP) to establish the path adapted to QoS restrictions [35-37]

Benefits of MPLS include using one unified network infrastructure. Speed of MPLS is no longer a reason for its deployment as nowadays Application-Specific Integrated Circuits (ASIC) are used in routers making the packets switched as fast as that of a label. However MPLS enables carrying protocols other than IP known as Any Transport over MPLS (AToM) [38] [39] and better IP over ATM integration. This is in addition to providing optimal traffic flow and traffic engineering [40].

MPLS packets are forwarded by label switching and not IP switching. Destination IP address is not required to forward the labeled packets. Packets are forwarded to edge network router based on label and this router is the one that runs Border Gateway Protocol (BGP). Routers in the middle of the MPLS network, also known as the core or intermediate routers do not need to have full internet routing tables and hence need less memory. Traffic Engineering involves optimal use of network infrastructure. Links that are underutilized can be used even if those links don't provide us the shortest path or the least cost path. Thus we can spread over the traffic on all the links and make sure all links are utilized to the full. MPLS Works well with overlay networks with VPN. Overlay networks are ones that interconnect different customer networks which are serviced by different L2 services.

MPLS Architecture:

To apply MPLS to an existing IP network, all routers in the network have to be converted to MPLS-enabled routers [41]. MPLS technology is called Layer 2.5 technology. It operates between the Layer 2 (Data Link Layer) and Layer 3 (Network Layer). It is a packet forwarding technology that's capable of layer 3 to layer 2 route mapping [42]. MPLS labels of 32 bit length are used instead of longer IP addresses (32 bits in Internet Protocol version 4 and 128 bits in Internet Protocol version 6) in switching of packets. Fig.3 depicts the syntax of MPLS Label [26] [43].

MPLS header, also known as Shim Header, is inserted between the layer-2 header and layer-3 header as shown in Fig. 4. MPLS header is fragmented into 4 fields: Label , EXP, S or BoS and TTL (Time to Live). Label is used for lookup and gives the next hop to which the packet is to be forwarded and the operation to be performed on the label stack. Experimental Bits (EXP) and are used for Quality of Service. Bottom of Stack (S) bit holds the value 1 if the label is the bottom label in the stack. Else it is set to 0. The purpose of TTL is to avoid getting stuck in a routing loop. It is decremented by 1 at each hop, shows how far the header could travel along the route [40] [43-45] .

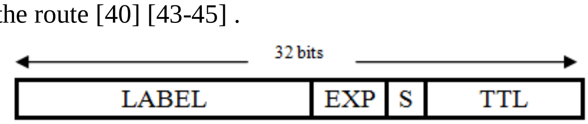

Figure 3. MPLS Label

MPLS capable routers might need more than one label on top of packet to route that packet through an MPLS network. This is achieved by packing labels on to the stack. Between the first and the last label, any number of labels can be there in the stack. Only the last label S bit will be set to 1, indicating bottom of stack. MPLS applications like VPN and AToM need more than one label in the stack to forward the labeled packets. The label stack is located in front of the L3 packet, before header of transported protocol (Layer 3 header).

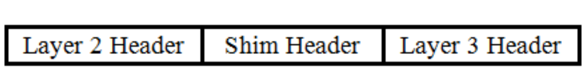

Figure 4. MPLS Shim header position

A label is used for making forwarding decisions in the MPLS network. MPLS does not use IP destination address for forwarding. Label Switch Router (LSR) is capable of understanding these labels and helps in forwarding of labeled packets. LSR has three types: Ingress LSR, responsible to add a label; Egress LSR, responsible to remove a label and Intermediate LSR responsible for correct switching of the packet. An Ingress LSR receives non labeled packets, inserts label stack and sends the packets to Data Link Layer. An Egress LSR receives labeled packets, removes labels and sends the packets to Data Link Layer. An Intermediate LSR receives incoming labeled packets, performs operations on the stack (push, pop, swap) and sends to the correct Data Link Layer. Push operation pushes one or more labels onto the label stacks and switches out the packet. Pop operation pops out one label before switching the packet out. Swap operation swaps the top of label with a new label and the packet is switched to outgoing data link. Ingress and Egress LSRs are Label Edge Routers (LER). An ingress LSR is also known as imposing LSR as it imposes labels onto the packets. Similarly an Egress LSR is a disposing LSR as it is responsible for removing labels before switching the packets out. In case of MPLS VPN, Ingress/Egress LSR's are also known as Provider Edge Routers.

A sequence of LSRs in MPLS network forms a path known as the Label Switched Path (LSP). MPLS flows are connection-oriented and packets are routed along pre-configured LSPs. MPLS flows incorporate label swapping forwarding paradigm with network layer routing. When a packet enters MPLS domain, it is assigned a label by the ingress LER specifying the path that the labeled packet has to take within the MPLS domain. A different label is used for each hop. The LSR that forwards the packet chooses the next label to be imposed on the packet. At the egress, LSR receives the labeled packet, removes the label and forward them based on layer 3 addresses for normal IP routing. [40] [46-48] . LSR that transmits with respect to the direction of data flow is called an upstream LSR. LSR that receives the MPLS packet is called downstream. The MPLS edge routers are called E-LSR (Edge-LSR) with the first LSR denoted as Ingress Router and the last as Egress router. Once the packet reaches the egress routers, the label is popped off and IP routing takes the packet to the destination [46].

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). FEC is therefore a subset of packets that are all treated in the same way by the router and are mapped to a label [48]. Packets with same Labels do not belong to the same FEC as the EXP bits might be different. Labels in general have no global meaning; they are just meaningful to adjacent routers which agree upon which labels to use.

The labels are to be distributed using the Label Distribution Protocol (LDP). For every IP prefix in the IP routing table a LSR creates a local binding that binds the IP prefix to a label. These bindings are then distributed to every LDP neighbor. Received bindings become remote bindings. Neighbors store these local and remote binding in a special table known as the Label Information Base (LIB). Each LSR has only one local binding per prefix. One local label binding can exist per prefix per interface. Each LSR gets more than one remote binding as it usually has more than one adjacent LSR's. Out of all remote bindings per prefix, the LSR needs to pick only one binding and use that to determine the outgoing label for that IP prefix. Routing Table (Routing Instance Base-RIB) determines the next hop of the IP prefix. LSR chooses remote binding received from downstream LSR, which is the next hop in the routing table for that prefix. This information is used to set up Label Forwarding Information Base (LFIB) [25]. In this table the label from the local binding serves as the incoming label and label from the one remote binding chosen via the routing table serves as the outgoing label. Thus, LFIB is a table used to forward packets. It is populated with incoming and outgoing labels for the LSP's and later on used for label switching. Incoming label is the local binding on LSR and outgoing label is the remote binding chosen by the LSR from the all possible remote bindings available to it. The remote binding is chosen based on which path in the routing table is considered the best path. LFIB can also be used to install the labels that the LDP does not assign. This is helpful in traffic engineering as we can manually set up paths for specific purposes.

4. Mobility Protocols In MPLS Domain

MPLS technology combines ease of IP routing with the high speed switching of ATM. It is being largely deployed in the Internet backbone to support traffic engineering and provide Quality of Service (QoS) requirements. Its features like fast switching, small state maintenance and high scalability has made it very attractive for deployment. Mobile IP on the other hand is a protocol that allows users to move with their devices while still being connected to the internet. It provides solution for roaming mobile users to retain connectivity to the internet.

Mobile MPLS is a scheme that integrates Mobile IP and MPLS protocols to allow mobility within a MPLS domain. With increased interest in moving MPLS to wireless access networks, providing roaming functionality for the millions of mobile devices within such a domain needs to be focused on. Mobile IP in its basic form does not provide Quality of Service functionality which can be incorporated by integrating MPLS and Mobile IP. Our focus of study is on existing integrated MPLS and micro mobility solutions and their comparison.

The protocols in discussion have no intermediate agents. They follow the basic mobility architecture as shown in Fig. 1. We name these protocols as category C0 protocols .Within this category the protocols are identified as static or dynamic LSP based depending if they use static or dynamic LSP. These will be designated by S-LSP and D-LSP respectively.

We will be discussing four C0 category protocols. There are no hierarchy levels and all the updates are supposed to go to the Home Agent (HA).

A. Integration of Mobile IP and MPLS

This is a category **C0-D-LSP** protocol [49]. In this protocol the integration of Mobile IP and MPLS aims to improve the scalability of the Mobile IP data forwarding process. This paper presents the simplest integration of Mobile IP and MPLS. The whole domain under consideration is taken to be an MPLS domain in one case as shown in Fig. 5. In another case HA and FA are assumed to be present in two separate MPLS domains with or without an IP cloud in between as shown in Fig. 6 and Fig. 7respectively.

The registration procedure and datagram delivery for MN movement when HA and FA are LER's of the same MPLS domain in consideration is shown in Fig.8 and Fig. 9 respectively. The MIP registration request is forwarded via hop-by-hop IP routing to the HA. The LSP between HA and FA transfers packets to the care of address of the MN. This protocol can be used to set up an LSP to satisfy specific QoS requirements and do traffic engineering. This protocol suggests using Constraint-Based Label Distribution Protocol (CR-LDP) described in [50] for the same.

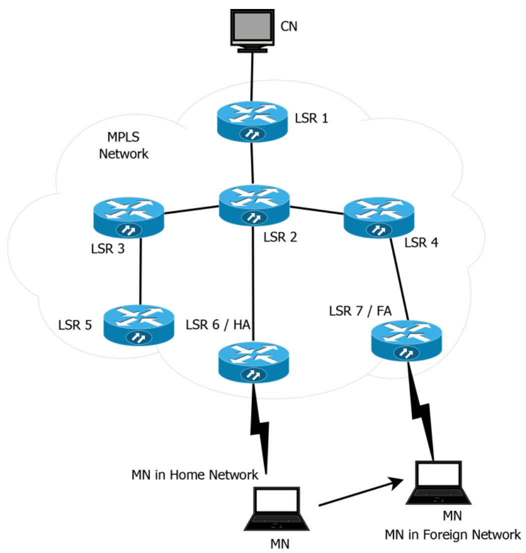

Figure 5. When the MN movement is within the MPLS domain [49]

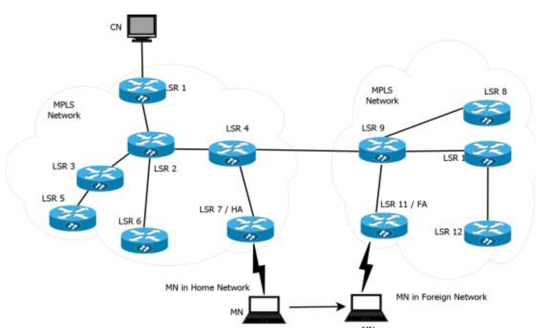

Figure 6. MN moves between two MPLS clouds without an IP network in between [49]

In another case, this protocol deals with HA and FA being the LER's of different MPLS domains. These can be directly connected or connected via an intermediate IP network. When the HA and FA LER's are LDP Border Gateway Protocol peers, they can exchange label information between them directly. Thus an LSP is created between the HA and FA and the signals and data is exchanged over this LSP. In case of an IP cloud in between two MPLS domains, an IP tunnel is needed to carry data from HA to the FA. This means that the LER in the FA to which HA directs communication should also be Mobile IP capable.

This evaluation works well when the whole domain in question is MPLS enabled. This method uses MPLS to switch packets and makes conventional IP in IP tunneling for the data forwarding process needless. Since label switching is faster than conventional IP forwarding, transmission delay and packet processing overhead is reduced. Also the core routers do not need to use extra memory to store routing tables as they can use the LFIB for forwarding packets on the LSP's. Label header is smaller than IP header, so traffic overhead is also reduced. However this scheme **does not incorporate route optimization** and as such the CN's have to communicate via HA and this HA can become a **single point of failure**. There is also **no packet recovery** scheme during handoff.

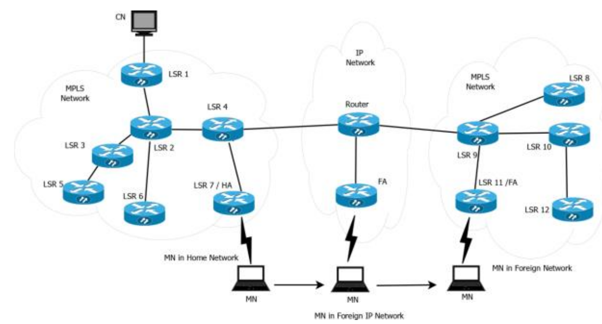

Figure 7. MN moves between two MPLS clouds with an IP network in between [49]

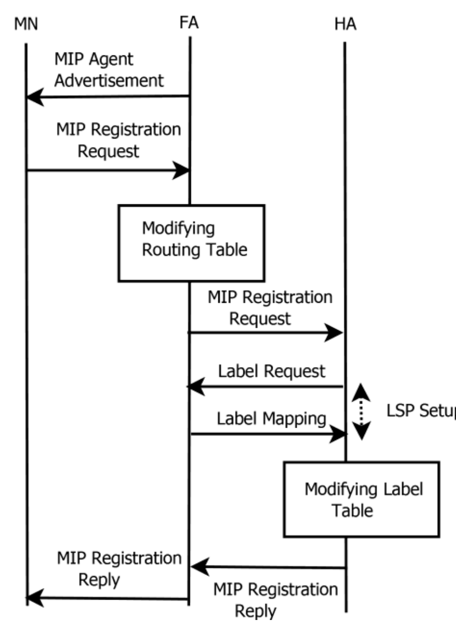

Figure 8. Registration Procedure for a MN on movement to a Foreign Network [49]

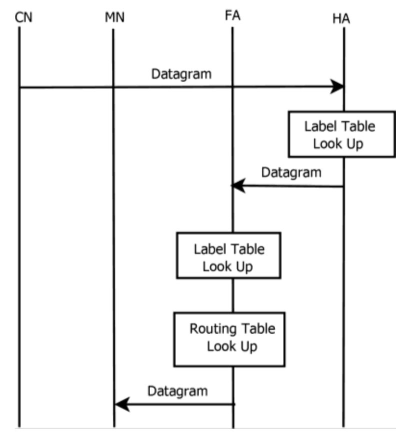

Figure 9. Datagram Delivery in the MPLS and Mobile IP Integration Scheme [49]

B. Mobility Label Based Network Support for Mobility using MPLS and Multi-Protocol Border Gateway Protocol (BGP)

This new mobility management protocol [51, 52] is a **C0-D-LSP** protocol and is based on MPLS architecture and new elements in MP-BGP. Mobile node registration and movement handling is achieved by Mobility Label Distribution at the network control plane and the optimal packet delivery by the network forwarding plane. Multi Protocol BGP is a set of extension to the BGPv4 [53].

In this protocol all nodes support MPLS and forwarding plane procedure. Edge MPLS nodes support Mobility Support Function (MSF). **There is no concept of Home Network and no Need to register at the Home Address. There is also no CoA as MN is always foreign to a network and always requires support.** MN's identify themselves dynamically to the MSF. MN must always register with the MSF and thus get associated with the Mobility Label. Only LER MPLS nodes need to implement MSF and not LSR nodes. The architecture for this Mobility Aware MPLS and Multi-Protocol BGP is shown in Fig. 10.

Distribution of Mobility Binding Information using MP-BGP can be achieved by constructing a flat or hierarchical MP-BGP peering topology amongst the participating LER nodes. Flat peering logical structure requires a full mesh of MP-BGP sessions. Whereas as Hierarchical peering structure can make use of BGP Route Reflectors in which some LER nodes are designated as the Route Reflectors(RR) and establish peering sessions between themselves and all other LER supporting MSF (RR Clients). BGP RRs capable of supporting MPLS Mobility are referred to as Mobility Route Reflectors. They need not support MSF but should relay and interpret MSF related MP_BGP messaging.

The Registration takes place as follows. The MN sends an ICMP Router Discover with a specific extension for Mobility Label Based Network (MLBN). The discovery is initiated by MN by sending a Router Solicitation Message with MLBN MSF Discovery Extension and TTL as 1. ICMP with MLBN Extension is the MSF Discover Message and carries information about the type of MN, whether it is MN Host or MN Router. MSF LER responds with ICMP Advertisement including MLBN specific extension known as the MSF Advertisement. It carries different information depending upon type of MN and Registration mode. MSF Discovery Messages are sent at an interval of one third of the Registration lifetime and MSF Advertisement should be replied in response to the MSF Discovery messages.

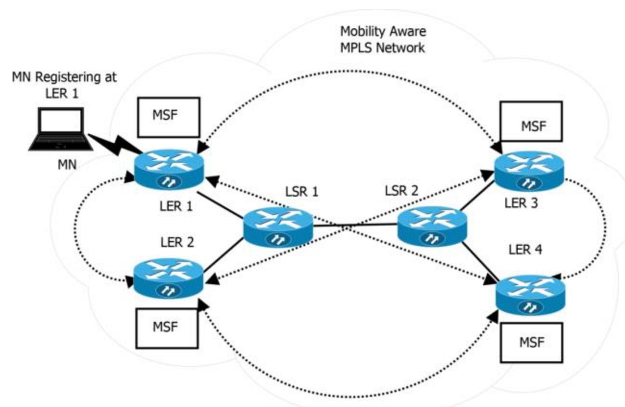

Figure 10. Mobility Aware MP-BGP. When MN registers, MSF of LER1 distributes Mobility Binding Updates to the rest of the LERs using MP-BGP [51]

There are three registration modes possible. Light Weight Registration, Full Registration and Group Registration. Lightweight registration is just a completion of MSF Discovery Process. The L flag is set in the MSF Advertisement message and MSF allocates Local Mobility Label and creates a Mobility Binding Structure immediately following the receipt of the MSF Discovery message from MN. In Full Registration, additional functions are performed as part of the registration process like Mobile Host authentication. The full registration is indicated using the R flag. In Group Registration, MPLS network is divided into groups or regions containing geographically close MSF enabled LER nodes. Each Group has unique ID (1-255). MN registers with one amongst the group LER and that LER forwards it to other LERs in the group using MP-BGP peering. Size of the region should be large enough to ensure a high probability that the range of movement of the MN will be covered by the service area of the group. It should not be so large that a large registration table size is shared among the group members.

Mobility Labels might be pre-allocated in group and have them ready before MN moves into the members serving area. Serving LER may indicate to MN that it is part of a group and should use a group virtual Link Layer address and Group Virtual IP address for further communication. MN after movement sends data packets to the group virtual Link layer address and virtual IP address. When a group member receives data from the MN, it forwards it to the destination and distributes new Mobility Binding to the network. The group registration is kept alive by MSF Discovery Messages. If there is No Update then the registration is removed and Mobility Binding withdrawn by MP-BGP Update. Group Registration Updates are sent periodically by the group members. Registration Information for multiple MNs may be aggregated in a single MP-BGP UPDATE message. MN registration Information may be explicitly withdrawn by the group member that was last to hear from the MN.

C. *An MPLS based architecture for scalable QoS and traffic engineering in converged multiservice mobile IP networks*

This paper [54] discusses a C0-D-LSP protocol. This protocol discusses the architecture of the MPLS mobile network core defining the roles of mobile hosts, their attachment base stations, access routers and intermediate switching nodes. It focuses on the procedures and protocols like registration, LSP establishment and LSP relocation for handover etc for classification, label distribution, encapsulation and resource reservation providing the necessary traffic engineering and QoS mechanisms. This architecture relates the radio interface and the mobile terminal in the traditional mobile packet network and the 2.5/3G communication systems. It basically discusses Mobile IP over MPLS in a converged multiservice network.

The Access Routers (ARs) can be SGSNs (Serving (GPRS) General Packet Radio Service Support Node) to provide packet data services in the GPRS/UMTS (Universal Mobile Telecommunication System) environment. These behave as LERs and provide switching, control and routing mechanisms. This is where the radio links on the user side terminate and the label paths from the network side end. The converged multiservice model is shown in Fig. 11. The intermediate backbone switching nodes provide the functionality of LSRs for the MPLS network. The AR manages the integration of the mobile node with the MPLS network. Each SGSN is attached to its Base Station over ATM or frame relay links and also to the corresponding GGSNs (Gateway GPRS Support Node) and service nodes over the MPLS transport backbone. GGSNs act as gateways to the internet. In the 3G model data packets move between the SGSN and the GGSN using IP tunnels through the GPRS Tunneling Protocol (GTP). In this proposed architecture, MPLS LSPs are set up using RSVP messages between the SGSNs and the GGSNs LERs are used for GTP tunneling. However this requires some slight modifications to the 3G network elements in the SGSN/GGSN, GTP-TCP/UDP-IP stack that can coexist with the conventional GTP stack.

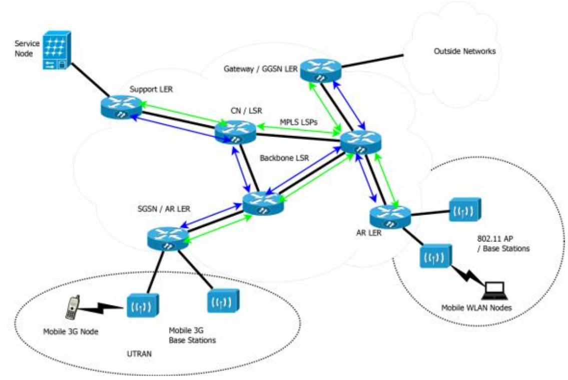

Figure 11. MPLS-based mobile data network architecture [54]

Traditional Mobile IP is used for host mobility in this proposal that needs to be supported on all ARs. The home agent (HA) and Foreign Agent (FA) can be located in the corresponding mobile access router (AR) LERs. In Mobile IP, packets meant for the MN are intercepted by the HA and encapsulated and tunneled to the current location of the MN via the FA. In this scenario, our HA and FA are LERs respectively name LER/HA and LER/FA. Packets destined for the MN are intercepted by the LER/HA and are encapsulated with a label header and tunneled to the current location of the MN via the LER/FA. The LSP that is set up between the HA and FA tunnels the packets with a relevant or defined Quality of Service (QoS). The IP-in-IP tunnels between the HA and the FA are merged into one or multiple LSP's in the MPLS network to provide better QoS. The packets arriving from the CN to the MN are tunneled via the HA. **This causes triangular routing problem as discussed earlier. To avoid that, a direct LSP can be established between the relevant AR and the CN. Fig.12 shows the LSP set up procedure for this protocol.**

When a MN discovers that it is in a foreign network, it acquires a temporary care of address from the foreign agent and sends a registration request to the home agent. The registration request is forwarded to the home agent located on one of the home network ARs using hop by hop routing. The home agent receives this registration request and reads the care of address of the MN and sends a reply to this care of address via the FA. The incoming data for the MN is still coming to the HA. HA sends a Label Request message to the FA with the care of address of the MN. The FA replies with a Label Mapping message and a path is set up as soon as this message arrives at the HA. **Then the HA starts relaying packets meant for the MN to its new location in the foreign network.** The registration procedure is repeated between the HA and the new FA every time a MN moves from one network to another.

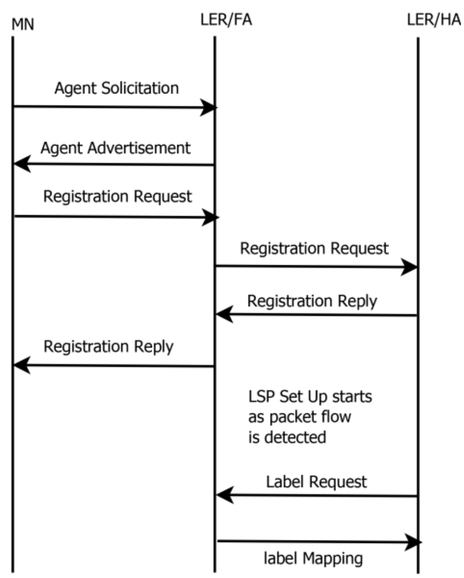

Figure 12. LSP set up for mobility management over MPLS [54]

D. GM-MPLS - Group-based Mobile MPLS for Mobility Management in Wired/Wireless Networks

It is a C0-D-LSP protocol. This protocol is based on a group concept [55]. A group of Access Routers is formed for a particular MN and this group is continually updated based on the latest location of the MN. As a result MN always moves within its group and handovers take place within the group only. The AR's in the group have all the necessary information about the handover making handover process easier and faster.

There is a Group Management Control server (GMC) to which the MN registers. And the MN sends updates to this GMC server when it moves. As it is a network based protocol, **there is no concept of Home Agent (HA).** MN is registered to a GMC server and moves within a group that is constituted by the server. The updates on changing the access point are sent to the GMC server. GMC assigns a unique IP address to the MN from a pool of IP addresses that is reserved for MNs. This IP address is known as the mobility-IP or the m-IP. This IP is used by the MN until the connection ends. The ARs around the MN form a group that is also managed by the GMC server. The information from all the ARs like location information, IP addresses etc is contained in the server. The architecture is shown in Fig. 13.

There are two types of ARs in this proposed network. One is the Core Access Router (CAR) to which the MN is connected and the others that surround the CAR are assigned to be the Assistant Access Routers (AAR) by the server using location information. Another network element is the Label Area Edge Router (LAER) that is a member of the group and is connected to the CN. Thus there is a group consisting of the MN, the CAR, the AARs and LAER connected to the CN and all elements of this group are provided with information about the MN by the GMC server. On movement of the MN, it moves within the group and connects to a new AR, which is one of the AARs of the group. This new AAR is converted into a CAR and this information is sent to the GMC by the AR. The MNs group location is then renewed by the server using location information. Thus whenever the MN moves it becomes part of a new group based on location information and this group is tracked by the GMC server.

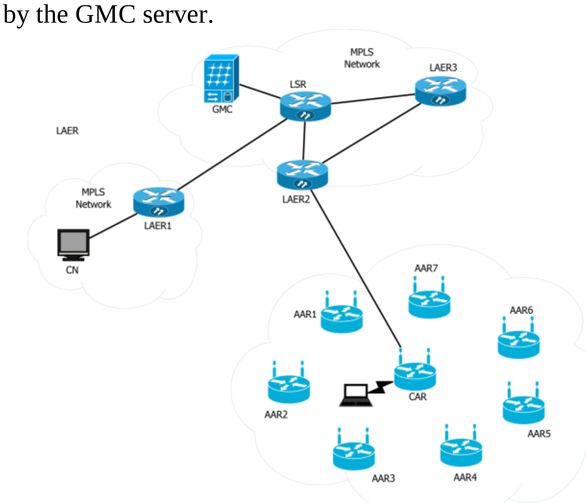

Figure 13. GM-MPLS Network Architecture [55]

Another modification proposed in this paper is the P-MPLS scheme that assigns a prefixed label to each AR and as a result the same label is used within the wireless network. The label for each AR is unique and an AR also forwards an advertised packet of Interior Gateway protocol (IGP) with its own label. Routing information about each other's labels is also retained.

The signaling procedure is shown in Fig. 14. MN selects the best AR via scanning and sends a MNAt (MN Attachment) message to the AR that contains the MN ID and information like MAC address etc. This AR sends a MNAReq (MN Authentication Request) message to the GMC server that contains the MN ID and the ARs IP Address. GMC replies with a MNCAAck (MN CAR

Authorization Acknowledgement) that contains authorization information for the AR and a list of neighboring ARs for the MN. On receipt of MNCAAck the sender AR scanned by the MN immediately becomes the CAR and sends AA (Authorization Acknowledgement) message to each of the neighboring ARs containing the MNs m-IP and the authorization information of the ARs for the MN. These neighboring ARs become the AARs. The CAR replies to the MN with an acknowledgement MNAtAck (MN Attachment Acknowledgement) that contains the authentication, MN ID and m-IP information. MN sets its IP address to m-IP and starts transmitting data. The MN sends data to the CN and when the CN replies it passes through the LAER of the CN. This LAER (LAER 1 in Fig 13) sends a Query CAR IP Address (QCI) message to the GMC server containing the MNs m-IP address asking to find a route to the MN. The GMC server receives this message and locates the group of the MN through its m-IP and replies with a QCIRp (Query CAR IP address reply) to LAER1 that contains the MNs m-IP address and the CARs IP address. The LAER adds the P-MPLS header instead of MPLS and sends it to CAR that passes it on to the MN.

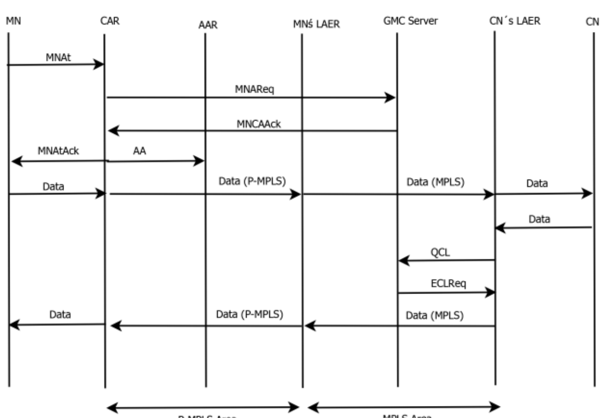

Figure 14. Mobile Node Attachment [55]

In case of a handover, the new AR which is an AAR to which the MN moves becomes the new CAR. The New CAR notification (NCN) is send from the new CAR to the previous CAR containing the MN's m-IP address and the new CAR's IP address. It also informs the GMC server through a MN Handover Notification (MNHN) message. The GMC server locates new AARs around the MN and upgrades the group. The GMC server sends a CAR AAR Appointment (CAA) message to the new CAR containing the list of AARs and the designation of the new CAR. GMC server also sends a New CAR IP address Notification (NCIN) to the LAER1 connected to the CN that contains the MN's m-IP and the new CAR's IP address. **Old CAR forwards packets to new CAR to minimize packet loss and delay.** This process if depicted in Figure 15.

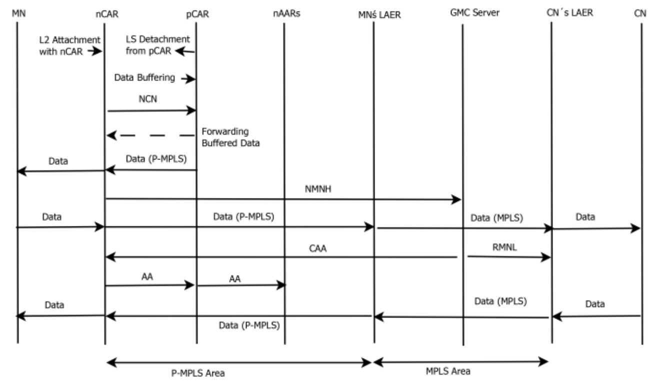

Figure 15. Mobile Node Handover [55]

5. Comparison of Mobility Protocols in MPLS Domain (Integrated Protocols)

Section 4 discussed in detail the different protocols proposed for integration of Mobility and MPLS. None of these protocols introduce a hierarchy in the architecture. As such the updates have to travel all the way to the HA if there is one.

In most of these protocols the anchor point can be a point of failure except for those where a distributed hierarchy has been imposed or those that have backup mechanisms. The C0 category of protocols has no hierarchy and as such no anchor point. The mapping table are centralized and as such HA can be a point of failure in case of Protocol A [49] and Protocol C [54], whereas the MSF can be a point of failure affecting only those MNs that are registered at that particular MSF in case of Protocol B [51,52]. GMC server holds all details in case of Protocol D and can be a point of failure. However this problem can be resolved in Protocol B by using group registration where other group members take care of the MN in case of failure of the particular MSF MN is communicating with. However in all other modes of registration MSF serves as a single point of failure for all MNs registered under it. Also since HA is a single point of failure, it effects the communication badly as all updates are communicated up to the HA in case of Protocol A and Protocol C. Protocol B the updates go all the way up to the MSF. However in case of Protocol D the updates go all the way up to the GMC server.

Route Optimization is presented as a solution to triangular routing only in Protocol C. There is no consideration for security in any of these protocols which is a major drawback. There is no LSP time accounting in the performance analysis and the improvements claimed in all of these protocols discussed. The LSPs are dynamically created in all the four protocols and hence will take some time till messages for LSP creation are exchanged. There is no packet recovery scheme during handoff proposed in any of these protocols. Once the new FA / nCAR is known, only then the HA / pCAR starts forwarding packets to the new locations. Protocol D is the only protocol that uses distributed mapping tables. In rest of the three protocols the mapping tables are centralized.

Experimental evaluation of Protocol A has been carried out that shows the HA processing delay in the MPLS-Mobile IP integration scheme is constant and lower compared to processing delays in Mobile IP and Mobile IP over MPLS. The low processing delay is due to the fact that in the integration scheme of Mobile IP and MPLS, the entire HA data forwarding process is executed in the MPLS layer.

Protocol	**Simulations**	**Improvements Claimed**	**Protocols used for comparison during simulations**
A	Yes	• Lower Processing delay at HA	Mobile IP, Mobile IP over MPLS
B	No	• Eliminates triangular routing • Improved delay and jitter	N/A
C	No	• Making Mobile IP in a MPLS domain viable in combined wireless and wired networks of next generation.	N/A
D	No	• Less Handover latency then the counterparts it is compared with • Lower Power Consumption	Protocol A, Integration of Mobile IP and MPLS

TABLE I. SIMULATION STUDIES OF C0-D-LSP PROTOCOLS

Also since no IP routing table is searched and only labels are looked up, the search becomes faster improving the performance of HA. This is true for the roundtrip delay between the MN and the CN. The delay is constant in the integration scheme as no IP tables are searched and only labels are matched and searched in the Label Table [49]. Mathematical results in Protocol B [51,52] show that triangular routing creates increased delay and jitter along with increased loss probability. This probability grows linearly with the maximum network diameter. Thus this protocol eliminates this increased delay and jitter by eliminating triangular routing by way of eliminating the HA from the protocol scene. Protocol C [54] focuses on elaborating the use of MPLS technology to address all the requirements of combined wireless and wired networks of the next generation.

Protocol D [55] does a mathematical analysis of Protocol A and several other protocols [56, 57] and shows that this particular protocol achieves less handover latency mathematically with lower power consumption. Table I gives details about simulations that have been carried out on C0-D-LSP protocols and the improvements claimed by the same. It also gives a list of protocols to which a particular protocol was compared during simulation or analytical studies. Table II gives a detailed comparison on the protocols discussed in this paper along different parameters.

6. CONCLUSION

Mobile IP is a simple and scalable global mobility solution. It may however result in excessive signaling traffic and long signaling delay. Handover in packet networks is administratively costly due to the number of signaling messages involved and the change of state in participating nodes. It has a large negative impact on the Quality of Service (QoS) of different applications, especially multimedia applications running on the MN. Handover inevitably leads to packet loss and/or packet delay. Quality of Service needs to be maintained in a communications networks to cater to the need of diverse applications. In a mobile environment, the wireless topology is dynamic so it becomes even more difficult to provide QoS. QoS guarantees can also be limited by network resources, unpredictable effective bandwidth and high error rate. The signaling involved in Mobile IP also requires some kind of QoS guarantee.

The protocols discussed in this paper generally state by way of analysis and simulations that MPLS improves the QoS of services in the Mobility framework. The way packet recovery and handoff are taken care of differs in each of these protocols. If we look at the proposed dates of these protocols, the most recent one is from 2010. The fact that there is no standard for a mobility protocol in the MPLS domain may be due to the fact that the protocols that include hierarchy points claim improvement in performance compared to these no hierarchy protocols. Most of these methods help in reducing packet drop and delay during handoff. These four protocols suggested for simple mobility scenarios in an integrated framework with MPLS haven't been compared exhaustively with other approaches to give a definite comparative performance analysis.

Since LSP creation time is not accounted for, we can consider establishment of LSPs prior to MNs actual movement to a new access point. This will help in faster packet forwarding and less drop and delay during handover. We suggest setting up C0-S-LSP based protocols. Such protocols will need a mesh of static LSPs set up so that as soon a movement is detected the communication can proceed using the previously created LSPs. Also static LSPs with required QoS guarantees can be used for control signaling during movement and handover.

This paper aims at providing a platform for the comparative study of basic Mobility Protocols in the MPLS domain. A lot of years have been spent in the study of this integration, however there is no standard defined for the integration of mobility with MPLS. Our future work aims at studying and resolving Mobility issues in MPLS framework, creating a standard framework for this problem and setting up simulated and experimental test bed environments for the same for both dynamic and static LSP creation.

TABLE II. DETAILED COMPARISON OF C0-D-LSP MOBILITY PROTOCOLS IN MPLS DOMAIN

Parameter	**Comparison of C0-D-LSP Protocols**			
	A	**B**	**C**	**D**
Proposed Date	2001	2008	2004	2010
Category	C0-D-LSP	C0-D-LSP	C0-D-LSP	C0-D-LSP
Anchor Point	No	No	No	No
Hierarchy / Hierarchy Type	NA/ No Hierarchy	Fixed / No Hierarchy	Fixed / No Hierarchy	Fixed/ No Hierarchy. Group Management Control (GMC) Server takes place of the HA.
Mapping Tables	Centralized	Centralized	Centralized	Distributed
MPLS Paths (LSPs)	Dynamically created	Dynamically created	Dynamically created	Dynamically created
Software Deployment	Some Nodes	Some Nodes	All Nodes	Some Nodes
Reliability Mechanism/ Effect of failure of new components	HA can be single point of failure / Affects all MNs	In Group Registration, failure of a MSF can be taken care of by other Group Members. Rest all registration cases, failure can affect all MNs registered at the failed MSFs.	HA can be single point of failure / Affects all MNs	CAR can be a single point of failure; a new CAR needs to be registered in place of the failed CAR by making one of the AARs as a CAR. GMC server can also be a single point of failure as all updates are sent to it.
Routing Information Update	Communicated all the way up to HA	Communicated always to the MSF as there is no HA and no CoA. MN is always foreign to a network.	Communicated all the way up to HA	The routing information goes up to the GMC Server only.
Security Consideration	No Security Associations	No Security Associations	No Security Associations	No Security Associations
Route Optimization	No	Not Required as there is no HA.	Route Optimization proposed to avoid triangular routing	No
LSP Creation Time Accounted	No	No	No	No
Packet Recovery during Handoff	No	No	No	No

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