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Mobility Support Using MPLS and MP-BGP Signaling
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Abstract

This document describes a new approach to handling user mobility at the network layer in the context of Multiprotocol Label Switched Networks (MPLS). This approach does not rely on the existing IP mobility management protocols such as Mobile IP, and is instead based on the combination of Multiprotocol BGP (MP-BGP) and MPLS. This document proposes to introduce new protocol elements to MP-BGP to achieve Mobility Label distribution at the network control plane and the optimal packet delivery to the mobile node by the network forwarding plane using MPLS.

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1. Requirements notation

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119].

2. Introduction

The requirements to support user mobility range from the physical aspects of wireless access networks to the logical aspects of the network control and forwarding plane operation. In the context of this work the main requirement for the mobility support architecture is to decouple the network layer addressing and the associated logical network topology from the ability of the network to optimally deliver the packets to the mobile user. The optimal traffic delivery is interpreted as the delivery of packets to the new node location following the best (often the shortest in terms of the routing protocol metrics) path between the mobile node and the correspondent node.

The issue is that this optimal path cannot be used by the network to communicate with the mobile user based on the IP address and routing protocols. This is due to the inability of a conventional IP network to react to the mobile user movements by adjusting the routing and forwarding information in the network nodes (routers) to reflect the new location of the mobile user with respect to the IP topology.

Thus a method is required to identify the logical location of the

user in the network topology in such a manner that the traffic delivery to the user at a new location follows the optimal path in the context of the routing protocol used in the network. A natural fit to provide this method is the MPLS architecture. MPLS does not perform the forwarding of IP traffic based on the IP addresses and uses labels instead. The important point, however, is that MPLS by itself cannot solve the mobility problem as ultimately the traffic must originate from the source IP address and terminate at the destination IP address (which would still be the old home address). In order to use MPLS to forward the traffic to the new user location along the optimal path the labels must be assigned specifically to the mobile node at the new location and distributed to the network nodes. These special labels are referred to as Mobility Labels and are associated (bound) to the mobile node IP address.

This document proposes to use the Mobility Label as a second label in the MPLS label stack. The first label in the stack is the one that identifies the LSP (Label Switched Path) between the two Label Edge Routers and the second label in the stack can be used to identify the IP address of the mobile node and deliver the traffic to it. The assignment and the distribution of the first label in the stack is handled by the conventional MPLS architecture elements and protocols such as LDP (Label Distribution Protocol [RFC5036]). It is proposed that the assignment and distribution of the second label - the Mobility Label - be based on the existing framework of MP-BGP (Multiprotocol Border Gateway Protocol [RFC4760]). The mobility

management scheme based on MP-BGP at the control plane level and MPLS at the forwarding plane level represents a system in which both the control and forwarding processes are integrated to ensure the optimal traffic delivery that is not fully achieved in the existing network layer mobility management approaches.

2.1. Architecture Requirements

Integrated control and forwarding plane - the network update process by the Control Plane must result in the optimal traffic delivery by the Forwarding Plane.

Robust and flexible protocol framework - the Mobility Management Control Plane Protocol and the associated functions must be placed at the intelligent network edges and allow to avoid the need to involve

all nodes in the network (including the core nodes) in the network update process.

The Mobility Management Control Plane Protocol must allow for flexible and seamless introduction of new features and for support for Mobile Hosts and Mobile Routers.

Evolutionary architecture and implementation approach - the Mobility Management scheme should be based as much as possible on the existing network architectures and protocol framework. Only minimal changes to the operation of mobile nodes should be expected.

Efficient network responsiveness - the impact on the mobile application due to the service disruption caused by the mobile node's movements and the associated network update and delivery processes should be reasonably minimal.

Acceptable network scalability and performance - the new requirements for Mobility Management functions should not result in decreased network scalability and performance.

2.2. Existing Solutions

2.2.1. Mobile IP

Mobile IP [RFC3344] was developed to provide macro mobility management for the mobile hosts using IP version 4 (IPv4). It was subsequently extended to support IPv6. Due to its complete reliance on the logical network topology determined by the distribution of the IP subnets Mobile IP solves the mobility problem by using the following two major techniques: mobile node registration and traffic tunneling. The main entities in Mobile IP are the Mobile Node (MN) itself, the Correspondent Node (CN) - the host that is communicating

with the MN, the Home Agent (HA) - this is the router that owns the original home subnet to which the MN is assigned, the Foreign Agent (FA) - this is the router that owns the subnet to which the MN has moved (the foreign subnet), and finally the Care-of-Address (CoA) - the IP address that belongs to the FA and that is used to represent the MN while it is located in the foreign subnet. The basic mobility handling by Mobile IP results in a sub-optimal forwarding path in the direction of traffic from the CN to the new location of the MN. This

is because the traffic is first sent to the HA and then tunneled to the FA/MN. Although the route optimization scheme exists where the mobility bindings are sent by the HA directly to the CN with the CoA of the MN for direct traffic forwarding, it requires the CN to i) implement the binding processing and ii) use IP tunneling to send packets to the MN.

2.2.2. Mobile IPv6/HMIP/NEMO

Mobile IPv6 [RFC3775] provides macro-mobility support for IPv6. It improves Mobile IPv4 by eliminating the need for the FA, use of the IPv6 neighbor discovery instead of ARP, use of the IPv6 Link Local (LLOC) address instead of CoA. It also provides basic support for mobile routers via NEMO (Network Mobility) [RFC3963] and enables hierarchical mobility management (HMIP). However MIPv6 does not provide for the integration of the control and forwarding planes and still requires the use of the HA which results in sub-optimal traffic routing. The routing optimization based on the direct binding exchange between the CN and the MN resolves the sub-optimal routing but introduces the requirement for the return routability procedure and the use of a special IPv6 routing header (similar in function to IPv4 tunneling) directly on the CN and MN. In addition, Hierarchical MIPv6 requires registrations to multiple entities (MAP - Mobility Anchor Point, HA) and supports IPv6 only.

2.2.3. MPLS Micro-Mobility

MPLS Micro-Mobility [MM-MPLS] integrates MIP and MPLS traffic forwarding to provide a solution in which MIP is used for macro mobility management and MPLS is used to support micro-mobility. Micro-mobility reflects the mobile host movements that can be handled without the re-registration with the MIP HA. To achieve this, the MN registers with a hierarchical set of Label Edge Mobility Agents (LEMA). The LEMA at the top of the hierarchical set is registered with the MIP HA as the FA for the MN. The MIP HA tunnels all packets from the CN to the MN to the top level LEMA as in regular MIP. The LEMA then sends packets on the MPLS LSP to the network location of the MN using MPLS labels. As the MN moves to new locations, the hand-off procedures are invoked that start with the MN requesting the hand-off and the LEMA(s) performing the set of signaling steps

resulting in the redirection of the MPLS LSP from the old serving

LEMA to the new serving LEMA. If the MN movement results in a condition in which the old top level LEMA can no longer serve the MN, the MN re-registers with the new hierarchical set of LEMA(s) and the top level LEMA is registered as the FA with the Mobile IP HA. Although MPLS Micro-Mobility makes use of the MPLS traffic forwarding it still is an extension of Mobile IP and therefore does not result in the elimination of triangular routing.

2.3. Protocol Overview

MP-BGP and its ability to carry the overlay MPLS label information [RFC3107] is proposed for the mobility management. Namely when the mobile hosts or routers change their network locations they can register with the edge nodes of the MPLS network (LER) and at that time assigned Mobility Labels. The Mobility Labels in turn are associated with the IP addresses of mobile hosts or routers thus forming the Mobility Bindings. These Mobility Bindings are then encoded in the Multiprotocol BGP Address Family messaging structure and are distributed among the rest of the MPLS network LER nodes using the MP-BGP protocol. The Mobility Binding provides an explicit association between the overlay MPLS label and a single or multiple individual IP addresses of mobile hosts or IP address ranges (prefixes) that are served by mobile routers. The MP-BGP NEXT_HOP attribute associated with the BGP UPDATE message [RFC4271] used to carry the Mobility Binding provides an implicit association between the overlay Mobility Label and the infrastructure MPLS label that is in turn associated with the LSP to reach the LER that sourced the Mobility Binding. The MPLS LER capability to provide mobility support can be referred to as the Mobility Support Function (MSF) (see Section 3). The MSF includes: a) Mobile Host/Router Discovery, Registration and Status Procedures, b) Mobility Label Association and de-Association Procedures, c) Integration with MP- BGP and d) Mobile Application Priority Indication and Recognition.

2.4. Architecture Overview

This mobility architecture is proposed in the context of MPLS networks. As such it is a requirement of this architecture that all nodes in the network support MPLS control and forwarding plane procedures and in particular it is a further requirement that the edge nodes of the MPLS network implement the Mobility Support Function described in Section 3. This architecture does not rely on Mobile IP for macro-mobility support. In other words there is no concept of a home network that the mobile node belongs to and therefore there is no requirement to register with the Home Agent. It is the assumption of this architecture that a mobile host or router is always identified as being in the foreign network thus

always requiring mobility support. In addition, there is no requirement for the CoA.

The simplest way to implement this assumption is to administratively allocate a range of IP addresses for all mobile hosts and routers of an organization and to implement in the MSF the configurable ability to recognize the pre-allocated mobility address ranges. As such, a service provider would assign IP addresses to all of their mobile subscribers from a pre-allocated address range. This range does not have to be flat and can be in turn subnetted. The IPv4 or IPv6 mobility address pre-allocation scheme allows utilization of this mobility management architecture as a separate overlay MPLS service. The only requirement related to the LER MSF pre-configuration is the static identification of the overall mobility address range in the scope of the LER-wide MSF.

Regardless of the static identification of the overall address range allocated to the mobile devices, the individual mobile nodes identify themselves dynamically to the MSF. This capability is especially useful when this architecture is applied to provide mobility support to both mobile hosts and routers. Specifically, during the registration procedure a mobile node could identify itself as either a mobile host or a mobile router. If it is a mobile router the MSF is expected to establish a routing protocol adjacency with the mobile router as well as to utilize an extended Mobility Binding structure in which multiple IP prefixes served by the mobile router may be sent in a single Mobility Binding optionally associated with a single Mobility Label.

The mobile node must always register with the serving MSF and thus be associated with the Mobility Label. This requirement will support the ability to implement specific mobility features such as the application sensitivity recognition via the processing prioritization scheme.

2.4.1. Node Roles

From the network architecture perspective the proposed mobility solution follows the classical MPLS network architecture with two major node classes: LSR and LER also known as P and PE respectively. The LER (PE) nodes reside at the edges of the network and perform the corresponding edge functions such as the customer interface management, label stack imposition/deposition and label information distribution for both the infrastructure MPLS transport and the overlay MPLS services. In addition to these edge functions we introduce the Mobility Support Function that integrates directly with

the LER control plane responsible for the overlay MPLS services. The role of the LSR (P) nodes remains exactly the same as in the

classical MPLS architecture - participate in the infrastructure label distribution process and switch traffic based on the MPLS labels (outer labels) between the LER nodes. The LSR (P) nodes need not implement the MSF. Other aspects of the architecture include the access interface, the interface to other networks and the network hierarchy.

2.4.2. Attachment Options

The two major access interface options considered here are: Direct Attachment of the LER node to the Radio Access Network and Indirect Attachment of the LER node to the Radio Access Network. The terms direct and indirect are not used to indicate that the LER node has or does not have the integrated wireless radio interface. The term direct is used to reflect that a direct layer 2 path exists between the mobile node and the MSF enabled LER either via the integrated radio interface or via the wireline grooming network to the wireline side of the Radio Access Network Base Stations. The term Indirect is used to reflect that there is no direct layer 2 path between the Radio Access Network and the MSF enabled LER node. The Indirect Attachment means that there is another layer 3 device (such as the Customer Edge - CE router in the MPLS Architecture terminology) between the MSF enabled LER and the Radio Access Network. The CE router in turn connects to the Radio Network via Direct Attachment (in the sense of the term defined here) by using the integrated wireless interface or by using the wireline grooming network. The reason for establishing these two access options relates to the type of service environments that the proposed architecture will most likely be applicable to.

The Direct Attachment option is most suitable for the use case where mobility is offered as an overlay service in a service provider's mobility enabled MPLS network. In this case the Mobility Support Function may be viewed as one of the functions in the MPLS for Mobile Networks Architecture. An example of such a use case is the Wireless Telephone service with data or multimedia capabilities (such as EV-DO) in which mobility management is handled by the MSF enabled MPLS network. The mobile nodes may be the wireless telephone sets with IPv4 or IPv6 stacks and the corresponding mobility addresses

assigned by the service provider, communicating via the Radio Access Network Base Stations to the MSF enabled LER nodes. A simple registration procedure triggers the assignment of the overlay Mobility Labels and the subsequent mobility management by MP-BGP.

The Indirect Attachment option is most suitable when the mobility service is integrated with other overlay MPLS services such as Layer 3 VPN [RFC4364]. This use case is applicable for the enterprise networking where the mobile nodes can be the wireless workstations or

wireless IP telephones, and the enterprise sites connecting to the service provider's mobility enabled MPLS network via the CE routers. The simplest way to accommodate the presence of the CE routers is to implement the MSF function on the CE router and use the MP-BGP and Mobility Labels between the CE router and the LER (PE) router in the context of the customer specific MPLS VPN. This also implies the use of MPLS and MP-BGP between the CE and PE routers for the delivery of traffic to the mobile nodes behind the CE router, but since there will be no LSR (P) routers between the MSF enabled CE and the PE router there is actually no need for the outer stack MPLS labels and therefore no need to integrate the CE routers with the service provider's MPLS infrastructure. The MPLS LER (PE) router will need to accept the Mobility Binding information via the use of MP-BGP from the CE router within the MPLS VPN and then propagate that information into the MPLS network using the L3 VPN MPLS overlay service also based on MP-BGP.

The direct attachment option is shown in Fig.1, where a MSF enabled LER node interfaces with multiple Radio Cells or Cell Clusters via the L2 network such as Ethernet. Each Radio Cell Cluster is assigned into a L2 Virtual LAN and associated with a L3 subnet that is terminated at a logical interface of the LER node. The logical interfaces are controlled by the MSF and the associated set of Radio Cells or Clusters forms a Mobility Region.

In Fig. 2 a similar arrangement is illustrated but in this case there is no direct L2 path between the Radio Access Network and the MPLS edge. A CE router provides the MSF and communicates the Mobility Binding information by means of MP-BGP to the MPLS LER (PE) router.

```
                            +-----+
                            |MSF ++------------+     +-------------+
               Radio Cell   +----++            |     |             |
                  ,-----.        |   LER      ........MPLS Network
                 /       \       |             |     |             |
                /  ((++)) \      +--+-+-++-+-++      +-------------+
               (     ||    )   L3 Logical Interfaces
           ,----+.   +`-._/       / / / / / /
          /       \      /`-. +--+-+-+-+-++
         /  ((++))`+----'    `+._ / /  /|  /|     .-----,
        (     ||   ,-----. ___|___ /  / / `-.    /       \
         \    ++--'''''''''   |   /  | `-.  |`. / ((++))  \
          \      // ((++)) \  |.-'   `.   `-.  `-.  ||     )
           `----('    ||   .-'+--------+----+`-.\ `-.+   .+----,
                 \    +_.-'/   L2 Network       `+.     /       \
                  \       /               \       ``-.-+'((++))  \
                   `-----'                 `.    .----`-.  ||     )
                Base Station                 \  /      \\`-.+    /
                                              `. ((++)) \\      /
                                              ( \  ||    `)----'
                                               \ `.++    /
                                                \       /
                                                 `-----'
                                                  Base Station
```

Direct Attachment Option

Figure 1


```
                            +-----+
                            |MSF ++-----------+        +-----------+
               Radio Cell   +----++           | MP-BGP+|           |
                  ,-----.        |   CE       ..........  MPLS LER |
                 /       \       |            |Mobility|           |
                /  ((++)) \      +--+-+-++-+-++        +-----------+
               (     ||    )   L3 Logical Interfaces
           ,----+.   +`-._/       / / / / / /
          /       \      /`-. +--+-+-+-+-+-++
         /  ((++))`+----'    `+._ / /  /|  /|     .-----,
        (     ||   ,-----. ___|___ /  / /  `-.   /       \
         \    ++--'''''''''   |   /  | `-.  |`. / ((++))  \
          \      // ((++)) \  |.-'   `.   `-.  `-.  ||     )
           `----('    ||   .-'+--------+----+`-.\ `-.+   .+----,
                 \    +_.-'/   L2 Network       `+.     /       \
                  \       /               \       ``-.-+'((++))  \
                   `-----'                 `.    .----`-.  ||     )
                Base Station                 \  /      \\`-.+    /
```

```
                                            `. ((++)) \\       /
                                            ( \  ||    `)----'
                                             \ `.++     /
                                              \        /
                                               `------'
                                              Base Station
```

Indirect Attachment Option

Figure 2

2.4.3. Network Hierarchy

The distribution of the Mobility Binding information using MP-BGP may be achieved by constructing a flat or hierarchical MP-BGP peering topology among the participating LER nodes. The flat peering logical structure requires a full mesh of MP-BGP sessions and the hierarchical peering structure can make use of the BGP Route Reflectors in which some LER nodes are designated as the Route Reflectors and establish peering sessions between themselves and all other LER supporting MSF (Route-Reflector-Clients). The BGP Route Reflectors capable of supporting MPLS Mobility are referred to as Mobility Route Reflectors. It is important to note that the Mobility Route Reflectors need not support the MSF but must be able to interpret and relay the MSF related MP-BGP messaging.

2.4.4. Interface to Other Networks

The interface to other networks depends on how the mobility is to be managed between the interconnecting networks. If all mobility

functions are to be managed by a service provider's network (given that the network has sufficient coverage) then the interface to other networks can be as simple as the peering gateway node that connects the service provider's MPLS network to the rest of the world. In this case there is no need to extend the MPLS processing over this interface, and since by construction all mobility IP addresses belong to the IP address space of the service provider, the general peering arrangement to other networks where the IP address range of the service provider is advertised out to the Internet will enable the communication between the mobile nodes and the outside destinations. In case of the mobile node roaming, this may be supported between the

service provider networks that both implement the customer facing Mobility Support Function and the Network-to-Network Interface (NNI) that employs the use of MPLS label exchange (including the Mobility Labels).

3. Mobility Support Function

This section describes the proposed set of functional elements of the MPLS LER node capable of providing mobility management services.

This document refers to these functional elements as a Mobility Support Function (MSF).

3.1. Mobile Node Discovery, Registration and Status

3.1.1. Discovery Process - IPv4

As in [RFC3344] the discovery of the MSF by the mobile nodes is based on the ICMP Router Discovery [RFC1256] with specific extensions for Mobility Label Based Network (MLBN). The format of the extensions used in this proposal also follows the [RFC3344] section 1.9.

The discovery process should be initiated by a mobile host or router by sending the ICMP Router Solicitation message with MLBN MSF Discovery Extension and the TTL set to 1. This ICMP message along with the MLBN Extension is referred to as the MSF Discovery message. The MSF Discovery message should carry the information about the type of the mobile node: Mobile Host or Mobile Router.

Upon receipt of the MSF Discovery message the MSF LER must respond with the ICMP Router Advertisement including the MLBN specific Extension. This message is referred to as the MSF Advertisement. The MSF Advertisement will carry different information depending on the type of the mobile node and the registration mode.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Code      |          Checksum             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Reserved                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            MSF Discovery Extension TLV (variable)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

ICMP Router Solicitation with MSF Discovery Extension

Figure 3

Link Layer Fields: Destination Address - This should be the multicast or broadcast Link Layer Address.

IP Fields: Source Address - IP Address of the Mobile Host or IP address of the interface of the Mobile Router from which this message is sent.

Destination Address - This is the all-routers multicast address 224.0.0.2 or the limited broadcast address 255.255.255.255.

TTL - TTL should be set to 1.

ICMP Fields: Type = 10 Router Solicitation.

Code = 1 MLBN MSF Discovery Extension included.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Code      |           Checksum            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Num Addrs   |Addr Entry Size|           Lifetime            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Router Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Preference Level                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    MSF Advertisement Extension (variable)                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

ICMP Router Advertisement with MSF Advertisement Extension

Figure 4

Link Layer Fields: Destination Address - This should be the source address used to deliver the MSF Discovery message from the mobile node.

IP Fields: Source Address - IP Address of the MSF.

Destination Address - This is the unicast IP address used in the IP header of the MSF Discovery message from the mobile node.

TTL - TTL should be set to 1.

ICMP Fields: Type = 9 Router Advertisement.

Code = 1 MLBN MSF Advertisement Extension included.

Please refer to [RFC1256] for the specification of the remaining fields in both of the above messages.

3.1.1.1. MSF Discovery by Mobile Hosts - IPv4

Mobile hosts should initiate the MSF Discovery process by sending the MSF Discovery message. The MSF Discovery Extension format for Mobile Hosts is shown below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |H|Pri. |L|ASTI | Region_ID     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Mobile Host IPv4 Source Address                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Correlation ID                                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Mobile Host MSF Discovery Extension for IPv4

Figure 5

Type - 0 = MSF Discovery

Length - Length of the message in octets.

H - Mobile Node Type Indication. 0 = Mobile Host.

Pri. - A 3-bit Priority Code (0-7).

L - Lightweight Registration Requested (1).

ASTI - Application Service Type Indication. This 3-bit field may

be used to indicate to the MSF what type of service is to be used by the mobile host. For example, "Internet Access Only" or Full Mobile-to-Mobile Routing". This indication can then be mapped to the Network Update Mode Code used in the Mobility Binding structure.

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

Correlation ID - a number used to keep track of the Lightweight Registration message pairs - MSF Discovery/MSF Advertisement.

3.1.1.2. MSF Discovery by Mobile Routers - IPv4

Mobile routers should initiate the MSF Discovery process by sending the MSF Discovery message. The MSF Discovery Extension format for Mobile Routers is shown below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Length    |R|Pri. |L|Res. | Region_ID     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Mobile IPv4 Router-ID                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Mobile Router MSF Discovery Extension

Figure 6

Type - 0 = MSF Discovery

Length - Length of the message in octets.

R - Mobile Node Type Indication. 1 = Mobile Router.

Pri. - A 3-bit Priority Code (0-7).

L - Always set to 0 in the MSF Discovery sent by a mobile router.

Res. - Reserved.

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

3.1.1.3. MSF Advertisement - IPv4

After receiving the MSF Discovery message from a mobile host or router the MSF should reply with the MSF Advertisement message using extension format shown below.


```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |        Sequence Number        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Registration Lifetime      |L|R|G|Reserved | Group ID      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               MSF IP Address                                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|        MSF Virtual Link Layer Address (first 32 bits)         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Last 16 bits                   | Reserved      | Region_ID     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Correlation ID                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

MSF Advertisement Extension

Figure 7

Type - 1 = MSF Advertisement

Length - Length of the message in octets.

Sequence Number - The sequence number of the MSF Advertisement message sent since the MSF is operational.

Registration Lifetime - the time in seconds until the registration entry in the MSF database expires.

L - Lightweight Registration Confirmed (1).

R - Full Registration Required (1).

G - Group Registration Supported (1).

Group ID - Unique Registration Group Number. Should be zero if G = 0

MSF IP Address - Virtual IP Address of the MSF (may be different from any particular MSF LER interface IP address

MSF Virtual Link Layer Address - a MAC address shared and recognized by all MPLS LER interfaces participating in the MSF. This address may specifically be used to support Local Micro-Mobility (see Section 4.3.1).

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

Correlation ID - a number used to keep track of the registration requests and the corresponding reply message pairs.

The MSF Advertisement should be sent to the unicast link layer address and the unicast IP address of the mobile host or router that were used in the MSF Discovery link layer header and the MSF Discovery Extension payload respectively.

Upon receipt of the MSF Advertisement mobile hosts should continue to send the MSF Discovery messages with the interval of 1/3 of the specified Registration Lifetime. The MSF should send the MSF Advertisements in response to the periodic MSF Discovery messages from the mobile hosts using the corresponding Correlation IDs. If a mobile host does not get responses to three MSF Discovery messages (serving as the keepalives) the mobile host should initiate a new MSF

Discovery process using a new Correlation ID.

If the L flag in the MSF Advertisement is set, and the R flag is not, indicating the Lightweight Registration mode (see Section 3.1.3.1), the mobile hosts may start sending datagrams to their IP destinations using the link layer address of the MSF. The L and R flags are mutually exclusive and cannot be set at the same time.

If the R flag is set in the MSF Advertisement, indicating that explicit registration is required, mobile hosts should transition to the Full Registration mode (see Section 3.1.3.1.2).

The R flag must always be set in the MSF Advertisement if it is in reply to the MSF Discovery sent by a mobile router. Upon receipt of the MSF Advertisement a mobile router must transition to the Routing Adjacency Establishment mode (see Section 3.1.3.2).

3.1.2. Discovery Process - IPv6

The MSF discovery process for IPv6 is identical to the discovery process for IPv4 with the exception of the use of IPv6 specific Router Solicitation and Advertisement messages based on ICMPv6 [RFC4443]. These messages are specified in [RFC4861]. As in the IPv4 case the Router Solicitation and Advertisement messages carry the MLBN extensions and are termed the MSF Discovery and the MSF Advertisement respectively.


```
    0                   1                   2                   3
    0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |     Type      |     Code      |          Checksum             |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |                            Reserved                           |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
   |           MSF Discovery Extension TLV (variable)              |
   +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

IPv6 Router Solicitation with MSF Discovery Extension

Figure 8

Link Layer Fields: Destination Address - This should be the multicast or broadcast Link Layer Address.

IP Fields: Source Address - IP Address of the Mobile Host or IP address of the interface of the Mobile Router from which this message is sent.

Destination Address - This is the all-routers multicast address FF02::2

ICMP Fields: Type = 133 Router Solicitation.

Code = 1 MLBN MSF Discovery Extension included.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Code      |          Checksum             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Cur Hop Limit |M|O|  Reserved |       Router Lifetime         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                         Reachable Time                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Retrans Timer                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|           MSF Discovery Extension TLV (variable)              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

IPv6 Router Advertisement with MSF Advertisement Extension

Figure 9

Link Layer Fields: Destination Address - This should be the source address used to deliver the MSF Discovery message from the mobile node.

IP Fields: Source Address - IP Address of the MSF.

Destination Address - This is the unicast IP address used in the IP header of the MSF Discovery message from the mobile node.

ICMP Fields: Type = 134 Router Advertisement.

Code = 1 MLBN MSF Advertisement Extension included.

Please refer to [RFC4861] for the specification of the remaining fields in both of the above messages.

3.1.2.1. MSF Discovery by Mobile Hosts - IPv6

The MSF Discovery message format for IPv6 mobile hosts is identical to the IPv4 message with the IPv6 Source Address used instead of the IPv4 (see Section 3.1.1.1).

3.1.2.2. MSF Discovery by Mobile Routers - IPv6

The MSF Discovery message format for IPv6 mobile routers is identical to the IPv4 message with the IPv6 Router ID used instead of the IPv4 (see Section 3.1.1.2).

3.1.2.3. MSF Advertisement - IPv6

The MSF Advertisement message format for IPv6 is identical to the IPv4 message format (see Section 3.1.1.3).

3.1.3. Registration and Status - IPv4

3.1.3.1. Mobile Host Registration - IPv4

3.1.3.1.1. Lightweight Registration - IPv4

MLBN eliminates the need for the registrations with the Home Agent and Care-of-Addresses. This makes it possible to implement a Lightweight Registration procedure which is simply the completion of the MSF Discovery process (Section 3.1.1). The Lightweight Registration is indicated by the presence of the L flag in the MSF Advertisement message. With the Lightweight Registration the MSF should allocate the local Mobility Label and create the Mobility Binding structure (Section 3.2.2) immediately following the receipt of the MSF Discovery message from a mobile host. The MSF should also

initiate the network update process (see Section 4) based on the selected update mode and the indicated mobile application priority.

The network update mode selection may be based on the Application Service Type Indication (ASTI) from the MSF discovery message sent by the mobile host. ASTI is a 3-bit field that may be used to indicate to the MSF what type of service is to be used by the mobile host. For example, "Internet Access Only" or "Full Mobile-to-Mobile Routing". This indication can then be mapped to the Network Update Mode Code used in the Mobility Binding structure.

3.1.3.1.2. Full Registration - IPv4

Full Registration is a registration mode which allows to perform additional functions as part of the registration process. An example of such function is the Mobile Host Authentication. Full registration mode is indicated in the MSF Advertisement by setting the R flag.

Full Registration messaging makes use of the UDP port RRR and may provide a mechanism for various functional extensions. Full Registration uses two message types:

Registration Request - Type 1

Registration Reply - Type 2

The Registration Message formats are shown below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |      Length     |H| Rri.|ASTI |   Region_ID   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Mobile Host IPv4 Source Address                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                MSF Address                                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Correlation ID                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Extensions
+-+-+-+-+-+-+....
```

Full Registration Request

Figure 10

Type - 1 = Full Registration Request

Length - Length of the message in octets.

H - Mobile Node Type Indication. 0 = Mobile Host

Pri. - A 3-bit priority code (0-7).

ASTI - Application Service Type Indication. This 3-bit field may be used to indicate to the MSF what type of service is to be used by the mobile host. For example, "Internet Access Only" or Full Mobile-to-Mobile Routing". This indication can then be mapped to the Network Update Mode Code used in the Mobility Binding structure.

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

Correlation ID - a number used to keep track of the registration requests and the corresponding reply message pairs.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |         Flags                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Registration Lifetime      | Reserved      | Region_ID     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Mobile Host IPv4 Source Address                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               MSF IP Address                                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         MSF Virtual Link Layer Address (first 32 bits)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Last 16 bits                   |           Reserved            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Correlation ID                                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Extensions
+-+-+-+-+-+-+....
```

Full Registration Reply

Figure 11

Type - 2 = Full Registration Reply

Length - Length of the message in octets.

Flags - To be defined

Registration Lifetime - the time in seconds until the registration entry in the MSF database expires.

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

MSF IP Address - Virtual IP Address of the MSF (may be different from any particular MSF LER interface IP address

MSF Virtual Link Layer Address - a MAC address shared and recognized by all MPLS LER interfaces participating in the MSF. This address may specifically be used to support Local Micro-Mobility (see Section 4.3.1).

Correlation ID - a number used to keep track of the registration requests and the corresponding reply message pairs.

3.1.3.1.3. Group Registration - IPv4

Clearly the discovery and registration procedure has a great effect on the network responsiveness especially when a mobile host moves from one serving MSF to another. The following enhanced registration scheme can be implemented to simplify the registrations resulting from the MSF-to-MSF handoff and therefore improve the network responsiveness. We refer to it as the Group Registration.

The entire MPLS edge network may be divided in groups or regions containing the geographically close MSF enabled LER nodes. Each

group should be assigned a unique Group ID (1-255). The mobile host will register with a LER node within a group using a Group Registration procedure. The LER node will distribute the registration information to the rest of the group members using the established MP-BGP peering sessions. These messages may be coded as another type of the NLRI in the Address Family structure. The size of the region should be large enough to ensure a high probability that the range of movements of a mobile host will be covered by the service area of the group but at the same time not too large to avoid a large registration table size shared among the group members. The group members can be identified administratively and preconfigured in the MSF serving LER nodes.

During the initial registration process and as part of the registration acknowledgement the serving LER may indicate to the mobile host that it is registered to a group and from now on should use a group virtual link layer address and a group virtual IP address for further communications (the addresses may be communicated in the acknowledgement payload).

The group registration allows to implement the implicit logic by which no further registrations are required from the mobile node due to its movements once the initial group registration has been established. The group members may also pre-allocate the Mobility Labels and have them ready in case the mobile node moves into the member's serving area. Once the mobile node has moved into the serving area of the new MSF group member it continues to send packets to the group virtual link layer address and the virtual IP address. As soon as the packet from the mobile node is received by the group member it will forward the packet to its destination and distribute the new Mobility Binding to the network. A mobile host should continue to send the MSF Discovery messages destined to the group link layer address in order to keep the group registration active.

The group member that is servicing the mobile host can periodically send the registration update messages to the group members in order to keep the Mobility Bindings in the standby status. If a group member has not received any keepalives or packets from the mobile host in a specified period of time it should silently deactivate its local registration entry and release the Mobility Label. If the mobile host happens to be serviced by another group member, this

member will be sending the registration update messages to the group keeping the registration active. If no group member hears from the mobile node, the registration must be removed from the group database after a specified time and the associated Mobility Binding may be withdrawn from the network by means of the MP-BGP update.

Group Registration message formats are very similar to the Full Registration message formats. The Group Registrations starts with the mobile host sending the MSF Discovery message and the MSF replying with the MSF Advertisement having the G flag set, indicating that the Group Registration is supported. After this the mobile host must transition to the Group Registration protocol using the same UDP port RRR as for the Full Registration.

Group Registration uses two message types:

Group Registration Request - Type 3

Group Registration Reply - Type 4

The Group Registration Message formats are shown below.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |      Length     |H| Rri.|ASTI |G| Group ID      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Mobile Host IPv4 Source Address                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               MSF Address                                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               Correlation ID                                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Region_ID     | Extensions
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+....
```

Group Registration Request

Figure 12

Type - 3 = Group Registration Request

Length - Length of the message in octets.

H - Mobile Node Type Indication. 0 = Mobile Host

Pri. - A 3-bit priority code (0-7).

ASTI - Application Service Type Indication. This 3-bit field may be used to indicate to the MSF what type of service is to be used by the mobile host. For example, "Internet Access Only" or Full Mobile-to-Mobile Routing". This indication can then be mapped to the Network Update Mode Code used in the Mobility Binding structure.

G - Group Registration Requested (1)

Group ID - Unique Registration Group Number. Should be zero if G = 0

Correlation ID - a number used to keep track of the registration requests and the corresponding reply message pairs.

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |    Length     |         Flags                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|    Registration Lifetime      |G| Reserved    | Group ID      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Mobile Host IPv4 Source Address                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
 |          Group Virtual IP Address                             |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |      Group Virtual Link Layer Address (first 32 bits)         |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |Last 16 bits                   |            Reserved           |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |               Correlation ID                                  |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 | Region_ID      | Extensions
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+....
```

Group Registration Reply

Figure 13

Type - 4 = Group Registration Reply

Length - Length of the message in octets.

Flags - To be defined

Registration Lifetime - the time in seconds until the registration entry in the MSF database expires.

G - Group Registration Supported (1).

Group ID - Unique Registration Group Number. Should be zero if G = 0

Group Virtual IP Address - Virtual IP Address that is supported by all MSF's that belong to the Registration Group identified by the Group ID. This address may specifically be used to support Group Micro-Mobility (see Section 4.3.2).

Group Virtual Link Layer Address - a MAC address shared and recognized by all MPLS LER interfaces of all MSF's that belong to the Registration Group identified by the Group ID. This address may specifically be used to support Group Micro-Mobility (see Section 4.3.2).

Correlation ID - a number used to keep track of the registration

requests and the corresponding reply message pairs.

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

As in the Full Registration case the Group Registration allows to perform additional functions as part of the registration process by means of using the functional extensions. An example of such a function is the Mobile Host Authentication.

After the completion of the Group Registration with the initial MSF that is part of the Registration Group, the mobile host must send the MSF Discovery messages destined to the Group Virtual Link Layer Address listing the Group ID and the Group Virtual IP Address. The registration information is communicated among the group members using MP-BGP signaling with the specific SAFI value assigned for this purpose (see Section 3.2.3). Any group member receiving the MSF Discovery messages from a mobile host for which the group registration is active must reply with the MSF Advertisement messages to the mobile host. When a mobile host moves from one group member to another it should continue to send packets to its IP destination using the Group Virtual Link Layer Address.

3.1.3.2. Mobile Router Registration - IPv4

Mobile routers should initiate the registration procedure by sending the registration message with the mobile router identification flag set and its Router ID (an IP address that belongs to the router) specified (see Section 3.1.1.2).

Upon receipt of this registration information the MSF should initiate the establishment of the dynamic routing protocol adjacency with the mobile router using protocols such as BGPv4 [RFC4271]. The mobile router should advertise to the MSF the IP prefixes it serves using the established routing adjacency.

3.1.3.2.1. Routing Adjacency Establishment

The MSF should receive the routing protocol update from the mobile router and allocate a single Mobility Label to represent all of the

served prefixes. This label should then be used in the Mobility Binding structure exported to the network by MP-BGP (see Figure 18). Optionally, each served IP prefix advertised by the mobile router can be associated with a separate Mobility Label. This can be used to provide different mobility processing priority to different IP prefixes.

The mobile router status detection can be based on the state of the dynamic routing protocol adjacency maintained by the periodic keepalive messaging common to the routing protocols.

3.1.4. Registration and Status - IPv6

The registration procedures described for IPv4 in Section 3.1.3 are fully extended to IPv6 using the same message formats and the UDP port number. In all messages the IPv4 addresses are replaced with their IPv6 equivalents (with the corresponding increase in the required field length).

Thus, for mobile hosts the Lightweight, Full and Group Registration modes are supported (see Section 3.1.3.1.1, Section 3.1.3.1.2, Section 3.1.3.1.3), and for mobile routers the same IPv4 procedure described in Section 3.1.3.2 and modified to include the IPv6 messages should be supported.

In addition to the use of the MSF Discovery/Advertisement message as keepalives for determining the status of the reachability of the serving MSF function, mobile nodes may utilize IPv6 Neighbor Unreachability Detection procedures specified in [RFC4861] section 7.3.

3.2. Integration with MP-BGP

In order to integrate the MSF on the LER with the MP-BGP processing, a new Address Family must be created. This Address Family must be assigned a new and unique AFI following the Address Family structure of MP-BGP. This Address Family may be referred to as the Mobility Address Family. In fact a number of Mobility Address Families may be created to support IPv4/IPv6 unicast/multicast protocols. In all cases the Address Families must use the structure that allows them to carry the overlay MPLS label information (a specially designated value of SAFI).

3.2.1. Mobility Address Family

In order to carry the Mobility Binding information the BGP UPDATE message with the MP_REACH_NLRI and MP_UNREACH_NLRI optional non-transitive attributes is used as specified in [RFC4760].

For the mobility management purposes a set of new Address Family Identifiers (AFI) and Subsequent Address Family Identifiers (SAFI) are defined. Specifically the following new AFI values are defined:

Mobility IPv4 Unicast - AFI X1 SAFI Y1

Mobility IPv6 Unicast - AFI X2 SAFI Y1

The MP_REACH_NLRI attribute is used to update the LER nodes with new Mobility Binding information. The structure of the attribute is shown below.

```
+---------------------------------------------------------+
| Address Family Identifier (2 octets)                    |
+---------------------------------------------------------+
| Subsequent Address Family Identifier (1 octet)          |
+---------------------------------------------------------+
| Length of Next Hop Network Address (1 octet)            |
+---------------------------------------------------------+
| Network Address of Next Hop (variable)                  |
+---------------------------------------------------------+
| Reserved (1 octet)                                      |
+---------------------------------------------------------+
| Mobility Binding (NLRI) Information (variable)          |
+---------------------------------------------------------+
```

MP_REACH_NLRI with Mobility Binding

Figure 14

The MP_UNREACH_NLRI attribute is used to withdraw the Mobility Binding information. The structure of the attribute is shown below.

```
+---------------------------------------------------------+
| Address Family Identifier (2 octets)                    |
+---------------------------------------------------------+
| Subsequent Address Family Identifier (1 octet)          |
+---------------------------------------------------------+
| Mobility Binding (Withdrawn Routes) (variable)          |
+---------------------------------------------------------+
```

MP_UNREACH_NLRI with Mobility Binding

Figure 15

The Mobility Binding itself is encoded in the NLRI format shown

below.

```
+--------------------------+
|   Length (1 octet)       |
+--------------------------+
|Mobility Binding (variable)|
+--------------------------+
```

NLRI Encoding for Mobility Bindings

Figure 16

For the definitions of the fields in the above figures (with the exception of the Mobility Binding related information) please see [RFC4760].

3.2.2. Mobility Bindings

Two types of Mobility Binding formats are proposed: Host Mobility Binding and Router Mobility Binding.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Origin MP-BGP NEXT_HOP                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Target MP-BGP NEXT_HOP                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Mobile Host Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|H| UT  |Res.   |   Mobility Label                      |Pri. |S|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

NLRI Encoding for the Host Mobility Binding

Figure 17

Origin MP-BGP NEXT_HOP - Router ID of the MPLS LER originating the Mobility Binding. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

Target MP-BGP NEXT_HOP - Router ID of the MPLS LER to receive the Mobility Binding using Selective Downstream Push. For the Unsolicited Downstream Push this field should be set to 0. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

Mobile Host Address - IPv4 or IPv6 Address of the mobile host. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

H - Mobile Node Type Indication. 0 = Mobile Host

UT - Update Type. This 3-bit code is mapped to the ASTI code in the MSF Discovery and Registration Request messages to indicate the Network Update Mode selection (see Section 4).

Res. - Reserved.

Mobility Label - Overlay MPLS Label (20 bits) associated with the IP address of the mobile host in the MSF database.

Pri. - A 3-bit priority code (0-7).

S - Bottom of Stack.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Origin MP-BGP NEXT_HOP                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Target MP-BGP NEXT_HOP                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Mobile Router ID                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
|R| UT  | Res.  |No of Prefixes | IP Prefix 1                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| IP Prefix 1                   | Prefix 1 Len. | Variable No.  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      of Prefixes/Len                                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Mobility Label                        |Pri. |S|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

NLRI Encoding for the Router Mobility Binding

Figure 18

Origin MP-BGP NEXT_HOP - Router ID of the MPLS LER originating the Mobility Binding. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

Target MP-BGP NEXT_HOP - Router ID of the MPLS LER to receive the Mobility Binding using Selective Downstream Push. For the Unsolicited Downstream Push this field should be set to 0. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

Mobile Router ID - IP Address of the mobile router. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

R - Mobile Node Type Indication. 1 = Mobile Router

UT - Update Type. This 3-bit code is mapped to the ASTI code in the MSF Discovery and Registration Request messages to indicate the Network Update Mode selection (see Section 4).

Res. - Reserved.

No. of Prefixes - Number of IP Prefixes carried in this Mobility Binding.

IP Prefix 1 - First IP Prefix (32 bits for IPv4, 128 bits for

IPv6)

Prefix 1 Len. - Length (in number of bits) of the network part of IP Prefix 1

Mobility Label - Overlay MPLS Label (20 bits) associated with each of the IP Prefixes served by the mobile router in the MSF database of the originating LER.

S - Bottom of Stack.

The receiving MSF must read the R flag in the Mobility Binding and associate the provided Mobility Label with each of the IP prefixes found in the body of the Mobility Binding. The derived associations must be installed in the MPLS forwarding table of the MPLS LER and in turn associated with the infrastructure label assigned to the "Origin MP-BGP NEXT_HOP" address indicated in the received Mobility Binding

3.2.3. Group Registration Management with MP-BGP

The Group Registration (Section 3.1.3.1.3) information obtained via the registration messaging with a mobile host is shared among the group members using existing MP-BGP peering sessions. To achieve this, the MSF should allow for a configuration capability to identify the group membership by assigning a Group ID to the MP-BGP peers that belong to the same group. The same capability should be provided

within the Mobility Route Reflectors in order to be able to successfully update the group members with the mobile node registration information.

The mobile host registration information includes the IP address of the mobile host, the Group ID, the priority and the ASTI codes as well as the MAC address of the mobile host. This information is encoded in the Address Family structure using the AFI values specified in Section 3.2.1 but with a specifically designated value of SAFI. The encoded information is then carried in the MP_REACH_NLRI or MP_UNREACH_NLRI.

Specifically the following new SAFI value is defined:

Mobility IPv4 Unicast - AFI X1 SAFI Y2

Mobility IPv6 Unicast - AFI X2 SAFI Y2

The NLRI encoding is shown below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  MP-BGP NEXT_HOP                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Reserved                  |H| Rri.|ASTI |G| Group ID      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Mobile Host IP Address                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Group Virtual IP Address                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Mobile Host MAC Address (first 32 bits)        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Last 16 bits                  |    Reserved                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                Correlation ID                                 |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Group Registration NLRI Encoding

Figure 19

MP-BGP NEXT_HOP - Router ID of the MPLS LER originating the Group Registration Update. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

H - Mobile Node Type Indication. 0 = Mobile Host

Pri. - A 3-bit priority code (0-7).

ASTI - Application Service Type Indication. This 3-bit field may be used to indicate to the MSF what type of service is to be used by the mobile host. For example, "Internet Access Only" or Full Mobile-to-Mobile Routing". This indication can then be mapped to

the Network Update Mode Code used in the Mobility Binding structure.

G - Group Registration Requested (1)

Group ID - Unique Registration Group Number. Should be zero if G = 0

Mobile Host IP Address - IPv4 or IPv6 Address of the mobile host. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

Group Virtual IP Address - IPv4 or IPv6 address assigned for the group and joined by all LER interfaces participating in the MSF. For IPv6 this may be the Anycast IP address.

Mobile Host MAC Address - MAC address of the mobile host.

Correlation ID - a number used to keep track of the registration requests and the corresponding reply message pairs.

The group registration information updates may be sent periodically by the group members. The registration information for multiple mobile hosts may be aggregated in a single MP-BGP UPDATE message. The mobile host registration information may be explicitly withdrawn by the group member that was the last to "hear" from the mobile host.

If a group member receives the MP-BGP registration information update listing a mobile host that has an active local registration entry, the local registration information must be silently discarded and the corresponding local Mobility Binding deleted. The local Mobility Label should be returned to the local available label pool.

If a local registration entry for a mobile host has expired, and if a mobile host registration information is not found in the incoming periodic MP-BGP registration information updates from any of the group members, the group member should send the MP-BGP registration information update carrying the host's registration information in the MP_UNREACH_NLRI attribute. In addition the group member should initiate a network update using the MP_UNREACH_NLRI with the encoded

Mobility Binding for the host in order to withdraw the Mobility

Binding from the MSF databases of the MPLS LER nodes.

3.2.4. BGP Capability Advertisement

The {AFI, SAFI} pairs defined in this document for mobility management must be supported by all BGP speakers participating in mobility management. A BGP Capability Advertisement as specified in [RFC4760] must be used by the BGP speakers to ensure compatibility.

3.3. Mobile Application Priority Indication and Recognition

Given the sensitivity of applications to the network service disruption the MSF function should include a mechanism by which an application may indicate the level of tolerance to the disruption due to the network handling of the handoff process. This indication may be encoded in the registration messaging payload and then incorporated into the Mobility Binding protocol structure. The application sensitivity prioritization scheme may be used to control the Mobility Binding processing priority during the distribution process. For example a mobile host running a real time interactive application may be given a higher processing priority over the mobile host running an elastic data transfer application. The prioritization of processing leads to a differential treatment of the mobile application at various processing points of the mobile network such as the ingress MSF, the intermediate hierarchical route processing by MP-BGP Route Reflectors and the egress MSF.

In addition to the processing priority, the priority indication mechanism may be used to implement the network update grouping and timing policies in a manner that could decrease the frequency of the updates and thus increase the scalability of the network. Specifically, the indicated application priorities may be mapped into the network update classes where the top priority may get an immediate network update and the lower priorities may be organized into classes. For each class the network update process may be delayed for a time period that is not expected to result in the unreasonable disruption to an application of a given priority level. The network updates for any new registration events of the same priority level that have occurred during the corresponding delay period may be grouped in a single MP-BGP update message. If a single update message cannot carry all of the newly arrived registrations an additional update should be created and sent. The update mode may be determined from the Application Service Type Indication communicated during the registration.

3.4. Application Service Type Indication

Application Service Type Indication (ASTI) is a 3-bit field that may be used to indicate to the MSF what type of service is to be used by the mobile host. For example, "Internet Access Only" or "Full Mobile-to-Mobile Routing". This indication may then be mapped to the Network Update Type Code used in the Mobility Binding structure. For example, if ASTI code 001 (binary) is used to indicate the "Internet Access Only" service, the local MSF may use the Selective Downstream Push (see Section 4.1.2) Network Update mode. In addition the MSF may include the corresponding Update Type code in the Mobility Binding structure in order to indicate to the Mobility Route Reflectors that the Selective Downstream Push is to be used.

4. Network Update and Hand-off Processing

4.1. Network Update Modes

The following four modes for the Mobility Binding Distribution or Withdrawal are proposed: i) unsolicited downstream push, ii) selective downstream push, iii) predictive downstream push, and iv) hierarchical on-demand distribution.

4.1.1. Unsolicited Downstream Push

In this mode the originating LER node updates all other MSF enabled LER nodes that are directly peered with it. In case of a hierarchical topology the originating LER node sends a MP-BGP update with the Mobility Binding information to a Route Reflector which in turn updates all of the participating MSF enabled LER Route Reflector clients. Thus the network wide update can only considered to be complete if and only if all of the MSF LER nodes are updated. Clearly this distribution mode has scalability limitations and may be applicable for a relatively small number of the MSF enabled LER nodes. The Update Type Code for this mode is binary 000.

4.1.2. Selective Downstream Push

In this mode the Mobility Binding updates are only sent to a select set of the MSF enabled LER nodes. The underlying idea for this mode is that it is very likely that the most used destinations from the mobile host when it communicates with the Internet are the destinations reachable via a finite set of the service provider's Internet gateway nodes which are in turn reachable via a finite set of the MSF enabled LER nodes. As such, when a mobile host registers with the serving MSF, instead of using the Unsolicited Downstream Push to all LER nodes, the Mobility Binding update for this mobile host would be sent to a finite set of the LER nodes connected to the service provider Internet gateways. This mode can be used for the initial update process and the Unsolicited Downstream Push can be used at a later point in time. The Update Type Code for this mode is binary 001.

4.1.3. Predictive Downstream Push

In this mode the Mobility Binding updates are sent to those MSF enabled LER nodes which are identified as a NEXT_HOP for the FEC (and the corresponding LSP) leading to the destination of the packet originated by a mobile node. This mode is based on the fact that if the destination FEC exists in the serving MSF LER's routing table, and the mobile node sends a packet to the FEC, the LER will perform the label imposition (for the infrastructure label) by selecting the

label corresponding to the FEC NEXT_HOP. This NEXT_HOP in turn identifies the destination MSF enabled LER node to which the Mobility Binding update needs to be sent. The predictive feature of this mode comes from the fact that the Mobility Binding update destination is predicted as the result of the originating LER's lookup of the destination FEC and its NEXT_HOP. Clearly it is likely that the LER node to which the predictive Mobility Binding update is sent may receive the reply packet from the mobile node's destination before the Mobility Binding for the originating host is received. In this case the LER that is being updated may buffer the reply packet for a reasonable period of time to wait for the mobility update. The Update Type Code for this mode is binary 010.

4.1.4. Hierarchical On-Demand Distribution

The Mobility Binding update is first sent by a serving MSF LER to a set of Mobility Route Reflectors using the Selective Downstream Push. Once the Mobility Route Reflectors have been updated, all other LER nodes must explicitly request Mobility Labels from the Mobility Route Reflectors for packets destined to a mobile node. The Update Type Code for this mode is binary 011.

4.1.4.1. On-Demand Requests for Mobility Binding Information

To support the Hierarchical On-Demand Distribution Network Update Mode the following explicit Mobility Binding information request procedure based on MP-BGP may be used. When a MPLS LER supporting MPLS Mobility receives an IP packet, it first should check if the Destination Address listed in the IP header belongs to the overall IP address range assigned to the mobility functions and the corresponding mobile device fleet. If the Destination Address falls within this range and the matching Mobility Binding is present in the

LER MSF database, the packet should be encapsulated using the appropriate MPLS label stack and forwarded on the LSP toward the LER that is listed as the "Origin MP-BGP NEXT_HOP" in the Mobility Binding. If the IP address is outside of the mobility fleet range the packet must be treated in accordance with the conventional rules based on either the IP or MPLS forwarding tables.

If the packet falls into the mobility fleet range and no matching Mobility Binding entry exists in the MSF database, the LER should send an on-demand request for Mobility Binding Information to the designated Mobility Route Reflector. This request is encoded as a special type of the MP_REACH_NLRI attribute using a specific SAFI value and one of the AFI values defined earlier. The Mobility Route Reflector should process the request and return the Mobility Binding update to the requesting LER using the NLRI encoding shown in Section 3.2.2.

Specifically the following new SAFI value is defined for the On-Demand Mobility Binding Information Request:

Mobility IPv4 Unicast - AFI X1 SAFI Y3

Mobility IPv6 Unicast - AFI X2 SAFI Y3

The NLRI encoding is shown below:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                MP-BGP NEXT_HOP                                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Request Type   |    Region_ID  |      Number of Addresses      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              IP Destination Address                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|              IP Destination Address
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+...
```

NLRI Encoding for On-Demand Mobility Binding Request

Figure 20

MP-BGP NEXT_HOP - Router ID of the MPLS LER originating the On-Demand Mobility Binding Information Request. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

Request Type - To be defined (may be "Specific, Partial, ALL or LRL").

Region_ID - An Identifier (1-255) associated with the Regional Mobility Route Reflector. Region_ID=0 must be used for initial registrations by mobile nodes.

Number of Addresses - Number of IP Destination Addresses listed in the On-Demand Request for which the Mobility Binding Information is requested

IP Destination Address - The IPv4 or IPv6 address of a mobile host for which the Mobility Binding Information is requested.

If the Request Type is not equal to LRL - Last Requestor List, the Mobility Route Reflector (mRR) should reply with a regular Mobility

Binding Update. If the request type is equal to LRL, then the following reply format should be used:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  MP-BGP NEXT_HOP                              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Request Type   |    Reserved   |     Number of Addresses       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            LRL Length         |   IP Destination +            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Address                   |   Last Requestor +            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Router_ID                 |L.R. Region_ID |  Last +       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
| Requestor Router_ID           |L.R. Region_ID | LRL +          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Length         |        IP Destination +                       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Address       |    Last Requestor +                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Router_ID      |L.R. Region_ID |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+...
```

NLRI Encoding for On-Demand LRL Reply

Figure 21

MP-BGP NEXT_HOP - Router ID of the MPLS LER originating the On-Demand LRL Reply. This address may be carried in the IPv4 or IPv6 format depending on the {AFI, SAFI} pair used.

Request Type - LRL Reply.

Number of Addresses - LRL's in the reply

IP Destination Address - The IPv4 or IPv6 address of a mobile host for which the LRL Information is requested.

Last Requestor Router_ID - IP Address of the LER from which the On-Demand Mobility Binding Information Request for the mobile node in question was last received (may be more than one).

L.R. Region_ID - ID of the Regional mRR serving the LER from which the On-Demand Mobility Binding Information Request for the mobile node in question was last received (may be more than one).

4.1.5. Network Hierarchy Considerations

The first three update modes are directly applicable for the flat MSF LER peering topology and the fourth to the hierarchical peering environment. In the hierarchical peering environment only Unsolicited Downstream Push does not require any modifications to the Route Reflector operation. The Selective and Predictive modes

require that the Route Reflectors perform selective MP-BGP updates for the Mobility Bindings distribution. This can be achieved by a modification of the Route Reflector update process where destinations of the selective updates indicated by the Update Type Code can be derived from the "Target NEXT_HOP" parameter in the Mobility Binding structure. The Hierarchical On-Demand mode requires the Route Reflectors to store the Mobility Bindings and respond to the on-demand Mobility Binding requests initiated by the client MSF LER nodes or other Mobility Route Reflectors.

4.1.6. Regionalization and Scalability

To improve the scalability of the network update process the entire serving network may be divided into the Registration Regions. Each registration region is served by a Regional Mobility Route Reflector (mRR) with the individual MSF LER nodes falling within the region serving as the Route Reflector Clients. Each MSF LER node in turn may serve a specific geographic area called a Mobility Region that is covered by a given set of Radio Access Networks using Direct or In-direct Attachment options. This type of the regionalized mobility signaling infrastructure is referred to as the Mobility Information Location System (MILS) and is shown in the figure below.


```
                mRR1                        mRR3
                +-----+                   +-----+
                |    +-------------------+     `.
               .++-+-+      mRR2         +--+-\ `.
```

```
                   .'//| |        +-----+         | |`. \
                 .' /| | +---------+    +----------+ |\ \ `.
          Registration Region 1   ++++-\      Registration region 4
              .'  /  /  |         /\ \ `.        | \  \  `.
            .'   /  |   |   Registration region 2   |  \   `.  `.
        +-.'    / +-/   |         /  | \   \        |   |   \   \
        +-+  +-/  +-+ +-\        |   \  \   \       \-+ \     `.-+`.
       LER11 +-+ LER13+-+      +-/    |  \-+ `.     +-+  \-+  +-+ +`.
        .   LER12  . LER14     +-+  +-\  +-+ +-\  LER31  +-+ LER33+-+
       / \    .   / \   .    LER21  +-+ LER23+-+     .  LER32  .  LER34
      ;   :  / \ ;   : / \     .   LER22  .   LER24 / \   .   / \   .
      |11 | ;12 :|13 |;14 :   / \    .   / \   .   ;   : / \ ;   : / \
      |   | |   ||   ||   |  ;21 :  / \ ;   : / \  |31 |;32 :|33 |;34 :
      |++ | |   ||   ||   |  |   | ;22 :|23 |;24 : |   ||   ||   ||   |
      :++MN |   |:   ;|   |  |   | |   ||   ||   | |   ||   ||   ||   |
       \ /  :   ; \ / :   ;  |   | |   ||   ||   | :   ;|   |:   ;|++ |
        '    \ /   '   \ /   :   ; |   |:   ;|   |  \ / :   ; \ / :++CN
              '         '     \ /  :   ; \ / :   ;   '   \ /   '   \ /
                               '    \ /   '   \ /         '         '
                                     '         '
                               Mobility Regions
```

Regionalized Mobility Information Location System

Figure 22

4.1.6.1. Mobility Information Location System (MILS)

The operation of MILS is based on the Hierarchical On-Demand Network Update mode and requires the individual MSF LER nodes to only directly update their respective Regional Mobility Route Reflectors (using the Selective Update). After the Regional mRR's have been updated with the Mobility Binding information, these bindings may be explicitly requested by the MSF LER's in the same Registration Region or the LER's in other regions via their mRR's. To facilitate the hand-off process a Last Requestor List (LRL) is introduced and associated with each Mobility Binding at the Regional mRR level. The LRL is a list of 2-tuples where each 2-tuple consists of the Router_ID and Region_ID of the MSF LER nodes that have requested Mobility Binding information for a particular mobile node. The logical operation of MILS is described below based on Figure 22.

1. Assume that a previously unknown MN initiated a Discovery and

Registration process in the Mobility Region 11. Upon successful registration MN communicates its IP address to the MSF in LER11 and receives the related MSF information including the Region_ID=1. (During the registration the newly initialized MN should use Region_ID=0).

2. LER11 creates a local Mobility Binding for the MN and updates mRR1 using the Selective Mode specifying the MN's IP address, It's own Router_ID, the Mobility Label and the initial Region_ID=0. LER11 stores the received Mobility Binding and associates an empty LRL with it.

3. Assume that a Correspondent Node (CN) in the Mobility Region 34 sends a packet to the MN in the Mobility Region 11. The packet reaches LER34.

4. LER34 identifies that the packet falls into the mobility address range and requests Mobility Binding information from its Regional mRR3 using On-Demand Mobility Binding Request (see Figure 20). LER34 uses the value of the Region_ID=3 in the request.

5. Since mRR3 does not have the Mobility Binding for the MN it forwards the requests to both mRR1 and mRR2. mRR1 replies with the Mobility Binding and mRR3 forwards the reply to LER34. Both mRR1 and mRR3 associate an LRL with the Mobility Binding listing the LER34 Router_ID and the Region_ID=3.

6. LER34 forwards the packet to the MN using the LSP between LER11 and LER34 and a stacked Mobility Label extracted from the received Mobility Binding.

7. Assume that MN now moves into the Mobility Region 22. It initiates a new Discovery and Registration procedure and registers with the MSF at LER22 specifying its IP address and the Last Region_ID=1.

8. LER22 creates a local Mobility Binding for the MN and updates its regional mRR2 using Selective Mode and sending the Region_ID=1 along with the Mobility Binding.

9. mRR2 receives the new Mobility Binding and examines the associated value of Region_ID. If it is not equal to 0 then the LRL for this binding must be requested from the mRR identified by the Region_ID. In this case mRR2 sends the On-Demand request to mRR1 asking for the associated LRL created in step 5.

10. mRR2 receives the LRL={Router_ID=LER34, Region_ID=3} from mRR1

(see Figure 21) and sends a Mobility Binding update to mRR3 using the

Selective Downstream Push Mode with the "Target MP-BGP NEXT_HOP" set to the LER34 Router_ID.

11. mRR3 receives the updated Mobility Binding and looks up the "Target MP-BGP NEXT_HOP". In this case it is equal to the LER34 Router_ID. mRR3 updates LER34 with the new Mobility Binding using Selective Downstream Push. LER34 starts to forward packets to the MN using the LSP between LER34 and LER22 (listed as the "Origin MP-BGP NEXT_HOP" in the updated Mobility Binding) and the new overlay Mobility Label.

4.2. Hand-off Processing

The use of the Multi-Protocol BGP for mobility management allows a simple basic hand-off processing scheme to be implemented. In particular, when a mobile node detects that it can no longer receive the keepalive acknowledgements from the serving MSF it initiates the new discovery and registration procedure. After the successful registration the new serving MSF will assign and distribute a new Mobility Binding to the rest of the participating LER nodes thus replacing the corresponding old Mobility Binding entries in their MSF databases. Once the entries have been replaced by the new Mobility Binding the LER nodes will automatically forward the packets destined for the mobile node onto the new LSPs connecting to the mobile node's new serving MSF and the corresponding new Radio Access Network.

The described hand-off procedure provides a basic hand-off handling in that it requires a new mobile node registration to trigger the Mobility Binding update to the network. The service disruption due to the time required to detect the loss of communication and to discover the new MSF and register with it can be minimized by selecting the fast keepalive timers but this in turn will result in the increased processing overhead and a possible impact on scalability. At the same time the frequency of the hand-offs between the MSF LER nodes can reasonably be expected to be much lower then the frequency of the Layer 2 hand-offs because the MSF enabled LER is expected to serve a large area potentially covered by multiple Radio Access Networks. Therefore a reasonable configuration of the keepalive timers and the low frequency of the MSF-to-MSF hand-offs may result in an acceptable network responsiveness especially for

disruption tolerant applications.

In cases where the application sensitivity requires a better network responsiveness a number of more sophisticated hand-off methods can be implemented. One of the methods may make use of the Group Registration as described above. In this case no discovery or registration is required from the mobile node when it moves into the new service area - it simply must continue to send packets to the

group address and whichever group member happens to be serving the mobile node will distribute the pre-assigned Mobility Label to update the network. Thus the hand-off latency becomes only a function of the MP-BGP update processing as opposed to being a function of a combination of a potentially lengthy discovery and registration as well as the MP-BGP update procedures. Again, this scheme requires a trade-off analysis between the gain in the network responsiveness and the cost in signaling and processing required to maintain the shared registration table.

4.3. Micro-Mobility Handling

In the context of Mobile IP Micro-Mobility can be defined as a range of the mobile node movements that do not require re-registrations with the Mobile IP HA. A number of proposals exist that are targeted to extend the range of micro-mobility by utilizing the hierarchical mobility management schemes.

In the context of this document micro-mobility is defined as the range of the mobile node's movements that do not result in the registration with a new MSF or the network update by MP-BGP, or both. As such the following two micro-mobility scenarios are considered by this proposal.

4.3.1. Local Micro-Mobility

Local micro-mobility is defined as the range of movements of the mobile node that is contained within the serving area of a given MSF enabled LER node. Referring to Figure 1 this moving pattern would correspond to the mobile node transitioning between the radio cells associated with the L3 logical interfaces local to the serving LER node. Clearly such a movement pattern should not result in either the re-registration with the MSF or the network update by MP-BGP.

In order to support Local Micro-Mobility the MSF should have the capability of "tracking" the mobile node association with the LER L3 logical interfaces. This "tracking" may simply be based on the reception of the datagrams from the mobile node. If the packets from the same L2 address and L3 source addresses started arriving on a new L3 logical interface of the LER and the MSF registration for the mobile node in question is active the MSF should associate the new L3 logical interface with the existing registration entry and the corresponding local Mobility Binding.

4.3.2. Group Micro-Mobility

Group Micro-Mobility makes direct use of the Group Registration described in Section 3.1.3. In this case the Group Micro-Mobility is

defined as the range of the mobile node's movements that do not result in the MSF re-registration process. Group Micro-Mobility still requires the network update by MP-BGP.

5. Datagram Delivery

The delivery of packets from the MSF registered mobile node to other network destinations uses the same processing as in the other MPLS services. Namely, when a packet is received from the mobile node the LER looks up the MPLS forwarding database to find a FEC to which the destination IP address belongs. Once the FEC is identified the corresponding MPLS label (or label stack) is used to send the packet on the LSP toward the destination.

For the packets destined to the mobile node, when the packet is received by the LER the MSF performs a lookup in the overlay MPLS forwarding table to find the Mobility Binding matching the destination address of the mobile node (this binding entry was populated as the result of the Mobility Binding Distribution process). Once the match is found the inner MPLS label is pushed onto the MPLS label stack. Then the LER performs an additional lookup to find a FEC and the corresponding label matching the "Origin MP-BGP NEXT_HOP" LER IP address associated with this Mobility

Binding. This outer label is then pushed onto the MPLS label stack and the packet is forwarded on the LSP.

At the receiving MSF enabled LER the packet is processed and the inner MPLS label is examined to find the reverse Mobility Binding match in order to identify the IP address of the mobile node. Once the IP address is identified the corresponding Layer 2 address is found in the MSF registration database. The packet payload is then encapsulated into the Layer 2 protocol and delivered to the mobile node.

In the case when the mobility service is provided to the mobile router, the forwarding of packets follows the same procedure for the service provider MPLS network segment. The packet forwarding between the mobile router and the serving MSF enabled LER does not have to use MPLS and can be based on IPv4 or IPv6 and the corresponding radio attachment layer 2 protocol.

6. Security Considerations

The Lightweight Registration procedure (see Section 3.1.3.1.1) and the associated Network Update and traffic processing provides the capability to bypass the Full Registration mode in favor of the ability to significantly decrease the registration processing time. From the security perspective this procedure should only be allowed if the layer 2 radio access network provides acceptable mobile node authentication.

To provide for stronger authentication, the Full or the Group Registration procedures must be used (see Section 3.1.3.1.2,

Section 3.1.3.1.3). These procedures allow to use additional authentication procedures by making use of the Registration Request and Reply message extensions (see Figure 10, Figure 11).

For the Mobile Routers, existing routing protocol security procedures such as the peer authentication may be used.

7. IANA Considerations

New ICMP code values for message types 9, 10, 133 and 134:

Type=10 - IPv4 Router Solicitation, Code=1 - MLBN MSF Discovery

Extension

Type=9 - IPv4 Router Advertisement, Code=1 - MLBN MSF Advertisement Extension

Type=133 - IPv6 Router Solicitation, Code=1 - MLBN MSF Discovery Extension

Type=134 - IPv6 Router Advertisement, Code=1 - MLBN MSF Advertisement Extension

New UDP port number:

UDP Port RRR for the MLBN Full and Group Registration Protocol.

New {AFI, SAFI} pairs for MP-BGP:

AFI=X1, SAFI=Y1 - MLBN Mobility Binding IPv4 Unicast

AFI=X1, SAFI=Y2 - MLBN Group Registration IPv4 Unicast

AFI=X1, SAFI=Y3 - MLBN On-Demand Binding Information IPv4 Unicast

AFI=X2, SAFI=Y1 - MLBN Mobility Binding IPv6 Unicast

AFI=X2, SAFI=Y2 - MLBN Group Registration IPv6 Unicast

AFI=X2, SAFI=Y3 - MLBN On-Demand Binding Information IPv6 Unicast

8. Acknowledgements

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9. IPR Notice

The IETF has been notified of intellectual property rights claimed in regard to some or all of the specification contained in this document. For more information consult the online list of claimed rights.

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