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Logical Interface Support for multi-mode IP Hosts
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Abstract

A Logical Interface is a software semantic internal to the host operating system. This semantic is available in all popular operating systems and is used in various protocol implementations. The Logical Interface support is desirable on the mobile node operating in a Proxy Mobile IPv6 domain, for leveraging various network-based mobility management features such as inter-technology handoffs, multihoming and flow mobility support. This document explains the operational details of Logical Interface construct and the specifics on how the link-layer implementations hide the physical interfaces from the IP stack and from the network nodes. Furthermore, this document identifies the applicability of this approach to various link-layer technologies and analyses the issues around it when used in context with various mobility management features.

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1. Introduction

Proxy Mobile IPv6 [RFC5213] is a network-based mobility protocol. Some of the key goals of the protocol include support for multihoming, inter-technology handoffs and flow mobility support. The PMIPv6 extensions chartered in the NETEXT WG) allow the mobile node to attach to the network using multiple interfaces (simultaneously or sequentally), or to perform handoff between different interfaces of the mobile node. However, for supporting these features, the mobile node is required to be activated with specific software configuration that allows the mobile node to either perform inter-technology handoffs between different interfaces, attach to the network using multiple interfaces (sequentially or simultaneously), or perform flow movement from one access technology to another. This document analyses from the mobile node's perspective a specific approach that allows the mobile node to leverage these mobility features. Specifically, it explores the use of the Logical Interface support, a semantic available on most operating systems.

A Logical Interface is a construct internal to the operating system. It is an approach where the link-layer implementations hide the physical interfaces from the IP stack and from the network nodes. This semantic is widely available in all popular operating systems. Many applications such as Mobile IP client [RFC3775], IPsec VPN client [RFC4301] and L2TP client [RFC3931] all rely on this semantic for their protocol implementation and the same semantic can also be useful in this context. Specifically, the mobile node [RFC5213] can use the logical interface configuration for leveraging various network-based mobility management features provided by the Proxy Mobile IPv6 domain. The rest of the document provides the operational details of the Logical Interface on the mobile node and the inter-working between a mobile node using logical interface and network elements in the Proxy Mobile IPv6 domain. It also analyzes the issues involved with this approach and characterizes the contexts in which such use is appropriate.

2. Requirements Language

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

3. Hiding link layer technologies - Approaches and Applicability

There are several techniques/mechanisms that allow hiding access technology changes or movement from host IP layer. This section classifies these existing techniques into a set of generic approaches, according to their most representative characteristics. We then refer to these generic mechanisms later in the document, when analyzing their applicability to inter-access technology and flow mobility purposes in PMIPv6.

3.1. Link-layer Abstraction - Approaches

The following generic mechanisms can hide access technology changes from host IP layer:

o Link layer support: certain link layer technologies are able to hide physical media changes from the upper layers (see Figure 1). For example, IEEE 802.11 is able to seamlessly change between IEEE 802.11a/b/g physical layers. Also, an 802.11 STA can move between different Access Points (APs) within the same domain without the IP stack being aware of the movement. In this case, the IEEE 802.11 MAC layer takes care of the mobility, making the media change invisible to the upper layers. Another example is IEEE 802.3, that supports changing the rate from 10Mbps to 100Mbps and to 1000Mbps.

```
             Mobile Node
      +-----------------------+
      |        TCP/UDP        |            AR1        AR2
      +-----------------------+           +-----+    +-----+
      |          IP           |           | IP  |    | IP  |
      +-----------------------+           +-----+    +-----+
      |    Link Layer (L2)    |           | L2  |    | L2  |
      +-----+-----+-----+-----+           +-----+    +-----+
      | L1a | L1b | L1c | L1d |<--------->| L1d |    | L1b |
      +-----+-----+-----+-----+           +-----+    +-----+
               ^                                        ^
               |________________________________________|
```

Link layer support solution architecture

There are also other examples with more complicated architectures, like for instance, 3GPP Rel-8. In this case, a UE can move (inter-RA handover) between GERAN/UTRAN/E-UTRAN, being this movement invisible to the IP layer at the UE, and also to the LMA logical component at the PGW. The link layer stack at the UE (i.e. PDCP and RLC layers), and the GTP between the RAN and the SGW (which plays the role of inter-3GPP AN mobility anchor) hide this kind of mobility, which is not visible to the IP layer of the

UE (see Figure 2).

```
 ---------
 | Appl. |<------------------------------------------------------>
 ---------                                             ----------
 |       |<+ - - - - - - - - - - - - - - - - - - - - - +>|        |
 |  IP   | . ----------------- . ------------------- . |   IP   |
 |       |<+>|     relay     |<+>|      relay      | . |        |
 --------- . ----------------- . ------------------- . ----------
 | PDCP  |<+>| PDCP | GTP-U  |<+>| GTP-U  | GTP-U  |<+>| GTP-U  |
 --------- . ----------------- . ------------------- . ----------
 | RLC   |<+>| RLC  | UDP/IP |<+>| UDP/IP | UDP/IP |<+>| UDP/IP |
 --------- . ----------------- . ------------------- . ----------
 | MAC   |<+>| MAC  |   L2   |<+>|   L2   |   L2   |<+>|   L2   |
 --------- . ----------------- . ------------------- . ----------
 |  L1   |<+>|  L1  |   L1   |<+>|   L1   |   L1   |<+>|   L1   |
 --------- . ----------------- . ------------------- . ----------
    UE     Uu     E-UTRAN     S1-U       SGW       S5/S8a  PGW
```

3GPP Rel-8 data plane architecture (GTP option)

o Logical interface: this refers to solutions (see Figure 3) that logically group/bond several physical interfaces so they appear to the upper layers (i.e. IP) as one single interface (where application sockets bind). Depending on the OS support, it might be possible to use more than one physical interface at a time -- so the node is simultaneously attached to different media -- or just to provide a fail-over mode. Controlling the way the different media is used (simultaneous, sequential attachment, etc) is not trivial and requires additional intelligence and/or configuration at the logical interface device driver. An example of this type of solution is the Logical interface [I-D.yokota-netlmm-pmipv6-mn-itho-support] or the bonding driver.

```
                                +-----------------------------+
                                |           TCP/UDP           |
             Session to IP   +->|                             |
             address binding |  +-----------------------------+
                             +->|              IP             |
              IP to logical  +->|                             |
           interface binding |  +-----------------------------+
                             +->|      Logical interface      |
         logical to physical +->|           (MN-HoA)          |
          interface binding  |  +-----------------------------+
                             +->|  L2  |  L2  |       |  L2  |
                                |(IF#1)|(IF#2)| ..... |(IF#n)|
                                +------+------+       +------+
                                |  L1  |  L1  |       |  L1  |
                                |      |      |       |      |
                                +------+------+       +------+
```

Logical IP Interface

3.2. Applicability Statement

We now focus on the applicability of the above solutions against the following requirements:

- o multi technology support
- o sequential vs. simultaneous access
- o no impact to the IP layer (e.g. Neighbor Discovery, path MTU)

3.2.1. Link layer support

Link layer mobility support applies to cases when the same link layer technology is used and mobility can be fully handled at these layers. One example is the case where several 802.11 APs are deployed in the same subnet and all of them share higher layer resources such as DHCP server, IP gateway, etc. In this case the APs can autonomously (or with the help of a central box) communicate and control the STA association changes from one AP to another, without the STA being aware of the movement. This type of scenario is applicable to cases when the different points of attachment (i.e. APs) belong to the same network domain, e.g. enterprise, hotspots from same operator, etc.

This type of solution does not typically allow for simultaneous attachment to different access networks, and therefore can only be considered for inter-access technology handovers, but not for flow mobility. Existing RFC 5213 handover hint mechanisms could benefit from link layer information (e.g. triggers) to detect and identify MN handovers.

Link layer support is not applicable when two different access technologies are involved (e.g. 802.11 WLAN and 802.16 WiMAX) and the same is true when the same access technology expands over multiple network domains. This solution does not impose any change at the IP layer since changes in the access technology occur at layer two.

3.2.2. Logical Interface

The use of a logical interface allows the mobile node to provide a single interface view to the layers above IP (thus not changing the IP layer itself). Upper layers can bind to this interface, which hides inner inter-access technology handovers or data flow transfers among different physical interfaces.

This type of solution may support simultaneous attachment, in addition to sequential attachment. It requires additional support at the node and the network in order to benefit from simultaneous attachment. For example special mechanisms are required to enable addressing a particular interface from the network (e.g. for flow mobility). In particular extensions to PMIPv6 are required in order to enable the network (i.e., the MAG and LMA) to deal with physical interfaces, instead to IP interfaces as current RFC5213 does. RFC5213 assumes that each physical interface capable of attaching to a MAG is an IP interface, while the logical interface solution groups several physical interfaces under the same IP logical interface.

Neighbor discovery in conjunction with the logical interface concept has been widely studied for IPv4. Link awareness and gratuitous ARP messages ensure neighbor reachability in case of media change. The same apply to IPv6 where Router Solicitation/Router Advertisement can be sent/received to efficiently manage neighbor cache population.

3.2.3. Conclusion

From the above it is clear that the logical interface is the best most appropriate solution. It allows heterogeneous attachement while leaving the change in the meadi transparent to the IP stack. Simultaneous and sequential network attachment procedures are possible enabling inter-technology and flow mobility scenarios. Thorugh link awareness the logical interface can keep consistent neighbor caches and move flows across access networks transparently to the upper layers.

4. Logical Interface Operation

On most operating systems, a network interface is associated with a physical device that provides the capability for transmitting and receiving network packets. In some cases a network interface can also be implemented as a logical interface which does not feature any packet transmission or receive capabilities, but relies on other network interfaces for such capabilities. This logical interface can be realized by means of a Logical interface.

```
                           +----------------------------+
                           |          TCP/UDP           |
        Session to IP +---->|                            |
        Address binding |   +----------------------------+
                      +---->|             IP             |
        IP Address    +---->|                            |
        binding        |    +----------------------------+
                      +---->|     Logical Interface      |
        Logical to    +---->|                            |
        Physical       |    +----------------------------+
        Interface     +---->|  L2  |  L2  |       |  L2  |
        binding             |(IF#1)|(IF#2)| ..... |(IF#n)|
                            +------+------+       +------+
                            |  L1  |  L1  |       |  L1  |
                            |      |      |       |      |
                            +------+------+       +------+
```

Figure 1: Logical Interface Implementation

From the perspective of the IP stack and the applications, a Logical interface is just another interface. A host does not see any difference between a Logical and a physical interface. All interfaces are represented as software objects to which IP address configuration is bound. However, the Logical interface has some special properties which are essential for enabling intert-technology handover and flow-mobility features. Following are those properties:

o Logical interface is a logical interface that appears to the host stack as any other interface. IP address configuration can be bound to this interface by configuring one or more IPv4 and/or IPv6 addresses to this interface.

o Logical interface has a relation to a set of physical interfaces on the host. These physical interfaces in the context of Logical interface are known as sub-interfaces. These sub-interfaces provide transmit and receive functions for sending and receiving packets over physical links. A Logical interface can receive packets sent to any of its sub-interfaces. In other words the MN

ccepts packets on any physical interface as long as the IP address is valid (downlink).

- The link-layer identifier of the Logical interface is used in the link-layer header of the IP packets sent through this interface, and the link-layer address of the physical interface will not be used.

- The send/receive vectors of a Logical interface are managed dynamically and are tied to the sub-interfaces. The mapping between this Logical interface and the sub-interfaces can change dynamically and this change will not be visible to the applications. The side effect of this is the ability for the application bound to the address configuration on the Logical interface, to survive across inter-technology handoffs. Applications will survive across the mapping change between a Logical interface and its sub interfaces.

- An IP link as seen by the applications that the Logical interface is being part of through specific sub interface(s), when changed to be as part of through a different set of sub interface(s), will not trigger session loss, address loss, as long as the prefix is valid, and the host continues to exchange Neighbor Discovery meesages [RFC4861] from the IP routers to the Logical interface over the sub-interface(s).

- The host has the path awareness of an IPv4/IPv6 link through a sub-interface and standard routing table(s) lookup (via the logical interface) uses the sub-interfaces for packet forwarding. Addresses from Prefix P1, P2 tied to the Logical interface, may have two different link paths, Prefix P1 over E0, Prefix P2 over E1, and this mapping may be reversed, without applications being aware of, and with the needed path changes on the network side.

- The Logical interface MUST transmit uplink packets on the same physical interface on which the downlink packet was received for the particular prefix/flow. This will guarantee that packets belonging to the same session (e.g. TCP connection) are routed along the same path (downlink and uplink). In other words a flow mobility decision taken at the LMA will be understood at the MN as an implicit decision when packets belonging to the same flow will arrive at a new interface.

5. Logical Interface Use-cases in Proxy Mobile IPv6

This section explains how the Logical interface support on the mobile node can be used for enabling some of the Proxy Mobile IPv6 protocol features.

5.1. Multihoming Support

A mobile node in the Proxy Mobile IPv6 domain can potentially attach to the Proxy Mobile IPv6 domain, simultaneously through multiple interfaces. Each of the attachment links are assigned a unique set of IPv6 prefixes. If the host is configured to use Logical interface over the physical interface through which it is attached, following are the related considerations.

```
                                        LMA's Binding Table
                                 +=================================+
                       +-----+   | HNP   MN-ID  CoA   ATT   LL-ID |
                       |LMA |   +=================================+
                       +-----+   | HNP-1  MN-1  PCoA-1  5    ZZZ  |
                        //\\    | HNP-2  MN-1  PCoA-2  4    ZZZ  |
              +---------//--\\-----------+
             (         //    \\           )
             (        //      \\          )
              +------//--------\\--------+
                    //          \\
             PCoA-1 //            \\ PCoA-2
                +----+          +----+
          (WLAN) |MAG1|          |MAG2| (WiMAX)
                +----+          +----+
                   \                /
                    \              /
              HNP-1 \            / HNP-2
                      \          /
                       \        /
                  +-------+ +-------+
                  | if_1  | | if_2  |
                  |(WLAN) | |(WiMAX)|
                  +-------+-+-------+
                  |     Logical     |
      (LL-ID: ZZZ) |    Interface    | HNP-1::zzz/128
                  +-----------------| HNP-2::zzz/128
                  |       MN        |
                  +-----------------+
```

Figure 2: Multihoming Support

- The mobile node detects the advertised prefixes from the MAG1 and MAG2 as the onlink prefixes on the link to which the Logical interface is attached.

- The mobile node can generate address configuration using stateless auto configuration mode from any of those prefixes.

- The applications can be bound to any of the addresses bound to the Logical interface and that is determined based on the source address selection rules.

- The host has path awareness for the hosted prefixes based on the received Router Advertisement messages. Any packets with source address generated using HNP_1 will be routed through the interface if_1 and for packets using source address from HNP_2 will be routed through the interface if_2.

5.2. Inter-Technology Handoff Support

The Proxy Mobile IPv6 protocol enables a mobile node with multiple network interfaces to move between access technologies, but still retaining the same address configuration on its attached interface. The protocol enables a mobile node to achieve address continuity during handoffs. If the host is configured to use Logical interface over the physical interface through which it is attached, following are the related considerations.

```
                                           LMA's Binding Table
                                    +=================================+
                           +----+   | HNP   MN-ID  CoA   ATT   LL-ID |
                           |LMA |   +=================================+
                           +----+   | HNP-1   MN-1  PCoA-1  5    ZZZ |
                            //\\                   (pCoA-2)(4) <-change
                 +---------//--\\----------+
                (         //    \\          )
                (        //      \\         )
                 +------//--------\\--------+
                       //          \\
               PCoA-1 //            \\ PCoA-2
                   +----+          +----+
            (WLAN) |MAG1|          |MAG2| (WiMAX)
                   +----+          +----+
                      \                /
                       \    Handoff   /
                        \    ---->  / HNP-1
                         \         /
                          \       /
                     +-------+ +-------+
                     | if_1  | | if_2  |
                     |(WLAN) | |(WiMAX)|
                     +-------+-+-------+
                     |     Logical     |
        (LL-ID: ZZZ) |    Interface    | HNP-1::zzz/128
                     +-----------------|
                     |       MN        |
                     +-----------------+
```

Figure 3: Inter-Technology Handoff Support

- o When the mobile node performs an handoff between if_1 and if_2, the change will not be visible to the applications of the mobile node. It will continue to receive Router Advertisements from the network, but from a different sub-interface path.

- o The protocol signaling between the network elements will ensure the local mobility anchor will switch the forwarding for the advertised prefix set from MAG1 to MAG2.

- o The MAG2 will host the prefix on the attached link and will include the home network prefixes in the Router Advertisements that it sends on the link.

5.3. Flow Mobility Support

For supporting flow mobility support, there is a need to support vertical handoff scenarios such as transferring a subset of prefix(es) (hence the flows associated to it/them) from one interface to another. The mobile node can support this scenario by using the Logical interface support. This scenario is similar to the Inter-technology handoff scenario defined in Section Section 5.2, only a subset of the prefixes are moved between interfaces.

Additionally, IP flow mobility in general initiates when the LMA decides to move a particular flow from its default path to a different one. The LMA can decide on which is the best MAG that should be used to forward a particular flow when the flow is initiated e.g. based on application policy profiles) and/or during the lifetime of the flow upon receiving a network-based or a mobile-based trigger.

As an example of mobile-based triggers, the LMA could receive input (e.g.by means of a layer 2.5 function via L3 signalling [RFC5677]) from the MN detecting changes in the mobile wireless environment (e.g. weak radio signal, new network detected, etc.). Upon receiving these triggers, the LMA can initiate the flow mobility procedures. For instance, when the mobile node only supports single-radio operation (i.e. one radio transmitting at a time), only sequential (i.e. not simultaneous) attachment to different MAGs over different media is possible. In this case layer 2.5 signalling can be used to perform the inter-access technology handover and communicate to the LMA the desired target access technology, MN-ID, Flow-ID and prefix.

6. IANA Considerations

This specification does not require any IANA Actions.

7. Security Considerations

This specification explains the operational details of Logical interface on an IP host. The Logical Interface implementation on the host is not visible to the network and does not require any special security considerations.

8. Contributors

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