Internet Engineering Task Force (IETF)
Request for Comments: 7847
Category: Informational
ISSN: 2070-1721
May 2016

T. Melia, Ed.
Kudelski Security
S. Gundavelli, Ed.
Cisco

Logical-Interface Support for IP Hosts with Multi-Access Support

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. Logical-interface support is required on the mobile node attached to 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 the logical-interface construct and the specifics on how link-layer implementations hide the physical interfaces from the IP stack and from the network nodes on the attached access networks. Furthermore, this document identifies the applicability of this approach to various link-layer technologies and analyzes the issues around it when used in conjunction with various mobility management features.

Status of This Memo

Table of Contents

1. Introduction

Proxy Mobile IPv6 (PMIPv6) [RFC5213] is a network-based mobility management protocol standardized by IETF. One of the key goals of the PMIPv6 protocol is to enable a mobile node to perform handovers across access networks based on different access technologies. The protocol was also designed with the goal to allow a mobile node to simultaneously attach to different access networks and perform flow-based access selection [RFC7864]. The base protocol features specified in [RFC5213] and [RFC5844] have support for these capabilities. However, to support these features, the mobile node is required to be enabled with a specific software configuration known as logical-interface support. The logical-interface configuration is essential for a mobile node to perform inter-access handovers without impacting the IP sessions on the host.

A logical-interface construct is internal to the operating system. It is an approach of interface abstraction, where a logical link-layer implementation hides a variety of physical interfaces from the IP stack. This semantic was used on a variety of operating systems to implement applications such as Mobile IP client [RFC6275] and IPsec VPN client [RFC4301]. Many host operating systems have support for some form of such logical-interface construct. But, there is no specification that documents the behavior of these logical interfaces or the requirements of a logical interface for supporting the above-mentioned mobility management features. This specification attempts to document these aspects.

The rest of the document provides a functional description of a logical interface on the mobile node and the interworking between a mobile node using a logical interface and the network elements in the Proxy Mobile IPv6 domain. It also analyzes the issues involved with the use of a logical interface and characterizes the contexts in which such usage is appropriate.

2. Terminology

All the mobility-related terms used in this document are to be interpreted as defined in the Proxy Mobile IPv6 specifications [RFC5213] and [RFC5844]. In addition, this document uses the following terms:

PIF (Physical Interface): A network interface module on the host that is used for connecting to an access network. A host typically has a number of network interface modules, such as Ethernet, Wireless LAN, LTE, etc. Each of these network interfaces can support specific link technology.

LIF (Logical Interface): A virtual interface in the IP stack. A logical interface appears to the IP stack just as any other physical interface and provides similar semantics with respect to packet transmit and receive functions to the upper layers of the IP stack. However, it is only a logical construct and is not a representation of an instance of any physical hardware.

SIF (Sub-Interface): A physical or logical interface that is part of a logical-interface construct. For example, a logical interface may have been created by abstracting two physical interfaces, LTE and WLAN. These physical interfaces, LTE and WLAN, are referred to as sub-interfaces of that logical interface. In some cases, a sub-interface can also be another logical interface, such as an IPsec tunnel interface.

3. Hiding Link-Layer Technologies -- Approaches and Applicability

There are several techniques that allow hiding changes in access technology changes from the host layer. These changes in access technology are primarily due to the host's movement between access networks. This section classifies these existing techniques into a set of generic approaches, according to their most representative characteristics. Later sections of this document analyze the applicability of these solution approaches for supporting features, such as inter-technology handovers and IP flow mobility support for a mobile node.

3.1. Link-Layer Abstraction -- Approaches

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

o Link-Layer Support -- Certain link-layer technologies are able to hide physical media changes from the upper layers. For example, IEEE 802.11 is able to seamlessly change between IEEE 802.11a/b/g physical layers. Also, an 802.11 Station (STA) can move between different access points within the same domain without the IP stack being aware of the movement. In this case, the IEEE 802.11 Media Access Control (MAC) layer takes care of the mobility, making the media change invisible to the upper layers. Another example is IEEE 802.3, which supports changing the rate from 10 Mbps to 100 Mbps and to 1000 Mbps. Another example is the situation in the 3GPP Evolved Packet System [TS23401] where the User Equipment (UE) can perform inter-access handovers between three different access technologies (2G GSM/EDGE Radio Access Network (GERAN), 3G Universal Terrestrial Radio Access Network (UTRAN), and 4G Evolved UTRAN (E-UTRAN)) that are invisible to the IP layer at the UE.

- A logical interface denotes a mechanism that logically groups several physical interfaces so they appear to the IP layer as a single interface (see Figure 1). Depending on the type of access technologies, it might be possible to use more than one physical interface at a time -- such that the node is simultaneously attached via different access technologies -- or just perform handovers across a variety of physical interfaces. Controlling the way the different access technologies are used (simultaneous, sequential attachment, etc.) is not trivial and requires additional intelligence and/or configuration within the logical-interface implementation. The configuration is typically handled via a connection manager, and it is based on a combination of user preferences on one hand and operator preferences such as those provisioned by the Access Network Discovery and Selection Function (ANDSF) [TS23402] on the other hand. The IETF Interfaces MIB specified in [RFC2863] and the YANG data model for interface management specified in [RFC7223] treat a logical interface just like any other type of network interface on the host. This essentially makes the logical interface a natural operating system construct.

3.2. Link-Layer Support

Link-layer mobility support applies to cases in which the same link-layer technology is used and mobility can be fully handled at that layer. One example is the case where several 802.11 access points are deployed in the same subnet with a common IP-layer configuration (DHCP server, default router, etc.). In this case, the handover across access points need not be hidden to the IP layer since the IP-layer configuration remains the same after a handover. This type of scenario is applicable to cases when the different points of attachment (i.e., access points) belong to the same network domain, e.g., enterprise, hotspots from same operator, etc.

Since this type of link-layer technology does not typically allow for simultaneous attachment to different access networks of the same technology, the logical interface would not be used to provide simultaneous access for purposes of multihoming or flow mobility. Instead, the logical interface can be used to provide inter-access technology handover between this type of link-layer technology and another link-layer technology, e.g., between IEEE 802.11 and IEEE 802.16.

3.3. Logical Interface

The use of a logical interface allows the mobile node to provide a single-interface perspective to the IP layer and its upper layers (transport and application). Doing so allows inter-access technology handovers or application flow handovers to be hidden across different physical interfaces.

The logical interface 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 mobile access gateway (MAG) and local mobility anchor (LMA)) to deal with the logical interface, instead of using extensions to IP interfaces as currently specified in RFC 5213. RFC 5213 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.

It is therefore clear that the logical-interface approach satisfies the requirement of multi-access technology and supports both sequential and simultaneous access.

4. Technology Use Cases

3GPP has defined the Evolved Packet System (EPS) for heterogeneous wireless access. A mobile device equipped with 3GPP and non-3GPP wireless technologies can simultaneously or sequentially connect to any of the available access networks and receive IP services through any of them. This document focuses on employing a logical interface for simultaneous and sequential use of a variety of access technologies.

As mentioned in the previous sections, the logical-interface construct is able to hide from the IP layer the specifics of each technology in the context of network-based mobility (e.g., in multi-access technology networks based on PMIPv6). The LIF concept can be used with at least the following technologies: 3GPP access technologies (3G and LTE), IEEE 802.16 access technology, and IEEE 802.11 access technology.

In some UE implementations, the wireless connection setup is based on creation of a PPP interface between the IP layer and the wireless modem that is configured with the IP Control Protocol (IPCP) and IPv6 Control Protocol (IPv6CP) [RFC5072]. In this case, the PPP interface does not have any layer 2 (L2) addresses assigned. In some other implementations, the wireless modem is presented to the IP layer as a virtual Ethernet interface.

5. Logical-Interface Functional Details

This section identifies the functional details of a logical interface and provides some implementation considerations.

On most operating systems, a network interface is associated with a physical device that offers the services for transmitting and receiving IP packets from the network. In some configurations, a network interface can also be implemented as a logical interface, which does not have the inherent capability to transmit or receive packets on a physical medium, but relies on other physical interfaces for such services. An example of such configuration is an IP tunnel interface.

An overview of a logical interface is shown in Figure 1. The logical interface allows heterogeneous attachment while making changes in the underlying media transparent to the IP stack. Simultaneous and sequential network attachment procedures are therefore possible, enabling inter-technology and flow mobility scenarios.

```
                                  +----------------------------+
                                  |          TCP/UDP           |
           Session-to-IP    +---->|                            |
           Address Binding  |     +----------------------------+
                            +---->|             IP             |
           IP Address       +---->|                            |
           Binding          |     +----------------------------+
                            +---->|     Logical Interface      |
           Logical-to-      +---->|      IPv4/IPv6 Address     |
           Physical         |     +----------------------------+
           Interface        +---->|  L2  |  L2  |       |  L2  |
           Binding                |(IF#1)|(IF#2)| ..... |(IF#n)|
                                  +------+------+       +------+
                                  |  L1  |  L1  |       |  L1  |
                                  |      |      |       |      |
                                  +------+------+       +------+
```

Figure 1: General Overview of Logical Interface

From the perspective of the IP stack and the applications, a logical interface is just another interface. In fact, the logical interface is only visible to the IP and upper layers when enabled. A host does not see any operational difference between a logical and a physical interface. As with physical interfaces, a logical interface is represented as a software object to which IP address configuration is bound. However, the logical interface has some special properties that are essential for enabling inter-technology handover and flow-mobility features. Following are those properties:

1. The logical interface has a relation to a set of physical interfaces (sub-interfaces) on the host that it is abstracting. These sub-interfaces can be attached or detached from the logical interface at any time. The sub-interfaces attached to a logical interface are not visible to the IP and upper layers.

2. The logical interface may be attached to multiple access technologies.

3. The Transmit/Receive functions of the logical interface are mapped to the Transmit/Receive services exposed by the sub-interfaces. This mapping is dynamic, and any change is not visible to the upper layers of the IP stack.

4. The logical interface maintains IP flow information for each of its sub-interfaces. A conceptual data structure is maintained for this purpose. The host may populate this information based on tracking each of the sub-interfaces for the active flows.

5.1. Configuration of a Logical Interface

A host may be statically configured with the logical-interface configuration, or an application such as a connection manager on the host may dynamically create it. Furthermore, the set of sub-interfaces that are part of a logical-interface construct may be a fixed set or may be kept dynamic, with the sub-interfaces getting added or deleted as needed. The specific details related to these configuration aspects are implementation specific and are outside the scope of this document.

The IP layer should be configured with a default router reachable via the logical interface. The default router can be internal to the logical interface, i.e., it is a logical router that in turn decides which physical interface is to be used to transmit packets.

5.2. Logical-Interface Conceptual Data Structures

Every logical interface maintains a list of sub-interfaces that are part of that logical-interface construct. This is a conceptual data structure, called the LIF table. Figure 2 shows an example LIF table where logical interface LIF-1 has three sub-interfaces, ETH-0, WLAN-0, and LTE-0, and logical interface LIF-2 has two sub-interfaces, ETH-1 and WLAN-1. For each LIF entry, the table should store the associated link status and policy associated with that sub-interface (e.g., active or not active). The method by which the routing policies are configured on the host is out of scope for this document.

Logical_Interface	Sub_Interface	Status/Policy
LIF-1	ETH-0	UP
LIF-1	WLAN-0	DOWN
LIF-1	LTE-0	UP
LIF-2	ETH-1	UP
LIF-2	WLAN-1	UP

Figure 2: Logical-Interface Table

The logical interface also maintains the list of flows associated with a given sub-interface, and this conceptual data structure is called the Flow table. Figure 3 shows an example Flow table, where flows FID-1, FID-2, FID-3, FID-4, and FID-5 are associated with sub-interfaces ETH-0, WLAN-0, LTE-0, ETH-1, and WLAN-1, respectively.

Flow	Sub_Interface
FID-1	ETH-0
FID-2	WLAN-0
FID-3	LTE-0
FID-4	ETH-1
FID-5	WLAN-1

Figure 3: Flow Table

The Flow table allows the logical interface to properly route each IP flow over a specific sub-interface. The logical interface can identify the flows arriving on its sub-interfaces and associate them to those sub-interfaces. This approach is similar to reflective QoS performed by the IP routers. For locally generated traffic (e.g., unicast flows), the logical interface should perform interface selection based on the Flow Routing Policies. In case traffic of an existing flow is suddenly received from the network on a different sub-interface from the one locally stored, the logical interface should interpret the event as an explicit flow mobility trigger from the network, and it should update the corresponding entry in the Flow table. Similarly, locally generated events from the sub-interfaces or configuration updates to the local policy rules can cause updates to the table and hence trigger flow mobility.

6. 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.

6.1. Multihoming Support

Figure 4 shows a mobile node with multiple interfaces attached to a Proxy Mobile IPv6 domain. In this scenario, the mobile node is configured to use a logical interface over the physical interfaces through which it is attached.

```
                                  LMA Binding Table
                             +=========================+
                   +----+    | HNP   MN-ID  CoA   ATT |
                   |LMA |    +=========================+
                   +----+    | HNP-1 MN-1  PCoA-1  5  |
                    //\\     | HNP-1 MN-1  PCoA-2  4  |
         +---------//--\\-----------+
        (         //    \\           )
        (        //      \\          )
         +------//--------\\--------+
               //          \\
      PCoA-1 //             \\ PCoA-2
           +----+          +----+
   (WLAN) |MAG1|          |MAG2| (3GPP)
           +----+          +----+
              \                /
               \              /
                \            /
                 \          /
                  \        /
             +--------+ +--------+
             | if_1   | | if_2   |
             |(WLAN)  | |(3GPP)  |
             +--------+-+--------+
             |     Logical       |
             |    Interface      |
             |     (HNP-1)       |
             +-------------------|
             |        MN         |
             +-------------------+
```

Figure 4: Multihoming Support

6.2. Inter-technology Handoff Support

The Proxy Mobile IPv6 protocol enables a mobile node with multiple network interfaces to move between access technologies but still retain the same address configuration on its attached interface. Figure 5 shows a mobile node performing an inter-technology handoff between access networks. The protocol enables a mobile node to achieve address continuity during handoffs. If the host is configured to use a 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  |
                         |LMA |  +===========================+
                         +----+  | HNP-1   MN-1  PCoA-1  5   |
                          //\\                (pCoA-2)(4) <--change
                +---------//--\\-----------+
               (         //    \\           )
               (        //      \\          )
                +------//--------\\--------+
                      //          \\
               PCoA-1 //           \\ PCoA-2
                   +----+          +----+
            (WLAN) |MAG1|          |MAG2| (3GPP)
                   +----+          +----+
                      \                /
                       \   Handoff    /
                        \            /
                         \          /
                     +--------+ +--------+
                     | if_1   | | if_2   |
                     |(WLAN)  | |(3GPP)  |
                     +--------+-+--------+
                     |     Logical       |
                     |     Interface     |
                     |     (HNP-1)       |
                     +-----------------|
                     |        MN         |
                     +-----------------+
```

Figure 5: Inter-technology Handoff Support

o When the mobile node performs a handoff between if_1 and if_2, the change will not be visible to the applications of the mobile node.

- 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.

6.3. Flow Mobility Support

To support IP flow mobility, there is a need to support vertical handoff scenarios such as transferring a subset of a 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 6.2; 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 the best MAG to 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. However, the specific details on how the LMA can formulate such flow policy is outside the scope of this document.

7. Security Considerations

This specification explains the operational details of a 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.

Different layer 2 interfaces and the access networks to which they are connected have different security properties. For example, the layer 2 network security of a Wireless LAN network operated by an end user is in the control of the home user whereas an LTE operator has control of the layer 2 security of the LTE access network. An external entity using lawful means, or through other means, obtains the security keys from the LTE operator, but the same may not be possible in the case of a Wireless LAN network operated by a home user. Therefore, grouping interfaces with such varying security properties into one logical interface could have negative consequences in some cases. Such differences, though subtle, are entirely hidden by logical interfaces and are unknown to the upper layers.

8. References

8.1. Normative References

[RFC5213] Gundavelli, S., Ed., Leung, K., Devarapalli, V., Chowdhury, K., and B. Patil, "Proxy Mobile IPv6", RFC 5213, DOI 10.17487/RFC5213, August 2008, <http://www.rfc-editor.org/info/rfc5213>.

[RFC5844] Wakikawa, R. and S. Gundavelli, "IPv4 Support for Proxy Mobile IPv6", RFC 5844, DOI 10.17487/RFC5844, May 2010, <http://www.rfc-editor.org/info/rfc5844>.

8.2. Informative References

[RFC2863] McCloghrie, K. and F. Kastenholz, "The Interfaces Group MIB", RFC 2863, DOI 10.17487/RFC2863, June 2000, <http://www.rfc-editor.org/info/rfc2863>.

[RFC4301] Kent, S. and K. Seo, "Security Architecture for the Internet Protocol", RFC 4301, DOI 10.17487/RFC4301, December 2005, <http://www.rfc-editor.org/info/rfc4301>.

[RFC5072] Varada, S., Ed., Haskins, D., and E. Allen, "IP Version 6 over PPP", RFC 5072, DOI 10.17487/RFC5072, September 2007, <http://www.rfc-editor.org/info/rfc5072>.

[RFC6275] Perkins, C., Ed., Johnson, D., and J. Arkko, "Mobility Support in IPv6", RFC 6275, DOI 10.17487/RFC6275, July 2011, <http://www.rfc-editor.org/info/rfc6275>.

[RFC7223] Bjorklund, M., "A YANG Data Model for Interface Management", RFC 7223, DOI 10.17487/RFC7223, May 2014, <http://www.rfc-editor.org/info/rfc7223>.

[RFC7864] Bernardos, CJ., Ed., "Proxy Mobile IPv6 Extensions to Support Flow Mobility", RFC 7864, DOI 10.17487/RFC7864, May 2016, <http://www.rfc-editor.org/info/rfc7864>.

[TS23401] 3rd Generation Partnership Project, "Technical Specification Group Services and System Aspects; General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access", TS 23.401, V13.6.0, March 2016.

[TS23402] 3rd Generation Partnership Project, "Technical Specification Group Services and System Aspects; Architecture enhancements for non-3GPP accesses", TS 23.402, V13.5.0, March 2016.

Acknowledgements

The authors would like to acknowledge all the discussions on this topic in the NETLMM and NETEXT working groups. The authors would also like to thank Joo-Sang Youn, Pierrick Seite, Rajeev Koodli, Basavaraj Patil, Peter McCann, Julien Laganier, Maximilian Riegel, Georgios Karagian, Stephen Farrell, and Benoit Claise for their input to the document.

Contributors

This document reflects contributions from the following individuals (listed in alphabetical order):

Carlos Jesus Bernardos Cano
Email: cjbc@it.uc3m.es

Antonio De la Oliva
Email: aoliva@it.uc3m.es

Yong-Geun Hong
Email: yonggeun.hong@gmail.com

Kent Leung
Email: kleung@cisco.com

Tran Minh Trung
Email: trungtm2909@gmail.com

Hidetoshi Yokota
Email: yokota@kddilabs.jp

Juan Carlos Zuniga
Email: JuanCarlos.Zuniga@InterDigital.com

Authors' Addresses

Telemaco Melia (editor)
Kudelski Security
Geneva
Switzerland

Email: telemaco.melia@gmail.com

Sri Gundavelli (editor)
Cisco
170 West Tasman Drive
San Jose, CA 95134
United States

Email: sgundave@cisco.com