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ISP IPv6 Deployment Scenarios in Wireless Broadband Access Networks
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Status of this Memo

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Abstract

This document provides detailed description of IPv6 deployment and integration methods and scenarios in wireless broadband access networks in coexistence with deployed IPv4 services. In this document we will discuss main components of IPv6 IEEE 802.16 access network and its differences from IPv4 IEEE 802.16 networks and how IPv6 is deployed and integrated in each of the IEEE 802.16 technologies using tunneling mechanisms and native IPv6.

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1. Introduction

Recently, broadband wireless access network is emerging for wireless communication for user requirements such as high quality data/voice service, fast mobility, wide coverage, etc. The IEEE 802.16 Working Group on broadband wireless access standards develops standards and recommended practices to support the development and deployment of broadband wireless metropolitan area networks.

Whereas the existing IEEE 802.16 standard [IEEE802.16] addresses fixed wireless applications only, the IEEE 802.16(e) standard [IEEE802.16e] will serve the needs of fixed, nomadic, and fully mobile networks. It adds mobility support to the original standard so that mobile subscriber stations can move during services. Currently, the standardization of IEEE 802.16e is underway, which plans to support mobility up to speeds of 70~80 mile/h that will enable the subscribers to carry mobile devices such as PDAs, phones, or laptops. IEEE 802.16e is one of the most promising access technologies which would be applied to the IP-based broadband mobile communication.

WiMAX Forum is an industrial corporation formed to promote and certify compatibility and interoperability of broadband wireless products mainly based on IEEE 802.16. The Network Working Group (NWG) of WiMAX Forum is defining the IEEE 802.16 network architecture (e.g., IPv4, IPv6, Mobility, interworking with different networks, AAA, etc). Similarly, WiBro (Wireless Broadband), Korea effort which focuses on the 2.3 GHz spectrum band, is also based on the IEEE 802.16 specifications.

As the deployment of wireless broadband access network progresses, users will be connected to IPv6 networks. In this document we will discuss main components of IPv6 IEEE 802.16 access network and its differences from IPv4 IEEE 802.16 networks and how IPv6 is deployed and integrated in each of the IEEE 802.16 technologies using tunneling mechanisms and native IPv6.

This document extends works of [I-D.ietf-v6ops-bb-deployment-scenarios] follows the structure and common terminology of the draft.

2. Wireless Broadband Access Network Technologies - IEEE 802.16

This section describes the infrastructure that exists today in IEEE 802.16 networks providing wireless broadband services to the customer. It also describes IPv6 deployment options in these IEEE 802.16 networks.

2.1. IEEE 802.16 Networks Elements

The IEEE 802.11 access network (WLAN) has driven the revolution of wireless communication but the more people use it the more its limitations like short range or lack of mobility support were revealed. Compared with such IEEE 802.11 network, IEEE 802.16 supports enhanced features like wider range and mobility. So it is expected that IEEE 802.16 network could be the next step of IEEE 802.11 network.

The mechanism of transporting IP traffic over IEEE 802.16 networks is outlined in [IEEE802.16], but the details of IPv6 operations over IEEE 802.16 are being discussed now.

Here are some of the key elements of an IEEE 802.16 network:

SS: Subscriber Station. A general equipment set providing connectivity between subscriber equipment and a BS.

MS: Mobile Station. A station in the mobile service intended to be used while in motion or during halts at unspecified points. A mobile station (MS) is always a subscriber station (SS).

BS: Base Station. A generalized equipment set providing connectivity, management and control of MS connections. A unidirectional mapping between BS and MS medium access control (MAC) peers for the purpose of transporting a service flow's traffic. Connections are identified by a connection identifier (CID). All traffic is carried on a connection.

Figure 1 illustrates the key elements of IEEE 802.16(e) networks.

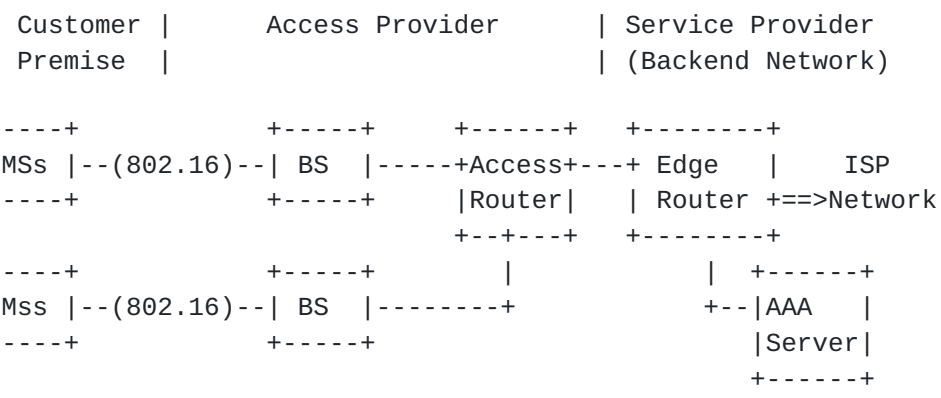

Figure 1: Key Elements of IEEE 802.16(e) Networks

2.2. Deploying IPv6 in IEEE 802.16 Networks

IEEE 802.16 supports two modes such as 2-way PMP (Point-to-Multipoint) and Mesh topology wireless networks. In this document, we focus on 2-way PMP topology wireless networks.

There are two different deployment options in current IEEE 802.16 networks: Cellular-like and Hot-zone deployment scenarios. IPv6 can be deployed in both of these deployment models.

A. Cellular-like Model

IEEE 802.16 BS can offer both fixed communications and mobile functions unlike IEEE 802.11. In particular, IEEE 802.16e working group has been standardizing the mobility features. The final specification of IEEE 802.16e will provide some competition to the existing cellular systems. This use case will be implemented only with the licensed spectrum. IEEE 802.16 BS might be deployed with a proprietary backend managed by an operator. All original IPv6 functionalities will not survive and some of them might be compromised to efficiently serve IPv6 to this 'Cellular-like' use case.

Under the use case, however, IEEE 802.16 standards are still IP-centric, providing packet-switched approach, while cellular standards like GSM have a more circuit-switched approach.

B. Hot Zone Model

The success of a Hotspot service with IEEE 802.11 has been prominent. The new IEEE 802.16 standards basically support such Hotspot services with large coverage area and high data rate. An area served by one base station is usually termed 'Hot Zone' because it is considerably larger than an IEEE 802.11 access point service area called Hotspot.

Large numbers of wireless Internet service providers (Wireless ISPs) have planned to use IEEE 802.16 for the purpose of high quality service. A company can use IEEE 802.16 to build up mobile office. Wireless Internet spreading through a campus or a cafe can be also implemented with it. The distinct point of this use case is that it can use unlicensed (2.4 & 5 GHz) band as well as licensed (2.6 & 3.5GHz) band. By using the unlicensed band, the IEEE 802.16 BS might be used just as a wireless hub which a user purchases to build a private wireless network in his/her home or laboratory.

Under 'Hot Zone' use case, the IEEE 802.16 BS will be deployed using an Ethernet (IP) backbone rather than a proprietary backend like cellular systems. Thus, many IPv6 functionalities will be preserved when adopting IPv6 to IEEE 802.16 devices.

Some of the factors that hinder deployment of native IPv6 core protocols include: [I-D.jee-16ng-problem-statement] [I-D.madanapalli-nd-over-802.16-problems].

1. Lacking of Facility for Native Multicasting

IEEE 802.16 is a PMP connection oriented technology without bi-directional native multicast support. IPv6 Neighbor discovery supports various functions for on-link determination and requires native multicast support. The consequence of the lack of optimal multicast supports in IEEE 802.16 is that any IP protocol (e.g. IPv4 ARP, DHCPv4, IPv6 NDP, DHCPv6 etc.) that depends on the lower layer multicast support may not be able to function normally. Especially, this lacking of facility for IPv6 native multicast results in inappropriateness to apply the standard Neighbor Discover Protocol specially regarding, address resolution, router discovery, stateless auto-configuration and duplicated address detection.

2. Impact of BS on Subnet Model

IEEE 802.16 is different from existing wireless access technologies such as IEEE 802.11 or 3G, and, while IEEE 802.16 defines the encapsulation of an IP datagram in an IEEE 802.16 MAC payload, complete description of IPv6 operation is not present. IEEE 802.16 can rather benefit from IETF input and specification to support IPv6 operation. Especially, BS should look at the classifiers and decide where to send the packet, since IEEE 802.16 connection always ends at BS, while IPv6 connection terminates at a default router. This operation and limitation may be dependent on the given subnet model.

Also, we should consider which type of Convergence Sublayers can be efficiently used on each subnet models. IEEE 802.16 Convergence Sublayer (CS) provides the tunneling of IP(v6) packets over IEEE

802.16 air-link. The tunnels are identified by the Connection Identifier (CID). Generally, CS performs the following functions in terms of IP packet transmission: 1) Receipt of protocol data units (PDUs) from the higher layer, 2) Performing classification and CID mapping of the PDUs, 3) Delivering the PDUs to the appropriate MAC SAP, 4) Receipt of PDUs from the peer MAC SAP. [IEEE802.16] defines several CSs for carrying IP packets, but does not provide a detailed description of how to carry them. The several CSs are classified into two types of CS: IP CS and Ethernet CS.

While deploying IPv6 in the above mentioned approach, there are four possible typical scenarios as discussed below.

2.2.1. Scenario A

Scenario A represents IEEE 802.16 access network deployment where a BS is integrated with a router, composing one box in view of implementation. In this scenario, a subnet consists of only single BS/router and single MS.

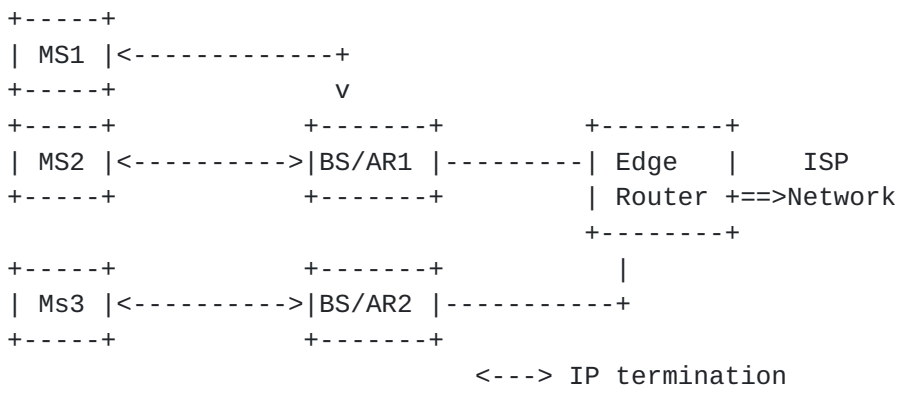

Figure 2: Scenario A

2.2.1.1. IPv6 Related Infrastructure Changes

IPv6 will be deployed in this scenario by upgrading the following devices to dual-stack: MS, BS/AR and Edge Router.

2.2.1.2. Addressing

IPv6 MS has two possible options to get an IPv6 address. These options will be equally applied to the other three scenarios below.

1. IPv6 MS can get the IPv6 address from an access router using stateless auto-configuration.

In this case Celluar-like IPv6 addressing scheme [RFC 3314] can be

used. That is, a unique prefix can be allocated to each MS. [RFC 3314] recommends that a given prefix should be assigned to only one primary PDP context so that 3GPP terminals are allowed to generate multiple IPv6 address using the prefix without the concerns of address confliction (DAD).

2. IPv6 MS can use DHCPv6 to get an IPv6 address from the DHCPv6 server. In this case the DHCPv6 server would be located in the service provider core network and Edge Router would simply act as a DHCP Relay Agent. This option is similar to what we do today in case of DHCPv4.

2.2.1.3. IPv6 Control and Data Transport

In this scenario, IEEE 802.16 connection and IPv6 termination point are the same, since a BS is integrated with a router. In addition, each MS can be on different IPv6 link. So, many IPv6 protocols can be operated without much consideration about the underlying network implementation.

Only IEEE 802.16 link will be taken into consideration for IPv6 adoption. For example, DAD operation is not needed since each MS has only a well-known neighbor, a router. The operation and transmission methods are being intensively discussed in other documents [I-D.shin-16ng-ipv6-transmission].

Note that in this scenario IP(v6) Convergence Sublayer (CS) type may be more suitable to transport IPv6 packets rather than Ethernet CS type.

The service providers are deploying tunneling mechanisms to transport IPv6 over their existing IPv4 networks as well as deploying native IPv6 where possible. Native IPv6 should be preferred over tunneling mechanisms as native IPv6 deployment option might be more scalable and provide required service performance. Tunneling mechanisms should only be used when native IPv6 deployment is not an option. This is can be equally applied to other scenarios - B, C, D.

2.2.1.4. Routing

In general, MS/Router is configured with a default route that points to the Edge Router.

No routing protocols are needed on these devices which generally have limited resources.

The Edge Router runs the IGP used in the SP network such as OSPFv3 or IS-IS for IPv6. The connected prefixes have to be redistributed.

Prefix summarization should be done at the Edge Router.

2.2.2. Scenario B

Scenario B represents IEEE 802.16 access network deployment where a BS is integrated with a router, composing one box in view of implementation, and a subnet consists of only single BS/router and multiple MSs.

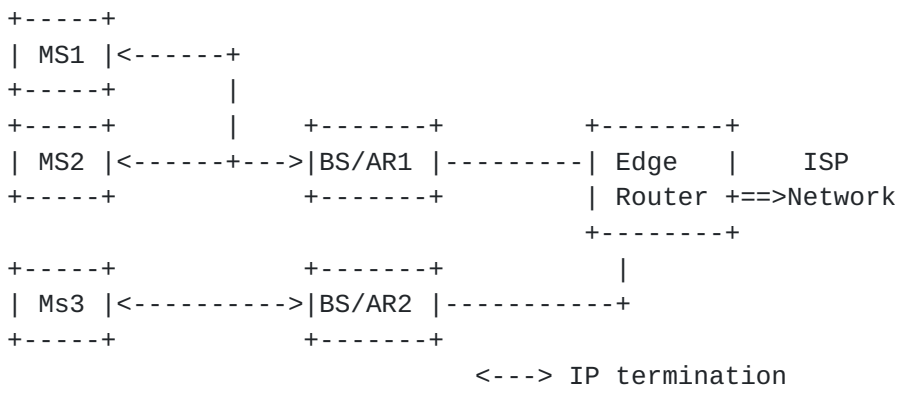

Figure 3: Scenario B

2.2.2.1. IPv6 Related Infrastructure Changes

IPv6 will be deployed in this scenario by upgrading the following devices to dual-stack: MS, BS/AR and Edge Router.

2.2.2.2. Addressing

In this scenario, a single prefix is allocated to all the attached MS. All MSs attached to same BS can be on same IPv6 link.

2.2.2.3. IPv6 Control and Data Transport

If stateless auto-configuration is used to get an IPv6 address, router discovery and DAD operations should be properly operated over IEEE 802.16 link. So, AR/BS must support IPv6 basic protocols such as ND using multicast emulation functions.

The operation and transmission methods are being intensively discussed in other documents [I-D.shin-16ng-ipv6-transmission]. Note that in this scenario Ethernet CS as well as IP CS may be used to transport IPv6 packets.

2.2.2.4. Routing

In general, MS/Router is configured with a default route that points

to the Edge router. No routing protocols are needed on these devices which generally have limited resources.

The Edge Router runs the IGP used in the SP network such as OSPFv3 or IS-IS for IPv6. The connected prefixes have to be redistributed. Prefix summarization should be done at the Edge Router.

2.2.3. Scenario C

Scenario C represents IEEE 802.16 access network deployment where a BS is separated from a router, and a subnet consists of only single BS, single router and multiple MSs.

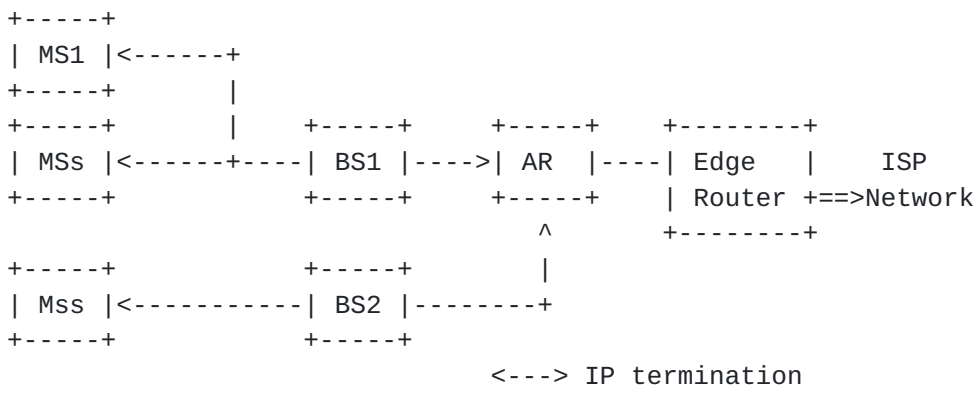

Figure 4: Scenario C

2.2.3.1. IPv6 Related Infrastructure Changes

IPv6 will be deployed in this scenario by upgrading the following devices to dual-stack: MS, BS (if possible), AR and Edge Router.

In this scenario the BS is Layer 3 unaware, so no changes are needed to support IPv6, but actually, BS should have functionalities for emulation of IPv6 NDP, multicast, etc. In addition, for management and configuration purpose, IPv4 stack is loaded to them, BS should be upgraded to IPv6, too.

2.2.3.2. Addressing

In Figure 4, routers are located separated with IEEE 802.16 BSs. In this case, IEEE 802.16 BSs have only MAC and PHY layers without router function. A router and one BS form an IPv6 subnet. Like scenario B, all Mss attached to same BS can be on same IPv6 link.

2.2.3.3. IPv6 Control and Data Transport

In a subnet, therefore, there are always two underlying links

including IEEE 802.16 wireless link between MS and BS.

If stateless auto-configuration is used to get an IPv6 address, router discovery and DAD operations should be properly operated over IEEE 802.16 link. So, AR/BS must support IPv6 basic protocols such as ND using multicast emulation functions. Especially, IEEE 802.16 connection terminates at BS, not a router. So, BS should look at the classifiers and decide where to send the packet.

The operation and transmission methods are being intensively discussed in other documents [I-D.shin-16ng-ipv6-transmission]. Note that in this scenario Ethernet CS as well as IP CS may be used to transport IPv6 packets.

Simple or complex network equipments may constitute the underlying wired network between BS and router. If the IP aware equipments do not support IPv6, the service providers are deploying IPv6-in-IPv4 tunneling mechanisms to transport IPv6 packets between an AR and an Edge router.

2.2.3.4. Routing

In general, MS/Router is configured with a default route that points to the Edge router. No routing protocols are needed on these devices which generally have limited resources.

The Edge Router runs the IGP used in the SP network such as OSPFv3 or IS-IS for IPv6. The connected prefixes have to be redistributed. Prefix summarization should be done at the Edge Router.

2.2.4. Scenario D

Scenario D represents IEEE 802.16 network deployment where a BS is separated from a router, and a subnet consists of multiple BS and multiple MSs.

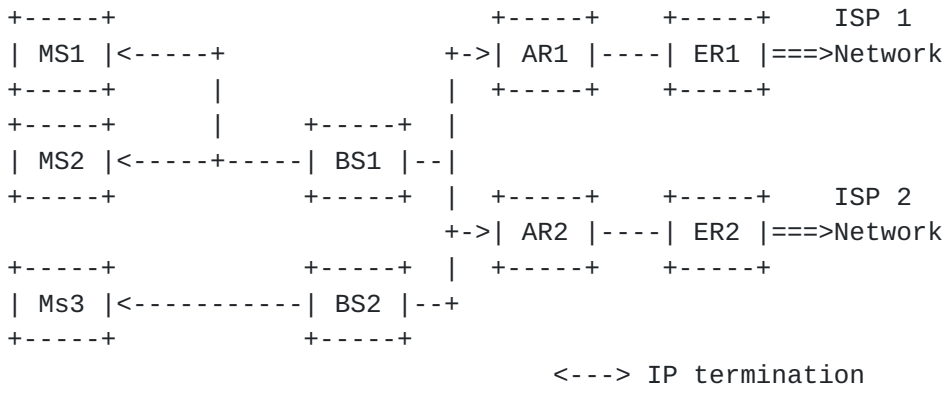

Figure 5: Scenario C

2.2.4.1. IPv6 Related Infrastructure Changes

IPv6 will be deployed in this scenario by upgrading the following devices to dual-stack: MS, BS (if possible), AR and Edge Router.

In this scenario the BS is Layer 3 unaware, so no changes are needed to support IPv6, but actually, BS should have functionalities for emulation of IPv6 NDP, multicast, etc. In addition, for management and configuration purpose, IPv4 stack is loaded to them, BS should be upgraded to IPv6, too.

2.2.4.2. Addressing

In Figure 5, routers are located separated with IEEE 802.16 BSs. In this case, IEEE 802.16 BSs have only MAC and PHY layers without router function. A router and multiple BSs and MSs form an IPv6 subnet. All MSs attached to different BSs, as well as same BS can be on same IPv6 link.

2.2.4.3. IPv6 Control and Data Transport

Like scenario C, in a subnet, therefore, there are always two underlying links including IEEE 802.16 wireless link between MS and BS. Moreover, there are multiple BSs on the same link.

If stateless auto-configuration is used to get an IPv6 address, router discovery and DAD operations should be properly operated over IEEE 802.16 link. So, AR/BS must support IPv6 basic protocols such as ND using multicast emulation functions. Especially, IEEE 802.16 connection terminates at BS, not a router. So, BS should look at the classifiers and decide where to send the packet. In addition, one BS can send the packet to other BSs, since multiple BSs are on the same link.

The operation and transmission methods are being intensively discussed in other documents [I-D.shin-16ng-ipv6-transmission]. Note that in this scenario Ethernet CS may be more suitable to transport IPv6 packets, rather than IP CS.

Simple or complex network equipments may constitute the underlying wired network between BS and router. If the IP aware equipments do not support IPv6, the service providers are deploying IPv6-in-IPv4 tunneling mechanisms to transport IPv6 packets between an AR and an Edge router.

2.2.4.4. Routing

In this scenario, IPv6 multi-homing considerations exist. For example, there are two routers, so default router must be selected.

The Edge Router runs the IGP used in the SP network such as OSPFv3 or IS-IS for IPv6. The connected prefixes have to be redistributed. Prefix summarization should be done at the Edge Router.

2.3. IPv6 Multicast

In order to support multicast services in IEEE 802.16, Multicast Listener Discovery (MLD)[RFC2710] must be supported between the MS and BS/Router. Also, the inter-working with IP multicast protocols and Multicast and Broadcast Service (MBS) should be considered.

Within IEEE 802.16 networks, an MS connects to its BS/router via point-to-point links. MLD allows an MS to send link-local multicast destination queries and reports. The packets are transmitted as normal IEEE 802.16 MAC frames, as the same as regular unicast packets. Especially, multicast CIDs can be used to transmit efficiently query packets on the downlink.

There are exactly two IP devices connected to the point-to-point link, and no attempt is made (at the link-layer) to suppress the forwarding of multicast traffic. Consequently, sending MLD reports for link-local addresses in IEEE 802.16 network environment may not always be necessary. MLD is needed for multicast group knowledge that is not link-local.

MBS defines Multicast and Broadcast Services, but actually, MBS seems to be a broadcast service, not multicasting. MBS adheres to broadcast services, while traditional IP multicast schemes define multicast routing using a shared tree or source-specific tree to deliver packets efficiently.

In IEEE 802.16 networks, two types of access to MBS may be supported: single-BS access and multi-BS access. Therefore, these two types of services may be roughly mapped into Source-Specific Multicast.

Note that it should be intensively researched later, since MBS will be one of the killer services in IEEE 802.16 networks.

2.4. IPv6 Mobility

As for mobility management, the movement between BSs is handled by Mobile IPv6 [RFC3775], if it requires a subnet change. Also, in certain cases (e.g., fast handover [I-D.ietf-mipshop-fast-mipv6]) the

link mobility information must be available for facilitating layer 3 handoff procedure.

Mobile IPv6 defines that movement detection uses Neighbor Unreachability Detection to detect when the default router is no longer bi-directionally reachable, in which case the mobile node must discover a new default router. Periodic Router Advertisements for reachability and movement detection may be unnecessary because IEEE 802.16 MAC provides the reachability by its Ranging procedure and the movement detection by the Handoff procedure.

In addition, IEEE 802.16 defines L2 triggers whether refresh of an IP address is required during the handoff. Though a handoff has occurred, an additional router discovery procedure is not required in case of intra-subnet handoff. Also, faster handoff may be occurred by the L2 trigger in case of inter-subnet handoff.

Also, IEEE 802.16g which is under-developed defines L2 triggers for link status such as link-up, link-down, handoff-start. These L2 triggers may make Mobile IPv6 procedure more efficient and faster. In addition, Mobile IPv6 Fast Handover assumes the support from link-layer technology, but the particular link-layer information being available, as well as the timing of its availability (before, during or after a handover has occurred), differs according to the particular link-layer technology in use.

This issue is also being discussed in [I-D.jang-mipshop-fh80216e].

2.5. IPv6 QoS

In IEEE 802.16 networks, a connection is unidirectional and has a QoS specification. The QoS has different semantics with IP QoS (e.g., diffserv). Mapping CID to Service Flow IDentifier (SFID) defines QoS parameters of the service flow associated with that connection. In order to interwork with IP QoS, IP QoS (e.g., diffserv, or flow label for IPv6) mapping should be provided.

2.6. IPv6 Security

When initiating the connection, the MS is authenticated by the AAA server located at the service provider network. All the parameters related to authentication (username, password and etc.) are forwarded by the BS to the AAA server. The AAA server authenticates the MSs and once authenticated and associated successfully with BS, IPv6 address will be acquired by the MS. Note the initiation and authentication process is the same as used in IPv4.

IPsec is a fundamental part of IPv6. Unlike IPv4, IPsec for IPv6 may

be used within the global end-to-end architecture. But, we don't have PKIs across organizations and IPsec isn't integrated with IEEE 802.16 network mobility management.

IEEE 802.16 network threats may be different with IPv6 and IPv6 transition threat models [I-D.ietf-v6ops-security-overview]. It will be discussed later.

2.7. IPv6 Network Management

The necessary instrumentation (such as MIBs, NetFlow Records, etc) should be available for IPv6.

Upon entering the network, an MS is assigned three management connections in each direction. These three connections reflect the three different QoS requirements used by different management levels. The first of these is the basic connection, which is used for the transfer of short, time-critical MAC and radio link control (RLC) messages. The primary management connection is used to transfer longer, more delay-tolerant messages such as those used for authentication and connection setup. The secondary management connection is used for the transfer of standards-based management messages such as Dynamic Host Configuration Protocol (DHCP), Trivial File Transfer Protocol (TFTP), and Simple Network Management Protocol (SNMP).

3. IANA Considerations

This document requests no action by IANA.

4. Security Considerations

Please refer to sec 2.5 "IPv6 Security" technology sections for details.

5. Acknowledgements

This work extends v6ops works on [I-D.ietf-v6ops-bb-deployment-scenarios]. We thank all the authors of the draft.

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