IPv6: Mobility Management and Roaming between IPv6 and IPv4

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Abstract

Mobility is becoming ubiquitous now-a-days; there have been tremendous advances in the next generation mobile communication systems recently, thereby, engendering the need to support all the advancements arising from new theories, algorithms, architectures, standards and protocols. Mobility management has been a growing concern in IPv6 with numerous problems originating from roaming between IPv6 access networks and IPv4 access networks owing to ever-growing research. This paper attempts to succinctly address the enhancement(s) required for IPv6 mobility management protocols for future access networks. Further, the solutions for roaming issues between IPv6 and IPv4 networks have also been highlighted.

1. Introduction

Mobility in cell-phones allows the accessibility to Internet on migration from one place or another for which is required a mobile VPN. Mobile IPv4 is a protocol that is employed by the mobile host with the premise of utilizing an IP address assigned in home network when accessing Internet at a foreign location(s). However, on account of investigated security reasons, address space constraints, accessibility to diverse networks etc., cellular phone service providers needed to adopt the proposed solution in form of IPv6 as a network protocol in near future [1]. The driving impulse here is: though new network protocols and mechanisms can be introduced easily by a small software upgrade in all (plethora) of handsets but eternal increase in critical mass of users and the networks deployed to support them have rendered it a difficult option to pursue, thereby, calling the researched IPv6 as proposed path to success in terms of eliminating the severe limitations of IPv4. The issue that has cropped is although there are solutions for mobility for IPv4 and IPv6, these do not solve the problems within a mixed network environment. This serves as the motivation for this paper to endeavor understanding the mobility solutions between IPv4 and IPv6 networks under such considerations.

2. IPv6 Overview

IPv6 was designed to be an evolutionary step from IPv4. It was not a design goal to take a radical step away from IPv4. The changes from IPv4 to IPv6 fall primarily into the following categories:

Expanded Routing and Addressing Capabilities- IPv6 increases the IP address space from 32 bits to 128 bits to support more levels of addressing hierarchy and provides support for much greater number of addressable nodes, and simpler auto-configuration of addresses.

The scalability of multicast routing is improved by adding a "scope" field to multicast addresses.

Header Format Simplification- Some IPv4 header fields have been dropped or made optional, to reduce the common-case processing cost of packet handling and to keep the bandwidth cost of the IPv6 header as low as possible despite the increased size of the addresses. Even though the IPv6 addresses are four times longer than the IPv4 addresses, the IPv6 header is only twice the size of the IPv4 header.

Improved Support for Options- Changes in the way IP header options are encoded allows for more efficient forwarding, less stringent limits on the length of options, and greater flexibility for introducing new options in the future.

Quality-of-Service Capabilities- A new capability is added to enable the labeling of packets belonging to particular traffic "flows" for which the sender requests special handling, such as non-default quality of service or "real-time" service.

Authentication and Privacy Capabilities- IPv6 includes the definition of extensions, which provide support for authentication, data integrity, and confidentiality. This is included as a basic element of IPv6 and will be included in all implementations.

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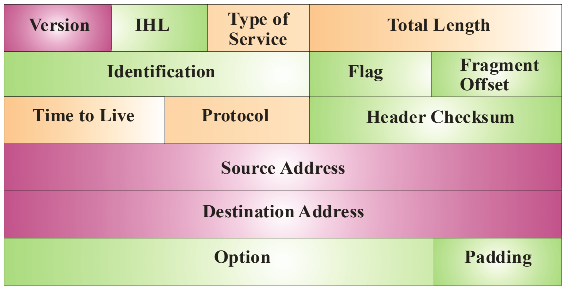

Fig. 1. IPv4 Header

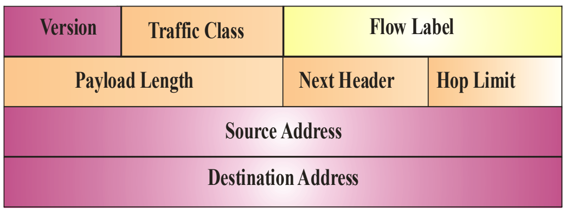

Fig. 2. IPv6 Header

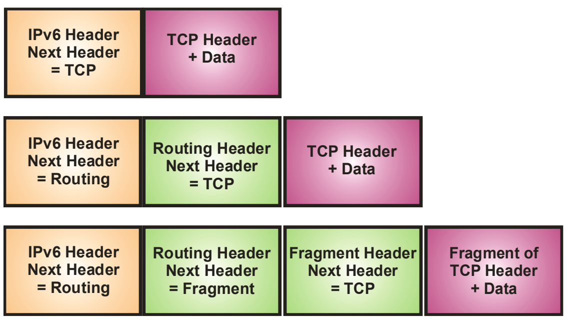

Fig. 3. IPv6 Header Option

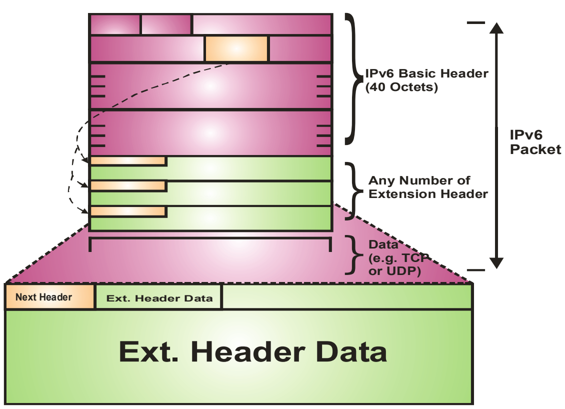

Fig. 4. IPv6 Extension Header

3. Mobility Management Features in IPv6

The mobility management features in IPv6 are:

1. *128-bit address* space provides a sufficiently large number of addresses
2. *High quality support* for real-time audio and video transmission, short/bursty connections of web applications, peer-to-peer applications, etc.
3. *Faster packet delivery*, decreased cost of processing –no header checksum at each relay, fragmentation only at endpoints.
4. *Smooth handoff* when the mobile host travels from one subnet to another, causing a change in its Care-of Address.

3.1. Enhancements to IPv6 Mobility Management Protocols Required for Future Network

Although the features mentioned above are suited for future networks, recently, there has been almost universal recognition that IPv6 needs to be enhanced to meet the need for future cellular environments [3]. In particular, the absence of a location management hierarchy (IPv6 uses only simple location updates for location management) leads to concerns about the signalling scalability and handoff latency. This is especially significant when we consider that fourth generation mobile communication systems aims at providing mobility support to potentially billions of mobile devices, within the stringent performance bounds associated with real time multimedia traffic.

There are three main areas where IPv6 needs to be enhanced before being used as the core networking protocol in future networks:

1). *Paging Support*: The base IPv6 specification does not provide any form of paging support. Hence to maintain connectivity with the backbone infrastructure, the mobile node needs to generate location updates every time it changes its point of attachment, even if it is currently in dormant or standby mode. Excessive signaling caused by frequent motion leads to a significant wastage of the mobile node's battery power, especially in environments with smaller cell areas (such as 802.11 based cellular topologies). It is thus impractical to rely completely on location updates, and becomes essential to define some sort of flexible paging support in the intra-domain mobility management scheme.

2) *Scalability*: IPv6 [4] allows nodes to move within the Internet topology while maintaining reachability and on-going connections between mobile and correspondent nodes. To do this a mobile node sends Binding Updates (BUs) to its Home Agent (HA) and all Correspondent Nodes (CNs) it communicates with, every time it moves. Authenticating binding updates requires approximately 1.5 round trip times between the mobile node and each correspondent node (for the entire return routability procedure in a best

case scenario, i.e. no packet losses). In addition one round trip time is needed to update the HA; this can be done simultaneously while updating CNs

These round trip delays will disrupt active connections every time a handoff to a new radio access technology is performed. Eliminating this additional delay element from the time-critical handover period will significantly improve the performance of IPv6. Moreover, in the case of wireless links, such a solution reduces the number of messages sent over the air interface to all CNs and the HA. A local anchor point will allow Mobile IPv6 to benefit from reduced mobility signalling with external networks. For these reasons a new Mobile IPv6 node, called the Mobility Anchor Point (MAP) is being suggested, that can be located at any level in a hierarchical network of routers. Unlike Foreign Agents in IPv4, a MAP is not required on each subnet. The MAP will limit the amount of Mobile IPv6 signalling outside the local domain. The solutions to the aforementioned problems are - (i) The MN sends binding updates to the local MAP rather than the HA (that is typically further away) and CNs . (ii) Only one binding update message needs to be transmitted by the MN before traffic from the HA and all CNs is re-routed to its new location. This is independent of the number of CNs that the MN is communicating with [5].

Thus, by decreasing signalling traffic, having an intermediate level in the hierarchy helps accommodate a larger number of mobile nodes in the system.

3). *Heterogeneous Access Technologies*: A mobile node switches from one network based on an access network technology like GPRS to another network based on a different access technology like WLAN in one of two cases: (a) When the signal from the network it is currently in starts to become weak, or (b) When the mobile host detects another network which is better suited to its application compared to its current network.

The decision of the mobile device on the suitability of the network can be based on signal strength, network bandwidth or certain policies which the user might have stored in his profile based on which switching between networks of different access technologies may occur. For example, when a user is streaming a video, she may use WLAN and when she is listening to highly compressed audio, she might switch to GPRS.

Further, another issue that needs to be resolved is that of informing the source/HA/CH when the MN has moved. In such a situation, the MN does a location update to its HA, which then takes charge of sending IP datagrams to the MN's new location using standard Mobile-IP mechanisms. However, these mechanisms are inadequate. In line with the 4G vision of bringing together wide-area (such as GPRS) and local-area packet-based (such as 802.11) technologies, mobile terminals are being designed with multiple physical or software-defined interfaces [6]. This is expected to allow users to seamlessly switch between different access technologies, often with overlapping areas of coverage and dramatically different cell sizes. Mobility management protocols should then be capable of handling vertical handoffs.

3.2. Present Solutions for IP Mobility

The two methods, Mobile IPv4 and Mobile IPv6 exist today and are described here in brief.

3.2.1. Mobile IPv4. The normal operation of Internet routers is to forward packets to the destination network as indicated by the destination IP address. Routing tables typically maintain the next-hop information for each destination IP network. The IP address identifies a network interface. However, as the Internet architecture has evolved, the network interfaces have come to be numbered by which network they are attached to. Thus, the IP address has in practice two functions. This means that the IP address has to change at a new point of attachment. To alter the routing of IP packets intended for a mobile client to the new point of attachment requires a new IP number associated with that new point of attachment. However, to maintain existing transport protocol layer connections as the client moves, the mobile client's IP address must remain the same. Mobile IP solves this problem by introducing two new functional entities within IP networks. Those are the Foreign Agent, FA and the Home Agent, HA. The two new entities together with enhancements in the Mobile Node (client), MN, are the basic building blocks for a Mobile IP enabled network. The last entity needed to provide a full reference for a basic Mobile IP enabled network is the Correspondent Node, CN. The CN is another IP entity, for example an Internet Server with which the MN communicates. Mobile IP is transparent to the CN, while the mobile host itself must implement the Mobile IP protocol [7].

3.2.2 Mobile IPv6. Mobile IPv6 is based on the concepts of Mobile IPv4, but as Mobile IPv6 is a part of the IPv6 standard the protocol is easily integrable into IPv6. This allows the correspondent nodes to the Mobile IPv6 aware which makes it possible to introduce security mechanisms for route optimization. There is no FA in Mobile IPv6, this is due to new functionality in IPv6 where IPv6 Neighbor Discovery and Address Auto-configuration allow hosts to operate in any location without any special support. Mobile IPv6 extends IPv6 by introducing new destination options to IPv6. The new options are Binding Update, Binding Acknowledgement and Home Address Option. The destination options are equivalent to the registration message of Mobile IPv4, except the Binding Request and Home Address option. However, because the options are carried to the destination options extension header of IPv6, the options can be piggybacked with any outgoing datagram with correct destination instead of having to send a separate UDP packet.

4. Roaming Between IPv4 and IPv6 Access Networks

This can be solved by mechanisms dual stack mobile IPv6

Dual Stack Mobile IPv6: IPv4 extensions to the Mobile IPv6 protocol are provided by dual stack Mobile IPv6. A node that has IPv4 and IPv6 addresses are being allowed by the above extension to roam within the Internet using Mobile IPv6 only, and at the same time maintaining connections using their IPv4 and IPv6 home addresses. When the mobile user is located on a dual stack or IPv6 only access network, the Mobile IPv6 signalling is sent over IPv6 to the Home Agent. When the mobile user is located on an IPv4 only access network, the Mobile IPv6 send the signals to IPv6 to the home agent. The dual stack mobile IPv6 mechanism has a drawback that it does not handle situations when only private IPv4 addresses are available in the access network, which is a common situation.

In this solution, the MN registers over IPv6 with the HA, and by using new extensions it is possible to transfer IPv4 traffic in the IPv6 tunnel as well as IPv6 traffic. The problem of IPv4 mobility from IPv6 access network is solved by this solution and also allows the users to use IPv6 mobility as well. Mobile IPv4 is used as normal for IPv4 mobility when a user moves from the IPv6 access network to an IPv4 access network. This solution is quite good if the IPv6 services are used in the home network. However those companies that have invested money in mobility solutions for IPv4 and only use IPv4 in their home network will not invest further money for IPv6 mobility so as to use IPv6 access network to maintain IPv4 mobility, also the vendors of Mobile IPv4 solutions will not include Mobile IPv6 support in their Mobile IPv4 solutions because it will require a large implementation effort to introduce Mobile IPv6 support. Thus a simpler solution is required that can be easily introduced as a part of IPv4 solution. The cost of implementation has to be also kept in mind. For Mobile IP vendors it is easy to implement Mobile IPv4 over IPv6 solutions because the Mobile users does not require to be aware of the network protocol used in the access network.

4.1. Mobile IPv4 over IPv6

The proposed way to solve the problem of running IPv4 applications when attached to IPv6 access networks is to extend Mobile IPv4 with the possibility to register over IPv6. The method has been named Mobile IPv4 over IPv6, as it is essentially Mobile IPv4 that is transported over IPv6. There exist a few prerequisites in order to use Mobile IPv4 over IPv6. (1)The Home Agent must be globally reachable through an IPv6 address. (2) The Mobile Node needs to know the IPv6 address of the Home Agent.

A Mobile Node is attached to an IPv6 access network, can configure itself with an IPv6 address using stateless or stateful address auto-configuration, or possibly DHCPv6. When the Mobile Node notices of being itself attached to an IPv6 network, it sends a Mobile IPv4 Registration Request in an IPv6 UDP datagram to the IPv6 address of the Home Agent. The Home Agent sets up IPv4 in IPv6 tunneling towards the Mobile Node and sends a Registration Reply back to the Mobile Node. For this to work, a new Mobile IPv4 extension needs to be defined that can store the IPv6 Care-of address of the Mobile Node as the care-of address field in the Registration Request is too small. This extension is attached to the Registration Request that is sent to the Home Agent. This solution will allow the mobile user to run IPv4 application while attached to an IPv6 access network. It even allows the Mobile IPv4 user to seamlessly roam between IPv4 and IPv6 access networks, which means that a mobile user that is running IPv4 applications does not need to be aware of the Internet protocol used in the access network.

4.2. IPv6 over Mobile IPv4

Mobile IPv4 over IPv6 solves the situation when the home network of the mobile user is running IPv4 and the mobile user wants to run IPv4 applications, while being away from the home network. If the home network is running IPv6, Mobile IPv6 can be used to allow the mobile user to run IPv6 applications. If the user is attached to an IPv4 access network, Mobile IPv6 services would not be available. One solution to solve this is to use IPv6 over Mobile IPv4, as specified in Dual MIPv4 [8]. This requires that the home network is dual stack as the registration is done using the IPv4 home address for the Mobile user. The registration request is extended with an IPv6 address extension which the Mobile Node can use to request usage of the IPv6 home address, or an assigned dynamic IPv6 address [9]. The Home Agent responds with a registration reply where the IPv6 address extension contains the IPv6 address to use.

5. The Complete Mobility Solution

If the home network of a mobile user is running IPv46 services on the same network, mobile users will need to be dual stack configured. In order to reach all services in the mixed environment of the home network, while outside the premises and away from the home network, a complete mobility solution for IPv4 and IPv6 mobility needs to be set up.

5.1. Combined Mobile IPv4 and Mobile IPv6 Solution

By combining the methods discussed in this thesis, it is possible to set up a complete solution for IPv4 and IPv6 mobility. In this environment, Mobile Nodes will have to be dual stack and Home Agents for Mobile IPv4 and IPv6 has to be set up in the home network. When the mobile user moves out from the corporate premises and connect to an access network, via cellular phone service, wireless LAN or LAN for instance, the user should be able to register with its Home Agent, either via IPv4, IPv6 or both in order to achieve mobility for both IPv4 and IPv6.

Table I. Mechanisms used for a combined environment

Mechanism	Specialization
Mobile IPv4	An IETF proposed standard specified in RFC 3344
Mobile IPv6	An IETF Internet draft named 'Mobility Support in Ipv6', draft-ietf – Mobile Ipv6-24 txt Soon to become an IEFT proposed standard.
IPpv6 over Mobile IPpv4	A personal draft named 'Dual Stack Mobile Ipv4', draft –tsirtsisp- v4v6-mipv6-00 txt
IPpv4 over Mobile IPpv6	A personal draft named 'Dual Stack Mobile Ipv6', draft soliman-v4v6-mipv4-00 txt
Mobile IPv4 over IPv6	A proprietary mechanism for ipUnplugged, developed during this master thesis.

There are different ways the mobile user can achieve mobility depending on the type of access network used. By combining the mechanisms as illustrated in table I in different ways, IPv4 and IPv6 mobility can be achieved from any access network.

The table II here illustrates the possible types of attachment to access networks, and which of the mechanisms that can be combined to achieve mobility in these access networks. As seen in the table II here that there are two ways to achieve mobility for IPv4 when attached to an IPv6 access network. One is IPv4 over MIPv6, but as this requires a full Mobile IPv6 implementation as well as IPv4 over Mobile IPv6 implementation in the Mobile Node and Home Agent.

Table II: Mobility from All Access Networks

Mobility / **Access network**	**IPv4 Mobility**	**IPv6 Mobility**	**IPv4 and IPv6 mobility**
IPv4	MIPv4	IPv6 over MIPv4	MPv4 + IPv6 over MIPv4
IPv6	MIPv4 over IPv6 IPv4 over MIPv6	MIPv6	MIPv4 over IPv6 + MIPv6 IPv4 over MIPv6 + MIPv6
Dual Stack	MIPv4	MIPv6	MIPv4 + MIPv6 MIPv4 + IPv6 over MIPv4 MIPv6 + IPv4 over MIPv6 MIPv6 + MIPv4 over IPv6

From a dual stack access network, there are numerous ways to achieve IPv4 and IPv6 mobility, but the most attractive of them is probably to use Mobile IPv4 and Mobile IPv6 separately as this allows the use of separate mobility solutions for IPv4 and IPv6. On the other hand, if fast had over times are essential, for voice over IP usage for instance, a combined solution that requires only one registration might be more attractive.

6. Deployment Scenarios

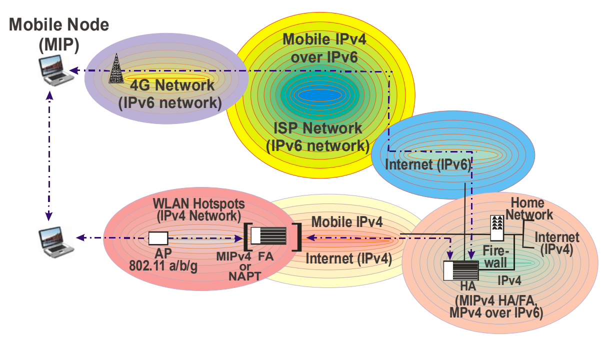

Fig. 5. Mobile IPv4 over IPv6 deployment scenario.

The Mobile IPv4 over IPv6 solution can be deployed as shown in fig. 5 where the Home Agent is accessible from the IPv4 and IPv6 Internet. A deployment such as this allow mobile nodes to security access IPpv4 services in the home network from IPv4 and IPv6 access networks.

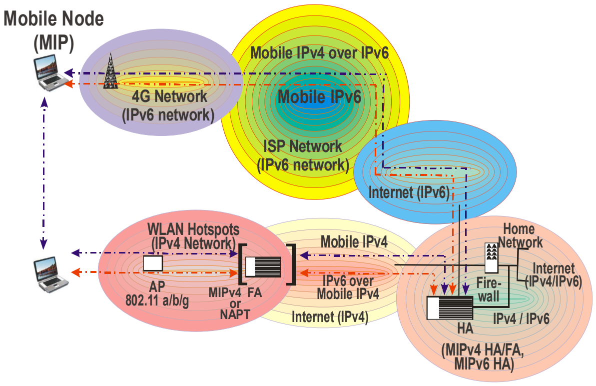

Fig. 6. Deployment Scenario for one of the possible combined mobility solutions for IPv4 and IPv6 mobility from any access network.

The complete mobility solution for IPv4 and IPv6 can be deployed as shown in fig. 6.

In this deployment scenario Mobile IPv4 and the dual stack mobile IPv4 solution is used when the Mobile Node is located on an IPv4 access network. Likewise, when the Mobile Node is located in an IPv6 access network, Mobile IPv6 is used together with the dual stack mobile IPv6 solution.

7. Developing Standards for Seamless & Secure Mobility [10]

Several industry consortia and standard development organizations such as the IEEE 802 LAN/MAN Standards Committee and the Internet Engineering Task Force (IETF) are expending considerable efforts to develop a common framework and extend existing mobility protocols in order to facilitate and optimize handover performance. Various activities are currently under way, including extensions to Mobile IP at the IETF, and the formation of the Media Independent Handover (MIH) working group in IEEE 802, in addition to several task groups within IEEE 802.11 in order to deal with roaming (IEEE 802.11r) and interfacing to external networks (IEEE 802.11u).

8. Conclusion

The mobile IPv4 over IPv6 solutions has been theoretically demonstrated to support IPv4 in mobile IPv6. Not only it will be cost-effective strategy, it will be easy to implement compared to the amount of efforts required to implement a full mobile IPv6 solutions with support for IPv4. When IPv6 and mobile IPv6 are used then all hosts are dual stack, thus eliminates the need for mobile IPv4 over IPv6. The deployment of IPv6 access networks must be expedited to facilitate mobile users to take full advantage of next generation cellular networks and wean away from IPv4 networks.

9. Acknowledgement

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10. References

[1] J. Govil and J. Govil, "On the Investigation of Transactional and Interoperability Issues between IPv4 and IPv6", *IEEE Electro/Information Technology Conference*, Chicago, U.S.A., May 2007.

[2] Cisco Systems http://www.cisco.com/ application/pdf/ en/us/guest/tech/tk872/c1482/cdccont_0900aecd80260042.pdf . 2005

[3] H. Soliman, G. Tsirtsis, V. Deverapalli, J. Kempf, H. Levkowetz, P. Thubert, and R. Wakikawa, "Dual Stack Mobile IPv6 (DSMIPv6) for Hosts and Routers", *Technical Report*, draft-ietf-mip6-nemo-v4traversal-01, IETF, March 2006

[4] D. Johnson, C. Perkins, and J. Arkko, "Mobility Support in IPv6", draft-ictf-mobileip-ipv6-24.txt, 3.\, June, 2000

[5] WIDE project. SHISA, 2006. http://www.mobileip.jp/.

[6] Nautilus6 project, 2006. http://www.nautilus6.org/

[7] C. Perkins, "IP Mobility Support for IPv4", REC 3344, August 2002.

[8] G. Tsirtsis, and H. Soliman, "Dual Stack Transition Mechanism", draft-bound-detmexp-00.txt. August 2003.

[9] P. R. Calhoun, P. E. Engelstad, T. Hiller and P. J. McCann, "IPv6 over Mobile IPv4", draft-mecann-mobileip-ipvvmipv4-03.txt., October 2002.

[10] Nada Golmie , "Seamless and Secure Mobility".9th DOD Annual Information Assurance Workshop in Philadelphia, PA, 7-10, February, 2005