ISSN 2320 -2602

International Journal of Advances in Computer Science and Technology (IJACST), Vol.2 , No.8, Pages : 07-11 (2013)
Special Issue of ICCECT 2013 - Held during 16-17 August, 2013, Thailand

Simulation and Evaluation of MPLS based PMIPv6 Network

Hatsadin Payappanon, Thossaporn Kamolphiwong, Kevin Robert Elz
Centre for Network Research, Computer Engineering Department, Faculty of Engineering
Prince of Songkla University
Songkla, Thailand
boy.hatsadin@gmail.com

Abstract *:* This paper gives some results for a simulation of a Proxy Mobile IPv6 (PMIPv6) network based upon Multi-Protocol Label Switching (MPLS) for handling packet forwarding through the network. These results are compared with results from a simulation of a standard PMIPv6 network. The simulation uses the OMNET++ network simulation framework. This paper represents work that remains in progress, with more scenarios yet to be tested. However, the tentative results so far indicate that the MPLS/PMIPv6 combination outperforms standard PMIPv6.

Key words : PMIPv6, IP-in-IP tunnel, MPLS, LSP Tunnel

INTRODUCTION

The Internet protocols were designed to use a single identifier, the IP address, to both identify a node to its peers, and to allow the network to locate the node and deliver data to it. This poses a problem for devices that move around the network, yet want to appear to other nodes as a single unchanging device, rather than a series of different devices with different addresses. The rapid growth of use of mobile devices makes providing good solutions to this problem more urgent that it was earlier.

For the next generation Internet, the protocols developed to deal with this issue include Mobile IPv6 (MIPv6) [5], Fast-MIPv6 (FMIPv6) [6], and Hierarchical-MIPv6 (HMIPv6) [7] and others more. The older Internet protocols (IP version 4) [1] have similar mechanisms [2][3][4]. These protocols provide a host based mobility management scheme that requires all mobile devices to participate in the signaling management required to allow the node to move while retaining its identity. For optimum performance, all nodes on the network must participate. The effect upon the mobile nodes is to increase their complexity, and also perhaps reduce battery life due to the requirements of the mobility protocols.

An alternative scheme has been created to allow for the common case of a mobile node that moves mostly within the limits of its parent network. This is Proxy Mobile IPv6 (PMIPv6) [8] which is a network-based mobility management protocol. That is, the network takes care of managing mobile nodes, rather than the nodes themselves, simplifying the software demands upon the mobile nodes. In a PMIPv6 domain, each mobile device communicates with its peers across the PMIPv6 domain via a tunnel between a Mobile Access Gateway (MAG) which is directly connected to the mobile node, and a Local Mobility Anchor (LMA) which provides the domain's visibility to the rest of the network.

Evaluation of the performance of mobility protocols concentrates upon two main aspects of the protocols. The overheads added to regular data flow to a node that has moved, and the delays involved in re-establishing connectivity after a node moves. There has been some recent works to provide mechanisms to reduce the handover delay [9][10], and in particular, Astudillo et al. [11] proposed use of a label switched path (LSP) tunnel, as used in multi-protocol label switching (MPLS) networks [13] instead of the traditional IP-in-IP tunnel of PMIPv6. This is intended to reduce hand over delay, and hence lost data packets during the hand over period, and also reduce hand over overheads, as well as reducing data transfer overheads.

Astudillo's work assumes the mobile node will connect to a MAG at its new location, perform the necessary network acquisition tasks, including securely proving its identity, the MAG would then send a binding update to the LMA, which would respond by creating a LSP tunnel to the MAG, which, given these tunnels are unidirectional, would also be creating a tunnel to the LMA.

We propose that, given the existing relationship between MAG and LMA, in that they are part of the infrastructure of the PMIPv6 domain, that the LSP tunnels between them could be pre-established, so that they are available for immediate use once the LMA has received the binding update from the MAG.

This research involves the simulation and evaluation of an MPLS based PMIPv6 network as proposed by Astudillo et al. - using an LSP tunnel instead of the traditional IP-in-IP tunnel. Then we change the hand over mechanisms by creating the tunnels between the edge routers (MAG and LMA) before any demand created by a binding registration. The proposed network is simulated using the OMNET++ Network Simulator [14] which provides detailed performance analysis of the quantitative performance parameters like hand over delay, hand over overhead, and end-to-end delay.

The remainder of this paper is structured as follows. The next section provides some background information on

ISSN 2320 -2602
International Journal of Advances in Computer Science and Technology (IJACST), Vol.2 , No.8, Pages : 07-11 (2013)
Special Issue of ICCECT 2013 - Held during 16-17 August, 2013, Thailand

PMIPv6 and MPLS. Section 3 presents our network designs and the scenarios to be simulated, along with explanations. Section 4 presents the results of the simulations performed to date, with an analysis of these results. Section 5 provides some conclusions, and indicates what work remains to be done.

BACKGROUND INFORMATION

To understand our simulation and evaluation of the MPLS based PMIPv6 network, some basic knowledge of Multi-protocol Label Switching technology and Proxy Mobile IPv6 technology is required. The following two sections provide that background.

Proxy Mobile IPv6

Proxy Mobile IPv6 (PMIPv6) [8] is a variant of the Mobile IPv6 protocols [5] that allows for a node to move within a localized domain without requiring any signaling between the mobile node and its home agent. The most significant components in a PMIPv6 domain are the Local Mobility Anchor (LMA) and the Mobility Access Gateway (MAG). The LMA is responsible for maintaining the mobile node's reachability via communications to the appropriate MAG. The MAG is responsible for detecting movement by a mobile node, and initiating a binding registration with the LMA.

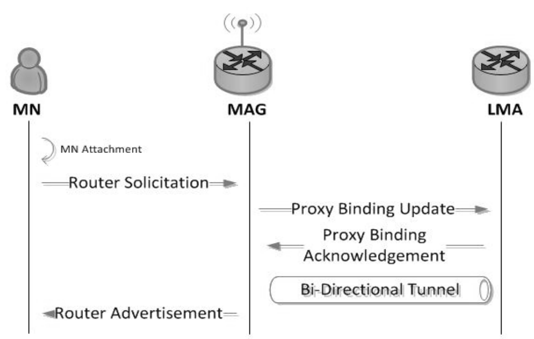

Fig 1: Handover procedures in Proxy Mobile IPv6 Domain

When any IPv6 node detects the presence of a new link, it attempts to obtain networking parameters for that link by sending a Router Solicitation (RS) to any routers that are connected [18]. If the router that receives the RS is a MAG, it will initiate the mobile node hand over procedure by sending a binding update to the LMA as illustrated in Fig 1. The LMA then creates a binding cache entry and responds with a proxy binding acknowledgment message which includes the appropriate home network prefix for the mobile node attaching. The MAG then creates a binding update list and sends a Router Advertisement (RA) message to the mobile node (MN) containing the MN's home network prefix. The MN sees the same RA advertised network prefix from any MAG to which it connects, thus believes that it is simply reconnecting to the same network. The MN configures its address based upon its home prefix in the normal way [19]. Communications between the MN and any peer nodes then operate via the MN to MAG link, over a tunnel between MAG and LMA, and then using regular IPv6 forwarding to or from the peer node.

Multi-Protocol Label Switching

Multi-Protocol Label switching (MPLS) [12] is a highly scalable technique that is widely used in the core network [20]. It implements packet forwarding using a label attached to each packet to assist with the forwarding decisions. MPLS introduces the Label Switched Path (LSP) tunnel which provides the mechanism to transport labeled data packets from the source node along the path to the destination node. There are three components in an MPLS network, ingress and egress Label Edge Routers (LER), and Label Switch Routers (LSR). LERs are located at the edges of the MPLS network. They are responsible for assigning a label to an incoming data packet, and also for removing the label from packets leaving the network. Other nodes in the MPLS network are LSRs. Those are responsible for forwarding packets, using the label from each incoming packet to select an appropriate outgoing link and next LSR (or LER) and the label to be included in the packet sent to that node.

MPLS BASED PMIPV6 NETWORK ARCHITECTURE

In this section we explain our modification to the MPLS based MIPv6 network proposed by Astudillo et al. [11], and follow that by a description of the model used to simulate this network so its performance can be evaluated.

MPLS based PMIPv6 Network Entities

The signaling management in the proposed network is similar to that of standard PMIPv6 [8] with the significant difference that an LSP based tunnel is used between the MAG and the LMA, as shown in Fig 2.

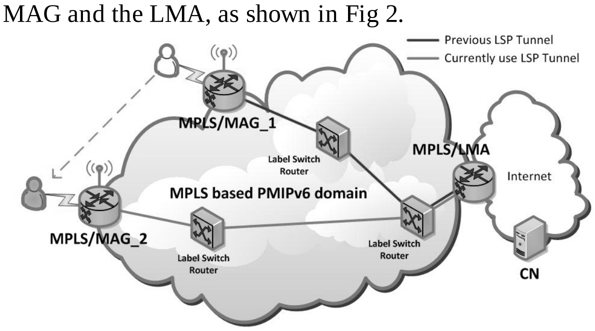

Fig 2: MPLS based PMIPv6 Network Environment

We propose that this tunnel be created as the PMIPv6 network is established, and then maintained by the LMA and the MAG as an aspect of normal operation. The process of establishing an MPLS tunnel (LSP tunnel) is not new to this work, and will not be discussed further here.

We justify expecting this to be pre-established by noting that the MAG must have pre-ordained knowledge of the LMA for any PMIPv6 scheme to operate. It is expected that the LMA and MAGs are all under common management. Given this knowledge, and the relatively small number of MAGs expected in a PMIPv6 network it seems reasonable to expect each MAG to contact its LMA soon after it is started, establish a tunnel (two tunnels for bidirectional operations) and maintain them thereafter. The possibility of some slight

ISSN 2320 -2602

International Journal of Advances in Computer Science and Technology (IJACST), Vol.2 , No.8, Pages : 07-11 (2013)
Special Issue of ICCECT 2013 - Held during 16-17 August, 2013, Thailand

extra cost in establishing a tunnel that might never be used seems immaterial compared with the cost of establishing the MAG which would necessarily also not be being used. Astudillo's work [11] shows that the handover delays can be reduced if the tunnel exists before the handover commences.

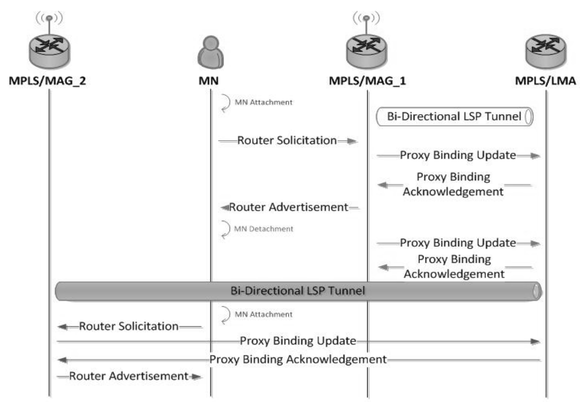

Fig 3: The signaling management via the ready-used LSP tunnel between the network entities

Fig 3 illustrates the signaling management for the MPLS based PMIPv6 network. A mobile node attaches to the MPLS/MAG and sends a Router Solicitation (RS) message. The MAG receives this RS and sends a Proxy Binding Update (PBU) message, with a status of binding registration, and the MN-identifier option, to the MPLS/LMA. The LMA determines the home prefix based upon the received MN-Identifier and creates a binding cache entry in its internal database, containing the MN-Identifier, the requesting MPLS/MAG address, and the home network prefix for the MN.

The MPLS/LMA then responds with a Proxy Binding Acknowledge (PBA) with status ACCEPTED and sends that to the MPLS/MAG. The MAG creates a binding update list entry containing the MN-Identifier, and the interface to which the MN is connected, and sends out that interface a Router Advertisement (RA) message containing the home network prefix for the mobile node. While the MN remains connected to the MAG the MAG periodically repeats its PBU to the LMA so the LMA knows the connection remains active.

When the MPLS/MAG detects that the mobile node has departed, it sends a PBU message to the LMA with a lifetime of zero, which indicates deregistration to the LMA. The LMA accepts this PBU, but does not immediately delete the entry from its binding cache - instead it will insert a delay to allow time for another MAG to send a PBU indicating that the MN has changed attachment points.

Network Simulation Model

OMNET++ [14] is a component-based, modular, open-architecture discrete event simulation framework. It provides component architecture for models programmed in C++ [22]. Instead of providing explicit hardwired support for particular computer networks, it provides an infrastructure for writing such simulations. Specific application areas are catered to by various frameworks. One of those is INET-2.0.0 [15] which introduces a simulation of the MIPv6 protocol called xMIPv6.

XMIPv6 was implemented by Yousaf et al. [16] and closely follows the IETF's MIPv6 protocol. We have used this as a base, and modified it to support the PMIPv6 protocol.

The Local Mobility Anchor (LMA) module, and Mobile Access Gateway (MAG) module were both created based upon the router6 module from [16]. These support the standard PMIPv6 functions, and become part of the NetworkLayer6 module as illustrated in Fig 4. All of the PMIPv6 functions will be handled by the PMIPv6 module that is composed of buList, bindingCache, and pmipv6 sub-modules as shown in Fig 5.

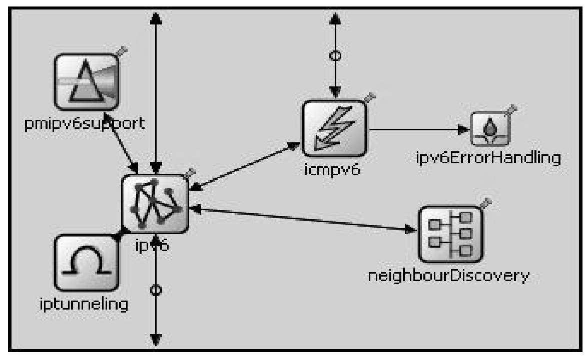

Fig 4: NetworkLayer6 Module

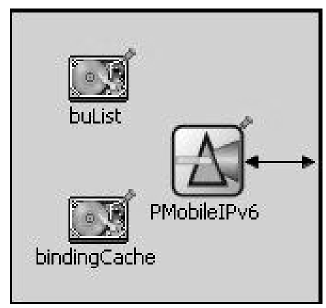

Fig 5: PMIPv6 Module

MPLS support in OMNET++ also required enhancement to support IPv6, and so support use for PMIPv6. MPLS with integrated IPv6 is added to the LMA and the MAG modules in order to support the MPLS/PMIPv6 functionality, as shown in Fig 6.

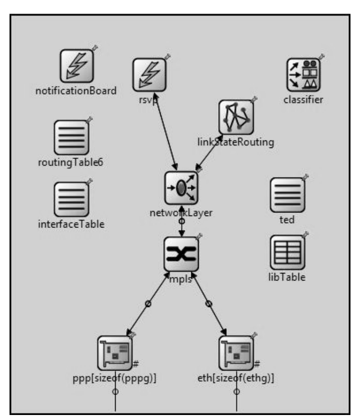

Fig 6: MPLS based PMIPv6 network module

ISSN 2320 -2602

International Journal of Advances in Computer Science and Technology (IJACST), Vol.2 , No.8, Pages : 07-11 (2013)
Special Issue of ICCECT 2013 - Held during 16-17 August, 2013, Thailand

PERFORMANCE EVALUATION AND ANALYSIS

This research studies the impact of introducing an LSP tunnel into a PMIPv6 network. PMIPv6 networks are under common management, so we anticipate that a typical network diameter would be between 3 and 6 hops. For this simulation we consider all of the cases from 2 to 10 hop diameter networks. We also simulate the cases of 12, 15 and 20 hops, not because we believe those are reasonable scenarios for PMIPv6, but just to determine whether the trend we observe for the more realistic networks would in fact continue in a much larger network.

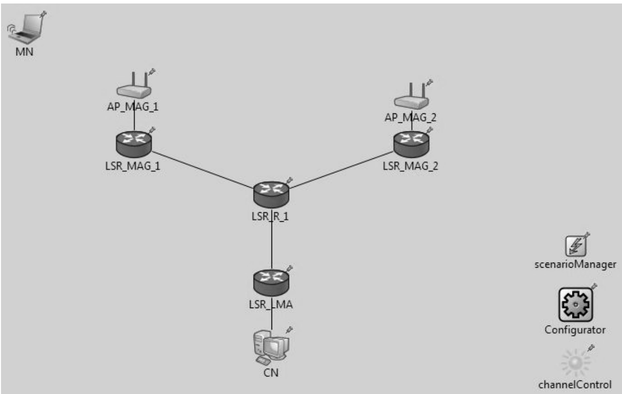

Fig 7: Network Scenario

Fig 7 illustrates the 2 hop scenario, where there are two hops (or one intermediate LSR) between the MAG and the LMA. The figure shows the case where the MN moves from LSR_MAG_1 to LSR_MAG_2. The scenarioManager, Configurator, and channelControl OMNET++ modules are used to support the simulation. The other scenarios simulated are similar, but with more hops introduced between the MAG and the LMA.

For this research we are concerned with measuring hand over delay, hand over overhead, and end-to-end delay. The MPLS based PMIPv6 network is simulated, and compared with a simulation of a normal PMIPv6 network.

Handover Delay

We assume use of IEEE 802.11 [17] WLAN as the access link between the MN and the MAG. Therefore there will be two aspects to the handover delay, WLAN hand over, and PMIPv6 hand over. We adopt the terminology proposed by Mishra et al. [17] and divide the link layer hand over procedure into three phases, the scanning phase, authentication phase, and re-association phase.

Table I: Parameters in handover procedures

Parameter	Description	Value (ms)
$T_{802.11}$	802.11 Handover delay	212
T_{wl}	Wireless link delay	2
T_{wi}	Wired link delay	2
T_{MAG}	MAG processing time	0.2
T_{LMA}	LMA processing time	0.5
T_{RT}	Router processing time	0.2

The parameters used for the link layer and PMIPv6 handovers for the simulations are set out in Table I. The values chose were somewhat arbitrary, and reflect one possible set of values. We believe them to be reasonable.

$$T_{Total} = T_{802.11} + T_{PMIPv6} \quad (1)$$

$$T_{PMIPv6} = 2(T_{wl} + T_{MAG} + n(T_{RT} + T_{wi}) - T_{RT} + T_{LMA} \quad (2)$$

$$T_{PMIPv6} = 2(T_{wl} + T_{MAG} + 3(n(T_{RT} + T_{wi}) - T_{RT}) - 2T_{wi}) + T_{LMA} \quad (3)$$

Given the signaling management call flow previously shown in Fig 3, determine that the total handover delay should be as calculated in equation (1). In that, T_{PMIPv6} gives the PMIPv6 aspect of the handover delay, which can be calculated in turn as shown in equation (2), where n is the number of hops. In some situations routers in a standard PMIPv6 situation would need to find the route (including next hop address resolution), which could mean that the PMIPv6 handover delay could be as much as shown in equation (3), where n is again the number of hops.

For the MPLS based PMIPv6 network, we exclude LSP tunnel setup time, as we are assuming that these tunnels are pre-configured. We measure the handover delay from when the MN attaches to the MAG, until it is finally able to configure its own IPv6 address after receiving the RA from the MAG.

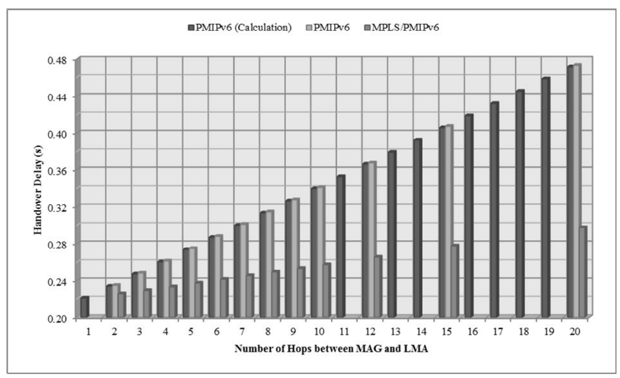

Fig 8: Handover delay

Fig 8 gives the results. As well as the simulated results for PMIPv6 and MPLS/PMIPv6 we show the expected PMIPv6 handover delay according to the equations, and for this we show the result for all network diameters from 1 to 20 hops, including those we did not simulate.

The results show that the MPLS/PMIPv6 combination performs better than standard PMIPv6, and that the handover delays increase more slowly for MPLS/PMIPv6 as the diameter of the network increases. This is largely due to the pre-configured LSP tunnel that avoids the additional set up time required otherwise.

Handover Overhead

The original PMIPv6 encapsulation adds a 40 byte IPv6 header to each packet. MPLS tunnels add just a 4 byte label to each packet. Thus the data traffic overhead for PMIPv6 is 10 times that of the MPLS variant. How significant this is depends upon the data packet sizes. For large data packets, a few extra header bytes make little operational difference. However for small packets, such as TCP acknowledge packets [21] the difference is significant.

End-to-End Delay

We measure end-to-end delay as the time from when a packet, whether from the mobile node, or its peer correspondent node, enters the PMIPv6 network after the handover procedures have completed, until the packet exits the PMIPv6 network. The results of measuring this delay for our various simulated networks are shown in Fig 9.

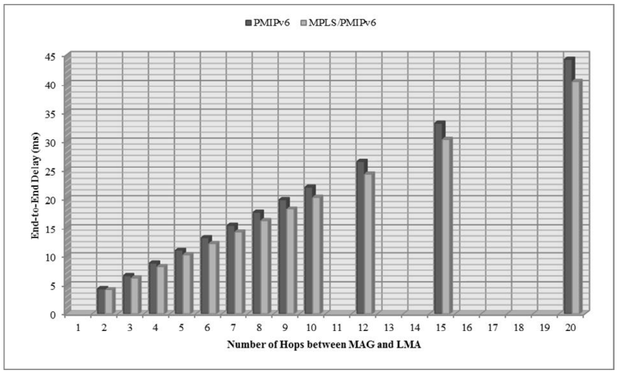

Fig 9: The End-to-End delay of PMIPv6 and MPLS/PMIPv6 network

For the purposes of this test we use packets each 52 bytes long. These results show that the MPLS/PMIPv6 introduces less delay than the original PMIPv6 network. There are two factors contributing to the saving, first, MPLS packets are slightly smaller, and hence transit the network slightly more quickly, and secondly, the processing time at each router is assumed to be smaller to forward an MPLS packet than is required for full IPv6 address lookup and forwarding.

CONCLUSION AND FUTURE WORKS

This paper begins the evaluation of a simulation of an MPLS based PMIPv6 network, using an LSP tunnel instead of IP-in-IP as would be used by a standard PMIPv6 network. We have also studied the impact of the use of an existing LSP tunnel during the handover procedures.

The results show that using the LSP tunnel during handover introduces less handover delay compared with using an IP-in-IP tunnel in a standard PMIPv6 network. The MPLS based PMIPv6 network also introduces less end-to-end delay because of lower processing time and smaller packets. The smaller packets also result in less network bandwidth consumption. From what we have studied to date, MPLS/PMIPv6 looks to be a clear winner.

However, we have not yet considered other scenarios, such as what happens when a link failure occurs within the PMIPv6 network. Here we are anticipating the opposite result, we expect the IP-in-IP PMIPv6 to recover more quickly, and so lose fewer packets than an MPLS implementation. However those results are not yet available, we continue to simulate this, and other scenarios in order to be able eventually give a comprehensive comparison of these two techniques of implementing PMIPv6.

REFERENCES

[1] Jon Postel, “INTERNET PROTOCOL”, RFC 791, September 1981.
[2] Charles E. Perkins, “IP Mobility Support for IPv4”, RFC 5944, November 2010.
[3] Basavaraj Patil, Phil Roberts, Charles E. Perkins and Pat R. Calhoun, “Mobile IP Network Access Identifier Extension for IPv4”, RFC 2794, March 2000.
[4] Kent Leung, Gopal Dommety, Vidya Narayanan and Alexandru Petrescu, “Network Mobility (NEMO) Extensions for Mobile IPv4”, RFC 5177, April 2008.
[5] Charles E. Perkins, David B. Johnson and Jari Arkko, “Mobility Support in IPv6”,RFC 6275, July 2011.
[6] Hidetoshi Yokota, Kuntal Chowdhury, Rajeev Koodli and Basavaraj Patil, “Fast Handovers for Proxy Mobile IPv6”, RFC 5949, September 2010.
[7] Hesham Soliman, Karim Elmalki and Ludovic Bellier, “Hierrachical Mobile IPv6 (HMIPv6) Mobility Management”, RFC 5380, October 2008.
[8] Sri Gundavelli, Kent Leung, Vijay Devarapalli, Kuntal Chowdhury and Basavaraj Patil, “Proxy Mobile IPv6”, RFC 5213, August 2008.
[9] Zhao Liang, Zhang Jun, Zhang Xuejun, Li Qingbo, "A Mobility Management Based on Proxy MIPv6 and MPLS in Aeronautical Telecommunications Network", The 1stInternational Conference on Information Science and Engineering (ICISE2009),December 2009.
[10] Rosario G. Garroppo, Stefano Giordano, Luca Tavanti, "Network-based micro-mobility in Wireless Mesh Networks: is MPLS convenient?", GLOBECOM, 2009.
[11] Carlos A. Astudillo, Oscar J. Calderon and Jesus H. Ortiz, "PM2PLS: An Integration of Proxy Mobile IPv6 and MPLS", IJCSI International Journal of Computer Science Issues, Vol. 8, Issue 3, No. 1, May 2011.
[12] Rosen E., Viswanathan A., and Callon R., "Multiprotocol Label Switching Architecture," IETF RFC 3031 (Proposed Standard), January 2001.
[13] Rosen Xia F. and Sarikaya B., "MPLS Tunnel Support for Proxy Mobile IPv6," IETF Draft, October 25, 2008.
[14] http://www.omnetpp.org, “OMNeT++ Network Simulation Framework”, December 2012.
[15] http://inet.omnetpp.org, “INET Framework | Main/Welcome to the INET Framework!”, December 2012.
[16] Faqir Zarrar Yousaf, Christian Bauer and Christian Weitfeld, “An Accurate and Extensible Mobile IPv6 (xMIPv6) Simulation Model for OMNeT++”, OMNeT++ 2008, Marseille, France, March 2008.
[17] Arunesh Mishra, Minho Shin and William Arbaugh, “An Empirical Analysis of the IEEE 802.11 MAC Layer Handoff Process”, ACM SIGCOMM Computer Communication Review, Vol.33, Issue 2, April 2003.
[18] Thomas Narten, Erik Nordmark, William Allen Simpson and Hesham Soliman, “Neighbor Discovery for IP version 6 (IPv6)”, RFC 4861, September 2007.
[19] Susan Thomson, Thomas Narten and Tatuya Jinmei, “IPv6 Stateless Address Autoconfiguration”, RFC 4862, September 2007.
[20] Alcatel-Lucent, “Deploying IP/MPLS in Mobile Networks”, 2010.
[21] Jon Postel, “TRANSMISSION CONTROL PROTOCOL”, RFC 793, September 1981.
[22] Juan Soulie, “C++ Language Tutorial”, June 2007.