nSCTP: A New Transport Layer Tunnelling Approach to Provide Seamless Handover for Moving Network

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Abstract- *In this paper, we propose a transport layer tunnelling for improving the handover parameter and providing a seamless handover in group mobility. Efficiency of this protocol in reducing the handover latency, increasing the end-to-end throughput in wireless access networks with frequent handovers has been considered. We show that the new scheme could significantly increase the throughput particularly when the mobile networks roam frequently.*

1. Introduction and Overview

The Internet has been designed for static wired connections. Demand for anywhere, anytime communications has been increasing recently. The mobile nodes need to keep their connectivity when they are moving. In some cases a group of mobile nodes roam together. Nowadays, the mobile networks introduced to cope with any group mobility scenarios such as public transport and body personal area networks. In moving networks a universal gateway or a Mobile Router (MR) is used as an interface between the radio network and the work stations. The MR also handles the connection between the public networks and its private moving network. The rationale for this work is providing seamless handover for moving networks to improve the Quality of Service (QoS) for the end-users. In this paper, a transport-layer solution to enhance the end-to-end connection robustness and throughput of a moving network has been investigated.

The single point of failure often is the main weakness of most end-to-end connections. This failure can happen in the wired or in the wireless part of the connection. In the wired part of the network, the failure may happen because of the medium or router problem that routing protocols can tackle using different rerouting techniques. In the wireless part, the link failure can occur because of random errors in the medium, low bandwidth and mobility. Link failure has direct effect on higher layers, as transport-layer connections rely on the network connectivity and applications rely on the transport-layer connections. This is the main drive behind this work, to develop a novel transport layer solution for dealing with random link failures in mobile networks.

The infrastructure of the considered scenario in this paper is shown in Figure 1. In this topology a MN belong to MN's Home Network, is attached to a multi interfaces MR with different home network. In the overlap area of the cells both interfaces are active and a soft handover for micro mobility (intra-domain handover) and macro-mobility (inter-domain handover) are achievable.

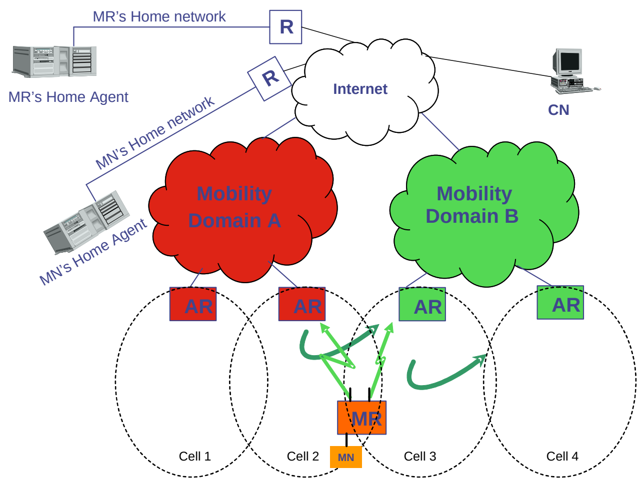

Figure 1: Micro and macro mobility in multihomed scenario with NEMO

a. Multihoming and SCTP

Multihoming is a concept that has been gaining more interest in the research communities. Multihoming addresses the problem of single point of failure by using the alternative connections. This feature provides both endpoints with multiple communication paths and thus the ability to failover (switch) to an alternative path when the link failure occurs. The simultaneous connectivity can be realised using multiple ISPs or multiple wireless access technologies, such as cellular networks (e.g. GPRS, UMTS) and wireless LANs and MANs (e.g. 802.11, WiMAX).

Multihoming can be achieved at different network layers. At the application layer, the firewall proxy services can provide this functionality. At the transport layer, session allows binding multiple IP addresses at each end point. Network layer approaches to multihoming are router-based and, finally, in the data link and physical layers multihoming can be implemented by manipulating MAC address to provide virtual server functionalities.

The current transport protocols, TCP and UDP, do not support multihoming. TCP allows binding to only one network address at each connection end. This is the main reason why a new transport-layer protocol, Stream Control Transmission Protocol (SCTP) [1], is being investigated in this research. SCTP is a general purpose transport layer protocol providing reliable ordered delivery of data (like TCP) and also unreliable data message (like UDP). An SCTP connection, called association, includes two major new capabilities, multi-homing and multi-streaming.

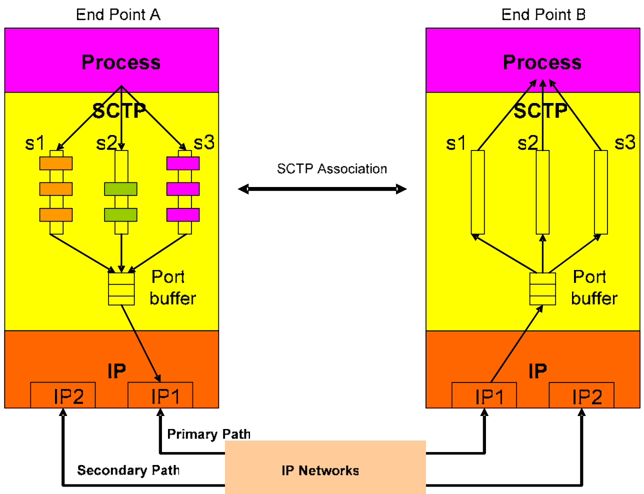

Figure 2: SCTP association with both multistreaming/multihoming features

The multi-homing feature of the SCTP allows binding of one transport layer association to multiple IP addresses at each end of the association. SCTP has a built-in failure detection and recovery system, known as *failover*, which allows associations to dynamically send traffic to an alternate peer IP address when needed. SCTP's *failover* mechanism is static and does not adapt to application requirements or network conditions.

The multistreaming allows independent delivery among data stream. Application data can be portioned into multiple streams. These portions or data chunks will be formed inside an SCTP packet and each packet can contain multiple data chunks from different applications. Chunks header contains Transmission Sequence Number (TSN), Stream ID and Stream Sequence Number (SSN) that can provide independent delivery of each stream to the application.

Figure 2 depicted the functionality of multistreaming and multihoming in an SCTP association.

b. Mobility Management

In order to have continuous communication when a mobile node is changing its point of attachment to the Internet, mobility solutions have been presented. Mobility management is an intelligent function of wireless mobile networks. When a mobile router is roaming through one or more service areas, mobility management mechanisms are required for location management and handover management. Location management is used for discovering the current position of the mobile nodes, data delivery and keeping track of mobile terminals. On the other hand, handover management enables the user to keep its connection alive as it moves and changes its point of connection to the network.

There are many proposals to manage mobility in different layer of protocol stack [2]. The natural question is which layer is preferable for mobility? A study done by Eddy [3] has compared three different layers for mobility. The work shows the common network layer solution, Mobile IP, has several weaknesses and limitation with regard to its effectiveness. The authors believed most of this problem can be tackled by a higher transport or session layer approach and suggested a transport layer solution as the strongest candidate among various levels. Ratola [4] introduces and compares three implementing mobility protocols, each from a different layer. The purpose of the comparison is to determine which layer – three (MIPv6), three and a half (HIP), or four (SCTP) - would be best suited for mobility management. The author [4] believes a new layer 3.5 is necessary because using lower layers do not have such a great impact and also a new transport layer protocol causes incompatibility in implemented software.

Mobile SCTP (mSCTP) [5] is the new extension of SCTP that uses multihoming feature of SCTP to manage handover in heterogeneous networks. The mSCTP needs to use a location management protocol like Mobile IP [6], Session Initiation Protocol (SIP) [7] or any other location management protocol to complete the mobility management process.

Performing individual handover for a group of users which roaming together can cause huge signalling overhead. Network mobility support is a solution to overcome this problem. In such a scenario the whole network is viewed as a single unit, which changes its point of attachment to the Internet and thus its reachability in the internet topology. In such a network one or more mobile routers connects the local fixed and visiting mobile nodes inside the network to the Internet. In definition, Local Fixed Nodes (LFNs) in a moving network are unable to change their point of attachment to the MR's network. These nodes are mobility unaware nodes, meaning that they do not have any mobility software running on them. Also a Visiting Mobile Node (VMN) is a node downstream of the MR which is capable of joining/leaving the MR's network when necessary. VMNs are mobility aware nodes, meaning that they must have mobility software such as MIPv6 installed and running.

NEtwork MObility (NEMO) [8] is a protocol extension to Mobile IPv6 (MIPv6) [9] to provide support for network mobility. It also allows every node in the Mobile Network to be reachable while moving around. The MR(s), which connects the network to the Internet, runs the NEMO Basic Support Protocol Solution with its Home Agent. The protocol is designed so that network mobility is transparent to the nodes inside the Mobile Network.

In this paper, nSCTP protocol, which is a SCTP extension of NEMO, has been proposed. This protocol provides a seamless handover and connection robustness in a moving network by employing a transport layer mobility support. A comparison of nSCTP and NEMO basic support protocol has been done and the simulation results showed that this new scheme can significantly improve the throughput in medium and high handover rate scenarios.

In the remainder of this paper, in the next section, the transport layer tunnelling has been introduced. nSCTP has been considered in section 4 followed by a simulation base analysis in section 5 and finally the work has been concluded with address of some future works in this area.

2. Transport Layer Tunnelling

In MIP to carry the packets from CN to the MN, IP encapsulation is being used. The CN transmits the packets to MN-HA which knows the current location of MN and the MN-HA in an IP-in-IP encapsulation forwards the packet towards the MN. At the MN a decapsulation process will be performed to extract the original packets. Packet encapsulation is based on data encapsulation or data hiding in OSI reference model. Application data should pass through the network layers to add relevant header and/or trailer to the received packet from upper layers to communicate with the other end.

NEMO is a developed case of Mobile IP which can handle data transmission using two different tunnelling mechanisms. In NEMO a VMN will get a CoA form the MR. This CoA has a prefix of the MR and will not be changed while the VMN is connected to the MR. If the CN wishes to communicate with the MN in the moving network the following process should be done:

- CN is aware of the MN's IP address that belongs to the home network's domain and will place this address in the destination IP header field of packet.
- The destination IP address has a prefix of the MN-HA and the packet is transmitted to the MN-HA.
- The MN-HA knows the CoA of the MN. A packet encapsulation with MN-HA and MN-CoA in source and destination address fields will be formed.
- As MN-CoA has a prefix of the MR, in the next stage this packet should be received by the MR-HA.
- The MR might be out of the home network. In that case, the MR-HA which has the current IP address of the MR, tunnels the packet again and sends it to the MR. Source and destination IP addresses in this IP header are MR-HA and MR-CoA respectively.

Figure 3 shows the source and destination IP addresses in each part of transmission when the CN is a sender. The reverse transmission form VMN to CN is formed by swapping the sender and receiver addresses in Figure 3.

The Current NEMO structure suffers from some well known weaknesses. The most important is vertical handover that can cause service disruption and disconnectivity. Load balancing and load sharing are other issues which have not been addressed in the NEMO architecture.

As explained before, SCTP is a transport layer protocol with the ability of multihoming. This facility enables more than one connection via different interfaces and transmission paths between two end nodes.

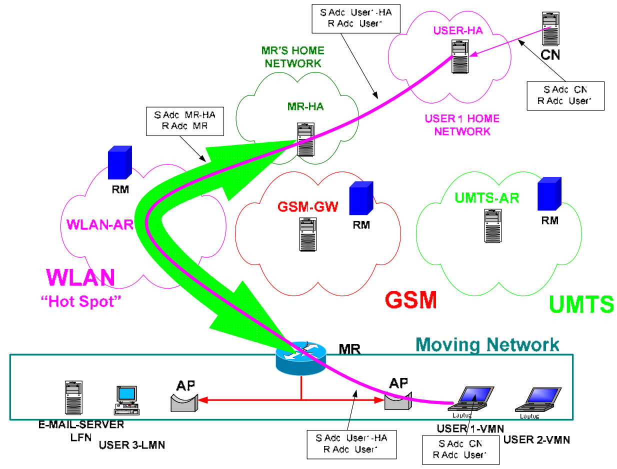

Figure 3: Sender and receiver IP address fields in NEMO when CN is sender.

In NEMO, the MR and the MR-HA are the candidates to run this protocol, at where the outer tunnel is performing. Running SCTP protocol on these multilayer routers (MR and its peer MR-HA) gives the opportunity to have another end-to-end protocol at the bottleneck of the network that always has to deal with the unreliability and the high packet error rate. On the other side based on the mSCTP [10], having more than one connection between MR and MR-HA via different wireless network technologies or BSs can provide seamless vertical or horizontal handover respectively. The other features that can be named are load balancing and load sharing that are out of scope of this paper.

For activating above facilities in NEMO scenario, we identified two tunnels that need to be worked:

- Router/Host tunnelling: this tunnel is bidirectional, between MN-HA and MN. The tunnel is an inner tunnel as shown in Figure 3. The tunnel provides a point-to-point link based on IPv4 or IPv6 at the network layer. IP encapsulator and IP decapsulator are the modules of this tunnel which are explained in the next section. The configuration of this particular tunnel will be setup at the time that the MN joins the moving network and will not be changed until the MN leaves the network.
- Router/Mobile Router tunnelling: this is the second bidirectional tunnel performing between MR and MR-HA (Figure 3). These routers should be able to process the transport layer data. SCTP/IP encapsulator and decapsulator are the modules of the tunnel. The tunnel configuration will be changed when the mobile router changes its point of attachment to the network or a new BS detects by MR interfaces.

3. NEMO-SCTP (nSCTP)

SCTP is an end-to-end transport layer protocol and for providing seamless handover based on SCTP necessarily more than on interface at the mobile end is needed. Also, there is a probability for software incompatibility causing by some programs that use TCP as a common reliable transport layer protocol. For avoiding these limitations and also using multihoming feature to improve the handover parameters, having another End-to-End connection between MR and MR-HA is proposed. In the standard NEMO structure an IP-in-IP tunnel between these two entities (MR and MR's HA) is available. Upgrading this tunnel to support transport layer tunnelling (described in section 2) can facilitate the soft and seamless handovers in the NEMO. Figure 4 depicted the moving network scenario with two data paths. The paths with label 1 and 3 are end to end that run transport layer protocols and the path with label 2 is an IP-in-IP tunnelled. Among the path 3 which is the wireless part of a heterogeneous wireless access technologies, multihoming feature of SCTP has been used. Therefore, two paths via WLAN and UMTS can be observed; the path from WLAN-AP chosen as a primary for handling the traffic and the other path via UMTS node-B is chosen as an alternative path that can be changed to primary in the case of handover or insatiability in the path via AP.

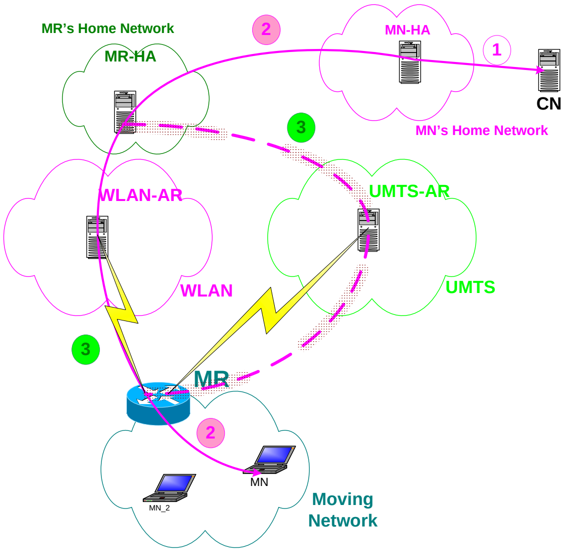

Figure 4: nSCTP scenario with two data paths via different technologies

Figure 5 shows the overall nSCTP mechanisms when a moving network changes its location and performs handover. The signal strength in wireless communications divides into two important thresholds; below a specific threshold (Cx Thresh) the received signal are quite weak and not recognisable, opposite Cx Thresh there is another threshold (Rx Thresh) that the signal strength is powerful enough for data transmission. The area between Rx and Cx thresholds the signals are partly detectable which is good for some signalling like route advertisement but not strong enough for data transmission. As shown in Figure 5 a three-zone can be observed namely; data transmission, detecting and soft handover zones. The soft handover zone, which is the area that is fully covered with both adjacent BS(s) and/or AP(s), is the place for getting the new IP address adding in the SCTP association and finally, changes the primary path and sends the binding updates to the home agent. When an MR moves into a neighboring BS coverage area at soft handover or the signal strength is greater than or equal to the Rx threshold value, it attempts to get an IP address with the help of DHCP, SIP or any other methods. The new IP address should be registered with SCTP association as an alternative path for data delivery.

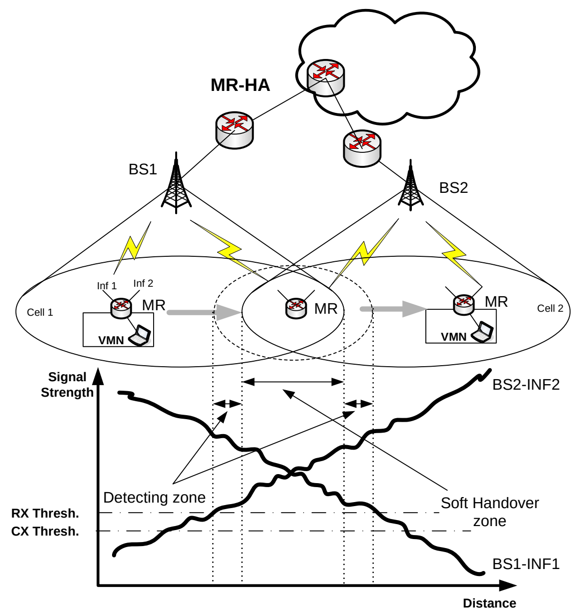

Figure 5: nSCTP handover management by the effect of signal strength thresholds

In the soft handover zone both MR's interfaces have their own IP addresses and they have added to the SCTP association between the MR and MR-HA. This zone is the suitable place for changing the primary IP address but the suitable time for this switching is a challenging issue.

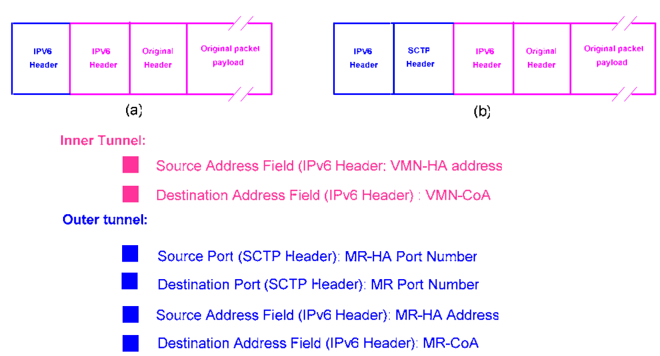

Figure 6: Packet format (a) In NEMO (b) In nSCTP

Figure 6(a) shows the packet configuration in the NEMO scenario which has changed to Figure 6(b) in the nSCTP configuration after deploying SCTP tunnelling header for the packet.

4. Simulation analysis for end-to-end parameters in nSCTP and NEMO

In this section, the simulation models and the relevant results have been presented. NS-2 network simulator [11] along with SCTP agent developed for ns-2 by the Protocol Engineering Lab [12] at University of Delaware have been used as the simulation platform.

Figure 7 depicts the implemented topology in the platform. The communication between the CN and the MN passes through a SCTP transport layer tunnel that should be setup between the MR-HA and the MR. For simplification an end-to-end SCTP agent with multihoming feature uses on both ends. To evaluate the performance of the nSCTP similar topology has been used for NEMO that using MIP to handle the handover. The mobile router has two interfaces that is used to cope with multihoming SCTP handover and just one interface is involved in the NEMO architecture.

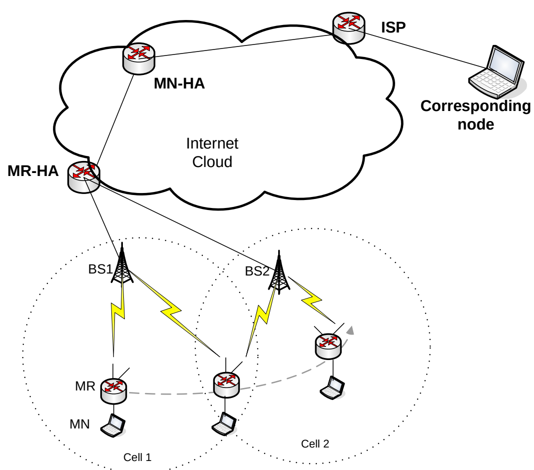

Figure 7: Simulation Topology

In the simulation we aim to compare the throughput and goodput of nSCTP and NEMO. In the definition the throughput is the number of successful bits transferred between the CN and the MN, consequently the goodput is the number of useful data bits transferred regardless of packet header and signalling control. The IP header sizes in all experiments are based on IPv6. Header for SCTP segments that should contain at least one chunk has been set to 16 bytes.

Figure 8 shows the simulation result for the explained structure in Figure 7 when the handover is between two WiFi cells with the data rate of 11Mbps that is shared with both control and data packets.

Movement scenario which is applied to mobile router follows a ping-pong motion between cell one and two. The number of handover shown in the x-axes and the bits transferred is on the y-axes that is a part of FTP application.

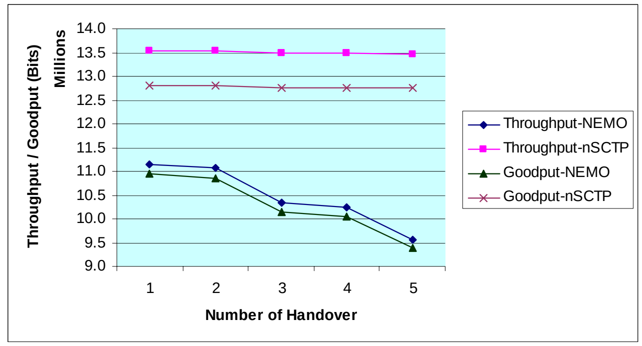

Figure 8: Comparison results of the nSCTP and NEMO in WLAN-WLAN handover

From the simulation results presented in Figure 8 the overall throughput and goodput for nSCTP is more than NEMO. An average improvement of 15% in low handover rate is observing the difference between throughput and goodput in nSCTP is almost three times more than the same ratio in the NEMO case. The reason is additional transport layer tunnelling on the new proposed protocol compare to NEMO. Outer tunnel in nSCTP causes additional overhead per transmitted packet also involved the MR and MR-HA with more processing overhead and that is the trade off for achieving a smooth ramp by increasing the handover rate. Therefore increasing the number of handovers does not change the performance of this protocol. NEMO regardless of having smaller amount of packet overhead in transmission is not able to cope with handover in a smooth manner and increasing the number of handovers significantly reduces the performance.

5. Conclusion and future work

In this paper, we proposed nSCTP, as a new mobility management mechanism for providing a seamless handover for moving network. First, we showed that a NEMO based handover scheme that uses MIP for handling the vertical handover has some drawback to meet the handover parameters. Second, we also show that an advance transport layer tunnelling with employing multihoming feature of SCTP can provide the seamless service by adjusting the overlap area for adjacent cells in a radio access network. Third, we developed nSCTP which is a transport layer based mobility management for a network in motion.

Using presented protocol besides providing a fully soft and seamless handover can get advantaged of having a reliable protocol in the bottleneck of the network with the cost of increasing the size of packet in this area. The wireless part of network is generally involved with higher bit error rate that in this scheme the lost packet can be solved locally without involving the rest of the network. End user transparencies, no disconnectivity and no changes in internet architecture are some of the main features of this protocol and also security consideration, load balancing and sharing are the open issues in this protocol that can be formed our feature works.

References:

[1] M. R. R. Stewart, Q. Xie, M. Tuexen, P. Conrad, "Stream Control Transmission Protocol (SCTP) Partial Reliability Extension," *IETF RFC 3758*, MAY 2004.

[2] A. S. R. M. Atiquzzaman, "Survey and Classification of Transport Layer Mobility Management Schemes," *PIMRC*, 2005.

[3] W. M. Eddy, "At What Layer Does Mobility Belong?" *Ieee Communications Magazine*, vol. 42, pp. 155-159, 2004.

[4] M. Ratola, "Which Layer for Mobility? - Comparing Mobile IPv6, HIP and SCTP," Helsinki University of Technolog, Telecommunications Software and Multimedia Laboratory 2004.

[5] M. Riegel, "Mobile SCTP," in *Internet Engineering Task Force (IETF)*, July 9, 2005.

[6] C. Perkins, "IP Mobility Support for IPv4," *IETF RFC 3344*, August 2002.

[7] J. Rosenberg, H. Schulzrinne, G. Camarillo, A. Johnston, J. Peterson, R. Sparks, M. Handley, and E. Schooler, "SIP: Session Initiation Protocol," in *RFC 3261 (Proposed Standard)*, F. Iet, Ed., 2002.

[8] V. Devarapalli, Wakikawa, R., Petrescu, A., and P. Thubert, "Network Mobility (NEMO) Basic Support Protocol," *RFC 3963*, January 2005.

[9] D. Johnson, Perkins, C., and J. Arkko, "Mobility Support in IPv6," *RFC 3775*, June 2004.

[10] S. J. Koh, M. J. Chang, and M. Lee, "mSCTP for Soft Handover in Transport Layer," *Ieee Communications Letters*, vol. 8, pp. 189-191, 2004.

[11] "The Network Simulator - **ns-2**, <http://www.isi.edu/nsnam/ns/>."

[12] "Protocol Engineering Lab, University of Delaware, http://pel.cis.udel.edu/."