# Performance Analysis on IP- based Soft Handover across ALL-IP Wireless Networks

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## Abstract

*Mobile users are facing the fact that many heterogenous radio access technologies coexist, ranging from wireless LANs to cellular systems. No technology has emerged as common and universal solution which makes the current trends today toward design of All-IP wireless networks, where radio cells are under the control of IP Access Routers for signalling and data transmission. In such as networks, an IP-device with multiple radio interfaces or software radio can roam between different radio networks regardless the heterogeneity of radio access technologies. The design of an All-IP wireless network requires an efficient and flexible IP-based handover management, and a major issue in handover control is how to reduce data loss and avoid additional end to end transmission delay. In this paper we propose and evaluate mechanisms to handle soft-handover management in IP layer over heterogenous networks. Those mechanisms coexist with Mobile IPv6 and allow efficient micro mobility management.*
***Keywords.*** *All-IP wireless networks, heterogeneous network, Soft Handoff, Mobile IP, IEEE 802.11.*

## 1. Introduction

One of the most important issues in IP-mobility protocols design is the IP handover performance. IP handover occurs when a mobile node changes its network point of attachment from an Old Access Router (AR1) to a New Access Router (AR2). If not performed efficiently, end-to-end transmission delay, jitters and packet loss directly impact and disrupt applications perceived quality of services. Because Soft handover provides same data receiving from multiples Access Router, it allows mobile station's session to progress without interruption when a Mobile Node moves from one radio cell to another. These can be done, if and only if 1.MN is able to communicate simultaneously with multiple ARs in the same time. 2. The network can duplicate and correctly merge the IP-flows from the correspondent node to the MN through different access routers. If the two conditions are verified, it is possible to eliminate packet loss and reduces end-to-end transmission delays, which provides a clear advantage to traffic requiring real time transmission. This paper presents pure IPv6 Soft Handover mechanisms [2], based on IPv6 flows duplication and merging in order to offer pure IP-based mobility management over heterogenous networks. Proposed solution does not impose any change to the Mobile IPv6 standard [3]. It is an extension to support an efficient Soft handover and micro mobility management, for Mobile Node (MN) with multiple radio interfaces (WLAN) [4] or with unique CDMA interface. This solution requires the introduction of new component called "Duplication & Merging Agent" (D&M) agent. It is a conventional router located at the core network used to duplicate and merge IPv6 flows to and from the MN.

## 2. Related Works

Mobile IPv4 and Mobile IPv6 [3][5] introduce basic mobility management services in Internet Protocol, their simplicity and scalability give them a growing success. MIP poor Handover performance makes it not appropriate for real time applications with heavy constraints in transmission delays and packets loss. Smooth handover [6] introduces packets buffering mechanisms in each access router to recover all lost packets during handover, but introduces additional end-to-end packets transmission delays. Basic MIP Fast Handover [7] is another approach that anticipates the obtention and the registration of future mobile address. "MIP fast handover bi-casting" [8] exploits this anticipation to simultaneously duplicate data to the old and new care of address (CoA) of MN, which allows MN to receive data immediately after performing layer 2 handover and removes layer 3 handover delays. Simulation work done in [9][10] , shows us that globally, smooth and fast handover can not avoid TCP performances degradation and UDP packets loss when MN moves from OAR to the NAR . In the following we propose a novel IP based handover scheme that addresses delays and packets loss issues in the same time and across heterogeneous networks.

## 3. IPv6 Soft handover mechanisms

IP Soft handover approach is based on four main processes, registration process, duplication process, merging process and handover process. They allow duplication and merging of IP flows without need to synchronise duplicated flows transmission [11].

### 3.1. Mobile registration process

In order to be connected to several ARs, MN must be associated with several CoAs, each CoA identifies MN connection through a unique AR. If we consider a special case of MN having data connection with two ARs in IPv6 network, and if a CN decides to send IP packets to the MN, sending device have to know all the addresses of MN in all sub networks. To perform such thing, Mobile IPv6 allows MN to have a primary CoA (PCoA), which is the temporary address obtained by MN for the first time it connects to the network. It is registered within home agent and D&M agent in the reference link of MN and it is the Address used by the different CN, which are likely to communicate with MN. Two additional local CoAs are used for packets transmission from D&M agents to MN through the two ARs. Those LCoAs are obtained by MN using IPv6 stateless auto-configuration addresses mechanism [3] and registered with in D&M agent Figure1

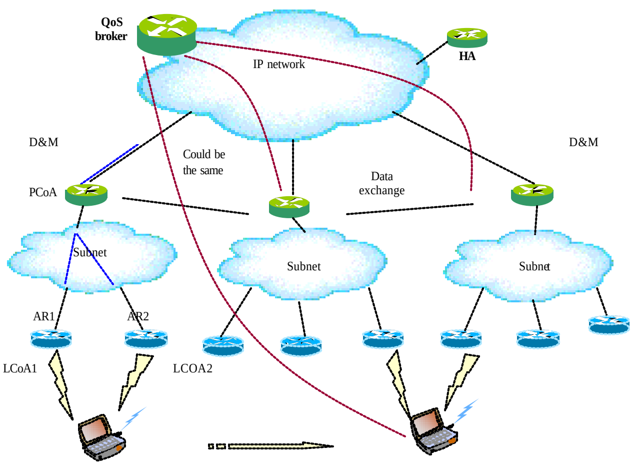


**Figure1: Soft handover across subnet.**

### 3.2. Duplication Process

To duplicate packets, D&M agent intercepts all packets sent by the CN and stores them in its internal memory, extracts from each packet the destination Address (PCoA) and looks for its corresponding LCoAs. Using those LCoAs, D&M agent creates a new IPv6 packet with same payload information, but with substitute LCoA as new destination address. Sequence number (*X*) is inserted in a Destination Identifier Option (DIO) field and added to each IPv6 packets header. This field is used to number all packets sent to the tunnel, same duplicated packets will be identified by same sender, same receiver and same sequence number. Duplicated and numbered packets are then tunnelled to MN via corresponding ARs (Figure 2).

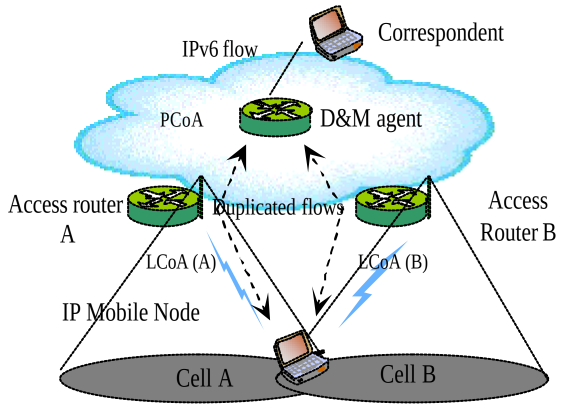


**Figure1: IPv6 flow duplication and merging**

Inversely, MN do same thing with uplink stream. It duplicates all packets and sends them to the D&M agent via the two ARs.

### 3.3. Merging process

The use of D&M agent (respectively MN) duplication process to send separate copies of same data via multiple ARs to MN (respectively D&M agent), introduces the need to filter the duplicated packets. To perform efficiently such thing, MN or D&M agent needs to match those multiples streams in IP layer at reception. In case of uplink traffic, D&M agent intercepts all tunnelled packets, checks if the DIO field is included in the IP packet. If there is DIO, which is mean that IP packet was not duplicated, process will route normally the payload information. D&M agent incorporate a set of tables, particularly a merging control table (MCT), which defines for each registered LCoA the parameter *e* and a list of *Xi*. *e* is the highest value *X* of all received packets plus one. *Xi* corresponds to packets that have been transmitted through the tunnel, but which are not yet received. Those values correspond to packets that are still missing

If DIO is included in the received packet and source-address has an entry in MCT table, packet has been duplicated, Thus the value of sequence number *X* and value of *e* in MCT table, will be used to determine if this packet is received or not. If received, IP packet will be discarded (the packet has already been received). Else the payload is routed normally. Figure3.

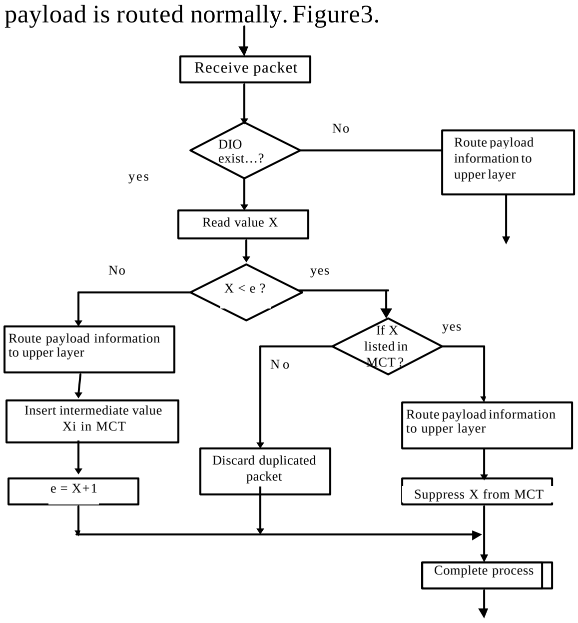


**Figure 3: IPv6 flow merging algorithm**

## 3.4. Handover Algorithm

We suppose a MN with two interfaces primary and secondary, the interfaces priority choice is dynamic; we assume that the primary interface is always the interface with better connexion quality. The MN must be kept connected through its primary interface. The secondary interface is used to perform the handover and avoid signal strength degradation if possible. The aim of this handover strategy is to efficiently exploit all available resources in order to avoid packet es and the introduction additional end-to-end delays during MN roaming from an AR to another one.

Two signal strength thresholds are defined, handover threshold (H_SH), which is the threshold used in Mobile IPv6 to initiate the handover. Primary threshold (P_SH) is used in soft handover to initiate secondary interface connection process. Figure 4.

We assume a MN connected on its primary interface with AR1, it has its PCoA and LCoA1, and both of them are registered with in D&M agent. When MN discovers AR2, and if quality of primary connexion is less then P_SH, secondary interface connexion is established with AR2, LCoA2 is registered within D&M, duplication and merging process will be UP.

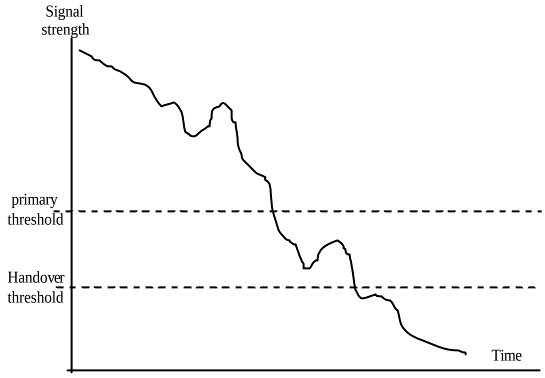


**Figure 4: primary and handoff thresholds.**

In this case: 1. Interface with better connexion quality will be assigned dynamically to be the primary one. 2. If signal strength of secondary connexion became worst then H_SH, the secondary connexion is closed and active scanning is initiated to connect it to new AR. 3. When the Signal strength quality became better then H_SH (very good connexion quality), MN closes secondary connexion, shut down duplication and merging process. Complete handover algorithm is described in Figure 5.

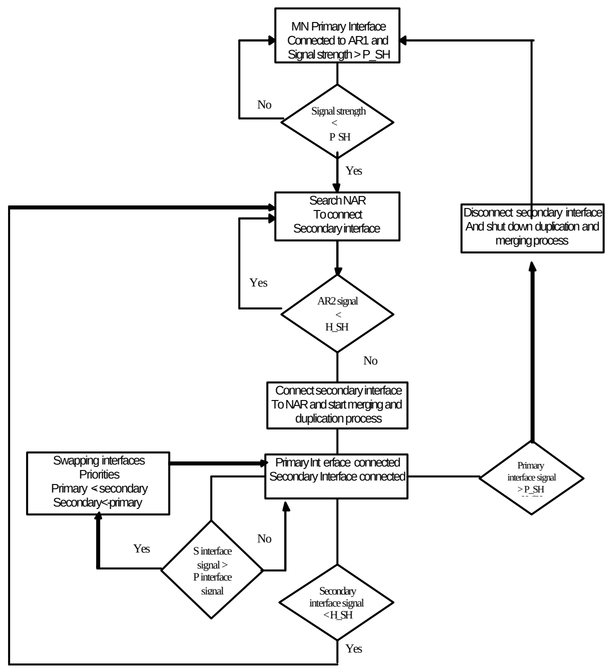


**Figure 5: Handover process.**

# 4. Performance Analysis

## 4.1 Simulation Environment

To analyse the performances of IPv6 soft handover mechanisms, we use Gemini2 simulator. Gemini2 simulator is a discrete time simulator developed in Eurecom It provides support for simple, open and efficient conception of a network topology to simulate complete wireless networks. Network topology parameters can be chosen at physicals, data link layers and 802.11 MAC protocol. Above it we have pre-implemented Mobile IPv6 module over IPv6 routing protocol and UDP is used as transport layer.

To implement soft handover module, we add D&M agent as special router and MN with two 802.11 radio interfaces. No changes have been done to the IPv6 stack.

The simulation model introduces an application in top of CN sending UDP packets to The MN. A number of IP Access Routers uniformly reparteed give MN optimal radio coverage for about 1000m.

A D&M agent is introduced between the CN and ARs in network topology to duplicate and merge IPv6 flows from CN to MN. A set of MN movement's scenarios are used as inputs to the simulation. Each movement scenario determines MN movement at different speeds across coverage area. The MN1 changes its point of attachment using basic mobile IPv6 handover and the MN2 is performing soft handover to change its point of attachment. Figure6.

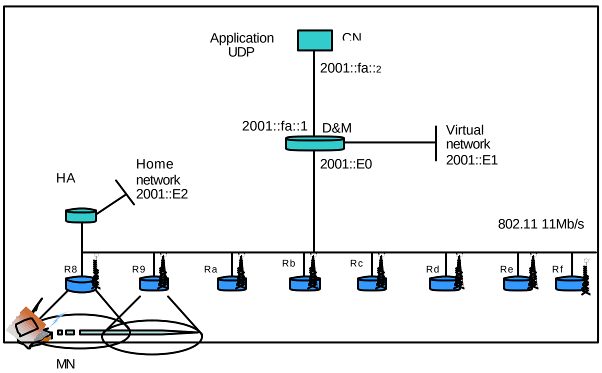


**Figure 7: Simulation network topology.**

Following metrics are used to analyse the performance of soft handover and to compare it with basic MIPv6 performance:

- End-to-end transmission delays: the delay needed by UDP packet sent by CN to correctly reach the application layer in the top of MN.
- UDP packets fraction delivery: the number of data packets correctly delivered to MN over the number of data packets sent by CN
- Control/signalling information load: the load of signalling data generated by MN handover from an AR to new one.

## 4.2 Simulation Results

First simulation set aims to determine end-to-end average packets delivery delays between the CN and the MN. In first simulation set, the MN uses basic mobile IPv6, and in second set, the MN uses Soft handover mechanisms.

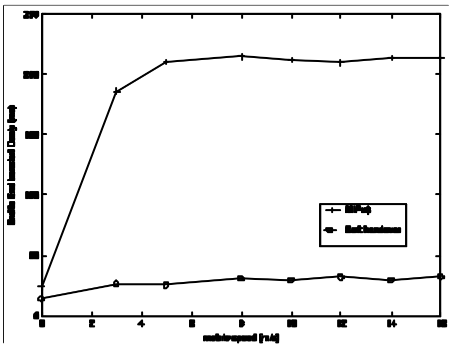

**Figure 5: Average End to end transmission delays.**

By looking at the trends in diagrams 5 showing average end-to-end transmission delays in both MIPv6 and Soft handover, the following consideration can be made.

- Soft handover allows MN to keep a minimal transmission delay, about 25ms when crossing coverage area.
- When MN uses MIPv6 basic handover, average transmission delay is to much bigger, about 170ms transmission.

To understand reasons of transmission delays differences between MIPv6 and soft handover, we plot in diagram 5 and diagram 6 End-to-end detailed delivery delays for all packets sent by CN to MN, during one MN movement across the coverage area at 5m/s speed.

When MN uses basic MIPv6, the handover is not initialised before OAR signal strength degradation (it became low than handover threshold). Before each handover, OAR signal strength degradation generates successive MAC retransmission of packets before their correct reception. Those successive retransmissions are responsible of the additional average packet delivery delays in MIPv6. After each handover, better signal strength from NAR allows correct reception of packet in Mac layer which avoid additional transmission delay.

Delivery delays of the MN that uses soft handover stays stable, because the MN establishes a second connection with NAR before severe degradation of OAR signal strength. Asynchronous emission of duplicated packets through the two ARs allows MN to receive the first among duplicated received packets at IP layer. That avoids the introduction of additional end-to- end transmission delays.

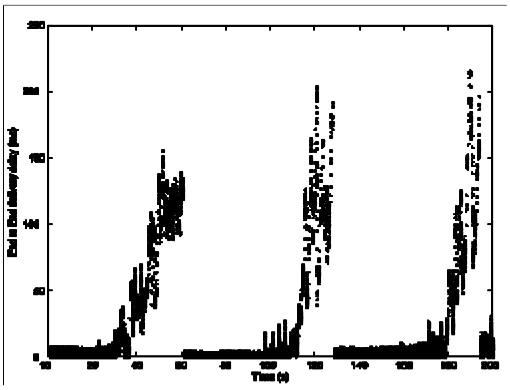

**Figure 6: MIPv6 End-to-end transmission delays.**

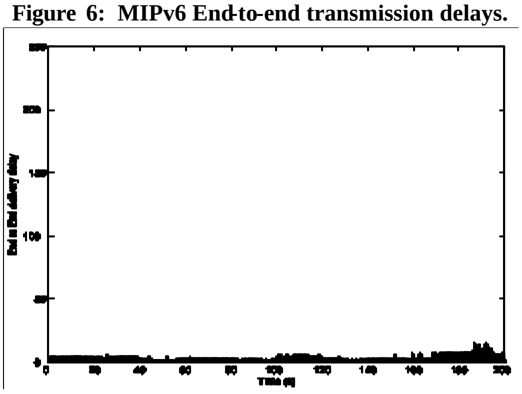

**Figure 7: Soft handover end-to-end transmission delay.**

Average UDP packets loss is determined using the same scenarios. The MN moves across same network topology using soft handover, and after using Mobile IPv6 basic mechanisms. Figure 7 shows us sum of UDP packets sent by CN and sum of the packets received by the MN in movement with 5m/s speed. Each handover using MIPv6 introduces packets loss because of 1. Signal degradation before handover 2. MN Layer2 and layer3 disconnection during the handover. The use of two simultaneous connections in soft handover suppresses packets loss during handover and reduces packets loss introduced by signal degradation.

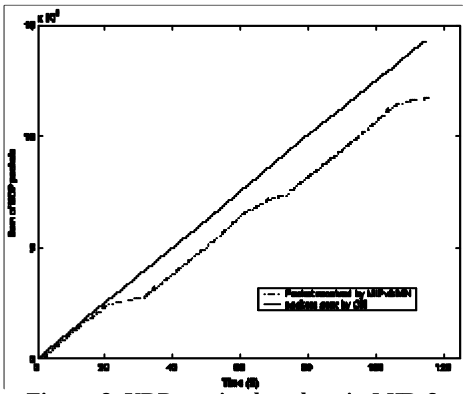

**Figure 8: UDP received packets in MIPv6.**

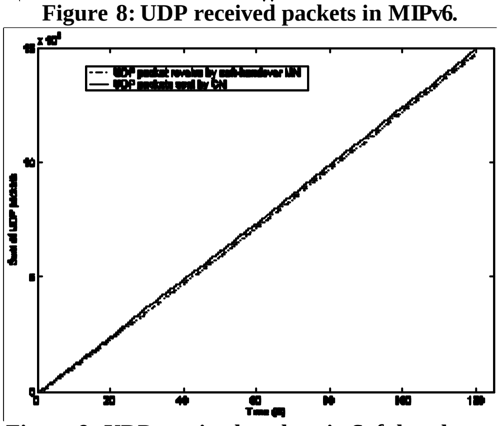

**Figure 9: UDP received packets in Soft handover.**

Several simulation runs with different MN speeds allows us to have diagram10. By looking at the trends shown in this diagram, the following consideration can be made.

- By performing Soft handover, MN registers an average of 98% of UDP packets delivery fraction. This value is stable even MN increase its speed.

When MN uses MIPv6 basic handover, initial delivery fraction is lowest and the increase of MN decreases the delivery ratio. That decreases from 90% in 5m/s speed to 75% in 16 m/s.

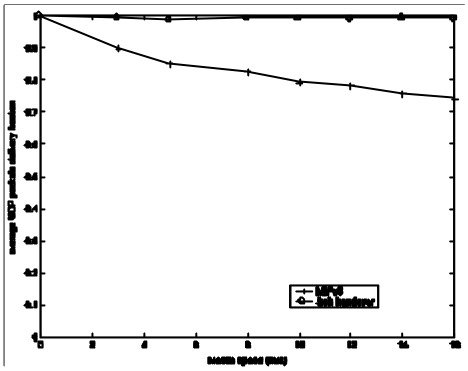

**Figure 10: Average UDP packets fraction delivery**

The last simulation set tries to determine and compare load control information generated by soft handover and MIPv6. To perform such thing, the same simulation topology is use to evaluate the control load generated by MN handovers. Diagram 11 shows that soft handover introduce additional control load information compares to mobile IPv6. The additional load is about 40% of basic MIPv6 handovers control load information.

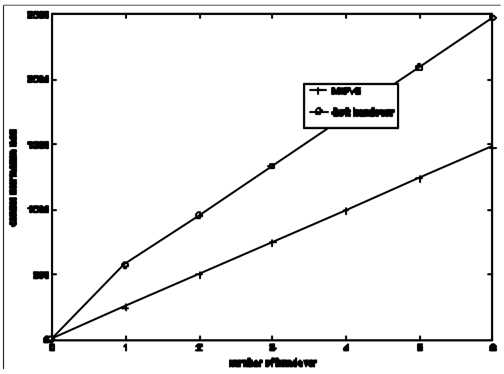


**Figure 11: layer 3 Control information load.**

## 5. Summary and Future Work

In this paper, we have presented a pure Pv6 Soft handover protocol and architecture that allow MN seamless roaming, with reduced end-to-end transmission delays compare to various mobile IP approaches. This solution exploit only IPv6 protocols futures, coexists with MIPv6, improves micro mobility management and can provides data transmission continuity for delayed constrained applications such as real time video playback. The Soft handover across heterogeneous networks can be done without any modifications to MN's radio system. Comparing to the other IP based soft handover approaches, the major issues is that there is no need to synchronize the distributed copies of data. The MN routes first received duplicated packets and simply ignore the others.

We have shown through UDP simulation that IP soft handover is capable, when enough resources are available, to reduce average packet loss to 2%. It also reduces end-to-end data transmission delays 6 folds when compared to the standard MIPv6. Those results show that IP soft handover can be exploited in order to guarantee a high level of QoS for real time applications.

On the other hand this approach requires the introduction of D&M agents in network, and introduces additional signal load over the air. Streams tunnelling and duplication introduces additional overhead of about 48 bytes to each duplicated IPv6 packets.

As future work, we would compare IP soft handover performance to fast Mobile IP handover (Bi Casting) and smooth handover. Comparison results will be exploited to develop an adaptive Handover control algorithm across All-IP networks that guarantee different level of services for applications.

## 6. References


[1] Yan Moret & All, European Patent "Process and apparatus for improved communication between a mobile node and a communication network", Patent No. 02368057.2.

[2] F.Belghoul, Y.moret, C.Bonnet, "*eurecom IPv6 soft handover*" ICWN 2003 proceeding, Las Vegas USA

[3] D. Johnson and C. Perkins. IETF Internet Draft *"Mobility Support in IPv6"*, draft-ietf-mobileip-ipv6-24.txt. June 2003

[4] "Wireless LAN Medium Access Control (MAC) and Physical layer", ANSI/IEEE Std 802.11, 1999 Edition.

[5] Charles Perkins, editor, *"IP mobility support for IPv4"*, RFC 3220, January 2002.

[6] Charles E. Perkins and Kuang-Yeh Wang. "*Optimized Smooth Handoffs in Mobile IP"*. Proceedings of the Fourth IEEE Symposium on Computers & Communications, July 1999

[7] Rajeev Koodli, Charles E. Perkins. IETF Internet Draft *"Fast Handovers in Mobile IPv6"*, draft-ietf-mobileip-fast-mipv6-07.txt. September 2003.

[8] K.El Malki, IETF Internet Draft *"Simultaneous bindings for mobile IPv6 Fast Handovers "*, draft-elmalki-mobileip-bicasting-v6-03.txt May 2003.

[9] H. Hartenstein, K.Jonas , M. Liebsch R.Schmitz, M. Stiemerling, D. Westhoff. *"Performance of TCP in the Presence of Mobile IP Handoffs"*, (ICT 2001) IEEE International Conference on Telecom, Bucharest, Romania, June 4-7 2001

[10] Doo Seop Eom, Masashi Sugano, Masayuki Murata, and Hideo Miyahara, *"Performance Improvement by Packet Buffering in Mobile IP Based Networks"*, IEICE Transactions on Communications, vol. E83-B, pp. 2501-2512, November 2000.

[11] Zhang T., Chen JC., Agrawal P., *"Distributed soft handoff in All-IP wireless networks"*, Proceedings of IEEE International Conference on Third Generation Wireless and Beyond (3Gwireless'01), San Francisco, CA, pp. 460-465, mai 2001.