IEEE 802.21 reliable event service support for network controlled handover scenarios

Telemaco Melia*, Luca Boscolo * Albert Vidal *, Antonio de la Oliva† and Michele Zorzi‡
*NEC Network Laboratories, Heidelberg, Germany
Email: melia,boscolo,vidal@netlab.nec.de
†Departamento de Ingenieria Telematica, Universidad Carlos III de Madrid, Madrid, Spain
Email: aoliva@it.uc3m.es
‡Departement of Infomation Engineering, University of Padova, Padova, Italy
Email: michele.zorzi@dei.unipd.it

***Abstract*—This paper evaluates, through an extensive simulation study, a flexible framework for centralized network-based handover control across wireless heterogeneous access. For handover decision-making algorithm, implemented in network elements, the approach encompasses events reported by the terminal side (e.g. radio conditions) as well as events reported by the network side (e.g. load change in the access). Based on standard contributions within the IEEE 802.21 Working Group we investigate and design the functionalities required for efficient network to network communication focusing on optimal device configuration and reliable transport. The study verifies that i) the signaling overhead introduced by the proposed framework does not impact negatively handover performance while allowing network reporting and ii) the implemented re-transmission mechanism reduces messages loss even under congestion conditions.**

I. INTRODUCTION

During the past years, Internet heterogeneous wireless mobile access has increasingly gained interest in the research community. Paradigms such as *always best connected* and *end to end seamless service delivery* impose new challenges in mapping the emerging wireless heterogeneous broadband access (e.g. cellular existing networks complemented by WLAN and WiMax deployments) into a single convergence layer, namely the Internet Protocol (IP). In parallel to this, the availability of multi mode devices integrating cellular, WLAN and WiMax technologies opens new business opportunities for mobile operators aiming at generating new revenue streams while offering novel services across multiple access network. In this new wireless heterogeneous landscape, mobility management of semi-static and mobile customers is not a trivial task. Traditional mechanisms which were designed and optimized for single technologies are now required to inter-operate across different networks while maintaining the same carrier grade service quality. Although user mobility across different wireless access networks is possible in legacy solutions, they are not optimal and mainly user centric, thus not allowing mobile operators a reasonable control and management of inherently dynamic users.

This work was supported in part by IST FP6 Integrated Project DAIDALOS. DAIDALOS receives research funding from the European Community's Sixth Framework Program. Apart from this, the European Commission has no responsibility for the content of this paper.

Several Standards Developing Organizations (SDOs) have already identified the aforementioned issues and are timely trying to address them. The IEEE 802.21 [1] Working Group is doing an effort to ratify the Media Independent Handover (MIH) standard, which will enhance mobile centric handovers and enable network controlled handovers across heterogeneous environments by sharing access networks information and a common set of events and commands. In parallel to this, the Internet Engineering Task Force (IETF) addresses at IP level the support for mobile heterogeneous access lately focusing on renewed interest for network based solutions. As an example, the NETLMM [2] Working Group is currently developing methods to control data plane update, upon user mobility, from the network side, hence meeting operators' requirements on delivering network based solutions.

In the research community, a number of approaches aiming at providing network support for mobility management have been proposed and examples are [3] [4] [5]. However, to the best of authors' knowledge, both network and terminal handover optimization schemes for heterogeneous networks, framed under a common set of functional components and associated protocol operations, are not yet accurately addressed and evaluated.

Considering the ongoing work [6] in the IEEE 802.21 as the baseline, this paper evaluates a flexible framework for heterogeneous technologies handover control focusing on network side strategies. Furthermore, it is evaluated a novel approach for network driven handover control encompassing events reported from the terminal, like the radio conditions, and events reported by the network, like the current load on the access network. Based on previous work [7] [8] [9] we investigate and design the functionalities required for efficient network to network communication focusing on optimal configuration and reliable transport of the information to a central entity for handover decision making. The study verifies that i) the signaling overhead introduced by the proposed framework does not impact negatively handover performance while allowing network reporting and ii) the implemented retransmission mechanism reduces messages loss up to 7% even when the network operates close to congestion conditions. We argue this collaborative environment leads to a better usage of the network resources while meeting emerging mobile

operators requirements.
The remainder of the paper is organized as follow. Section II gives a brief overview to the IEEE 802.21 standard shedding light on the relevant aspects affecting our study. Section III presents the framework design describing functional components and the associated signaling. Section IV introduces the simulation setup for performance evaluation. Section V presents a thorough evaluation of the results. We conclude in section VI.

II. IEEE 802.21

The IEEE 802.21 [1] or Media Independent Handover (MIH) technology enables optimized handovers across heterogeneous IEEE 802 systems as well as between IEEE 802 and cellular (3GPP and 3GPP2) systems. The goal is to provide the means to facilitate and improve the intelligence for handover procedures, allowing vendors and operators to develop their own handover strategies based on mobile centric or network based policies. The MIH aims at optimizing the handover procedure between heterogeneous networks by specifying a Media Independent Handover Function (MIHF), which allows the communication between different components, either locally (within same protocol stack) or remotely (between different network entities).
Three main mobility services are being defined. The Media Independent Event Service (MIES) provides event classification, event filtering and event reporting, corresponding to dynamic changes in link characteristics, status and quality. The Media Independent Command Service (MICS) enables MIH nodes to manage and control link behavior related to handovers and mobility. It also provides the means to mandate actions to lower layers, in a local or in a remote protocol stack. Lastly, the Media Independent Information Service (MIIS) provides details on the characteristics and services provided by the serving and surrounding networks. Through the use of these services, layer three mobility management protocols control the handover procedure in a more efficient way while enabling seamless handover.
Figure 1 depicts the MIH network communication model with its functional entities and associated interfaces. Network components are classified either as Point of Attachment (PoA), where the Mobile Node (MN) is directly connected to at L2, or non-PoA. At the same time, MIH network entities can be divided into Point of Service (PoS), which provide any kind of mobility service directly to the MN, or non-PoS, which do not exchange MIH messages directly with MN, but only with other MIH network entities. Transitions between PoAs belonging to the same technology are intra-technology or horizontal handovers and they are described already by the technology specific solutions (e.g. fast BSS transition in 802.11). Transitions between two PoAs of different technologies are named as inter-technology or vertical handovers, in which cross layer communication and handover optimizations are required and are not trivial tasks due to link diversity. Interfaces R1 and R2 in figure 1 are typically specified at layer two, while interfaces R3, R4 and R5 are specified at layer three aiming at technology independence. In order to analyze vertical handovers between WLAN and cellular systems, our work exploits the protocol communication over interface R3 between MN and PoS, as well as over interface R5 for network to network communication. The necessary event and command services for link detection and handover initiation flows over the R3 interface, while the PoA refreshes PoS records about link status characteristics through event services flowing over the R5 interface (e.g. load).

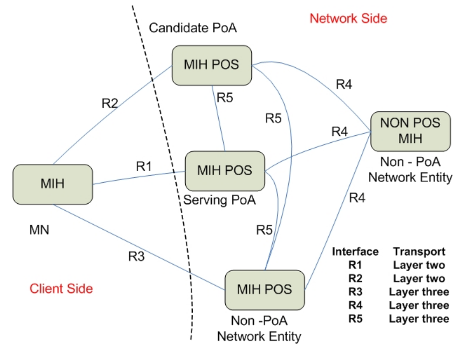

Fig. 1. IEEE 802.21 Communication Model

III. Framework

The considered framework, depicted in figure 2, features a MN, a PoS and several PoAs, all being MIH enabled. Mobility control is centralized at the PoS where handover decision making instructs the terminal where to perform handover. In the scenario we consider only vertical handovers, namely WLAN⇒3G and 3G⇒WLAN, and global reachability is ensured by deploying Mobile IPv6 services.
The MN architecture is derived from the one presented in [9]. The MIHF is configured with the appropriate thresholds for WLAN cell detection, 802.21 signaling initiation and Mobile IP binding update procedures. As described in [9], 802.21 signaling is triggered at the association threshold (known as active scanning threshold) in case of 3G⇒WLAN handover, while Mobile IP signaling is triggered when crossing the configured WLAN⇒3G and 3G⇒WLAN thresholds. The PoAs MIHF implements two thresholds for load report to the PoS. Finally the PoS, via the MIHF, informs the intelligence, implemented as MIH user, for handover decision making.
In Figure 2 (from left to right) the signaling over interface R3 and R5 is presented and herein after described.

A. R3 Interface Handover Signaling

3G⇒WLAN Handover

As a follow up of previous work [9], the scenario assumes a MN connected to 3G approaching a WLAN cell. As soon as an access point (AP) is detected as result of an active scanning procedure, the MIH Function at the MN receives a corresponding indication from the specific link layer technology, WLAN in our case, and sends message (1) to the PoS including information about the target AP just discovered. This MIH message is sent using a layer three transport protocol. In

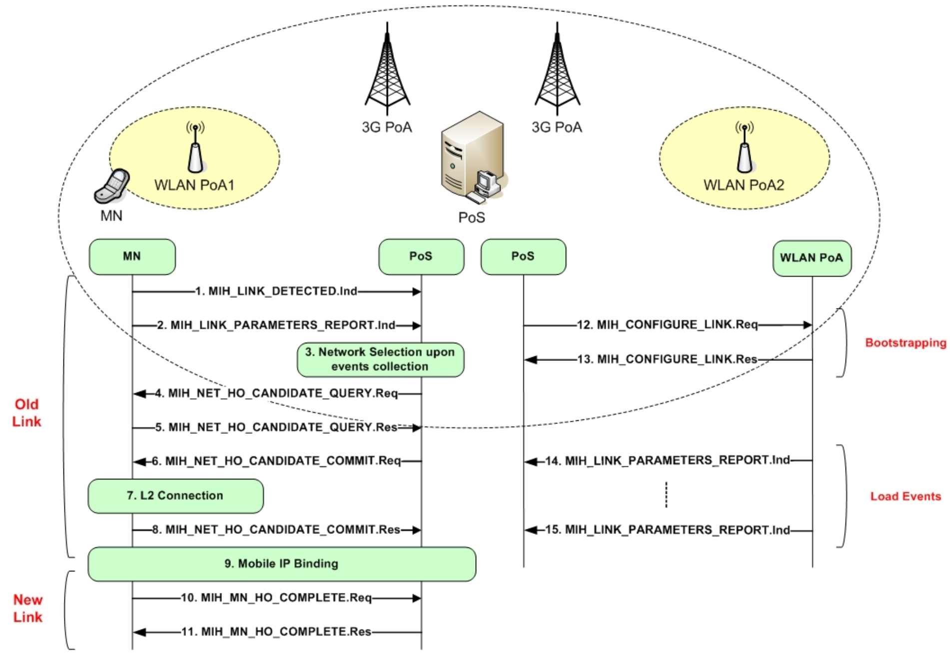

Fig. 2. R3 and R5 Interfaces Handover Signaling

our implementation we have chosen UDP as transport protocol [10], further detailed in section IV. This message is followed by message (2), notifying to the PoS that certain level of signal strength has been reached. Notice, that (1) only informs about network detection (the sensitivity threshold), while (2) assures the association threshold is crossed.

Upon reception of the previous indication, the PoS might select (3) a new target access network based also on other information related to target PoAs, such as the current work load. In case a new network has been selected for a specific MN, the PoS sends message (4) proposing a single target PoA or a list of PoAs which might be suitable, according to the information stored at the PoS. After convenient verifications, the MN replies with message (5) including the list of preferred PoAs, from those provided by the PoS. Note that there might be the case where the MN is out of range from all the PoAs proposed by the PoS because of terminal mobility. Also note that in our scenarion only one PoA at the time is reported since there is no WLAN overlapping area.

The PoS, after reception of MN's feedback, sends the commitment to initiate an handover to the target PoA (6). Thus the MIHF instructs in step (7), via the local stack, the wireless interface for specific link layer operations. Upon successful layer two association[1], message (8) is sent to the PoS. After verification of the radio conditions, the MN executes a layer three handover (9) (i.e. MIP Registration) through the new link. In case the layer three handover succeeds, the message (10) is sent to the PoS to indicate completion of the complete handover. After the correspondent operations at the PoS (e.g. releasing resources at the old link), it replies with message (11). At this point the MN is able to receive layer three traffic through the new link. Note that the difference between a soft and hard handover is only related with the moment when data is not further received through the old link, and does not affect the basic structure of the signaling flow.

WLAN⇒3G Handover

This case supposes an MN associated to an AP, and the MIH Function continuously evaluating the signal level provided by the lower layers. Triggered by low WLAN signal power detection, the MIH sends message (2) to the PoS, indicating deterioration of the received signal level. This will initiate a signaling exchange with the same messages and sequence as the 3G ⇒ WLAN handover, except for the message (1) which is not required, for the 3G connectivity is assumed always available and active (i.e. PDP context always active).

B. R5 Interface Handover Signaling

As explained before, interface R5 carries the signaling required for network to network communication. The purpose of the selected messages is to convey in a single central point sensitive information needed for handover decision making. In the illustrated scenario the central entity, the PoS, gathers data related to the load of each PoA and decides whether a mobile node should roam to a specific AP depending on the available resources. For this purpose the PoS, during the bootstrapping phase, configures the thresholds in every PoA it should monitor, thus enabling events generation. Assuming, for instance, that the MN is already associated to the 3G leg, during the startup sequence, message (12) is sent from the PoS to the PoAs to configure the aforementioned thresholds. PoAs then confirm the setup by mean of messages (13). When load levels change, events are generated at the PoAs and reported

[1]Please note that in the simulator an active scanning procedure has been implemented to guarantee favorable radio conditions.

to the PoS via message (14). That is, message (14) is sent asynchronously every time the set thresholds are crossed. The network to network communication support provides the PoS with timely information for enhanced handover decision. It follows, that in case of outdated information, the intelligence may take wrong decisions impacting mobility performance and handover management. The main purpose of this study is to detect possibilities and limitations of the approach by analyzing the impact of the introduced signaling on the overall handover performance as compared to an ideal case where the information is anytime available at the mobility management entity in the network.

IV. Simulation Setup

Our framework is based on the OMNeT++ [11] simulation setup described in [9]. The scenario is composed by a MN moving accordingly to a Random Waypoint model within a complete cellular coverage area complemented by specific WLAN hotspots spread all over the scenario.
We argue that the reliability of MIH signaling is the relevant issue to consider when assessing performances of handovers, therefore an acknowledgment system for the signaling introduced over R5 interface (see Figure 2) has been implemented. [1] provides guidelines about reliability of MIH communication specifying retransmission of packets, acknowledge messages, Retransmission Timeout (RTO) management and congestion control (i.e. [12] and [13]). Nevertheless, our implementation differs from the aforementioned solutions by introducing a method to send updated information in retransmitted messages. That is, in case of RTO expiracy, a new message with updated parameters is sent through the retransmission procedure instead of a copy of the old message, which might contain obsolete information. We argue that, since the RTO could be preconfigured to values in the order of seconds, re-sending a copy of the unsuccessfully transmitted message could lead the PoS to enforce decisions based on outdated information. Moreover, the recommendation about rate limiting mechanism by means of token bucket as in [13] is not followed. Yet we argue that, in an implementation with a token bucket throughput limiter, a priority system should be implemented in order to avoid delaying of message(14) due to queuing. The transport protocol selected is UDP/IP [10]. Two different setups have been considered.

A. Setup for Network Communication Study

Since the scope of the paper is to detect the impact of network to network communication on handover performance, the ideal PoS presented in [9] (information for decision making is available with zero delay) is here extended with the required signaling for PoA to PoS communication as specified in [6]. In this first set of runs the speed of the MN is set to 2m/s, 5m/s and 10m/s and for each speed the 3G $\Rightarrow$ WLAN threshold ranges from -74dBm to -65dBm. The WLAN $\Rightarrow$ 3G threshold has been set to -75dBm. The load on each of the PoAs has been modeled on a birth-death process with an average of 80% load at the PoAs. These values have been chosen accordingly to the results obtained in, [14], [7] and [9]. Measures have been gathered from 120 runs using different Random Number Generator (RNG) seeds.

B. Setup for Network Congestion Study

In order to detect the effect of packet loss and Retransmission Timeout (RTO) of message (14) on HO performance, data streams have been introduced in the network accordingly to the actual load on the PoAs. A VoIP stream of 83kbps at a Constant Bit Rate (CBR) for each user is assumed. In this second set of runs the MN's speed is set to the fixed value of 2m/s. We varied the birth-death processes' inter-arrival time to get the average load ranging from 77.5% to 87.5%. In this setup, the use of 60 different RNG seeds guaranteed a clear differentiation of the resulting confidence intervals.

V. Evaluation

In this section we evaluate the results gathered from the simulations for the two different setups. The selected metrics for setup 1 are:

- Percentage of L2 handover without MIP registration (incomplete handovers)
- Number of 3G$\Rightarrow$WLAN handovers
- Number of WLAN$\Rightarrow$3G handovers
- WLAN utilization time

Regarding the first metric, an incomplete handover is a situation in which the mobile node detects the WLAN cell and starts the signaling procedure in figure 2 but, after receiving message (6) the signal level never goes over the 3G$\Rightarrow$WLAN threshold. Consequently, the procedure is not complete, in particular a layer three registration to send the traffic to the WLAN interface does not take place. Notice that this situation does not imply any service interruption, since the mechanism implemented allows always the backup communication channel through the other interface, still active.
Regarding the last metric, the amount of time the user is connected through the WLAN is computed, from the moment right after a handover to WLAN until a handover to the cellular or a loss of WLAN coverage happens.

A. Network Communication Study

Figure 3 shows the average percentage of L2 associations not followed by a MIP binding update, computed over the different thresholds. The explanation of the graph is as follow. The dashed lines represent the number of layer two associations not followed by a full Mobile IP registration due either to non favorable radio or load conditions in the ideal case (C). It can be derived that the effect on the increasing number of failures is a direct consequence of the mobility pattern. Upon measurements it has been verified that the signaling up to step (6) of figure 2 is always completed before crossing the threshold for MIP registration (this matches the results in [9] where the optimal threshold configuration to start the handover signaling has been proved to be at the association

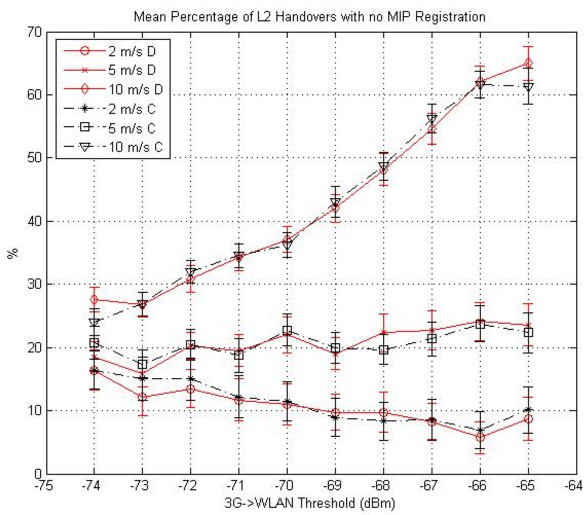

Fig. 3. Number of incomplete handovers for different terminal speeds: ideal case (C) vs real network signaling case (D).

threshold). That is, the solid lines representing the real network signaling case (D), confirm that introducing a network to network communication model does not negatively impact this metric.

Figure 4 shows the average number of handovers to the

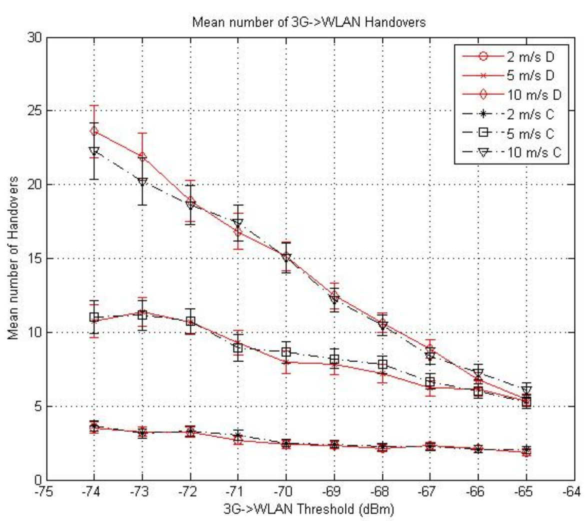

Fig. 4. Number of handovers to the WLAN for different terminal speeds: ideal case (C) vs real network signaling case (D).

WLAN performed by the MN. It can be seen that, for different terminal speeds, the total number of handovers decreases as the threshold values are more restrictive, i.e. WLAN coverage areas are smaller. Also in this case, this is a consequence of the terminal mobility pattern. Comparing the ideal case (C) with the real case (D), it seems clear that the PoA to PoS communication does not negatively affect the metric.

Figure 5 depicts the average time spent by the MN attached

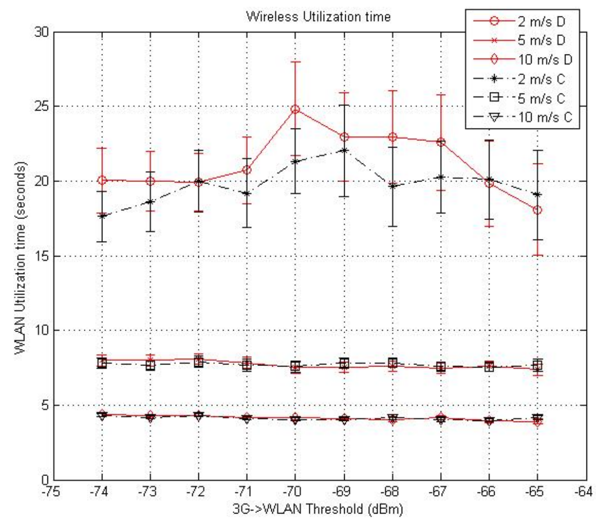

Fig. 5. WLAN utilization time for different terminal speeds: ideal case (C) vs real network signaling case (D).

to the WLAN per handover. Although a small difference in absolute values can be noted, we argue that even this metric, due to the overlapping confidence intervals, is not affected by the PoA to PoS communication. We derive that the model presented is consistent with respect to the selected metrics, already presented in previous studies. We further proceed analyzing the second setup to verify the impact of network load and RTO.

B. Network Congestion Study

The simulation was performed both with and without the addition of VoIP streams in the network. The average load on the PoAs is varied ranging from 77.5% to 87.5%. This setup is necessary to identify the requirements on the transport for events delivery between network components. Although recommendations are given in [1] and in [10] we argue a detailed evaluation study of the parameters configuration is required for optimal network nodes thresholds setup. That is, the following graphs taking as reference points the results for one threshold and one speed, analyze the metrics by comparing obtained performance with and without network load.

Table I presents two of the three aforementioned metrics when

Average load on PoAs	77.5%	80%	82.5%	85%	87.5%
WLAN time w traffic (s)	22±3	21±3	21±3	18±3	18±3
WLAN time w/o traffic (s)	18±2	20±3	16±3	19±3	20±3
3G ⇒ WLAN HO w traffic	2.8±0.4	3.1±0.4	3.3±0.5	2.8±0.4	2.7±0.5
3G ⇒ WLAN HO w/o traffic	3.3±0.5	2.7±0.4	2.8±0.4	2.9±0.4	3.0±0.5

TABLE I
WLAN UTILIZATION TIME AND NUMBER OF HANDOVERS TO THE WLAN, WITH AND WITHOUT THE INTRODUCTION OF VOIP STREAMS IN THE NETWORK

traffic load is applied. It can be noted that the effect of loosing up to 7% of messages (14) depicted in figure 6 does not impact both WLAN utilization time and the number of 3G⇒WLAN handovers. This behavior is helped by the implementation of a special purpose acknowledgement system where the lost packets are not recorded, since the information they carry is time critical. This optimization allows the retransmission, in case of packet loss, of a fresh message by conveying to the PoS new information for optimal decision making. We argue this is a major highlight of the presented work, introducing a mechanism that avoids the retransmission of obsolete reports and at the same time provides reliability to the network to network communication, providing the mobility management entity in the network information enough to make accurate handover decisions. This can not be further avoided if the MIHF relies on the retransmission capabilities available at the transport layer as identified in [10].

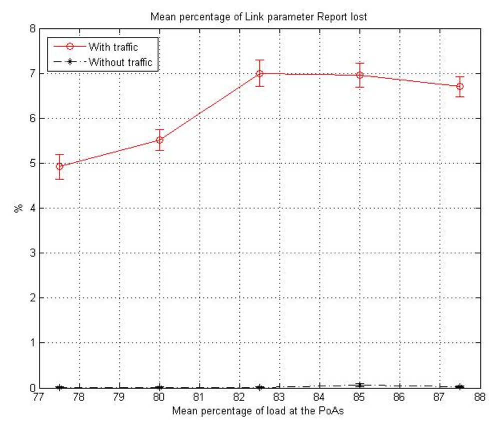

Fig. 6. Mean Percentage of Link Parameters Report lost messages before and after the introduction of VoIP streams in the network.

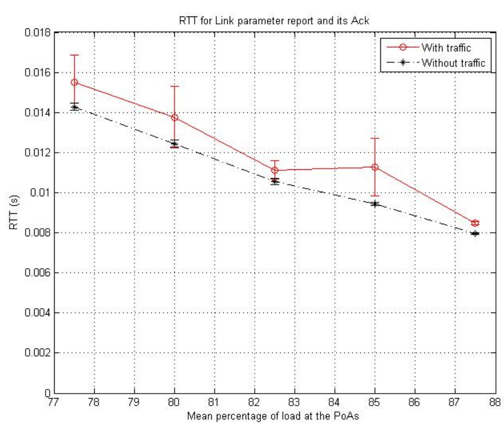

Fig. 7. Round Trip Time of Link Parameters Report messages before and after the introduction of VoIP streams in the network.

Figure 7 verifies that the RTT values are consistent throughout the setup. Although it would be expected to have increasing RTTs while increasing the load in the network, the probability of crossing thresholds (load changing rapidly) and therefore to generate more events reports from the PoA to the PoS is higher at 77% of the load than at 88%. It derives that the number of total link parameter reports decreases with the increase of load. It should be noted that, however, the percentage of link parameter reports varies between 5% and 7%. This is a desirable effect proving that the system has a constant response to load increase.

VI. Conclusions

The paper presents and evaluates a network based approach for enhance vertical handover control in future IP based networks. The framework is based on the upcoming IEEE 802.21 standard and is implemented according to the contribution presented in [6]. The setup considers a MN moving in a full cellular coverage area complemented by WLAN hotspots. The simulation study analyzes the handover performance of centralized network controlled and initiated handovers and exploits two well defined interfaces of the IEEE 802.21 communication reference model. The paper demonstrates that the network to network support for network controlled handovers does not degrade handover performance compared to the ideal scenario with information available at the central entity with zero delay. Further, the paper shows how congestion in the access network could impact parameter report loss, thus reduce handover performance. We demonstrate that trough an appropriate retransmission mechanism, even in presence of a 7% packet loss, the mobility is not impacted. We argue such considerations and results highlight the benefit of applying centralized network controlled handovers in future 4G networks, thus meeting emerging mobile operators' requirements.

References

[1] IEEE, "Draft IEEE Standard for Local and Metropolitan Area Networks: Media Independent Handover Services," in *IEEE P802.21/D04.00*. IEEE, February 2007.

[2] http://www.ietf.org/html.charters/netlmm charter.html.

[3] D.Kutscher and J. Ott, "Service Maps for Heterogeneous Network Environments," in *7th Mobile Data Managament Conference*, 2006.

[4] Y. Khouaja, P. Bertin, K. Guillouard, and J. Bonnin, "Hierarchical mobility controlled by the network," in *Multiaccess, Mobility and Teletraffic for Wireless communications*, 2002.

[5] F. Akyildiz, J. Xie, and S. Mohanty, "A survey of mobility management in next-generation all-IP-based wireless systems," in *IEEE Wireless Communications*, August 2004.

[6] A. Vidal, T. Melia, and A. Banchs, "Support for Centrally Coordinated Network Initiated Handovers," in *Contribution to IEEE P802.21/D02.00, 21-06-0783-00-0000-centralized_NIHO*, October 2006. [Online]. Available: {http://www.ieee802.org/21/doctree/2006-11_meeting_docs/}

[7] A. de la Oliva, T. Melia, A. Vidal, C. Jesus, I. Soto, and A. Banchs, "A case study: IEEE 802.21 enabled mobile terminals for optimized WLAN/3G handovers," in *Accepted for publication in Mobile Computing and Communication Review*, 2007.

[8] T. Melia, A. de la Oliva, I. Soto, P. Serrano, and R. Aguiar, "Network controlled handovers: challenges and possibilities," in *To be published in Wireless Personal Communications Journal*, January 2007.

[9] T. Melia, A. de la Oliva, I. Soto, D. Corujo, A. Vidal, and R. Aguiar, "Impact of heterogeneous network controlled handovers on multi-mode mobile device design," in *IEEE Wireless Communications and Networking (WCNC), Hong Kong*, March 2007.

[10] A. Rahman, U. Olvera-Hernandez, J. Zuniga, M. Watfa, and H. Kim, "Transport of Media Independent Handover Messages Over IP," in *Internet-Draft, draft-rahman-mipshop-mih-transport-02.txt*, February 2007.

[11] http://www.omnetpp.org.

[12] V. Paxson and M. Allman, “Request for Comments: 2988,” in *RFC 2988 - Computing TCP’s Retransmission Timer*, November 2000.

[13] A. Conta, S. Deering, and E. M. Gupta, “Request for Comments: 4443,” in *Internet Control Message Protocol (ICMPv6) for the Internet Protocol Version 6 (IPv6) Specification*, March 2006.

[14] T. Melia, A. de la Oliva, A. Vidal, C. Jesus, and I. Soto, “Analysis of the effect of mobile terminal speed on WLAN/3G vertical handovers,” in *Wireless Communication Simposium, Globecom, San Francisco, USA*, November 2006.