An Experimental MIH Platform for Testing Video Streaming Services across Heterogeneous Radio Access Technology Networks

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Abstract. This paper presents an experimental wireless platform allowing the seamless handoff of mobile terminals with on-going video sessions across heterogeneous radio access technology networks. The handover decision is taken by considering parameters from the physical and network layers from both the mobile terminal and radio access networks using Media Independent Handover (MIH) concept. It is demonstrated that when the network is congested, triggering handover from MIH improves and maintains the perceived video quality of service.

Keywords: Vertical Handover, Seamless Mobility, MIH, Video over Wireless.

1 Introduction

The last few years, the rapid evolution of wireless technologies have further increased the heterogeneity of the wireless radio access networks (HSDPA, WiMAX, 802.11g, LTE) 1. Along with the wireless evolution, there are available advanced mobile terminals that support more than one type of wireless connectivity (e.g. WLAN, 3G). Next Generation Networking (NGN) aims to provide a single All-IP network architecture that will converge heterogeneous access networks and services and leave back the "Single network per service" design of the past. This convergence will give the ability to the mobile terminals to be Always Best Connected (ABC) 2. This philosophy is also referred as connected anywhere, anytime and anyhow and it is based on the idea that a mobile terminal can choose the best available network that will cover its QoS requirements (throughput, delay, packet loss) and user's preferences (cost, security, QoE) 3.

Until today, the handover decision functionality was triggered by the physical and link layers (i.e. SNR drops below a threshold) and totally ignoring both network and application layer metrics. The main challenge for a transparent seamless mobility is to consider both network and application layer requirements 3. As an effect, having full knowledge of the current and candidate neighbor networks the handover decision can

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be optimized. That is the approach that has been adopted by Media Independent handover framework in 2003, IEEE with the 802.21 Media Independent Handover (MIH) came to standardize the way of which the network and the terminals exchange information, events and handover commands for an optimal seamless handover between heterogeneous networks 4.

With the increase of the bandwidth in the wireless networks and the encoding bit rate due to advanced encoding technologies (H.264), video services have evolved (i.e. Mobile TV, VoD, Live Streaming) to cover the increasing users' desires and are now one of the most used services in wired and wireless networks. However, video services create one of the most demanding traffic for wireless networks. Video traffic demands high throughput, low delay and packet loss. While, packet loss at wired networks reveal congestion this is not a fact for the wireless networks where packet loss can be due to interference from external sources or loss of signal. MIH is a framework that will give the ability to maintain the video QoS by selecting the best candidate network

The aim of this paper is to examine the impact of handovers in the QoS of ongoing video services under the MIH framework. Having no other option but moving to another available network, MIH will provide the essential information to make the optimal choice. This Paper is organized as follows: Section 2 describes the MIH Framework, Section 3 presents the design and implementation of the experimental MIH platform, Section 4 analyses test cases and performance evaluation results and Section 5 concludes the paper.

2 Seamless Handover across Heterogeneous RATs, IEEE-802.21 Media Independent Handover (MIH) Framework

IEEE created the 802.21 standard in order to challenge one of the main issues in wireless mobility, seamless handovers across inter-technology RATs. Mobility protocols such as Mobile IP are suffering from sensible latency and they have not knowledge about the application layer parameters and candidate network conditions 4. IEEE 802.21 proposes the MIH Framework where mobile nodes and the network exchange information and commands for an optimal handover. Entities that are responsible for the handover procedure receive information and events from the MIH services and execute the handover with the available standardized commands. For hiding the heterogeneity of the MAC and PHY layers, MIH inserts an intermediate layer between layer 3 (and above) and the divert Layer 2 technology specifics. This new abstract layer is referred as Media Independent Function (MIHF) and provides a media-independent interface to the MIH users (i.e. mobility protocols, applications, handover policies) for controlling and getting information from the lower layers (i.e. WLAN, 3GGP). The communication between these three entities is grouped into three different Service Access Points (SAPs): MIH_SAP, MIH_LINK_SAP and MIH_NET_SAP 5.

- MIH_SAP enables the communication between the MIH users and the MIHF.
- MIH_LINK_SAP allows the communication between the MIHF and the link layers. MIHF takes care of handling Link layer events and passing this information to the upper layers as well as translating upper layers commands to Link

layer commands. Actually it is mapping of MIH_LINK_SAP primitives to technology-dependent Link layer SAPs.

- MIH_NET_SAP makes feasible the communication between the MIHF entities

The communication between the MIHF entities of the network makes handoff a cooperative procedure between the client and the network. Thus, handoff may be originated either by the network, by the client or by the client with assistance from the network.

The MIH framework (Fig. 1) describes three different types of communication that act as services 6: Event Service, Command Service and Information Service.

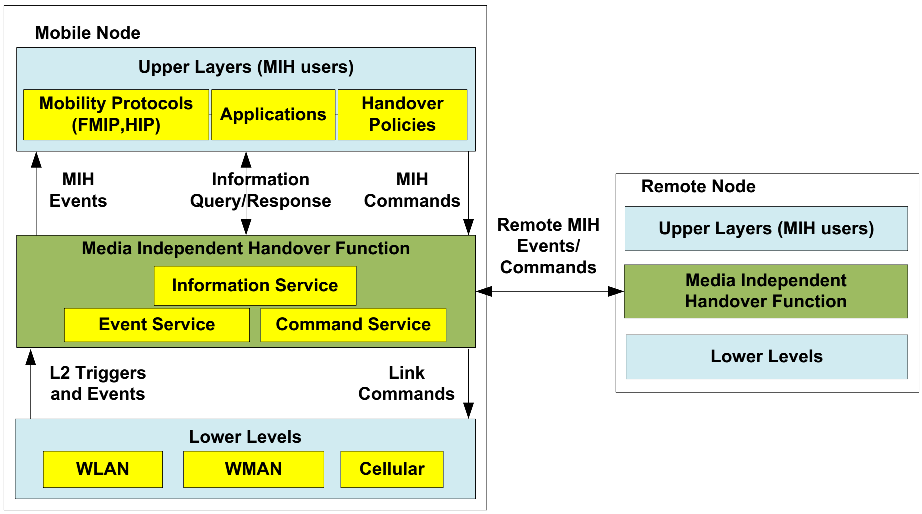

Fig. 1. Media Independent Handover Framework

The Media Independent Event Service (MIES) is a communication procedure where indications for handoff (Events) are passed to the MIH users for further handling. There are two types of Events: Link events and MIH events. The Link events are originating from the Link or Physical layer and can be a change in the state of the parameters of these layers or statistical information. MIH events are Link layer events that are received from the MIHF and are either propagated to the MIH users or to a remote MIH entity.

The Media Independent Command Service (MICS) provides a set of handover commands in order for the MIH users to be able to implement their handover decisions. The local link commands are received from the MIHF and are being mapped to Link layer commands. Also remote MIH commands are sent through the MIHF to remote MIH entities to enable network or client originated handovers.

The Media Independent Information Service (MIIS) is one of the most important services in the MIH framework. MIIS is a database that contains all the available information about the network ranging from channel parameters to presence of application layer services. It is used by mobility protocols in order to find appropriate networks that can facilitate a handover.

Figure 2 presents two examples of usage of the MIH Framework. In the first scenario, the mobile user wants to start a video session and makes use of the MIIS in order to find the appropriate network that guarantees the desired QoS. In the second scenario MIH with information such as current received signal strength and geographical position handovers the mobile node in order to preserve his/her VoIP session while it is moving out of the range of the WiFi network.

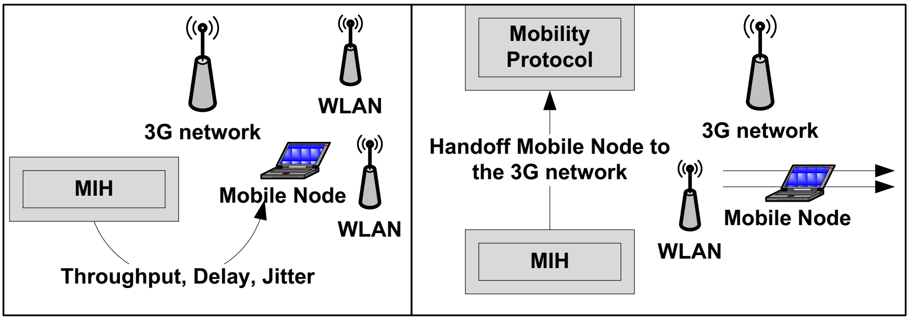

Fig. 2. MIH Framework Example Scenarios

3 Design and Implementation of the Experimental MIH Platform

3.1 Experimental Framework

Our experimental platform based on MIH (Fig. 3) consists of two WiFi networks and one virtual 3G network. Each access network experiences different network load over time. The mobile node that is in the coverage of these wireless networks starts a video session with the video server by selecting randomly one of the network. During the streaming session, events (handover indications), are collected from the MIH server which contains the handover decision and initiation modules (target radio access network). These modules compare this information with predefined thresholds to handover the client to the best network (Network Originating Handover). Test cases will be executed both with the MIH server enabled and disabled in order to evaluate the impact of MIH on the perceived video quality.

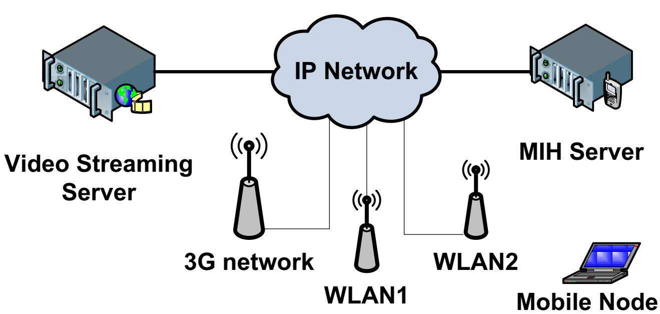

Fig. 3. Design of the Experimental Platform

3.2 MIH Framework

The MIH Server in the platform (Fig. 4) collects packet loss events (link 1) from the available wireless network as well as from the current session of the video client.

The handover mechanism is a part of the centralized architecture 3 and consists of the following steps:

1. **Handover decision:** A handover module is responsible to collect statistics from the MIES from both mobile terminal and radio access networks (SNR, packet loss). The monitored MIH parameters will be evaluated and compared against a set of predetermined threshold values. These thresholds are either determined be the network provider and are specified in each user's profile.
2. **Handover initiation:** When one or more threshold values are violated, the MIH initiation module is responsible of finding the best wireless network that can facilitate the current video service; this is done by comparing the packet loss metrics of every wireless network that are found at the MIH Information Service (MIIS) with the predefined thresholds. When the best network that fulfils the conditions is found, the Handover Initiation Module sends a handover Execute command (link 2) with the old and the new IP address to the Mobility Protocol.
3. **Handover execution:** The final stage is the execution of the vertical handover to the decided neighbouring network. The Mobile IP platform is responsible of handling the vertical handover and of ensuring seamless service continuity. For Simplicity, we have emulated a Mobile IP protocol by adding a handoff delay (Home Agent Registration and Route Optimization) that corresponds to the latency experienced in a real environment 7. With this module the video server upon the receipt of the handover execute command routes the traffic to the new IP address for having a seamless handover.

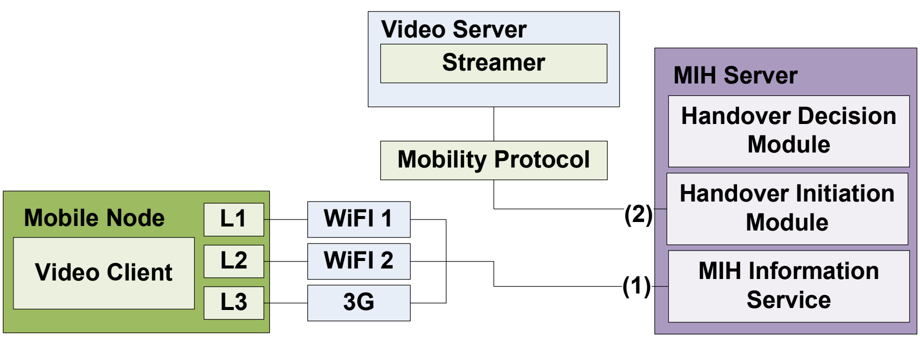

Fig. 4. MIH Design of the Experimental Framework

3.3 Network Load at the Radio Access Networks

In a testing environment it is necessary to find ways of introducing packet loss or traffic to the connections so that handover decision is triggered.

The background traffic at each radio access network has been emulated by a Markov chain. Without loss of generality, the background traffic will be emulated as multiplexed video traffic from N homogeneous video sources. The most important statistical characteristic in a single video source is the degree of correlation between adjacent frames is based on a 3-state Markov chain represents not only correlation between frames of the same type, but of different type as well 8. The scene detection algorithm which is applied in order to distinguish statistical scene changes is based on the measurement of significant changes in the sizes of two consecutive GOPs 9. The statistical scene change in an MPEG coded video may occur at any frame type 10. The two conditions that need to be satisfied together are:

$$\frac{\left|GOP(n+k+1)-GOP(n+k)\right|}{\frac{\sum_{j=n}^{n+k} GOP(j)}{k+1}} > T_1 \tag{1}$$

$$\frac{\left|GOP(n+k+2)-GOP(n+k)\right|}{\frac{\sum_{j=n}^{n+k} GOP(j)}{k+1}} > T_2 \tag{2}$$

Where GOP(n), n=1,2,3,… is the nth GOP size and T1 and T2 are thresholds that depend on the specific characteristics of the video. If the nth GOP is the initial GOP of the i-th scene, and the above conditions are satisfied, then the (n+k)th GOP is the last GOP of the i-th scene and (n+k+1)th GOP is the starting GOP of the (i+1) scene. The K states within the Markov chain represent the scene changes, where each scene is allocated to the appropriate state. It has been found that the pdf distribution of the states follows the gamma distribution 7, 10. The number of states K has been decided according to the following formula:

$$\begin{gathered}\frac{max\_scene\_frame\_size-min\_scene\_frame\_size}{K-1}=step\\ \left\lceil \frac{average\_scene\_frame\_size-min\_scene\_frame\_size}{step}+1 \right\rceil = state\_number\end{gathered} \tag{3}$$

Assuming that the scene state at the n-th frame time is S_n then the transition probabilities from one scene state to another in the state transition diagram, are defined as follows:

$$\begin{gathered}p_{i,i}=P\left(S_{n+1}=i \middle| S_n=i\right)=\frac{Nf_i-Ns_i}{Nf_i}\\ p_{j,i}=P\left(S_{n+1}=j \middle| S_n=i, j\neq i\right)=\frac{Ns_{ij}}{Nf_i}\end{gathered} \tag{4}$$

Where, $p_{i,i}$ is the probability that the next frame will belong to the same scene state i as the current frame. Additionally, $p_{i,j}$ is the probability that the next frame will belong to state j when the current frame belongs to scene state i. Nf_i and Ns_i are the total number of frames and the total number of scenes in scene state i respectively. Finally, Ns_{ij} is the number of scene changes from state i to state j. The above statistical model represents video traffic from a single MPEG-4 video source. In order to generate video traffic in a radio-access network, several homogeneous and mutually independent statistical video sources have been used. Thus, the aggregate video traffic model can be obtained by creating multiple instances of the single traffic model 11.

$$P_{loss} = \frac{\sum_t \left(\sum_{i=1}^{K} \sum_{j=1}^{N} \hat{I} + \hat{B} + \hat{P} - C_k \right)}{\sum_t \left(\sum_{i=1}^{K} \sum_{j=1}^{N} \hat{I} + \hat{B} + \hat{P} \right)} \tag{5}$$

Where, Ploss is the packet loss probability, t is the video transmission time period, $\hat{I}, \hat{B}, \hat{P}$ are the mean frame bit rates of I, B, P frame types, respectively, K and N are the number of scene states and video sources, respectively. Ck refers to the capacity (throughput) of the kth specific radio access network. In the case of WLAN, the throughput has been set to 5Mbps, whereas in the case of 3G throughput has been set to 2Mbps.

4 Test Scenarios and Performance Results

Our experimental platform comprises the following elements: one 3G virtual network and two WLAN APs. Multiplexed video traffic is inserted to each wireless network according to the description of the previous paragraph. Each radio access network is stressed with up to 100% network load of its maximum throughput. This is due to the fact that the platform has been stressed in order to evaluate handover triggering in case of network congestion. Dummynet has been used in order to emulate the packet loss and delay in each radio access network 12. A real-time H.264 video is monitored throughout the experimental seamless handoff process. A long video sequence (2500 frames-PatrasTV YUV video sequence) in QCIF format (176 x 144 pixels) has been used in order to test the MIH. The testing video sequence has been encoded using the H.264/Advance Video Coding reference software from Vanguard Software Solutions 13. The q-step size has been set to 12; the GOP of the encoded video sequence is structured as *IPPPPPPPPPPPIP...*, with an intra-frame period of 12 frames and a *0*-list of reference frames, 5 frames long. When either the monitored instantaneous packet loss of the video session reaches a threshold or the aggregate packet loss at the radio access network exceeds a limit, handover will be triggered by the MIH functionality. During the experimental phase, we have measured the following: RTP throughput, RTP Packet loss and video Y-PSNR of MIH enabled versus MIH disabled handoff scenarios.

The following two figures(Fig 5, Fig 6) illustrate the received RTP Throughput and RTP Packet loss on the client for MIH triggered experiment (it is accomplished by choosing the best available access network in terms of network load) versus MIH disabled (MIP chooses the radio access network in randomly manner by applying network discovery) over time. In the MIH Enabled scenari,o it is clear that the best candidate network is chosen, thus both throughput and packet loss are optimised under certain network conditions. In the MIH Disabled scenario the mobile IP chooses randomly the radio access networks and this leads to sequential improper selections that except the increased packet loss of the new network add additional overhead due to network discovery that leads to high packet loss at the client.

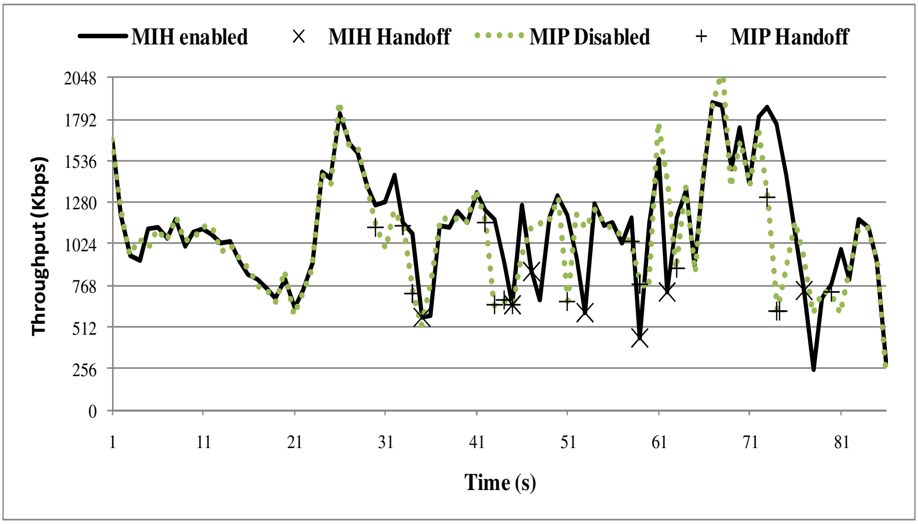

Fig. 5. Client Throughput (MIH Enabled versus MIH Disabled)

Table 1. Average Client Throughput per Test Case

Test Case	Average Throughput (Kbps)
MIH Enabled	1115.72
MIH Disabled	1083.74

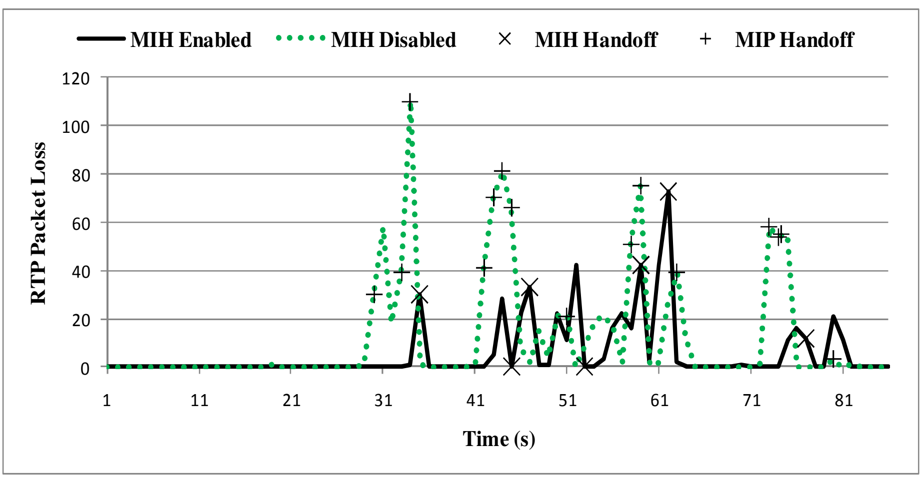

Fig. 6. Client RTP Packet Loss (MIH Enabled versus MIH Disabled)

Table 2. Average RTP Packet Loss per Test Case

Test Case	RTP Loss
MIH Enabled	2.7%
MIH Disabled	5.7%

The following figure (Fig 7) shows the perceived video quality on the client. In the MIH Disabled scenario the video quality drops suddenly 10.9 dB for a long time period (28 – 35 second) due to three sequential improper handoffs. In the scenario where the MIH framework is used the video quality is maintained to acceptable levels by handing over always to the best candidate network.

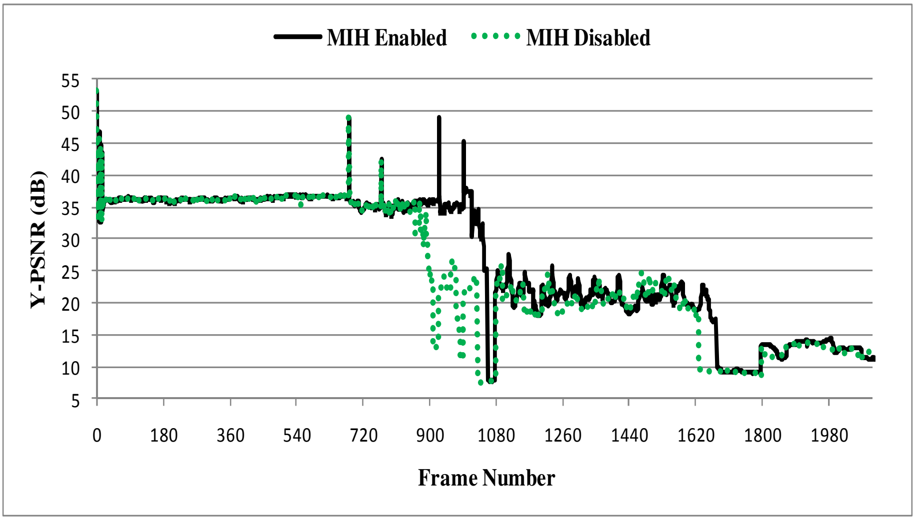

Fig. 7. Video Y-PSNR (MIH Enabled versus MIH Disabled)

Table 3 illustrates the average PSNR of the MIH enabled versus the MIH disabled scenario, throughout the experiment. It has been show that the average Y-PSNR is improved by a factor of 1.09dB.

Table 3. Average Video PSNR and MIH Delay per Test Case

Test Case	PSNR (db)
MIH Enabled	24.59
MIH Disabled	23.50

Finaly Figure 8 and Figure 9 depict the video frame loss per handoff over time. Due to the fact that network discover procedure in Mobile IP adds significant delay overhead, the percentage of frame loss in MIH disabled scenario is higher than that of MIH enabled scenario. Table 4 illustrates the average Frame Loss, where the average loss in MIH disabled is 8% higher than MIH enabled.

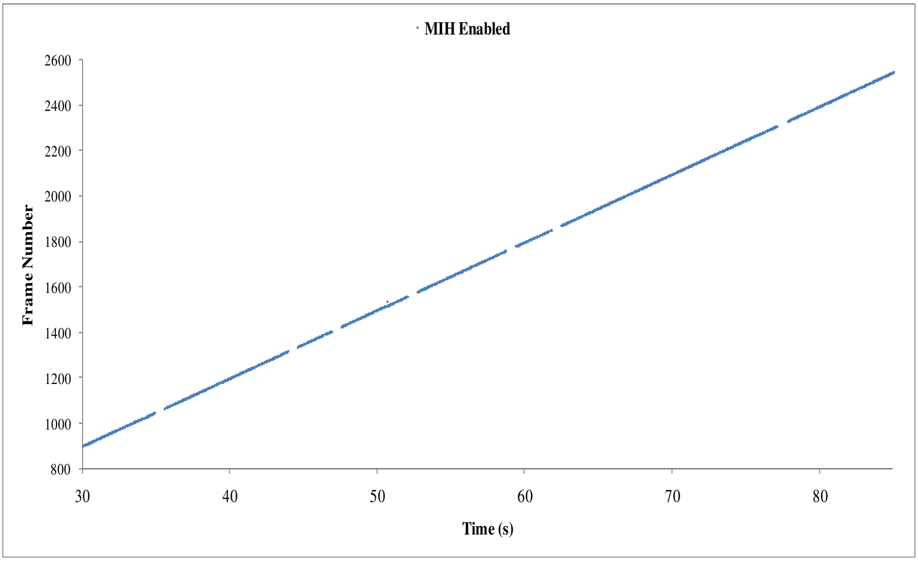

Fig. 8. MIH Enabled Frame Number/time

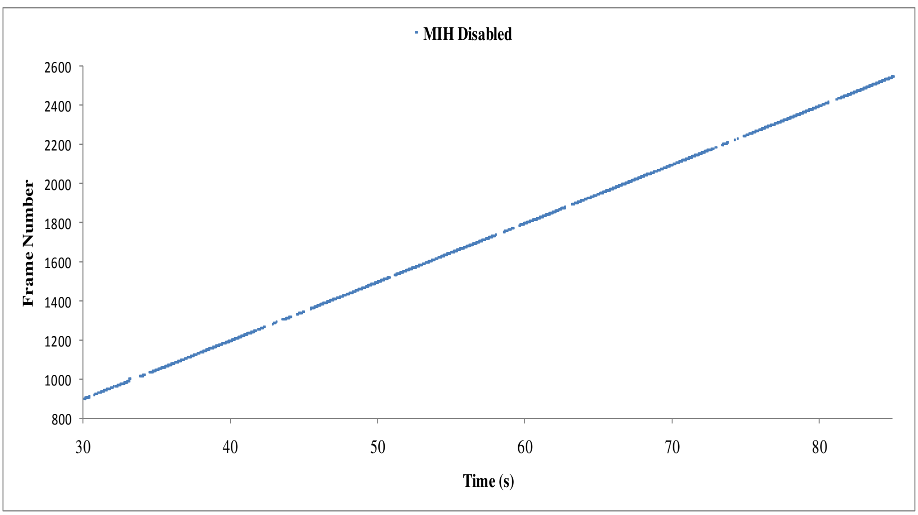

Fig. 9. MIH Disabled Frame Number/time

Table 4. Average Frame Loss per Handoff per Test Case

Test Case	Average Frame Loss per Handoff
MIH Enabled	18
MIH Disabled	26

5 Conclusions

This paper presents an experimental platform for video streaming services across heterogeneous radio access technology networks. The MIH platform collects statistics from the both network layer and physical layer. In the proposed MIH platform, triggers from the network layer have been studied from both the network and the mobile terminal. When packet loss reaches a threshold, handover is initiated and MIH selects as candidate radio access network, the least congested. It has been shown that MIH maintains the video quality of an on-going session by selecting the least congested radio access network. Through experimentation MIH-enabled handover improve substantially perceived video quality against MIH-disabled handover.

Future steps, include on the fly adaptation of video session in case that the mobile node should handover in a radio access network with limited bandwidth, use of estimation methods by determining the level of packet loss that is due to physical impairments from that that is due to network congestion and use of network metrics within a time window in order to estimate its status.

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