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Interaction and Interconnection Between 802.16e & 802.11s

Tarek Bchini and Mina Ouabiba
*ARTIMIA, Malakoff
France*

1. Introduction

1.1 Problematic

With the rapid evolution of wireless and mobile networks, and the emergence of several standards that use different technologies, the problem of compatibility between these technologies, or the transition from one technology to the other by the mobile station without interruption of services, becomes a real challenge to face, to ensure a good Quality of Service (QoS) for the client.

In this context, we will analyze Mobile Stream Control Transport Protocol (MSCTP) and IEEE 802.21 technology as two vertical handover mechanisms between two of mobile networks: IEEE 802.11s, and mobile WIMAX. The simulations will be run under Network Simulator 2 (NS2) [1].

1.2 Mobile Wimax (IEEE 802.16e)

The mobile WiMAX (IEEE 802.16e) [2] is a mobile extension of the IEEE 802.16 standard [3].

IEEE 802.16 defines the specifications for radio metropolitan networks or WMAN (Wireless Metropolitan Area Network), offering broadband to achieve a high flow rate and using techniques to cover large areas [3].

The IEEE 802.16e is suitable for any kind of traffic thanks to its flexibility justified by its three MAC layers [2] and its use of IP protocol.

There are two kinds of Handover in the mobile WiMAX: Intra-ASN Handover (layer 2: no change of IP address) and Inter-ASN Handover (layer 3: IP address change) [4] [5]. For Intra-ASN, two mechanisms have been specified: Hard handover for the low speed and Soft handover for the high speed; and for Inter-ASN Handover it defines: Mobile IPv4 or Client-MIPv4, and Proxy-MIPv4 [4].

The architecture of 802.16e is composed of mobile stations (MS), that communicate freely (radio link) with base stations (BS), which act as an intermediates gateways with the terrestrial infrastructure of IP network. The base stations themselves are connected to the network elements called ASN-GW (gateways) which manages their connection with the IP network [4] [5].

The NAP (Network Access Provider) is an entity that provides the infrastructure for radio access to one or more providers of network services. It can control one or more ASN (Access Service Network) which is composed of one or more BS and one or more gateways.

The NSP (Network Service provider) is an entity that provides IP connectivity and network services to subscribers compatible with the level of service it establishes with subscribers. An NSP may also establish roaming agreements with other providers of network services and contractual agreements with third-party providers of application (for example, ASP: Application Service Provider) to provide IP services to subscribers.

A NSP control one or more CSN (Connectivity Service Network) which is the core of the WiMAX network.

The architecture of mobile WiMAX is presented in the figure 1:

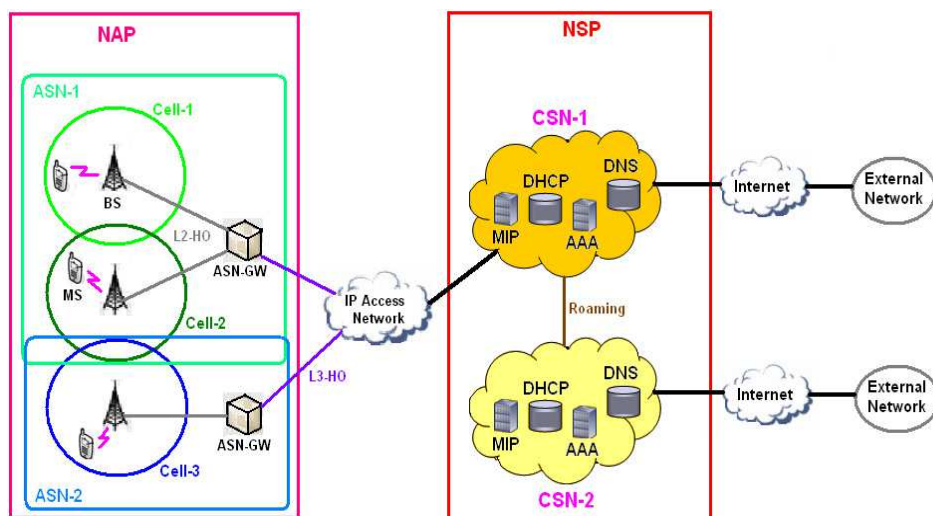


Fig. 1. IEEE 802.16e Architecture [4] [5]

1.3 IEEE 802.11s

IEEE 802.11s [6] [7] is an amendment being developed to the IEEE 802.11 WLAN standard, and aims to implement mobility on Ad-Hoc networks with acceptable debit.

In September 2003, IEEE formed the 802.11s SG which, in July 2004, became the "Extended Service Set (ESS) Mesh Networking" or 802.11s Task Group (TGs), and it is the most advanced group of the 802.11 WG.

The current objective of this TG is to apply mesh technology to WLANs by defining a Wireless Distribution System (WDS) used to build a wireless infrastructure with MAC-layer broadcast/multicast support in addition to the unicast transmissions. The TG should produce a protocol that specifies the installation, configuration, and operation of WLAN mesh. Moreover, the specification should include the extensions in topology formation to make the WLAN mesh self-configure and self-organized, and support for multi-channel, and multi-radio devices. At the MAC layer, a selection path protocol should be incorporated, instead of assigning the routing task to the network layer.

The WLAN Mesh architecture comprises the following IEEE 802.11 based elements:

- Mesh Point (MP) which supports (fully or partially) mesh relay functions, and implement operations such as channel selection, neighbor discovery, and forming and association with neighbors. Additionally, MPs communicate with their neighbors and forward traffic on behalf of other MPs.
- Mesh Access Point (MAP= MP+AP) which is a MP but acts as an AP as well. Therefore, MAPs can operate in a WLAM Mesh or as part of legacy IEEE 802.11 modes.
- Mesh Portal (MPP=MP+Bridge) is another kind of MP that allows the interconnection of multiple WLAN meshes to form a network of mesh networks. Moreover, MPP can function as bridges or gateways to connect to other wired or wireless networks in the DS.
- Simple Station (STA): outside of the WLAN Mesh, connected via Mesh AP.

The architecture of IEEE 802.11s is presented in the figure 2 below:

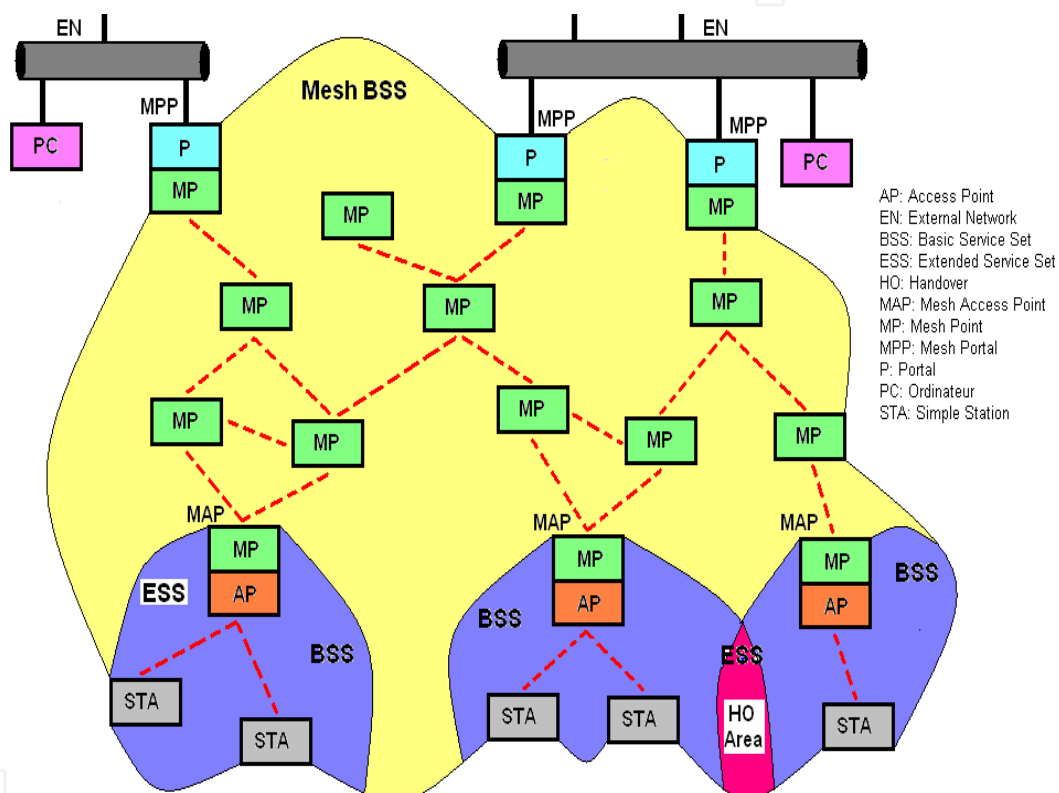


Fig. 2. IEEE 802.11s Architecture

2. Vertical handover mechanisms proposed

In our work, we analyze two vertical handover mechanisms that will be used between the mobile WiMAX and the IEEE 802.11s, and in this section we will present the two proposed mechanisms.

2.1 MSCTP protocol

The transport layer mobility is proposed as an alternative to the network layer mobility to support integrated mobility. The management of mobility in the transport layer is made exclusively by Stream Control Transmission Protocol (SCTP) [8] and its extension: Dynamic Address Reconfiguration (DAR) [9].

SCTP extended with DAR constitute Mobile SCTP (MSCTP) [10] [11] [12].

MSCTP was designed in order to avoid the connection disruptions observed with TCP or UDP during a change of IP address. It is a transport layer protocol similar to Transmission Control Protocol (TCP). It provides point-to-point communication oriented connection between applications running on different hosts. The major difference with TCP is the multi-homing; it allows by multi-homing to manage multiple IP addresses in terminal nodes by conserving the point-to-point connection intact (see figure 3).

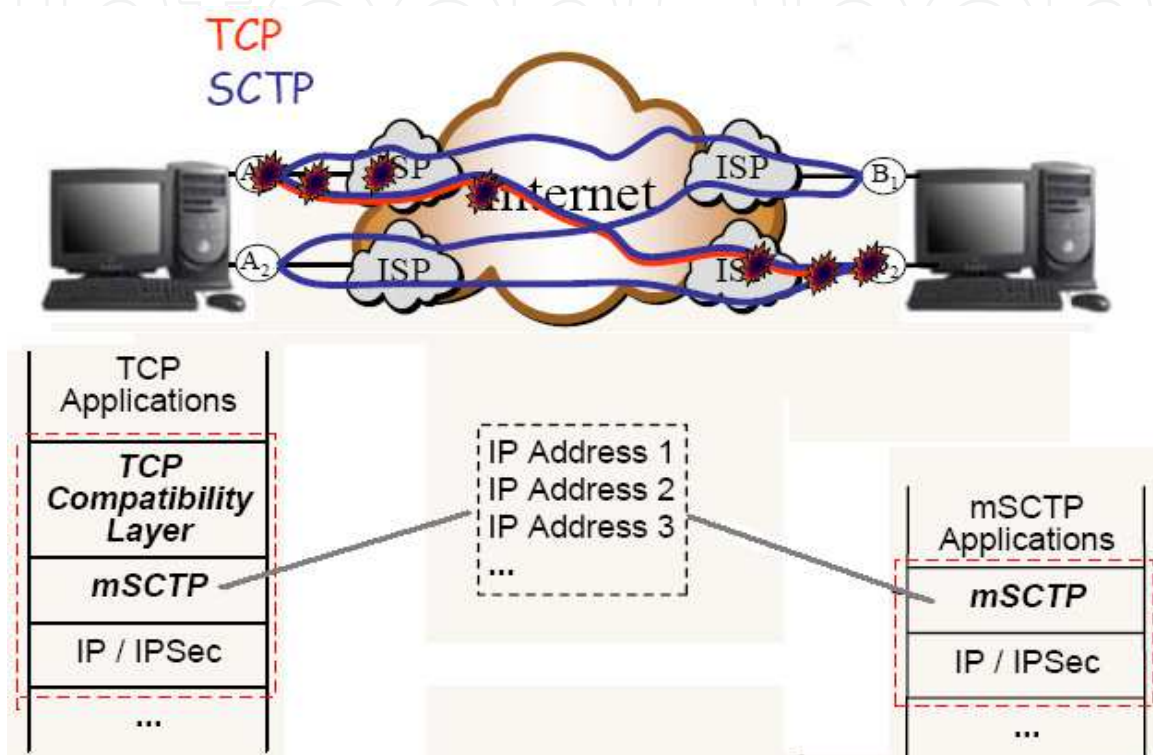


Fig. 3. MSCTP vs TCP and protocol stack

In the beginning of the communication between a mobile station (MS) and its correspondent (CN) implementing both MSCTP protocol; in the MS, there is only one IP address chosen as primary address, and used as destination address for the current transmission. The other IP addresses are used only for retransmissions. The DAR extension allows to MS to add, delete and change IP addresses during a SCTP session, without affecting the connection established, by using address configuration messages.

During the communication with the CN; when the MS changes from its home network to a foreign network passing by handover Area (at the beginning of the coverage area of foreign network), it receives an IP address from the foreign network either by contacting a DHCP, or by automatic configuration of IPv4 address. The MS is now able to establish other link with its CN through this second IP address obtained, and may become accessible via the foreign network. Then it sends its second IP address via the home network to its CN, and the CN will add the new IP address to the association identifying the connection with the MS and sends an ACK to the MS to confirm. After, when the MS begin to leave the coverage area of its home network to the coverage area of the foreign network, it notifies the CN to assign the new IP address as primary IP address, which the CN approves with an ACK.

The new primary IP address is now the second IP address obtained. The CN sends at this moment all the messages to the new IP address of MS via the foreign network. And finally, when the MS leave definitively the coverage area of the home network, it informs the CN to delete the first IP address of the association, which the CN confirms with an ACK [10] [11] [12]. To use MSCTP, the only requirement is that the both endpoints should implement MSCTP protocol.

By applying the MSCTP in the case of vertical handover between 802.16e and 802.11s, the protocol will use the multi-homing technique to open two IP sessions with the BS of the mobile WiMAX network and the AP of the Wireless mesh network to avoid the service interruption during handover.

2.2 IEEE 802.21 or MIH

IEEE 802.21 or Media Independent Handover (MIH) [13] [14] [15] is a recent evolution for all networks, that providing capabilities to detect and initiate handover from one network to another. It designed a new function to control access to the lower layers (Layers 1 and 2). This new function provides new service access points (SAPs) and allows the information to be queried by the upper layers (Layer 3 and higher). Both mobile device and network hardware must implement the standard to work, but everything should remain backward compatible for non-MIH aware devices.

The standard allows simply to provide information that help to the initiation of handover, the selection of the network and the activation of the interface. The execution and the decision of handover is not part of the standard.

In MIH Function (MIHF), there are three services that allow the passage of messages along the stack. The table 1 below compiled from IEEE 802.21, outlines the basic functions of these services [14].

MIH services	Origin	Destination	Use cases
Event	MIHF or lower layer	MIHF or upper layer Remote or local stack	Link up/ down/ going down, transmissions status
Command	MIHF or upper layer	MIHF or lower layer Remote or local stack	switch links, get status
Information	Upper or lower layer Secure or insecure port	Upper or lower layer Remote or local stack	information elements (IEs), neighbor reports

Table 1. MIH services

The MIH architecture is illustrated in the figure 4 below:

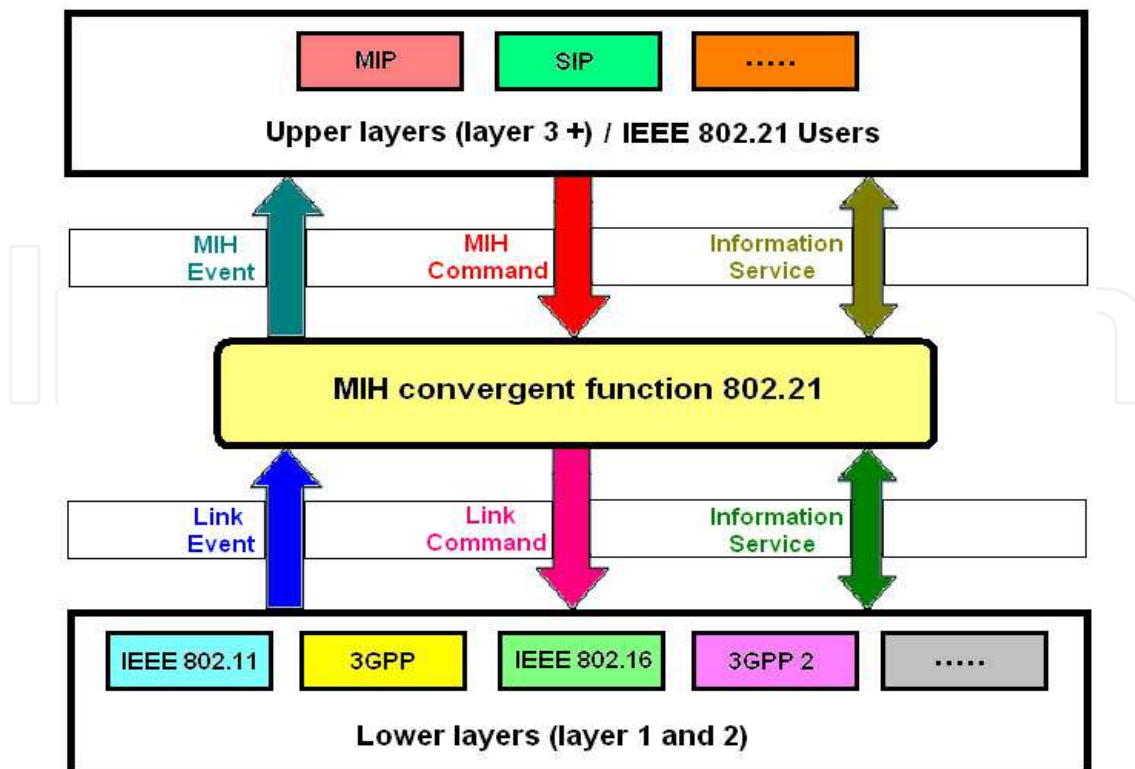


Fig. 4. MIH architecture

3. Interconnection models proposed

3.1 Common simulation model and common scenario

We describe in this section the common interconnection model proposed between IEEE 802.16e and IEEE 802.11s using MSCTP or IEEE 802.21 during the vertical handover; and the MS mobility scenarios between the two networks. We will assume an 802.16e cell with coverage of 1 km radius and an 802.11s cell with coverage of 300 m radius (these choices of radius values are based on the nature of the test environment that is an urban area which is not very dense). And, the two cells have a common area (handover area) with a variable and maximum distance of 180 m between both limits of cells (this choice of the surface of common area between cells is based on the time needed for the handover simulation).

The Base station (BS) of 802.16e network is linked to an ASN-GW that is linked too via IP network to a CSN (WiMAX ISP); the Access Point (AP) of 802.11s network is linked to a router that is linked too via IP network to a WIFI CSN; and the two CSNs are connected together and with the distant servers via Internet network.

We will evaluate the mechanisms through two mobility scenarios for the simulations: the case where the mobile move from 802.16e cell to 802.11s cell, and the opposite case. In the two scenarios, the mobile station (MS) traverses 200 m in 802.16e or 802.11s cell, and traverses in handover area (common area between 802.16e and 802.11s cells) 100 m.

We will propose three MS speeds to see the impact of speed increasing on the handover. So, we will propose: 5 m/s = 18 km/h; 10 m/s = 36 km/h; and 20 m/s = 72 km/h as mobile speeds for the simulations.

3.2 Simulation model based on MSCTP protocol

Based on common model proposed in the section before, with MSCTP protocol, the end users (the MS moving between the two cells and its correspondent node or server) must implement the MSCTP protocol.

The architecture of simulated model proposed for the interconnection between IEEE 802.16e and IEEE 802.11s using MSCTP is illustrated in the figure 5 below:

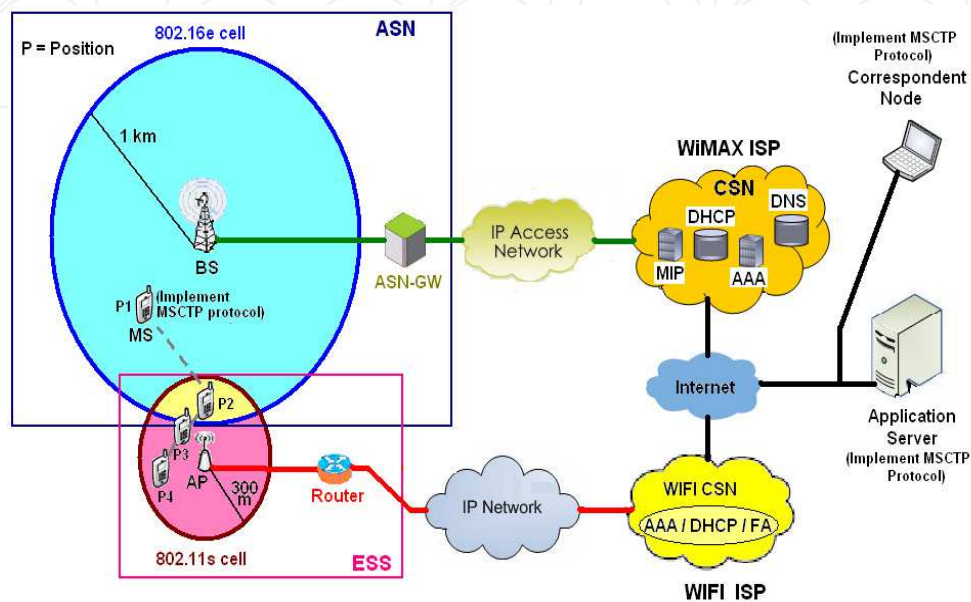


Fig. 5. Interconnection model using MSCTP

The exchange of information between the MS and its correspondent node (CN) during the MS mobility scenario between IEEE 802.16e and IEEE 802.11s using MSCTP is illustrated in the figure 6 below:

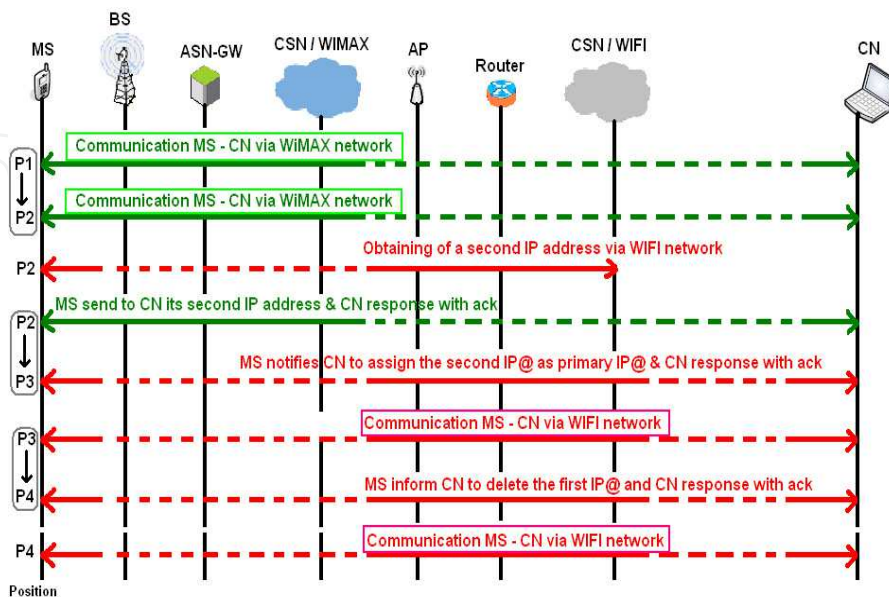


Fig. 6. Messages exchanged during simulation of the protocol MSCTP

3.3 Simulation model based on 802.21 architecture

Based on the common model already described; with IEEE 802.21 architecture, an MIH server must be implemented in the Internet network, more precisely between the WiMAX CSN, and the WIFI CSN; and MIH modules must be implemented in the two CSNs and in the MS.

The architecture of the interconnection model proposed between the two networks using IEEE 802.21 is illustrated in the figure 7 below:

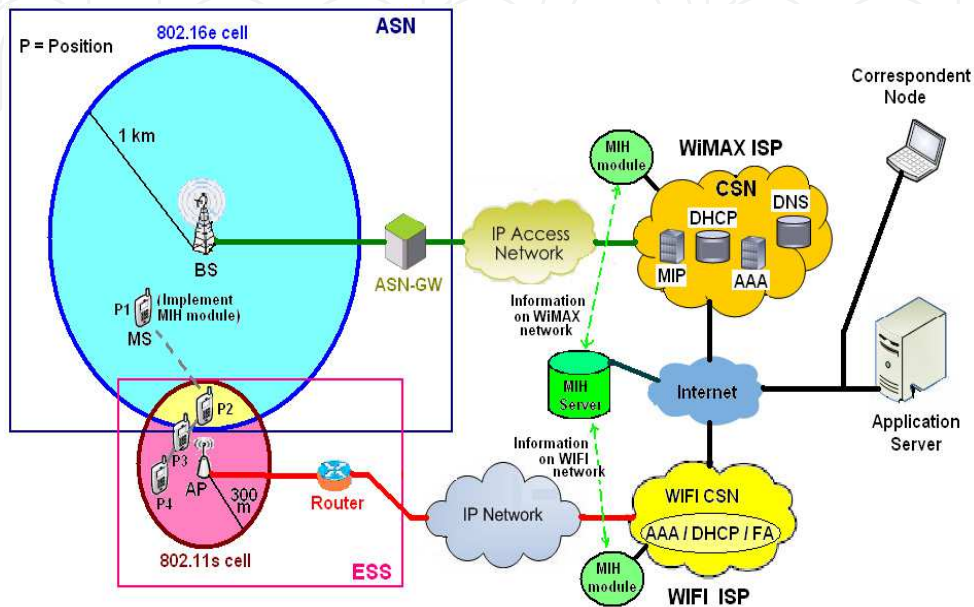


Fig. 7. Interconnection model using IEEE 802.21

The exchange of information between the MS and its correspondent node (CN) during the MS mobility scenario between IEEE 802.16e and IEEE 802.11s using the MIH module is illustrated in the figure 8 below:

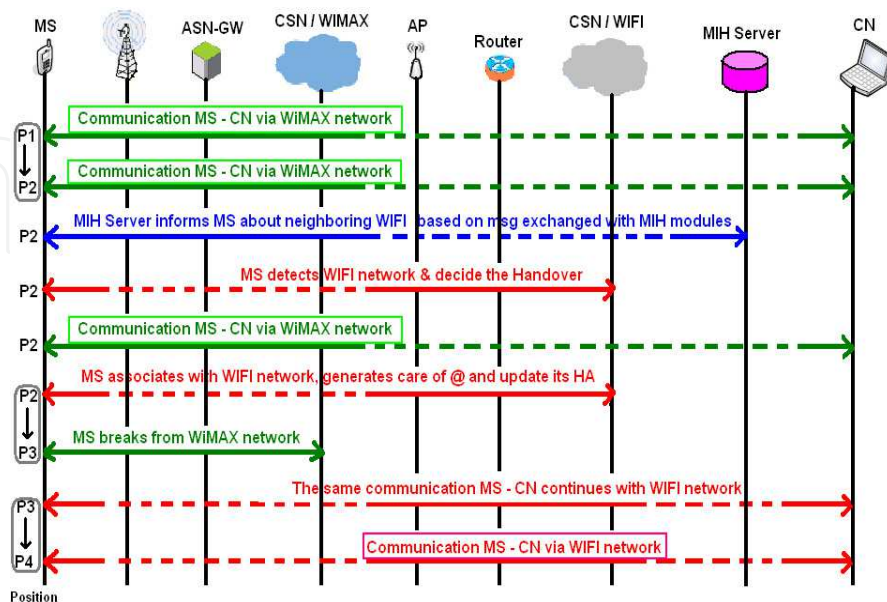


Fig. 8. Messages exchanged during simulation of the protocol MIH

For the simulations, we choose to use Proxy Mobile IP (PMIP) [16] as layer 3 protocol that interacts with lower layers via MIH module.

PMIP is an amelioration of MIP, it introduces a functional entity called Proxy Mobile IP to help MIP traversal across VPN or “NAT and VPN” gateways. The PMIP is in the path between MS and its corresponding HA (Home Agent), and acts as a surrogate MS and HA.

PMIP does not involve a change in the point of attachment address when the user moves, and there is no need for the terminal to implement a client MIP stack.

3.4 Simulation parameters under NS2 simulator

During the simulations and with the two handover mechanisms, we will test three traffics types: the VoIP with a fixed size to 160 byte and a rate of 300 packet/sec, the Data with a fixed size to 640 bytes and a rate of 200 packet/sec, and the video streaming with a fixed size to 1280 bytes and a rate of 100 packet/sec (optimal values usually chosen in NS2).

Under NS2, with MSCTP protocol we use the CBR over MSCTP traffic type; and with IEEE 802.21 architecture, we use the CBR over UDP traffic type.

The duration of one simulation are fixed to 250 seconds, and the results are calculate every 10 seconds in 802.16e or 802.11s cell area, and every 5 seconds during the handover process in common area.

For the two networks: IEEE 802.16s and IEEE 802.11s, the simulation parameters under NS2 are illustrated in the table 2 below:

	IEEE 802.16e	IEEE 802.11s
Transmission Power (Pt _l)	15 W	0.2818 W
Receiving Threshold (RXThresh _l)	7.59375e-11 W	1.76148e-10 W
Carrier Sending Threshold (CSThresh _l)	4.34219e-12 W	3.32874e-11 W
Coverage Radius (Distance D)	1 km	300 m
Radio Propagation Model	Two-Ray Ground [17] $P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L}$	
Transmit Antenna Gain (Gt _l)	1 dB	
Receive Antenna Gain (Gr _l)	1 dB	
System Loss (L _l)	1 dB	
Transmit Antenna Height (ht _l)	1.5 m	
Receive Antenna Height (hr _l)	1.5 m	
Modulation	OFDMA	OFDM
Frequency (Freq _l)	3.5 Ghz	2.4 Ghz

Table 2. Simulation parameters

3.5 Performance criteria

The performance criteria adopted in our simulations to compare MSCTP and IEEE 802.21 mechanisms in the case of vertical handover between 802.11s and 802.16e networks are: End-to-end delay, packets loss ratio and debit. These parameters are the main criteria of QoS measuring in the networks. To evaluate the QoS degree of these criteria, we will compare simulation results obtained with theoretical thresholds estimated to evaluate the QoS depending on traffic type.

4. Results

4.1 End-to-end delays

The end-to-end delay is a very important parameter to evaluate the QoS for the real time traffic. It is the time needed for a packet to be transmitted across a network from source to destination.

In this section, we will calculate the delays of packets during the simulation time for the three mobile speeds and the three traffic types; with the two vertical handover techniques: MIH architecture and MSCTP protocol; and applying the two scenarios: handover from 802.16e to 802.11s and from 802.11s to 802.16e.

We start by present the results for the VoIP traffic (see figures 9 and 10).

In the two figures 9 and 10, first for all the curves we see that during the handover process, the delays obtained with MSCTP are slightly lower than those obtained with the MIH; and the handover are executed with MIH before that with MSCTP.

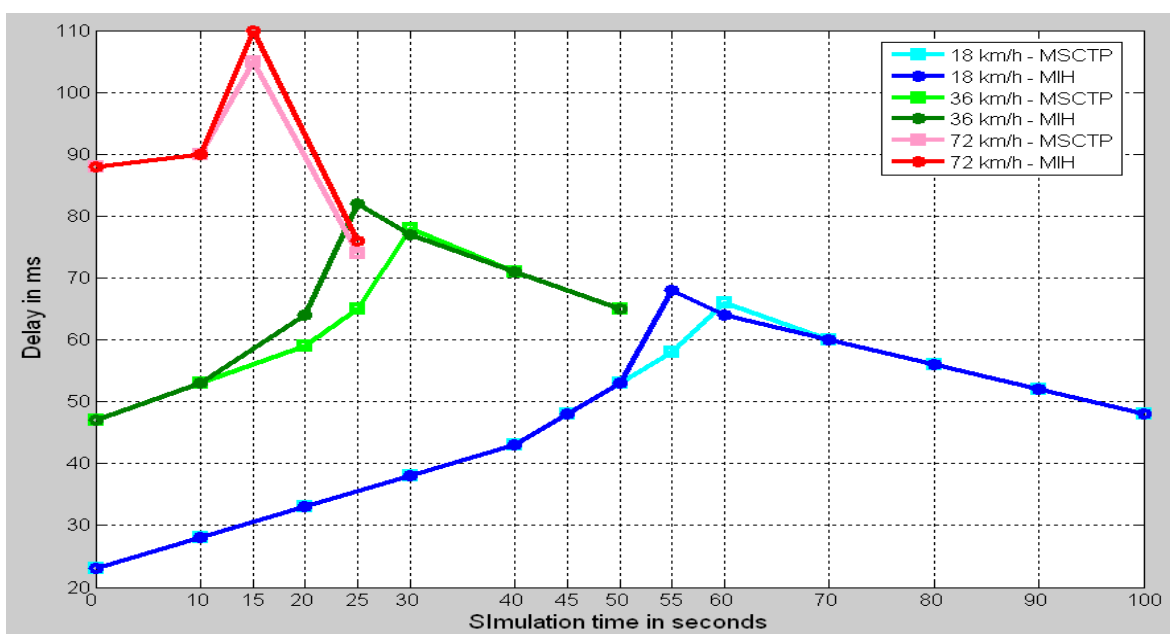


Fig. 9. Delay of HO from 802.11s to 802.16e / VoIP

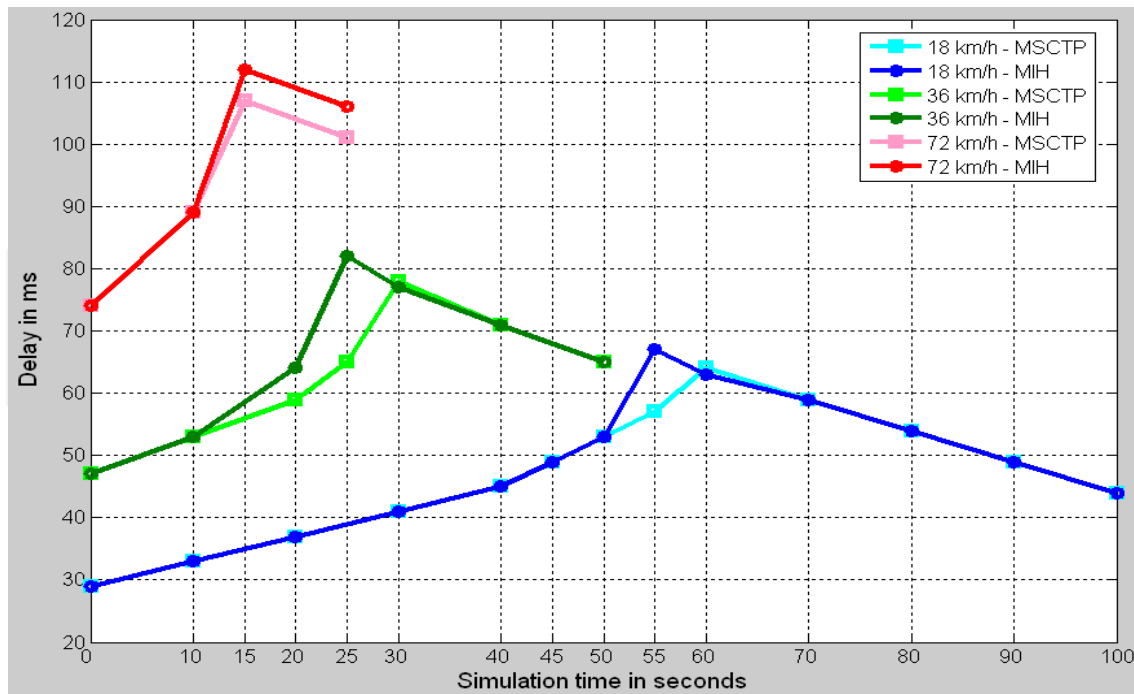


Fig. 10. Delay of HO from 802.16e to 802.11s / VoIP

With the two speeds: 18 and 36 km/h, the QoS level is accepted for the VoIP traffic that needed a minimum delay of 100 ms [18]; but with the speed equal to 72 km/h, the QoS degrades during the handover.

Finally, with a speed of 18 km/h, the QoS is better in 802.11s network; with 36 km/h the QoS is equivalent in the two cells; and with 72 km/h of speed the QoS is better in 802.16e cell.

We present now the results of data traffic (see figures 11 and 12):

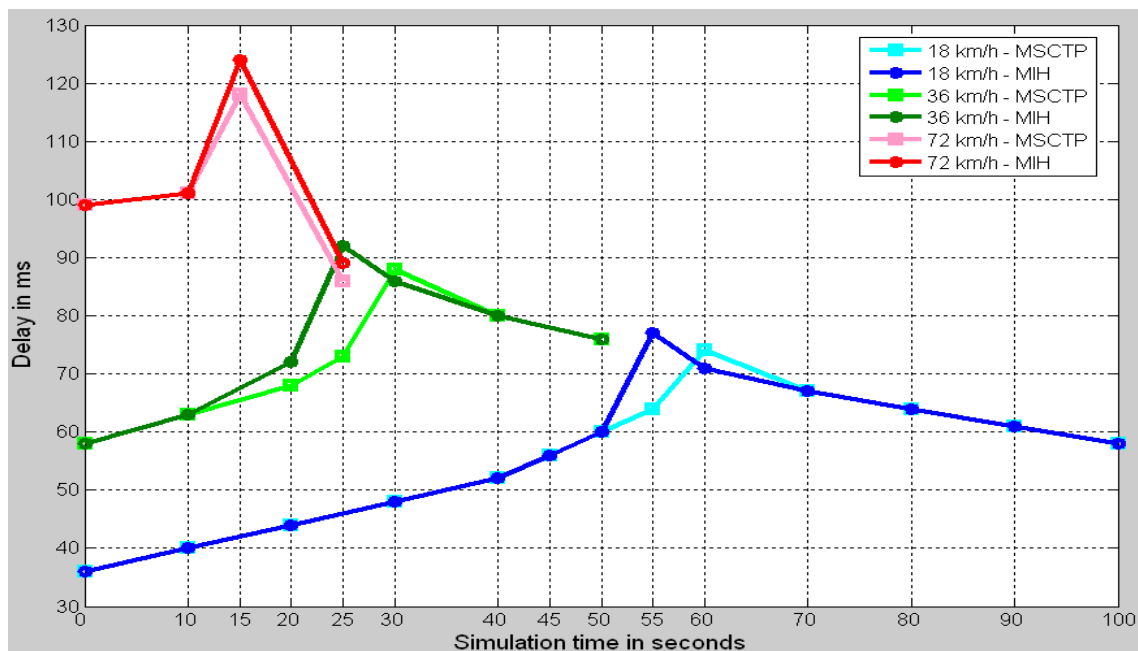


Fig. 11. Delay of HO from 802.11s to 802.16e / Data

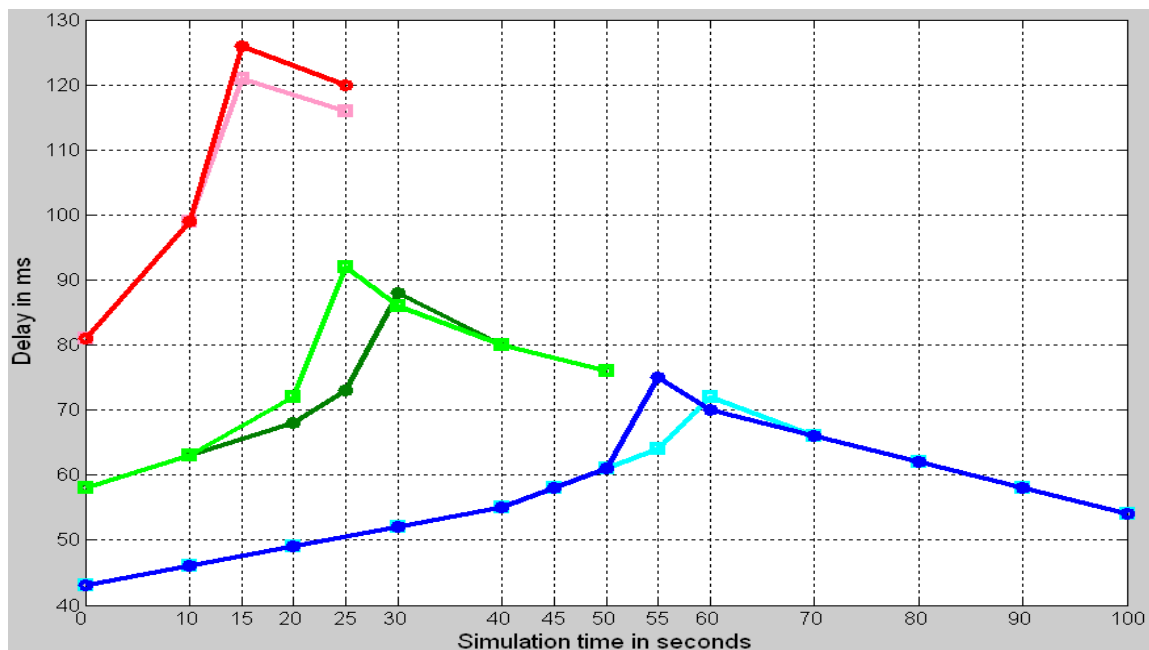


Fig. 12. Delay of HO from 802.16e to 802.11s / Data

With the data traffic, there is no delay constraint, so we can consider the QoS level acceptable for all the cases.

We note that the delays obtained with data are higher than those obtained with the VoIP traffic; for example with MSCTP protocol and with a speed of 18 km/h, the maximum delay obtained of the VoIP traffic is 65 ms versus 73 ms of the data traffic.

We present finally in this section the results of video streaming traffic (see figures 13 & 14):

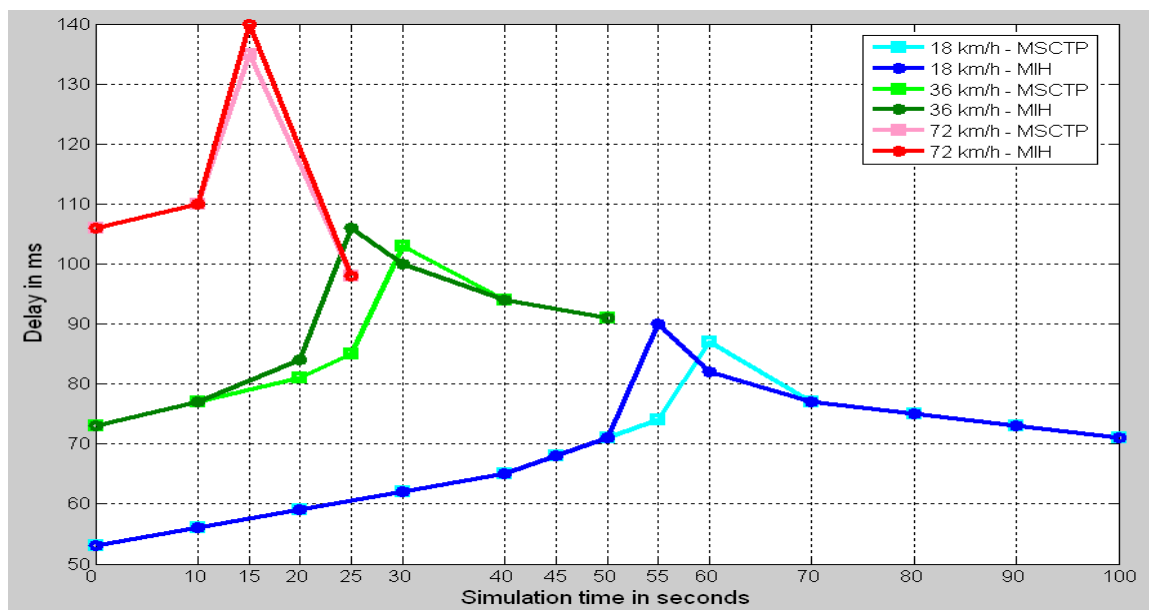


Fig. 13. Delay of HO from 802.11s to 802.16e / Video

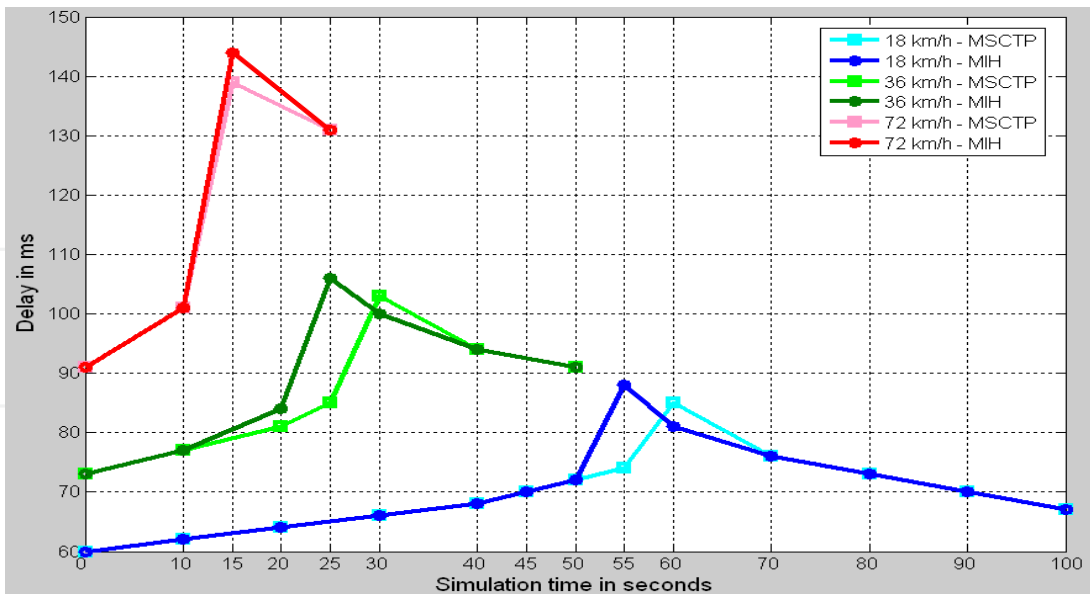


Fig. 14. Delay of HO from 802.16e to 802.11s / Video

With the video traffic, the delay values increase comparing by the VoIP or the data traffic.

With the speed of 18 km/h, the delays not exceed 100 ms; with the speed of 36 km/h the delays exceed slightly 100 ms during the handover; and with the speed of 72 km/h, the delay values exceed largely 100 ms during the handover and in the 802.11s cell.

The delays with MSCTP are slightly lower than those with MIH.

4.2 Packet loss ratio

We calculate in this section the percentage of lost packets with the same cases as those described in the section 4.1. We start with the VoIP traffic (see figures 15 and 16):

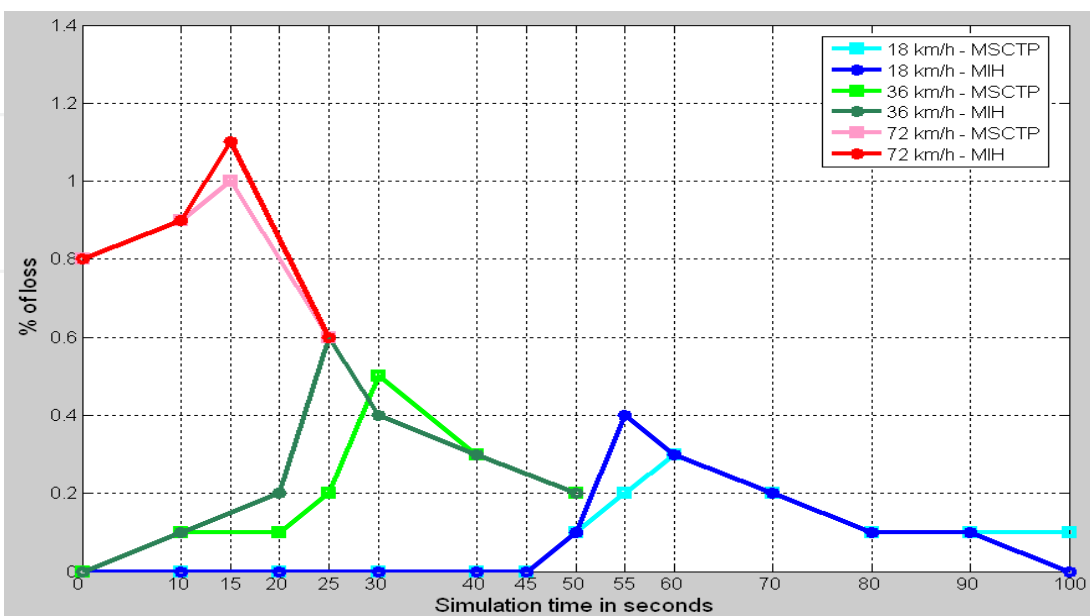


Fig. 15. Percentage of packets lost with HO from 802.11s to 802.16e / VoIP

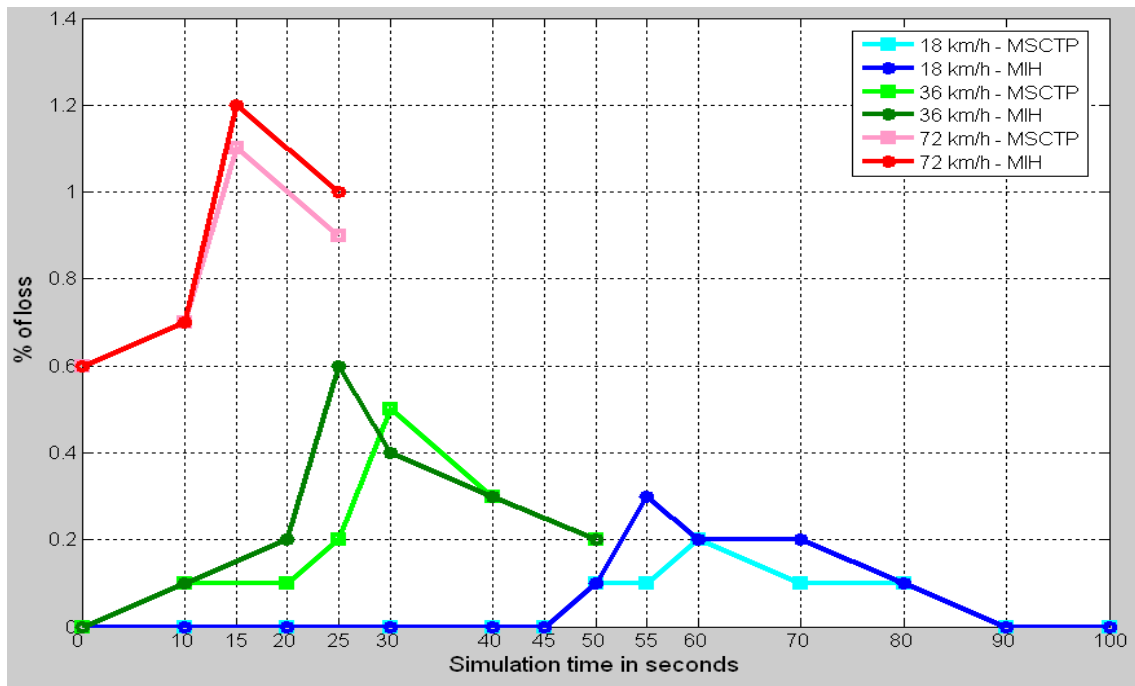


Fig. 16. Percentage of packets lost with HO from 802.16e to 802.11s / VoIP

During the Handover, the only results that converge to the threshold of 1% [18] required by the VoIP traffic] are those corresponding to the speed of 72 km/h. For the two other speeds the QoS level is acceptable.

We present now the results of data traffic (see figures 17 and 18):

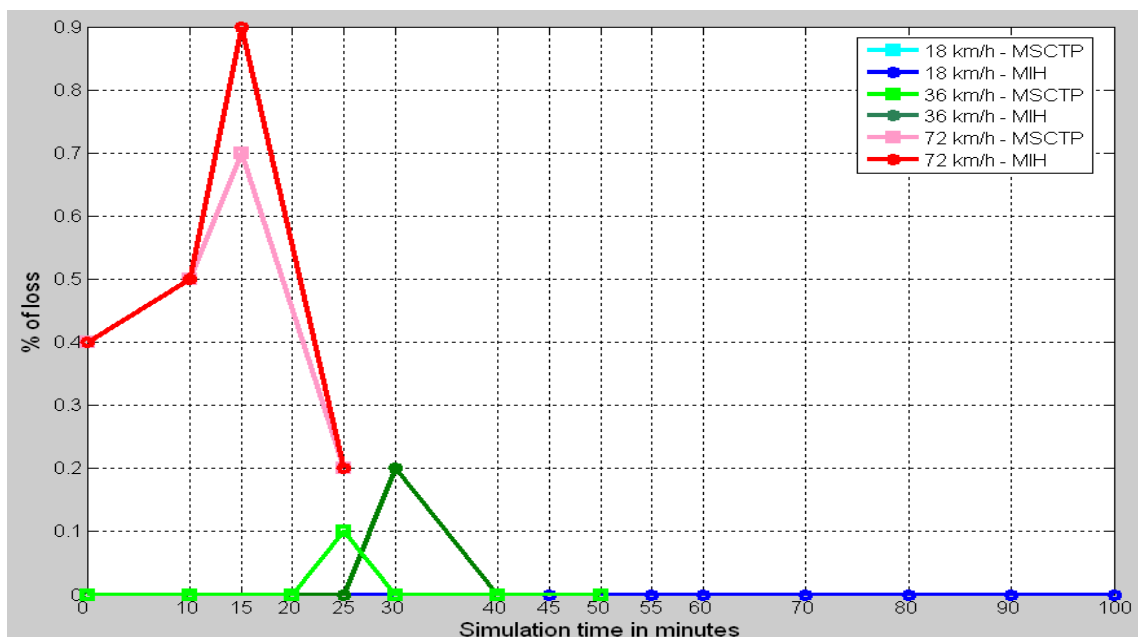


Fig. 17. Percentage of packets lost with HO from 802.11s to 802.11e / Data

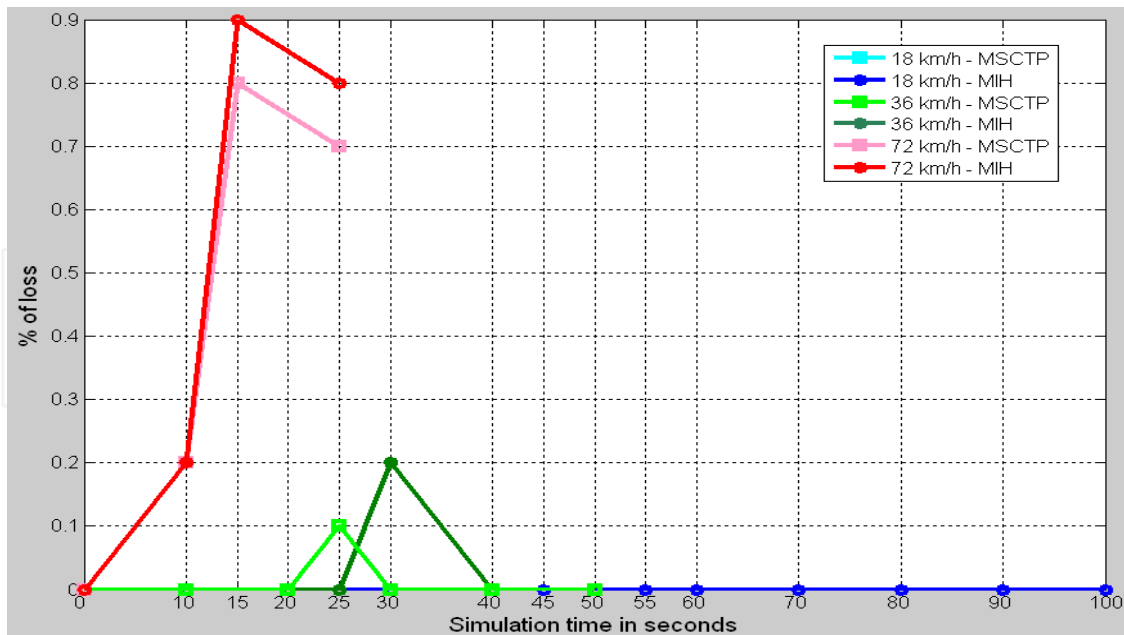


Fig. 18. Percentage of packets lost with HO from 802.16e to 802.11s / Data

With the data traffic, the percentage of loss is zero with a speed of 18 km/h, and it is acceptable with a speed of 36 km/h. It has a maximum of 0.1% with MSCTP and 0.2% with MIH during the Handover.

But with a speed of 72 km/h, the percentage of loss is not acceptable during the handover and in the 802.11s cell.

We pass now to video streaming traffic (see figures 19 and 20):

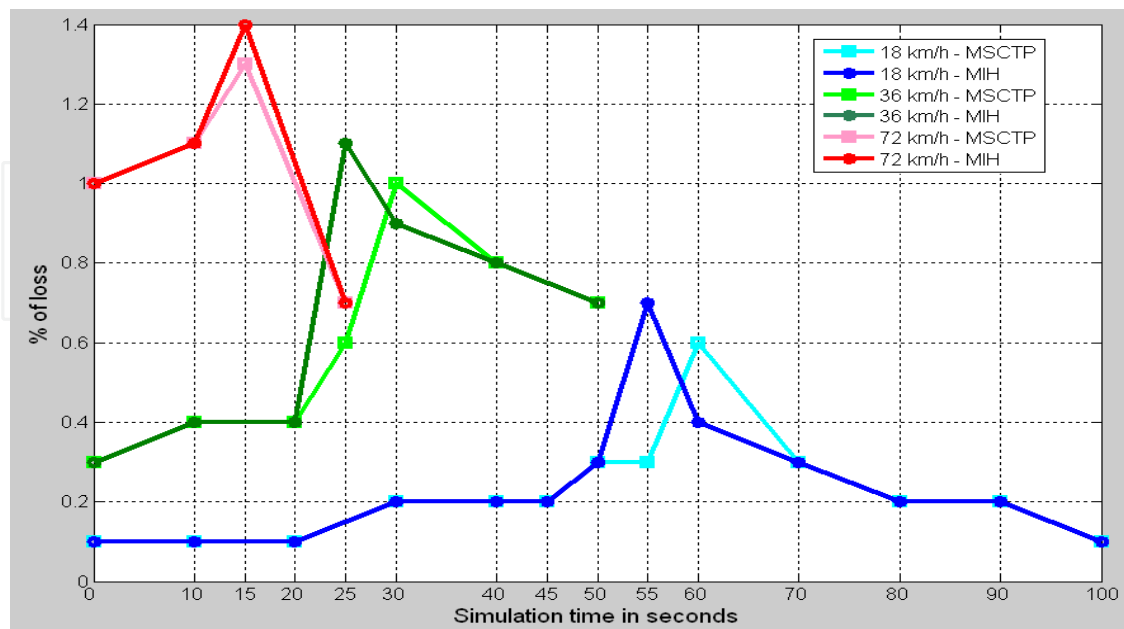


Fig. 19. Percentage of packets lost with HO from 802.11s to 802.16e / Video

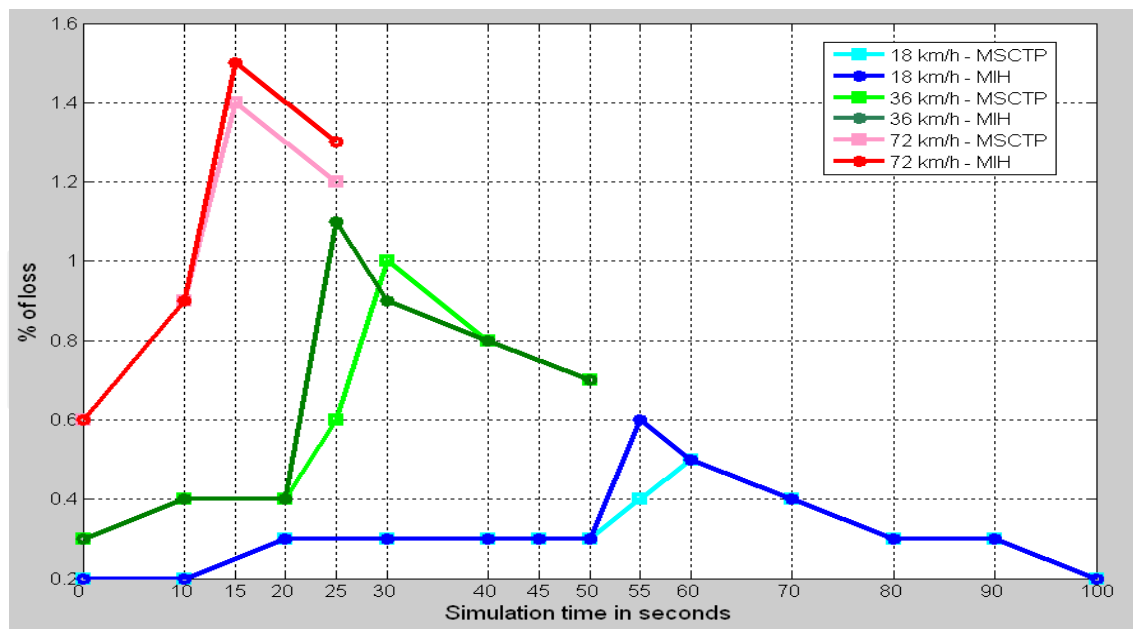


Fig. 20. Percentage of packets lost with HO from 802.16e to 802.11s / Video

With the video traffic, the loss values are higher than those with VoIP or data traffic, and with a speed of 18 km/h the results are acceptable because they not exceed 1% which is a maximum of loss required for video traffic [18].

We note that the case of handover from 802.16e to 802.11s produce results slightly better than those obtained with the opposite case during the handover.

With the speed of 36 km/h, the maximum of the % of loss exceeds slightly 1% with MIH, and is equal to 1% with MSCTP; and the results are equivalent in the two ways of handover.

With a speed of 72 km/h, the results are not acceptable with the two mechanisms during the handover because they exceed largely 1%, and the results of the handover from 802.11s to 802.16e are better than those of the opposite case. And finally with this speed, the results are acceptable in the 802.16e cell but not in the 802.11s cell.

4.3 Debit

Finally, in this section we will evaluate the debit experimented by the mobile during the handover cases already proposed for the simulations in section 4.1. We start with the VoIP traffic (see figures 21 and 22).

Concerning the debit of VoIP traffic and with a minimum required by this type of traffic fixed to 4 kb/s [18]; the all cases proposed with the two speeds: 18 and 36 km/h present an acceptable debit; but with the speed of 72 km/h and during the handover, the results are lower than 4 kb/s, and the debit obtained with MSCTP during the handover is slightly higher than that obtained with MIH.

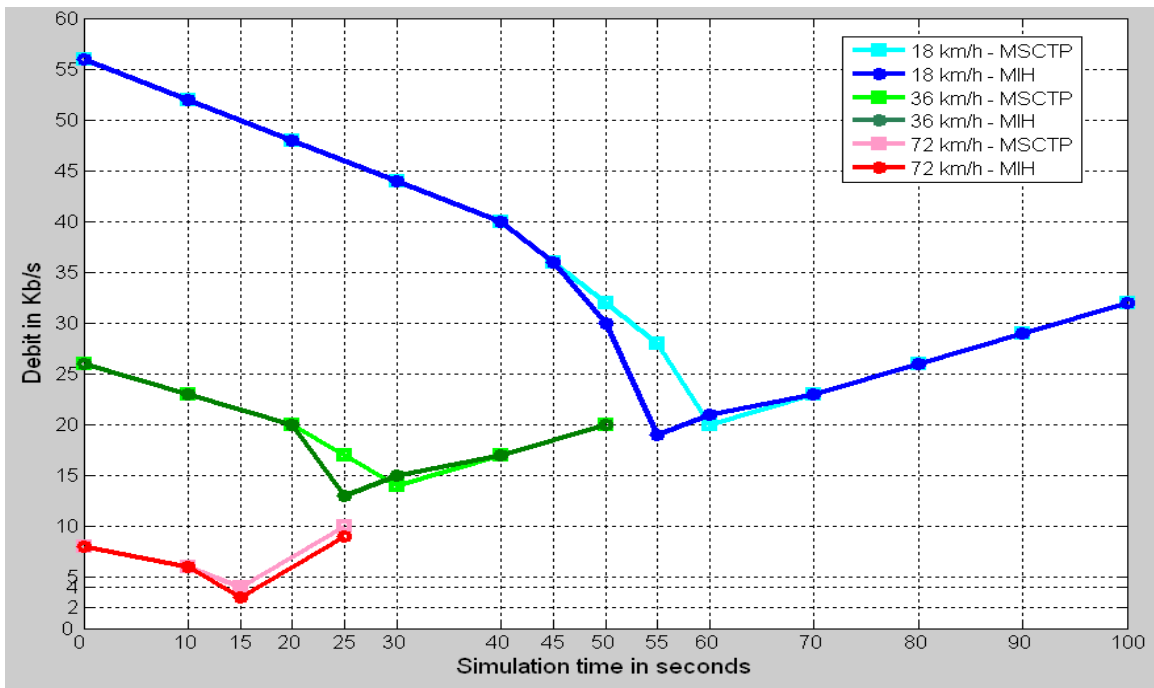


Fig. 21. Debit of HO from 802.11s to 802.16e / VoIP

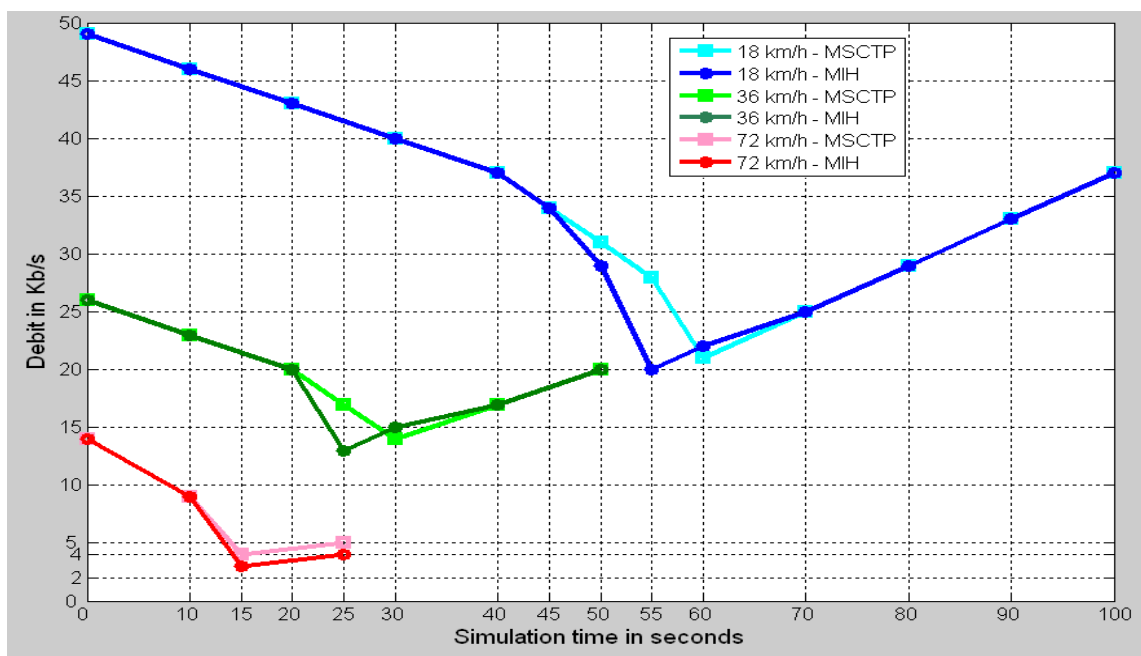


Fig. 22. Debit of HO from 802.16e to 802.11s / VoIP

We present now the results of data traffic (see figures 23 and 24):

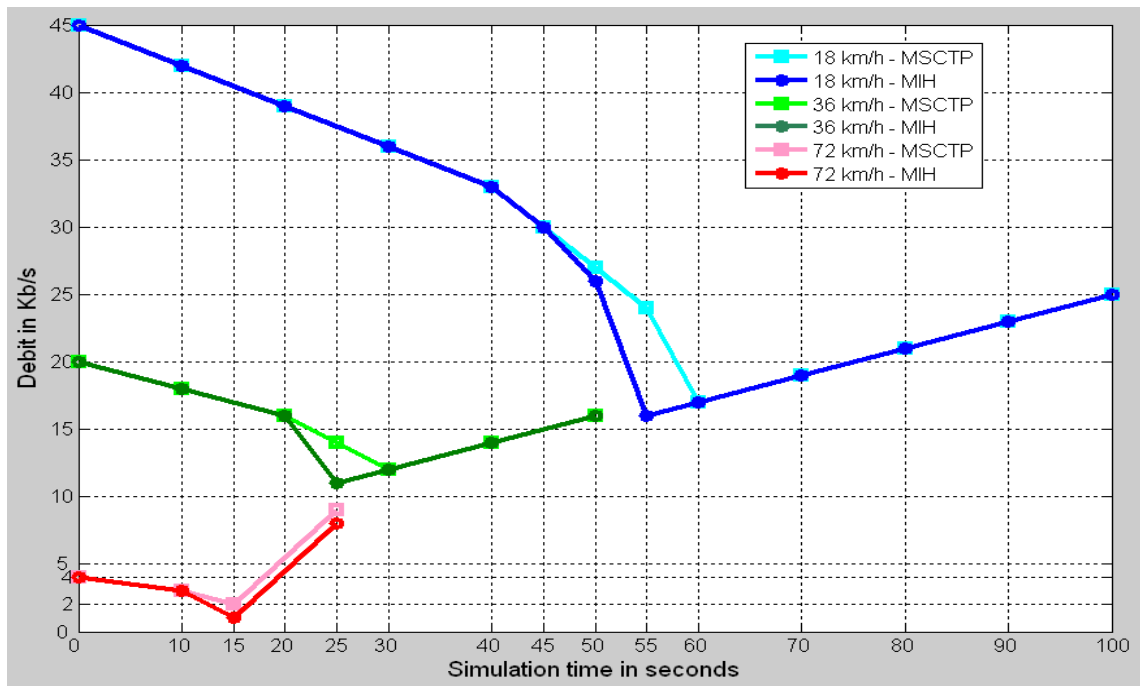


Fig. 23. Debit of HO from 802.11s to 802.16e / Data

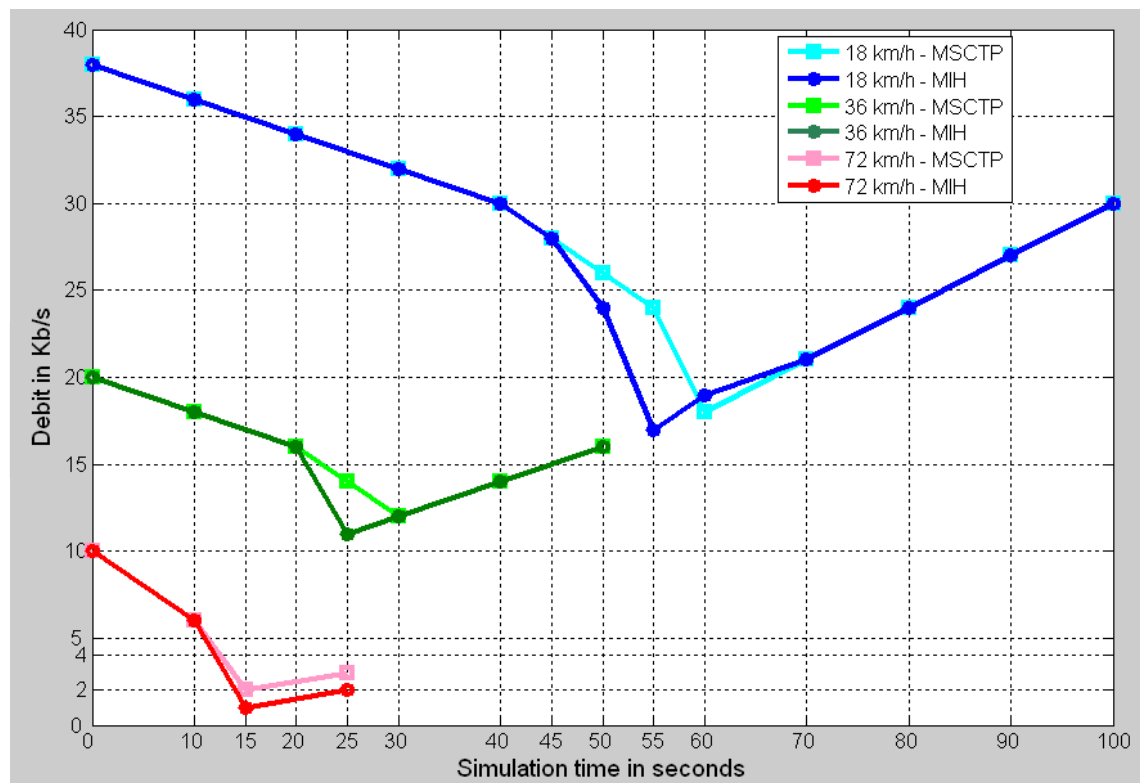


Fig. 24. Debit of HO from 802.16e to 802.11s / Data

With the data traffic, the debit decrease when the speed increase. The debit is better in 802.11s cell when the speed is weak, and it is better in 802.16e when the speed is high.

We present finally the results of video traffic (see figures 25 and 26):

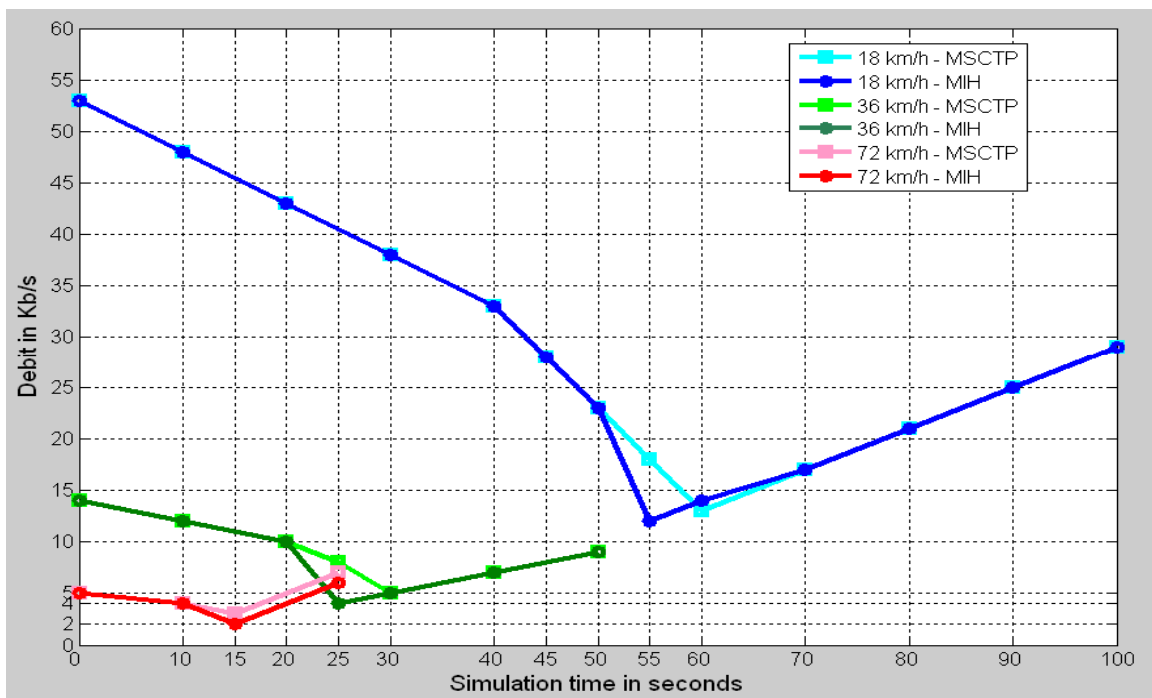


Fig. 25. Debit of HO from 802.11s to 802.16e / Video

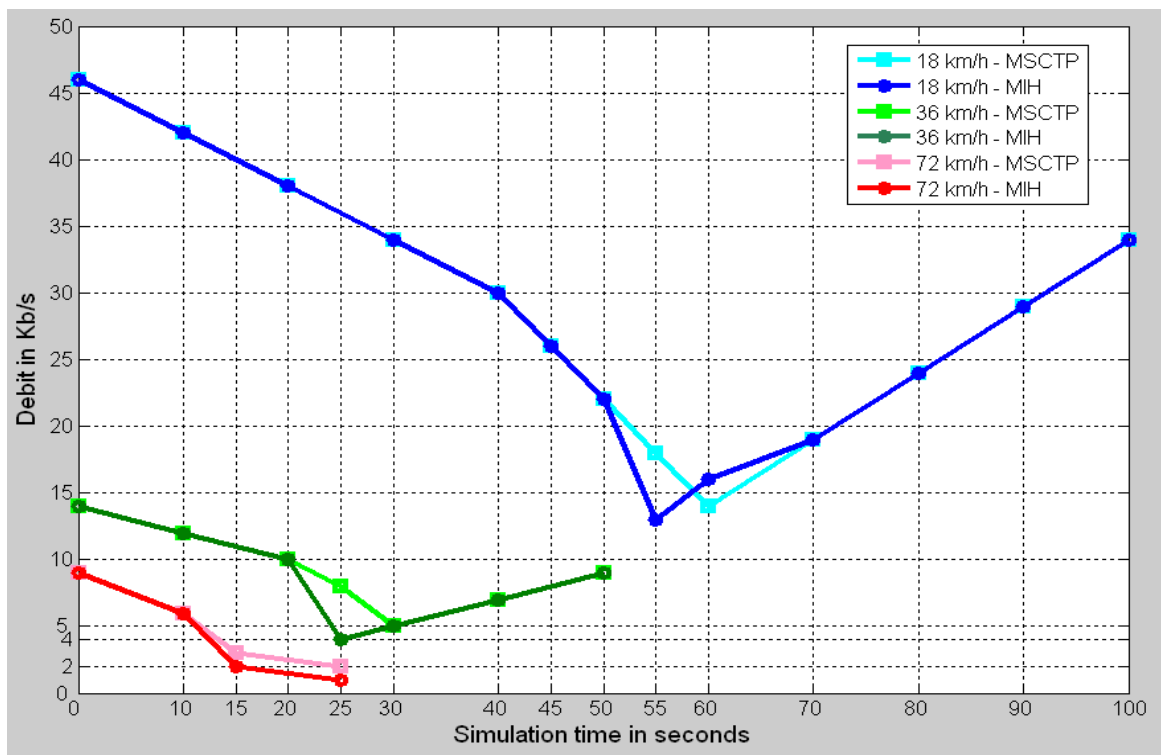


Fig. 26. Debit of HO from 802.16e to 802.11s / Video

With the video traffic, the debit values decrease comparing to the other traffic types.

5. Conclusion

The interoperability and the vertical handover between different networks present currently a real challenge to overcome. The difference of networks operation is the main reason of this problem. And, for pass to the 4G networks, it is important to resolve this problem of interoperability between different networks.

Our work has focused on the interconnection between two wireless radio networks of the IEEE 802 family, and we are concentrating on the QoS aspect for several traffics types especially during the handover process. For doing that, we have proposed two interconnection models based on two recent handover mechanisms, and we have simulated those two models with three mobile speeds and in the both directions of networks.

Observing the results obtained, we can conclude that with a low or medium speed of displacement of a mobile station, the both techniques: IEEE 802.21 and MSCTP present a good solution during the vertical handover. With the two techniques, there are very few interruptions during the vertical handover. But based on details of simulation results, we notice that with MSCTP protocol we obtained a QoS level slightly better than that obtained with MIH architecture.

Also the handover from 802.11s to 802.16e generates results better than the opposite case of handover. But with a high speed, it is the opposite rather because the mobile WiMAX supports better the increasing speeds; and also the results in this case are still not acceptable comparing by QoS level needed for each traffic type.

It should be noted that during all the simulations, the scenarios proposed does not include cell congestion or lack of available resources.

For future work, we will propose interconnection models between networks of different family, we will mix a network world with a telecommunication world, and we will try to propose a handover mechanism adapted to the two entities that we will define.

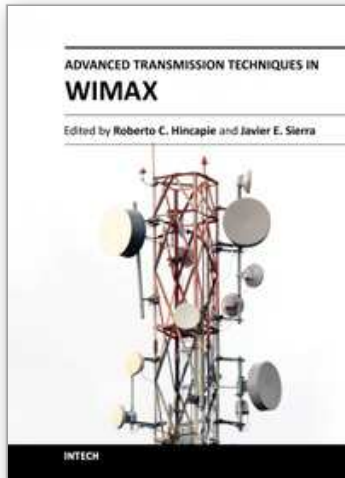
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This book has been prepared to present the state of the art on WiMAX Technology. The focus of the book is the physical layer, and it collects the contributions of many important researchers around the world. So many different works on WiMAX show the great worldwide importance of WiMAX as a wireless broadband access technology. This book is intended for readers interested in the transmission process under WiMAX. All chapters include both theoretical and technical information, which provides an in-depth review of the most recent advances in the field, for engineers and researchers, and other readers interested in WiMAX.

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University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
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Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

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