Smart Network Selection and Packet Loss Improvement during Handover in Heterogeneous Environment

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***Abstract*—Seamless Handover between networks in heterogeneous environment is essential to guarantee end-to-end QoS for mobile users. A key requirement is the ability to select the next best network. Currently, the implementation of the IEEE 802.21 standard by National Institute of Standards and Technology (NIST) considers only the signal strength as a parameter to determine the best network. In this paper, we propose including additional parameters such as available bandwidth, mobile node speed and type of network during selecting a new network to improve the QoS for mobile user's application. The results of the experiments that we performed using Network Simulator show that there is a need for a new framework taking into account these parameters to guide network selection process during handover and to provide mobile users with QoS guarantee.**

Keywords-Seamless vertical handover; QoS parameters; IEEE 802.21 MIH

I. INTRODUCTION

Communicating from anywhere at any time is becoming a requirement of great importance for mobile users. However, the rapid expansion of wireless network technologies creates a heterogeneous environment. Nowadays, mobile users would like to acquire, directly from their device, different kinds of services like Internet, audio and video conferencing which sometimes require switching between different operators. Moreover, user preferences differ, some are interested in service costs only; others will be satisfied with broadband networks that cover large geographic areas, etc. Consequently, to satisfy the above requirements, user mobility should be covered by a set of different overlapping networks forming a heterogeneous environment. Mobile device should be able to choose, from all available networks in its environment, the one that meets its needs and ensures accordingly the transition from one cell to another in the same technology (horizontal handover) or between different types of technologies (vertical handover). During this period of handover the challenge is to conserve the QoS parameters guarantee.

The remainder of this paper is organized as follows: Section II describes the background. Section III describes the main components of IEEE 802.21 standard and its implementation using NS2 simulator. Section IV provides an overview of wireless protocols used in our simulation environment. Section V describes the simulation scenarios and results and we conclude in Section VI.

II. BACKGROUND

The IEEE 802.21 [1] is an emerging standard, also known as Media Independent Handover (MIH) that supports management of seamless handover between different networks in a heterogeneous environment. The current implementation of the IEEE 802.21 standard for the network simulator NS by National Institute of Standards and Technology (NIST) based on draft 3 [2][3] considers only the signal strength as a unique parameter to determine the best network [4]. We argue in this paper that this parameter alone is not sufficient to satisfy user requirement. Indeed, signal strength, available bandwidth, traffic on the serving network and packet loss ratio are among the other parameters that affect the requirement of mobile user in terms of QoS guarantee. For example, a bad QoS, when using a real time application in a handover process, may be due to a lack of available bandwidth because of high load in the visited network while the signal strength is good.

Several attempts have been made to improve the handover within the MIH framework. Chandavarkar et al. [5] proposed an algorithm for network selection based on the energy of the battery, the speed of the mobile, and the coverage radius of the network in order to avoid power loss during handover and to improve the efficiency of seamless handover. Siddiqui et al. [6] proposed a new algorithm named TAILOR that uses different parameters of QoS with the user preferences to select the destination network. Also this algorithm optimizes the power consumption.

Jiadi et al. [7][8], modified the Media Independent Handover component (MIH) where handover is performed in three steps: initiation, selection and execution. The proposed process aims to improve the handover delay by adding new events to the initiation step that can be generated from the application layer instead of lower layer upon the user's satisfaction. Moreover they added a new algorithm at the selection step based on price, delay, Jitter, Signal Noise Ratio (SNR) and available data rate within the MADM (Multi Attribute Decision Making) function to improve the QoS during selection process.

The research work initiated in [9][10] proposed a selection algorithm based on the willingness of users to pay for a given service, while Cicconetti et al. [11] provided an algorithm based on three parameters: connectivity graph, connectivity table between nodes and the current geographical position of the serving network. The proposed algorithm reduces the handover time and the energy consumption of mobile node due to scanning.

The MIIS component (see Section III) of MIH is not fully implemented by NIST. Arraezet al. [12] implement this service and install it on each access point allowing user to save the energy of the battery by just activating a single interface. According to the IEEE 802.21 standard, an MIH user communicates, through the link layer, with its MIHF which sends a query to MIIS to retrieve the list of all networks in the vicinity. Alternatively the authors of [13][14] developed a new method to communicate with the MIIS through the upper layers using Web Services.

Moreover, 802.11 protocols defined 11 channels for communication and force the MN during the handover to scan all channels looking for the active one. Khan et al. [15], proposed a new algorithm based on the Media Independent Information Server (MIIS), to provide user with a list of only active channel to be scanned in order to save time during handover.

An et al. [16] added two new parameters to MIH that allow FMIPV6 to save the steps of proxy router solicitation and advertisement (RtSolPr/PrRtAdv). This resulted in a decrease of handover latency and improvement of packet loss ratio.

In this paper, we investigate the effect of the inclusion of three parameters with the signal strength into the destination network selection mechanism during handover. These parameters are: Available Bandwidth, type of network and mobile speed. As far as we know, these parameters have not been investigated at the same time before. As it will be detailed in Section V, our first experiment will show that by including the available bandwidth parameter (ABW) the packet loss will be improved. The second experiment will show that upon the type (WI-FI, WIMAX) of the current and destination network we can save on packet loss. The third experiment will show that it is worthily significant to consider the velocity of MN while selecting new network during handover.

III. IEEE 802.21 STANDARD

User mobility can be achieved at different levels of the protocol stack. The IEEE802.21 standard, also known as Media Independent Handover (MIH), provide mobility management at layer 2.5, by being inserted between layer 2 and layer 3. As depicted in Fig. 1, the Media Independent Handover Function (MIHF) is the main entity of the standard that allows communication in both directions between lower and upper layers through three services: event (MIES), command (MICS) and information (MIES) [3][17].

A. *Media Independent Event Services, MIES*

This service detects changes in the lower layers (physical and link) to determine if it needs to perform handover. Two types of events can occur: "MIH Event" sent by the MIHF to the upper layers (3 +), and "Link Event" that spreads from the lower layers to the MIHF.

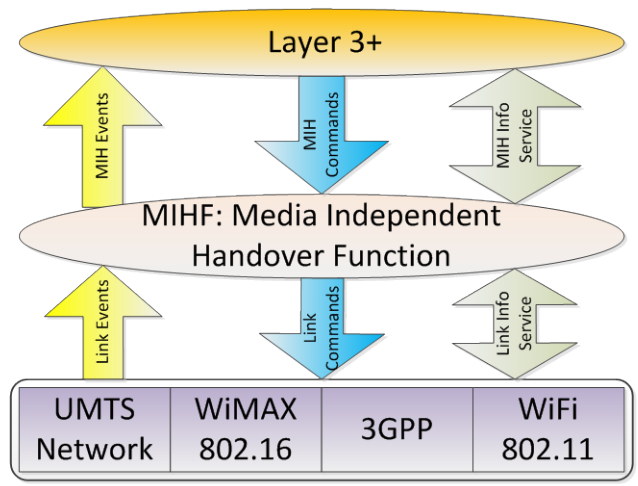

Figure 1. MIH architecture.

B. *Media Independent Command Services, MICS*

This service uses two types of events. The "MIH Commands" transmitted by the user towards the MIHF and "Link Commands" sent by MIHF to lower layers.

C. *Media Independent Information Services, MIIS*

The MIIS let the mobile user discover and collect information about features and services offered by neighboring networks such as network type, operator ID, network ID, cost, and network QoS, etc. This information helps doing a more efficient handover decision across heterogeneous networks.

IV. WI-FI AND WIMAX STANDARDS

A. *IEEE 802.11, WIFI*

IEEE 802.11, Wireless Fidelity (WI-FI) [18], is a wireless local network technology designed for a private LAN with a small coverage area (hundreds of meters). Different versions of 802.11 exist and communicate on different frequency bands with a different bit rate. In all simulations that we performed in this paper we use 802.11b. Mobility support in conventional IEEE 802.11 standard is not a prior consideration and horizontal handover procedure does not meet the needs of real time traffic [19]. WI-FI's QoS is limited in supporting multimedia or Voice over Internet Protocol (VoIP) traffic and several research activities have been carried out in an attempt to overcome this short fall[20].

B. *IEEE 802.16, WIMAX*

IEEE 802.16, WIMAX (Worldwide Interoperability for Microwave Access), technology is for metropolitan area network (MAN) covering a wide area at very high speed. QoS in WI-FI is relative to packet flow and similar to fixed Ethernet while WIMAX define a packet classification and scheduling mechanism with four classes to guarantee QoS for each flow: Unsolicited Grant Service (UGS), Real-Time Polling Service (RTPS), non-real-Time Polling Services

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(nrtPS) and Best Effort (BE). WIMAX mobile (802.16e) adds a fifth one called extended real-time Polling System (ertPS) [21]. WIMAX supports three handover methods: Hard Handover (HHO), Fast Base Station Switching (FBSS) and Macro-Diversity Handover (MDHO). The HO process [22] is composed of several phases: network topology advertisement, MS scanning, cell reselection, HO decision and initiation and network re-entry [23][24].

V. MIH PERFORMANCE EVALUATION

In this section, we will present three scenarios to evaluate the impact of the available bandwidth, type of network, and user velocity on selecting a destination network during handover.

A. *Simulation Environment*

To show the limits of using one parameter to select an access network and to motivate the need of advanced selection methods that combine several constraints, we present in this section several simulation scenarios using NS2, v2.29, which support the Media Independent Handover (MIH) module implemented by National Institute of Standards and Technology (NIST).

The studied scenarios focus on the importance of some criteria other than radio signal strength while evaluating network in the vicinity for handover. The First scenario studies the impact of the selected network available bandwidth. The second one tryout the type of destination network, and the third scenario experiments the speed effect of the MN on QoS during handover.

Simulation parameters are shown in Table I. Traffic used is a CBR (Constant Bit Rate), packet size is always constant to 1500 bytes and the throughput is determined by varying the interval of sending packet during simulation.

TABLE I. SIMULATION PARAMETERS

WI-FI Access Point AP1 and AP2 Parameters	
Transmission Power (Pt_)	0.027 W
Receiving Threshold (RXThresh)	1.17557e-10 W
Carrier Sending Threshold (CXTresh)	1.058.13 e-10 W
Coverage Radius	150 meters
Radio Propagation Model	Two-RayGround
Frequency (Freq)	2.4 GHz
Sensitivity to link degradation (lgd_factor_)	1.2
WIMAX Parameters	
Transmission Power (Pt_)	30 W
Receiving Threshold (RXThresh)	3e-11 W
Carrier Sending Threshold (CXTresh)	2.4 e-11 W
Coverage Radius	1500 meters
Radio Propagation Model	Two-RayGround
Frequency (Freq)	3.5 GHz
Sensitivity to link degradation (lgd_factor_)	1.2
Antenna Type	Omni Antenna
Modulation	OFDM

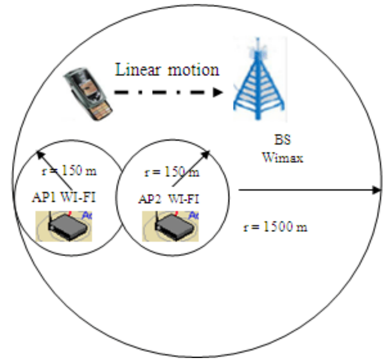

Figure 2. Scenario I topology.

B. *Scenario I : NIST Selection Weakness*

1) Topology Description: Topology of this scenario, shown in Fig. 2, consists of two WLAN Access Points AP1 and AP2 (802.11b) located inside an 802.16 base station (BS) coverage area and one Mobile Node (MN) equipped with multiples interfaces. It is important to note that other stream of traffic source is connected to AP2 consuming its bandwidth. At the beginning, MN connected to AP1, starts moving to the center of the BS and on its way detect AP2. According to the NIST handover algorithm, that selects a new network based on the Radio Signal Strength only, AP2 is considered a better network than WIMAX and the MN will make a handover from AP1 to AP2. Once the MN reaches the limit coverage area of AP2, the handover to WIMAX base station occurs.

2) Scenario I Results: By increasing the throughput generated by the CBR application on the MN, we observe a greater number of packet loss overall scenarios. Fig. 3 shows the packet loss during HO. When a MN loses the signal on AP1 it needs to make a HO to another network, it has 2 choices: handover to AP2 or to WIMAX. According to NIST algorithm, which selects a new network based on the signal strength only, AP2 is selected and Fig. 3 shows the number of packet loss during handover AP1-AP2. When the MN reaches the limit coverage area of AP2, it makes the handover to WIMAX and we observe another amount of PL during HO AP2-WIMAX. 3) *Critics of the NIST algorithm*: select a destination network based on the signal strength received by the mobile node still unsatisfactory. Indeed, a mobile node, near to an overloaded base station, receives a strong signal. According to NIST algorithm, the MN handover to this base station and meet a high packet loss rate due to a lack of available bandwidth.

C. *Multi Criteria Selection Algorithm*

In this section, we propose a new selection algorithm named Multi Criteria Selection Algorithm (MCSA) which is a modified version of the algorithm proposed by NIST to select a destination network based on two criteria: Radio Signal Strength (RSS) and available bandwidth (ABW) of destination network. We assume that the user preference consists of selecting a network with the largest available bandwith whatever the cost is. Then, we compare the number of packet loss during HO between MCSA and NIST algorithm.

1) Strategy of MCSA: A Mobile Node (MN) that is connected to a serving network receives beacons and router advertisement (RA) from Wi-Fi and WIMAX network in the vicinity. According to our proposed algorithm, MN will

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select the network that has the biggest available bandwidth (ABW). In order to get the value of ABW to the mobile node, we needed to change the structure of the beacons and router advertisement in NS2 by adding a new field that holds the value of ABW.

2) *MCSA results*: in order to compare MCSA and NIST results, we use the same topology of simulation cited in Fig. 2. By using our proposed MCSA algorithm, which aims to find among the visible list of networks, the one that have the largest available bandwidth (ABW), WIMAX is selected instead of AP2 and the total number of handovers decreases improving the total number of PL and the Quality of Service is preserved during the mobility of the MN

For a user who gives importance for the number of Packet Loss rather than type of network (WIFI or WIMAX), it is better to follow the strategy of our proposed MCSA algorithm that improves the packet loss ratio by 33%. Table II shows the improvement in number of HO and PL with MSCA for a given throughput.

We can conclude that selecting a destination network using only RSS as indicator does not meet the needs of all users. More accurate choice of destination network during handover would consider the ABW of the destination network. A new framework is needed to consider the values of different criteria to take a decision and make a better choice concerning the destination network during handover.

In order to better understand the sequence of events that a MN and Network perform during successful HO, we provide a short description of messages sequence chart in Fig. 4. The dashed and non-dashed bloc represents the flow of handover messages according to NIST and MCSA algorithm. By using our MCSA algorithm, we can save all messages in the dashed bloc which enables less signaling over the network and improvement in number of packet loss for a better QoS guarantee provided to a mobile user.

A detailed description of the events sequence according to the implementation of the IEEE802.21 standard by NIST is as follow:

1) MIH user on the MN sends MIH Capability Discovery Request to discover link capability supported (events and commands) for each mac of each node.

2) MIH user on the MN sends MIH Register Request to register to the local and remote MIHF.

3) MIH User on the MN sends MIH Get Status requesting the available network interface; it discovers the presence of 2 interfaces (WIFI and WIMAX) both interfaces support events and commands services of MIHF.

4) MIH user on the MN sends MIH Event Subscribe request to subscribe to the events on the given links for local and remote MIHF. This latter send MIH Event Subscribe response to the MIH User of the mobile node

5) Since the BS decides of the reservation of bandwidth, it informs the MN of the frame structure in the uplink and downlink. It sends the DL-MAP/UL-MAP to the WIMAX interface of the mobile node MN. The WIMAX base station is detected and generates a link up event toward the MIHF of MN.

6) MIHF of the MN order the WIMAX interface of MN to connect to the BS.

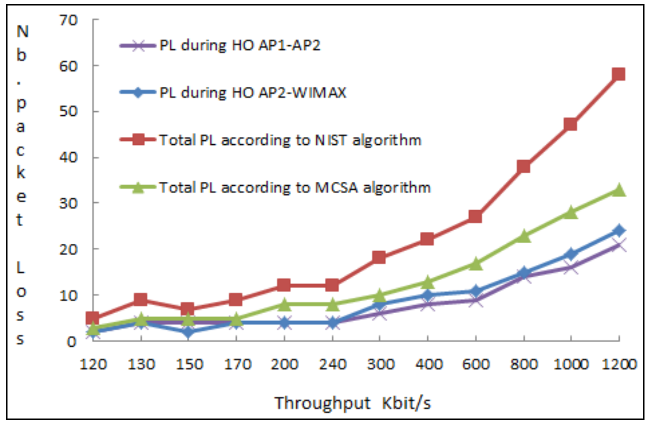

Figure 3. Packet loss according to NIST and MCSA algorithm.

TABLE II. COMPARISON OF HO NUMBER AND PL WITH EACH ALGORITHM

According to NIST algorithm		According to MCSA algorithm	
Number of HO	***Total PL***	***Number of HO***	***Total PL loss***
2 (AP1 to AP2 andAP2 to WIMAX)	20 AP1 to AP2:9 and AP2 to WIMAX:11	1 (AP1 to WIMAX)	10 AP1 to WIMAX:10

7) In this case, a router solicitation is sent form the MIPV6 module of MN to the neighbor discovery module of the BS.

8) Neighbor discovery module of BS reply by sending a router advertisement (RA) to the MIPV6 module of MN with the network prefix of WIMAX base station = 3.0.0; router-life time = 1800s and advertisement interval = 10s.

9) MN's WIFI interface receive a beacon message with a power above the threshold value and trigger a link Detect event; the available bandwidth of AP1 is largely available (not consumed by any other traffic), according to the both algorithm MCSA and NIST, AP1 is considered as a better network.

10) MIHF of MN sends a link connect message to the WiFi interface of MN; exchange of association Request/Response between MN and AP1.

11) The WIFI interface of the MN send a link up message to the MIHF and MIH user of MN.

12) Exchange of router advertisement and router solicitation between the MIPV6 of MN and the neighbor discovery module of AP1 (first WIFI access point).

13) Starting of traffic flow between the WIFI interface of the MN and the correspondent node through the AP1 access point.

14) Once MN reaches the limit coverage of AP1, it starts receiving the beacon message coming from AP2. Detect the presence of a beacon power above the defined threshold.

15) WIFI interface of MN sends a link going down and link down to the MIH user of MN through the MIHF

16) MIH user of MN sends a link scan request to the MIHF of MN.

17) The WIFI interface of MN send a probe request and start scanning the 11 channels of WIFI interface looking for an active one.

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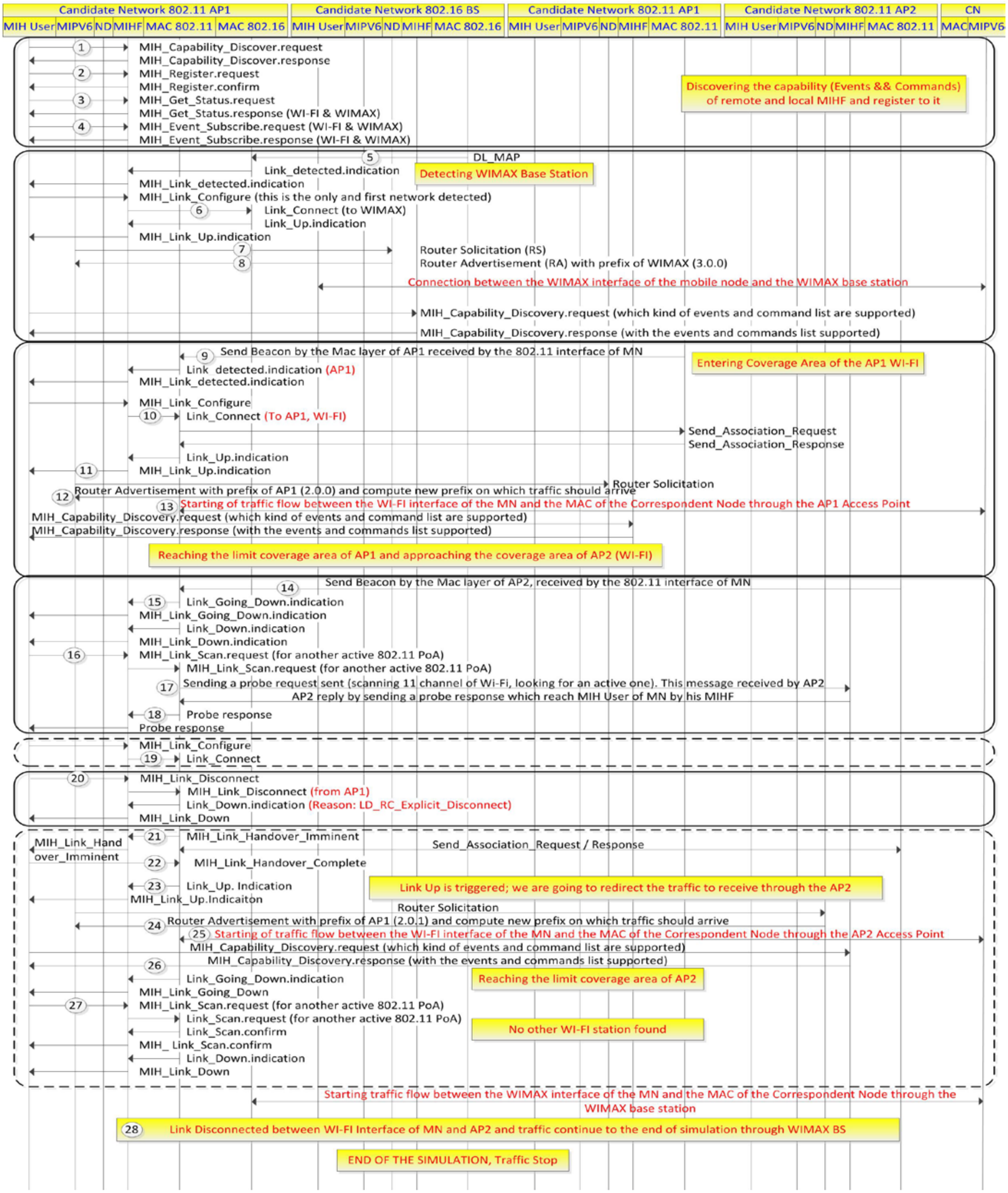

Figure 4. Handover Flow Chart Messages.

18) This message received by AP2 which reply by sending a probe response to the MIH user of MN through its MIHF. MIH user of MN detects the presence of AP2.
According to NIST algorithm, that considers this access point as better network decide to handover to it (and continue with step 19). But according to MCSA algorithm which evaluate the available bandwidth of AP2 before handover to it, find its available bandwidth, consumed by other traffic, very small comparatively to WIMAX, ignore this network and handover to WIMAX directly (jump to step number 20).
19) MIH user sends to MIHF an MIH Link ConFig. this generates a Link Connect to the WIFI interface of MN (connection to AP2).
20) MIH user sends to the MIHF a MIH Link Disconnect which disconnects the connection between the WIFI interface of MN and AP1. According to NIST algorithm, we continue with step 21 and according to MCSA we jump to step 28 saving by that all steps between 21 and 27.
21) The WIFI interface of MN sends a link handover imminent message to the MIHF of MN.
22) MIH user of MN sends link handover complete to the MHIF of MN.
23) WIFI interface of MN send link up indication event to the MIH user of MN through his MIHF announcing the detection of AP2 (second WIFI access point).
24) MIPV6 module of MN sends router solicitation to the WIFI interface of AP2 which answer by a router advertisement with the new prefix (2.0.1).
25) Starting of traffic between the WIFI interface of MN and correspondent node (CN) through AP2.
26) MIH user sends the MIH Capability Discovery Request and response to the Mac layer of AP2 testing if the Events and Commands events list is supported.
27) The MN reaches the limit coverage of AP2, start a link going down event, the WIFI interface of MN send a link scan event looking for others network (delaying the connection to WIMAX) don't find anyone else WIMAX.
28) MN connect to WIMAX and a link disconnect event with WIFI is triggered and traffic continue to the end of the simulation through WIMAX.

D. *Scenario II : Type of Network Impact*

1) Topology Description: Fig. 4 illustrates the topology of scenario II. During this simulation we compare the delay taken by MN when it makes a HO from WI-FI to WIMAX (Fig. 5a) versus handover from WIMAX to WI-FI (Fig. 5b). Measurements are done according to handover algorithm of NIST only.

During the simulation, the MN moves from WI-FI (AP1) toward the center of BS. Once it reaches the limit coverage of AP1, a "link going down" trigger is fired announcing the need for handover. Since the only available network is 802.16 (WIMAX), the handover is made to this network. We also study the same simulation when the mobile moves from WIMAX to WI-FI.

2) Scenario II Results: Fig. 6 shows a decreasing curve of the handover delay as a function of the throughput generated by the MN application. Handover delay is the time difference between the first packet received on the destination network and the last packet received on the current served network. When we increase the throughput, the time between two consecutive packets is smaller and packets reach the destination network earlier, which explains the appearance of the downward curves of handover delay in Fig. 6.

Handover delay from WIMAX to WI-FI is less than the handover delay from WI-FI to WIMAX. When the MN connected to AP1 moves to the center of BS (Fig. 5a), it reaches the limit coverage area of AP1 and generates a "link going down" trigger. In this case, a scan process starts looking for a new network delaying the connection to BS (Fig. 6). While for handover from WIMAX to WI-FI network (Fig. 5b), the MN don't trigger this event because it is still in the coverage area of WIMAX (no loss of WIMAX signal) that's why we have less handover time (Fig. 6).

As a conclusion of this experiment, we can say that upon the type of destination network, we can have different values of handover delay and as a consequence different value of PL.

As shown in Fig. 6, we can note that by varying the throughput values between 120Kbit/s and 170Kbit/s, the handover time varies between 275ms and 200ms hence exceeding the maximum acceptable value of the QoS end-to-end delay parameter (150ms) for real time application. This criterion is worthy to be considered when selecting a new network during HO.

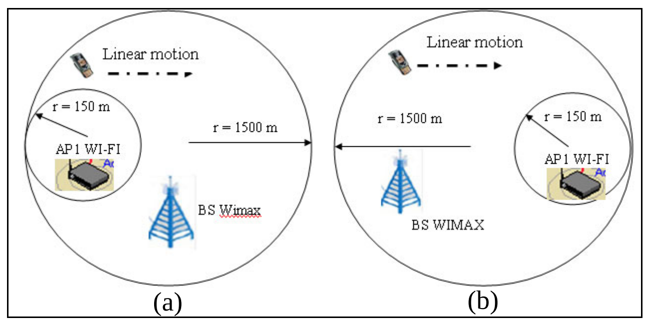

Figure 5. (a) Handover WI-FI-WIMAX, and (b) Handover WIMAX-WI-FI

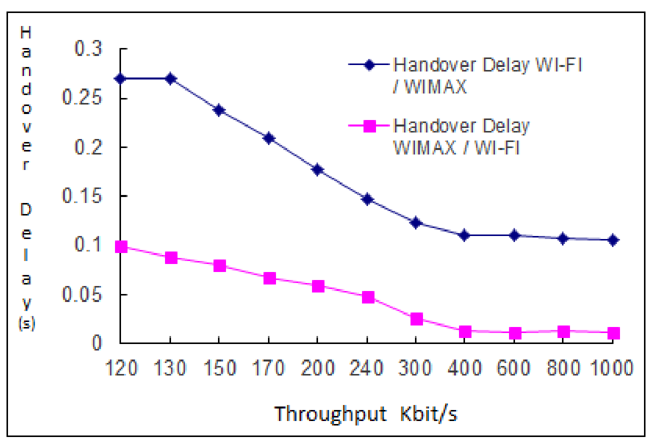

Figure 6. Handover Delay Curves

E. Scenario III : Speed Impact

1) Topology Description: In this scenario, shown in Fig. 7, we study the effect of MN speed on the packet loss during HO. At the beginning, the MN connected to WIMAX, moves to the center of the BS, resulting on a handover to AP1 and AP2 according to NIST algorithm. Once the MN reaches the limit coverage of AP2, it returns to WIMAX network.

2) Scenario III Results: For the three different experimented speeds the packet loss on WIMAX is null because 802.16e WIMAX is designed to support high speed mobile users [25]. Once a MN starts moving toward the center of the BS, it detects the presence of AP1, and according to NIST algorithm it makes a HO to AP1. Some PL happen during this HO and the value of this PL increases with mobile speed (Fig. 8) because WI-FI, unlike WIMAX, is limited in high-speed transport communications environment [26]; and doesn't support high speed mobility, e.g., for a speed of 20m/s we can see a great impact of Doppler Effect on the system performance [27].

The same process happens during handover from AP1 to AP2 as we experienced other number of packet loss that increases with mobile speed. Also when the MN handover from AP2 to WIMAX some packet loss occur whose number increase with mobile speed. Accordingly, we conclude that users who place importance on the number of packet loss and MN speed would prefer to stay on WIMAX and never stream through AP1 or AP2. Moreover, we concluded that NIST fails to meet the requirement of mobile user moving at a speed higher than the pedestrian speed (1m/s). Thus, we argue that there is a need for a new framework that takes into account the user speed.

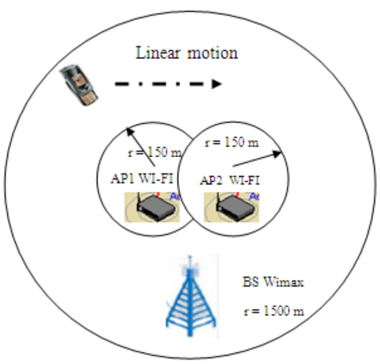

Figure 7. Scenario III topology

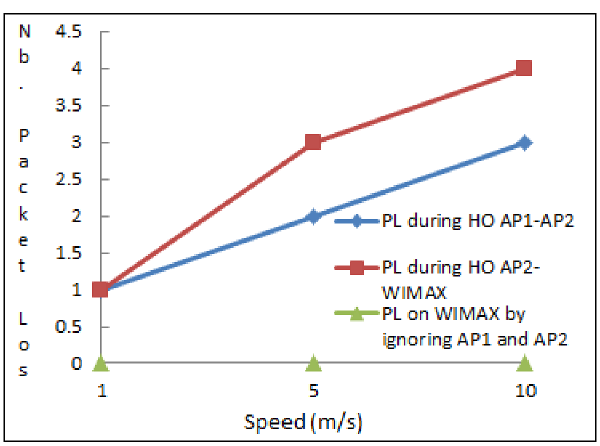

Figure 8. Packet loss as a function of mobile speed

VI. Conclusion and Future Work

In this paper, we have evaluated the effect of some parameters like Radio Signal Strength, available bandwidth, type of network (802.11 or 802.16) and mobile speed for choosing the best network in the vicinity. We conclude that choosing a network based on the Radio Signal Strength only is not always a good strategy. The experiments that we conducted using the NS-2 simulator showed that the inclusion of additional parameters significantly improves the packet loss ratio and so the QoS guarantee for mobile users. In future work, we will propose a framework with a generic model that takes into consideration different levels of constraints such as network parameters with users and operators preferences to improve the selection of the best candidate network and optimize QoS parameters in terms of packet loss ratio, delay and jitter for real time applications.

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