Handover mechanism of mobile WiMAX (802.16e) with Wi-Fi (802.11g) Technology

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***Abstract*—IEEE 802.16e Mobile WiMAX (Worldwide Interoperability Microwave Access) standard is proposed to support mobility, handover has become one of the most important QoS (Quality of Service) factors. Applications like mobile VoIP (Voice over Internet Protocol) and multimedia gaming greatly benefits from low-latency, to maintain such low-latency and keeping high QoS, various advanced handover schemes are being proposed and developed. The hybrid networks of Wi-Fi (Wireless Fidelity and WiMAX networks can provide high data rate and enhanced multimedia services, but it is challenging to obtain optimized handover decision based dynamic QoS information.**

The first goal of this project is to implement various techniques used for handover in mobile WiMAX technology and compare the performance of such techniques in different physical channel environment. The second phase of this project is to implement and simulate the handover techniques from WiMAX to Wi-Fi without degradation in the QoS, i.e. maintaining the connectivity of the MS (Mobile Station) to either base station. The third stage is the coordination of both technologies at the same time, i.e. keeping the MS connected to both technologies so that the SS (Subscriber Station) sense the huge bandwidth available when both technologies are simultaneously available.

We will divide this project into 3 phases so we can build and model our system in the right way for easy debugging. However, our first goal is to accomplish the first stage, and as time permits we will continue the other phases. We intend to complete our model with a full documentation as an open source for interested students.

I. Introduction

A. Why Multi-Mode?

In many electronic devices such as notebooks and smart phones, Wi-Fi becomes a default option, in the mean time WiMAX attracted a lot of attention in the telecommunication community including researchers, product developers and service providers. In the sense that Wi-Fi provides internet access for small coverage area, WiMAX take the customers to the far end by covering miles away from the nearest Wi-Fi hot spot. Huge deference in internet speed if we Compare The high speed internet offered by Wi-Fi or WiMAX technology to the wide area Internet connectivity offered by 2.5G and 3G cellular data services.

Combining WiMAX and Wi-Fi access together, make the concept of ”internet on the Go” really works. Since these two technologies have different usages in the sense that Wi-Fi provide high speed WLAN (wireless local area network) while WiMAX provide high speed WWAN (Wireless Wide Area Network). Moreover, coupling these technologies together enable service providers to provide fixed, portable and mobile broadband Internet services. Optimizing the network by routing traffic based on the subscriber’s need for mobility, QoS, and bandwidth. Moreover, combining takes advantage of device cost savings.

WiMAX Forum which develops interoperability specifications for equipment using IEEE 802.16 standards consist of a number of members including service providers, equipment vendors, chip vendors, researchers and users. All of them collaborate to introduce the specification which comes out from IEEE standard. These coming out specification have many options and allow a wide range of parameters. This generality is good in the since all of us look at the same standard, nevertheless, it’s difficult for an equipment from two vendors to interoperate unless they both choose the same set of optional features and similar values of various parameters. Limiting the standard options to a set of profiles that can be implemented in products is the job of WiMAX Forum members.

The NWG (Network Working Group) within the WiMAX Forum has developed specifications for users transitioned between WiMAX at different access technologies, such as Wi-Fi. Inter-working between WiMAX and Wi-Fi is significantly simplified as both networks are deployed using IETF (Internet Engineering Task Force) protocols and comply with IETF IP policy definition and policy enforcement rules.

Since at the first stage of this project, we are going to investigate the various mechanism of handover technique in mobile WiMAX , for sure we will follow the standard parameters in a way to visualize the effect of these parameters in certain environment. Before deeply discuss our idea we will introduce a background of the various mechanism used in WiMAX to reduce the handover time.

B. Handover

Mobility is the most challenging research in WiMAX networks that are highlighted in broadband wireless communications. The Mobile WiMAX system basically supports the hard handover which is known as (break-before-make) scheme, which disconnects the existing link to the in-service BS first and then makes a new connection to another BS, but it is also possible to implement a soft handover scheme that can support a reliable handover by maintaining connection with two or more BSs (Base Stations) in the transition period.

Two main processes to perform handover: network topology acquisition process, (i.e. the parameter values needed for making handover decisions between the MS and the BS are periodically updated) and handover execution process which refers to practically executing the handover through neighbor scanning, handover capability negotiation, MS release, and network re-entry processes [1].

C. related work

Various handover mechanisms in WiMAX are proposed in the literature for example in [2], they proposed GPS (Global Positioning System) as a method to perform the handover mechanism faster. A method they claim that it reduces the interruption time in handover, consequently reducing this factor will improve the overall handover mechanism, especially for some services which is sensitive to long delays, for example, (IPTV and VoIP).

In our opinion, a lot of draw back in this mechanism, first of all every wireless station must equipped with GPS modem which is not practical, secondly the computation and analysis claimed to be at the MS which consumes more power, lastly the main factor to handoff was the distance which also not sufficient

TABLE I
PARAMETERS VALUES OF THE MOBILE STATIONS

Attribute	Value	Unit
Base Frequency	5.8	(GHz)
Bandwidth	20	(MHz)
Maximum transmission power	.5	W
Antenna Gain	-1	dB
Physical Profile Type	OFDM	
Scanning Threshold	20	(dB)
Scan Duration(N))	4	Frames
Interleaving Interval(P)	40	Frames
Scan Iterations (T)	10	
Start Frame (M)	6	(Frames)
Resource Retain Time(100 ms)	2	milliseconds
Number of transmitter	SISO	
Frequency Division UL Zones	PUSC	512-FFT
Frequency Division DL Zones	PUSC	512-FFT
Frame Duration	5	(milliseconds)
Symbol Duration	100.8	(microseconds)
Number of Subcarriers	512	
Duplexing Technique	TDD	
Frame Preambles	1	(symbols)
TTG	100.8	(microseconds)
RTG	302.4	(microseconds)
UL/DL Boundary	Fixed	
DL Information Element Size (bits)	32	
Fast Feedback Area	Two Slots (1x6)	
Initial Ranging Area	One Slot	(6x2)
Periodic Ranging(Bandwidth Request Area)	One Slot	(6x1)

factor for handing over. In [3], they propose an inter-FA (Frequency Assignment) handover algorithm in order to reduce handover latency and message overhead. In their work they claim that the high latency handover comes from the inter-FA, i.e. when a Base Station (BS) can request serving MS to change frequency band from current Serving FA to others attached in the serving BS in order to avoid Congestion in the FA that MS is connected. In [4] they reduced handover latency by transmitting downlink data before uplink synchronization is completed in handover procedure. In [5] adaptive channel scanning algorithm is proposed to reduce time for scanning in association mode.

II. SYSTEM MODEL AND MATHEMATICAL ANALYSIS

We choose the OPNET Modeler 14 to develop a simulation model of the IEEE 802.16e standard. Our main focus lies on the performance evaluation of the TDD MAC Layer so its functionality is in detail implemented according to the standard. The simplified PHY (Physical) Layer model implements the OFDM (Orthogonal Frequency division Multiplexing) with 512 subcarriers PHY Layer. We use QPSK (Quadrature Phase Shift Keying) with coding rate (3/4) as the modulation scheme. Also we apply this modulation schema to all nodes in our topology resulting in the same effective data rate per OFDM symbol. Following the Standard of IEEE 802.16e [6], table II and table I shows the configuration parameters we use for BS and MS nodes respectively.

The topology used for this project consist of three WiMAX BSs, a number of MS nodes, a backbone router, traffic flow and server as shown in Fig [1].
Every base station has a coverage area of 1 km, The location of BS_0 with respect to other two base station is carefully designed. Since our main goal is the handover process performance, the distances between these base station is very important, and this will be addressed and analyzed below.
The signal strength is a dominant factor for the handover decision in this type of handover. The power received at the MS node will be

$$P_r\,[mW] = \frac{P_t G_t G_r}{PL(d)L}, \tag{1}$$

where P_t is the transmitted power, L is the system loss factor and G_t, G_r are the transmitter and receiver gain respectively. PL is the path loss at distance d, since we are assuming only the line of sight path between the transmitter and the receiver, then the path loss can be approximated as

$$PL(d) = 92.4 + 20\log(d) + 20\log(f). \tag{2}$$

The antenna gain G can be found using the following equation

$$G = \frac{4\pi A_e}{\lambda^2}, \tag{3}$$

where A_e is the effective aperture of the antenna and λ can be obtained easily by ${}^{c}/_{f}$, where f is the carrier frequency. The signal to noise ratio is defined as:

$$SNR[dB] = P_r[dBm] - N_\circ[dBm]. \tag{4}$$

Then using equations [1], [4], we can obtain the signal to noise ratio as

$$SNR[dB] = P_t + G_t + G_r - PL(d) - L - N_\circ, \tag{5}$$

where N is defined as $N_\circ[dBm] = -174[dBm] + 10\log B + F[dB]$, F and B is the noise figure and the bandwidth of the system respectively.

III. FIRST PHASE: HANDOVER IN WIMAX

The HO mechanism implemented in WiMAX allows a movement of a Mobile Station (MS) from the air interface of one Base Station (BS) to the air interface provided by another BS. The HO process is composed of several phases: Network topology advertisement, MS scanning, Cell Reselection, HO decision-initiation and Network Re-entry [7]. In this phase of our project we are focusing on the MS scanning phase, cell reselection and handover decision.

TABLE II
PARAMETERS VALUES OF THE BASE STATIONS

Attribute	Value	Unit
Base Frequency	5.8	(GHz)
Bandwidth	20	(MHz)
Maximum transmission power	2	W
Antenna Gain	15	dB
Physical Profile Type	OFDM	
Minimum Power Density	-100	dBm-subchannel
Maximum Power Density	-60	dBm-subchannel
Scanning Threshold	20	(dB)
Scan Duration(N))	4	Frames
Interleaving Interval(P)	40	Frames
Scan Iterations (T)	10	
Start Frame (M)	6	(Frames)
Resource Retain Time(100 ms)	2	milliseconds
Number of transmitter	SISO	
Frequency Division UL Zones	PUSC	512-FFT
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Frame Duration	5	(milliseconds)
Symbol Duration	100.8	(microseconds)
Number of Subcarriers	512	
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Frame Preambles	1	(symbols)
TTG	100.8	(microseconds)
RTG	302.4	(microseconds)
UL/DL Boundary	Fixed	
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Fast Feedback Area	Two Slots (1x6)	
Initial Ranging Area	One Slot	(6x2)
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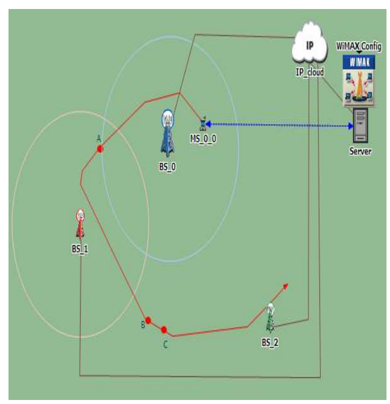

Fig. 1. Network Model for Handover Process

A. First Scenario: SNR BASED HANDOVER

In this scenario we use one MS node with the configuration mentioned earlier in table I, and define a trajectory of 5120 m long with the speed of the MS node 6.4 m/s. We set up the simulation run time to be the time for the MS to finish its trajectory. According to this mechanism the MS will handover from the SBS (Serving Base Station) to the TBS (Target Base Station) based on SINR (Signal to Noise Ratio) or the signal strength. a simple HHO (Hard HandOver) mechanism or (break before make) is investigated, where the MS visit the three BS and connect to every BS for a specific time.

In this type of handover the MS communicates with just one BS at each time instance, i.e. all connections with the previous BS (called Serving BS) are broken

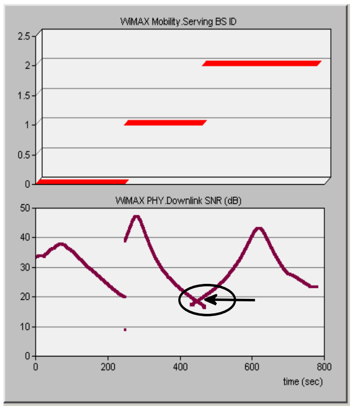

Fig. 2. Received SNR from different BS, BS_ID

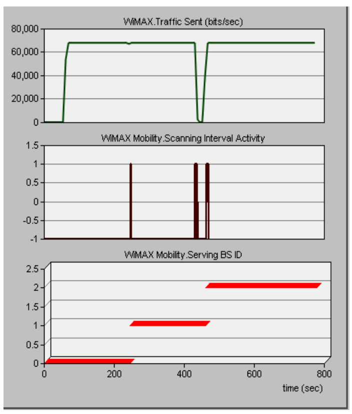

Fig. 3. Initial ranging, Scanning interval and Traffic sent

before the connection with a new Targeting BS is established. For the sake of easy interpretation of the Serving BS ID statistics, each BS has assigned a MAC address (or equivalently, BS ID) corresponding to its name, i.e. MAC 0 for BS_0, MAC 1 for BS_1, MAC 2 for BS_2. Fig [1] shows the topology for this scenario. One MS node is Mobile IPv4 enabled, with Home Agent set to BS_0. The MS node moves away from the Home Agent and visits 2 Foreign Agent BS nodes. Bi-directional application traffic is configured between the MS and the server node in the backbone, as follows:
* Uplink: 64 kbps mapped to the System Default (Best Effort connection).
* Downlink: 64 kbps mapped to the System Default (Best Effort connection).
Fig [1], shows the MS_0_0 visit the other two base stations and successfully did the handover process according to the signal strength criteria, i.e. when

$$SNR(TBS) - SNR(SBS) \geq 0.4(dB)$$

is satisfied, as depicted in Fig [2]. The downlink traffic experiences more interruptions due to Layer 3 handover

TABLE III
PARAMETERS VALUES OF SCAN DURATION

Type	Scan duration	Interleaving interval	Iterations
light	4	240	10
dense	20	240	10

delays (via Mobile IPv4) in addition to the Layer 2 handover delays (via WiMAX MAC functionality).
Point A correspond to the starting point of scanning threshold, where the SNR of MS_0_0 transmission to BS_0 drops below 20 (dB) configured in the MS_0_0. Once SNR drops below the scanning threshold, scanning activity is started in the hope of identify other SBS as a candidate for handover.
At point A we design our system to make the handover directly, i.e. we minimize the scanning interval to the least. Because of this design the Serving BS ID statistic with the Initial Ranging Activity statistic shown in Fig [3], indicate that the MS did the handover successfully without entering the scanning stage.
At (423 second) exactly (point B of Fig [1] of the network topology) MS_0_0 start scanning without successfully handover, and this is expected in the sense that we define the scanning interval to start when the SNR of any serving BS be less than or equal (20) dB, so that, this condition is met but no handover occurred. However, at about (441 second) of the MS_0_0 trajectory path (point C in Fig [1]) the condition for handover is met, i.e. $SNR(TBS) - SNR(SBS) \geq 0.4(dB)$, so MS_0_0 successfully handover from BS_1 to BS_2 as depicted in Fig [3]. After the MS attaches to the new serving BS, scanning still continues until the SNR at the MS receiver gets within a comfortable zone (higher than the scanning threshold).

B. Second scenario: the effect of scanning interval on handover mechanism

In this scenario we test the effect of increasing the scan duration on the whole handover mechanism, we define the scan duration as follows:
where the scan duration (in frames) represent the MS scans the neighbor BSs. Measurements are used to evaluate which BS is the best candidate to handover as defined IEEE [6].
We run the simulation using the same configuration defined earlier. Our result shows that as we increase the scan duration the chance for the MS to handover is better than decreasing this interval and this is expected in the since that the time spent for searching a targeting BS is bigger, which gives a good chance for the mobile station to pick its targeting base station earlier as shown

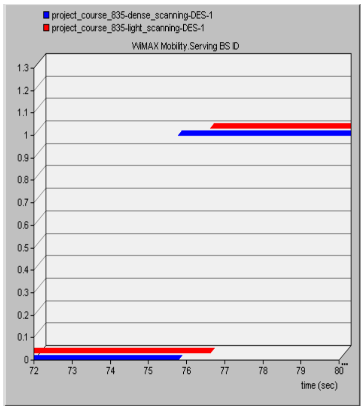

Fig. 4. Handover with deferent scanning interval

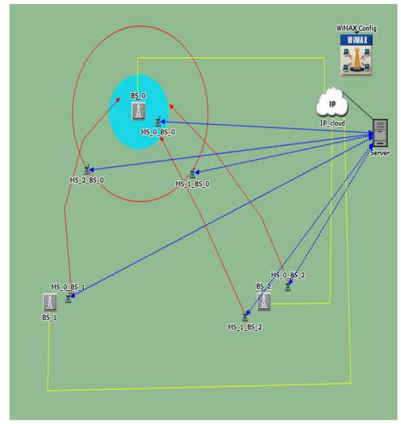

Fig. 6. Third scenario topology (BS trigger the handover mechanism)

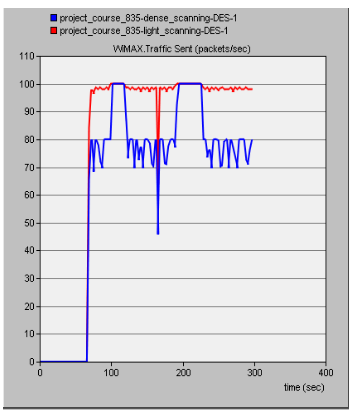

Fig. 5. Traffic sent for the two scenario with deferent scanning interval

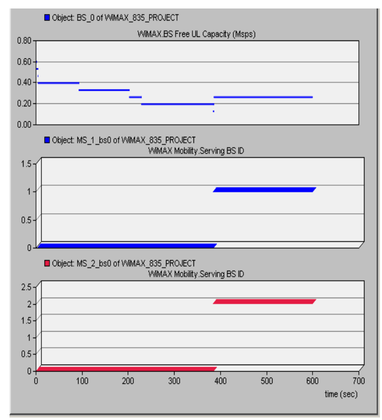

Fig. 7. Third scenario,free uplink capacity of BS_0

in Fig [4].

At the same time this will affect the traffic sent, i.e. the throughput will decrease since at this time period the MS will not send any data as shown in Fig [5].

C. Third scenario: handover mechanism based on QoS

QoS is characterized by the service level prediction. The service level prediction indicates the level of service expected by MS from target BS. Fig[6], shows the topology we use for handover mechanism triggered by the BS according to the criteria:

$$(\text{current\_capacity}) \geq 0.75 * (\text{maximum\_capacity})$$

Moreover, one of the requirement for implementing this mechanism is to configure BS_0 to exchange the MOB_NBR_ADV messages between others BSs as well, so BS_0 is a ware of the neighboring base stations. That means the serving BS which trigger the handover process for a certain MS has information about neighboring BS devices for that MS.

The BS can trigger a handoff if they detect bandwidth resources being reduced below a certain threshold. Using the topology we designed shown in Fig [6], Mobile nodes MS_1_BS_0 and MS_2_BS_0 are positioned at the cell boundary of BS_0. Some modification is made to the code of the control process of the BS and other configurations also have to be made to the BS attribute (DL subframe size),where this attribute express The size (in symbols) of the DL subframe in each TDD (Time Division Duplex) frame.
Our result shown in Fig [7]. It's obvious that at about 385 (second) of our simulation where the MS_1_BS_1,MS_1_BS_2 and MS_2_BS_2 entering the range of BS_0 and successfully make the hand over, BS_0 trigger the hand over mechanism for the two MS that are in the boundary region .i.e, the SNR received by those mobiles from BS_0 is the least.
Fig [8], shows the uplink capacity BS_1 which originally support MS_1_BS_1 and MS_2_BS_1, As we seen

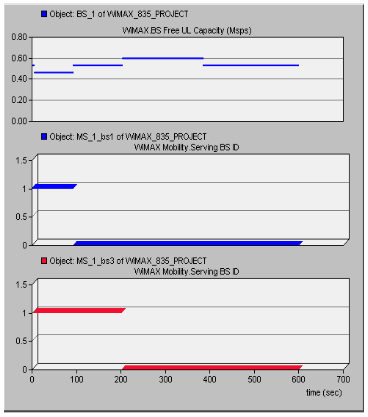

Fig. 8. Third scenario, free uplink capacity of BS_1

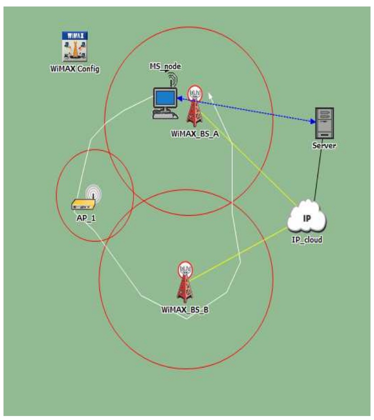

Fig. 9. Second Phase, Topology

from the figure, at the time those mobiles connected to BS_0, the uplink capacity increase which means more resources at this base station is released.

IV. Second Phase

In this phase we implement the handover between two heterogenous technology 802.16e [8] and 801.11g [9], Fig [9] shows our topology, which consist of two WiMAX BSs, MS node and Wi-Fi access point. The SINR as the wireless trigger for the handover mechanism is not a sufficient metric for handover decision. In the sense that both technology operate in different frequencies, as a result SINR cant be compared directly. The MS_node travel toward AP_1 leaving BS_A, as the SINR degrades below a certain threshold, MS_node will handover to the AP_1. Since we are using QPSK with coding rate 3/4, the SINR requirement for this modulation technique is about 5.9 dB to be within the standard of packet loss. Our initial result shows that the MS_node successfully did the handover as depicted in FIG [10]. According to this criteria The MS_0 will not handover to The AP_1 if SINR is above this threshold.

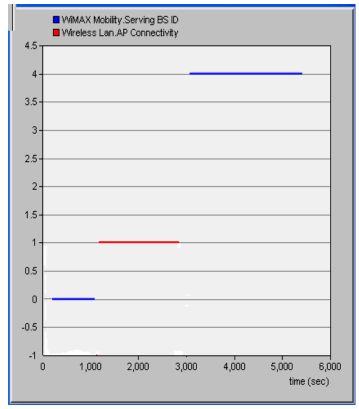

Fig. 10. Second Phase, MS_node Connectivity

That means some more work need to be done to modify the decision to be based on other parameters beside to SINR.

V. Conclusion and Future Work

In this project we study the hard handover mechanism in WiMAX technology from different prospective. First we simply create our topology using opnet 14 to study the behavior of hard handover process and the parameters that effect this process. In the first scenario we find that frequency planning is an important issue for the behavior of this process, in the since that the most important factor triggers the process is the received signal to noise ratio at the MS, assuming that the MS trigger the hand over, where it usually does. Also we find that the MS trigger the process when certain condition is met, which is obviously shown in Fig [2].

To investigate more and show how we should design our network to implement the hand over process according to this criteria we run another scenario, in this scenario we show that this condition should be designed carefully to prevent the MS from early handover or lately hand over. In case of early handover, some cells in the topology become more congested than others and in the second case it effect the QoS of the MS node, in the sense that the received signal from the serving BS will degrade, which effect the QoS at the MS node.

In the third scenario we put more constrains in the handover process, i.e. we let the base station trigger the handover process based on the capacity and the available resources on the serving BS. As we expect those nodes at the boundary are more likely to be a good candidate for hand over process, so that the serving BS decide to handover those mobiles to the suitable targeting base station. Doing so prevent the serving base station from going to congested state, and at the same time keep the QoS factors as high as expected. But nothing is free, as we cant do that without letting the serving base station aware about the neighboring BS around it using the MOB_NBR_ADV messages in the backbone.

In the second phase of our project we implement the handover process between two different technology (Wi-Fi and WiMAX), an initial result showed that this process cant be easily implemented based on SINR only. And we need some more parameters to base the handover decision on. Some of the suggested parameters are data rate,cost and QoS. Combining these parameters together will eventually indicate a highly desirable algorithm for handover decision.

To this end, we study deeply this mechanism in a way to understand the behavior and the various parameters that affect its performance. At the mean time, we are planing to proud our knowledge more, and try to derive a mathematical expression to model the various parameters that effect this mechanism. Also we plan to modify the implementation of the second phase according to the aforementioned parameters, i.e. vertical handover between Wi-Fi and WiMAX. Due to time limitation we postponed this work and the third phase to be completed later.

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