# Handover and Power Control in WIMAX Networks

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***Abstract*** **- WIMAX is an acronym that stands for "Worldwide Interoperability for Microwave Access". IEEE 802.16 is working group number 16 of IEEE 802, specializing in point-to-multipoint broadband wireless access. It also is known as WIMAX. IEEE 802.16 standard was developed to deliver NLOS (Non Line Of Site) connectivity between a SS (Subscriber Station) and BS (Base Station) with typical cell radius of three to ten kilometers. Mobile communication is increasingly oriented towards the usage of all Internet Protocol (IP) networks. Mobile IP technology is one of the important supporting technical in the construction of pervasive computing environment. This paper explains the WIMAX technology and focuses on the WIMAX mobility and scanning procedure using OPNET IPv4 model. WIMAX mobility allows Mobile Node (MN) to remain reachable while moving around in the Internet and the scanning procedure is used to determine if it could acquire a connection with a more suitable BS.**

***Keywords*** *–***Wimax handover, Wimax, Mobile Wimax power**



## I. INTRODUCTION

The emerging IEEE 802.16 and IEEE 802.16estandards commonly known as Worldwide Interoperability forMicrowave Access (WIMAX), which provide high throughputservices over long distance, are becoming the most popularbroadband wireless access technologies. Such advances intechnologies pose many challenges time-varying wirelesschannel fluctuations, limited bandwidth resources, coping withambient noises and interferences, dealing with transmission biterrors and packet losses and complexity and fairness ofscheduling. All of these factors have significant impacts onempirical WIMAX field test studies and precise evaluations.Thus, it is desirable to design and implement a complete andaccurate WIMAX simulation model to provide evaluation convenience [1].This paper, focus on the implementation the range of connectivity between the mobile station and the base station as the mobile station starts moving away from one base station along a certain trajectory, towards to the other BS, and then again moving away up to a certain proximity and stopping toanalyze power received from MN and BS's throughputs .

Compared to the complicated wired network, a WIMAX system only consists of two parts: the WIMAX BS and WIMAX SS also referred to as CPE (Customer Premise Equipment). Therefore, it can be built quickly at a low cost. Ultimately, WIMAX is also considered as the next step in the mobile technology evolution path. The potential combination of WIMAX and CDMA (Code Division Multiple Access) standards is referred to as 4G (Fourth Generation) [2].

Users want to be able to enjoy all of the applications, including multimedia, voice, and data, while still being able to access them in a mobile and/or fixed environment. IEEE 802.16 and its WIMAX technology are part of the solution which will enablethat sort of uncompromised data transmission in a wireless environment. This technology also has hugeadvantages over some of its alternatives as it was designed to supportQoS as one of its major features [3].Mobile WIMAX takes the fixed wireless application a step further and enables cell phone-like applications on a much larger scale.[4].

## II. WIMAX HANDOVERS

The handover is an important process in mobile systems and it is defined by the migration of a MS between air-interfaces belonging to different BS. The reason for such a change could be that a cell is overloaded or that the MS gets out of the BS transmission range. The BS associated with the MS before the handover is often called the SBS while the new BS is referred to as the target BS as shown in Fig1.

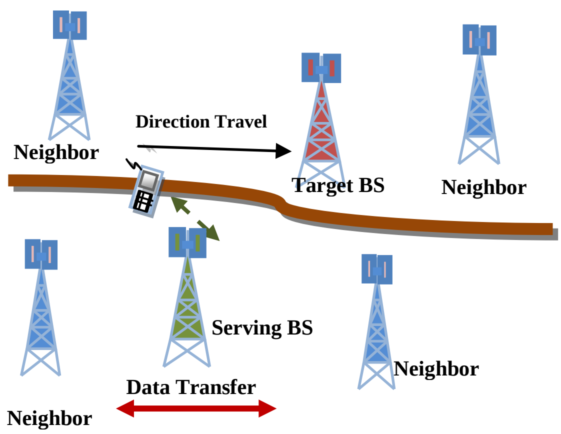


Fig 1WIMAX handover

A handover can be divided into two parts, the pre-registration phase and the actual handover. The pre-registration phase includes messages such as a handover request and a list of possible target BSs. During this phase the MS can also measure the signal strength from adjacent BSs to help in the decision about which BS to use as target BS. When the actual handover takes place the MS will close the connection to the serving BS and open a new to the target BS [5].

The main target of handover in cellular mobile networks is to provide the continuity of services during a MS traveling across the cell boundaries of BS [6].

## III. HANDOVER TYPES

Handover mechanism handles SS switching from one BS to another. Different handover techniques have been developed. In general, they can be divided into soft handover and hard handover [7].

- **HARD HANDOVER**

Within hard handover, the MS communicates with just one BS in each time as shown inFig 2.

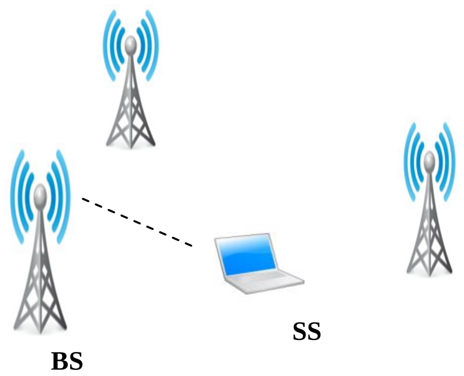


Fig. 2 Hard handover

All connections with the old BS (called SBS) are broken before the connection to a new BS (Target BS) is established. It means that there is a very short time when MS is not connected to any BS. Handover is executed after the signal strength from neighbor's cell exceeds the signal strength from the current cell [6].

The hard hand over mechanism as shown in Fig.3 uses the principle of break before make. This is the MS will break the connection with the original BS before making a new connection with another BS. Although it may lower the handover quality, an improved hand over mechanism must be used. When the MS moves from BS1 to BS2, it has to disconnect the original connection with BS1 before it can make a new connection with BS2 [8].

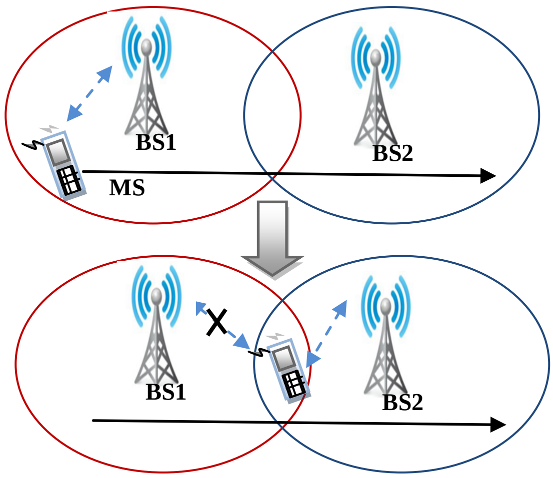


Fig. 3 Hard handover mechanism

- **SOFT HANDOVER**

During a soft handover the MS will keep contact with both BS's throughout the second phase of the handover, often called make-before-break as shown in Fig.4.



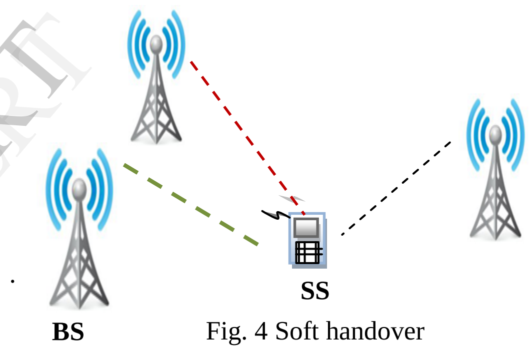


Fig. 4 Soft handover

The MS will in this way always be connected during the handover.There are however some drawbacks with the use of two connections, the overhead in the system will increase and the MS will use more network resources since there will be e.g. several channels reserved.

When a MS is leaving the cell of the serving BS it can make a request for a handover to find a better BS. If soft handoveris being used the MS will commence the registration phase with the target BS before aborting the connection to the serving BS. During the handover the MS will receive signals from both BSs. When the setup of the new connection is completed thetransmissions from/to the serving BS will end [5].

## IV. HANDOVER PROCEDURES

The handover (HO) allows MSs to handover between neighboring BSs while moving across the corresponding coverage areas. Furthermore, the mechanism can be used by BSs to trigger a HO in order to optimally balance the traffic load of cells within a network. Fig.5 shows an example with three BSs. Each BS is connected to the operator's backbone network either by wired or by wireless connections. The MS is moving away from its SBS, where it is currently associated.

The other two BSs are termed neighboring BSs. While crossing the cell boundary, the MS initiates a HO to the most favorable BS, the target BS [9].

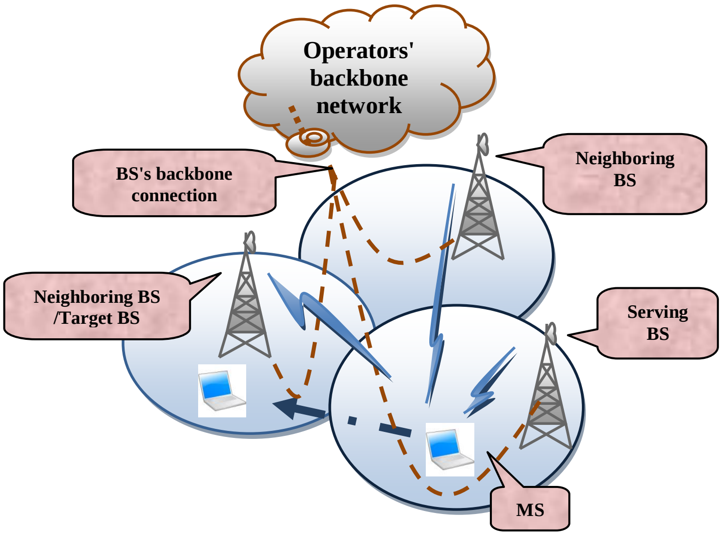


Fig. 5 Network model

Each BS periodically broadcasts information about the current network topology using the Mobility Neighbor Advertisement (MOB-NBR-ADV) message. At least every 30s, the message provides channel information of neighboring BSs. The BSs obtain that information over the backbone by exchanging its own DCD/UCD (Downlink Channel Descriptor/Uplink Channel Descriptor) messages. Fig 6 shows the MSC (Message Sequence Chart) of the advertisement [9].

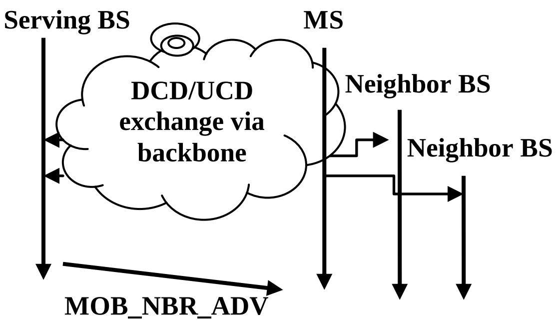


Fig.6Network topology advertisements

The channel knowledge facilitates an efficient MS synchronization with neighboring BS by removing the need to monitor transmission from the neighboring BS for DCD/UCD broadcasts [9]. Additionally, the NBR message includes the number of neighbors defined in the message, the Operator ID, trigger criteria for handover and settings that define what optional information is included. Optional information may include additional handover optimization and QoS information [9].

While a WIMAX MS is moving, it constantly scans for neighboring BS's and transfers data between itself and the BS that it is currently connected with. The purpose of these scans is to determine if it could acquire a connection with a more suitable BS. This could be because of a better wireless signal SNR (Signal to Noise Ratio), a BS with lower traffic, etc.

When a MS first communicates with a BS, it is responding using MOB_SCN-REQ (Mobile Scan Request) message to an advertising message that is sent out periodically by the information clients of various conditions of the BS. A MOB_SCN-REQ message may be transmitted by an MS to request a scanning interval for thepurpose of seeking available BSs and determining their suitability as targets forHO. The MOB_SCN-REQ message includes three key parameters were modified and measured the impact of: scan duration, interleaving interval,and number of iterations. The process of sending the request is shown in Fig 7.

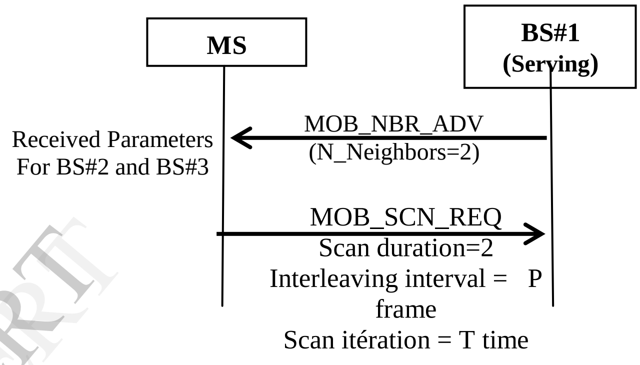


Fig.7 Mobile station requests

The scan duration is a period of N frames during which the MS scans neighboring BS's and acquires information about them. The interleaving interval is a period of P frames during which the MS handles normal data transmission between itself and the BS it is currently connected to. It repeats pairs of N scan frames and P interleaving interval frames T times [10].

When the MS is synchronized to the channel it needs to perform initial ranging or handover ranging. Ranging is a procedure where the MS receives the correct transmission parameters, e.g. time offset and power level [5]. Initial ranging is used to determine the transmit power requirements of the MS in order to reach the BS [11]. Ranging is necessary because SS's may be moving or have been moved, and their radio waves' arrival time at the BS depends on their changing distance from the BS. The greater the distance, the more delay in the signal's arrival time.

The WIMAX system uses two types of ranging: initial ranging and periodic ranging. During initial ranging, the WIMAX SS transmits a brief ranging request message that allows the system to send back a ranging response message with the amount of timing offset that the SS must use when it begins transmitting. After the SS has attached to the system, the BS will continually send time alignment messages (periodic ranging) to the SS to adjust (finetune) its timing advance as it moves in the radio coverage area [12].

## V. POWER CONTROL

RF power control is a process of adjusting the power level of a mobile radio as it moves closer and further away from a transmitter. RF power control is typically accomplished by sensing the received signal strength level to determine the necessary power level adjustments. The BS then sends power control messages to the mobile device to increase or decrease the mobile device's output power level.

Fig.8 reveals how the radio signal power level output of a SS is first determined by the received signal power level and is then adjusted by commands received from the BS to reduce the average transmitted power from the SS. This lower power reduces interference to nearby cell sites and helps to ensure the signal level received by the BS from all the SS's is approximately the same. As the SS moves closer to the BS, less power is required from the SS and it is commanded to reduce its transmitter output power level. The BS transmitter power level can also be reduced [12].

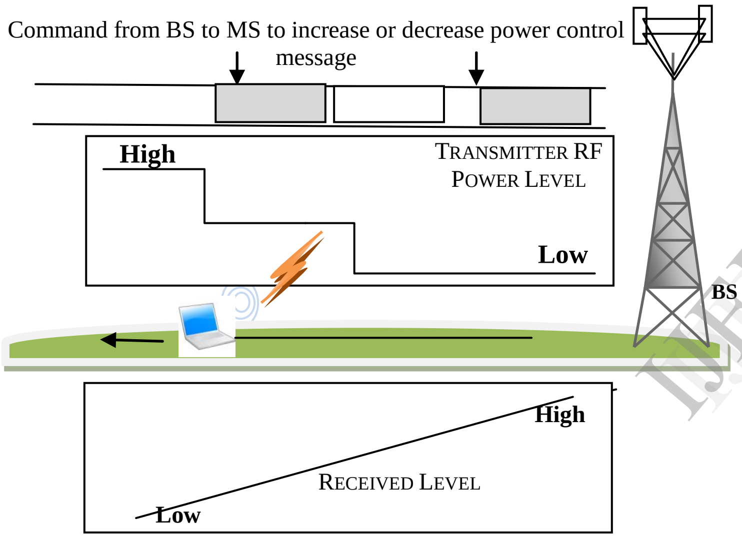


Fig.8 WIMAX power control

## VI. MOBILE WIMAX MODEL OVERVIEW

In order to perform mobility operations, the OPNET MIPv4 model has been designed and developed.

The main topologies were simulatedmobile handover with vector and random direction of movement, mobile handover with different speed of vector direction. The effect of different parameters, applications, movement, multipleBS's were taking into consideration for the mentioned scenarios.

The simulation strategy was made to examine the possible topologies and configuration for the network.Fig. 9 shows the simulated scenarios.

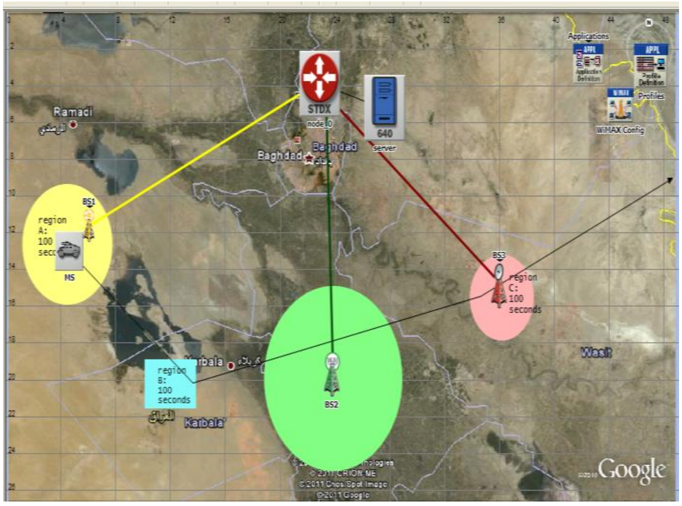


Fig.9 Mobile handover with vector direction of movement

The arrangement of objects in these scenarios contains multiple objects which it explained below:

- MN: a node was moved from specific location through different numbers of BS'sto implementing handover in the network.
- BS: Multiple BS's connected with IP_Cloud object which was used to represent a collection of routers viewed as a "black box." Packets enter the cloud at well-defined entry points and later exit at well-defined exit points. In principle, all of the routers within a cloud are internally connected.
- WIMAX configuration: the global configuration object is used to configure parameters such as PHY profiles, efficiency mode and MAC service class definitions are chosen.The efficiency modes will be used in these scenarios is the Mobility and Ranging Enabled mode,this mode can be used for mobile node. The simulation accounts for mobility and ranging effects.
- Servers: To complete the designed network, server with different supported Profile (Engineer, Multimedia, and Researcher) was used.
- Application Definition: to define multiple application configurations.
- Profile Definition: to define multiple profile configurations.

## VII. CONFIGURATION

### A. WIMAX configuration

The WIMAX simulation parameters were chosen based on 20MHz bandwidth and the base frequency was set to 3.5 GHz and The MAC service class definition parameters as shown in Table 1

Table 1 MAC service class definition parameters

| Service Class Name | Scheduling Type | Maximum Sustained Traffic Rate(bps) | Minimum Reserved Traffic Rate(bps) | Maximum Latency (milliseconds) |
|---|---|---|---|---|
| Gold | UGS | 96000 | 96000 | 10 |
| Silver | rtPS | 1Mbps | 1Mbps | 30 |
| Bronze | BE | 384Kbps | 384Kbps | 30 |

### B. Mobile Node Configuration

The parameters of MNin these scenarios aresummarized in Table 2. In MN, the global IP address should use the same network prefix as the IP address of SBS. And other parameters are set as default.

Table 2 MN configuration parameters

| | | |
|---|---|---|
| DL | Service Class Name | Silver |
| | Modulation and Coding | Adaptive |
| UL | Service Class Name | Silver |
| | Modulation and Coding | Adaptive |
| ARQ Parameters | | disable |
| Application | | Video conference and VoIP |
| Pathloss parameter | | Free space |
| Shadow fading | | disable |
| Max transmission power | | 0.5 W |
| Position (X,Y) Km | | (4.62,13.06) |

### C. BS's configuration parameters

The MAC address of BS is used which represents BS ID and is set to 1, 2 and 3 for BS1, BS2 and BS3 respectively.The other settings and parameters of each BS are explained in Table 3.

Table3 BS's paramerters

| | Parameters | Value |
|---|---|---|
| 1 | Antenna gain (BS1,BS2,BS3) | 15 dBi |
| 2 | Classifier Definition (BS1,BS2,BS3) | Silver |
| 3 | MAC Address (BS1,BS2,BS3) | (1,2,3) |
| 4 | Neighborhood ID (BS1,BS2,BS3) | (0,2,1) |
| 5 | Position (X,Y) Km | BS1(608,11.64), BS2(23.67,19.73), BS3(36,14.91) |
| 6 | Received power tolerance (BS1,BS2,BS3) | Min=-90 dBm , Max=-70 dBm |
| 7 | Max transmission power | 0.5 W |



### D. Trajectory Configuration

Trajectory was configured to control the MN movement and it can be configured with different ways such as vector movement and also there's movement and speed can be changed during the simulation and the important parameters of scenario in Fig. 9 are shown in Table 4.

Table 4Trajectory paramerters of MN in Fig. 9

| X Pos (Km) | Y Pos (Km) | Distance (m) | Traverse Time(sec) | Ground Speed (m/sec) | Waiting time (sec) |
|---|---|---|---|---|---|
| 0 | 0 | n/a | n/a | n/a | 100sec |
| 9.025 | 7.150 | 11,514.027 | 319.83 | 36 | 0 |
| 30 | 2.425 | 21,500.656 | 358.34 | 60 | 100sec |
| 44 | -4 | 15,404.053 | 01.00 | 15,404.054 | 100sec |

## VIII. RESULT ANALYSIS

- **Throughput**

Fig.10 shows BS's throughput due to the MN movement, when it is stationary in three regions: region A (near BS1) waiting for 100 sec and then, region B (mid-way between BS1 and BS2) was waiting for 100 sec, passes near BS1 without stopping then region C (near BS3) waiting for 100 sec.

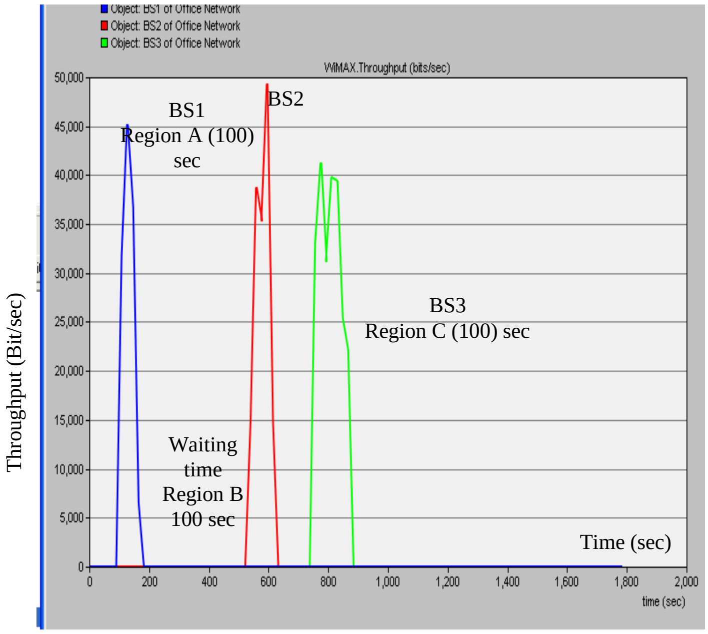


Fig. 10 BS's throughputs

- Power received from MN

Initially BS1 feels more power than BS2 (region A); then both feel a reasonable amount of power but when the MS moves away from the BS_1, the receive power drops down to zero (see Fig.11) which causes the receive power is down for BS_1 at the mid-point (stop B). The receive power approaches its peak value for the BSnumber 2 as the MN reaches a certain proximity of BS_2. At the same time the radio transmission power has a drop in a distance away from BS_2, and then no connectivity is achieved until the MS reaches the threshold circle of the BS_3. Finally, the BS3 feels more power than BS2. Equation (1) can be used to calculate the received power from MN in dBm, these results will be within the range of power tolerance at the BS [Min=-90 dBm, Max=-70 dBm].

$$\text{Power (dBm)} = 10*\log10(\text{power (W)}*10^3) \quad (1)$$

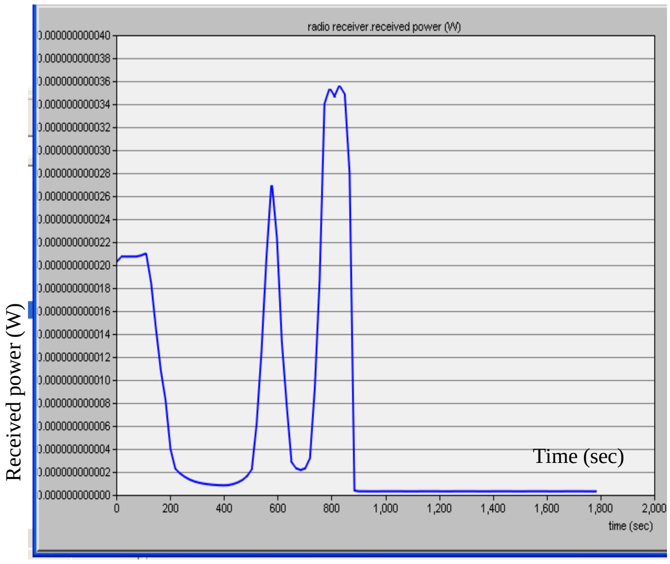


Fig. 11 Power received from the MN

The received power tolerance at the BS was changed from[Min=-90 dBm, Max=-70 dBm] to [Min=-100 dBm, Max=-80dBm] in order to analyzethe range of connectivity between the MS and the BS and to show its effects on thethroughput. The followingresults are gathered and explained in detail.

Fig.12 shows BS's throughput when the range of received power tolerance at each BS is [Min=-90 dBm, Max=-70 dBm] while in Fig.13 represents BS's throughput when the range of received power each BS is [Min=-100dBm, Max=-80dBm].

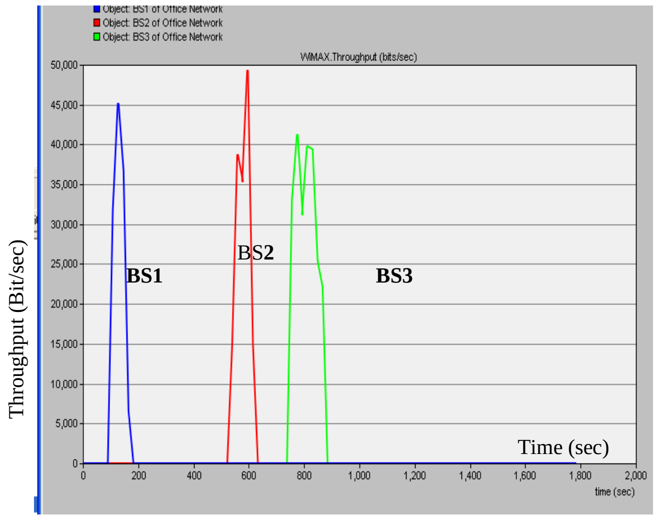


Fig. 12 WIMAX throughput when received power tolerance at each BS [Min=-90 dBm, Max=-70 dBm]

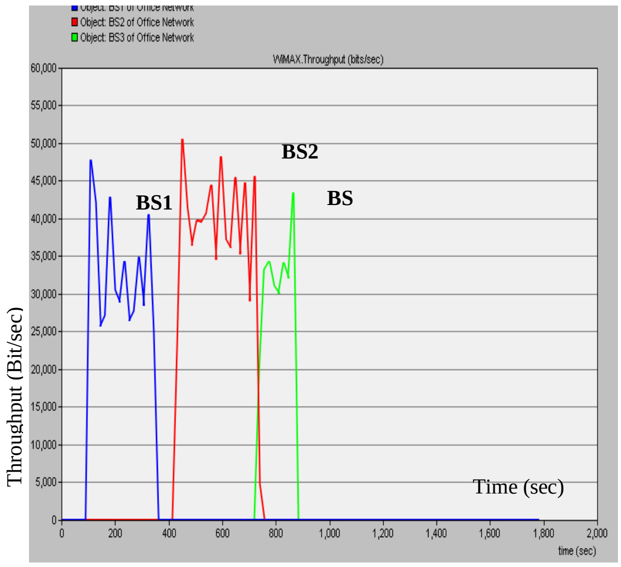


Fig. 13 WIMAX throughput when received power tolerance at each BS [Min=-100dBm, Max=-80dBm]

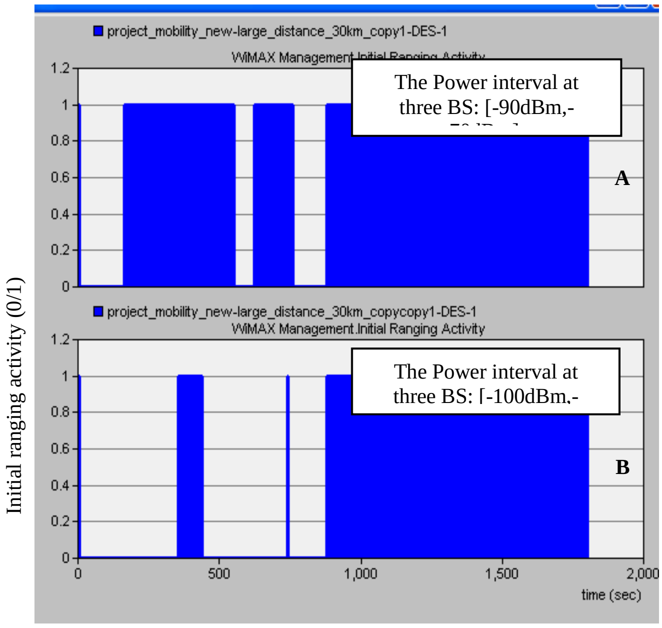


Fig. 14 Initial ranging activity comparisons between two received power ranges

It can be noticed that when the received power tolerance at each BS increase, the sensitivity of it will also increase so the coverage area of each BS will increase and the traffic switching between three BSs happens faster.



- Ranging activity

Fig.14 and Fig.15 show the difference in initial and periodic ranging activity between two received power ranges.

It can be noticed the MN in graph A persists longer in initial ranging, while graph B, there is no persists into initial ranging at the mid-point between BS's, but is otherwise mostly in periodic ranging as shown from graph A and B in Fig.15.

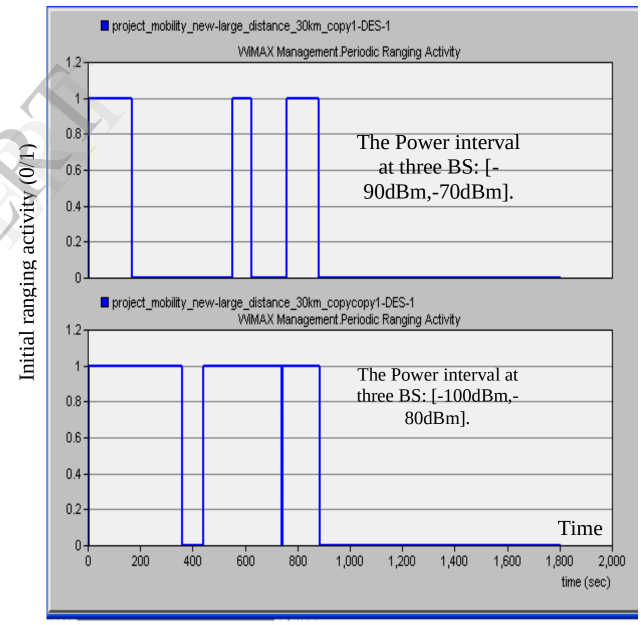


Fig. 15 Periodic ranging activity comparisons between two received power ranges

## IX. CONCLUSION

Handovers play a critical role for mobility in mobile WIMAX networks. Themobile WIMAX specification 802.16e provides a variety of hard and soft handovertechniques.

There is decrease in the throughput as the mobile station moves out of coverage area of BS, and also during the hand over process no packets are transferred, after handover the packets are transferred through the neighbor BS. At the point where MN changed its location (handover), there were some data dropped, happened without making disconnection for data from MN to servers and vice versa.

According to the results for ranging connectivity loss, when the received power tolerance at each BS increase, its sensitivity will also increase so the coverage area of each BS will increase and the point at which the MS enters the threshold circle of the second BS will be faster.

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