Effect of Spatial and User Variations on the Performance of VoIP over WiMAX Network

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ABSTRACT
WiMAX (Worldwide Interoperability for Microwave Access) is one of the hottest broadband wireless access technologies [1]. It is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL [2]. In this paper, simulative investigations have been done for the WiMAX network using different number of subscriber station. The effect of spatial variation between subscriber station and base station has also been investigated in terms of performance metrics such as throughput, delay, packet end to end delay, jitter and mean opinion score. Considering VoIP as major application, extensive results have been obtained to facilitate the network engineers in planning and design.

General Terms
WiMAX network, voice jitter, subscriber station.

Keywords
WiMAX, VoIP, OPNET, MOS.

1. INTRODUCTION
WiMAX [3] is the Next Generation of Wireless Broadband based on IEEE 802.16 [4] standard. It provides broadband connectivity anywhere, anytime, for any device and on any network and can connect to the internet in faster speed and wider coverage. WiMAX is most suitable for home users, individual, small office and home office etc [5]. It erases the suburban and rural blackout areas that currently have no broadband Internet access.

The standard defines the use of bandwidth between the licensed 10GHz and 66GHz and between the 2GHZ and 11GHz (licensed and unlicensed) [6] frequency ranges. It supports very high bit rates in both uploading to and downloading from a base station up to a distance of 30 miles to handle services such as VoIP, video conference and online gaming [7]. The WiMAX supports multiple-antenna techniques like beam-forming, space-time coding, and spatial multiplexing to enhance the system capacity and spectral efficiency.

Number of users and their location from the Base Station play an important role in the network performance. Thus, in this paper, the simulative investigation includes the variation in the number of subscriber stations requesting for VoIP traffic and the distance between the subscriber station and base station.

The rest of the paper is organized as follows: Section II describes the related work. Section III provides about simulation methodology. Results are discussed in Section IV, before we finally conclude in section V.

2. RELATED WORK
There have been recent studies focusing on the performance evaluation of WiMAX networks.

The performance of VoIP traffic over WiMAX networks in terms of various voice codec schemes and statistical distributions has also been investigated [8]. The simulation results indicate that better choice of voice codecs and statistical distributions have significant impact on VOIP performance in the WiMAX networks. It shows that VoIP applications perform better under exponential traffic distribution.

A lot of information about WiMAX network can be found in literature [9]. The authors have studied the effect of base frequency on the performance of WiMAX and shown the effect of base frequency on MOS, packet end to end delay and throughput with G.711 as voice codec. The study also includes the influence of distance between BS and SS on the parameter path loss. They conclude that the best performance can be achieved at lower base frequencies.

Another manuscript [10] reports the location based performance of WiMAX network with optimal base station. Performance is evaluated for the scenarios with different number of stationary and mobile nodes. The research helps for the deployment of WiMAX system to any country with good QoS. The results show that QoS has affected with the applications, voice over IP and MPEG.

The performance of WiMAX and UMTS (Universal Mobile Telecommunication Systems) for VoIP traffic is evaluated by Jadhav et al. [11]. The performance is evaluated in terms of performance metrics such as MOS, end-to-end delay, jitter and packet delay variation. The results show that WiMAX outscores the UMTS and is the better technology to support VoIP applications.

3. SIMULATION SETUP
To evaluate the performance of the WiMAX network, a scenario was designed in the network simulator OPNET [12] with the assumption that the traffic generated in this network model is VoIP only. There are only peer-to-peer voice calls throughout the simulation, which means there is no voice conferencing and the subscriber stations (SS) are considered as fixed during the simulation runs. Fig. 1 illustrates the WiMAX network model considered in the simulations.

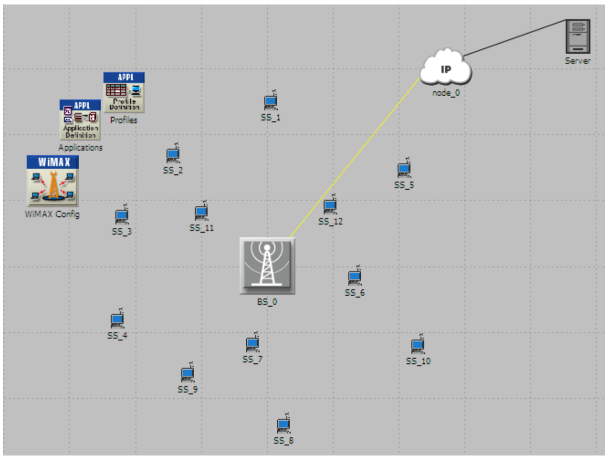

Fig.1 WiMAX Network Model

In this simulation setup, three scenarios are designed. In Scenario 1, distance between SS and BS is set to 1 Kilometers. In Scenario 2, distance between SS and BS is set to 3 Kilometers. In Scenario 3, distance between SS and BS is set to 5 Kilometers. The performance of the WiMAX network is then studied for number of SSs varying from 4 to 12 for three scenarios. The WiMAX parameters used in the network are same in all the cases and are listed in the Table 1 & Table 2.

Table1. Network Design Parameters

WiMAX Physical Profile	Wireless OFDMA 20MHz
Bandwidth	20MHz
FFT	512
Duplexing Technique	TDD
Efficiency Mode	Physical Layer Enabled
WiMAX Service Class	ertPS
BS Transmission Power	10W
SS Transmission Power	0.5W
Modulation & coding	16 QAM 3/4
Multipath Channel Model	ITU Pedestrian B
Path loss Model	Suburban Fixed (Erceg)
Terrain Type	Terrain B
Application	Voice over IP
Voice codec	G.711

Table2. Traffic Characteristics

Match Property	IP ToS
Match Condition	Equals
Match Value	Interactive Voice

4. RESULTS AND DISCUSSION

Network constituents play an important role in the network deployment. The performance of the WiMAX network is compared for the three scenarios in terms of performance metrics throughput, delay, packet end to end delay, MOS and jitter.

4.1 Throughput

Throughput represents the total data traffic in bits per second forwarded from WiMAX layer to higher layers in all WiMAX nodes of the network. Figure 2 shows the average throughput in bps for different scenarios in the network.

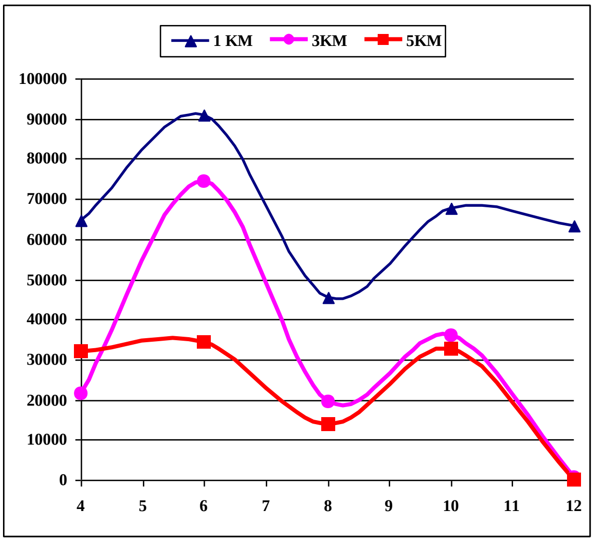

Fig.2 Throughput (bps)

4.2 Mean Opinion Score

Mean Opinion Score is one of the most important performance metric used to measure the voice quality in VoIP. It gives a numerical indication of the perceived quality of the media received after being transmitted and eventually compressed using codecs. MOS is expressed in one number, from 1 to 5, 1 being the worst and 5 the best. Figure 3 shows the comparative results of average MOS values for different scenarios in the network.

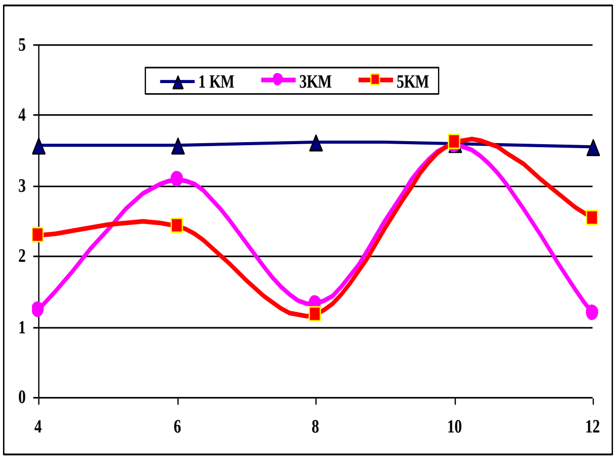

Fig.3 Average Mean Opinion Score

4.3 Jitter

Jitter is technically the measure of the variability over time of the latency across a network i.e. the variation in arrival time of consecutive packets. If two consecutive packets leave the source node with time stamps t1 & t2 and are played back at the destination node at time t3 & t4, then:

$$Jitter = (t4 - t3) - (t2 - t1)$$

Negative jitter indicates that the time difference between the packets at the destination node was less than that at the source node. Figure 4 shows the comparative results of average jitter for different scenarios in the network.

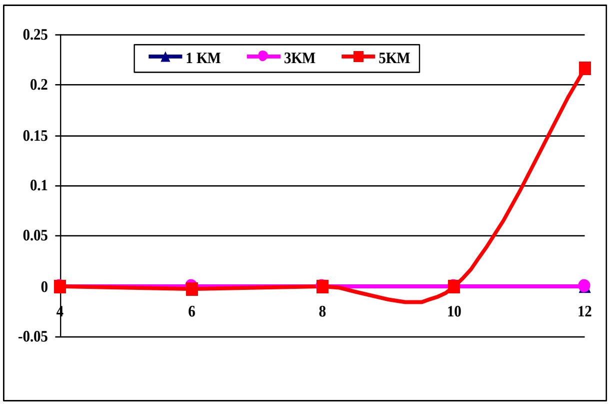

Fig.4 Relative Jitter (sec)

4.4 Delay

Delay represents the end-to-end delay of all the packets received by the WiMAX MACs of all WiMAX nodes in the network and forwarded to the higher layer. Figure 5 shows the comparative results of average delay for different scenarios in the network.

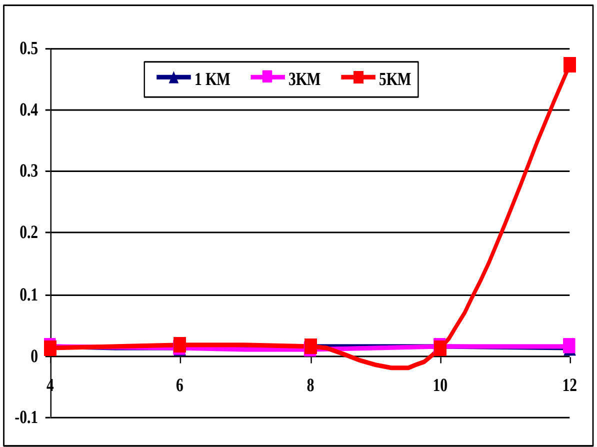

Fig.5 Average delay

4.5 Packet end-to- end delay

Packet End to End delay or latency is characterized as the amount of time it takes for speech to exit the speaker's mouth and reach the listener's ear. The total voice packet delay is calculated as:

De2e = Dn + De + Dd + Dc + Dde

Where De2e represents the end-to-end delays while Dn, De, Dd, Dc, Dde represent the network, encoding, decoding, compression and decompression delays, respectively. Figure 6 shows the comparative results of average packet end to end delay for different scenarios in the network.

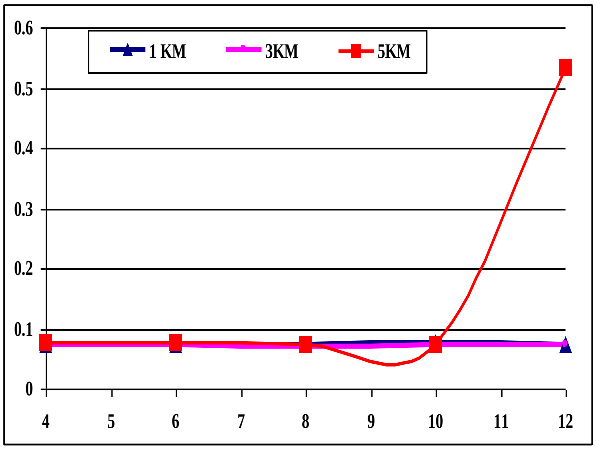

Fig.6 Relative Packet End to End Delay (sec)

From the results shown above, it is clear that throughput and MOS is not giving the clear verdict. Delay and jitter shows that for 10 Subscriber Stations, the performance is satisfactory up to the distance of 5Km. The performance deteriorates when the more subscriber stations i.e, greater than 10 are brought in the scenario for the same distance. The parameters delay and jitter indicates the remarkable degradation to the extent that VoIP application becomes useless.

5. CONCLUSION

There is a strong requirement to study the effect of spatial and user variation on the performance of VoIP over WiMAX network. So as a result, considering G.711 voice codec for VoIP over WiMAX network through Suburban Fixed Terrain type B path loss model performance evaluation have been done in terms of QoS parameters such as throughput, jitter, MOS and packet end to end delay for spatial and user variations.

Extensive simulations have been carried out that shows satisfactorily up to 10 SS for a given subscriber station to base station distance of 5Km. beyond it, it renders useless. It has been obtained through simulation that value of delay and jitter increases exponentially when the number of user is increased beyond 10 that will result in very poor quality of voice if the number of users increased beyond limits. In future, more realistic parameters can be incorporated in the scenario to identify the usable limits.

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