which is a measure of elapsed time taken during modulation of the signal and the time taken by the packets to reach from source to destination. Here the packet losses some energy as well in the form of noise which is also taken into consideration. End to end delay could be measured as the difference of Packet arrival and packet start time [9]. Equation 1 shows the calculation of average end to end delay.

$$Delay = \sum Packet\ Arrival_i - Packet\ Start_i \quad (1)$$

Delay equation

B) Packet Delay variance (Jitter):
Jitter could be termed as the variation in delay or packet delay variation. The value of jitter is calculated from the end to end delay. Measuring jitter is critical element to determining the performance of network and the QoS the network offers. It is the variation in the time between packets arriving. Jitter is commonly used as an indicator of consistency and stability of a network. Equation 2 shows how to calculate jitter.

$$Jitter = \frac{\sum_{i=0}^{n} square\left(Delay_i - \overline{Delay}\right)}{N} \quad (2)$$

Jitter Equation

C)Packet Delivery Ratio (PDR):
Packet delivery ratio signifies the the total number of packets successfully delivered to the destination. Equation 3 shows how to calculate PDR (Packet Delivery Ratio).

$$PDR = \frac{\sum_i Packets\ Delivered}{\sum_i Packets\ Sent} x100 \quad (3)$$

PDR Equation

D) Packet Loss Ratio (PLR): Packet loss affects the perceived quality of the application. Several causes of packet loss or corruption would be bit errors in an erroneous wireless network or insufficient buffers due to network congestion when the channel becomes overloaded [7]. Some of the packets are lost due to network congestion or due to noise. Packet loss ratio should be minimum, so as to keep the successful delivery of high QoS. According to ITU (International Telecommunication Union) standards, the value of packet loss should be kept at minimum level.

$$PLR = \frac{\sum_i Packets\ Lost}{\sum_i Packets\ Sent} x100 \quad (4)$$

PLR Equation

E)Throughput (Th): Throughput is measure of numberof packets successfully delivered in a network. It ismeasuredin terms of packets/second. The value of throughput shouldbe

$$Th = \frac{\sum_i Packets\ Delivered}{\sum_i Packet\ Arrival - Packet\ Start\ time_i} \quad (5)$$

Throughput Equation

5. Simulation Results and Discussion

To analyze the quality of service parameters in WiMAX network, a simulation environment for WiMax was set up as per the methodology and routing protocol explained before. MATLAB R2011 was used as a simulation tool. Here an assumption was made that all the SS (Subscriber Station) have routing capability of their own. The simulation was carried out for Nodes starting from 20, up to 500 nodes. QoS parameters were calculated for each simulation and a database was created with increasing number of nodes and regression analysis was done on it. Goodness of fit and R square was calculated for each QoS parameter. The simulation results are discussed below.

Delay:
To calculate delay/Latency for the Wimax network, equation (1) is used. According to ITU standards, the value of delay should be within 150 ms for VoIP in Wimax. Here we have calculated delay for nodes up to 500. The graph for delay vs. number of nodes is shown below in figure

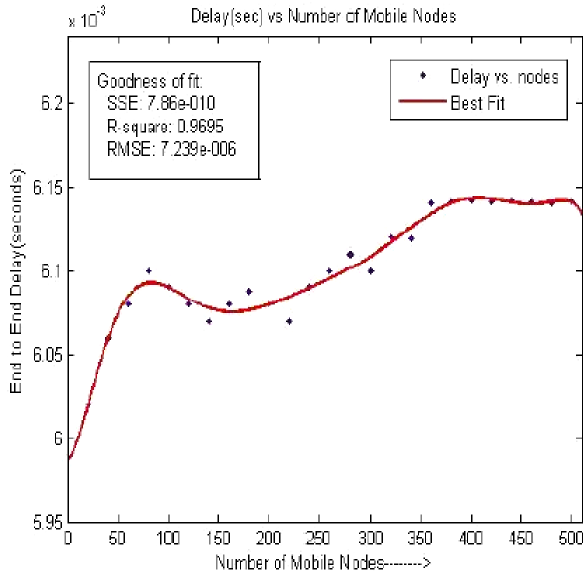

Figure 2: Delay v/s Number of Mobile Nodes

The graph drawn in figure shows that as the number of node increases, the delay increases up to a certain point due to high network traffic but the nit becomes constant to up to an average value of 6.15ms. Here a very low value of delay is obtained. The graph also shows a best fit curve which is drawn to analyze the results. Here the mobile nodes were moving so randomly that the data points were very scattered, So we have applied regression technique. The goodness of fit is also shown in the text box of the graph. A very high value of R square is achieved which shows that our data fitsaround97percent.

Packet Delay Variance (Jitter)
Equation (2) is used to calculate the Jitter (PDV). The figure 3 shows the graph between PDV and number of mobile nodes. Here it shows that a very low value of jitter is obtained. The value of jitter increases with increase in number of nodes but reaches an optimum level. On the average 1.033x10-9 seconds of jitter is obtained, which is very low as per ITU standards. The fit1 line in the graph

shows the best fit curve for random data and regression analysis results were shown in the text box drawn in the figure.

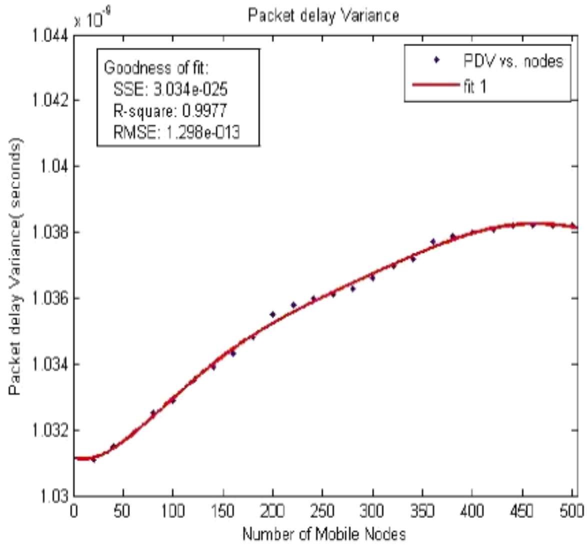

Figure 3: Packet delay Variance Vs Number of Mobile Nodes

Packet delivery Ratio (PDR):
Packet delivery Ratio is the measure of successful delivery of packets. It is calculated by equation (3). The Graph is drawn between PDR and number of mobile nodes, which is shown in figure 4. With increase in number of mobile nodes, the value of PDR increases but then it actually becomes constant. Regression analysis is done on the data and a very high value of R square (0.937) is achieved which shows that the data fits 97 percent successfully.

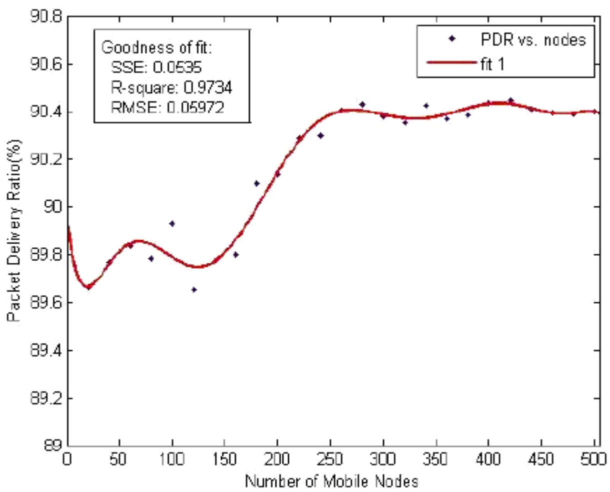

Figure 4: Packet Delivery ratio Vs Number of Mobile Numbers

Loss Ratio (PLR):
Packet loss Ratio (PLR) signifies the number of packets lost during the transmission from source to destination. It is actually the measure of number of packets undelivered or lost in the network . PLR is calculated from equation (4). The value should be kept to minimum according to ITU standards. The graph is drawn between PLR and number of mobile nodes shown in figure 6. It shows that if we keep on increasing the number of mobile nodes, then the value of PLR decreases but it eventually becomes constant after 250 mobile nodes. Regression analysis is performed on the results from the simulations and the calculated values were shown in the text box, drawn in the graph. Regression analysis shows that a very high value of R square (0.97).

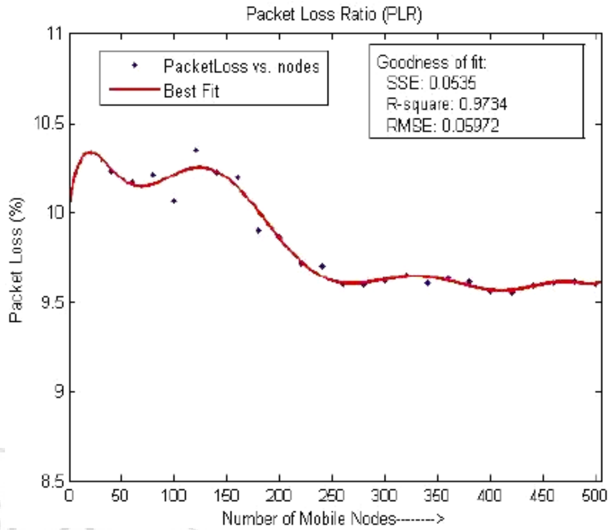

Figure 5: Packet Loss Ratio Vs Number of Mobile Nodes

Throughput:
Throughput is a measure of successful delivery of packets in a given interval of time. The calculation of throughput was done by equation (5). The graph between Throughput Vs number of mobile nodes is shown in figure 6. It depicts that as the number of mobile nodes increases, throughput increases as well. The regression analysis shows that a very high value of fit is achieved. The results of regression analysis is shown in the form of text box in the graph which depicts a high value of R square (0.99) and low value of mean square error (MSE).

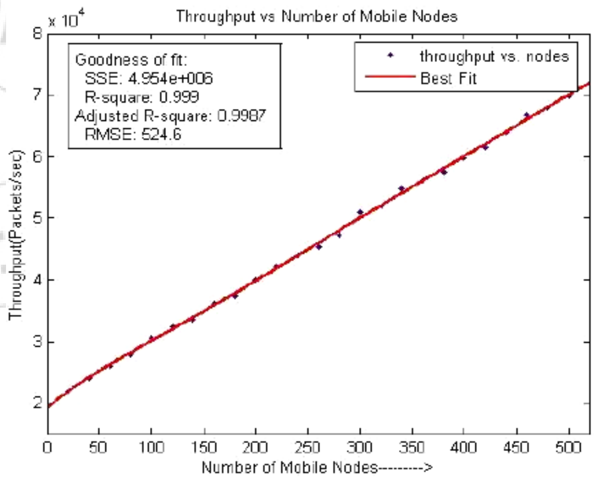

Figure 6: Throughput Vs Number of Mobile Nodes

6. Conclusion

Measurement of QoS is essential for any Wimax / broadband wireless communication. In order to ensure that a user- centric broadband experience becomes a reality, the broadband wireless access networks must meet a number of Quality of Service (QoS) parameters, including guaranteed throughput, and low delay, jitter and packet loss. Today in broadband wireless access (BWA) the perception is that as adoption grows, so does the need for guaranteeing a good

QoS. The issue of QoS, therefore, has become a critical area of concern for suppliers of broadband wireless access equipment and their customers too. Enforceable QoS is an essential foundation for widespread acceptance of broadband wireless, since it allows for more efficient sharing of the operators infrastructure, as demand for capacity increases with subscriber take-up. Our paper helps in analyzing various essential WimaxQoS parameters which are critical in determining the performance of a Wimax network. A very low value of Jitter (approx. 1x10 power-9 seconds), delay(6 milliseconds) and packet loss(9 percent) is achieved , whereas a very high average value of throughput and packet delivery is obtained using AODV protocol. From the results it could be interpreted that as the mobile nodes keep on increasing, an optimum value of QoS parameters is obtained. Therefore our paper helps in understanding these critical QoS parameters which helps in improving performance for a given Wimax network.

References

[1] IEEE Standard for Local and Metropolitan Area Networks-Part 16 , Air Interface for fixed Broadband Wireless Access Systems, special international ed.
[2] IEEE Std 802.16m/D6 Draft, " IEEE Standard for Local and Metropolitan Area Networks-Part 16:, Air Interface for fixed Broadband Wireless Ac- cess Systems-draft D6 Amendment, April 2011., 0.5em minus 0.4emBPB Publications, 2003.
[3] ZakhiaAbichar, YanlinPeng, and J. Morris Chang, WiMAX: The Emer- gence of Wireless Broadband, IT Pro magazine IEEE computer society July-Aug. 2006.
[4] Y. Zhang and H. Chen,, Mobile WiMAX: Toward Broadband Wireless Metropolitan Area Networks, edited New York: CRC Press,, 2008.
[5] Ramjee Prasad, Fernando J. Velez, Wimax Networks: Techno Economic Vision and Challenges Springer., 2010.
[6] Jeffrey G Andrews, ArunabhaGhosh, Riaz Mohamed ,Fundamentals of Wimax: understanding broadband wireless networking,Prentice Hall Communications Engineering and Emerging Technologies Series,2013.
[7] Rohit A. Talwalkar, Mohammad Ilyas, Analysis of Quality of Service (QoS) in WiMAX networks ICON IEEE,,12-14 Dec. 2008.
[8] Rakesh Kumar Jha, Idris Z. Bholebawa, Upena D. Dalai, Location Based Performance of WiMAX Network for QoS with Optimal Base Stations (BS) Wireless Engineering and Technology,March 2011.
[9] RuhaniAbRahman, MurizahKassim, Cik Ku HaroswatiChe Ku Yahaya, Mariamah Ismail, Performance Analysis of Routing Protocol in WiMAX Network IEEE International Conference on System Engineering and Technology (ICSET),27-28 June 2011,.
[10] Mohd. Noor Islam, MostafaZamanChowdhury, Young Min Seo, Young Ki Lee, Sang Bum Kang, Sun Woong Choi, and Yeong Min Jang', Measurement and Statistical Analysis of QoS Parameters for Mobile WiMAX Network ICACT,17-20 Feb. 2008,,.
[11] EliamaniSedoyeka, ZiadHunaiti, Daniel Tairo, Evaluation of WiMAXQoS in a Developing Countrys Environment , Computer Systems and Applications (AICCSA) IEEE/ACS International Conference,16-19May2010.