Chapter 6

Performance Evaluation of Connection Admission Control, ARQ Mechanism and Handover in IEEE 802.16e Networks

Summary

WiMAX has witnessed a tremendous growth and evolved as one of the potential broadband wireless access (BWA) technology. Mobile WiMAX is designed to support seamless mobility while maintaining Quality of Service (QoS). In order to support seamless mobility, WiMAX makes use of techniques like Connection Admission Control (CAC), Adaptive Modulation and Coding (AMC), Automatic Repeat reQuest (ARQ), handover etc. CAC is the ability of a network to control admission of new traffic based on the availability of resources. In this work performance of the WiMAX network is evaluated by considering minimum reserved rate, average rate and maximum sustained rate of the connections as admission criteria for CAC. Also, an attempt has been made to study the effect of implementation of ARQ on the performance of WiMAX network. In addition, the impact of handover on the performance of WiMAX network is studied by varying the number of handovers, values of Neighbour-BS-Scanning-RSS-Trigger and Handover-RSS-Trigger. Simulation studies have been carried out to evaluate the performance of WiMAX network for CAC, ARQ and Handover mechanisms by considering number of connections admitted, throughput, delay and jitter as metrics.

6.1 Introduction

The IEEE 802.16 standard also known as WiMAX has been ratified by IEEE as a Wireless Metropolitan Area Network (WMAN) technology. Mobile WiMAX developed based on IEEE 802.16e [1] is capable of providing mobility to users pertaining to their QoS requirements. Introduction of mobility in the standard raised many issues as the wireless channels are unpredictable. In order to overcome the channel uncertainties and to maintain seamless connectivity, mobile WiMAX makes use of many techniques like connection admission control (CAC), adaptive modulation and coding (AMC), channel reinforcement techniques, handover etc.

Quality of Service (QoS) is supported in WiMAX standard by classifying services into different service types namely, UGS, ertPS, rtPS, nrtPS and BE services. Even though such services provide the basis for QoS provisioning, in order to provide QoS traffic control mechanisms such as CAC and scheduling are required, which are not defined in the standard. The traffic control mechanisms enable a balance between the utilization of the network resources and the QoS provisioning. CAC concerns about how to minimize the blocking of connection requests and the QoS violation due to many admitted connections [2]. CAC admits the new connection only if such admission will not compromise the performance of existing traffic. Whenever a new connection request comes, based on availability of resources CAC will admit or reject the connection.

As the WiMAX provides Broadband Wireless Access (BWA), occurrence of errors in data transmissions is common since wireless channels are unreliable. Erroneous packets cannot be used for further processing without correction. For this purpose, WiMAX uses channel reinforcement techniques like Automatic Repeat reQuest (ARQ), Forward Error Correction (FEC) method and combination of both methods known as Hybrid ARQ (HARQ) techniques. The ARQ mechanism uses a feedback channel for the confirmation of error-free packet delivery or for packet retransmission request if the erred packet is received [3]. This method can increase network throughput if radio channel conditions are getting worse [4]. On the other hand, the ARQ method increases the delay of packets by time spent for the retransmission of erroneous packets.

In order to support seamless vehicular mobility while maintaining differentiated QoS, the Mobile WiMAX defines handover mechanism. Handover (HO) is a means of maintaining the QoS of an ongoing connection in reaction to the user mobility across the cell boundary [2]. In IEEE 802.16e standard, handover process may be triggered for two reasons. One is due to fading of the signal, interference level, etc. within the current cell and other is due to the fact that another cell can provide a higher level of QoS for the subscriber station (SS). To perform a handover, a SS continuously scans its neighborhood and monitors the channel parameters, for example the signal strength or packet delay, of all available base stations (BSs). If some of the monitored signal parameters of the serving BS drop below a predefined level or below the level of a neighboring BS, the SS performs handover in order to get the required QoS [5].

In this work the performance of Mobile WiMAX network is evaluated using QualNet simulator [6] for the aforementioned techniques: CAC, ARQ and handover. The rest of the chapter is organized as follows: Section 6.2 outlines the related work in the literature. Sections 6.3, 6.4 and 6.5 describe the CAC, ARQ and handover mechanisms in Mobile WiMAX respectively. Section 6.6 presents simulation results followed by conclusion in Section 6.7.

6.2 Related Work

The performance evaluation of any new emerging technology with different applications is imperative in order to understand and improvise the system to the desired level. Many researchers worked for evaluating the performance of the WiMAX network and proposed algorithms to improvise the performance. The related work in literature for CAC, ARQ and Handover issues of WiMAX are discussed below.

6.2.1 Connection Admission Control (CAC)

As the CAC is one of the major issues in providing QoS for WiMAX network, many researchers have proposed the algorithms for CAC. Authors of [7] evaluated the performance of CAC and AMC in WiMAX network. S Ghazal et.al [8] analyzed the performance of UGS, rtPS, nrtPS CAC mechanism**.** In [9] queuing analytical framework for CAC scheme is presented, based on the queuing model, both the connection-level and the packet-level performances are studied. Authors of [10-11] proposed CAC algorithms which provide the highest priority for UGS flows and maximizes the bandwidth utilization, in [10] bandwidth borrowing and degradation method is employed and in [11] handoff connections are given higher priority. In order to avoid the QoS degradation authors of [12] have proposed a statistical CAC mechanism which considers the traffic variability and overflow. Authors of [13-15] have proposed CAC algorithms which are based on bandwidth estimation of connections, in which [15] considers the shadow cluster concept to estimate the resources. Y. Ge et.al [16] proposed a CAC scheme for adaptive multimedia services. Authors of [17-18] have proposed CAC scheme and bandwidth allocation for Mobile WiMAX networks. In [18] two strategies for CAC namely conservative and non-conservative have been proposed. Authors of [19-22] have proposed CAC scheme along with packet scheduling algorithm. In [19] dual partition of the bandwidth for CAC and priority earliest deadline for packet scheduling is proposed. CAC scheme of [23] admits new traffics based on condition of the link bandwidth. Paper [24] presents CAC with dual partition (DP), in which total link bandwidth is divided into two partitions, one partition is dedicated to all traffics which have variable bit rate (VBR) and the second portion is dedicated to constant bit rate (CBR) traffics.

6.2.2 Automatic Repeat Request (ARQ)

The performance of ARQ depends on the parameters such as size of user data carried in a frame, size of ARQ block, size of Packet Data Unit (PDU), retransmission timeout or on the type of packet acknowledgement [25]. Many researchers have worked on the optimization of ARQ parameter settings. Evaluation of the type of packet acknowledgment for different channel condition is presented in paper [26]. In [27, 28] authors evaluated the ARQ performance for different ARQ parameters. Authors of [28] evaluated the impact of the ARQ parameters on IEEE 802.16 MAC layer performance. In [29] guidelines on how to set the ARQ parameters to achieve a good balance between the VoIP delay and packet loss is provided. Sayenko et.al [30] provides a comparison of ARQ and HARQ performance in IEEE 802.16 networks. In paper [31] a review of ARQ and HARQ mechanisms implemented or proposed on IEEE 802.16 standard family and Long Term Evolution (LTE) is presented.

6.2.3 Handover

Many researchers have been worked on the handover mechanisms in WiMAX. Authors of [32] proposed a Trusted Distributed Vertical Handoff Decision (T-DVHD) scheme, which provides trusted and seamless vertical handover for heterogeneous networks. In [33] loss-free handover scheme called LPM (last packet marking) is developed to minimize the handover delay and packet loss. Optimization of handover mechanism in 802.16e using fuzzy logic is described in [34]. In [35] Z Yan et.al, proposed a scheme that combines adaptive FEC with retransmission to offer extra protection for handover signaling messages to enhance the probability of a successful handover, especially at a higher velocity. Authors of [36] studied handover with a continuous scanning algorithm. Authors of [37] presented a mobility improvement handover algorithm.

6.3 Connection Admission Control (CAC) Mechanism in WiMAX

CAC is the ability of a network to control admission of a new traffic, based on resource availability. When a new connection is generated or parameters of ongoing connection are to be updated, the SS sends a message to the BS through dynamic service addition/change/delete (DSA/DSC/DSD) requests. The CAC module in BS handles these requests, checks whether the requested QoS can be guaranteed or not. If requested QoS can be guaranteed then that connection will be accepted and will be allotted a unique connection identifier (CID). The CAC informs the acceptance of the connection to the SS through DSA response message [2].

As per the WiMAX standard specification, the CAC considers minimum reserved rate (MRR) of a connection as an admission criterion (min-rate CAC) [1]. If the available bandwidth is more than the MRR, then that connection will be admitted, otherwise will be rejected. The available bandwidth after admitting ***n*** connections is given by the equation 6.1.

$$BW_{available} = BW_{total} - \sum_{i=1}^{n} R_i \qquad (6.1)$$

Where BW_{total} is the total link bandwidth and R_i is the MRR of i^{th} connection. A new connection request ***k*** with minimum reserved rate R_k will be admitted only if $BW_{available}$ is greater than R_k. BS updates the available bandwidth after admitting the connections [17].

In this chapter performance of WiMAX network is evaluated by considering minimum reserved rate (min-rate CAC), average data rate (avg-rate CAC) and maximum sustained rate (max-rate CAC) of the connections as admission criteria of CAC.

***Min-rate CAC*:** The CAC considers minimum reserved rate of a connection as an admission criterion. If the available bandwidth is more than the minimum reserved rate of the connection, then that connection will be admitted, otherwise will be rejected.

***Avg-rate CAC*:** The CAC considers average of minimum reserved rate and maximum sustained rate of a connection as an admission criterion. If the available bandwidth is more than the average rate of the connection, then that connection will be admitted, otherwise will be rejected.

***Max-rate CAC*:** The CAC considers maximum sustained rate (MSR) of a connection as an admission criterion. If the available bandwidth is more than the MSR of the connection, then that connection will be admitted, otherwise will be rejected.

6.4 Automatic Repeat request (ARQ) in WiMAX

ARQ also known as Automatic Repeat Query, is an error-control method for data transmission to achieve reliable data transmission over an unreliable service. It is a control mechanism of data link layer based on acknowledgment and retransmission mechanism [2]. The receiver informs the transmitter about the error-free reception and erroneous reception through acknowledgement (ACK) and no acknowledgement (NACK) messages using a feedback channel. If the transmitter receives NACK message it will retransmit the data.

The ARQ is a MAC mechanism which is mandatory for Mobile WiMAX systems. For ARQ-enabled connections in the 802.16 system, a MAC Service Data Unit (SDU) is logically partitioned into several blocks and a partitioned block maps to a continuous Block Sequence Number (BSN). The sets of blocks selected for transmission or retransmission are encapsulated into a Packet Data Unit (PDU) through fragmentation and packing procedure. A source transmits the ARQ blocks to a destination through a sliding window. After receiving the ARQ blocks, the destination transmits an ARQ feedback message to the source. The ARQ feedback message signals positive or negative acknowledgment to the source using ACK Maps indicating which blocks are received without errors. After receiving the ARQ feedback message, the source adjusts a window and retransmits the ARQ blocks which the destination fails to receive.

6.5 Handover in Mobile WiMAX

The seamless mobility of SSs is realized through the handover function among the neighboring BSs. Handover refers to the operation of converting the wireless link connecting an SS to the serving BS to the another wireless link connecting to the another BS in such a way that the communication connection is seamlessly maintained without degrading the QoS while an SS moves from a cell to another. In WiMAX two types of handover mechanisms are supported, SS initiated handover and BS initiated handover. In SS initiated handover, the SS periodically receives the channel parameter information of the neighboring BS via the serving BS. It initiates the handover process if the Received Signal Strength (RSS) of the serving BS is less compared to the neighboring BSs. In BS initiated handover process, the BS initiates the handover process by utilizing the scanning results periodically reported by the SSs.

The handover process can be split into several stages: network topology advertisement, scanning of the SS's neighborhood, cell reselection, handover decision and initiation and network re-entry. The first two stages are performed before the beginning of handover process, when the RSS value of the serving BS goes below the threshold value called Neighbour-BS-Scanning-RSS-Trigger value. During both stages, the SS searches its neighborhood and collects information on neighboring BSs with the aim of finding a suitable target BS. Based on the results of the scanning process the possible target BS is selected in the frame of the cell reselection phase. If all the conditions for handover are met and when the RSS value of the serving BS goes below Handover-RSS-Trigger value, the handover initiation phase is performed. Then, the SS starts synchronization with the downlink of the target BS. As soon as the synchronization is finished, the SS initiates the network re-entry consisting of three substages: ranging, re-authorization and re-registration. After successful accomplishment of all three substages, the SS can start with normal operation, that is, it can exchange data with the new serving BS. The handover process is explained in figure 6.1.

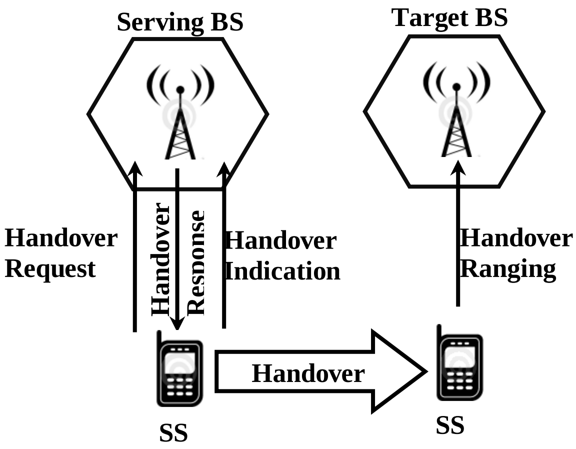

Figure 6.1 Handover process

6.6 Simulation and Results

An extensive simulation work is performed to study the effect of considering different admission criteria for connection admission control (CAC), automatic repeat request (ARQ) and handover mechanisms on the performance of WiMAX network using QualNet 5.0.2 [6]. The simulation parameters settings are mentioned in table 6.1.

Table 6.1 Simulation parameters

Property	**Value**
Channel bandwidth	20 MHz
FFT size	2048
Antenna model	Omni directional
BS antenna gain	2 dB
SS antenna gain	0 dB
BS antenna height	5 m
SS antenna height	1.5 m
Pathloss model	two ray
Shadowing model	Constant
Shadowing mean	4dB

6.6.1 Connection Admission Control (CAC)

The performance of WiMAX network is evaluated by considering the admission criteria of CAC as min-rate, avg-rate and max-rate through simulation studies. For the evaluation, UGS, ertPS, rtPS and nrtPS traffic classes are considered, BE traffic is not considered since it does not go through admission control. A single WiMAX cell is considered in the simulation area of 1Km x 1Km working at a frequency 2.4 GHz. The simulation time considered is 45 seconds.

6.6.1.1 Scenario 1

In this scenario a single BS and eight SSs are considered. This scenario is designed to study the performance of CAC mechanism with increase in number of connection. Initially, the simulation studies are carried out by considering 4 connections, each with datarate of 2Mbps. Among 4 connections UGS, ertPS, rtPS and nrtPS connections of one each are considered. The performance of CAC mechanism with min-rate, avg-rate and max-rate admission criteria is studied by considering metrics such as number of connections admitted, throughput and average end-to-end delay of connections through simulations. The simulation studies are repeated by varying the number of connections from 8 to 32 insteps of 4 connections, i.e., in each trial connections of each service type are increased by one.

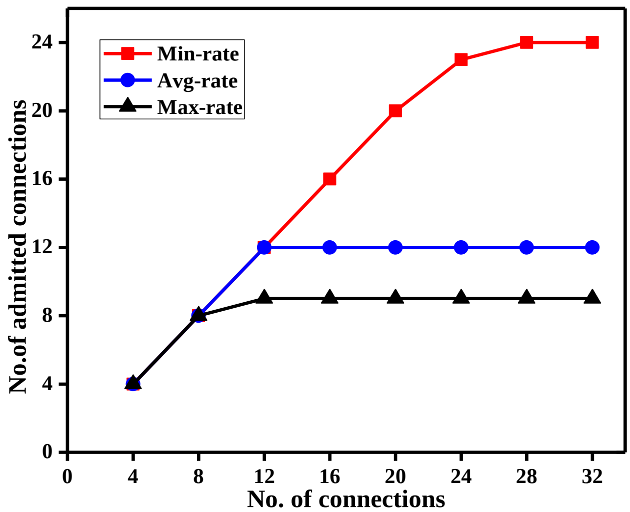

Figure 6.2 Number of connections admitted for varying number of connections

Figure 6.2 gives the plot of number of connections admitted by CAC mechanism with respect to increase in number of connections for min-rate, avg-rate and max-rate admission criteria. It is observed from the figure 6.2 that for lesser connections (upto 8 connections) the number of connections admitted is same for all the three CAC mechanisms. As the number of connections increases, the min-rate CAC admits more connections compared to other two CAC mechanisms, since the min-rate CAC is required to guarantee only minimum reserved rate [18]. The max-rate CAC admits lesser connections as it is required to guarantee maximum sustained rate to each connection and the performance of avg-rate CAC is in between the min-rate and max-rate CAC.

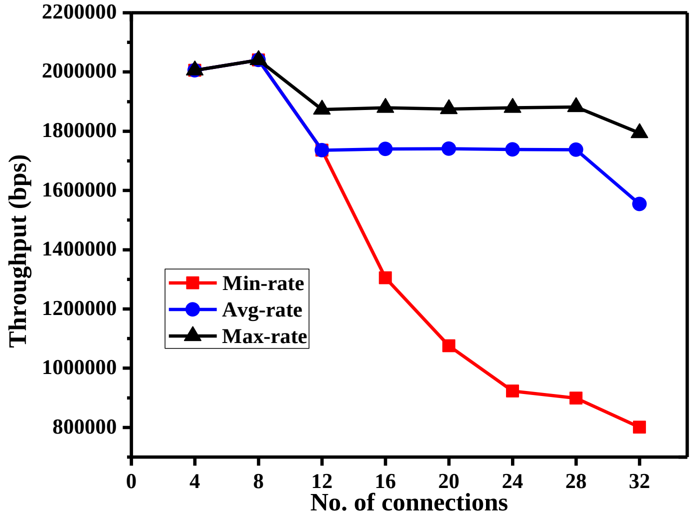

Figure 6.3 Throughput performances for varying number of connections

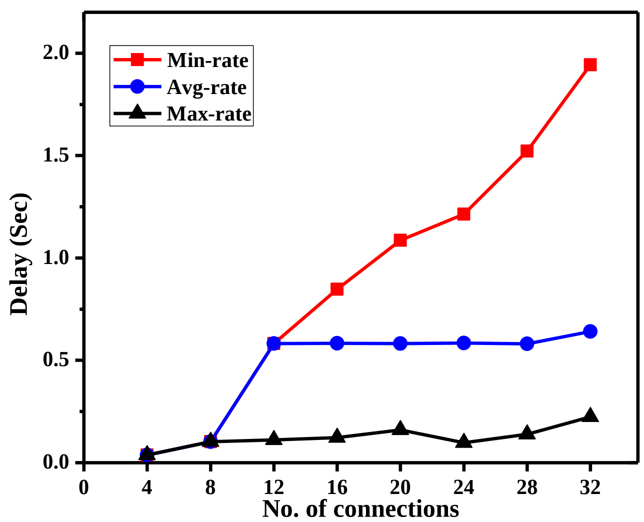

Figure 6.4 Delay performances for varying number of connections

The throughput and delay performances for increase in number of connections are shown in figures 6.3 and 6.4 respectively. The throughput and delay performances of max-rate CAC are good compared to min-rate and avg-rate CAC, since admitted connections by max-rate CAC are guaranteed with maximum sustained rate. The min-rate CAC has poor throughput performance, as it guarantees only minimum reserved rate to each connection and the packets encounters larger delays compared to other two CACs, since number of admitted connections is more. The throughput and delay performances of avg-rate CAC are in between that of min-rate CAC and max-rate CAC, as the admitted connections by avg-rate CAC are guaranteed with average data rate.

6.6.1.2 Scenario 2

In this scenario all the parameters of scenario 1 are retained and number of connections is kept constant at 12 (UGS, ertPS, rtPS and nrtPS connections of three each). The simulation studies are carried out by increasing the data rate of each connection from 1Mbps to 5Mbps insteps of 1Mbps. Performances of WiMAX CAC for min-rate, avg-rate and max-rate admission criteria are studied by considering the number of connections admitted, throughput and delay as performance metrics. The simulation studies are repeated by considering 20 connections (UGS, ertPS, rtPS and nrtPS connections of five each).

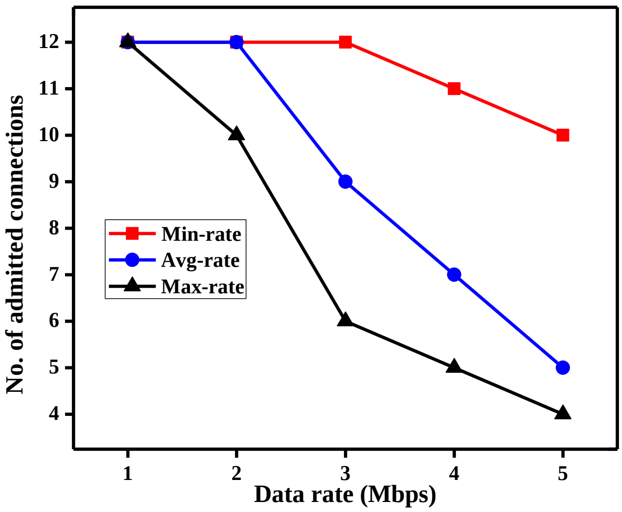

Figure 6.5 Number of connections admitted for varying data rate for 12 connections

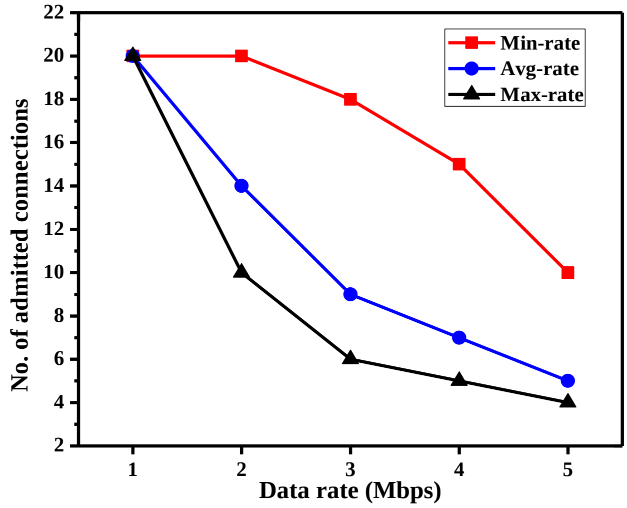

Figure 6.6 Number of connections admitted for varying data rate for 20 connections

Figures 6.5 and 6.6 give the number of connections admitted for varying data rate for 12 and 20 connections respectively. It is observed from the figures 6.5 and 6.6 that as the data rate increases, the number of connections admitted by all the three CACs decreases. Since with the increase in datarate of the connections, the QoS parameters like minimum reserved rate, average rate and maximum sustained rate of the connections increases. The number of connections admitted by min-rate CAC is more compared to avg-rate and max-rate CAC, as in min-rate CAC only minimum reserved rate is guaranteed.

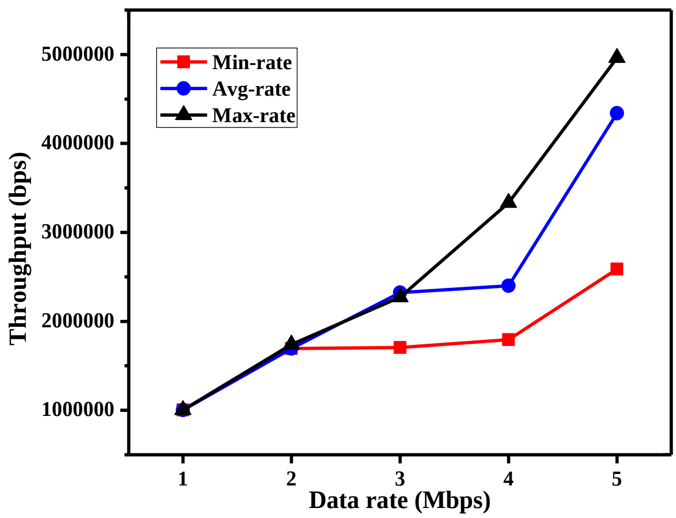

Figure 6.7 Throughput performances for varying data rate for 12 connections

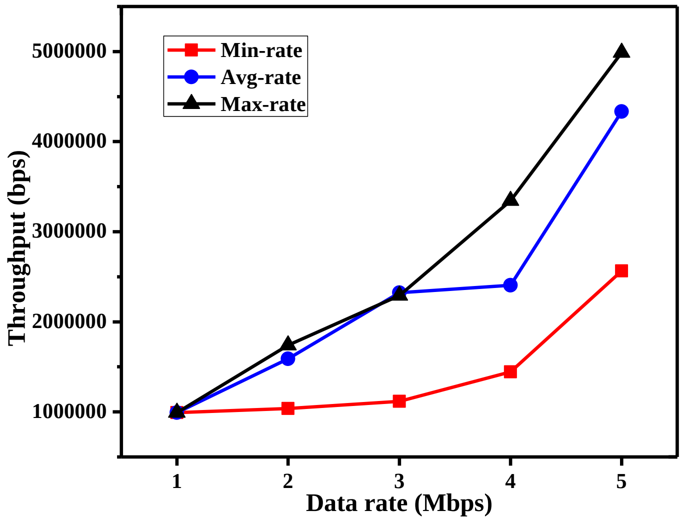

Figure 6.8 Throughput performances for varying data rate for 20 connections

The throughput performances for varying data rate for 12 and 20 connections are shown in figure 6.7 and 6.8 respectively. Figures 6.7 and 6.8 depict that as the data rate increases, throughput of connections increases for both 12 and 20 connections. The throughput performance of max-rate CAC is good compared to other two CAC mechanisms, as the max-rate CAC guarantees maximum sustained data rate for the admitted connections.

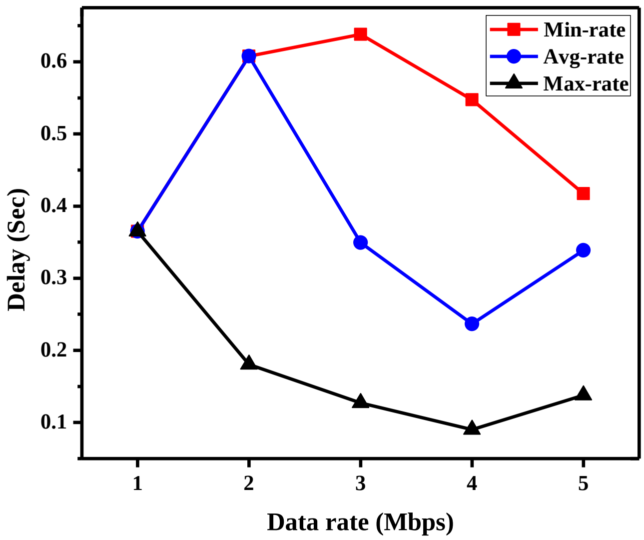

Figure 6.9 Delay performances for varying data rate for 12 connections

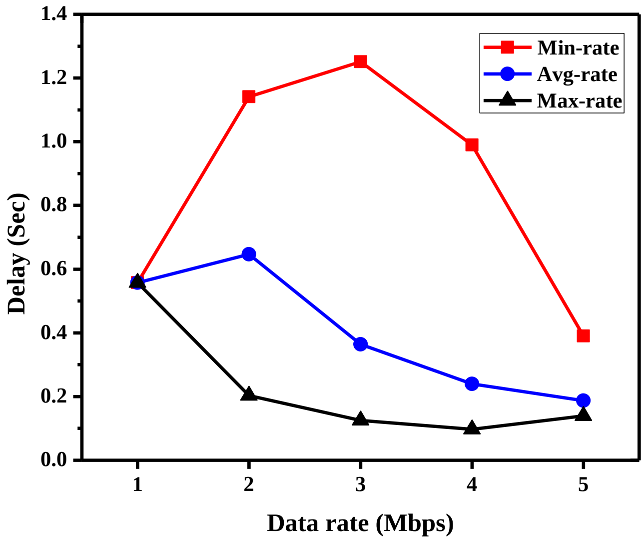

Figure 6.10 Delay performances for varying data rate for 20 connections

The delay performances for varying data rate are given in figure 6.9 and 6.10 for 12 and 20 connections respectively. The delay performance max-rate CAC is better compared to avg-rate and min-rate CAC.

6.6.2 Automatic Repeat Request (ARQ)

The effect of implementation of ARQ on the performance of the WiMAX network is studied through simulation. A single WiMAX cell is considered in the simulation area of 1Km x 1Km, working at a frequency 2.4 GHz. The simulation time considered is 300 seconds. Since the ARQ can increase network throughput when radio channel condition is worse, the SSs are placed at bad channel condition.

This scenario is designed to study the performance of the network with and without ARQ for varying load condition that is by varying the number of connections. In this scenario the number of connections is varied from 4 to 20 insteps of 4 with data rate of 512 Kbps for each connection. The performance metrics like throughput, delay and jitter for the network with and without ARQ are obtained using simulation.

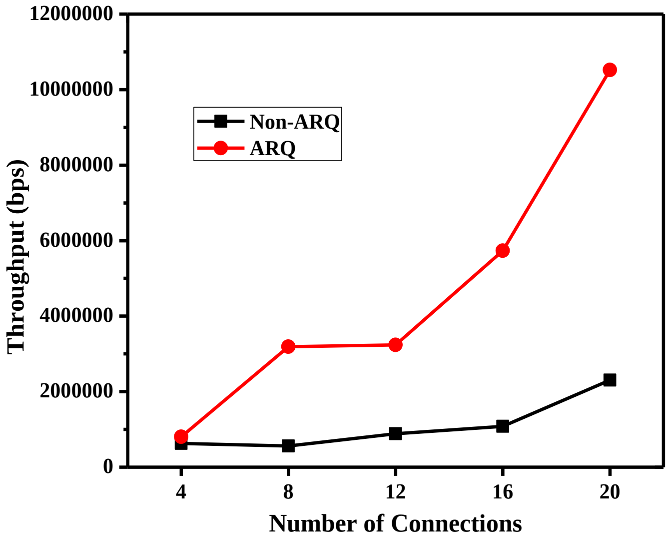

Figure 6.11 Throughput performance for varying number of Connections

Figure 6.11 gives the plot of throughput performance for ARQ and non-ARQ network for varying number of connections. As the number of connections increases the performance of ARQ enabled network is better compared to the non ARQ network. Since ARQ is used to achieve reliable data transmission through acknowledgement and retransmit methods, the ARQ enabled network achieves higher throughput compared to non-ARQ network [2].

Delay performance for ARQ and non-ARQ network for varying number of connections is given in figure 6.12. For lesser connections (upto 12) the delay performance of ARQ and non-ARQ network is almost same. As the number of connections increases the delay performance of ARQ enabled network deteriorates compared to the non-ARQ network, since the ARQ mechanism waits for acknowledgement [3]. The jitter performance with increase in number of connections is shown in figure 6.13. For lesser connections (upto 8) the jitter performance of ARQ and non-ARQ network is almost same. As the number of connections increases the ARQ enabled network performs better compared to the non ARQ network [2].

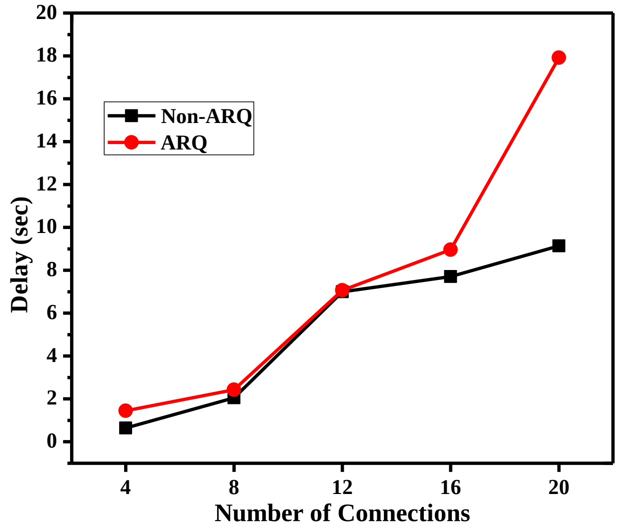

Figure 6.12 Delay performance for varying number of Connections

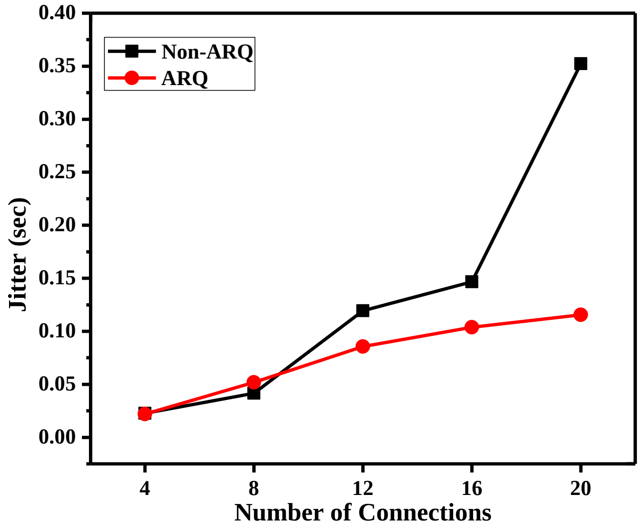

Figure 6.13 Jitter performance for varying number of Connections

6.6.3 Handover (HO)

In this subsection, the effect of handover process on the performance of SS in WiMAX network is studied through simulation. A multi cell WiMAX scenario is designed to study the performance of mobile SS. The simulation time considered is 300 seconds.

6.6.3.1 Scenario I

In this scenario, four WiMAX cells are considered as shown in figure 6.14. Each WiMAX cell contains one BS and three SSs. The BSs are connected to each other through backbone network. The mobility is given to one of the SS (mobile SS which is under study) using user defined mobility model, in which the path is defined such that the mobile SS moves through all the four WiMAX cells by performing handovers with the corresponding BSs and comes back to its first serving BS. The mobile SS under study is made to transmit CBR traffic of 4Mbps data rate to one of the SS which is in the initial serving BS cell. The snapshot of scenario is shown in figure 6.15.

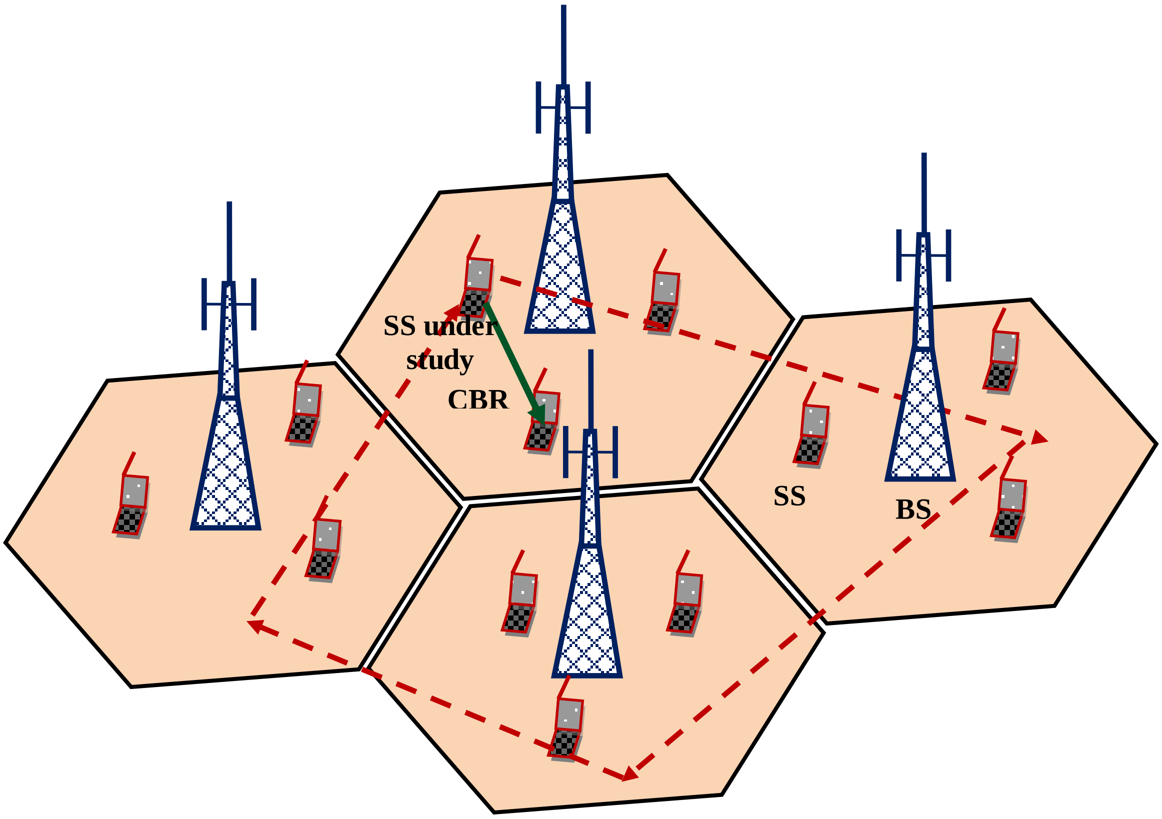

Figure 6.14 Scenario design consisting of 4 WiMAX

In handover process, the SS starts scanning the neighbour BSs when the RSS value of the serving BS goes below Neighbour-BS-Scanning-RSS-Trigger and SS performs handover when the RSS value of the serving BS goes below Handover-RSS-Trigger value. As the handover process is depending on these two values, optimum value selection is vital, hence simulation studies are carried out by varying Neighbour-BS-Scanning-RSS-Trigger and Handover-RSS-Trigger values simultaneously from -80dBm to -72dBm and -82dBm to -74dBm respectively.

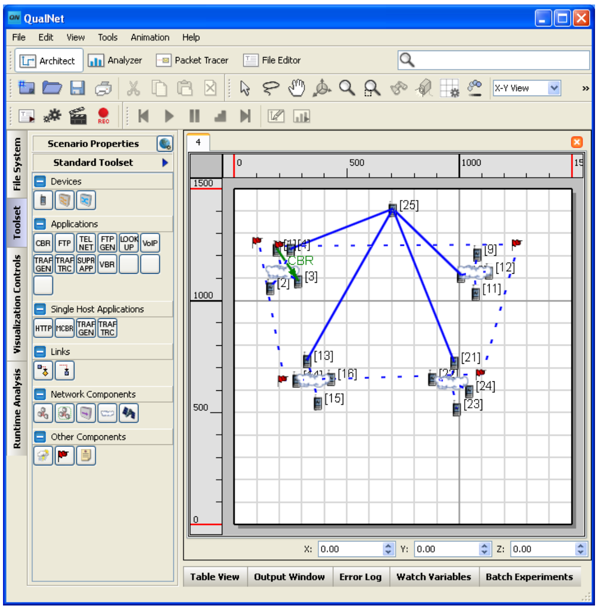

Figure 6.15 Snapshot of the scenario consisting of 4 WiMAX

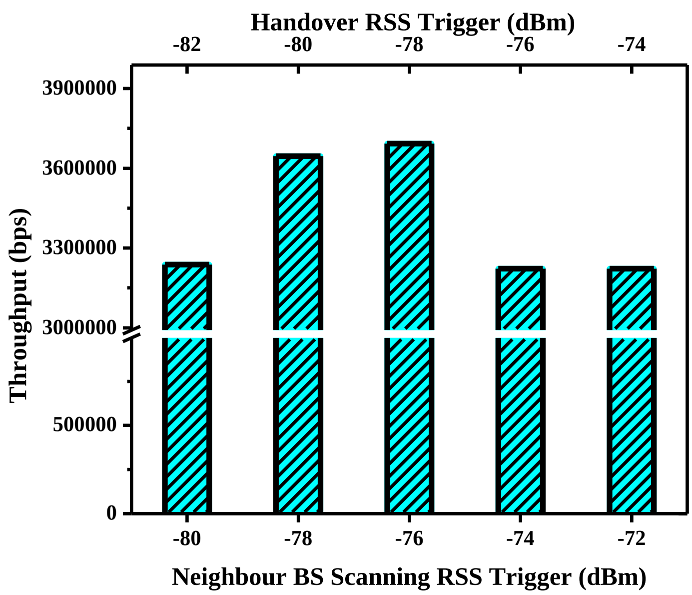

Figure 6.16 Throughput performances

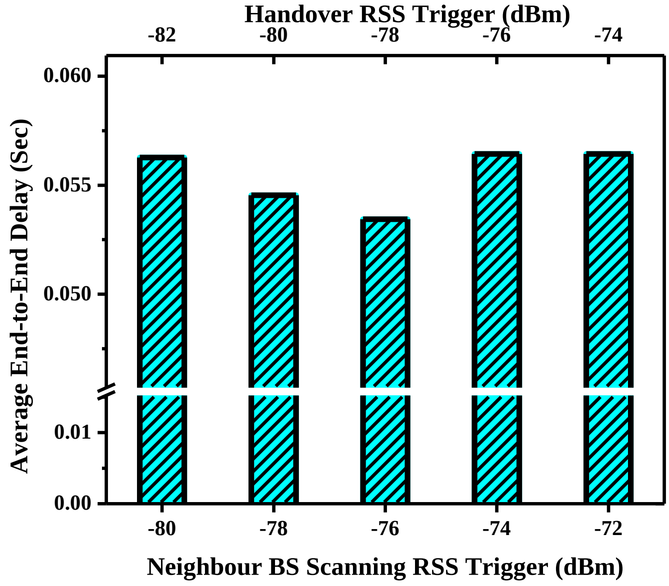

Figure 6.17 Delay performances

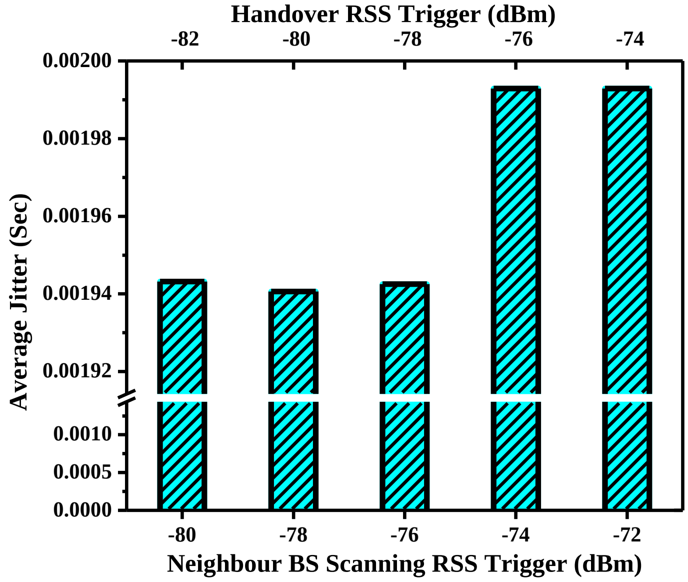

Figure 6.18 Jitter performances

Figures 6.16-6.18 give the throughput, delay and jitter performances for varying *Neighbour-BS-Scanning-RSS-Trigger* and *Handover-RSS-Trigger* values. It can be observed from figures 6.16-6.18 that throughput, delay and jitter performances are comparatively better at *Neighbour-BS-Scanning-RSS-Trigger* and *Handover-RSS-Trigger* values of -76dBm and -78dBm respectively. When the RSS is good (-72dBm/-74dBm), the serving BS itself can suffice the QoS requirements, in which handover introduces unnecessary overheads, hence QoS deteriorates. Similarly when RSS is bad (-80dBm/-82dBm), the serving BS cannot satisfy the QoS, hence QoS deteriorates. Hence the performance is better for the values of *Neighbour-BS-Scanning-RSS-Trigger* and *Handover-RSS-Trigger* at -76dBm and -78dBm respectively.

6.6.3.2 Scenario II

In this scenario, design of scenario I is retained and the Neighbour-BS-Scanning-RSS-Trigger and Handover-RSS-Trigger values are kept at -76dBm and -78dBm respectively, since it is observed from the results of scenario 1 that, these values provide high QoS performance. The simulation studies are carried out by increasing the number of WiMAX cells from 1 to 6 in turn the number of handovers performed is increased from 0 to 6. The snapshot of the scenario consisting of six WiMAX cells is shown in figure 6.19. The purpose of this study is to evaluate the QoS performance of the mobile SS under study as it performs number of handovers. Hence mobility is given to mobile SS under study in such a way that number of handover performed in each trial is increased from 0 to 6. The mobile SS under study transmits CBR traffic of data rate 400Kbps. The simulation studies are repeated by considering the data rate of 4Mbps.

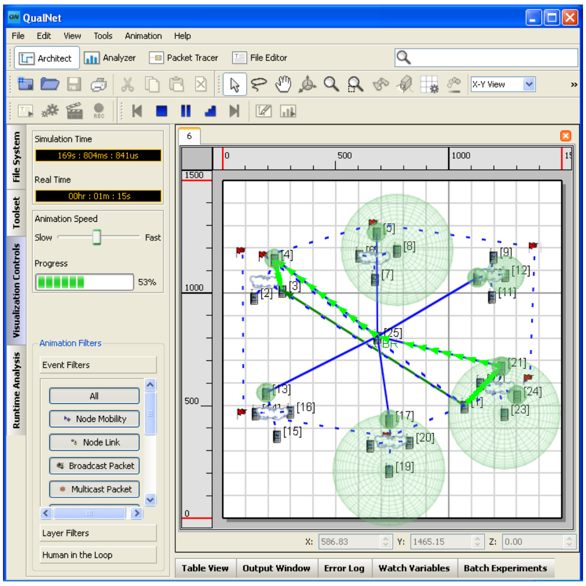

Figure 6.19 Snapshot of the scenario consisting of 6 WiMAX cells

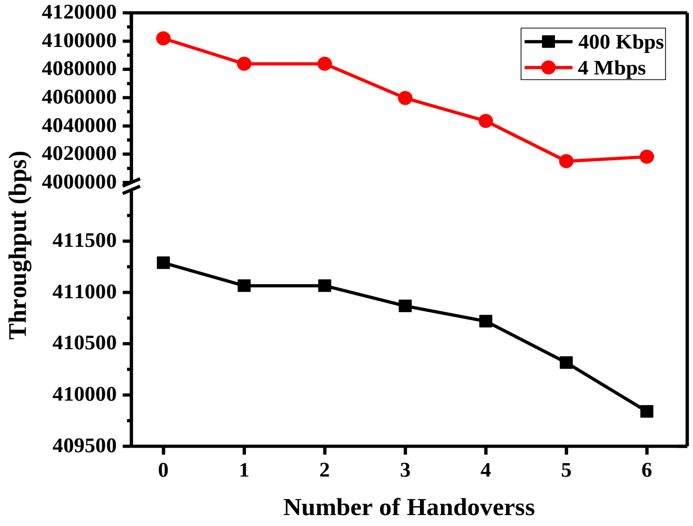

Figure 6.20 Throughput performances for varying number of handovers

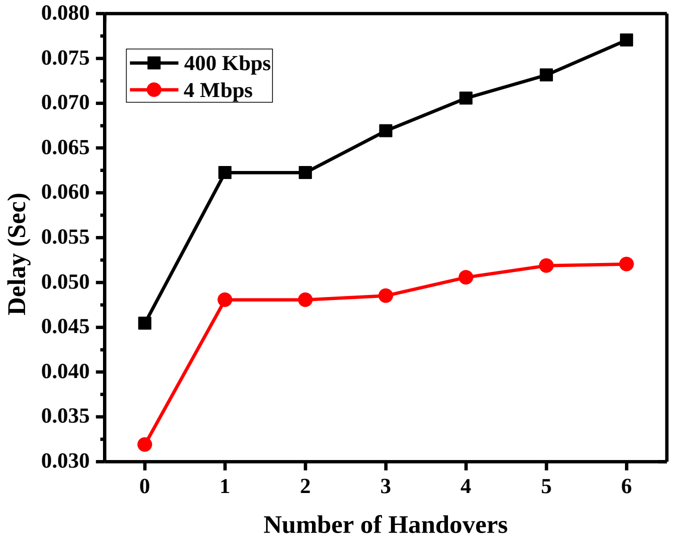

Figure 6.21 Delay performances for varying number of handovers

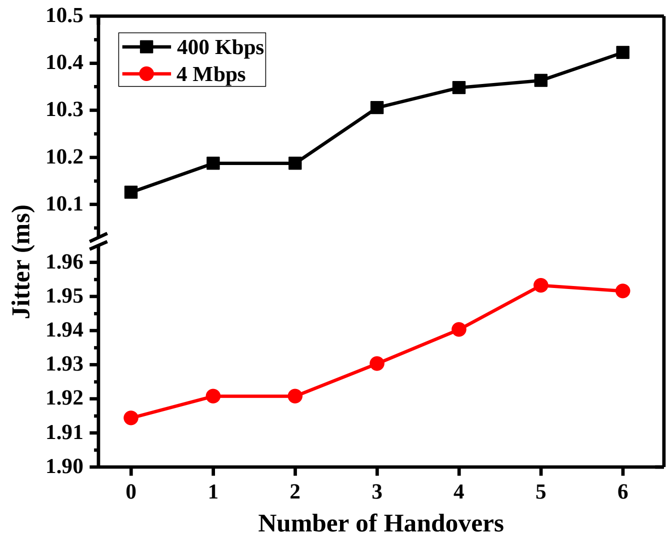

Figure 6.22 Jitter performances for varying number of handovers

Figure 6.20-6.22 give the throughput, delay and jitter performances respectively with respect to number of handovers performed by the SS under study. Figure 6.20-6.22 depict that as the number of handover increases throughput decreases, delay and jitter increases. In handover process, the SS closes all connections with the serving BS and initiates establishment of new connections to the target BS. After connections with the serving BS are closed the SS remains disconnected from the network until new connections to the target BS are established. This short time break, known as handover delay decreases the QoS performances [5]. Hence as the number of handovers increases, throughput decreases, delay and jitter increases.

6.7 Conclusions

In this work performance of CAC, ARQ and handover mechanisms in WiMAX network is evaluated through simulation. In CAC average rate, maximum sustained rate and minimum reserved rate are considered as the admission criteria. It is observed from the results that the throughput and delay performances of max-rate CAC are good but it admits lesser connections. The throughput and delay performances of avg-rate CAC are better compared to min-rate CAC and number of connections admitted is more than that of max-rate CAC. The number of connections admitted is more in min-rate CAC, but its throughput and delay performances are worse. Also the performances of ARQ enabled WiMAX network is compared with the non ARQ network. The simulation results show that the throughput and jitter performances of ARQ enabled network are better compared to non ARQ network. The delay performance of non ARQ network is good compared to ARQ network. In addition, the impact of handover on the QoS performance of WiMAX is studied by varying the number of handovers. The study reveals that as the number of handovers performed by SS increases, the QoS performance deteriorates.

References

[1] IEEE802.16e: IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems, 2009.

[2] Byeong Gi Lee and Sunghyun Choi, "Broadband Wireless Access and Local Networks: Mobile WiMAX and WiFi", *Artech House*, 2008.

[3] Jeffrey G. Andrews, Anurabha Ghosh and Rias Muhamed, "Fundamentals of WiMAX", *Prentice Hall Communications*, 2007.

[4] Klaus Sambale, Zdeneck Becvar and Ardian Ulvan, "Identification of the MAC/PHY key reconfiguration parameters", *ICT ROCKET project milestone* 5M2, ICT-215282 STP, 2008.

[5] Loutfi Nuaymi, "WiMAX: Technology for Broadband Wireless Access", *John Wiley & Sons Ltd*, 2007.

[6] http://www.scalablenetworks.com\qualnet\documentation, Documentation of QualNet simulator.

[7] Salah-Eddine Elayoubi and Benoît Fourestié, "Performance Evaluation of Admission Control and Adaptive Modulation in OFDMA WiMax Systems", *IEEE/ACM Transactions on Networking*, Vol. **16**, No. 5, 1200, 2008.

[8] Sahar Ghazal, Lynda Mokdad and Jalel Ben-Othman, "Performance Analysis of UGS, rtPS, nrtPS Admission Control in WiMAX Networks", *ICC proceedings*, 2696, 2008.

[9] Abdelali EL BOUCHTI Said EL KAFHALI and Abdelkrim HAQIQ, "Performance Modelling and Analysis of Connection Admission Control in OFDMA based WiMAX System with MMPP Queuing", *World of Computer Science and Information Technology Journal* (WCSIT) Vol. **1**, No. 4, 148, 2011.

[10] Haitang Wang, Wei Li and Dharma P. Agrawal, "Dynamic admission control and QoS for 802.16 wireless MAN", *Wireless Telecommunications Symposium*, 60, 2005.

[11] Kalikivayi Suresh, Iti Saha Misra and Kalpana Saha (Roy), "Bandwidth and delay Guaranteed Call Admission Control Scheme for QoS Provisioning in IEEE 802.16e Mobile WiMAX", *Proceedings of IEEE GLOBECOM*, 1245, 2008.

[12] Ke Yu, Xuan Wang, Songlin Sun, Lin Zhang and Xiaofei Wu, "A Statistical Connection Admission Control Mechanism for Multiservice IEEE 802.16 Network", *In Proceedings of VTC Spring,* 2009.

[13] R Murali Prasad, "An Efficient Connection Admission Control Mechanism for IEEE 802.16 Networks", *Global Journal of Computer Science and Technology,* Vol. **10**, Issue 8, 97, 2010.

[14] Sarat Chandra and Anirudha Sahoo, "An Efficient Call Admission Control for IEEE 802.16 Networks", *In Proceedings of the 15th IEEE Workshop on Local & Metropolitan Area Networks*, 188, 2007.

[15] David A. Levine, Ian F. Akyildiz and Mahmoud Naghshineh, "A Resource Estimation and Call Admission Algorithm for Wireless Multimedia Networks Using the Shadow Cluster Concept", *IEEE/ACM Transactions on Networking*, Vol. **5**, No. 1, 1, 1997.

[16] Y. Ge and G.S. Kuo, "An Efficient Admission Control Scheme for Adaptive Multimedia Services in IEEE 802.16e Networks", *IEEE 64th Vehicular Technology Conference (VTC Fall)*, 1, 2006.

[17] Ahlem Saddoud, Lamia Fourati Chaari and Lotfi Kamoun, "Admission Control Scheme and Bandwidth Allocation for Mobile WiMAX Networks", *The 7th International Conference on Informatics and Systems* (INFOS), 2010.

[18] ZHANG Yidan and WANG Jiechao, "Call Admission Control and Bandwidth Allocation Mechanism for WiMax QoS Guarantee", *International Conference on Information, Networking and Automation* (ICINA), 2010.

[19] Sarabjot Singh, Sanjay K. Bose and Maode Ma, "Analytical and Simulation Studies for Call Admission and Resource Allocation Schemes proposed for WiMAX system", *IEEE International Conference on Communication Systems* (ICCS), 522, 2010.

[20] D. S. Shu'aibu and S. K. Syed Yusof, "Link aware call admission and packet scheduling for best effort and UGS traffics in mobile WiMAX", *International Journal of the Physical Sciences,* vol. **6**(7), 1694, 2011.

[21] Wan Kim and Hwangjun Song, "QoS-aware joint working packet scheduling and call admission control for video streaming service over WiMAX network", *Springer - Wireless Networks,* 1083, 2011.

[22] Shafaq B. Chaudhry and Ratan K. Guha, "Adaptive Connection Admission Control and Packet Scheduling for QoS Provisioning in Mobile WiMAX", *IEEE International Conference on Signal Processing and Communications* (ICSPC), 2007.

[23] D. S. Shu'aibu, S. K. Syed-Yusof, N. Fisal and Y.S. Baguda, "An Efficient Method of Call Admission Control in Mobile WiMAX IEEE802.16e", *conference IGCESH.*

[24] D.S.Shu'aibu, S.K.Syed Yusof and N. Fisal, "Call Admission Control in Mobile WiMAX IEEE802.16e with Dual partitioning", *International Conference on Intelligent Network and Computing* (ICINC), 2010.

[25] Min-Seok Kang and Jaeshin Jang, "Performance evaluation of IEEE 802.16d ARQ algorithms with NS-2 simulator", *Asia-Pacific Conference on Communications*, 1, 2006.

[26] Vitaliy Tykhomyrov, Alexander Sayenko, Henrik Martikainen, Olli Alanen and Timo Hamalainen, "Performance Evaluation of the IEEE 802.16 ARQ Mechanism", *In Proceedings of 7th International Conference Next Generation Teletraffic and Wired/Wireless Advanced Networking*, NEW2AN, 148, 2007.

[27] Alexander Sayenko, Vitaliy Tykhomyrov, Henrik Martikainen and Olli Alanen, "Performance analysis of the IEEE 802.16 ARQ mechanism", *Proceedings of the 10th ACM Symposium on Modeling, analysis and simulation of wireless and mobile systems* (MSWiM), 2007.

[28] P.Latkoski and B. Popovski, "Delay and throughput analysis of IEEE 802.16 ARQ mechanism", *IFIP International Conference on Wireless and Optical Communications Networks* (WOCN), 1, 2009.

[29] Henrik Martikainen, Olli Alanen and Alexander Sayenko, "ARQ parameters for VoIP in IEEE 802.16 networks", *Wireless Telecommunications Symposium* (WTS), 1, 2009.

[30] Alexander Sayenko, Henrik Martikainen and Alexander Puchko, "Performance comparison of HARQ and ARQ mechanisms in IEEE 802.16 networks", *In Proceedings of the 11th international symposium on Modeling, analysis and simulation of wireless and mobile systems* (MSWiM), 2008.

[31] A.M. Cipriano, P.Gagneur, G.Vivier and S. Sezginer, "Overview of ARQ and HARQ in beyond 3G systems", *IEEE 21st International Symposium on Personal, Indoor and Mobile Radio Communications Workshops* (PIMRC Workshops), 424, 2010.

[32] Rami Tawil, Jacques Demerjian and Guy Pujolle, "A Trusted Handoff Decision Scheme for the Next Generation Wireless Networks", *International Journal of Computer Science an d Network Security* (IJCSNS), Vol.**8** No.6, 174, 2008.

[33] Kyung-ah Kim, Chong-Kwon Kim and Tongsok Kim, "A Seamless Handover Mechanism for IEEE 802.16e Broadband Wireless Access", *IEEE International Conference on Communication Systems* (ICCS), 527, 2005.

[34] Ewa Kozlowska, "Optimization of Handover Mechanism in 802.16e using Fuzzy Logic", *IFIP Personal Wireless Communications*, 115, 2007.

[35] Zhiwei Yan, Lei Huang and C.C. Jay Kuo, "Seamless High-Velocity Handover Support in Mobile WiMAX Networks", *11th IEEE International Conference on Communication Systems* (ICCS), 1680, 2008.

[36] Kai Daniel, Sebastian Rohde, Sebastian Subik and Christian Wietfeld, "Performance Evaluation for Mobile WiMAX Handover with a Continuous Scanning Algorithm", *IEEE Mobile WiMAX Symposium*, 2009.

[37] Md. Imtiyaz Anwar, Arun Khosla and Neetu Sood, “A Mobility Improvement Handover Scheme for Mobile-WiMAX”, *International Journal of Computer Applications,* Volume **11**, No.3, 28, 2010.