RESOURCE ALLOCATION ALGORITHMS FOR QoS OPTIMIZATION IN MOBILE WiMAX NETWORKS

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ABSTRACT

WiMAX is based on the standard IEEE 802.16e-2009 for wireless access in Metropolitan Area Networks. It is one of the solutions for 4G IP based wireless technology. WiMAX utilizes Orthogonal Frequency Division Multiple Access which also supports Multicast and Broadcast Service with appropriate Modulation and Coding Scheme. Presently, Scheduling and Resource allocation algorithm in Opportunistic Layered Multicasting provides multicasting of layered video over mobile WiMAX to ensure better QoS. Initially, the knowledge based allocation of subcarriers is used for scheduling. In addition, to reduce the burst overhead, delay and jitter, SWIM (Swapping Min-Max) algorithm is utilized. Another promising technology that can greatly improve the system performance by exploring the broadcasting nature of wireless channels and the cooperation among multiple users is the Cooperative Multicast Scheduling (CMS) technique. The simulation results show, Swapping Min-Max performs better with lesser number of bursts, Zero jitter and with optimal throughput. The results with Cooperative Multicast Scheduling show the enhanced throughput for each member in the Multicasting Scenario.

KEY WORDS

OFDMA, SWIM, CMS,Jitter, QoS, WiMAX.

1. INTRODUCTION

Last few years wireless communication has explored different technologies which include High Speed Packet Access (HSPA), Universal Mobile Telecommunication System (UMTS), Long Term Evolution (LTE), Evolution-Data Optimized (EV-DO), Wireless Interoperability for Microwave access (WiMAX) and Multimedia Broadcast and Multicast Service (MBMS). Out of these EV-DO and WiMAX has gained more popularity among broadband solution. The first acceptable high speed mobile internet access around 5Mbps is EV-DO, however WiMAX approaches to have higher speed as the networks continue to be deployed andcan deliver up to 70Mbps. In recent years, Broadband Wireless Access networks have been rapidly involved to satisfy increasing user scalability and Quality of Service (QoS) [9].

The salient features of Mobile WiMAX are the higher data rate, mobility, scalability and Quality of Service. Certain advanced features are the smart antenna technologies, multicast and broadcast service and fractional frequency reuse.One of the main real time applications of Mobile WiMAX is the Internet Protocol Television. Video, voice and data are all IP data services, but each has its own Quality of Service (QoS) requirements. High availability,

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sufficient guaranteed bandwidth, low transmission delay and jitter are the QoS requirement for video services. To support QoS for various types of traffic, WiMAX medium access control protocol defines bandwidth request-allocation mechanisms and five types of scheduling classes: extended real time Polling Service (ertPS), Best Effort (BE), Unsolicited Grant Service (UGS), non real time Polling Service (nrtPS) and real time Polling Service (rtPS).Both UGS and rtPS are proposed to support real-time service generating packets periodically. While UGS is based on constant Bit Rate (CBR) traffic such as VoIP, rtPS supports Variable Bit Rate (VBR) traffic such as MPEG video. The core problem in mobile WiMAX network is the scheduling and resource allocation. There are different modes for resource allocation such as partially used Subcarrier (PUSC) and fully used subcarrier [8]. The PUSC mode is recommended for mobile users scenarios. The Mobile WiMAX scheduling is designed to efficiently deliver broadband services such as data, voice and video.

The rest of the paper is organized as follows. Section 2 discusses the literature survey. Section 3 elaborates transmission of the video over Mobile WiMAX. Swapping Min-Max algorithm is discussed in section 4.Section 5describes the system model, Cooperative Multicast Scheme (CMS) and analysis of the CMS scheme. Simulation results are analyzed in section 6 and finally section 7 concludes the paper

2. LITERATURE SURVEY

Fen Hou, et al [5] developed an analytical model to evaluate the performance of the multicasting scheme, in terms of service probability, power consumption and throughput of each group member and multicast groups. C.W.Huang, et al [4], proposed a resource allocation algorithm that provides enhanced QoS and efficiency for layered video Multicast. S.-M. Huang, et al, [3] proposes a weakly consistent Opportunistic Multicast Scheduling (OMS) scheme for feedback reduction. Chakchai So-In, et al, [2] introduces a technique called Swapping Min-Max (SWIM) for UGS scheduling that not only meets the delay constraint with optimal throughput, but also minimizes the delay jitter and burst overhead. Chih-Wei Huang, et al, [1] proposed Opportunistic Layered Multicasting (OLM), a joint user scheduling and resource allocation algorithm that provides enhanced quality for the layered Video.

3. WIRELESS IPTV OVER MOBILE WIMAX

Internet Protocol Television (IPTV) is widespread to deliver the content to users whenever they want and wherever they are. Traditional wired access networks can deliver the contents only to the stable users. Hence, a novel technology which can deliver the content to mobile users when needed and mobile WiMAX is identified as a better choice. For real time application like IPTV and VoIP a guaranteed QoS level is very important because these are CBR (Constant Bit Rate) applications and are delay sensitive.

To support high data rate multicast and broadcast service in WiMAX, the techniques like OFDM and OFDMA are used. Orthogonal Frequency Division Multiplexing (OFDM) is a method which divides the bandwidth into multiple subcarriers at any given time. In mobile WiMAX, Orthogonal Frequency Division Multiple Access (OFDMA) is used to access multiple users simultaneously [6, 7]. The OFDMA symbol structure consists of Data, Pilot and Null sub-carriers. The data and pilot subcarriers are clustered into subsets of subcarriers called sub channels. The WiMAX OFDMA supports sub-channelization in both downlink and uplink. There are two modes in WiMAX for sub-channelization, diversity and contiguous permutation. The contiguous permutation draws the subcarriers as the block to form a sub-channel and the diversity permutation draws sub-carrier pseudo-randomly to form a sub-channel. Due to the frequency diversity and inter-cell interference averaging provided, the diversity permutation is advised for mobile users. IPTV transmission over WiMAX requires coding techniques for high quality video. In order to get high quality video, Scalable Video Coding (SVC) is used. SVC is one of the challenging solutions to the problems caused by the characteristics of modern video transmission systems. The word "scalability" refers to the elimination of parts of the video bit stream in order to adapt it to the user's need. The Scalable Video Coding is an extension of the H.264/AVC standard. The motive of the SVC standardization is to enable the encoding and the decoding of a high-quality video bit stream with the similar quality and the complexity that can be achieved using the H.264/AVC design with the same quantity of data as in the subset bit stream.

4. SWAPPING MIN- MAX ALGORITHM

The scheduler for rtPS service should meet the QoS criteria like Optimal system throughput , maximum latency guarantees, Minimal delay jitter and Minimal number of bursts in order to reduce the MAP overheads[2].The resource is fixed in terms of number of slots per downlink sub frame. This is denoted by variable number of slots. The number of bytes corresponding to a slot depends upon the modulation and the coding. For the rtPS, at the connection setup, MSs declares the total demand (denoted by the subcarriers for the required data size) and period (denoted in terms of frames). For example, connection_1 asks for 540 bytes (1080 frames) every 4 sub carriers. WiMAX profiles specify a size of each frame about 5ms.The complexity of the SWIM in the worst case is in the order of O (n^2log n), where n is the number of active connections.

Complexity = O (allocation s + sorting) = O (n^2log n) (1)

And the Complexity = O (n^2) (2)

when the information is known about the number of flows.

The procedure for algorithm has two parts, Initialization with the optimal throughput/delay and Resource swapping steps.The swapping procedure is as follows,

1. Determine the min_res connection and the max_res connection.
2. The two connections swap their resources such that min_res gives up its resources in the current frameand it gains an equal amount of the resources in the forecoming frames.
3. The swapping procedure ensures that each burst is at least Minburstsize. (Minburstsizeis considered here as 1).
4. If any connection has the resource equal to Minburstsize, they are excluded from swapping (leaving Minburstsize value as non-zero).

The special cases which may exist are

1. The new max_res connection cannot accept any resources more than it needs and so the min_res connection may not get eliminated.
2. If there is two or more max_res connection in the current frame, the connection which has the resources higher in the next frame will be chosen.
3. If there is two or more max_res connection with same resources in the next frame, the connection with more deadline with be selected.
4. If there are two or more min_res connections, the connection whose deadline is earlier will be chosen.

5. If there are two or more min_res connections with the same deadline, the connection withleast resources in the next will be selected.

4.1 Swapping Min-Max examples

Table 1. Static Flows

	C1	C2	C3	C4	C5
Data Size (bytes)	62	35	500	60	580
Period (frames)	260	160	900	240	1200
No of Subcarriers	4	4	6	6	12

Table 1 shows a simple example of 5 connections (C1-C5) and their demands (Data Size) in bytes, Period in terms of WiMAX frames and the number of subcarriers. The total allocated slots are 395. The throughput is optimal, that is (260*3) + (160*3) + (900*2) + (240*2) + (1200*1) = 4740 frames. Table 2 and 3 show the EQual Allocation (EQA) and Earliest Deadline First (EDF) algorithms respectively. In EQA, the resource is allocated equally in every frame. In EDF, the resource is allocated whose deadline is the first. In the next frame, the scheduler allocates the remaining resources to meet the guaranteed throughput.

Table 2. EQA allocations

Time	C1	C2	C3	C4	C5
0	65	40	150	40	100
1	65	40	150	40	100
2	65	40	150	40	100
3	65	40	150	40	100
4	65	40	150	40	100
5	65	40	150	40	100
6	65	40	150	40	100
7	65	40	150	40	100
8	65	40	150	40	100
9	65	40	150	40	100
10	65	40	150	40	100
11	65	40	150	40	100

Table 3. EDF allocations

Time	C1	C2	C3	C4	C5
0	105	0	290	0	0
1	0	0	215	0	180
2	155	160	0	80	0
3	0	0	295	0	100
4	135	0	100	160	0
5	125	160	0	0	110
6	0	0	295	0	100
7	0	0	0	80	315

8	25	0	210	160	0
9	0	0	395	0	0
10	130	160	0	0	105
11	105	0	0	0	290

Table 4 shows the initial swapping steps. In the first frame, the max_res connection is C3 and the min_res connection is C2. Therefore, C2's allocation in the frame is given to C1 and taken back in the second frame. This results in C3 obtaining 150 + 40 = 190 and C2 obtaining 40 – 40 = 0 in the first frame. C3 obtains 150 – 40 = 110 and C2 obtains 40 + 40 in the second frame. The resulting allocations are shown in Table 4 (a).Thus, the swapping has reduced the number of bursts by one. In the next swapping step, C3 and C4 swap their allocations in the frame 1 and 2 resulting in the Table 4 (b) and swapping proceeds till the last frame. This results in the final allocation shown in Table 5.

Table 4 SWIM initial steps

(a)

Time	C1	C2	C3	C4	C5
0	65	0	190	40	100
1	65	80	110	40	100
2	65	40	150	40	100

(b)

Time	C1	C2	C3	C4	C5
0	65	0	230	0	100
1	65	80	70	80	100
2	65	40	150	40	100

Table 5 SWIM Final Steps

Time	C1	C2	C3	C4	C5
0	0	0	255	0	140
1	195	0	0	40	160
2	0	145	0	0	250
3	65	15	315	0	0
4	0	80	135	0	180
5	0	0	195	200	0
6	0	0	295	0	100
7	260	80	0	55	0
8	0	0	155	0	240
9	0	0	395	0	0
10	195	0	0	145	55
11	65	160	55	40	75

4.2 Need for Cooperative Communication

SWIM performs efficiently, only when newly demanded resources are lesser than the available number of slots. It leads to the complexity of the design when the number of information flow is not known prior to the transmission. To meet all these considerations and support heavy traffic Cooperative Multicast Scheduling Scheme is proposed particularly to cater live multicasting and ensures higher throughput than existing multicast schemes.

5.COOPERATIVEMULTICAST SCHEDULING SCHEME

In Mobile WiMAX network consisting of a BSand multiple subscriber stations (SSs).IEEE 802.16 standards support mesh and Point-to-Multi Point (PMP) mode.

The TDD-OFDM/TDM MAC structure is considered as shown in Fig.1. The time domain is divided into MAC frames withequal duration, each of which is composed of a downlink sub-frame (DL sub-frame), an uplink sub-frame (UL sub-frame),a transmit/receive transition gap (TTG), and a receive/transmittransition gap (RTG).

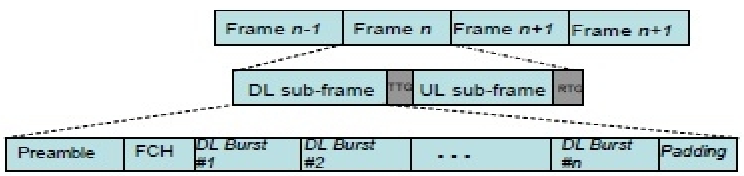

Fig.1 MAC structure for a conventional IEEE 802.16 network

In a conventional IEEE 802.16 network, SSs only receivedata from the BS in DL sub-frames. To achieve cooperativemulticasting, the transmission burst assigned for multicast transmission is divided into two phases as shown in Fig.2

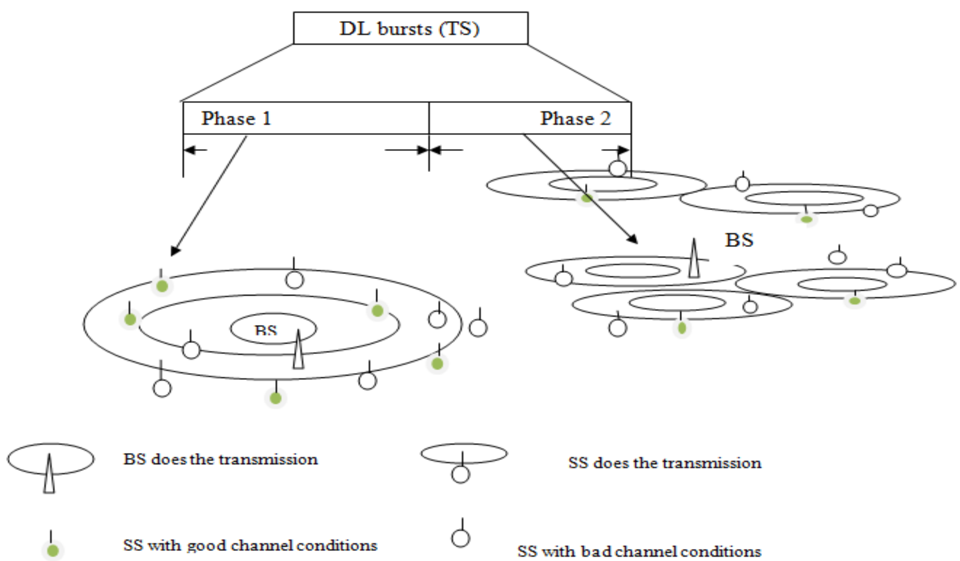

Fig. 2 Cooperative multicast scheduling

In multicast networks, for an IPTV service, an MGroup corresponds to a group of users requesting the same TV channel. As Mobile stations could be a residential house or office building consisting of multiple users accessing different channel simultaneously and thus may belong to several MGroups. To select the appropriate MGroup, the schemes adopted are random MGroup and channel-aware MGroup.

5.1 Multicast Group Selection

1. Random MGroup selection

The Base Station randomly chooses an MGroup for service with a pre-defined probability. Each group is served with the probability of 1/T for achieving a good fairness performance. It is easy to implement. To further improve the performance, the channel-aware MGroup selection is used.

2. Channel-aware MGroup selection

This selection MGroup is considers the channel conditions into account on the group basis, rather than a single group member. By using the multi-group channel diversity and taking into account fairness, a criterion of MGroup selection is given by eqn. (3),

$$i^* = \arg\max_i C_i \qquad (3)$$

and the normalized relative channel condition is given by eqn. (4)

$$C_i = \frac{\sum_{j\epsilon G_i} \gamma_{i,j}/\overline{\gamma_{i,j}}}{N_i} \qquad (4)$$

Based on (3), the BS selects MGroup which has the maximum value of the normalized relative channel condition.

5.2Co-operative Multicast transmission

After an MGroup is selected, the next step is to multicast data to all group members in the chosenMGroup. To exploit the diversity gain in wireless channels, two phase transmission technique is used to multicast the datain the downlink transmission, where every downlink burst is divided into two phases. In Phase I, the BS multicasts data to all group members of MGroup*i* at a high data rate of R^1suchthat only a particular portion of group members in MGroup*i* can successfully decode the data and is shown in Fig.2. Due to the high data rate, the remaining group members with unfavourable channel conditions may not be able to successfully decode all the data in Phase I. Therefore, in Phase II, cooperative communication is utilized to promise reliable transmission of the remaining group members.To investigate the performance of the Co-operative Multicast Scheduling service probability of each MGroup, throughput of each user, throughput of each MGroup and the whole network throughput is simulated[5].

5.3 Service Probability of MGroup i

Service probability is defined as the probability that the particular Multicast group is chosen to be served when the system is stable. For the channel-aware MGroup selection, the service probability (5) of the MGroup *i* is given by

$$\pi_i = \int_0^{\infty} \left| \frac{N_i^{N_i}}{(N_i-1)!} x^{N_i-1} e^{N_i x} \prod_{j=1, j\neq i}^{T} \left(1 - e^{-N_j x} \sum_{k=0}^{N_j-1} \frac{(N_j x)^k}{k!} \right) \right| dx \qquad (5)$$

5.4 Throughput Analysis

The probability that a group member in MGroup*i*can successfully receive the data in phase I is

$$P_r\left(E^1 \geq \left(2^{R^1} - 1\right)N_o\right) = e^{-\left(\left(2^{R^1}-1\right)N_o\right)/\bar{E}_B} \qquad (6)$$

If the Subscriber Station fails to receive the data in phase I. It is still possible for them to receive the data in phase II and the probability is

$$P_r\left(E^2 \geq \left(2^{R^2} - 1\right)N_o\right) = \sum_{G_i^1 \in C_{i,j}} P_r\left(G_i^1\right) P_r\left(E^2 \geq \left(2^{R^2} - 1\right)N_o | G_i^1\right) \qquad (7)$$

The throughput of subscriber's station is given by,

$$\alpha t^2 R^2/(t^1 + t^2) \qquad (8)$$

The group throughput of all the group members in MGroup*i*is given by,

$$Th_i^{CMS} = \sum_{j=1}^{N_i} Th_{i,j}^{CMS} \qquad (9)$$

In addition to the analysis based on channel capacity, the impact of the promising adaptive modulation and coding (AMC) technique is also investigated. The transmission rate corresponding to different modulation and coding levels is given by

$$r_n = I_n/T_s \qquad (10)$$

The throughput achieved by the group member using AMC technique is given by,

$$Th_{i,j}^{CMS} = \pi_i \left[\frac{\alpha t^1 R^1}{t^1+t^2}\right] e^{-\frac{b_n N_o}{E_{i,j}}} + \left[\frac{\alpha t^2 R^2}{t^1+t^2}\right]\left(1 - e^{-\frac{b_n N_o}{E_{i,j}}}\right).*$$

$$\sum_{G_i^{`} \in C_{i,j}} P_r\left(G_i^1\right)\left[1 - F\left(E^2 \geq \left(2^{R^2} - 1\right)N_o | G_i^1\right)\right] \qquad (11)$$

6. Simulation Results

The numerical results in terms of average number of bursts, delay jitter, delay of the EQA, EDF and SWIM algorithms are simulated. The Swapping Min-Max algorithms are analyzed for base and enhancement layers. Further, to effectively utilize the resources and to enhance the throughput performance the multicast scheduling is carried out. The simulation parameters are shown in Table 6 and the list of notations used is quoted in Table 7.

Table 6.performance evaluation parameters

PARAMETERS	VALUE
SWIM	
Frame Length	5ms
System Bandwidth	10MHz
CMS	
Number of MGroups	10
Number of group members in MGroup	20
Frequency Band	3.5GHz
Noise Figure	7 dB
OFDM System duration	23.8µs

Table 7. Table of Notations

Notations	Explanations
T	The total number of MGroups
G_i	The set of all members belonging to MGroup*i*
N_i	The total number of group members in MGroup*i*
G_i^1	A set of members in MGroup*i* successfully receive data
E	The received signal power
R	The rate of the BS
1,2	Phase 1, Phase 2
T	The transmission time
α	Time ratio for multicast transmission
Th_i^{CMS}	The group throughput of the MGroup*i*
I_n	Information bits/ OFDM symbol
b_n	Lower boundaries of SNR
C_i	Normalized relative channel conditions of the MGroup*i*
$\gamma_{i,j}$	Instantaneous channel conditions

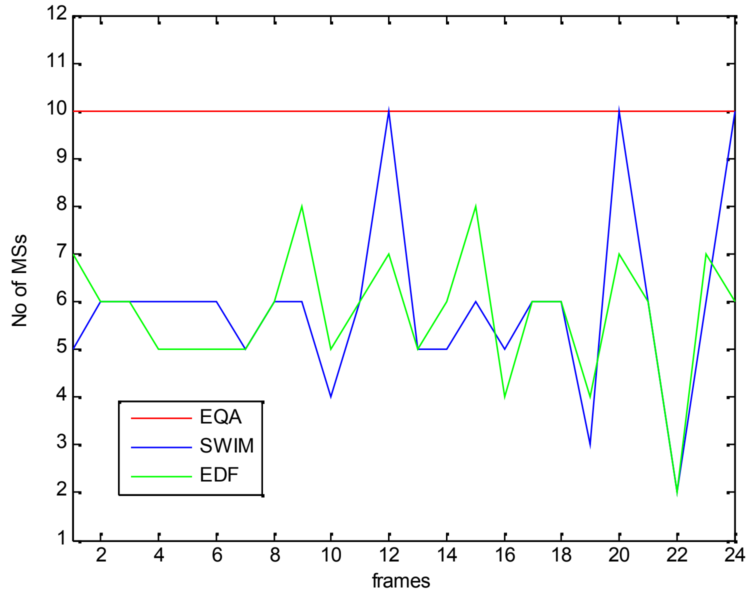

Fig.3 Number of bursts for EQA, EDA and SWIM

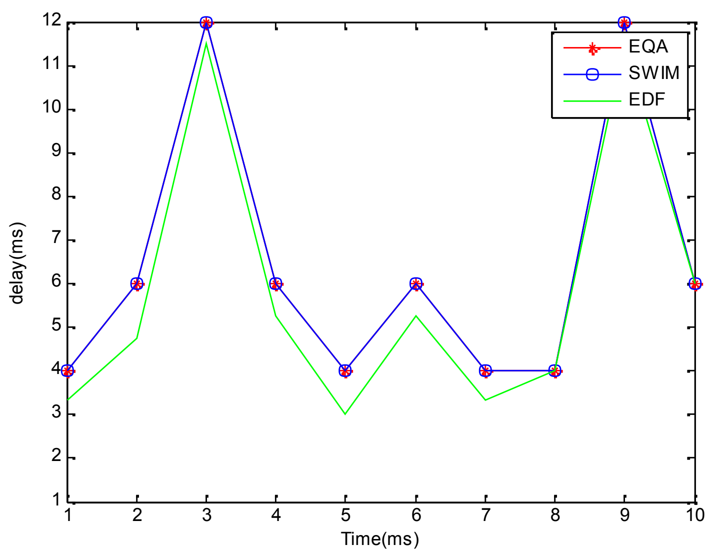

Fig.4 Delay for the EQA, EDF and SWIM

Fig.3 shows the numerical results for the number of bursts in each frame. In equal allocation, there is no reduction in number of bursts as it utilizes all slots in all Mobile Stations. Both the EQA and EDA, minimizes the number of slots to reduce the MAP overheads.

From the Figs. 3, 4 and 5 it is inferred that the SWIM algorithm minimizes the number of bursts with zero jitter and optimizes throughput as shown in Fig.6.

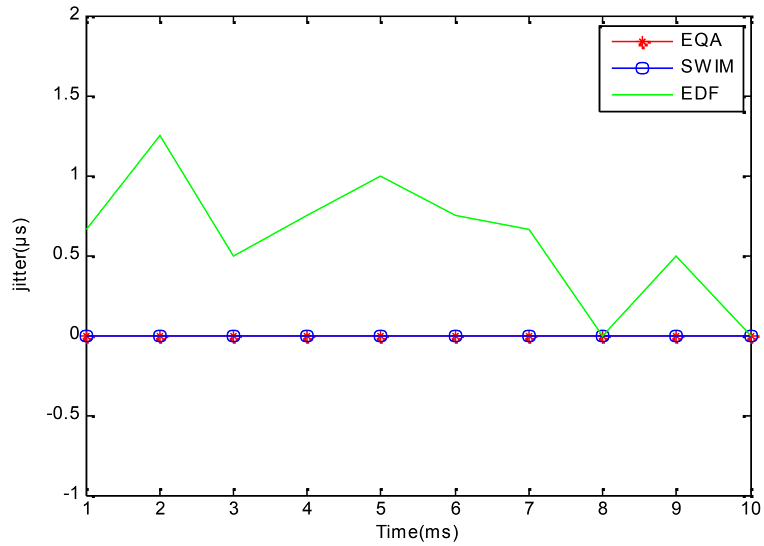

Fig.5 Delay Jitter for EQA, EDF and SWIM

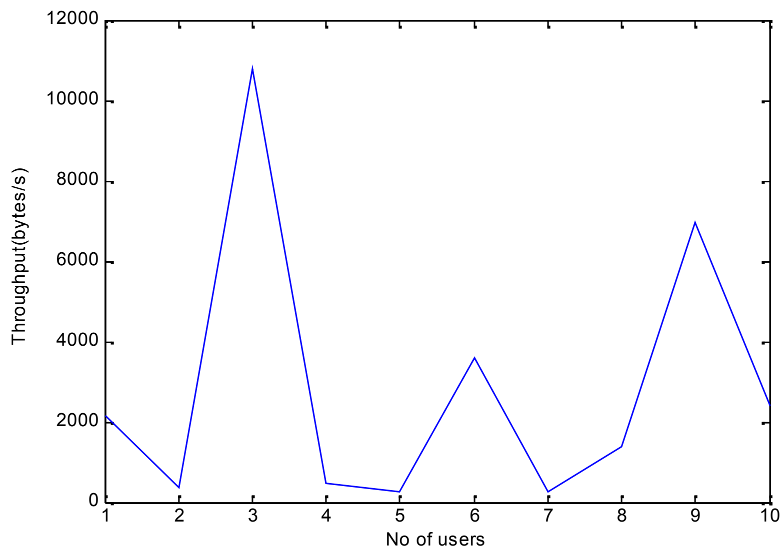

Fig.6 Throughput of the SWIM algorithm for 10 users

Fig.4 shows the delay of EQA, EDF, and SWIM. The delays for EQA and SWIM are the same which are equal to the periods. For EDF, even though delay is reduced when compared to the other two algorithms it will in turn introduce the delay jitter as shown in Fig.5.But the delay jitter is almost zero for SWIM.

Fig.7 shows the steady state probability that an MGroup is selected to be served at an arbitrary frame. It is observed that each MGroup obtains almost the same service probability which achieves the good fairness in terms of channel conditions.

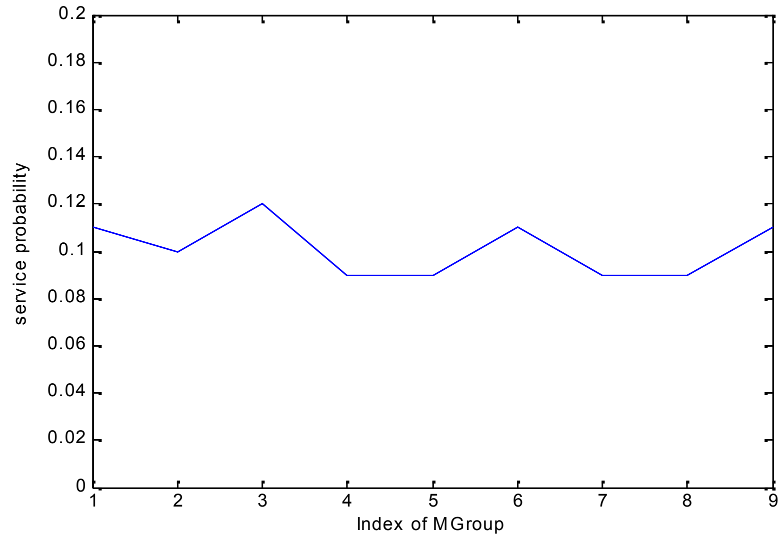

Fig.7 Steady State Service Probability

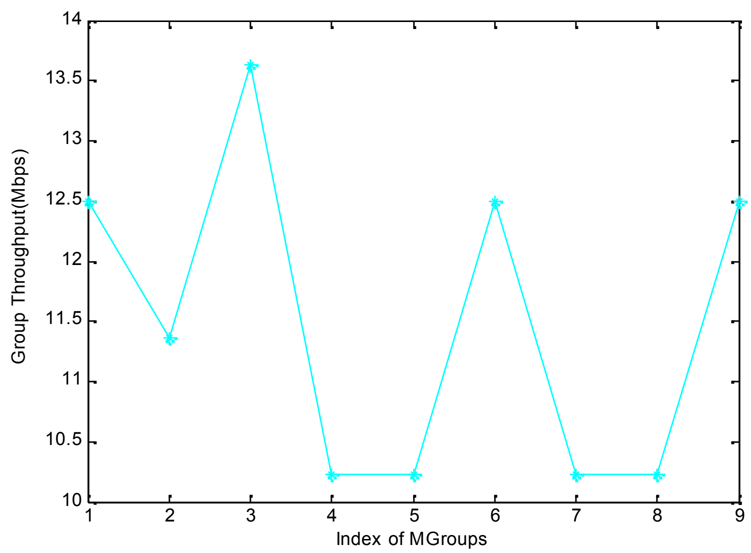

Fig.8 Throughput for each Multicast group

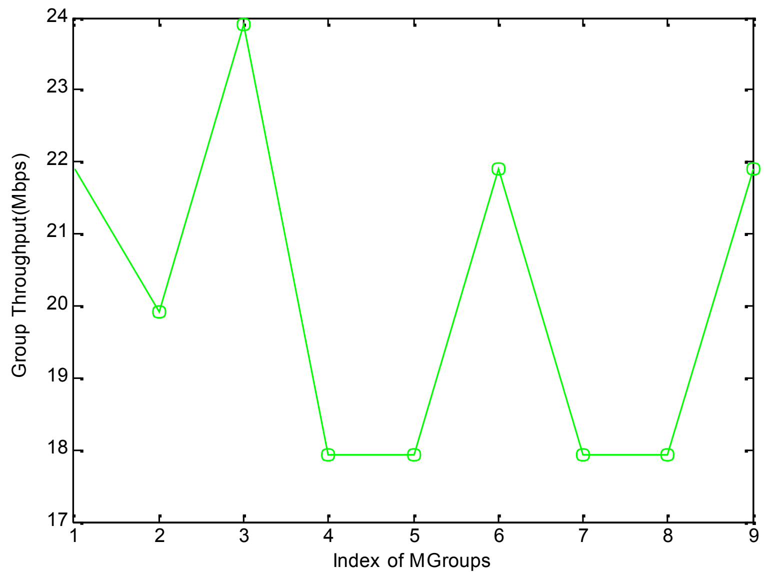

Fig.9 Throughput for each Multicast group using AMC

Fig.8shows the throughput of the each Multicast group for which each MGroupis chosen based on channel aware method. From the Fig.9it is clear that the throughput is still enhanced for the each multicast group due to adaptive modulation and coding scheme used.

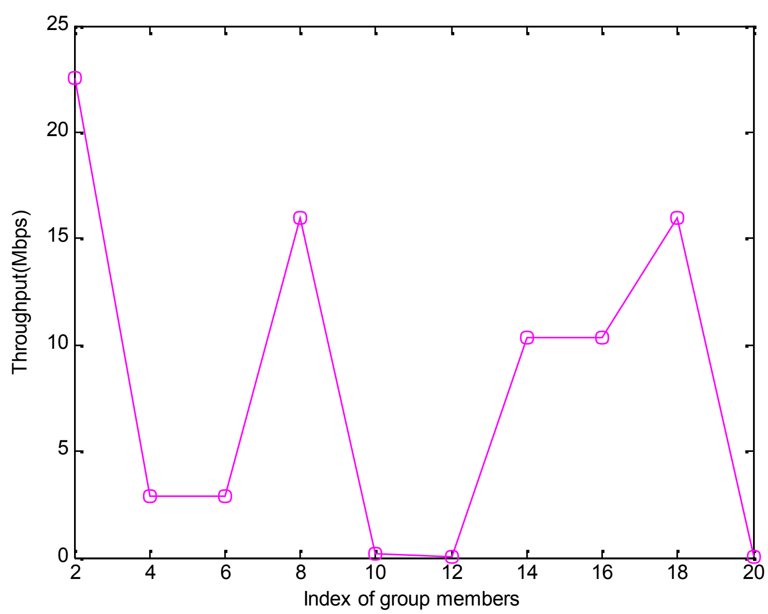

Fig.10 Throughput for each group members

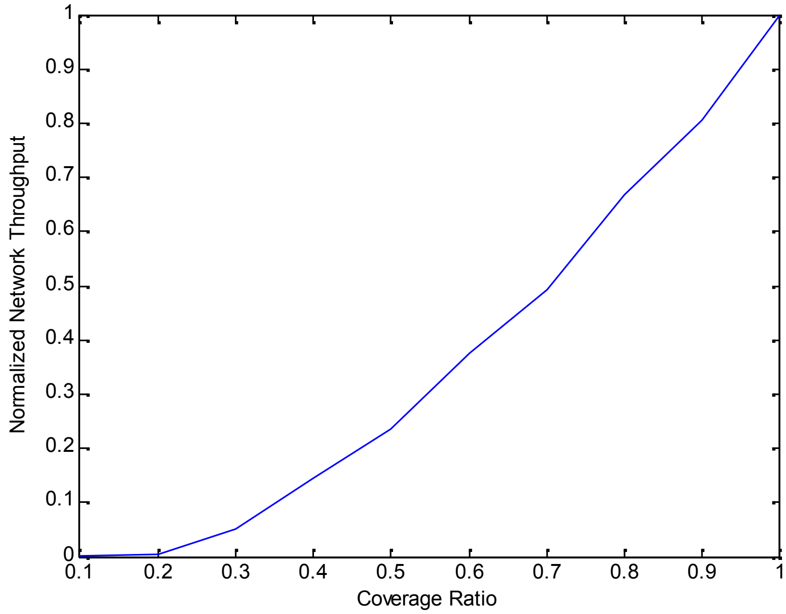

Fig.11 Normalized network throughput Vs Coverage ratio

Fig.10 shows the throughput for each group members and Fig.11 shows the normalized network throughput. From the figure it is seen that the as the coverage area increases the throughput of the network also increases.

7. Conclusion

WiMAX is one of the emerging technologies that can be used for all types of wireless services (voice, data and multimedia, IPTV) which require higher capacity and data rates. In this paper, Wireless IPTV istransmitted over Mobile WiMAX. To support various bandwidth requirements, video streams are coded into base and enhancement layers by Scalable Video Coding (SVC) technology. Efficient algorithms are carried out for the effective utilization of the resources. The performance of the Swapping Min-Max algorithm minimizes the number of bursts and achieves approximately zero jitter. Further, Cooperative Multicasting Scheduling is realized which still optimizes throughputand exploits multi-channel diversity among the group members which are involved in multicasting.

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