Application Specific Scheduling in WiMAX: Ensuring QoS in Application Mix Environment

Abdul Q. Ansari, Abdul L. Memon and Faisal K. Shaikh

Abstract — **In wireless network deployments, scheduling at MAC is deterministic and of empirical importance to ensure QoS. The Quality of Service centric Medium Access Control architecture of WiMAX helps providing services with different QoS requirement. In WiMAX, Service Specific Convergence Sub-layer (CS) CS-MAC enables service differentiation and thus provides basis for allocating different scheduling types to different applications. The IEEE 802.16 group working on standardization of WiMAX does not explicitly define the scheduling class to be used and has left for vendors and operators to come up with adaptable frameworks to accommodate different applications with differing QoS requirement. In this article we have focused on QoS requirements in application mix environment wherein real time applications with stringent QoS requirements and non-real time applications with very flexible QoS requirements coexist. We used OPNET modeler to simulate a WiMAX network with seven cell sites and IP backbone. MSs in the network are using both the real time voice and non-real time data applications. Network performance is reviewed in terms of load offered, throughput, delay and, application response time. Initially network was configured with UGS class for real time voice and BE for data application. The network response shows that in application mix environment UGS class with fixed size, periodic allocations is not useful and may result in underutilization of BW assigned periodically to application configured with UGS class and on the other hand applications running with BE class may observe waiting for indefinite time to transmit. Having observed this, we re-simulated network with ertPS class (an adaptable scheduling scheme) for real time applications. From results of the reconfigured network it is followed that using ertPS for real-time applications in application mix environments is advantageous as ertPS class provides polling based assignment to real time flows and thus support non-real time applications using BE class to flow.**

Index Terms — **WiMAX, Quality of Service, Scheduling, Real Time and Non-Real Time**

I. INTRODUCTION

WiMAX was originally designed for Broadband Wireless Access and evolved with time until becoming a candidate technology for 4G mobile networks. In 90s, IEEE started the working group IEEE 802.16 to create a Point-to-Multi-Point (PMP) air interface alternative to cable and digital subscriber lines. The original standard was modified to produce the IEEE 802.16d standard for fixed applications. IEEE 802.16d uses Orthogonal Frequency-Division Multiplexing (OFDM) as the PHY layer scheme. In 2005, mobility support was incorporated based on Scalable Orthogonal Frequency-Division Multiple Access (SOFDMA), resulting in the amendment 802.16e, also known as Mobile WiMAX [1, 2, 3]. Later, the standard IEEE 802.16-2009 was released to support both fixed and mobile wireless communications. A complete survey of the historical evolution of the standard up to 2010 can be found in [4]. In 2011, WiMAX evolved to 802.16m [5], which focuses on providing an advanced air interface to fulfill the requirements of IMT-Advanced while maintaining backward compatibility with existing specifications. In August 2012, the IEEE 802.16-2012 [6] was released, consolidating material from IEEE 802.16j-2009 for relay-based networks and the amendment 802.16h-2010, which implements coexistence enhancement for license-exempt operation. Such a standard also incorporated the IEEE 802.16m-2011, but excluding the WirelessMAN Advanced Air Interface, which is now specified in the IEEE 802.16.1-2012 [7]. Finally, improvements focused on Machine-to-Machine (M2M) applications are examined in amendments 802.16p-2012 [8]. The developments made in recent year have regained the focus of industry back to WiMAX as a candidate technology for 4G network deployments [9]. This is only because of very strong QoS framework and its ability to address application specific requirements of a user from network. Thus the IEEE 802.16 based broadband wireless access (BWA) networks have become the candid option for migration from existing wired solutions with comparable speed and for both real and non-real time applications.

Ensuring QoS in wireless networks is more challenging than in wired networks. Last mile wireless access is unpredictable and highly variable in time and with respect to user location. In WiMAX the MAC architecture is QoS centric and manages service level agreement to ensure wired equivalent experience [10]. In all telecommunication networks, the user experience is usually gauged with application end-to-end delay and for a service provider this is very important metric to evaluate network performance. The applications running over a wireless network such as WiMAX may be classified with respect to the requirement from operator's network such as prioritizing real time flows, provisioning of polling based grants, activation of committed bitrate service profiles for delay intolerant applications such as video conferencing, live streaming and online gaming, on the other hand applications with no QoS requirements may also be given adequate chance to transmit.

The Convergence sub-layer (CS-SAP) in MAC provides service diversity. This differentiation can be exploited to provision different scheduling classes for different applications types.

IEEE 802.16 standard define WiMAX defines UGS for Committed Bitrate(CBR), rtPS for Variable Bitrate (VBR)

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real time, nrtPS for VBR non real time and BE for unscheduled grants with no QoS commitments.

The rest of the paper is organized as follows. Sec. 2 introduces the WiMAX MAC layer and its QOS support. Sec. 3 describes the related work followed by Sec. 4 where we described the simulation setup for the evaluation of supporting the QoS in application mix environment. Results are discussed in Sec. 5. Sec. 6 concludes the paper.

II. WIMAX MAC AND QUALITY OF SERVICE

The QoS framework of WiMAX is designed to support different types of applications and services. Fig. 1 gives layered architecture of QoS centric MAC layer of WiMAX.

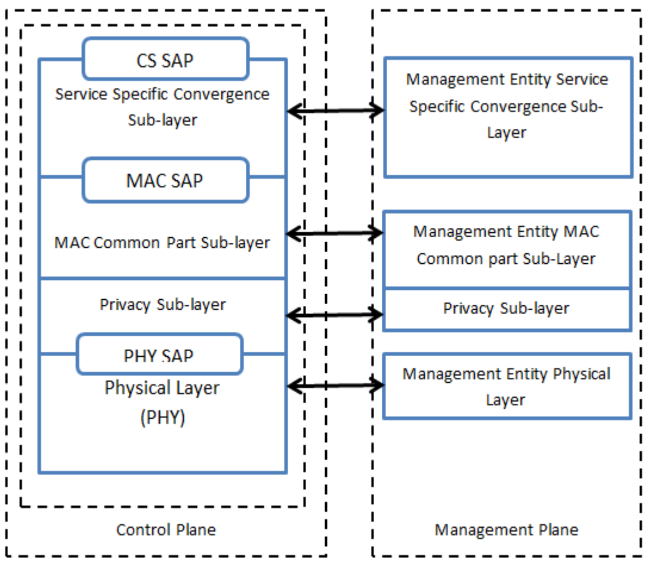

Fig. 1 Reference model of WiMAX MAC

The reference model is divided in three layers

1. Service Specific Convergence Sub-layer (CS): this layer offers conversion of data from upper layers (external network data) to MAC common part sub-layer.
2. MAC Common Part Sub-layer (MAC CPS): It classifies external network service data units (SDUs) and associates these SDUs to proper MAC service flow and Connection Identifier.
3. Privacy Sub-layer: Deals with authentication, secure key exchange, and encryption.

WiMAX MAC is connection oriented and is quite similar to the process of TDMA. |A SS cannot transmit or receive unless it forms one or more links/connections with BS. To achieve committed service quality the SS undergoes link adaptation and ARQ. The allocation of bandwidth is made to SS through a polling based assignment method and is controlled at base station. BS implements UL request/grant scheduling for all SSs so that each SS may get chance to poll to request for bandwidth. MAC carryout scheduling, fragmentation and ARQ periodically [12,13]. These periodic activities are performed at the frame level and have real time fixed deadlines. On the other hand aperiodic activities are executed not in accordance with a frame and do not have real time fixed deadlines [13]. The IEEE 802.16 MAC provides QoS based differentiation for different types of applications [14] and defines QoS framework to put up distinct QoS requirements; however techniques to ensure QoS like assignment of scheduling classes, admission control are not included in the standard.

Table I IEEE 802.16 Scheduling Services

S. No.	Service	Definition
1	Unsolicited Grant Service	Real-time data streams comprising fixed-size data packets issued at periodic intervals
2	Extended Real-time Polling Service	Real-time service flows that generate variable-sized data packets on a periodic basis
3	Real-time Polling Service	Real-time data streams comprising variable-sized data packets that are issued at periodic intervals
4	Non-real-time Polling Service	Delay-tolerant data streams comprising variable-sized data packets for which a minimum data rate is required
5	Best Effort	Data streams for which no minimum service level is required and therefore may be handled on a space-available basis

A. Unsolicited grant service (UGS)

UGS service class is defined for real time applications. Interactive voice, video conferencing, video streaming and online gaming are example application that may be configured with UGS class. UGS provides transmission opportunities for fixed size data packets on a periodic basis, such as T1, E1. For UGS, BS reserve UL grants but do not maintain any estimate of backlog; therefore UGS is configured with uncalled-for grant of bandwidth assignment and never explicitly request for bandwidth .The BS make an estimation of grants and on the basis a minimum reserved traffic rate(time averaged) is calculated and configured for applications using UGS class.

B. Extended real-time variable rate (ERT-VR)

ERT-VR is designed for delay sensitive applications that need aperiodic and variable opportunities for data transfer.

The BS schedules enough resources for ERT-VR flow to ensure that delay intolerant applications with committed bandwidth are served accordingly. This requirement can be analytically stated as follows

Allocated Bandwidth= min{S, R _ T}

S = Data arrived (During time interval T)
R = Reserved traffic rate (Minimum).

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C. Non-real-time variable rate (NRT-VR)

NRT-VR service is designed for delay insensitive applications that need aperiodic and variable opportunities for data transfer. The QoS constraints include reserved traffic rate- minimum, sustained traffic rate-maximum and priority [14].

D. Best Effort (BE)

BE class characterizes majority of data traffic. The QoS parameters for BE include maximum sustained traffic rate, traffic priority, and request/transmission policy [14]. Applications configured with BE usually do not demand for QoS guarantees. SS running application configured with BE service class contend to request for opportunities to transmit. When SS successfully access the media, it conveys its reservation request to BS. The base station responds by assigning the required bandwidth in successive frames.

III. RELATED RESEARCH REVIEW

The IEEE 802.16 Standard defines different scheduling classes to be configured depending upon the network deployment scenario. It is aimed that allocation of scheduling classes as defined in standard may be optimally done by the operator for effective utilization of bandwidth. Thus freedom is there for vendors/operators to come up with such application specific scheduling techniques so that they may differentiate their products, optimize the use of BW resources and can exactly meet the QoS requirements of end users, even with limited bandwidth allocations. The research to analyze scenarios of various network deployments may be carried by operators/vendors to come up with optimal selection but the research literature on application specific scheduling for wireless networks built around the IEEE 802.16 standard is inadequate. The standard document for IEEE 802.16 based BWA networks [1] specifies number of features that can be used, but does not specify the exact scheduling algorithms optimized for different application classes. In [15, 16] authors have worked on maximizing system utilization, user utility, or minimizing packet delay and loss and have attempted to maximize the throughput. In [17] authors have presented a complete survey of wireless MAC protocols, such as general network concepts, wireless MAC issues, performance metrics, classification of MAC protocols and comparison. Lai and Lin proposed Fair admission control in QoS capable networks [18]. Core changes are advised in MAC architecture in [19] to increase throughput but have not provided comprehensive discussion on its effect ton delay. Performance analysis with respect to QoS architecture, UL and DL allocation, and admission control are analyzed in greater detail in [20]. Performance evaluation of various scheduling schemes was presented by Jayaparvathy et al [21]. A novel QoS architecture for the IEEE802.16a MAC protocol is given in [22], authors have presented a bandwidth allocation and admission control policy to support and prioritize real-time traffic. Performance evaluation of IEEE 802.16 for broadband wireless access MAC layer that supports a range of physical layer technologies is presented in [23] by Ramachandran et al. Lee et al [24] presented an efficient uplink scheduling algorithm based on voice activity for VoIP services in IEEE 802.16d/e systems but remained specific to it only. In [25, 26 ,27] authors have analyzed the basic scheduling classes of WiMAX and based on parametric review the scheduling schemes are recommended for improved fairness, to minimize delays and to have resultant improvement in network throughout but have not suggested selection of scheduling classes in environments where real time and non-real time applications coexist.

IV. ENSURING QUALITY OF SERVICE IN APPLICATION MIX ENVIRONMENT

In application mix environment some applications are very sensitive to user experience and some are not. Real time voice/ video are very sensitive to user experience, on the other hand FTP, E-mail etc. can afford not to have committed bit rate. Data centric applications can only afford to use BE scheduling as such applications have very accommodative behavior with respect to time for transfer; although the real time applications have very stringent requirement for time to transfer. The core drive for this research is to endorse that WiMax support application mix environment wherein real-time and non-real–time applications co-exist.

A. Simulation Setup

A baseline network consisting 7 cells with each Mobile Stations connected to IP backbone was simulated using OPNET Modeler 14.5. There are five MSs in each cell configured with data application using oracle transactions and one MS configured for real time PCM quality voice application. To establish connectivity between WiMAX network BSs and IP backbone we have used OC-12 link. Database server to run ORACLE transactions, application server and voice server are used for respective application management. The data application is built on three-tier oracle transactions. Using PCM quality voice codecs, each voice packet has 640 bits and for real time voice experience 100 packets per second is the required transmission rate. Thus total load of each voice call is 64 Kbps. UGS class (QoS centric- for real time applications) is configured for voice application being delay intolerant and BE class (with no QoS guarantees) is configured for data applications, initially. The UGS scheduling is configured with maximum sustained traffic rate and minimum reserved traffic rate of 64Kbps for real time voice application.

B. Methodology

To evaluate the effect of using fixed and variable service flows for real time applications in application mix environment was analyzed using steps enumerated below

a. A baseline WiMAX network, consisting of 7 cells and an IP backbone was simulated in OPNET.
b. Application service profiles containing both voice and data applications are configured.
c. Layer 2 QoS configurations activated.

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d. Optimize the QoS parameters of network at Layer 2 for voice application and examine the effect on data applications running parallel.
e. Change service profile for voice application from UGS based fixed flow to ertPS based variable allocation to see effect on data application without compromising the performance of voice
f. Review and summarize simulation results.

V. RESULTS AND ANALYSIS

A. Network Response to Voice and Data Application Mix Environment

Referring to configuration presented in section IV, the voice flow is configured with UGS flow having maximum sustained traffic rate and minimum reserved traffic rate of 64Kbps. The 64 Kbps voice application traffic will also add 320 bits header (IP and TCP headers of 160 bits each). Thus voice application requires transmitting at 96 Kbps rate. It is worth to observe that load of voice application is 96 Kbps and link output is only 64Kbps and is thus suggesting some queuing (Fig. 2-a and Fig.2-b).

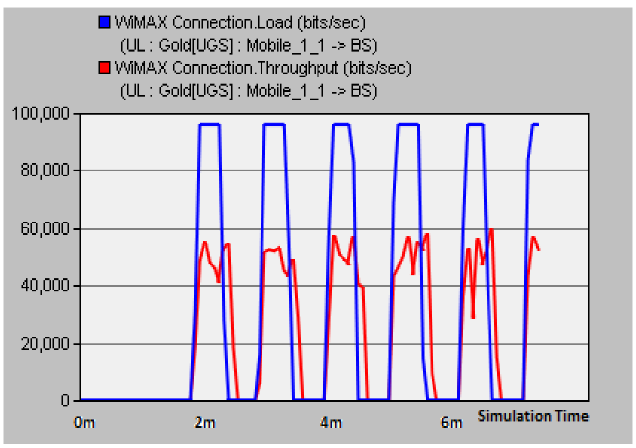

Fig. 2a WiMAX Connection Load vs. Throughput (Pre-optimization)

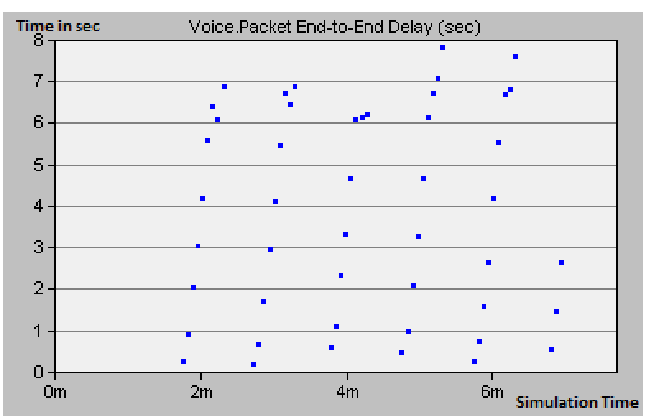

Fig. 2b Voice Packet end-to-end Delay (Pre-Optimization)

B. Configuring WiMAX QoS-Optimized for Real Time Voice

As discussed above, variation of load and capacity of assigned resources is resulting in delay/wait for voice traffic; for instance we resized UGS flow for voice application running on MS-1in Cell no 1 to 96Kbps. Referring Fig. 3(a), with the redefinition of UGS flow for voice application according to offered traffic load the end to end delay for voice application reduced from 7~8 seconds to 7~8 milliseconds. This could be further verified form simulation results in Fig. 3-b that matching link capacity with application load expectedly improves the performance of voice application and throughput increased from noticeably.

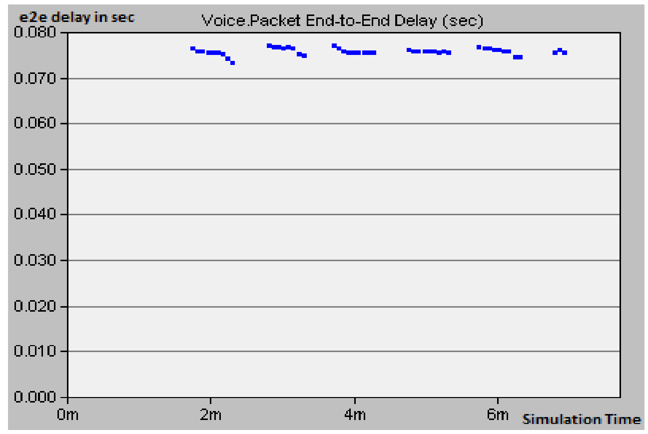

Fig. 3a Voice Packet end-to-end Delay Optimized for voice

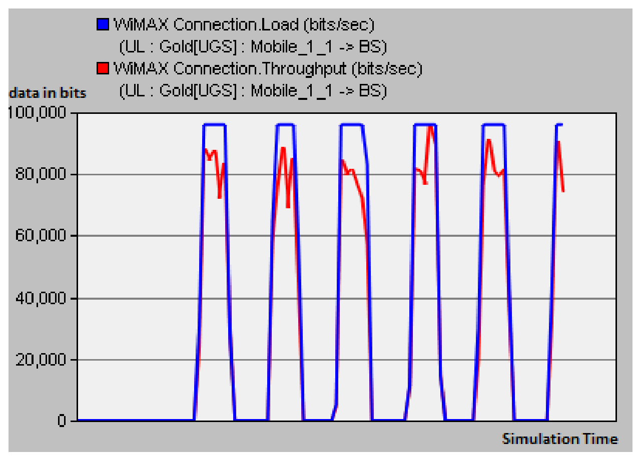

Fig. 3b WiMAX Connection Load vs. Throughput-Optimized for voice

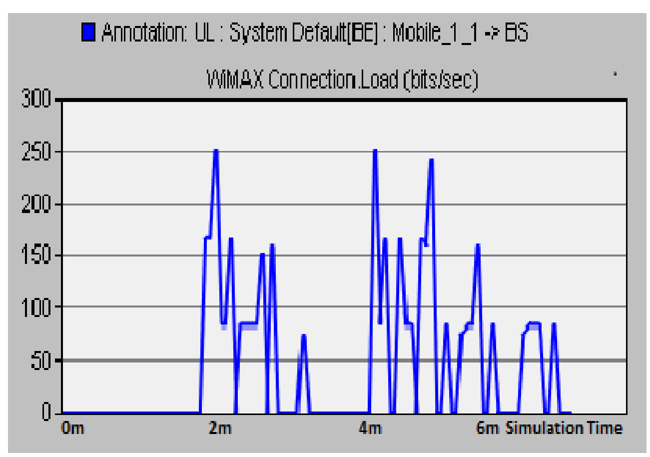

Fig. 3c Data Traffic Load-Optimized for voice

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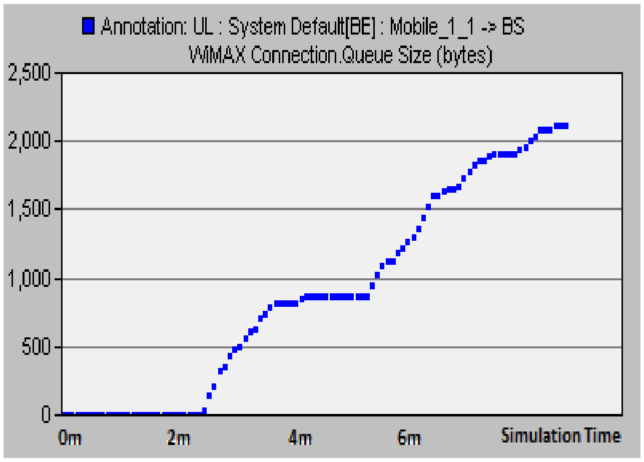

Fig. 3d Data Traffic Queuing - Optimized for voice

Optimizing configuration for Voice flow the data application running on BE has undergone catastrophic failure (Fig.3-c). Referring to simulation results of Fig 3-c and d it is noticed that data packets are accumulating just after 2 minutes i.e. just with the start of voice application; resultantly data packets keep queuing and throughput is not noticeable.

C. Configuring WiMAX QoS-Optimized for Real Time and Non-Real Time Applications

In application mix environment, the use of fixed allocation schemes for real time applications however ensure committed quality of experience for end user but on network side it may lead to situations where optimized use of resources may not be achieved, for example even at times of silence during voice communication the resources remain allocated with the service flow and non-real-time applications using service classes with no QoS guarantees and (only served when space to transmit is available) are not improving even. Keeping this in context need is to configure the real time applications with adaptable service flows/classes when such applications coexist with non-real time applications using lowest priority service flows. ertPS scheduling is an adaptable allocation scheme. In ertPS when there is no traffic load, BW allocation is reduced temporarily. Thus by freeing of unutilized BW resources by ertPS the Best Effort flow is benefited and data start flowing without compromising the experience of voice application.

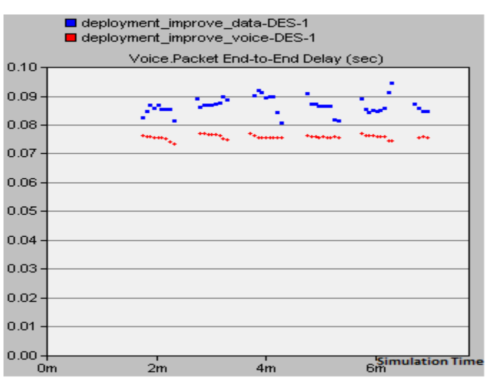

Fig. 4a Voice e2e Delay-Tradeoff for voice and data application

Having this discussion, we changed the service class for voice application from UGS (fixed allocation) to ertPS (poling based variable sized allocation), enabling the Best Effort traffic to drift. From Fig. 4-a, the application delay for all mobiles in the network is lower in this scenario. Also the data application using BE class has started flowing and its throughput matches its load for Mobile1_1 (Fig. 4-b and Fig. 4-c). It should be noted that the application delay over all mobiles in the network is lower in this scenario-red trace than in the earlier configuration-blue trace (Fig. 4-d).

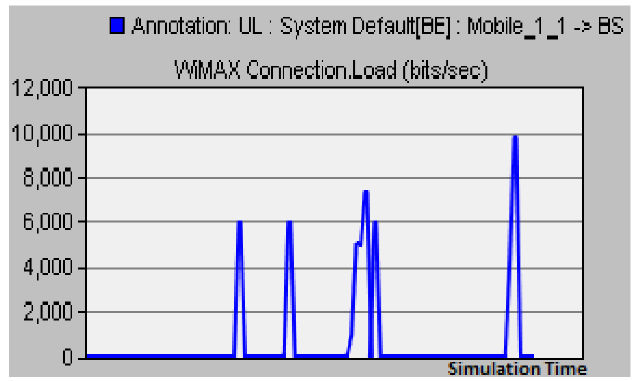

Fig. 4b WiMAX Connection Load-Tradeoff for voice and data application

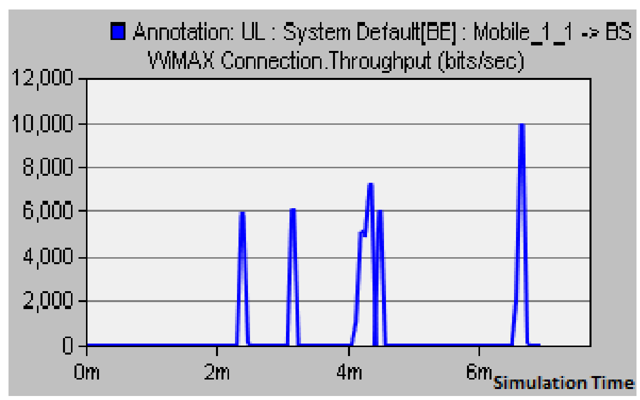

Fig. 4c WiMAX Throughput-Tradeoff for voice and data application.

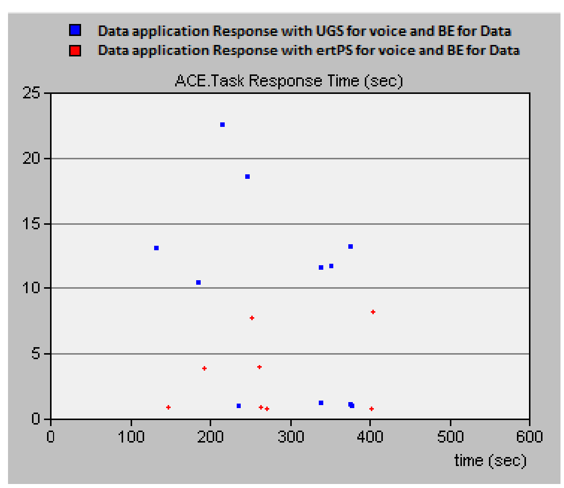

Fig. 4d Oracle Application Response Time-Tradeoff for voice and data application

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VI. CONCLUSION

QoS support in WiMAX is a fundamental design requirement, and is considerably more difficult than in wired networks, mainly because of the variable and unpredictable characteristics of wireless links. Moreover the stringent requirements of real-time applications require some definite priority in resource assignment when coexist with Non-Real Time applications. This paper provides simulation based analysis of scheduling classes in WiMAX and suggest optimal selection of scheduling classes in application mix environment where applications with distinct QoS requirements coexist. We have reached to the conclusion that delay sensitive traffic with variable requirement of link capacities may be ideally configured with ertPS scheduling class instead of UGS flow especially in application mix environment so as to avoid freezing of unutilized resources due to unsolicited grants in UGS and thus to increase chance of applications using BE class to transmit.

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REFERENCES

[1] Air Interface for Fixed Broadband Wireless Access Systems, IEEE STD 802.16 – 2004, October 2004.

[2] Air Interface for Fixed and Mobile Broadband Wireless Access Systems," IEEE P802.16e/D12, February 2005.

[3] Hassan, Y. (August 2004), "Scalable OFDMA Physical Layer in IEEE 802.16 WirelessMAN", Intel Technology Journal, Vol. 08(3), pp.201-212.

[4] Pareit, D., Lannoo, B., Moerman, I., Demeester, P. (December 2012), "The history of WiMAX: a complete survey of the evolution in certification and standardization for IEEE 802.16 and WiMAX", IEEE Communications Surveys Tutorials, 14(4), pp.1183–1211.

[5] IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems Amendment 3: Advanced Air Interface. IEEE Std 802.16m-2011(Amendment to IEEE Std 802.16-2009), 2011

[6] IEEE Standard for Air Interface for Broadband Wireless Access Systems. IEEE Std 802.16-2012 (Revision of IEEE Std 802.16-2009), 2012.

[7] IEEE Standard for WirelessMAN-Advanced Air Interface for Broadband Wireless Access Systems. IEEE Std 802.16.1-2012, 2012.

[8] IEEE Standard for Air Interface for Broadband Wireless Access Systems–Amendment 1: Enhancements to support machine-to-machine applications. IEEE Std. 802.16p-2012 (Amendment to IEEE Std 802.16-2012, 2012.

[9] Claudio C., Alessandro E., Luciano L., and Enzo M., "Performance Evaluation of the IEEE 802.16 MAC for QoS Support", IEEE Transactions on Mobile Computing, Vol.6(1), 2007, pp.26-38.

[10] Lenzini, C., Mingozzi, E., Eklund, C (March 2006), "Quality of service support in IEEE 802.16 networks, IEEE Network, Vol. 20(2), pp. 50-55.

[11] Kwang-Cheng, C. and J. Roberto B. de Marca, 'Mobile WiMAX', IEEE PRESS, IEEE Communications Society, John Wiley & Sons, 2008.

[12] Govindan, N., et al (Aug 2004), IEEE 802.16 Medium Access Control and Service Provisioning", Intel Technology Journal, Vol.8 (3), pp.214-228.

[13] Syed, A. and Muhammad, I., 'WiMAX: Technologies, Performance Analysis, and QoS", CRC Press Taylor & Francis Group, 2008.

[14] Jeffery G., Andrews, A., Gosh and Rias, M., "Fundamentals of WiMAX", Prentice Hall, 2007.

[15] Liang, Y., Zhang, R. and Cioffi, J. (August 2006), "Transmit optimization for MIMO-OFDM with delay-constrained and no-delay-constrained traffic", IEEE Trans. Signal Process., vol. 54(8), pp. 3190–3199.

[16] Koutsopoulos, I., and Tassiulas, L. (October 2006), "Cross-layer adaptive techniques for throughput enhancement in wireless OFDM-based networks", IEEE/ACM Trans. Network., vol. 14, pp. 1056–1066.

[17] Chandra, A., Gummalla, V., and Limb, J., "Wireless Medium Access Control Protocols", IEEE Communications Surveys and Tutorials; pp. 2–14, 2000.

[18] Lai, Y., and Lin, Y. (Feb. 2005) "Fair admission control in QoS capable networks", IEE Proceedings, Communications, vol. 152(1), pp. 22–27.

[19] GuoSong C., Deng, W. and Shunliang, M (2002)., "A QoS architecture for the MAC protocol of IEEE 802.16 BWA system" Communications, Circuits and Systems and West Sino Exposition Proceedings Vol.1, pp 435-439.

[20] Dong-Hoon, C., Jung-Hoon, S., Min-Su, K. and Ki-Jun, H., "Performance analysis of the IEEE 802.16 wireless Metropolitan Area Network", Proceedings DFMA'05, IEEE Computer Society, 2005, pp.130-137.

[21] Jayaparvathy, R., Sureshkumar, G., and. Kankasabapathy, P., "Performance Evaluation of Scheduling Schemes for Fixed Broadband Wireless Access Systems", IEEE, International Conference on Communication Networks (MICC ICON 2005), Kaulalampur, Malaysia, pp.16-18, 2005.

[22] Min-Su Kim, Dong-Hoon Cho, Jung-Hoon Song, Ki-Jun Han, (Feb. 2005), "Performance Analysis of the IEEE 802.16 Wireless Metropolitan Area Network," Proc. First Int'l Conf. Distributed Frameworks for Multimedia Applications (DFMA '05), pp. 130-137

[23] Ramachandran, C., Bostian, W., Midkiff, F., 'Performance Evaluation of IEEE 802.16 for Broadband Wireless Access", Proceedings of OPNETWORK, 2002.

[24] Lee, H., Kwon, Cho, D., "An efficient uplink scheduling algorithm based on voice activity for VoIP services in IEEE 802.16 d/e systems", IEEE Communication Letters, vol. 9, no. 8, Aug. 2005.

[25] Wail M., Mai M. Abu Alfoul (2011), "Modified WRR scheduling algorithm for WiMAX networks", Network Protocols and Algorithm, Volume 3, , pp.24-53.

[26] Harpreet K., Gurpal S., "Implementation and Evaluation of scheduling algorithm in point to multipoint mode in WiMAX network" (2011), IJCST, Vol. 2, No. 3, PP. 540-546.

[27] Ahmed H. Rashwan, Hesham M. ElBadawy and Hazem H. Ali. (2009). Comparative Assessments for Different WiMAX Scheduling Algorithms. Proceedings of the World Congress on Engineering and Computer Science WCECS 2009. Vol. I. 20-22 October, 2009. San Francisco, USA. pp. 362-366.