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PERFORMANCE ANALYSIS OF ARQ MECHANISM IN WiMAX NETWORKS

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Abstract:

WiMAX (Worldwide Interoperability for Microwave Access) is the IEEE 802.16 standards-based wireless technology, provides Broadband Wireless Access (BWA) for Metropolitan Area Networks (MAN). The Automatic Repeat reQuest (ARQ) mechanism in WiMAX uses a feedback channel for the confirmation of error-free packet delivery or for packet retransmission request. This method can increase network throughput when radio channel condition is worse. In this paper attempt has been made to study the effect of implementation of ARQ on the performance of WiMAX network through simulation. Simulation study has been carried out for WiMAX network with and without enabling ARQ. The performance is been compared by considering the performance metrics like throughput, delay and jitter.

Keywords: WiMAX, ARQ, Base station, Subscriber Stations, Simulation.

1. Introduction

WiMAX (Worldwide Interoperability for Microwave Access) is the acronym for IEEE 802.16 standard which defines Air Interface for fixed and mobile Broadband Wireless Access (BWA) Systems [1-2]. The IEEE 802.16 standard includes MAC and PHY layer specifications and it is designed to achieve goals like easy deployment, high speed data rate, large spanning area and large frequency spectrum. The 802.16e standard was developed to support mobile BWA with requirements to support the wireless communication at vehicular mobility and seamless handover while maintaining differentiated Quality of Service (QoS). QoS in 802.16e standard is supported by allocating each connection between the Subscriber Station (SS) and the Base station (BS) to a specific QoS class. In 802.16e standard, there are 5 QoS classes: Unsolicited grant service (UGS), extended real-time-polling services (ertPS), real time polling services (rtPS), non-real time polling services (nrtPS) and best effort (BE). The standard does not define a slot allocation criterion or scheduling architecture for any type of service. A scheduling module is necessary to provide QoS for each class.

Generally, errors occur during data transmission in wireless networks. Erroneous packets cannot be used for further processing without a method of correction. For this purpose, wireless networks commonly use techniques based on Automatic Repeat reQuest (ARQ) or Forward Error Correction (FEC) method or combination of both methods known as Hybrid Automatic Repeat Request (HARQ). The ARQ mechanism uses a feedback channel for the confirmation of error-free packet delivery or for packet retransmission request [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. The FEC method allows an increase in data throughput within an impaired channel quality by adding redundant coding information on the transmitter side. All the above mentioned methods should implement a mechanism on link layer that control and manage these techniques to achieve optimal performance on a wireless link. In this paper the effect of implementation of ARQ for WiMAX network is studied by considering the performance metrics like throughput, delay and jitter. The rest of this paper is organized as follows. Section 2 outlines the related work in the literature. Section 3 and 4 describe the overview of WiMAX network and ARQ mechanisms respectively. Section 5 presents simulation results followed by conclusion in Section 6.

2. Related Work

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 [5]. 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 [6]. In [7] authors evaluated the ARQ performance for different ARQ parameters. Sayenko et.al [8] provides a comparison of ARQ and HARQ performance in IEEE 802.16 networks. The optimal PDU size and MAC overhead due to the packets retransmission is analyzed in [9]. To achieve the best ARQ performance authors of [10] have proposed to adjust the MAC PDU size depending on the channel state. Chen and De Marca [11] investigated the optimization of ARQ parameter setting from the link throughput point of view. Authors of [12] proposed a cross-layer ARQ mechanism, which substitutes the transmission of TCP acknowledgment packet with a short request transmitted on the MAC layer of the wireless link. In paper [13] Krishnamachari et.al proposed a novel adaptive cross-layer protection strategy for video transmission. Combination of application layer FEC and MAC layer ARQ and optimum setting of parameters of those techniques is also investigated in this paper.

3. Overview of WiMAX Network

WiMAX is the acronym for IEEE 802.16 standard, which includes MAC and PHY layer specifications and it is designed to achieve goals like easy deployment, high speed data rate, large spanning area and large frequency spectrum. The 802.16e standard was developed to support mobile BWA with requirements to support the wireless communication at vehicular mobility and seamless handover while maintaining differentiated QoS. Scalable OFDMA (SOFDMA) was introduced to support scalable channel bandwidths from 1.25 to 20 MHz, which provides true QoS. Mobile WiMAX (802.16e) is equipped with novel technological tools, such as orthogonal frequency division multiple access (OFDMA), time division duplexing (TDD), multi-input multi-output (MIMO), adaptive modulation and coding (AMC), Internet protocol (IP), security and others, which are combined together to offer high-rate, low-cost, wide-area, secured mobile multimedia services.

The 802.16e supports Point to Multi Point (PMP) architecture, in which a centralized BS controls all communications among the SSs and the BS. In PMP mode, the BS schedules the traffic flow for SSs and SSs do not communicate directly. The communication between BS and SS are bidirectional i.e., a downlink (from BS to SS) and an uplink (from SS to BS). The downlink channel is in broadcast mode. The uplink channel is shared by various SS's through Time Division Multiple access (TDMA) manner. The standard supports two type of duplex mode, Time Division Duplex (TDD) and Frequency Division Duplex (FDD).The TDD frame consists of downlink and uplink subframes, the duration and the number of subframe slots are determined by the BS scheduler. The downlink subframe has downlink map (DL map) and uplink map (UL map). DL map contains information about the duration of subframes and which time slot belongs to a particular SS as the downlink channel, UL map consists of information element (IE) which includes transmission opportunities [14].

Table 1- The details of QoS classes

QoS Service Type	QoS specifications	Applications
Unsolicited Grant Service (UGS)	Minimum reserved rate, Maximum sustained rate, Maximum latency tolerance, Traffic priority	T1/E1 transport
Extended Real-time Polling Service (ertPS)	Minimum reserved rate, Maximum sustained rate, Maximum latency tolerance, Traffic priority, Jitter tolerance	VoIP
Real-time Polling Service (rtPS)	Minimum reserved rate, Maximum sustained rate, Maximum latency tolerance, Traffic priority	MPEG Video
Non-real-time Polling Service (nrtPS)	Minimum reserved rate, Maximum sustained rate, Traffic priority	FTP with guaranteed minimum throughput
Best Effort (BE)	Maximum sustained rate, Traffic priority	HTTP

The MAC layer is connection oriented i.e. all data communications, for both transport and control, are in the context of a unidirectional connection. Each packet has to be associated with a connection at MAC level. Each connection is assigned a unique Connection ID (CID) and a Service Flow ID (SFID) with an associated service class. The SS cannot transmit data until it has been allocated a channel by the BS. This provides a way for bandwidth request, association of QoS and other traffic parameters and data transfer related actions. This allows 802.16e to provide strong support for QoS. QoS in 802.16e is supported by allocating each connection between the SS and the BS (called a *service flow* in 802.16 terminologies) to a specific *QoS class* (Servicetype). In 802.16e, there are 5 QoS classes, the Table 1 gives the details of QoS classes.

4. Automatic Repeat request (ARQ)

Automatic Repeat reQuest (ARQ) also known as Automatic Repeat Query, is an error-control method for data transmission that uses acknowledgements (messages sent by the receiver indicating that it has correctly received a data frame or packet) and timeouts (specified periods of time allowed to elapse before an acknowledgment is to be received) to achieve reliable data transmission over an unreliable service. If the sender does not receive an acknowledgment before the timeout, it usually re-transmits the frame/packet until the sender receives an acknowledgment or exceeds a predefined number of re-transmissions [3].

The ARQ is a control mechanism of data link layer where the receiver asks the transmitter to send again a block of data when errors are detected. The ARQ mechanism is based on acknowledgement (ACK) or no acknowledgement (NACK) messages, transmitted by the receiver to the transmitter to indicate a good (ACK) or a bad (NACK) reception of the previous frames.

The ARQ is a MAC mechanism which is mandatory for Mobile WiMAX systems. An ARQ block is assigned a sequence number (SN) or a Block Sequence Number (BSN) and is managed as a distinct entity by the ARQ state machines. The block size is a parameter negotiated during connection establishment. 802.16 standard supports four ARQ ACK variants: cumulative, selective, selective with cumulative and cumulative with block. When ARQ is enabled, SDU is treated as fragmented into logical ARQ blocks with fixed block size [1-2].

5. Simulation and Results

An extensive simulation work is performed to study the effect of ARQ on the performance of WiMAX network using Qualnet 5.0.2 [15]. A single WiMAX cell is considered in the simulation area of 1Km x 1Km, working at a frequency 2.4 GHz. The values of parameters considered for simulation are mentioned in Table 2. Since the ARQ can increase network throughput when radio channel condition is worse, the subscriber stations are placed at worst channel condition.

Table 1: Simulation Parametrs

Property	Value
Simulation time	300 Sec
Channel bandwidth	20 MHz
FFT size	2048
Antenna model	Omni directional
BS antenna gain	10 dBi
SS antenna gain	0 dBi
BS antenna height	12 m
SS antenna height	1.5 m
Pathloss model	two ray
Shadowing model	Constant
Shadowing mean	4dB
Fading model	Rayleigh

Scenario-1:

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 1 gives the plot of throughput performance for ARQ and non-ARQ network with respect to increase in number of connections. For less number of connections (upto 4), the throughput performance of ARQ and non-ARQ network is almost same. 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 compare to non-ARQ network [4].

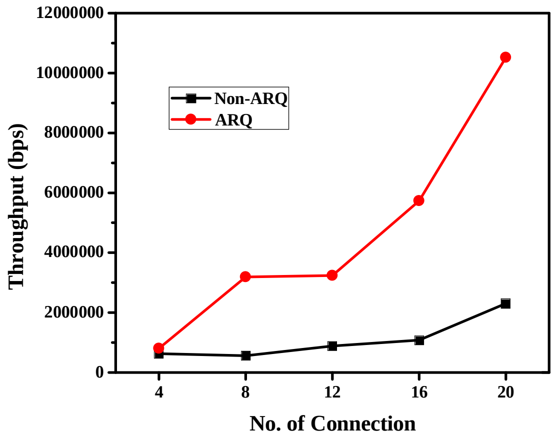

Figure 1: Throughput performances for varying no. of connections

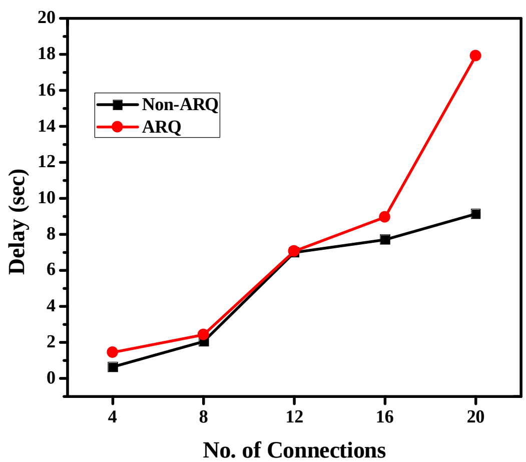

Figure 2: Delay performances for varying no. of connections

Delay performance for ARQ and non-ARQ network with respect to increase in number of connections is given in figure 2. For lesser connections (upto 12) the delay performance of ARQ and non-ARQ network is almost same. As the number of connections increases the 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 3. 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.

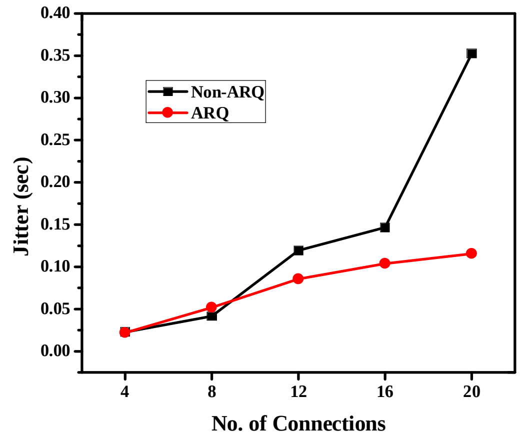

Figure 3: Jitter performances for varying no. of connections

Scenario-2:

It is known that the performance of ARQ depends on its parameters [5]. Hence in this scenario, an effort has been made to study the ARQ performance by varying the ARQ parameter called ARQ block size. The WiMAX standard specifies the ARQ block size ranging from 16 to 1024 bytes (power of 2). In this scenario all the settings of scenario 1 are retained with 12 connections. ARQ block size is varied from 32 to 1024 bytes for the ARQ transmission window size of 1024 bytes. Figure 4 gives the throughput performance for varying ARQ block size. It is observed that as the block size increases the throughput increases upto 512 bytes, afterwards it decreases.

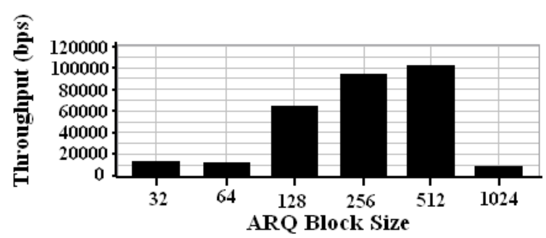

Figure 4: Throughput performances for varying ARQ block size

6. Conclusion

In this paper the effect of implementation of ARQ for WiMAX network is studied by considering the performance metrics like throughput, delay and jitter. 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. The simulation study is also carried out by varying ARQ block size for the ARQ enabled network.

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References

[1] IEEE802.16e: IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, 2005.

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

[3] Jeffrey G. Andrews, Anurabha Ghosh and Rias Muhamed, “Fundamentals of WiMAX”, Prentice Hall Communications.

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

[5] Byeong Gi Lee and Sunghyun Choi, (2008), “Broadband Wireless Access and Local Networks: Mobile WiMAX and WiFi”. Artech House.

[6] Min-Seok Kang and Jaeshin Jang, (2006). “Performance evaluation of IEEE 802.16d ARQ algorithms with NS-2 simulator”, Asia-Pacific Conference on Communications, pp 1 - 5

[7] Vitaliy Tykhomyrov, Alexander Sayenko, Henrik Martikainen, Olli Alanen1and Timo Hamalainen, (2007). “Performance Evaluation of the IEEE 802.16 ARQ Mechanism”, In Proceedings of 7th International Conference Next Generation Teletraffic and Wired/Wireless Advanced Networking, NEW2AN 2007, pp. 148-161

[8] Alexander Sayenko, Henrik Martikainen and Alexander Puchko, (2008). “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 '08.

[9] Hoymann, C. (2005). “Analysis and performance evaluation of the OFDM-based metropolitan area network IEEE 802.16”, Computer Networks, 49, 341-363.

[10] Sengupta, S., Chatterjee, M., Ganguly, S., Izmailov, R. (2005). Exploiting MAC Flexibility in WiMAX for Media Streaming. World of Wireless Mobile and Multimedia Networks,

[11] Chen, K.C, De Marca, J.R.B. (2008). Mobile WiMAX. West Sussex: Wiley&son Ltd.

[12] Kliazovich, D., Tommaso, B., Dalsass, S., Serrelli, F., Redana, S., Granelli,F. (2008). Cross- Layer Error Control Optimization in WiMAX. Global Telecommunication Conference 2008, New Orleans, USA, 2008.

[13] Krishnamachari. S, van der Schaar, M., Choi, S., Xu, X. (2003) Video Streaming over Wireless LANs: A Cross-layer Approach. IEEE Packet Video Workshop, Nantes, France.

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

[15] http://www.scalablenetworks.com\qualnet\documentation, Documentation of QualNet simulation tool.