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Multimedia Application Support on WiMAX: Cost / Benefit Analysis

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Abstract

There are several restrictions in the current access wireless technologies, such as General Packet Radio Service (GPRS) and High Speed Packet Access (HSPA), for the transmission of the multimedia applications. Worldwide Interoperability for Microwave Access (WiMAX) is a broadband wireless technology based on the Institute of Electrical and Electronics Engineers (IEEE) 802.16 standard and aims at enabling the development of wireless broadband services anytime and anywhere. Therefore, it is a strong candidate to support multimedia applications in various deployment scenarios.

This work presents the state of the art of the WiMAX technology and discusses the comparison with its major competitors. The assessment includes a technical study and a thorough conceptual analysis of the trade-off cost/benefit of the technologies under evaluation. A real testbed evaluation of the capabilities of both Fixed and Mobile WiMAX to support the most popular multimedia applications, Voice over IP (VoIP) and Video Streaming, is performed.

The experimental study allowed the quantification of the scalability levels supported by Fixed and Mobile WiMAX for the transmission of multiple VoIP and Video Streaming flows. Moreover, the results obtained in the scenarios tested, using different VoIP CODECs and videos with several distinct compression levels, provided insight on the tradeoffs that Internet Service Providers may achieve in order to provide good quality services to the maximum amount of clients. Overall, both Fixed and Mobile WiMAX showed interesting capabilities as a Broadband Wireless Access technology for the support of multimedia applications in the next generation communication systems.

keywords: IEEE 802.16, Multimedia Applications, Quality of Experience, Quality of Service, WiMAX

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Abbreviations and acronyms

1G	First Generation of mobile phone standards and technology
2G	Second Generation of mobile phone standards and technology
3G	Third Generation of mobile phone standards and technology
3GPP	Third Generation Partnership Project
4G	Fourth Generation of mobile phone standards and technology
8PSK	8 Phase Shift Keying
AAA	Authentication, Authorization and Accounting
ARQ	Automatic Repeat reQuest
ASN	Access Service Network
ATM	Asynchronous Transfer Mode
BE	Best Effort
CCID	Congestion Control IDentifier
CDMA	Code Division Multiple Access
CEPT	Conference Europeenne des Postes et Telecommunications
CID	Connection Identifier
CPE	Customer Premises Equipment
CPS	Common Part Sublayer
CS	Convergence Sublayer
CSN	Connectivity Service Network
DAMA	Demand Assignment Multiple Access
DCCP	Datagram Congestion Control Protocol
DSL	Digital Subscriber Line
EAP	Extensible Authentication Protocol
EDGE	Enhanced Data rates for Global Evolution
EPC	Evolved Packet Core
ertPS	Extended Real-Time Polling Service
EUTRAN	Evolved Universal Terrestrial Radio Access Network
FBSS	Fast Base Station Switching
FDD	Frequency Division Duplexing

FEC	Forward Error Correction
FFT	Fast Fourier Transform
GPCS	Generic Packet Convergence Sublayer
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HHO	Hard Handover
HSDPA	High Speed Download Packet Access
HSPA	High Speed Packet Access
HSPA+	Evolved HSPA
HSUPA	High Speed Uplink Packet Access
HVS	Human Visual System
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFFT	Inverse Fast Fourier Transform
IP	Internet Protocol
IPPM	IP Performance Metrics
IPTV	Internet Protocol Television
LAN	Local Area Network
LOS	Line of Sight
LTE	Long Term Evolution
MAC	Medium Access Control
MBWA	Mobile Broadband Wireless Access
MDHO	Macro Diversity Handover
MIB	Management Information Base
MIH	Media Independent Handover
MIMO	Multiple-Input and Multiple-Output
MIP	Mobile IP
MMS	Multimedia Message Service
MOS	Mean Opinion Score
NAP	Network Access Provider
NAT	Network Address Translation
NCMS	Network Control and Management System
NLOS	Non Line of Sight
NRM	Network Reference Model
nrtPS	Non-Real Time Polling Service

NSP	Network Service Provider
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiplexing Access
PDF	Probability Distribution Function
PHY	Physical Layer
PKM	Privacy Key Management
PMP	Point-to-Multipoint
PPP	Point-to-Point Protocol
PSNR	Peak Signal Noise to Ratio
QAM	Quadratic Amplitude Modulation
QoE	Quality of Experience
QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying
RTP	Real-Time Protocol
rtPS	Real-Time Polling Service
SAE	System Architecture Evolution
SAP	Service Access Point
SDU	Service Data Unit
SFID	Service Flow Identifier
SMS	Short Message Service
SNMP	Simple Network Management Protocol
SSIM	Structural Similarity
TCP	Transport Control Protocol
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
TFRC	TCP-Friendly Rate Control
UDP	User Datagram Protocol
UGS	Unsolicited Grant Service
UMTS	Universal Mobile Telecommunications System
VBR	Variable Bit Rate
VoIP	Voice over IP
WAP	Wireless Application Protocol
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

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Introduction

This work presents the analysis of the trade-off cost/benefit of using the WiMAX technlogy to transmiting multimedia applications.

The first section presents the motivation for the work done. The next two sections describe the objectives and author contributions, respectively. The last section shows the thesis organization.

1.1 Motivation

Today almost every person has Internet access, either at home or using mobile devices. In the last years, we have witnessed a change of the Internet contents, which include more and more multimedia applications.

Broadband wired access technologies, such as Digital Subscriber Line (DSL), are well deployed and are able to fulfill the major requirements of almost all multimedia applications. Global System for Mobile Communications (GSM) and High Speed Packet Access (HSPA) are the most well deployed wireless technologies, but they are not enough for the current needs of many multimedia applications, which need high bandwidth, low latency, among other requirements.

As new types of multimedia applications arise, more and more people will use them. Due to the characteristics of these types of applications, the users' demands of the access technology will also become greater. Moreover, today everyone wants to the always connected to the Internet, everywhere.

Worldwide Interoperability for Microwave Access (WiMAX) is a broadband wireless technology based on the IEEE 802.16 standard and aims at enabling the development of wireless broadband services anytime and anywhere. WiMAX can be used in various scenarios such as fixed, portable, nomadic and mobile.

Despite that WiMAX is not yet a widely deployed technology, it is a candidate for the last mile access in both urban and rural areas. Therefore, it is important to assess the capabilities of WiMAX to transmit multimedia applications, as well as, the trade-off between the cost and associated benefits of using the WiMAX technology in these scenarios.

1.2   Objectives

The main objective of this work is to study the WiMAX technology capabilities integrated in an all-IP end-to-end architecture, to support multimedia applications.

Broadband capabilities of WiMAX, associated with the support of different levels of service and mobility, make this technology a strong candidate for last mile access in both urban and rural areas. However, the analysis of the tradeoff cost/benefit of using this technology for both operators and end-users still needs to be addressed. This work aims at studying the feasibility of using the WiMAX technology to support multimedia applications in fixed and mobile scenarios.

The achievement of this challenging objective includes the study, on a real scenario test-bed, of the WiMAX technology performance integrated on an end-to-end IP architecture. Coupled with this technical study, a thorough conceptual analysis of the cost/benefit trade-off of using such a technology when compared with its main competitors, from General Packet Radio Service (GPRS) to Long Term Evolution (LTE), will be targeted.

1.3   Contributions

The author has performed some important contributions to the assessment of WiMAX in nowadays' networks, as described next.

A detailed analysis of Institute of Electrical and Electronics Engineers (IEEE) 802.16 and WiMAX was performed, in order to evaluate the current state of the art of the technology. A unique comparison of WiMAX and its competitors was done. The author performed an overview of the technologies under study and played an important role in the definition of the comparison parameters. Moreover, a clear table comparing the more important technologies was done.

In order to evaluate multimedia applications on WiMAX, the major needs of each type of application were identified. A Fixed WiMAX testbed was configured in order to assess the capabilities of Fixed WiMAX to support VoIP applications. Moreover, the Datagram Congestion Control Protocol (DCCP) with two different congestion control algorithms was tested against the User Datagram Protocol (UDP), in order to evaluation the performance of each one to deliver Voice over IP (VoIP) on Fixed WiMAX.

The Fixed WiMAX testbed was reconfigured in order to show the potential of Fixed WiMAX to support video streaming, taking into account the operator view of the WiMAX channel utilization and cost/benefit of employing different video compression levels in the transmission as well as the

Quality of Experience (QoE) perceived by the end-users.

In order to perform a unique multi-client video streaming evaluation over Mobile WiMAX, a complex Mobile WiMAX testbed encompassing one base station and four Customer Premise Equipments (CPEs) were configured by the author. Moreover, to accomplish this evaluation more correctly, the author has also developed a new evaluation methodology by extending a well-known evaluation framework.

The author also conducted a VoIP evaluation over Mobile WiMAX. To the best of his knowledge, this is the first study on a real WiMAX demonstrator that addresses both the use of different CODECs and scalability, in a scenario with multiple CPEs and simultaneous upstream and downstream traffic in a Mobile WiMAX testbed.

The author has submitted an application to a "Short-Term Scientific Mission" (STSM) of the COST Action IC0703 "Data Traffic Monitoring and Analysis" (TMA). The COST TMA committee approved the application, which enable the author visit to the Converging Networks Laboratory of VTT Technical Research Centre of Finland in Oulu, Finland. The tasks performed in the Mobile WiMAX testbed have been performed in this laboratory. The author contributions were not limited to the scope of this work and he also performed the evaluation of video transmission over TCP. Currently, the COST committee already approved the final results achieved within this STSM and the final report from the author can be found in Appendix E.

In the course of this work three scientific articles were accepted for publication in international conferences, and a couple are planned to be submitted until September. The publications accepted are the following:

V. Bernardo, L.Cordeiro, I. Caramelo, B. Sousa e M. Curado, E. Monteiro, "A Seamless Mobility Scenario for IP over WiMAX", 2nd International Workshop on Future Multimedia Networking - FMN 09, 22-23 June 2009, Coimbra, Portugal

This publication includes some work done by the author within the context of the WEIRD - WiMAX Extension to Isolated Research Data networks - European Project. This initial work was enriched by the technological knowledge about WiMAX that the author obtained during the thesis, which was fundamental for the success of the paper.

Vitor Bernardo, Bruno Sousa, Marilia Curado, "VoIP over WiMAX: Quality of Experience Evaluation", IEEE Symposium on Computers and Communications (ISCC 2009) - 4th IEEE Workshop on multimedia Applications over Wireless Networks, MediaWiN 2009, 5 July 2009, Sousse, Tunisia

This article is an extended version of the VoIP over Fixed WiMAX evaluation presented in this document.

Vitor Bernardo, Kostas Pentikousis, Jarno Pinola, Esa Piri, Marilia Curado, "Multi-client Video Streaming over WirelessMAN-OFDMA", submitted to the 4th ACM Workshop on Performance Monitoring, Measuring and Evaluation of Heterogeneous Wireless and Wired Networks (4th ACM PM2HQ2N 2009), October 26-30, Tenerife, Canary Islands, Spain

Full thesis is available upon e-mail request

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Conclusion

This thesis has addressed the WiMAX capabilities to support multimedia applications in next generation networks. WiMAX is well positioned to be one of the main technologies for Broadband Wireless Access, mainly due to its native quality of service support, long range and high capacity. There are however other drivers not directly related to the technological potential, such as government strategies and the large investments already made by operators, which will influence the solutions that will prevail in 4th Generation networks.

In this context, the work performed started with the analysis of the state-of-the-art technologies in 3rd Generation networks and the candidates for 4th Generation networks, comparing WiMAX and the most challenging competitors. Then, an extensive experimental study concerning the evaluation of WiMAX capabilities to support the most common multimedia applications namely, VoIP and video streaming, was performed on two WiMAX testbeds, one with Fixed WiMAX at the University of Coimbra, and one with Mobile WiMAX at the Converging Networks Laboratory of VTT Technical Research Centre of Finland in Oulu.

The experimental study allowed the quantification of the scalability levels supported by Fixed and Mobile WiMAX for the transmission of multiple VoIP and Video Streaming flows. In order to identify the best approach to obtain the highest advantage from the WiMAX technology in which concerns the support of multimedia applications from a variable number of users, the evaluation of VoIP was done with the most common CODECs, namely, G.711, G.723.1 and G.729.2, which have distinct bandwidth requirements. Following a similar approach, video streaming was also evaluated using videos with different compression levels, ranging from the rather low 32kbps compression rate, up to a variable bit rate encoded video, with 540kbps peak rate.

The evaluation of the WiMAX capabilities to support the VoIP and video streaming applications was performed taking into consideration the commonly used network level parameters, one-way delay and loss rate, and also quality of experience metrics, which depict the user perception about the quality of the communication system. The Mean Opinion Score metric was used to asses the quality

of experience of both VoIP and video streaming, and the Structural Similarity Index metric was used to measure the video streaming quality of experience in a more complete way. This dual assessment approach provides an integrated view of the system performance, being an important contribution that can assist operators on network design and management tasks.

The results obtained in the scenarios tested provided insight on the tradeoffs that Internet Service Providers may establish in order to provide good quality services to the maximum amount of clients. For instance, concerning the video evaluation, the results have shown that by using the CBR-256kbps video, it is possible to guarantee a good quality for twice more concurrent streams than with both CBR-512kbps and VBR versions. Taking these results into consideration, a more conservative compression is able to satisfy a higher number of clients with a reasonable perceived quality. Moreover, from the user perspective, the quality level obtained with the different compression levels is not significantly affected by using a lower compression. Overall, the results have shown that the operators can maximize the number of supported users by deploying mechanisms that adapt the video rate according to the network conditions. Such mechanisms will also improve the overall quality of the videos when there are problems with a link or even when the link has a very limited amount of bandwidth available.

The work presented in this thesis has shown, both in the conceptual comparison between WiMAX and its main competitors, and in the results obtained with the extensive experimental evaluation performed, that Fixed and Mobile WiMAX have strong and competitive capabilities as a Broadband Wireless Access technology for the support of multimedia applications in the next generation communication systems.

It is the opinion of the author, that the future of the WiMAX technology will be directly affected by the implementation on the market in the next couple of years. The first commercial version of LTE is expected to be released in 2012, which means that, at this moment, WiMAX is two years ahead of LTE. However, LTE is part of 3GPP and it will represent a smooth and not very expensive migration for all the companies that have currently 3GPP systems, such as HSDPA.

The WiMAX can really play an important role in a different market, for instance, in markets that only have rudimentary telecommunication access, such as several countries in Africa and South America.

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