Experimental Performance Evaluation of Networked Virtual Reality Services in UMTS Network

Mladen Gorseta*, Igor Cipar* and Dario Mikic**
* HTmobile LLC, Zagreb, Croatia
** Department of Telecommunications, FER, Zagreb, Croatia
mladen.gorseta@htmobile.hr, igor.cipar@htmobile.hr, dario.mikic@fer.hr

Abstract — **The Universal Mobile Telecommunications System (UMTS) represents an evolution in terms of services and data speeds from "second generation" mobile networks, providing a solution for communication between mobile devices and Internet hosts. UMTS has packet switching capabilities and potentially sufficient data rate for accessing advanced Internet services by using a mobile terminal. Advanced multimedia services, such as Networked Virtual Reality (NVR) services with near real-time interactivity requirements, present a good case study to evaluate the performance of a test UMTS network. In this paper we report the measured performance parameters for NVR services in a UMTS test network and determine the capability of the network to support such services. Results are shown for two different NVR applications that required different Quality of Service (QoS) parameters.**

I. INTRODUCTION

Virtual Reality (VR) represents new generation of services, which request development of New Generation of Networks (NGN) [1] with convergence of mobile and broadband networks into one network. The Third Generation Partnership (3GPP) has proposed standards for layered Quality of Service (QoS) architecture to be used in UMTS network [2]. 3GPP specifications define four UMTS QoS classes, which cover broad range of applications, based mainly on delay sensitivity [3].

The Universal Mobile Telecommunications System (UMTS) is new, third generation (3G) network in mobile communications. The UMTS is expected to meet the QoS requirements to provide support for VR services. Networked VR (NVR) services impose certain QoS requirements for network that provides them [1]. Previous research on NVR communication requirements [5] has demonstrated that the second generation of mobile telephony - GSM/GPRS (Global System for Mobile Communication / General Packet Radio Service) - provides insufficient capability to support NVR services. In the above mentioned paper it is concluded that bandwidth and asymmetric link design are sometimes a problem, though high latency, which is more than 1s, is always a service deterioration factor because high delay has high influence on human perception of NVR services.

We used two representative NVR applications, which were selected to analyze "real-time" interactivity and bandwidth parameters of UMTS network. NVR applications have high requirements for underlying network through communication established between server and client. Network QoS is adequately described with bandwidth, delay and jitter values.

A classification of NVR services based on delivery requirements and degree of interactivity that maps to existing UMTS QoS classes is proposed in [4]. They had demonstrated that the end-to-end QoS requirements specified for UMTS satisfy the requirements of VR service model in an emulated network environment.

In this paper we examine test UMTS network in providing capability of QoS requirements of NVR services. We have used two different NVR applications for measuring QoS parameters, which could prove (or disprove) capability of UMTS network in deploying broad range of NVR services. Three basic parameters, bandwidth, delay and jitter were measured and analyzed to determine network capabilities for deploying NVR services [6].

The paper is organized as follows. Section II presents architecture of the UMTS test network. Section III introduces the specific NVR applications used in our experiments. Section IV describes the test UMTS network environment used to conduct the measurements. Section V covers the test procedures and brings the analysis and discussion of results. Conclusion is given in Section VI.

II. UMTS TEST NETWORK ARHITECTURE

An UMTS [7] network consists of three interacting domains: Core Network (CN), UMTS Terrestrial Radio Access Network (UTRAN) and User Equipment (UE) (Fig 1).

The UMTS core network is based on the GSM/GPRS network topology and its main function is to provide the switching, routing, transport, and database functions for user traffic. The core network contains circuit-switched elements such as the Mobile Services Switching Center (MSC), Visitor Location Register (VLR), and gateway MSC (GMSC). It also contains the packet-switched elements SGSN and GGSN. The Equipment Identity Register (EIR), Home Location Register (HLR), and Authentication Center (AuC) support both circuit- and packet-switched data. The Asynchronous Transfer Mode (ATM) is the data transmission method used within the UMTS core network. ATM Adaptation Layer type 2

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(AAL2) handles circuit-switched connections, AAL5 is used for data delivery. The major difference between GSM/GPRS [8] networks and UMTS networks is in the air interface transmission. Time division multiple access (TDMA) and frequency division multiple access (FDMA) are used in GSM/GPRS networks.

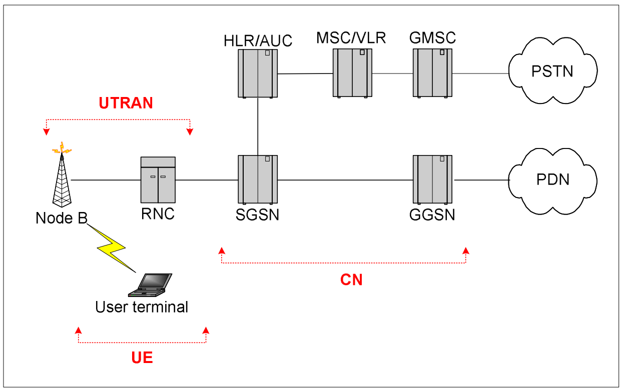

Figure 1. UMTS network architecture

The air interface access method for UMTS networks is wide-band code division multiple access (WCDMA), which has two basic modes of operation: frequency division duplex (FDD) and time division duplex (TDD). This new air interface access method requires a new radio access network (RAN) called the UTMS terrestrial RAN (UTRAN). Two new network elements are introduced in the UTRAN: the radio network controller (RNC) and Node B. The RNC in UMTS networks provides functions equivalent to the base station controller (BSC) functions in GSM/GPRS networks and Node B is equivalent to the base transceiver station (BTS). In this way, the UMTS extends existing GSM and GPRS networks; it enables new services by offering higher data rates and new QoS parameters. Although theoretical maximum date rate in UMTS network is 2 Mbps, currently imposed data rate is 384 kbps. This limitation is inherent to mobile phones, which are unable to support data rates above 384 kbps.

Service network and application layer domains are not in the scope of this paper, thus are not discussed here.

III. NVR APPLICATIONS

Two NVR applications were selected in order to better represent different QoS classes of NVR services, namely, Demy and Medal of Honor. In [4], Demy is classified as single user VR application belonging to streaming QoS class and Medal of Honor is classified as multi-user interactive game belonging to hard real time interactive class.

Demy is a Web-based virtual character [11] with the ability to answer questions typed in English language. To use the application Java support must be installed on Web browser because VRML character is animated by Java applet using Shout3D technology. Demy application is example of singe-user virtual environment, which means that we have interaction between the user and the environment. When Demy is downloaded in a Web browser, virtual character and text box can be seen. Answer consists of two files, one for speech (.wav) and other for lip synchronization (.fba). These files are streamed on the fly when answer is requested.

Medal of Honor is a multi-user 3D network game [10], characterized by high quality 3D graphics that utilize the powerful Quake III engine. In multi-user VEs, multiple users from geographically different locations can communicate and interact through network infrastructure. Communication can have several aspects; and the users can collaborate or interact with each other and with an environment. Requirements on bandwidth of this kind of NVR services depend on number and distribution of users. *Medal of Honor* belongs to first person shooter games (FPS), which are very sensitive on latency requirement [12]. Acceptable value for latency for FPS games is between 100 ms and 200 ms.

IV. TESTBED NETWORK ENVIRONMENT

The network environment used for measurements consists of three parts: Faculty of Electrical Engineering and Computing (FER) intranet, HTmobile intranet and 3G test network. Servers for Demy and Medal of Honor applications are located in a 100 Mbps Ethernet LAN situated at the Department of Telecommunications (FER, Zagreb). The FER LAN is connected to the HTmobile intranet through Internet. The slowest link between two intranets is link between HTmobile and local Internet service provider, 4 Mbps. HTmobile PC is located in HTmobile intranet with bandwidth of 100 Mbps, where delay between mobile terminal and server is minimized. Mobile terminal is connected to network via UMTS radio interface. Connection speed between mobile terminal and rest of network is limited to 384 kbps, because mobile phone can’t support faster connection.

The environment used for measurements is shown in Fig. 2. The following hardware and software have been used:

- **Demy server**: Pentium IV (2.4 GHz, 512 MB RAM), Windows XP professional OS, Apache httpd Server v.1.2.17; Savant Web server; Alicebot.net Server 4.0.
- **Medal of Honor server**: Pentium IV (2.4 GHz, 512 MB RAM, 100 Mbps network), Windows XP professional OS
- **Mobile terminal used for Demy application**: Pentium III, laptop – Siemens (500 MHz, 128 MB RAM) Windows XP OS. Laptop is connected to UMTS mobile phones Siemens U-15
- **Mobile terminal used for Medal of Honor**: Pentium III (1 GHz, 256 MB RAM) Windows 2000 OS. PC is connected to UMTS mobile phones Siemens U-15
- **HTmobile PC**: Pentium IV (2.4 GHz, 512 MB RAM, 100 Mbps network)
- **FER PC**: Pentium IV (2.4 GHz, 512 MB RAM, 100 Mbps network), Windows XP professional OS

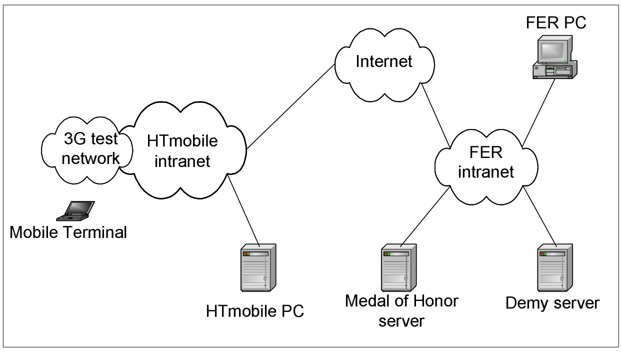

Figure 2. Network environment

V. MEASUREMENTS AND RESULTS

A. Demy application

Measurements of round-trip time (RTT) were performed using standard ping application between UMTS mobile terminal, HTTP server (Demy) and HTmobile PC. Delay is key value to have real-time interactivity in NVR services.

The first set of measurements was performed to determine delay time between UMTS mobile terminal and Demy server localized in FER LAN. Average RTT value was approximately 459 ms (Fig. 3), which is acceptable for Demy application. The second set of measurements was performed to determine RTT between mobile terminal and host situated in HTmobile intranet. Delay in HTmobile intranet is less than 1 ms, which means that delay in the second set of measurements represents delay in radio part of the connection. Delay generated by Internet is difference between the first and the second measured value (approximately 40 ms).

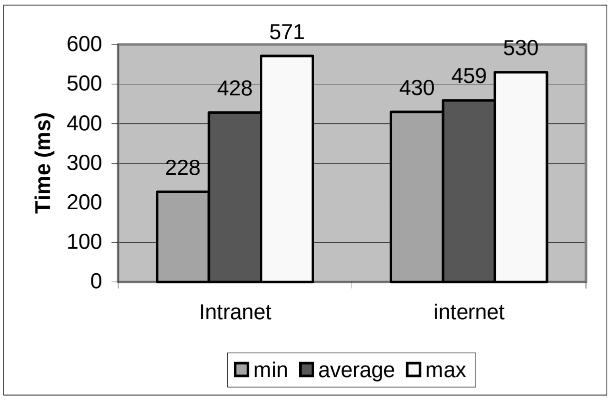

Figure 3. Round-trip time

Delay variation is important for human perception quality of NVR service. We discovered that delay variation has value more than 50 ms, caused by conditions on radio interface.

Second measured value is the time necessary for the virtual character to respond to a question asked by user (Time to answer - TTA). When the Web server receives question, it generates two kinds of files (.wav and .fba) afterwards these files are streamed across Internet and radio link to the end user. Test questions and size of files generated for those questions are shown in Table I.

Average TTA is calculated from log files made with Ethereal (http://www.ethereal.com), which was installed on PC connected to UMTS mobile terminal. Fig. 4 shows the average TTA for Demy application. This result is two times worse than accessing from the Internet, but it is about four times better compared to the GPRS network (results reported in [5]).

TABLE I.
SIZE OF ANSWER FILES

Question	Answer	.fba file [B]	.waw file [kB]
Hello?	Hi there!	90	1.83
How are You?	I'm fine. Thank you.	153	3.48
What do you do?	Human, I talk to the people on the Web. What do you do?	281	6.97

In this case, measurements of throughput show that bandwidth of UMTS network is not limitation for Demy application. The maximal download throughput never came up to maximal available bandwidth, which is 385 kbps. Relatively high TTA is caused by delay and delay variation, which can be major problem in deploying similar NVR services in UMTS environment.

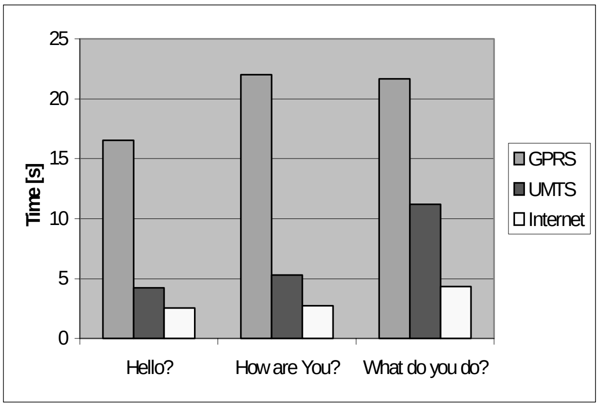

Figure 4. Time to answer

Perception of real-time interactivity in the first two questions is acceptable. In the third question “real-time” interactivity is reduced (TTA is about 11 seconds), but still relatively acceptable.

B. Medal of Honor

The set of measurements was performed to determine the capability of UMTS network to support multi-user 3D game. Dedicated server for Medal of Honor and one user were situated in FER LAN and the other user was connected to the server via UMTS and Internet (Fig. 2).

Throughput is measured with Microsoft management console 2.0 (standard tool for Windows OS) installed on UMTS mobile terminal. Measurements showed that download throughput is about 2200 bytes/s in both directions what is minimum necessary for playing the game (Fig. 5). Measurements of download throughput were concluded that bandwidth of UMTS network completely satisfies requirements of game for normal playing.

Delay is determined by tool integrated in the game, which shows ping time for all connected users. Performed measurements shows that delay between user connected via UMTS and server was approximately 336 ms (Fig. 6) with variation more than 50 ms, which is more than recommended 200 ms for FPS games [12]. Delay between LAN user and server was less than 1 ms.

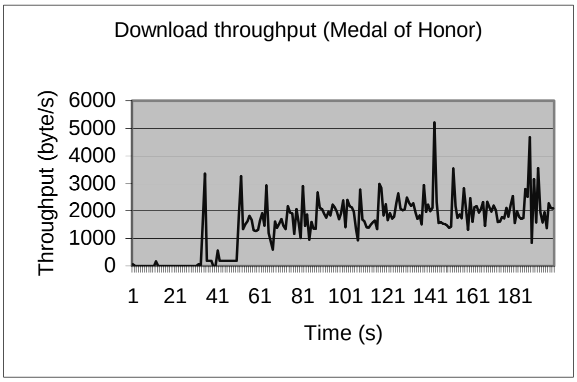

Figure 5. Download throughput of Medal of Honor

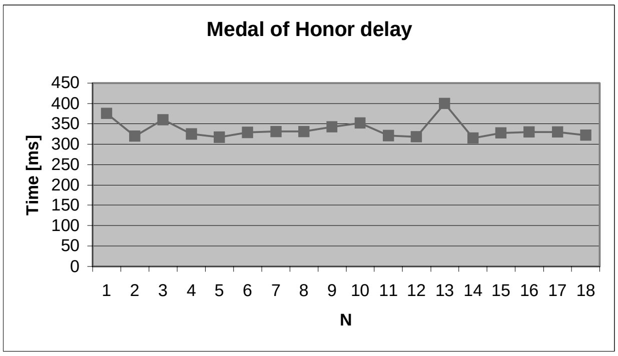

Figure 6. Delay for Medal of Honor

Installation of server into HTmobile intranet could decrease one-way delay for approximately 50 ms. The best way to find out quality of play is to ask users for fair play of game. The user connected via LAN didn't notice any delay. The UMTS user reported that the game is acceptable to play, but sometimes he noticed shaking during continuous walk or continuous shooting, the expression is similar when computer provide insufficient processor power to support game. These appearances are issued by delay variation caused by retransmission of packets. Perception of fair play for both users is acceptable during all game. We concluded that the UMTS network provide narrowly acceptable capability to support FPS games. Measurements show that UMTS could provide capability to support Real time strategy (RTS) games, which are more delay tolerable. For that service type less than 500 ms is acceptable delay.

VI. CONCLUSION

In this paper we evaluated performance of UMTS network to provide support for two diverse NVR applications. The measurements performed on Demy application showed that UMTS network provide capability to support single user interactive VE belonging to streaming QoS class. The second set of measurements showed that capabilities of test UMTS network provide sufficient support for FPS games, despite measured delay that is higher than recommended minimum for this kind of NVR application.

It has been demonstrated that he bandwidth (currently, 384 kbps) provided by the UMTS network meets the requirements of both NVR applications.

Delay still presents a serious problem for deploying near real-time NVR services (RTT is 300-580 ms), and so does jitter, which is unpredictable and impossible to compensate, as it is caused by retransmission of packets on radio link due to the conditions affecting the air interface.

ACKNOWLEDGMENT

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REFERENCES

[1] M. Matijasevic, I. Lovrek, D. Mikic, A. Caric and D. Huljenic, “Designing Bandwidth-Aware Virtual Reality Services for the New Generation Networks”, Proc. 9th Int. Conf. on Telecommunication Systems, Modeling and Analysis, Dallas, TX, March 2001, pp. 84-89

[2] 3GPP TS 22.105, “Services and Service Capabilities”, Release 6, September 2002

[3] 3GPP TS 23.107, “QoS Concept and Architecture”, Release 5, September 2002

[4] L. Skorin-Kapov , D. Mikic, D. Huljenic, “End-to-end QoS for Virtual Reality Services in UMTS”, Proceedings of the 7th International Conference on Telecommunications ConTEL 2003, pp. 337-344, June 11-13 2003, Zagreb, Croatia

[5] I. Perovic, L. Skorin-Kapov, D. Vilendečić, “Performance Evulation of Networked Virtual Reality Services in a GPRS Network”, Proceedings of the 7th International Conference on Telecommunications ConTEL 2003, pp. 359-366, June 11-13 2003, Zagreb, Croatia

[6] K.S. Park and R.V. Kenyon, “Effects of Network Characteristics on Human Performance in a Collaborative Virtual Environment”, Proceedings of IEEE VR `99, pp. 104-111, Houston, TX, March 1999.

[7] H. Holma, A. Toskala, WCDMA for UMTS - Radio Access for Third Generation Mobile Communications, John Wiley & Sons, 2002, ISBN 0-470-84467-1

[8] G. Heine, GPRS Signaling & Protocol Analysis, INACON, 2002, ISBN 1-58053-575-5

[9] L. Skorin-Kapov, D. Vilendecic and D. Mikic, “Experimental Performance Evaluation of Networked Virtual Reality Services”, Proc. of MIPRO, Opatia, Croatia, May 2002, pp. 76-81.

[10] Electronic Arts Web site, Medal of Honor – Allied Assault: http://www.ea.com/eagames/official/moh_alliedassault/home.jsp

[11] I.S. Pandzic and R. Forchheimer (editors), MPEG-4 Facial Animation Framework for the Web and Mobile Platforms in "MPEG-4 Facial Animation - The standard, implementations and applications". John Wiley & Sons, 2002, ISBN 0-470-84465-5.

[12] J. Smed, T. Kaukoranta, H. Hakonen. Aspects of Networking in Multiplayer Computer Games. Proc. of Intl. Conf. on Application And Development of Computer Games in the 21st Century, 2001.