Interoperability and Testing in Broadband Satellite Networks

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Abstract - By combining satellite and terrestrial (wireless) technologies, full coverage and high capacity can be achieved for true broadband services. The interoperability of such diverse networks imposes a number of challenges regarding service provision and management. The end-to-end quality of service (QoS) management implies that features such as service scalability between different networks have to be available. On the other hand, wireless QoS capabilities provide a promising diversity for a wide range of seamless applications. However, differences in QoS properties between both the wired and the wireless applications have a considerable effect on the quality level as well as platform and application dimensions of network interoperability. This paper examines the so-called interoperability requirements in integrated uses of satellite communication technology together with terrestrial (wireless) network technology for seamless delivery of broadband services (using ISABEL and CLIX e-learning applications) in rural and remote areas. This is demonstrated with an example of two educational, real-time and recorded, eLearning services.

I. INTRODUCTION

The satellite communications systems are essential in establishing the global information infrastructure [1]. The satellite community however should consider "the satellite as an integrated part of the global telecommunications infrastructure rather than as an individual entity" [2]. In a related context, another study [6] shows roaming possibilities between satellite and terrestrial networks. The study explains in detail the technical framework requirements to realize a satellite and terrestrial roaming and its advantages to the end user. Accordingly, it highlights that fully proven network components that can make global satellite roaming practical and valuable feature is within the 2.5G and 3G operator's service portfolio. Having this in mind, the author [3][6] predicts that the trend will continue into the 3G networks and multi-standard handsets where data services and especially Internet-based services become increasingly important.

From a more theoretical perspective, Abuelma'atti et al [4] aim to design wireless networked appliances interoperability architecture. In their approach, the interoperability is associated with many operational phases including Coexistence, Internetworking, System Interoperability and End-to-end Interoperability. An OSI-based interoperability architecture for managing hybrid Networks confirms that interoperability could be investigated at various levels of OSI model [5]. For example, coexistence problem caused by the interference of devices that use same frequency and/or end-to-end interoperability issues due to application communication protocol mismatch.

The aim of this paper is to establish the so-called interoperability requirements in integrated uses of satellite communication technology together with terrestrial (wireless) network technology for seamless delivery of the broadband services. This is demonstrated with an example of a satellite-enabled educational service in rural and remote areas (using ISABEL and CLIX e-learning applications) under the $BASE^2$ EU project. The main purpose of the $BASE^2$ service architecture is to facilitate the sustainable provision of integrated tele-education services and applications to a large number of distributed interconnected sites over a variety of telecommunication infrastructures [6]. Figure 1 presents the $BASE^2$ generic network architecture.

In this study, the implemented hybrid broadband network is tested with the aim to identify the interoperability issues and the main challenges in the development and operation of heterogeneous satellite-terrestrial networks.

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Figure 1. Base 2 Generic Satellite and Wireless Network Architecture

The focus is to ensure that the combined wireless technologies meet the QoS resource requirements of demanding real-time applications.

In our BASE^2 interoperability evaluations, we assume that there is no coexistence problem at the physical level. Therefore, our aim in this study is to investigate the problems at application level

II. Description of the Developed Integrated Broadband Learning Systems (DIBLS)

In this section, user interfaces of the two platforms that the BASE^2 DiBLS is composed of are introduced.

A. Asynchronous Tele-education via the CLIX Platform

The CLIX learning platform has been conceived as a classic web application, for which the user needs merely a simple web browser (client) in order to be able to utilize the entire CLIX function range. Program logic and data maintenance are distributed to the server system components, which are not perceptible to the end user.

During the BASE^2 user trials, the asynchronous part of the tele-education process is conducted via the CLIX LMS/LCMS platform. In this mode, the student login's to the CLIX application server located at NCSR premises i.e. http://elearn.dat.demokritos.gr from the tele-education site, after filling in their username and password, provided by NCSR.

For the agrarian sites, the platform is provided in Greek language, while for the maritime community it is provided in English. In addition, the CLIX platform also supports German, French, Italian and Spanish languages.

B. ISABEL Teleclass

The ISABEL application is a group collaboration tool for the Internet (or other IP networks), which uses TCP-UDP/IP protocols (IPv4, IPv6 and dual stack). ISABEL supports the realization of distributed meetings, classrooms, congresses etc by using a service concept which has a very effective management of multipoint configurations [7].

ISABEL application in the BASE^2 trials consist of teacher(s) giving lecture(s) from NCSR facilities to the learners located in remote areas where the ISABEL Teleclass service is used.

The Teleclass service is intended for performing distributed corporate classes. In this mode, there are two roles of interaction with the application: the teacher, who is able to control the floor of the class (by changing the interaction mode: chat mode, presentation mode, questions mode…) and the students, who are only able to interact when the teacher allows them (for example by "raising the hand" to ask a question).

In a Teleclass, there must be at least one control site able to set which site will be the Teacher's site, what sites will be the students' sites and which sites will be hidden. In the BASE^2 case, the control site will be NCSR. The hidden sites are the sites, which are able to participate using a question panel but their audio and video streams are shown by default when activating a new interaction mode. Their video and audio streams are only activated when the teacher gives them the floor using a question panel. The sites which are not hidden are called "enabled sites".

III. Testing Different Link Configurations and Architectures

The test bed of this study is the network developed in the BASE^2 EU project, which designed and deployed a hybrid, satellite- and wireless-based network infrastructure, and learning services to support distance learning for geographically isolated communities. BASE^2 focuses on the empowerment (enabling learning) for members of the agrarian or maritime isolated communities.

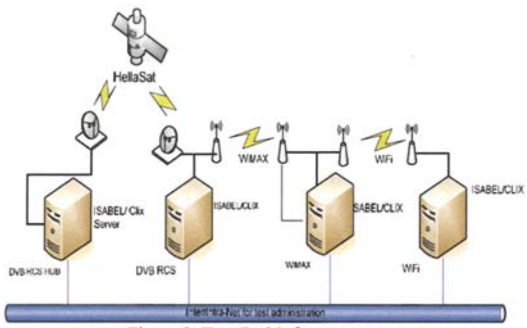

Figure 2. Test Bed Infrastructure

The BASE² project involves the deployment of the service and network infrastructure and a number of trials. Ten agrarian community sites in Greece and two in Cyprus are now active with full network and service deployment. A number of different network testing scenarios have been carried out. These tests aim to study connectivity-related issues for the various architectural scenarios of BASE² link configurations. This includes Satellite only, Satellite and WiMax and finally Satellite, WiMax and WiFi as shown in Figure 2.

The four test machines located close to the HUB station, the DVB-RCS terminal and the intermediate WiMax/WiFi nodes are connected to the Inter/Intra-net via a separate interface so that no extra management traffic influences the satellite/WiMax/WiFi link measurements. In actual implementation of network, all machines behind DVB-RCS machine are connected through ISABEL flows server. The ISABEL flow server machines connect to ISABEL server in NCSR through public internet. The CLIX server is also at NCSR which connects through public internet to the DVB-RCS hub which connects the user behind DVB-RCS terminals.

IV. Measurement tools and Methodology

In order to verify that the BASE² infrastructure is suitable for the eLearning applications, CLIX and ISABEL, we have chosen to use the following tools and methodology.

A. CLIX

TCP is the underlying transport protocol used by CLIX. As long as there is two-way IP connectivity, TCP will provide reliable communication. What this test should provide is an indication of how fast/smooth CLIX will run on top of the examined link.

Two main aspects of CLIX's communication are the maximum and sustained TCP throughput, which are measured using httpperf [8]. Each test was run five times and the mean and the standard deviation were calculated and reported. The results can be visualized with gnuplot.

B. ISABEL

UDP and IP Multicast are the main transport protocols used by ISABEL. From the application point of view, IP Multicast packets are treated much like UDP packets. However, IP Multicast routing is very different from plain IPv4 routing and often causes problems in real-world scenarios since it is not thoroughly tested and implemented. The setup of IP Multicast routing is beyond the scope of this test plan. Another issue is the way technologies like WiMAX and Wi-Fi treat multicast/broadcast packets. Unlike in a wired environment (i.e. Ethernet), the reception and therefore the maximum bandwidth available to reach a node may vary significantly. In order to reach all nodes in a cell, the more robust but also less efficient modulation is used, which inherently limits the available bandwidth.

For Wi-Fi this limit can be as low as 1Mbps for 802.11b and 6Mbps for 802.11a/g. Since BASE² uses 802.11g hardware only and our expected total multicast bandwidth requirements are less than 2Mbps, this should not be an issue.

The 802.16d specs (fixed WiMAX) however limit multicast traffic to 64kbps [9]. It is essentially treated like management traffic.

C. NETAnalyzer

Our project partner FOKUS has developed a tool called NETAnalyzer, which uses mgen at its core to perform the actual UDP performance measurements. The mgen is a well-accepted tool to generate unicast datagram flows for a given bandwidth at a given frame size. It can be used to measure loss, jitter, latency and throughput.

A number of perl and shell scripts have been written to facilitate mgen scripts generation from templates in order to automate test with various traffic patterns. This is done by synchronizing the clocks between the two test machines and correcting for (linear) clock drifting during the tests. This tool is used to measure loss, jitter, latency and throughput in order to verify that the traffic generated by ISABEL can be transmitted across the BASE² infrastructure.

V. RESULTS

Extensive tests were performed in order to assess the performance of the BASE² network infrastructure, in meeting the QoS requirements of the eLearning applications. Interoperability requirements of such networks as well as methodological issues and best practice (lessons learned) in testing of hybrid networks are discussed below.

A. TCP Measurements

Native TCP performs rather poorly over links with long RTTs (long fat pipe problem). Satellite links are a very good example. The performance limitations are caused by the TCP flow control mechanisms (i.e. slow start, window size limitations and congestion control).

The main limiting factor is the standard TCP window size limit of 64kBytes. Assuming an RTT of about 600ms, the maximum sustained throughput is capped at about 110Kbps. The current maximum window size to be utilized is controlled by the TCP congestion avoidance algorithm. They, too, are often RTT driven. The classic 'Reno' is a good example.

Modern TCP stacks usually support Window Scaling, which allows the TCP window to grow exponentially to a maximum of 1GByte. A number of less RTT-dependent (i.e. Vegas) or even satellite-optimized (i.e. Hybla) congestion avoidance algorithms have been proposed, but are not yet widely used.

Also, since slow start is dependent on the RTT, it takes about 2-3 seconds for a TCP connection to

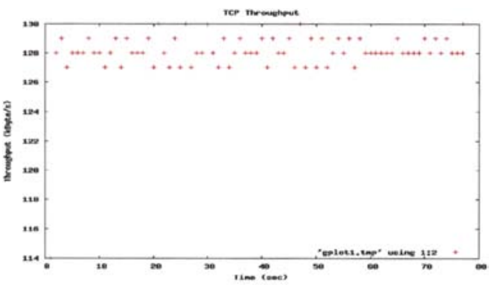

Figure 3. TCP Throughput HAI hub station (PEP enabled)

reach its maximum throughput. Therefore, short transfers, for example HTTP transactions, suffer from a significant drop in throughput. Similar limitations apply to the recovery after packet loss or congestion.

Figure 3 shows the typical TCP throughput for HAI DVB-RCS hub with the PEP enabled. The bandwidth limit of about 120kByte/s is configured at the hub station. The slow start effect is almost eliminated and the throughput is very constant.

B. UDP Measurements

To analyze the datagram forwarding behaviour, 'mgen' was used to generate UDP traffic across the various links. The mgen scenarios used have been modelled after actual ISABEL traffic pattern. On the forward channel, 950kbps are used for the video stream while 96kbps are used for the audio stream. On the return channel, only 96kbps audio stream is sent. In order to measure accurate latency times, the clocks on the two test machines were synchronized using the NTP protocol before the test was carried out. After the test, the clocks were synchronized again and a possible (linear) drift was corrected for. This functionality is part of the NetAnalyzer package as developed by FOKUS.

The measurements show that the main impact in terms of packet trip time and jitter is caused by the satellite links and the WiMAX connection. The impact of Wi-Fi is within the tolerance band. We present here the graphical summary of the measurements using the HAI DVB-RCS platform with CRA turned on in connection with WiMAX and Wi-Fi.

As expected, the guaranteed nature of link provided by the HAI platform yields cleaner results. There is no packet loss and the jitter is 25ms, which is very low for a shared satellite channel.

Figures 4 and 5 show that on an idle link, the loss is negligible and, the trip time is constant, therefore the inter-arrival jitter is very low. The forward and return channels of a DVB-RCS system have very different characteristics, especially concerning the jitter.

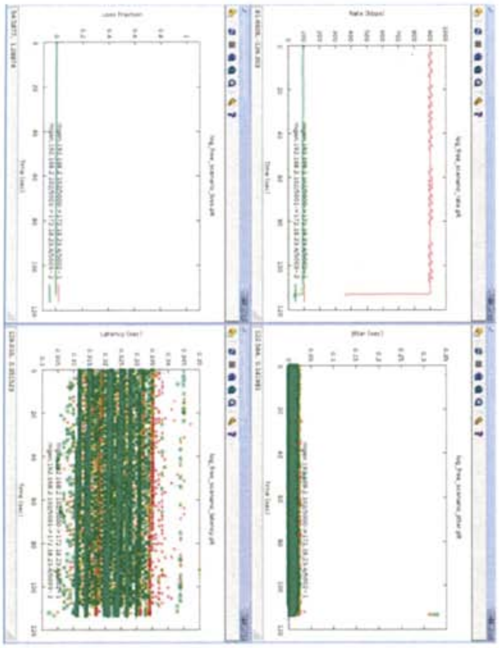

Figure 4. DVB-RCS: HUB-to-SIT UDP Results

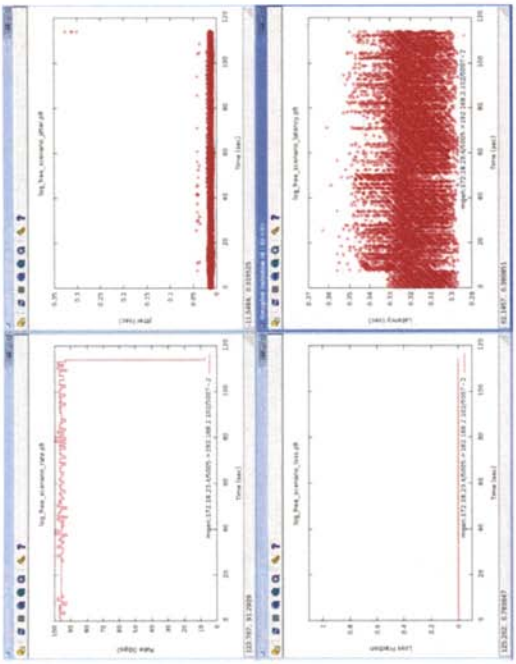

Figure 5. DVB-RCS: SIT-to-HUB UDP Results

VI. CONCLUSIONS

Terrestrial services, like WiMax IEEE802.16 can transport and deliver IP data symmetrically in both directions. Round trip time is around 20-40 ms between sector controller and subscriber station. The maximum throughput is around 23Mbps in both directions and the channel size does not matter with regards to broadband channel requirements.

Satellite services, such as DVB-RCS, do have a substantial round trip time of approximately 640 to 680ms due to the speed of light when communicating over the geostationary satellite Hellas-Sat 2 on 39 degrees East. Since RCS is a highly asymmetric service (large Mbps-sized bandwidth on downlink and some tens or hundreds of kbps throughput on the individual uplink), broadband requirements can be met when delivering through downlink towards the target area. Additionally, by introducing a clever traffic prioritization and carrier management on the return channel, the jitter of the round trip time has been minimized and throughput numbers have been optimized at the same time.

Finally, a synoptic review of testing strategies and methods, suitable for interoperability testing of hybrid networks is presented, based on the findings of the network testing performed on the BASE^2 network.

ACKNOWLEDGMENT

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