A Ka/Ku BAND INTEGRATED SATELLITE NETWORK PLATFORM FOR EXPERIMENTAL MEASUREMENTS AND SERVICES: THE CNIT EXPERIENCE

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Abstract. The paper presents the main characteristics of the CNIT satellite network platform. The Ka- and Ku-band segments are briefly described, international interconnections are highlighted, and the main services (Teledoc2, distributed measurements and laboratories) are sketched. Some exemplary measurements results on TCP performance comparisons are also presented.

1. Introduction

Networks and commercial service offerings in Ka Band have started to be deployed since a couple of years. In this context, it is now possible to test a number of applications and protocols on-line on the real systems in operation.
The National Consortium for Telecommunications (CNIT) has deployed and is currently operating a Ka band network that comprises 18 earth stations all over Italy, on the HOT BIRD™ 6 (HB6) satellite. The stations' number will be increased to 24 within a few months. The network is operating over the Skyplex platform, managed by Eutelsat. The Skyplex Ka-band terminal can receive a downlink stream of up to 38 Mbps. This stream is assembled on board the HB6 satellite from as many as 6 uplink carriers, each with a net bit rate of approximately 6 Mbps, or 18 uplink carriers, each with a net bit rate of approx 2 Mbps. The CNIT network is implemented on a shared 2 Mbps uplink. Skyplex can be operated in either continuous (SCPC) or burst (TDMA) mode, depending on the traffic pattern. HB6 has 4 uplink European regions. CNIT is operating on the Italian spot; however, it is worth noting that this satellite system also enables pan-European broadcast diffusion, due to the downlink Ka coverage of HB6. At the network layer, IP is adopted, with multicast capability.
In order to increase its coverage and to allow reaching users with simple inexpensive terminals, the network has been complemented with a Ku part, provided by Aersat, which implements DVB-IP "one-way" broadcasting. This is based on a "receive-only" Ku star-shaped network with a centralized hub. The flows that are intended to be replicated from the CNIT Ka network reach the hub via a receive-only Ka earth station. The satellite adopted for Ku broadcasting is Eutelsat's W3, positioned at 7° E.
The integrated satellite network is currently used by CNIT for two main purposes. The first one is multicasting Teledoc2 live interactive lectures. Teledoc2 is a project, funded by the Italian Ministry of Education, University and Research (MIUR), whose goal has been the enhancement of multimedia courses (about 30 of which already prepared during a previous edition of the project) on all areas of Telecommunications for PhD students in Information and Communications Technology, and their live IP multicasting over the CNIT network [1]. The Ku extension adds a challenge to this task, as there is a mismatch between the

transmission speeds over the two network segments: audio/video MPEG2 flows are transmitted at 384 kbps on the Ka band, whereas the current Ku bandwidth is tailored for a service at 256 kbps. The flows are therefore trans-coded (together with the still images of PowerPoint slides) at the hub before broadcasting.
The second main experimental application regards testing of various TCP protocol modifications and enhancements on a real operating network. In particular, the Linux Kernel patches of TCP Westwood+, TCP Peach and CK-STP satellite transport protocols, already tested in an emulated setting [2], in addition to TCP NewReno, are available at various CNIT sites and will be used for performance measurements and comparison under different operating conditions.
Experiments with the interconnection of remote laboratory equipment, which is available in a rich hardware and software environment at the CNIT Laboratory for Multimedia Communications in Naples, are currently being planned.
The present paper reports the detailed description of the integrated Ka/Ku satellite network, and highlights the measurement setting for experiments to be performed on both the real-time lecture service and the TCP testing set-up.

2. The Ka-Band Network

The main Ka Band CNIT network is designed to provide high-speed satellite connections, capable of supporting advanced telecommunication services, based on high quality audio, video and data transmission, to be integrated via web interfaces. The realization of the network has been carried on mainly within the MIUR (Italian Ministry of Education, University and Research) funded projects Formsat and Didanet. Within the latter, a Ku distribution segment has also been implemented, which will be described in the next Section.
The overall satellite infrastructure includes:

- A core satellite platform, aimed at the delivery and reception of multimedia flows (as in the Teledoc2 project) among the main CNIT sites (including all CNIT locations in southern Italy, to which the Formsat and Didanet projects were dedicated), with meshed topology, operating in Ka band (20-30 GHz);
- A satellite distribution network, with star topology, that reaches all sites not currently equipped with the Ka receivers, as well as a number of sites in Europe and in the Mediterranean area (North Africa and Middle East), requiring only low cost Ku receivers and DVB-IP boards;
- A hub for the interconnection between the two networks (currently located in Turin), which receives the contributions from a Service Centre (currently located in Naples); the latter has also the function of managing node for the storage and distribution of multimedia contents.

In the SkyplexData platform provided by Eutelsat (Fig. 1), some of whose technical characteristics were anticipated in the Introduction, the DVB-S stream [3] is generated on-board the satellite with the contributions at 2 or 6 Mbps, coming from a number of Service Centres that operate in TDMA (Time Division Multiple Access) or SCPC (Single Channel Per Carrier). There is no earth station serving as unique Service Centre, to which all contributions should be directed to form a DVB-S flow, but there is rather a sort of distributed Service Centre, over the Principal Sites: in this way, the centralization of bandwidth resources and the use of costly terrestrial interconnections are avoided. Each content provider (such as CNIT) can create its own satellite network and operate in complete autonomy. Thus, the architecture adopts satellites capable of demodulating the contributions received from the Service Centres and on-board multiplexing (hence the term Sky-Plex) them within a DVB IP flow.

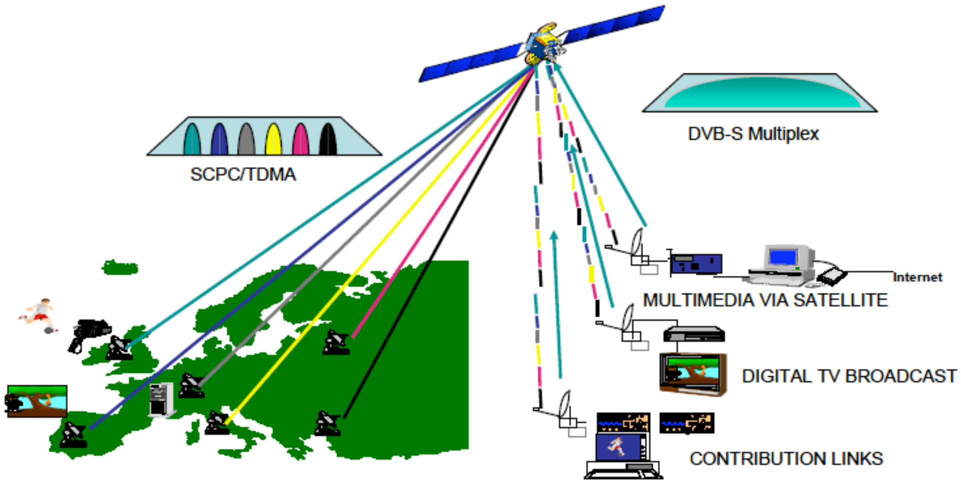

Fig. 1. SkyplexData system architecture.

The multiplexed signal is transmitted towards scalable earth terminals (i.e., operating as receivers-transmitters or as receive-only devices), which are composed by an outdoor unit, interconnected in L band to the indoor unit. The latter demodulates the DVB IP flow and feeds it to a network server via an Ethernet interface. Fig. 2 shows the scheme of a possible two-way terminal. The figure highlights the possibility, which has been adopted in our implementation, of switching to a simple set-top box unit, should the terminal be used as receive-only. In this way, the Skyplex unit can be switched off, in order to avoid the waste of a data slot (44 kbps), which would be anyway required for signaling, whenever the terminal must have the capability of transmitting. By means of an on-line management interface, one can configure one's own portion of the global Skyplex data network, by activating for transmission only the earth station that really need to be, and providing them for on-demand use also the up-link slots that would otherwise have been unnecessarily occupied by the receive-only terminals.

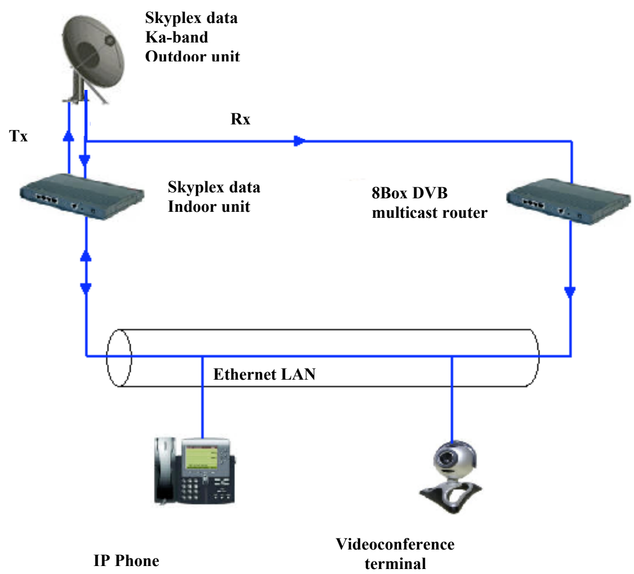

Fig. 2. User terminal general architecture.

2.1. Skyplex Payload Structure

One of the most innovative aspects of the described satellite system is represented by the integration of a regenerative satellite with a transparent DVB-S subsystem.
The on-board switching functions provided by the Skyplex subsystem collect all single low-rates MPEG-2 transport streams (TS) and build a single MPEG-2 TS, broadcasted by a standard DVB-S signal. The multiplexing scheme is reported in figure 3.

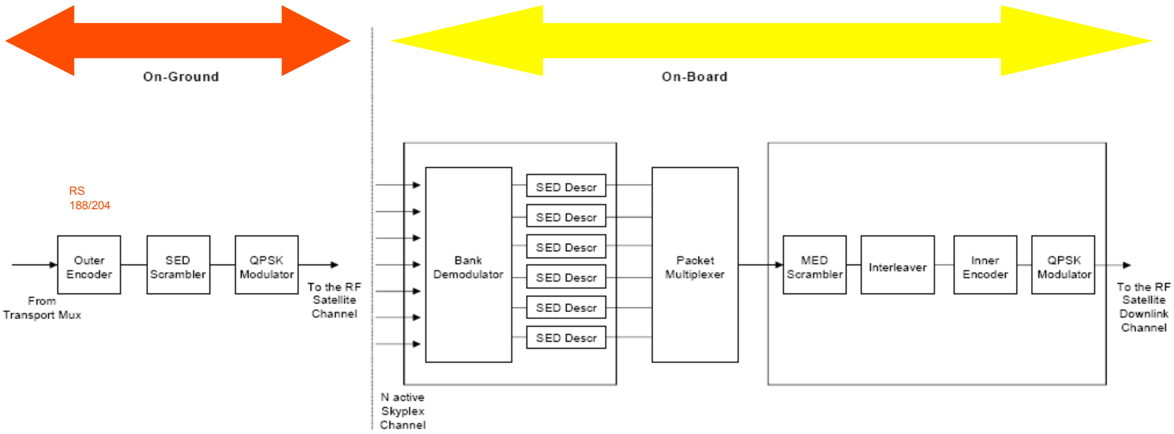

Fig. 3. Skyplex MPEG-2 on-board multiplexing.

Each Ka earth terminal aggregates the outbound MPEG-2 traffic within a single TS, which it then encodes with the outer (DVB-S standard) outer decoder, implementing Reed Solomon (188, 204).
The bit-stream is then scrambled with a Short Energy Dispersal (SED) algorithm, before modulation and transmission on the up-link Ka channel. The multiple access scheme is MF-TDMA with a two level framing structure: a base up-link frame, consisting of 48 DVB packets, shared among 6 user stations, and a super-frame of 8 up-link frames, defining the maximum population of 48 user stations. Each active earth station is given a pre-allocated burst (or slot) per superframe, resulting in 44 kbps (2112 kbps / 48 allocable slots).
The received bursts are demodulated on-board. Each uplink stream is then passed through a SED descrambler, obtaining the users streams after the outer encoding. A packet multiplexer creates a single down-link TS, before completing the DVB-S compliant scrambling, interleaving and coding. The MED (Modified Energy Dispersal) algorithm is adopted to obtain full DVB-S compliance in the re-encoding process. The resulting signal is transmitted on the down-link channel.

2.2. Coverage

Figs. 3 and 4 represent the footprins of HB6 for the up- and down-link, respectively. It can be noted that the satellite indeed provides European coverage. As regards the up-link, this comes at the expense of leasing bandwidth over multiple spots; however, the down-link coverage has been indeed used for the interconnection of the CNIT satellite network to the satellite platform of SatNEx [4], a European Network of Excellence (NoE) with 22 participant institutions among the major scientific research players in satellite communications, of which CNIT is a partner.

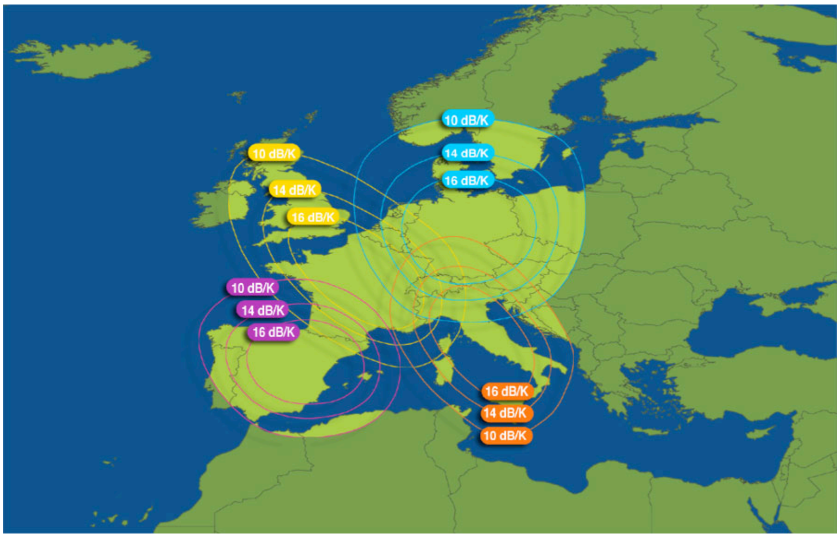

Fig. 3. Up-link Skyplex footprint.

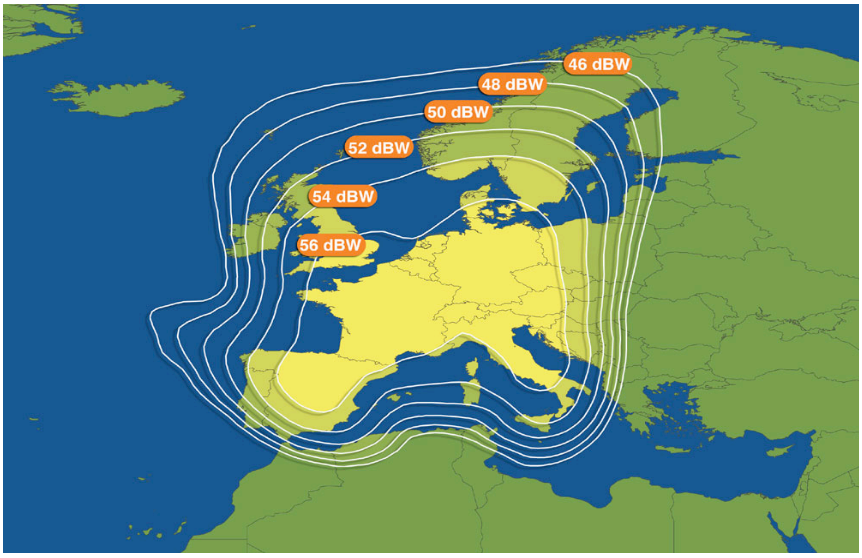

Fig. 4. Down-link Skyplex footprint.

3. The Ku-Band Network

The Ku-band network segment, whose service is provided by Aersat S.p.A., is based on receive-only technology, with a star architecture, organized with a central hub. The IP multicast flows (as no return channel is currently adopted, only multicast connections on UDP and no TCP flows are being transmitted on the Ku segment) reach the hub via a Ka-band receive-only station, which is located at the Skylogic Operating Centre in Turin. After transcoding, they are transferred to the multicast hub for transmission to W3. The Ka receiving station is equipped with antenna (Patriot 1-m Ka-Band Broadband Microterminal), 20-GHz phase-locked LNB with internal reference (Newtec NTC/2506/lx), and IP router (IPricot IPR-S1000). DVB-S PCI boards (Hauppage WinTV NEXUS-s) are adopted in the Ku receiving terminals to provide the PC with a DVB-IP interface. The overall architecture is depicted schematically in Fig. 5.

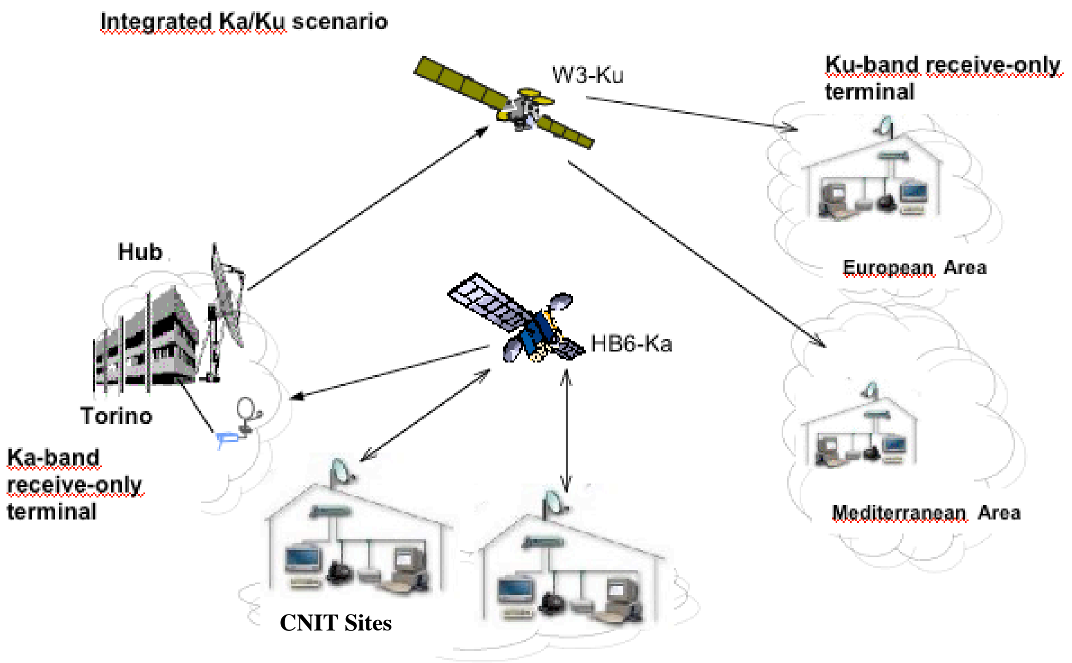

Fig. 5. Integrated Ka/Ku platform.

The coverage of W3 is illustrated in Fig. 6, as regards the European and Middle East areas, respectively.

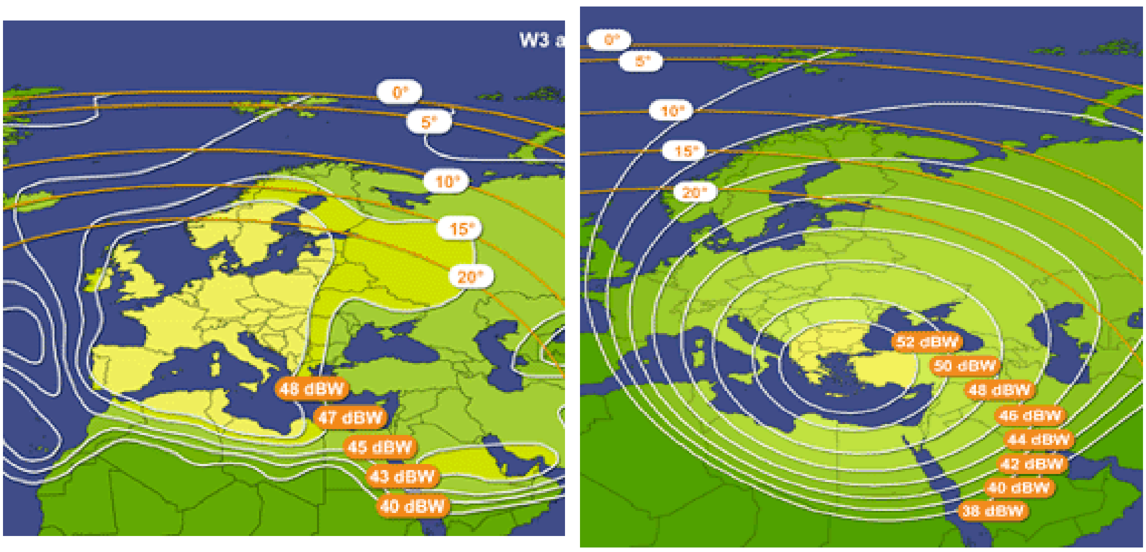

Fig. 6. W3 down-link footprints.

A similar scenario is being developed by the SatNEx NoE, where a hub in the Fraunhofer FOKUS Institute in Bonn, Germany, will deliver services to the other 21 European partners, by using Eutelsat's W6 satellite. The hub is reached from the CNIT network via Ka band, as mentioned in Subsection 2.2.

4. Measurement Testbeds

On the Ka-band network, the relevant transmission and transport performance and parameters are evaluated through a series of analysis tools. The instantaneous allocated bandwidth, the Burst Time Plan and possible alarms are obtained from the Network Operator's NCC (Network Control Center) through the satellite system software.
Historical logging and metering is performed locally on one of the CNIT sites; data are then merged with those obtained from network and transport layers, collected from all involved CNIT sites (Fig. 7).

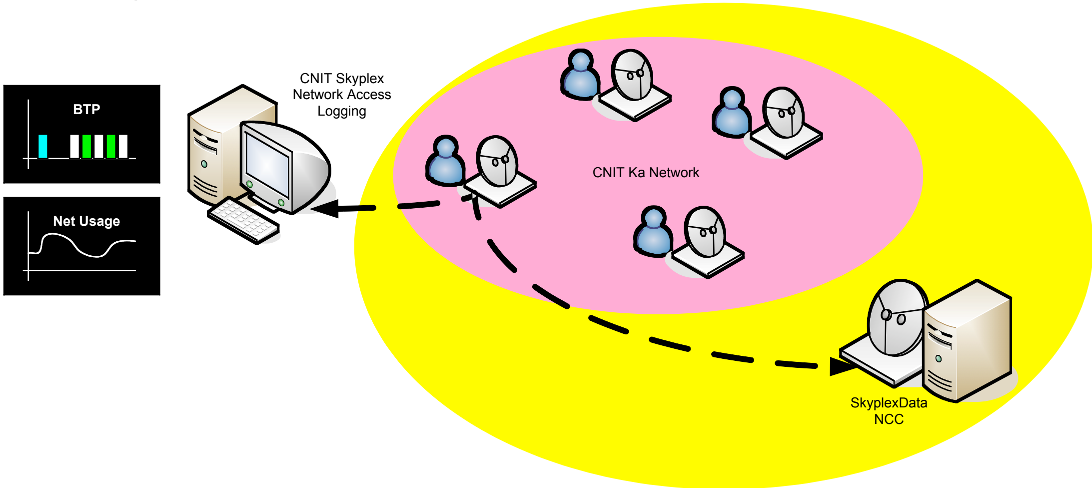

Fig. 7. Ka-band network monitoring and measurement system.

The National Laboratory for Multimedia Communications in Naples has available a large number of hardware and software tools for tele-measurements and for the interconnection of distributed cooperative laboratories, also in the satellite scenario. In particular, we are currently using, in cooperation with ISTI-CNR in Pisa, where a connection is active with the CNIT Ka-band network, TCP experimental platforms over the Linux Kernel and some measurement tools to test and compare the performance of various TCP implementations over the real satellite channel. In a short-term perspective, measurements will be performed also over Wireless LAN (IEEE 802.11) platforms, in both infrastructure and ad-hoc configurations, interconnected via satellite.
By using this set up, some initial measurements have been performed, in order to compare different TCP implementations and TCP modifications on the real satellite channel. Examples of some throughput (actually, goodput) measurements are reported in Figs. 8-10. The TCP traces have been obtained by means of *tcpdump* and processed with *tcptrace*. Each point represents the throughput, averaged over a 10 s window, for TCP NewReno [5] and Westwood [6], respectively, as implemented in the Linux Kernel 2.6.8 (for Intel single processor architecture). The results presented where obtained under similar conditions as a more complete measurement campaign conducted by ISTI-CNR [7]. In [7], the overall round-trip-time (RTT) on the CNIT Skyplex network between Pisa and Naples has been estimated by means of the *mtr* diagnostic tool, giving a minimum of 620 ms and an average of 840 ms. The nominal overall bandwidth is 2 Mpbs; however, the MAC dynamically allocates the bandwidth to the stations. No precise monitoring of the instantaneous bandwidth seen by the transmitting station has been done so far. In our measurements, the default TCP buffers of the Linux kernel (64 Kbytes) have not been modified to match the bandwidth delay product. Therefore, the throughput behaviour tends to be dominated by the sender buffer length. Though still in a more qualitative way, the results confirm, in a scaled version, the ones previously obtained on an emulation of the satellite channel performed in the Lab [2]: the

channel utilization increases with the number of connections, and the best compromise between overall and individual throughput is obtained in the case of 5 active connections. The values obtained from the real system are in fact scaled with respect to those provided by the emulated channel, owing to the effect of the dynamic bandwidth allocation.

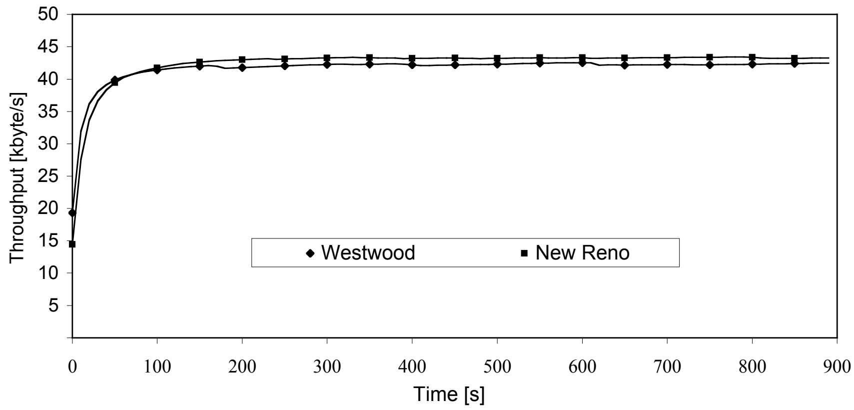

Fig. 8. Throughput with 1 connection.

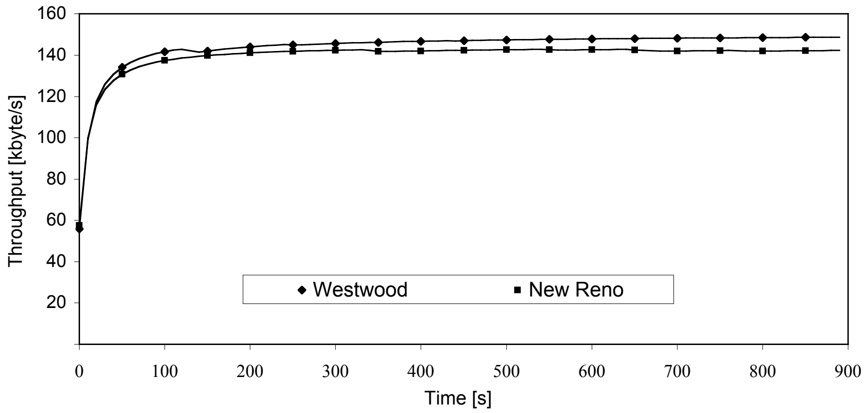

Fig. 9. Overall throughput with 5 active connections.

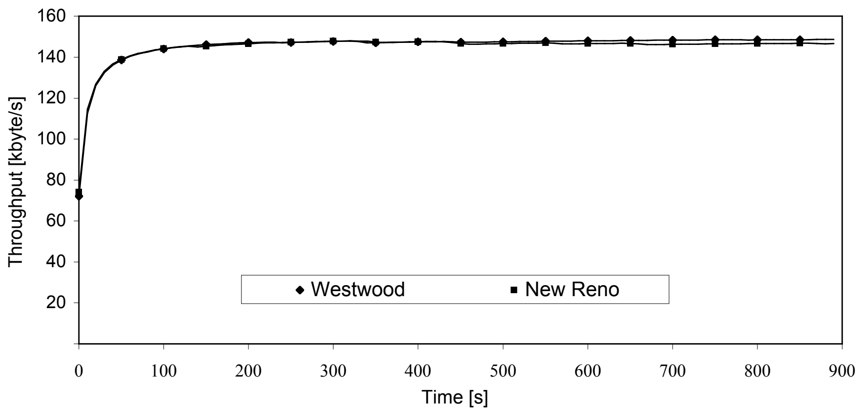

Fig. 10. Overall throughput with 10 active connections.

A more thorough measurement campaign is currently being planned, both as regards TCP performance comparisons and the evaluation of the quality of Teledoc2 lectures, including also the Ku segment.

5. Conclusions

The main characteristics of the satellite network developed by CNIT for its own connectivity services and experimental activity have been outlined in the paper. The network includes a Ka band part, over a regenerative payload, operated in Skyplex mode, and a broadcast Ku part. It is entirely IP-based, with multicast capability. Its main use so far has been in the live transmission of Teledoc2 lectures [1]. Experiments are being planned to conduct measurements, to provide services to the SatNEx community, to foster the use of IPv6, and to interconnect distributed laboratory equipment.

Acknowledgment

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