Accepted Manuscript

Improvement of Ka-band satellite link availability for real-time IP-based video contribution

G. Berretta, P. Dvorak, M. Luglio, L. Luini, C. Riva, C. Roseti, F. Zampognaro

PII: S2405-9595(16)30144-8
DOI: http://dx.doi.org/10.1016/j.icte.2017.04.001
Reference: ICTE 79

To appear in: *ICT Express*

Received date: 7 September 2016
Accepted date: 12 April 2017

ICT Express
Information & Communications Technology

Improvement of Ka-band satellite link availability for real-time IP-based video contribution

G. Berretta[1], P. Dvorak[2] , M. Luglio[3], L. Luini[4], C. Riva[4], C. Roseti[3] and F. Zampognaro[3*]

[1] DBW Communications, via G. Pisanelli 4, Rome, Italy (e-mail: g.berretta@dbwcommunications.it)
[2] Czech Technical University in Prague, Technicka 2, Prague, Czech Republic (e-mail: p.dvorak@upol.cz)
[3] University of Rome Tor Vergata Via del Politecnico 1, Rome, Italy (luglio|roseti|zampognaro@ing.uniroma2.it)
[4] Politecnico di Milano, Piazza L. Da Vinci 32, Milan, Italy (carlo.riva|lorenzo.luini@polimi.it)

[*] Corresponding author. Authors in alphabetical order.

ABSTRACT

New High Throughput Satellite (HTS) systems allow high throughput IP uplinks/contribution at Ka-band frequencies for relatively lower costs when compared to broadcasting satellite uplinks at Ku band. This technology offers an advantage for live video contribution from remote areas, where the terrestrial infrastructure may not be adequate. On the other hand, the Ka-band is more subject to impairments due to rain or bad weather. This paper addresses the target system specification and provides an optimized approach for the transmission of IP-based video flows through HTS commercial services operating at Ka-band frequencies. In particular, the focus of this study is on the service requirements and the propagation analysis that provide a reference architecture to improve the overall link availability. The approach proposed herein leads to the introduction of a new concept of live service contribution using pairs of small satellite antennas and cheap satellite terminals.

Index Terms: HTS, IP video streaming, Ka-band, network availability, propagation.

I. INTRODUCTION

This study aims to identify and evaluate the most suitable solution for the transmission of high-quality live video flows gathered from a large territory. This need is associated with a market-driven service aimed at offering live coverage of sport events of minor leagues, which require reliable transmission capability across the Italian national territory. The goal is to provide a continuous transmission (few hours every week) of video in High Definition (HD) quality at 4 to 6 Mbit/s.

With the current availability of High Throughput Satellite (HTS) platforms operating at Ka-band frequencies over Europe [1], it is possible to achieve high-rate (up to 20 Mbit/s) uplinks through fixed Very Small Aperture Satellite Terminals (VSATs) [2]. This is paired with a cost per bit lower than classical Ku-band OB-Van (Outside Broadcasting - Van vehicle) satellite transmissions (reference case for Premier Leagues and major events), owing to bandwidth on demand and traffic shaping [3].

The need for using cheap satellite links on demand, coupled with unavailability of adequate cabled or wireless high throughput terrestrial systems (e.g., where LTE [4] or ad-hoc hybrid networks are not available [5]), makes the satellite transmission using fixed terminals and HTS systems the most cost-effective technology for lower budget sport leagues. The possibility of using low cost commercial off-the-shelf (COTS) fixed satellite terminals and the use of Ka-band implies cost savings with respect to Ku-band.

Nevertheless, the increased criticality associated with operational frequencies in the Ka-band and consumer equipment calls for a more accurate analysis, of architecture and propagation level, in order to identify solutions useful for supporting such a service. In fact, for instance, rain and issues associated with satellite interconnection with terrestrial networks, in past tests on the field and in the laboratory, severely compromise service continuity.

To mitigate propagation impairments, COTS modems implement Adaptive Coding and Modulation (ACM) on the return link so that, in the presence of weather attenuations, stronger coding and modulation can be used (at the cost of lowering the available output rate).

As introduced in [6], the feasibility of using HTS platforms to implement such recently identified services was investigated based on previous trials performed. The scope of this study is to offer a theoretical analysis of the link availability suitable for live video contribution, identifying a possible configuration and the expected performance of the newly defined architecture. The outcomes of this study will be used to configure real installations in some sites identified for a follow-up pilot project.

II. SYSTEM MODEL AND METHODS

The identification of the telecommunication model that is to be used as a reference in the remainder of the paper is based on the simplified transmission chain depicted in Fig. 1. The target service is the transmission, in real-time, of video contributions from a remote area (video camera with SDI interface), through the HTS platform using Ka-band to a collection center (where the video is processed and distributed to Internet clients through a Web platform).

The goal is to achieve uninterrupted video contribution during live events, i.e., to avoid, for instance, video stream freezes due to the live nature of the events, which can compromise service quality. The continuity of the video stream is associated with multiple factors at different layers associated to the OSI stack. For instance, failure can occur at the application layer (encoder implementation), at the transport layer or the network layer (gateway, buffer overflow, protocols robustness), and at lower layers associated with the satellite technology (air interface – MAC and physical layer –, modems, hardware). In a satellite system, the air interface is typically considered the “weak-link” in terms of availability and therefore adequately protected (e.g., using Forward Error Correction, FEC, and ACM). Nonetheless, these measures can have an indirect effect on transport and application layers, for the proposed live video delivery system. This aspect is clarified in the next section.

A. Problem identification and preconditions

For the proposed application, the continuity of the video stream requires adequate available channel capacity (at network layer), which is affected by lower layers operations (specifically ACM). This creates a non-trivial relation among different layers of the stack.

In summary, the key factors that will affect the system performance, the analysis of which are presented herein, are mainly: i) the expected attenuation values at Ka-band frequencies when using commercial equipment for the video IP uplink (e.g., typically a 75 cm antenna dish with a 3 Watt TX unit); ii) the modem response to these (ACM) in terms of offered network throughput.

In order to estimate tropospheric attenuation at Ka band frequencies, ITU-R recommendations have been used, specifically considering the derivation of worst-month statistics [8]. To provide some general figures based on the propagation measurements collected at Spino d’Adda, during the ITALSAT propagation experiment (link elevation of 37.7°) [9], the attenuation due to gases and clouds for a system availability of 99.99% is approximately 0.7 dB and 1 dB, respectively, while the fade caused by rain for the same availability level is around 15 dB.

Strong attenuations experienced by the modem (through feedback to the Gateway) will cause a reduction in the data rate, which occurs by switching to another carrier (with lower Symbol Rate) and a more robust coding, as reported in Table 1. This table is extracted from official Eutelsat documentation [10] and includes ranges and gaps between intervals (due to hysteresis) on the ACM process and possible multiple coding setup for the same carrier. The consequence at the network level is that the maximum Mbit/s available is lowered from top (best case at more than 20 Mbit/s) to bottom (worst case to 312.5 kbit/s). It is worth recalling that, for the proposed study, a target of at least 4 Mbit/s for the video to be sent is assumed.

The propagation impairment analysis was applied to the practical case of the third league football championship in Italy (Lega Pro), where 54 teams, widely spread on the territory, play matches on a weekly basis. The distribution of the sites where video streams are collected is reported in Fig. 2.

Because the encoders available on the market have multiple IP interfaces as output for the video, the model proposed in this paper considers the possibility of using more than one COTS satellite modem in parallel. The means through which the encoder splits the IP flows into multiple outputs is outside the scope of this paper, although positive tests have been run on an emulation platform [11] that will be dealt with in a future paper.

III. RESULT

Based on the initial assessment of system requirements, terminals and equipment constraints, propagation models, and attenuations ranges (supported by early trials performed), it was clear from the beginning that the use of a more VSAT COTS terminals to implement the transmission chain is an interesting approach, if supported correctly at the IP level (multiple output flows of the encoder). In fact, even if a single terminal can support the required bitrate in nominal conditions, it may underperform during attenuation events with ACM enforcement, which may result in a much lower bitrate channel.

When, for instance, in the presence of an attenuation of 10–13 dB, the modem is forced to a carrier of 1.25 MSym/s, it cannot support the required rate of 4 Mbit/s.

For this reason, owing to the availability of encoders with multiple output channels support at the IP level, the opportunity of using multiple COTS terminals and antennas in parallel is introduced. This decision allows, in principle, the use of many satellite terminals per installation; nevertheless, to reduce costs, it is important to minimize the number of terminals to adopt.

Because all terminals are distributed over the national territory, each terminal site is affected by very specific climatic conditions. The system availability typically associated with commercial HTS services, such as Ka-Sat, corresponds to a contractual system outage of 40 hours per year (i.e., 0.46% of yearly time). In addition, given the live service to be provided, a target quality of service (QoS) was decided to avoid interruptions of longer than 12 consecutive minutes in each single match. Considering the outage requirements (system available for 100–0.46 = 99.54% of the yearly time), the attenuation margin lies approximately between 10 and 16 dB (using worst-month attenuation statistics). In addition, in order to meet the QoS target, the margin lies in the range of 13 and 16 dB (using fade duration statistics). Considering these attenuations in relation to the ACM mechanism (see Table 1), these margins do not always grant the transmission at IP layer of the reference video flow (4 Mbit/s).

The proposed solution adopts more than one link to improve overall Ka-band satellite service availability. To support the validation of this proposed approach, we focused on the site with the worst propagation conditions, namely Salerno (Lat: 40.65° N, Long: 14.82° E). The estimated attenuation statistics shown in Fig. 3 determine the percentage of time for which a given attenuation is exceeded. As an example, the attenuation exceeds 5.55 dB for 1% of time in a year. Fig 3 shows that the attenuation exceeds 10 dB (limit value for which a modem can guarantee the minimum 4 Mbit/s rate) for 0.3% of the yearly time.

IV. Discussion

To determine the overall channel improvement from the network perspective, when using multiple terminals, we focus on the percentage of time when the service can be offered at nominal speed (thus providing an overall link of at least 4 Mbit/s). In case of a single modem in Salerno, for 99.7% of the yearly time the transmission conditions are adequate, with a maximum attenuation of 10 dB and with a Symbol Rate of at least 2.5 MSym/s.

By introducing a second modem, the system can tolerate an extra attenuation of 4 dB (see Table 1), with modems that can reach 1.25 MSym/s each, therefore offering an aggregate throughput of 5 Mbit/s. In addition, with reference to the curve in Fig. 3, the percentage of time for which the attenuation does not exceed 14 dB (10+4) is approximately 99.9%. This means that, in terms of service, a 0.2% increase in the availability time is experienced. Considering all the matches played in the same stadium in a year (20), the 0.2% gain results in an increased service time of about 5 minutes.

This association between attenuation and network bitrate can help decide whether an additional modem (and antenna) is to be installed. In fact, it is possible to define as "bad" a site for which attenuation does not exceed 10 dB (Symbol Rate at least 2.5 MSym/s) for 99.8% of time (99.7% being the worst case of Salerno). In such cases, two antennas provide a measurable benefit. In the remaining cases (i.e., with a simplification, where average weather conditions are better), the benefits would be rather limited: for example, adding a second antenna where the service is available for 99.9% of the time will only offer a 0.03% increase in the availability time. Finally, the addition of a third antenna will only slightly improve QoS and so it is always discouraged.

In conclusion, the introduction of two COTS modems can also improve general system availability associated with possible failures in the hardware or in the HUB stations receiving the data flow.

Further studies, requiring processing of attenuation time series measured during operations with real equipment and protocols (using e.g. emulation platform, other hardware in the loop solutions [12] or including alternative backup lines [13]), are necessary to adjust the architecture configuration. This aspect and other open issues discussed in this paper will be the subject of future work.

V. Conclusions

This paper presents a possible design of a communication system for the transmission of IP-based video flows through HTS VSAT commercial services in Ka-band. After the problem formulation, a possible solution for system, network, communication, and propagation issues was proposed and described.

The link budget calculation for such a system is quite challenging because the availability and QoS requirements are essentially related to consecutive outage periods during specific events.

The results of the study show that the system can meet such requirements with low cost terminals and that, by considering service continuity, link budget, ACM, and networking performance, two terminals should be installed in most critical sites.

This work will be followed by a pilot and trial project on the territory, which can help verify if the outcomes of this work are consistent, and it will allow further refinement of the analysis and system architecture.

Acknowledgments

The results presented herein are in part founded by the European Space Agency ESA/ESTEC Artes 3/4 contract No. 4000113073/14/NL/US.

References

[1] A. Patacchini, Ka-band becoming reality for consumer and Professional Services,15th Ka and Broadband Communications, Navigation and Earth Observation, Cagliari, Italy, Sept. 2009.

[2] Cost-effective Satellite News and Data Gathering Service in Ka-band, Eutelsat NewsSpotter SNG website, accessed online on Jan 2016 at: http://www.eutelsat.com/en/services/broadcast/professional-video/newsspotter.html

[3] L. Carniato, F. Fongher, M. Luglio, W. Munarini, C. Roseti, F. Zampognaro, Traffic analysis and network dimensioning through simulation and emulation for Ka band high capacity satellite systems, IEEE 18th International Workshop on CAMAD, Berlin, Germany Sept. 2013.

[4] LTE specification, 3GPP working group accessed onoine at: http://www.3gpp.org/technologies/keywords-acronyms/98-lte on Sept. 2016.

[5] M. Luglio, C. Monti, C. Roseti, A. Saitto and M. Segal, Interworking between MANET and Satellite Systems for Emergency Applications, International Journal of Satellite Communications & Networking, vol. 25, n 5, pp.551-558,ISSN:1542-0973, 2007.

[6] G. Berretta, Live events via Ka-band High Throughput Satellite with high availability, 21st Ka and Broadband Communications Conference, Bologna, Italy, Oct. 2015.

[7] M. Bacco, A. Gotta, C. Roseti, F. Zampognaro, A study on TCP error recovery interaction with random access satellite schemes, in Proceedings of ASMS/SPSC 2014, pages 405-410, 2014.

[8] ITU-R P.679-4, Propagation data required for the design of broadcasting-satellite systems, Geneva, Switzerland, ITU-R recommendation, 2015.

[9] C. Riva, Seasonal and diurnal variations of total

attenuation measured with the ITALSAT satellite at Spino d'Adda at 18.7, 39.6 and 49.5 GHz, International Journal of Satellite Communications and Networking, No. 22, pp. 449–476, 2004.

[10] Eutelsat Technical Note of the News Spotter service, accessed online on Jan 2016 on http://www.eutelsat.com/files/contributed/news/media_library/brochures/NewsSpotter_Spotlight.pdf

[11] M. Luglio, C. Roseti, F. Zampognaro, F. Belli, An Emulation platform for IP-based satellite networks, 27th International Communication Satellite Systems Conference (ICSSC 2009), Edinburgh, UK, June 2009.

[12] F. Belli, M. Luglio, C. Roseti, F. Zampognaro, Evaluation of TCP performance over DVB-RCS multiple RCSTs, International Workshop on Satellite and Space Communications 2009, Siena, Italy, pp 424-428, Sep. 2009

[13] M. Luglio, C. Roseti, G. Savone, F. Zampognaro, Cross-layer architecture for a satellite-Wi-Fi efficient handover, IEEE Transactions on Vehicular Technology, 2009.

[14] M. Luglio, C. Roseti, G. Savone, F. Zampognaro, TCP Noordwijk for high-speed trains, Proceedings - 1st International Conference on Advances in Satellite and Space Communications, SPACOMM, 2009.

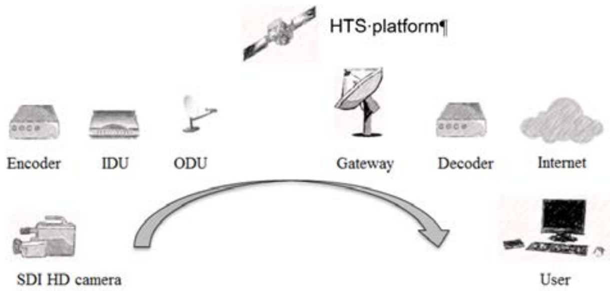

Figure 1. General system configuration.

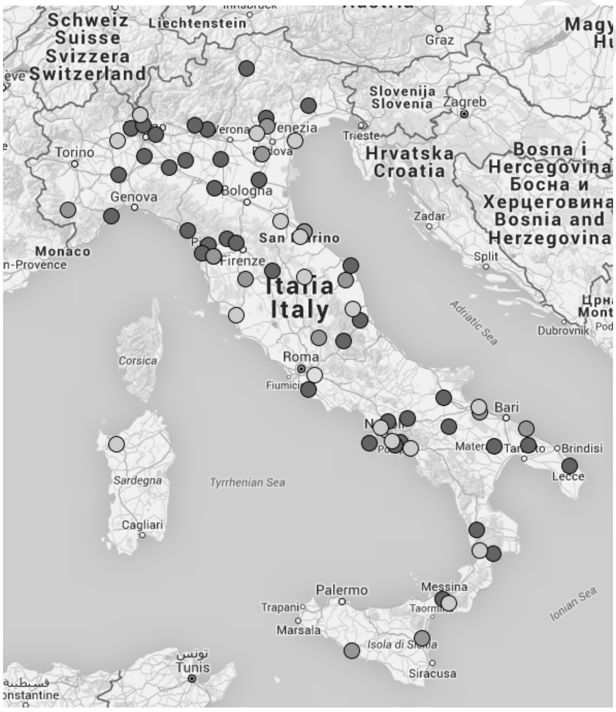

Figure 2. Locations considered for the propagation analysis.

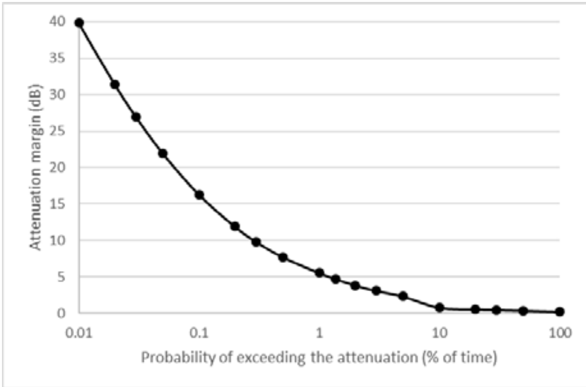

Figure 3. Estimated total attenuation statistics for Salerno

Table 1. Available output bitrate according to experienced attenuation.

Symbol Rate (Msym/s)	**Max. Bit rate (Mbit/s)**	**Total SNR loss (dB)**
10	22.5	–
	20	
5	11.25	5-6
	10	
2.5	5.625	9-10
	5	
1.25	2.5	13-14
0.625	1.25	16-18
	0.937	
	0.625	
	0.312	