TCP PERFORMANCE EVALUATION OVER A DVB-RCS SATELLITE-HAPS INTEGRATED SYSTEM

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Document No: COST297-0314-WG10-000-P00
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Abstract—An integrated satellite-HAPS system is particularly suitable for supporting emergency communications. A key element for the efficient adoption of such systems is the enhancement of transport layer capability to support TCP-based applications. This paper proposes a detailed analysis of TCP performance over the target scenario, involving a DVB-RCS protocol stack for satellite air interface. I-PEPs play a fundamental role in improving transport layer performance thanks to advantages coming from both TCP splitting adoption and the use of an optimized transport protocol over the satellite link. Ns-2 simulations have supported the overall analysis.

Key Words: HAPS, DVB RCS, Satellite

1. INTRODUCTION

This paper deals with an integrated communication system composed of HAPS, providing access to user terminal through a widespread wireless interface (i.e. WiFi, WiMax, etc.), and a geostationary satellite segment, which is used to connect HAPS to remote sites. This architecture is particularly suitable for emergency situations, since HAPS double communication interface allows short-range wireless connectivity with small user terminals (UTs), while it can ensure very long-range connectivity via satellite, to reach remote headquarters/command. Figure 1 provides a sketch of the reference scenario.

In order to efficiently support bi-directional broadband communications via satellite, DVB-RCS interface [1][2] is considered on board the HAPS. In the return channel (from HAPS to remote station), bandwidth is assigned by a Network Control Centre (NCC) through a Demand Assignment Multiple Access (DAMA) scheme [3]. In general, DAMA may introduce an extra-delay to data delivery, defined as “access delay” [4][5], because it is necessary to perform explicit requests for bandwidth. Three main DAMA algorithms are defined by DVB-RCS standard:

1. Continuous Rate Assignment (CRA), which is a fixed and static allocation of resources made at the setup of the satellite terminal (ST);
2. Rate-Based Dynamic Capacity (RBDC), which dynamically requires capacity on the basis of rate measurements performed by ST;
3. Volume-Based Dynamic Capacity (VBDC), which dynamically requires capacity on the basis of data volume measurements performed by ST.

TCP/IP communications are herein envisaged, since IP is currently the most used network protocol, TCP is the reliable transport layer protocol currently used for large part of applications and equipments implementing TCP/IP are low-cost and widespread in the market (PDA, laptop, IP-based sensors, camera, VoIP phone, etc.). In particular, this paper addresses TCP-based applications supporting transmission of information (data, audio, video) useful from the emergency area to a remote headquarters.

2. TCP OVER LONG/VARIABLE DELAY LINKS

The target communication environment is harsh for the Transmission Control Protocol (TCP) currently used
as a transport protocol for most of common Internet applications [4][6], mainly due to the high end-to-end delay. In fact, TCP uses Round Trip Time (RTT) measurements as a meter of the network congestion: the higher is RTT, the longer is the time needed to achieve the maximum allowed rate [7][8]. In addition, UT TCP initial settings (i.e. initial slow start threshold - ssthresh) are usually tailored to the characteristics of the access network (terrestrial wireless network), dealing with a bandwidth-delay product (BDP) of few hundreds of bytes. Instead, the presence of a satellite link in the end-to-end path increases BDP of (at least) two orders of magnitude. In addition, TCP acts defensively to variations in available bandwidth, potentially leading to under-use of communication resources [4]. Then, TCP interprets dynamic bandwidth assignment as continuous congestion occurrences (RTT variations can be very large), further slowing down TCP congestion window (cwnd) increase. From a performance point of view, the three above-mentioned DAMA algorithms can be described as follows:

1. CRA reserves bandwidth irrespective of the actual use; RTT is about constant (500 ms) over satellite link but any unused bandwidth is wasted;
2. RBDC has a RTT similar to CRA, except some extra delay on first request and in case of variations of the source rate;
3. VBDC leads to a much longer RTT (typically around 1.6 s), due to the high “access delay”. Capacity is requested only for data already in the buffer, so that bandwidth utilization is 100%.

In definitive, improvements on resource utilization due to DAMA are paid in terms of TCP performance. The rest of the paper will aim to identify the best transport layer design supporting all the considered access schemes.

3. IMPROVING TCP PERFORMANCE

To improve TCP performance, Interoperable-Performance Enhancing Proxy (I-PEP) specification [9][10] defines a protocol stack for the edges of DVB-RCS links, which performs TCP splitting in order to divide end-to-end connection into two “sub-connections”. In addition, I-PEP specification guarantees interoperability among different-vendor implementations. Both TCP version and TCP configuration can be different over the so-built “sub-links”. In the considered architecture, TCP connection is split on board the HAPS, identifying a TCP connection from UT to HAPS and another from HAPS to the remote site, supposed implementing I-PEP stack. The former run standard TCP, guaranteeing compatibility with mass-market equipment, while the latter runs SCPS-TP protocol [11], which is the transport protocol used between I-PEPs. SCPS-TP envisages two congestion control algorithms, TCP Vegas (default) and a standard TCP based on Van Jacobson’s Slow Start and Congestion Avoidance algorithms [9] (herein referred as TCP Newreno), as well as a set of TCP options including the possibility to use a custom congestion control algorithm. In this frame, TCP Noordwijk is a new transport protocol specifically designed to optimize performance in DVB-RCS links between I-PEPs [12][12]. The main protocol objectives are the optimization of WWW-like traffic performance, good performance for large file transfers and efficient bandwidth utilization over DAMA schemes.

The aim of this paper is to evaluate TCP performance over the reference scenario with and without the adoption of I-PEP on board of HAPS and considering both different DAMA configurations and transport protocol over satellite link. The goal is to determine the best transport layer configuration.

4. SIMULATION RESULTS

Analysis has been carried out though Ns-2 simulation platform [13] enhanced with both DVB-RCS and TCP split modules. Furthermore, a TCP Noordwijk implementation has been added to the simulator.

The main simulation parameters are hereafter listed:

- Wireless link bandwidth: 2 Mbit/s;
- Wireless link delay: 2 ms;
- Satellite link bandwidth: up to 2 Mbit/s;
- Satellite link delay: ~ 250 ms;
- Error free channels;
- DAMA enabled over return satellite link: CRA, RBDC and VBDC can be alternatively run;
- I-PEP transport protocols: either TCP Newreno or TCP Vegas with initial settings optimized for satellite BDP (slow start threshold = 400 kbytes) and TCP Noordwijk;
- Application protocol: FTP.

4.1. Impact of DAMA implementation

Figure 2 presents a simulation result concerning measurement at the final receiver side (headquarter) of the average throughput of a long TCP Newreno transfer (100 s) enabling/disabling I-PEP splitting and alternatively selecting one of the DAMA algorithms. In the case of end-to-end TCP connection, the initial ssthresh is set equal to the terrestrial wireless pipe. Instead, I-PEP allows re-setting of initial ssthresh over satellite sub-connection large enough to always achieve maximum window within Slow Start algorithm. The goal is to show effectiveness of the I-PEP tuning although transport protocol is kept unchanged in both the sub-links.
TCP Noordwijk gets the whole bandwidth in a couple seconds. This is a great achievement if compared with the time needed to both TCP Newreno (> 10 s) and TCP Vegas (> 50 s). The rationale relies on the fact that TCP Noordwijk replaces the “window based” congestion scheme with a “burst-based” rate control schemes, able to estimate the available bandwidth in 1-2 RTT. More details are provided in [12].

In case of RBDC (Figure 4), performance gap between TCP Noordwijk and TCP Newreno is slightly increased. TCP Noordwijk capability of quickly get the whole bandwidth is verified also with RBDC. On the other hand, TCP Vegas attempts to determine the optimal cwnd comparing current RTT with the minimum RTT [14] but, since it is not able to distinguish DAMA delay within the overall RTT, transmission rate is erroneously fixed to less than 200 kbit/s.

Finally, VBDC further degrades performance of both TCP Newreno and TCP Vegas: the former slows down cwnd increase due to the larger RTT (> three times the physical RTT), while the latter achieve an average throughput well below 100 kbit/s (Figure 5).
5. CONCLUSIONS

I-PEP, enabled on board the HAPS, leads to a significant improvement on TCP performance. In fact, TCP splitting permits to properly tune the initial TCP parameters accordingly to characteristics of each “sub-link”. In addition, transport protocol between I-PEP (from HAPS to satellite gateway) can be opportunely chosen in order to optimize performance when DAMA algorithms run at the MAC layer. TCP Noordwijk greatly outperforms other transport protocols supported by SCPS-TP, as demonstrated by the performed simulations.

REFERENCES