

# Cost-efficient design of hybrid network for video transmission in tropical areas

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## I. INTRODUCTION

The necessity of providing broadband connectivity to low-densely populated areas has given rise to a big interest for hybrid networks, specially those composed of a satellite backhaul and a wireless terrestrial network. In this paper, we focus on a DVB-S2/RCS system with Adaptive Coding and Modulation (ACM) for the satellite link and a Wi-Fi network for the indoor terrestrial wireless link. Figure 1 depicts the considered scenario, which reproduces the hybrid network used to give service to small villages along the Amazon River [1]. The video stream is transmitted by the video stream server to the satellite transmitter, which broadcasts it to the satellite network.

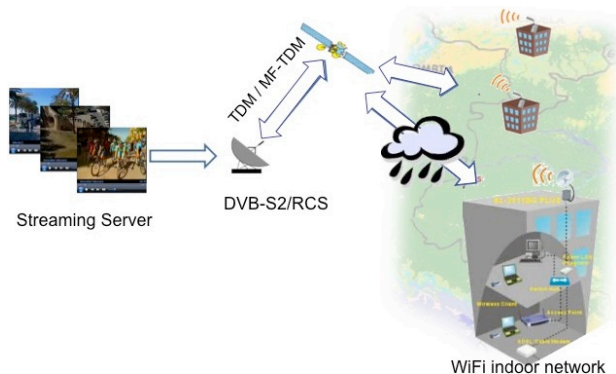


Fig. 1. The video server broadcasts a video stream to the indoor wireless network by means of a satellite network.

Each satellite receiver broadcasts the video stream to a terrestrial indoor wireless network. For the Amazon scenario considered here, the satellite link is the bottleneck of the system in terms of capacity, since the users in the indoor WiFi network are fixed; consequently, the terrestrial link condition has no impact on the overall conditions of the hybrid channel.

One of the most challenging issues of satellite reception in tropical areas is implementing countermeasures for the atmospheric fading, which is more severe than in temperate areas [2], resulting in more urgent requirements for cost-efficient design.

## II. PROBLEM STATEMENT

In [3], it is shown that, for some rain events, the DVB-S2

ACM modes can not cope with the deepest attenuations, as exemplified in Figure 2, where the  $E_b/N_0$  of the tropical rain is below the intervention threshold of the minimum ACM mode (-1.5 dB for QEF PER of  $10^{-7}$ ). In this paper, we propose to use for the forward link the same Link Layer FEC (LL-FEC) that have been recently standardised in DVB-RCS Mobile (DVB-RCS+M) following the DVB policies of re-using already standard solutions.

However, since the maximum size of FEC frames is limited, and deep fading duration can be in the order of seconds, we additionally propose an Application Layer FEC solution (AL-FEC) like the one standardized for DVB-H (Handheld) and DVB-SH (DVB Satellite to Handheld), where FEC frames are

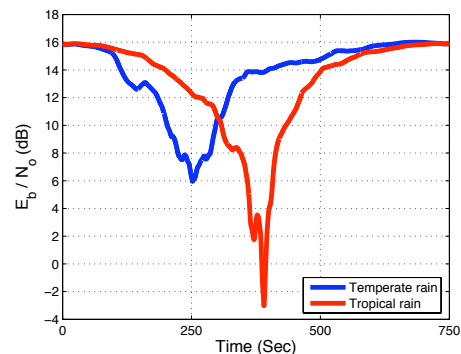


Fig. 2. Examples of channel conditions caused by a rain event in Temperate and Tropical areas.

allowed to be larger. Since the error protection we propose causes a noticeable delay, it cannot be used for real-time applications therefore we focus on videostreaming applications. In this paper we also demonstrate that, during the rain event, the delay in the ACM reaction to fade changes can affect the Quality of Service (QoS) of a multicast videostreaming. Specifically, there is a noticeable delay (RTT of about  $2 \cdot 250$ ms plus DVB super-frame length) from the moment an RCS Terrestrial (RCST) detects an ongoing fade event to when it receives from the NCC the transmission with the modulation and coding rates appropriate to cope with the increased atmospheric attenuation. We verify that the LL-FEC, super-frame (SF) length and the intervention threshold are useful to compensate the packet errors introduced by the ACM switching delay.

Therefore, this work aims at demonstrating the improvement in QoS of the video transmitted in the hybrid network by using the proposed techniques and shows how to make efficient use of bandwidth in order to reduce costs in Amazon areas. The main parameters evaluated for this purpose are the packet error rate, the delay, and the bandwidth overhead due to the use of the proposed techniques. The received video will be evaluated in the final paper by using the PSNR (Peak Signal to Noise Ratio) metric.

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### III. SYSTEM MODEL

We consider a GEO (Geostationary Earth Orbit) Multibeam Broadband Satellite (MBS) link with a DVB-S2/RCS [4, 5] air interface. DVB-S2 incorporates ACM on a time slot basis, chosen on the base of the SNIR (Signal-to-Noise-plus-Interference Ratio) at the destination terminal. We assume transmission in the  $K_a$  band (20-30 GHz) and therefore rain is the most affecting atmospheric event. The Wi-Fi access point is in charge of utilizing the limited radio spectrum resources efficiently. On the satellite side, the RCST measures the downlink attenuation and signals it to the NCC, which in turn adapts the transmission parameters to the observed fading.

### IV. PRELIMINARY RESULTS

An LL-FEC simulation platform has been developed in order to quickly assess the performance of different parameter configurations without repeating the time-consuming physical layer simulations. Given that, this performance assessment entails many layers, in particular, from the physical to the network layers of the protocol stack, a modular approach has been considered. The ACM switch Physical-Layer module, which generates the time series of satellite channel attenuations, interfaces with the Link Layer simulator. The simulator takes stream of IP packets as input and applies the MPE-FEC encoding technique as described in [5], generating an MPEG-2 TS by encapsulating Multi-Protocol Encapsulation (MPE) sections and MPE-FEC sections. At this point, the output of the physical-layer simulator is used to mark the MPEG-2 Transport Stream (TS) packets as correctly received or being erroneous. Next, the MPE-FEC decoding process is applied by reconstructing columns of the FEC matrix applying the correction capabilities of different FEC codes (RS or Raptor). Finally, the sequence of IP packets affected by the unreliable columns is obtained and the PER at the IP level is computed.

The introduced LL-FEC framework allows a significant variability in terms of parameter settings. The amount of data (bits), that can be protected with target delay  $\tau_{ll}$ , can be computed as  $S_{protect} = \tau_{ll} B_s M r_{phy} r_{ll}$ . Where  $B_s$  is the symbol rate,  $M$  (modulation constellation) and  $r_{phy}$  (physical layer coding rate) depend on the ACM selected, and  $r_{ll}$  is LL-FEC coding rate.

A data rate of 530 kb/s has been chosen to evaluate the performance of the videostreaming application. The PER estimate without the use of the proposed techniques is 2,9%; Figure 3 shows that for a FEC coding rate of 3/4 a target delay of 2 s is not enough to reduce the packet loss, and we need the longest delay (4 s). For the lowest-rate code (1/4), we verify that LL-FEC can recover the corrupted bits due to the ACM switched delay, but can not recover the residual packet loss due to the deep fading event (dotted line). Therefore, AL-FEC should be introduced to mitigate this type of tropical channel conditions. Its performance will be fully investigated in the full paper. In order to increase the coding rate and to make efficient use of bandwidth we investigate also the other parameters that influence the PER: SF length and margin on the intervention threshold. In fact, we consider a simple threshold-based algorithm, where the NCC changes the ACM mode when the

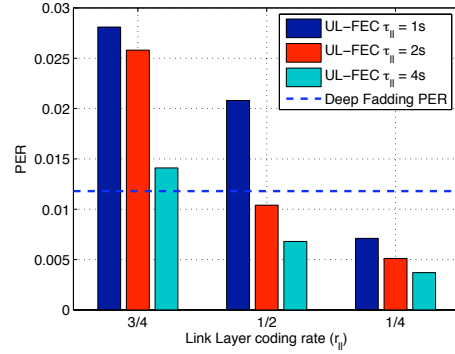


Fig. 3. PER for different LL-FEC configurations using RS (SF length equals to 250 ms and no threshold optimization ( $thr_m=0dB$ ))

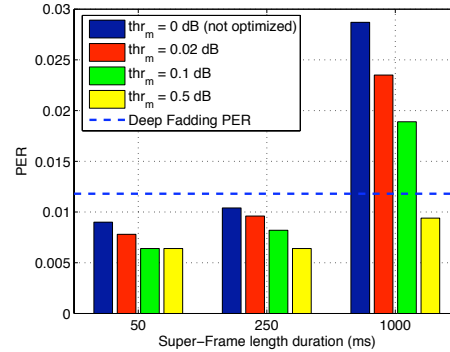


Fig. 4. PER for different SF lengths and threshold optimization using RS (LL-FEC  $r_{ll} = 1/2$  and  $\tau_{ll}=2$  sec).

standardized threshold of DVB-S2 is reached, with a given margin  $thr_m$  (in dB). Figure 4 shows the performance obtained changing these parameters.

As expected, the PER is strongly affected by the SF length. In particular, decreasing the SF length, the ACM delay decrease and consequently the PER, without significantly increase the bandwidth on the forward link. As far as the threshold margin is concerned, note that even for low values of  $thr_m$ , the PER is reduced. In particular by using the combination of  $r_{ll} = 1/2$  and  $thr_m = 0,5$  dB we obtain a PER similar to what we obtain using only a  $r_{ll} = 1/4$ ; but saving 24,8% of bandwidth and costs. The trade-off between PER and available bandwidth will be investigated in the full paper in order to optimize the intervention threshold.

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