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Enhancement of DVB-S2 Network Stability and Performance for Mobile User Groups

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ABSTRACT

Digital Video Broadcast-Satellite 2 (DVB-S2) is a second generation technology which is developed and standardized as an evolution of Digital Video Broadcast (DVB-S) by European Telecommunication Standard Institute (ETSI). This investigation is mainly based on the study and analysis of DVB-S2 networks for mobile users. The DVB-S revolutionizes broadcasting industry in terms of providing TV contents to sub-continent over satellite. While the DVB-S2 provides enhancements in broadcasting television contents such as high definition TV, which can be provided to viewers on a reduced cost. The DVB-S2 describes the methods in which the data is framed, encoded and modulated for transmission over a satellite channel. The DVB-S2 comes from the same family of DVB-S with robust features. Applications related to broadcast industry covered in DVB-S2 are High Definition TV (HDTV), SDTV, Digital Satellite NEWS Gathering (DSNG) and TV distribution to terrestrial transmitters. This study presented DVB-S2 capabilities of handling mobility issues specifically on mobile platforms including the simulation of Adaptive Coding Modulation (ACM), atmospheric effects and noisy channels. This study introduced ACM engine which allows tuning of satellite systems and analyzing system stability and performance. This study highlighted the importance for conducting further study in order to propose an appropriate solution to enhance the link stability under bad climate conditions.

Key words: DVB-S2, DVB-S2 mobility, mobile networks, broadcasting, wireless communication

INTRODUCTION

Digital Video Broadcast-Satellite2 (DVB-S2) is an improved version of DVB-S which was introduced in 2004 for internet and TV use. Due to an increased demand of IP-based information and entertainment services, it is implemented in different sectors of technologies such as internet access and internet trucking services as a next generation satellite protocol. The DVB-S2 is a more competitive transmission technology than DVB-RCS for return traffic from user groups

(DVB., 2010). Signal spreading issues and mobility problems occur due to bad weather conditions. The DVB-S supports only a single modulation mode which is Quadrature Phase-Shift Keying (QPSK). Currently, four modulation modes namely DVB-S2 supports QPSK, 8PSK, 16APSK and 32APSK are available in DVB-S2. According to Doost *et al.* (2014), the quality of QPSK is robustness in nature which can operate even under poor link conditions, down to (Carrier to Noise Ratio) $C/N > -2.4$ dB with appropriate coding on the transmission side.

The DVB-S2 uses a very powerful and complex Forward Error Correction (FEC) scheme which is highly efficient in performance in the presence of high level of noise and interference. Also, Morello and Mignone (2004, 2006) pointed out that the new coding scheme in combination with available modulation modes in DVB-S2 allows operation within 0.7-1.2 dB of the theoretical Shannon limit. Recently, Ugolini *et al.* (2014) stated that the capacity for DVB-S2 is increased by 30% on DVB-S. Also, DVB-S2 supports multiple streams of mobile applications in audio, video and data which are compatible with Moving Picture Expert Group (MPEG), MPEG2 and MPEG4. According to Doost *et al.* (2014), the Adaptive Coding Modulation (ACM) dynamically sets individual stream modulation and protection parameters in real time environment and allows interactive service systems. Previous studies suggested that the Quality of Service (QoS) should be deployed through fading periods where the availability of critical services is required. Because, the QoS can distinguish the critical services from low priority or routine data (European Commission, 2005; Lee *et al.*, 2014). Also, the benefits of ACM were realized on a per user basis thus allowing a system of diverse terminals and link conditions to operate with greater efficiency than VCM alone. A system employing ACM can realize capacity gains up to 200% when compared to systems using CCM (ETSI., 2009a, b). The DVB-S2 scheme uses Frequency Division Multiple Access (FDMA) that increases the capacity by reducing the information rate and using the efficient digital codes. As the transmission is continuous and less number of bits are needed for synchronization and framing. Furthermore, DVB-S2 uses both Single Carrier Per Channel (SCPC) and Multiple Carrier Per Channel (MCPC) for broadcasting (Fontan *et al.*, 2001; Scalise *et al.*, 2002; Radzik *et al.*, 2007, 2009; Erl and de Cola, 2014; Erunika *et al.*, 2015). The background and basics of mobility factors, an integral part of satellite transmission on mobile user platform, were described by Erunika *et al.* (2015).

The propagation considerations influencing the radio channels were divided into; (1) Tropospheric effects and (2) Ionospheric effects. The troposphere effects include gaseous absorption, attenuation due to rain, cloud and fog, troposphere scintillations and depolarization due to troposphere. Whereas, the ionosphere effects include Faraday effect.

As reported by Satcom Resources (2014), attenuation due to rain occurs only when a rain storm passes through the communication link. Therefore, the prediction of the possible consequences for a link can be done by a combination of practical measurements and theoretical modelling as follows:

$$\text{Attenuation} = \int_0^L \alpha \, d\alpha$$

where, α is the specific attenuation of rain in dB km^{-1} . This is estimated by:

$$\alpha = aR^b$$

where, a and b are frequency and time-dependent constants and R is the rain-rate at the particular location on earth. The values of a and b were estimated by the measurements and fitting the data to model by following method described in Satcom Resources (2014).

The specific attenuation is:

$$\alpha = \frac{A_{\text{total}}}{L} = 4.343 \int_0^{\infty} N(D) \times C(D) dD$$

where, $C(D)$ can be calculated using Mie theory:

Empirical rain model;

$$\alpha = aR^b$$

where, R is Rain rate in mm h^{-1} .

On the other hand, Gregson *et al.* (2007) reported that the designer of the satellite systems needs a link margin to know by how much the rain will influence the signal depending on the desired percentage reliability. Also, as explained by Satcom Resources (2014), the typical attenuation values due to rain for in dB/km can be predicted as and when required.

The radio waves are affected by a rotation in polarisation or the Faraday effect (Satcom Resources, 2014). Interference must be avoided between adjacent satellites and the two earth stations by using high quality antennas. Propagation considerations for mobile satellite communications are the path length and the variation of profile and the mobile terminals use broad-beam antennas with limited discrimination against unwanted signals reflected or scattered from buildings, trees etc. These result in signals attenuated when path is shadowed, signals fluctuate randomly as reflected and scattered components interact and the power spectral density of the noise as a function of the speed of movement.

The impairment in the wireless channel can be conveniently divided into three types of fading namely path loss, shadowing (slow fading) and fast fading (or multipath fading) as described by Niddam and Pirio (2005).

In a study, Vieira *et al.* (2006, 2008) reported that path mobility considerations show the multiple copies of signal arriving at different phases if the phases add destructively, the signal level relative to noise declines, making detection more difficult fast fading (Vieira *et al.*, 2006, 2008). One or more delayed copies of a pulse may arrive at the same time as the

primary pulse for a subsequent bit (Choi *et al.*, 2008). Many types of fading were reported by Niddam and Pirio (2005) such as slow fading, fast fading, Rayleigh fading, Rician fading-Los, flat fading and selective fading. All these types of fading affect the transmission of RF signal between the sender and receiver. While, different types of fadings showed limited signal spread without Inter-Symbol Interference (ISI) as described by Chen *et al.* (2014). The doppler shift is basically due to the receiver motion relative to the source which could be transmitter or scatterer thus showing a shift in the apparent carrier frequency. Frequency changes as a result of the Doppler shift principle which may be in evidence with signals from some satellites. This form of satellite propagation effect is important because it plays a major role in the design of a satellite system. The shifts resulting from the Doppler phenomenon need to be taken into account as a part of the overall design. In many instances the effects will subtract because of the way the satellite mixing process is configured according to Erunika *et al.* (2015).

This study addressed the mobility issues of DVB-S2 based on the BER, LDPC and ACM simulations, investigated the effects of Adaptive Coding Modulation (ACM) in efficiency of transmission for mobile users, emphasized the Multiple Access scheme of DVB-S2 and demonstrated the performance

of Forward Error Correction (FEC) of DVB-S2 useful in handling problems common in mobility environment.

MATERIALS AND METHODS

The study proposed the DVB-S2 link layer model suitable for mobility conditions as described in Fig. 1.

Adaptive Coding Modulation (ACM) is a key feature of DVB-S2 and is very flexible in terms of frame adaptation. The capacity of system can be increased with ACM which replaces rain fade. The ACM could increase system capacity by balancing the rain fade in the same way as it does in situations with fixed terminal and non-LOS scenarios. Since the rain cell and terminals both are stirring, faster dynamics of channel are expected to happen in worst situations. The ACM can also trounce the difference in satellite antenna gain when routing terminal moves across the spots. However, in case of non-LOS scenarios physical impairments may affect control loop and channel estimation mechanisms. Designing the control loop architecture can help evade negative collision of blockages in ACM functionality. Careful SNR measurements were required to balance longer delays to sort out the consequences from multipath and micro-interruption. The efficiency of ACM was achieved through Field trials at such locations.

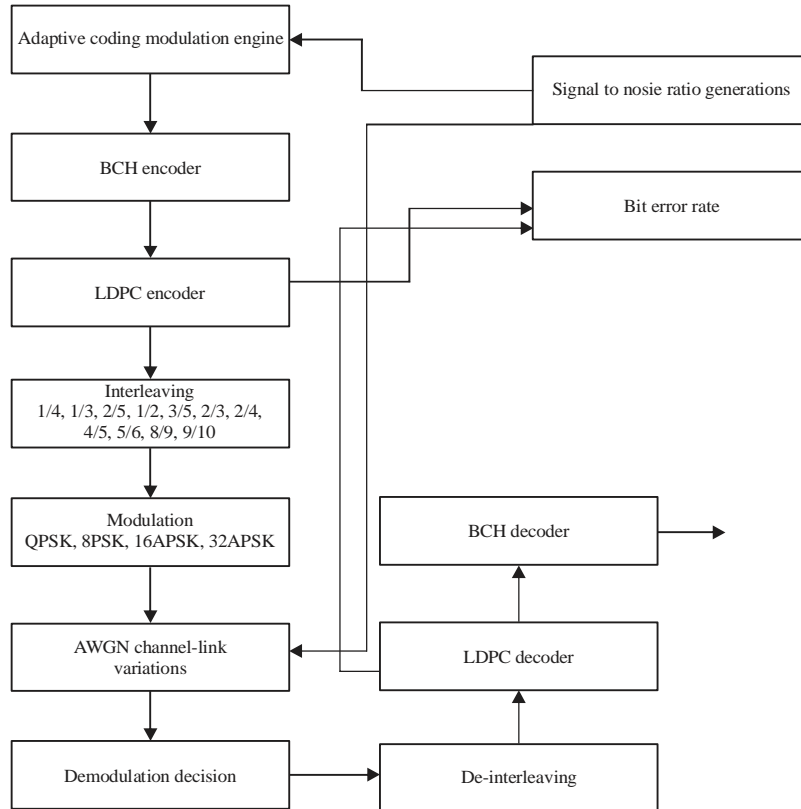


Fig. 1: DVB-S2 proposed model for mobility

RESULTS AND DISCUSSION

As shown in Fig. 2, the Adaptive Coding Modulation (ACM) engine using ACM algorithm in this model was based on the standard required E_s/N_0 by ETSI to support a Quasi Error Free transmission. In order to make decisions among link conditions, offsets were provided as equidistance thresholds between adjacent modulations. The SNR of received signal at the receiver was sent to ACM block to be used for next frame mode of transmission.

The performance of the model was checked by simulating modulation and various code rates (FEC) with different constellations on AWGN channel as shown in Fig. 2-5. About 64800 bits were chosen as packet size for QPSK, 8PSK, 16 and 32 APSK modulation. The authors took multiple MPEG packets for each LDPC frame with 188 bytes each. Error rate requirements of DVB-S2 are rather stringent (10⁻⁷ packet error rate), an outer BCH code with the same block length as LDPC frame and an error correction capability of up to 12 bits was employed according to Ugolini *et al.*

(2014). The results agree with the findings of Morello and Mignone (2004, 2006) who stated that the new coding scheme in combination with available modulation modes in DVB-S2 allows operation within 0.7-1.2 dB of the theoretical Shannon limit.

The ACM was followed to counter fading effects in which it automatically adjusts modulation scheme according to link conditions. For example, it adopted QPSK when the link was poor and 8PSK when the link seemed to be in good condition which means that sky conditions were clear. In mobile environment, ACM was applied on long term basis (slow fluctuation in the signal power) and short duration fading events as well. According to the results, shown in Fig. 2-5, the main importance of power control was that it kept the Signal to Noise Ratio (SNR) point constant in the given mode of ACM. When the actual transmit power crossed the mode's power level boundaries, the mode was adapted according to current situation of link and power. Similar result were reported by Ugolini *et al.* (2014) who stated that the capacity for DVB-S2 is increased by 30% on DVB-S. The

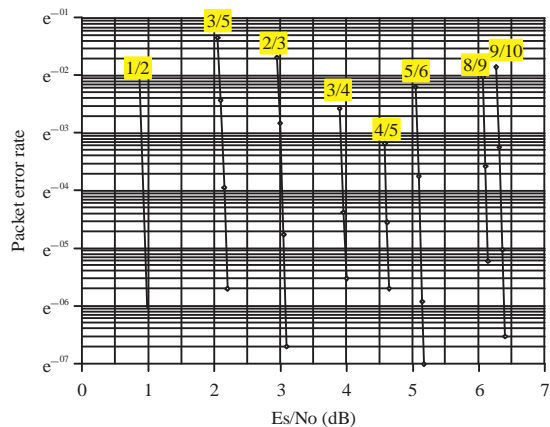


Fig. 2: Performance of codes rates over AWGN channel for QPSK

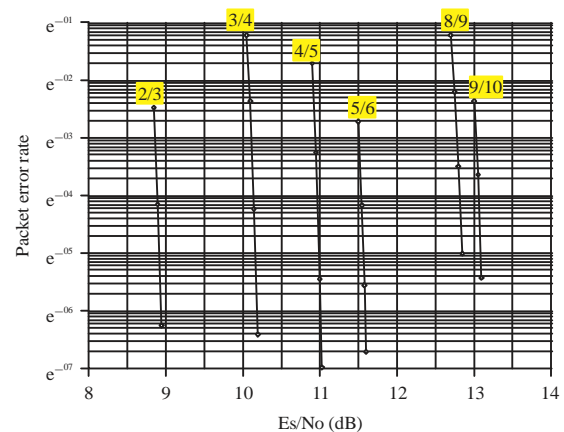


Fig. 4: Performance of codes rates over AWGN channel for 16 APSK

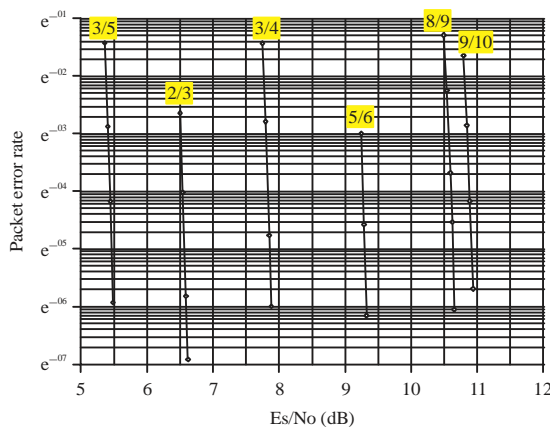


Fig. 3: Performance of codes rates over AWGN channel for 8 PSK

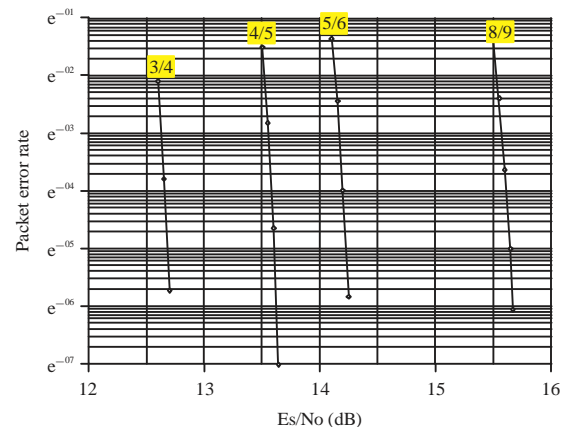


Fig. 5: Performance of codes rates over AWGN channel for 32 APSK

DVB-S2 supports multiple streams of mobile applications in audio, video and data which are compatible with Moving Picture Expert Group (MPEG), MPEG2 and MPEG4.

CONCLUSION

This study described the basic technical features and principles of the DVB-S2 system for mobility platforms. However, careful study of the background and architecture of DVB-S2 and its functionalities in mobility environment allowed to draw the following conclusions:

- Adaptive Coding Modulation (ACM) helped to improve the efficiency of transmission for mobile users by switching modulation schemes according to link conditions. But, Multiple Access scheme of DVB-S2 helped in mobile environment where switching of satellite transponders needed
- Synchronization of transceiver and receiver was much easier due to the absence of overhead
- Time inter-leaver and FEC of DVB-S2 prevented the signal blockage issues that are common in mobility environment
- Bit Error Rate (BER) performances of Forward Error Correction (FEC) showed significant increase of spectrum and reduction of delay in transmission
- DVB-S2 is fully flexible standard that can be adapted and used in several network architectures which could be deployed in future for long term perspective

The proposed model can be tested to determine the accuracy of approach in different communication applications. Also, depending on the results, further improvements can be made to it.

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