COMBINED ADAPTIVE SPREADING GAIN CONTROL AND UNEQUAL ERROR PROTECTION FOR REAL-TIME VIDEO COMMUNICATIONS OVER WCDMA SYSTEMS.

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ABSTRACT

This paper investigates the deployment of joint link adaptation and unequal error protection techniques to enhance the performance of real-time video communications over time-varying error-prone environments. An adaptive spreading gain control is used as a powerful means of exploiting the time varying channel quality fluctuations of wireless channels. The MPEG-4 data partition based unequal error protection scheme, which exploits different levels of importance of video data for perceptual quality, is applied in conjunction with the link adaptive technique to achieve maximum received perceptual quality for a given channel condition. The effectiveness of the combined algorithm is demonstrated for MPEG-4 coded video transmissions over simulated UMTS networks. Results show a significant performance improvement in received video quality compared to non-adaptive schemes.

1. INTRODUCTION

As shown in [1], adaptive modulation coding schemes are a powerful means of exploiting the time varying channel quality fluctuations of wireless channels. Spreading gain is the key variable in determining user data rates and associated channel quality in CDMA based communication systems. Therefore, in addition to channel coding schemes, adaptive spreading gain can be used to exploit time varying channels in CDMA systems.

A variety of adaptive rate schemes have been proposed in the literature for CDMA based communications systems. The performance of a transmitter power adaptation and information rate adaptation scheme was compared in [2]. It was concluded that rate adaptation provided the higher average information rate for a given average transmit power and given BER condition. Spread Adaptive Quadrature Amplitude Modulation was proposed in [3]. It exploited the time variant channel quality of mobile channels by switching either the modulation mode or the spreading factor on a burst-by-burst basis. Bit rate adaptation strategies to solve local coverage problems for uplink transmission were discussed in [4]. A dynamic spreading code assignment algorithm, which efficiently shares a WCDMA downlink between data traffic sources and different Quality of Service requirements have been presented in [5, 6]. Both analytical and simulation results show that the dynamic code allocation algorithm provides higher bandwidth utilisation compared to the non-adaptive code allocation scheme.

Spreading gain control related research has been carried out mainly at the system level with a focus on improvement in system level performances, which can be categorised into:

- System capacity maximisation,
- System throughput maximisation,
- Quality improvement in terms of average channel BER or BLER,
- Service flexibility and service multiplexing,
- Higher system utilisation
- Cell coverage.

However, little attention is given to the application level performances, such as received video quality in multimedia communications. Perceptual video quality is a function of quantisation distortion, concealment distortion and distortion due to error propagation, thus received video quality greatly depends on the encoder format, error resilience techniques, and error concealment techniques applied. Therefore, it is necessary to investigate the effect of spreading gain control on multimedia performance at the application level. In this paper, performance gain, which can be achieved by means of adaptive spreading gain control for real-time video communication over UMTS systems, is discussed.

2. JOINT ADAPTIVE SPREADING GAIN CONTROL AND UNEQUAL ERROR PROTECTION SCHEME (JAS-UEP

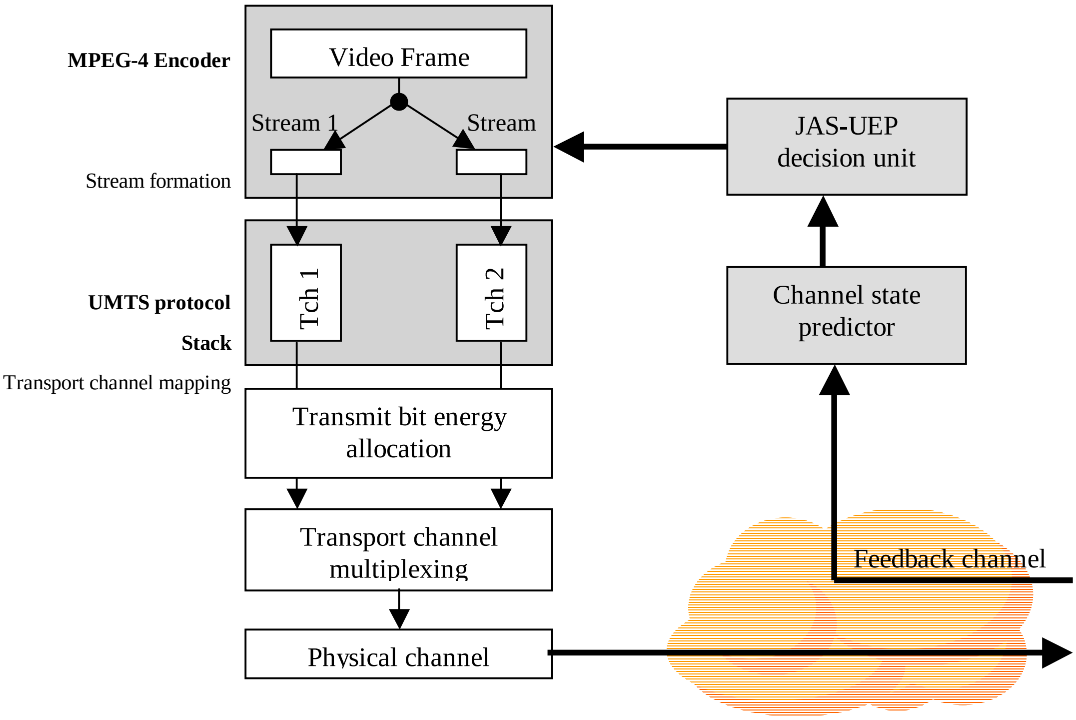

Figure 1: Realisation of proposed JAS-UEP over UMTS.

The adaptive spreading gain control technique attempts to improve the received video quality by switching between different spreading codes levels depending on the state of the transmission channel. Source bit rate is varied according to the selected spreading factor on a basis of Transmission Time Interval (TTI), while keeping the chip rate constant. In good channel conditions, quantisation distortion becomes the dominating factor in received video quality. Therefore, in order to reduce the quantisation distortion, a code with low spreading factor, which supports a higher source rate, is selected. Conversely, in hostile channel conditions, a high spreading factor is used to minimise the channel distortion.

The rate switching threshold is selected according to the link level simulation results [7]. The transmission power is kept at a constant level for a certain channel SNR. This ensures that the interference power experienced by other users is not affected by the adaptive spreading gain control. Eb/No and SNR are inter-related and the derivation of SNR from E_b/N_o is as shown in Equation 1.

$$SNR = \frac{R \cdot E_b}{W \cdot N_o} \qquad (1)$$

where W and R denote the channel bandwidth and source rate respectively. The condition used to switch between spreading factors (hence source rates) is set according to received video quality as:

$$\text{Switching mode} = \begin{cases} SF = 16 & for \quad SNR > -7dB \\ SF = 32 & for \quad SNR < -7dB \end{cases}$$

Due to the varying value of R, the adaptive spreading gain control technique results in a variation of transmit bit energy (Eb) over the duration of the transmission.

An MPEG-4 data partition based UEP scheme [8] is combined with the adaptive spreading gain control scheme. The overall joint adaptive spreading gain control and unequal error protection scheme is depicted in Figure 1. The encoded video frame is separated into two streams based on MPEG-4 data partitioning. Then the high priority data stream is channel protected with 1/3 convolutional coding, while 1/2 rate convolutional code is used to protect the low priority data stream. Channel coded streams are allocated with different transmit bit energy levels based on the JAS-UEP decision command. Transport channels are multiplexed onto same physical channel for transmission over the wireless link.

UEP supports higher source bit rates than the 1/3 convolutional coding scheme on its own. In order to maintain the same channel SNR, information bits should be transmitted with lower energy in the JAS-UEP scheme. This results in lower video quality for a given channel SNR. This problem is overcome with the use of unequal bit energy allocation for different bearers in the JAS-UEP scheme.

Average bit energy, E_b, for the transmission can be calculated from Equation 1. Let E_{b1} and E_{b2} denote the allocated bit energy for stream 1 and stream 2 respectively. In order to satisfy the average bit energy requirement,

$$\frac{\varphi}{(1+\varphi)} \cdot E_{b1} + \frac{1}{(1+\varphi)} \cdot E_{b2} = E_b \quad (2)$$

Say $E_{b1} = E_b + x$ and $E_{b2} = E_b - y$, then

$$x / y = 1/\varphi \quad (3)$$

where φ is the ratio between the amount of data in the first partition to the amount of data in the second partition. In the experiment, y is assumed to be $0.25E_b$. Selected operation modes, corresponding source rate and transmit bit energies for transmission of "Suzie" sequence are listed in Table 1.

Table 1: Operation modes of JAS-UEP scheme.

Mode	Mode 1		Mode 2	
	Stream1	Stream2	Stream1	Stream2
Spreading factor	32		16	
Source rate	88 kbps		190 kbps	
Channel code	CC 1/3	CC 1/2	CC 1/3	CC 1/2
Bit energy (dB)	E_{bm1}+2.33	E_{bm1}-1.25	E_{bm2}+3.15	E_{bm2}-1.25

Where, E_{bm1} and E_{bm2} indicate the average bit energy with mode 1 and mode 2 respectively.

3. EXPERIMENTAL SETUP

The channel model used in the simulator follows the description of the UMTS mobile radio multi-path propagation model described in [7]. In addition to the fading and multi-path characteristics of the channel, shadow fading with a lognormal variance of 10 dB and a propagation path loss model were included in the calculation of SNR of the channel for down link transmission. Standard (ideal) hexagonal cells and perfect sectorisation are assumed. The parameters used in the implementation are listed in Table 2.

Table 2: Parameter values used in the UMTS channel simulation

Parameter	*Value*
Propagation environment	VehA
Mobile speed	50 km/h
Log-normal variance	10 dB
De-correlation length	20 m
Hexagonal cell radius	2 km
Fading Characteristics	Raleigh fading
Othorganality factor	0.65
Channel coding	CC1/3

Mobile terminals are uniformly distributed and their direction is randomly chosen at initialisation. A pseudo-random mobility model with semi-directed trajectories is used to model the user mobility. The terminal's position is updated according to the de-correlation length and the direction is changed at each position update with probability of 0.2.

The QCIF test sequence "Suzie" is selected as the source signal considering its characteristics, which are typical of a video conferencing scenario. The video codec parameters used in the experiment are listed in Table 3.

Table 3: Video codec parameters used in the experiment.

Parameter	*Value*
Video codec	MPEG-4
Frame rate	10 fps
Video packet size	600 bits
No of frames	700
Reversible variable length code (RVLC)	enabled
Data partitioning	enabled
Adaptive Intra Refresh (AIR)	enabled
Number of intra-Marco-Block per frame	10 (fixed)
Video quality measure	Peak Signal to Noise Ratio (PSNR)

4. RESULTS AND DISCUSSION

Perfect SNR estimation is assumed. Therefore, the obtained results show an upper-bound of performance estimates. Full error resilience MPEG-4 coded video sequences were transmitted over simulated time varying channels. The performance results in terms of average frame PSNR vs average channel SNR (of time varying channel) are presented in Figure 2. Each point is produced by averaging frame PSNR values for 50 different runs over at least 15 different channel profiles with the same mean SNR. For comparison, the performance of the Adaptive Spreading (AS) gain control scheme alone and performances of non-adaptive schemes with spreading factor 32 and 16 are also shown in the figure. Adaptive schemes show significant quality improvement compared to non-adaptive schemes. As the theory suggests, the performance of adaptive schemes gets closer to that of spreading factor 16 operation for good channel conditions. For poor channel conditions, the performance gets closer to that of spreading factor 32 operation.

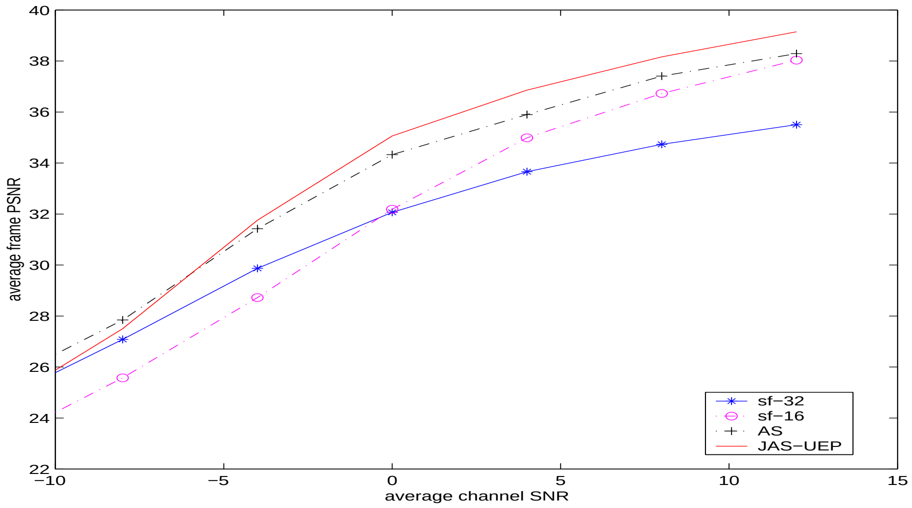

Figure 2: performance of JAS-UEP scheme.

The JAS-UEP scheme outperforms the adaptive spreading gain control scheme with good channel conditions. However, slightly lower performance is visible compared to that of the adaptive spreading gain control scheme for poor channel condition. This is due to the poor performance of the MPEG-4 data partition based UEP scheme at very poor channel conditions. As channel distortion dominates in poor quality channel, careful design strategies should be followed to avoid any performance degradation. Also the transmit energy levels on two streams are kept constant for selected transmission modes independent of the instantaneous channel quality. These energy levels can be optimally controlled according to the characteristics of the channel. Therefore, optimal performance gain can be obtained over a wide range of channel conditions.

5. CONCLUSION

An adaptive spreading gain control technique is proposed and analysed for real time video communications over UMTS networks. The conducted experiments show significant improvements in received video quality. In addition, an unequal error protection scheme is applied in conjunction with the adaptive spreading gain control scheme. It was shown that the joint adaptive spreading gain control and unequal error protection scheme can be used to achieve further improved video performance in wireless networks.

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