POWER-CONTROLLED H263-BASED WIRELESS VIDEOPHONE PERFORMANCE IN INTERFERENCE-LIMITED SCENARIOS

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ABSTRACT

An H.263-based video transceiver is contrived, which maintains a near-constant bitrate and due to the proposed packetisation and packet dropping regime it provides near-unimpaired video quality for frame error rates upto 5%. The target frame error rate is maintained by invoking a novel power-control technique.

1. INTRODUCTION

In recent years, there has been increased research activity in the field of mobile videophony, proposing proprietary [1] or standard H.261 and H.263 based schemes [2, 3]. Due to its inherent error sensitivity, the H.261 and H.263 [4] coded video stream requires Automatic Repeat reQuest (ARQ) or some other powerful error control mechanism. Naturally, using ARQ introduces latency both due to the delay of the acknowledgement feedback information and due to the repeated transmission of the same packet, when the radio channel is particularly hostile.

In this contribution we suggest an alternative solution to ARQ, which is based on dropping, rather than re-transmitting video packets, when they become corrupted. The paper briefly describes the video transceiver used in Section 2, providing some video performance figures in Section 3, but its main emphasis is on the power control scheme described in Section 4. The power control scheme's performance is characterised in Section 5.

2. VIDEO TRANSCEIVER

The proposed video transceiver is based on the H.263 video codec. For specific details on the codec the interested reader is referred to [4]. The video coded bitstream was protected by binary Bose-Chaudhuri-Hocquenghem (BCH) coding [5] combined with a 4-level Pilot Symbol Assisted (PSA) Quadrature Amplitude Modulation (QAM) modem [6]. Here we refrain from detailing the modulation and forward error correction (FEC) aspects of our system due to lack of space and simply summarise the main system features in Table 2.

A novel feature of the proposed video scheme was that it employed a packetiser, which assisted in controlling the bitrate of the inherently vulnerable, variable-length coded H.263 codec. Hence at the output of the packetiser a near-constant bitrate was maintained. Furthermore, the packetiser supported the system's robust operation by allowing the system to drop corrupted video packets upto dropping rates of about 5% without significantly impairing the perceived video quality. The FEC-coded signalling rate became 7.3 kBaud. When opting for a modulation excess bandwidth of 50%, and a system bandwidth of 200 kHz, as in the Pan-European GSM system, the maximum signalling rate becomes 133.33 kBaud. At this signalling rate INT(133.33/7.3)=18 time-slots can be created, where INT indicates integer division. Assuming an identical speech signalling rate of 7.3 kBd, 9 audio/video users can be supported by the proposed scheme in the GSM system's 200 kHz bandwidth. A range of further system aspects can be inferred from Table 2. Let us now consider the system's video performance.

Feature	Value
Video rate	8.55 Kbit/s
Modem	4-PSAQAM
FEC	BCH(255,171,11)
FEC coded rate	12.75 Kbit/s
ARQ	None
User Signal. Rate	7.3Kbaud
System Signal. Rate	131.4Kbaud
No. of Spch./Video Users	9
System Bandwidth	200 KHz
Effective User Bandwidth	11.1 KHz
TDMA frame length	20ms
Vechicular Speed	28mph or 12.5 m/s
Propagation Frequency	1.8GHz
Normalised Doppler Freq.	6.2696×10^{-4}
Shadowing Frequency	0.9Hz
Log-Normal Standard Dev.	6dB
Noise Floor	-104dB
Mobile Transmission power	30 dBm
Frequency reuse factor	7
Frequency reuse distance	1Km
Radius of hexagonal cell	218m
Pathloss Model	3.5 Power law
Min. AWGN PISNR	9 dB
Min. Rayleigh PISNR	20 dB

Table 1: GSM-like videophone system parameters

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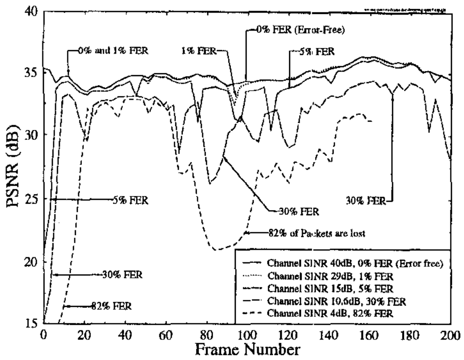


Figure 1: Decoded video PSNR versus video frame index for transmission over Rayleigh fading channels using 4QAM for various packet dropping (FER) rates

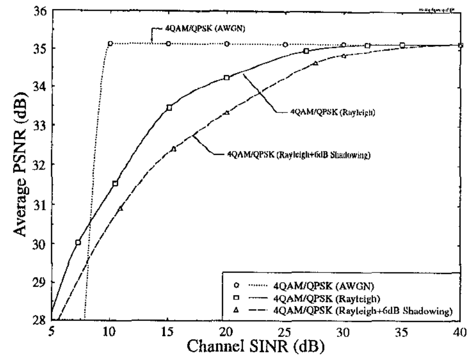


Figure 2: Video PSNR versus channel SINR performance of the proposed transceiver for the channel conditions of Table 2 over Rayleigh channels with and without shadow fading, as well as over stationary AWGN channels

3. VIDEO SYSTEM PERFORMANCE

Figure 1 shows the decoded video peak signal to noise ratio (PSNR) versus the video frame index performance of the system for various video packet dropping rates using 4QAM for transmissions over the Rayleigh fading channel characterised in Table 2. This is the most appropriate video performance measure for our system, since the packets are either error-free or dropped and the target dropping rate and its associated video quality can be maintained by the power control scheme to be described in Section 4. The different packet dropping rates were engendered by using various channel signal-to-interference+noise (SINR) values. In order to prevent excessive video degradations, according to this Figure a packet dropping rate of 5% does not result in objectionable video PSNR degradation. Hence the video system can be configured to maintain this packet dropping or corruption rate, by appropriately controlling the transmitted power of both the mobile station (MS) and the base station (BS). The associated subjective effects are characterised by the corresponding demonstrations that can be viewed on the WWW [1].

The PSNR versus channel SINR performance of the transceiver is portrayed in Figure 2 for the channel conditions of Table 2 over Rayleigh channels in a 7-cell cluster with and without shadow fading, as well as over conventional AWGN channels, again inflicting identical co-channel degradations, as for the Rayleigh channels. Having characterised the system's video performance, let us now concentrate on the power-control scheme used in our system, which maintaines the required FER and hence the targeted video quality across the whole traffic cell.

4. POWER CONTROL

An attractive power control algorithm based on a combination of BER and RSSI estimates was proposed by Chuang and Sollenberger [7]. In this contribution we set out to quantify the benefits of using a BER-based power control algorithm in an interference limited environment.

In our proposed BER-based power control algorithm the main channel quality indicator was the frame error flag (FEF). In order for the transmitter to infer, whether a transmission burst was received correctly, an acknowledgement has to be sent from the receiver, which is associated with a delayed indication of the channel quality. If this delay is too high, the frame error flag may be of little use. This delay is one of the disadvantages of BER-based techniques in comparison to systems that use a RSSI-reading carried out by the receiver in order to set the transmission power. However, the RSSI-based systems assume reciprocity of the uplink and downlink, an assumption, which is also affected by interference.

In our forthcoming discourse we first highlight the rationale behind the proposed power control algorithm and then formalise its description by providing the flow-chart of it, albeit due to space limitations we refrain from detailing the optimisation of its parameters. The true number of bit errors in a transmission burst is only known to the receiver, if the channel coding used has not become overloaded by too many errors. This is true for both convolutional and block codes, although convolutional codes are oblivious of being overloaded, while block codes are capable of detecting these events. Hence block codes are more attractive in this application. Clearly, when the channel coding is overloaded, a frame error (FE) results. We use the binary Bose-Chaudhuri-Hocquenghem BCH(255,171,11) forward error correction (FEC) coding, correcting up to $t = 11$ errors and if the number of errors is higher than $t = 11$, then a frame error occurs. Note, however, that the algorithm is generic, irrespective of the FEC code used.

In addition to the frame error flag, our proposed power control algorithm uses the actual number of error corrected by the channel coding as an additional indicator of channel quality. If the number of errors in the BCH-coded frame is zero, the channel is considered good, and reducing the transmission power should be considered. By contrast, if the number of errors in the frame is higher than the correcting capability of the FEC code, then a frame error has occurred, and increasing the transmission power should be of urgent consideration. However, if the number of errors contained in the BCH-coded frame is correctable by the FEC, there are three possible situations that should be considered. Firstly,

[1] http://www-mobile.ecs.soton.ac.uk/peter/robust-h263/robust.html

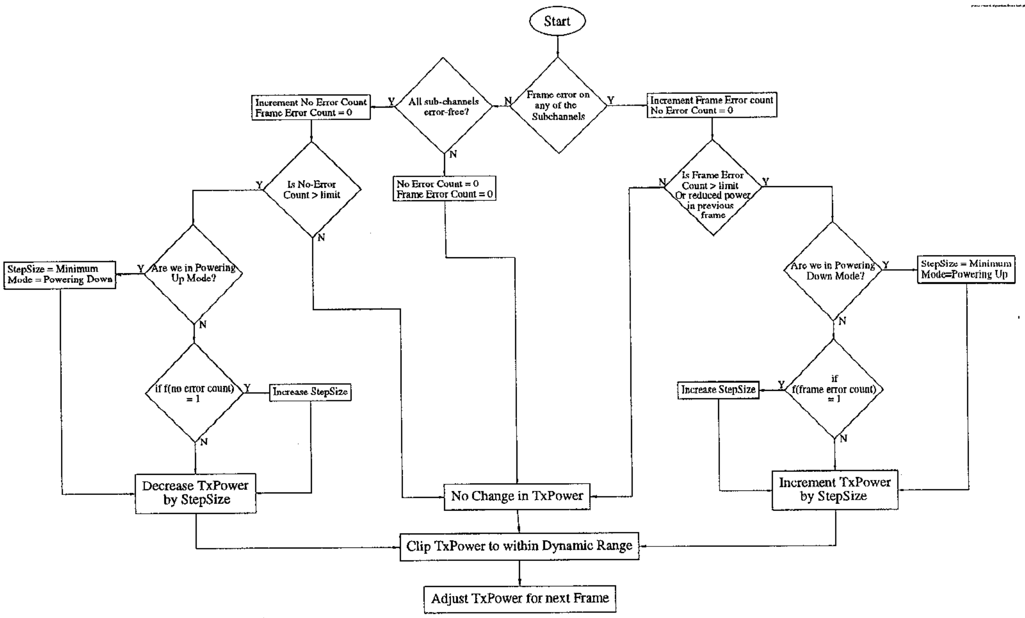


Figure 3: Flow Chart of the BER-based Power Control Algorithm

Feature	Value
Delay (TDMA frames)	1
Minimum StepSize (dB)	1
Maximum StepSize (dB)	16
Max. TxPower (dBm)	30 (1 Watt)
TxPower Dynamic Range (dB)	64

Table 2: Power Control Algorithm's Features

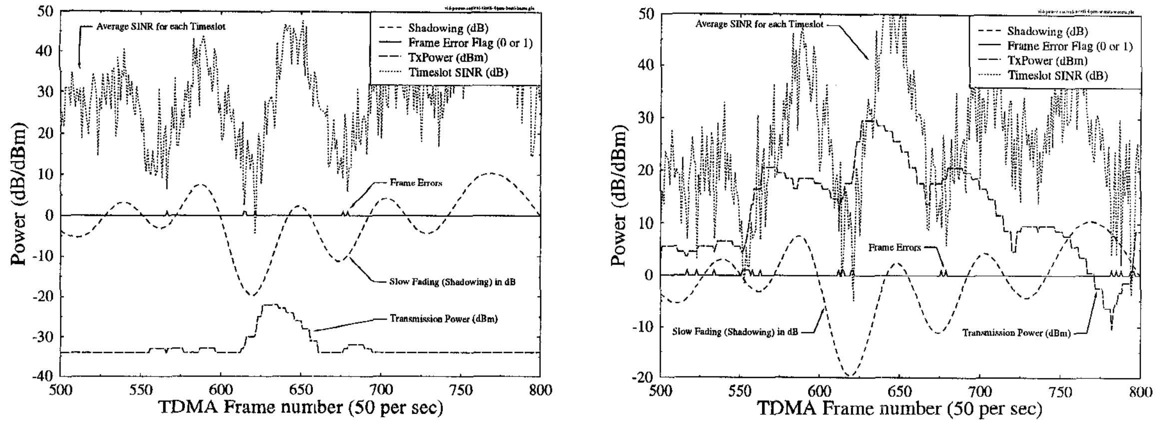
if the number of errors is near to the error correction capability of the code, where a frame error would occur, or the number of errors in successive frames has been increasing, then the transmission power should be increased. Secondly, if the number of errors in the frame is low and has been reducing in previous frames, then the power should be reduced. Lastly, when the frame is not error-free, but the errors are correctable by the FEC, it is logical to keep the transmission power constant.

The amount of time to delay an action, before the power control algorithm increases or decreases the power depends on many factors, such as the modulation scheme employed, the channel conditions, the target Frame Error Rate (FER), etc. The power control algorithm proposed in this contribution exhibits a variable stepsize and has been tested with a power control delay of one TDMA frame. Work is currently under way to optimise the algorithmic parameters for different modulation schemes and delays. Based on the above rationale, the power control algorithm's main features are shown in Table 2. We used a typical maximum transmission power of 1 Watt, with dynamic range of 64dB, as in GSM.

The simplified flow-chart of the power control algorithm is shown in Figure 3, which will be briefly highlighted below. The algorithm has a set of variable parameters that can be modified with varying channel conditions, modulation

Parameter Name	Type	Comment
NearFrameError	%	If number of bit errors is greater than a percentage of the number of correctable errors then the event is classified as a frame-error
NearErrorFree	%	If number of bit errors is less than a percentage of the number of correctable errors then classified as an error-free frame
IncPowCount	Number	Number of successive frame errors to initiate transmission power increments
DecPowCount	Number	Number of successive error-free frames to trigger transmission power decrements
IncPowStepSize	Function	Function of successive frame error count, decides, when to increase stepsize and by how much
DecPowStepSize	Function	Function of successive error-free frames count, decides when to increase stepsize and by how much

Table 3: Power Control Algorithm Parameters



(a) Best Case

(b) Worst Case

Figure 4: Various waveforms associated with the error rate based Power Control Algorithm (a) Best case situation when both interfer and user are close to their basestation, the best (b) Worst case situation, when both interfer and user are at the edge of their cell

schemes or other factors. These parameters are summarised in Table 3. Before the commencement of transmission the MS receives a control signal from the BS informing the MS of the number of errors corrected or whether there was a frame error. If there was a frame error, or the number of errors was close to causing a frame error, the frame error counter was incremented. Explicitly, if the number of bit errors in a BCH-coded frame was close to the FEC overload condition, which in our current system was $t = 11$, this event was considered a 'NearFrameError' (NFE) condition, as seen in Table 3. The parameter 'frame error count' registered the number of frame errors that have occurred in successive frames. When the 'frame error count' is incremented, the 'no error counter' (NEC) is reset, where the 'no error count' was defined as the number of consecutive error-free frames received in a row.

When a received video packet did not contain any errors even before FEC was invoked, then the 'no error counter' was incremented, while the 'frame error counter' was reset. The transmission bursts received with a low number of errors, constituting a low proportion of the FEC code's error correction capability, were classified as error free, where the corresponding 'NearErrorFree' threshold of Table 3 was a further optimised algorithmic parameter.

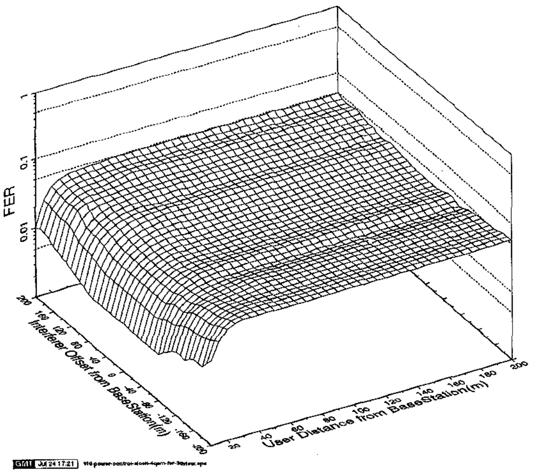
If the previous transmission burst was received with errors, which were corrected by the channel coding, but the number of errors was lower than what would be considered as a 'NearFrameError', although higher than that, which would be classed as a 'NearErrorFree' frame, then the 'frame error counter' and 'no error counters' are reset and the transmission power is left unchanged.

Following a number of successive frame errors, the MS decides to increase the transmission power. The number of erroneous frames, 'IncPowerCount' in Table 3, which is required to initiate power boosting, is another optimised parameter of the algorithm. Upon powering up, the MS initially starts increasing the power by the smallest stepsize. However, if frame errors continue to occur, the stepsize is increased. The stepsize increase is a function of the frame error counter value, and this function, which we refer to as 'IncPowerStepSize' in Table 3 is a further optimised parameter of the algorithm.

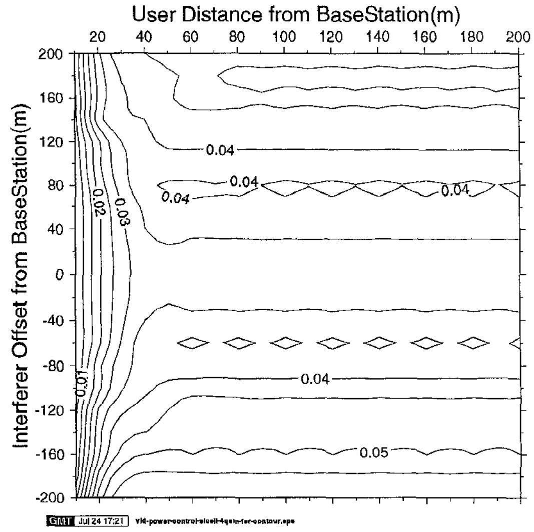
When the MS is informed by the error rate feedback channel that the last N frames have been received error-freely, the handset decreases the transmission power. The number of error-free frames, 'DecPowCount' in Table 3, encountered before the handset powers down is yet another optimised parameter of the algorithm. As with powering up, the initial reduction of power is carried out using the smallest stepsize. If, however, after powering down the next few frames are still error-free, then the reduction stepsize is increased. The stepsize increment is governed by the function 'DecPowerStepSize' of Table 3, which is dependent on the the number of successive error-free frames received. This function is also a fundamental optimised parameter of the algorithm. We note furthermore that the absolute dynamic range of the algorithm is limited by the maximum transmission power of 30 dBm and by the 64 dB dynamic range of the algorithm. In summary, the parameters that govern the behaviour of the power control algorithm are shown in Table 3, while its operation is summarised in the flow-chart of Figure 3. Further details of its inner workings can be inferred by referring to the flow-chart. In the next Section let us now briefly characterise the performance of the power control algorithm.

5. PERFORMANCE OF THE POWER CONTROL

The power control algorithm was simulated using 4QAM and the worst-case scenario of a single interfer was employed to inflict co-channel interference. Examples are shown in Figures 4(a) and 4(b) for the best and worst case situations, where the best case is when both the interferer and the user are close to their corresponding BSs and the worst case is when they are at the edge of their cells, respectively. Spe-



(a) 3D view



(b) Contour View

Figure 5: Frame error rate (FER) with Power Control, versus user and interferer distance from basestation

cifically, Figure 4(a) shows the transmission power variation versus time, demonstrating that the transceiver is operating close to the minimum of -34 dBm. Both of the Subfigures display the slow fading, the signal-to-interference+noise-ratio (SINR) average over each timeslot, the Frame Error Flag, and the Transmission power. The worst-case situation seen in Figure 4(b) shows more clearly, how the power control reacts to the fluctuating SINR. Observe in the Figures that the frame error flag suggests a moderate FEC overloading event frequency, irrespective of the pathloss and slow-fading experienced. Furthermore, it can also be seen that the transmission power is limited to the maximum power of 30 dBm at one point.

As expected, the power control algorithm maintains a near-constant BCH-coded frame error rate across the whole cell area, which is demonstrated by Figure 5. Specifically, Figure 5(a) portrays the global three-dimensional (3D) view, while Figure 5(b) represents the contour plot of constant FER trajectories. The target FER was adjusted to around 5%, as required by the video transceiver to maintain the target PSNR, but in the extreme vicinity of the BS the power could not be reduced below the 30-64=-34 dBm level, which resulted in the reduced FER observed in the Figure.

6. SUMMARY AND CONCLUSIONS

A power-controlled H.263-based robust video transceiver scheme was proposed and evaluated in an interference-limited 7-cell cluster. The main system parameters are summarised in Table 2. The proposed combination of algorithms guarantees a robust videophone performance over wireless channels across the area of traffic cells.

7. ACKNOWLEDGEMENT

The financial support of the EPSRC, UK in the framework of the contract GR/K74043 is gratefully acknowledged.

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