ARQ-assisted H261 and H263-based Programable Video Transceivers

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Motivation, Scope and Background

Motivated by the the rapid emergence of wireless visual communications as a major research area [1, 4, 5, 6, 7, 8, 9, 10], in this treatise we set out to contrive and investigate an intelligent, adaptively re-configurable wireless video transceiver. The proposed wireless video communicator can adapt to a range of service requirements, video quality, bit-rate and robustness constraints by invoking the best possible system configuration under time-variant optimisation criteria.

Although the main target of the recently formed MPEG4 working group is to standardise a very low-rate videophone codec suitable also for mobile applications, currently no wireless video standard exists. In our former work we contrived a range of proprietary video codecs and embedded them in appropriate wireless transceivers[4, 5, 7, 9, 10].

In this treatise we embarked on investigating the feasibility of and documenting the performance of two wireless candidate systems based on the standard H261 and H263 ITU codecs. The challenge of these endeavours was to overcome the deficiencies of these codecs due the fact that they were designed for benign Additive White Gaussian Noise (AWGN) channels, while maintaining compatibility with the Recommendations. Hence both the H261 and the H263 video codecs were subjected to rigorous bit sensitivity analysis and their robustness was improved using sensitivity-matched embedded binary Bose-Chaudhuri-Hocquenghem (BCH) coding combined with a re-configurable Pilot Symbol Assisted (PSA) and Automatic Repeat Request (ARQ) aided Quadrature Amplitude Modulation (QAM) modem [12].

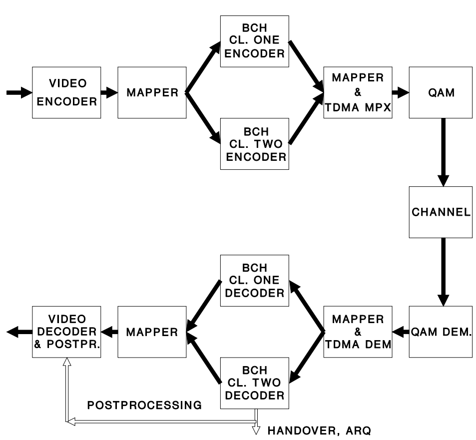

Figure 1: System's Schematic

The proposed system shown in Figure 1 can re-configure itself under network control in a variety of modes of operation, which span a wide range in terms of video quality, bit-rate, robustness against channel errors and implementational complexity. Specifically, the transceiver operates using highly bandwidth efficient 64-level Pilot Symbol Assisted Quadrature Amplitude Modulation (64-PSAQAM) in a benign indoors cordless environment, where high signal-to-noise ratio (SNR) and signal-to-interference ratio (SIR) prevail. The number of modulation levels is dropped from 64 to 16, when the portable station (PS) is handed over to an outdoors street microcell, and can be further reduced to 4 in less friendly propagation scenarios.

The H.261 video coding standard

In 1990 the International Telecommunications Union (ITU) published the H.261 video coding standard[3]. This is a definition of a video codec for use in audio-visual services. The H.261 codec was designed to generate a bit stream to be transmitted over data links with capacities which are multiples of 64 Kbit/s, and so it is sometimes referred to as a p x 64Kbit/s standard, where p is in the range of 1 to 30. These data-rates were designed to match the capacity available in the Integrated Services Digital Network (ISDN).

The coding algorithm is a hybrid of inter-frame prediction, transform coding, and motion compensation. The data-rate of the coding algorithm was designed to range between 40 Kbits/s and 2 Mbits/s. The inter-frame prediction removes temporal redundancy, while the transform coding removes the spatial redundancy inherent in moving pictures. Motion vectors are used to help the codec compensate for motion. In order to remove any further redundancy in the transmitted bitstream, variable length coding is used.

The H.261 standard supports two video resolutions, Quarter Common Interchange format (QCIF) and Common Interchange format (CIF).

The H.261 codec used in this study was a software implementation that was derived from an early version of the H.261 codec, which is now used in the so-called INRIA Videoconferencing System (IVS). The original source code is no longer available, but further information on IVS and its source code is available on the World Wide Web*.

The H.263 video coding standard

The H.263 Recommendation is a provisional ITU-T standard[2], which is due to be published in 1995/1996. It was designed for low bit-rate communication and early drafts specified data-rates less than 64 Kbits/s, however this limitation has now been removed. It is expected that the standard will be used for a wide range of bit-rates, not just low bit-rate applications. It is expected that the H.263 standard will replace the H.261 scheme in many applications.

The coding algorithm of the H.263 scheme is similar to that used by the H.261 recommendation, however with some improvements and changes in order to enhance its

*http://www.inria.fr/rodeo/personnel/Thierry.Turletti/ivs.html performance and error resilience. The main differences between the H.261 and H.263 coding algorithms are as follows. In the H.263 standard half pixel precision is used for motion compensation, whereas H.261 used full pixel precision and a loop filter. Some parts of the hierarchical structure of the datastream are now optional, hence the codec can be configured for a lower data-rate or better error recovery. There are now four negotiable configuration options included, in order to improve the coding performance: Unrestricted Motion Vectors, Syntax-based arithmetic coding, Advance prediction, and predicted-(P) as well as bi-directional (B) frames.

The H.263 standard supports five different video resolutions. In addition to QCIF and CIF that were supported by H.261 there is Sub-QCIF (SQCIF), 4CIF, and 16CIF. SQCIF is approximately half the resolution of QCIF, while 4CIF and 16CIF represent 4 and 16 times the resolution of CIF, respectively. The support of 4CIF and 16CIF implies that the codec could then compete with other higher bit-rate video coding standards such as the Motion Picture Experts Group (MPEG) standards for encoding high-resolution images.

The H.263 codec used in our studies was a modified version of a software implementation developed by Telenor Research and Development[11]. The original source code is available from the Telenor World Wide Web site [*].

Table 1 summarises the video formats and the associated source rates supported by the H.261 and H.263 standards.

Performance comparison of the H.261 and H.263 codecs

In our comparative studies the H.261 simulations were carried out with and without motion compensation. When motion vectors were used, the optional loop filtering was turned on in order to reduce the effects of block edge artifacts. In our H.263 simulations we used none of the negotiable options, but the codec employed motion vectors and inter-frame prediction for motion compensation. Our simulations were carried out at 10 and 30 frames/s, using different resolution versions of the same video sequence, resulting in a wide range of bit-rates, in order to quantify the maximum and minimum bit-rates of the codecs.

Figure 2 shows a comparison of the H.261 and H.263 video codecs in terms of image quality expressed in Peak Signal-to-Noise Ratio (PSNR) versus bit-rate (Kbit/s). As the pair-wise comparisons reveal, irrespective of the bit-rate, the performance of the H.263 codec is significantly higher than that of H.261 scheme in all scenarios.

Table 2 shows the decrease in terms of bit-rate achieved for the same PSNR, when using the H.263 scheme instead of the H.261 arrangement. The reductions are relative to the H.261 simulations at 10 frames/s without motion compensation. The table includes a column for the best H.261 performance, which uses motion vectors (MV) and loop filtering. This table clearly demonstrates that the H.263 codec easily outperforms the H.261 scheme,

[*]http://www.nta.no/brukere/DVC/

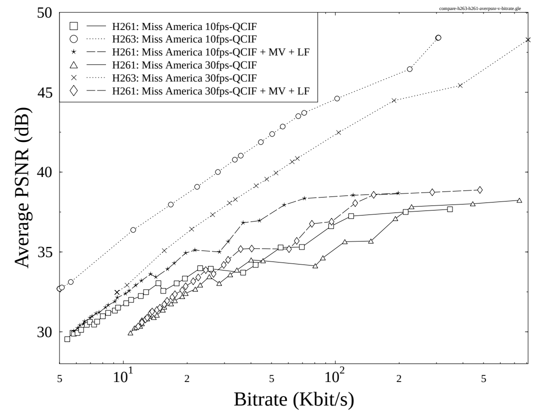

Figure 2: Image quality (PSNR) versus coded bit-rate, for H.261 and H.263 simulations using grey scale QCIF “Miss America” video sequences at 10 and 30 frames/s

even when the frame rate is three times higher than that of the H.261 simulations.

Our next results summarised in Table 3 show the increase in image quality (PSNR) achieved at the same bit-rate. The gains are relative to the H.261 simulations at 10 frames/s without motion compensation. Again it is clear that the H.263 codec outperforms the H.261 arrangement.

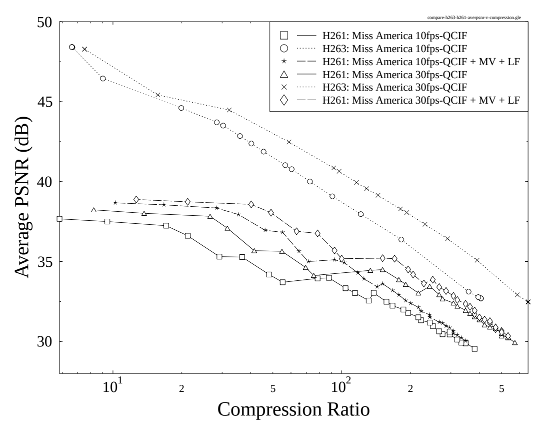

Figure 3: Image quality (PSNR) versus coded bit-rate, for H.261 and H.263 simulations using grey scale QCIF “Miss America” video sequences at 10 and 30 frames/s

Figure 3 provides a comparison of the H.261 and H.263 video codecs from a different perspective, as image quality (PSNR) versus compression ratio. As can be seen from the Figure, the H.263 codec is significantly more efficient than the H.261 scheme in all investigated scenarios. We note again that these results were obtained without the H.263 using the negotiable options that can be invoked to increase image quality or reduce bit-rate, at the cost of increased codec complexity. Let us now focus our attention on some of the error control issues.

Picture Format	Luminance pixels	Luminance lines	H.261 support	H.263 support	Uncompressed bit-rate (Mbit/s)			
					10 frame/s		30 frame/s	
					Grey	Colour	Grey	Colour
SQCIF	128	96		Yes	1.0	1.5	3.0	4.4
QCIF	176	144	Yes	Yes	2.0	3.0	6.1	9.1
CIF	352	288	Optional	Optional	8.1	12.2	24.3	36.5
4CIF	704	576		Optional	32.4	48.7	97.3	146.0
16CIF	1408	1152		Optional	129.8	194.6	389.3	583.9

Table 1: Picture Format supported

Fixed	Percentage Bitrate Reduction (%)				
PSNR(dB)	10fps+MV+LF	H263-10fps	30fps+NoMC	30fps+MV+LF	H.263-30fps
33	19.53	62.28	-61.08	-41.31	26.90
35	60.57	82.99	-85.16	33.34	70.30
37	59.46	87.86	-72.33	10.19	77.78

Table 2: Percentage reduction in bit-rate required to achieved the same PSNR, for H.261 and H.263 simulations compared with the H.261 simulation at 10 frames/s using no motion compensation

Forward error correction coding

Aa an example let us consider transmitting QCIF images, where the video codecs were programmed to generate 3560, 2352 and 1176 bits per frame, which at scanning rate of 10 frames/s resulted in bit-rates of 35.6 kbps, 23.52 kbps and 11.76 kbps, respectively.

Forward error correction (FEC) codes can reduce the number of transmission errors at the expense of an increased baud rate. Therefore the use of FEC can increase the range of channel signal-to-noise ratio (SNR) for which transmissions are error-free. When the error rate becomes too high a FEC is said to become overloaded, this causes a very sharp increase in BER.

In our earlier work we have shown that in Quadrature Amplitude modulation (QAM) schemes the bits can be assigned to a number of different integrity classes. The number of integrity classes depends on the number of modulation levels, and in 4-QAM there is only one integrity class, in 16-QAM there are 2, while in 64-QAM there are 3 classes, often also referred to as sub-channels. By using different strength FEC codes on each QAM sub-channel it is possible to equalise the probability of errors on the sub-channels. This means that all sub-channels FEC codes should break down at approximately the same channel SNR. This is desirable if all bits to be transmitted are equally important. Since our data-streams are variable length coded, one error can cause a loss of synchronisation. Therefore in this case most bits are equally important, and so equalisation of QAM sub-channels BER is desirable. The FEC codes used in our system are summarised in Table 4. The corresponding transmission packet sizes are summarised in Table 5 along with the initial quantiser identifiers, which predetermine the achieveable bit-rate. After including a control header, pilot and ramp symbols [12], the FEC-coded single-user signalling rates became 11.84 kBd in all three operating modes. In case of a Nyquist excess bandwidth of 50% this implies a single-user bandwidth requirement of 17.74 kHz. For example in the 200 kHz bandwidth of the Pan-European GSM system 8 voice-only users are supported, which corresponds to a 25 kHz user bandwidth. Consequently, our videophone stream can replace a speech stream, making wireless videophony realistic, if the cost of an additional timeslot is acceptable to the users.

Modulation scheme	FEC codes used
4 QAM	BCH(255,147,14)
16 QAM	Class 1: BCH(255,179,10) Class 2: BCH(255,115,21)
64 QAM	Class 1: BCH(255,199,7) Class 2: BCH(255,155,13) Class 3: BCH(255,91,25)

Table 4: FEC codes used for 4, 16 and 64 QAM

Modulation	TX. packet size	Initial Quantiser
4 QAM	147	9
16 QAM	294	6
64 QAM	445	4

Table 5: H.261 packet size and initial quantiser used for 4, 16, and 64 QAM

System Performance

The video system performance was evaluated under the propagation conditions of a vehicular speed of 30 mph, signalling rate of 11.84 kBd and propagation frequency of 1.9 GHz. In the various operating modes investigated the PSNR versus channel SNR curves of Figures 4 and 5 were obtained for Additive White Gaussian Noise (AWGN) and Rayleigh channels, respectively. Since both the H.261 and H.263 source codecs have had similar robustness against channel errors, and their transceivers were identical, the associated ’corner SNR’ values, where unimpaired communications broke down were virtually identical for both systems over both AWGN and

Fixed	PSNR increase (dB)				
Bitrate(Kbit/s)	10fps+MV+LF	H263-10fps	30fps+NoMC	30fps+MV+LF	H.263-30fps
20	1.54	5.20	-0.98	-0.51	2.76
30	1.51	6.43	-0.57	0.39	3.98
50	2.55	7.50	-0.44	0.35	4.91
100	1.73	7.81	-1.56	0.32	5.59
190	1.22	8.49	-0.41	1.18	7.04

Table 3: Increase in PSNR(dB) achieved at the same bit-rate, for H.261 and H.263 simulations compared with the H.261 simulation at 10 frames/s without motion compensation

Rayleigh channels. However, as expected, the H263 codec again exhibited always higher video quality at the same bit-rate or system bandwidth.

Our current endeavours are focussed on exploring the quality versus bit-rate performance of both systems for various image resolutions, in order to be able to provide the required video quality, bit-rate, frame rate, image size and resolution on a demand basis in intelligent adaptive multimode transceivers.

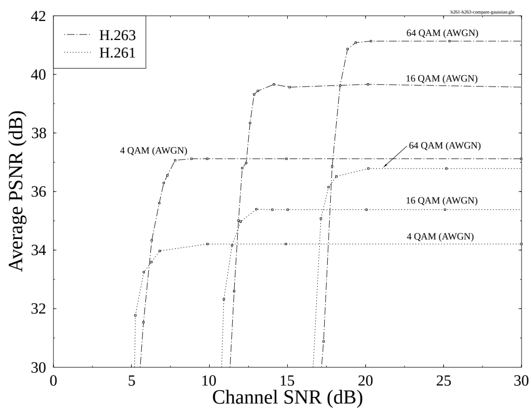

Figure 4: Performance comparison of the proposed adaptive H261 and H263 transceivers over AWGN channels

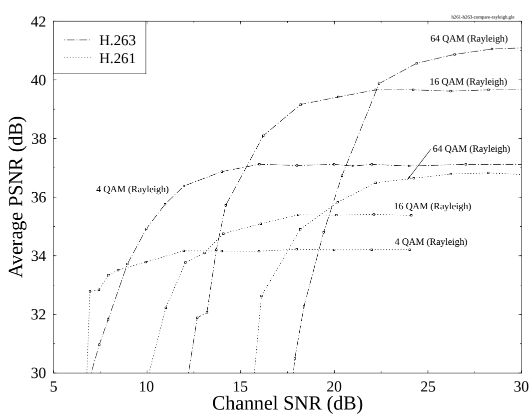

Figure 5: Performance comparison of the proposed adaptive H261 and H263 transceivers over Rayleigh channels

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