# Modern Video Compression and Communications over Wireless Channels: From Second to Third Generation Systems, WLANs and Beyond

by

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# Preface and Motivation

## The Wireless Multimedia Communications Scene

Against the backcloth of the emerging third - generation wireless personal communications standards and broad-band access network standard proposals, this book is dedicated to a range of topical wireless video communications aspects. *The transmission of multimedia information over wireline based links* can now be considered a mature area, where a range of interactive and distributive services are offered by various providers right across the globe, such as Integrated Services Digital Network (ISDN) based H.261/H.263 assisted video telephony, video on demand services using the Motion Pictures Expert Group (MPEG) video compression standards, multimedia electronic mail, cable television and radio programmes, etc. *A range of interactive mobile multimedia communications services are also realistic in technical terms* at the time of writing and their variety, quality as well as market penetration is expected to exceed that of the wireline oriented services during the next few years.

*The wireless multimedia era is expected to witness a tremendous growth with the emergence of the third-generation (3G) personal communications networks (PCN) and wireless asynchronous transfer mode (WATM) systems*, which constitute a wireless extension of the existing ATM networks. All the three global 3G PCN standard proposals, which originate from the USA, Europe and Japan are based on Code Division Multiple Access (CDMA) and are capable of transmitting at bitrates in excess of 2 Mbps. Furthermore, the European proposal was also designed to support multiple simultaneous calls and services. The WATM solutions often favour Orthogonal frequency Division Multiple Access (OFDM) as their modulation technique and indeed, the imminent so-called Broadband Access Network (BRAN) standard also advocates OFDM. A range of WATM video aspects and mobile digital video broadcast (DVB) issues are also reviewed in Part IV of the book.

Research is also well under way towards the definition of a whole host of new modulation and signal processing techniques and a further trend is likely to dominate this new era, namely **the merger of wireless multimedia communications, multimedia consumer electronics and multimedia computer technologies**. These trends are likely to hallmark the community's future research in the forthcoming years. This book is naturally limited in terms of its coverage of these aspects, simply due to space limitations. We endeavoured, however, to provide the reader with a broad range of applications examples, which are pertinent to scenarios, such as transmitting low-latency interactive video as well as distributive or broadcast video signals over the existing second generation (2G) wireless systems, 3G arrangements and the forthcoming fourth generation systems. We also characterised the video performance of a

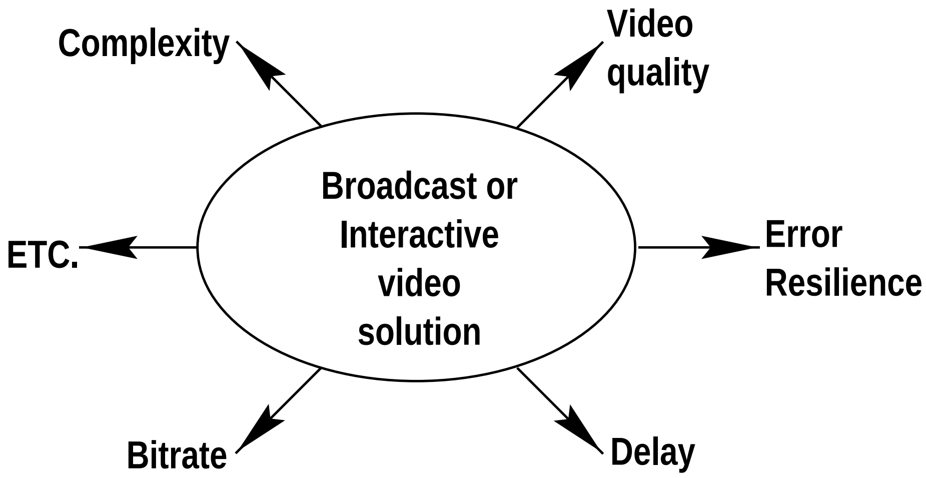


**Figure 1:** Contradictory system design requirements of various video communications systems

range of high bitrate Local Area Network (LAN) type systems as well as various video broadcast systems, transmitting broad-cast quality video signals to mobile receivers both within the home and farther afield - to demanding bussiness customers on the move.

**These enabling technologies facilitate a whole host of wireless services, such as video telephony, electronic commerce, city guide, Internet access for games, electronic mail and web browsing. Further attractive applications can be found in wireless in-home networks, DVB reception in busses, trains, cars, on board of ships, etc - for example using multi-media laptop PCs. Again, the books does not delve in the area of specific applications, it rather offers a range of technical solutions, which are applicable to various propagation and application environments.**

*We hope that the book offers you a range of interesting topics, sampling - 'hopefully without gross aliasing errors' - the current state-of-the-art in the associated enabling technologies. In simple terms, finding a specific solution to a distributive or interactive video communications problem has to be based on a compromise in terms of the inherently contradictory constraints of video quality, bitrate, delay, robustness against channel errors, and the associated implementational complexity, as suggested by Figure 1. Analysing these trade-offs and proposing a range of attractive solutions to various video communications problems is the basic aim of this book. Below we attempt to raise your interest in this book by providing a brief guided tour of its topics.*

## Video Over Wireless Systems

Over the past decade second generation (2G) wireless systems have been installed right across the globe and in some countries about a third of the population possesses a mobile telephone. These systems typically exhibit a higher spectral efficiency than their analogue counterparts and offer a significantly wider range of services, such as data, fax, email, short messages, high-speed circuit switched data, etc. However, due to their relatively low bitrates the provision of interactive wireless videotelephony has been hindered. Potentially there are two different options for transmitting video over the 2G systems, namely over their data channel, or - provided that the standards can be amended accordingly - by allocating an additional spech channel for video transmissions. Considering the latter option first, the low-rate speech channel of the 2G systems constrains the achievable bitrate to such low values that the spatial video resolution supported is limited to 174×144-pixel so-called Quarter Common Intermediate Format (QCIF) or to the 128×96-pixel Sub-QCIF (SQCIF) at a 5-10 frames/s video frame scanning rate.

The range of standard video formats are summarised in Table 1, along with their uncompressed bitrates at frame scanning rates of both at 10 and 30 frames/sec for both grey and colour video signals. This table indicates the extremely wide range of potential bitrate requirements. Clearly, the higher resolution formats can only be realistically used for example in the context of high-rate WATM systems.

The so-called Cordless Telephone (CT) schemes of the second generation typically have a 32 kbit/s speech rate, which is more readily amenable to interactive video telephony. For the sake of supporting a larger video frame size, such as the 352x288-pixel Common Intermediate Format (QCIF), higher bitrates must be supported, which is possible over the DECT system upon linking a number of slots at a rate in excess of 500 kbps.

By contrast, the data channel of the 2G systems can often offer a higher data rate, than that of the speech channel, for example by linking a number of time-slots, as it was proposed in the so-called Digital European Cordless Telecommunications (DECT) scheme or in the high-speed circuit switched data (HSCSD) mode of the Global System of Mobile communications known as GSM. CT schemes typically refrain from invoking channel coding, since they typically operate over benign channels and hence they do not employ channel interleavers, which is advantageous in video delay terms, but disadvantageous in terms of error resilience. The data transmission mode of cellular systems, however, typically exhibits a high so-called interleaving delay, which assists in increasing the system's robustness against channel errors. This is advantageous in terms of reducing the channel-induced video impairments, but may result in 'lip-synchronisation' problems between the speech and video output signals.

Both the speech and data channels of the 2G systems tend to support a fixed constant bitrate. However, the existing standard video codecs, such as the H.263 and MPEG2 codecs, generate a time-variant bitrate. This is, because they endeavour to reduce the bitrate to near the lowest possible bitrate constituted by the so-called entropy of the source signal. Since this is achieved by invoking high-compression variable-length coding schemes, their time-variant bitstream becomes very sensitive against transmission errors. In fact a single transmission error may potentially render the video quality of an entire video frame unacceptable. Hence the existing standard-based video codecs, such as the H.263 and MPEG2 schemes require efficient system-level transport solutions, in order to address the above mentioned deficiencies. This issue will be discussed in more depth in Part IV of the book. An alternative solution

| Video Format | Luminance dimensions | No. of Pels per frame | Uncompressed bitrate (Mbit/s) | | | |
|---|---|---|---|---|---|---|
| | | | 10 frame/s | | 30 frame/s | |
| | | | Grey | Colour | Grey | Colour |
| SQCIF | 128 x 96 | 12 288 | 0.983 | 1.47 | 2.95 | 4.42 |
| QCIF | 176 x 144 | 25 344 | 2.03 | 3.04 | 6.09 | 9.12 |
| CIF | 352 x 288 | 101 376 | 8.1 | 12.2 | 24.3 | 36.5 |
| 4CIF | 704 x 576 | 405 504 | 32.4 | 48.7 | 97.3 | 146.0 |
| 16CIF | 1408 x 1152 | 1 622 016 | 129.8 | 194.6 | 389.3 | 583.9 |
| CCIR 601 | 720 x 480 | 345 600 | 27.65 | 41.472 | 82.944 | 124.416 |
| HDTV 1440 | 1440 x 960 | 1 382 400 | 110.592 | 165.888 | 331.776 | 497.664 |
| HDTV | 1920 x 1080 | 2 073 600 | 165.9 | 248.832 | 497.664 | 746.496 |

SQCIF: Sub-Quarter Common Intermediate Format
QCIF: Quarter Common Intermediate Format
CIF: Common Intermediate Format
HDTV: High Definition Television

**Table 1:** Various video formats and their uncompressed bitrate. Upon using compression 10-100 times lower average bit rates are realistic.

is invoking constant-rate proprietary video codecs, which - to a degree - sacrifice compression efficiency for the sake of an increased robustness against channel errors. This philosophy was pursued in Part II of the book, which relies on much of the compression and communications theory, as well as on the various error correction coding and transmission soutions presented in Part I.

At the time of writing the standardisation of three third generation (3G) systems is approaching completion in Europe, the United States and in Japan. These systems - which are characterised in Part I of the book, along with their 2G counterparts - were designed to further enrich the range of services supported and they are more amenable to interactive wireless videotelephony, for example, than their 2G conterparts. This book aims to propose a range of video system solutions bridging the evolutionary avenue between the second and third generation systems.

Part I of the book provides an overview of the whole range of associated transmission aspects of the various video systems proposed and investigated. Specifically, Chapter 1 summarises the necessary background on information-, compression- and communications theory. This is followed by Chapter 2, which is dedicated to the characterisation of wireless channels. The impairments inflicted by these channels can be counteracted by the channel codecs of Chapters 3 and 4. Various modulation and transmission schemes are the topic of Chapter 5. We then provide a discourse on video traffic modelling and evaluate the proposed model's performance in the context of various statistical multiplexing and multiple access schemes in Chapter 6. The effects of co-channel interferences - which constitute the most dominant performance limiting factor of multiple access based cellular systems - are characterised in Chapter 7. Dynamic channel allocation schemes - which rely on the knowledge of the co-channel interference and the multiple access scheme employed - are the topic of Chapter 8. The video transmission capabilities of 2G wireless systems are discussed in Chapter 9. These elaborations are followed by an indepth treatise on various CDMA schemes in Chapter 10, including a variety of novel so-called residual number system based CDMA schemes and on the global 3G CDMA proposals, which concludes Part I of the book.

Part II is dedicated to a host of fixed, but arbitrarily programmable rate video codecs based on fractal coding, on the discrete cosine transform (DCT), on vector quantised (VQ) codecs and quad-tree based codecs. These video codecs and their associated quadrature amplitude modulated (QAM) video systems are portrayed in Chapters 11-14. Part III of the book is dedicated to high-resolution video coding, encompassing Chapters 15 and 16.

Part IV is constituted by Chapters 17-21, which are dedicated to the characterisation of the H.261 and H.263 video codecs, constituting one of the most important representative of the family of state-of-the-art hybrid DCT codecs. Hence the associated findings of these chapters can be readily applied in the context of other hybrid DCT codecs, such as the MPEG family, including the MPEG2 and MPEG4 codecs. Chapters 17-21 also portray the interactions of these hybrid DCT video codecs with reconfigurable multimode QAM transceivers. The book is concluded by Chapter 21, which offers a range of system design studies related to wideband burst-by-burst adaptive TDMA/TDD, OFDM and CDMA interactive as well as distributive mobile video systems and their performance characterisation over highly dispersive transmission media.

## Motivation

The rationale of this book was outlined above from a technical perspective. **Another important motivation of the book is to bring together two seemingly independent research communities, namely the video compression and the wireless communications communities by bridging the philosophical difference between them**. These philosophical differences are partially based on the contradictory requirements portrayed and discussed in the context of Figure 1. Specifically, whilst a range of exciting developments have taken place in both the image compression and wireless communications communities, most of the video compression research was cast in the context of wire-line based communications systems, such as ISDN and ATM links, for example. These communications systems typically exhibit a low bit error rate (BER) and low so-called packet or cell loss rate. For example, ATM systems aim for a cell-loss rate of $10^{-9}$. Hence the error resilience requirements of the video codecs were extremely relaxed.

In the increasingly pervasive wireless era, however, such extreme transmission integrity requirements are simply irrealistic, since they would impose unreasonable constraints on the design of wireless systems, such as for example WATM systems. For example, the ATM cell-loss rate of $10^{-9}$ could only be maintained over wireless links at a high implementational cost, potentially invoking Automatic Repeat Requests (ARQ). ARQs, however, would increase the system delay, potentially precluding real-time interactive video communications, unless innovative design principles are invoked. Again, all these trade-offs are the subject of this book.

Part I of the book aims for providing sufficient background for readers requiring an overview in wireless communications, potentially for example video compression experts. Part II assumes a sound knowledge of the issues treated in Part I of the book, whilest offering an effortless introduction to the associated video compression aspects. Hence wireless experts may skip Part I and commence reading Part II of the book. Part III is exclusively on video compression. Hopefully readers from both the video compression and wireless communications communities will find Part IV of the book informative and fun to read, since it integrates the knowledge base of both fields, aiming to design improved video systems.

Again, it is our hope that the book underlines the range of contradictory system design trade-offs in an unbiassed fashion and that you will be able to glean information from it, in order to solve your own particular wireless video communications problem, but most of all that you will find it an enjoyable and relatively effortless reading, providing you with intellectual stimulation.

*Lajos Hanzo*

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*Lajos Hanzo*

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# Part I

# Transmission Issues

# Part II

# Video Systems based on Proprietary Video Codecs

# Part IV

# Video Systems based on Standard Video Codecs

# Glossary

**16CIF** Sixteen Common Intermediate Format Frames are sixteen times as big as CIF frames, and contain 1408 pixels vertically and 1152 pixels horizontally

**4CIF** Four Common Intermediate Format Frames are four times as big as CIF frames, and contain 704 pixels vertically and 576 pixels horizontally

**ACO** Augmented Channel Occupancy matrix, which contains the channel occupancy for the local and surrounding basestations. Often used by locally distributed DCA algorithms to aid allocation decisions.

**ACTS** Advanced Communications Technologies and Services. The 4th framework for European research (1994-98). A series of consortia consisting of universities and industrialists considering future communications systems.

**ADPCM** Adaptive Differential Pulse Coded Modulation.

**ARQ** Automatic Repeat Request, Automatic request for retransmission of corrupted data

**AV.26M** A draft recommendation for transmitting compressed video over error-prone channels, based on the H.263 [182] video codec.

**AWGN** Additive White Gaussian Noise

**BCH** Bose-Chaudhuri-Hocquenghem, A class of forward error correcting codes (FEC)

**BER** Bit error rate, the fraction of the bits received incorrectly

**BS** A common abbreviation for Base Station

| | |
|---|---|
| **CBER** | Channel bit error rate, the bit error rate before FEC correction |
| **CBP** | Coded block pattern, a H.261 video codec symbol that indicates which of the blocks in the macroblock are active |
| **CBPB** | A fixed length codeword used by the H.263 video codec to convey the coded block pattern for bi-directionally predicted (B) blocks |
| **CBPY** | A variable length codeword used by the H.263 video codec to indicate the coded block pattern for luminance blocks |
| **CCITT** | Now ITU, standardisation group |
| **CD** | Code Division, a multiplexing technique where signals are coded and then combined, in such a way that they can be separated using the assigned user signature codes at a later stage. |
| **CDF** | Cumulative density function, the integral of the probability density function (PDF) |
| **CDMA** | Code Division Multiple Access |
| **CIF** | Common Intermediate Format Frames containing 352 pixels vertically and 288 pixels horizontally |
| **CIR** | Carrier to Interference Ratio, same as SIR. |
| **COD** | A one bit codeword used by the H.263 video codec, that indicates whether the current macroblock is empty or nonempty. |
| **DC** | Direct Current, normally used in electronic circuits to describe a power source that has a constant voltage, as opposed to AC power in which the voltage is a sine-wave. It is also used to describe things which are constant, and hence have no frequency component. |
| **DCA** | Dynamic Channel Allocation |
| **DCS1800** | A digital mobile radio system standard, based on GSM, but operates at 1.8GHz at a lower power. |
| **DCT** | A discrete cosine transform, transforms data into the frequency domain. Commonly used for video compression by removing high frequency components of the video frames |
| **DECT** | A Pan-European digital cordless telephone standard. |

**DQUANT** A fixed length coding parameter used to differential change the current quantiser used by the H.263 video codec.

**EOB** An end of block variable-length symbol used to indicate the end of the current block in the H.261 video codec

**EREC** Error Resilient Entropy Coding. A coding technique improving the robustness of variable length coding, by allowing easier re-synchronisation after errors.

**FA** First Available, a simple centralised DCA scheme, which allocates the first channel found that is not reused within a given preset reuse distance.

**FBER** Feedback error ratio, the ratio of feedback acknowledgement messages that are received in error.

**FCA** Fixed Channel Allocation

**FD** Frequency Division, a multiplexing technique, where different frequencies are used for each communications link.

**FDD** Frequency-Division Duplex, a multiplexing technique, where the forward and reverse links use a different carrier frequency.

**FDMA** Frequency Division multiple access, a multiple access technique, where frequency division (FD) is used to provide a set of access channels.

**FEC** Forward Error Correction

**FEF** Frame Error Flag

**FER** Frame error rate

**FIFO** First-In First-Out, a queuing strategy in which elements that have been in the queue longest are served first.

**fps** Frames per second

**GBSC** Group of blocks (GOB) start code, used by the H.261 and H.263 video codecs to regain synchronisation, playing a similar role to PSC

**GEI** Functions similar to PEI, but in the GOB layer of the H.261 video codec

**GFID** A fixed length codeword used by H.263 video codec to aid correct re-synchronisation after an error

| | |
|---|---|
| **GMSK** | Gaussian Mean Shift Keying, a modulation scheme used by the Pan-European GSM standard by virtue of its spectral compactness. |
| **GN** | Group of block number, an index number for a GOB used by the H.261 and H.263 video codecs |
| **GOB** | Group of blocks, a term used by the H.261 and H.263 video codecs, consisting of a number of macroblocks. |
| **GOS** | Grade of Service, a performance metric to describe the quality of a mobile radio network. |
| **GQUANT** | Group of blocks quantiser, a symbol used by the H.261 and H.263 video codecs to modify the quantiser used for the GOB |
| **GSM** | A Pan-European digital mobile radio standard, operating at 900MHz. |
| **GSPARE** | Functions similar to PSPARE, but in the GOB layer of the H.261 video codec |
| **H.261** | A video coding standard [505], published by the ITU in 1990 |
| **H.263** | A video coding standard [182], published by the ITU in 1996 |
| **HCA** | Hybrid Channel Allocation, a hybrid of FCA and DCA. |
| **HTA** | Highest interference below Threshold Algorithm, a distributed DCA algorithm also known as MTA. The algorithm allocates the most interfered channel, whose interference is below the maximum tolerable interference threshold. |
| **IS-95** | North American mobile radio standard, that uses CDMA technology. |
| **ISDN** | Integrated Services Digital Network, digital replacement of the analogue telephone network |
| **ITU** | International Telecommunications Union, formerly the CCITT, standardisation group |
| **LFA** | Lowest Frequency below threshold Algorithm, a distributed DCA algorithm which is a derivative of the LTA algorithm, the difference being that the algorithm attempts to reduce the number of carrier frequencies being used concurrently. |

| | |
|---|---|
| **LIA** | Least Interference Algorithm, a distributed DCA algorithm that assigns the channel with the lowest measured interference that is available. |
| **LODA** | Locally Optimised Dynamic Assignment, a centralised DCA scheme, which bases it allocation decisions upon the future blocking probability in the vicinity of the cell. |
| **LOLIA** | Locally Optimised Least Interference Algorithm, a locally distributed DCA algorithm, that allocates channels using a hybrid of the LIA and an ACO matrix. |
| **LOMIA** | Locally Optimised Most Interference Algorithm, a locally distributed DCA algorithm, that allocates channels using a hybrid of the MTA and an ACO matrix. |
| **LP-DDCA** | Local Packing Dynamic Distributed Channel Assignment, a locally distributed DCA algorithm that assigns the first channel available that is not used by the surrounding basestations, whose information is contained in an ACO matrix. |
| **LTA** | Least interference below Threshold Algorithm, a distributed DCA algorithm, which allocates the least interfered channel, whose interference is below a preset maximum tolerable interference level. |
| **MA** | Abbreviation for Miss America, a commonly used head and shoulders video sequence referred to as Miss America |
| **Macroblock** | A grouping of 8 by 8 pixel blocks used by the H.261 and H.263 video codecs. Consists of four luminance blocks and two chrominance blocks. |
| **MB** | Macroblock. |
| **MBA** | Macroblock address symbol used by the H.261 video codec, indicating the position of the macroblock in the current GOB |
| **MBS** | Mobile Broadband System |
| **MCBPC** | A variable length codeword used by the H.263 video codec to convey the macroblock type and the coded block pattern for the chrominance blocks |
| **MODB** | A variable length coding parameter used by the H.263 video codec to indicate the macroblock mode for bi-directionally predicted (B) blocks |
| **MPEG** | Motion Picture Expert Group, also a video coding standard designed by this group that is widely used |

**MQUANT** A H.261 video codec symbol that changes the quantiser used by current and future macroblocks in the current GOB

**MS** A common abbreviation for Mobile Station

**MSQ** Mean Square centralised DCA algorithm, which attempts to minimize the mean square distance between cells using the same channel.

**MTA** Most interference below Threshold Algorithm, a distributed DCA algorithm also known as HTA. The algorithm allocates the most interfered channel, whose interference is below the maximum tolerable interference level.

**MTYPE** H.261 video codec symbol that contains information about the macroblock, such as coding mode, and flags to indicate whether optional modes are used, like motion vectors, and loop filtering

**MV** Motion Vector, a vector to estimate the motion in a frame

**MVD** Motion vector data symbol used by H.261 and H.263 video codecs

**MVDB** A variable length codeword used by the H.263 video codec to convey the motion vector data for bi-directionally predicted (B) blocks

**NCC** Normalised Channel Capacity

**NN** Nearest-Neighbour centralised DCA algorithm, allocates a channel used by the nearest cell, which is at least the reuse distance away.

**NN+1** Nearest-Neighbour-plus-one centralised DCA algorithm, allocates a channel used by the nearest cell, which is at least the reuse distance plus one cell radius away.

**OFDM** Orthogonal Frequency Division Multiplexing is a technique splitting a highly dispersive high-rate channel into a high number of low-rate non-dispersive subchannels using Fast Fourier Transform (FFT) based modulation [10].

**PCN** Personal Communications Network

**PCS** Personal Communications System, a term used to describe third generation mobile radio systems in North America

**PDF** Probability Density Function

**PEI** Picture layer extra insertion bit, used by the H.261 video codec, indicating that extra information is to be expected

**PQUANT** A fixed length codeword used by the H.263 video codec to indicate the quantiser to use for the next frame

**PRMA** Packet Reservation Multiple Access, a statistical multiplexing arrangement contrived to improve the efficiency of conventional TDMA systems, by detecting inactive speech segments using a voice activity detector, surrendering them and allocating them to subscribers contending to transmit an active speech packet.

**PSAM** Pilot symbol assisted modulation, a technique where known symbols (pilots) are transmitted regularly. The effect of channel fading on all symbols can then be estimated by interpolating between the pilots

**PSC** Picture start code, a preset sequence used by the H.261 and H.263 video codec, that can be searched for to regain synchronisation after an error

**PSNR** Peak Signal to Noise Ratio, noise energy compared to the maximum possible signal energy. Commonly used to measure video image quality

**PSPARE** Picture layer extra information bits, indicated by a PEI symbol in H.261 video codec

**PTYPE** Picture layer information, used by H.261 and H.263 video codec to transmit information about the picture, e.g. Resolution, etc

**QAM** Quadrature Amplitude Modulation

**QCIF** Quarter Common Intermediate Format Frames containing 176 pixels vertically and 144 pixels horizontally

**RACE** Research in Advanced Communications Equipment Programme in Europe, from June 1987 to December 1995.

**RING** A centralised DCA algorithm, which attempts to allocate channels in one of the cells, which is at least the reuse distance away that forms a "ring" of cells.

**RSSI** Received Signal Strength Indicator, commonly used as an indicator of channel quality in a mobile radio network.

**SAC** Syntax based arithmetic coding is an alternative to variable length coding. It is a variant of arithmetic coding

**SCS** Sequential Channel Search distributed DCA algorithm, searches the available channels in a pre-determined order, picking the first channel found, which meets the interference constraints.

**SINR** Signal to Interference plus Noise ratio, same as signal to noise ratio (SNR), when there is no interference.

**SIR** Signal to Interference ratio

**SNR** Signal to Noise Ratio, noise energy compared to the signal energy

**SQCIF** Sub-Quarter Common Intermediate Format Frames containing 128 pixels vertically and 96 pixels horizontally

**TCOEFF** An H.261 and H.263 video codec symbol, that contains the transform coefficients for the current block

**TD** Time Division, a multiplexing technique where several communications links are multiplexed onto a single carrier, by dividing the channel into time-periods, and assigning a time-period to each communications link.

**TDD** Time-Division Duplex, a technique where the forward and reverse links are multiplexed in time.

**TDMA** Time Division Multiple Access

**TR** Temporal reference, a symbol used by H.261 and H.263 video codecs to indicate the real time difference between transmitted frames

**UMTS** Universal Mobile Telecommunications System, a future Pan-European third generation mobile radio standard.

**VAF** Voice activity factor, the fraction of time the voice activity detector of a speech codec is active

**WLAN** Wireless Local Area Network

**WWW** World Wide Web is the name given to computers that can be accessed via the Internet using the HTTP protocol. These computers can provide information in a easy to digest multimedia format using hyper-links.

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