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Preface

Philip Machanick, Overall Chair: SAICSIT'99

Running SAICSIT'99, the annual research conference of the South African Institute for Computer Scientists and Information Technologists, has been quite an experience.

SAICSIT represents Computer Science and Information Systems academics and professionals, mainly those with an interest in research. When I took over as SAICSIT president at the end of 1998, the conference had not previously been run as an international event. I decided that South African academics had enough international contacts to put together an international programme committee, and a South African conference would be of interest to the rest of the world.

I felt that we could make this transition at relatively low cost, given that we could advertise via mailing lists, and encourage electronic submission of papers (to reduce costs of redistributing papers for review).

The first prediction turned out to be correct, and we were able to put together a strong programme committee.

As a result, we had an unprecedented flood of papers: 100 submitted from 21 countries. As papers started to come in, it became apparent that we needed more reviewers. It was then that the value of the combination of old-fashioned networking (people who know people) and new-fashioned networking (the Internet) became apparent. While the Internet made it possible to convert SAICSIT into an international event at relatively low cost, the unexpected number of papers made it essential to find many additional reviewers on short notice. Without the speed of e-mail to track people down and to distribute papers for review, the review process would have taken weeks longer, and it would have been much more difficult to track down as many new reviewers in so little time.

Even so, the number of referees who were willing to help on short notice was a pleasant surprise.

The accepted papers cover an interesting range of subjects, from management-interest Information Systems, to theoretical Computer Science, with subjects including database, Java, temporal logic and implications of e-commerce for tax.

In addition, we were very fortunate in being able invite the president of the ACM, Barbara Simons as a keynote speaker. Consequently, the programme for SAICSIT'99 should be very interesting to a wide range of participants.

We were only able to find place in the proceedings for 36 papers out of the 100 submitted, of which only 24 are full research papers. While this number of papers is in line with our expectation of how many papers would be accepted in each category, we did not have a hard cut-off on the number of papers, but accepted all papers which were good enough, based on the reviews. Final selection was made by myself as Programme Chair, and Derrick Kourie, as editor of the *South African Computer Journal*. Additional papers are published via the conference web site.

We believe that we have put together a quality programme, and hope you will agree.

Acknowledgments

I would like to thank the *South African Computer Journal* production team, Andries Engelbrecht and Herna Viktor, respectively from the Department of Computer Science and Informatics, University of Pretoria, for their work on producing the proceedings.

The reviewers listed overleaf did an excellent job: many wrote very detailed reports, sometimes after being called in on very short notice. Inevitably, there were some glitches resulting from the unexpected workload, but the buck stops with the programme chair: I promise to do better next time.

I would also like to thank my own department for putting up with the extra work and expense that running a conference entails. I tried not to burden them with too much extra work, but our secretaries, Zahn Gowar and Leanne Reddy, inevitably had to take on some extra work. John Ostrowick provided valuable assistance with design of our web pages and call for papers poster. Carol Kernick, who handles our finances and membership records, did a fine job of keeping up with the demands of the conference.

Finally, I would like to thank our sponsors, whose contribution made this conference been possible:

- PricewaterhouseCoopers – sponsored generous prizes and the conference banquet
- National Research Foundation (NRF) – provided financial support
- University of the Witwatersrand – provided financial support
- Programme for Highly Dependable Systems, University of the Witwatersrand – provided financial support
- Standard Bank – provided financial support

- Apple Computer – provided equipment for the conference
- Qualica – provided technical support including helping with the conference web site

Web Site

For more information about SAICSIT, including a pointer to the conference site, see <http://www.saicsit.org.za>.

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Approaches to Video Transmission over GSM Networks

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Abstract

Real-time video delivery adds an aspect of reality when used in conjunction with other computer and human communications facilities (eg in videophone or videoconferencing applications). However, the complex and time-critical nature of video coding usually demands high-power computation and high band-width channels to support it. This paper provides a brief description of the GSM (Global System for Mobile Communications) mobile telecommunications standard and video coding standards, and suggests how appropriate use could be made of the GSM system for the transport of certain low bandwidth video services.
Keywords: *mobile telecommunications, video transmission, video coding, GSM, H.263*
ACM CR Categories: *I.4.2, C.2.2*

1 Introduction

Interpersonal communication systems have become a major consumer technology today, and many current developments in this area are driven by perceived future market needs and expectations. The rapid growth of interest in mobile computing and wireless LANs are two contemporary examples of this. The worldwide uptake of mobile telephones continues to grow and soon the technology and supporting infrastructure will be ubiquitous. The future services that could be supported by mobile telecommunications systems therefore deserve consideration.

Computing environments have become increasing graphical in order to give more rapid and natural understanding of high density information to the human user. This has impacted on user expectations, so now a high proportion of information sought is in visual form. Many multimedia applications contain digital images and video clips, for which compressed representations (e.g. JPEG, Quicktime) are widely used. Supporting real-time video transmission over wireless connections is a demanding problem, where the communication channel is the most restrictive bottleneck.

In this paper we explore how aspects of the GSM mobile telecommunications standard might be used to provide video delivery in real-time, taking into account the dynamic channel bandwith usage capabilities within that system, and marrying these with the variable bit rate (VBR) characteristics of compressed video. The scope of this project is large, and impacts on many associated areas such as commercial provision of services, traffic management and modelling, intelligent monitoring and control, systems integration, picture quality and human factors issues. Here we will present only the fundamental concepts of how the video transmission might be achieved, via careful matching of the coding and delivery systems, and appropriate handling of transmission errors.

2 Data services in GSM networks

Four kinds of data services are supported in the GSM (Global System for Mobile communications) Phase 2+ system, as listed below:

- Packet data on signalling channels service (PDS).
- Short message service (SMS).
- High speed circuit switched data services (HSCSD).
- General packet radio service (GPRS).

Each of these services will be described briefly, in order to identify whether their protocols and operating characteristics support video delivery or not.

2.1 PDS and SMS

The GSM standard defines the meaning of PDS[1] as below: PDS is a bearer service enabling circuit oriented point to point transfer in GSM networks of very small data packets on radio interface signalling channels for applications using short dialogues with a data throughput rate capability in the range of 600 to 9200 bits/s and with a duration in the range of a few seconds[1]. As an alternative service, SMS[2] provides a means to transfer short messages packets (of up to 140 octets) between a GSM mobile system and an SME (Short Message Entity) via a SC (Service Center), through a signalling channel (SDCCH or SACCH)[2]. In Phase 2+ the standard enhances the SMS by allowing for multiple SMS packets to be concatenated, using a flag indicating more information to follow. Obviously PDS and SMS are not suitable to transfer video over GSM networks due to the extremely limited packet and message size, therefore they are not considered further here.

2.2 HSCSD

HSCSD[3][12] is a feature enabling the co-allocation of multiple (up to 8) Full Rate Traffic Channels (TCH/F) into a multislot configuration, consisting of one or several full rate traffic channels intended expressly for data transmission [3].

Although a TCH (Traffic Channel) is optimised to be able to carry 13kbps speech information, for data transmission the data rate is adapted to the standard V.32 bit rate of 9.6 kbps. In implementing HSCSD, a higher air interface user rate of 14.4 kbps per TCH is supported, so the basic GSM circuit data service is extended to higher speed (up to 115 kbps). This data rate is sufficient to support real-time compressed video transmission applications like videophone or videoconferencing.

Both transparent and non-transparent HSCSD connections are supported, with symmetric and asymmetric configuration. In an asymmetric configuration, the network gives priority to fulfilling the air interface user rate requirement in the downlink direction. For a non-transparent HSCSD connection the network can use dynamic allocation of resources (i.e. TCH/F), as long as the configuration is not in contradiction with the limiting values defined by the Mobile System, and the actual mobile equipment is capable of handling the allocated channel configuration.

For a transparent HSCSD connection, dynamic resource allocation is applicable, provided the air interface user rate is kept constant. The change of channel configuration within the limits of minimum and maximum channel requirements is done with resource upgrading and resource downgrading procedures during the call. The Mobile System may request a service level up- or downgrading during the call, negotiated in the beginning of the call. This modification of channel requirements and/or desired air interface user rate is applicable to non-transparent HSCSD connections only.

2.3 GPRS

For bursty data communication application, circuit allocation is a wasteful use of the radio link. As an alternative, GPRS (General Packet Radio Service)[9[[13][14][15] optimises the use of network and radio resources by using a packet-mode technique to transfer high-speed and low-speed data and signalling in an efficient manner. The highest supported bitrate in GPRS is 170 kbps, which lays the foundation to support videophone or videoconferencing applications (e.g. based on H.261 or H.263). In a GPRS network two types of services are supported:

- Point-to-point (PTP)
- Point-to-multipoint (PTM)

Based on the existing GSM network, this enhancement introduces two new network nodes in the GSM PLMN (Public Land Mobile Network): the Serving GPRS Support Node (SGSN) and the Gateway GSN (GGSN). The SGSN, being at the same hierarchical level as the MSC and connected to the base station system with Frame Relay, keeps track of the individual Mobile System location and performs security functions and access control. The GGSN provides interworking with external packet-switched networks, and is connected with SGSNs via an IP-based GPRS backbone network. In addition, the HLR (Home Location Register) is enhanced with GPRS subscriber data and routing information.

The GPRS air interface protocol is concerned with communications between the Mobile System and BSS at the physical, MAC (Medium Access Control) and RLC (Radio Link Control) protocol layers. The RLC/MAC sublayers allow efficient multiuser multiplexing on the shared packet data channels and utilise a selective ARQ protocol for reliable transmissions across the air interface.

The MAC layer, derived from a slotted ALOHA protocol[16][17], is responsible for access signalling procedures for the radio channel governing the attempts to access the channel by the Mobile Systems and the control of this access by the network. Therefore it is understandable that the crucial part of the network determining whether the network is able to accommodate a variety of service types including speech, data, video mainly depends on MAC.

3 Video coding

So far five international standards for video coding have been created. H.261[4] addresses videophone and videoconference applications at bitrates of multiples of 64kb/s. H.263[5] is intended for similar applications as H.261, but at lower bitrates less than 64kb/s. MPEG-1[6] aims at digital storage media application up to about 1.5 Mb/s. MPEG-2[7] is for broadcast television at bitrates of 3-30 Mb/s while MPEG-4[8] is for multimedia application at 5kb/s to 4Mkb/s. Among these standards the smallest video format is sub-QCIF supported by H.263 with 96 lines and 128 pels per line. Due to the limitation of bandwidth of the GSM system, it is only possible to send video compressed using H.261 and H.263 over a GSM network. All above mentioned video coding standards support encoding methods which exploit both the spatial redundancies and temporal redundancies inherent in the video sequence. Spatial redundancies are exploited by using block-based Discrete Cosine Transform (DCT) coding of 8 by 8 pel blocks followed by quantization, zigzag scan, and variable length coding of runs of zero quantized indices or the amplitudes of the non-zero indices. Temporal redundancies are exploited by using motion compensation in which the difference picture of the current frame and its prediction in the reference frame is coded based on the DCT scheme. In addition H.263 may use optional coding techniques to further improve its performance, as listed below:

- Unrestricted Motion Vector mode (UMV-mode)
- Advanced Prediction mode (AP-mode)
- PB-frame mode (PB-mode)
- Syntax-based Arithmetic Coding mode (SAC-mode)

In the default prediction mode of H.263, motion vectors are limited within the coded picture area. When the UMV-mode is switched on, this restriction need not hold. When a pixel referenced by a motion vector lies outside the picture, the closest edge pixel is used instead.

In AP-mode, the motion vectors (MV) for each luminance block are supported. Also overlapped block motion compensation is introduced, to reduce the blocky artefacts.

An intra-coded picture, which uses block coding without any motion estimation technique, is called an I picture. A P picture is an inter-coded picture, which is coded using either an I picture or a P picture as the reference for motion estimation. In PB-mode, a PB-frame consists of two pictures coded as one unit. The P picture is uni-directionally predicted from the last decoded P picture and the B picture is bi-directionally predicted from both the last and current P picture.

In SAC-mode, all variable length coding/decoding operations with the Huffman table are replaced by arithmetic coding/decoding operations.

With these four optional operations, H.263 improves the overall compression performance significantly[10]. Because of its acceptable reconstructed visual quality at very low bit rate, H.263 is assumed in this paper as the video coding technique. Moreover, due to the high error proneness of mobile channels, robust video coding is needed. In both the new version of H.263, referred to as H.263+[11], and MPEG-4, error resilient mechanisms have been incorporated, some of which can be adapted in mobile video coding.

4 Possibilities for video over GSM networks

4.1 Video over HSCSD

From the above description we can see that HSCSD provides the possibility to transmit H.263 video over a HSCSD connection, but is not ideal as we face a problem in deciding how to allocate the radio channels. The bit rate for I pictures is much higher than for P pictures or B pictures, so if we allocate channels based on I picture size, most of the time the channel resource is wasted when transferring P or B pictures. On the other hand, if we allocate channels according to the bit rate for P pictures or B pictures, we will be unable to transfer complete I pictures, which are the most important pictures for the video decoding process.

Though it is possible to allocate the channels dynamically, this is only applicable to non-transparent transmission applications. This non-transparent scheme improves the reliability of the transmission with the cost of the accumulation of transmission delay, which may be out of the range of tolerance for real-time applications including video. From the point of view of the non-delay requirement of real-time video applications, transparent transmission is more favourable, but the BER (Bit Error Rate) due to the harsh wireless environment may degrade the video application unacceptably over the GSM network.

To improve the efficiency of channel utilisation, a mechanism to dynamically allocate radio channels for transparent transmission should be developed coupled with error resilient source coding at encoder and error concealment at decoder. The other solution is to use limited FEC and ARQ functions in non-transparent configuration with dynamic channel allocation. Again error resilient coding and error concealment techniques will be necessary. How to minimise the latency from the reconfiguration of radio channel will be the key issue in implementation of both the suggested schemes.

4.2 Video over GPRS

The bottleneck of video over GPRS lies in the MAC (Medium Access Control) protocol, since it has been designed mainly for data (non real-time) applications in the current GPRS system (though it can support speech communication quite well). The MAC is used to share the radio channels among mobile stations in the cell and to allocate the physical radio channel for a mobile station (MS) when needed for transmission or reception.

An MS initiates a packet transfer by making a Packet Channel Request on Packet Random Access channel (PRACH) on a contention basis with other MS. If the contention is successful, the network responds on Packet Access Grant Channel (PAGCH). It is possible to use either one- or two-phase packet access methods.

In one-phase access, the packet channel request message contains all the information needed for establishment of the channel including multislot related information and quality of the requested service. As the response, a packet immediate assignment reserving the resources on Packet Data Channels (PDCH) for uplink transfer of user information is sent to the MS. The MS then starts sending information to BTS for transmission.

In two-phase access, the Packet Channel Request is responded to with a Packet Uplink Assignment to reserve the uplink resources for transmitting the Packet Resource Request, which carries the complete description of the requested resources for the uplink transfer. A two-phase access can be initiated by the network or a MS. The network can order the MS to send a Packet Resource Request message by setting a parameter in Packet Uplink Assignment message. A mobile station can require two-phase access in a Packet Channel Request message. In this case, the network may order the MS to send a Packet Resource Request or continue with one-phase access procedure.

From the description above it is clear that bandwidth assigned to one MS can be varied dynamically. It works well with constant bitrate transmission, or variable non real time applications, but is not effective for variable bitrate real-time video applications. During transmission of live video, the variable bit rate of live video requires the dynamic allocation of bandwidth with acceptable delay and every reallocating of the radio channel requires access to the PRACH. However, the contention mechanism of PRACH access does not guarantee the delay requirement, which is crucial on real-time video applications.

One possible solution is that the reconfiguration of the multislot to have more than the set of current active channels by means of the communication between MS and BSS, rather than by means of the reaccess of PRACH during the real time transmission which would involve further contention. Though the compressed video is variable bitrate, the temporal frame structure, (i.e. the appearance of I, P or B picture) is periodic, so the arrival of I picture or P picture for transmission can be anticipated. Therefore the allocation of multislot channels according to the picture type can be realised. Moreover this scheme requires classes of different video types to be defined based on the statistical modelling of the video sources that every class corresponds to a certain bitrate level, so that the bitrate for I picture, P picture or B picture can be estimated for Packet Channel request purposes.

4.3 Error concealment

Robust video source coding and error control techniques in transmission cannot eliminate the occurrence of errors completely. Therefore some processes are needed in decoder to minimise the severity of artifacts resulting from transmission errors, usually these processes are referred to as error concealment. The most common methods to handle error include postprocessing and interactive concealment between encoder and decoder, as described below.

In temporal error concealment, the missing blocks are restored using the information in the temporal adjacent frames. One simple way to exploit the temporal correlation in video signals is by replacing a damaged block with the spatially corresponding block in the previous frame. however method can produce adverse visual artifacts in the presence of large motion. Significant improvement can be achieved by replacing the damaged macroblock with the motion compensated block (i.e., the block specified by the motion vector of the damaged block). If the motion vector is damaged also, it can be estimated using the motion vectors of the adjacent block. One problem associated with these methods is that if the adjacent blocks are intra-coded, then there would not be any data available to estimate the missing motion vectors. When no motion information is available, we have no choice except using the information in the current frame. In this case, spatial error concealment methods, in which some kind of interpolation from adjacent blocks is performed to restore the damaged block, are needed. These methods are widely known and more information about spatial concealment can be found in [18][19][20][21][22][23][24].

When a backward channel from the decoder to the encoder (usually referred to as back-channel), is available, better performance can be achieved if the encoder and decoder cooperate in the process of error concealment. This cooperation can be realised at either source coding or transport level. At the source coder, coding parameters can be adapted based on the feedback information from the decoder. At the transport level, the feedback information can be employed to change the percentage of the total bandwidth used for FEC or retransmissions. One simple and effective use of the back channel is in conjunction with reference picture selection mode. Other examples include Intra macroblock tracking and refreshment, and more information can be found in [25][26][27][28].

5 Conclusion

Although GPRS lays the foundation for real-time video applications, before such applications can be put into practice, more work needs to be done on optimising the utilisation of shared scarce radio channels with guaranteed bandwidth for different picture types and time delay limits. The fundamental issue is the compromise that is needed between wide variations in bitrate needed to cater for all picture types, modelled by an unbounded VBR scheme, and the inflexibility imposed by the network in allowing only quantum channel allocation, modelled by step-function bitrate performance variations or variable constant bitrate (VCBR). The resolution of this dilemma relies on better system integration and interoperation between the network behaviour and the video coding process, by extracting useful bit-rate information over many successive frames and exerting careful intelligent control throughout the transmission. This possibility requires the development of further layers of complexity than exist at present, to create a more compliant and flexible protocol that matches system capabilities with these severe user needs.

6 Acknowledgment

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