CCITT SGXV
Working Party XV/1
Experts Group for ATM Video Coding

Document AVC-357
October 16, 1992

SOURCE : Experts Group for ATM Video Coding in CCITT Study Group XV
TITLE : Status Report on ATM Video Coding Standardization, Issue 3
Date : September 23, 1992
Purpose : Report

Contents

Note 1 - { } indicates Editor's note, particularly items to be worked out.
Note 2 - Editors are listed at the end of this document.

1. Introduction

The Experts Group for ATM Video Coding was established at the July 1990 meeting of Study Group XV to develop video coding standards (Recommendation H.26X) appropriate for B-ISDN using ATM transport. The group consists of members from FRG, Australia, Belgium, Canada, Korea, Denmark, USA, France, Italy, Japan, Norway, The Netherlands, UK, Sweden and Switzerland under chairmanship of Mr. S. Okubo (NTT, Japan). It is now collaborating with ISO/IEC JTC1/SC29/WG11 (MPEG) to develop a common video coding standard H.26X/MPEG-2 by having joint meeting sessions.

The terms of reference for the group are as follows;

1) to study video coding algorithm appropriate to the ATM environment for conversational services, particularly to study whether modifications are necessary to make the present AV Recommendations applicable to the ATM network;

2) to study the relationships between video coding algorithm and network parameters such as average and peak rates, burstiness, and peak duration to achieve good picture quality and traffic characteristics;

3) to study feasibility of a unified coding standard for various applications in all service classes using the ATM network for which different hardware versions (codecs) can be realized;

4) to investigate potential applications for ATM coding systems (conversational, distributive, retrieval of stored information, etc.) and network-related constraints on potential system performance, and to develop a set of requirements and constraints to guide the work of the Group;

5) to study compatibility of the new algorithms with audiovisual systems covered by Recommendation H.200;

6) to coordinate directly with the experts of other CCITT Groups, CMTT and ISO/IEC on video coding;

7) to draft Recommendation(s) for video coding under the ATM environment.

This document has objectives to form a common ground among members of the group, to clarify the points to be worked out, and thus to promote further progress. It is also intended that this document serves to publicize the activities of the Experts Group. The contents will be updated according to the obtained study results.

The current issue covers the outcome of the following seven meetings;

1st	November 1990	The Hague
2nd	May 1991	Paris
3rd	August 1991	Santa Clara.
4th	November 1991	Yokosuka
5th	January 1992	Singapore
6th	March 1992	Stockholm and Haifa
7th	July 1992	New Jersey and Rio de Janeiro

Annex 1 lists all the AVC-numbered documents which were considered during the meeting and reports which were produced as outcome of respective meetings

It is noted that Study Group XVIII has issued "Integrated Video Services (IVS) Baseline Document" AVC-320 which is intended to provide a basis for harmonizing the work of the wide range of groups involved in video services to ensure consistency with B-ISDN. The group is in a position to contribute to enhancing the parts under its responsibility.

{We should set our firm objectives in terms of target Recommendations for those aspects surrounding the generic video coding (Recommendation H.26X). The issue is how we should timely reflect the outcome of the Experts Group studies into audiovisual Recommendations in broadband environments. Can this status report be a mechanism to reach such Recommendations?}

2. Terminology

Here is given terminology for terms particular to the ATM video coding. Note that general B-ISDN terms are defined in Recommendation I.113.

The following items are defined in Annex 2.

GENERAL TERMS

CODEC
CIF (Common Intermediate Format)
compression
FEC (Forward Error Correction)
interoperability
lip synchronization
motion compensation coding
multipoint
QCIF
quantization
teleconferencing
videoconferencing

videophone
visual telephone

COMPATIBILITY RELATED TERMS

backward compatibility
downward compatibility
embedded bit stream
forward compatibility
layered coding
scalability
simulcast
standard families
switchable encoder
syntactic extension
upward compatibility

3. Applications

Possible applications in B-ISDN and their requirements are listed in Table 1, which are summarized in general term as;

- conversational services,
- distributive services,
- retrieval services,

with stress on their multimedia nature. It is also noted that Draft I.211 gives an extensive list of B-ISDN services.

Our objective is to define a unified (generic) coding which can cover the above mentioned services, rather than to confine to a specific service. We envisage that a communication terminal be capable of serving all those three categories of applications.

4. Boundary conditions for ATM video coding

4.1 Target networks

We focus on B-ISDN for networks to which the new video codec is applied but do not preclude such networks as LAN and MAN as far as they are ATM based and/or are connected to B-ISDN as NT2.

4.2 Network characteristics

ATM network characteristics to which our new video coding should adapt are summarized in Table 2, listing opportunities as well as limitations (see AVC-20, AVC-4).

\A list of questions have been formulated and sent to SGXVIII concerning ATM network characteristics that affect the design of the video coding. Items of our concern are as follows;

- Cell loss ratio
- Cell loss burst behavior
- CLP bit
- Usage parameters
- Multimedia connections
- Bit Error Rates
- Cell delay jitter
- Network model for hardware experiments
- AAL
- Network interworking

Table 1 Matrix of applications and technical issues

Tech issues / Applications	Network	Storage media	Resolution	Quality objective	Delay
Video conference	N,B-ISDN LAN	-------	CIF ~ CCIR601	~ 3.5	Short
Video conference with wide screen	B-ISDN LAN	-------	EDTV ~ HDTV	~ 3.5	Short
Video conference with multi-screen	B-ISDN LAN	-------	CIF ~ CCIR601	~ 3.5	Short
Videophone	N,B-ISDN LAN	-------	CIF ~ CCIR601	~ 3.5	Short
Video surveillance	N,B-ISDN	-------	QCIF/CIF ~CCIR601	3~4.5	Mid
TV broadcasting	DBS CATV-net	-------	Current TV ~ HDTV	~ 4.5	Mid
Video distribution on storage media	B-ISDN LAN	Disk Tape	Current TV ~ HDTV	~ 4.5	Mid
Video database	N,B-ISDN LAN	Disk Tape	CIF ~ HDTV	~ 3.5	Long
Videotex	N,B-ISDN LAN	Disk	CIF ~ HDTV	~ 4.5	Long
Video mail	N,B-ISDN LAN	Disk	CIF ~ CCIR601	~ 3.5	Long
Video instruction	B-ISDN LAN	Disk	Current TV ~ CCIR601	~ 4.5	Mid

note-1: The Quality grade is referred to the following:

Quality	Impairment
5 Excellent	5 Imperceptible
4 Good	4 Perceptible . but not annoying
3 Fair	3 Slightly annoying
2 Poor	2 Annoying
1 Bad	1 Very annoying

note-2: The "Long Delay" means even non-realtime transmission is acceptable

Table 2 ATM network characteristics

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Opportunities

1) Availability of high bandwidths
2) Flexibility in bandwidth usage
3) Variable bit rate capability
4) Use of CLP(Cell Loss Priorly)
5) Multipoint distribution in the network
6) Flexibility in multimedia multiplexing or multiple connections
7) Service integration

Limitations

1) Cell loss
2) Cell delay jitter
3) Packetization delay
4) Usage Parameter Control (Peak and/or Average)

::

SGXVIII have responded to these questions. These questions and answers are covered in Annex 2 "Network aspects" to the IVS Baseline Document.

We endorse the IVS baseline document approach which was made in the SGXVIII meeting in November 1991 and we keep contributing to its upgrading. Comments for this purpose have been sent to SGXVIII in each meeting of the Experts Group.

4.3 Technical requirements for ATM video coding

4.3.1 Video signals to be handled

Initially we concentrate on video coding of QCIF/CIF and "CCIR-601 class" standard television signals but intend to cover a wide range of video signals, accommodating extension to EDTV and HDTV as well.

4.3.2 Picture quality target

The target is defined as a range between conversational service quality and distribution service quality, awaiting the quantification in the future.

{Who could provide for this quantization? SGXII? SGXV? Quality aspect of visual telephony has been included in a SGXV question for the new study period.}

4.3.3 Processing delay target

Processing delay of the new video coding should be less than that of the current systems, e.g. less than about 150 ms.

Note - The "less than about 150ms" example comes from the HRD definition (buffer size = 4 times CIF picture period) in H.261. A consideration is that the new video coding in broadband environments should significantly improve in the delay aspect compared to the existing one.

Document AVC-266 from SGXII gives current status of study for the effect of end-to-end delay (transmission and processing delay) on the communication quality. Revised G.114 recommends 0-150ms as "acceptable for most applications, noting that some highly interactive voice and data applications may experience degradation for values below 150ms", and 400ms as the upper limit of acceptable one way end-to-end delay, recognizing that this limit will be exceeded in some exceptional cases (including videotelephony over satellite circuits). A summary of various evaluation results is also given which addresses the subject in audio only as well as audiovisual communications, indicating that highly interactive tasks require less than 400 ms pure delay (without echo) but that the effects of pure delay on speech quality appears to modestly increase as the delay is increased, hence that further study is necessary.

4.3.4 Average bit rate

It should cover a range up to several tens of Mbit/s.

4.4 Compatibility issues

Further study is necessary on the balance of achieving compatibility and highest coding performance. We agree on a guideline that the compatibility between the new coding system and existing and emerging systems should be highly respected, and that the means for interworking between H.320 terminals connected to the N-ISDN and H.32X terminals connected to the B-ISDN should be developed in this group. This is an essential requirement.

Compatibility is classified into four types, i.e., upward/downward and forward/backward, and the five methods to achieve this property are defined. These are simulcasting, embedded bit stream, syntactic extension, switchable encoder and standard families. See Annex 2.

Layering is one of the solutions and the idea of "flexible layering" which exploits B-ISDN characteristics and provides service integration is recognized interesting. "Flexible layering" realizes interworking among different "service classes" by switching off some constituent layers as necessary. Such layered coding examples are found in Documents AVC-74, 94, 100, 103, 135, 181, 286,293, etc.

AVC-278 clarified H.261 compatibility requirements for H.26X coder and decoder by analyzing several communication patterns. We note that all of these situations should be taken into account when we discuss the compatibility issue. If embedded scheme is adopted for H.26X, every coder and decoder should have the embedded structure. In a point to point communication between two H.26X terminals, embedded coding may degrade performance, thus a mechanism to switch off the base layer as necessary should be considered.

Though exact ways to implement compatibilities require further study, the method is now converging to use upconverted base layer pictures as a prediction for the upper layer.

4.5 Requirements for H.26X

In conclusion, a list of H.26X requirements is given in Annex 3.

4.6 Framework for H.26X/MPEG-2

4.6.1 Aim of H.26X/MPEG-2

The aim of H.26X and MPEG-2 (second phase of MPEG) is to cover a range of video applications, bit rates, resolutions, qualities, and services; thus the video coding algorithm should be "generic". Functional requirements for this generic video coding have been collected, out of which CCITT Experts Group are particularly concerned with the following;

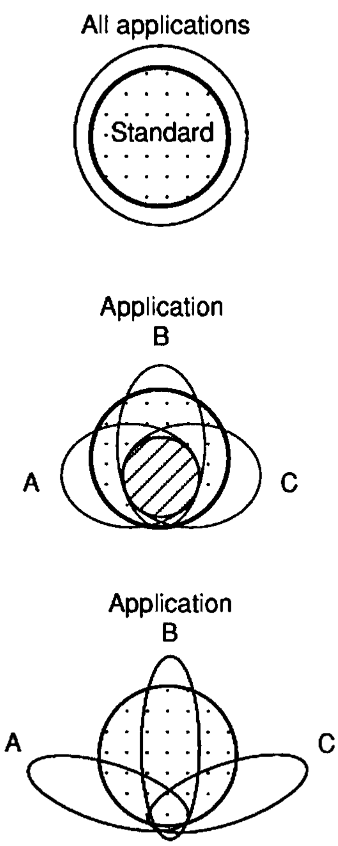
- low end-to-end delay,
- compatibility with H.261 (scalability),

- cell loss resilience, and
- lower bit rate operation.

Though the current efforts of coding algorithm optimization are focused on coding of CCIR-601 signals, it is being discussed that perhaps we need not another standard for coding of HDTV signals. Extension to higher formats is identified as one of the study items.

4.6.2 Clarification of "generic standard"

There are three possibilities to structure a generic standard which is applicable to wide range of applications as illustrated in Figure 1.



	Scale Merit	Cross-application Bitstream Interchange	Cheap Imple. for Particular Application
Single standard	yes	yes	no*
Toolkit with common core	yes		
Toolkit standard	yes	no	yes

*cost: unnecessary elements, sub-optimum parameters

Figure 1 Three approaches to generic standard

The first option (single standard solution) means that all the decoders conforming to the standard can understand all the bitstreams and reconstruct full pictures as far as the bitstream conforms to the standard. In the third option (toolkit solution), on the contrary, the standard provides all the necessary elements to cover wide range of applications. Application standards specify the elements to be used for their purposes. Decoders for a particular application may not understand the bitstreams of another application. The second option (toolkit with maximum core solution) is intermediate between the first and the third solution. There may be some standardized elements which are used only for a particular application.

One benefit of the generic standard is to achieve scale merit, allowing use of the same hardware and/or software in various application fields. Another benefit is more importantly to allow cross application bitstream interchange. Some application fields may require very cheap implementation dedicated to respective particular applications. These factors are indicated in Figure 1.

In view of the intention of the generic standard we concluded that the objective of our work should be to achieve the first option as far as possible, but in practice the second option with maximum core may be the solution.

4.6.3 Materializing the "generic standard" philosophy through the Test Model work

To reflect the above mentioned objectives into the Test Model work currently being carried out, we reached the following common understanding;

1) Since the generic standard is intended to meet the performance and functionality requirements of each particular application, one way is to emulate the situation in the Test Model work.

2) Each contributor may have some application in mind as user of the standard and be willing to do his/her best efforts to optimize the Test Model for the particular application, Test Model refinement should be integration of such efforts in a harmonized way.

3) To avoid divergence in the current convergence phase work, above mentioned improvement efforts should be done using a single syntax defined in the Test Model.

4) Based on the analysis to relate functionality with necessary elements in the standard, the following items are identified as normative for the new standard to support (see AVC-325);

a. Single integrated syntax to support normative and optional features
b. A range of picture formats
c. High quality
d. Evaluation of various sources in addition to CCIR-601 interlaced ones
e. CBR and VBR
f. Low delay mode
g. Random access and channel hopping
h. Scalability (Note)
i. Compatibility with DIS11172 and H.261
j. Compatibility with higher and lower resolution formats
k. Combinations of high performance/high complexity and low performance/low complexity
l. Editing encoded bitstreams
m. Trick modes
n. Error resilience

Note: See AVC-324 for terms and other information on video requirements.

5) The improved syntax should be reviewed each time to implement the "maximum core" objective as well as to reflect the coding efficiency and implementation consideration. Use of good engineering sense is expected.

4.6.4 Procedure for improvement of the test model

The procedure for incorporating new ideas in the test model was clarified as follows;

- Assume that a promising idea is presented at a meeting. If more than one lab finds the idea interesting for further testing, sufficient documentation is included in the test model to be able to make comparative tests at different labs.

- If the result of this test is positive (the definition of "positive" is not clearly defined) the idea is incorporated in the test model.

5. Picture format

5.1 Background

An increasingly diverse range of picture formats is likely to be important for visual communications in the future, reflecting developments in computer-based video manipulation and display, and convergence of the telecommunications, computing and broadcasting industries. Window-based computer-screen presentation, for example, is likely to be increasingly used. However, one of the most important video service qualities will continue to be that near broadcast TV quality, where there are 625/50 and 525/60 versions of CCIR Rec. 601, future progressive scan television signals, etc. The Experts Group has been discussing what approach be taken in H.26X to cope with these situations.

At the Santa Clara meeting in August 1991 the Experts Group had determined to make a decision on video formats at the earliest opportunity in 1992.

5.2 Possible solutions

One proposal was the Super Common Intermediate Format (SCIF), being an upscaled version with twice the number of pixels in horizontal, vertical and temporal axes of CIF from Recommendation H.261. The SCIF concept would provide the guaranteed compatibility between all equipments including connections between 525 and 625 line regions in the same way as CIF in H.261. The other benefits of more commonality in equipments and ease of multipoint working would also apply.

Another proposal offered much more flexibility of the internal format used for coding. A modest number of classes would be defined, characterised by maximum numbers of pels in the three axes. Decoders belonging to a class would be able to decode any image smaller than the relevant maxima. (Spatial dimensions could be restricted to integer multiples of 16 to fit the macroblock configuration.) In this proposal the issue of possibly different capture and display formats (pels per line, lines per picture, pictures per second, pel or picture aspect ratio) would be handled entirely by the receiving terminal. Coding would take place in the originating scanning format thus avoiding any quality degradations from unnecessary standards conversion in connections where the display format was the same as the originating format. Conversion might or might not be employed in receiving terminals after decoding in connections where display and originating formats were not the same.

These two proposals can be regarded as the extreme ends of a range with many others in between. These would comprise a number of defined formats available for use in the coding kernel, probably comprising the natural formats of the major applications requiring the highest quality. Other source formats could be converted before coding to the nearest suitable one of the set of defined formats. Receivers would display the decoded version directly or after conversion to any other required format.

5.3 Experimental results

For the March 1992 meeting much work had been done on the proposed SCIF, including simulations of various conversions and coding performances. Facilities were available at the meeting for viewing all the relevant formats, some for the first time such as SCIF directly. After these informal assessments the Experts Group agreed that:

1) Line number conversion can be achieved with small or invisible quality loss.

2) Conversion from interlace to progressive format is not totally satisfactory from a quality viewpoint though several methods have been tried.

3) Picture rate conversions are almost always accompanied by visible defects.

Thus it was concluded that the use of SCIF in circumstances requiring conversions other than of line number cannot, at least with the methods tried, yield the picture quality expected of H.26X at bit rates in excess of about 5 Mbit/s.

One demonstration where the progressive format was used throughout the capture, coding and display processes was acknowledged to provide very pleasing pictures and showed the potential benefits of progressive over interlaced formats.

5.4 Agreements at the March 1992 meeting

A contribution at the March 1992 meeting pointed out the approach adopted so far by ISO/MPEG would result in their video coding algorithm being able to cover all the formats discussed in the CCITT Experts Group. The Experts Group anticipates that H.26X will be the same or fundamentally the same as the MPEG one. Therefore, a decision by the Experts Group would not hasten the algorithm development and can be deferred.

The Experts Group agreed:

1) to defer a final decision on picture formats to be specified in H.26X.

2) to continue to use both 525/60 and 625/50 versions of CCIR-601, and where possible the related Extended Definition (EDTV) and High Definition (HDTV) formats, in the development of the H.26X coding algorithm.

3) to continue investigation of format conversion methods. In some circumstances these will be unavoidable and availability of satisfactory methods is highly desirable even if not subject to standardisation. Guidelines are listed at the end of this section. (More advanced methods exist, such as motion compensated techniques, though they may be uneconomic for widespread use in terminals.)

4) to study application scenarios to identify issues which really need solutions and the performance targets which should be met, and try to have a common understanding by the London meeting (November 1992).

5) to be aware that square pixels are utilized in some potential applications. (Currently displays with square pixels are available, but the corresponding digital acquisition equipment is not.)

6) to be aware that formats other than those from the television industry may be applicable for some applications. An example is computer displays.

7) that the specification of complete systems giving interworking is required by CCITT. Though it is not yet clear whether the format issue will be dealt with entirely by the video coding Recommendation H.26X or entirely by the terminal Recommendation H.32X or by both in combination, the expertise of the Experts Group is needed by SGXV.

8) to recognise the potential of progressive formats and endeavour to support them in H.26X/H.32X for eventual use sooner or later.

Requirement guidelines for format studies

1) Degradation from standards conversion must be consistent with intended use.

2) Any loss of coding efficiency caused by standards conversion must be acceptably small.
3) Delay introduced by standards conversion must be acceptably small for the intended use.
4) Equipment complexity overhead must be acceptable. More study is required to determine the true impact of formats with higher numbers of pels.
5) In circumstances when standards conversion is required there are the two approaches of going directly from one to the other or of going via a third (intermediate) format (such as SCIF). The two approaches should be compared.

5.5 Outcome of the July 1992 meeting

Since H.26X should be generic and be able to cope with a wide range of formats, the current format issue is rather of H.32X terminal. During the discussion, it was stressed that the problem is how to achieve interworking between various types of terminals with different source formats which are connected through B-ISDN. One way is to define a default format every terminal should have, the other way is to define that every decoder of the same class be able to decode and display any format smaller than a defined maximum.

The meeting confirmed the previous decision in Stockholm to endeavor to reach a common understanding in Ipswich next October.

5.6 Discussion points

The key issues in the discussion may be summarized as:

- Should there be one common(worldwide) format with higher resolution than CIF?
- Should there be a relation between a possible new common format and CIF similar to the relation CIF/QCIF - progressive or interlaced?
- To what extent is it feasible to have different input- and transmission formats?
- When will there be cameras available supporting other formats than CCIR 601?
- Is the maximum format to be defined as SCIF?
- Which subset of the maximum format is allowed?
- Square pels or not?
- How should the "601" class of formats be related to the next class (EDTV or HDTV)?

{At the moment there is no satisfactory solution to conversion between 50 and 60 Hz signals. A common format therefore seems to require the availability of cameras to produce the common format directly. Clarification of this possibility therefore seems to be crucial in the discussion of one or two formats.}

6. Video coding algorithms

6.1 Kurihama tests

Subjective tests for the thirty algorithm proposals were carried out at JVC-Kurihama R&R Center in November 1991 according to the double-stimulus continuous quality-scale method defined in CCIR Rec. 500-3. Three test sequences were used for the 4 Mbit/s test and four sequences for the 9 Mbit/s test. According to the average scores, rank orders for 525 and 625 systems were obtained. Furthermore, the top ranking group whose members are mutually indistinguishable in a statistical sense was identified by using Duncan's method. (see AVC-180)

Top ranking proposals were in the frame work of hybrid coding which consists of motion compensated interframe prediction and DCT and had been employed in H.261 and MPEG-1 (first phase of MPEG). General feeling was that we could start with MPEG-1 syntax using simple field merging.

The work to evaluate encoder and decoder complexity of those proposed algorithms were also carried out to obtain rankings, and analysis of influential factors was also given. (see Annex 4 to AVC-206R)

6.2 Test Model definition and improvements

6.2.1 Test Model development

Test Model is a reference video coding scheme against which proposed improvements are tested. If tests results are promising, those improvements are incorporated into the next generation Test Model for further comparison.

A preliminary working draft document (PWD) for definition of the first test model was made available as outcome of the Singapore meeting. The first Test Model (TM1) was defined in March 1992 and it evolved into TM2 in July 1992. This TM document includes definition of the coding algorithm as well as necessary experiments (see AVC-323).

6.2.2 Elements of coding algorithm

The coding algorithm consists of the following elements;

- Pre/post-processing for source format conversion
- Layered structure of video data
- Motion estimation and compensations
- Modes and mode selection
- Transformation and quantization
- VLC
- Bitstream syntax
- Rate control and quantization control

6.2.3 Experiments

Currently the following experiments are described in the TM2 document;

1) Prediction modes

Both coding structure (frame based, field based) and prediction modes are dealt with. The pure field structure was removed from the TM. The frame based frame and field coding remain and they should satisfy the needs both from compatibility and low delay point. In addition to frame MC and field MC, some new prediction modes (FAMC, SVMC, DUAL', reverse order field coding) that could be of interest specially for low delay are included as core experiments.

One of the outstanding requirements for the new coding standard H.26X/MPEG-2 is that it should deal with both interlaced and progressive scan signals as input to the source coder (note that H.261 and MPEG-1 encode only progressive scan signals).

Many experiments had been performed and the results were presented at the Haifa and Rio de Janeiro meetings. Most of the experiments focused on improving the picture quality. Much focus was on the use of different prediction modes. This resulted in a considerable increase of prediction modes and therefore also complexity of the test model. The intention is that experiments shall make it possible to point out the most useful prediction modes and that a large amount of the others may be discarded at a later stage.

2) Compatibility

Extended core experiments are included. Some of them intend to cross check the merits of different techniques. Core experiments were also defined for compatibility with H.261 and higher formats (e.g. HDTV). A modification of the syntax to use field structure for compatibility was made in the TM.

3) Cell loss

Although not stated in the requirements, the group expressed interest in checking cell loss performance for high loss rates (up to 10E-2). The core experiments defined in Annex 6 to AVC-317R from CCITT were adopted.

4) Quantization

Core experiments were defined to perform test of the following items:

- Weighting matrices.
- Scanning of coefficients.
- Quantization (e.g. increase upper limit of reconstructed coefficients from 256 to 2000).
- Other transforms than 2D DCT. 8*1 DCT and NTC (Non Transform Coding) will be examined.

5) Scalability

The following items will be addressed in core experiments:

- Pyramid/subband approach.
- Coefficient scanning.
- Interlace/interlace extraction problems.
- Drift corrections.

7. Network loading model

7.1 Simplified model

We feel it would facilitate our making a good progress of VBR study if we use a common network loading model. The first model has been established and updated as in Annex 4. This is based on the probability that the total of bit rates for multiple calls, each of which has given peak and average rates, becomes greater than the capacity of the transmission pipe assuming on/off model sources. An example of the use of this model is shown in Figure 2.

7.2 Necessary improvements

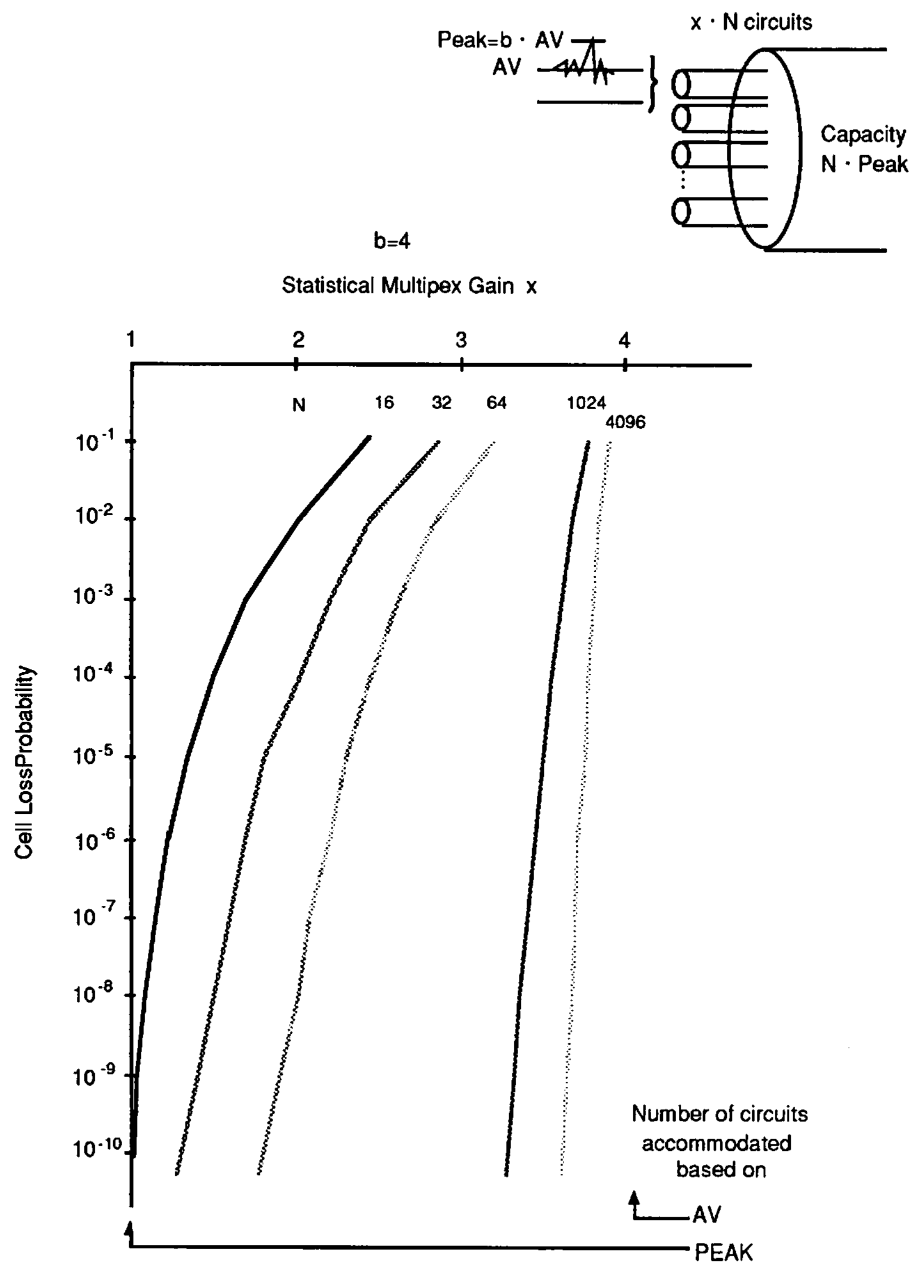
We feel at the same time this model is not sufficient for more precise study and deeper insight due to the following facts;

- The aggregate model does not take into account correlation between arriving frames.
- Video source cannot be accurately modeled by a memoryless ON/OFF model.
- Document AVC-61 shows that a two-state model which takes into account correlation overestimates cell loss ratio.
- A second order AR (autoregressive) model underestimates cell loss ratio.
- It does not take into account dynamics of statistical multiplexing (i.e. source periodicity effect).

The necessary improvements, however, require further detailed studies taking other models, such as in AVC-43,61,75,97, into consideration.

7.3 Cell loss for multiplexed VBR sources

Long term characteristics of cell loss are presented for multiplexed VBR video sources in AVC-296. An implication is that once congestion takes place, very bad condition with



Statisitical Multiplex Gain approaches b=4 as N becomes infinity.

Figure 2 Statistical multiplex gain calculated using the network loading model

CLR=0.01 may continue for tens of frame time due to autocorrelation of the video source signal. Study of visual effects of CLR=0.01 is proposed. There is a general comment whether the result would change if the source is regulated in average by a leaky bucket mechanism etc.

If the source coding should cope with this high CLR by using e.g. layered coding, redundancy should be included in the coded video, thus the number of channels to be accommodated decreases. Another way to cope with this situation may be to accommodate a slightly less number of channels containing less redundant coded video.

This periodic bunching may happen for non-video traffic. The meeting recognized necessity to communicate with SGXVIII on this matter. The coming IVS Technical Session will be a good opportunity to exchange views on this and other network related topics.
Possible feedback of this study result on the current network model was raised, and it was clarified that this result will supplement the network model, but not change. The exact way of reflection is for further study.

8. VBR vs CBR

8.1 Advantages of VBR

Advantages of VBR over CBR could be expected in following domains:

- statistical multiplexing gains
- reduced coding delay
- picture quality
- others

VBR coding benefits, however, largely depend on the UPC (usage parameter control, or policing) mechanism in the network by which the average bit rate of the source is monitored and the input cells are regulated. This is because the encoder should emulate this UPC mechanism to regulate its coded output as a preventive measure. Therefore, we recognize it as an urgent study item to clarify the advantages of VBR video coding against CBR video coding under restriction of the UPC mechanism. It is also a common understanding that applications should be clarified where VBR is most effective.

The liaison statement from SGXVIII (AVC-312) indicated that the traffic parameter for the average is likely to be defined in terms of a reference algorithm as currently done for the peak rate in I.371. The Experts Group is greatly concerned with the time constant of the reference algorithm. If it is short in the order of e.g. 1 ms, the coder should regulate the coding rate much more tightly than the current CBR system where a transmission buffer of several tens of ms is used. This should be communicated with SGXVIII.

8.2 CBR as a special case of VBR

It was recognized that CBR is a special case of VBR, and that as such, depending on the application, a VBR codec could operate in CBR or VBR mode.

8.3 Framework for further study

For facilitating the study, a framework for further study has been drafted as in Annex 4 to AVC-65R. {inputs are expected to elaborate all indicated issues}

The document provides some guidelines to reduce the ambiguity when comparing VBR and CBR:

- to freeze as much as possible the following variables for the comparison (illustrated in Figure 3)

  * buffer size
  * picture quality
  * bit rate
  * codec complexity

- to define a 'long' video sequence for statistical evaluation

The document classifies the parameters that influence SMG's:

- use of priority bit and layered coding
- whether the B-ISDN can offer different QOS's
- Cell Loss Ratio
- possible correlation between sources (including source periodicity)
- control of VBR operation (including buffer size)
- network model used

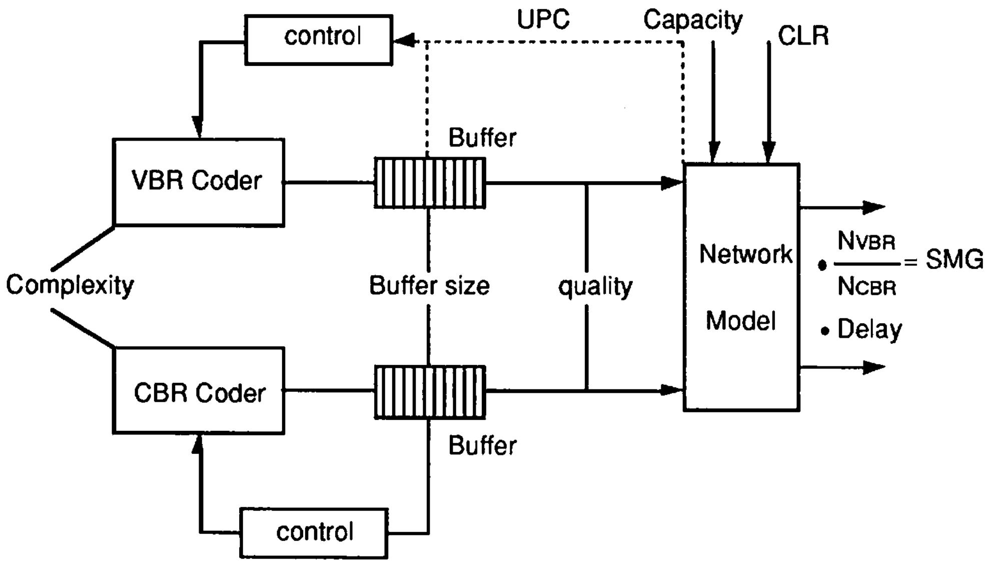


Figure 2 Model for comparison between VBR and CBR

The document also indicates clock recovery issues, and the possibility of VBR codecs operating in CBR mode.

More detailed questions and issues that have to be solved are found in the document.

8.4 Statistics

VBR bit rate statistics have been presented in AVC-44, 49, 61, 99, 171, 267, 307, 314. It has been demonstrated that a relatively small buffer makes a significant difference to the shape of the source, and that the number of cells per frame for videoconferencing scene with moderate motion and no scene cuts or changes follows a Gamma distribution when measured with an open loop VBR encoder.

In AVC-267, using a hardware hybrid coder (without motion compensation), several VBR statistics are collected for TV programmes in ATM environments; cell inter-arrival times, cell rate for unbuffered packetization, cell rate for slice buffered packetization, and bit rate for image buffered packetization. It is suggested that data may be used for estimating statistical multiplex gain and determining the policing function for TV codecs.

AVC-307 provides detailed statistics for VBR operation of MPG-1 coder, which have been collected through simulation of more than 3000 frames of video;

1) frame-by-frame bit rate, probability density function and autocorrelation plots for each test sequence,
2) SNR versus average and peak rates,
3) effect of different peak rate control levels on the image quality,
4) comparison of CBR versus VBR image quality for the same average bit rate.

In AVC-314, by analyzing a 32,000 frame traffic data produced by a H.261 codec with motion compensation, it is confirmed that the number of cells per frame for video conferences follows a gamma distribution. It is also shown that the density function fits with that of a Markov chain.

{Statistics of "real life" sequences (from both TV programs and videoconference communications) coded by a MC based algorithm are strongly solicited.}

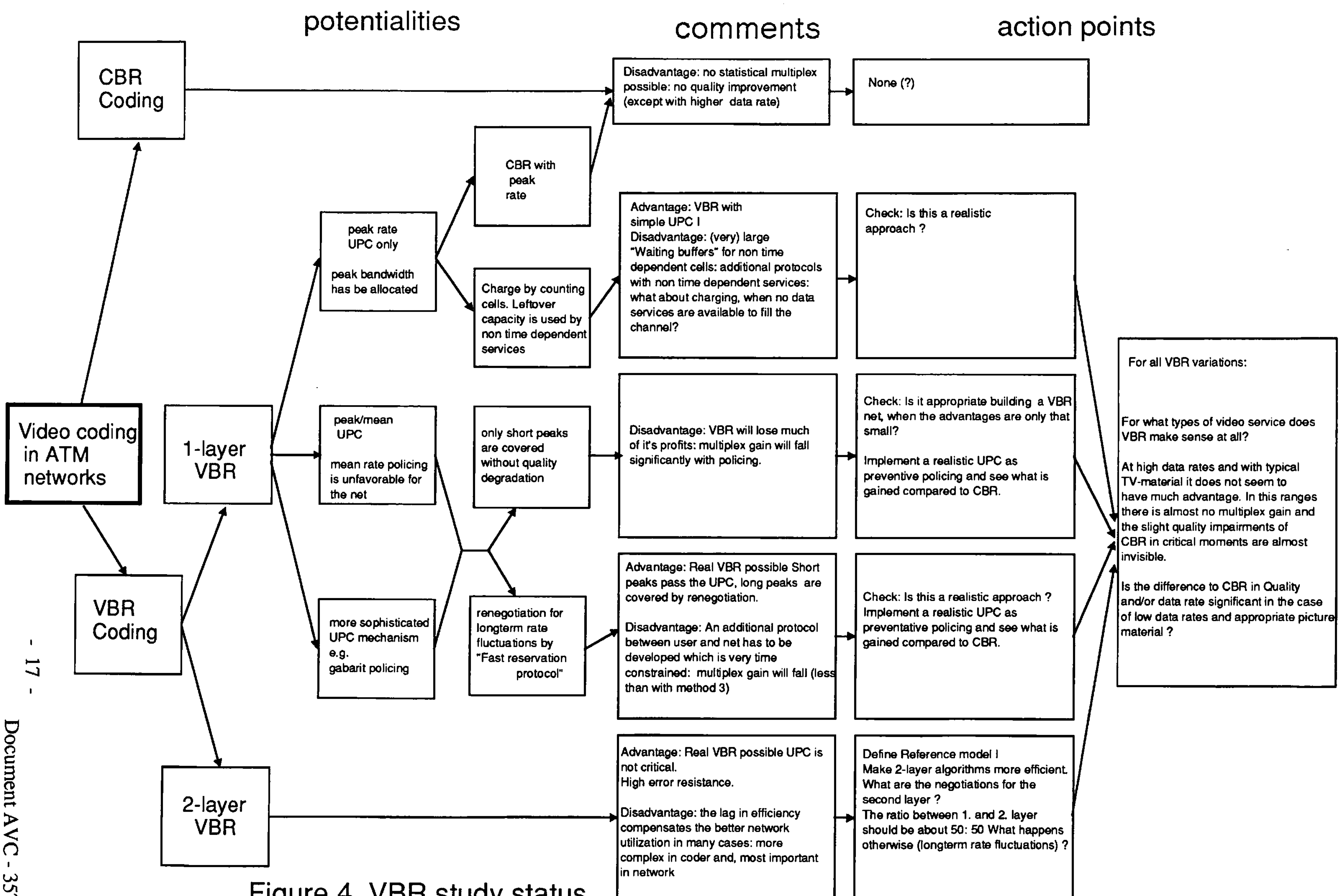


Figure 4 VBR study status
(from AVC-255)

{Also statistics of closed loop VBR encoders are invited. The provision of data files containing bit rate in function of time (both for closed loop and open loop) may help to validate network models.}

8.5 Delay of VBR coding

Transmission delay is analyzed for CBR and VBR using an information generation model in AVC-272. Sliding window and leaky bucket are compared as average rate UPC methods for VBR assuming the same mechanism is applied to the coder for preventive policing. It is concluded that leaky bucket VBR can provide shorter delay than CBR, but sliding window VBR can not except for a particular case of periodical variation of information generation.

8.6 Comparison between VBR and CBR

The current status of the study is summarized in Figure 4, leaving most of the questions open.

9. Picture quality assessment

9.1 Demonstration of particular topics

For demonstration of hardware processed or computer simulated pictures, the hosting organization is kindly requested to provide the following equipment:

- VCR: multi-standard U-matic, D-1 machine
- monitors: NTSC, PAL, SECAM inputs, 50 and 60 Hz component inputs (R, G, B)

{monitors to assess progressively-scanned signals, interchange of processed picture data, format and hardware for storing progressively-scanned material on D1?}

9.2 Formal subjective tests

{Need to have formal subjective tests? At what stage of standard development?}

{CCIR method - double stimulus continuous quality-scale method, Rec. 500-3, as adopted in the "Kurihama tests"}

10. Multimedia multiplexing

10.1 Multiplexing methods

The following methods for multimedia multiplexing are conceivable in the B-ISDN environment (Figure 5);

1) Cell multiplex : each medium is identified by the cell header.
2) Message multiplex: each medium is identified by the IT of SAR.
3) Media multiplex : each medium is identified by the CS header.
4) User multiplex : multimedia signals are multiplexed in the layer above AAL

The Experts Group is considering audiovisual and other multimedia services support on the B-ISDN, and therefore possible multimedia multiplexing alternatives. VC-based multiplexing has been identified as a long-term target, but early service implementation may have to use other means of multiplexing, since

- interworking with audiovisual equipment on other networks (64 kbit/s ISDN) will require a user multiplex mode of operation, which may also be used for communications through B-ISDN instead of equipping two multiplex modes;

- we understand that the network will not be able to support VC-based multimedia multiplexing at the early stages of standardisation.

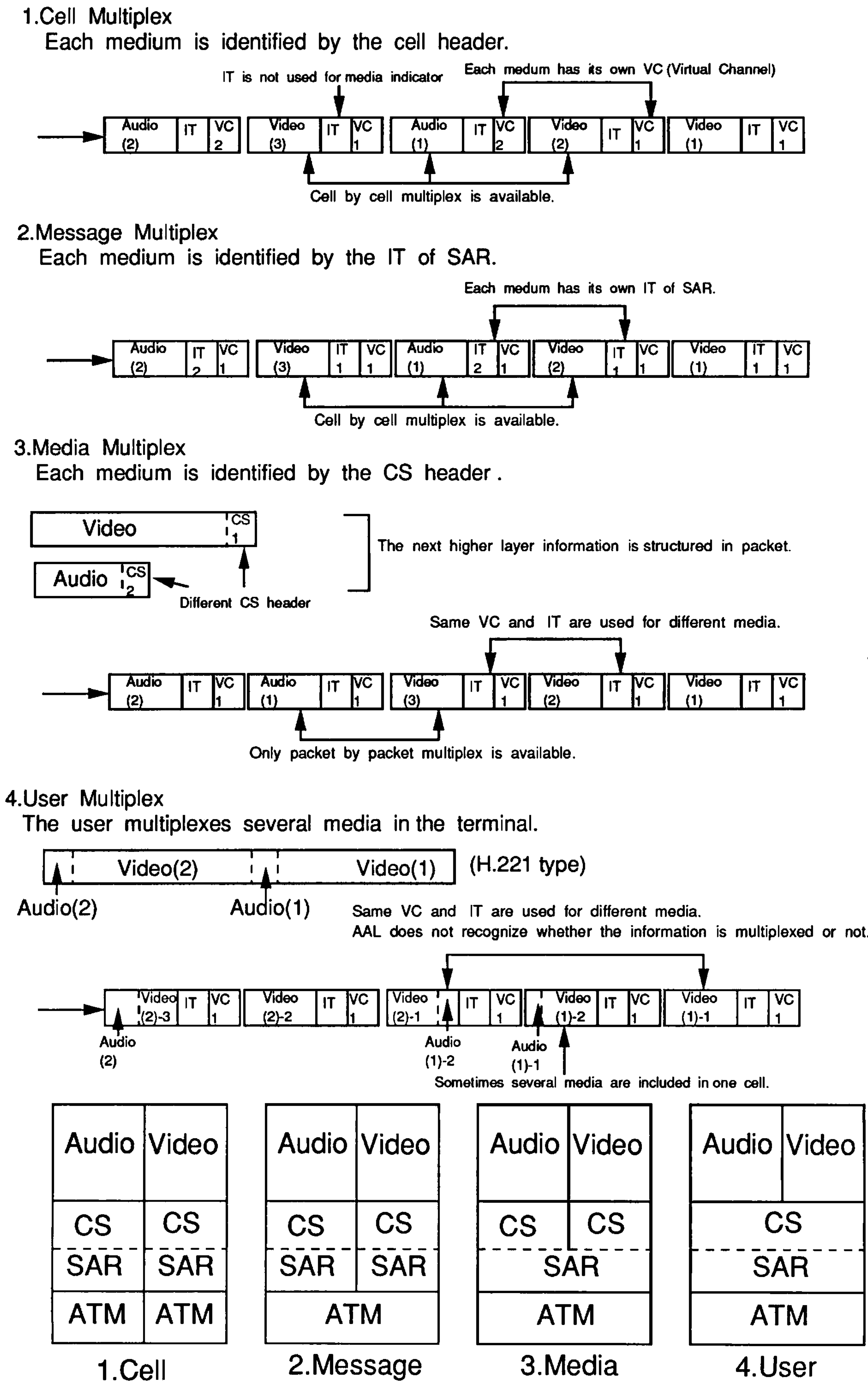


Fig.5 Multimedia multiplex methods

Table 3 : The comparison of three multi-media multiplex methods

REQUIREMENTS \ SCHEMES		Cell multiplex (VC multiplex : VCI approach) merit : Variety of services	SAR multiplex (SAR-PDU multiplex : Packet approach) merit : Easiness for VBR?	User multiplex (Bit multiplex : H.221 approach) merit : Compatibility with H.320
1.Efficient channel utilization	Over head	0	192/(packet size+192) + 4/384 - (UW) (dummy bits) (IT bits) (Unique Words) *1)	16/640 or 16/(p*640)
	Sharing with other media	Impossible	Possible	
2.Multiplexing delay		No delay due to multiplexing.		
3.Compatibility	with H.320	H.221 is necessary (switchable)		Easy (Embedded)
	with MPEG	MPEG bit stream should be transmitted as data. MPEG demultiplexer is necessary.		
4.Multi-media	Media identification	HLC or user information at call setup	Indicated by IT?	BAS
	Bit rate identification	Call signaling	User protocol?	BAS
	Cross media synchronization	Not guaranteed now	Guaranteed	
5.Media selectability in Multi-point conference		Easy but copy function for each medium in network or MCU is required. Otherwise mesh type connection is required.	Difficult but possible by MCU with some transmission efficiency loss.	
6.Real time transmission for the low bit rate (eg. 2400bps) data		Delay and transmission efficiency is a trade off. delay = 384bits/bit rate*efficiency		300/1200/4800 bits etc.
7.The influence of one cell loss		One medium Recover at the next packet?		Several media Recover at the next packet? (The probability of FAS,BAS errors due to cell losses is assumed significantly low.)
8.Easy to implement		Easy by using media-VCI's table	Easy by using media-IT table	Already implemented in H.221 using LSI chip
9.QOS(Quality of Service)		Any QOS for each medium	QOS must be that of the most demanding medium	
10.Transmission cost		Multiple VCs may be expensive because of OAM for each VC	-	

*1) If GOB is aligned with cell, UW is GOB start code. If such alignment is not used, first term and third term can be deleted.

Table 3, which summarises our current perceptions regarding multiplexing approaches.

10.2 A study method for making progress

The following steps are followed;

1) Clarification of requirements to ATM networks from audiovisual terminal point of view.
2) Concrete multimedia multiplex method to realize the requirements.

Furthermore the idea to assume an intermediate virtual layer between AAL and codecs, called media control layer, is introduced in AVC-53, 92, 129, 268 to identify the requirements for ATM and AAL layers. Further development of the idea is awaited.

10.3 Current action

It is a view of the Experts Group that a particular solution is not wise at this stage and we should study several alternatives in parallel until network conditions (cell loss, cost of separate VCs, differential delay between separate VCs, B-N interworking, etc.) become clearer.

11. Network aspects

11.1 Background

Since B-ISDN is still in the formative stage, the Experts Group are studying network related issues from the user point of view and identifying requirements to the network. We are having close liaison with SGXVIII in this respect.

11.2 Timing synchronization - AAL (ATM Adaptation Layer) Type 1

Based on the agreement that we provide a mechanism in H.26X which allows video sampling clock recovery (note that H.261 does not explicitly support this feature), we considered whether this be achieved using AAL's SRTS function or as part of video codec functions.

This should be further studied considering VBR operation of the video codec and clock recovery for multiple sources. The following facts should also be taken into account;

- At T/S reference points, 150 MHz network clock is available, but its submultiples may have to be generated inside the terminal.
- Some NT2 equipment, such as LAN and PBX, does not provide precise clock frequency nor are locked with B-ISDN clock frequency. SRTS method is based on the availability of the identical clock at both ends.

Though we have not yet reached a firm conclusion, there is general support for the video codec to have this functionality.

Document AVC-315 provided a solution for timing recovery of audiovisual signals transmitted through a variable rate channel where a common clock is not available between the encoder and decoder. This work is based on MPEG system study and is useful for the database access where pre-recorded video is involved and a common clock does not solve the problem even if it is available at both ends.

11.3 Required functions of AAL Type 2

SGXVIII intends to finalize the protocols for video transport in the 1994 Recommendations, thus welcomes the input from this group on required functions. We listed some possible items on a "may be required" basis, awaiting further study;

- multiplexing capabilities
- sequence number
- cell payload length indication
- requests for priority level
- alignment of packet data to cell boundary.

11.4 Bit error and cell loss protections

Since the preventive measures against bit errors and cell losses have crucial impacts to the structure of audiovisual terminals for B-ISDN, the Experts Group expanded the content in relevant parts of the IVS Baseline Document covering the above concerns by notes as a step in the ongoing iterative process (see Table 4).

There was discussion on where necessary error correction and cell loss protection be carried out, at SAR, CS or user layer depending on the network performance. The following factors should be considered in this study:

- Interworking with N-ISDN terminals should also be considered where bit errors are taken care of at the user layer.
- It should be noted that scrambling in ATM layer causes correlated errors in SAR-PDU.
- Order of scrambling, error correction and encryption should be carefully considered.
- If video is layered, different layers may take advantage of different levels of bit error and cell loss performance

The Experts Group received SGXVIII's response to our question concerning the network performance; cell error ratio and cell loss estimated from the G.82X specification. It was noted that these values are based on the radio transmission systems and optical fibre systems are used in actual B-ISDN, thus much better performance is expected. It was also noted, however, that the estimation in this liaison document does not include cell losses which may be caused by ATM nodes at the time of congestion, thus worse performance than this may be provided.

We felt it safe that the video codec be resilient to this level of network performance; by means of e.g. including FEC to cope with bit errors as in H.261, and cell loss resilience techniques in the video source coding. Possible elements for cell loss resilience are as follows though they are not exhaustive;

- use of CLP bit (transmission coding)
- layering (source and/or transmission coding)
- leaky prediction (source coding)
- FEC/interleave (AAL)
- structured packing of video data into cells (transmission coding)
- concealment (outside the standard)

The question is what elements should be standardized for the cell loss resilience. This is one of the areas we need further extensive study and included in the Test Model experiments.

Related to this topic, we recognize that study is required on implications of LAN/MAN characteristics on the ATM video coding standard. LAN/MAN may be used as an access to B-ISDN.

11.5 CLP

We agreed that CLP bit be used only for cell loss priority indication, not for indication of video coding layers.

Table 4 SERVICE AND NETWORK REQUIREMENTS

Service	Bit rate	QOS require ments (***)	Required BER/CLR without error handling in AAL	AAL type	Required BER/CLR after single bit error correction on cell basis in AAL(*)	Required BER/CLR after single bit EC on cell basis and additional cell loss correction in AAL(**)
Communication						
videophone	64kbps/2Mbps FBR (H261)	30 min. error free	BER<1e-6 CLR<1e-7 (BCH(511, 493) FEC in user layer)	type 1	in user layer	BER<... CLR<8e-5
videophone	2Mbps VBR	30 min. error free	BER<3e-10 CLR<1e-7	type 2	BER<1.2e-6 CLR<1e-7	BER<2.3e-5 (CLR=1e-6) CLR<8e-5
videoconference	5Mbps VBR	30 min. error free	BER<1e-10 CLR<4e-8	type 2	BER<8e-7 CLR<4e-8	BER<1.8e-5 (CLR=1e-6) CLR<5e-5
video distribution						
TV distribution	20-50Mbps VBR	2 hours error free	BER<3e-12 CLR<1e-9	type 2	BER<1.2e-7 CLR<1e-9	BER<6e-6 (CLR=1e-6) CLR<8e-6
MPEG1 core	1.5Mbps VBR	30 min. error free	BER<4e-10 CLR<1e-7	type 2	BER<1.4e-6 CLR<1e-7	BER<2.5e-5 (CLR=1e-6) CLR<9.5e-5
MPEG2 core	10Mbps VBR	30 min. error free	BER<6e-11 CLR<2e-8	type 2	BER<5.4e-7 CLR<2e-8	BER<1.5e-5 (CLR=1e-6) CLR<4e-5

(*) Payload scrambling polynomial 1+x**43 produces double, correlated bit errors.
(**) Based on parity cell built from 31 consecutive data cells (see AVC-69). The cell losses are assumed to be isolated. With this simple correction scheme, single cell losses can be corrected if combined with cell loss detection by cell numbering. Also non-corrected but detected bit errors in a cell are handled by replacing this faulty cell by a dummy cell followed by correction of this cell by the cell parity mechanism. The BER calculations are done in the assumption that all double ATM link errors(2 times 2 correlated errors due to payload scrambling) can be detected.
(***) QOS requirements, as visualized by viewers: not directly related to channel errors.

Notes

-These values are calculated under the assumption that cell losses are isolated. If cell losses tend to occur successively, another cell loss ratio and another cell loss correction technique may be required.

-We assumed that one cell loss always causes a picture degradation. The visual perception of the picture, however, may be acceptable even if cell loss concealment technique is not used. Therefore there is a possibility that these requirements will be relaxed.

11.6 UPC (Usage Parameter Control)/TD (Traffic Descriptor)

SGXVIII intends not to standardize the UPC mechanisms. This causes fundamental problems to VBR realization.

- Difference of methods to monitor the traffic between the terminal and the network may cause cell discards which the terminal can not predict.
- If a UPC mechanism is not standardized, different UPC methods in different networks may further cause unpredictable cell discards.

Since these are quite serious for achieving VBR video coding, the issues should be kept on the agenda for liaison with SGXVIII until they can be resolved.

A contribution also brought up the issue of using performance metrics for UPC performance evaluation. As long as different UPC algorithms conform to the performance metrics bounds specified, no standardization of a UPC algorithm may be needed. Its implication on the VBR coding should be addressed.

11.7 Interworking between N-ISDN and B-ISDN terminals

There is a question whether audiovisual terminals use AAL Type 1 as well if both VBR and CBR are covered by AAL Type 2. One of the cases identified is interworking between B-ISDN and N-ISDN as illustrated in Figure 6. We feel ambiguous about whether Type 1 for interworking be required in H.32X terminal, or it may be covered by the interworking unit in the network. It is also pointed out that the existing N-ISDN terminals are quite susceptible to cell loss if it occurs in the circuit emulation mode.

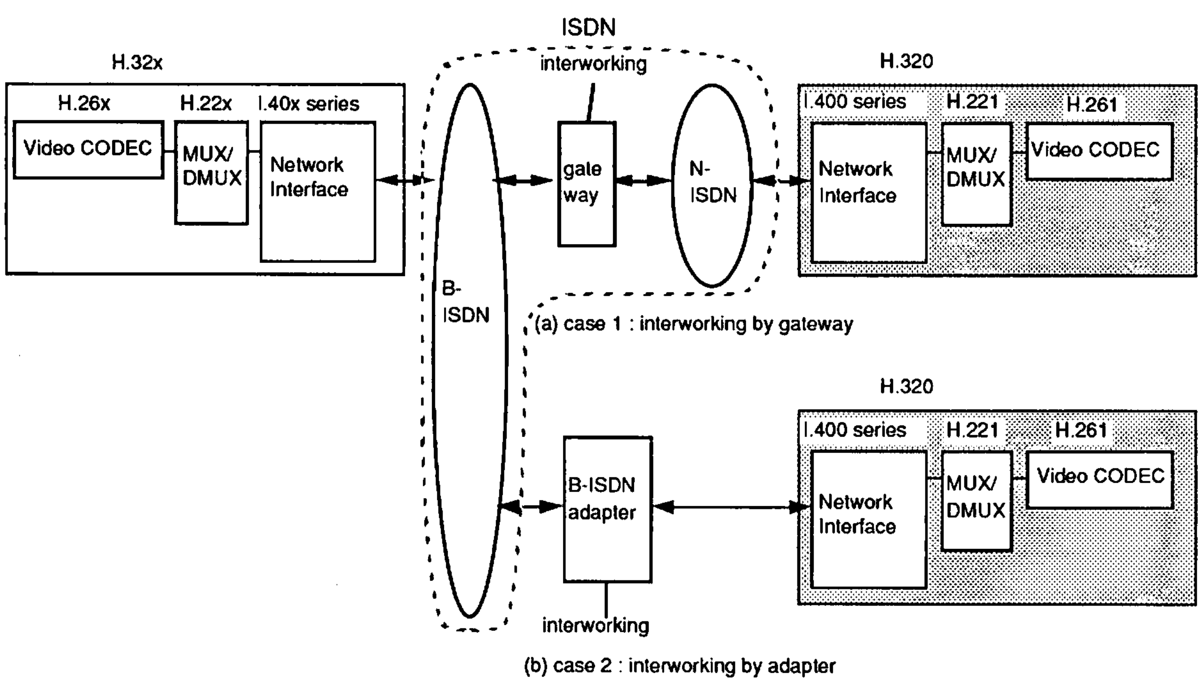


Figure 6 Two cases of interworking between H.32X and H.320 terminals

11.8 Reference terminal configuration

We recognized the importance of reference configuration of the audiovisual ATM terminal toward the following;

- identification of reference points and interface signals at those reference points
- clarification of responsibility for specification

- identification of missing elements for designing audiovisual communication terminals connected to B-ISDN

and identified Figure 7 as a useful input for further elaboration.

12. Work plan and work method

12.1 Overall work plan

There is consensus on the plan that Recommendation H.26X be made official in 1994, taking into account the completion of the B-ISDN Recommendations in 1992 and subsequent service provision.

{We need a staged approach for video coding and other audiovisual Recommendations to adapt to the evolutionary development of B-ISDN Recommendations.}

The following methods practiced in the previous Specialists Group for H.261 are supported for the H.26X work;

- Study is phased as "divergence" and "convergence",
- Step by step using Reference Models, and
- Hardware verification at the final stage.

As to the reference model, it was clarified that this time we need two kinds of model; one for network aspects study and the other for video coding aspects study. It was also clarified that the latter includes source coding as well as channel coding.

As a summary for the work plan and method, the current time table is shown in Figure 8.

12.2 Hardware verification

Document AVC-283 gave a stimulus to plan hardware trials which is required at the later stage of the Experts Group activities. First of all, at least two volunteers are solicited who independently develop hardware for the testing purpose. Various components and their interfaces of the trial system should be clarified (see Figure 9).

13. Harmonization with other standardization bodies

This group seeks to carry out joint work with TG CMTT/2 Special Rapporteur's Group and ISO/IEC JTC1/SC29/WG11 (MPEG) in order to avoid different standards in the same or similar areas and to avoid duplication of standardization work as well.

To this end the CCITT group proposed to MPEG and CMTT/2 SRG that joint meeting sessions be arranged in the areas of overlapping interest and responsibility, namely:

- source video coding algorithm and video multiplexing,
- system issues concerning multimedia multiplexing and synchronization,
- implementation considerations.

The MPEG Berlin meeting of December 4-7, 1990 concluded in response to our liaison statement that the ongoing phase of work on audiovisual coding at bit rates up to about 10 Mbit/s be carried out in collaboration with CCITT, by holding joint meetings on matters of common interest such as video, systems, implementation. It was confirmed there that both groups have a common target date of freezing draft specifications as end of 1992. It was also confirmed that a "Test Model" would be defined after subjective tests of candidate algorithms for further collaborative elaboration.

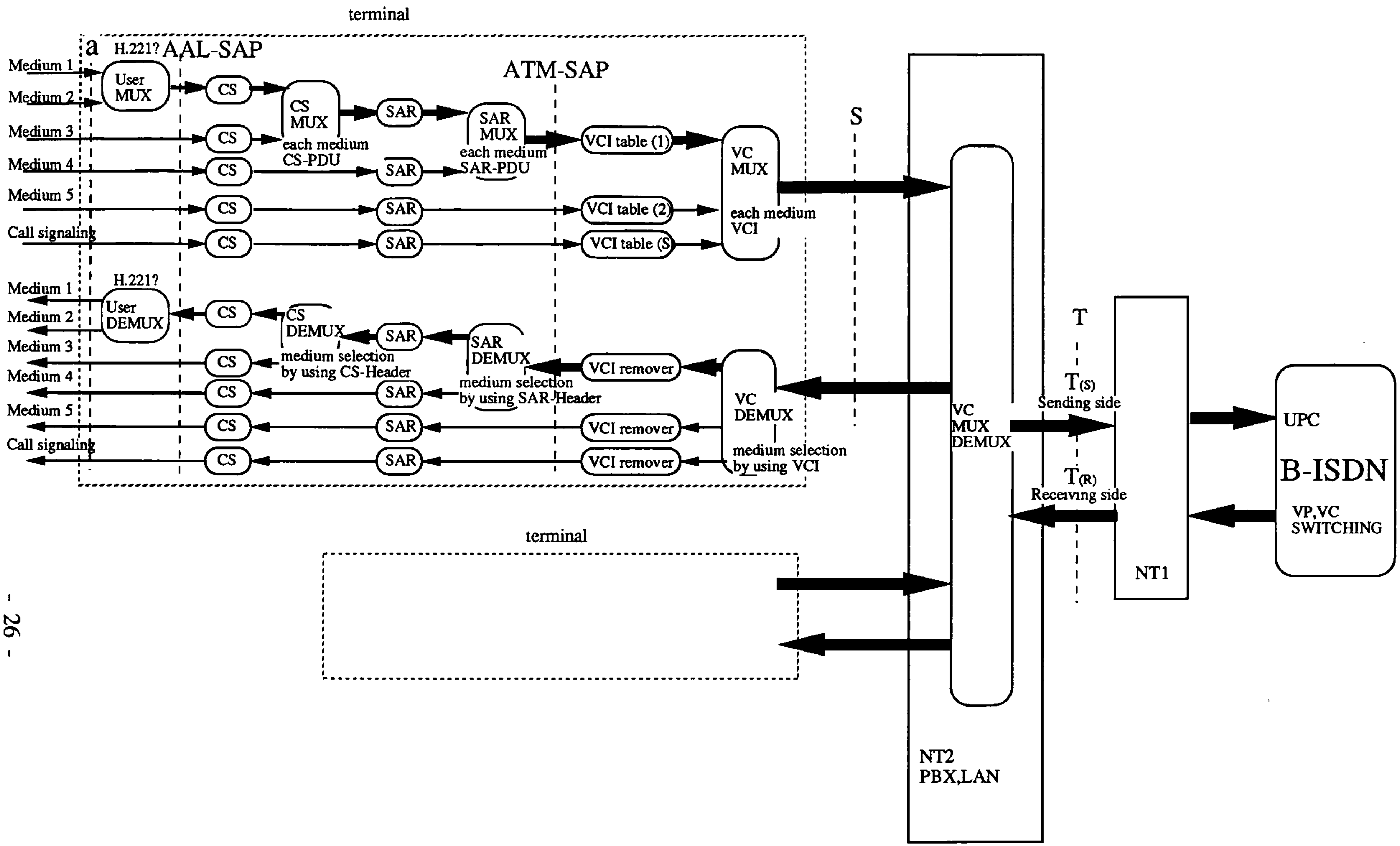
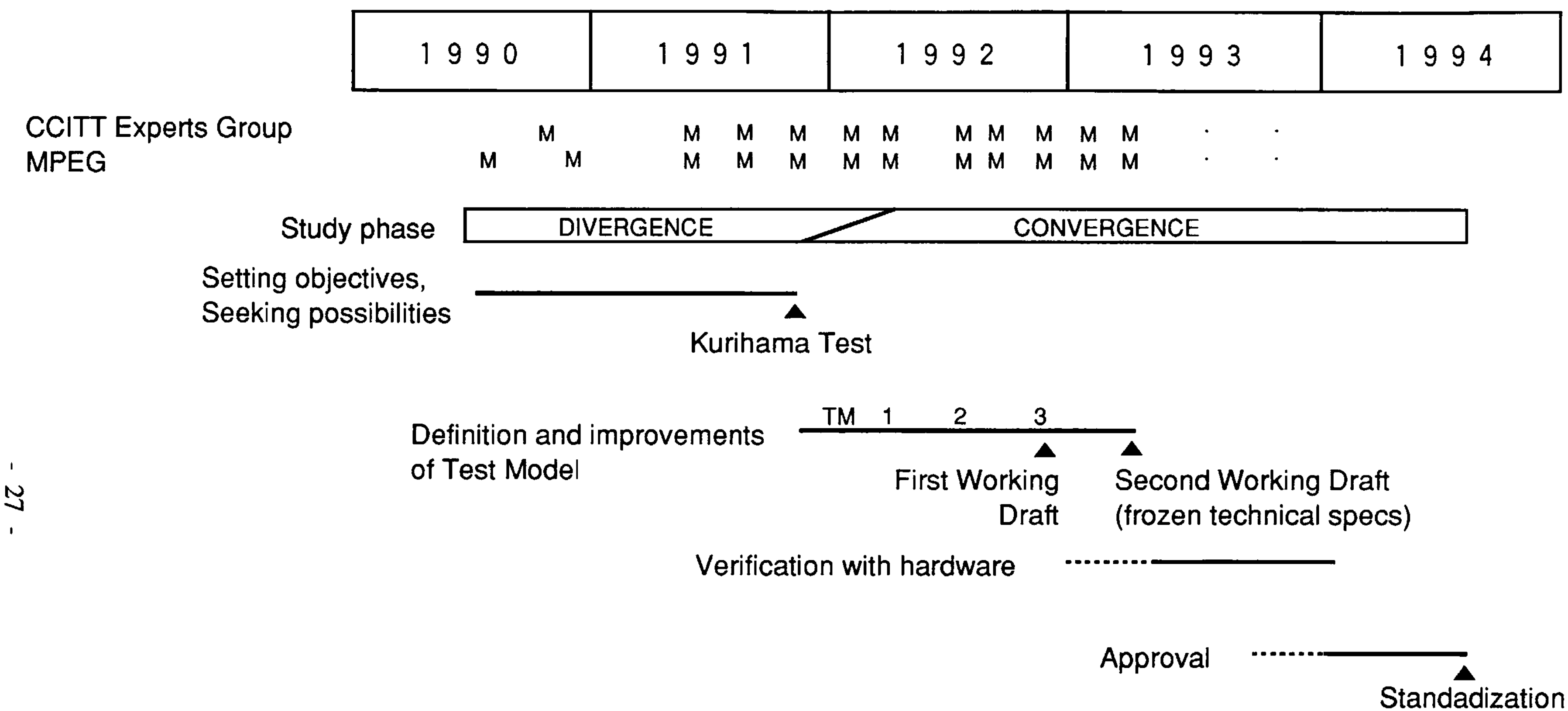


Fig. 7 Terminal configuration

Figure 8 WORK PLAN FOR H.26X/MPEG - 2 VIDEO CODING



Kurihama test : Subjective picture quality test for simulation results of 30 proposed algorithms

TEST MODEL : A reference coding model against which improvements are experimented. Convincing improvements are incorporated into the next version of Test Model.

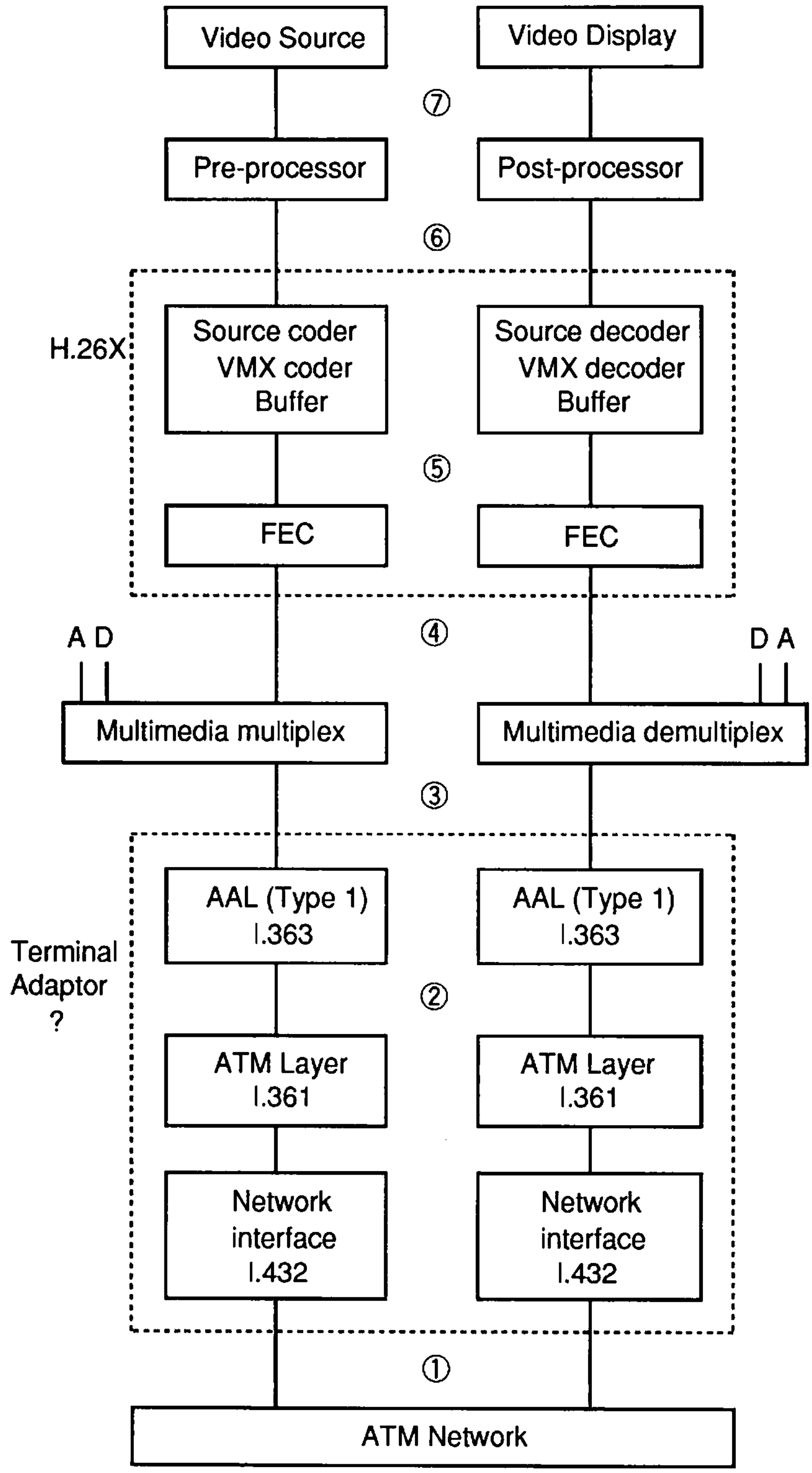


Figure 9 System configuration for H.26X hardware verification

In May 1992, CCITT Study Group XV endorsed the formalization of the collaborative work between the Experts Group and MPEG in response to the request of Experts Group and the proposal of ISO/IEC JTC1/SC29.

The TG CMTT/2 Tokyo meeting of March 25-28, 1991 concluded that the aspects of practical collaboration with Study Group XV are addressed through Special Rapporteur and that a delegation of TG CMTT/2 is expected to attend common meetings of Study Group XV and ISO/MPEG.

14. Conclusion

This status report provides summary information on what the Experts Group have achieved up to the end of July 1992. There are still a number of items which should be studied toward establishing Recommendation H.26X in 1994.

END

* * * *

EDITORS FOR "STATUS REPORT"

The editor is in charge of the following tasks;

- to collect materials of common understanding,
- to list items requiring further study indicating different views if any,
- to add any editor's comments in { } to encourage further work.

Issue 2	Editor
1. Introduction	S. Okubo
2. Terminology	R. Schaphorst
3. Applications	A. Tabatabai
4. Boundary conditions for ATM video coding	M. Wada
5. Picture format	G. Bjoentegaard
7. Network model	D.G Morrison
8. VBR vs CBR	W. Verbiest
9. Simulation guidelines for video coding study	D. Schinkel
10. Picture quality assessment	D. Lemay
11. Multimedia multiplexing in B-ISDN	T. Tanaka
12. AAL	T. Tanaka
13. Work plan and work method	S. Okubo
13. Harmonization with other standardization bodies	S. Okubo
14. Outstanding questions	S. Okubo

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8. VBR vs CBR	O. Poncin
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10. Multimedia multiplexing	T. Tanaka
12. Network aspects	T. Tanaka
13. Work plan and work method	S. Okubo
13. Harmonization with other standardization bodies	S. Okubo
14. Conclusion	S. Okubo

ANNEXES to AVC-357

List of AVC-numbered documents

Documents for the first meeting of the Experts Group

AVC-1	ADDRESS OF COORDINATING MEMBERS AND LIAISON REPRESENTATIVES	SECRETARIAT
AVC-2	EXCERPT OF THE WPXV/1 MEETING REPORT - JULY 1990	CHAIRMAN
AVC-3	PHASE-2 WORK OF MPEG	CHAIRMAN
AVC-4	IMPACT OF ATM NETWORKS ON VIDEO CODING	AUSTRALIA
AVC-5	UNIVERSAL VIDEO CODING FOR ATM NETWORKS	AUSTRALIA
AVC-6	SIGNALLING FOR AUDIOVISUAL OR MULTIMEDIA CONNECTION ON ATM NETWORKS	AUSTRALIA
AVC-7	JAPANESE ACTIVITIES ON ATM VIDEO CODING STANDARDS	JAPAN
AVC-8	CONSIDERATION ABOUT ATM CODING APPLICATIONS AND FEATURES	JAPAN
AVC-9	CONNECTIVITY WITH CURRENT SYSTEM AND RECOMMENDATION SCHEDULE	JAPAN
AVC-10	TECHNICAL PROBLEMS AND PROCEDURES	JAPAN
AVC-11	ATM ADAPTATION LAYER - AAL	JAPAN
AVC-12	VIDEO CODING ACTIVITIES IN CMTT	LIAISON REPRESENTATIVE FOR CMTT
AVC-13	COMPENDIUM ATM - CODING PROCEDURES	NETHERLANDS,GERMANY, UNITED KINGDOM, FRANCE, NORWAY, SWEDEN, PORTUGAL, ITALY, SPAIN, BELGIUM
AVC-14	INTERCONNECTIVITY OF FUTURE AV-SYSTEMS	THE ROYAL NETHERLANDS PTT, PTT CONTEST
AVC-15	ATM VIDEO CODING	AT&T, DIS, DAVID SARNOFF LABS, PICTURETEL, APPLE COMPUTER
AVC-16	COMMENTS ON "MEMORANDUM OF TOPICS"	BELGIUM, FRANCE, FRG, ITALY, NETHERLANDS, NORWAY, UK
AVC-17	OUTSTANDING ISSUES ON LOW BIT RATE VIDEO CODING FOR ATM NETWORKS	BELGIUM, FRANCE, FRG, ITALY, NETHERLANDS, NORWAY, UK
AVC-18	CONSIDERATIONS CONCERNING THE STANDARDISATION OF AAL(S) FOR VIDEO SERVICES	BELGIUM, FRANCE, FRG, ITALY, NETHERLANDS, NORWAY, UK
AVC-19	VIDEO CODEC DEVELOPED IN THE BELGIAN BROADBAND EXPERIMENT	RTT BELGIUM
AVC-20	IMPACT OF THE ATM TECHNIQUE ON VIDEO CODING	BELL TELEPHONE
AVC-21	TWELFTH MEETING REPORT OF ISO/IEC JTC1/SC2/WG11	CONVENOR

Documents for the second meeting of the Experts Group

AVC-22R	REPORT OF THE FIRST MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN THE HAGUE	CHAIRMAN
AVC-23	REPORT OF MPEG BERLIN MEETING	CHAIRMAN
AVC-24	EXCERPT FROM WPXVIII/8 MEETING REPORT	CHAIRMAN

AVC-25	INTEGRATED VIDEO SERVICES - IVS - BASELINE DOCUMENT	WORKING PARTY XVIII/8
AVC-26	REPORT OF THE 13TH MEETING IN BERLIN	MPEG
AVC-27	EXCERPT FROM THE REPORT OF THE GENEVA MEETING	WORKING PARTY XV/1
AVC-28	LIAISON STATEMENT TO CCITT STUDY GROUP XV	TG CMTT/2
AVC-29	COMMON PROGRESSIVE PICTURE FORMAT FOR HIGH QUALITY APPLICATIONS	BELGIUM, FRANCE, FRG, ITALY, NORWAY, THE NETHERLANDS, UK
AVC-30	IMPROVEMENTS OF HYBRID DCT CODING	NORWAY
AVC-31	ON BIT RATES IN A TWO-LAYER CODING SCHEME	RTT BELGIUM
AVC-32	COMPATIBILITY METHODS FOR VIDEO CODING SYSTEMS	THE NETHERLANDS, FRG, NORWAY, ITALY, UK, SWEDEN, FRANCE, BELGIUM
AVC-33	SET UP OF CCIR 601 MULTI-PURPOSE CODING SCHEME	PTT RESEARCH, THE NETHERLANDS
AVC-34	FRAMEWORK FOR STANDARDISATION OF VIDEO SERVICES ON THE B-ISDN	AUSTRALIA
AVC-35	ARCHITECTURE OF VIDEO SERVICE INTEGRATION ON THE B-ISDN	AUSTRALIA
AVC-36	PICTURE FORMATS SUPPORTED BY VIDEO CODECS ON THE B-ISDN	AUSTRALIA
AVC-37	MULTI-POINT VIDEO COMMUNICATION FOR B-ISDN	AUSTRALIA
AVC-38	A COMPARISON STUDY OF VBR vs CBR FOR CONVERSATIONAL SERVICES	AUSTRALIA
AVC-39	VIRTUAL CHANNELS FOR MULTIMEDIA SUPPORT IN THE B-ISDN	AUSTRALIA
AVC-40	RESPONSE TO INTEGRATED VIDEO SERVICES - IVS - BASELINE DOCUMENT	AUSTRALIA
AVC-41	STATISTICAL MULTIPLEX GAIN FOR VARIABLE BIT RATE VIDEO	RTT BELGIUM
AVC-42	MULTIMEDIA MULTIPLEX IN ATM NETWORKS USED IN THE BELGIAN BROADBAND EXPERIMENT	BELGIUM
AVC-43	ATM NETWORK MODEL	SWEDEN, UK
AVC-44	CELL LEVEL STATISTICS FOR A TWO-LAYER CODING SCHEME	UK
AVC-45	DESCRIPTION OF A COMPATIBLE CODING APPROACH FOR MPEG1 AND MPEG2	UK
AVC-46	CONSIDERATIONS ON PICTURE FORMAT IN ATM NETWORKS	JAPAN
AVC-47	CONSIDERATIONS ON STATISTICAL MULTIPLEX GAIN ACCORDING TO THE FIRST SIMPLIFIED NETWORK MODEL	JAPAN
AVC-48	VBR CODING UNDER USAGE PARAMETER CONTROL	JAPAN
AVC-49	SOME OBSERVATIONS ON VARIABLE BIT RATE CODED VIDEO SIGNALS	JAPAN
AVC-50	CONSIDERATIONS ON CELL LOSS IN ATM NETWORKS	JAPAN
AVC-51	REQUIREMENTS OF THE HIGH QUALITY VIDEO CODING STANDARD H.26X - CONSIDERATION OF MULTIPOINT SYSTEMS, DISTRIBUTION SERVICES AND FUTURE ENHANCEMENT	JAPAN
AVC-52	REVISION TO THE ANNEX 3 TO DOC. AVC-22R	JAPAN
AVC-53	INVESTIGATION OF MULTIMEDIA MULTIPLEX ON ATM NETWORKS	JAPAN
AVC-54	CLOCK RECOVERY FOR VARIABLE BIT RATE AUDIOVISUAL CODING	JAPAN
AVC-55	H.261 COMPATIBLE 2-LAYER VIDEO CODEC WITH HIGH CELL LOSS RESILIENCE	DAIMLER-BENZ RESEARCH - FRG
AVC-56	CONSTRAINTS ON VARIABLE BIT-RATE VIDEO FOR ATM NETWORKS	AT&T BELL LABS

AVC-57	PREPARATORY DRAFT PROPOSAL PACKAGE DESCRIPTION FOR MPEG PHASE 2	MPEG
AVC-58	SIMULATION RESULTS FROM A SUBBAND SPLITTING CODING SCHEME COMPATIBLE WITH MPEG1/H261	CNET
AVC-59	PICTURE FORMATS FOR HIGH QUALITY APPLICATIONS	CANADA
AVC-60	PICTURE FORMAT FOR HIGH QUALITY INTERACTIVE VIDEO SERVICES	BELLCORE
AVC-61	STATISTICAL ANALYSIS OF VIDEO TELECONFERENCE TRAFFIC IN ATM NETWORKS	BELLCORE
AVC-62	A SIMULATION STUDY OF VIDEO TELECONFERENCE TRAFFIC IN ATM NETWORKS	BELLCORE
AVC-63	LIAISON STATEMENT TO CCITT WORKING PARTY XVIII/8	TG CMTT/3
AVC-64	ASPECTS ON PICTURE FORMAT FOR HIGH QUALITY APPLICATIONS	SWEDEN

Documents for the third meeting of the Experts Group

AVC-65R	REPORT OF THE SECOND MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN PARIS	CHAIRMAN
AVC-66	REPORT OF THE 14TH MPEG MEETING IN PARIS	MPEG
AVC-67	LIAISON STATEMENTS AND MEETING NOTICE	SPECIAL RAPPORTEUR OF TG CMTT/2
AVC-68	LIAISON STATEMENTS AND IVS BASELINE DOCUMENT	SGXVIII
AVC-69	CLR AND BER PROTECTION FOR ENHANCED END-TO-END USERS QOS	RTT BELGIUM
AVC-70	UPDATED DRAFT PROPOSAL PACKAGE DESCRIPTION FOR MPEG PHASE 2	CHAIR OF MPEG REQUIREMENTS SUB-GROUP
AVC-71	THE IMPACT OF THE NETWORK ON VIDEO CODING	AUSTRALIA
AVC-72	REQUIREMENTS FOR ATM VIDEO CODECS	AUSTRALIA
AVC-73	ARCHITECTURE FOR VIDEO SERVICE PROVISION	AUSTRALIA
AVC-74	THE EFFICIENCY OF A LAYERED PYRAMID CODER	AUSTRALIA
AVC-75	SOURCE/NETWORK MODEL	AUSTRALIA
AVC-76	VIRTUAL PATH SUPPORT OF MULTIMEDIA MULTIPLEXED	AUSTRALIA
AVC-77	THE SAR SUBLAYER OF AAL2 FOR VIDEO SERVICE SUPPORT	AUSTRALIA
AVC-78	REMOTE VIDEO SURVEILLANCE AS A B-ISDN SERVICE	AUSTRALIA
AVC-79	LOSS OF CODING EFFICIENCY BY USING SCIF	JAPAN
AVC-80	CONVERSION SIMULATION BETWEEN 525 LINE INTERLACED FORMAT AND SCIF	JAPAN
AVC-81	PROGRESSIVE SCANNING CAMERA	JAPAN
AVC-82	MERITS AND DEMERITS OF THE PROGRESSIVE AND INTERLACED FORMATS	JAPAN
AVC-83	COMPARISON OF PICTURE QUALITY AND ENCODING EFFICIENCY BETWEEN SCIF - SUPER CIF - AND INTERLACED FORMAT USING MPEG ENCODING	JAPAN
AVC-84	ADDITIONAL SUBMISSION MATERIALS FOR 'KURIHAMA TEST'	JAPAN
AVC-85	CONSIDERATION ON ACCEPTABLE PROCESSING DELAY IN THE VIDEO CODEC	JAPAN
AVC-86	REQUIREMENTS FOR THE VIDEO CODING STANDARD H.26X	JAPAN
AVC-87	CONSIDERATION ON MULTI-POINT COMMUNICATION IN B-ISDN	JAPAN
AVC-88	THE EVALUATION OF SUBBAND CODING EFFICIENCY	JAPAN
AVC-89	CONSIDERATIONS ON THE WINDOW SIZE OF TRAFFIC DESCRIPTOR	JAPAN
AVC-90	CONSIDERATION ON DELAY WITH VBR CODING	JAPAN
AVC-91	MULTIMEDIA MULTIPLEX METHOD	JAPAN

AVC-92	VIRTUAL LAYER APPROACH FOR MULTIMEDIA MULTIPLEX FUNCTION	JAPAN
AVC-93	REQUIREMENTS TO THE FUNCTION OF AAL TYPE 1	JAPAN
AVC-94	COMPATIBLE CODING OF CCIR 601 IMAGES: PREDICT THE PREDICTION ERROR	PTT RESEARCH - THE NETHERLANDS
AVC-95	ESTABLISHMENT OF NEW SC29 CONVENOR OF	ISO/IEC JTC1/SC2/WG8
AVC-96	STATUS REPORT ON ATM VIDEO CODING STANDARDIZATION	EXPERTS GROUP
AVC-97	COMPARISON OF NETWORK LOADING MODELS FOR TWO LAYER VARIABLE BIT RATE CODING	UK
AVC-98	REQUIREMENTS ANALYSIS FOR VIDEO SERVICES RTT	BELGIUM
AVC-99	VBR VIDEO STATISTICS	RTT BELGIUM
AVC-100	LAYERED CODING FOR COMPATIBILITY	UK
AVC-101	COMMENTS ON THE IVS BASELINE DOCUMENT AVC-25	BELGIUM, FRANCE, FRG, NORWAY, THE NETHERLANDS, SWEDEN, UK
AVC-102	COMMENTS ON PICTURE FORMAT - ANNEX 3 TO DOC. AVC-65R	BELGIUM, FRANCE, FRG, NORWAY, THE NETHERLANDS, SWEDEN, UK
AVC-103	SIMULATION RESULTS ON A PEL SPLIT COMPATIBLE ALGORITHM	CNET - FRANCE TELECOM
AVC-104	SUMMARY DESCRIPTION OF VADIS/COST ALGORITHM GROUP 2 FORWARD PREDICTION METHOD	NORWAY
AVC-105	TERMINOLOGY CHAPTER FOR THE STATUS REPORT	DIS, NCS

Documents for the fourth meeting of the Experts Group

* indicates that the same material is in MPEG91/??? document.

AVC-106R	REPORT OF THE THIRD MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN SANTA CLARA - PART I	CHAIRMAN
AVC-107R	REPORT OF THE THIRD MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN SANTA CLARA - PART II	CHAIRMAN
AVC-108	PROPOSAL PACKAGE DESCRIPTION FOR MPEG PHASE 2	CHAIR OF MPEG/REQUIREMENTS SUB-GROUP
AVC-109	STATUS REPORT ON ATM VIDEO CODING STANDARDIZATION, ISSUE 2	EXPERTS GROUP
AVC-110	MEETING REPORT	ITU IVS CO-ORDINATION MEETING
AVC-111	ACTIVITIES OF CCIR SG11 FOR DIGITAL TELEVISION	CHAIRMAN OF WP-11B
AVC-112	REPORT OF MEETING	WPXVIII/8-5, 8-3
AVC-113	PICTURE FORMAT FOR CONVERSATIONAL VIDEO APPLICATIONS	CANADA
AVC-114*	ATM COMPENDIUM	THE NETHERLANDS, BELGIUM, FRG, FRANCE, SWEDEN, ITALY, GREEK, UK
AVC-115*	FEATURES OF MUPCOS	PTT RESEARCH, THE NETHERLANDS
AVC-116	BUFFERING AND DELAYS FOR A SLIDING WINDOW CONSTRAINT	AT&T
AVC-117*	CELL LOSS RESILIENCE IN A TWO-LAYER CODING SCHEME	UK
AVC-118*	Algorithm proposal	BT

AVC-119	LAYERED INTERFRAME CODING SYSTEM BASED ON MOTION QUANTITY	JAPAN
AVC-120*	CELL LOSS RECOVERY BY CODING ALGORITHM	JAPAN
AVC-121	VIDEO CLOCK JUSTIFICATION	JAPAN
AVC-122	COMPARISON BETWEEN COMPATIBLE AND NON-COMPATIBLE CODING	JAPAN
AVC-123*	INTERWORKING OF H.32X TERMINALS	JAPAN
AVC-124*	CONSIDERATIONS ON PROCESSING DELAY WITH HYBRID CODING	JAPAN
AVC-125	SCIF ON A SQUARE PIXEL DISPLAY	JAPAN
AVC-126	OPTIMIZATION OF 2-D VLC FOR SCIF CODING	JAPAN
AVC-127	TRANSITION OF THE BUFFER OCCUPANCY UNDER VBR ENVIRONMENTS	JAPAN
AVC-128	COMPARISON BETWEEN SLIDING WINDOW AND LEAKY BUCKET AS A UPC MECHANISM	JAPAN
AVC-129	COMPARISON OF MULTIMEDIA MULTIPLEX	JAPAN
AVC-130	REQUIREMENTS FOR SGXVIII	JAPAN
AVC-131	NETWORK MODELS	SWEDEN, BELGIUM, FRANCE, FRG, GREEK, ITALY, THE NETHERLANDS, UK
AVC-132	POLICING FUNCTION FOR VBR CODING	SWEDEN, BELGIUM, FRANCE, FRG, GREEK, ITALY, THE NETHERLANDS, UK
AVC-133	Algorithm proposal	PTT Research
AVC-134	PICTURE FORMAT CONSIDERATIONS	AUSTRALIA
AVC-135	FLEXIBLE LAYERED CODING EFFICIENCY	AUSTRALIA
AVC-136	B-ISDN MULTIMEDIA SERVICE INTERWORKING	AUSTRALIA
AVC-137	B-ISDN NETWORK STANDARDIZATION - ITS IMPACT ON THE DEVELOPMENT OF ATM VIDEO CODING	AUSTRALIA
AVC-138	SECOND PROGRESS REPORT TO WPXV/1	CHAIRMAN
AVC-139	TRANSPORT AND ERROR CONCEALMENT FOR MPEG-2	DAVID SARNOFF RESEARCH, THOMSON CONSUMER ELECTRONICS
AVC-140	STATISTICAL MULTIPLEX GAINS FOR VARIABLE BIT RATE	BELGIUM, FRANCE, FRG, GREEK, ITALY, THE NETHERLANDS, SWEDEN, UK
AVC-141 to 168	Algorithm proposals	
AVC-142	MPEG91/202 #03	Aware (I)
AVC-143	MPEG91/203 #04	Aware (II)
AVC-144	MPEG91/204 #05	Bellcore, NTT
AVC-145	MPEG91/206 #06	BBC et al.
AVC-146	MPEG91/206 #07	NTA
AVC-147	MPEG91/208 #09	CCETT et al.
AVC-148	MPEG91/209 #11	GCT et al.
AVC-149	MPEG91/210 #12	HHI
AVC-150	MPEG91/211 #13	Hitachi, Fujitsu
AVC-151	MPEG91/212 #14	IBM
AVC-152	MPEG91/213 #16	JVC
AVC-153	MPEG91/214 #17	KDD
AVC-154	MPEG91/217 #22	Matsushita
AVC-155	MPEG91/218 #23	MIT
AVC-156	MPEG91/219 #24	Mitsubishi
AVC-157	MPEG91/220 #25	NEC et al.
AVC-158	MPEG91/221 #26	NHK

AVC-159	MPEG91/223,255 #27,28,35	TCE, PCE, David Sarnoff, PTT Research
AVC-160	MPEG91/224 #30	RTT, UCL
AVC-161	MPEG91/225 #31	Sharp
AVC-162	MPEG91/226 #33	SONY
AVC-163	MPEG91/227 #34	Thomson-CSF/LER
AVC-164	MPEG91/228 #36	Toshiba
AVC-165	MPEG91/229 #37	UCL
AVC-166	MPEG91/230 #38	Waseda University
AVC-168	MPEG91/231 #39	Columbia University
AVC-169	PICTURE FORMAT FOR HIGH QUALITY INTERACTIVE VIDEO SERVICES	BELLCORE
AVC-170	ATM CELL HEADER FIELD	BELLCORE
AVC-171	STATISTICAL ANALYSIS OF VIDEO TELECONFERENCE TRAFFIC	BELLCORE
AVC-172	DSM/ATM WORKSHOP	EXPERTS GROUP
AVC-173	PRELIMINARY FUNCTIONAL REQUIREMENTS FOR SECONDARY DISTRIBUTION OF TV AND HDTV SIGNALS	TG CMTT/2 SRG
AVC-174	REPORT OF THE ACTIVITIES OF THE GROUPS OF EXPERTS ASSISTING THE SPECIAL RAPPORTEUR	TG CMTT/2 SRG
AVC-175	RESOLUTIONS ADOPTED DURING THE FIRST PLENARY MEETING OF ISO/IEC JTC1/SC29, 21-23 NOVEMBER 1991, IN TOKYO, JAPAN	SECDREATRIAT ISO/IEC JTC1/SC29
AVC-176	PICTURE PERFORMANCE OF 1.3, 4 AND 9 MBIT/S BELLCORE ALGORITHMS AND OTHER TEST PROCESSES	BELLCORE, NTT

Documents for the fifth meeting of the Experts Group

* indicates that the same material is in MPEG92/??? document.

AVC-177R	REPORT OF THE FOURTH MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN YOKOSUKA	CHAIRMAN
AVC-178	reserved for the report of SGXVIII meeting in Melbourne	
AVC-179*	DEFINITION OF END TO END DELAY	CCITT EXPERTS GROUP
AVC-180	SUBJECTIVE TEST RESULTS OF MPEG-2, KURIHAMA MEETING	CHAIRMAN OF MPEG/TEST
AVC-181*	EFFICIENT FLEXIBLE LAYERED CODING	AUSTRALIAN "UNIVERSAL VIDEO CODEC" PROJECT
AVC-182	PATENT INFORMATION	DAIMLER-BENZ
AVC-183*	CORE EXPERIMENT ON COMPATIBILITY	BT
AVC-184*	SIMULATION RESULTS OF PROPOSAL 30	RTT BELGIUM
AVC-185*	EXPERIMENT OF LOW DELAY MODE	GCT
AVC-186	LOW DELAY CODING MODE	FUJITSU
AVC-187*	CODING EFFICIENCY IN LOW DELAY MODE	KDD
AVC-188*	COMPARISON AMONG COMPATIBLE CODING, NON-COMPATIBLE CODING, AND SIMULCAST	FUJITSU
AVC-189*	COMPARISON BETWEEN PYRAMID (EMBEDDED) AND SIMULCAST	TOSHIBA
AVC-190*	CONSIDERATIONS ON CELL LOSS RECOVERY TECHNIQUES	JAPAN
AVC-191*	RATE CONTROL METHOD BASED ON SUB-BAND CODING FOR VBR TRANSMISSION	OKI ELECTRIC
AVC-192*	COMPARISON OF PREDICTION/CODING METHODS IN AN RM8-BASED SCHEME	NTT
AVC-193*	OBSERVATION OF SEQUENCES WITH CYCLICALLY DISTORTED PICTURES	NTT
AVC-194*	FIELD ADJUSTED MC FOR FRAME-BASE CODING	MATSUSHITA

AVC-195*	CODING EFFICIENCY COMPARISON BETWEEN FRAME FORMAT AND FIELD FORMAT	HITACHI
AVC-196*	GUIDING PRINCIPLES FOR THE SINGAPORE MEETING	CCITT EG
AVC-197	SIMULATION OF RANDOM CELL LOSS	UK
AVC-198	CORE EXPERIMENT FOR TESTING B-FRAMES/NO B-FRAMES	NTA
AVC-199*	A STUDY ON THE EFFECT OF B FRAME	NEC
AVC-200*	A STUDY ON SUBSAMPLING OF CHROMINANCE SIGNALS	NEC
AVC-201*	SUMMARY OF FUNCTIONALITY PROPOSALS	CHAIRMAN OF MPEG/REQ
AVC-202	SELECTION OF TRAFFIC DESCRIPTORS AND THE IMPACT OF BUFFERING	AT&T
AVC-203	CONVERSION FILTER FOR PRODUCING SCIF	NTA
AVC-204*	EVALUATION OF SM3 FOR MPEG2	PTT RESEARCH
AVC-205*	CELL LOSS EXPERIMENT SPECIFICATIONS	EXPERTS GROUP

Documents for the sixth meeting of the Experts Group

* indicates that the same material is in MPEG92/??? document.

AVC-177R	REPORT OF THE FOURTH MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN YOKOSUKA	CHAIRMAN
AVC-178	REPORT OF SGXVIII MELBOURNE MEETING	SGXV REPRESENTATIVE TO SGXVIII MELBOURNE MEETING - M. BIGGAR
AVC-206R	REPORT OF THE FIFTH MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN SINGAPORE	CHAIRMAN
AVC-207	REPORT OF THE MEETING OF SWP XVIII/8-3 - SERVICES, IVS AND AAL TYPES 1 AND 2	SWP XVIII/8-3
AVC-208	LIAISON STATEMENTS TO ATM VIDEO CODING EXPERTS GROUP	SGXVIII
AVC-209	IVS BASELINE DOCUMENT	SWP XVIII/8-3 - EDITOR OF IVS BASELINE
AVC-210	OUTCOME OF AAL STUDY	SGXVIII
AVC-211	LIAISON STATEMENT TO EXPERTS GROUP FOR ATM VIDEO CODING IN SGXV	WPXVIII/5 - MELBOURNE MEETING
AVC-212*	PRELIMINARY WORKING DRAFT - PWD	PWD EDITING GROUP
AVC-213	FILTERS FOR CONVERSION BETWEEN CCIR-601 AND SCIF	NORWAY
AVC-214	INTRODUCTION TO AAL TYPE 1	SPECIAL RAPPORTEUR SWP XVIII/8-3 - K. YAMAZAKI
AVC-215	CONSIDERATIONS ON SUPER CIF	BELGIUM, FRG, ITALY FRANCE, THE NETHERLANDS, NORWAY, SWEDEN, UK
AVC-216	THE NETWORK ACCESS FOR MULTI-LAYER AND MULTI-RESOLUTION VIDEO SERVICES OVER THE B-ISDN	UK
AVC-217*	PROPOSAL FOR THE JOINT WORK BETWEEN ISO/MPEG AND CCITT/AVC EG	BELGIUM, FRANCE, FRG, ITALY, NORWAY, THE NETHERLANDS, SWEDEN, UK
AVC-218	A SURVEY ON CBR VERSUS VBR	DBP-TELEKOM
AVC-219	FLEXIBLE SPATIAL RESOLUTIONS	AUSTRALIA
AVC-220	FLEXIBLE FRAME RATES	AUSTRALIA
AVC-221	TRANSPORT OF LAYERED VIDEO ON B-ISDN	AUSTRALIA
AVC-222	ATM ADAPTATION LAYER TYPE 2 FUNCTIONALITY	AUSTRALIA
AVC-223	END TO END SIGNIFICANCE OF THE ATM HEADER CLP BIT	AUSTRALIA
AVC-224	NETWORK REQUIREMENTS FOR MULTIMEDIA INTERWORKING	AUSTRALIA

AVC-225	DISPLAY FACILITIES	SWEDEN
AVC-226	CONSIDERATIONS ON MULTIMEDIA MULTIPLEX METHODS	JAPAN
AVC-227	REQUIREMENTS FOR TD - TRAFFIC DESCRIPTOR, ESPECIALLY CDV - CELL DELAY VARIATION	JAPAN
AVC-228	CONSIDERATION OF LAN AND MAN	JAPAN
AVC-229*	STUDY ITEMS FOR EMBEDDED CODING	JAPAN
AVC-230	JITTER PERFORMANCE OF AN ADAPTIVE CLOCK METHOD	JAPAN
AVC-231*	CODING EFFICIENCY COMPARISON BETWEEN MULTI-FIELD PREDICTION AND ADAPTIVE FRAME/FIELD PREDICTION	JAPAN
AVC-232	FIELD ADJUSTED MC FOR FRAME-BASE CODING - 2 -	JAPAN
AVC-233*	A STUDY OF LOW DELAY MODE	JAPAN
AVC-234*	SIMULATION RESULTS ON COMPATIBLE CODING	JAPAN
AVC-235*	CELL LOSS COMPENSATION METHOD	JAPAN
AVC-236*	COUNTERMEASURES AGAINST CELL LOSS FROM VIEWPOINT OF IMAGE DETERIORATION AND TRANSMISSION EFFICIENCY	JAPAN
AVC-237	SIMULATION RESULTS ON HALF PIXEL ACCURACY MOTION ESTIMATION	JAPAN
AVC-238	EVALUATION OF TM0 ALGORITHM AT LOW BIT RATE	JAPAN
AVC-239	PERFORMANCE OF PROGRESSIVE SCIF	JAPAN
AVC-240	PICTURE FORMAT CONVERSION ACCORDING TO AVC-203	JAPAN
AVC-241	IMPACT OF SCIF CONVERSION ON PREDICTION STRUCTURE	JAPAN
AVC-242	HARDWARE CONSIDERATION ON LINE SCANNING CONVERSION	JAPAN
AVC-243	COMMENTS ON THE PICTURE FORMAT FOR ATM VIDEO CODING	JAPAN
AVC-244	OBJECTIVE EVALUATION SCHEME FOR PICTURE FORMAT CONVERSION	JAPAN
AVC-245	TM0 AND IMPROVEMENTS	NORWAY
AVC-246	SCIF FORMAT + REQUIRED TESTS	SWEDEN
AVC-247	MONITORING VBR VIDEO TRAFFIC	BELLCORE
AVC-248	COMMENTS ON THE TABLE FOR MULTIMEDIA MULTIPLEXING METHODS	BELLCORE
AVC-249	CLOCK RECOVERY FOR VIDEO	BELLCORE
AVC-250	MERITS OF SQUARE-PEL ASPECT RATIO	AT&T, BELLCORE, DIS, NCS
AVC-251*	IMPROVED PREDICTION FOR LOW DELAY VIDEO CODING MODE	FRG - DAIMLER-BENZ
AVC-252*	CODING RESULTS FOR SCIF PROGRESSIVE IMAGES	AT&T
AVC-253	LIST OF REQUIREMENTS FOR VIDEO REQUIREMENTS LISTING	ADHOC GROUP FOR VIDEO REQUIREMENTS LISTING
AVC-254*	COMPATIBLE CODING STRUCTURE	PTT RESEARCH
AVC-255*	ABOUT THE CONSTRAINTS ON VARIABLE BIT RATE CODING	DBP-TELEKOM

Documents for the seventh meeting of the Experts Group

* indicates that the same material is in MPEG92/??? document.

AVC-256R	REPORT OF THE SIXTH MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN STOCKHOLM/HAIFA - PART I	CHAIRMAN
AVC-257R	REPORT OF THE SIXTH MEETING OF THE EXPERTS GROUP FOR ATM VIDEO CODING IN STOCKHOLM/HAIFA - PART II	CHAIRMAN
AVC-258	LIST OF REQUIREMENTS FOR MPEG-2 VIDEO	REQUIREMENTS GROUP
AVC-259	GUIDE FOR THE VIDEO WORK	REQUIREMENTS GROUP

AVC-260	TEST MODEL 1	TEST MODEL EDITING COMMITTEE
AVC-261	THIRD PROGRESS REPORT	CHAIRMAN
AVC-262	LIAISON STATEMENTS SUBMITTED BY THE EXPERTS GROUP	CHAIRMAN
AVC-263	MEETING REPORT	WPXV/1
AVC-264	RULES FOR PRESENTATION OF CCITT|ISO/IEC COMMON TEXT	CCITT
AVC-265	SOME HELPFUL INFORMATION TO EDITORS OF CCITT/ISO COMMON TEXT	CCITT SECRETARIAT
AVC-266	NETWORK PLANNING FOR VIDEOTELEPHONY & VIDEOCONFERENCE SERVICES	CCITT SGXII
AVC-267	BIT RATE STATISTICS OF A TV DISTRIBUTION CODEC	RTT BELGACOM
AVC-268	MULTIMEDIA MULTIPLEX AND NEGOTIATION METHODS	JAPAN
AVC-269	SEGMENTATION TRICK TO IMPROVE STRUCTURED PACKING EFFICIENCY OF CODED SIGNALS	JAPAN
AVC-270	CONSIDERATION OF LAN	JAPAN
AVC-271	MERIT OF VBR TRANSMISSION	JAPAN
AVC-272	IMPROVEMENT OF DELAY UNDER AVERAGE BITRATE CONSTRAINT	JAPAN
AVC-273	CLOCK RECOVERY FOR VIDEO	JAPAN
AVC-274	PICTURE QUALITY COMPARISON OF FORMAT CONVERSION THROUGH / NOT THROUGH SCIF	JAPAN
AVC-275*	SCENE CHANGE HANDLING IN LOW DELAY MODE	JAPAN
AVC-276*	COMPARISON OF PREDICTION METHODS OF THE LOW DELAY MODE OF TM1	JAPAN
AVC-277	SIMULATION RESULT ON COMPATIBILITY	JAPAN
AVC-278*	H.261 COMPATIBILITY REQUIREMENT	JAPAN
AVC-279*	CELL-LOSS COMPENSATION SCHEME	JAPAN
AVC-280	SIMPLIFICATION OF FAMC	JAPAN
AVC-281	COMPARISON OF REQUIRED PROCESSING BETWEEN FRAME/FIELD AND FAMC	JAPAN
AVC-282	CODING/DECODING DELAY AND REQUIRED MEMORYS FOR THE PREDICTION IN TM1	JAPAN
AVC-283	HARDWARE VERIFICATION OF H.26X SPECIFICATIONS	JAPAN
AVC-284	EXPERIMENT ON LOW DELAY MODE	JAPAN
AVC-285	TM1 PURE FIELD CODING SIMULATION RESULTS	PTT RESEARCH - NETHERLANDS
AVC-286	TM1 PYRAMID CODING AND COMPATIBILITY VERSUS SIMULCAST	PTT RESEARCH - NETHERLANDS
AVC-287	ATM CELL LOSS EXPERIMENTS WITH TM1	PTT RESEARCH - NETHERLANDS
AVC-288	ERROR SENSITIVITY OF THE TM1 SYNTAX	PTT RESEARCH - NETHERLANDS
AVC-289	PSTN VIDEO CODING ON 8 AND 16 KBIT/S USING A DOWN SCALED H.261	PTT RESEARCH - NETHERLANDS
AVC-290	RACE 2072 MOBILE AUDIO VISUAL TERMINAL; PROJECT INFORMATION	PTT RESEARCH - NETHERLANDS
AVC-291	LOW-DELAY CODING EXPERIMENT	BELLCORE - USA
AVC-292	FREQUENCY SCANNING AND ENTROPY CODING USING MUVLC	HHI - FRG, RTT BELGACOM, SIEMENS GERMANY
AVC-293	TM1 COMPATIBILITY EXPERIMENTS	UK
AVC-294	A PROPOSAL FOR AAL TYPE 2	BELGIUM, GERMANY, ITALY, NETHERLANDS, NORWAY, SWEDEN, UK
AVC-295	ISSUES CONCERNING THE SUPPORT OF FLEXIBLE SPATIAL RESOLUTIONS	AUSTRALIA
AVC-296*	CELL LOSS CHARACTERISTICS FOR STATISTICALLY MULTIPLEXED VIDEO SOURCES	AUSTRALIA

AVC-297*	THE ATM ADAPTATION LAYER FOR VIDEO SERVICES IN THE B-ISDN	AUSTRALIA
AVC-298*	ADAPTING MPEG1 VIDEO FOR ATM TRANSMISSION	AUSTRALIA
AVC-299	SCALABLE CODING ARCHITECTURE	AUSTRALIA
AVC-300*	PROPOSAL FOR CELL LOSS CORE EXPERIMENTS ON LAYERED AND NON-LAYERED CODERS	AUSTRALIA
AVC-301	FLEXIBLE ENCODER DEFINED PREDICTIONS	NTR - NORWAY
AVC-302	SIMULATION WITH FIELD CODING AND M=1 FOR LOW DELAY	NTR - NORWAY
AVC-303	SIMULATIONS WITH VERY LOW BITRATES - (8-16) KB/S	NORWAY
AVC-304	VERY LOW BITRATE VIDEOTELEPHONY STANDARDIZATION	BELGIUM, FRANCE, GERMANY, ITALY, THE NETHERLANDS, NORWAY, SWEDEN, UK
AVC-305	VERY LOW BIT RATE "H.261 LIKE" VIDEO CODING SIMULATION	CNET - FRANCE
AVC-306	TM1 PYRAMID CODING FOR THE SCALABILITY REQUIREMENT	PTT RESEARCH - NETHERLANDS
AVC-307*	VBR MPEG BIT-RATE CHARACTERISTICS	DAVID SARNOFF - USA
AVC-308*	ERROR CONCEALMENT FOR MPEG VIDEO OVER ATM	DAVID SARNOFF -USA
AVC-309	VIDEO TRANSMISSION OVER A RADIO LINK USING H.261 AND DECT	BT - UK
AVC-310	MODIFICATIONS TO TM1 TO SUIT BROADCAST APPLICATIONS	AT&T -USA
AVC-311	IVS ACTIVITIES	SWP XVIII/8-3
AVC-312	LIAISON STATEMENTS	SGXVIII
AVC-313	NON-COMPATIBLE VS SIMULCAST VS COMPATIBLE - EXPERIMENT G.3	BELLCORE - USA
AVC-314	STATISTICAL ANALYSIS OF VIDEO TELECONFERENCE TRAFFIC - III	BELLCORE - USA
AVC-315*	TIMING RECOVERY FOR VARIABLE BIT-RATE VIDEO ON ATM NETWORKS	AT&T - USA
AVC-316	RECOMMENDATIONS FOR CELL LOSS EXPERIMENTS	DAVID SARNOFF - USA

Documents for the eighth meeting of the Experts Group

[???] indicates MPEG92/???.

AVC-317R	Report of the seventh meeting in New Jersey and Rio de Janeiro - July 1992, Part 1	Chairman
AVC-318R	Report of the seventh meeting in New Jersey and Rio de Janeiro - July 1992, Part 2	Chairman
AVC-319	to be considered in Ipswich	
AVC-320	to be considered in Ipswich	
AVC-321	to be considered in Ipswich	
AVC-322	to be considered in Ipswich	
AVC-323 [N0245]	Test Model 2	Test Model Editing Committee
AVC-326 [413]	TM2 Erratum	Test Model Editing Committee
AVC-324 [229rev]	Information on requirements for MPEG-2 video	Requirements Group
AVC-325 [230rev]	Guide for the video work, Rio revision	Requirements Group
AVC-327 [431]	Results of low delay core experiment	Japan
AVC-328 [469]	Scene change handling without picture skipping in low delay mode	Japan

AVC-329 [455]	Intra slice/column and leaky prediction	Japan
AVC-330 [470]	Buffering for low delay mode	Japan
AVC-331 [471]	Coding efficiency of leaky prediction	Japan
AVC-332 [472]	Cell-loss compensation scheme	Japan
AVC-333 [473]	Experiments on cell loss resilience	Japan
AVC-334 [458]	Simulation results of compatibility core experiment	Japan
AVC-335 [474]	Proposal of TM2 rate control modification for low delay mode	Japan
AVC-336 [475]	Picture header modification for source clock recovery	Japan
AVC-337 [432]	Simulation results on prediction and DCT mode coupling for S-FAMC	Japan
AVC-338 [433]	Simulation results on S-FAMC and Dual'	Japan
AVC-339 [456]	Simulation results on prediction core experiment (Dual-prime, SFAMC) in TM2	Toshiba
AVC-340 [454]	Results of low delay core experiments on TM2 - Among prediction modes	KDD
AVC-341 [430]	Results on the comparison of error prediction versus reconstructed signal prediction	PTT Research
AVC-342	Short term PSTN videotelephone standardisation	UK, France, Italy, Denmark, FRG, Belgium, The Netherlands, Sweden
AVC-343 [488]	Results of Core Experiments I.4 - Scalable Side Information	Aus. UVC consortium
AVC-344 [489]	A Frequency Pyramid Architecture with Improved Coding Efficiency	Aus. UVC consortium
AVC-345 [490]	Considerations on ATM cell loss experiments	Aus. UVC consortium
AVC-346 [491]	Results of Core Experiment I.1 - Interlace-in-Interlace extraction	Aus. UVC consortium
AVC-347 [492]	Result of the compatibility experiment 1c : H.261 SIF based prediction of Prediction Error vs Prediction of Input in Frame structure pictures	CNET-FRANCE TELECOM
AVC-348 [461]	Clarification of Appendix H in TM2	T. Yukitake
AVC-349 [493]	Leaky prediction: Eliminating the limit cycle	AT&T
AVC-350 [494]	Leaky prediction: Experimental results	AT&T
AVC-351 [484]	Progress Report for Ad-hoc Group on ATM, Packet Loss and General Error Resilience	Chair, MPEG Ad-hoc Group on ATM, Packet Loss and General Error
AVC-352 [495]	TM2 compatibility experiments	BT
AVC-353 [503]	Core Experiment I.8 results	BELGACOM, UCL
AVC-354 [498]	Simulation results of the basic TM2	CNET

Terminology

GENERAL TERMS

CODEC: Acronym for COder/DECoder. An electronic device that converts analog signals, typically video, voice, and/or data, into digital form and compresses them into a fraction of their original size to save frequency bandwidth on a transmission path or storage media.

compression: The application of any of several techniques that reduce the number of bits required to represent information in data transmission or storage, therefore conserving bandwidth and/or memory.

CIF: Common Intermediate Format. A video format defined in H.261 that is characterized by 360 pels on each of 288 lines, with half as many chrominance pels in each direction, and 29.97 pictures per second.

FEC: Forward Error Correction. A system of error control for data transmission wherein the receiving device has the capability to detect and correct any characters or code block that contains fewer than a predetermined number of symbols in error.

interoperability: The condition achieved among communication-electronics systems or items of communication-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or to their users. The degree of interoperability should be defined when referring to specific cases.

lip synchronization (lip-sync): The relative timing of audio and video signals so that there is no noticeable lag or lead between audio and video.

motion compensation coding: A type of interframe coding used by picture processors in the compression of video images. The process relies upon an algorithm that examines a sequence of frames to develop a prediction as to the motion that will occur in subsequent frames.

multipoint: A telecommunication system which allows each of three or more sites to both transmit signals to and receive signals from all other sites.

QCIF: Quarter CIF. A video format defined in H.261 that has 1/4 as many pels as CIF per picture.

quantization: A process in which the continuous range of values of a signal is divided into nonoverlapping subranges, a discrete value being uniquely assigned to each subrange.

teleconferencing: Generally, the transmission of audio and/or video communications of a conference such that two or more locations are connected and can function in the live exchange of information.

videoconferencing: Two-way electronic form of communications that permits two or more people in different locations to engage in face-to-face audio and visual communication. Meetings, seminars, and conferences are conducted as if all of the participants are in the same room.

videophone: A symmetrical, bidirectional, real-time, audiovisual communication generally involving two persons in case of point-to-point connection.

visual telephone: A group of audiovisual communications covering videoconferencing and videophone.

COMPATIBILITY RELATED TERMS

Upward and downward compatibility

Compatibility here refers to a transmission system, where different picture formats are used for the video encoder and video decoder. Different picture formats do not imply different standards. The system is:

- **upward compatible** if a higher resolution receiver is able to decode pictures from the signal transmitted by a lower resolution encoder.

- **downward compatible** if a lower resolution receiver is able to decode pictures from the signal or part of the signal transmitted by a higher resolution encoder. Two ways of downward compatibility can be discerned:

  * The decoder reconstructs the entire picture at lower resolution.
  * The decoder reconstructs a window of the input picture.

  When no further notice is made, it is assumed the decoder reconstructs the entire picture at lower spatial resolution. The frame rate is not necessarily equal.

Forward and backward compatibility

Here, compatibility refers to a transmission system where different standards are used for video encoder and video decoder, i.e. an existing standard and a new standard. The picture formats of these standards can, but need not differ. The system is:

- **forward compatible** if the new standard decoder is able to decode pictures from the signal or part of the signal of an existing standard encoder.

- **backward compatible** if an existing standard decoder is able to decode pictures from the signal or part of the signal of a new standard encoder.

It is assumed the entire input picture is reconstructed by the decoder, possibly at different spatial or temporal resolutions.

Simulcasting

In this case the encoder system is characterized as follows. Typically, two encoders operate in parallel, one according to an existing standard and picture format, the other according to a new standard and/or picture format.

a - It transmits N (with N > 1) multiplexed streams of data, which may be separated at the decoder.
b - Data streams 1..K-1 (with K <= N) are decodable by an existing standard decoder after demultiplexing.
c - In a new standard decoder pictures are decoded from a set of one or more data streams K..N without making reference to data streams 1..K-1.

Backward compatibility is achieved by feature b, whereas forward compatibility is not guaranteed. A new standard decoder will discard the existing standard data streams 1..K-1. Decoding of the existing standard may or may not be included as a special option.

Considering upward and downward compatibility, downward compatibility is achieved by feature b, while upward compatibility is not guaranteed, as the information for the two picture formats is transferred and processed independently.

In principle, this compatibility method under certain circumstances could be wasteful of bandwidth as the same picture information is transferred several times in different multiplexed data streams.

<u>Embedded bit stream</u>

In this case the encoder is characterized as follows:

a - It transmits N (with N > 1) multiplexed streams of data, which may be separated at the decoder.
b - Data streams 1..K-1 (with K <= N) are decodable by an existing standard decoder (backward) or a decoder with smaller picture format (downward) after demultiplexing.
c - From data streams 1..K-1 pictures may be decoded without reference to the other data streams, but decoding pictures from a data stream M (with K <= M <= N) is not possible without making reference to one or more of the data streams 1..K-1. Data streams K..N carry information additional to data streams 1..K-1.

Backward or downward compatibility are achieved by feature b. Forward compatibility is achieved as the new standard decoder can decode pictures of existing standard quality from data streams 1..K-1 only.

This also implies that upward compatibility is achieved, as data streams 1..K-1 carry lower resolution pictures, while data streams K..N carry the additional information for full resolution pictures.

In principle there is no waste of bandwidth since the N multiplexed data streams carry complementary information only. In practice however, the constraint of an existing standard or for the data streams 1..K limits the achievable coding efficiency when comparing with an equivalent stand-alone system.

<u>Syntactic extension</u>

In this case only one data stream is transmitted. The data stream produced by the new standard encoder has a syntax which is an extension of the existing standard. This allows for forward compatibility, as the new standard decoder is equipped for the syntax of the existing standard and may decode the existing standard when little adaptations in the decoding process are made.

A similar description is possible for upward compatibility: the data stream for the full resolution pictures is an extension of the data stream for the lower resolution pictures, such that the full resolution decoder can decode the signal of the lower resolution encoder.

Backward or downward compatibility is not achieved by this method, as the signal for the existing standard or lower resolution decoder as such is not embedded or simulcasted in the data stream. A transcoder with more than a demultiplexer and multiplexer would be needed to obtain the existing standard or lower resolution signal.

Switchable encoder

This method of compatibility is mainly intended for services where the type of receiver(s) can be identified by the transmitter, e.g. for point to point conversational services.

The encoder is characterized as follows:

a - It transmits one stream of data only.
b - To achieve forward and backward compatibility, the encoder is capable to operate in new standard or existing standard mode. For upward and downward compatibility, the encoder must be capable to produce the signal for full resolution or for lower resolution decoders.
c - Encoder and decoder(s) negotiate to determine which standard and/or picture format will be used for the connection.

Standard families

This is not a compatibility method, but allows for joint developments for several standards. A new standard having many commonalities with an existing standard, or a family of standards for several picture formats, may reduce efforts for development and optionally facilitate development of dual(or multiple) standard equipment. This may be beneficial for introduction of a new service.

Layered Coding

Both "Embedded Bitstream" and "Syntactic Extension" compatibility methods are versions of layered coding. The difference between the methods is that all the data passes through the decoder (though some may be ignored) in the case of "syntactic extension". With the "embedded bitstream" method, the unused bitstreams need not be presented to the decoder.

"Flexible layering" was introduced in Doc. AVC-35 (May 1991) and provides for layers which could represent baseband or incremental information as appropriate in a given application. In the terminology above, decoding of data stream M is possible by making reference to data streams B...M, where B is the baseband picture signal and $1 \le B \le M$. This system includes single layer coding (B=M) as a special case.

END

H.26X REQUIREMENTS

<u>Status notation</u>

(A) Agreed
(P) Preferable
(M) Mandatory
(T) Target
(FS) Implementation method is for further study

1. BIT RATE

up to several 10s Mbit/s	(A)

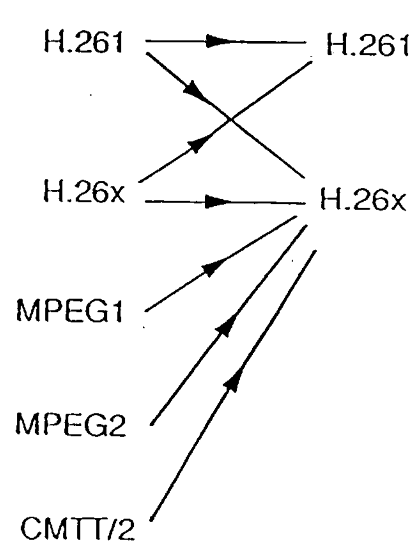
2. CODEC SOURCE FORMAT

QCIF/CIF	(A)
"601" class	(FS)
EDTV	(?)
HDTV	(?)

3. COMPATIBILITY

encoder		decoder		
H.320	--->	H.32X	(terminal)	(A,M)
H.32X	--->	H.320	(terminal)	(A,M)
H.261	--->	H.26X		(P,FS)
H.26X	--->	H.261		(P,FS)
MPEG1	--->	H.26X		(P,FS)
MPEG2	--->	H.26X		(P,FS)
*"CMTT/2"	--->	H.26X		(P,FS)

* Secondary distribution, which may include classes above "601"

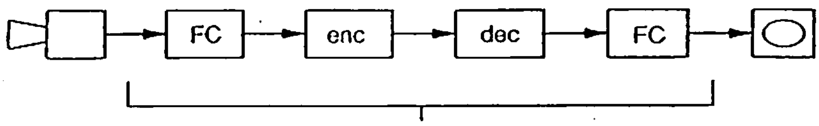


4. PICTURE QUALITY

"PAL/NTSC" at 3-5 Mbit/s and delay=?	(T,FS)
"Rec. 601" at 8-10 Mbit/s and delay=?	(T,FS)

5. DELAY

less than about 150 ms at bit rate > 2 Mbit/s	(FS)



6. CODEC COMPLEXITY

complex/high performance
vs
simple/low performance
ex. pure intra-codec

7. APPLICATIONS

CTV	Cable TV Distribution on optical networks, copper, etc.
ENG	Electronic News Gathering (including SNG, Satellite News Gathering)
IPC	InterPersonal Communications (videoconferencing, videophone, etc.)
ISM	Interactive Storage Media (optical disks, etc.)
NDB	Networked Database Services (via ATM, etc.)
RVS	Remote Video Surveillance
SSM	Serial Storage Media (digital VTR, etc.)
STV	Satellite TV Broadcasting
TTV	Terrestrial TV Broadcasting

8. ATM

VBR and CBR	(A,M)
Cell loss resilience	(M,FS)
Bit error resilience	(M,FS)
High/low priority cell utilization	(P,FS)
High/low priority cell independent rate control	(P,FS)
Usage Parameter Control	(M,FS)

9. MULTIPOINT

Continuous presence possible (P,FS)

- Time-sliced decoding
- Editing without decoding-recoding

Mix of H.320 and H.32X (M,FS)

10. H.32X TERMINAL

Interwork with

H.320 terminal	(A,FS)
Network database	(P,FS)
Distributive service	(P,FS)
Multipoint	(A,FS)
Stored bitstream	(P,FS)

Multimedia multiplexing	(M,FS)
Audio quality > ?	(FS)
Relative audio/video delay < ?	(FS)
Video clock recovery	(FS)
Encryption/scrambling	(FS)

END

Update of the First Simplified Network Model

The first simplified network model, Annex 4 to AVC-22R (Hague), has been updated to calculate the cell loss ratio. See AVC-97. It is noted that the cell loss ratio CLR is calculated in general according to the following equation:

$$CLR = L(R) * p(R) dR \ / \ R * p(R) dR$$

where R is instantaneous rate of multiplexed signals, p(R) is probability density for instantaneous rate being R, L(R) is loss function. L(R) can be approximated as

$$L(R) = 0 \quad \text{for } R < CAP \text{ (capacity of the multiplex)}$$
$$= R - CAP \quad \text{for } R \geqq CAP$$

1) A single stage multiplex is assumed.

2) The network is assumed to exhibit a cell loss/network load characteristics as shown in Appendix 1. An example of these characteristics are shown in Appendix 2.

3) The multiplex is assumed to have a maximum available bandwidth (CAP) of 100 Mbit/s.

4) Cell loss is assumed to be random.

5) The model is independent of the shape of the source.

6) The model provides the lower limit for the network loading, ie it is a conservative model because of point 5 above.

<u>Note</u> - We need more accurate model(s) for the precise study of VBR vs CBR issue and to obtain better understanding and deeper insight to the statistical multiplexing problem. Suitable models for this purpose need continued study.

Appendix 1

Psat = exp(-n * k) where Psat is the probability of saturation

k = (a * ln(a/p)) + ((1-a) * ln((1-a)/(1-p)))

a = CAP / (n * Peak) Note: 0 < a < 1

CAP = Maximum capacity of the multiplexer output in Mbit/s

n = percentage of network loading

Note: n is the number of sources, 0 < n <= 100. The illustration corresponds to the case of Mean = 1 Mbit/s.

Peak = The maximum bit rate over simulation interval (measured on a per frame basis)

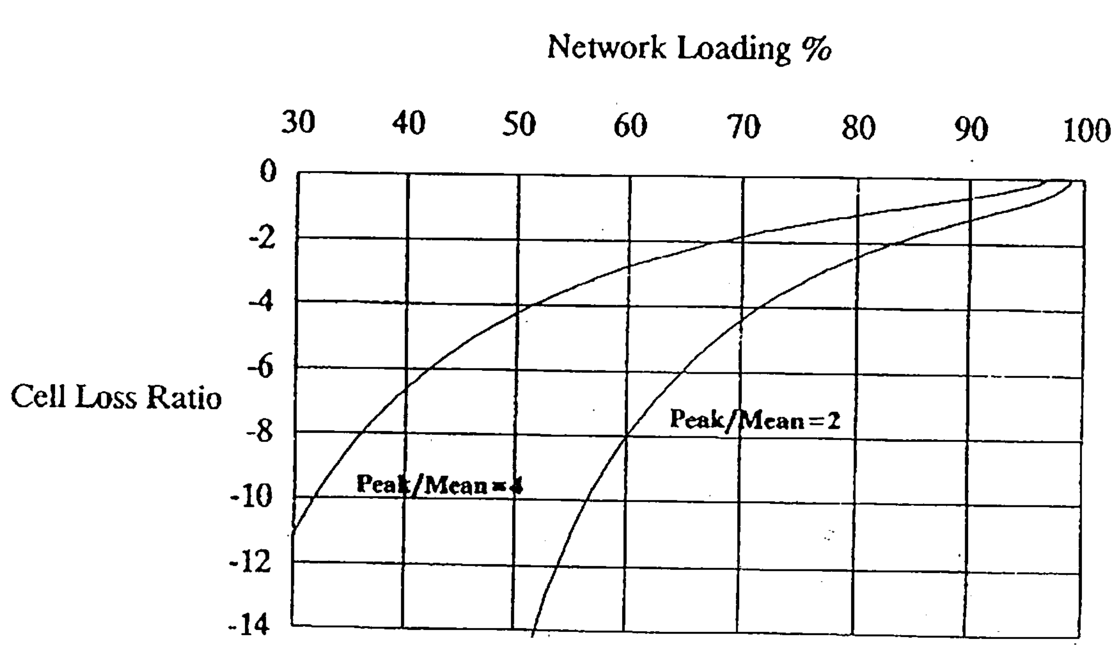
p = Mean/Peak Note: 0 < p <= 1

Mean = The average bit rate over the simulation interval

CLR = Psat / (n * p * ln ((a * (1-p))/(p * (1-a))))
where CLR is the cell loss ratio.

ln = log to the base 'e'

Appendix 2



Cell Loss Ratio vs. Network Loading (Example)