Annex A **End To End Jitter** [Informative]

Annex A.1 Introduction

Transporting time critical information streams using higher protocol layers requires the exchange of timing information between the protocol layers. The layer adaptation processes between protocol layers transform the jitter of one layer into the jitter of another layer. Within each layer, there are processes (e.g., switching) that introduce additional jitter terms. A comprehensive framework is needed to assemble all these different jitter terms.

A simple end-to-end model of the transport connection for a time critical information stream is introduced using the standard trail and connection nomenclature from G.803 [i]. This model then serves as the basis for identification and discussion of several different jitter phenomena. In particular, this layering approach separates the cumulative jittering effects that occur within each layer from the transformational jitter effects of layer adaptation. To aid the proper accumulation and transformation of the jitter, it is helpful to keep all jitter measures to the same accuracy (e.g., Probability [peak-to-peak jitter exceeding value] < 10^{-10}).

For real network services based on ATM connections, there may be many different jitter effects present. This is not intended to be a comprehensive analysis of all jitter components for all types of services. Examples of the jitter terms associated with the transport of an MPEG-2 Single Program Transport Stream are described.

Annex A.2 End to End Connection Model

An MPEG-2 Single Program Transport Stream is encapsulated in an AAL-5 PDU and then transmitted as ATM cells over a SONET transport network from a source equipment to a sink equipment. A diagram can be drawn using the G.803 notation to show the adaptation functions that are required to transform the characteristic information of one trail layer into another. The various sources of jitter can be associated with either the layer adaptation functions or the connection termination functions. The relative importance of these sources of jitter may be different in each layer. The VC-4 layer and ATM VC layer are identified in G.803.

Jitter is dimensioned in units of time. More specifically, jitter terms describe a time deviation from some expected significant instant *for a specific signal type*. Each layer of the G.803 model represents a different specific signal type. This signal type is referred to as the ‘characteristic information’ that is transported by that layer. Jitter should be expressed in terms that are relative to the characteristic information of the layer concerned (e.g., Cell Delay Variation for the ATM VC layer, PDU Delay Variation (PDV) for AAL-5 PDUs, etc.).

Annex A.2.1 Layer Synchronization

In order to understand the propagation of jitter through these networks, it is important to understand the timing configurations possible. The public networks typically provide a synchronization source that is traceable to national standards. In some applications, the source equipment may generate its own timing. The different layers can be operated with independent synchronization. There may be advantages for this in particular deployment scenarios. If two layers have different independent timing, the layer adaptation processes must accommodate this by including, for example, a rate adaptation process.

Annex A.2.2 SONET Network Example

The SONET bitstream is typically synchronized to the public transmission network. In this case, the timing should be traceable to stratum 1 standards. In stand alone configurations, or during fault conditions, SONET equipment can operate from stratum 3 references.

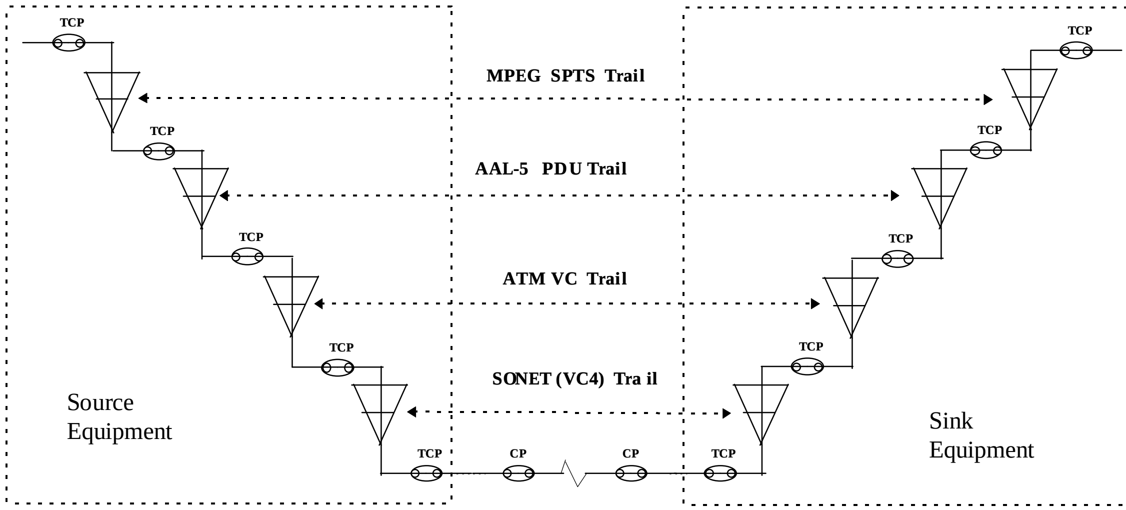

Figure A-1 SONET Network Example

Annex A.2.3 ATM Network Example

The ATM Network example is similar to the SONET network example, except that connections are made at the ATM layer rather than the SONET layer. In this case, additional jitter terms due to the ATM layer connection processes will be present.

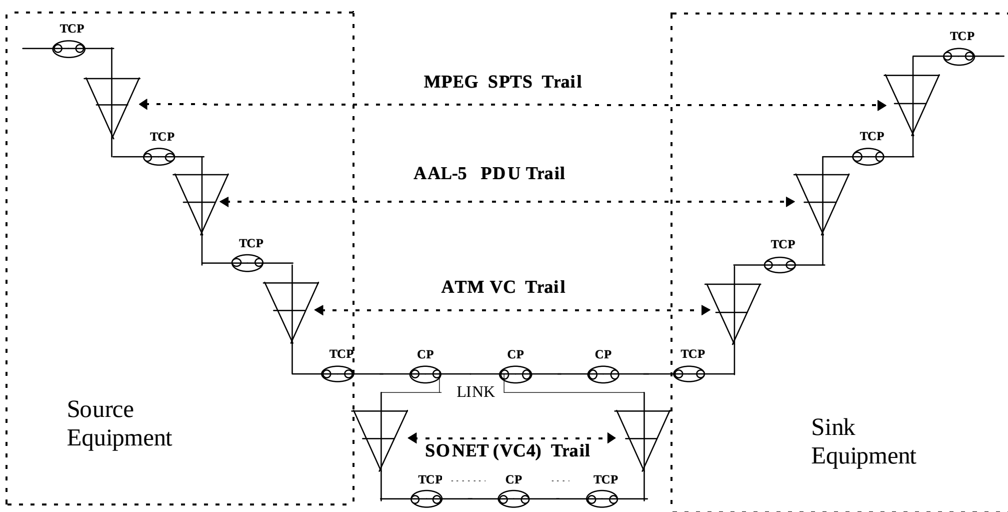

Figure A-2 ATM Network Example

Annex A.2.4 HFC Network Example

The HFC Network example is similar to the ATM network example, in that connections are made at the ATM layer rather than the SONET layer. In addition, the MPEG TS packets are remapped into a new modulation scheme for transport over the HFC cable plant. In this case, additional jitter terms due to the remapping between the ATM transport and the HFC transport processes, as well as jitter introduced by the HFC modulation scheme will be present. The jitter terms present in a particular deployment are highly implementation dependent and may be affected by many aspects, e.g. buffering, remapping of MPEG-2 PCRs etc as well as the network topology.

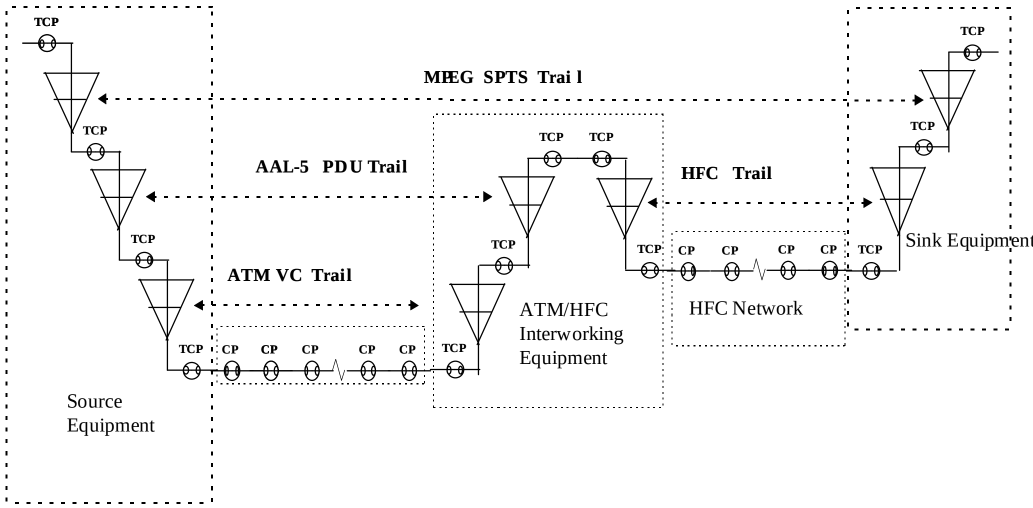

Figure A-3 HFC Network Example

Annex A.3 Layer Adaptation Processes

Annex A.3.1 Generic Processes

Annex A.3.1.1 Rate Adaptation

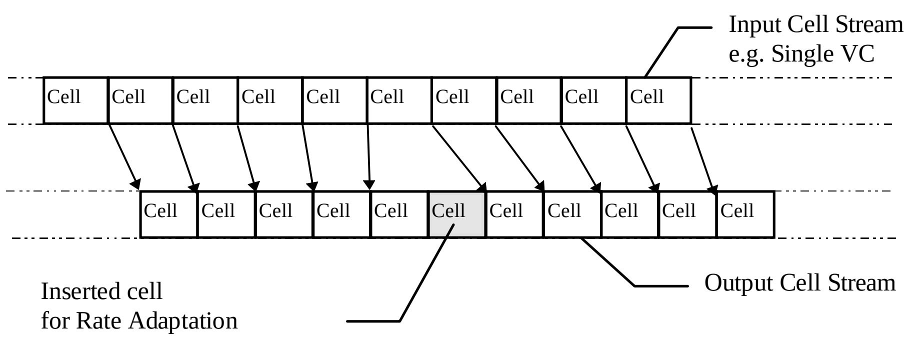

Figure A-4 Rate Adaptation Example

Rate adaptation, or rate decoupling, occurs when the characteristic information rates of two layers are different. When this occurs, additional "stuffing" information is inserted in order to maintain the transmission rate of the higher bit rate stream. Rate decoupling is a layer adaptation process. It could be used between any two layers with independent timing. Figure A-4 shows an example where an ATM cell stream (e.g. a single VC) is rate adapted into a higher rate cell stream. In this case, the stuffing is quantized to one cell period.

Cell rate decoupling in the ATM Forum UNI 3.0 specification[ii] refers to an ATM layer process where the sending process inserts “unassigned” cells as necessary to form a contiguous cell stream. ITU-T uses the term to refer to a PHY layer process that involves the insertion of “idle” cells. Both processes result in a displacement of a source traffic cell by one or more cell periods .

Annex A.3.1.2 Multiplexing

Consider the cell stream comprising one VC that is to be mixed into a composite cell stream with other cells. The CDV of a VC is affected by the other traffic in the composite ATM cell stream. The ATM cell stream contains cells from many VCs as well as overhead cells such as OA&M cells and rate adaptation cells (“idle” or ”unassigned”).

The CDV of a VC cell stream is quantized with a granularity of the cell period of the composite ATM cell stream. The jitter functions associated with cell switching or multiplexing may result in CDV quantization steps greater than one cell. The maximum CDV quantization step is related to the burst size that can exist in cells extraneous to the VC. The burst lengths tend to increase as the utilization of a composite ATM cell stream increases. Hence the CDV can be expected to be related to the utilization of a particular ATM connection.

The existence of correlating traffic patterns between different VCs may also complicate the analysis. Multiple VCs with the same nominal CBR rate may produce repetitive effects over multiple cell periods. VBR traffic is more likely to be non stationary in nature.

Annex A.3.1.3 Traffic Shaping

Traffic shaping can be applied in various ways. One could introduce traffic shaping at the AAL-5 level , or at the MPEG-2 level. One could argue that a CPR MPEG-2 SPTS has already been shaped (to a constant packet rate). The most common use of the term is associated with shaping of traffic on a single connection by end user equipment (e.g., CPE) in order to comply with the traffic contract agreed between the user and the network operator.

ATM Traffic shaping is applicable to all traffic types except UBR. In the case of a VC with a traffic contract specifying a CBR traffic descriptor, end user equipment may be required to provide buffering and scheduling functions at the source in order to ensure that cells of that VC comply with the cell spacing requirements expected of a CBR cell stream. Delay variations in these buffering and scheduling functions of the end user equipment may result in additional jitter terms.

Annex A.3.1.4 PDU Segmentation

A PDU consist of the SDU from the next highest layer plus the PDU-specific information (e.g., AAL-5 CS-PDU trailer fields). The time to make a PDU from an SDU (e.g., appending length, CRC-32, etc. for AAL-5) is assumed to be constant. The PDU is divided into some integer number of 48-byte ATM cell payloads. The cells from the PDU are associated with a VCC, and are multiplexed onto the ATM link as described in section A-3.1.2 above. The cells from the PDU may be metered out in any burst size up to the PDU size, at a rate proportional to the PDU rate such that the process receiving the PDU should neither overflow or underflow its PDU buffer. i.e.,

cell rate = PDU rate * PDU size (cells) / burst size (cells)

The delay to segment a PDU is constant, and depends on the time to transfer the individual cells:

PDU segmentation delay = 1 / cell rate

Annex A.3.1.5 PDU Re-Assembly

The process of reassembly of cells into a PDU takes an interval of time that is assumed to be equal to the time to accumulate the necessary number of cells. The time to extract the PDU from the accumulated cells is assumed to be constant and negligible in magnitude compared with one cell period. The cell arrival times are assumed to be jittered by some probabilistic CDV function. Figure A-5 shows the basic model of cell arrival and PDU re-assembly. The nominal PDU interval (in this example) is 8 times the nominal cell interval. The actual PDU interval value adds the CDV values from the last cell of the current PDU and the previous PDU.

The cumulative distribution of the PDV could be considered as a sample distribution drawn from the cumulative CDV population. The central limit theorem would suggest that samples would tend toward the mean rather than extremes. Since this is essentially an infinite population, and the sample size is also infinite, the effect due to such sampling is likely to be small. A worst case assumption is that a peak to peak CDV of less than x mS with a confidence of 10^{-10} implies a peak to peak AAL-5 PDV of less than x mS with a confidence of 10^{-10}.

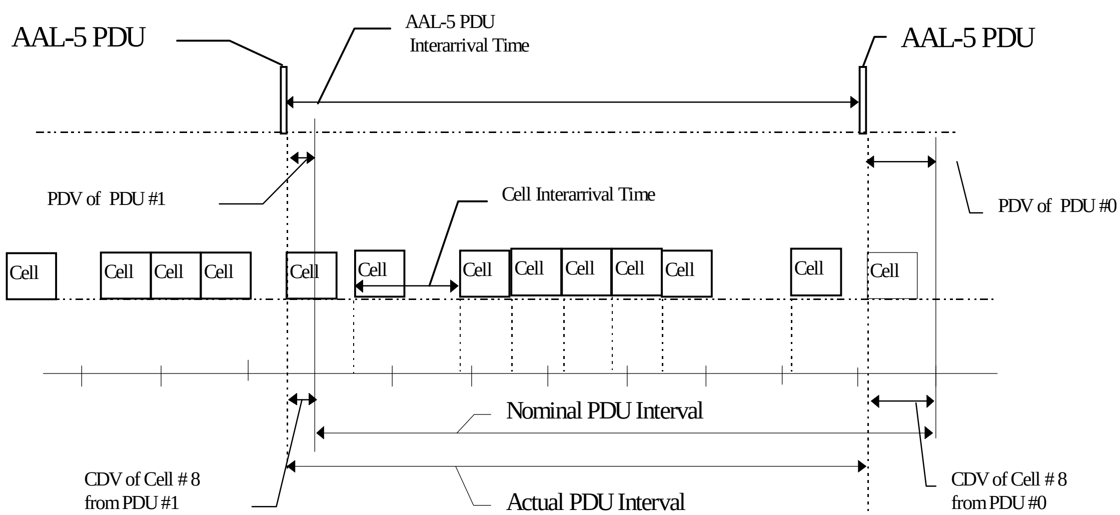

Figure A-5: CBR Model for CDV

Annex A.3.1.6 SDU Accumulation

When more than one MPEG-2 Transport Stream Packet is used to fill an AAL-5 SDU, the first TS packet to arrive at the SDU accumulation function is delayed until the last packet to be inserted in the AAL-5 PDU arrives. If we assume that the SDU accumulation process takes a fixed delay, then the first TS packet suffers a rate dependent delay equal to the number of TS packets in the AAL-5 PDU. For a two TS packet AAL-5 SDU, the delay is one TS Packet period at the Transport Stream rate. The last TS packet suffers only the fixed delay of the SDU accumulation process. If multiple TS packets are sent in one SDU, then the intermediate packets suffer proportional delays. A similar dis-accumulation function can also be seen. The delay suffered by different TS packets depends on the position within the AAL-5 PDU. This is illustrated in Figure A-6.

The delay is rate dependent. For a 1Mb/s Transport Stream, each TS packet represents 1µS of delay. For a 10Mb/s Transport Stream, each TS packet represents only 100nS of delay. This buffer size required to accommodate this delay during dis-accumulation is not rate dependent - it is fixed by the maximum AAL-5 PDU size.

MPEG2-PCR / AAL-5 SDU Alignment

The specification does not require alignment of MPEG2-PCRs with AAL-5 SDUs - i.e. it is "PCR unaware".

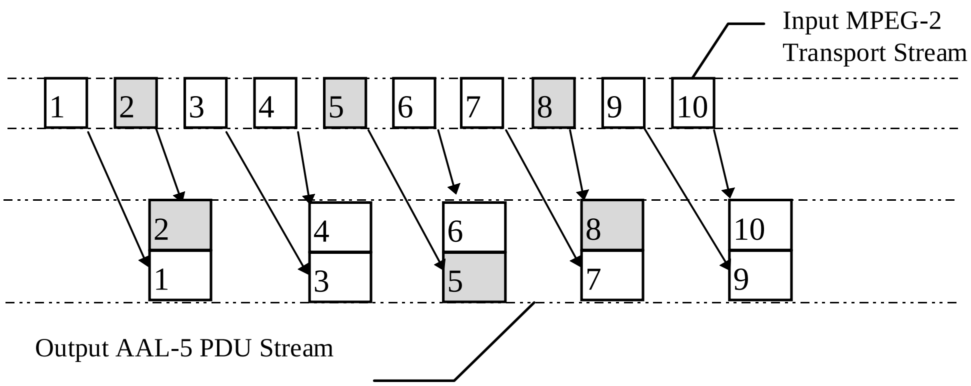

Figure A-6 Example Non-Alignment of MPEG-2PCRs with AAL5 PDU Boundary

The interval between insertions of a MPEG-2PCR into the MPEG TS is not strictly constrained by the MPEG standards. The maximum interval between MPEG-2PCRs is constrained to 100mS.

One method to align MPEG2PCR timestamps within AAL-5 SDU's for stored program replay is to pre-process the Transport Stream to ensure that the MPEG-2PCRs are inserted into the stream at intervals based on an integral multiple of the (fixed) AAL-5 PDU size.

Annex A.3.1.7 SDU Dis-accumulation

The AAL-5 PDU structure provides for multiple MPEG SPTS packets to be multiplexed into one AAL-5 SDU. When dis-accumulating this SDU, these SPTS packets become available at the same time. This burstiness may create problems for the next (higher) layer. While the segmentation and reassembly function can be expected to preserve the order of the packets, this SDU dis-accumulation operation represents a severe jitter as shown in Figure A-7. Successive MPEG SPTS packets would be sent resulting in successive inter-arrival intervals of zero and twice the nominal interarrival rate. If a buffer of the MPEG SPTS packets is required, then the control of the buffers could become complex. Sending the TS packets as soon as they become available treats MPEG SPTS packets uniformly. The jitter term varies according to the bandwidth assumption. For a nominal CBR MPEG bit rate, the jitter term is one MPEG SPTS packet period.

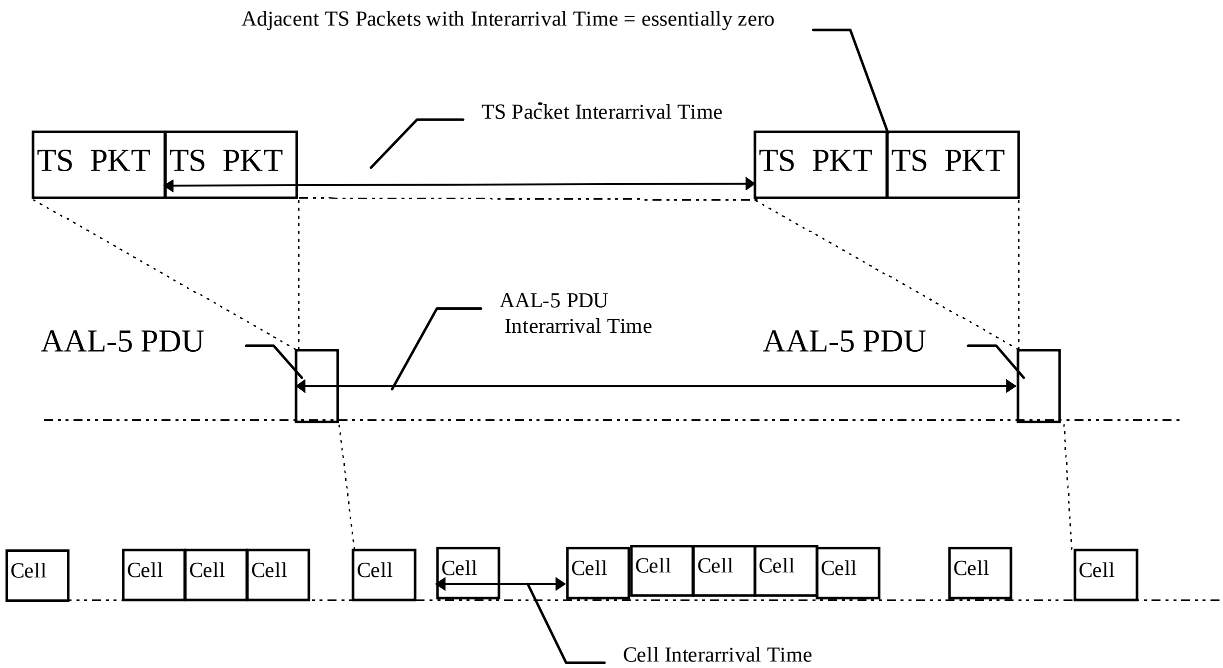

Figure A-7 Demultiplexed TS Packets

Annex A.3.2 Specific Layer Adaptations

Specific layer adaptation functions apply between specific layers.

Annex A.3.2.1 ATM Cell Stream to/from SONET

SONET layer jitter effects can be caused by normal equipment tolerances and environmental variations. Physical layer jitter effects associated with the recovery of the bit level timing is well documented by T1X1 and others. There are some systematic jitter effects associated with the frame structure of the SONET frame but these are regular in nature.

For example, one of the largest SONET jitter terms is associated with the systematic jitter introduced by the SONET frame header. At OC-3c rates, the jitter magnitude is 9 octets representing one row of header information. 9 octets is less than the cell period of 53 octets. SONET systematic jitter terms are typically eliminated by the pointer manipulation buffers associated with layer adaptation function of the SONET trail termination equipment. Some equipments may provide a burst interface to the higher layer. For the purposes of this contribution, we assume that the payload provided from the SONET layer to the ATM Layer is a contiguous payload bitstream.

The ATM layer may operate in a manner synchronized to the incoming SONET payload stream. Some equipments may terminate multiple SONET payload streams. Rate adaptation of the incoming SONET payload stream to an internal time reference is a typical layer adaptation process to accommodate this. If the incoming SONET payload stream is not jittered, the rate adaptation process would introduce a systematic jitter based on the rate difference. Jitter in the timing of the SONET payload stream would be manifest at the ATM layer as randomization of the insertion point of the rate decoupling cells.

The jitter transformation of this layer adaptation process is not linear. A jitter quantization effects occurs. Consider a contiguous ATM cell stream recovered from a SONET layer. The local timing of the cell intervals is fixed. Jitter at the cell level must occur in discrete intervals equal to the cell period. Hence small jitter effects from the SONET layer can be aggregated into a probabilistic jitter function with a magnitude of 1 cell period. At OC-3c rates, one cell period is approximately 3µS.

Annex A.3.2.2 AAL-5 PDU stream to/from ATM

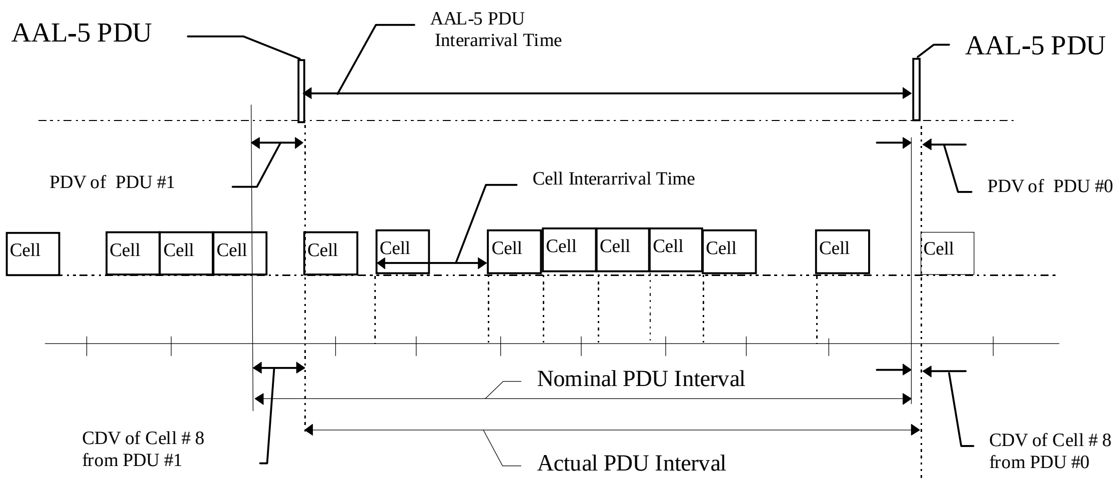

Figure A-8 AAL-5 PDU Stream to/from ATM

When the AAL-5 PDU is available, it is segmented into ATM cells with constant delay, and multiplexed with other cells on the same physical interface. The jitter on the AAL-5 PDU when reassembled at the receiving end depends on the CDV between the AAL-5 PDU sender and receiver. The actual PDU interarrival time adds the CDV values from the last cell of the current and previous PDU to the nominal PDU interarrival time. For a CBR cell stream, the CDV will be less than or equal to x msec, to some quantile, as derived from the cell delay distribution function. Then, the delay distribution on the PDU interarrival time will be equal to the convolution of the cell delay distribution with itself. The value for x, and the method to derive it, are for further study.

Annex A.3.2.3 MPEG-2 Transport Stream to/from AAL-5 PDU Stream

The delay to accumulate TS packets into an AAL-5 PDU is constant, and depends on the number of packets per PDU and the packet rate:

PDU Accum. Delay = (# packets/PDU)/(Packet rate)

For a 6 Mbps packet rate, and the assumption of two TS packets per PDU, the PDU delay is 501.34 microseconds.

Dis-accumulating the TS packets from the AAL-5 PDU causes all the packets to become available at the same time, producing a maximum jitter on the packets equal to the PDU accumulation delay as shown above.

Annex A.4 Jitter Accumulation from Connections in a Trail

In an end to end service delivery multiple connections can be made at the different layers. The effect on the jitter of such connections may be different in each layer. In some cases, the sequential connections within a layer can accumulate jitter.

Annex A.4.1 SONET connections

The nature of SONET connections preserves the Synchronous Payload Envelope (SPE) timing at the source rate. Within specified limits, the timing jitter and frequency deviations of intermediate SONET connections are essentially eliminated by the SONET pointer mechanisms. The desynchronizer buffers associated with SONET pointer mechanism can reduce the jitter to less than 1 bit period in magnitude (< 7 nS at OC-3 rates). There is transmission delay, but no significant increase in delay variation. The result is that jitter present in the SPE at the source is essentially transferred to the sink at the termination of the SONET SPE.

Annex A.4.2 ATM connections

Cell level multiplexing and cross connection functions would occur (at the ATM VC level CTPs) in arbitrary networks with ATM level cross-connections. Cell level multiplexing in an arbitrary ATM network introduces a jitter or Cell Delay Variation (CDV) into the cells of the VC carrying the time critical information. This CDV is constrained per switch by various specifications[iii].

Various approaches could be taken to characterizing the jitter distribution of an arbitrary network of ATM switches. One approach is to simply add the worst case CDV of the successive switches in the ATM network. A more sophisticated approach requires describing the CDV at each switch as a probability density function (pdf). The cumulative effect of successive switches is the described by the convolution of these individual pdfs. Both mechanisms require a specific number of switches to be considered. ATM BISDN standards are international in scope. Hence we must consider enough switches for international public network connections. However, for service definition across an arbitrary public network, some aggregate specification must simply be assumed for the CDV.

A CDV accumulation mechanism is required for the QoS negotiation and service assurance signaling in the switched network. Convolution is a computationally intensive process that is unsuitable for the real - time processing demands of a CDV accumulation algorithm used for the signaling algorithms. Simple addition of the individual specification for CDV generated within a specific switch is likely to lead to a significant overestimate of the actual CDV generated within the switch network. The ATM Forum BICI specification version 1.1 proposes a $\sqrt{n}$ estimator for accumulating the CDV generated end to end by a network.

The role of $CDV_{tolerance}$ specifications at NPC locations and other traffic shaping functions that may be performed by the network require further study.

The accumulation algorithms for the QoS parameters will be specified in the ATM Forum Traffic Management Specification 4.0.

A maximum peak-to-peak CDV of 1mS (p-p,$\alpha=10^{-10}$) across the ATM layer is commonly assumed. This assumption is based on the DS-3 circuit emulation jitter absorption delay buffer size specified by Bellcore [iv]. Other assumptions are equally possible.

Annex A.4.3 AAL-5 PDU Connections

In an ATM network, connections are performed at the ATM layer, not at the AAL-5 layer. Other types of networks, and some IWUs may perform connections at the AAL-5 layer. Such connections may introduce additional jitter terms. These aspects are beyond the scope of this IA.

Annex A.4.4 MPEG Transport Stream Connections

In the delivery of the VoD service, there may be some elements that perform operations on the MPEG-2 SPTS directly , (e.g. splicing operations etc.) If such operations are performed in real time on a SPTS, then additional jitter terms may be introduced. These aspects are beyond the scope of this IA

Annex A.4.5 End to End Jitter Budgets

The aggregate jitter expected for a particular implementation can be calculated by identifying and combining the individual jitter terms associated with the layer adaptation functions and layer cross-connection functions.

The jitter tolerance of the MPEG-2 transport Stream decoder is not clearly specified in ISO/IEC International Standard 13818-1. It is clear from the MPEG-2 system model that there are different defects that can result from jitter on the MPEG-2 Transport Stream, depending on the data that is jittered. As a simple approach, we can consider two basic jitter tolerance figures. One for TS packets containing general data. The jitter consequence here is overflow or underflow of the decoder's buffers.

A second jitter tolerance can be associated with the TS packets containing MPEG-2PCRs. A MPEG-2PCR is a timestamp used to recover the MPEG system clock for the decoder. The system clock recovery function of the decoder can be considered a type of Phase Locked Loop (PLL). The parameters of that PLL will determine the capture range and tracking range that can be provided. Jitter on a MPEG-2PCR can be considered as an error step function into the PLL. If the error step exceeds the PLL tracking range, then decoder will lose its lock on the MPEG system clock, resulting in degraded performance.

Further study may reveal other jitter constraints on the MPEG-2 Transport Stream, e.g. , concerning jitter on PTS, DTS timestamps, etc. For the purposes of developing a jitter budget for the VoD service, we need to assume a specification for the jitter tolerance of the MPEG-2 Stream. The following is proposed for maximum peak to peak jitter for MPEG-2 Transport Stream Packets:

- without MPEG-2PCRs.......................... x mS
- with MPEG-2PCRs.............................. y mS, (where $y \le x$)

The values for x and y are currently for further study. If $y > x$, the decoder PLL can track jitter deviations of greater magnitude than its buffers and a separate specification is not necessary. Previous contributions have identified 1mS of CDV across the ATM network. This identifies a minimum. Aggregating other jitter terms will increase the required jitter tolerance. The MPEG-2 standards do not normatively bound the jitter tolerance.

MPEG standards mention[1] 4mS being intended as the maximum amount of jitter expected in a well behaved system. This figure is related to the multiplexing of multiple Transport Streams and is not directly relevant to the end-to-end jitter budget discussion.

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[i] .... ITU-T Recommendation G.803, "Digital Networks - Architectures of Transport Networks Based on the synchronous Digital Hierarchy (SDH)", 03/93.

[ii] .... ATM Forum "User-Network Interface Specification", version 3.0 Prentice Hall September 1993.

[iii] .... Bellcore TA-NWT-001110 "Broadband ISDN Switching System Generic Requirements", Issue 2 August 31, 1993, Table 5.8 pg 60.

[iv] .... Bellcore TA-NWT-001110 "Broadband ISDN Switching System Generic Requirements" Issue 2 August 31,1993, table 5.12 pg 62.

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[1] ISO/IEC 13818-1 | ITU-T Rec. H.222.0 "Information Technology - Generic Coding of Moving Pictures and Associated Audio - Part 1: Systems" Annex D .

Annex B Example Networks [Informative]

Annex B.1 Telco Hybrid Fiber Coax Networks

ATM may be terminated in the video node (A type of IWU) or the STT/PC for the hybrid fiber coax network shown in Figure B-1.

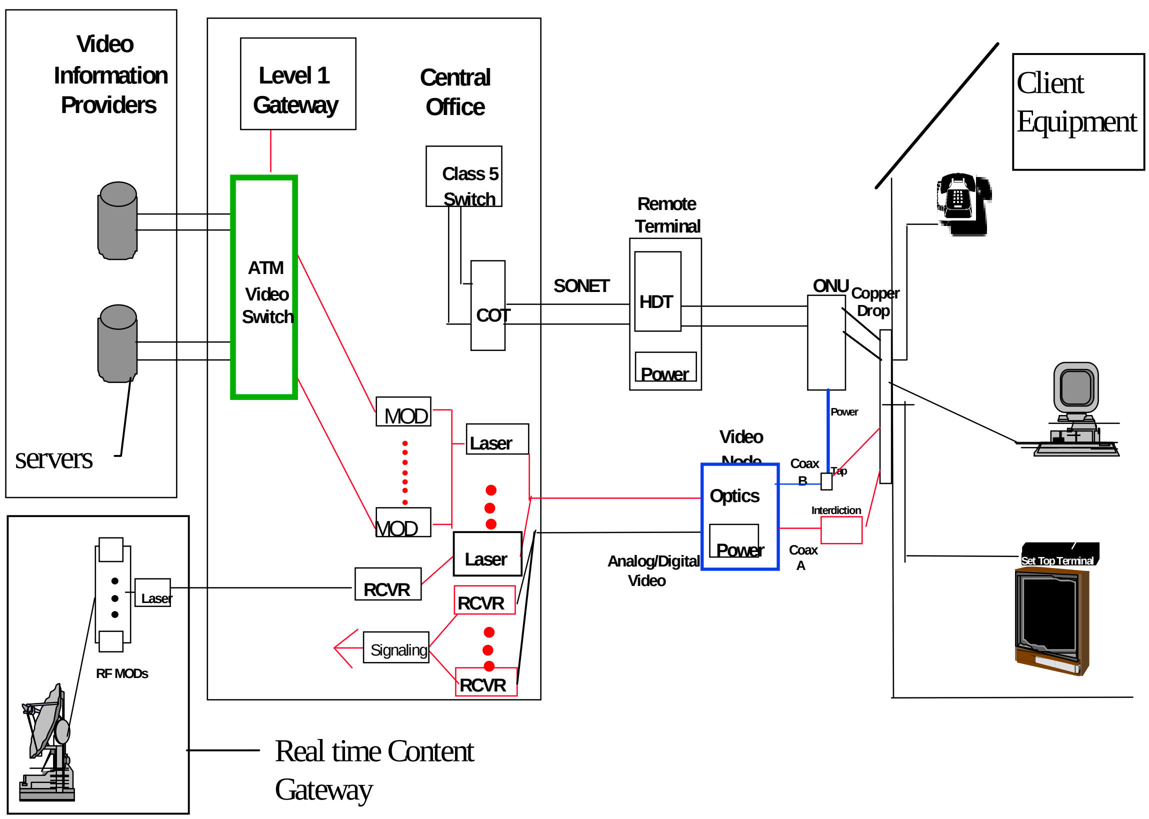

Figure B-1 Hybrid Fiber Coax Network VoD Example

Annex B.2 Digital Baseband Networks

ATM is terminated in the STT for the digital baseband network reference configuration shown in Figure B-2.

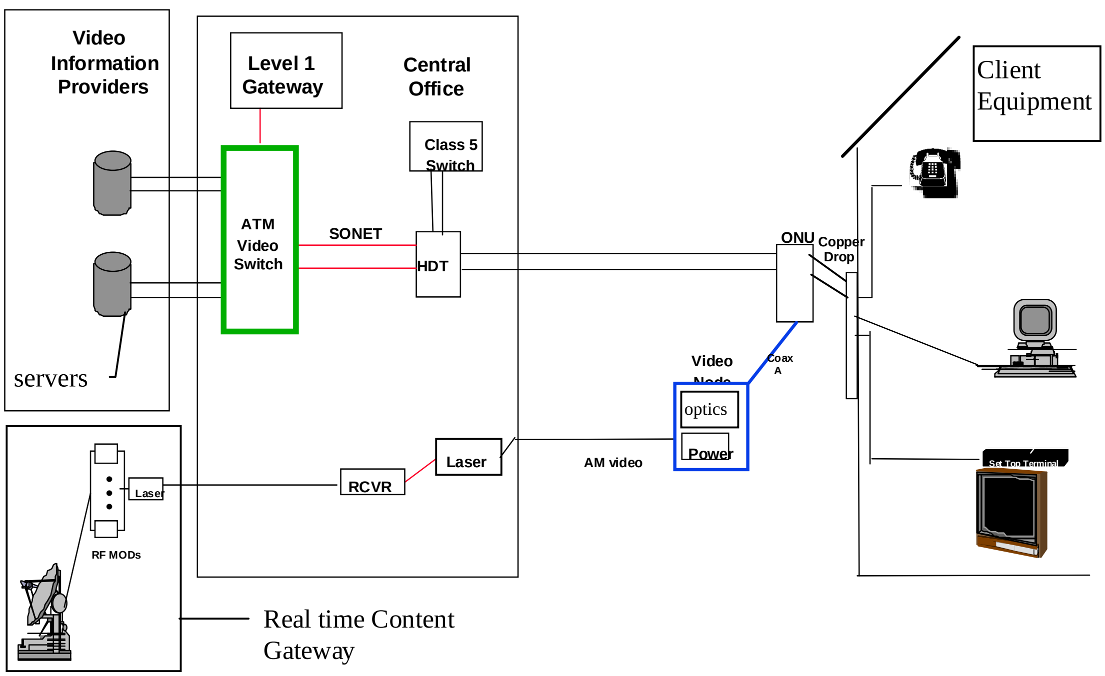

Figure B-2 Digital Baseband Network VoD Example

Annex B.3 Telecommunications Network Example

The VoD network example shown in Figure B-3 presents two types of access network, namely an Asymmetrical Digital Subscriber Loop (ADSL) over existing copper pairs and a fiber passive optical network (PON). Both carry broadband and narrowband traffic, i.e., Plain Old Telephone Service (POTS) and VoD.

For the optical network, the ATM transmission may terminate at the PON head end (H/E), the optical network unit (ONU), or in the set top terminal. Whereas for copper distribution, the ATM transmission may terminate at the ADSL exchange unit (EU), the ADSL remote unit (RU) or in the STT (or PC or IWU).

The core network is based on a number of ATM switches. The session controller/ ATM connection controller (L1GW) is likely to be implemented using the functionality of the intelligent network (IN), i.e., the service control point (SCP) and the intelligent peripheral (IP).

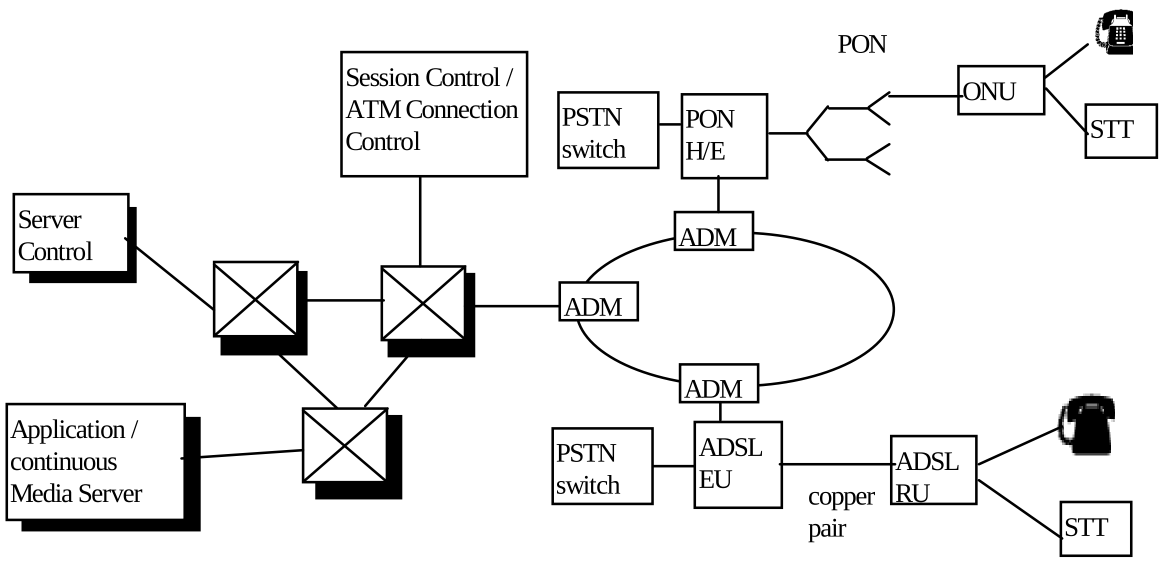

Figure B-3 Telecommunications Network Example

For a given session the end user can ‘direct dial’ the destination VoD server, if known. However, it is more likely that the user will choose to be connected through to a L1GW which will provide navigation facilities, specifically a choice of service providers (SPs) to which that user subscribes or can access. SPs can be brokers who might offer information as the best server to choose for a given movie but don’t actually offer movies themselves, or the end SP who offers detailed navigation and content, i.e., movies.

The L1GW ‘connects’ the user to the server control (L2GW) of the chosen SP, either directly by setting up the connection or by telling either the user (or SP) the address of the party to call. Similarly a SP acting as a broker can ‘forward’ the address of a user to the chosen destination server. The server control provides detailed navigation assistance to the user.

Two types of server are indicated, namely application servers and continuous media servers (CMS) both of which could be integrated into a single ‘box’ with a single network address or be separate. Application servers tend to be general purpose computers, whereas CMS tend to be massively parallel computing platforms.

The concepts of session and connection need to be understood. A session exists from the time the user pushes the ‘go’ button to request service. At any given time, a given session can utilize any number of connections (or even zero connections). Some entity has to manage the session, i.e., the session manager. The session manager could reside in the STB, in the L1GW or with the SP(s).

Annex B.4 Hybrid Fiber/Coax Cable TV Networks

Cable TV networks may be used as part of the delivery network for the VoD Service. Figure B-4 provides an example network architecture of the type currently planned by various cable TV network operators.

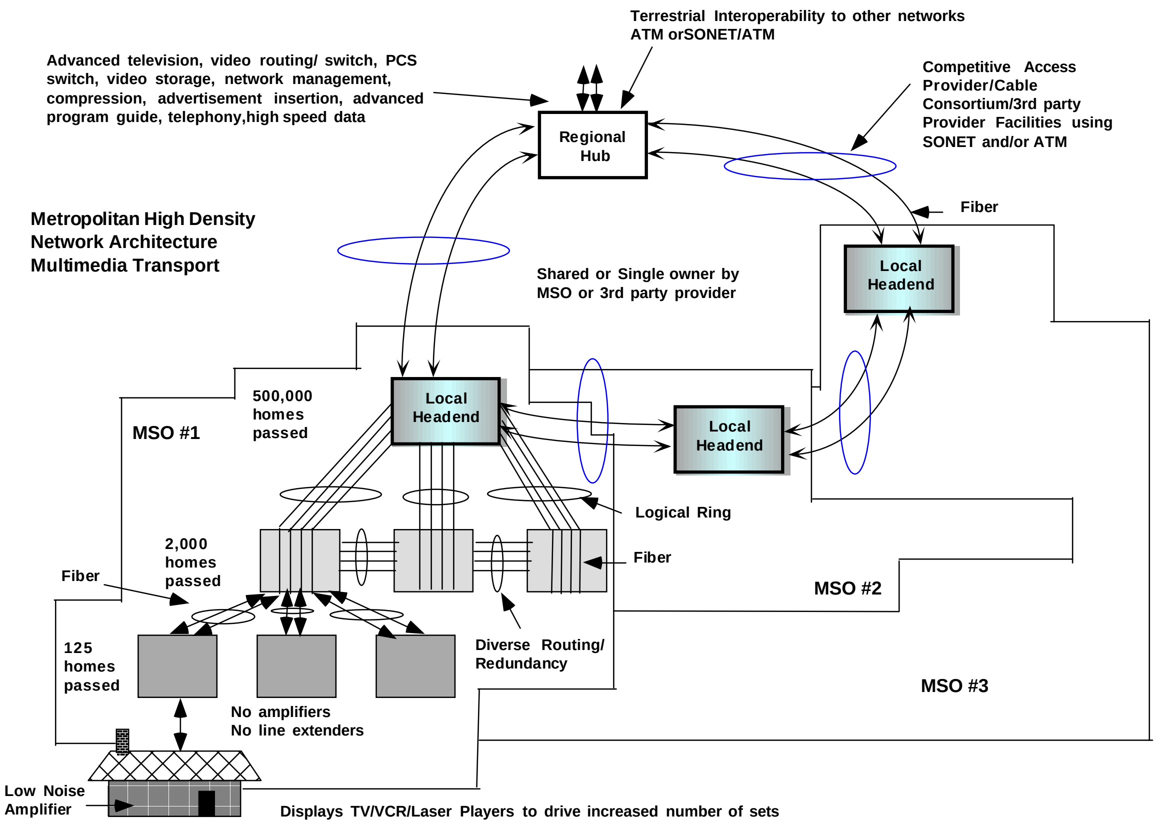

Figure B-4 Cable TV Network Example

Cable television HFC architecture often includes the implementation of the regional hub concept. A regional hub is a centralized facility that utilizes a rich network topology to interconnect headends that are located in a common geographic area. This topology may interconnect a single cable operator’s central headends or the headends from any number of Multiple System Operator’s (MSO’s) in adjacent serving areas. The regional hub can provide an access point to other networks and a common centralized platform for deployment of advanced services.

Fiber optic cables span from the local headends to fiber hubs that are geographically centered among approximately 2,000 passed. These hubs feed fiber nodes that serve about 125 homes passed. The connections between the local headends, fiber hubs fiber nodes and hub-to-hub interconnections provide virtual ring capability and physical routing diversity.

Currently, about 14% of the typical HFC network consists of trunk, with local distribution accounting for 36% of the network and 50% of the network is deployed in the drop. The trunk is fiber optic cable and the remainder of the infrastructure is coaxial.

Annex C AMS QoS Parameters [Informative]

Annex C.1 AMS Control Plane QoS Parameters for VoD

SAA-AMS expects the following parameter to be of interest for evaluating the performance of VoD applications:

- *Latency for ATM Connection Establishment/Release* This includes the time for the *Setup* message to be sent from a client (e.g., STT/PC) to the ATM Network, and the time for that connection control function to establish or release a connection or session in that ATM network. Specific values are implementation dependent. Information concerning this performance aspect may be provided by the service provider , if necessary.

Annex C.2 AMS User Plane Quality of Service Parameters

Two Quality of Service (QoS) parameters are identified that can be used to capture the accuracy and dependability aspects of AMS services. These AMS QoS parameters are defined from the AMS service users' perspectives. There is a given relationship between these user-oriented service specific QoS parameters and the network-oriented service independent ATM layer QoS parameters - this allows an appropriate ATM layer connection to be established in order to be able to deliver the service. Annex C describes the relationship between the two AMS QoS parameters and the relevant ATM layer QoS parameters.

For AMS services, the effect of either a single error or a burst error is essentially the same if the error is confined within a single cell block of consecutive cells associated with a given ATM connection. Therefore, the two AMS QoS parameters, Errored Cell Block Rate and Maximum Errored Cell Block Count, are defined in terms of cell blocks. In this document, a cell block is defined as a sequence of cells transmitted consecutively on a given ATM connection. This should not be confused with the term 'cell block' as used by [4]. Cell blocks are non-intersecting and contiguous within a VC. A received cell block is an Errored Cell Block if one or more errored cells, lost cells, or mis-inserted cells are observed in that received cell block. For AMS services, cell block size is application dependent; however, a cell block can be at most 1536 cells in length.

Annex C.2.1 Errored Cell Block Rate (ECBR)

Errored Cell Block Rate , ECBR, is defined as:

$$ECBR = N / T_{ECBR}$$

Where N is the total number of errored cell blocks observed during a specified time interval T_{ECBR}. . The value of T_{ECBR} is for further study. The value of *ECBR* can range from at least once per second to more than once per 2 hours.

Annex C.2.2 Maximum Errored Cell Block Count (MECBC)

Maximum Errored Cell Block Count , *MECBC*, is defined as the maximum number of errored cell blocks observed in any time interval of a specified length *T*. The commitment associated with this QoS parameter in general is a statistical commitment; that is, the observed number of errored cell blocks in any time interval of specified length *T* will be less than *MECBC* with a probability of $1\text{-}10^{-\alpha}$. The values of *T* and α are for further study.

Annex C.3 AMS QoS Parameters in Relation to ATM Layer QoS Parameters

This annex describes how the two AMS accuracy/dependability QoS parameters can be approximated by the corresponding ATM layer accuracy/dependability QoS parameters. The detailed definition of a complete list of ATM layer QoS parameters can be found in ITU-T Recommendation I.356 and the ATM Forum Traffic Management 4.0 Specification. The following symbols are used in showing the relationship between the two AMS accuracy/dependability QoS parameters and the corresponding ATM Layer accuracy/dependability QoS parameters.

ECBR.................the Errored Cell Block Rate in cell blocks per second,
MECBC..............the Maximum Errored Cell Block Count observed in any time interval T,
B ....the average number of cells per cell block,
r ....the average cell rate in cells per second of the ATM connection,
P_b ....the probability of a cell block being an errored cell block,
CLR....................the Cell Loss Ratio, an ATM Layer QoS parameter,
CER ....the Cell Error Ratio, an ATM Layer QoS parameter,
CMR...................the Cell Mis-insertion Rate in cells/second, an ATM Layer QoS parameter,
SECBR ....the Severely Errored Cell Block Ratio, an ATM Layer QoS parameter

Since *CER* , *CLR* and *SECBR* all represent ratios of different sources of cell error to (approximately) the total number of cells transmitted, they can be aggregated to approximate the ratio of errored cell block outcomes to total cells transmitted (excluding mis-inserted cells). Therefore, the AMS QoS parameter , *ECBR*, can be approximated by ATM Layer QoS parameters as follows:

$$ECBR = r \times (CER + CLR + SECBR) + CMR$$

The probability that no more than *MECBC* errored cell blocks are observed during any time interval *T* is given by

$$\sum_{i=0}^{MECBC} \binom{M}{i} P_b^i (1 - P_b)^{M-i}$$

where *M* is the average number of cell blocks (truncated to an integer value) sent on the given ATM connection during any time interval *T*, i.e.,

$$M \approx \left\lfloor \frac{r \times T}{B} \right\rfloor$$

The statistical commitment to *MECBC* is captured by the parameter α, as described in the following equation,

$$10^{-\alpha} \geq 1 - \sum_{i=0}^{MECBC} \binom{M}{i} P_b^i (1 - P_b)^{M-i}$$

P_b, the probability of an errored cell block , can be approximated by dividing the average number of errored cell blocks observed in time interval T, by the average number of blocks sent in the same time interval, that is

$$P_b = \frac{ECBR \times T}{M}$$

Annex D Cell Delay Variation Tolerance [Informative]

When several VCs are multiplexed together, by the Server, into a multiple VC ATM Cell stream for transport over a single physical UNI, there may be some Cell Delay Variation introduced by the multiplexing process. The ATM network can accommodate some Cell Delay Variation by selecting an appropriate value of for the $CDV_{tolerance}$ parameter of the UPC/NPC function.

The $CDV_{tolerance}$ parameter value is specified by the network operator. The $CDV_{tolerance}$ parameter value is not a negotiable (signaled) parameter. The $CDV_{tolerance}$ parameter value is static for the duration of the call. The network operator may choose to maintain the $CDV_{tolerance}$ parameter value as static for a particular interface (e.g. based on the line rate) , or for a particular service.

If considerable information is available about the architecture of the Server, it may be possible to develop a queuing model that describes the CDV that can be expected to be generated. It is not practical to do this for a large number of different server architectures.

A simpler approach making suitable assumptions for the server configuration is required. For a dedicated video server, it may be reasonable to assume that the VCs are all based on CBR traffic characteristics. The bandwidth allocated for other traffic types is assumed negligible.

The worst case is likely to occur when all of the VCs destined for one specific physical UNI arrive at the Server's VC multiplexing function at the same time. If *n* VCs are to be multiplexed together, then a burst of *n* cells may be generated (one per VC). If there is a random sequencing of VCs in the cell burst then a specific cell may suffer a cell delay variation of *n-1* cell periods at the line rate. Careful design of the scheduling functions associated with the server VC multiplexer should be able to reduce this considerably.

Other CDV generating effects besides VC multiplexing should also be considered. systematic jitter effects from the physical layer overhead can be approximated as a CDV of one cell period (or less) at the line rate. Similarly support of OAM cells etc. may also introduce an additional 1 cell CDV.

Hence for a physical UNI carrying an ATM multiplex with 6 CBR VCs , a worst case CDV of 7 cell periods at the line rate is a reasonable estimate. i.e. for *n* VCs, use *n+1* cell periods (line rate) as the $CDV_{tolerance}$ parameter value. For a group of CBR VCs with the same Shape Rate (Peak Cell Rate), the burst of *n* VCs should be less than 1/Peak Cell Rate i.e. back to back cells are not expected in this shaped traffic stream. Table 1 provides examples of the delay that could be introduced by clumping groups of cells at different ATM cell rates.

Line Rate (cells /sec)	ATM Cell Rate	Cell Period	5 Cell Periods	10 Cell Periods	20 Cell Periods	50 Cell Periods
	cells /sec	µS	µS	µS	µS	µS
DS-3 Line Rate (PLCP mapping)	96000	10.42	52.08	104.17	208.33	520.83
DS-3 Line Rate (HEC mapping)	104268	9.59	47.95	95.91	191.81	479.53
OC-3c line rate	353200	2.83	14.16	28.31	56.63	141.56
OC-12c line rate	1416900	0.71	3.53	7.06	14.12	35.29

Table 1 Examples of n Cell Periods at line rate

Consider the following examples:

1) A server is expected to generate a maximum of 7 VCs with Peak Cell Rate of 5Mb/s each on a DS-3 (HEC mapping) interface:

n = 7 VCs

$CDV_{tolerance} = (n+1) * 9.59\ \mu S = 76.72\ \mu S$

2) A server is expected to generate a maximum of 19 VCs with Peak Cell Rate of 7.5Mb/s each on an OC-3c interface:
n=19
$CDV_{tolerance} = (n+1) * 2.83\ \mu S = 56.6\ \mu S$

Note that these are just examples to assist a network operator in choosing appropriate values. The network operator should also consider the potential tradeoff between $CDV_{tolerance}$ and link utilization. As the CDV tolerance increases, the link utilization will decrease (for the same CLR). These guidelines are for the UNI from the Server. Other UNIs with different traffic mixes may require a different approach.

The network operator may also wish to consider other aspects (e.g. equipment limitations, administrative convenience etc.) in selecting appropriate values to offer. Bellcore's GR-1110-CORE (Issue 1, September 1994, Table 6-2, page 6-10) specifies a set of specific $CDV_{tolerance}$ values that Bellcore deemed appropriate for administering the UPC function in a Broadband Switching System.

Annex E **Proxy Signaling Capability** [Informative]

*[**Note:** The proxy signaling capability description is derived from the ATM Forum Signaling 4.0 specification. In the event of discrepancies in the description of the functions, the ATM Forum Signaling 4.0 specification should be considered as definitive.]*

The proxy signaling capability is described in the Annex 2 of the 4.0 ATM Forum Signaling 4.0 Specification .

Annex E.1 Facility Description

Proxy signaling is an optional capability for both the network and the user. This capability, when supported, requires prior agreement (e.g., subscription) between the user and the network. Proxy signaling allows a user called the Proxy Signaling Agent (PSA) to perform signaling for one or more users that do not support signaling.
Within a VoD service environment the proxy signaling call model is performed with the ATM Connection Controller being the PSA (refer to section 8). The ATM Connection Controller/PSA is acting on behalf of both the Client and/or the Server. The PSA not being connected to the same switch as the one the user it is acting for is qualified as remote proxy signaling agent.

In the following only the case where neither the Server nor the Client support signaling is described. The case where either the Server or the Client support signaling can be easily deduced.

Annex E.2 Provisioning

The ATM Connection Controller/PSA must provision one or more signaling VCs and (if needed) an ILMI VC to each of the switches where there are UNIs controlled by the ATM Connection Controller/PSA. The ATM switch to which the ATM Connection Controller/PSA is directly connected will treat these VCs as PVCs and need not be aware of the intended use.

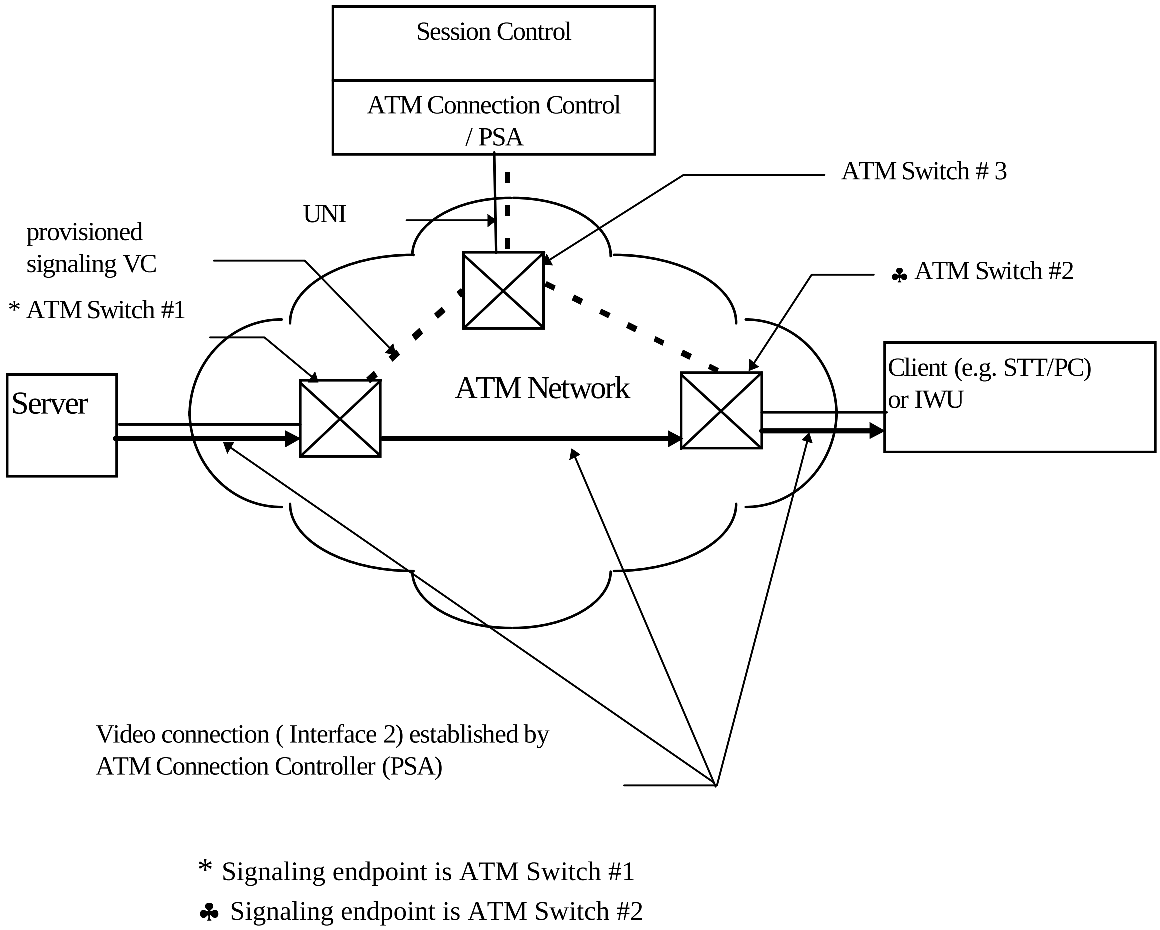

Figure E-1 Proxy Signaling Example

Annex E.3 Interfaces

- The provisioned signaling VCs from the ATM Connection Controller terminates on the ATM switch where the Client / Server is located. Thus every switch which has a user (Client or Server) under the control of an ATM Connection Controller/PSA must support the ATM Forum Signaling 4.0 specification.

- The Client and the Server have a UNI 3.0 (or higher) interface with the ATM network which has no signaling VC.

Annex E.4 Procedure

At subscription time the controlled Client(s) and Server(s) should provide the following information for each signaling VC:

- The list of directory numbers that are routed to the ATM Connection Controller/PSA over the signaling VC.
  (Information provided to the ATM switch on which the Clients and Servers are located)

- A mapping of VPCI values to a specific UNI and VPI combination for each VP controlled by the ATM Connection Controller/PSA over a signaling VC.
  (Information provided to the ATM Connection Controller/PSA)

- The VPI and VCI for the signaling VC and of the associated ILMI VC (if present).

The switches where the clients and servers are directly connected must support ATM Forum Signaling 4.0 (non associated signaling).

Annex E.5 Message flow

Assuming that neither the VIP nor the C1...Cn end users have signaling capability, a call established by the VIP to the end user would require the following set of message exchanges.

Annex E.5.1 Call/Connection at the originating interface

The ATM Connection Manager/PSA sends over the signaling VC which corresponds to the Server a SETUP message with the address of the Client in the called user address IE, the VIP VPCI and possibly VCI in the connection identifier IE.

The ATM switch to which the Server is connected will send back:

- a CALL PROCEEDING or a CONNECT message specifying the VCI and confirming the VPCI or confirming both VPCI/VCI
  or
- a RELEASE COMPLETE message denying the availability of the requested VPCI/VCI.

For more detail please refer to §5.1.2.2/Q.2931.

Annex E.5.2 Call/Connection at the destination interface

On an incoming call, offered to the ATM Connection Controller, the ATM network can only specify one of the following two options:

Option 1:
Only case a): << Exclusive VPCI, any VCI >> **AND** case c): << No indication >> of §5.2.3.2/Q.2931 shall be used.
Option 2:
Only case c) << No indication is included >> of §5.2.3.2/ Q.2931 shall be used.

In the incoming call offering side, the node to which the Client is connected shall send through the client related signaling VC a SETUP message with the Client address as the called user address and an explicit VPCI (option (a) §5.2.3.2/Q.2931) or no connection identifier (option (c) §5.2.3.2/Q.2931). In the first message sent back to the network, the ATM connection Controller/PSA shall specify the connection identifier to be used.

Annex E.5.3 Message Sequence Chart

In the following diagram a message is given only two IEs (for simplicity) : the called user address and the connection identifier.

```
ACC                                     Nserver          NClient                    ACC
                                        |                |
SETUP(@Client, VPCI_v/VCI_v*)           |                |
---------------------------------->     |                |
CALL PROCEED(VPCI_v/VCI_v)              |                |
<-----------------------------------    |                |SETUP(@Client, VPCI_e~)
                                        |                |------------------------------->
                                        |                |CALL PROCEEDING(VPCI_e/VCI_e)
                                        |                |<------------------------------
                                        |                |
                                        |                |CONNECT
                                        |                |<-------------------------------
                                        |                |CONNECT ACKNOWLEDGE
                          CONNECT       |                |------------------------------->
<-----------------------------------    |                |
       CONNECT ACKNOWLEDGE              |                |
------------------------------------>   |                |
```

ACC = ATM Connection Controller
NServer = network node to which the server (VIP) is connected
NClient= network node to which the client is connected
VPCI/VCI* = Option a) or b) of §5.1.2.4.2/Q.2931 is used
VPCI~ = Option a) or c) If option c) is used no connection identifier IE is sent by the network. A connection identifier IE with the VPCI/VCI of the End User will be sent by the first message in response to the SETUP message sent by the Connection Manager.
CALL PROCEEDING is an optional message in both directions.

Annex F Table of VoD Service Attributes [Informative]

The attributes of the Video on Demand Service can be summarized using the tabular format described in I.211 and F.722.

SERVICE ATTRIBUTES	VALUES OF ATTRIBUTES
1. Information Transfer Capability, Service Components (SC)	
1.1 Mandatory Service Components	SC no. 1 High Quality Video [2] SC no. 2 High Quality Audio [2]
1.2 Optional Service Components	SC no. 3 to n Unrestricted Digital Information [2]
2. Information Transfer Mode	ATM
2.1 Connection Mode	Connection Oriented
2.2 Traffic Type (Service Specific)	SC no. 1&2 : CBR SC no. 3-n: implementation specific
2.3 Timing end-to-end (Service Specific)	SC no. 1&2: required SC no. 3-n: not required
3. Information Transfer Rate (service specific)	SC no. 1&2: Peak Cell Rate (CBR) SC no 3-n: implementation specific
4. Structure (service specific)	SC no: 1&2 multiplexed as MPEG-2 Single Program Transport Stream via AAL-5 in one VC. SC no. 3-n : implementation specific
5. Establishment of Communication	demand, reserved
6. Symmetry	SC no. 1&2: unidirectional SC 3-n: unidirectional, bidirectional symmetric
7. Communication configuration	point-to-point
Access Attributes	
8. Access Channels and rates	
8.1 for user information	VC no. 1: SC no. 1&2 VC no. 3-n : SC no. 3-n
8.2 for signaling	signaling VC
9. Access protocols	
9.1 Signaling access protocol - physical layer	ATM Forum Signaling 4.0
9.2 signaling access protocol - ATM layer	ATM Forum Signaling 4.0
9.3 signaling access protocol	ATM Forum Signaling 4.0

[2] Service components SC1 and SC2 are multiplexed as MPEG-2 SPTS. An MPEG-2 SPTS may also contain Private Data. In this case, MPEG-2 Private Data could be considered a unidirectional instance of SC 3.

SERVICE ATTRIBUTES	**VALUES OF ATTRIBUTES**
9.4 signaling access protocol - layer 3 above AAL	ATM Forum Signaling 4.0
9.5 information access protocols - PHY layer	for further study
9.6 Information Access protocols - ATM layer	I.150, 1.361
9.7 Information Access Protocols - AAL	AAL-5
GENERAL ATTRIBUTES	
10 Supplementary Services	for further study
11 Quality of Service (service Specific)	for further study
12 Interworking capabilities	with other video retrieval services (for further study)
13. Operational and Commercial aspects	for further study

Annex G Interim Connection Management Arrangements Prior to ATM Forum Signaling 4.0 Specification [Informative]

Annex G.1 First Party Interim Signaling Arrangements

To use UNI 3.1 for 1st Party Connection Setup for Video-on-Demand, the signaling parameters should be set in accordance with section 8 (ATM Signaling Setup Information Elements) but with the following simplifying assumptions concerning the Broadband Low Layer Information (B-LLI) and the Quality of Service Parameter.

1) For the Broadband Higher Layer Information element, since Phase 1 only supports CBR MPEG-2 VOD, the proposed terminal protocol multiplexing scheme parameters will always be set to:

- Terminal Protocol = H.310 ROT & SOT
- Forward Multiplexing Capability = TS
- Backward Multiplexing Capability = no multiplexing

2) Since the terminal and multiplexing operation is already known, the B-HLI does not need to signal this information. Instead, the B-HLI shall contain the 7 byte DSM-CC session/resource ID (as defined in Annex D of [B]) by setting the high layer information type to "user specific"

3) For the Quality of Service Parameter, use QoS Class 1, 2, 3, or 4 in accordance with what your network provider has defined for carrying VOD services.

Annex G.2 Proxy Signaling Interim Arrangements

Prior to the availability of ATM Forum Signaling 4.0, proxy signaling can be implemented by using the existing text in the current ATM Forum Signaling 4.0 draft on proxy signaling. This is considered a complete and self contained specification of the proxy signaling capability. It requires the use of existing procedures defined by ITU-T in their Recommendation Q.2931.

ATM Forum UNI 3.1 mandates that ATM connection resources (e.g. VPI/VCI) are assigned only by the network. This limitation does not exist in ATM Forum Signaling 4.0, since it allows either the user or the network to assign these parameters. Proxy signaling requires VC negotiation capability which enables the Proxy Signaling Agent (PSA) , a user of the ATM network , to select the interface and VPI/VCI for an incoming or outgoing call to use. The ITU-T recommendation Q.2931 supports VC negotiation capability and hence, can be used, in the interim, in place of the ATM Forum Signaling 4.0 specification.

Annex G.3 Third Party Interim PVC Arrangements

Where SVC capability is not available, the client to server connection may be a PVC, provided that PVCs with acceptably low latency can be configured dynamically between the end-user and the server. In this case, the dynamic configuration of PVCs takes place using management plane procedures.