QoS and ATM

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1 Abstract

The Quality of Service from the user point of view has a meaning of providing information in timely manner. The information has to be delivered fast and reliable. From the technical point of view the Quality of Service (QoS) is characterized by different measurable variables. Technical QoS parameters are adjusted to get the best possible perceived performance from the network. Classifying different types of traffic for different uses can do this.

2 Introduction

ATM network is designer to transport a wide variety of traffic classes satisfying a range of transfer capacity needs and network performance objectives[4].

The quality parameters are measured based of the aspect of data loss, minimal (or no) induced delay or latency, consistent delay characteristics (also known as jitter), and the capability to determine the most efficient use of network resources (such as the shortest distance between two endpoints or maximum efficiency of circuit bandwidth) [6].

This paper concentrates on Quality of Service in ATM networks. The subject is studied based classification of services in ATM networks.

3 ATM Network architecture

ATM involves the transfer of data in discrete chunks and it allows multiple logical connections to be multiplexed over a single physical interface. The information flow in ATM networks in each logical connection is organized into fixed-size packets called cells.

ATM protocol in itself does not have any error controlling mechanisms except for header error control. This is done to prevent the distribution of erroneously routed packets to the application. Also the flow control capabilities are minimal in ATM networks, as flow control is understood as method of destination entity to regulate the flow of Protocol Data Units (PDUs) sent by the source entity[11].

The minimized error control and flow control mechanisms reduce the needed overhead of processing ATM cells and the number of overhead bits required with each cell. ATM is designed for high data rates and fixed cell size simplifies the needed methods of ATM switching.

The ATM protocol architecture is based on two-layer model. The basic architecture model is an interface between user and network. The layer below ATM model is the physical layer, which is the transmission medium and a signal-encoding scheme. The data rates specified at the physical layer include 155.52 Mbps and 622.08 Mbps. Also higher and lower data rates are possible. Currently 1000 Mbps[2] and 2488 Mbps[3] connections are in draft stage.

The maximum possible data transfer rate is limited by the electronics at both ends of fiber to between 50 and 1000 Gbps. This is still below the fiber's maximum transfer capability, which is between 50 and 75 terabits per second. [6]

Two layers of the protocol architecture relate to ATM functions. There is an ATM layer common to all services that provide packet transfer capabilities, and an ATM Adaptation Layer (AAL) that is service dependent. The ATM layer defines the transmission of data in fixed size cells and the use of logical connections.

The use of ATM creates the need for an adaptation layer to support information transfer protocols other than ATM. The AAL maps higher layer information into ATM cells to be transported over an ATM network and then collects information from ATM cells for delivery to higher layers.

4 ATM Traffic Management Functions

The capability to control traffic in the ATM network is crucial to ensuring the success of delivering differentiated QoS to the various applications that request and rely on the controls themselves. The primary responsibility of traffic management mechanisms in the ATM network is to promote network efficiency and avoid congestion situations so that the overall performance of the network does not degenerate. It is also a critical design objective of ATM that the network utilization imposed by transporting one form of application data does not adversely impact the capability to efficiently transport other traffic in the network.[6]

To deliver stability in the networks ATM Forum has defined the following traffic management and control of network resources [7]:

- Connection Admission Control (CAC) is defined as the set of actions taken by the network during the call set up phase in order to determine whether a connection request can be accepted or should be rejected (or whether a request for reallocation can be accommodated).
- Feedback controls are defined as the set of actions taken by the network and by end systems to regulate the traffic submitted on ATM connections according to the state of network elements.
- Usage Parameter Control (UPC) is defined as the set of actions taken by the network to monitor and control traffic, in terms of traffic offered and validity of the ATM connection, at the end system access. Its main purpose is to protect network resources from malicious as well as unintentional misbehavior, which can affect the QoS of other already established connections, by detecting violations of negotiated parameters and taking

appropriate actions. Such actions may include cell discard and cell tagging.

- Cell Loss Priority control: For some service categories the end system may generate traffic flows of cells with Cell Loss Priority (CLP) marking. The network may follow models, which treat this marking as transparent or as significant. If treated as significant, the network may selectively discard cells marked with a low priority to protect, as far as possible, the QoS objectives of cells with high priority.
- Traffic Shaping: Traffic shaping mechanisms may be used to achieve a desired modification of the traffic characteristics.
- Network Resource Management (NRM): The service architecture allows logical separation of connections according to service characteristics. Although cell scheduling and resource provisioning are implementation and network specific, they can be utilized to provide appropriate isolation and access to resources. Virtual Paths are a useful tool for resource management.
- Frame Discard: A congested network that needs to discard cells may discard at the frame level rather than at the cell level. The concept of a frame is defined in below.
- Available Bit Rate (ABR) Flow Control: The ABR flow control protocol may be used to adaptively share the available bandwidth among participating users.
- Other generic functions are for further study.

If a network element needs to discard cells, it is in many cases more effective to discard at the frame level rather than at the cell level. The term "frame" means the AAL protocol data unit. The network detects the frame boundaries by examining the SDU-type in the payload type field of the ATM cell header. Frame discard may be used whenever it is possible to delineate frame boundaries by examining the SDU-type in the payload type field of the ATM cell header. [7]

Frame discard is effective if AAL frame size is bigger than the ATM cell and the application cannot tolerate errors in transfer. In case of TCP a single lost ATM cell corrupts the entire data packet, which means that the data must be retransmitted.

5 ATM connections and cell structure

ATM switches are connected by using physical medium to transfer information. Control cost of network is becoming an increasingly higher proportion of the overall network cost. The transmission medium is able to transfer in higher data rates than switches. In ATM networks transmission path is divided into multiple virtual paths, which in turn are divided into multiple virtual channels.

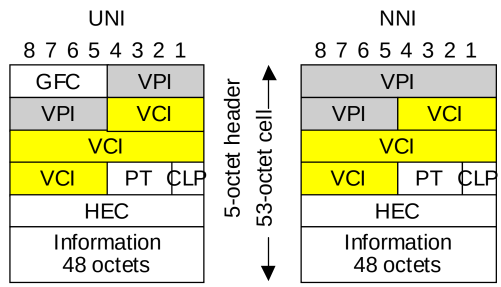
Virtual channel is formed between two end users through the network and thus a Virtual Channel Connection (VCC) is formed. VCCs are also used for user and network information exchange in the form of control signaling and between network elements for network management and routing information sharing.

A Virtual Path Connection (VPC) is a bundle of VCCs that have the same end points. Thus, all of the cells flowing over all of the VCCs in a single VPC are switched along the same path. [11]

5.1 ATM Cell Structure

ATM cells consists of a 5-octet header and a 48-octet information field. The fixed cell size reduces queuing time for priority cells and switching is easier to make by using hardware implementations.

ATM has specific cell structures for user connection to network and connections between networks, which are User to Network Interface (UNI) and Network to Network Interface (NNI). Figure **Error! Not a valid link.** shows the UNI and NNI cell structures.



GFC General Flow Control
VPI Virtual Path Identifier
VCI Virtual Channel Identifier
PT Payload Type
CLP Cell Loss Priority
HEC Header Error Control

Figure 1: ATM cell structure

General Flow Control appears only in UNI interface and it can be used to assist the customer in controlling the flow of traffic for different qualities of service. The use of this field is currently under study [11].

The Virtual Path Identifier (VPI) constitutes a routing field for the network. It is 8 bits at the user-network interface and 12 bits at the network-network interface, allowing for more virtual paths to be supported within the network. The Virtual Channel Identifier (VCI) is used for routing to and from the end user. [11]

The Payload Type (PT) field indicates the type of information in the information field. Table **Error! Not a valid link.** indicates the use of PT field.

Table 1 Payload Type (PT) Field Coding

PT Coding	*Interpretation*
000	User data cell, congestion not experienced, SDU type = 0
001	User data cell, congestion not experienced, SDU type =1
010	User data cell, congestion experienced, SDU type = 0
011	User data cell, congestion experienced = 1
100	OAM segment associated cell
101	OAM end-to-end associated cell
110	Resource management cell
111	Reserved for future function

SDU = Service Data Unit, OAM = Operations, Administrations, and Maintenance

A value of 0 in the first bit indicates user information. That is information from the next higher layer. In this case, the second bit indicates whether congestion has been experienced. The third bit service data unit SDU is dependant on the context.

A value 1 in the first bit of the payload type field indicates that this cell carries network management or maintenance information (OAM = Operations, Administration and Maintenance)

The Cell Loss Priority (CLP) is used to provide guidance to the network in the event of congestion. A value 0 indicates a cell of relatively higher priority, which should not be discarded unless no other alternative is available. A value 1 indicates that this cell is subject to discard within the network. A value 1 is set at the UNI if user transmits data at the higher rate than specified in agreement concerning traffic parameters.

Each ATM cell includes 8 bit Header Error Control (HEC) field that is calculated based on the remaining 32 bits of the header.

5.2 ATM connection

A VCC is a connection between two communicating ATM end entities, which may consist of a concatenation of several ATM Virtual Channel (VC) links. All communication proceeds along the same VCC, which preserves cell sequence and provides a certain quality of service. A VCC is set up between any source and any destination in the ATM network, regardless of the way it is being routed across the network. The network sets up the connection by using signaling.

Virtual Channel Identifier (VCI) in the ATM cell header is assigned per network entity-to-entity link. This VCI may change across the network within the same VCC. [5]This is explained in the picture **Error! Not a valid link.**:

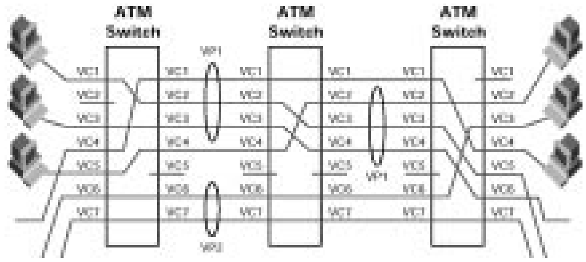


Figure 2 Virtual channels and virtual paths[5]

A Virtual Path (VP) groups VCs carried between two ATM entities and may also involve many ATM VP links. The VCs associated with a VP are globally switched without unbundling or processing the individual VC. Thus, the VCI numbers of a VP are preserved on a single VP connection. The sell sequence of each VC is preserved, and the quality of service of the VP depends on the most demanding VC.

5.3 ATM Adaptation Layer

The use of ATM creates the need for an adaptation layer to support information transfer protocols not based on ATM. The AAL is used to map between ATM transfer modes and user data modes.

To minimize the number of different AAL protocols that must be specified to meet a variety of needs, ITU-T has defined four classes of service that cover a broad range of requirements. The traffic is classified according to the following classes: [7]

- Service Class A: Circuit Emulation, Constant Bit Rate Video
- Service Class B: Variable Bit Rate Audio and Video
- Service Class C: Connection-Oriented Data Transfer
- Service Class D: Connectionless Data Transfer

Table **Error! Not a valid link.** gives the different AAL protocols to meet different types of requirements.

Table 2 Service Classification for AAL

	Class A	Class B	Class C	Class D
Timing relation between source and destination	Required		Not required	
Bit rate	Constant	Variable		
Connection mode	Connection oriented			Connectionless
AAL Protocol	Type 1	Type 2	Type 3/4	
			Type 5	

The AAL protocol is divided into two different sublayers: the Convergence Sublayer (CS) and the Segmentation and Reassembly sublayer (SAR). The Convergence Sublayer provides the functions needed to support specific applications using AAL and the CS sublayer is service dependant. In all AAL protocols a block of data is from a higher layer is encapsulated into a Protocol Data Unit (PDU).

The SAR sublayer is responsible for packaging information received from CS into cells for transmission and unpacking the information at the other end. CD layer is above SAR layer. The SAR is responsible of

packaging SAR headers and CS information into 48 payload octets of ATM cell.
AAL Type 1 is intended for constant bit rate applications. AAL Type 2 deals with variable bit rate information such as video and audio, which require timing information but do not require a constant bit rate. AAL Type 3/4 and AAL Type 5 can both be used for data transfer. AAL Type 5 is becoming increasingly popular, especially in ATM LAN applications. AAL Type 5 has been introduced to reduce protocol processing overhead, reduce transmission overhead and ensure adaptability to existing transport protocols [11]. AAL Type 3/4 has processing overhead compared with AAL Type 5.

5.4 ATM signalling

ATM is a connection-oriented technology in which one must establish a connection a priori information transfer. ATM signaling has different standards for connection establishment.
A User to Network Interface UNI signaling consists of definitions done for dynamically establishing, maintaining and clearing ATM connections. The signaling is based on a broadband signaling protocol standards Q.2931. The signaling protocol is extended with necessary capabilities to support the parameters defined by ATM forum. On a connection basis the following end-to-end parameters can be specified[4]:

- The AAL type (e.g., Type 1, 3/4, or 5)
- The method of protocol multiplexing (e.g., LLC vs. VC).
- For VC-based multiplexing, the protocol that is encapsulated (e.g., any of the list of known routed protocols or bridged protocols).
- Protocol above the network layer

LLC is a Logical Link Control and is defined by IEEE standard 802.2. LLC is part of Data Link layer, which is responsible for transmission of data between two adjacent nodes on the network. [10] The ATM Forum defines LAN traffic to be routed in ATM networks by LAN Emulation (LANE). [1]
The signaling between switches is done according to Private to Network-Node Interface (PNNI). The PNNI protocol is used between private ATM switches, and between groups of private ATM switches[8,9].

6 ATM Service Categories

An ATM network is designed to be able to transfer different types of traffic simultaneously, including real-time flows such as voice, video, and bursty TCP flows. Although each such traffic flow is handled as a stream of 53-octet cells travelling through a virtual channel, the way in which each data flow is handled within the network depends on the characteristics of the traffic flow and the requirements of the application. [11]
ATM

- CBR Constant Bit Rate: Requires that a fixed data rate be made available by the ATM provider. The network must ensure that this capacity is available and also policies the incoming traffic on a CBR connection to ensure that the subscriber does not exceed its allocation
- rt-VBR Real-Time Variable Bit Rate: Intended for applications that require tightly constrained delay and delay variation but does not exhibit the fixed data rate of CBR. rt-VBR connections are characterized in terms of a Peak Cell Rate (PCR), Sustainable Cell Rate (SCR), and Maximum Burst Size (MBS) [7]
- nrt-VBR Non-Real-Time Variable Bit Rate: The non-real-time (VBR) service category is intended for non-real-time applications, which have bursty traffic characteristics and which are characterized in terms of a PCR, SCR and MBS. For those cells, which are transferred within the traffic contract, the applications expects a low cell loss ratio. Non-real-time VBR service may support statistical multiplexing of connections[7]. In statistical multiplexing the network sets the capacity of VPC to be grater than or equal to the average data rates of all the VCCs but less than aggregate peak demand. No delay bounds are associated with statistical multiplexing service category. [7]
- UBR Unspecified Bit Rate: This is a best effort service. No amount of capacity is guaranteed, and any cells may be discarded.
- ABR Available Bit Rate: Provides the user with a guaranteed minimum capacity. When additional capacity is available, the user may burst above the minimum rate with minimized risk of cell loss.

These service categories relate traffic characteristics and QoS requirements to network behavior. Functions such as routing, CAC, and resource allocation are, in general, structured differently for each service category. Service categories are distinguished as being either real-time or non-real-time. For real-time traffic, there are two categories, CBR and rt-VBR, distinguished by whether the traffic descriptor contains only the Peak Cell Rate (PCR) or both PCR and the Sustainable Cell Rate (SCR) parameters. [7]
Non real time services are intended for applications that have bursty traffic characteristics and do not have tight constraints on delay and delay variation. Accordingly, the network has greater flexibility in handling such traffic flows and can make greater use of statistical multiplexing to increase network efficiency. [11] There are three non-real-time categories (nrt-VBR, UBR, and ABR). All service categories apply to both VCCs and VPCs [7].

Attribute	ATM Layer Service Category				
	CBR	rt-VBR	nrt-VBR	UBR	ABR
Traffic Parameters:					
PCR and CDVT(4,5)	specified			specified$_2$	specified$_3$
SCR, MBS, CDVT(4,5)	n/a	specified		n/a	
MCR$_4$	n/a			n/a	specified
QoS Parameters:					
peak-to-peak CDV	specified		unspecified		
maxCTD	specified		unspecified		
CLR$_4$	specified			unspecified	See Note 1
Other Attributes:					
Feedback	unspecified				specified

Notes:

1. CLR is low for sources that adjust cell flow in response to control information. Whether a quantitative value for CLR is specified is network specific.
2. May not be subject to CAC and UPC procedures.
3. Represents the maximum rate at which the ABR source may ever send. The actual rate is subject to the control information.
4. These parameters are either explicitly or implicitly specified for PVCs or SVCs.
5. CDVT refers to the Cell Delay Variation Tolerance. CDVT is not signaled. In general, CDVT need not have a unique value for a connection. Different values may apply at each interface along the path of a connection.

ATM service categories use following QoS parameters[7]

- Maximum Cell Transfer Delay (maxCTD)
- Peak-to-peak Cell Delay Variation (peak-to-peak CDV)
- Cell Loss Ratio (CLR)

Cell transfer delay consists of fixed minimum delay and variable delay. Fixed minimum delay is due to the processing on the network and transmission, which cannot be reduced for given connection. Variable delay is caused by variations in network traffic.
The maximum allowed delay for the connection is defined with maxCTD and it is the sum of fixed minimum delay and maximum variable delay for connection. Peak-to-peak CDV is the maximum allowed variation in network delay for connection.
The cell loss ratio is the ratio of lost cells to total transmitted cell on a connection[11].

6.1 Available Bit Rate

Available Bit Rate (ABR) is an ATM layer service category for which the limiting ATM layer transfer characteristics provided by the network may change subsequent to connection establishment. A flow control mechanism is specified which support feedback to control the source rate in response to changing ATM layer transfer characteristics. This feedback is conveyed to the source through control cells called Resource Management Cells, or RM-cells.
The end system is expected to adapt its transfer capabilities according to feedback.
On the establishment of an ABR connection, the end-system specifies to the network both a maximum required bandwidth and a minimum usable bandwidth. These parameters are specified by using Peak Cell Rate (PCR), and the Minimum Cell Rate (MCR). The MCR may be specified as zero. The bandwidth available from the network may vary, but shall not become less than MCR[7].Additionally the ABR connections have Allowed Cell Rate (ACR) and initial cell rate (ICR). ACR is the maximum cell rate, which may be used at the connection. The sender is allowed to use any data rate between zero and ACR. ICR is the initial value assigned to ACR.
Feedback is used to control transfer in the ABR connection. The Figure illustrates the effect of feedback on ACR.

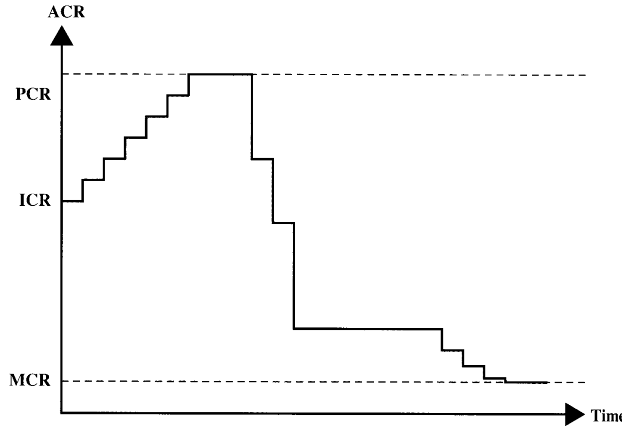


Figure 3 Variations in allowed cell rate

There are three possible operation modes in ABR transfer: sender is allowed to increase, sender must decrease or sender ABR must stay the same. If the sender is allowed to increase ACR, the increase is linear. In case the sender must decrease the amount of traffic, the rate of decrease is exponential. The actual amount of decrease is defined as fraction of current ACR and the rate may vary.
With linear increase and exponential decrease, the source will slowly increase its rate when there is no evidence of congestion, but at high rates will rapidly decrease the rate when there is indication of congestion[11].

7 TCP over ATM

A typical implementation of TCP/IP over ATM uses the following protocol stack[11]:

- TCP
- IP
- AAL5
- ATM

Figure **Error! Not a valid link.** is an example of the relationship among the various layers. In this example, an entire TCP segment is carried in an IP datagram. If it is necessary, the TCP segment can be fragmented into pieces carried in multiple IP datagrams.
The IP datagrams are mapped to CS PDUs. This mapping must be one to one mapping between an IP datagram and the CS PDU that carries it. That is each CS PDU carries exactly on IP datagram. The CS PDU includes an 8-octet trailer any padding required to make the CS PDU an integer multiple of 48 octets.
The CS PDU is segmented into blocks of 48 octets and packed into ATM cells. In each cell except the last, the SDU type bit is set to zero. The SDU type bit is set to one in the last cell to signal the SAR sublayer that an entire CS PDU has been delivered.

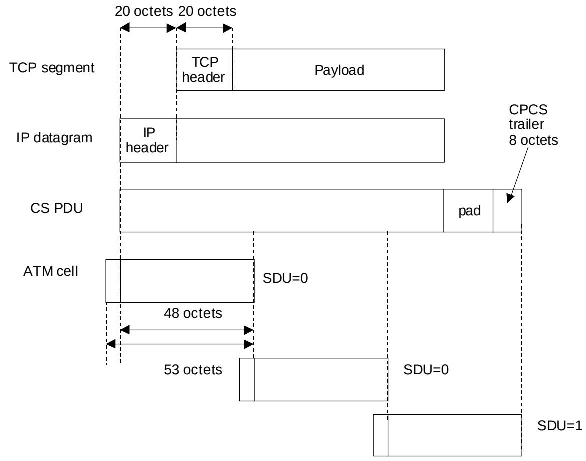


Figure 4 TCP/IP over AAL5/ATM

The IP datagram is padded to fit exactly with fixed size ATM cells. In addition CPCS (Common Part Convergence Sublayer) is added at CS PDU for error control and length of data [1]. Data length is needed to separate the padding from the payload data.

The number of needed ATM cells varies according to IP packet size. The packet size varies usually between 512 octets to 9180 octets. A packet size of 512 is common in IP networks; 1500 is the maximum for Ethernet[11] and 9180 is the default for IP over ATM [RFC 1626].

ATM switches must be able to discard cells at frame level in order to support high quality TCP traffic. TCP connections cannot handle missing data packets in the TCP packet. If part of TCP packet is missing, the entire TCP packet must be resent.

8 Conclusion

The current development of Internet and telephone companies are directed to higher transferred data rates in the network.

The Internet community is used to inexpensive connections and are demanding decreasing prices on services. The telephone connection prices are expected to decrease. The Internet transfers information on best effort method and data throughput is sometimes sacrificed.

The telecommunication companies have traditionally provided constant bit rate end to end connection for speech. The end users are demanding more throughput for data transfer and cheaper telephone prices.

The third previously unrecognized user type is a corporate user who demands predictable data throughput. An example of this type of customers is stock market, where the data becomes invalid in a matter of seconds.

The speech may be transferred in the future by using AAL Type 2 traffic. The end user may not be able to recognize if some parts of the speech are missing and variable bit rate AAL Type 2 suits to speech transfer better than constant bit rate AAL Type 1. This requires that PCM like speech is transferred to more suitable compressed data.

The AAL Type 5 is most suitable for Internet data traffic. The debate is whether to use UBR or ABR service category.. ABR connections include more processing than UBR, which is currently the bottleneck in ATM switching.

The business critical users cannot accept the general reliability of Internet traffic. One possible way is to use PPP links between end points and transfer data using AAL Type 1 or 2. If network service providers are able to differentiate the customers and dedicate network resources, the AAL Type 5 can be used for business critical data.

The customer specified Quality of Service can be provided by classifying user data to different groups and prioritizing the traffic by user interest. The premium customer must also be willing to pay premium price for better service. If the premium customer is only willing to pay slightly higher price than standard customer then the best effort business model is going to dominate the markets.

The increasing demand for bandwidth is likely going to continue. The switching capability is going to stay the limiting factor of information transfer and the different classes of service are needed.

9 References

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