

# QoS - ATM versus Differentiated Services

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## Preface

Due to the increasing requirements on quality of service (QoS) for multimedia applications, wide area networks must be able to provide end-to-end performance guarantees. The ATM protocol, which offers an extensive traffic management functionality, achieves QoS in networks by providing various categories with different quality of service features. However, it is expensive and incompatible to the existing Internet infrastructure. On the other hand side, the "best effort" service of the IP protocol is not able to fulfill these demands.

The capability of adding quality of service features to the IP protocol can be achieved by the Differentiated Services architecture. Depending on negotiated quality characteristics for the given data streams, their respective IP packets are classified and assigned to service classes. These service classes determine the scheduling and the resource allocation in the network nodes.

This paper is organized as follows: In section one, the ATM architecture is presented together with a description of the Differentiated Services concept, following in section two. In section three the two approaches will be compared theoretically as well as by presenting empirical measurements.

## 1 ATM

In order to furnish connections with the choice of different QoS characteristics, the ATM Forum has defined several service categories [ATM96]. Four of the most common categories are presented here. Constant Bit Rate (Cbr) traffic requires a fixed data rate and a predictable response time. It is used for video conferencing and interactive audio (e.g. telephone). Real-time Variable Bit Rate (rt-Vbr) is intended for traffic streams with timing constraints and a variable bit rate. Compressed video streams with image frames of varying size are transmitted by rt-Vbr connections. The non-real-time Variable Bit Rate (nrt-Vbr) category guarantees an average transmission rate with bursty character. There is no time synchronization between traffic source and destination. Rt-Vbr is used for multimedia applications which tolerate a small amount of losses like e. g. adaptive applications. The Unspecified Bit Rate (Ubr) category can be used by applications which can tolerate variable delay and cell losses, as e.g. file transfer and email. The categories Cbr and rt-Vbr can be grouped into high priority Real-time services. The class of non-real-time services consists of the categories nrt-Vbr and Ubr. The service category must be specified by the user before a connection is established. This is done by a service contract which in addition to the service category contains traffic parameters that characterize the traffic patterns of the cell stream.

During connection setup, the network checks through the Call Admission Control (CAC) function, if enough resources are available on the way, the connection will take through the network. The CAC function will then accept or reject the call. If the call is accepted, the required performance and QoS is guaranteed during the lifetime of the connection. Apart from the CAC function, there are traffic management functions that control the network resources and avoid congestion in network components [ATM96]. The Usage Parameter Control (UPC) monitors and controls the traffic and the validity of a connection. The actual traffic profile is compared with the traffic contract. If the contract is violated, cells may be passed, discarded or tagged. In this way, the UPC function protects network resources by active data stream regulation. The Traffic Shaping mechanism can be used to modify the traffic profile according to the traffic contract by delaying the cell transmission or by discarding cells.

## 2 Differentiated Services

The differentiated services (DiffServ) architecture [Nic98] enlarges the IP protocol by a scalable mechanism that provides different levels of service quality. IP packets are classified and aggregated in service classes with different quality of service features, according to the value of the Type of Service Byte in the IPv4 Header, the so-called *Differentiated Services Code Point* (DSCP).

After entering a network node, a classifier assigns each IP packet to the correct service class and marks the DSCP with the corresponding value (figure 1). A meter checks the conformity of the traffic profile of all classes. The result of this function is used to relabel the DSCP or to change the traffic profile of this service class by policing or shaping. The labeling of a packet is useful if, e.g., the profile of the packet stream does not comply with the contract between user and provider. A non-conform packet can be assigned to a lower service class by changing the DSCP value.

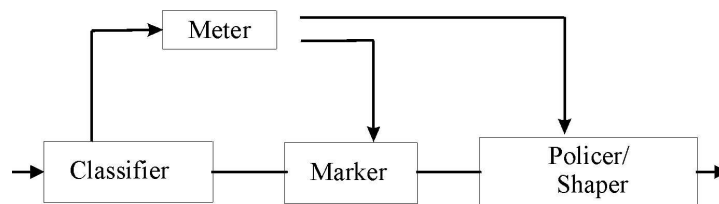


Figure 1 Traffic conditioning in the DiffServ architecture.

For each service class, specified by the corresponding DSCP value, a different behavior on the outgoing router interface has to be established. This is called the *Per Hop Behavior* (PHB). It is implemented by scheduling algorithms or by congestion avoidance mechanisms. Scheduling algorithms control the buffer management at the outgoing interfaces of routers and are able to support several outgoing queues with different behavior. Congestion avoidance algorithms try to remove congestion as soon as there is a sign of an overload

situation. Random Early Detection (RED) [FJ93] for example continuously watches the average queue length. If it exceeds a given threshold, the router begins to discard packets at random. Protocols like TCP/IP react to lost packets by reducing the sending rate and entering a Slow Start phase [Jac88].

Routers using the default "Tail Drop" behavior drop all packets that arrive when the queue is filled. In the worst case, packets of nearly all established connections can be affected, leading to all respective connections entering the Slow Start phase at the same time. This mechanism implicitly generates global synchronization with waste of bandwidth in the start phase and cyclic repetition of the phenomenon. RED avoids this problem by discarding packets of only some TCP connections, which then enter the Slow Start phase. As a result, the bandwidth is used better and the transmission delay is reduced, because the outgoing queue is never completely filled.

### 3 Comparison of ATM and DiffServ

In this section, the ATM and DiffServ will be compared with respect to their ability to provide QoS to applications.

First of all, a mechanism must be introduced that is able to distinguish packets of different service classes. A service class model has to be implemented in the network components that handles packets according to their class. To classify packets, ATM uses the VC and VP identifiers. The classification of a connection is done at connection setup. It remains unchanged during the lifetime of a connection. According to the VP and VC identifiers, the ATM switches assign the service category to a connection. They know how to handle the packet such that timing requirements are met. DiffServ uses the DSCP to fulfill the classification task. Since the classification is not implemented in applications, the network components must be able to change the DSCP value before a packet enters a network. Since the value depends on the provider, different providers must agree on it in the case of packets passing network boundaries.

Figure 2 a) shows the setup for a test run to demonstrate that the classification task requires high performance in the router interfaces. A Cisco Router 7507 with IOS 12.0(10)S is connected to a traffic generator Smartbits 6000 via two Packet over Sonet (PoS) interfaces. The interfaces in the router are Versatile Interface Boards, where the classification functionality is performed on the interface cards themselves. This is in contrast to central architectures, where all tasks are fulfilled by the central unit. The traffic generator sends packets on different flows. Here a *flow* denotes all packets of an end-to-end connection with the same source and destination address. The number of the flows is increasing continuously. The classification of the packets is based on their addresses.

Figure 2 b) illustrates how the CPU load of a router interface is influenced by the classification task that has to process an increasing number of flows. On the abscissa, the number of flows is plotted. On the ordinate, the influence of this number on the CPU load of a router's interface is shown. First, there are 5 flows sending 429 Byte packets at a rate of 5 Mbit/s. Relabelling the packets requires a CPU load at the router's entrance of 15 %. It increases up to 99 % if there are 27 flows relabeled at the incoming router interface. If

there are 30 flows entering the system, the load is so large, that packets may be lost. This is a very critical issue, since there are usually thousands of flows on an entrance interface at a network's boundary.

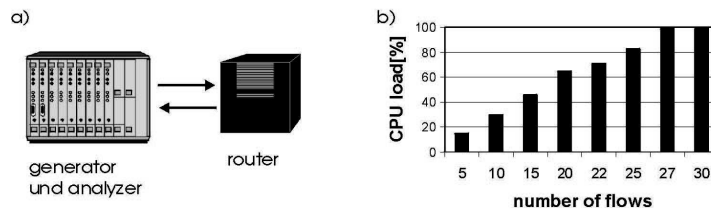


Figure 2 Setup and result of the test to see the CPU load needed to change the value of the DSCP.

The UPC and Traffic Shaping functionality which discards data from malicious streams is imperative to avoid congestion and is found in ATM and DiffServ. They are both able to check and control the bandwidth of traffic streams. The ATM protocol checks the values in the traffic contract using the UPC or Traffic Shaping function for each VC and VP. In the DiffServ concept bandwidth control functionality is implemented, in addition [HH99].

An important fact concerning QoS is the capability to react to congestion. The ATM concept is based on a strict priority idea in contrast to the DiffServ model, where only relative guarantees can be provided. This fact will be demonstrated in the following test: Two traffic streams send data with different priority. The stream with the higher priority sends data at a constant rate while the other stream increases the transmission rate continuously. This test is done on Cisco 7500 routers using the RED functionality to implement two different service classes, which are in our test "assured service" with guaranteed QoS and the "best effort" service [HH99].

Two workstations are connected with two routers via FDDI (figure 3), the routers via a STM-1 Sonet connection [Gor97]. In order to achieve an overload situation at the outgoing interface of the first router, a traffic generator is sending low priority UDP traffic, which is forwarded by the first router to the second on the same physical link as the TCP traffic. RED is configured on the outgoing interface of router1, on a Versatile Interface Board. On Cisco routers, there exists an implementation of RED which allows to configure different discard thresholds for different service classes. Two SUN Ultra 1 Solaris workstations exchange TCP packets with high priority. The packets are marked in the DSCP. The UDP packets are discarded at a very low average queue length, whereas the discarding of the TCP packets does not start until the queue is nearly filled.

In figure 4 the throughput of the UDP and the TCP connections in this test is presented. Increasing the UDP traffic up to 70 Mbit/s does not change the TCP traffic. However if the UDP traffic continues to increase such that an overload situation is reached on the outgoing interface of the router, the throughput of the high priority TCP traffic decreases. When the UDP traffic source sends with a rate of 150 Mbit/s the throughput of the TCP traffic is only about 59 Mbit/s. This test demonstrates that there are *no throughput guarantees* in

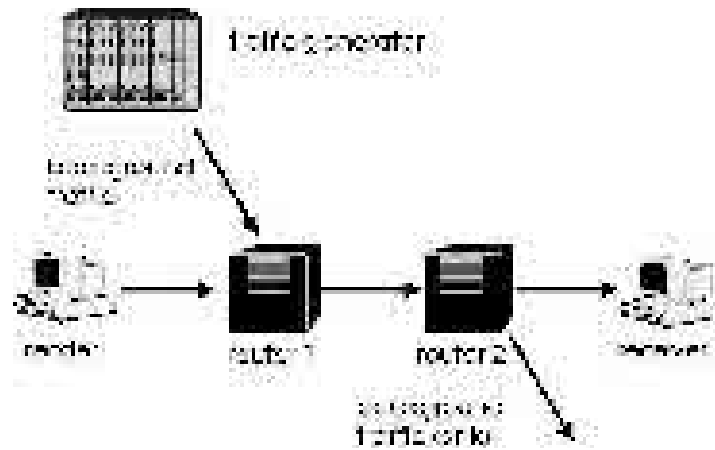


Figure 3 IP test setup.

overload situations when the RED mechanism is used, because the UPD traffic does not reduce its load on the network when exposed to packet drops.

In figure 5, the setup for a corresponding test with the ATM protocol is illustrated. An ATM traffic generator (HP 4200B) is connected via three interfaces with a Fore ASX1000 ATM switch, which is configured to an 85 Mbit/s Cbr VC on one interface and a 150 Mbit/s Ubr VC on the second. Both VCs are connected to one outgoing STM-1 interface so that there is an overload condition on this interface if the Ubr stream sends data with line rate. The interface is connected to an ATM analyzer that monitors the throughput on the two VCs.

The monitor sends a constant rate of 85 Mbit/s on the Cbr VC. The sending rate on the other VC increases during the experiment from 0 to 100 Mbit/s. The result of our first test is shown in figure 3. The throughput of the Ubr VC is denoted by the dotted line, that of the Cbr VC by the continuous line. The throughput on the Cbr VC is constant during the entire experiment independent of the increasing sending bandwidth of the Ubr stream. The throughput of this VC does not exceed 65 Mbit/s and the surplus of cells is discarded on the outgoing interface of the ATM switch. This corresponds to the maximum throughput which can be achieved on a STM-1 link if already 85 Mbit/s are used by the Cbr VC. The test clearly shows that the bandwidth of a VC with service category Cbr is guaranteed and protected against traffic on an Ubr stream.

In another experiment, the sending rate on the Ubr VC is 150 Mbit/s and the sending rate of the Cbr VC is increasing continuously. Figure 7 shows that the throughput of the Ubr VC decreases to 65 Mbit/s.

Our measurements demonstrate, that the bandwidth which is reserved for the Cbr VC can be used in case it is idle by other connections. It is clear that the ATM protocol ensures service quality guaranteed to a connection during the setup. From our point of view, this is the main difference between ATM and DiffServ. In the DiffServ concept

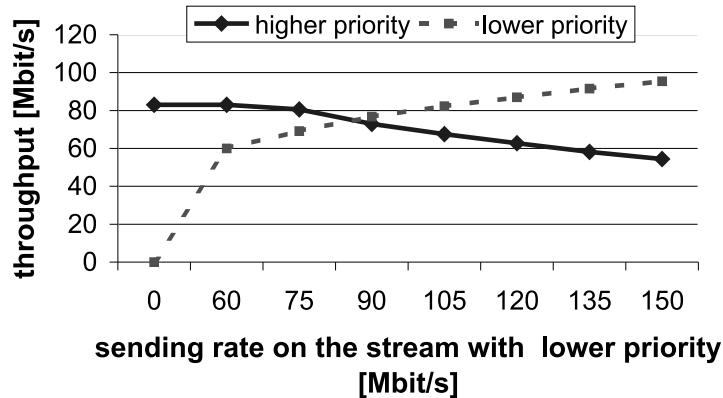


Figure 4 Result of the RED test to check the throughput of high priority stream when the low priority stream produces congestion.

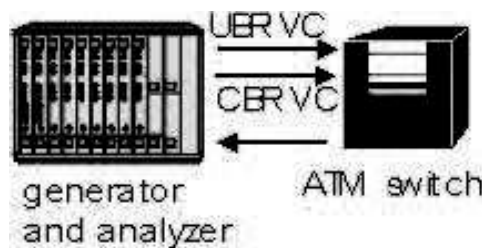


Figure 5 ATM test setup.

there is no resource reservation. In case of congestion, this results in classes with high priority suffering from an overload condition as well as the lowest priority classes. The Resource Reservation Setup Protocol (RSVP) [Bra97] aims to remove this shortcoming. Unfortunately, this protocol does not scale in WANs [Man97].

Considering the PHB in the DiffServ concept, the ability to distinguish different service classes depends on the scheduling mechanisms implemented in the network's routers. With FIFO queuing (First in First out), the packets which come first are first sent to the output link. Fair Queuing, another scheduling strategy, implements several queues which all obtain the same part of outgoing bandwidth on an interface. Both mechanisms are not able to give priority to special packets. Weighted Fair Queuing is an extension to Fair Queuing. Here, each queue is assigned a weight that determines the part of the outgoing bandwidth belonging to this queue, thus allowing different behavior for several classes. In addition, this scheduling algorithm guarantees an upper bound on delay [Par92]. The quality of the algorithm depends on an efficient implementation in the network components. ATM on the other hand has strict priority algorithms for the handling of the outgoing queues. In some implementations, the ATM cells of different traffic classes are stored in different buffer

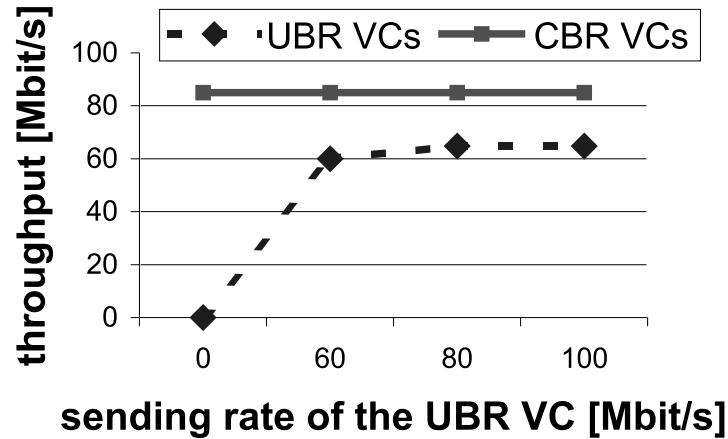


Figure 6 Result of the ATM test to check the throughput of high priority stream if the low priority stream produces congestion.

pools. The buffer with the higher priority traffic, e.g. the Cbr cells, is served first, so that transmission according to the priority is achieved.

## 4 Conclusion

IP networks enlarged by the DiffServ architecture are at the moment not ready to transport real-time traffic. One problem is the lack of bandwidth guarantees that is caused by missing resource reservation in the DiffServ model. Another problem is the CPU performance, which is insufficient for adding the DiffServ functionality to router interfaces. In addition, it is a very complex task for a network administrator to configure all network components consistently in the DiffServ concept. So far, it has not been possible to automate this task.

For real-time applications it therefore seems to be the best solution to use the ATM protocol despite the fact that the ATM infrastructure does not reach up to the end user. At the moment, there are networks where an ATM backbone coexists with an IP infrastructure. Hence the ATM protocol that includes QoS guarantees can be used for traffic with hard real-time constraints.

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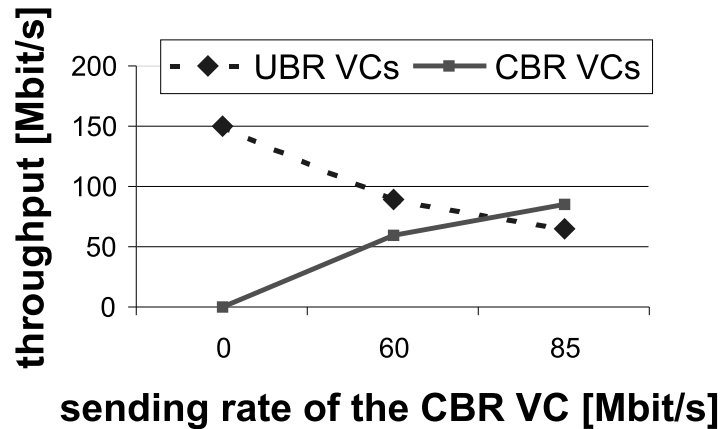


Figure 7 Result of the ATM test.

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