

Mapping IP Services to ATM Network

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Abstract

The best-effort service model in the Internet does not provide any form of service differentiation. To support service differentiation in the Internet, the Internet community has developed integrated service architecture (Intserv) and differentiated service architecture (Diffserv). On the other hand, ATM has been widely deployed in Internet backbones. Thus, service mapping between IP over ATM network is an important issue. In this paper, we summarize how to provide Intserv and Diffserv on ATM. First, the mapping between Intserv and ATM is described. Then we discuss the service mapping between Diffserv and ATM according to the absolute and relative services.

Keywords: QoS, Differentiated Service, Integrated Service, Per-hop behavior, ATM service category.

1. Introduction

The Internet has provided a broad range of services, which vary from a simple E-mail to complex client/server applications or delay-sensitive multimedia services such as World Wide Web, audio/video transport. However, it is difficult to offer multiple levels of service because the best-effort model treats all packets in the same way. For examples, Internet telephony is sensitive to latency and, in contrast, E-mail can tolerate a fair amount of delay. Obviously, the Internet needs to support different services requirements. To do that, the Internet community has developed two service architectures: integrated service architecture (Intserv) [1,2,3,4] and differentiated service architecture (Diffserv) [5,6,7,8]. The capability to provide service differentiation and resource assurance in a network is commonly referred to as quality of service (QoS). To guarantee services that have specific performance requirements, QoS concerns itself with bandwidth, latency, jitter, and loss.

The Intserv was the first attempt to

enhance the Internet with QoS capabilities. It provides end-to-end guaranteed or controlled load services on a per flow basis. A flow is a single stream of packets transmitted by a specific sender to one or more specific receivers. Each flow can request specific levels of service, i.e., minimum service rate, end-to-end delay bound or loss ratio, from the network through Resource Reservation Protocol (RSVP) [1,2]. The guaranteed service [4] is defined to support real-time traffic and the controlled load service [3] to support a non-real time service. Based on per-flow resource reservation, a flow must make a reservation before it can transmit traffic onto the network. Although the Intserv provides absolute service guarantees, maintaining per flow states causes the scalability and manageability problems. It does not cope with a very large number of flows.

Alternative solution, Diffserv, is proposed to support QoS in the Internet. It avoids the limitations of Intserv architecture by focusing on traffic aggregates, rather than individual flow, and provides more scalable/manageable architecture in IP network. Diffserv aggregates flows into forwarding classes by the edge router at the boundaries of the network. Within the network, packets are forwarded according to the Per-Hop Behavior (PHB). The Diffserv does not define end-to-end services. Services can be seen to be traffic conditioning plus concatenation of PHBs.

ATM was “designed for QoS “ so to speak. ATM Forum has proposed QoS service model on the ATM network that is the QoS-enabled network, 80 percent of network service providers intend to build their multiservice networks on ATM infrastructures. It has been widely deployed in Internet backbones. Thus, Intserv and Diffserv over ATM network are important issues and are addressed by the IETF and the ATM Forum. This paper summarizes the current development of both Intserv and Diffserv over ATM.

The mapping between Intserv, including guaranteed services and controlled-load services, to ATM is described. Then we discuss the service mapping between Diffserv and ATM

according to the absolute and relative services.

The rest of this paper is as follows. Section 2 introduces the Intserv. Section 3 makes an overview of Diffserv. The ATM service category is described in Section 4. According to the IETF and the ATM Forum recommendations, we briefly summarize how to provide Intserv and Diffserv on ATM network in Section 5. Finally, Section 6 concludes this work.

2. Integrated Services

The Intserv focuses on real-time applications. It assumes that resources in the network must be controlled in order to deliver QoS. The traffic must be subject to admission control mechanisms. The Intserv argues that real-time applications cannot be realized without resource guarantees, and that resource guarantees cannot be realized without resource reservations. So, in addition to admission control, the Intserv makes resource provisions with RSVP.

The real-time applications are further classified into two subcategories: those that are tolerant and those that are intolerant of jitter. Tolerant applications can be characterized as those that can function in the face of nominal jitter. Examples are audio- or video-streaming applications. Intolerant applications can be characterized as those in which jitter and delay result in enough distortion. Examples are two-way telephony applications and circuit-emulation services.

Integrated services for the Internet has two broad classes of quality of service: the guaranteed services [4] and the controlled-load services [3]. For intolerant applications, the Intserv recommends a guaranteed service model that provides a reliable upper bound on delay. For tolerant applications, the Intserv recommends the use of a controlled-load service model that provides a less-than-reliable delay bound. The two models are described as follows.

- **Controlled-Load Service**

The Intserv definition for controlled-load service [4] attempts to provide end-to-end traffic behavior that closely approximates traditional best-effort services within the environment of unloaded or lightly utilized network conditions. The controlled-load service does not use specific values for control parameters that include information about delay or loss. Acceptance of a controlled-load request implies a commitment to provide a better-than-best-effort service that approximates network behavior under nominal network-utilization conditions. The packets can expect to find conditions very close to that where the network is not congested.

To ensure that the network conditions is met, the application requesting the controlled-load service provides the network with an estimation of the traffic it will generate—the traffic specification (TSPEC). The controlled-load service uses TOKEN_BUCKET_TSPEC to describe a data flow's traffic. Each node ensures that sufficient resources are available to accommodate the request.

- **Guaranteed Services**

Guaranteed Service on the other hand provides tighter guarantees. It provides a framework for delivering traffic for applications with a bandwidth guarantee and delay bound. It only computes the queuing delay in the end-to-end traffic path. The guaranteed service asserts that the queuing delay is a function of two factors— token-bucket depth and token rate the application requests. Because the application controls these values, the guaranteed service has a priori knowledge of the queuing delay.

Guaranteed Service does not control the minimal or average delay of traffic, and does not control or minimize jitter. It only controls the maximum queuing delay. Guaranteed service will accept the traffic only if it can assure the application of a guaranteed upper bound on the maximum delay that the datagrams will experience.

Because of the end-to-end and hop-by-hop calculation of errors, every node in the data path must implement the guaranteed service.

3. Differentiated Services Framework

Differentiated services aims at providing differential treatments to flows or aggregates of flows by using the type of service byte in the IP header. Instead of making per-flow reservation in Intserv, Diffserv aggregates flows into forwarding classes by the edge router at the boundaries of the network and forwarding classes are assigned to different behavior aggregates. Each behavior aggregate is identified by a single Diffserv Code Point (DSCP), which is contained in the packet header. Within the network, packets are forwarded according to the Per-Hop Behavior (PHB) associated with DSCP [6].

3.1 Concepts behind Diffserv

The basic concepts behind Diffserv [6,7,8] are introduced as follows.

- To address the scaling concerns, the Diffserv divides traffic flows into a number of traffic aggregations called forwarding classes.

Each forwarding class represents a predefined forwarding treatment. Resources are allocated to individual forwarding classes rather than individual flows.

- Forward classes can be defined for a single domain. Domain service provider may map their service definitions through bilateral agreements.

- Diffserv model provides relative resource allocation rather than absolute resource guarantee. No QoS requirements are exchanged between the source and destination. Diffserv provides resource assurance for a forwarding class through prioritization and provisioning. That is, a forwarding treatment defines drop priority and bandwidth allocation. However, network traffic will become dynamic and the QoS guarantee becomes more difficult. For this reason, the Diffserv does not attempt to support an absolute resource assurance, but rather strives for a relative ordering of forwarding classes such that some will receive better or worse treatment relative to other.

- Diffserv model emphasis service level agreement (SLA) rather than dynamic signaling. The purpose of Diffserv is to ensure that the SLAs between customers and service providers are honored.

- Diffserv have its distinction between the edge and the core in Diffserv domain (DS domain). A DS domain refers to a set of hosts and routers supporting the same service policies and behaviors. In Diffserv, only boundary nodes of a DS domain classify traffic and mark packets. The interior nodes of a DS domain use the forwarding classes to determine the forwarding treatment of the packets. In contrast, Intserv requires all nodes to perform packet classification to identify packets and schedule them with per-flow queuing.

Figure 1 shows the network architecture for the deployment of Diffserv, consisting of a set of interconnected Diffserv domains. Figure 2 shows the function modules of the Diffserv architecture. Traffic classification and conditioning are done in the boundary nodes and a limited set of PHBs in the interior nodes. Traffic entering the domain must be classified, marked and possibly conditioned according to the Traffic Condition Agreement (TCA) and Service Level Agreement (SLA).

3.2 Per-Hop Behaviors (PHBs)

The differentiated services define a base set of behaviors or groups of behaviors called the per-hop behavior (PHB). Each PHB would correspond to a particular forwarding treatment.

Each PHB is represented by a 6-bit value called a DSCP. These behaviors will in

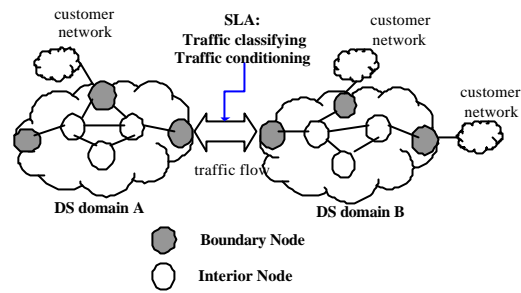


Figure 1: Diffserv network architecture

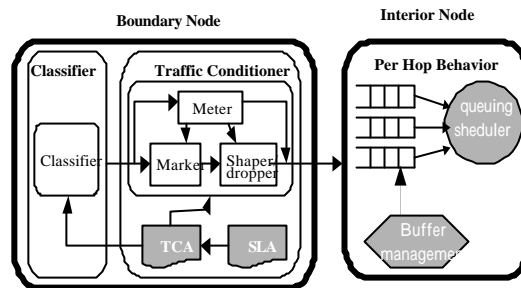


Figure 2: the function modules in Diffserv architecture

all probability be implemented by using appropriate queuing policies. All packets with the same code point are referred to as a behavior aggregate, and they receive the same forwarding treatment. A set of PHBs may form a PHB group that describes resource allocation in relative in terms of bandwidth allocation and drop priority. They are typically implemented by means of buffer management and packet scheduling. In [12], four PHB groups are defined as follows.

- **Expedited Forwarding (EF):** The EF PHB is characterized by a configurable amount of bandwidth that is available all the time irrespective of the fluctuations of the other traffic sharing the link. The EF PHB is defined as a forwarding treatment for a particular aggregate where the departure rate of the aggregate's packets from any Diffserv node must equal or exceed the configured rate. The EF PHB is used to build a low loss, low latency, low jitter, and assured bandwidth and provide a premium service (i.e., virtual leased line, VLL).

- **Assured Forwarding (AF):** The AF PHB group provides four independently forwarded AF classes. Within each AF class, an IP packet can be assigned one of three different levels of drop precedence. A configurable, minimum amount of forwarding resources (e.g. buffer space and bandwidth) is allocated for each class. However, there is no standard relationship

between the performances of the four AF classes

- **The Class Selector (CS) PHB group:** The Class Selector (CS) PHB group was created to enable partial backward compatibility with the IP v4 Type of Service (TOS) field. Its coding (xxx000) subsumes the bit patterns most commonly used in the TOS field. At least two levels of precedence (to which the 8 possible CS values are mapped) should be implemented. The probability of time forwarding for traffic with a given CS code point should be not less than that with a numerically smaller CS code point.

- **The Default PHB:** The Default PHB was created to explicitly grandfather the most common setting of the TOS field (000000). The associated forwarding behavior is expected to be “best effort”. Note that by virtue of coding, the Default PHB is actually one of the 8 CS PHBs.

Note that a DS node must implement all four AF classes. Although the AF standard does not specify how excessive bandwidth above the minimum allocation should be shared, implementation must describe the exact algorithm for allocation and configuration.

A service can be implemented with a forwarding treatment and admission control. Forwarding treatment refers to the externally observable behavior of a specific algorithm or a mechanism that is implemented in a node. In contrast, service is defined by the overall performance that a customer’s traffic receives. For example, we define a service called no-loss service, which guarantee no packet losses for customers of this service. The no-loss service can be implemented with the express forwarding by assigning high priority to the packets of the customers. Proper traffic control, such as admission control, is also needed to prevent too many high-priority packets from arriving at the output link.

The Diffserv architecture does not define end-to-end services. Services can be seen to be traffic conditioning plus concatenation of PHBs. Network service provider needs to mutually agree with their customers on service level agreements (SLA).

4. ATM Services Categories (ASC)

ATM networks are designed to provide end-to-end transport of user data with specified QOS, which is expected to satisfy through effective traffic control. When the network receives a new connection request associated with traffic descriptors and performance parameters, the connection admission control (CAC) procedure is executed to decide whether to accept or to reject the call. The ATM end

system can specify traffic descriptors [9] including peak cell rate (PCR), maximum burst size (MBS), sustainable cell rate (SCR) and minimum cell rate (MCR) to concretely describe the intrinsic source traffic characteristics. Since a new connection request will be accepted if the network has enough resources to provide the QOS requirements of the connection without affecting the QOS already established in the network. Hence, when a new connection request satisfies the above two conditions, the CAC procedure must further decide whether admitting the new connection causes the QOS violation of existed low priority connection or not.

ATM technology is intended to support a wide variety of services as well as to satisfy various users’ quality needs. As defined by the ATM Forum, the different types of services are categorized into four service classes: constant bit rate (CBR), variable bit rate (VBR), available bit rate (ABR), and unspecified bit rate (UBR).

In the following, discussions of ATM service type with the associated traffic descriptors are presented.

- **Constant Bit Rate (CBR) Service:**

This service category is used by connections that request a static amount of bandwidth that is continuously available during the connection lifetime. The offering of this service over ATM network is designed for circuit emulation, which requires a constant bandwidth capacity for each call. A typical example is 64 Kbps voice as in PSTN to be transported over ATM. This amount of bandwidth is characterized by a peak cell rate (PCR) value. In the CBR capability, the source can emit cells at the PCR at any time. The performance parameters are characterized by CTD and CDV and the cell loss CLR.

- **Real-time Variable Bit Rate (rt-VBR) Service:**

This service category is intended to support real-time applications. Sources are expected to transmit at a rate that varies with time or at “bursty”, for example, multimedia applications that can tolerate a small amount of cell loss without noticeably degrading the quality of the presentation. An rt-VBR connection is characterized in terms of PCR, SCR, and MBS. Also rt-VBR connections have stringent delay and cell loss ratio (CLR) requirements.

- **Nonreal-time Variable Bit Rate (nrt-VBR) Service:**

This service category is intended for nonreal-time applications that have bursty data without delay sensitivity. It is used for connections that transport variable bit rate traffic

for which there is no inherent reliance on time synchronization between the traffic source and destination. We can use nrt-VBR for transaction-oriented applications, such as interaction reservation systems, where traffic is sporadic and bursty. This service is characterized in terms of a PCR, SCR, and MBR. In addition, it expects a low cell rate.

- **Available Bit Rate (ABR) Service:**

The ABR service is not expected to support real-time applications. Since many data applications are unable to precisely specify their traffic parameters such as bit rate, these applications generally require a dynamic share of the available bandwidth among all active connections. On the establishment of an ABR connection, the end system specifies to the network both a PCR and MCR. They can be adjusted. Cell delay variation is not controlled in this service.

- **Unspecified Bit Rate (UBR) Service:**

The UBR service is intended for non-real time applications such as file transfer and e-mail. ATM networks mainly supports absolute services except UBR. An UBR source may send as fast as it desires (up to its PCR), but the network does not guarantee any QoS for it. The UBR service category does not specify traffic-related service guarantee. The UBR service category is enhanced with an associated per-hop Behavior Class Selector (BCS) value. In [12], the specification defines a mechanism by which a UBR connection may be associated with one of a set of network-specific behavior classes. The behavior class is indicated via the Behavior Class Selector (BCS) parameter. The mechanism we will describe in the next section.

Table 1 shows the parameters needed for ATM service category.

Table 1: the parameters for ATM service categories

	Rate	Delay	Loss
CBR	PCR	CTD&CDV	CLR
rt-VBR	SCR&PCR	CTD&CDV	CLR
nrt-VBR	SCR	no guarantee	CLR
ABR	MCR&ACR	no guarantee	CLR
UBR	no guarantee	no guarantee	no guarantee

5. Intserv and Diffserv over ATM

QoS is one such important weakness of IP. However ATM boasts of an architecture which has relatively sophisticated methods of providing QoS. This section will review the current state of affairs in the interoperation of ATM and IP QoS discussed in the previous section. First we consider Intserv over ATM and then Diffserv over ATM.

5.1 Intserv over ASC

The service models in Intserv and in the ATM network have many similarities. The mapping between the two appears to be straightforward [13]. The ATM traffic management specification also makes use of the token bucket parameters. Thus the peak rate, token rate, and maximum burst size in TSpec can easily map to the corresponding parameters in ATM, such as PCR, SCR and MBR.

The guaranteed service requires reliable delivery of traffic with a bandwidth guarantee and delay bound. Guaranteed service shares many characteristics with the CBR and rt-VBR. CBR does not adapt to changing data rates and can leave large portions of bandwidth underutilized. Therefore, rt-VBR is the most appropriate ATM service for guaranteed service traffic because of its inherent adaptive characteristics.

The selection of the rt-VBR service requires two specified rates to be quantified: SBR and PCR. When mapping guaranteed service onto an rt-VBR, IETF suggests that the ATM traffic descriptor values for PCR, MBS and SCR should be set with the following bounds:

$$\begin{aligned}
 R &\leq \text{PCR} && \leq \text{minimum } p \\
 r &\leq \text{SCR} && \leq \text{PCR} \\
 0 &\leq \text{MBS} && \leq b
 \end{aligned}$$

where $R = RSpec$
 $p = \text{peak rate}$
 $r = \text{Receiver TSpec}$
 $b = \text{bucket depth}$

The traffic appropriate for the controlled-load service is characterized as tolerant real-time applications. In the remaining ATM service categories, only nrt-VBR and ABR service provide characteristics that are the most compatible with the controlled-load service. UBR does not provide any mechanism to allocate network resources, which is the goal of the controlled-load service. Best-effort traffic fits well into the UBR service.

The ABR service category best aligns with the model for controlled-load service, which is

characterized as being somewhere between best-effort and a requiring service guarantees. Therefore, if the ABR service is used for controlled-load traffic, it requires that an MCR (Minimum Cell Rate) be specified to provide a lower bound for the data rate. The TSpec is used to determine the MCR. The nrt-VBR service also can be used for controlled-load traffic. However, maxCTD (Maximum Cell Transfer Delay) and CDV (Cell Delay Variation) must be chosen for the edge ATM device and is done manually as a matter of policy.

When mapping controlled-load service onto an nrt-VBR, IETF suggests that the ATM traffic descriptor values for PCR and MBR should be set within the following. Table 2 is the mapping between Intserv and ASC.

$$r \leq \text{SCR} \leq \text{PCR} \leq \text{minimum } p$$

$$0 \leq \text{MBS} \leq b$$

where p =peak rate
 r =Receiver TSpec
 b = bucket depth

Table 2: mapping between Intserv and ASC

Intserv	ASC
Guaranteed service	CBR or rt-VBR
Controlled-load	nrt-VBR or ABR
Best effort	UBR or ABR

5.2 Diffserv over ASC

Before discussing the service mapping between Diffserv and ASC, it is certainly to distinguish the supported services between Diffserv and ATM network. Then we discuss how ATM supports Diffserv and how Diffserv defines the services.

First, Diffserv can support both absolute and relative services, while ATM QoS objectives are always absolute. The absolute QoS is that the QoS commitment of one connection is defined solely and is not relative to the service provided to any other connection. In contrast, the relative QoS may be influenced by the services of other connections. Second, per-hop behavior is the basic component of the Diffserv architecture but ASC is based on end-to-end notion. A particular PHB can be used to build a variety of services depending on other factors, e.g., the traffic conditioning rules implemented at the edge nodes. PHBs may be mapped to any appropriate ASC. Third, the Diffserv architecture supports service differentiation among aggregated flows. Traffic flows are classified upon ingress nodes and interior nodes determine the correct PHB and thus need not provide per-flow discrimination. In the following, according to the absolute and relative services, we discuss the service mapping between Diffserv and ATM.

Table 3 : examples of IP-based service to ATM service mapping

Application Example	IP		ATM	
	IP-based services (examples)	PHB	Service Category	Parameter mapping
Virtual leased line (VLL)	Premium service	EF	CBR or rt-VBR	Peak rate → SCR, PCR
Voice and video	Real-time service	AF (one of the AF classes)	ABR or nrt-VBR	CIR → MCR
Voice and video	Real-time service	AF (one of the AF classes)	rt-VBR or ABR	Application specific parameters to be mapped to PCR, MBS and SCR
VPN	Olympic service	AF (three of the AF classes)	UBR	BCS values

Table 4 : an example of IP service based on AF PHB mapping to ATM service VBR

	Internet service : Service based on AF PHB	ATM service: VBR
Policing	Strict control of the assured traffic descriptor. Violation results in degradation of transport quality to best effort for the violating packets.	Strict control of the “SCR” and “MBR” traffic descriptors. Violation results in degradation of transport quality to best effort.
Traffic descriptors	Assured packet rate Maximum burst size	Peak cell rate > sustainable cell rate; maximum burst size
QoS	Moderate loss, delay. Best effort other packets	Low loss guarantee and moderate delay for the traffic up to SCR/MBS. Best effort up to PCB

Table 5 : an example of IP service based on EF PHB mapping to ATM service rt-VBR

	Premium service and other services based on EF PHB	ATM service: rt-VBR
Policing	Strict control of traffic descriptor. Violation results in discard.	Strict control of the “PCR” and “SCR” traffic descriptors. Violation results in cell discard
Traffic descriptors	Peak Packet Rate Maximum Packet Size	Peak Cell Rate Cell Delay Variation Tolerance Sustainable Cell Rate Maximum Burst Size
QoS	Low Loss and low delay guarantee; Suiting real time requirements	Class 1: Low loss and low delay guarantee; Suiting real time requirements
Buffer policy	Highest Priority Queue (or similar) Depth 1 or 2 packets	Highest Priority Queue Depth ca. 100 cells

5.2.1 Absolute Services

Since the Diffserv does not include service definitions, the solutions of how to map an IP QoS to an ATM service category is depend on the granularity of services. A network provider has the flexibility to define those services that suit to the user requirements. To support absolute service, the choice of the service mapping between ATM and Diffserv should be based on QoS measures. For example, a delay-sensitive service based on Diffserv can be mapped to one of the real-time ATM service categories. As a result, a different service mapping within the network providers will occur. Although [12,14,15] does not provide a precise criterion to map an IP absolute service to an ATM service, it can consider the mapping according to traffic policy, traffic parameters and QoS characteristics. For example, the premium service (e.g., virtual leased line) could be mapped to the CBR service category in order to meet its low loss and delay.

Table 3 shows examples of IP-based service to ATM service mapping [12,14,15]. For example, premium service is a low loss, low latency, low jitter, assured bandwidth, end-to-end service. Loss, latency and jitter are all

due to the queues traffic experiences. Therefore, providing low loss, latency and jitter for some traffic aggregate means ensuring that the aggregate sees no queues or very small queues. This service is only characterized by its peak rate. Obviously the premium service could easily be mapped to CBR service of ATM in order to meet its low loss and delay objectives. The peak rate of the premium service is mapping to the CBR PCB. Assured rate service, another example, is defined by a minimum rate that is assured on a statistical basis. That is, a flow is allowed to exceed its minimum rate if the network is not congested. Since assured rate service does not emphasize the real-time characteristic. In ATM, the assured rate service can be mapped to either nrt-VBR or ABR service categories.

Table 4 is an example of IP service based on AF PHB plus policing mapping to ATM service VBR. Table 5 is an example of IP service based on EF PHB, for example premium service, mapping to ATM service rt-VBR.

5.2.2 Relative Services

A characteristic of a relative service is that no service request needs to be denied due to lack of resources. Performance may be allowed

to degrade as the increase of resource competition. It depends on relative treatments, which is identified by assigning different DSCP. Because ATM UBR does not guarantee QoS characteristics, UBR service category is well suited for this type of behavior. To support relative services, ATM Forum has proposed Differentiated UBR to support differentiated service [10].

To support Diffserv, multiple UBR virtual channel connections are established between each pair of ATM-attached IP devices. Behavior class selector (BCS) is proposed to be a function module in ATM network. BCS is that it defines which PHB is mapped on the output port. DSCP in the packet header will be translated into a BCS value. Then, according to the BCS value, a corresponding cell switch behavior for a virtual channel will be selected. The translation from DSCP to BCS value is shown in Figure 3.

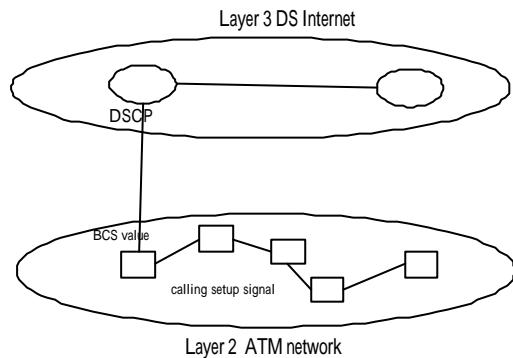


Figure 3 : the translation DSCP to BCS value

6. Conclusions

Since ATM has been widely deployed in Internet backbones, service mapping between Intserv and Diffserv over ATM network are important issues. In this paper, we survey how ASC supports Intserv and how it supports both absolute and relative services. For absolute services, there is no particular service-to-service mapping between Diffserv and ATM. To support the relative services of Diffserv, ATM UBR service category is well suited for this type of behavior. Since the ATM-based Internet is popular in the world and the Internet provides several differentiated services, the service management between ATM, Intserv and Diffserv is more important. Because the Diffserv does not include service definitions and its services classification are heuristic, it needs to consider the service classes of Diffserv for performance assurance and network utilization in ATM network. The mapping between Diffserv and ATM is under way. We will observe the

development continuously.

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