Advanced Management and Provisioning of Next-Generation DSL Services

Definition

Next-generation, service-capable networks are defined as networks that are capable of differentiating between subscribers and subscriber sessions and of understanding application requirements over the network. In comparison to the public Internet, where all traffic competes for resources with equal priority and without control structure, next-generation networks segregate traffic types, users sessions, or individual users into defined access channels. Subscriber sessions may continue onto the public Internet, where traffic returns to a best-effort format, but sessions that remain within the carriers' sphere of control maintain an explicit network and service contract. The most condensed definition of the next-generation, service-capable network is "control."

Overview

This tutorial will focus on digital subscriber line (DSL) access using asynchronous transfer mode (ATM) permanent virtual circuits (PVCs) as the underlying transport mechanism for ATM–native and Internet protocol (IP) sessions (see *Figure* 1).

Figure 1. DSL Using ATM PVCs

Topics

1. Introduction

Today's networks have evolved from simple dialup systems with broad access to content (the Internet) into full-featured, service-oriented systems. As access has become nearly universal by means of DSL, cable-modems, dialup, and wireless, it has also become more of a commodity.

Networks that originated under a simple Internet access–business plan have found customer demand for more resource-intensive applications increasing. Additionally, the promise of high-speed broadband access has raised the expectations of the average consumer; networks must not only provide access to applications and services, but these functions must be easily accessible, uniform between subscribers, and predictable in terms of behavior. Networks are under pressure from the application providers themselves. New products, which test the capacity and load-sharing ability of the networks, are released regularly—each sharpening the subscriber appetite for more applications and bandwidth.

Finally, competition between network providers has focused on the ability of providers to offer applications, content, and services to subscribers; access is no longer a key differentiating point.

2. Provisioning Next-Generation, Service-Capable Networks

Applications

Applications and specific requirements per application, as well as a need to rate, or, more explicitly, manage, subscriber sessions are driving the requirement for next-generation, service-capable networks. *Table 1* illustrates a number of applications and services that require the additional control mechanisms described in this tutorial. Note that the actual quality-of-service (QoS)/class-of-service (CoS) definition is dependent on a carrier's ability to provision the following services.

Table 1. Applications/Services with Additional Control Mechanisms

Application/ Service	Quality of Service Type	Details
voice over IP (VoIP)	real-time constant bit rate (CBR) or variable bit rate (VBR)–RT	VoIP requires that sessions be subjected to minimal delay. Additionally, VoIP sessions must sustain minimal packet loss to retain a high metal oxide semiconductor (MOS) score (remain near-toll or toll quality). These sessions require symmetric data sessions and vary in total bandwidth requirement, depending on level of compression used at the point of encapsulation. These connections are most efficient over the network when established on demand or request.
voice over ATM (VoATM)	real-time CBR or VBR–RT	VoATM requires that sessions be subjected to minimal delay. Additionally, VoATM sessions must sustain minimal cell loss or damage in order to retain a high MOS score (remain near-toll or toll quality). These sessions require symmetric data sessions and vary in total bandwidth requirement, depending on the level of compression used at the point of encapsulation. These connections are most efficient over the network when established on demand or request.
videoconferencing	real-time CBR or VBR–RT	Videoconferencing sessions require symmetric data sessions. Additionally, as a result of the video and voice components, videoconferencing requires more bandwidth than most applications. Minimal delay and cell loss are required for videoconferencing. These connections are most efficient over the network when established on demand or request.
video on demand (VOD)	non-real time VBR–NRT	VOD requires asymmetric network connections. A limited amount of user input may be transmitted in the upstream for control functions (play, pause, stop, rewind, etc.). Additionally, VOD requires a consistent cell delay—although buffering may be used to compensate for throughput irregularities. The total bandwidth requirement for VOD is sizeable downstream, limited upstream. The level of compression for the video service also affects bandwidth utilized. These connections are most efficient over the network when established on demand or request.
broadcast video	non-real time/real time VBR–RT/VBR–NRT	Broadcast video requires subscribers to join data sessions in progress. Many users may receive broadcast sessions using IP or ATM multicast functions. Broadcast video also requires asymmetric network connections. A limited amount of user input may be transmitted in the upstream

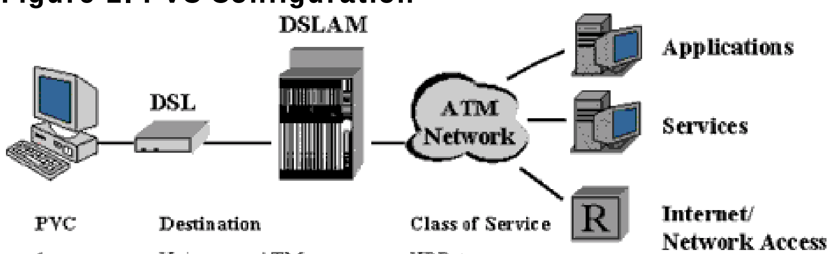
		for control functions (play, pause, stop, rewind, etc.). Additionally, broadcast video requires a consistent cell delay, although buffering may be used to compensate for throughput irregularities. The total bandwidth requirement for broadcast video is sizeable downstream, limited upstream. The level of compression for the video service also affects bandwidth utilized. These connections are most efficient over the network when established on demand or request, although at which point in the network the carrier signal is broken into individual subscriber sessions is the primary determining point of overall network efficiency.
network games	real-time VBR–RT	Network-based games commonly require small amounts of bandwidth—but must sustain minimal delay over the network. Often, the game itself is hosted on the subscriber system, which only player information transmitted between the network and other users. Actual network requirements vary widely between game applications, and connections are best when created specifically according to individual application requirements. These connections are most network-efficient when established on demand or request.
Internet access	nonreal time/best effort VBR–NRT/UBR	Internet access is one of the most basic network applications. Bandwidth requirements vary widely, depending on content requested. Commonly, Internet access is treated as best-effort unspecified bit rate (UBR) data sessions, as any QoS/CoS definition in the carrier network remains dependent on the capacity and congestion of the Internet itself and the content or application host. Best-effort sessions to the Internet are most commonly permanent connections; the network control resources used in creating on-demand or on-request connections are not efficiently used for this type of connection.
virtual private network (VPN) access	variable	Access into VPNs—for access to corporate or otherwise private networks—vary in requirements. Access may range from CBR to best-effort UBR sessions. Commonly, these connections are permanent.
account access/private applications	variable	Access to user account information, configuration tools, or other private, subscriber-specific information and functions may vary in network requirements for throughput, delay, or loss. These functions are defined uniquely by carrier.The key aspect of private network access is the ability to segregate public from private sessions. Commonly, these connections are permanent.

Default and Explicit Configuration

Provisioning of next-generation, service-capable networks is simplified into two installation models in this tutorial: default configuration with subscriber (or carrier-initiated configuration after service initiation) and explicit configuration with subscriber (or carrier-initiated configuration after service initiation). Once service is initiated, changes to a subscriber's configuration are discussed as service adjustment.

For the purposes of this tutorial, all connections are presumed to be configured over the management plane; switched virtual circuits (SVCs) are not assumed to be available. PVC configuration over the management plane is the most common form of network configuration tool available today.

Figure 2. PVC Configuration



PVC	Destination	Class of Service
1	Voice over ATM	VBRrt
2	Game Server	VBRrt
3	Internet Access	UBR
4	Management Access	UBR

Default Configuration

Default configuration is defined as a minimum configuration built into hardware and software provisioned to a subscriber. This configuration must provide immediate access into management and configuration systems that allow subscribers to request that connections be created for access to services, applications, or external networks. The subscribers, once access into the management and configuration systems is available, must structure their accounts to provide the required access. Subscribers may continue to adjust connections though the network over the life of their subscriptions, with the exception of the primary (default) connection to the management and configuration systems. The key differentiating aspect of the default configuration is that subscribers must establish all connections other than the basic management access before the service is active.

Explicit Configuration

Explicit configuration is defined as an exhaustive examination of the subscribers' requirements, which are then programmed into the necessary hardware and software as well as engineered through the network for availability and capacity. Configuration details may range from specific external networks to access (other than the Internet through a network access point [NAP] or peering point), connections to application servers, or access to other connection-specific content or functions on the network. Configuration may be set remotely via phone interview or on-site during installation.

Service Adjustment

Service adjustment is defined as any change to the subscriber configuration after service initiation. These changes are defined as PVC constructions between ATM network points and access requests for applications or services that are transported over an existing PVC. Service adjustment may be requested from the network by individual subscribers or initiated by customer-service technicians. For the purposes of this document, both subscribers and network technicians are assumed to use the same automatic provisioning tools.

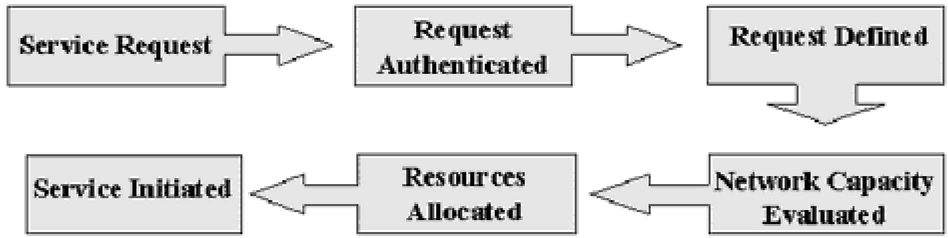
Subscriber- and application-driven configuration of the network on demand is essential for effective utilization of bandwidth resources. Many applications, of which voice and video are two examples, require sustained throughput of a large volume of traffic and would unnecessarily occupy network capacity. Additionally, the ability to provision high-margin, though bandwidth-intensive, connections on demand is an integral part of next-generation network models.

Provisioning Mechanisms: On-Request PVC Configuration

One mechanism for adjustments to subscriber configurations is the management plane. While SVCs are defined by ATM user network interface (UNI) 3.1 and 4.0 as a signaled construction, dynamic PVCs are structured using network-based management tools. In this scenario, the required network engineering per PVC request is completed through all affected systems and the necessary configuration information is inserted into the network elements.

Each PVC request must be evaluated on a per-connection basis for availability and network resources required. Requests for transition networks must be defined as appropriate per network; for example, virtual circuits are continued through ATM and frame-relay networks. *Figure 3* demonstrates one process for configuring virtual circuits:

Figure 3. On-Request PVC Configuration



- **service request**—Subscriber requests a service through the network.
- **request authenticated**—Specific request is authenticated given subscriber account profile; for example, access to some services may be blocked.
- **request defined**—Resource requirements are defined per service request; circuits that transition networks are defined under each network's QoS characteristics.
- **network capacity evaluated**—Available capacity over the network is evaluated per service request; if capacity is available though the network segments effected, service provisioning is authorized.
- **resources allocated**—All network elements through which the session is provisioned are configured; PVC definitions are created end to end.
- **service initiated**—After network configuration, service is initiated.

Once services are initiated through the network, billing and customer records must be updated. As sessions through the network are configured in a dynamic manner, billing records must be continuously updated. Additionally, records may be kept that detail all access to specific networks, services, or applications in cases where the carrier provides billing services for third-party functions.

Dynamic service creation is fundamental to next-generation networks. The ability for customers to create connections on request to applications, services, and content in an automated manner is required for the large number of service requests. Additionally, the ability to create and tear down bandwidth-intensive connections automatically allows network capacity to be best shared between a maximum number of users.

Mechanisms for Session Routing

Several mechanisms exist for placing subscriber IP sessions into the proper virtual circuits. Point-to-point protocol (PPP) over ATM and 1483 routing are two mechanisms. IP tagging and setting priority markers on IP packet headers are less effective, although employed, mechanisms.

PPP over ATM

The subscriber's ATM–enabled protocol stack within the personal computer (PC) may create PPP–over–ATM sessions. In this model, the DSL modem is most commonly installed directly into the subscriber's personal computer as a network interface card (NIC). IP–based applications direct sessions to the network interface, which is responsible for identifying individual sessions, creating PPP over ATM sessions, and managing subscriber authentication between applications, content, and services. PPP–over–ATM service creation requires software drivers to be installed into the subscriber system, as well as a per-destination or port-filtering function to determine how sessions must be routed into the appropriate virtual circuits. If a single PVC is available, or subscribers are allowed to initiate only one PPP over ATM session simultaneously, the network's ability to provide advanced services and applications is severely limited in that it is unable to manage user sessions separately. Additionally, PPP–over–ATM sessions may be initiated directly by the DSL network termination systems. Proxy PPP access does not require additional drivers to be installed on the subscriber system.

PPP–over–ATM sessions require PPP–over–ATM routing equipment in the carrier network to terminate and manage subscriber sessions. Examples of PPP–over–ATM routers are Redback's SMS 1000, Shasta Networks, and Cisco Systems.

PPP–over–ATM connection systems may use 1483 routing to place user sessions into specific virtual circuits.

1483 Routing

1483 routing allows individual IP packets to be placed in ATM virtual circuits depending on destination. Additionally, a default route may be defined for traffic routed to outside destinations. Next-generation networks will have a number of PVCs defined and available in the 1483 routing table. As access to services and applications is requested, the network provisions PVCs between ATM end points and updates the routing table housed in the subscriber's DSL network termination device. 1483 routing may be used in connection with PPP–over–ATM functions—provided that multiple PPP sessions are allowed and by-service PVCs are available.

Request for comment (RFC) 1483 also specifies an IP bridging function, where all IP sessions are placed into a single ATM virtual circuit. Most commonly used in networks that provide only best-effort Internet access, 1483 bridging does not provide the session-control capabilities required for next-generation networks.

Tagging and Precedent Bit Setting: IP Packets

A final mechanism for prioritizing IP sessions into ATM networks or over router-based connectionless networks is tagging or utilizing the precedent bit field in the IP packet header. This function allows applications to define several levels of service on a per-application basis. Routers must identify the priority set per packet and place user sessions into the appropriate transport links.

This function, however, lacks the shaping and policing mechanisms available to IP–over–ATM networks and is a less-effective manner of controlling subscriber sessions. Finally, all IP routers in the network must recognize precedent pit usage and have the capability to route sessions appropriately.

3. Management of Next Generation Service-Enabled Networks

Overview

As networks become more complex in adding service and applications, management systems must also evolve. New applications and services are changing how networks are managed and maintained. Also, the constantly changing dynamics of a network based on on-demand connections present increasingly complex management requirements.

Advanced management tools also reduce the total operational cost for network monitoring and maintenance. Operations such as spectrum monitoring over the outside plant for DSL compatibility, as well as collection total error seconds per connection must be automated; the personnel required to evaluate these functions manually would be prohibitive to the business model.

One new application that requires an advanced level of management is voice services. Voice, as a data application, has the most stringent requirement for dependency and is the most affected application when the network experiences fault. Voice services are dependent on low-delay, consistent bandwidth throughput. Any interruption in network service is immediately noticeable to voice sessions. Videoconferencing sessions also have a low tolerance to network faults. As videoconferencing combines voice and real-time video functions into a single application, interruptions in service are immediately noticeable.

Network management includes network maintenance. Updated software must be downloaded into subscriber DSL equipment. This function is best performed in an automated fashion—either by DSL modems querying the network for new software to download, or by commanded mass download.

Management Tools

Management tools include automated functions as well as alarm correlation tools. Several examples of automated functions are included in *Table 2*:

Table 2. Automated Functions

signal-to-noise-ratio (SNR) testing	Spectral compatibility is essential in maintaining robust, dependable, DSL–based services. As density of DSLs increases in binder groups, the background noise increases between lines. Additionally, other services, such as T1s and high-bit rate digital subscriber line (HDSL), as well as outside interferes such as amplitude modulation (AM) radio and other radio frequency interference (RFI), may reduce the SNR on individual DSL lines. Finally, each DSL line may be impacted differently by interferes in the distribution plant. Testing of noise levels throughout the distribution plant on a constant or scheduled basis is essential for fault prevention. Carriers may identify interference trends before service interruption.
bit-error rate (BER) testing	BERs or rates of severely erred cells may increase as a result of conditions that affect many of only a few DSL lines. The ability to monitor error conditions over a number of DSL circuits may be used to isolate plant-impairing conditions.

In addition to automated loop- and circuit-testing tools, the ability to perform alarm correlation for root-cause analysis is essential for maximum efficiency over the management plane, particularly in cases where one point of failure may generate many redundant errors from all lower elements affected.

One example of multiple alarms generated by a single component failure involves the failure of a primary network uplink. Where the affected network element is capable of transmitting alarms though a path outside of the failed uplink, the central management systems will receive loss of connectivity for all lower elements (individual DSL elements). Alarm aggregation allows for cause analysis of a multitude of faults resulting in a single overarching alarm in cases where the alarms are related.

4. Summary

Next-generation networks require operation and management systems to continue to evolve in tandem with applications and services. A number of provisioning and management tools are available; others are conceptual or in the process of development. Most importantly, as competition for customers becomes fiercer, networks that minimize operational costs and yet continue to provide a superior customer experience will retain the best opportunity for successful business cases.

Self-Test

1. ________________ is defined as a minimum configuration built into hardware and software provisioned to a subscriber.

    a. service adjustment

    b. default configuration

    c. explicit configuration

2. ________________ is defined as an exhaustive examination of the subscriber's requirements.

    a. service adjustment

    b. default configuration

    c. explicit configuration

3. ________________ is defined as any change to the subscriber configuration after service initiation.

    a. service adjustment

    b. fault configuration

    c. explicit configuration

4. Each PVC request must evaluated on per-connection basis for availability and network resources required.

    a. true

    b. false

5. Which step in the configuration process follows the service request?

    a. request defined

    b. network capacity evaluated

    c. request authenticated

d. resources allocated

6. Which session routing mechanism allows individual IP packets to be placed in ATM virtual circuits depending on destination?

    a. PPP over ATM

    b. 1483 routing

    c. tagging and precedent bit setting

7. Which session routing mechanism requires that software drivers be installed into the subscriber system?

    a. PPP over ATM

    b. 1483 routing

    c. tagging and precedent bit setting

8. Which session routing mechanism allows applications to define several layers of service on a per-application basis?

    a. PPP over ATM

    b. 1483 routing

    c. tagging and precedent bit setting

9. Voice has the most stringent requirement for dependency and is the most affected application when the network experiences fault.

    a. true

    b. false

10. Network management does not include network maintenance.

    a. true

    b. false

Correct Answers

1. _________________ is defined as a minimum configuration built into hardware and software provisioned to a subscriber.

    a. service adjustment

    b. default configuration

    c. explicit configuration

    See Topic 2.

2. _________________ is defined as an exhaustive examination of the subscriber's requirements.

    a. service adjustment

    b. default configuration

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Glossary

AM
amplitude modulation

ATM
asynchronous transfer mode

BER
bit error rate

CBR
constant bit rate

CoS
class of service

DSL
digital subscriber line

HDSL
high-bit rate digital subscriber line

IP
Internet protocol

MOS
metal oxide semiconductor

NAP
network access point

NIC
network interface card

PC
personal computer

PPP
point-to-point protocol

PVC
permanent virtual circuit

QoS
quality of service

RFC
request for comment

RFI
radio frequency interference

SNR
signal-to-noise ratio

SVC
switched virtual circuit

UBR
unspecified bit rate

UNI
user network interface

VBR
variable bit rate

VoATM
voice over ATM

VOD
video on demand

VoIP
voice over IP

VPN
virtual private network