# Emerging Multiservice Network Architecture

## Definition

Multiservice network architecture combines the multiple layers of legacy architecture into fewer network elements, thereby removing barriers to operational efficiency and flexibility. Convergence creates a unified network that operates cohesively to promote efficiency, enhance service features, and offer cost savings—key elements of today's competitive marketplace.

## Overview

This tutorial examines major market trends leading to changes in legacy network architecture, which has become complicated and inefficient in its attempts to meet new telecommunications demands. It describes how that architecture has evolved and how it operates today. The next section compares the legacy network with the new converged network and examines the benefits of the new architecture. Finally, the tutorial describes the technology that enables this new paradigm.

## Topics

# 1. Introduction

Network service providers in today's deregulated telecommunications market have a tremendous opportunity to build competitive advantage into their network architectures. Market factors and technological advances are joining forces to enable service providers to offer unsurpassed service and feature capabilities and dramatically reduce the cost and complexity of building and operating their networks.

Emerging network technologies will soon render today's complex mix of network elements obsolete and will help network operators run simpler and more flexible networks. The array of equipment required to string together time-division multiplex (TDM), asynchronous transfer mode (ATM), and frame-based packet-switching functions has become increasingly complicated and inefficient. Network service providers must run separate operations for multiple network overlays. This requires expertise in multiple technologies with equipment from multiple vendors to manage each transport-network type. In addition to the expense of supporting this infrastructure, the length of time required to provision services from such a platform reduces network-operator competitiveness.

The new paradigm for building or expanding the network infrastructure, on the other hand, converges the functions of time-division backbone switches into fewer network elements. The result is an infrastructure that is simpler, less expensive to manage, and capable of delivering more sophisticated and flexible functions. These newer architectures remove barriers to operational efficiency and flexible provisioning by creating a unified network that can be operated and managed cohesively.

Converged architectures combine the functions of multiple layers of the open systems interconnection (OSI) network model into fewer pieces of equipment. This dramatically simplifies network topology and reduces capital investments and the cost of operations. In addition, this design significantly enriches service features because of the intelligent capabilities within the consolidated device.

Convergence is already occurring in the transport segment of many public network backbones through the integration of TDM–based, 3/3 digital cross-connect systems (DCSs) with ATM switches. Thus, the ATM switches provide both ATM switching and the 3/3 DCS function of grooming multiple, partially filled, distributed single-layer test method 3 (DS–3) links by aggregating traffic from them onto fewer, more fully utilized DS–3 circuits.

Many network cores have migrated from circuit-switched TDM platforms to packet-switched ATM infrastructures. ATM is run over synchronous optical network (SONET) or newer wave-division multiplexing (WDM) and dense wave-division multiplexing (DWDM) Layer-1 infrastructures.

After its success in the backbone, ATM switches or DCS convergence is now being extended to the access network, where the functions of legacy 3/1/0 DCSs are being integrated into a new generation of multilayer, multiservice access switches. Again, this consolidation will yield huge savings in equipment and operations costs. In addition, service providers will achieve more efficient utilization of access bandwidth, while building a network with unprecedented flexibility, simplicity, scalability, and manageability.

# 2. Major Market Trends Affecting Carrier Network Architectures

Several industry trends are fueling the evolution to new public switched–network architectures. These factors are discussed in the following paragraphs.

## Data Traffic Explosion Exposes TDM Inefficiencies

The different characteristics of voice and data traffic have been well recognized in the industry. Data traffic tends to be bursty, consuming large volumes of bandwidth for occasional, short intervals. Legacy TDM circuit-based networks, on the other hand, were originally designed to carry more predictable streams of voice traffic, and they do not efficiently support bursty data traffic. With data growth now outpacing voice, service providers face important challenges and must shed the baggage of inefficient TDM infrastructures while preserving the integrity and quality of private-line and voice traffic through the use of ATM classes of service (CoS). Service providers are also optimizing their networks to handle rapidly growing volumes of bursty data traffic through the use of statistical multiplexing, which enables an entire transmission medium to be filled with packets. This is a more bandwidth-efficient mechanism than dedicating connection-oriented TDM circuits to particular applications, which wastes bandwidth while circuits sit idle during periods when nothing is transmitted.

## Demand for Connectivity Experiences Explosive Growth

Service providers face the challenge of connecting an enormous number of diverse, relatively low-speed access services into their high-speed backbones. Supporting a wide range of access interfaces is a potentially complex and expensive undertaking but is necessary if all customers are to be served.

Because of their installed infrastructures and preferences, for example, some customers demand private-line connectivity, while others require frame relay, Internet protocol (IP), or dial-up point-to-point protocol (PPP) connections. Still others are ready to buy DS–1–speed ATM access links or use inverse multiplexing for ATM (IMA), which combines multiple DS–1/E1 lines into one logical interface for integrated voice and data access.

These new market dynamics represent the potential to achieve the following goals:

- engineering dense support of access services into the network and supporting typical copper rates of DS–0 (e.g., 64 kbps), fractional DS–1, DS–1, and inverse multiplexed n x DS–1
- designing the network to adapt to the changing service mix for private line, frame relay, IP, PPP, ATM, IMA, and other access technologies
- designing the network for integrated access of voice and data over a common DS–1 line; this is TDM–integrated access today, evolving to ATM integrated access tomorrow

## Service Providers Require More Flexible Network Platforms

The pace at which new network services and features are being developed is faster today than ever before. As the race to acquire market-share becomes increasingly fierce, the service providers who will have the competitive edge are those who can most rapidly introduce new services and respond to customers' changing needs. This agility hinges on network infrastructures with a rich set of features and functionality, the support of multiple interfaces, and distributed, software-defined intelligence.

## Service Providers Seek Ways to Minimize the Cost of Providing Service

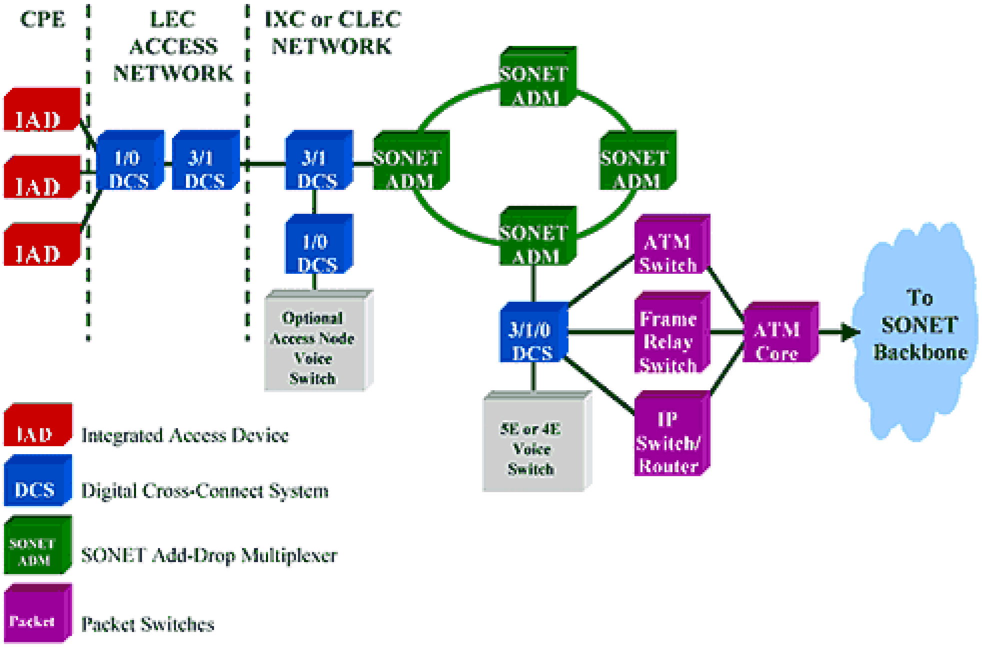
As network technologies mature, price tends to become one of the dominant selection factors for purchasers of network services. To compete on price, service providers must contain the cost of provisioning these services by squeezing as much expense as possible out of service provisioning and support.

Service providers must tightly manage network-infrastructure costs to be able to build and expand networks rapidly. In addition, operations can represent a large portion of the life-cycle costs and can be heavily influenced by the network architecture's inherent manageability, flexibility, and simplicity. As a result, the network service provider must design a cost-efficient network, avoiding layers of legacy network elements and their associated operational complexity and high costs.

## 3. Provisioning Integrated Services on Legacy Platforms

Many challenges are associated with provisioning integrated services using a legacy architecture, as shown in *Figure 1.*

**Figure 1. Integrated Services on a Legacy Network Architecture**



Note: the DCS provides both voice and data segregation and DS–0/DS–1/DS–3 grooming.

Voice-data overlay networks result in duplicate equipment and facilities. In addition, running separate operations for Layers 2 and 3 (transport and network layers) yields high costs and slows down service provisioning. These networks are also more difficult to troubleshoot. Legacy networks have evolved into a complex mix of equipment because of advances in technology, regulatory changes, and evolving customer demand that have caused service providers to tack new capabilities onto them over the years. Generally, the architecture that was designed more than thirty years ago to carry constant-bandwidth voice circuits has been incrementally augmented with overlay components to carry data traffic.

The copper local loop used to access public network services can carry voice and data over separate DS–0s. TDM DCSs are deployed to separate voice and data and to groom multiple, partially filled DS–1s onto full DS–1s. TDM DCSs were created for fixed-bandwidth circuits; as such, they are part of an outdated network architecture and tend to impose a costly operational burden.

The operations and management systems of these DCSs are not compatible with newer data services–management systems, thus requiring the service-provisioning process to cross multiple departments, systems, and personnel. This situation increases the cost of service provisioning, can cause provisioning delays, and can introduce a high margin for error—factors that could result in the loss of frustrated customers. Once provisioned, the ongoing operations, troubleshooting, and fault management again require multidepartment, multisystem coordination.

Today, it is in the high-speed SONET transport backbone that voice, private line, and data are finally integrated, albeit using inflexible TDM to handle traffic. This infrastructure migrates to a more dynamic platform based on ATM, which operates using more efficient statistical multiplexing to aggregate traffic in a more scalable fashion.

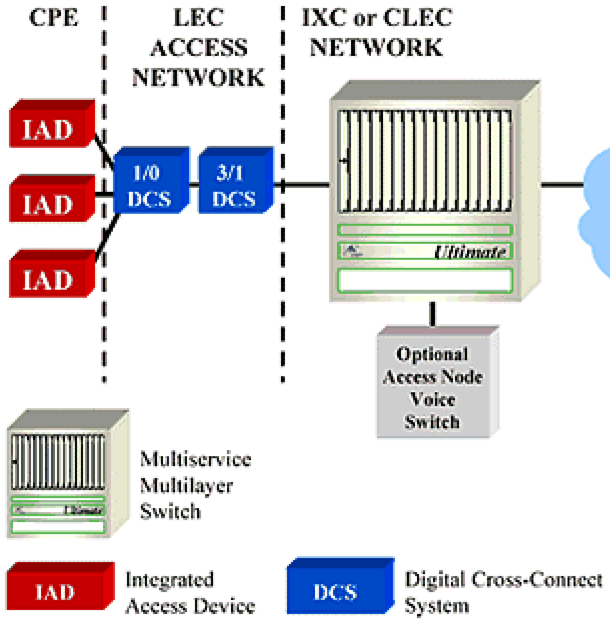
As a quick fix for the equipment-complexity problem at smaller network access points, some service providers back-haul traffic across a SONET ring or a DS–3/OC–3 pipe to a larger point of presence (POP) by means of TDM technology. This system, however, constitutes an inefficient use of trunk-bandwidth resources. At this larger POP, DCSs are used again to distribute different types of traffic to different network components such as voice switches, frame-relay switches, IP switches and routers, and ATM switches. In many networks, this traffic must once again converge onto a common ATM backbone, causing an inefficient series of aggregating and splitting traffic.

The problems of these legacy network architectures can only be solved by embracing the new technologies that are designed to address the service providers' evolving opportunities and challenges described in the previous section. *Topic 4* explores how emerging technology can remedy the problems and give service providers who embrace this new technology a competitive edge.

# 4. The New Converged Multilayer Switch Platform

By leveraging an architecture based on multilayer switching, as shown in *Figure 2*, service providers can dramatically simplify their networks, offer a richer set of services, and gain flexibility while significantly reducing the cost of infrastructure and operations. A multilayer, multiservice switch combines circuit-switching and DCS functions at Layer 1 with Layer 2 or 3 packet-switching functions in a single device. In addition, the same switch supports multiple types of packet services via an integrated multiprotocol engine. The architectural integration of these key components into a single unified system offers an elegant solution with the simplicity, scalability, and efficiency required to handle many complex functions.

**Figure 2. Simplified Network Architecture Using a Multiservice, Multilayer Switch**



A multilayer, multiservice switch enables multiservice access to an ATM backbone, including support for frame relay, IP, PPP, and ATM access interfaces. It also supports channelized voice and data streams on an integrated TDM access link and support for voice over an ATM virtual circuit in the backbone using circuit emulation services (CES).

The resulting converged network architecture offers service providers a cost-effective, simple, scalable, and manageable network infrastructure with the following features:

- simplified network design
- unified operations for transport and data layers
- lower cost of equipment and operations
- bandwidth efficiencies of statistical multiplexing in access and backbone network segments
- voice and data integration in access and backbone network segments
- TDM and packet convergence over an ATM network

- single-step, end-to-end provisioning of private lines with automatic rerouting and restoration

Some key aspects of this network architecture include the following:

- **raw transport**—For an interexchange carrier (IXC) or a competitive local exchange carrier (CLEC) leveraging the access capabilities of an incumbent local exchange carrier (ILEC), the ILEC provides raw transport, aggregated by DCSs, with no awareness of which TDM DS–0 is used for which service or how to groom it. The IXC or CLEC, which provides service to the end user, however, should leverage such intelligence to run a more efficient network and enable service flexibility. Once traffic hits the IXC/CLEC's network, it can go straight into a multilayer, multiservice switch with integrated DCS capabilities. From there, integrated voice and data traffic can be handled in whatever way is necessary.

- **voice and data integration on the access link**—If the customer integrates voice and data traffic using TDM multiplexing over a DS–1 circuit, the integrated DCS function in a multilayer, multiservice switch can split the voice and data and direct each stream to the appropriate long-haul network. If the voice switch is in the same POP, the voice traffic can be handed off over the TDM interfaces to the voice switch with the appropriate mapping of signaling formats. If the voice switch is at another POP, the groomed voice traffic can be transported over ATM CES to the remote voice switch. If the customer integrates voice and data traffic in the access network using ATM, the ATM switching fabric in a multilayer, multiservice switch can segregate the voice and the data traffic for handoff to the appropriate long-haul network. If the voice switch is in the same POP, the voice traffic must travel across the derived TDM interface to the voice switch. If the voice switch is at another POP, the integrated ATM traffic is switched to that destination, and then voice is split off and delivered to the voice switch.

- **the important role of integrated access DCSs**—The integrated access (3/1/0) DCS function, with full access to DS–0s within every DS–1/DS–3, enables the integrated access of voice and data on a single DS–1 or fractional DS–1 customer access circuit. The mapping of common channel signaling (CCS) or channel associated signaling (CAS) enables intelligent connectivity to a co-located or remotely located voice switch. These are important functions, once performed by a stand-alone DCS, that are incorporated into a multilayer, multiservice switch at a fraction of the cost and space required for a stand-alone DCS. The integrated DCS function of a multilayer, multiservice switch also takes care of packing partially filled TDM pipes to full density before handing them off to the integrated protocol engines to optimize the performance and cost of a multilayer, multiservice switch.

- **cost savings from elimination of stand-alone DCS**—The cost savings of convergence are already being designed into the transport backbone, which is migrating from TDM to ATM/SONET, ATM/WDM, or ATM/DWDM and is incorporating the 3/3 DCS functions into the backbone ATM switch. Now this convergence can be extended to the access network.

  The network architecture leveraging this integrated DCS function in a multilayer, multiservice switch can eliminate the legacy stand-alone DCS, resulting in savings of $500 to $700 per DS–1 in network equipment. This translates into saving as much as half the cost of overall access equipment, up to a third of the total network equipment cost for data services, and up to 50 percent in the cost of operations.

- **service agility**—The multiservice protocol engine functionality of a multilayer, multiservice switch supports the full array of data services that customers demand, including frame relay, IP/PPP, ATM DS–1, and IMA. It also supports private lines by circuit emulation and their various service features, such as network and service interworking, switched virtual circuits (SVCs), usage billing, quality of service (QoS), and monitoring and control for service-level agreements (SLAs). The multiprotocol engine supporting these various services has been designed to adaptively incorporate new protocols in the future.

- **scaling the network edge and the backbone**—The edge of the network can now scale to incorporate more kinds of traffic, a greater number of physical locations, higher density, and increased service bandwidth. At the same time, service providers can scale the backbone bandwidth at the core of their networks. A multilayer, multiservice switch routes traffic from a remote switch through the ATM backbone, which need not deal with the complexity of different services and service intelligence, allowing the ATM backbone to be simple, efficient, and scalable.

- **simplified provisioning, rerouting, and restoration for private lines**—With the routing and traffic management intelligence of this new converged network, private lines can be provisioned across the network in a single step, rather than using manual or rule-based segment-by-segment provisioning. In the event of any severe network conditions or failures, rerouting or restoration happens automatically.

- **operations simplicity and manageability**—Thanks to the new multilayer switching architecture, provisioning the TDM access portion and the packet or ATM service portion can all be accomplished using a single network component in a single step. The same is true for ongoing operations, fault isolation, troubleshooting, and all other management functions.

Leveraging the multilayer switching architecture, the service provider can flexibly provide any service (e.g., voice, private line, and advanced data service) at any time to any customer's port. Further, the same customer could use a mix of these services, and the service provider could easily and flexibly alter this mix to meet the customer's needs at different times with just a few simple keystrokes at the management system console. The operations cost savings can easily reach up to 50 percent.

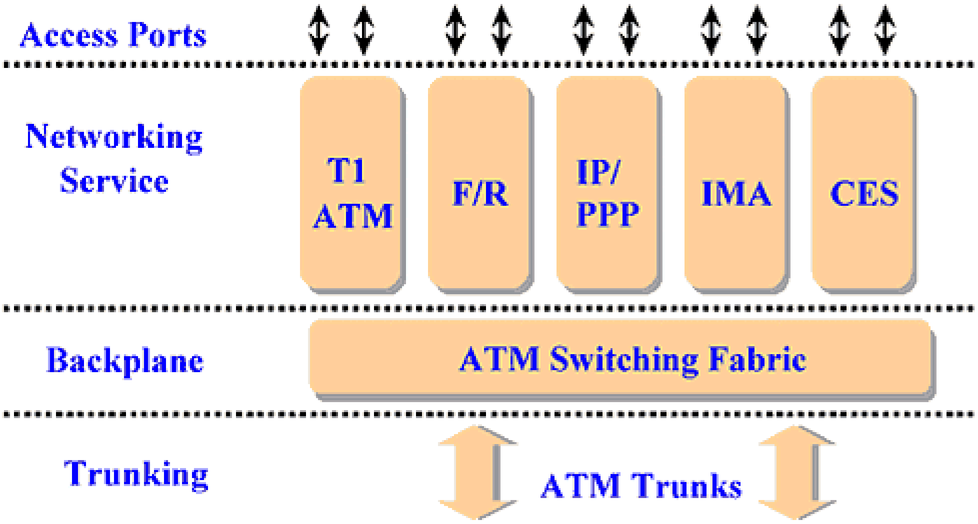
Instead of disparate operations environments for the access and backbone portions of the network, service providers achieve a unified operations environment that is simple and efficient, resulting in enormous savings. Instead of a rigid, fixed service–network infrastructure, the newer, more agile network not only delivers any service that any customer might request today, but enables the service provider to provision new services on the existing infrastructure quickly. Service providers obtain a future-proof network that gives them an unprecedented competitive edge—the edge to race to market leadership.

## 5. Multilayer Switching Architecture

Early multiservice devices emerged in the market as an afterthought when vendors added a hodgepodge of ATM, switched multimegabit data service (SMDS), and IP cards into frame-relay switches.

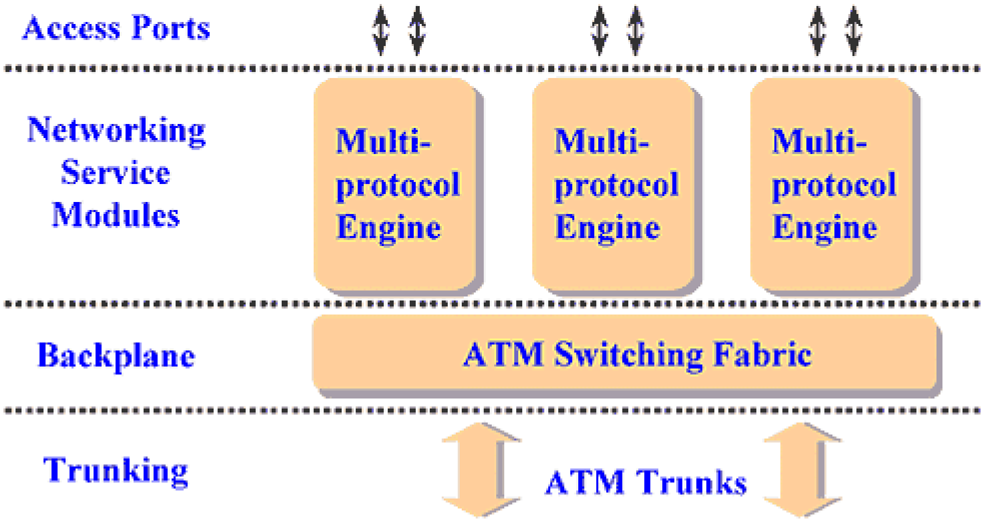
Following that, the first generation of multiservice switches used a switching fabric based on ATM technology, which was specifically designed for supporting multiple services (see *Figure 3*). These products offered better integration of multiple advanced data services into a common chassis and avoided the necessity of purchasing and managing several different switches to support many different protocols. However, these switches still required protocol-specific hardware within each chassis to cope with the varying needs of customers and suffered from the high cost of implementing several protocol engines. The result was poor protocol and service agility.

**Figure 3. First-Generation Multiservice Switches**



The second generation of multiservice switches introduced the breakthrough concept of any service on any port at any time. ASAP@ multiprotocol uses a software-defined network infrastructure, as shown in *Figure 4*. An ASAP@ multiprotocol engine allows the configuration of any advanced data service on any customer port, without requiring a varied inventory of protocol-specific hardware modules. No juggling of cables and connectors to configure services is necessary; all services are provisioned on a software-defined basis by the touch of a keyboard in a network operations center.

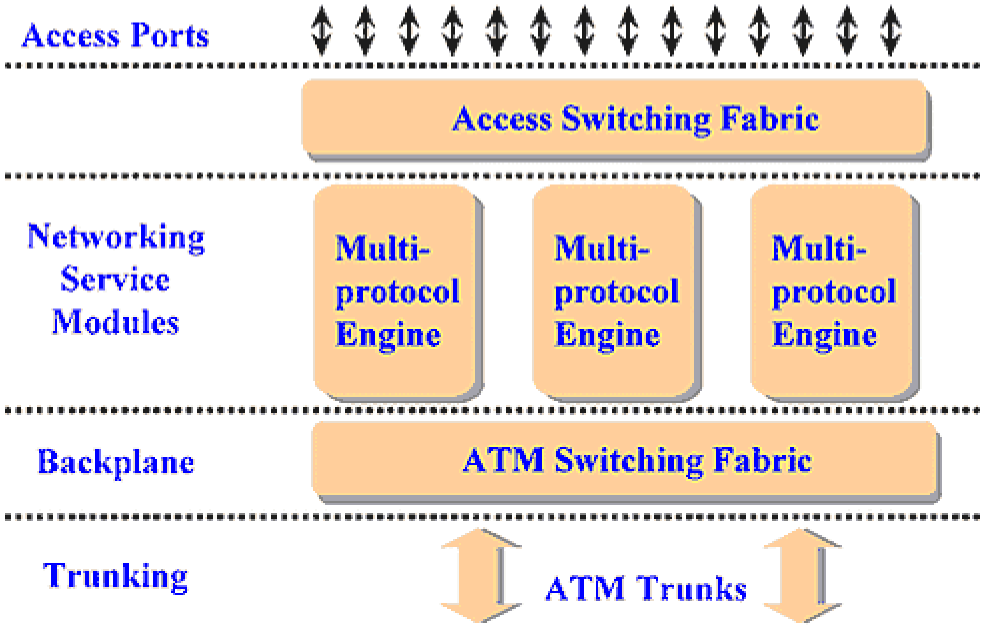
**Figure 4. Second-Generation Multiservice Switches**



The third generation of multiservice switches revolutionizes the entire network architecture through integration and multilayer switching, as shown in *Figure 5*. Integrated circuit and packet switching occurs on the access side, while ATM–

based packet switching takes place in the backbone. In between the two switching fabrics resides the full array of protocol engines, enabling an enormous number of various access interfaces to be accommodated.

**Figure 5. Third-Generation Multilayered Switching**



Multilayered, converged networks are the answer to the service providers' problems of disparate network operations, expensive equipment infrastructure, and inefficient utilization of expensive facilities. They provide a way for service providers to respond quickly to the exploding service demand with a rapidly evolving service and feature mix.

## 6. Conclusion

The emergence of the new multilayer, multiservice switching technology presents the potential to revolutionize the way networks are built. Service providers who embrace this new technology and construct the new converged network have the opportunity to build unprecedented competitive advantage right into their networks and to rise to market leadership in the historic race for market-share in the deregulated telecommunications market.

## Self-Test

1. Data traffic is characterized as which of the following?

    a. a predictable stream, like voice traffic

   b. a predictable stream, unlike voice traffic
   c. bursty, like voice traffic
   d. bursty, unlike voice traffic

2. Statistical multiplexing is efficient for bursty traffic because it accomplishes which of the following?
   a. fills the transmission medium with packets, which can be utilized as needed
   b. allows the circuit to sit idle when nothing is being transmitted
   c. dedicates connection-oriented TDM circuits to particular applications
   d. devises a queue for traffic

3. The agility to respond to customers' changing needs fastest comes from which of the following sources?
   a. network infrastructures with a rich set of features and functionality
   b. the support of multiple interfaces
   c. distributed, software-defined intelligence
   d. all of the above

4. Legacy voice-data overlay networks accomplish which of the following tasks?
   a. lower costs
   b. duplicate equipment and facilities
   c. speed up service provisioning
   d. make troubleshooting easier

5. Voice, private line, and data are integrated today in the __________.
   a. TDM DCS
   b. copper local loop
   c. SONET transport backbone
   d. none of the above

6. Leveraging an architecture based on multilayer switching provides which of the following benefits?

   a. simplifies the network

   b. provides flexibility to offer a wider range of services

   c. reduces the cost of infrastructure and operations

   d. all of the above

7. Which of the following is an advantage of the first-generation multiservice switches?

   a. support for many different protocols

   b. a variety of protocol-specific hardware in each chassis to meet customer needs

   c. better integration of multiple advanced services into a common chassis

   d. both a and c

8. Which of the following is a disadvantage of the first-generation multiservice switch?

   a. support for many different protocols

   b. a variety of protocol-specific hardware in each chassis

   c. better integration of multiple advanced services into a common chassis

   d. no need to purchase and manage several different switches to support many different protocols

9. The breakthrough concept of the second generation of multiservice switches was which of the following?

   a. SONET

   b. QoS

   c. ASAP@

10. The third generation of multiservice switches _______________.

   a. like its predecessors, provides ATM–based packet switching in the backbone

   b. requires a varied inventory of protocol-specific hardware

   c. scraps the software-based network infrastructure used in second-generation switches

   d. requires physical manipulation of cables and connectors to configure services

## Correct Answers

1. Data traffic is characterized as which of the following?

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   **d. bursty, unlike voice traffic**

   See Topic 2.

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See Topic 5.

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    d. requires physical manipulation of cables and connectors to configure services

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# Glossary

**ASAP@**
a multiprotocol that enables any service on any port at any time

**ATM**
asynchronous transfer mode

**CAS**
channel associated signaling

**CCS**
common channel signaling

**CES**
circuit emulation services

**CLEC**
competitive local exchange carrier

**CoS**
class of service

**DCS**
digital cross-connect system

**DWDM**
dense wave-division multiplexing

**ILEC**
incumbent local exchange carrier

**IMA**
inverse multiplexing for ATM

**IP**
Internet protocol

**IXC**
interexchange carrier

**OSI**
open systems interconnection

**POP**
point of presence

**PPP**
point-to-point protocol

**QoS**
quality of service

**SLA**
service-level agreement

**TDM**
time-division multiplexing

**WDM**
wave-division multiplexing