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Contemporary data networking technology is changing in ways that require network managers to rethink their assumptions about how networks should be designed. Traditionally, the LAN environment has been distinct and separate from the Wide Area Network environment. When it was necessary to send LAN traffic to a remote location, the solution was to introduce routing technology to transfer data between the LAN and WAN environments. This model, in which LANs and WANs communicated over a relatively low throughput, difficult-to-configure, expensive interface, will not work in the future as the volume of traffic between the WAN and LAN environments increases dramatically. For many of today's corporate network environments, there is now a better solution. As traffic becomes increasingly WAN-oriented and the disparity between LAN and WAN wire speeds decreases, the technical distinctions between LAN and WAN networking has been considerably reduced. Today's technologies offer the ability to design a data communication environment based on switching technology that integrates LANs and WANs to achieve high performance, cost-effective networking solutions. This Guide examines the issues involved in integrating LANs and WANs, highlights developments that have created a synergy between these previously disparate environments, and illustrates the value and importance of integrated LAN-WAN switching technology in satisfying user requirements.

Introduction

Enterprise networks have changed dramatically over the last decade, partly because of their increasing contribution to business success, but also due to radical improvements in technology and the explosive growth of the Internet. The most recent wave of change has been the emergence of high speed LAN and WAN switching. Switch-based networks blur the distinction between local area and wide area, and are promising an era in which communications is virtually seamless across the enterprise and beyond. Integration of LAN and WAN switching offers new opportunities to satisfy end-user requirements in ways that are more efficient, more affordable, and more universal than ever before. Many experts argue that switching technology has become the critical networking technology for the foreseeable future.

This Guide examines the issues involved in LAN-WAN integration and helps the network designer understand how switching technology is being used to achieve this integration. It will explain the convergence of previously independent network environments and disparate networking technologies, and show the value and importance of merging LAN and WAN traffic into an integrated switching environment.

The Changing Application Environment

LANs were initially deployed to share expensive office resources (printing and disk storage, for example). However, as LAN technology has matured, the variety of user applications that generate network traffic have increased dramatically. In a typical corporate network, applications such as database access, electronic mail, distributed scheduling calendars, shared files, collaborative documents, and Internet browsing are now common place. But this is only the beginning. In the near future, multimedia applications that generate real time video or audio network traffic will begin to be used in important applications. The critical common element among these new applications is that their full benefits cannot be realized without a high performance data communication infrastructure.

As users seek to take complete advantage of these new applications, networks that were once independent
and isolated will need to be fully integrated into the corporate environment. It has become a common network design for multiple remote office locations to be tied into a central corporate facility for server and application support. Not only is access to the corporate network a requirement for many remote offices, it is often desirable even for customers and suppliers. It has been historically true that 80% of the traffic on the LAN has remained within the same network segment, while 20% traveled to off net locations. However, in the future, this traffic pattern is likely to be completely reversed, with 80% of traffic destined for remote addresses.

In order for these new networked applications to be useful to all users regardless of their geographic location, new strategies for LAN/WAN integration are rapidly evolving. To achieve this integration, certain critical technical issues must be addressed:

- the imbalance in transmission speeds between LAN and WAN technologies, and
- the connection oriented approach of WAN technologies versus the connection-less oriented approach of LAN technologies.

LAN Versus WAN: Transmission Speed Differentials

Historically there has been a quantum difference in transmission speeds between LAN and WAN technologies. However, the improvements in transmission speeds that have been achieved in both LAN and WAN technologies has implications for the integration of these two domains that needs to be understood.

SPEED IMPROVEMENTS IN THE LAN: Shared vs. Switched Access

When Ethernet technology was introduced in the 1970's, a quiet revolution began. The concept of a communication media transmitting information at a rate of 10M bps was just short of astonishing. But what may be equally amazing is that twenty years later, this 10M bps Ethernet technology is still key in network design. However, the way in which 10M bps Ethernet is used in contemporary network design is dramatically different from the way it was used 20 years ago. Originally, Ethernet served as a shared medium backbone among all of the devices in the network. At that time, 10M bps was tremendously more bandwidth than could be utilized by any single device connected to the network. As a result, it was not uncommon in early Ethernet networks for there to be several hundred devices all sharing a single Ethernet segment.

However, the advance of computer workstation and networked applications technologies during that same time frame has given everyone in the organization a desktop networked computer that is capable of transmitting a sustained 10M bps bandwidth on its own. As a result, audio and video applications, which require a high speed, constant rate transmission, are introduced onto the LAN, the original Ethernet, with its shared media design, will be unable to keep up. This has created a need for new LAN technologies that address the requirements for increased network bandwidth.

Since the advent of Ethernet, there have been a variety of other LAN technologies that have been introduced to solve this problem. Some of these new technologies, such as FDDI and Fast Ethernet simply increase the speed of the shared media (to 100M bps or 1G bps for Ethernet), which minimizes (but does not eliminate) the chances of network traffic collisions. Other new technologies, such as Switched Ethernet
and ATM, provide a dedicated channel for network devices, thereby eliminating traffic collisions altogether. The adoption of Ethernet switching technology allows each workstation to be given its own dedicated 10Mbps channel, thereby eliminating bandwidth sharing and network traffic collisions.

No one of these new technologies will be used to the exclusion of all others. In fact, various combinations of these technologies are already proving to be successful in the market. However, in consideration of the increasing need for real time data transport, it is likely that the switching technologies will be the most important in the long run. The various LAN technologies that have provided significant bandwidth improvement are shown in the table below:

<table>
<thead>
<tr>
<th>Technology (Speed)</th>
<th>Released</th>
<th>Approximate Increase over 10Mbps Ethernet</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDDI (100 M bps)</td>
<td>1987</td>
<td>X 10</td>
<td>Shared media technology. Widely used as a backbone technology connecting to workgroups through routers.</td>
</tr>
<tr>
<td>Switched Ethernet (10 M bps)</td>
<td>1991</td>
<td>X 0</td>
<td>Improves Ethernet performance by reducing the number of users sharing the 10Mbps bandwidth.</td>
</tr>
<tr>
<td>Fast Ethernet (100 Mbps)</td>
<td>1994</td>
<td>X 10</td>
<td>Shared media technology. Rapidly adopted for backbone and workgroup applications.</td>
</tr>
<tr>
<td>Switched Fast Ethernet</td>
<td>1995</td>
<td>X10</td>
<td>Improved Fast Ethernet performance by reducing the number of users sharing the 100Mbps bandwidth.</td>
</tr>
<tr>
<td>ATM - OC3 (155 M bps)</td>
<td>1993</td>
<td>X15</td>
<td>Switched technology. Supports LAN &amp; WAN backbones. Supports QoS.</td>
</tr>
<tr>
<td>Gigabit Ethernet (1000 M bps)</td>
<td>1997</td>
<td>X100</td>
<td>No significant usage yet. No WAN support.</td>
</tr>
</tbody>
</table>

Each of these various technologies provides improved performance relative to the original Ethernet shared media environment. Those new LAN technologies that have been most widely adopted have increased the original 10Mbps Ethernet bandwidth by a factor of 10 to 15 times.

**SPEED IMPROVEMENTS IN THE WAN: Dedicated versus Switched Circuits**

Transmission speeds for wide area networks have, until recently, been relatively slow. Even now, in the late 90’s, T1 bit rate of 1.544M bps (2.048 in Europe) is considered to be a relatively high speed WAN transmission. In fact, BRI-ISDN circuits, which only provide full duplex 64Kbps, are being used for many WAN applications. However, as with LAN technologies, the transmission speed of WAN technologies must increase in order to accommodate new network applications.

Recognizing the need for faster transmission speeds, many WAN service providers have begun to offer new data transmission services that are changing the perception that transmission speeds in the WAN are relatively slow. The most important of these services are Frame Relay and ATM, which provide scaleable transmission speeds from T-1 (1.544 M bps) up to OC-3 (155 M bps). Frame Relay services are now available from a number of service providers at speeds of 4, 6, or 8 M bps, and increases to DS-3 speeds (45 M bps) will be available in the near future. In addition, ATM services are being introduced that will operate at speeds as low as T-1, but will also scale up to 155 M bps, and ultimately 622 M bps.

It is significant to observe that the new WAN technologies that are being introduced to deliver higher transmission speeds are all based on cell and frame switching technologies, rather than on dedicated leased line circuits. Traditionally, WAN data services have
been provisioned using dedicated point-to-point circuits. However, over time, service providers realized that such dedicated circuits usually wasted significant amounts of bandwidth which could otherwise be supplied to other customers. As a result, WAN data switching services, such as Frame Relay, which allow a much higher utilization of the service provider’s transmission capacity, are becoming the more common WAN technology.

Frame Relay not only makes better use of the service provider’s transmission capacity, but also lowers the cost of WAN services to the customer.

The following table shows the improvement in data rates for various WAN technologies in comparison to the 64 Kbps DS-0 circuit which has been a standard offering from all WAN service providers for many years.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Introduced</th>
<th>Approximate Increase over DS-0 Circuit</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISDN</td>
<td>1987</td>
<td>X 2</td>
<td>Important improvements include the complete replacement of analog with digital facilities</td>
</tr>
<tr>
<td>(64Kbps FD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-1</td>
<td>1970</td>
<td>X 24</td>
<td>Traditionally used in enterprise WANs for leased line service</td>
</tr>
<tr>
<td>(1.544Mbps)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-3</td>
<td>1980</td>
<td>X 600</td>
<td>Traditionally used for high capacity leased line service for large network backbones</td>
</tr>
<tr>
<td>(45Mbps)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame Relay (T-1 to T-3 speeds)</td>
<td>1989</td>
<td>X 24</td>
<td>Originally offered at T-1 speeds. New services being offered at 4M bps, 8M bps, and up to T-3 (45Mbps) speeds.</td>
</tr>
<tr>
<td>ATM-OC3 (155Mbps)</td>
<td>1993</td>
<td>X 1800</td>
<td>No significant usage yet.</td>
</tr>
</tbody>
</table>

Bridging the Transmission Speed Gap

As a result of the transmission speed differences between the LAN and WAN technologies, specialized network devices had to be designed before LANs and WANs could be interconnected. In fact, this transmission speed imbalance was one of the original justifications for Router technology. With such a transmission speed imbalance between the WAN and LAN, it was absolutely essential to route traffic based on Layer 3 protocols, rather than to bridge traffic based on Layer 2 protocols, so that the relatively limited bandwidth available on the WAN was allocated in the most efficient manner.

As a consequence, most existing Enterprise networks use routers to connect the WAN and LAN technologies. A typical configuration would include a LAN switch linked to a multi-protocol router, as is illustrated in the following figure.

As long as the WAN transmission speed was so much slower than that of the LAN, this latency and processing overhead were not an issue, since they were not the primary transmission bottlenecks.

However, as the transmission speeds of WANs and LANs continue to approach parity, the latency and processing overhead associated with this traditional configuration becomes a real performance issue. This can be overcome by providing an integrated LAN-WAN switching device to replace the awkward combination of a LAN switch and a WAN router.
Such an integrated LAN-WAN switching device could incorporate some limited routing functionality, but would not be subject to the latency problems of routers. If WAN and LAN transmission speeds are balanced (i.e. equalized), the need to install routers for speed adaptation between the LAN to the WAN will be reduced significantly. And, in an all ATM networks, there may be no need to install routers at all. It certainly will not be possible to eliminate the need for some routing functions such as protocol conversion, address resolution, firewall protection, and more, but for an increasing number of network configurations, the necessity of elaborate router deployment between all WAN - LAN interfaces will be significantly reduced. In many cases, routing functionality can be replaced by switch technologies such as VLANs.

The reduced need for routers in the LAN-WAN interface comes as good news, because it is increasingly difficult for traditional routers to support the large volumes of traffic generated by new network applications and increased use of both the Internet and corporate intranets. The transition away from routing to switching technology is playing an essential role in enabling the integration of WAN and LAN technologies into seamless networking. Ultimately, the integration of WAN and LAN switching functionality will improve both cost and performance in enterprise networks.

LAN Versus WAN: Connection-Less or Connection-Oriented

It would be nice if the integration of LAN/WAN switching could be achieved merely by reducing or eliminating the transmission speed imbalance. Unfortunately, this is not the case. Historically, LAN and WAN technologies have been based on diametrically opposing concepts: the LAN originated as a connection-less technology, whereas the WAN has been a connection-oriented technology.

The difference in these concepts is fundamental and relatively straightforward. A connection-oriented technology requires that either a physical or logical communications path must be established between the sender and receiver before traffic can be forwarded. The traffic stream is then sent contiguously over that path. A connection-less technology does not establish a preset path but, instead, includes routing information in the header of each frame, from which a route is selected for each frame as it moves through the network to reach its destination.

Attempts at merging these two disparate technical concepts has been a central problem in achieving the integration of LAN and WAN technologies. Once again, routers evolved to perform the critical function of mapping connection-less LANs, such as Ethernet or Token Ring, into connection-oriented WANs, such as Frame Relay. However, the performance bottleneck that traditional stand-alone router devices are beginning to create, as previously described, has made it increasingly difficult to maintain that paradigm.

When ATM was first introduced, it was hoped that this connection-oriented technology could meet the network switching requirements for both the LAN and the WAN, thereby achieving an integration of the LAN-WAN functions into a single switch technology. However, the overwhelmingly large, and growing, installed base of Switched Ethernet has made it impractical to create a LAN-WAN switching environment based entirely on ATM. Consequently, in order to achieve the integrated LAN-WAN switching environment, there is a great need to develop a technology that merges the Ethernet switching environment with ATM, as well as with other connection-oriented technologies such as Frame Relay.
The integration of ATM with legacy Ethernet LANs has proven to be complicated. A variety of strategies for such integration have been proposed, most of which involve some coordination between Layer 2 and Layer 3 (mostly IP) protocols. These include:

- VLANs,
- Classical IP over ATM,
- LANE,
- MPOA,
- Tag Switching, and
- IP Switching.

**VLANS**

Virtual LANS, or VLANs, have been a topic of discussion in the networking industry since the early '90s. The VLAN theory is that end devices can be configured in logical rather than physical grouping as traffic demands dictate. However, most of the potential benefits of VLANs have not been fully realized. Furthermore, most vendors viewed VLANs as an opportunity to sell value-added differentiated capabilities which only served to make VLAN technology less attractive due to the incompatibilities between different vendors implementations. However, when integrating LANs and WANs, VLANs can be very useful as a tool for mapping a connection-less LAN domain into a connection oriented WAN domain.

For example, in the previous section, a network configuration was described that combined a Switched Ethernet LAN backbone with an 8 M bps Frame Relay WAN backbone. Carrying this example further, let's assume that there are three sites, each with a Switched Ethernet LAN and with an 8M bps Frame Relay backbone connecting them together (see following diagram).

In this configuration, VLAN technology could be used nicely to guide network traffic between the three locations. By mapping the VLAN structure defined in the Ethernet Switches to Frame Relay PVC’s, it would be possible to direct traffic between the three locations in a very efficient manner without the use of routers. In this example, the Frame Relay PVC’s would provide the connectivity once the mapping between the Ethernet VLAN and the Frame Relay PVC were defined. Of course, this configuration is only possible using a network communication device that combines Ethernet Switching with Frame Relay switching.

The use of VLANs to map connection-less LAN traffic to the appropriate WAN virtual circuit is an attractive solution due to its simplicity and high performance. However, routing of inter-VLAN traffic will still be required, as will initial path determination for the WAN. The best integrated LAN-WAN Switch solutions include inter-VLAN routing as an optional capability to provide a common routing engine between the LAN and WAN switching environments. Without such an internal capability, it becomes necessary to connect an external router to the switch, thereby sacrificing performance, reducing usable switch ports, and increasing costs.
Classical IP over ATM (RFC 1577)

Classical IP over ATM was proposed by the IETF as a method for integrating connection-less LAN environments with a connection-oriented ATM backbone environment. Far from eliminating or minimizing the function of routers in a network, this approach actually utilizes router technology heavily. In this model, ATM PVC’s (permanent virtual circuits) are pre-configured to connect ATM edge devices to a router, where each edge device is assigned its own IP subnet address. In a larger network with multiple routers, PVC’s are pre-configured to connect routers together (see diagram). As a result, all traffic between IP subnets must still be forwarded by the router (or multiple routers in a larger network). There is no ability in this model to establish ATM SVC’s (switched virtual circuits) between edge devices to “cut through” the router-based IP subnet structure and take full advantage of the ATM switching technology. Furthermore, this approach does not take advantage of the QoS capabilities provided by ATM.

Therefore, although this approach achieves integration between connection-less and connection-oriented technologies, it fails to take advantage of some of the greatest benefits provided by the connection-oriented switch technologies. Considering the performance bottlenecks that routers are creating, this approach is unlikely to be viewed as an effective method of integrating the two environments.

ATM Forum LAN Emulation (LANE)

The ATM forum has developed a standard for integrating the legacy LAN environments with ATM called LAN Emulation (LANE). In this model, multiple Ethernet LAN segments can communicate with one another through an ATM backbone without any routing functionality required. This is accomplished by using the ATM backbone to perform Layer 2 bridging between the edge devices that are all members of a single emulated LAN. There are several significant issues with this approach.

- **Performance**: Different emulated LANs using the same ATM backbone cannot communicate with one another without an external router function. In other words, there is no “cut through” switching between two emulated LANs connected to the same ATM backbone.

- **Scalability**: LANE essentially establishes a Layer 2 bridged environment between the various LAN edge devices that are members of a particular emulated LAN. This introduces the potential for propagation of broadcast traffic throughout the network, which can adversely affect network performance. To avoid this, the number of devices in each emulated LAN must be limited.

- **Management**: The configuration and operation of an emulated LAN is fairly complex, due to the various specialized LANE functions that must be performed in the ATM network.

- **Reliability**: Depending on how a LANE environment is configured, there is a potential for a single point of failure, which reduces the reliability of the LANE environment.
**Service Attributes:** The ATM QoS standards are completely ignored, so that no QoS features are provided.

**PNNI:** Private Network to Network Interface

**UNI 3.1:** ATM Signaling & Circuit set-up

In order to implement MPOA, these standard functions must be configured together, introducing a high level of complexity for both the vendor developing the products, and the end-user installing the systems. With this high level of complexity, vendor interoperability will be difficult to achieve. The following diagram depicts a fully configured MPOA network configuration.

**ATM Forum Multi-Protocol Over ATM (MPOA)**

MPOA is the ATM Forum's ultimate solution for multiprotocol LANs with ATM. A large amount of effort has been expended to define the MPOA standards, and the potential benefits of the technology are significant. MPOA defines a mechanism for performing a “cut through” routing function, to combine the control and scalability of routing with the performance and QoS of ATM switching.

Unfortunately, the ATM Forum has been slow in reaching agreement on the details of MPOA standards and it is not yet broadly implemented in vendor products. A full implementation of MPOA requires the following standards.

- **LANE:** Uses ATM to bridge VLANs between Ethernet networks.
- **NHRP:** IP to ATM address resolution. Allows cut-through switching, avoiding IP hop by hop method.
- **Traffic Mgt 4.0:** QoS with traffic shaping and queuing.

**Tag Switching**

Tag Switching is a proprietary approach to integrating LANs and ATM network environments. Tag switching attempts to deliver the scalability and control of routing with the performance of switching by separating the route calculation process from the frame forwarding process. In the Tag Switching model, there are two principal components: Tag Edge routers, and Tag Switches (see following diagram). As the name suggests, Tag Edge Routers perform the route calculation between two Layer 3 network addresses (usually for IP networks) as was previously performed in the original router-based network. However, once the route...
calculation has been performed by the Tag Edge router, a “tag” is applied to the transmission between these two Layer 3 addresses. This tag is used by switches in the network core to forward the transmission to the appropriate location without performing any additional route calculations.

The Tag Switching concept, like MPOA, is intended to provide the control and scalability of routing, with the performance of switching, thereby achieving a very attractive integration of connectionless and connection-oriented network environments. However, in order to achieve the greatest benefit from the Tag Switching model, the size of the network must be very large, so that there are more core Tag Switches than Tag Edge Routers. In practice, the only networks that will be large enough to achieve this relation between the two devices are the largest Internet Service Providers or carriers. For the typical Enterprise network, the ratio of Tag Switches to Tag Edge Router devices will be too low to achieve any real performance advantage over the traditional router environment.

**IP Switching**

Perhaps the most promising technical development towards achieving the integration of connectionless and connection-oriented networks is the concept of IP Switching. This model has been endorsed and adopted by a wide range of leading networking vendors, and all of the technology associated with IP Switching is public domain intellectual property. The network protocols associated with IP Switching have been submitted for IETF approval as draft RFC's. However, even though approval of these RFC's has not been finalized, IP Switching has become a de facto standard, given its large base of vendor support.

On first analysis, IP Switching bears a resemblance to Classical IP over ATM, although the terminology used is slightly different. In IP Switching, a device called an IP Switch controller takes the place of the router in the Classical IP model, and there are many similarities in their function. However, the most important functions that IP Switching supports, and Classical IP does not, is the identification of traffic flows between source and destination address pairs, and the dynamic creation of SVC's to which the transmission of the identified traffic flow is transferred.

By transferring the transmission of flow traffic from the PVC's between the edge-devices and the IP switch controller to SVC's which completely bypass the IP switch controller, IP Switching is truly capable of merging the control and scalability of routing with the performance and throughput of switching.
In addition to the high performance provided by IP switching, another major advantage to this technology is its scalability. IP switching is equally usable in a network that supports 1,000 users, as it is in a network that supports 10,000 or even 100,000 users or more. Therefore, the benefits of this technology can be attained by medium-size enterprise networks or the largest ISP or Telephone company networks. Furthermore, IP Switching provides support for QoS characteristics and rate shaping that take full advantage of the underlying switching technology. Towards the objective of achieving an integrated LAN/WAN switching network, the IP Switching model is a very attractive solution.

Key Attributes of an Integrated LAN-WAN Switch

Having reviewed some of the major technical issues that affect the integration of the LAN-WAN switching environment, it is now possible to identify specific characteristics required in networking devices that will be capable of achieving such integration.

The integrated switching model suggests a single network device that supports both LAN and WAN switching; that eliminates unnecessary handling and routing activities, and that provides an easy to manage, cost effective platform for multiple applications.

The key elements of any integrated LAN-WAN switching device are:

• A high performance switching fabric that minimizes switching delays and supports very high speed transfers;

• LAN interfaces that allow port-switching, virtual LAN groupings, and on-board inter-VLAN communications (such as inter-VLAN routing);

• A WAN interface with a high speed internal connection to the switching fabric. This helps to avoid bottlenecks between WAN and LAN devices. Access speeds must be scalable to allow for ever increasing WAN access speeds (at least up to T3 speeds);

• The software intelligence to support various types of connection services over the WAN including:
  - Local switching for multiple speed LANs,
  - VLAN management and inter-VLAN routing,
  - VLAN support over Frame Relay or ATM virtual circuits, and
  - IP Switching with flow identification and SVC connections.

• Common management interface—See discussion below.

• Optional features:
  - Support for classical IP,
  - Virtual Private Networks using encryption and compression,
  - Firewall capabilities, and
  - Support for Quality of Service and rate shaping.

Common Management Platform

A particularly key attribute of a successfully integrated LAN/WAN solution is a management platform that allows remote users to operate systems in a transparent manner.

Protocol integration across all sub networks, as implied in an integrated solution, allows the creation of a common network services platform interface which can establish a platform for a single management standard for all users and applications. Common "middleware" reduces the complexity of the network, increases the uniformity of control, and improves manageability. This enhances the value of this solution.
Benefits of an Integrated LAN-WAN Switching Network

As could be deduced from the foregoing discussion, LAN and WAN integration can be implemented in varying degrees and in various forms, depending on the network designer’s objectives. However, regardless of the strategy employed, there are a number of important benefits that can be derived by achieving this integration. These benefits can be placed in two categories: physical integration, and logical integration. Achieving the optimal solution will be possible only when both the physical and logical aspects of the network infrastructure are properly addressed.

Physical Integration

Physical integration involves the combination of the LAN and WAN switching functions into a single hardware and software platform to support the requirements of both environments. Such physical integration yields a number of important benefits, including:

- Improved performance due to reduced latency and higher bandwidth in the LAN-WAN interface.
- Elimination of a data link (between the LAN switch and WAN switch) in favor of high speed internal bus or memory transfers, thereby reducing the possibility of congestion;
- Separate LAN and WAN devices require separate forwarding functions, resulting in increased latency and possible congestion over the connecting link.
- Increased reliability and availability through the use of fewer network devices.

- Assurance that technical incompatibilities between components cannot occur; and
- Ability to keep the routing tables and path information synchronized.

- Improve scalability by matching the capacity of an integrated device with the needs of the network to which it is attached.
- Integrated LAN-WAN switches can more closely suit the needs of remote offices.
- Reduce costs by having fewer network devices to maintain and support.
- Simplify network management with fewer devices to manage.

Logical Integration

The logical integration of the LAN and WAN resolves the inherent contradiction between the connection-less LAN and the connection-oriented WAN. There are various strategies available to achieving this integration, as described in previous sections. However, the major benefits of this logical integration include:

- Attaining the performance of a switched network environment,
- Attaining the scalability of a routed network, and
- Achieving Quality of Service standards and predictable delays needed for real time multimedia transmissions.
Conclusion

Corporate networks must keep up with changes in business and organizational requirements. As network traffic increasingly travels from the WAN to the LAN, increasing the network performance between the local and wide area environments will become a strategic imperative. These new network traffic patterns need new network technology which increasingly will be based on switching in both the LAN and the WAN. Integrated LAN-WAN switching is a new, promising way to think about how networks should be configured in order to improve performance for new bandwidth-hungry network applications.

Switch-based WAN technologies enable integrated solutions that simplify the design of large scale networks and allow a degree of flexibility never before achievable. Extending the carrier switching hierarchy to include the customer premises—reminiscent of the structures of telephony—permits integrated global switched networks that are easier to manage, higher in performance, and lower in cost.

The evolution of LAN technologies to switching is a serendipitous occurrence in that it is happening at the same time as the move toward high speed WAN switching. Combining LAN and WAN switching into a single integrated solution enables the design of faster, easier to operate, and less expensive networks than did routing technologies of the past. As a result, the multimedia network applications of the future will have the network infrastructure they need to be successful.

Glossary

10BaseT—The IEEE 802.3 specification for ethernet over unshielded twisted pair (UTP).

100BaseFX—100 (M bps) Ethernet implementation over fiber.

100Base-T Fast Ethernet—A 100 M bps technology based on the Ethernet/CD network access method.

100BaseTX—100 M bps Ethernet implementations over Category 5 and Type 1 cabling.

Adapter Card—Circuit board or other hardware that provides the physical interface to the communications network.

Address Resolution Protocol (ARP)—A member of the TCP/IP protocol suite used to resolve a destination host's hardware MAC address from its known IP address.

Asynchronous Transfer Mode (ATM)—(1) The CCITT standard for cell relay wherein information for multiple types of services (voice, video, data) is conveyed in small, fixed-size cells. ATM is a connection oriented technology used in both LAN and WAN environments. (2) A fast-packet switching technology allowing free allocation of capacity to each channel. The-SONET synchronous payload envelope is a variation of ATM. (3) ATM is an international ISDN high speed, high-volume, packet switching transmission protocol standard. ATM currently accommodates transmission speeds from 64 K bps to 622 M bps.

ATM Adaptation Layer (AAL)—Each AAL consists of two sublayers: the segmentation and reassembly (SAR) sublayer and the convergence sublayer. AAL is a set of four standard protocols that translate user traffic from higher layers of the protocol stack into a standard size and format contained in the payload of an ATM.
cell and return it to its original form at the destination node.

**AAL 1** addresses CBR (constant bit rate) traffic such as digital voice and video and is used for applications that are sensitive to both cell loss and delay and to emulate conventional leased lines.

**AAL 2** is used with time-sensitive, variable bit rate traffic such as packetized voice.

**AAL 3/4** handles bursty connection-oriented traffic, such as variable-rate connectionless traffic, like LAN file transfers. It is designed for traffic that can tolerate some delay but not the loss of a cell.

**AAL 5** accommodates bursty LAN data traffic with less overhead than AAL 3/4.

**ATM Application Program Interface (ATM API)**—The specification that allows ATM applications to be written. No standard ATM Application Programming Interface currently exists.

**ATM Data/Channel Service Unit (ATM DSU/CSU)**—Segments ATM-compatible information into ATM cells and then reassembles them at their destination.

**ATM Forum**—The organization developing and defining ATM standards. Members participate in committees to vote on ATM specifications; audition members receive marketing and technical documentation; user members may participate only in end-user roundtables.

**ATM Peer-Peer Connection**—Between adjacent devices; half duplex ATM access device.

**Available Bit Rate (ABR)**—A class of service in which the ATM network makes its "best effort" to meet traffic bit rate requirements.

**Backbone**—(1) The part of a network used as the primary path for transporting traffic between network segments. (2) A high-speed line or series of connections that forms a major pathway within a network.

**Backward Explicit Congestion Notification (BECN)**—A bit in the frame relay header. The bit is set by a congested network node in any frame which is traveling in the reverse direction of the congestion. (In frame relay, a node can be congested in one direction of frame flow but not in the other.)

**Bandwidth**—(1) Measure of the information capacity of a transmission channel. (2) The difference between the highest and lowest frequencies of a band that can be passed by a transmission medium without undue distortion, such as the AM band—535 to 1705 kilohertz. (3) Information carrying capacity of a communication channel. Analog bandwidth is the range of signal frequencies that can be transmitted by a communication channel or network. (4) A term used to indicate the amount of transmission or processing capacity possessed by a system or a specific location in a system (usually a network system).

**Bandwidth on Demand (BoD)**—Dynamic allocation of line capacity to active users, inherent in FastComm FRADs.

**Bits Per Second (bps)**—(1) The number of bits passing a point every second. The transmission rate for digital information. (2) A measurement of how fast data are moved from one place to another. (Example: a 28.8 modem can move 28,800 bps.)

**Border Gateway Protocol (BGP)**—Protocol for communications between a router in one autonomous system and routers in another.

**Bridge/Router**—A device that can provide the functions of a bridge, router or both concurrently. Bridge/router can route one or more protocols, such as TCP/IP and/or XNS, and bridge all other traffic.
**Broadcast**—(1) A message sent to all network destinations. (2) To send or transmit by radio or television.

**Broadcast and Unknown Server (BUS)**—ATM Forum-defined specifications in support of LAN-to-LAN connectivity, called LAN emulation. BUS defines that set of functions implemented in an ATM network that provide LAN-to-LAN transmission support while a LAN connection is being established. It also supports LAN broadcast services.

**Broadcast Domain**—Defines the set of all devices which will receive broadcast frames originating from any device within the set. Broadcast domains are normally bounded by routers.

**Broadcast Storm**—Multiple simultaneous broadcasts that typically absorb available network bandwidth and can cause network time-outs.

**Broadcast Storm Firewalls**—A mechanism that limits the rate at which broadcast/multicast packets are forwarded through the system.

**Collapsed Backbone**—A non-distributed backbone where all network segments are interconnected via an internetworking device. A collapsed backbone may be a virtual network segment existing in a device such as a hub, a router, or a switch.

**Connection Identifier (CI)**—Frame or cell address.

**Connection-Oriented Architectures**—Cell switching or packet multiplexing based on individual virtual circuits with virtual circuit identifiers. ATM is a connection-oriented technology.

**Connection-Oriented Network (CON)**—Defines one path per logical connection.

**Connectionless Architectures**—Cell switching or packet multiplexing that identifies individual network channels by global addresses rather than by predefined virtual circuits.

**Data Link Control (DLC)**—The SNA layer responsible for transmission of data between two nodes over a physical link.

**Data Link Layer**—Layer 2 of the OSI reference model. This layer takes a raw transmission facility and transforms it into a channel that appears, to the network layer, to be free of transmission errors. Its main services are addressing, error detection and flow control.

**Digital Transmission**—A method of sending and receiving information coded with on-and-off pulses of electricity or light.

**Dynamic Bandwidth Allocation (DBA)**—A process that optimizes overall network efficiency by automatically increasing or decreasing the bandwidth of a channel to accommodate changes in data flow from end-user equipment.

**Ethernet**—(1) A baseband LAN specification invented by Xerox Corporation and developed jointly by Xerox, Intel, and Digital Equipment Corporation. Ethernet networks operate at 10 Mbps using CSMA/CD to run over coaxial cable. Ethernet is similar to a series of standards produced by IEEE referred to as IEEE 802.3. (2) A very common method of networking computers in a local area network (LAN). Ethernet will handle about 10,000,000 bits per second and can be used with almost any kind of computer.

**Flow Control**—A technique for ensuring that a transmitting entity does not overwhelm a receiving entity. In IBM networks, this technique is called pacing.

**Fractional E1**—A carrier service that offers data rates between 64 kbps and 2.048 mbps (E1) in increments of 64 K bps.

**Fractional E3/ T3**—Fractional E3/ T3 refers to the leasing of portions of E3/ T3 bandwidth (a specific number of time slots) by carriers. FE3 or FT3 allows for more economical networking in some applications.
Fractional T-1—A WAN communications service that provides the user with some portion of a T1 circuit which has been divided into 24 separate 64 K b channels. Fractional E-1 is in Europe.

Frame—A logical grouping of information sent as a link-layer unit over a transmission medium. The terms packet, datagram, segment, and message are also used to describe logical information groupings at various layers of the OSI reference model and in various technology circles.

Frame Relay—High-performance interface for packet-switching networks. Considered more efficient than X.25 which it is expected to replace. Frame relay technology can handle “bursty” communications that have rapidly changing bandwidth requirements.

Frame Relay Forum—A voluntary organization composed of Frame Relay vendors, manufacturers, service providers, research organizations, and users. Similar in purpose to the ATM Forum.

IEEE 802.3u—IEEE LAN protocol that specifies an implementation of the physical layer and MAC sublayer of the link layer. IEEE 802.3 uses CSMA/CD access at a variety of speeds over a variety of physical media. One physical variation of IEEE 802.3 (10Base5) is very similar to Ethernet.

Integrated Services Digital Network (ISDN)—(1) The recommendation published by CCITT for private or public digital telephone networks where binary data, such as graphics and digitized voice and data transmission, pass over the same digital network that carries most telephone transmissions today. (2) An overall application of the technology to provide for both newer digital and more traditional telephone services in an integrated network and incorporates the new network and interfacing standards which are being adopted worldwide. (3) A method for carrying many different services over the same digital transmission and switching facilities. (4) A digital telephone system made up of two 64kbps “B” channels for data and one “D” channel for message trafficking.

Internet—A collection of networks interconnected by a set of routers which allow them to function as a single, large virtual network.

Internet Address—Also called an IP address. It is a 32-bit address assigned to hosts using TCP/IP. The address is written as four octets separated with periods (dotted decimal format) that are made up of a network section, an optional subnet section, and a host section.

Internet Engineering Task Force (IETF)—An organization that provides coordination of standards and specifications development for TCP/IP networking.

Internet Protocol (IP)—A Layer 3 (network layer) protocol that contains addressing information and some control information that allows packets to be routed. Documented in RFC 791.

Internet Service Provider (ISP)—(1) Any of a number of companies that sell Internet access to individuals or organizations at speeds ranging from 300bps to OC-3. (2) A business that enables individuals and companies to connect to the Internet by providing the interface to the Internet backbone.

Internetworking—General term used to refer to the industry that has arisen around the problem of connecting networks together. The term can refer to products, procedures, and technologies.

Intranet—A private network that uses Internet software and standards.

IP Datagram—The fundamental unit of information passed across the Internet. Contains source and destination addresses along with data and a number of fields.
Local Area Network (LAN)— (1) A network covering a relatively small geographic area (usually not larger than a floor or small building). Compared to WANs, LANs are usually characterized by relatively high data rates. (2) Network permitting transmission and communication between hardware devices, usually in one building or complex.

Media Access Control (MAC)— A method of controlling access to a transmission medium. For example, token ring, Ethernet, FDDI, etc.

Megabit (Mbit/s)— One million bits.

Megabyte— A million bytes. A thousand kilobytes.

Multicast Address— An address that refers to multiple network devices. Synonymous with group address.

Network Address— (1) Also called a protocol address. A network layer address referring to a logical, rather than a physical, network device. (2) Numeric character string used to specify the location of the called customer.

Network Layer— Layer 3 of the OSI reference model. Layer 3 is the layer at which routing occurs.

Open Shortest Path First (OSPF)— Routing protocol for TCP/IP networks.

Packet Filtering— A second layer of filtering on top of the standard filtering provided by a traditional transparent bridge. Can improve network performance, provide additional security, or logically segment a network to support virtual workgroups.

Packet Switching— (1) Type of data transfer that occupies a communication link only during the time of actual data transmission. Messages are split into packets and reassembled at the receiving end of the communication link. (2) A transmission technique that segments and routes information into discrete units. Packet switching allows for efficient sharing of network
resources as packets from different sources can all be sent over the same channel in the same bitstream.

**Permanent Virtual Circuit (PVC)**—A defined virtual link with fixed end-points that are set-up by the network manager. A single virtual path may support multiple PVCs.

**Physical Layer (PHY)**—The bottom layer of the OSI and ATM protocol stack, which defines the interface between ATM traffic and the physical media. The PHY consists of two sublayers: the transmission convergence (TC) sublayer and the physical medium-dependent (PMD) sublayer.

**Physical Media**—Any physical means for transferring signals between OSI systems. Considered outside the OSI M oddel, and sometimes referred to as “Layer O,” or the bottom of the OSI Reference Model.

**Private Network-to-Network Interface (P-NNI)**—A routing protocol that allows multiple vendors’ ATM switches to be integrated. It automatically and dynamically distributes routing information, enabling any switch to determine a path within the network.

**Quality Of Service (QOS)**—Term for the set of parameters and their values which determine the performance of a given virtual circuit.

**Quality Of Service (QOS) classes**—Five categories have been outlined by the ATM Forum’s UNI 3.0 implementation. Specifics are to be determined in the future.

- **Class 1** specifies performance requirements. ATM’s quality of service should be comparable with the service offered by standard digital connections.
- **Class 2** specifies service levels for packetized voice and video.
- **Class 3** defines requirements for interoperability with other connection-oriented protocols like frame relay.
- **Class 4** specifies interoperability requirements for connectionless protocols, including IP, IPX, and SMDS.
- **Class 5** is a “best-effort” attempt for delivery; intended for applications not requiring a specific class of service.

**Router**—(1) An OSI Layer 3 device that can decide which of several paths network traffic will follow based on some optimality metric. Also called a gateway (although this definition of gateway is becoming increasingly outdated), routers forward packets from one network to another based on network-layer information. (2) A dedicated computer hardware and/or software package which manages the connection between two or more networks.

**Routing**—The process of finding a path to the destination host. Routing is very complex in large networks because of the many potential intermediate destinations a packet might traverse before reaching its destination host.

**Routing Information Protocol (RIP)**—An IGP supplied with Berkeley UNIX systems. It is the most common IGP in the Internet. RIP uses hop count as a routing metric. The largest allowable hop count for RIP is 16.

**Routing Protocol**—A protocol that accomplishes routing through the implementation of a specific routing algorithm. Examples of routing protocols include IGRP, RIP, and OSPF.

**Routing Table**—A table stored in a router or some other internetworking device that keeps track of routes (and, in some cases, metrics associated with those routes) to particular network destinations.
**Switched Ethernet**—Configuration supporting an Ethernet hub with integrated MAC layer bridging or switching capability to provide each port with 10 or 100 M bps of bandwidth. Separate transmissions can occur simultaneously on each port of the switching hub, and the switch filters traffic based on the destination MAC address.

**Switched LAN**—Refers to a LAN implemented with frame switches.

**Switched Virtual Circuit (SVC)**—A virtual link, with variable end-points, established through an ATM network. With an SVC, the user defines the end-points when the call is initiated that are subsequently terminated at the end of the call. With a PVC, the end-points are predefined by the network manager. A single virtual path may support multiple SVCs.

**T1**—(1) Digital transmission facility operating with a nominal bandwidth of 1.544 M bps. Also known as Digital Signal Level 1 (D1). Composed of 24 DS-0 channels in many cases. The T1 digital transmission system is the primary digital communication system in North America. (2) A high-speed 1.5 mbits/sec leased line often used by companies for access to the Internet.

**T3**—(1) Digital transmission facility operating at 45 M bps bandwidth. Composed of 28 DS-1 channels in many cases. Also known as DS-3. (2) A leased-line connection capable of carrying data at 45 mbits/sec.

**Transmission Control Protocol/Internet Protocol (TCP/IP)**—(1) The common name for the suite of protocols developed by the U.S. Department of Defense in the 1970s to support the construction of world-wide internetworks. TCP and IP are the two best-known protocols in the suite. TCP corresponds to Layer 4 (the transport layer) of the OSI reference model. It provides reliable transmission of data. IP corresponds to layer 3 (the network layer) of the OSI reference model and provides connectionless datagram service. (2) The collection of transport and application protocols used to communicate on the Internet and other networks.

**Transmission Path**—An electrical path capable of transmitting signals within the range of the service offering, e.g., a voice grade transmission path is capable of transmitting voice frequencies within the approximate range of 300 to 3000 Hz. A transmission path is comprised of physical or derived channels consisting of any form or configuration of facilities typically used in the telecommunications industry.

**Trunk**—A communications path connecting two switching systems in a network, used in the establishment of an end-to-end connection.

**Uplink**—The transmission power that carries a signal or material from its earth station source up to a satellite.

**User**—A person who has access to the Staffware system via a computer workstation.

**Virtual Circuit (VC)**—(1) A portion of a virtual path or a virtual channel used to establish a virtual connection between two end nodes. (2) Logical channels established as a result of the call initiation procedure to a network address that exists for a period of time.

**Virtual Path Identifier/Virtual Channel Identifier (VPI/VCI)**—Combined, these fields identify a connection in the ATM network.

**Virtual Private Network (VPN)**—A network service offered by public carriers in which the customer is provided a network that in many ways appears as if it is a private network (customer-unique addressing, network management capabilities, dynamic reconfiguration, etc.) but which, in fact, is provided over the carrier's public network facilities.
Web Browser — Client software that requests and displays HTML documents and other Internet or intranet resources.

Web Server — (1) A networked host computer that contains HTML pages and possible other forms of content served to clients via HTTP. (2) A server that stores and retrieves HTML documents and other Internet or intranet resources using HTTP. Also called an HTTP server.

Wide Area Network (WAN) — (1) A network which encompasses interconnectivity between devices over a wide geographic area. Such networks would require public rights-of-way and operate over long distances. (2) A network that covers an area larger than a single building or campus.

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Albert Einstein
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