ForeThought and the ATM Internetwork
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FORETHOUGHT BACKGROUND

FORE included ATM network signaling software when it shipped the first ForeRunner ATM network adapters in 1991. Early in 1992, the first ForeRunner ATM switch provided a plug-and-play, IP-over-ATM workgroup solution. FORE has more ATM network experience than any other vendor. Experience gained by deploying real ATM networks. This has been an invaluable asset to FORE throughout the development of four generations of ForeThought software.

ATM Today

FORE plays a key role in the development of ATM specifications, actively participating in both the ATM Forum and Internet Engineering Task Force (IETF) efforts to provide standard specifications for ATM networks.

From its inception, the ATM Forum has developed standards that enable ATM connectivity over a variety of physical media. Current signaling standards allow dynamic connections to be established between ATM devices across multiple ATM switches.

The ATM Forum recently finalized the LAN Emulation v1.0 specification, enabling transparent connectivity between ATM network devices at the data link layer, regardless of the network layer protocol.

The ATM Forum is now working on the Private Network-to-Network Interface (PNNI)—a specification that will enable dynamic exchange of inter-switch routing information.

The IETF has also recognized the significance of ATM for the Internet community. Specifications have been developed by the IETF to support multi-protocol encapsulation over ATM (RFC1483) and IP-over-ATM (RFC1577).

Efforts within the IETF have yielded protocols that support multiple subnets (Next Hop Resolution Protocol—NHRP), and broadcast/multicast for IP in an ATM internetwork (Multicast Address Resolution Server—MARS). The IETF has also formed an IP-over-ATM working group to further investigate IP-over-ATM protocols.

NETWORK MIGRATION

The migration to an ATM network should be implemented in phases. This allows a network administrator to:

• introduce ATM into the existing corporate network with minimal disruption
• construct an ATM backbone in parallel with the existing corporate backbone
• ultimately, build an ATM-based corporate internetwork

NOTE:

This document outlines the migration path from an existing corporate network to an ATM-based internetwork and describes the ForeThought Internetworking Software features that enable this migration.

NOTE:

The following sections outline a migration path that meets the immediate need for a high-speed ATM network and also begins to build the future corporate ATM infrastructure.
A phased approach maximizes the benefits of ATM while protecting the investment in the existing network infrastructure.

**PHASE 1: INTRODUCING THE ATM WORKGROUP OR ATM BACKBONE**

Introducing ATM into a corporate network supports:
- Existing bandwidth-intensive applications
- New applications
- Network growth

Network administrators may follow either of two approaches to introduce ATM into the corporate network: the ATM workgroup or the ATM backbone.

**The ATM Workgroup**

The most common reason for installing an ATM workgroup is to provide high-speed bandwidth to a workgroup application. ATM is ideally suited for this task because it supports up to 155 Mbps to each desktop and has an inherent quality of service (QoS) capability that guarantees bandwidth to each member of the workgroup.

**Connecting Workgroups**

FORE’s ForeRunner product line has all the equipment needed to build an ATM workgroup. This includes a low-cost ATM LAN switch, ATM adapters for each device (i.e., PC or workstation) in the ATM workgroup, and a conventional LAN access device to connect the ATM workgroup to the corporate LAN backbone.

The ForeRunner ASX-200WG workgroup switch provides economical high-speed dedicated LAN connections in the workgroup environment. The ASX-200WG supports up to 16 full duplex OC-3c (155 Mbps) ports or 24 TAXI (100 Mbps) ports. A single ASX-200WG can build a workgroup with up to 24 ATM-attached devices. Multiple ASX-200WG switches can be clustered to build ATM workgroups with more than 24 devices.

**ForeRunner** ATM adapters provide full duplex OC-3c connections from each desktop to the ATM switch network. The ForeRunner ATM adapter product family supports a wide variety of UNIX, PC, and Macintosh platforms. An on-board RISC processor enables future standards compliance via software upgrades.

An ATM-ready router, bridge, or LAN switch forwards traffic between the ATM workgroup and an existing Ethernet or FDDI backbone. The ForeRunner LAX-20 LAN access switch is an example of a device that can bridge or route between ATM and Ethernet, or ATM and FDDI networks.
Supporting Network Protocols

The Internet Protocol (IP) can be supported within the ATM workgroup using the IETF Classical IP (RFC1577) specification or FORE IP. Classical IP provides dynamic point-to-point connections between workgroup devices using switched virtual circuits (SVC). ForeThought software, running on ForeRunner workgroup switches, includes all of the required services for Classical IP.

![Diagram](image)

**Figure 1.** ForeRunner ATM switches support network protocols and link an ATM-based workgroup to a LAN backbone network.

In addition, FORE IP provides services beyond point-to-point, SVC-based connectivity, such as IP broadcast and IP multicast. IP broadcast and IP multicast are required by some LAN protocols and multi-media applications, such as NIS and MBONE.

LAN Emulation (LANE) is used if support for multiple protocols is needed. ForeThought software implements all required services specified by the ATM Forum LANE v1.0 specification on ForeRunner switches along with additional features that improve the performance and robustness of LANE services.

Whether the workgroup is designed with LANE, IP-over-ATM, or a combination of the two, the workgroup should initially be configured as a single broadcast domain. If IP is used, all devices should be on the same Logical IP Subnetwork (LIS). If LANE is used, a single emulated LAN should be used, simplifying the initial implementation. This prepares the workgroup for integration with other workgroups in Phase 2 of the ATM migration.

The ATM Backbone

Figure 2a shows a typical router-based network topology. The core of the network is the data center, where most of the corporate information resources (e.g., servers) are located on one or more dedicated FDDI rings. Backbone segments provide connections via routers, from campus buildings or office floors, to the data center.

**An ATM Backbone:**
- Eases congestion on backbones
- Reduces server NIC congestion
- Shortens time for high-speed server backup
All traffic directed toward corporate servers must traverse the data center network. Since backbone segments are interconnected only at the data center, all traffic between backbone segments must also traverse the data center network, making the data center a likely point of congestion.

![Diagram of network topology](image)

**Figure 2a:** Router-based corporate backbone network topology with FDDI backbone.

An ATM switch (or switches) located in the data center provides dedicated high-speed links to backbone routers and common servers. This eliminates congestion by offering more bandwidth to each server and router. In addition, the bandwidth management capabilities of *ForeRunner* ATM switches optimize the use of the available bandwidth.

**Connecting the Corporate Data Center**

Figure 2b shows a *ForeRunner* backbone ATM switch in the corporate network. If existing routers have ATM interfaces, they can connect directly to the data center’s ATM network.

If existing routers do not support ATM, then a *ForeRunner* LAN access switch can be used to connect LAN backbone segments to the data center ATM network. Servers can be directly connected to the data center’s ATM network using *ForeRunner* ATM adapters.
Supporting Network Protocols and Virtual LANs

As in the ATM workgroup, Classical IP, FORE IP and LANE implementations provide the required protocol support within the ATM network. To simplify addressing and routing, the data center ATM network should be configured as a single subnetwork. Later, multiple subnetworks will be established with the introduction of VLAN workgroups.

PHASE 2: BUILDING A PARALLEL ATM BACKBONE

During Phase 1, ATM can be introduced into the corporate network as either a backbone or a workgroup. Once ATM is established in the network, subsequent workgroup installations should be native ATM workgroups or ATM-attached switched LAN segments. During Phase 2, the ATM network expands to include both a backbone portion and workgroups of ATM-attached devices.

Interconnecting ATM Workgroups

In Phase 2, multiple ATM workgroups are created, then interconnected, forming an ATM backbone network. Common servers and centrally-located routers can also be directly attached to the ATM backbone. The network migrates to ATM by operating in parallel with the existing backbone, as shown in Figure 3 or by building ATM workgroups, as shown in Figure 4.
Figure 3: Migrating to an ATM network—a parallel ATM backbone network.
Adding Workgroups to the ATM Backbone

During Phase 2, native ATM workgroups and ATM-attached switched LAN workgroups can be connected to the backbone ATM network. Like the ATM backbone migration, the ATM workgroup operates in parallel with the existing corporate backbone as shown in Figure 4.

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Figure 4: Migrating to an ATM network—building ATM workgroups.
Virtual LANs

A ForeThought Virtual LAN (VLAN) is a logical association of users that share a common broadcast domain. Since broadcast traffic is contained within a VLAN, the load on any single broadcast service is proportional to the number of members of the VLAN.

Creating multiple VLANs within the ATM network creates a logical division between network users. By distributing the broadcast load to each individual VLAN, the ATM network can support a greater number of users without excessively loading any single broadcast service.

VLANs are formed within the ATM network using the VLAN Configuration Application (VCA) to assign ATM devices to one or more VLANs. VLAN boundaries are not limited to the ATM network. Devices attached to an Ethernet workgroup switch can be assigned to VLANs, and segments on an Ethernet segment switch, or LAX-20 LAN access switch, can also be assigned to VLANs.

Connecting VLANs

During the migration, an interim solution for connecting VLANs can be provided using an ATM-based router belonging to multiple VLANs. A device on one workgroup sends a packet to the router which forwards the packet out the same ATM interface to a device on another VLAN. Forwarding packets via a single physical interface is commonly referred to as one-armed routing. (See Figure 5.) The LAX-20 is capable of routing among many logical VLAN interfaces on single physical ATM interface.

Figure 5: VLAN Workgroups interconnected using a "one-armed" router.

NOTE:
For more information on ForeThought VLANs, refer to the white paper, "ForeThought and the ATM Internetwork".

NOTE:
During Phase 2—Migrating to a parallel ATM backbone, take this opportunity to reduce the number of network protocols being used in the corporate network.

As LAN segments are migrated to the ATM backbone, consolidate as much as possible the number of network protocols used on that segment.
By the end of Phase 2, a parallel ATM backbone is fully established. VLAN workgroups are in place and the ATM network is ready to take advantage of ForeThought’s distributed routing capabilities.

**PHASE 3: ADDING DISTRIBUTED ROUTING**

The introduction of ForeThought distributed routing with cut-through capability eliminates the need for one-armed routers in the ATM backbone. ForeThought distributed routing provides a direct network connection between devices on different LISs. (see Figure 6). Any device supporting Classical IP can take advantage of ForeThought’s distributed routing and cut-through capability.

![Figure 6: Direct cut-through ATM connectivity between VLAN workgroups.](image)

Distributed routing on the ATM network supports many IP subnetworks without introducing additional load on existing IP routers and prepares the network for Phase 4 of the migration to ATM.
PHASE 4:
COMPLETING THE END-TO-END ATM SOLUTION

Figure 7: The ATM Internetwork.

Workgroups can be attached to the backbone segments directly, or via a LAN access device such as an Ethernet workgroup switch, Ethernet segment switch, or LAX-20 LAN access switch (see Figure 7). The migration of workgroups to the ATM backbone network is outlined below.

**Migrating Workgroups to the ATM Backbone**

The *ForeRunner* product family can create several types of workgroups that meet the networking and budgetary constraints. *ForeRunner* network components create the high-speed ATM workgroup, the switched Ethernet workgroup, and the shared Ethernet workgroup. (See Figure 8A, 8B, and 8C.)
Figure 8B: The switched Ethernet workgroup uses an *ForeRunner* ES-3860 switch to provide dedicated switched Ethernet connectivity for up to 72 workstations with an OC-3c connection to the ATM backbone. Switched 100 Mbps Ethernet ports provide low cost connectivity to workgroup servers.

Figure 8C: The shared Ethernet workgroup uses a *ForeRunner* LAX-20, to provide Ethernet or FDDI to ATM connectivity. Each LAN segment can be shared by multiple workstations.

As workgroup applications evolve, they will require dedicated bandwidth and guaranteed QoS. The *ForeRunner* product family provides a simple cost-effective migration path to address these requirements.
Since VLANs can include ATM-attached devices as well as legacy LAN segments and legacy devices, the migration to the ATM network can be implemented gradually. For example, servers can be migrated first, followed by those end user devices requiring the most bandwidth. (see Figure 9)

*ForeRunner* ES-3810 switches can be upgraded with an ATM interface to become ES-3860 switches. Segments on existing LAX-20s can then be re-deployed in the migration of other shared Ethernet workgroups to the ATM backbone by providing Ethernet-to-ATM via ATM Forum LANE v1.0.

Existing switched Ethernet workgroups can be migrated from an ES-3860 to an ASX-200WG to become ATM workgroups. Shared Ethernet workgroups can be moved from LAX-20-attached LAN segments to switched segments or desktops on dedicated ES-3860 switches. As devices are moved off of the LAX-20 switches, the number of devices on each segment decreases, thereby increasing the bandwidth available to each device.
When Phase 4 is complete, the parallel ATM backbone has become the corporate backbone. Routers used in the original backbone network become edge devices on the ATM backbone and provide access to services such as PPP, ISDN, IBM/SNA, etc. (See Figure 10.) By continuing to use routers where appropriate, the existing investment in router-based technology is preserved and the routers are used to do what routers do best—route packets.

The ForeRunner product line and ForeThought software provide a migration path to an ATM-based corporate internetwork. The ForeThought ATM Internetwork provides a scaleable high-performance infrastructure that solves existing congestion problems while providing the bandwidth and services needed by new internetworking applications. Investment in existing internetworking equipment is protected because this equipment is incorporated into ATM network, serving as edge devices to the ATM backbone.
**FORERUNNER PRODUCT OVERVIEW**

**ForeRunner ASX-200WG ATM Workgroup Switch**

The ASX-200WG ATM switch provides desktop ATM access in a workgroup configuration of up to 24 devices. Low cost LAN connectivity and high performance are key issues in designing today’s ATM network. This switch is the market leader in both.

**ForeRunner ASX-200BX ATM Backbone Switch**

The ASX-200BX switch provides backbone connectivity, with redundancy, between workgroups at higher speeds than conventional LANs. Enhanced reliability features, flexible connectivity options, and WAN access make these switches ideal for crucial ATM backbone applications. Additional capabilities include environmental monitoring and higher port density.

**ForeRunner ASX-1000 ATM Backbone Switch**

The ASX-1000 provides high bandwidth connectivity between ATM switches and LAN and WAN access devices with direct connections to high-end servers. Its non-blocking switching capacity is scalable from 2.5 Gbps up to 10 Gbps. Its enhanced fault tolerance and reliability includes hot-swappable multi-processors and switching fabrics as well as redundant, hot-swappable fans.

**ForeRunner LAX-20 LAN Access Switch**

The LAX-20 is an internetworking device designed that provides conventional LANs (e.g., Ethernet, Token Ring, and FDDI) access to ATM. Routing IP and IPX, MAC layer bridging, and source routing are supported. Advanced ATM connection capabilities include FORE IP, LAN Emulation, large VC capacity, and ATM network performance at millions of bits per second.

**ForeRunner 200E-Series ATM Network Adapters**

The 200E-Series network adapters are designed with FORE’s Advanced Cell Processing Architecture based on a dedicated Intel i960 RISC processor. FORE has custom silicon designed to offload segmentation and reassembly (SAR) processing from the workstation central processor. This architecture not only provides high performance and throughput but also supports emerging standards via software upgrades.
**FORETHOUGHT v3.4 OVERVIEW**

*ForeThought* software implements existing standards while providing features and capabilities not yet addressed by standards. By providing a complete interoperable software base with many unmatched features and capabilities, *ForeThought* software enables the immediate deployment of ATM networks.

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Figure 11: *ForeThought* v3.4 features and *ForeRunner* platforms supported.

**ForeThought Native ATM Services**

**Bandwidth Management**

A wide range of bandwidth management capabilities are required to optimize network resources in an ATM network. Several complementary features have been implemented to prevent cell loss.

- Policing at the ATM switch input using the ATM Forum-standard dual leaky bucket algorithm to tag (or drop) non-compliant cells
- Multiple output priorities guarantee cells on delay-sensitive connections (CBR, VBR) are not delayed by bursty data traffic (UBR, ABR)
- Per VC queuing, along with weighted scheduling, guarantees each connection in a given priority gets access to the available bandwidth
- Early Packet Discard (EPD) and Partial Packet Discard (PPD) increase the overall “goodput” of ATM Adaptation Layer (AAL5) data connections. They also decrease the downstream congestion by discarding cells that would have been dropped by the receiving ATM device.
- Shared output buffers increase the overall buffer capacity of any single port by pooling the buffers of several ports into one larger buffer which can be used by the port needing the most buffer space.

**End-to-End Timing**

The ASX-200BX and ASX-1000 ATM switches are capable of using timing derived on a single port as the timing source for any other port on the switch. This allows all of the ports on a single ASX-200BX or ASX-1000 to be synchronized to a single clock source. By propagating the clock source between switches, every port in the ATM network can be synchronized to a single clock source.
The end-to-end timing capability enables the interconnection of timing-dependent CBR devices, such as ATM access muxes. Any device using the AAL1 Synchronous Residual Time Stamp (SRTS) algorithm for recovery and regeneration of the network clock requires end-to-end timing in the ATM network.

**Virtual Path Tunneling**

*ForeThought* software can use a virtual path connection (VPC) as a SPANS-NNI or FT-PNNI interswitch link. Multiple VPCs can be used to create multiple SPANS-NNI or FT-PNNI links on a single physical port (i.e., SVCs operating across a PVC backbone). This capability is called VP tunneling. It can be used to make portions of a network more secure. For example, in Figure 12, a WAN link supports two different applications for a financial investment firm. The two applications supported by the network need to be isolated from each for security reasons. Using VP tunneling, each application operates over the WAN link on its own separate virtual path. There is no way for users on one application to access the other.

![Figure 12: VP tunneling provides separate logical backbones for the investment banking and the stock trading applications. User connections assigned to one virtual path cannot access any other.](image)

**Virtual Path Shaping**

Each connection in an ATM network has an associated traffic contract. The timing of cells entering the ATM network must comply with the traffic contract of the associated connection. This means cells must not enter the network faster than specified in the traffic contract. If they do, they are eligible to be dropped by the ATM network.
Traffic on conventional LANs is typically sent in bursts of packets that occur irregularly, often exceeding the size of an ATM cell. When traffic of this type is sent over an ATM network, many ATM cells are sent into the network back-to-back. If the data transfer is using a connection with a strict traffic contract, as is generally the case in public ATM networks, some cells will be dropped by the ATM network.

A VP shaper converts non-compliant bursty traffic into fully-compliant Constant Bit Rate (CBR) traffic by buffering bursts of cells within the ATM switch and then sending the cells at a configurable, constant rate (see Figure 13).

*ForeThought* v3.4.0 software can convert any port on a *ForeRunner* Series C network module into a single VP shaper. Multiple virtual paths can be shaped individually on separate ports and then directed out a single port.

Using the VP shaping feature, traffic from many LAN devices can be combined and shaped to comply with the traffic contract specified by a public CBR PVPC (permanent virtual path connection) service. VP tunneling and VP shaping combine to enable SVC connections between two *ForeRunner* ATM switches across a public CBR PVPC service.
**UNI v3.0 PVC Contracts**

The ATM Forum User-to-Network Interface (UNI) v3.0 specification details seven acceptable combinations of Usage Parameter Control (UPC) parameters that can be used to specify a traffic contract. ForeThought software supports all seven combinations for both PVCs and SVCs.

**ATM Network Signaling**

**SPANS**

SPANS (Simple Protocol for ATM Network Signaling) is an ATM network signaling protocol developed by FORE. It has provided switched virtual channel connections (SVCC) to FORE’s customers for more than four years. Today, it allows FORE to more rapidly deploy advanced ATM features, such as a complete Network-to-Network Interface (SPANS-NNI), group addressing, multicasting with leaf-initiated join, anycast addressing, smart PVCs (SPVCs), and an ATM applications program interface (API) prior to the ATM Forum’s standardization of these features.

**SPANS SPVCs**

Using SPVCs, the network administrator manually defines the endpoints of a connection, allowing SPANS to determine the optimal path between the endpoints. While the endpoints of the connection are static, the connection’s path through the network is dynamic. This allows SPVCs to respond to changes in the network topology (e.g., a failed link) by reconnecting the endpoints through an alternate path. SPVCs make setting up network signaling more convenient and add link redundancy to PVC-bound devices.

**UNI v3.0 Signaling**

The ATM Forum UNI v3.0 signaling specification defines the interface between an ATM device and an ATM switch. Each device in the ATM network has a unique address called a Network Service Access Point (NSAP). This address consists of a network prefix and an end system identifier. Each switch has a unique NSAP prefix and each ATM device has a unique end system identifier. Devices form a complete NSAP address by combining the network prefix with the end system identifier. This information is automatically registered with the ATM switch using the ATM Forum’s Interim Local Management Interface (ILMI).

ATM devices use the NSAP address to request a connection to another ATM device. The prefix is used as a location identifier by the ATM switches to route the connection setup message to a remote ATM switch, ultimately forwarding the message to the destination device. If the destination device accepts the connection, the ATM switches create a bi-directional connection, allowing data to flow between the devices in both directions.
ForeThought supports the ATM Forum UNI v3.0 signaling specification, along with the ILMI, across the entire ForeRunner ATM switch product line and on all UNIX ATM adapters. This provides interoperability with ATM switches and devices from other vendors that support UNI v3.0 signaling and ILMI.

**ForeThought PNNI**

The Private Network-to-Network Interface (PNNI) distributes NSAP-based routing information among ATM switches. This information is used by the ATM switches to route UNI v3.0 signaling messages through the network. The ATM Forum’s PNNI specification is under development. For now, the Interim Interswitch Signaling Protocol (IISP) enables switch-to-switch connectivity using statically-configured NSAP routing information. Using IISP, the network administrator must configure each switch with static NSAP routes to all other switches in the ATM network.

ForeThought currently provides a complete PNNI implementation called ForeThought PNNI (FT-PNNI). FT-PNNI is based on existing SPANS-NNI technology. Because FT-PNNI is modeled closely after ATM Forum PNNI draft specification, the transition to a standards-based implementation will be seamless.

Using FT-PNNI, network administrators do not need to configure static NSAP routes between ForeRunner ATM switches. Each switch exchanges link-state information with adjacent switches which then propagate this information to their adjacent switches. This information propagates through the network allowing each ATM switch to acquire a link-state database that includes every switch-to-switch link in the ATM network.

**Interoperability and Scalability**

IISP is supported across the ForeRunner product line so that ForeRunner products can interoperate with ATM switches from other vendors. While static routes must be used across IISP links, these routes are distributed throughout the FT-PNNI network. So, the entire FT-PNNI network learns the route without intervention from the network administrator.

NOTE:

ForeThought PNNI can support networks consisting of as many as 2,500 to 5,000 ATM switches.
Since link-state information is not propagated across IISP links, they can be used in a network containing all ForeRunner ATM switches to limit the size of the FT-PNNI NSAP routing domains. This reduces the size of the link-state database on each ATM switch. It also increases the overall scalability of the UNI v3.0 signaling network and improves network performance.
LANE v0.4 SVC-based LAN Emulation

To support multiple protocols over the ATM LAN using existing protocol drivers, LANE must be supported by the ATM devices. To provide this capability before an ATM Forum standard was completed, FORE developed a pre-standard LANE solution called LANE v0.4.

FORE’s LANE v0.4 includes:
• SPANS for dynamic call setup
• Distributed Connectionless Server (CLS) for LES and BUS services
• Support for a single emulated LAN per each SPANS network
• Connections to native Ethernet and FDDI LANs via the LAX-20
• Support for both Ethernet and Token Ring emulation

Transparent Bridging Over PVCs

Transparent bridging is a technique used to connect local or remote LAN segments to a logical network. While connecting LAN segments, a transparent bridge keeps traffic out of areas where it doesn’t need to go. A bridge does this by examining the source MAC (Media Access Control) address of each LAN frame to determine which devices reside on which LAN segment. The bridge then forwards subsequent frames only to the LAN segment where a device is known to reside. This forwarding decision is based on the destination MAC address field.

Figure 16: Transparent bridging over a PVC.

Figure 16 shows two transparent bridges connecting remote LAN segments across the ATM network. Notice that the LAN frame is specially encapsulated while traveling across the ATM link. This encapsulation is called “RFC1483 LLC SNAP encapsulation of a bridged PDU”, and allows Ethernet, Token Ring, and FDDI data packets to flow across the same ATM PVC between remote sites.

Remote LAN segments can be connected via transparent bridging over PVCs using the LAX-20. Furthermore, the LAX-20 can create a high-speed, ATM-based
backbone. (See Figure 17.) Multiple Ethernet, Token Ring, and FDDI LAN segments can be connected across an ATM backbone.

IP-Over-ATM

Figure 18: Network using IP-over-ATM to link existing LANs to an ATM network.
Classical IP

Classical IP (RFC1577) provides a standard native IP-over-ATM solution based on UNI v3.0 Signaling. FORE provides full Classical IP support including ARP Server support on all ForeRunner ATM switches and UNIX adapters, client support on all switches and UNIX adapters, and PVC/SVC support. Each UNIX adapter supports up to four virtual Classical IP interfaces enabling membership in multiple Classical IP Logically Independent Subnetworks (LIS).

FORE IP

FORE IP is FORE's pre-standard IP-over-ATM solution based on SPANS. In addition to IP unicast, FORE IP supports IP multicast and IP broadcast services, making it the only complete IP-over-ATM solution available today. FORE IP is supported across the ForeRunner ATM switch product line.

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<td>- Early Packet Discard (EPD)</td>
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<td>• 802.1d Bridging Over PVCs</td>
<td>- PVC Support</td>
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<tr>
<td>- Partial Packet Discard (PPD)</td>
<td>• SPANS Anycast Addresses</td>
<td>• Source Routing Over PVCs</td>
<td>- PVC Support</td>
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<tr>
<td>- Shared Output Buffering</td>
<td>• UNIX API</td>
<td></td>
<td>- PVC Support</td>
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<tr>
<td>- Rate Control on UNIX Adapters</td>
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</tbody>
</table>

Figure 19: A summary of ForeThought v3.4 features.
**FORETHOUGHT v4.0 OVERVIEW**

*ForeThought* v4.0 is available in December 1995 and has the features from the *ForeThought* v3.x release plus the following:

**Additions to the ForeRunner Product Family:**
- ES-3810 Workgroup Ethernet Switch
- AIX 4.1.2 Drivers for the MCA-200 ATM Adapters

**ATM Layer Services:**
- Variable Bit Rate (VBR) Overbooking

**ATM Network Signaling:**
- FT-PNNI Peergroups
- SPANS-NNI Peergroups

**LAN Emulation (LANE):**
*ForeThought* v4.0 support for ATM Forum LANE v1.0 includes:
- LAN Emulation Client (LEC) support for:
  - ForeRunner Family of ATM Switches including ASX-200WG, ASX-200BX, and ASX-1000.
  - ForeRunner ATM Adapters including UNIX, PC, and Macintosh adapters
  - ForeRunner ES-3850 Ethernet Workgroup Switch
- LAN Emulation Services include:
  - Broadcast and Unknown Server (BUS), LAN Emulation Server (LES), LAN Emulation Configuration Server (LECS)
  - ForeRunner Family of ATM Switches
  - ForeRunner SBA-200 ATM Adapter under SunOS 4.1.3
- Multiple Virtual LANs
- Ethernet Emulation
- Virtual LAN Configuration Application (VCA)

*ForeThought* v4.0 supports ATM Forum LANE v1.0 specification. In addition to LANE v1.0 support, the new LAN access products and scaleable NNI protocols can create large scale multivendor internetworks with FORE’s ForeRunner hardware running *ForeThought* v4.0 software as the core.
NEW FORERUNNER PRODUCT

ForeRunner ES-3810 Ethernet Workgroup Switch

The ES-3810 provides switched 10 Mbps Ethernet connections to a workgroup of up to 71 workstations plus an Ethernet uplink port. Connectivity from the Ethernet workgroup to an ATM backbone is provided by the ForeRunner LAX-20.

NEW FORETHOUGHT FEATURES

SPANS-NNI and FT-PNNI Peergroups

In order to make SPANS-NNI and FT-PNNI networks scaleable to large networks, the addressing and routing must be made hierarchical. With hierarchical routing, networks can be logically partitioned into areas, similar to areas in OSPF. Scalability is achieved by:

- limiting the flow of link state information local to an area to the boundaries of an area.
- summarizing reachability information to an area for switches external to the area.

In SPANS-NNI, an addressing hierarchy is defined by designating a prefix of the SPANS ATM address as an area identifier. Switches in an area that have links to other switches that belong to a different area are called border switches. A border switch advertises its reachability to switches outside the area and hides the internal topology. SPANS-NNI features such as Group Addressing and SPVCs are supported by the hierarchical routing.
In FT-PNNI, areas are called peergroups. Switches in a peergroup have common, variable length prefix in their NSAP addresses. This prefix is called the peergroup identifier. Topology distribution of FT-PNNI takes place in a manner similar to that of SPANS-NNI. Exterior reachable addresses and static routes across IISP interfaces are also supported by hierarchical FT-PNNI.

The only switch-to-switch or private-NNI interface currently specified by the ATM Forum is the Interim Interswitch Signaling Protocol (IISP). While the IISP defines the message format for signaling messages between switches, it does not provide any distribution of routing information. Static routes must be configured on each switch to properly forward (i.e., route) UNI signaling messages.

The ATM Forum is working on a PNNI implementation that will specify how to distribute this routing information—the ATM Forum Private Network to Network Interface (ATMF PNNI).

The following list defines what FT PNNI does today:

- Pre-standard PNNI (phase 1) implementation
- Distributes NSAP routing information
- Provides load balancing of UNI v3.0 signaled connections between switches
- Two-level hierarchy (i.e., peergroups) for scalability

NOTE:
ForeThought PNNI can support networks consisting of as many as 2,500 to 5,000 ATM switches.
• Will interoperate with ATMF PNNI peergroups in the future
• Source route Information Element reduces routing overhead
• Distributes static routes throughout FT PNNI network
• Supports alternate static routes with cost metrics

In the future, when the ATMF PNNI is complete, FT-PNNI will exist as a superset of the ATMF PNNI, continuing to add value with pre-standard features.

ATM Forum LANE v1.0

The ATM Forum recently finalized the LANE v1.0 specification. LANE v1.0 defines three key services that work together using ATM Forum UNI v3.0 Signaling to allow end stations, referred to as LAN Emulation Clients (LEC), to communicate as if they were attached to a traditional Ethernet. These services are the LAN Emulation Server (LES), LAN Emulation Configuration Server (LECS), and the Broadcast and Unknown Server (BUS).

Figure 22: LANE v1.0 supporting multiple virtual LANs.
LAN Emulation Configuration Server (LECS)
The LECS is responsible for the initial configuration of LECs (i.e., LANE clients). The LECS provides information about different virtual LANs (VLANs) available on the ATM network and the LESs and BUSs that serve each VLAN. The LES and BUS provide the services needed to enable LECs to create UNI v3.0 connections and transfer data through the network. Each LEC must register with both the BUS and LES before it can participate in the VLAN.

Broadcast and Unknown Server (BUS)
Unlike traditional shared media LAN architectures, ATM is connection-based. It has no built-in mechanism for handling connectionless traffic such as broadcasts, multicasts, and unknown unicasts. Using LANE, the BUS is responsible for servicing these traffic types by accepting broadcast, multicast and unknown unicast packets from the LECs via dedicated point-to-point connections and forwarding the packets to all of the members of the VLAN using a single point-to-multipoint connection.

LAN Emulation Server (LES)
Before a UNI v3.0 connection can be requested by a LEC, it must know the NSAP address of the remote LEC. The LEC will learn the MAC address of the remote LEC in the same manner used on a traditional Ethernet. Once the LEC has the MAC address of the remote LEC, it can send a request to the LES to learn the NSAP address of the remote LEC. Each LEC will resolve MAC addresses to NSAP addresses by sending a request to the appropriate LES.

ForeThought LANE v1.0 Implementation Feature Summary
The ForeThought LANE v1.0 implementation will include all of the necessary services as well as client support across all platforms. The specifics of the FORE LANE v1.0 implementation are as follows:

- The services will be supported across the switch product line as well as on SunOS workstations
- Multiple Emulated LANs are supported on a single ATM network
- The initial implementation will support only Ethernet emulation
- Each LEC can be a member of up to 16 Virtual LANs (VLANs)
- Configuration of the LECS is simplified with a Graphical User Interface (GUI).
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</tbody>
</table>

Figure 23: A summary of ForeThought v4.0 features.

**ForeRunner/ForeThought Version Compatibility**

UNIX hosts with FORE IP will interoperate with ForeRunner ATM switches using ForeThought v4.0 and ForeRunner ATM switches using ForeThought v3.x will interoperate with hosts that use ForeThought v4.0.

However, the pre-standard version of ForeThought LANE v0.4 is replaced by ForeThought v4.0/ATM Forum-compliant LANE v1.0 on ForeRunner PC and Macintosh ATM adapters.

ForeThought v4.0 replaces FORE IP with IP-over-LANE support using Q.2931 signaling on ForeRunner PC and Macintosh ATM adapters. FORE will make both LANE v0.4 and ForeThought v4.0/LANE v1.0 available to PC and Macintosh ATM adapter customers.
CONCLUSION

*ForeThought* software and the *ForeRunner* family of ATM products combine to provide the components needed to introduce ATM into the corporate internetwork. Future versions of *ForeThought* software will enable the initial ATM network to continue the migration to a complete ATM internetwork, delivering the features and capabilities promised by ATM technology.
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