The Intelligent Bandwidth Manager and Its Role in Enterprise Networks

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As the era of broadband networking dawns, network managers in the private sector will be faced with many choices—among competing technologies, products, and services—in providing what is called the Enterprise network "solution." Enterprise networking is the interconnection of corporate, departmental, local, and remote network resources to create company-wide information utility. This paper discusses the issues that network managers face, and proposes an approach to the Enterprise network solution based on a concept known as intelligent bandwidth management (IBWM). Intelligent bandwidth managers are a class of devices based on asynchronous transfer mode (ATM) technology. These devices provide an effective transition methodology from narrowband networking to broadband networking.

Introduction

This paper discusses the role of premises-based networking as the broadband integrated-services digital network (BISDN) era begins to evolve. Network "drivers" and implications are reviewed, with particular emphasis on the real-world issues of network managers. Next, a brief history of private networks is provided, explaining the drivers for a new architecture based on ATM technology. The paper then introduces IBWM, and details the features and functions that an IBWM must provide to meet the needs of network managers in implementing the Enterprise network solution. Finally, the paper describes a new paradigm of network management solutions, the relationship of the IBWM to other products, and the role of the IBWM in the evolving network.

Networking Drivers and Implications

There are a number of drivers that will define the networking industry into the next century. They include end-user behavior, new carrier services, and the emergence of many new products and networking vendors. Network managers (individuals responsible for managing Enterprise networks) must contend with constantly changing end-user requirements, pressures to minimize networking costs, the desire to extend networking control from headquarters to remote locations, and the continuing trend to expand businesses around the globe. In addition, new services from U. S. interexchange carriers (IXCs), regional Bell operating companies (RBOCs), and foreign postal telephone and telegraph (PTT) companies are being introduced at an ever-increasing rate. To further complicate the issues for network managers, many new products that incorporate the latest technology are being developed. These products hold the promise of solving the myriad problems network managers face in attempting to implement the Enterprise network solution.

Additionally, network end-users often require new computer applications to help them meet their business objectives. These new end-user applications may depend on computing platforms that are distributed around the Enterprise network, as opposed to those that are centralized at a headquarters location. Such client/server applications require a fundamentally different network architecture from the classic, hierarchical networks epitomized by the IBM (IBM is a registered trademark of International Business Machines Corp.) systems network architecture (SNA). Client/server applications will require networks that often must support higher bandwidth, "bursty" traffic, as

Panel 1. Abbreviations, Acronyms, and Terms

API—application-programming interface
ASDS—ACCUNET® Spectrum of Digital Services
ATM—asynchronous transfer mode
branch controller—a device that provides many of the capabilities of an IBWM at remote branch locations within the Enterprise network
CSU—channel service unit
DME—distributed management environment
drivers—factors that will define the networking industry into the next century
DSU—data service unit
Enterprise network—a networking "solution" that interconnects corporate, departmental, local, and remote network resources to create company-wide information utility
frame relay—a packet switching protocol and technique
hub of hubs—a hub that provides for switching and hubbing of data traffic from traditional Ethernet or token-ring LANs, and workstations with high-speed connectivity needs
hybrid networking—integration of digital voice and data signals on a single facility, and termination of either type of signal on a remote, private-network vehicle or off the public network
IBWM—intelligent bandwidth management; or, intelligent bandwidth manager
IM&M—information management and movement
ISDN—integrated-services digital network
IXC—interexchange carrier
LAN—local-area network
network managers—individuals responsible for managing Enterprise networks
NMS—network-management system
PBX—private branch exchange
PTT—foreign postal telephone and telegraph companies
RBOC—regional Bell operating company
router—an interface between two networks, or any device that is designed to perform the routing function (routing is the process of choosing a path over which to send data)
SBNM—standards-based network management
SDLC—synchronous data-link control
SDM—Subrate Data Multiplexing
SDN—software-defined network
SMDS—Switched Multimegabit Data Services
SNA—systems network architecture
T1—a 1.544-Mbits/s private leased line comprised of 24 DS0s (56/64 Kbits/s)
TDM—time-division multiplexing
WAN—wide-area network
X.25—packet-switching protocol at link and packet layers; also, packet-switching protocol and standard (CCITT)

opposed to traditional, low-speed predictable traffic, such as host-to-mainframe access and private voice networking. Video, imaging, and multimedia applications will demand considerably more bandwidth across local-area networks (LANs), campus networks, and wide-area networks (WANs), as compared to traditional applications. End-users also will expect 100-percent availability of applications critical to their business missions. Network managers are normally charged with the responsibility of ensuring that a network is able to support end-user expectations.

In addition to end-user demands, network managers are often compelled by upper management to reduce expenditures wherever possible. Network managers must continue providing support for legacies, such as SNA applications, while building a network infrastructure that will support newer applications having greater bandwidth needs and less predictable traffic profiles. All this must be done within "flat" or even decreasing budgets, which often include substantial charges for personnel, equipment, and recurring network-services costs.

Over the past several years, many departments utilizing the Enterprise network solution have chosen to manage and install their own LANs, rather than relying on corporate systems support to administer them. This decision frequently was driven by their desire to:

- Accelerate the installation of specific applications,
- Reduce costs, and
- Provide a sense of departmental autonomy.

However, many department managers are now realizing there is a need to access applications and databases outside their own LANs. This realization has shifted the importance of system administration back to corporate network managers. Now, department heads view network managers as a vital resource in providing a network architecture that will effectively bring departmental LAN "islands" into the Enterprise network, allowing access to all available on-line corporate resources.

The emergence of many new network services, from the IXCs and RBOCs in the United States, and from the PTTs in other countries, has created a plethora of cost-effective choices to assist Enterprise network managers in meeting end-user needs. Network service providers have shifted their emphasis from pure transport, for private networking, to providing more "intelligent" services. Such services include virtual private voice networks, frame-relay packet switching, and Switched Multimegabit Data Services (SMDS) networks. The common vision of today's networking industry is a "seamless" network that combines voice, data, image, video, and multimedia-based information by means of ATM technology, then transports the combined information through broadband ISDN capabilities.

To facilitate the job of network management, many new suppliers and products are emerging, each aimed at fulfilling end-user expectations at the lowest possible cost. Some examples of newly developed networking products include intelligent LAN hubs and hub/router combinations. These products extend connectivity throughout a network, and can be managed from a central location.

Vendors are taking several distinct approaches to solving networking problems. Existing T1 multiplexer vendors are incorporating frame-relay packet switching[1] and router add-ons to many of their existing products. At the same time, separate ATM-based products are also appearing. Likewise, start-up companies are introducing ATM switch/hubs in an attempt to change the overall networking "landscape." And finally, the trend for businesses throughout the world to expand beyond their traditional boundaries, becoming true multinational or global enterprises, requires sophisticated, seamless networks that span the globe.

Issues for Network Managers

Several substantial challenges these issues present to network managers include:

- How to manage life-cycle costs while supporting new "bursty" applications,
- How to ensure that the performance and availability of traditional applications are maintained, or even improved, as networks begin carrying new applications,
- How to include a local area within an Enterprise network seamlessly,
- How to maintain an integrated network as a business globalizes, and
- How to determine if near-term networking purchases will be as useful when ATM and broadband ISDN networking arrive.

The concept of IBWM attempts to respond to each of these challenges by:

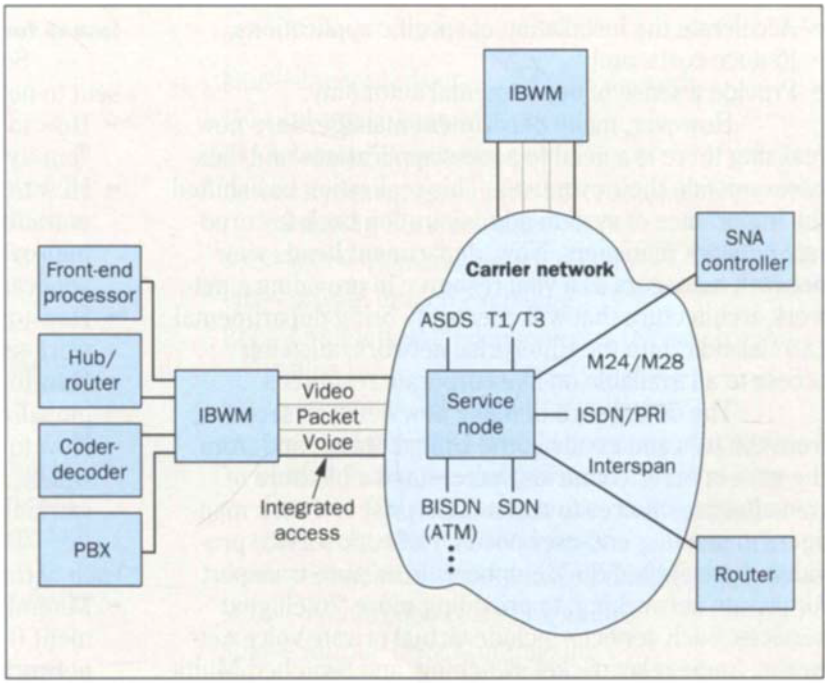
- Minimizing total information management and movement (IM&M) life-cycle expenses, including costs for network services, equipment, and operations,
- Sustaining end-user applications' performance and availability,
- Providing smooth evolution to broadband networking,
- Providing Enterprise networking to the desktop, and
- Supporting multinational and global networks.

Intelligent Bandwidth Management

Several generations of equipment have been used in private networks to provide Enterprise network solutions. As applications, tariffs, and public-network service offerings evolved, underlying equipment platforms and network topologies have also changed as network managers sought to increase system performance, reduce costs, and extend manageability. This section examines several previously discussed networking solutions, and proposes the role of an ATM-based IBWM as central to implementing private networking topologies.

Background. In the mid 1980s, private data networking was largely dominated by T1 multiplexers based on time-division multiplexing (TDM) technology. The basis for deploying a T1 multiplexer network is the economics of a private voice network versus a network provided by an IXC. Also during the 1980s, the price of T1 facilities dropped dramatically, allowing tariff arbitrage to take effect, meaning that a nominal DS0 requirement (15-20) justified the purchase of an entire T1 facility.

Figure 1. This drawing shows the breadth of network services and an IBWM's role in Enterprise networking. By integrating the output of router traffic with other traffic on a premises destined for connection to a WAN, network managers can realize cost efficiencies on access.



Network managers rationalized equipment purchases by building business cases, proving that a privately-owned, integrated, voice-and-data network would pay for itself in several years (usually three). In this scenario, the aggregate bandwidth required for data connectivity paled in comparison to voice-bandwidth requirements. Therefore, data generally rode the network for free. In fact, very few data-only networks were deployed, as private companies simply did not have the bandwidth requirements to justify the expenditure.

The private data networks that were deployed generally used X.25 packet switches as the backbone, along with low-speed access links. It is important to note that these networks did not have a solution for voice-connectivity needs. This necessitated the installation of parallel networks to complete the corporate system.

During this era, public network services simply did not exist, with the notable exception of the X.25 packet switching protocol. Therefore, any voice and data signals originating on one particular vendor's equipment—for example, a voice call—also had to terminate on the same vendor's equipment. Equipment expenditures represented inflated costs, because compatible equipment had to be placed at every network location. In addition, each vendor implemented a proprietary means of interworking between equipment. There were no public-service definitions. Thus, a network was generally owned by a single vendor. This was because endpoints terminating on different vendors' equipment could not interwork, and the ability to terminate on a device connected to the public network did not exist.

Changing Times. Several separate trends have changed the criteria for the underlying platform of corporate data networks, driving the need for IBWM devices. Personal computers are the largest single influence behind the changes taking place in most corporations. The combination of these ever-more-powerful machines, widespread and easy-to-use applications, and the ease of file sharing through LANs have radically changed the nature of the corporate-network purchase decision.

LANs require wide-area connectivity. As a result, an entire industry appeared almost overnight, specializing in LAN bridging and routing equipment. These devices allowed remote "islands" of users to communicate easily over long distances, and established the need for bandwidth-on-demand connectivity. Bandwidth-hungry applications began to change the ratio of data to voice on the private-network backbone.

T1 multiplexers have been used in many of these applications—with a few drawbacks. First, in order to provide "meshed" connectivity between router locations, T1 multiplexers require many costly interface cards. Second, because each router was connected point to point, there was no ability for "bursting" over the backbone beyond the configured link speed.

Separately, IXCs began to offer a plethora of public services, some of which specifically targeted existing private networks. A prime example of this type of service is the AT&T software-defined network (SDN), which is essentially a publicly provided, virtual, private-voice network. The economics of SDN services began to swing the pendulum of networking solutions back toward the IXCs. Additional IXC solutions, such as M24, Subrate Data Multiplexing (SDM)[2], ACCUNET Spectrum of Digital Services (ASDS), 800 inbound and outbound services, and ISDN services[3], spawned a new style of networking known as *hybrid networking*[4].

Hybrid-networking technology allows an end-user to integrate digital voice and data signals on a single facility, and to terminate either type of signal on a remote, private-network vehicle or off the public network. Network services, such as M24, provide the ability to aggregate up to 24 remote DS0s on a single facility, terminating at a single location over a T1[5]. Hybrid networking reduces costs through the efficiencies that network services provide, and by reducing the overall deployment of private equipment in the network solution. Thus, a network manager can choose the exact types of services that best meet established price and performance criteria. Capital outlay for equipment can be reduced, as well as the administrative overhead associated with maintaining an Enterprise network solution.

A New Architecture

The widespread deployment of routers—and the movement away from hierarchical topologies, such as SNA, has opened the door for a new architecture to support private data networks. With the addition of frame-relay interfaces, packet switches can effectively meet the need for the bandwidth-on-demand services required by LAN-based applications. They also address the cost issues, for both equipment and facilities, that traditional T1 multiplexers are not capable of addressing. These solutions still lack an effective voice-transfer capability, however, and are not compatible with network services, which also makes them unsuitable for integration into an Enterprise network. Clearly, a more fundamental architecture that addresses the key network-owner issues—one that merges the best attributes of traditional T1 multiplexers and packet switches, and one that provides hybrid networking capability—is required.

Given these needs, the new architecture must be based on ATM technology[6], which can support both TDM (constant-bit-rate) services and frame-relay packet switching (variable-bit-rate services). ATM technology also facilitates network-services compatibility. Because the new architecture is ATM based, interfaces can easily be added, as necessary, to support new applications. Evolving network services, including publicly available ATM services, can also be supported. Such a device would effectively support the concept of IBWM.

Characteristics of IBWM

IBWM provides cost-effective and reliable aggregation, management, and transport of disparate data traffic (voice, video, image, and so on). IBWM accomplishes this through efficient data-packing techniques and dynamic, intelligent use of available LAN/WAN network services.

IBWM is based on matching the native application, such as SNA or LAN interconnect, to the network service that best meets a customer's price and performance criteria. This encompasses a wide variety of applications in today's premises-based networking environment. Among the applications are low-speed asynchronous for e-mail; synchronous data-link control (SDLC)/SNA, generally used in transaction-oriented environments; circuit-switched voice and video connectivity; and LAN/WAN connectivity, which is required by client-servers. Each of these applications has decidedly different performance criteria and price tags that also vary widely. Figure 1 shows the breadth of network services and an IBWM's role in Enterprise networking.

A network manager's mission is to extend the global presence of a corporation. Concurrently, the IBWM must comply with all relevant safety, emissions, and licensing standards to facilitate true global networking. IBWM provides the robust, fault-tolerant, and redundant components needed to meet corporate goals and maximize network availability.

Integration of voice and data solutions over common facilities reduces primary networking costs. Customers' price and performance requirements can be met by complying with standard network-service definitions.

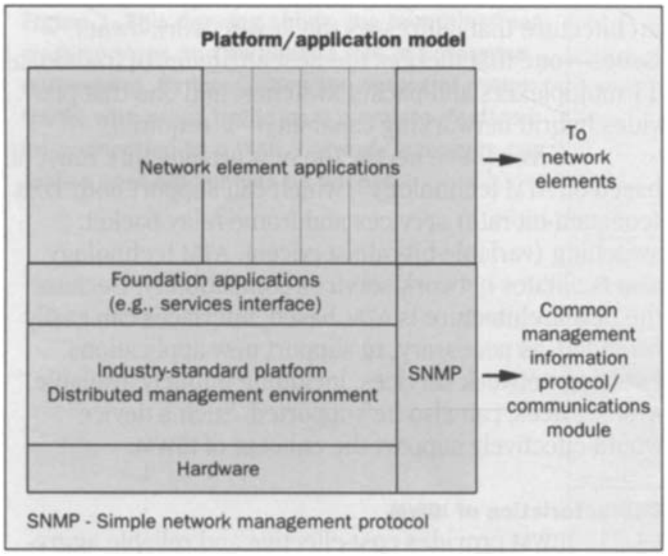


Figure 2. This illustration shows a network-management architecture model for what the networking industry has termed standards-based network management (SBNM).

IBWM extends the boundary of private LANs into the WAN, and uses Enterprise-solution resources to achieve cost-effective broadband networking. For example, network managers can provide additional (dynamic) bandwidth for both recovery from network outages and additional capacity during periods of high usage.

As technology matures, network managers will be able to provide tariff shopping "on the fly," so customers can use the optimum network solution at any given time. IBWM must support voice and data services, compatibility with existing and future capabilities, and an architecture that allows graceful evolution to next-generation networking technology. Many existing T1 multiplexers and packet switches can satisfy some customer requirements. However, the existing equipment lacks many important features that prevent a complete single-platform solution.

Based on the need to support traditional technologies and high-bandwidth applications, the premises-resident IBWM must be based on ATM technology. ATM is the technology of choice to support voice, data, video, and multimedia applications. A high-capacity architecture, ranging from hundreds of megabits per second to several gigabits per second, provides life-cycle management and a smooth migration from narrowband to broadband networking. Thus, network managers can deploy an IBWM based on ATM technology today, provided that the interconnections to the current network elements are supported and new interfaces, such as ATM, are added. By taking this approach, IBWMs can satisfy network managers' foremost concerns.

Network Management

A new paradigm is emerging with respect to network management (see Figure 2). In the past, vendors of WAN equipment, such as modems, data service units (DSUs), and T1 multiplexers, also provided proprietary network-management systems (NMS) to maintain their own network elements. This has contributed to the proliferation of NMSs within the Enterprise network, resulting in higher costs and greater difficulty for network mangers. Figure 2 illustrates a network-management architecture model for what the networking industry has termed standards-based network management (SBNM). There are three major aspects of SBNM:

- A standards-based agent in the element that network managers are attempting to manage,
- Standards-based interfaces on the NMS, and
- Standard application-programming interfaces (API) on the NMS.

There are two contending standards for both the network-element agent and the NMS interface: the simple network-management protocol and the common management-information protocol. In addition, the open-systems foundation has created a framework for SBNM platforms, known as the distributed management environment (DME). The essence of DME is a set of APIs. Vendors can write application programs to these APIs that provide support for management of their network elements (IBWM, router, LAN hub, and so on), or applications that are generic across a broad range of network elements (network map, trouble ticket, and so forth).

Some advantages of this approach to network management are:

- All network elements that provide a standards-based agent can be managed from a single platform, resulting in opportunities for true integrated management and reduced operating and capital costs.
- Third-party software providers can write applications to the standard APIs, which will be portable across a number of platforms from multiple-platform vendors. The network manager is then able to choose from a

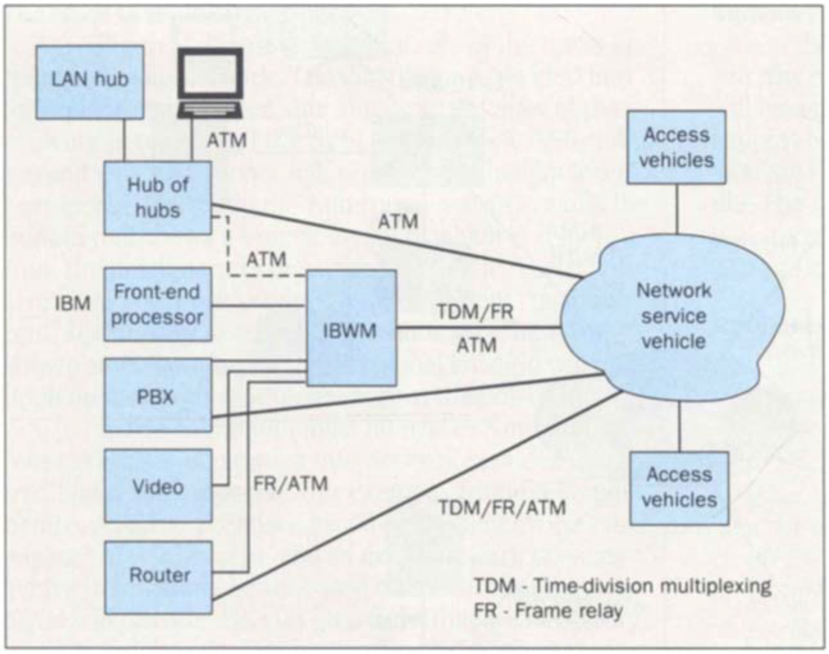


Figure 3. The relationship of the IBWM to other premises-based and network-services-based equipment is shown in this drawing.

number of third-party applications, integrating them with specific applications from the network-element vendors. The vendors may also choose to provide NMSs, which combine their network-element-specific applications with third party applications, thereby providing turnkey network-management solutions.

- Network-element vendors can focus on providing specific applications that support their own elements, as opposed to building complete network-management solutions from the ground up. Network managers will have access, therefore, to better application support for the network elements they plan to deploy.

IBWM Relationship to Other Premises Equipment

Figure 3 illustrates the relationship of the IBWM to other premises-based and network-services-based equipment. As shown, the IBWM is the primary vehicle for aggregation of traffic from other premises-based equipment, providing the gateway into a multitude of network services. Equipment that interfaces with the IBWM includes IBM front-end processors, which may present a number of different interfaces, such as TDM, frame relay, and X.25. Private branch exchanges (PBXs) for voice traffic may feed into the IBWM, or present an interface directly into the network. Examples of value-added IBWM functions—where the PBX feeds into the IBWM—include rerouting of traffic around failed network facilities, ensuring delivery of traffic to its intended destination, and compression of traffic by a factor of up to eight to one, thereby reducing overall WAN costs.

As the number of LANs and the transfer speeds required by end-users continue to grow exponentially (driven by new high-bandwidth applications), so too will the numbers, types, and configurations of LAN hubs and routers. LAN hub and router vendors are adding ATM interfaces to address and support these high-bandwidth applications. For LAN-to-LAN internetworking over a WAN, multiple LANs may be switched through a router, whose output may go directly into a WAN service or through an IBWM. By integrating the output of router traffic with other traffic on a premises destined for connection to a WAN, network managers can realize cost efficiencies on access, as shown in Figure 1. Also, the IBWM may act as a frame-relay or ATM switch, providing network managers additional bandwidth efficiencies through statistical multiplexing of traffic from multiple routers, or by providing a frame-relay or ATM "hubbing" point in the WAN.

One of the latest entries in the premises environment is the *hub of hubs*. This entry is based on multigigabit ATM technology. It provides for switching and hubbing of data traffic from traditional Ethernet or token-ring LANs and workstations with high-speed connectivity

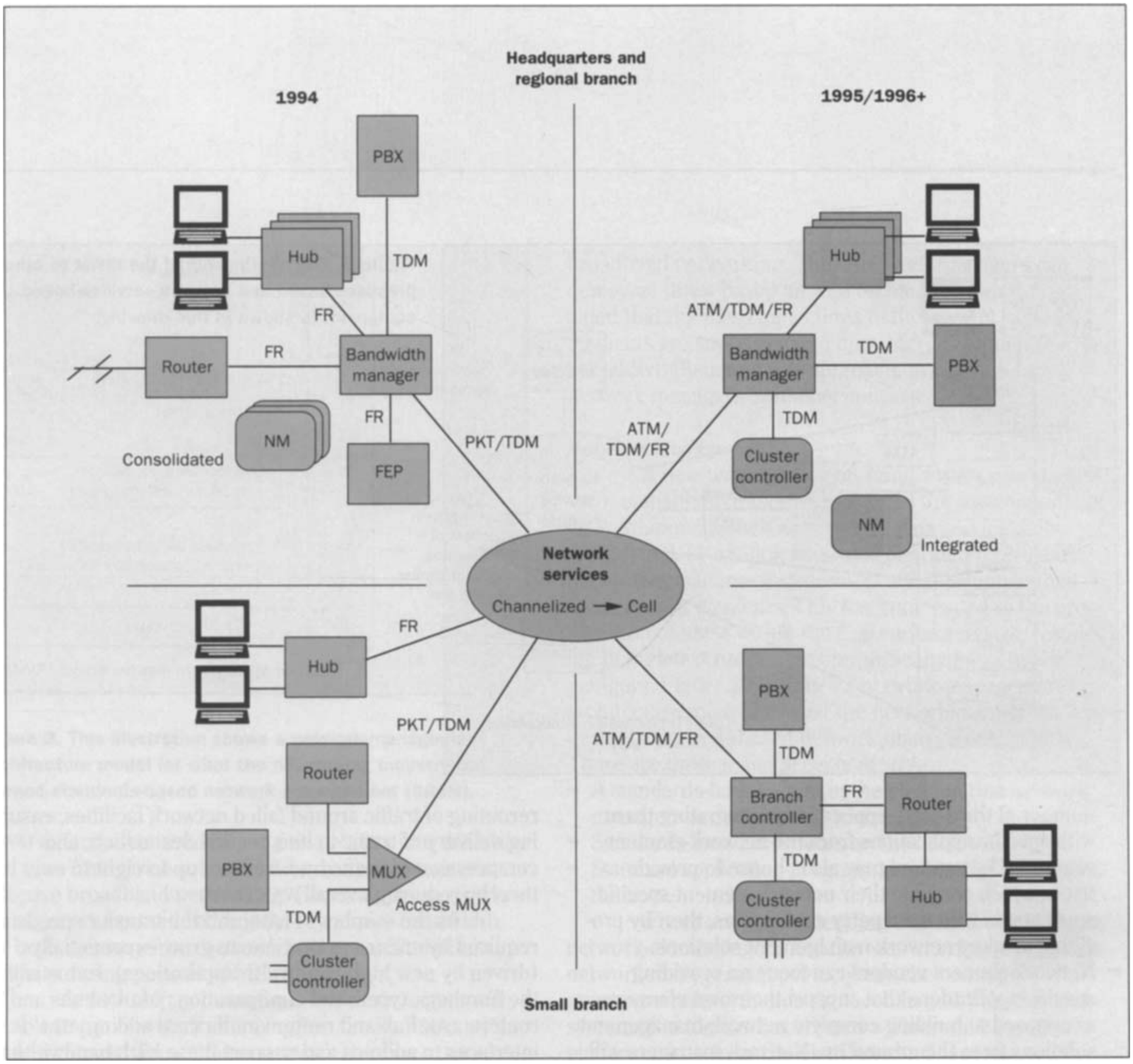


Figure 4. The vital role of the IBWM in the developing network is shown in this drawing. The upper half represents a headquarters or regional site within the Enterprise network, while the bottom half shows a branch location. Also shown are network services migrating from "channelized" technology to cell-based technology. The IBWM at the headquarters or regional location will be implemented with ATM technology at the outset.

needs. The hub of hubs provides the backbone infrastructure for the local area. Hubs for token-ring or Ethernet LANs are emerging with ATM interfaces, which permit tying them into the hub of hubs. ATM interfaces for workstations with high-speed connectivity needs are also appearing. The hub of hubs may provide an interface directly into the IBWM, or directly into a WAN, through an appropriate network adapter, such as the ATM data service unit/channel service unit (DSU/CSU), or the digital signal level-3 (DS3) DSU/CSU. Until broadband ISDN network services are introduced, the most likely high-speed interfaces for this application are either T3 or fractional-T3 services. Right now, however, the hub of hubs is limited to proprietary networking.

Another segment of the IM&M marketplace, which is growing rapidly, is video. Examples of where the IBWM adds value to video services include integrated access with other types of information, obtaining bandwidth on demand for "video calls," and payment only for the amount of bandwidth that is required for the duration of a call.

The IBWM in the Evolving Network

Figure 4 illustrates the vital role of the IBWM in the developing network. The illustration is divided into four quadrants. The left side shows a 1994 view of the evolving network, and the right side shows a 1995-and-beyond view. The upper half represents a headquarters or regional site within the Enterprise network, while the bottom half shows a branch location, which is remote from the headquarters or regional site. The illustration also shows network services migrating from "channelized" technology to cell-based technology. The IBWM shown at the headquarters or regional location will be implemented with ATM technology at the outset.

In the beginning, most interfaces from the other premises equipment into network services will be traditional TDM or packet (for example, frame relay) in nature. As other premises-based equipment evolves to support ATM interfaces, and as many network services evolve to broadband ISDN based on ATM technology, the IBWM will provide the ATM interfaces that are necessary to accommodate the services and applications requiring broadband technology.

At remote branch locations within the Enterprise network, services and equipment—similar to those provided at the headquarters or regional site—are required. Researchers envision that a device known as a *branch controller* will be developed and introduced, providing many of the capabilities of the IBWM. One major difference, however, is bandwidth scale. The total bandwidth requirements for the IBWM are in the gigabit range, while those for the branch controller will be less (on the order of hundreds of megabits per second), due mainly to the number of end-users each controller must serve. There is some speculation that the branch controller may mature to encompass the functions of the IBWM, LAN hubs, routers, and voice equipment, such as key telephone systems.

Within the scope of Enterprise networking, IBWMs must provide solutions for hybrid networks and purely private networks. The primary value of the IBWM is that network managers can select the interfaces and services that will meet specific end-user needs as networks migrate from narrowband to broadband services. The value of the IBWM is based on several considerations. These include availability and reliability of the network, reduction in overall IM&M life-cycle costs, and network investment protection.

Summary

Looking forward into the 21st century, the IBWM will play a key role in Enterprise networking. The IBWM will become the most important premises equipment to support both end-user legacy applications, such as SNA/SDLC, and developing applications, such as multimedia. The IBWM will also help customers make the transition from narrowband to broadband services, such as ISDN, as carrier network services evolve.

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(Manuscript approved October 1993)

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