♦ The WaveStar™ BandWidth Manager: The Key Building Block in the Next-Generation Transport Network

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The WaveStar™ BandWidth Manager (BWM) is Lucent Technologies' flagship product platform for providing bandwidth management within network nodes. It provides broadband (OC-3/12/48/192 and STM-1/4/16/64), asynchronous transfer mode (ATM), and Internet protocol (IP) bandwidth management within a highly-integrated, scalable, single network element. The WaveStar BWM's broadband synchronous transfer mode (STM) fabric scales from 1152 STS-1/384 STM-1 (60 Gb/s) to 9216 STS-1/3072 STM-1 (480 Gb/s) port capacity. With such a high range in capacity scalability across the broadband STM fabric, the BWM can be sized to meet most carriers' growth projections while protecting them from unforeseen growth within network nodes. The WaveStar BWM also addresses the growing need for enhanced bandwidth management capabilities within central offices. It integrates all access and transport facilities within a network node and efficiently manages bandwidth among these facilities via a cost-effective, scalable, multiservice switching architecture. The BWM facility interfaces, which feature integrated self-healing rings, eliminate the need for stand-alone add/drop multiplexer (ADM) ring terminals in the central office. Furthermore, the switching architecture, which includes an STM fabric as well as ATM and IP functionality, replaces the need for stand-alone broadband digital cross-connect systems (BDCSs) and ATM and IP core switches/routers. The WaveStar BWM also supports direct integration of Lucent's dense wavelength division multiplexing (DWDM) systems—the WaveStar optical line system (OLS) 400G and the WaveStar OLS 40G.

WaveStar™ BWM Overview and Value Proposition

The WaveStar BandWidth Manager (BWM) is Lucent Technologies' flagship product platform for managing bandwidth within network nodes. This section provides an overview of the WaveStar BWM and describes its value in the network.

WaveStar BWM System Capacities

The WaveStar BWM, shown in **Figure 1**, is a modular, highly cost-effective, multiterminal lightwave system, add/drop multiplexer (ADM), asynchronous transfer mode (ATM)/Internet protocol (IP) switch, and digital cross-connect system combined. The BWM is designed to meet customers' long-term lightwave and bandwidth management needs. As capacity requirements in the network increase, the WaveStar BWM grows in a way that minimizes both equipment and operational costs. To meet the needs of any size of office application, three configurations of the BWM are available:

- The 1152 STS-1/384 STM-1 capacity system, designed for smaller offices, is shown in **Figure 2**. The 2-bay start-up configuration consists of one bay of common equipment that

Panel 1. Abbreviations, Acronyms, and Terms

ADM—add/drop multiplexer
APS—automatic protection switching
ATM—asynchronous transfer mode
AU-3—administrative unit level 3, with a transmission rate of 35 Mb/s in SDH hierarchy
AU-4—administrative unit level 4, with a transmission rate of 140 Mb/s in SDH hierarchy
BDCS—broadband digital cross-connect system
BLSR—bidirectional line-switched ring
BWM—BandWidth Manager
DCC—data communication channel
DS3—digital signal level 3, with a transmission rate of 44.736 Mb/s (672 64-kb/s channels) in TDM hierarchy
DWDM—dense wavelength division multiplexing
EC-1—electrical carrier level 1, with a transmission rate of 51.84 Mb/s in TDM hierarchy
FT-2000—lightwave system
GNE—gateway network element
I/O—input/output
IP—Internet protocol
IPsec—secure IP
IS—intermediate system
ISO—International Organization for Standardization
LAN—local area network
LISP—list-processing language
MS—multiplex section
OC-3—optical carrier digital signal rate of 155 Mb/s in a SONET system
OC-12—optical carrier digital signal rate of 622 Mb/s in a SONET system
OC-48—optical carrier digital signal rate of 2.488 Gb/s in a SONET system
OC-192—optical carrier digital signal rate of 9.953 Gb/s in a SONET system
OLS—optical line system
OSI—open systems interconnection
QoS—quality of service
RTP—real-time protocol
SDH—synchronous digital hierarchy
SMTP—simple mail transfer protocol
SNA—systems network architecture
SNCP—subnetwork connection protection
SONET—synchronous optical network
SPRing—shared protection ring
STM-1—synchronous transfer mode optical signal at 155 Mb/s
STM-4— synchronous transfer mode optical signal at 622 Mb/s
STM-16— synchronous transfer mode optical signal at 2.488 Gb/s
STM-64— synchronous transfer mode optical signal at 9.953 Gb/s
STS-1—synchronous transfer signal rate of 51.84 Mb/s on an electrical facility
STS-3—synchronous transfer signal rate of 155 Mb/s on an electrical facility
STS-12—synchronous transfer signal rate of 622 Mb/s on an electrical facility
STS-48—synchronous transfer signal rate of 2.488 Gb/s on an electrical facility
STS-192—synchronous transfer signal rate of 9.953 Gb/s on an electrical facility
SWIF—switch interface
TCP—transport control protocol
TDM—time division multiplexing
UPSR—unidirectional path-switched ring
VC-3—virtual container at a rate of 34 Mb/s in SDH hierarchy
VOD—video on demand
VPN—virtual private network

includes the controller, the synchronizer, and the switch fabric—all fully duplicated for reliability—and one bay that supports up to two input/output (I/O) universal modules. Capacity growth is achieved by adding additional bays and universal modules as needed.

- The 4608 STS-1/1536 STM-1 capacity system, designed for larger applications, is shown in **Figure 3**. The 4-bay start-up configuration consists of two bays that house the duplicated switch fabric, one bay for the duplicated controller and synchronizer, and one I/O bay with two universal modules. I/O growth is achieved in a manner similar to that of the 1152/384 system.
- The 9216 STS-1/3072 STM-1 capacity system, designed for very large applications, is shown in **Figure 4**. This system requires four bays for the duplicated switch fabric, one bay for the duplicated controller and synchronizer, and I/O bays as required to meet service needs. The

4608/1536 system can be upgraded in service to the 9216/3072 capacity system by adding two additional switch bays and taking advantage of the duplicated switch fabric.

Facility Interfaces and Cross Connections

The WaveStar BWM supports all of the common synchronous optical network (SONET) and synchronous digital hierarchy (SDH) facility interfaces used today. Within the first year of availability, the interfaces supported include DS3/EC-1, STM-1E, OC-3/STM-1o, OC-12/STM-4o, OC-48/STM-16o, and OC-192/STM-64o. The DS3/EC-1 circuit pack features a programmable interface that allows the user to program the pack to operate as either a DS3 or an EC-1. Protection for the pack is performed in either a 0×1 or a $1 \times N$ configuration. The STM-1E circuit pack provides an electrical connection for SDH applications and is protected in either a 0×1 or a $1 \times N$ configuration. The optical interfaces feature integrated self-healing ring capabilities, thus eliminating the need for stand-alone access and transport ADM ring terminals in the office. The integrated ring interfaces on the WaveStar BWM include OC-3/STM-1o and OC-12/STM-4o unidirectional path-switched rings (UPSRs) and subnetwork connection protection (SNCP) as well as OC-48/STM-16o and OC-192/STM-64o bidirectional line-switched rings (BLSRs) and multiplex-section shared protection rings (MS SPRings). These rings provide 50-ms survivability against fiber facility failures. Alternatively, many of the optical interfaces can also be provisioned for operating in 0×1, $1 + 1$, and $1 \times N$ protection environments.

As with the DS3/EC-1 pack, the OC-3/STM-1o, OC-12/STM-4o, OC-48/STM-16o, and OC-192/STM-64o packs are programmable so that the user can choose the desired format for provisioning, depending on the application (SONET or SDH) as shown in **Figure 5**. The WaveStar BWM optical interfaces support optics compatible with the WaveStar optical line systems (OLSs). Equipping the WaveStar BWM with I/O packs that are compatible with both the WaveStar OLS 400G system (80 wavelengths) and the WaveStar OLS 40G system (16 wavelengths) eliminates the need for optical translating units (OTUs). This results in an additional 15 to 20% network cost savings.

Figure 1.
The WaveStar™ BWM.

The design of the WaveStar BWM switch fabric allows the system to support a variety of cross-connect rates, including DS3, AU-3/STS-1, DS3/STS-1 gateway, AU-4/STS-3c, STS-12c, STS-48c/AU-4-16c (2.5 Gb/s), and STS-192c/STM-64c (10 Gb/s). Such flexibility with interface types and cross-connection rates allows the system to be deployed and used globally. Not only is the type of rate supported important, but the speed at which the signals are cross-connected is significant when restoration is the application of choice. The WaveStar BWM can support at least 20 cross connects per second. Higher speeds will be available in future releases.

Ring Integration and Network Element Consolidation

The ability to terminate multiple rings and ring types on one system is a key feature of the WaveStar BWM. One universal module can support up to two 4-fiber OC-48/STM-16 rings or up to four 2-fiber OC-48/STM-16 rings, including full protection access. Higher densities will be available in future releases. Thus, equipment configurations previously requiring nearly three bays of equipment can now be handled in a single shelf. Network service providers continue to

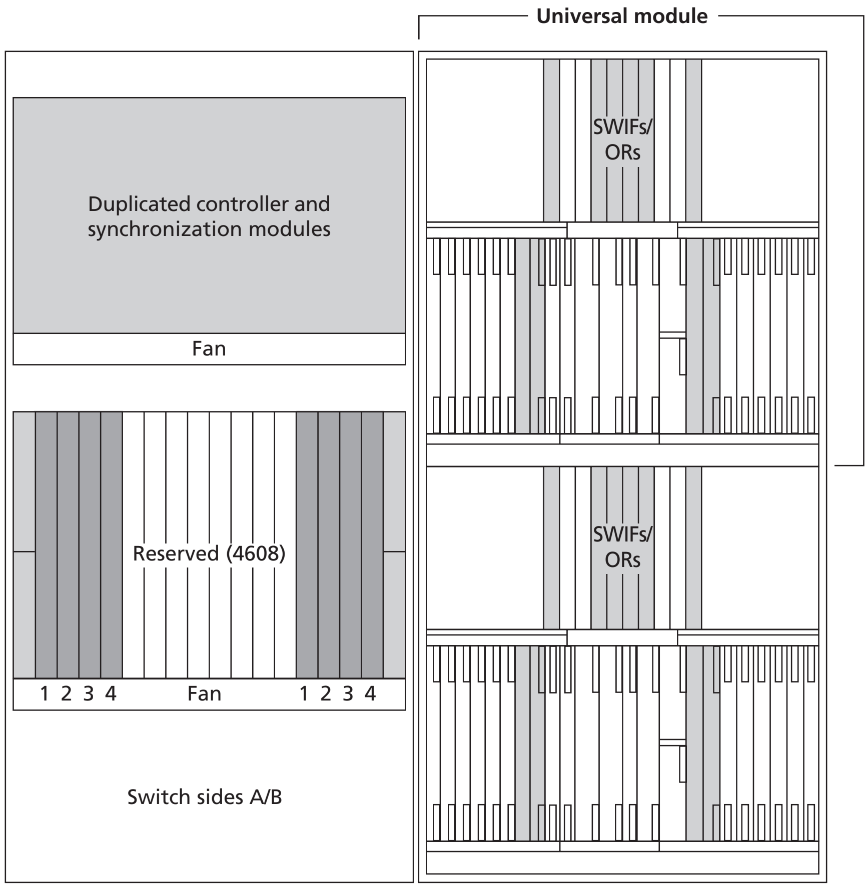

Figure 2.
The WaveStar™ BWM 1152/384 2-bay start-up configuration.

face a number of problems today in the central office, including pressure to reduce costs, to save floor space, to provide highly reliable networks with short service intervals, and to manage many network elements across a range of transport rates. The WaveStar BWM addresses these concerns as follows:

- *Significant cost savings*. Ring integration studies conducted at Bell Labs show up to 60% reductions in equipment cost alone. First-cost equipment savings include eliminating back-to-back ring terminals and associated cabling, eliminating all low-speed intraoffice interfaces, eliminating manual cross-connect panels, and eliminating the broadband cross-connect system that typically connects ring terminals.
- *Floor space savings*. Bell Labs' studies have shown floor space reductions between 70 and 86% in offices with as few as two 4-fiber ring terminals. An example showing cost savings as well as floor space savings with eight 4-fiber ring terminals is shown in **Figure 6**. Floor space is growing in importance not only with the onslaught of new telecommunications companies, but also with the renewed emphasis on cost-effective networks so that providers can keep pace with their competition.
- *Increased reliability*. Reducing the number of individual ring terminals in the office directly relates to reducing the points of failure. With the WaveStar BWM, the number of network elements in a medium-to-large office is reduced from several to just one. For example,

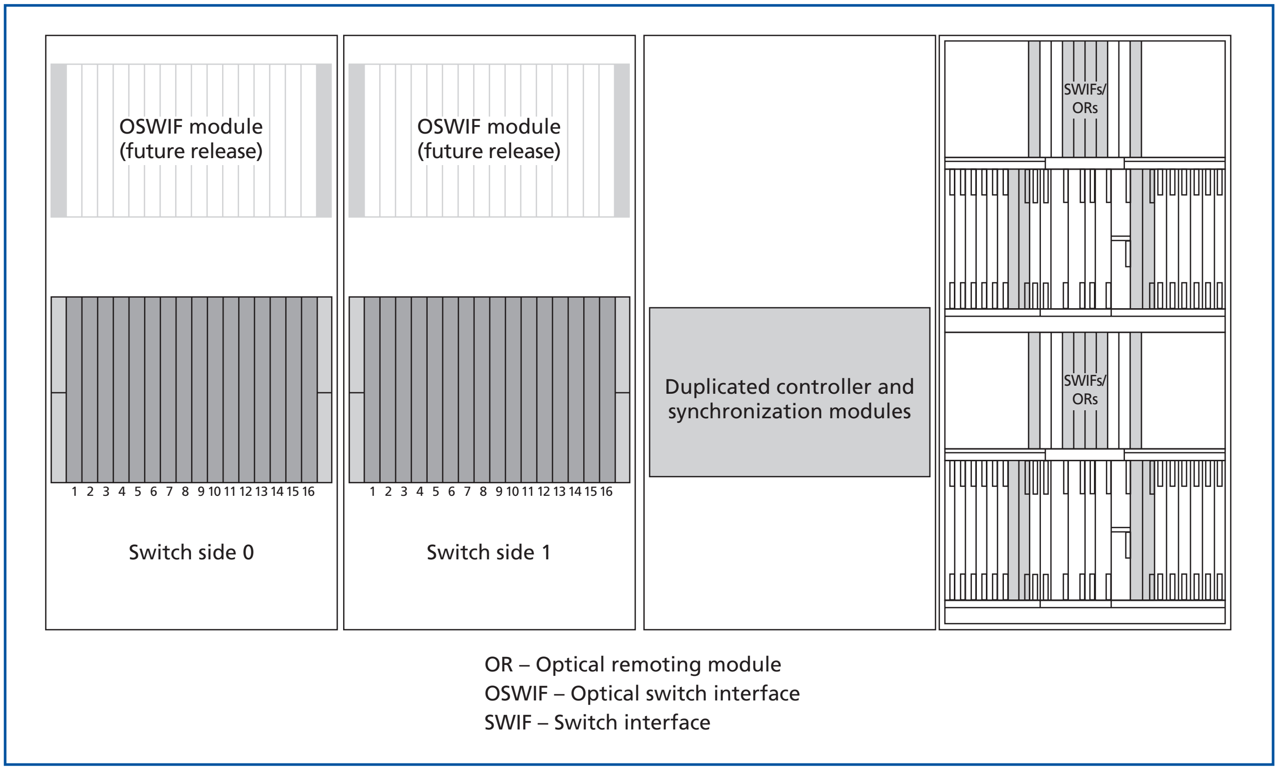

Figure 3.
The WaveStar™ BWM 4608/1536 4-bay start-up configuration.

in a large office with 8 interoffice rings, there are 8 individual ring terminals plus a broadband digital cross-connect system (BDCS), or a large manual cross-connect panel, to interconnect the ring terminals for a total of 9 network elements. The WaveStar BWM replaces all 9 network elements, thus reducing the number of transmission terminals from 9 to 1. Manual cross-connect panels and intraoffice cabling, traditionally prone to failure and difficult to maintain, are eliminated with ring integration. With the amount of capacity provided in networks today, reliability is a key factor for service providers. The WaveStar BWM provides substantial improvements in network reliability and survivability.

- *Efficient operations*. The WaveStar BWM meets both SDH and SONET operations and maintenance requirements for maximum benefits with fault isolation and performance monitoring. Provisioning a multiring network is now much simpler and less expensive than ever before; it is a command instead of a physical interconnection between many network elements.

Network Reliability, Restoration, and Survivability

Reliability, restoration, and survivability continue to be important aspects of building networks today. In order for service providers to compete, they must demonstrate robust networks that can efficiently respond to failures, both equipment-related and transmission-related. The WaveStar BWM is designed to meet very high reliability standards for both transmission and control availability. The system includes:

- Duplicated transmission, control, and timing;
- A fully cross-coupled transmission architecture;
- A fully nonblocking cross-connect architecture;
- Errorless cross-connect fabric switching; and
- A graceful power-degrade shutdown and restoration.

All protection switching, including rings, is completed within 50 ms, thus maximizing network survivability.

Restoration is key to the survival of networks, and the overall mission is to restore the network fast after a

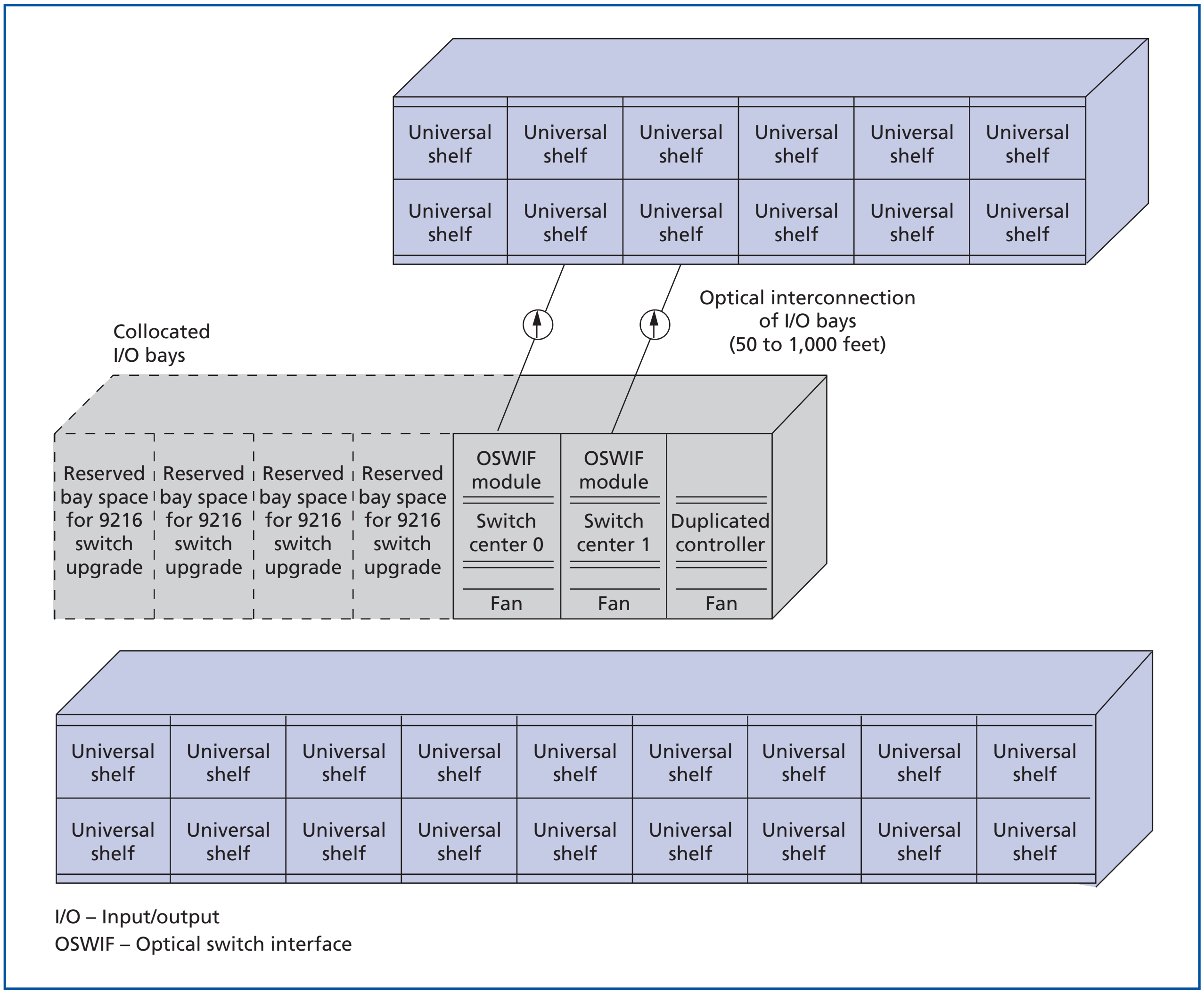

Figure 4.
The WaveStar™ BWM 4608/1536 system with reserved space for the 9216/3072 system.

failure—a realizable task with restoration at 2.5 Gb/s and higher. Maintaining, provisioning, restoring, and operating networks at the DS3 or VC-3 rate is becoming more difficult every day. Increased capacity demands for more service in less time are forcing service providers to consider managing their networks at the 2.5 Gb/s rate. Cross connections at 2.5 Gb/s and 10 Gb/s in the WaveStar BWM support provisioning at the optical level of the network and improve overall network restoration speed. Restoration is moving from the SONET/SDH layer (2.5 Gb/s and lower) of networks to the optical layer (2.5 Gb/s and higher), thus allowing bandwidth to be managed at a higher bit rate (2.5 Gb/s and higher).

The WaveStar BWM supports distributed restoration and provisioning. This feature uses the WaveStar advanced routing platform, a distributed real-time path-search method that allows nodes to autonomously restore traffic streams at 622 Mb/s, 2.5 Gb/s, and above. The protocol implements leading-edge concepts and technology to provide:

- Ultrabandwidth (2.5 Gb/s and higher) and optical network restoration;
- Broadband (622 Mb/s) restoration;
- Provisioning of shortest paths between WaveStar nodes;
- Determination of percent restorability of specific network failures; and

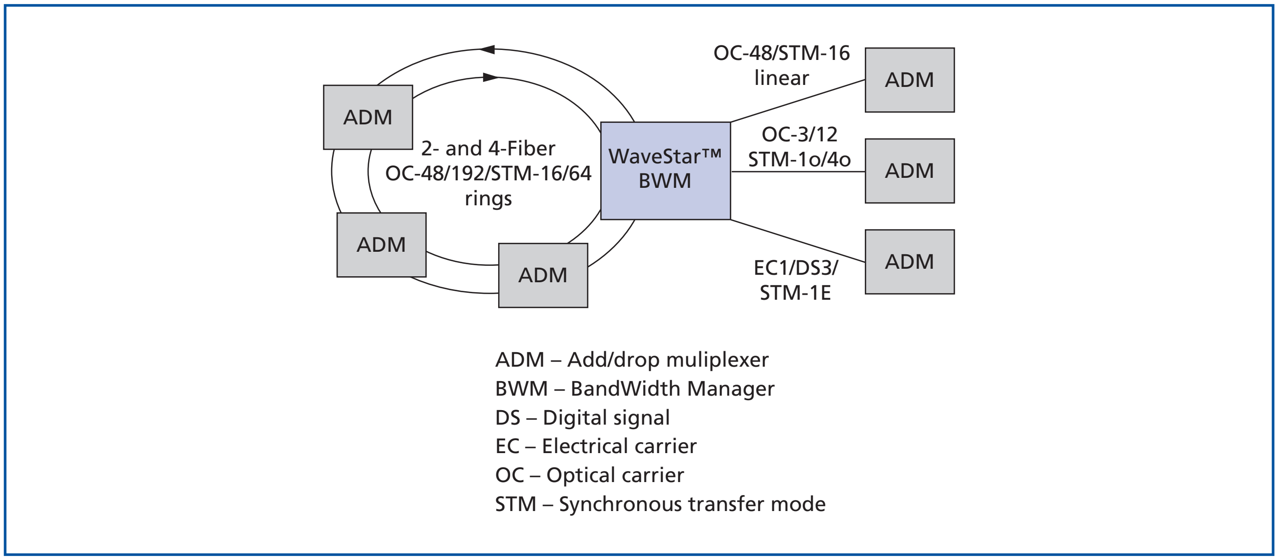

Figure 5.
The WaveStar™ BWM SONET/SDH interfaces.

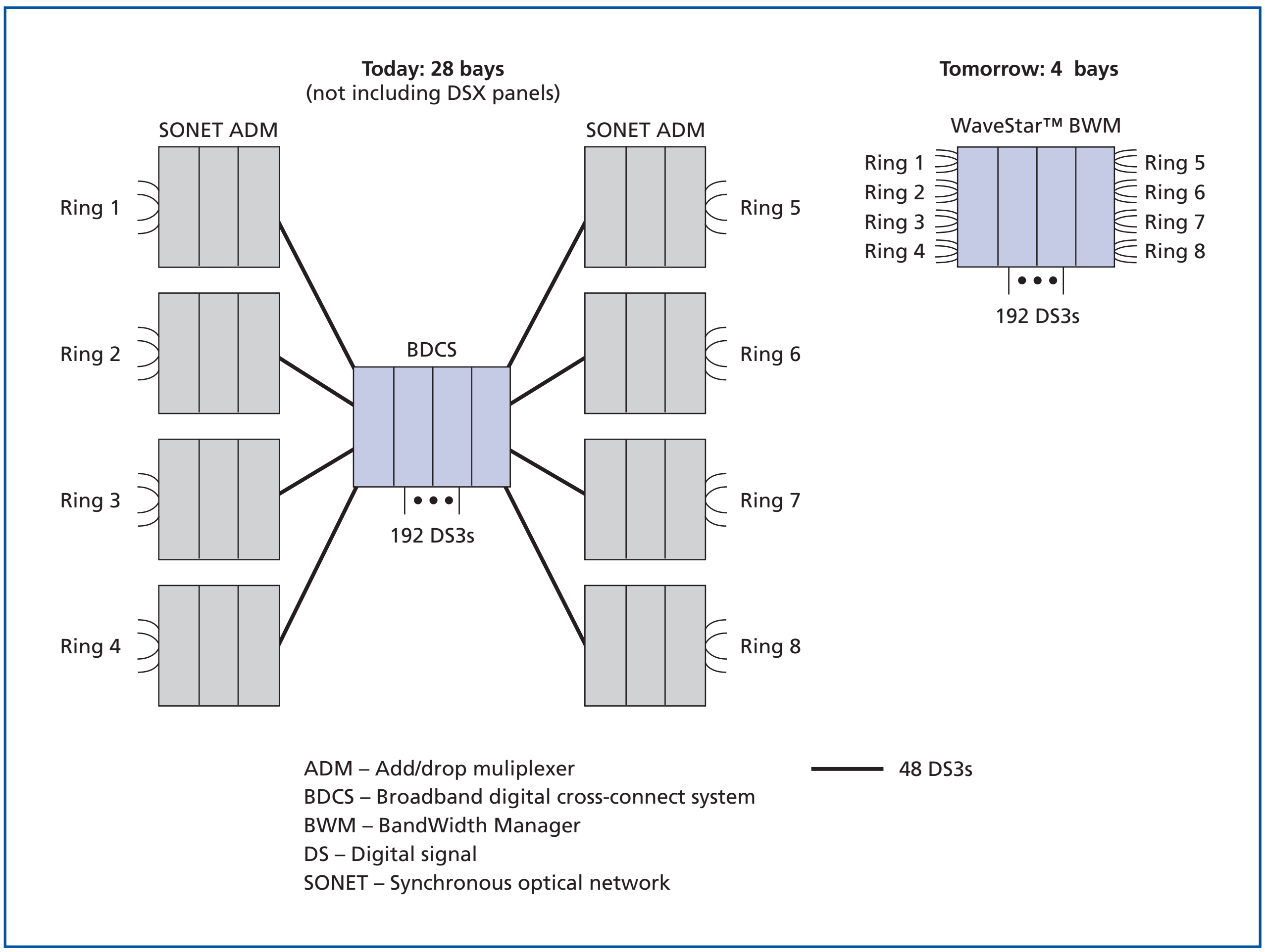

Figure 6.
The WaveStar™ BWM savings with an 8-ring office example: a 2.5 Gb/s, 4-fiber system.

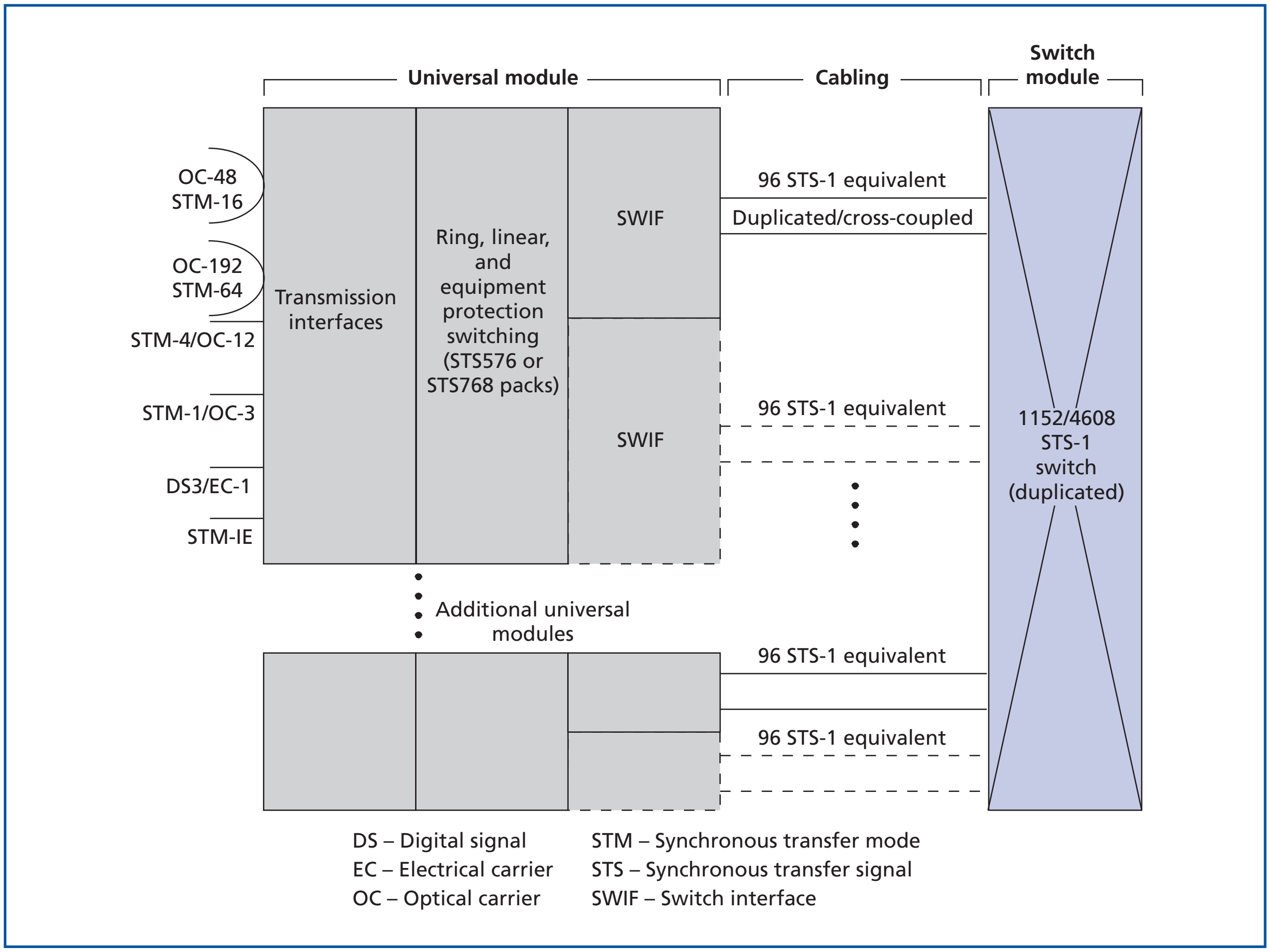

Figure 7.
High-level transmission functional diagram.

- Capacity forecasting, given actual network-derived traffic patterns and growth.

The protocol is independent of network topology and, because it is distributed, is inherently scalable and free from central database and processing requirements and communications vulnerability.

WaveStar BWM Architecture

At the physical level, the WaveStar 4608 STS-1/1536 STM-1 capacity system, shown in Figure 3, consists of a 2-bay switch complex, a control bay adjacent to the switch bays, and multiple interface bays containing two universal modules, each interconnected to the switch complex. Placement of interface bays is highly flexible, with both electrical and optical interconnect options between the switch and interface bays at distances up to 1,000 feet. Universal modules support mixing of all interface types and associated protection groupings allowed in the system.

The WaveStar BWM system has redundant switch fabrics, with each switch side housed in a separate bay, and an associated physical design that enables rapid, unambiguous delineation of the two switch sides and associated cabling. Switch sides operate in an active-active mode and are additionally cross-coupled onto the universal modules, providing superior transmission reliability as well as manual and autonomous errorless protection switching, as shown in **Figure 7**. Multiple levels of cross-coupling between the switch sides, universal module switch interfaces (SWIFs), and individual interface packs further enhance this excellent reliability performance by decoupling protection

groups across multiple stages. System control and timing are fully duplicated in the switch system, both in the switch bays and in the individual universal modules, providing high reliability for all key subsystems.

At a high level, Figure 7 shows the functional transmission blocks of the WaveStar BWM. Initially, connectivity between the duplicated switch fabric and the universal modules can be equipped for up to 192 STS-1s/64 STM-1s of bandwidth via the in-service addition of SWIF circuit packs. This bandwidth provides nonblocking connectivity between one universal module and all other universal modules in the system. This connectivity supports a 1152 STS-1/384 STM-1, 4608 STS-1/1536 STM-1, and 9216 STS-1/3072 STM-1 equivalent-capacity nonblocking broadband cross connect among all the ring and low-speed interfaces in the system. The 576 × 576 cross-connect switches (STS576 circuit packs) perform all local I/O protection and ring-switching functions in the universal modules and allow for up to 192 STS-1/64 STM-1 equivalent ports to be dropped into the large switch center. Every universal module requires only one pair of these local switches for fully redundant and cross-coupled connectivity to the main switch fabric.

Key to the design of this large, scalable, broadband cross-connect system is a 4608 × 4608 STS-1 or 1536 × 1536 STM-1 (fully connected) *N*-squared switch fabric design. This design offers many advantages over traditional Clos switch fabric designs[1] in terms of performance, reliability, and economics. A proprietary byte-slice approach is utilized, allowing for the large size, superior performance capability, and upgradeability of the system. This architecture is strictly nonblocking for any cross-connection arrangements, including unlimited 1 × *N* multicasting. Because path hunt is not required with this design, cross connections can be rapidly reconfigured in support of network restoration activities.

Fully duplicated switch fabrics operate in an active-active mode with identical cross-connect maps maintained in each one. The physical separation between sides of the duplicated fabric, along with the ability of each switching fabric side to maintain independent cross connections, is designed to make system upgrades to larger sizes extremely reliable.

All of the switch packs in a switch side are individually and independently protected by a corresponding switch pack on the other switch side. Switch packs are individually cross-coupled to each of the duplicated SWIFs equipped in the universal modules, independent of other switch packs, on both side 0 and side 1 of the main switch. In the universal modules, each of the duplicated SWIFs is independently cross-coupled to both switch sides on a switch-pack-by-switch-pack basis (independent of each other). In the event of a switch pack failure, a "best-link selection" process is utilized by each of the SWIFs to choose the corresponding switch pack on the other switch side. For example, if switch pack 4 fails on side 0, the universal modules, via a best-link switch, autonomously switch to switch pack 4 on side 1. Similarly, if a SWIF pack or link goes bad on the ingress side of the switch, the switch packs autonomously switch to the "protection" SWIF in that particular universal module. This architecture and the best-link selection scheme ensure that the largest transmission pack fault group in this system is one pack. The WaveStar BWM is extremely robust and reliable, with a total switch unavailability of only 0.0002 minutes per year. The same architectural philosophy exists for all system sizes.

Modularity for flexible office arrangements is provided via two interconnection options. Electrical interconnection is provided between the switch and the interface bays for collocated interface bay arrangements. Optionally, interface bays can be individually and optically interconnected to the switch bays up to 1,000 feet away. This optional flexibility in the interface bay is provided via a choice of electrical or optical SWIF packs configured in the universal modules on a per-universal module basis. Associated cabling types between the switch and the interface bays are fully duplicated, consistent with the redundancy of the rest of the transmission architecture.

The universal module supports highly flexible mixing of all interface types. All interface port unit types use the same physical, double-high universal module, shown in Figure 2. Equivalent interface capacity of the shelf depends on interface type, protection scheme, mixing of interface types, and service drop on rings.

A full range of optical and electrical interfaces is supported in the universal modules. Each of the modules has a fully integrated (duplicated) 576 × 576 STS-1 cross-connect capability (STS576 circuit packs) that can be operated independently of the main fabric. These local switches provide the 1 × *N* flexible equipment protection switching of the interfaces, independent of the main switch. This allows unprecedented flexibility in ring management. The STS576 fabrics provide a fully duplicated drop capacity of 192 STS-1/64 STM-1 equivalent ports per universal module. In addition, the STS576 switch provides the flexibility to perform pass-through, add/drop, and drop-and-continue connections for support of ring management. Every universal module requires only one pair of STS576 switches for fully redundant and cross-coupled connectivity to the main switch fabric. A higher-density version of these local fabrics will be available in a subsequent release, providing 384 STS-1/128 STM-1 equivalent ports of drop capacity into the switch and hence up to twice the I/O port density per universal module. This I/O port density in the universal module represents the highest I/O capacity density in the industry.

The WaveStar BWM 1152/384 system supports up to 12 SWIF pairs (corresponding to 6 to 12 universal modules, depending on how they are equipped), whereas the WaveStar BWM 4608/1536 system supports up to 48 universal modules. Accordingly, a WaveStar BWM 1152/384 system contains from 3 to 6 interface bays, whereas the WaveStar BWM 4608/1536 system includes from 12 to 24 interface bays. Similarly, the WaveStar BWM 9216/3072 system supports twice as many SWIF pairs as the 4608/1536 configuration.

System control is based on a three-level hierarchy consisting of the system controller, the universal module and switch shelf controllers, and the board controllers. Control is fully duplicated at all levels, including intrasystem communication capabilities. The software is based on an object-oriented paradigm. This new design approach and the use of common controllers and software architecture in Lucent's next-generation WaveStar transport product family will enable significant multiuse of system components and software across multiple products.

The fully duplicated switch and control architecture allows in-service upgrade between system sizes (for example, 1152 STS-1/384 STM-1 to 4608 STS-1/1536 STM-1) to be very reliable without affecting traffic. Upgrades between system sizes do not require any reconfiguration of interfaces. The system is designed so that smooth, in-service upgrades to larger sizes are available to customers who require them. The hooks for this feature are designed into the system without taxing the size and cost of the 4608 STS-1/1536 STM-1 system.

WaveStar BWM Features and Applications

This section describes features and applications of the WaveStar BWM, including ring management, hairpinning in the universal module, cross connections and gateway applications, protection of facility interfaces, and operations support.

Ring Management

Full ring management is provided at each ring interface within a universal module in the WaveStar BWM. Each interface provides full cross-connect flexibility, including the ability to provide pass-through, add/drop, and drop-and-continue connections on an STS-n/AU-m basis, where n can be equal to 1, 3, 12, or 48, and m can be equal to 3, 4, or 4-16. Pass-through signals are not terminated at the ring node (that is, the WaveStar BWM) but rather are *passed through* the ring node. Drop-and-continue cross connects entail dropping the incoming signal to the local switch—usually for applications that include signal broadcasting or dual-ring interworking—while continuing, or bridging the signal to the outgoing side of the ring interface to be terminated at a different ring node. Add/drop cross connects entail dropping the STS-n/AU-m signal to the local ring node for cross connection to a lower-speed interface while at the same time adding a new signal from the switch fabric to the outgoing direction on the ring.

Hairpinning in the Universal Module

The WaveStar BWM can support cross connections between various interfaces locally within a universal module without tying up bandwidth to the main synchronous transfer mode (STM) switch fabric. The ability to provide cross-connect functionality between interfaces within the same module without

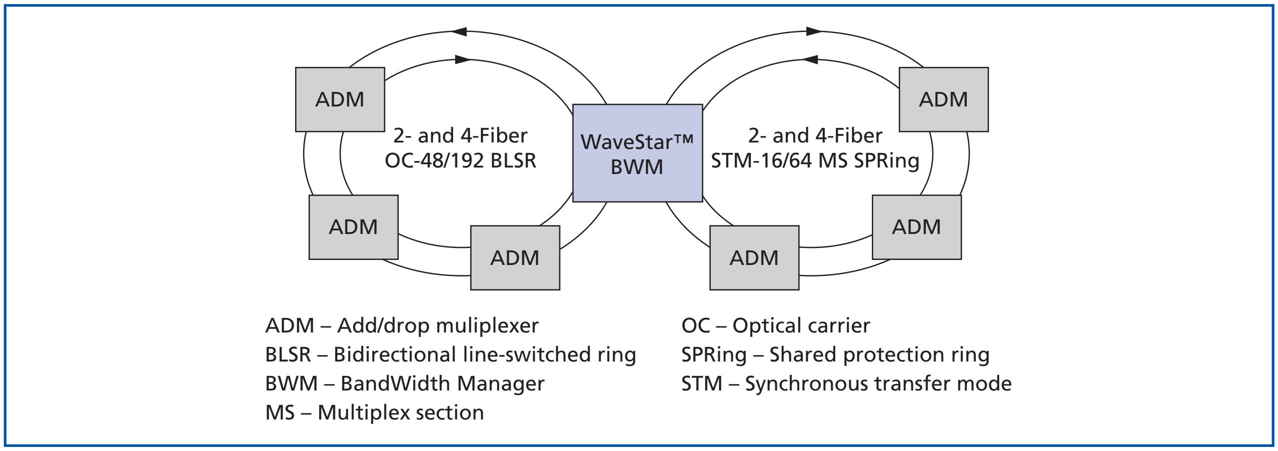

Figure 8.
The WaveStar™ BWM SONET/SDH ring interworking.

using the STM switch fabric is known as *hairpinning*. This feature provides the following functions:

- Bandwidth shedding, by which only connections requiring cross connection to other universal modules traverse the STM switch fabric;
- Ring-to-linear (optical or electrical) connections within the same universal module for intraoffice linear drops; and
- Ring-to-ring connections within the same universal module across multiple rings.

Hairpinning allows the customer to "oversubscribe" the STM cross-connect fabric without tying up the actual bandwidth of the switch fabric.

Cross Connections and Gateway Applications

The WaveStar BWM supports the cross connection of signals larger than the granularity of the main STM switch fabric. Although the STM switch fabric is STS-1 based, the fabric is capable of supporting cross connections of asynchronous DS3 signals, AU-3/STS-1 signals, and concatenated signals at the following rates: 155 Mb/s (AU-4/STS-3c), 622 Mb/s (STS-12c), 2.5 Gb/s (AU-4-16c/STS-48c), and 10 Gb/s (STM-64c/STS-192c). The support of larger-bandwidth cross connections allows network service providers to use the WaveStar BWM as a vehicle for managing their networks at the STM-16/OC-48 or STM-64/OC-192 rates for network restoration purposes.

The WaveStar BWM supports a number of gateway cross-connect applications ranging from asynchronous to synchronous—that is, from DS3 to STS-1 (EC-1) to SONET-to-SDH-based gateway applications, which include the following types of cross connects: STS-1 to AU-3, STS-3c to AU-4, STS-48c to AU-4-16c, and STS-192c to STM-64c. The DS3 to STS-1 gateway application would typically be used to transport asynchronous facilities across a SONET network within a SONET-based signal. The SONET-to-SDH gateway applications would typically be used to interface a North American SONET application with an SDH application for distribution or connectivity to a European country, for instance. An interexchange carrier having network connectivity in both SONET and SDH markets might also have such a need.

The WaveStar BWM system is capable of supporting multiple ring interfaces for both 2-fiber and 4-fiber applications within the same universal module. This functionality is unique to the WaveStar BWM—most lightwave terminal ADMs only provide termination for a single ring in a system. This flexibility allows interconnection between rings within the same universal module as well as consolidation of ring interfaces. **Figure 8** illustrates an application in which the WaveStar BWM provides a SONET/SDH gateway for a SONET ring on one "side" and an SDH ring on the other. These two rings could exist either in the same universal module or in different modules. For this type of gateway application in which the actual signals are cross-connected and passed between the SONET and SDH rings, the STS-*n* signals cross-connected between the two rings must pass through the STM switch fabric.

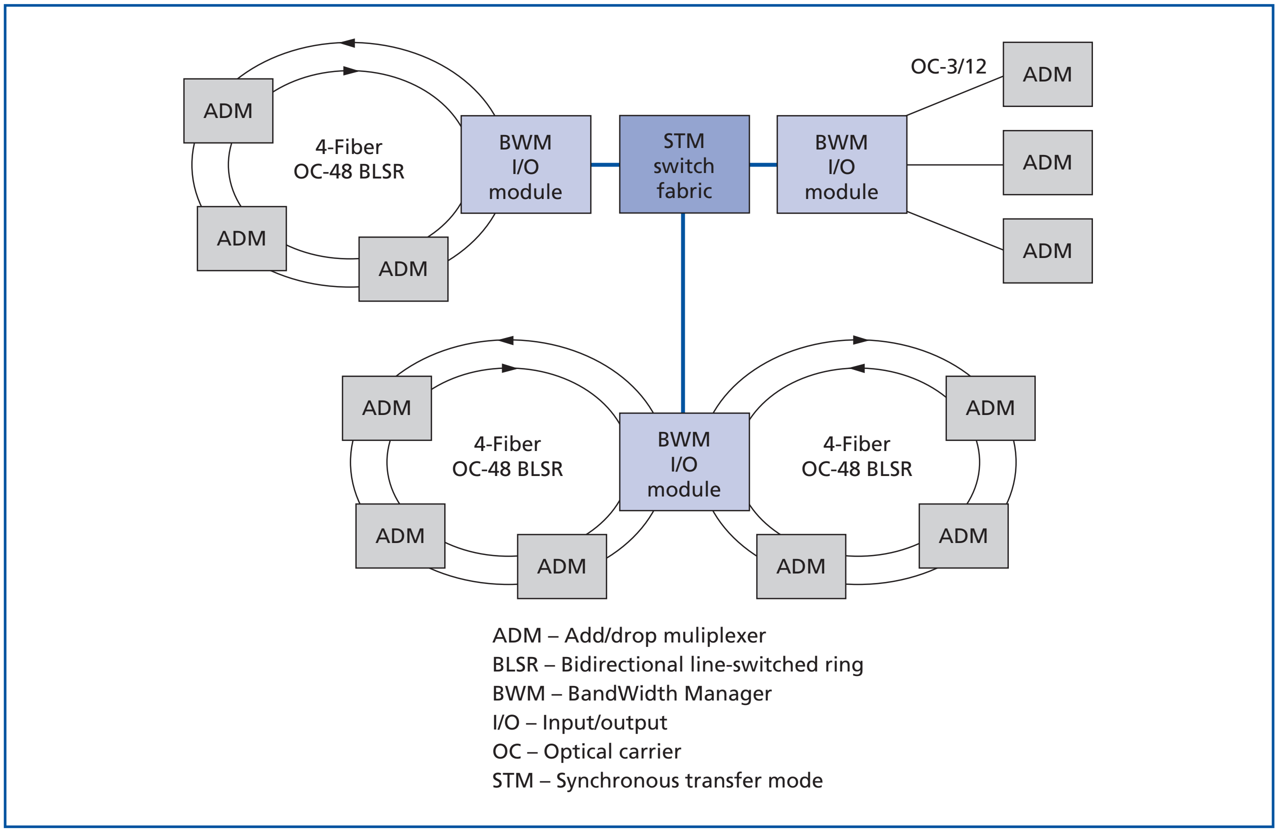

Figure 9.
The WaveStar™ BWM bandwidth management flexibility.

Figure 9 depicts the WaveStar BWM supporting network topologies of multiple OC-48 4-fiber rings, with one universal module supporting multiple OC-48 BLSRs while another universal module supports OC-3 and OC-12 interfaces for dropping STS-*n* signals intraoffice to other ADMs. The WaveStar BWM is capable of supporting single ring interfaces (both 2-fiber and 4-fiber), multiple ring interfaces, and linear interfaces for both SDH and SONET formats within a universal module.

Protection of Facility Interfaces

Protection of the facility interfaces supported on the WaveStar BWM is based on whether the interface is an electrical linear interface (DS3, EC-1, or STM-1e) or an optical linear or ring interface (OC-3/STM-1o, OC-12/STM-4o, OC-48/STM-16o, or OC-192/STM-64o). The electrical linear interfaces can be protected in either a 0×1 (no protection) configuration or a $1 \times N$ (shared protection) configuration. The protection of these interfaces is performed on a circuit pack basis. The optical linear interfaces can be protected in either a 0×1 configuration, a $1 + 1$ configuration, or a $1 \times N$ (shared protection) configuration. Protection of the optical linear interfaces is performed on an interface-by-interface basis.

For SDH applications, the optical ring interfaces (that is, STM-16 and STM-64) are available for protection using the MS SPRing protocol. Upon completion of a ring switch, the protection channels not required to support the switch can be reconnected to protection access. During a span switch, the protection channels not required to support the switch remain connected without signal interruption. The WaveStar BWM also supports the transoceanic protocol specification. Unlike the BLSR protection switch algorithm for ring protection, the transoceanic protocol provides the functionality to determine the shortest route for traffic to follow when a protection switch is required. Thus, routing traffic during protection scenarios can be accomplished without the

cost of placing traffic on long haul undersea routes unnecessarily.

Operations Support

The WaveStar BWM is designed to support management of its interfaces, both linear and ring, either directly via local area network (LAN) interfaces on the system or remotely via any number of SONET/SDH data communication channels (DCCs). The DCCs are available within the overhead bytes of an optical interface terminating on the WaveStar BWM. Since the BWM can terminate numerous optical interfaces and therefore numerous DCCs, the system provides connectivity to the DCCs on behalf of the management systems that support the network. This provides connectivity and access for management systems to subtending network elements, which are connected via optical interfaces to the WaveStar BWM from a single interface.

The protocol stack used to support the operations of network elements—and therefore the WaveStar BWM—in both the SONET and SDH environments consists of OSI protocols conforming to the 7-layer OSI model. Included in this stack is a dynamic routing protocol that operates between routing nodes, or intermediate systems (ISs), in the network. This dynamic routing protocol conforms to ISO 10589 and is commonly known as *IS-IS*. The WaveStar BWM contains an IS within each universal module that supports optical interfaces where the DCC is active. In a sense, the BWM can be regarded as a collection of interconnected IS nodes from an operations standpoint. The IS functionality within the WaveStar BWM consists of two levels—Level 1 and Level 2. A Level 1 IS provides routing functionality within an OSI area, or *subnet*, while a Level 2 IS provides routing functionality between areas or subnets. The use of Level 2 IS routing provides the capability to support a large network from a data communications perspective by allowing the network to be partitioned into manageable segments.

In addition to supporting large interconnected networks, both from a transport perspective and a data communications perspective, the WaveStar BWM also provides gateway network element (GNE) functionality for the SONET/SDH network from the backbone operations data communications network. The GNE function allows a network service provider to specify points of access to the SONET/SDH network for interconnecting between the backbone operations network and the embedded DCC network within the optical interfaces in order to extend the operations management network across multiple networks. This functionality can be as easy as a simple protocol relay—from a LAN interface to a point-to-point interface such as the DCC—or as complicated as a protocol translation—from a transport control protocol (TCP)/IP-based network to a "pure" OSI-based network. The WaveStar BWM provides the GNE functionality to support both the simple protocol relay and the complicated protocol translation.

Figure 10 depicts the WaveStar BWM with the embedded GNE functionality as well as the interconnected IS functionality between DCC controllers, which reside in each universal module providing optical connectivity. Note that network connectivity from the data communications perspective extends from the GNE function to the DCC controllers and out onto the optical interfaces, both linear and ring. The DCC controllers in the WaveStar BWM universal modules can act as either a Level 1 IS or a Level 2 IS, depending on the network topology and the functionality required. The ADMs connected to the BLSR interfaces as well as those connected to the WaveStar BWM linear interfaces act as a Level 1 IS for this topology.

In support of ring management, each ring node requires interface port connectivity information relating to the neighboring nodes, a complete ring connectivity map, and an assigned node ID, unique to each ring. For the WaveStar BWM, this information is shared autonomously across the DCC among all ring nodes on a specific ring. The ring map and node ID information is used in the determination of ring continuity and ring protection switching. The collection and distribution of this information is unique to each ring interface and is pertinent to that ring interface only. Since the WaveStar BWM supports multiple ring interfaces within a single universal module, the DCC controller within a universal module must separately track and manage the ring information for each ring termination on that universal module. To support ring interworking between all nodes on the ring, the ring signaling protocol for automatic protection switching

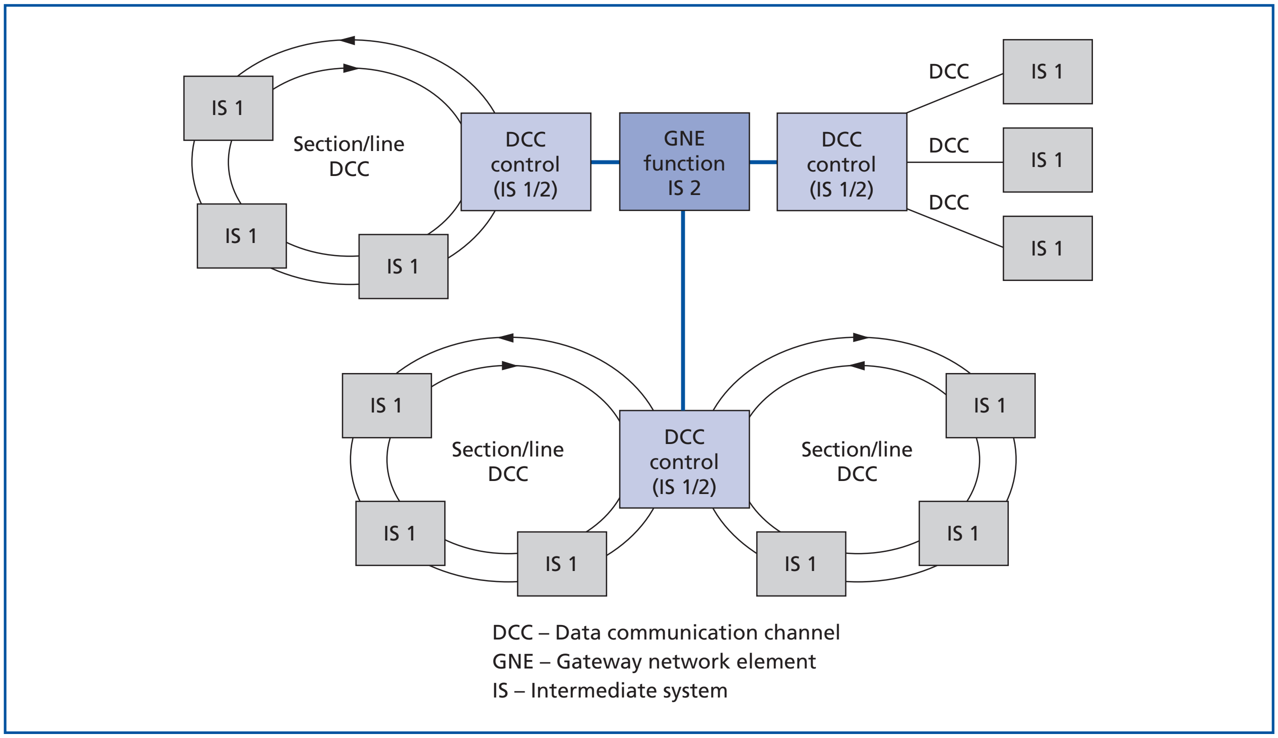

Figure 10.
The WaveStar™ BWM GNE and ring management functionality.

(APS) as well as the additional information in the ring connectivity map and the node IDs must be shared and supported by all nodes on the ring. The WaveStar BWM interworks not only with other WaveStar BWM systems on the ring, but also with existing Lucent ring products—for example, the ADM 16/1 and the FT-2000 lightwave system—using the APS and the aforementioned ring management information. In addition, the WaveStar BWM is uniquely positioned to interwork with other vendors' products that meet the APS standard and contain the ring map and node ID information on a ring interface.

The Future of Transport Networks: WaveStar BWM Evolution Toward ATM and IP

The WaveStar BWM is evolving to become a truly universal transport vehicle, integrating into a single platform a number of network elements traditionally used to provide transport functions. The notion of transport technologies has traditionally been associated with those functions that provide basic connectivity, error correction, and link reliability in the context of voice and private-line traffic. These transport functions, however, must now be extended to the new applications being supported as part of carrier services. The WaveStar BWM is thus moving to integrate new technologies, such as ATM and IP, that are more appropriate for the traffic types and applications of future networks.

In addition to the WaveStar BWM, there is other evidence of this new type of integrated transport vehicle. Major vendors have announced multiservice switches and platforms that integrate IP and ATM transport options. While the directions of some of these services are based on marketing issues ("IP won"), the trend is toward overall optimization of the transport network by taking advantage of each technology supported on the platform. Current transport infrastructure, which provides reliability and growth, was designed only with the support of private lines and voice trunking in mind.

Most major carriers have deployed ATM as a key technology in their backbone networks to handle the transport of the new traffic mix resulting from the "data explosion." Some have been working to make ATM the main core transport technology to deliver

new services, taking advantage of ATM's advanced features. By deploying ATM on access networks, some of these carriers have made this technology the centerpiece of offerings such as video on demand (VOD) and LAN interconnection.

The popularity of the World Wide Web and the Internet has increased the importance of IP. The ubiquitous nature of IP has made it a potential ultimate mechanism to deliver different traffic types end to end. With the addition of application-specific layers and capabilities such as real-time protocol (RTP), TCP, simple mail transfer protocol (SMTP), secure IP (IPsec), and other tunneling protocols, IP has all the elements to become a universal transport protocol or convergence layer. While the performance and capabilities of this transport protocol are being improved, it is now possible to carry not only traditional data traffic—systems network architecture (SNA) on IP—but voice, video, and virtual private networks (VPNs) as well. VPNs, presenting a major trend in the use of IP networks, are directed at emulating a private-line setting to interconnect a number of corporate sites. VPNs take advantage of the new mechanisms that have been added to IP—specifically, encryption, authentication, and tunneling.

The WaveStar BWM's multiservice architecture provides a platform that supports both transport bandwidth management and data capabilities within network nodes. The STM and ATM/IP functionalities can be upgraded separately, allowing each individual technology to expand to meet any mix of service requirements. For example, the WaveStar BWM could initially be deployed strictly for the integration of multiple access and transport rings within a given network node. For this application, only the STM fabric would be needed for connecting tributaries between ring interfaces. ATM or IP functionality could be added to support evolving applications—for example, IP-based services such as VPNs. The WaveStar BWM's ATM and IP data capabilities provide the following benefits:

- Efficient support of the existing SONET/SDH infrastructure;
- Support of the new transport protocols and formats (cells and packets)—in particular, support of ATM switching and IP forwarding functions;
- Protection options on all the I/O interfaces;
- Ability to perform STM grooming before handling packets or cells;
- Support of traffic growth independently of the format (for example, time division multiplexing (TDM), packet, or cells);
- Smoother upgrade to higher capacities by decoupling access interfaces from switching fabrics (users can upgrade the ATM or IP switching capacity independently of the access interfaces);
- A convergence function for the different transport types (for example, protocol stacks) and a transition vehicle to allow carriers to move transport functions from one technology to another;
- Support of existing operations infrastructures and evolution to new capabilities required for new traffic. Specifically, support of service-level management (that is, the support of provisioning, traffic data collection, and trouble isolation spanning different protocol layers); and
- The ability to optimize the overall transport options by taking advantage of the strengths of each transport option (for example, using SDH/SONET to provide network restoration and using ATM for handling quality of service [QoS]).

Summary

The WaveStar BWM is a highly integrated, cost-effective, scalable, and evolvable multiservices platform. The consolidation of multiple network elements into this single platform can result in a 30 to 60% equipment cost savings, a 70 to 86% reduction in space requirements, a 60 to 80% improvement in transport reliability, and significantly improved efficiency in operations. The WaveStar BWM multiservice architecture maximizes the utilization of each technology, resulting in minimized transport costs, maximized reliability, and improved performance. With a broad range in capacity scalability, the WaveStar BWM can be sized to meet any projected network node application.

Reference

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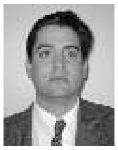

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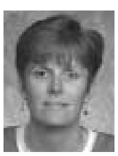

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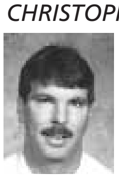

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