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Multiple Access for BISDN

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For future applications requiring bit rates of significantly more than 64 kb/s, the standard bit rate in the existing and still evolving narrowband networks, the Asynchronous Transfer Mode (ATM) is internationally agreed upon as the target multiplexing and switching principle, at least for interactive services. Thus, ATM has become the basis of a future Broadband Integrated Services Digital Network (BISDN).

The main objectives leading to the definition of this target principle have been:

- Flexibility with respect to bit rates. For a large variety of bit rate requirements of future services, the currently small set of fixed discrete bit rate values of the standard transmission systems is not appropriate.
- Asymmetrical connections—Several applications (e.g., database browsing, retrieval of graphics, etc.) require a high bit rate only in one direction. Existing switched networks establish symmetric connections.
- Capability of supporting services with variable bit rates (e.g., video services) without requiring constant peak bit rate connections.
- Universal multiplexing and switching principle—All possible services should be supported by a single network in order to avoid a large number of small, service-specific networks that are undesirable from an economic point of view.
- Support of multimedia applications—Multiple connections of a single call with different service requirements (e.g., data, graphics, voice annotation, and video) can be handled most efficiently within a homogeneous network.

This article deals with some possible access scenarios for an ATM-based BISDN. In the first part, *MANs As Access Networks to BISDN*, emphasis is on the use of existing or emerging networks such as Local Area Networks (LANs) or Metropolitan Area Networks (MANs). These networks are well suited for data oriented information that is seen as the first main application in the BISDN. Following the geographical extension of existing LAN applications, multimedia is generally seen to be a very important broadband application.

Possible access schemes based directly on ATM cells and not restricted to a specific service are the focus in the second part of this article, *ATM-Based Access to BISDN*. Finally, the actual status of the discussions in the International Consultative Committee for Telephone and Telegraph (CCITT) on the Generic Flow Control (GFC) is summarized. GFC has a close relationship to ATM-based networks in the customer premises.

Besides the access scenarios described in this article, some other interesting points are not covered here: Passive Optical Networks (PON) for interactive services [1] and the wide field of Television/High Definition Television (TV/HDTV) distribution.

MANs AS ACCESS NETWORKS TO BISDN

LANs And MANs

LANs have become well-established, economically viable systems for high-speed data communications, interconnecting workstations, and computers in the same or adjacent buildings. Most LANs exist today as islands of communication, and inter-LAN connectivity is commonly provided through bridges, routers, or gateways connected via low-speed leased lines. With the continued success, LANs are evolving towards higher bit rates, wider areas, and integrated services.

The technology and architecture of MANs have evolved from those of LANs. MAN uses public transmission systems (e.g., DS3 and STM-1) to interconnect corporate locations, university campus, or government agencies distributed throughout a metropolis. The Institute for Electrical and Electronics Engineers (IEEE) 802.6 committee adopted the architecture and protocol of the physical and Medium Access Control (MAC) layers of the Distributed Queue Dual Bus (DQDB) system [2]. The protocol defined in IEEE 802.6 can be used to transport high-speed bursty data (asynchronous traffic), and can also meet, with appropriate enhancements, the needs of voice services with constant bit

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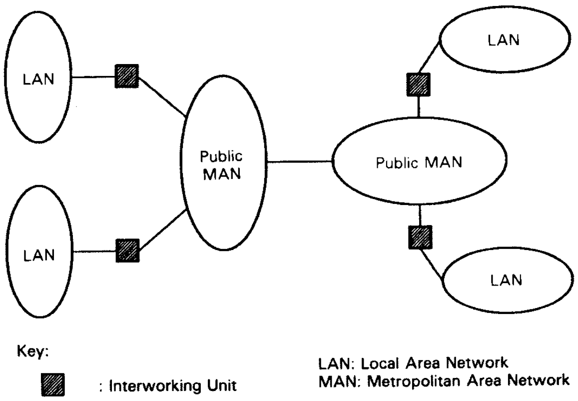


Fig. 1. Interconnection of LANs using MANs.

rate (isochronous traffic). The network architecture involves a dual loop of the buses, which can be arranged as a physical ring providing self-healing capabilities.

The DQDB MAN is based on a distributed switching/multiplexing technique. The MAC protocol is used to control the writing and reading of slots on the bus. Each distributed switching node reads the labels (addresses) of all slots passing through the bus and copies the entire slot from the bus when there is a match between the address of the slot and the node. Each node also holds a counter indicating the number of slots awaiting access to the bus downstream. When a node has a slot for transmission, it uses this counter to determine when it should write the slot onto the bus (distributed queuing algorithm).

The DQDB MAN is considered a kind of introduction for supporting broadband services because there is some synergism between this MAN and BISDN. The physical layer of the IEEE 802.6 standard is defined at DS3 (44.736 Mb/s) and Synchronous Digital Hierarchy/Synchronous Optical Network (SDH/SONET) STM-1 (STS-3c; 155.52 Mb/s) on each fiber to maintain link speed compatibility with BISDN. In addition, the protocol adopted in the MAN is based on fixed-sized slots (similar to cells) of 53 octets, in which 5 octets are used for the header and 48 are available to carry user information. This format is very similar to the format defined for ATM protocols of the BISDN. Thus it eases the terminal interchanging and leads to simple interfaces between DQDB and BISDN.

MANs can be used for private network applications as well as an addition to the existing public networks. The telephone companies (telcos) can enhance their existing Operation Support Systems (OSSs) to provide maintenance, billing, provisioning, and security to the business users; these OSSs can also provide the gateway functions to allow the users of MANs to interwork with other networks (e.g., public switched data network). Bell Communications Research (Bellcore) defined as the background of the DQDB technology the public connectionless data service Switched Multimegabit Data Service (SMDS) for high-speed applications and LAN interconnection. The service definitions allow the use of MANs in the public domain. MANs may be a viable alternative to conventional private networks, in which the bottlenecks are usually created at the low-speed links interconnecting the LAN gateways. Several trials of MAN technology have been conducted by the telcos. Figure 1 shows as an example two public MANs, allowing several attached LANs to communicate.

For private network applications (e.g., campus network), an alternative backbone network to interconnect LANs is the Fiber Distributed Data Interface (FDDI) [3] [4] which uses a token-ring protocol and operates on private fibers at a transmission bit rate of 100 Mb/s on each of the two rings.

MAN field trials are still running and some operators have scheduled the commercial service to begin soon. Therefore, MANs will already be installed and in service when the first ATM pilot networks are expected. This brings importance to the use of MANs as access to BISDN.

MANs (DQDB) And BISDN

CCITT has defined that BISDN should be based on the ATM principle [5] [6]. With the ATM approach, the transmission capacity of the BISDN User-Network Interface (UNI) will be filled with fixed-length cells. A cell consists of a header containing Virtual Channel Identifier/Virtual Path Identifier (VCI/VPI) and an information field. The header is also used to identify different levels of cell loss priorities. The sizes of the information and header fields of the ATM cells are the same as the slots of the MAC protocol in IEEE 802.6 [2].

ATM cells are transmitted by the network in a connection-oriented manner; they are switched using the label in the cell header (VPI/VCI). The ATM switch also performs the header translation. The translation rule of the VPI/VCI values in the cell header at the input of the switch to the new values at the output is established during the connection establishment and stored in the switching node until the end of the connection.

In the Central Office (CO), the broadband capabilities can be provided with add-on switch modules (ATM switch modules, service modules, etc.) to the existing narrowband ISDN switch. The ATM switching module performs switching and multiplexing functions of ATM cells and supports a wide range of connection-oriented services. To provide

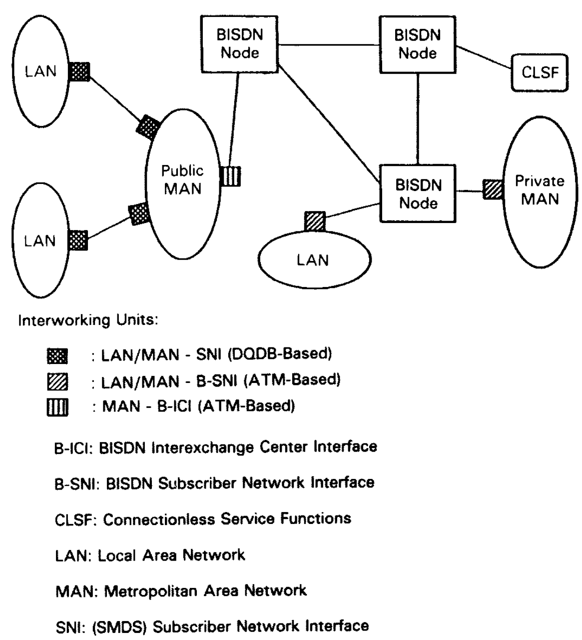
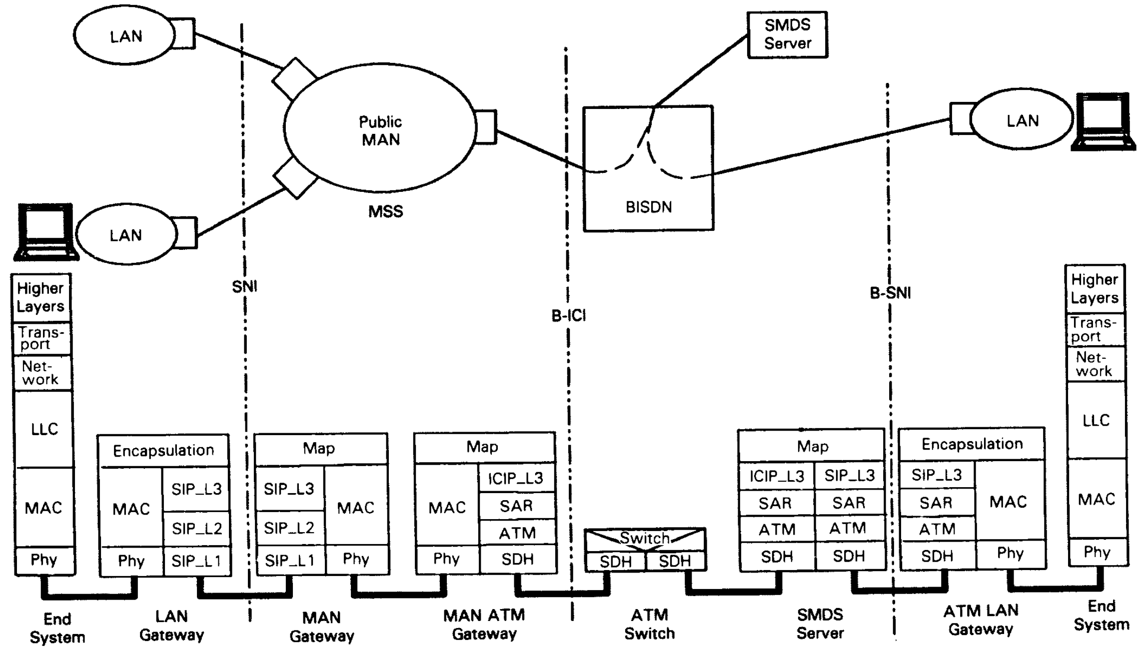


Fig. 2. Interconnection of MANs and LANs using BISDN.



Key:

B-ICI: BISDN-Inter-exchange Carrier Interface
B-SNI: BISDN-Subscriber Network Interface
LLC: Logical Link Control
MAC: Media Access Control
Map: Mapping Entity
MSS: MAN Switching System
Phy: Physical Layer
SDH: Synchronous Digital Hierarchy (Sonet)
SIP: SMDS Interface Protocol
SNI: Subscriber Network Interface (for SMDS)

Fig. 3. Interworking of LAN via public MAN and BISDN.

connectionless services such as SMDS, a specialized service module providing the Connectionless Service Functions (CLSF), is used in conjunction with the ATM switch.

Figure 2 tries to present access scenarios to BISDN using current data networks. MANs (public and private) as well as LANs are used to concentrate (mainly data) traffic, and allow internal communication. As these are separate networks with their own data formats and services, interworking units (bridges/routers) between MANs or LANs are required. The complexity of these units depends on the protocol processing necessary to bridge both networks and on the required performance. The similarity of IEEE 802.6 (DQDB) and BISDN may allow simpler interworking units, as the formats are very similar.

MANs, public as well as private, can be connected in a BISDN environment using the capabilities of ATM. Appropriate Interworking Units (IWUs) interface a MAN to the BISDN. Full connectivity can be achieved by intelligent IWUs maintaining virtual connections to all other MAN IWUs (see Figure 2).

Besides the use of direct virtual connections between MAN IWUs, the connectionless service in the BISDN may also be used. CLSF provides all functions required to perform the connectionless service on top of the connection-oriented ATM network. Single LANs may also be connected to the BISDN using the same possibilities as MANs.

In Figure 3, the functionality of the various IWUs is shown by means of the protocol stacks required at each unit. In this figure, as an example, a transparent end-to-end encapsulation of the LAN data is assumed, providing transparent transport of the Logical Link Control (LLC) frames between the attached LANs. However, other interworking scenarios, e.g., at the network or transport layer, may be applied.

The whole evolution scenario from MAN to BISDN is described in detail, e.g., in *The Evolution from LAN/MAN to Broadband-ISDN* [7].

ATM-BASED ACCESS TO BISDN

In addition to the need to offer high-speed data communication services, there is a need of supporting a variety of concurrent applications over an integrated UNI. Figure 4 shows an example of BISDN access architecture. The narrowband and broadband services are multiplexed together and transmitted via optical fibers between subscribers and a broadband CO. Similar to today's access networks, subscribers can be connected to the public network in a physical star architecture. In some areas, the use of remote switching can help to reduce the cost of massive deployment of fibers in the distribution area. Several architectures, e.g., self-healing physical ring, star with route diversity, looped dual bus, the use of ATM Crossconnects (ATM-CC) [8] for flexibility, availability, and concentration purposes, as well as optical network (PON) can be used in the feeder network for economics and reliability. More details are given in *Transmission Systems for the BISDN* [1].

Figure 4 shows the possibilities to use direct ATM-based access schemes, which are explained in more detail in the rest of this article.

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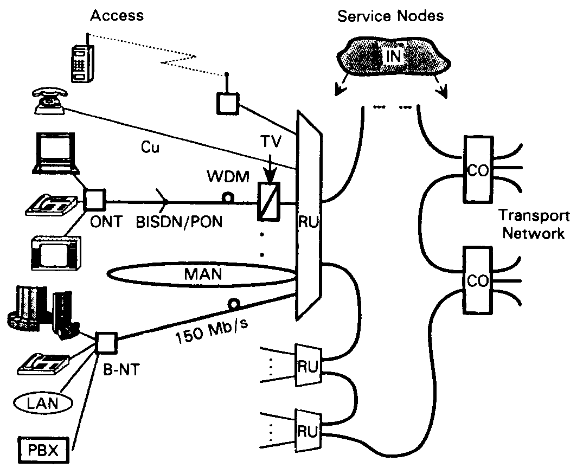


Key:

CO: Central Office
IN: Intelligent Network
ONT: Optical Network Termination
PON: Passive Optical Network
RU: Remote Unit
WDM: Wavelength Division Multiplex
▬▬ : SDH-Based Transmission (including SDH Crossconnects)
PBX: Private Branch Exchange
Cu: Copper

Fig. 4. Example of BISDN access architecture.

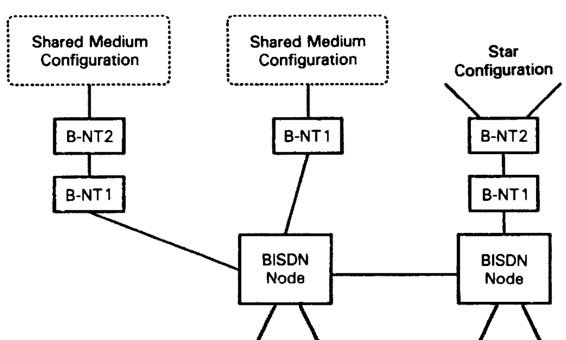
Customer Networks

Access networks located in the customer premises are discussed here. These networks are called Customer Networks (CNs); sometimes they are named customer premises networks or subscriber premises networks.

Functional Description

Various architectures are proposed to allow numerous terminals access to BISDN. Figure 5 gives three major possibilities that are discussed later.

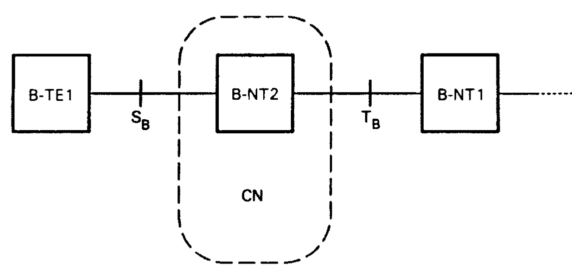
The functional description of a CN is based on the reference configuration of the BISDN UNI which is shown in



Key:

B-NT: Network Termination for BISDN

Fig. 5. Generic BISDN access architecture.



Key:

B-NT: Network Termination for BISDN
B-TE: Terminal Equipment for BISDN
CN: Customer Network

Fig. 6. Reference configuration of the BISDN UNI.

Figure 6 [9]. It contains the following entities:

- Functional groups: B-TE1, B-NT1, and B-NT2
- Reference points: S_B and T_B

B-NT1 and B-NT2 are acronyms for broadband network terminations and B-TE denotes a broadband terminal with standardized interface. A B-NT2 can be seen, e.g., as a broadband Private Branch Exchange (PBX).

The CN makes it possible for the customer to access the public network via his terminals. Hence, the CN is the part of the network that is located between the reference points S_B and T_B (the CN coincides with the functional group B-NT2).

At the physical layer the interfaces at the reference points S_B as well as T_B are point-to-point (i.e., there is one receiver in front of one emitter); however, at higher layers point-to-multipoint configurations are possible. Between B-NT1 and B-NT2 (at the reference point T_B) only one interface exists, whereas at B-NT2 several interfaces towards the terminals are possible. Normally, broadband interfaces are used. It should be noted that BISDN will also support 64 kb/s ISDN services and that B-NT2 may provide standardized interfaces for the 64 kb/s ISDN (this interface is not shown in Figure 6).

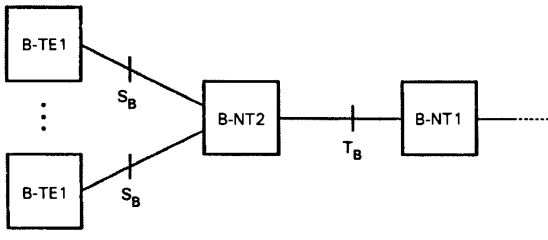
B-NT1 performs line transmission termination, transmission interface handling, as well as the appropriate operation and maintenance. The functions included in the B-NT2 are dependent on the requirements of the customer and are as follows:

- A *null B-NT2* means that no B-NT2 exists; this allows the connection of a terminal to the B-NT1 (S_B coincides with T_B).
- The B-NT2 only provides adaptation of functions for different physical media.
- The B-NT2 includes multiplexing/demultiplexing functions as well as traffic concentration.
- The B-NT2 is a switch (e.g., PBX). In this case signaling protocol handling, resource allocation, and internal switching capabilities must be provided.

Star Configuration

According to CCITT Recommendation I.413 [9], the star configuration that is well-known from existing CNs is a possible solution for the CN implementation. Each terminal is directly connected to the B-NT2 via its own transmission line (see Figure 7).

Cells, originating from a terminal and destined for the public network are sent towards the network only. These cells do not pass any other terminal. In the opposite direction (cells destined for terminals) two possibilities exist. A



Key:

B-NT: Network Termination for BISDN
B-TE: Terminal Equipment for BISDN

Fig. 7. Star configuration.

simple B-NT2 sends copies of all cells destined for terminals to all terminals. Each terminal will extract the cells pertaining to it. In the other case, the B-NT2 is more *intelligent* and sends cells only to the proper destination.

The functionality of the interface at S_B is defined independently of the B-NT2 realization. This allows the implementation of the B-NT2 as a centralized or distributed system. In the case of a distributed system, a bus or ring structure like those in LANs can be used. Then, terminals are attached via terminal adaptors to the common medium. This distributed system may be advantageous in terms of cabling efforts and its ability to expand. The B-NT2 internal operation is not a matter of standardization and therefore manufacturer specific solutions for the medium adaptors may arise. This prevents interchangeability of medium adaptors. The customer is restricted in selecting terminal adaptors from different manufacturers. This highly modularized structure has the advantage that the CN can be easily expanded by only adding a new terminal adaptor.

Shared Medium Configurations

In addition to the star configuration, CCITT agreed to configurations in which several terminals share a single access using one standardized UNI. In order to avoid collisions, the access to the shared medium has to be controlled by a standardized mechanism. This will be supported by the GFC procedure (see *Generic Flow Control*) using the 4 bit GFC field in the cell header. GFC should provide fair and orderly access to the transmission line.

The major motivations for these shared medium configurations are saving transmission lines in terms of meters of cable, simple expansibility by only adding a new terminal to the existing configuration, simplification of deployment, and evolution of preexisting networks towards BISDN [10]. In addition to these advantages, these configurations need no medium adaptors that have the drawback of being manufacturer specific solutions.

At the physical layer, connections are point-to-point with one transmitter and one receiver. This implies that no *passive* bus configurations are possible. Passive bus systems are restricted in terms of transmission distance and number of connectable terminals, and there is no suitable media access control procedure for such high bit rates. Therefore, they have been excluded from being appropriate for BISDN. Only *active* systems (daisy-chain principle) can be used.

An active bus configuration with only one transmission direction (single bus) cannot be used for the CN implementation. This configuration would not allow the transfer of cells from and towards the network simultaneously. A single active ring may be restricted in throughput [11] and will not be described in this article.

In the following, the two most promising configurations—dual bus and dual ring—will be discussed in more detail. Both configurations avoid the throughput bottleneck of the single ring because they use separate transmission lines for each direction.

Figure 8 shows the active dual bus configuration. Each terminal is connected to the preceding and succeeding ones. A new terminal is simply added by connecting it to the last terminal of the bus or inserting it in the existing configuration. All terminals have the same standardized interface. This allows the customer to employ terminals of different manufacturers simultaneously.

The dashed box of the B-NT2 means that it can be present or have null functionality (*null B-NT2*). In the case of a *null B-NT2* the B-NT2 functions are distributed among the terminals (e.g., internal switching) and the CO. The CO may, for example, perform signaling functions and transmission resource allocation.

In Figure 8, a new reference point called SSB was introduced. This point is located between two adjacent terminals. In order to enable terminal interchangeability the interface at S_B should be unique, it should be identical with the interface at SSB and be compatible with the interface at T_B. The last requirement results from the *null B-NT2* where the reference points S_B and T_B coincide. However, whether this goal can be met is uncertain as two physical layer interface options at T_B (SDH-based interface and cell-based interface) currently exist, and for each option either optical fiber or coaxial cable can be used.

In Figure 9, the dual ring configuration depicted is also a candidate for shared medium configurations. As already mentioned, at T_B only one interface is possible. Therefore, the dual ring configuration always requires a B-NT2.

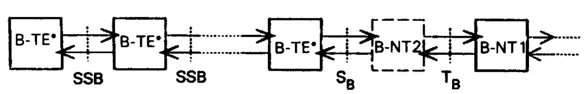
In order to prevent retransmission of cells towards the network destined for a terminal, each terminal should extract all cells pertaining to it and insert idle cells. Due to the cell extraction and idle cell insertion, bandwidth can be reused and the throughput will be increased. One advantage of the ring configuration may be the possibility to select the shortest path from the B-NT2 to the destined terminal and vice versa. However, this feature requires additional complexity within the B-NT2 and terminals. The possibility of transmitting cells on two independent ways to the terminal allows a proper load sharing.

In principle, the dual ring can be operated as a dual bus. In this case the only advantage is the high reliability of the ring configuration. If a cable failure occurs simple reconfiguration is possible.

Until now two extreme cases of CNs have been discussed:

- Each terminal is attached to the B-NT2 via its own line
- All terminals share a common medium

It is also possible to use any combination of both (e.g., starred bus). This depends on the customer's needs. Shared medium configurations may predominantly be employed in



Key:

B-NT: Network Termination for BISDN
B-TE: Terminal Equipment for BISDN
B-TE* includes media access functions
Interface at SSB is identical to the interface at S_B

Fig. 8. Dual bus configuration.

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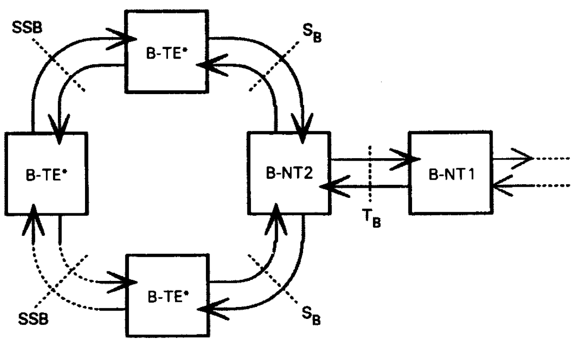

Key:

B-NT: Network termination for BISDN
B-TE: Terminal equipment for BISDN
B-TE*: Includes media access functions
Interface at SSB is identical to the interface at S_B

Fig. 9. Dual ring configuration.

small and medium size CNs. Large CNs (hundreds of terminals) may be better implemented as a combination of shared medium configuration and star configuration. In large CNs a single shared medium configuration may result in a throughput bottleneck.

Internal Communication Within A CN

In the star configuration for internal communication no direct terminal-to-terminal communication (i.e., a terminal sends its cells directly to the destined terminal) is possible. All internal traffic must be handled by the B-NT2 or CO.

In shared medium configurations the same operation mode can be applied. Each terminal sends all its cells towards the network. The B-NT2 or CO then decides which cells belong to internal or external communications. In the case of internal communication, the B-NT2 or CO sends the cells back towards the terminals. Terminals used in this mode are called *unidirectional* because they only transmit cells towards the public network and receive cells pertaining to it from that direction. The shared medium is only used for multiplexing and demultiplexing.

However, in shared medium configurations direct terminal-to-terminal communication is possible. This requires additional complexity within the terminals because each terminal has to know the location of its partner; but the B-NT2 or CO are unburdened from internal switching. These terminals are called *bidirectional* because they can send to, and receive from, both directions. During the connection set-up phase the connection handler informs the terminals of the location of their partners. For this purpose, the connection handler needs an exact picture of the CN configuration and has to be informed of all changes within the CN.

Both modes can be applied for the information transfer. Further studies are required to decide which service will benefit most from which mode. It should also be taken into account that a mix of unidirectional and bidirectional terminals can be connected to the same shared medium configuration. This depends on the communication requirements of the customer.

For call/connection establishment and release no direct terminal-to-terminal communication should be used, because this requires that each terminal has to be informed of establishment and release of any call/connection, and all call/connection relevant data have to be present in each terminal. For call/connection establishment and release a centralized approach should be used. All terminals send their cells containing signaling information to a centralized call/connection handler (e.g., B-NT2 or CO) and receive a signaling message pertaining to it from this centralized entity.

In star and shared medium configurations, which use a centralized entity for internal switching, unidirectional terminals can be employed. In shared medium configurations with direct terminal-to-terminal communication bidirectional terminals are used. This seems to be in contradiction with the requirement of terminal interchangeability. However, it should be noted that bidirectional terminals can be operated in the unidirectional mode.

Generic Flow Control

The GFC field is only present at the BISDN UNI. For this purpose the first 4 bit of the cell header are used (only at the BISDN UNI). The functional description of GFC is given in CCITT Recommendation I.150 [12].

GFC is intended to be used to control the traffic flow of terminals within the CN in order to provide various quality of service (QOS) and alleviate short term overload situations. All CN configurations presented in *Customer Networks*, should be supported by a unique GFC protocol. GFC will only control the traffic originating from terminals; it does not influence the traffic stream coming from the public network.

A GFC protocol has to ensure that each terminal gets access to its guaranteed capacity and the remaining spare capacity will be partitioned fairly among all terminals contending for it. In shared medium configurations direct terminal-to-terminal communication should be provided by the GFC protocol. The GFC procedure should be insensitive to traffic and system parameters and robust against errored, lost, and misinserted GFC information.

The exact GFC procedure has not yet been defined by CCITT; only proposals have been made. It is envisaged to support constant bit rate traffic and different CN configurations. Some of these proposals are based on a distributed queuing algorithm well known from the DQDB protocol [2]. Other proposals use a modified Orwell protocol [13]. Other proposals are described in e.g., by Sato *et al.* and Woloszynski [14] [15].

CCITT mentioned that only one GFC procedure will be standardized. In order to find out the *best* protocol, CCITT defined test criteria (e.g., number of terminals, traffic mix, and bit rate mix) that are the base for performance evaluation. However, it should be noted that the decision should not only be made on obtained performance results. Other factors like implementation complexity, cost, and reliability will also be taken into account.

CONCLUSION AND OUTLOOK

Various scenarios to access BISDN have been shown. First, LANs and MANs have been discussed which can be considered as one of the pioneers towards the ATM-based BISDN. LANs and MANs are primarily applied for high-speed data communication. In the second part, there are presented different CN configurations that are also based on the ATM technique. These networks transport all kind of services supported by BISDN and do not require any IWU.

Some of these CNs have LAN-like structures providing all the advantages and disadvantages from LANs and MANs in addition with higher bit rates and the ATM technique. These *ATM-LANs* need a suitable MAC protocol. For this purpose, GFC, which has also been described in this article will be used.

LANs and MANs are reality. Pilots and trials for BISDN with bit rates in the range of 150 Mb/s are already running or will be started in the near future. Trends to higher bit rates, e.g., 622 Mb/s and also 2.5 Gb/s are clearly visible. This evolution is not restricted to the transit network; also in the local access network and even in the CN higher bit rates are desirable.

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Biography

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