

*Recognized as an
American National Standard (ANSI)*

IEEE Std 802.6-1990

**Distributed Queue Dual
Bus (DQDB) Subnetwork
of a Metropolitan Area
Network (MAN)**

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American National Standard (ANSI)

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IEEE Standards for
Local and Metropolitan Area Networks:
**Distributed Queue Dual Bus (DQDB)
Subnetwork of a Metropolitan Area
Network (MAN)**

Sponsor

Technical Committee on Computer Communications
of the
IEEE Computer Society

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Abstract: This standard is part of a family of standards for local area networks (LANs) and metropolitan area networks (MANs) that deals with the Physical and Data Link Layers as defined by the ISO Open Systems Interconnection Reference Model. It defines a high-speed shared medium access protocol for use over a dual, counterflowing, unidirectional bus subnetwork. The Physical Layer and Distributed Queue Dual Bus (DQDB) Layer are required to support a Logical Link Control (LLC) Sublayer by means of a connectionless Medium Access Control (MAC) Sublayer service in a manner consistent with other IEEE 802 networks. Additional DQDB Layer functions are specified as a framework for other services. These additional functions will support Isochronous Service Users and Connection-Oriented Data Service Users, but their implementation is not required for conformance.

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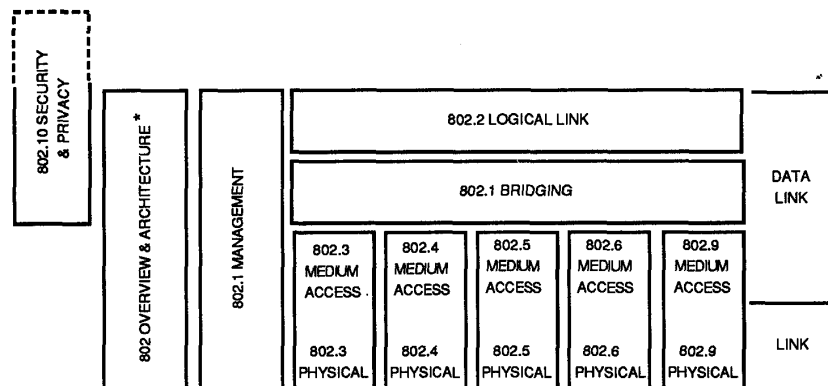
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Foreword

(This Foreword is not a part of IEEE Std 802.6-1990, Distributed Queue Dual Bus (DQDB) Subnetwork of a Metropolitan Area Network (MAN).)

This standard is part of a family of standards for local and metropolitan area networks. The relationship between the standard and other members of the family is shown below. (The numbers in the figure refer to IEEE Standard numbers.)



* Formerly IEEE Std 802.1A.

This family of standards deals with the physical and data link layers as defined by the ISO Open Systems Interconnection Basic Reference Model (ISO 7498:1984). The access standards define several types of medium access technologies and associated physical media, each appropriate for particular applications or system objectives. Other types are under investigation.

The standards defining these technologies are as follows:

- IEEE Std 802[†]: Overview and Architecture. This standard provides an overview to the family of IEEE 802 Standards. It is a part of the 802.1 scope of work.
- IEEE Std 802.1D: MAC Bridging. Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.

[†] The 802 Architecture and Overview Specification, originally known as IEEE Std 802.1A, has been renumbered as IEEE Std 802. This has been done to accommodate recognition of the base standard in a family of standards. References to IEEE Std 802.1A should be considered as references to IEEE Std 802.

- IEEE Std 802.1E: System Load Protocol. Specifies a set of services and protocol for those aspects of management concerned with the loading of systems on IEEE 802 LANs.
- ISO 8802-2 [ANSI/IEEE Std 802.2]: Logical Link Control.
- ISO/IEC 8802-3 [ANSI/IEEE Std 802.3]: CSMA/CD Access Method and Physical Layer Specifications.
- ISO/IEC 8802-4 [ANSI/IEEE Std 802.4]: Token Bus Access Method and Physical Layer Specifications.
- IEEE Std 802.5: Token Ring Access Method and Physical Layer Specifications.
- IEEE Std 802.6: Metropolitan Area Network Access Method and Physical Layer Specifications.

In addition to the family of standards are technical advisory groups as follows:

- IEEE Std 802.7: Broadband Technical Advisory and Physical Layer Topics and Recommended Practices.
- P802.8: Fiber Optic Technical Advisory and Physical Layer Topics.

The reader of this document is urged to become familiar with the complete family of standards.

The purpose of this standard is to lay the foundation for a set of standards to allow DQDB subnetworks to provide a range of telecommunications services within a metropolitan area. Based on this set of standards, equipment vendors will be able to build the components that will allow telecommunications services to be offered to end users within a metropolitan area.

The interconnection of DQDB subnetworks to form a metropolitan area network will be possible via a Multiport Bridge[‡] or via dual-port bridges, routers, and gateways, as shown in Fig A. DQDB subnetworks can be used to provide switching, routing, and concentration of high-speed data, voice, and certain video services, as well as to interconnect LANs, hosts, workstations, and PBXs.

The user's attention is called to the possibility that compliance with this standard may require the use of inventions covered by patent rights. All enquiries should be sent to the IEEE Standards Board at the address given at the end of the Foreword.

[‡] The services of a Multiport Bridge are the subject of ongoing work under IEEE Project Authorization P802.6a, Multiple Port Bridging for Metropolitan Area Networks.

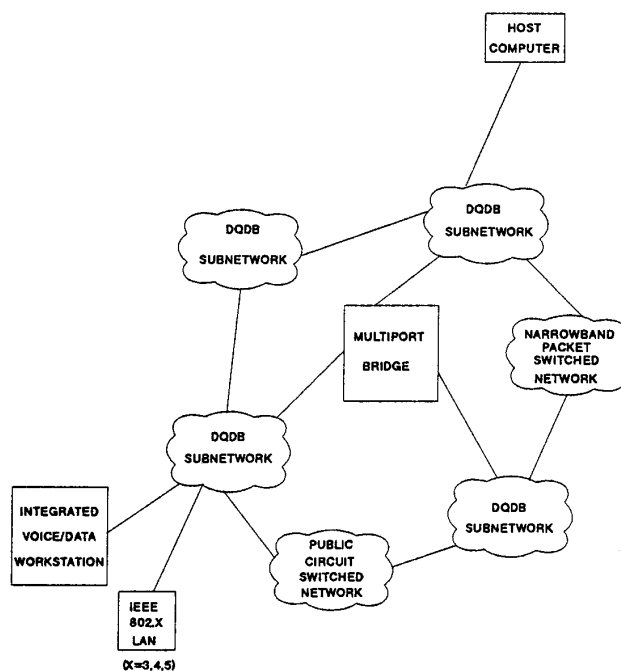


Fig A
DQDB Metropolitan Area Network

This edition of the standard defines general principles for the operation of a number of physical layers. A physical layer capable of using a DS3 transmission system (ANSI T1.102 and T1.107) is defined in this edition of the standard. It is anticipated that future editions of the standard will provide additional implementations of the physical layer to support different needs (for example, media, data rates, network operator requirements).

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material. Information on the current revision status of this standard may be obtained by contacting

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We are especially grateful for the dedicated work of Peter Evans and Sayeed Ghani, editors of this standard, who have translated the complexities of a protocol involving many thousands of silicon gates into an accurate and usable document. Particular thanks are due also to Dan Sze, who authored several proposals in earlier stages of the MAN standard development and also served as vice chair of the committee; and to Mary Kelly, whose work behind the scenes helped to make it all come together.

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IEEE Standards for Local and Metropolitan Area Networks:

Distributed Queue Dual Bus (DQDB) Subnetwork of a Metropolitan Area Network (MAN)

1. Introduction

1.1 Scope. This standard for a Distributed Queue Dual Bus (DQDB) subnetwork of a metropolitan area network (MAN) defines a high-speed shared medium access protocol for use over a dual, counter-flowing, unidirectional bus subnetwork. The standard specifies the Physical Layer and DQDB Layer required to support

- Logical Link Control (LLC) Sublayer
by a connectionless Medium Access Control (MAC) Sublayer service provided to support an LLC Sublayer in a manner consistent with other IEEE 802 local and metropolitan area networks.

This standard also specifies additional DQDB Layer Functions as a framework for other services. In this edition of the standard, they are provided for tutorial purposes only; their implementation is not required for conformance.

These additional functions will support

- Isochronous Service Users (ISUs)
by a connection-oriented service, which may be used to transport isochronous data; for example, conventional digitized voice.
- Connection-Oriented Data Service Users
by an asynchronous, connection-oriented service, which may be used to transport bursty data; for example, signaling.

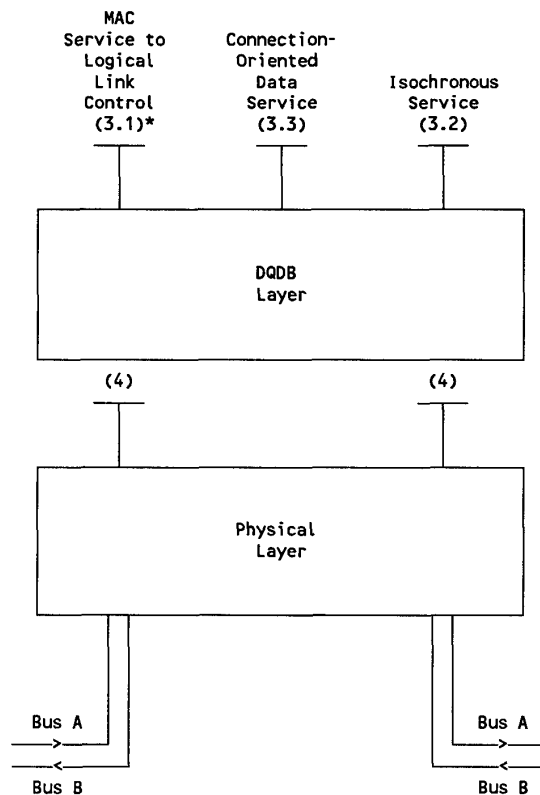
The scope of this standard is shown diagrammatically in Fig 1-1.

The DQDB Layer supports these services by employing the following access methods:

- A Queued Arbitrated access method with three priority queues for medium access arbitration and fixed-length slots for data transfer. Each priority level provides distributed queue access for the support of connectionless MAC service and connection-oriented data service.
- A Pre-Arbitrated access method that uses assigned octet positions in particular slots for the transfer of individual octets of data. This access method supports isochronous connection-oriented services.

The Queued Arbitrated access method uses fixed-length slots for data transfer. This transfer mechanism is enhanced by a MAC convergence function to the service expected by the LLC Sublayer. The MAC convergence function is defined in this standard.

Fig 1-1
Scope of IEEE Std 802.6-1990



* Numbers in parentheses refer to sections and subsections of this standard where the service are defined.

This standard defines the DQDB Layer Functions to allow access to the medium to read and write data to support the isochronous service and the connection-oriented data service. The signaling procedures for establishing, maintaining, and clearing a connection are outside the scope of this standard.¹

The Physical Layer is defined to allow the use of different underlying transmission systems. The standard supports a DS3 interface operating at 44.736 Mb/s, as specified in ANSI T1.102 [1]² and T1.107 [2]. The support of CCITT Recommendation G.703 [4], operating at 34.368 Mb/s and 139.264 Mb/s, and CCITT Recommendations G.707 [5], G.708 [6], and G.709 [7] SDH, as well as other standard transmission systems, is under consideration by the DQDB MAN committee. Other appropriate media and transmission rates may be considered for standardization in the future.

Each transmission system may need to be enhanced to provide the Physical Layer service that is required by the DQDB Layer. This enhancement function, if required, is provided by a suitable Physical Layer Convergence Procedure (PLCP). This standard will define a PLCP for each transmission system that is supported.

1.2 Applicability. DQDB subnetworks are intended to support a range of service types including statistical data traffic. Subnetworks should therefore be dimensioned by the network provider so as to ensure that periods of expected peak demands do not cause excessive delay to the particular services that are intended to be supported.

During the periods of overload, which may still occur, a DQDB subnetwork will continue to operate at close to maximum throughput, but some service degradation must necessarily occur. To ensure manageable degradation of the services supported by a DQDB subnetwork, three mechanisms have been provided:

- Pre-Arbitrated access
- Queued Arbitrated access with priority
- bandwidth balancing

A description of these mechanisms is provided in 2.1.2, and their areas of application are outlined in 2.1.4.

1.3 Definitions. This section defines the terms used in this standard. Words in *italics* indicate terms that are defined elsewhere in the list of definitions.

Access Control Field (ACF). The *protocol control information* in a slot, which is used to support the *access control function*.

access control function. The generic name for the *Queued Arbitrated (QA) Access* and *Pre-Arbitrated (PA) Access Functions* in the *DQDB Layer* that control access to the medium in this standard.

¹ Appendix A gives a tutorial description of the sequence of events that are required to support complete isochronous communication capability.

² The numbers in brackets correspond to those of the references listed in 1.5.

access unit (AU). The functional unit in a *node* that performs the *DQDB Layer Functions* to control access to both *buses*. Access units attach to each bus via a *write connection* and a *read tap* placed *upstream* of the write connection.

address. An identifier that tells where a *service access point (SAP)* may be found (ISO 7498 [13]).

address field. The part of a *protocol data unit (PDU)* that contains an *address* that identifies one or more addressable entities. (The address may be a single-source address, single-destination address, or multiple-destination address (*multicast*).)

bandwidth balancing mechanism. A procedure to facilitate effective sharing of the bandwidth, whereby a *node* occasionally skips the use of *empty Queued Arbitrated (QA) slots*.

bridge. A functional unit that interconnects two subnetworks that use a single *Logical Link Control (LLC) procedure* but may use different *Medium Access Control (MAC) procedures*. *Local area networks (LANs)* and metropolitan area networks (MANs) are examples of the subnetworks that a bridge may interconnect.

broadcast address. A predefined destination *address* that denotes the set of all *service access points (SAPs)* within a given *layer*.

bus. The concatenation of the *transmission links* between *nodes* and the data path within nodes that provides unidirectional transport of the digital bit stream from the *head of bus function* past the *access unit (AU)* of each node to the end of bus.

NOTE: This differs from the bidirectional bus as used in ISO/IEC 8802-3 [IEEE Std 802.3] and ISO/IEC 8802-4 [IEEE Std 802.4].

busy slot. A *slot* that contains information and is not available for *Queued Arbitrated (QA) access*.

Configuration Control Function. The function that ensures that the resources of all *nodes* of a *DQDB subnetwork* are configured into a correct dual bus topology. The resources that are managed are the *head of bus function*, the *External Timing Source Function*, and the *Default Slot Generator Function*.

connection. An association established by a *layer* between two or more users of the layer service for the transfer of information (ISO 7498 [13]).

convergence function. A function or procedure that provides sufficient additional services to enable a layer to provide the services expected by a particular higher layer. For example, the Physical Layer Convergence Procedures (PLCP) enable the IEEE 802.6 MAC to run over specific physical transport systems (such as DS3 (ANSI T1.102 [1], T1.107 [2])) provided by the public telephone network.

Data Link Layer. In Open Systems Interconnection (OSI) architecture, the *layer* that provides services to transfer data over a *transmission link* between open systems.

In IEEE 802 *local area network (LAN)* standards, the Data Link Layer is formed by the *Logical Link Control (LLC) Sublayer* and the *Medium Access Control (MAC) Sublayer*.

Using this standard, the Data Link Layer is formed by the operation of the LLC Sublayer (ISO 8802-2 [15]) over the MAC Sublayer service offered by the *DQDB Layer*.

Default Slot Generator Function. The function that defines the identity (i.e., Bus A or Bus B) for each *bus* of a *dual bus subnetwork*. Additionally, the function that provides *head of bus functions* for both Bus A and Bus B in a *looped dual bus subnetwork*. (If the looped dual bus subnetwork is reconfigured to an *open dual bus subnetwork* due to *transmission link* faults, then the head of bus functions for either one or both buses are assigned to other nodes for the duration of the fault.³)

Derived MAC Protocol Data Unit (DMPDU). The *protocol data units (PDUs)* of a length of 48 octets formed by the addition of *protocol control information* (including *message identifier* and error protection information) to each of the 44-octet *segmentation units* created from the *segmentation* of an *Initial MAC Protocol Data Unit (IMPDU)*. Each DMPDU is carried as the payload of a *Queued Arbitrated (QA) segment*.

Distributed Queue. The *Medium Access Control (MAC) procedure* in this standard for *Queued Arbitrated (QA) access*.

downstream. The direction of data flow along a *bus*, i.e., away from the *head of bus function*.

DQDB Layer. The *sublayer* in this standard that uses the services of the *Physical Layer* to provide the following:

- *Medium Access Control (MAC) Sublayer* service to the *Logical Link Control (LLC) Sublayer*, and
- *isochronous* service, and
- *connection-oriented data* service.

dual bus. A pair of *buses* carrying digital bit streams flowing in opposite directions. One bus is referred to as Bus A and the other bus as Bus B.

empty Queued Arbitrated (QA) slot. A *Queued Arbitrated (QA) slot* that was designated by the *head of bus function* as being available for transfer of a *QA segment*, and that does not contain a *QA segment*.

External Timing Source Function. The function of providing the primary point of synchronization of the *DQDB subnetwork* to some external timing reference, for example, that provided by a public network operator.

³ Note that all *DQDB subnetworks*, whether in an *open* or *looped dual bus* configuration, contain exactly one *node* with an active Default Slot Generator Function at network initialization. This node is nominated prior to network initialization. In an *open dual bus subnetwork*, the Default Slot Generator Function may be activated at any single node having this capability.

gateway. A functional unit that interconnects a *local area network (LAN)* with another network having different higher layer protocols.

group address. A predefined destination *address* that denotes a set of selected *service access points (SAPs)* from the *Medium Access Control (MAC) Sublayer* service offered by the *DQDB Layer* to the *Logical Link Control (LLC) Sublayer*.

head of bus function. The function that generates *empty Queued Arbitrated (QA) slots*, *Pre-Arbitrated (PA) slots*, and *management information octets* at the point on each bus where data flow starts. The head of bus function also inserts the *virtual channel identifier* in the *PA segment header* of *PA slots*.

individual address. An *address* that identifies a single source or destination *service access point*.

Initial MAC Protocol Data Unit (IMPDU). A *protocol data unit (PDU)* formed in the *DQDB Layer* by the addition of *protocol control information* (including address information) to a *MAC Service Data Unit* received from the *Logical Link Control (LLC) Sublayer*. The IMPDU is segmented into 44-octet *segmentation units* for transfer in *Derived MAC Protocol Data Units (DMPDUs)*.

island. An operating part of a *DQDB subnetwork* that is isolated from the node containing the *default slot generator function*.

isochronous. The time characteristic of an event or signal recurring at known, periodic time intervals.

isochronous service octet. A single *octet* of data passed *isochronously* between the *DQDB Layer* and the *Isochronous Service User (ISU)*.

Isochronous Service User (ISU). The entity that uses the *isochronous* service provided by the *DQDB Layer* to transfer *isochronous service octets* over an established *isochronous connection*.

layer. A subdivision of the Open Systems Interconnection (OSI) architecture, constituted by *subsystems* of the same rank (ISO 7498 [13]).

layer management. Functions related to the administration of a given Open Systems Interconnection (OSI) *layer*. These functions are performed in the layer itself according to the protocol of the layer and partly performed as a subset of *network management* or *systems management*.

Layer Management Entity (LME). The entity in a *layer* that performs local management of a layer. The LME provides information about the layer, effects control over it, and indicates the occurrence of certain events within it.

Layer Management Interface (LMI). The service interface provided by the *Layer Management Entity (LME)* to the *Network Management Process (NMP)*.

local area network (LAN). A non-public data network in which serial transmission is used without store and forward techniques for direct data communication among data stations located on the user's premises.

Logical Link Control (LLC) procedure. In a *local area network (LAN)* or a metropolitan area network (MAN), the part of the protocol that governs the assembling of *Data Link Layer* frames and their exchange between data stations independently of how the *transmission medium* is shared.

Logical Link Control (LLC) Sublayer. In a *local area network (LAN)* or metropolitan area network (MAN), that part of the *Data Link Layer* that supports medium-independent data link functions, and uses the *Medium Access Control (MAC) Sublayer* service to provide services to the *Network Layer*.

looped dual bus. A DQDB *subnetwork* with the *head of bus functions* for both Bus A and Bus B collocated.

MAC address. An address that identifies a particular *Medium Access Control (MAC) Sublayer service access point (SAP)*.

MAC Service Data Unit (MSDU). The user data unit received in an MA-UNITDATA request for transfer by the *Medium Access Control (MAC) Sublayer*.

management information octets. *DQDB Layer Protocol Data Units (PDUs)* used to carry DQDB Layer Management Protocol information between peer *DQDB Layer Management Entities (LMEs)*.

Medium Access Control (MAC) procedure. In a *local area network (LAN)* or metropolitan area network (MAN), the part of the protocol that governs access to the *transmission medium* independently of the physical characteristics of the medium, but taking into account the topological aspects of the *subnetwork*, in order to enable the exchange of data between *nodes*.

The MAC procedures include framing, error protection, and acquiring the right to use the underlying transmission medium.

Medium Access Control (MAC) Sublayer. In a *local area network (LAN)* the part of the *Data Link Layer* that supports topology-dependent functions and uses the services of the *Physical Layer* to provide service to the *Logical Link Control (LLC) Sublayer*.

In this standard, the combined set of functions in the *DQDB Layer* that support the MAC Sublayer service to the Logical Link Control (LLC) Sublayer.

message identifier. An identifier used to identify *Derived MAC Protocol Data Units (DMPDUs)* derived from the same *Initial MAC Protocol Data Unit (IMPDU)*.

MID (Message Identifier) page. A set of one *message identifier* value.

multicast address. See *group address*.

multiport bridge. A *bridge* that interconnects two or more DQDB *subnetworks*.

Network Layer. In Open Systems Interconnection (OSI) architecture, the *layer* that provides services to establish a path between open systems with a predictable quality of service.

network management. Within IEEE 802, the functions related to the management of *Data Link Layer* and *Physical Layer* resources and their status across an IEEE 802 *local area network (LAN)* or metropolitan area network (MAN).

Network Management Process (NMP). The entity that provides access to *network management* functions on behalf of the user of the network management services. In order to perform this function, NMPs may intercommunicate in a peer-to-peer manner and may use the services of NMPs in other *nodes* via a network management protocol. The NMP at a node is the user of the service provided at the *Layer Management Interface (LMI)*.

node. A device that consists of an *access unit (AU)* and a single point of attachment of the access unit to each *bus* of a *DQDB subnetwork* for the purpose of transmitting and receiving data on that subnetwork. Adjacent nodes are connected by a *transmission link*.

octet. A group of eight adjacent bits.

offset. The *octet* position relative to the start of a *Pre-Arbitrated (PA) segment* used to carry an *isochronous service octet* for a particular *Isochronous Service User (ISU)*.

open dual bus. A *DQDB subnetwork* with the *head of bus function* for Bus A and the head of bus function for Bus B at different *nodes*.

Physical Layer. In Open Systems Interconnection (OSI) architecture, the *layer* that provides services to transmit bits or groups of bits (such as an *octet*) over a *transmission link* between open systems.

In this standard, the Physical Layer provides the protocol to allow transfer of *slot octets*, *management information octets*, and *DQDB Layer* timing information over the *transmission link* between *DQDB Layer subsystems* at adjacent *nodes*. The Physical Layer provides the service to the *DQDB Layer*.

Physical Layer Convergence Procedure (PLCP). In this standard, the part of the *Physical Layer* that supports the transfer of *slot octets*, *management information octets*, and *DQDB Layer* timing information in a manner that adapts the capabilities of the *transmission system* to the service expected by the *DQDB Layer*.

pipelining. Forwarding of some or all of the Beginning of Message (BOM), Continuation of Message (COM) *Derived MAC Protocol Data Units (DMPDUs)* before receipt of the End of Message (EOM) *DMPDU*.

Pre-Arbitrated (PA) Access Function. The *access control function* in this standard that uses assigned *offsets* in *Pre-Arbitrated (PA) slots* for the transfer of *isochronous service octets*.

Pre-Arbitrated (PA) segment. A multi-user *segment* transferred using *Pre-Arbitrated Access (PA) Functions*. The payload of the *PA segment* contains *isochronous service octets* from zero or more *Isochronous Service Users (ISUs)*.

Pre-Arbitrated (PA) slot. A *slot* that is dedicated by the *head of bus function* for transfer of *isochronous service octets* in the payload of a *PA segment*.

protocol control information. Information exchanged between entities to coordinate their joint operation.

protocol data unit (PDU). Information that is delivered as a unit between peer entities of a *local area network (LAN)* or metropolitan area network (MAN) and that contains control information, address information, and may contain user data.

Queued Arbitrated (QA) Access Function. The *access control function* in this standard that uses the *Distributed Queue* to access *empty Queued Arbitrated (QA) slots* for the transfer of *QA segments*.

Queued Arbitrated (QA) segment. A *segment* transferred using *Queued Arbitrated (QA) Access Functions*.

Queued Arbitrated (QA) slot. A *slot* that is used for the transfer of a *QA segment*.

read. The process of an *access unit (AU)* copying bits of a data stream as they pass on the *bus*.

reassembly. The function in the *DQDB Layer* that provides for the reconstruction of an *Initial MAC Protocol Data Unit (IMPDU)*. Reassembly is performed by concatenating the *segmentation units* received in *Derived MAC Protocol Data Units (DMPDUs)*. This is the inverse process to segmentation.

reconfiguration. The process by which the *Configuration Control Function* activates and deactivates resources of a *DQDB subnetwork* to take account of a change in the operational status of a cluster, *node*, or *transmission link* in the subnetwork.

router. A functional unit that interconnects two computer networks that use a single *Network Layer* procedure but may use different *Data Link Layer* and *Physical Layer* procedures.

segment. The *protocol data unit (PDU)* of 52 octets transferred between peer *DQDB Layer* entities as the information payload of a *slot*. It contains a *segment header* of 4 octets and a *segment payload* of 48 octets. There are two types of segments: *Pre-Arbitrated (PA) segments* and *Queued Arbitrated (QA) segments*.

segment header. The *protocol control information* in a *segment*.

segment payload. The unit of data carried by a *segment*.

segmentation. The function in the *DQDB Layer* that fragments a variable length *Initial MAC Protocol Data Unit (IMPDU)* into fixed-length *segmentation units* for transfer in *Derived MAC Protocol Data Units (DMPDUs)* (cf., *reassembly*).

segmentation unit. The fixed-length data units of 44 octets formed by the fragmentation of an *Initial MAC Protocol Data Unit (IMPDU)*.

service access point (SAP). The point at which services are provided by one *layer* (or *sublayer*) to the layer (or sublayer) immediately above it (ISO 7498 [13]).

service data unit (SDU). Information that is delivered as a unit between peer *service access points (SAPs)*.

service primitive; primitive. An abstract, implementation-independent interaction between a service user and the service provider.

slot. The *protocol data unit (PDU)* of 53 octets used to transfer *segments*. It contains a segment of 52 octets and a 1 octet *Access Control Field (ACF)*. There are two type of slots: *Pre-Arbitrated (PA) slots* and *Queued Arbitrated (QA) slots*.

sublayer. A subdivision of a *layer* in the Open System Interconnection (OSI) reference model.

subnetwork. In this standard, a functional unit comprised of a single *dual bus* pair and those *access units (AUs)* attached to it. Subnetworks are physically formed by connecting adjacent *nodes* with *transmission links*.

subnetwork configuration. The topological arrangement of *nodes* to form a *subnetwork*. In normal operation a DQDB subnetwork can have one of two configurations, *open dual bus* or *looped dual bus*.

subsystem. An element in a hierarchical division of an open system that interacts directly only with elements in the next higher division or the next lower division of that open system (ISO 7498 [13]).

systems management. Functions in the application *layer* related to the management of various Open Systems Interconnection (OSI) resources and their status across all layers of the OSI architecture.

transmission link. The physical unit of a DQDB *subnetwork* that provides the transmission connection between adjacent *nodes*. Each transmission link accommodates both *buses* of the *dual bus* pair between the adjacent nodes.

transmission medium. The material on which information signals may be carried; e.g., optical fiber, coaxial cable, and twisted-wire pairs.

transmission system. The interface and *transmission medium* through which peer *Physical Layer* entities transfer bits.

upstream. The direction along a *bus* that is towards the *head of bus function*. This is opposite to the direction of data flow along a bus.

Virtual Channel Identifier (VCI). A label that is used to distinguish between the different virtual channels. A virtual channel is a logical association between entities that enables unidirectional transfer of *segments* between the

entities. In the context of this standard, the VCI label can be used to allow a transmitter to distinguish between different outgoing *protocol data units (PDUs)*, and is used to allow a receiver to determine whether to receive an incoming segment as well as to distinguish between incoming PDUs.

write. The process of an *access unit (AU)* sending data downstream on a bus by logically ORing its outgoing data with the data pattern (normally all zeros) arriving from *upstream* on that bus.

1.4 Acronyms

ACF	Access Control Field
ANSI	American National Standards Institute
AU	Access Unit
BAsize	Buffer Allocation size
BCD	Binary Coded Decimal
BEtag	Beginning-End tag
BIF	Bus Identification Field
BOM	Beginning Of Message
BWBM	BandWidth Balancing Machine
BWB_CNTR	BandWidth Balancing CouNTeR
BWB_MOD	BandWidth Balancing MODulus
CC	Configuration Control (function)
CC_1	Configuration Control type 1 function
CC_2	Configuration Control type 2 function
CC_D	Default Configuration Control function
CCITT	the International Telegraph and Telephone Consultative Committee
CD	CountDown (counter)
CE	Connection Endpoint
CIB	CRC32 Indicator Bit
COCF	Connection-Oriented Convergence Function
COM	Continuation Of Message
CMIP	Common Management Information Protocol
CMIS	Common Management Information Service
CRC	Cyclic Redundancy Check
CRC32	32-bit Cyclic Redundancy Check
DA	Destination Address
DMPDU	Derived MAC Protocol Data Unit
DQDB	Distributed Queue Dual Bus
DQSM	Distributed Queue State Machine
DSG	Default Slot Generator
DSGS	Default Slot Generator Subfield
EOM	End Of Message
ETS	External Timing Source
ETSS	External Timing Source Subfield
GPSM	Get Page State Machine

HCS	(segment) Header Check Sequence
HEL	Header Extension Length
HOB	Head Of Bus
HOBS	Head Of Bus Subfield
HOB_A	Head Of Bus A
HOB_B	Head Of Bus B
ICF	Isochronous Convergence Function
IMPDU	Initial MAC Protocol Data Unit
ISDN	Integrated Services Digital Network
ISDU	Isochronous Service Data Unit
ISO	International Organization for Standardization
ISU	Isochronous Service User
KPSM	Keep Page State Machine
LAN	Local Area Network
LLC	Logical Link Control
LME	Layer Management Entity
LMI	Layer Management Interface
LSS	Link Status Signal
MAC	Medium Access Control
MAN	Metropolitan Area Network
Mb/s	Megabits per second
MCF	MAC Convergence Function
MCP	MAC Convergence Protocol
MID	Message IDentifier
MPA	MID Page Allocation
MPAF	MID Page Allocation Field
MSAP	MAC Service Access Point
MSDU	MAC Service Data Unit
NMP	Network Management Process
OSI	Open Systems Interconnection
PA	Pre-Arbitrated
PCC	Page Counter Control (subfield)
PCI	Protocol Control Information
PCM	Page Counter Modulus (Subfield)
PCSM	Page Counter State Machine
PDU	Protocol Data Unit
Ph-SAP	Physical layer Service Access Point
PI	Protocol Identification
PL	PAD Length
PLCP	Physical Layer Convergence Procedure
PLCSM	Physical Layer Connection State Machine
POI	Path Overhead Identifier (octets)
PR	Page Reservation (subfield)
PSR	Previous Segment Received
QA	Queued Arbitrated
QOS	Quality Of Service

REQ	REQuest
RIT	Reassembly IMPDU Timer
RQ	ReQuest (counter)
RQM	REQ Queue Machine
RSM	Reassembly State Machine
SA	Source Address
SAP	Service Access Point
SDH	Synchronous Digital Hierarchy
SDU	Service Data Unit
SG_1	Slot Generator type 1 function
SG_2	Slot Generator type 2 function
SG_D	Default Slot Generator function
SNCF	SubNetwork Configuration Field
SSM	Single Segment Message
VCI	Virtual Channel Identifier

1.5 References. The following publications shall be used in conjunction with this standard:

- [1] ANSI T1.102-1987, American National Standard for Telecommunication—Digital Hierarchy—Electrical Interfaces.⁴
- [2] ANSI T1.107-1988, American National Standard for Telecommunications—Digital Hierarchy—Format Specifications.
- [3] CCITT Recommendation E.164, Numbering plan for the ISDN era. In Vol. II, Fascicle II.2 of the *CCITT Blue Books*—Telephone network and ISDN—Operation, numbering, routing and mobile service. Geneva: International Telecommunications Union, 1988.⁵
- [4] CCITT Recommendation G.703, Physical/Electrical characteristics of hierarchical digital interfaces. In Vol. III, Fascicle III.4 of the *CCITT Blue Books*—General aspects of digital transmission systems; terminal equipments. Geneva: International Telecommunications Union, 1988.
- [5] CCITT Recommendation G.707, Synchronous digital hierarchy bit rates. In Vol. III, Fascicle III.4 of the *CCITT Blue Books*—General aspects of digital transmission systems; terminal equipments. Geneva: International Telecommunications Union, 1988.
- [6] CCITT Recommendation G.708, Network node interface for the synchronous digital hierarchy. In Vol. III, Fascicle III.4 of the *CCITT Blue Books*—General aspects of digital transmission systems; terminal equipments. Geneva: International Telecommunications Union, 1988.

⁴ ANSI publications are available from the American National Standards Institute, Sales Department, 1430 Broadway, New York, NY 10018, USA.

⁵ CCITT publications are available from the CCITT General Secretariat, International Telecommunications Union, Sales Section, Place des Nations, CH-1211, Genève 20, Switzerland/Suisse.

- [7] CCITT Recommendation G.709, Synchronous multiplexing structure. In Vol. III, Fascicle III.4 of the *CCITT Blue Books*—General aspects of digital transmission systems; terminal equipments. Geneva: International Telecommunications Union, 1988.
- [8] IEEE Std 802-1990, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.⁶
- [9] P802.1B/D18, LAN/MAN Management (May 1991).⁷
- [10] P802.1F/D7, Recommended Practices for the Development of IEEE 802 LAN/MAN Management Standards (May 1991).
- [11] ISO DIS 2382-25, Information technology—Vocabulary—Part 25: Local area networks.⁸
- [12] ISO CD 2382-26, Information technology—Vocabulary—Part 26: Open systems interconnection architecture.
- [13] ISO 7498:1984, Information processing systems—Open Systems Interconnection—Basic Reference Model.
- [14] ISO/TR 8509:1987, Information processing systems—Open Systems Interconnection—Service conventions.
- [15] ISO 8802-2:1989 [ANSI/IEEE Std 802.2-1989], Information processing systems—Local area networks—Part 2: Logical link control.
- [16] ISO/IEC 9595:1990, Information processing systems—Open Systems Interconnection—Common management information service definition.
- [17] ISO/IEC 9596:1990, Information processing systems—Open Systems Interconnection—Common management information protocol specification.
- [18] Hammond, J.L., J.E. Brown, and S.S. Liu. Development of a Transmission Error Model and Error Control Model. Technical Report RADC-TR-75-138. Rome: Air Development Center, 1975.

1.6 Conformance. An implementation may be called conformant with this standard if all mandatory functions in this standard are implemented according to the respective mandatory specification.

Additional optional features need not be implemented. However, if they are implemented, they should conform with the specification in this standard, if applicable.

⁶ IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, (800) 678-4333.

⁷ The IEEE 802 Committee's authorized standards projects are available from IEEE Computer Society Documents, c/o AlphaGraphics, ATTN: P. Thrush, 10215 N. 345th Ave., Suite A & B, Phoenix, AZ 85051, (602) 863-0999, FAX (602) 866-8801.

⁸ ISO and ISO/IEC documents are available from ISO Central Secretariat, 1 rue de Varembe, Case Postale 56, CH-1211, Genève 20, Switzerland/Suisse; and from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, USA.

By way of example, support for 48-bit universally administered MAC Service Access Point (MSAP) addresses is mandatory. However, if 60-bit MSAP addresses are implemented to carry numbers allocated according to CCITT Recommendation E.164 [3], the coding shall be as specified in this standard.

1.7 Notation

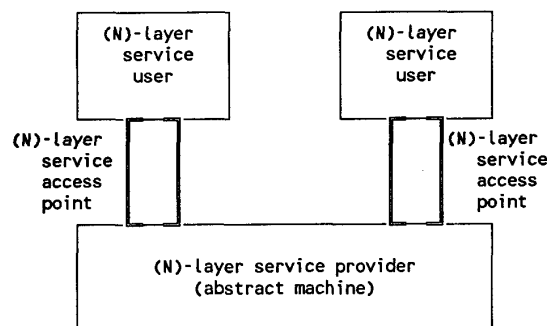
1.7.1 Service Specification Method and Notation. This section covers the method of specification for the services required of the DQDB Layer by the LLC Sublayer, by the ISUs, and by the Connection-Oriented Data Service Users. It also covers the method of specification for the services required of the Physical Layer by the DQDB Layer.

In general, the services of an (N)-layer (or sublayer) are the capabilities that it offers to an (N)-user in the next higher layer (or sublayer). In order to provide its service, a layer (or sublayer) builds its functions on the services it requires from the next lower layer (or sublayer). Figure 1-2 illustrates the layer service model.

Services are specified by describing the information flow between the (N)-user and the (N)-layer (or Sublayer). This information flow is modeled by discrete, instantaneous events, which characterize the provision of a service. Each event consists of passing a service primitive from one layer (or Sublayer) to the other through the (N)-layer (or sublayer) service access point (SAP) associated with an (N)-user. Service primitives convey the information required in providing a particular service. These service primitives are an abstraction in that they specify only the service provided rather than the means by which the service is provided. This definition of service is independent of any particular interface implementation.

Services are specified by describing the service primitives and parameters that characterize each service. A service may have one or more related primitives that constitute the activity that is related to the particular service. Each

Fig 1-2
Layer Service Model

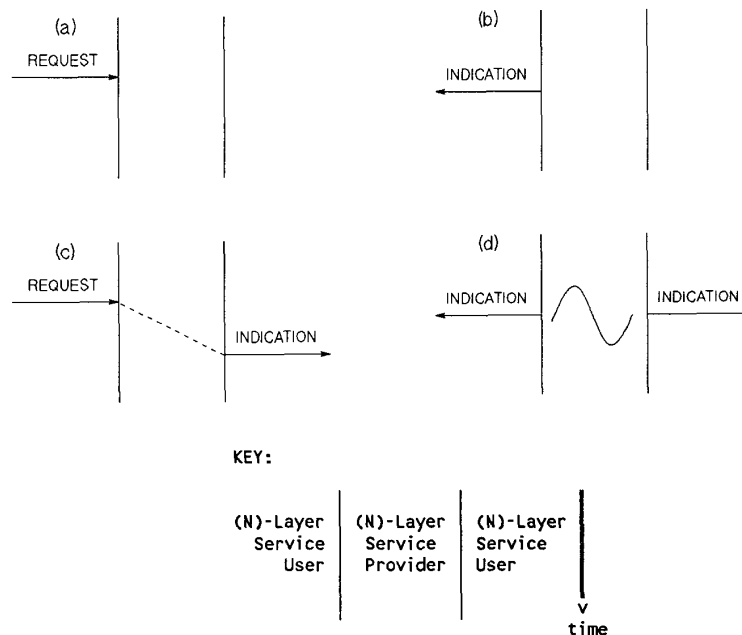


service primitive may have zero or more parameters that convey the information required to provide the service.

Primitives are of four generic types:

- REQUEST** The request primitive is passed from the (N)-user to the (N)-layer (or sublayer) to request that a service be initiated.
- INDICATION** The indication primitive is passed from the (N)-layer (or sublayer) to the (N)-user to indicate an internal (N)-layer (or sublayer) event that is significant to the (N)-user. This event may be logically related to a remote service request, or may be caused by an event internal to the (N)-layer (or sublayer).
- RESPONSE** The response primitive is passed from the (N)-user to the (N)-layer (or sublayer) to complete a procedure previously invoked by an indication primitive.
- CONFIRM** The confirm primitive is passed from the (N)-layer (or sublayer) to the (N)-user to convey the results of one or more associated previous service request(s).

Fig 1-3
Time Sequence Diagram



This standard only requires the use of request and indication primitives. Possible relationships among primitive types are illustrated by the time sequence diagrams shown in Fig 1-3. The figure also indicates the time relationship of the primitive types. The key of Fig 1-3 depicts the time sequence framework used to illustrate the interactions between the two correspondent service users and their associated service provider. Primitive types occurring earlier in time and connected by dotted lines are the logical antecedents of subsequent primitive types. If there is no specific relationship between events, in that it is impossible to predict which will occur first, but both must occur within a finite period of time, then a tilde (~) is used.

This standard uses the conventions for naming service primitives contained in Annex A of ISO/TR 8509 [14].

1.7.2 State Machine Notation. The operation of a protocol can be described by subdividing the protocol into a number of interrelated functions. The operation of a function can be described by state machines. Each machine represents the domain of a function and consists of a group of connected, mutually exclusive states. Only one state of a function is active at any given time.

Each state that the function can assume is represented by a vertical line. All permissible transitions between states of a function are represented by arrows from one state to the next state. The condition that causes a change from one state to another is shown above the transition arrow. The affected signals and flags are shown below the transition arrow.

Signals and flags refer to the form by which one functional block communicates with another. Both terms arise from the use of the state machines as a descriptive method in this standard. Signals are transient communications (in theory, they are of infinitesimal time width) that occur during a change of state. Flags are steady, nontransient indications that remain constant until explicitly changed.

1.8 Organization of the Standard. Section 2 contains an overview of the operation of a DQDB subnetwork and the communication services supported. It also provides an introduction to the functional architecture of a DQDB node.

Section 3 contains the service definition for the DQDB Layer, which gives a formal definition for the MAC Sublayer service offered to LLC and for the isochronous service, and a statement on the requirements for the connection-oriented data service.

Section 4 contains the definition of the Physical Layer service to the DQDB Layer.

Section 5 gives a rigorous description of the internal operation of a DQDB node, with forward references to Sections 6, 7, 8, 9, and 10. Section 6 describes the DQDB Layer PDU formats (with the exception of the management information octets, which are described in Section 10). Section 7 describes the facilities required for operation of the DQDB Layer, such as timers, counters, parameters, and status indicators. Section 8 specifies the state machines that describe peer-to-peer communication by DQDB Layer entities.

DQDB Layer Management is described in Sections 9 and 10. Section 9 describes the services offered at the DQDB LMI to the NMP. This interface can support remote management of a DQDB node using management protocols such as those specified in P802.1B [9] and in ISO 9595 (CMIS) [16] and ISO 9596 (CMIP) [17]. Section 10 describes the operation of the DQDB Layer Management Protocol, which is the mechanism by which DQDB Layer Management Entities communicate to perform layer-wide management of DQDB Layer resources.

Section 11 describes the principles of operation of the Physical Layer. Section 12 describes the operation of the Physical Layer Convergence Procedure (PLCP) required to support a DS3 rate (as specified in ANSI T1.102 [1] and T1.107 [2]). Subsequent sections will describe the operation of the PLCPs required to support transmission systems, including CCITT Recommendation G.703 [4] (Section 13) and CCITT Recommendations G.707 [5], G.708 [6], G.709 [7] SDH (Section 14).

2. Overview

This section is intended as an introduction to the DQDB access mechanism and is not intended as a rigorous definition of the protocol. The first part of this section, 2.1, provides an overview of the operation of a DQDB subnetwork. The second part, 2.2, provides a focused view describing the functional architecture of a DQDB node. Rigorous descriptions of the node functional operation, and of the DQDB Layer protocols, are given in Section 5, and Sections 8 and 10, respectively.

2.1 DQDB Subnetwork. The purpose of a MAN is to provide integrated services, such as data, voice, and video, over a large geographical area. This standard describes the DQDB subnetwork that can be used as a component part of a MAN. Typically, a MAN would consist of interconnected DQDB subnetworks. The interconnection of subnetworks could be via bridges, routers, or gateways, but this is not covered in this document. MANs can be interconnected by suitable means to form a wide area network.

The DQDB subnetwork is a distributed multi-access network that supports integrated communications. In particular, the DQDB subnetwork supports connectionless data transfer, connection-oriented data transfer, and isochronous communications (e.g., voice). The various communication transfer functions share flexibly the total capacity of the subnetwork.

In the first part of this section, 2.1.1, there is a description of the Dual Bus architecture and the format by which nodes communicate. The second part of the section, 2.1.2, describes the control of access to the dual bus. This includes Distributed Queue access control for non-isochronous communications and Pre-Arbitrated access control for isochronous communications.

The third part of this section, 2.1.3, describes the functions specified in addition to the access control mechanism to support the DQDB Layer services. For example, it describes how LLC is supported by the DQDB subnetwork.

The fourth part of this section, 2.1.4, provides guidance to network administrators in the application of the standard.

The final part of this section, 2.1.5, describes the Configuration Control Function, which is important in subnetwork start-up and in subnetwork reconfiguration in the case of bus faults.

2.1.1 Dual Bus Architecture. The Dual Bus architecture of a DQDB subnetwork consists of two unidirectional buses and a multiplicity of nodes along the buses, as shown in Fig 2-1. The buses, denoted Bus A and Bus B, support com-

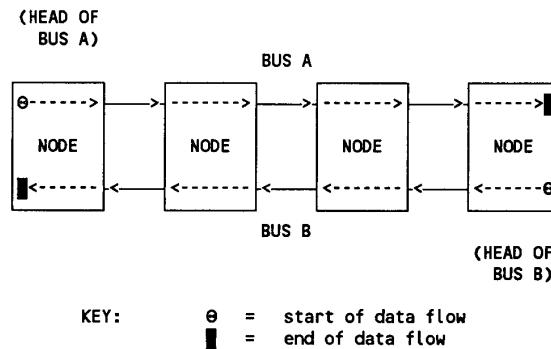


Fig 2-1
Dual Bus Architecture

munications in opposite directions allowing full duplex communications between any pair of nodes on the subnetwork. Therefore, it is desirable for a node to know which bus to use to communicate to another node. Appendix B provides information as to how this can be done for connectionless services.

As both buses are operational at all times, the capacity of the subnetwork is up to twice the capacity of a single bus. The operation of the two buses in the transfer of data is independent.

The data on each bus are formatted into either DQDB Layer Management information octets or fixed-length slots, this format being generated by the node at the head of each bus. Hence, there must be one node at the head of Bus A and one node at the head of Bus B. The management information octets are used to maintain the operational integrity of the subnetwork. The slots are used to carry data between the nodes. That is, nodes may write into slots under the control of the access protocol. All data flow terminates at the end of the bus.

The nodes on the subnetwork consist of an access unit and the attachment of the access unit to the two buses. The access unit performs the node's DQDB Layer Functions and attaches to a bus via one read and one write connection. The writing of data to the bus is a logical OR of the data from upstream with the data from the access unit. The read connection is placed logically ahead of the write connection and allows all data to be copied from the bus unaffected by the unit's own writing.

The read and write functions can be implemented using either passive or active techniques.⁹ An example implementation of the AU connection is shown in Fig 2-2. With this connection arrangement, an AU can copy data that passes on the bus, but can never remove it, and only alter data when it is permitted by the access protocol.

⁹ A passive optical implementation would limit the number of nodes on the bus according to the optical power budget.

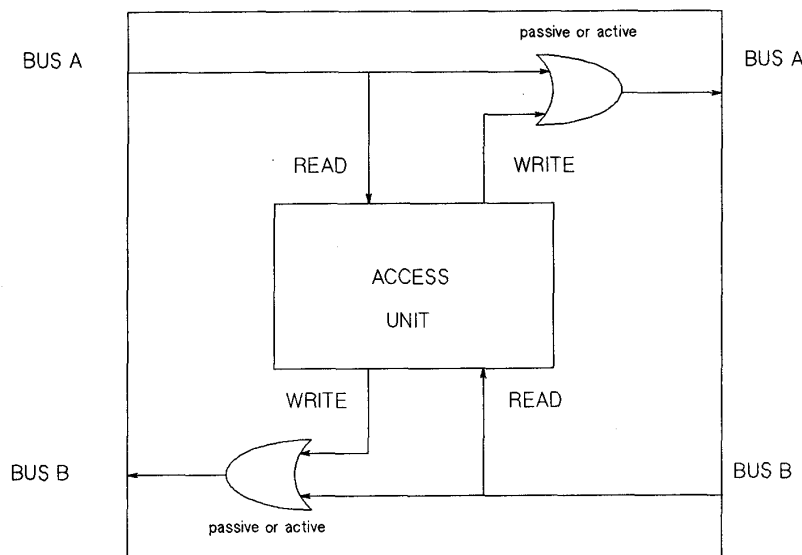


Fig 2-2
Example Access Unit Attachment

With the exception of AUs performing the head of bus functions, the operation of the bus is only loosely coupled to the operation of each AU; an AU can fail (provided that it does not destructively write to the bus), or even be removed from the subnetwork, with no consequence on the operation of the rest of the subnetwork.

Under normal conditions there is a single source of slot timing for the subnetwork, which is used to ensure that all nodes in the subnetwork transfer data (i.e., slots and management information octets) at the same average rate. This is necessary to ensure stable operation of the Distributed Queue access mechanism (see Appendix C) and to ensure that isochronous communications can be supported without slips being introduced by different timing sources at the two communicating entities.

The timing source can be traceable to an external timing source, such as that provided by a public telecommunications network. Any node or nodes can be designated by network operations procedures to provide the External Timing Source Function. If the subnetwork is supporting certain isochronous services and is connected to a public network, then the external timing source may be required. However, in the absence of an external timing source, one node with the capability specified below will be selected by subnetwork configuration control procedures to be the source of subnetwork timing. In this case,

the selected node must have available and operate a local clock that has a nominal period of 125 μ s.

2.1.2 Access Control to the Dual Bus Subnetwork. The DQDB Layer protocols and protocol data units allow a DQDB subnetwork to be operated at a variety of speed and distance combinations. This permits a wide range of transmission systems to be used in the underlying Physical Layer.

The DQDB Layer provides two modes of access control to the dual bus. These are Queued Arbitrated (QA) and Pre-Arbitrated (PA), which use QA and PA slots for access respectively. Each slot contains an ACF and a segment, which forms the payload of the slot.

Queued Arbitrated access is controlled by the Distributed Queueing protocol and would be used typically to provide non-isochronous services. Pre-Arbitrated access would be used typically to provide isochronous services. The Distributed Queue and Pre-Arbitrated access protocols are described below.

2.1.2.1 The Distributed Queue Access Protocol. Distributed Queueing is a media access protocol that controls the access to the payload of QA slots on the DQDB bus. The fixed-length payload of a QA slot is called a QA segment.

The protocol provides deterministic access control for services that are typically bursty in nature. In particular, the protocol can enable all of the payload bandwidth to be used and the average slot access delay approximates that of a perfect scheduler up to high levels of subnetwork loading.

The operation of the protocol is based on two control fields: the BUSY bit, which indicates whether or not a slot is used, and the REQUEST Field, which is used to indicate when a segment has been queued for access. Each node, by counting the number of requests it receives and unused slots that pass, can determine the number of segments queued (i.e., in line) ahead of it. This counting operation establishes a single queue across the subnetwork of segments queued for access to each bus.

With such queued access, levels of priority can be established by operating a number of queues, one for each level. Within each level the performance characteristics described above are maintained. Segments will gain access as soon as capacity becomes available, but priority is always given to segments in higher level queues. This standard specifies three levels of priority.

The operation of Distributed Queueing is fundamentally different from other MAC protocols. In Distributed Queueing, information that explicitly indicates the queueing state of the subnetwork is kept in the nodes. Hence, when a node has data to transmit, the node need not first derive information from the subnetwork to tell it when it can gain access.

With Distributed Queueing, a current state record that holds the number of segments awaiting access to the bus is kept in every node. When a node has a segment for transmission, it uses this count to determine its position in the distributed queue. If no segments are waiting, permission for access is immediate, otherwise deference is given only to those segments already queued.

To facilitate effective sharing of the bandwidth, the Distributed Queue protocol includes a bandwidth balancing mechanism to occasionally skip the use of empty QA slots.

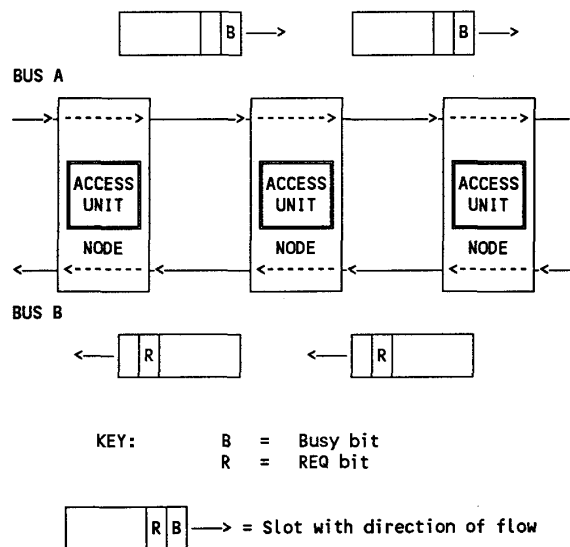
2.1.2.1.1 The Basic Distributed Queueing Algorithm. The operation of the basic Distributed Queueing algorithm for access to Bus A is illustrated in Fig 2-3. In this case, Bus A is the forward bus and Bus B is the reverse bus. An identical, but independent, arrangement applies for access to the opposite bus, Bus B.

Each slot on the buses (whether a QA or PA slot) contains an ACF that includes a BUSY bit and a REQUEST Field of three Request bits (henceforth referred to as REQ bits), one for each priority level. The BUSY bit indicates whether or not the slot is used. The REQ bits are to signal when a QA segment has been queued on the reverse bus.

The operation of the Distributed Queueing algorithm within a single priority level is described first. The description of the multiple priority scheme follows, as does a description of the bandwidth balancing mechanism.

When an AU has a QA segment for transmission on the forward bus it will cause a single REQ to be sent on the reverse bus. This REQ will eventually be written into the next free REQ bit of the required priority on the reverse bus. The bit once written will pass to all upstream AUs, where upstream is defined in relation to data flow on the forward bus, in this case Bus A. This REQ bit serves as an indicator to the upstream AUs that an additional QA segment is now queued for access. For each AU, the Distributed Queueing algorithm al-

Fig 2-3
Queue Formation on Bus A



lows, at most, one QA segment per priority level, to be queued for access to each bus.

Each AU keeps track of the number of QA segments queued downstream from itself for access to the forward bus by counting the REQ bits as they pass on the reverse bus, as shown in Fig 2-4(a). The request (RQ) counter is incremented for each REQ passing on the reverse bus. For a node that is not queued to send, one REQ in the RQ counter is cancelled each time an empty slot passes on the forward bus. This is done since the empty slot that passes the AU will be used by one of the downstream queued QA segments. Hence, with these two actions, the RQ counter keeps a record of the number of segments queued downstream.

In addition to issuing the REQ for the reverse bus, an AU with a QA segment to send will transfer the current value of the RQ counter to another counter, the countdown (CD) counter, as shown in Fig 2-4(b), with the RQ counter then being reset to zero. This action loads the CD counter with the number of downstream segments queued ahead of it. This, along with the issuing of the REQ for the AU's segment, effectively places the QA segment in the distributed queue. The distributed queue at a given level of priority approximates a first-in-first-out (FIFO) queue of the QA segments at the heads of the local queues in each node.

To ensure that the segments registered in the CD counter gain access before the newly queued segment in the given AU, the CD counter is decremented for every empty slot that passes on the forward bus. This operation is shown in Fig 2-4(b). The given AU can transmit its QA segment in an empty slot provided the CD count is zero. For this single priority description, this is equivalent to claiming the first free slot after the CD count reaches zero, which ensures that no downstream segment that queued after the given segment can access out of order.

During the time that the AU is waiting for access for its segment, any new REQs received from the reverse bus are added to the RQ counter, as shown in Fig 2-4(b). Hence, the RQ counter still tracks the number of segments newly queued downstream and the count will be correct for the next QA segment access.

It should be noted that the control of the access of the QA segment to the forward bus is determined solely by the values of the counters. Access is not inhibited if the value of the CD counter is zero but the REQ bit associated with the QA segment has not yet been written to the reverse bus. That is, the operation of writing REQ bits and sending QA segments is independent.

Thus, with the use of two counters in each AU, one counting unsatisfied access requests and the other counting down before access, a FIFO queue is established for access to the forward bus. The queue formation is also such that, except for bandwidth balancing considerations (described later in this section), a slot is never wasted on the subnetwork if there is a segment queued for it. This is guaranteed since the CD count in AUs with segments queued represents the number of downstream segments ahead in the queue. Since at any

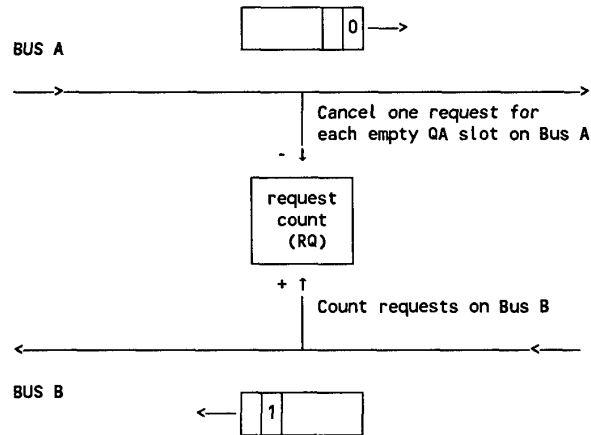


Fig 2-4 (a)
Node Not Queued to Send (Bus A)

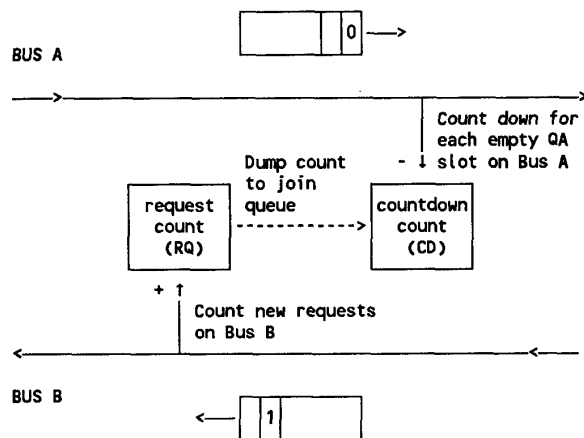


Fig 2-4 (b)
Node Queued to Send (Bus A)

point in time¹⁰ one segment must have queued first, then at least one AU is guaranteed to have a CD count of zero. It is the most upstream of these that will gain access.

As an example of the operation of Distributed Queueing, consider Fig 2-5, which shows a subnetwork consisting of five AUs, three of which will queue for access. Assume that each request counter, the value of which is indicated by RQ at the AU, and each CD counter, the value of which is indicated by CD at the AU, are all initially zero and that all slots passing on Bus A are used. AUs 5, 2, and 3 queue in that order, using the operations described above. The counters in the final state can be interpreted as follows:

- AU 1: There are three AUs downstream on Bus A that have QA segments queued for access.
- AU 2: There is one downstream AU with a QA segment queued for access before AU 2, as represented by the one in the CD counter. There is also one downstream AU with a QA segment queued for access after AU 2, as represented by the one in the RQ counter.
- AU 3: There is one downstream AU with a QA segment queued for access before AU 3, as represented by the one in the CD counter, and no downstream AU with a QA segment queued after AU 3, as represented by the zero in the RQ counter. (Note that the REQ from AU 2 is not registered at AU 3.)
- AU 4: There is one downstream AU with a QA segment queued for access.
- AU 5: There are no downstream AUs from AU 5; hence, both the RQ and CD counts are zero.

Now consider Fig 2-6, which shows the AUs gaining access. Assume no further requests are received on the reverse bus and that empty QA slots pass on bus A. The AUs then gain access in the order 5, 2, then 3, which is the order of queueing. Note that after AU 5 gains access both AU 2 and AU 3 have a CD count of zero. AU 2 will gain access first as it is the most upstream.

2.1.2.1.2 Priority Distributed Queueing. The Distributed Queueing protocol supports the assignment of priority to QA segment access. However, all connectionless data segments must be sent at the lowest priority, priority level 0 (see 7.3.3). Future use of priorities for other services is under study. For upward compatibility, Distributed Queues for each level of priority are required in this standard.

The operation of separate distributed queues for each level of priority is achieved by using a separate REQ bit on the reverse bus for each level of priority and separate RQ and CD counters for each priority level. The counters operate similarly to the single priority case, except that account must be taken of REQs at higher levels.

¹⁰ More correctly, at the same point in time normalized for propagation delay of the slot along the bus.

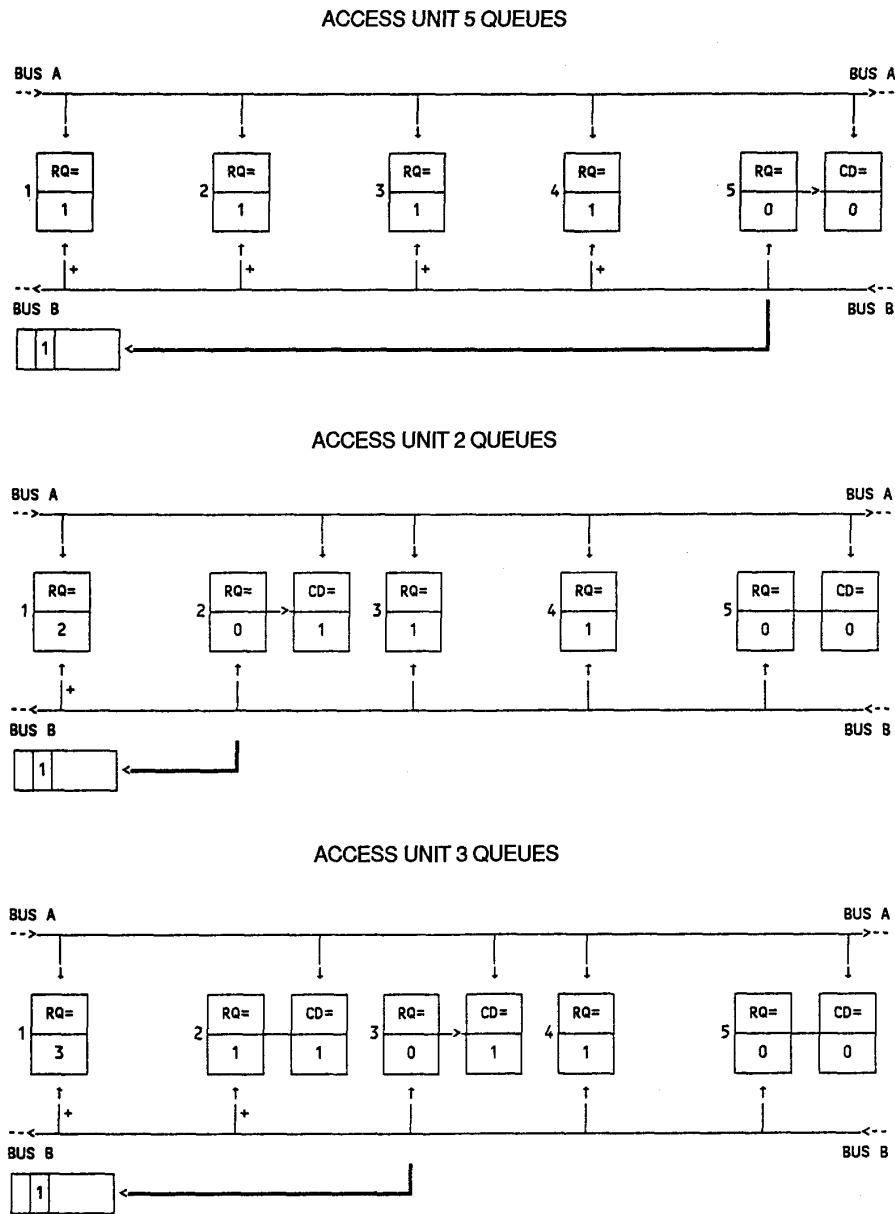


Fig 2-5
Queueing for Access (Bus A)

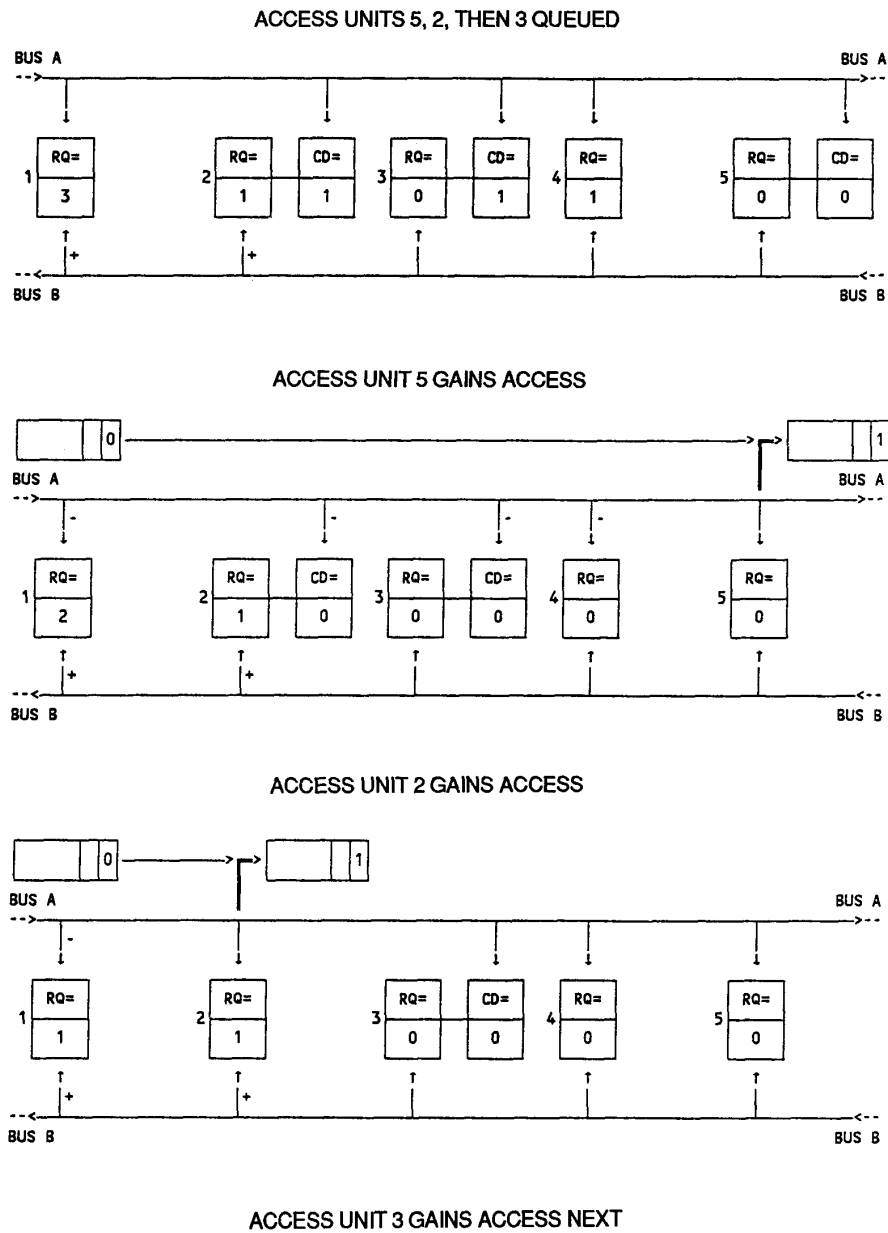


Fig 2-6
Gaining Access (Bus A)

That is, for an AU that does not have a QA segment queued at a particular priority level, the RQ counter operating at that level will count REQs at the same *and higher* priority levels. Thus, the RQ counter records all queued segments at equal and higher priorities.

If the AU does have a QA segment queued at a particular priority level, then the RQ counter operating at that level will only count REQs at the same priority level. However, the operation of the CD counter at that priority level is slightly altered. The CD counter will, in addition to counting down the received empty slots, increment for REQs received at higher priority levels. This allows the higher priority segments to claim access ahead of already queued segments.

It should be noted that decrementing of the RQ counters and CD counters at all priority levels occurs when an empty QA slot is received at the function within the node operating the Distributed Queue, not when it is sent by this function. This ensures that the correct counter values are maintained if the highest priority segment queued by the AU gains access to the empty slot and the AU marks the slot as busy.

The intent of the priority scheme is for the access performance of the highest priority traffic to be unaffected by lower priority traffic. Such a feature is very important in network signaling. However, it should be noted that priority should not be relied upon for all subnetwork distance, speed, and loading conditions. (See 2.1.4.)

This standard specifies three levels of access priority. The definition of how these levels are used is a matter for the operator of the particular DQDB subnetwork, although it is likely that the highest level would be used for network management and signaling. The DQDB Layer assumes that the user of the QA access requests the appropriate priority level for a particular segment transfer.

2.1.2.1.3 Bandwidth Balancing. To facilitate effective sharing of the bandwidth, the Distributed Queue access protocol includes a bandwidth balancing mechanism to occasionally skip the use of empty QA slots. To support this function, the Distributed Queueing Function in the node operates a bandwidth balancing counter for each bus. There is also a system parameter called the Bandwidth Balancing Modulus, denoted BWB_MOD. If BWB_MOD is set to zero, the bandwidth balancing mechanism is disabled. If BWB_MOD is set to a value greater than zero, it indicates when the value of the bandwidth balancing counter should roll over to zero, as explained below.

Whenever the node transmits a QA segment on one of the buses, the bandwidth balancing counter for that bus is incremented by one, provided that the counter does not have a value of (BWB_MOD - 1). If the counter does have a value of (BWB_MOD - 1) when the QA segment is transmitted, the bandwidth balancing counter is reset to zero instead.

When the bandwidth balancing counter for a bus is reset to zero, this is an indication that the node should skip the use of one empty QA slot on that bus. To make that happen, the Distributed Queueing Function increments the request counters for that bus for all priority levels for which no QA segment is queued,

and increments the countdown counters for that bus for all priority levels for which a QA segment is queued.

NOTES: (1) Resetting the bandwidth balancing counter for a bus has no effect on the queue of requests waiting to be sent on the opposite bus.

(2) If the value of BWB_MOD is one, the bandwidth balancing counter always has the value zero. This means that every time the node transmits a QA segment on the bus, the request or countdown counter corresponding to each priority level for that bus is incremented, as described above.

2.1.2.2 Pre-Arbitrated Access Control. Pre-Arbitrated (PA) slot access will be used typically to provide for transfer of isochronous service octets. The access to PA slots and the use of PA segment payloads differ from that for QA access. The access differs in that PA slots are designated by the node at the head of bus and that more than one AU may share access to the slot. A PA segment payload consists of a number of octets, each of which can be used by a different AU. Therefore, an AU may write zero, one or more isochronous service octets into designated positions of a PA segment payload. The AU is notified of the offsets of these octet positions relative to the start of the PA segment payload via the DQDB Layer Management procedures.

The designation of slots to PA access and the marking of the PA slot and PA segment header is controlled by functions in the node at the head of the bus. In particular, the head of bus function must write the Virtual Channel Identifier (VCI) Field into PA slots. The head of bus function must also ensure that the PA slots for each VCI value are provided in a periodic manner on the bus to guarantee that sufficient bandwidth is available for the Isochronous Service Users (ISUs).

The access to the PA slots by an AU commences by examining the VCI. For each VCI value that the AU must access, the AU will have a table that indicates which octet offsets within the slot the AU should use for reading and writing. The AU will write isochronous service octets into those write positions and will read from positions the table has marked for reading. The PA slot is ignored if the VCI is not one in use by the AU.

2.1.3 Provision of DQDB Layer Services. The Queued Arbitrated and Pre-Arbitrated Functions of the DQDB Layer provide access control to the dual buses. These access control functions are used by a range of convergence functions to create the DQDB Layer services shown in Fig 2-7 and defined formally in Section 3. This standard specifies the convergence function for the provision of the IEEE 802 MAC Sublayer service to the LLC Sublayer (ISO 8802-2 [15]). Also specified is a general isochronous service. Future services, such as a connection-oriented data service, are the subject of further study.

At no time do two convergence functions simultaneously use the same VCI at a given node. Hence, if a node is to receive a particular segment, the VCI can be used to direct the segment to the appropriate convergence function at the node. An overview of the convergence functions specified in this standard is given below.

2.1.3.1 Provision of MAC Service to LLC. The provision of MAC service to LLC consists of the segmentation of the MAC Service Data Unit (MSDU) at the