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**International Standard ISO/IEC 10038 : 1993
ANSI/IEEE Std 802.1D, 1993 edition**

(This edition contains ANSI/IEEE Std 802.1D-1990,
ANSI/IEEE Std 802.1i-1992, and IEEE Std 802.5m-1993)

**Information technology—
Telecommunications and information exchange
between systems—Local area networks—
Media access control (MAC) bridges**

Sponsor

**Technical Committee on Computer Communications
of the
IEEE Computer Society**

Abstract: An architecture for the interconnection of IEEE 802 Local Area Networks (LANs) below the level of the MAC Service, which is transparent to logical link control (LLC) and higher layer protocols, is defined. Transparent Bridging between Fibre Distributed Data Interface (FDDI) LANs and between FDDI LANs and IEEE 802 LANs is included. The operation and management of the connecting Bridges is specified. A Spanning Tree Algorithm and Protocol ensures a loop-free topology and provides redundancy. The Bridging method is not particular to any MAC Type; criteria for additional MAC-specific Bridging methods are defined. Source-Routing Transparent (SRT) Bridges are defined in an annex, and the protocols for the operation of source routing in an SRT Bridge are specified.

Keywords: data processing, information interchange, local area networks, metropolitan area networks, fibre distributed data interface (FDDI), mode of data transmission, network interconnection, models, source routing, Source-Routing Transparent (SRT) Bridge

**Adopted as an International Standard by the
International Organization for Standardization
and by the
International Electrotechnical Commission**

**Published by
The Institute of Electrical and Electronics Engineers, Inc.**

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017-2394, USA

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Printed in the United States of America

ISBN 1-55937-325-3

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July 8, 1993

SH16345

International Standard ISO/IEC 10038 : 1993

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In 1992, ANSI/IEEE Std 802.1D-1990 was adopted by ISO/IEC JTC 1, as draft International Standard ISO/IEC/DIS 10038. A further revision was subsequently approved by ISO/IEC JTC 1 in the form of this new edition, which is published as International Standard ISO/IEC 10038 : 1993.

Foreword to International Standard ISO/IEC 10038 : 1993

This standard is part of a family of standards for Local and Metropolitan Area Networks. 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:

- (1) ISO/IEC 8802-3 [ANSI/IEEE Std 802.3, 1992 Edition], a bus utilizing CSMA/CD as the access method,
- (2) ISO/IEC 8802-4 [ANSI/IEEE Std 802.4-1990], a bus utilizing token passing as the access method,
- (3) ISO/IEC 8802-5 [ANSI/IEEE Std 802.5-1992], a ring utilizing token passing as the access method,
- (4) ISO 8802-7, a ring utilizing slotted ring as the access method.

ISO 8802-2 [ANSI/IEEE Std 802.2-1989], *Logical Link Control protocol*, is used in conjunction with the medium access standards.

ISO/IEC 10038 [ANSI/IEEE Std 802.1D, 1993 Edition], *Media access control (MAC) bridges*, specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.

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

The main body of this standard serves for both the ISO/IEC 10038 and the IEEE Std 802.1D standards. ISO and IEEE each have unique foreword sections. The Annexes contain normative and informative material to both standards.

ANSI/IEEE Std 802.1D, 1993 Edition

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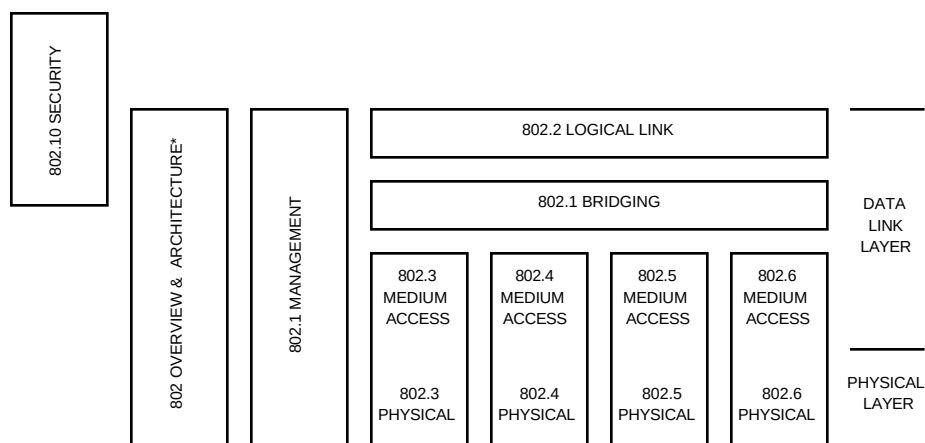
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Foreword to ANSI/IEEE 802.1D, 1993 Edition

(This edition contains ANSI/IEEE Std 802.1D-1990,
ANSI/IEEE Std 802.1i-1992, and IEEE Std 802.5m-1993)

(This Foreword is not a part of this International Standard or of ANSI/IEEE 802.1D, 1993 Edition.)

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 International Organization for Standardization (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. This document forms part of the 802.1 scope of work.
- IEEE Std 802.1B: LAN/MAN Management. Defines an Open Systems Interconnection (OSI) management-compatible architecture, and services and protocol elements for use in a LAN/MAN environment for performing remote management.
- ISO/IEC 10038 : 1993 [ANSI/IEEE Std 802.1D]: MAC Bridging. Specifies an architecture and protocol for the interconnection of IEEE 802 LANs below the MAC service boundary.
- 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
- ISO/IEC 8802-5 [ANSI/IEEE Std 802.5]: Token Ring Access Method and Physical Layer Specifications

[†] 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 802.6: Metropolitan Area Network Access Method and Physical Layer Specifications
- IEEE Std 802.10: Interoperable Local Area Network (LAN) Security, *Currently Contains Secure Data Exchange (SDE)*

In addition to the family of standards, the following is a recommended practice for a common technology:

- IEEE Std 802.7: IEEE Recommended Practice for Broadband Local Area Networks

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

Conformance Test Methodology

Another standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. This makes the correspondence between the various 802 standards and their applicable conformance test requirements readily apparent. Thus the conformance test documents for 802.3 are numbered 1802.3, the conformance test documents for 802.5 will be 1802.5, and so on. Similarly, ISO will use 18802 to number conformance test standards for 8802 standards.

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ANSI/IEEE Std 802.1D-1990 was approved by the American National Standards Institute (ANSI) on October 18, 1990.

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Information technology— Telecommunications and information exchange between systems—Local area networks— Media access control (MAC) bridges

1. Overview

IEEE 802 Local Area Networks (LANs) of all types may be connected together with media access control (MAC) Bridges. Each individual LAN has its own independent MAC. The Bridged Local Area Network created allows the interconnection of stations attached to separate LANs as if they were attached to a single LAN. A MAC Bridge operates below the MAC Service Boundary, and is transparent to protocols operating above this boundary, in the Logical Link Control (LLC) Sublayer or Network Layer (ISO 7498:1984 [9]¹). A Bridged Local Area Network may provide for the following:

- (1) The interconnection of stations attached to 802 LANs of different MAC types.
- (2) An effective increase in the physical extent, the number of permissible attachments, or the total performance of a LAN.
- (3) Partitioning of the physical LAN support for administrative or maintenance reasons.

1.1 Scope. For the purpose of compatible interconnection of data processing equipment using the IEEE 802 MAC Service supported by interconnected IEEE 802 Standard Local Area Networks using different or identical Media Access Control methods, this standard specifies a general method for the operation of MAC Bridges. To this end it

- (1) Positions the bridging function within an architectural description of the MAC Sublayer.
- (2) Defines the principles of operation of the MAC Bridge in terms of the support and preservation of the MAC Service, and the maintenance of Quality of Service.
- (3) Specifies the MAC Internal Sublayer Service provided by individual LANs to the Media Access Method Independent Functions that provide frame relay in the Bridge.
- (4) Identifies the functions to be performed by Bridges, and provides an architectural model of the internal operation of a Bridge in terms of Processes and Entities that provide those functions.
- (5) Establishes the requirements for a protocol between the Bridges in a Bridged Local Area Network to configure the network, and specifies the distributed computation of a Spanning Tree active topology.
- (6) Specifies the encoding of the Bridge Protocol Data Units (BPDUs).
- (7) Establishes the requirements for Bridge Management in the Bridged Local Area Network, identifying the managed objects and defining the management operations.
- (8) Specifies how the management operations are made available to a remote manager using the protocol and architectural description provided by IEEE Std 802.1B [3].
- (9) Specifies performance requirements and recommends default values and applicable ranges for the operational parameters of a Bridge.
- (10) Specifies the requirements to be satisfied by equipment claiming conformance to this standard.

¹The numbers in brackets correspond to those of the references listed in 1.2.

(11) Specifies criteria for the use of MAC-specific bridging methods.

This standard specifies the operation of MAC Bridges that attach directly to LANs as specified in the relevant MAC standards for the MAC technology or technologies implemented. Though not part of the IEEE 802 or ISO 8802 series LAN standards, the Fibre Distributed Data Interface (FDDI) token ring, described in the ISO 9314 series of standards, can be considered an equivalent MAC. Unless indicated otherwise, mention in this standard of 802 LANs includes FDDI.

The specification of Remote Bridges, which interconnect LANs using Wide Area Network (WAN) media for the transmission of frames between Bridges, is outside the scope of this standard.

1.2 References. This standard shall be used in conjunction with the following publications or their approved revisions. References to IEEE and ANSI standards are not a part of this International Standard.

[1] ANSI X3.159-1989, American National Standards for Information Systems—Programming Language—C.²

[2] IEEE Std 802-1990, IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture (ANSI).³

[3] IEEE Std 802.1B-1992, IEEE Standards for Local and Metropolitan Area Networks: LAN/MAN Management (ANSI).

[4] ISO 8802-2:1989 [ANSI/IEEE Std 802.2-1989], Information processing systems—Local area networks—Part 2: Logical link control.⁴

[5] ISO/IEC 8802-3:1992 [ANSI/IEEE Std 802.3, 1992 Edition], Information technology—Local area networks—Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications.

[6] ISO/IEC 8802-4:1990 [ANSI/IEEE Std 802.4-1990], Information processing systems—Local area networks—Part 4: Token-passing bus access method and physical layer specifications.

[7] ISO/IEC 8802-5:1992 [ANSI/IEEE Std 802.5-1992], Information technology—Local area networks—Part 5: Token ring access method and physical layer specifications.

[8] ISO 6937-2:1983, Information processing—Coded character sets for text communication—Part 2: Latin alphabetic and non-alphabetic graphic characters.⁵

[9] ISO 7498:1984, Information processing systems—Open Systems Interconnection—Basic Reference Model.

[10] ISO 8824:1987, Information processing systems—Open Systems Interconnection—Specification of Abstract Syntax Notation One (ASN.1).

[11] ISO 8825:1987, Information processing systems—Open Systems Interconnection—Specification of Basic Encoding Rules for Abstract Syntax Notation One (ASN.1).

²ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁴ISO [IEEE] and ISO/IEC [IEEE] documents are available from ISO Central Secretariat, 1 rue de Varembé, Case Postale 56, CH-1211, Genève 20, Switzerland/Suisse; and from the Service Center, Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.

⁵ISO and ISO/IEC documents are available from the ISO Central Secretariat, 1 rue de Varembé, 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.

[12] ISO/IEC 9595:1990, Information processing systems—Open Systems Interconnection—Common management information service definition.

[13] ISO/IEC 9596:1990, Information processing systems—Open Systems Interconnection—Common management information protocol specification.

[14] ISO 9314-2:1989, Information processing systems—Fibre Distributed Data Interface—Part 2: FDDI Token Ring Media Access Control (MAC).

[15] ISO/IEC 10039:1991, Information technology—Open Systems Interconnection—Local area networks—Medium Access Control (MAC) service definition.

1.3 Definition. The following definition is specific to this standard:

Bridged Local Area Network. A concatenation of individual Local Area Networks interconnected by MAC Bridges.

1.4 Abbreviation. The following abbreviation is specific to this standard:

BPDU. Bridge Protocol Data Unit.

1.5 Conformance. A MAC Bridge that claims conformance to this standard

- (1) Shall conform to
 - (a) The relevant MAC standards for the MAC technology or technologies implemented, i.e., ISO/IEC 8802-3 [5], ISO/IEC 8802-4 [6], ISO/IEC 8802-5 [7], or ISO 9314-2 [14] as described in 2.5, and
 - (b) ISO 8802-2:1989 [4] for the implementation of a Class I or Class II LLC, to support Type 1 operation as required by 3.2, 3.3, and 3.12.
- (2) Shall relay and filter frames as described in 3.1 and specified in 3.5, 3.6, and 3.7.
- (3) Shall either
 - (a) Filter frames with equal source and destination addresses, or
 - (b) Not filter frames with equal source and destination addresses, as specified in 3.7.
- (4) May provide the capability to control the mapping of the priority of forwarded frames as specified in 3.7.
- (5) Shall maintain the information required to make frame-filtering decisions as described in 3.1 and specified in 3.8 and 3.9.
- (6) Shall use stated values of the following parameters of the Filtering Database (3.9):
 - (a) Filtering Database Size, the maximum number of entries that can be held in the Filtering Database.
 - (b) Permanent Database Size, the maximum number of entries that can be held in the Permanent Database.
- (7) May provide the capability to read and update the Filtering and Permanent Databases as specified in 3.9.
- (8) May provide the capability to set the Ageing Time as specified in 3.9. A Bridge that provides this capability shall implement the full range of values specified in Table 3-3.
- (9) This number has been deleted.
- (10) Shall conform to the provisions for addressing specified in 3.12.
- (11) May implement the optional provisions for addressing Bridge Management as specified in 3.12.4, for associating the Bridge Address with a Bridge Port as specified in 3.12.5, and for preconfiguring group addresses in the Permanent Database as specified in 3.12.6.
- (12) Shall provide
 - (a) A means of assigning a group MAC Address to identify the Bridge Protocol Entity if 48-bit Universally Administered Addresses are not used,

- (b) A means of assigning an address unique within a Bridged Local Area Network to uniquely identify the Bridge if 16-bit Locally Administered Addresses are used, as specified in 4.5, and
 - (c) A distinct Port identifier for each Port of the Bridge, as specified in 4.5, as required by 4.2 for operation of the Spanning Tree Algorithm and Protocol.
- (13) Shall implement the Spanning Tree Algorithm and Protocol described in Section 4, as specified in 4.7.
- (14) Shall not exceed the values given in 4.10.2 for the following parameters:
- (a) Maximum bridge transit delay
 - (b) Maximum Message Age increment overestimate
 - (c) Maximum BPDU transmission delay
- (15) Shall use the value given in Table 4-3 for the following parameter:
- (a) Hold Timer
- (16) May provide the capability to assign values to the following parameters to allow configuration of the Spanning Tree active topology:
- (a) Bridge Priority
 - (b) Port Priority
 - (c) Path Cost for each Port A Bridge that provides this capability shall implement the range of values specified in 4.10.2 and Tables 4-4 and 4-5.
- (17) May provide the capability to set the values of the following parameters of the Spanning Tree Algorithm and Protocol:
- (a) Bridge Max Age
 - (b) Bridge Hello Time
 - (c) Bridge Forward Delay
- A Bridge that provides this capability shall implement the range of values specified in 4.10.2 and Table 4-3.
- (18) Shall encode transmitted BPDUs and validate received BPDUs as specified in Section 5.
- (19) May support management of the Bridge. Bridges claiming to support management shall support all the management objects and operations defined in Section 6.
- (20) May support IEEE 802.1 remote management. Bridges claiming to support IEEE 802.1 remote management shall
- (a) Conform to IEEE Std 802.1B [3].
 - (b) Support remote management by the use of the network management operations and encodings specified in Section 7.
- (21) Shall specify a Guaranteed Port Filtering Rate for each Bridge Port, a Guaranteed Bridge Relaying Rate for the Bridge, and the related time intervals T_F and T_R as specified in Section 8. Operation of the Bridge within the specified parameters shall not violate any of the other conformance provisions of this standard.

The supplier of an implementation that is claimed to conform to this standard shall complete a copy of the PICS proforma provided in Annex A and shall provide the information necessary to identify both the supplier and the implementation.

1.6 Recommendations

1.6.1 Management. Support of the managed objects and management operations specified in Section 6 is highly recommended.

1.7 MAC-specific Bridging Methods. MAC-specific bridging methods may exist. Use of a MAC-specific bridging method and the method specified in this standard on the same LAN shall

- (1) Not prevent communication between stations in a Bridged Local Area Network.
- (2) Preserve the MAC Service.
- (3) Preserve the characteristics of each bridging method within its own domain.
- (4) Provide for the ability of both bridging techniques to coexist simultaneously on a LAN without adverse interaction.

2. Support of the MAC Service

MAC Bridges interconnect the separate LANs that comprise a Bridged Local Area Network by relaying frames between the separate MACs of the bridged LANs. The position of the bridging function within the MAC Sublayer is shown in Fig 2-1.

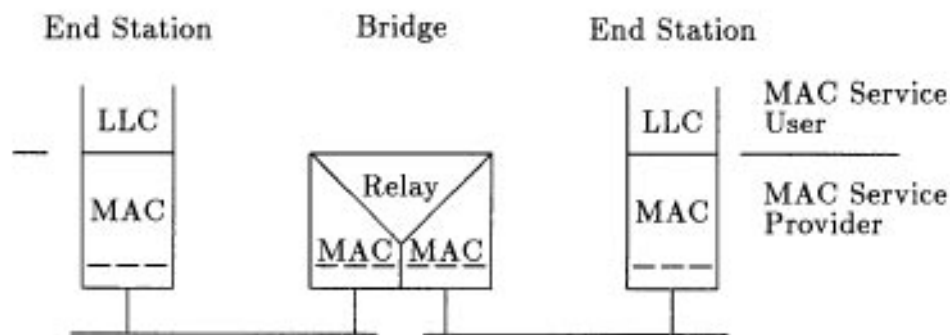


Fig 2-1
Internal Organization of the MAC Sublayer

The MAC Service is provided to the MAC Service User in the end stations and is supported by the relay function in the Bridge. This may exclude features specific to individual medium access technologies.

This section discusses provision of the MAC Service to end stations, support of the MAC Service by Bridges, preservation of the MAC Service offered by the Bridged Local Area Network, maintenance of Quality of Service in the Bridged Local Area Network, and the Internal Sublayer Service offered to Bridges themselves to enable them to connect individual LANs.

2.1 Support of the MAC Service. The MAC Service provided to end stations attached to a Bridged Local Area Network is supported by the Bridges in that Bridged Local Area Network. Bridges support MA_UNITDATA.request primitives and corresponding MA_UNITDATA.indication primitives conveying user data with unconfirmed service. The use of confirmed service by end stations communicating across a Bridge is not supported.

The style of Bridge operation maximizes the availability of the MAC Service to end stations and assists in the maintenance of the Bridged Local Area Network. It is therefore desirable that Bridges be capable of being configured in the Bridged Local Area Network:

- (1) So as to provide redundant paths between end stations to enable the Bridged Local Area Network to continue to provide the Service in the event of component failure (of Bridge or LAN).
- (2) So that the paths supported between end stations are predictable and configurable given the availability of Bridged Local Area Network components.

2.2 Preservation of the MAC Service. The MAC Service offered by a Bridged Local Area Network consisting of LANs interconnected by MAC Bridges is similar (2.3) to that offered by a single LAN. In consequence,

- (1) A Bridge is not directly addressed by communicating end stations, except as an end station for management purposes: frames transmitted between end stations carry the MAC Address of the peer-end station in their Destination Address field, not the MAC Address, if any, of the Bridge.
- (2) All MAC Addresses must be unique and addressable within the Bridged Local Area Network.
- (3) The MAC Addresses of end stations are not restricted by the topology and configuration of the Bridged Local Area Network.

2.3 Quality of Service Maintenance. The quality of the MAC Service supported by a Bridge should not be significantly inferior to that provided by a single LAN. The Quality of Service parameters to be considered are those which relate to

- (1) Service availability
- (2) Frame loss
- (3) Frame misordering
- (4) Frame duplication
- (5) The transit delay experienced by frames
- (6) Frame lifetime
- (7) The undetected frame error rate
- (8) Maximum service data unit size supported
- (9) User priority
- (10) Throughput

2.3.1 Service Availability. The MAC Sublayer provides the MAC Service to end stations attached to a LAN or a Bridged Local Area Network. Service availability is measured as that fraction of some total time during which the service is provided. The operation of a Bridge can increase or lower the service availability.

The service availability can be increased by automatic reconfiguration of the Bridged Local Area Network in order to avoid the use of a failed component (e.g., repeater, cable, or connector) in the data path. The service availability can be lowered by failure of a Bridge itself, through denial of service by the Bridge, or through frame filtering by the Bridge.

A Bridge may deny service and discard frames (2.3.2) in order to preserve other aspects of the MAC Service (2.3.3; 2.3.4) when automatic reconfiguration takes place. Service may be denied to end stations that do not benefit from the reconfiguration; hence, the service availability is lowered for those end stations. Bridges may filter frames in order to localize traffic in the Bridged Local Area Network. Should an end station move, it may then be unable to receive frames from other end stations until the filtering information held by the Bridges is updated.

To maximize the service availability, no loss of service or delay in service provision should be caused by Bridges, except as a consequence of a failure, removal, or insertion of a Bridged Local Area Network component, or as a consequence of the movement of an end station. These are regarded as extraordinary events. The operation of any additional protocol necessary to maintain the quality of the MAC Service is thus limited to the configuration of the Bridged Local Area Network, and is independent of individual instances of service provision.

2.3.2 Frame Loss. The service provided by the MAC Sublayer does not guarantee the delivery of Service Data Units. Frames transmitted by a source station arrive, uncorrupted, at the destination station with high probability. The operation of a Bridge introduces minimal additional frame loss.

A frame transmitted by a source station can fail to reach its destination station as a result of

- (1) Frame corruption during physical layer transmission or reception.
- (2) Frame discard by a Bridge because
 - (a) It is unable to transmit them within some maximum time and, hence, must discard the frame to prevent the maximum frame lifetime (2.3.6) being exceeded.
 - (b) It is unable to continue to store the frame due to exhaustion of internal buffering capacity as frames continue to arrive at a rate in excess of that at which they can be transmitted.
 - (c) The size of the service data unit carried by the frame exceeds the maximum supported by the medium access control procedures employed on the LAN to which the frame is to be relayed.

- (d) Changes in the connected topology of the Bridged Local Area Network necessitate frame discard for a limited period of time to maintain other aspects of Quality of Service.

2.3.3 Frame Misordering. The service provided by the MAC Sublayer does not permit the reordering of frames transmitted with a given user priority. MA_UNITDATA.indication service primitives corresponding to MA_UNITDATA.request primitives with the same requested priority are received in the same order as the request primitives were processed. The operation of the Bridges does not misorder frames transmitted with the same user priority.

Where Bridges in a Bridged Local Area Network are capable of connecting the individual MACs in such a way that multiple paths between any source station–destination station pairs exist, the operation of a protocol is required to ensure that multiple paths do not occur.

2.3.4 Frame Duplication. The service provided by the MAC Sublayer does not permit the duplication of frames. The operation of Bridges does not introduce duplication of user data frames.

The potential for frame duplication in a Bridged Local Area Network arises through the possibility of duplication of received frames on subsequent transmission within a Bridge, or through the possibility of multiple paths between source and destination end stations.

A Bridge shall not duplicate user data frames.

2.3.5 Transit Delay. The service provided by the MAC Sublayer introduces a frame transit delay that is dependent on the particular media and media access control method employed. Frame transit delay is the elapsed time between an MA_UNITDATA.request primitive and the corresponding MA_UNITDATA.indication primitive. Elapsed time values are calculated only on Service Data Units that are successfully transferred.

Since the MAC Service is provided at an abstract interface within an end station, it is not possible to specify precisely the total frame transit delay. It is, however, possible to measure those components of delay associated with media access and with transmission and reception; and the transit delay introduced by an intermediate system, in this case a Bridge, can be measured.

The minimum additional transit delay introduced by a Bridge is the time taken to receive a frame plus that taken to access the media onto which the frame is to be relayed. Note that the frame is completely received before it is relayed as the Frame Check Sequence (FCS) is to be calculated and the frame discarded if in error.

2.3.6 Frame Lifetime. The service provided by the MAC Sublayer ensures that there is an upper bound to the transit delay experienced for a particular instance of communication. This maximum frame lifetime is necessary to ensure the correct operation of higher layer protocols. The additional transit delay introduced by a Bridge is discussed above.

To enforce the maximum frame lifetime a Bridge may be required to discard frames. Since the information provided by the MAC Sublayer to a Bridge does not include the transit delay already experienced by any particular frame, Bridges must discard frames to enforce a maximum delay in each Bridge.

The value of the maximum bridge transit delay is based on both the maximum delays imposed by all the Bridges in the Bridged Local Area Network and the desired maximum frame lifetime. A recommended and an absolute maximum value are specified in Table 4-2.

2.3.7 Undetected Frame Error Rate. The service provided by the MAC Sublayer introduces a very low undetected frame error rate in transmitted frames. Undetected errors are protected against by the use of a FCS that is appended to the frame by the MAC Sublayer of the source station prior to transmission, and checked by the destination station on reception.

The FCS calculated for a given Service Data Unit is dependent on the medium access control method employed. It is therefore necessary to recalculate the FCS within a Bridge providing a relay function between IEEE 802 MACs of dissimilar types. This introduces the possibility of additional undetected errors arising from the operation of a Bridge. For frames relayed between LANs of the same MAC type, the Bridge shall not introduce an undetected frame error rate greater than that which would be achieved by preserving the FCS.

2.3.8 Maximum Service Data Unit Size. The Maximum Service Data Unit Size that can be supported by an IEEE 802 LAN varies with the media access control method and its associated parameters (speed, etc.). It may be constrained by the owner of the LAN.

The Maximum Service Data Unit Size supported by a Bridge between two LANs is the smaller of that supported by the LANs. No attempt is made by a Bridge to relay a frame to a LAN that does not support the size of Service Data Unit conveyed by that frame.

2.3.9 Priority. The service provided by the MAC Sublayer includes user priority as a Quality of Service parameter. MA_UNITDATA.request primitives with a high priority may be given precedence over other request primitives made at the same station, or at other stations attached to the same LAN, and can give rise to earlier MA_UNITDATA.indication primitives.

The MAC Sublayer maps the requested user priorities onto the access priorities supported by the individual medium access control method. The requested user priority may be conveyed to the destination station.

Since a Bridge shall not reorder frames originating from MA_UNITDATA.request primitives of the same user priority, the mapping of priority must be static.

2.3.10 Throughput. The total throughput provided by a Bridged Local Area Network can be significantly greater than that provided by an equivalent single LAN. Bridges may localize traffic within the Bridged Local Area Network by filtering frames.

The throughput between end stations on individual LANs, communicating through a Bridge, can be lowered by frame discard in the Bridge due to the inability to transmit at the required rate on the LAN forming the path to the destination for an extended period.

2.4 Internal Sublayer Service Provided within the MAC Bridge. The Internal Sublayer Service provided by the MAC entities to the MAC Relay Entity within a Bridge is that provided by the individual, independent MACs. The Bridge observes the appropriate MAC procedures and protocol for each LAN to which it is connected. No control frames (also known as MAC frames) that govern the operation of an individual LAN are forwarded off the LAN of their origin.

The Internal Sublayer Service is derived from the MAC Service ISO/IEC 10039 [15] by augmenting that specification with elements necessary to the performance of the relay function. Within the attached end station, these additional elements can be considered to be either below the MAC Service boundary, and pertinent only to the operation of the service provider; or local matters not forming part of the peer-to-peer nature of the MAC Service. Three parameters are added to the list of parameters associated with the MA_UNITDATA.request and MA_UNITDATA.indication primitives defined by the Local Area Networks MAC Service Definition [15]. These are frame_type, MAC_action, and frame_check_sequence. The definition of the Internal Sublayer Service does not add any new service primitives to be defined by the LAN MAC Service Definition.

The Internal Sublayer Service excludes MAC-specific features and procedures whose operation is confined to that of the individual LANs. The unit-data primitives that describe this service are

```
M_UNITDATA.indication  (
    frame_type,
    mac_action,
    destination_address,
    source_address,
    mac_service_data_unit,
    user_priority,
    frame_check_sequence
)
```

Each data indication primitive invoked corresponds to the receipt of a MAC frame from an individual LAN.

The `frame_type` parameter indicates the class of frame. The value of this parameter is one of `user_data_frame`, `mac_specific_frame`, or `reserved_frame`.

The `mac_action` parameter indicates the action requested of a MAC entity receiving the indication. If the value of the `frame_type` parameter is `user_data_frame`, then the `mac_action` parameter is one of `request_with_response`, `request_with_no_response`, or `response`. For `mac_specific_frames` and `reserved_frames`, this parameter does not apply.

The `destination_address` parameter is either the address of an individual MAC entity or a group of MAC entities.

The `source_address` parameter is the individual address of the source MAC entity.

The `mac_service_data_unit` parameter is the service user data.

The `user_priority` parameter is the priority requested by the originating service user. The value of this parameter, if specified, is in the range 0 (lowest) through 7 (highest).

The `frame_check_sequence` parameter is explicitly provided as a parameter of the primitive so that it can be used as a parameter to a related request primitive without recalculation.

The identification of the LAN from which particular frames are received is a local matter and is not expressed as a parameter of the service primitive.

```
M_UNITDATA.request (
    frame_type,
    mac_action,
    destination_address,
    source_address,
    mac_service_data_unit,
    user_priority,
    access_priority,
    frame_check_sequence
)
```

A data request primitive is invoked to transmit a frame to an individual LAN.

The `frame_type` parameter indicates the class of frame.

The `mac_action` parameter indicates the action requested of the destination MAC entity.

The `destination_address` parameter is either the address of an individual MAC entity, or a group of MAC entities.

The `source_address` parameter is the individual address of the source MAC entity.

The `mac_service_data_unit` parameter is the service user data.

The `user_priority` parameter is the priority requested by the originating service user. The value of this parameter, if specified, is in the range 0 (lowest) through 7 (highest).

The `access_priority` parameter is the priority used by the local service provider to convey the request. It can be used to determine the priority attached to the transmission of frames queued by the local MAC Entity, both locally and amongst other stations attached to the same individual LAN—if the media access method permits. The value of this parameter, if specified, is in the range 0 (lowest) through 7 (highest).

The `frame_check_sequence` parameter is explicitly provided as a parameter of the primitive so that it can be used without recalculation.

The identification of the LAN to which a frame is to be transmitted is a local matter and is not expressed as a parameter of the service primitive.

2.5 Support of the Internal Sublayer Service by Specific MAC Procedures. This section specifies the mapping of the Internal Sublayer Service to the MAC Protocol and Procedures of each individual IEEE 802 MAC type, and the encoding of the parameters of the service in MAC frames. The mapping is specified by reference to the IEEE 802 Standards that specify the individual media access methods. The mapping draws attention to any special responsibilities of Bridges attached to LANs of that MAC type.

2.5.1 Support by ISO/IEC 8802-3 [5] (CSMA/CD). The CSMA/CD access method is specified in ISO/IEC 8802-3 [5]. Section 3 of that standard specifies the media access control frame structure, and Section 4 specifies the media access control method.

On receipt of an M_UNITDATA.request primitive, the local MAC Entity performs Transmit Data Encapsulation, assembling a frame using the parameters supplied as specified below. It appends a preamble and a Start Frame Delimiter before handing the frame to the Transmit Media Access Management Component in the MAC Sublayer for transmission ([5], 4.2.3).

On receipt of a MAC frame by Receive Media Access Management, the MAC frame is passed to Receive Data Decapsulation which validates the FCS and disassembles the frame, as specified below, into the parameters that are supplied with an M_UNITDATA.indication primitive ([5], 4.2.4).

The frame_type parameter only takes the value user_data_frame and is not explicitly encoded in MAC frames.

The mac_action parameter only takes the value request_with_no_response and is not explicitly encoded in MAC frames.

The destination_address parameter is encoded in the destination address field of the MAC frame ([5], 3.2.3).

The source_address parameter is encoded in the source address field of the MAC frame ([5], 3.2.3).

The number of octets in the mac_service_data_unit parameter is encoded in the length field of the MAC frame ([5], 3.2.6), and the octets of data are encoded in the data field ([5], 3.2.7).

The user_priority parameter is not encoded in MAC frames and takes the value unspecified on corresponding M_UNITDATA.indication primitives.

The frame_check_sequence parameter is encoded in the FCS field of the MAC frame ([5], 3.2.8). The FCS is computed as a function of the destination address, source address, length, data and pad fields. This parameter, therefore, also conveys the value of the PAD field necessary to meet the requirement for a minimum frame size ([5], 3.2.7). If an M_UNITDATA.request primitive is not accompanied by this parameter, it is calculated in accordance with [5], 3.2.8.

No special action, above that specified for the support of use of the MAC Service by LLC, is required for the support of the MAC Internal Sublayer Service by the CSMA/CD access method.

2.5.2 Support by ISO/IEC 8802-4 [6] (Token-Passing Bus). The token-passing bus access method is specified in ISO/IEC 8802-4 [6]. Section 4 of that standard specifies frame formats. Section 5 discusses the basic concepts of the access protocols, and Section 7 provides the definitive specification of the token-passing bus MAC operation.

On receipt of an M_UNITDATA.request primitive the local MAC Entity Interface Machine (IFM) queues a frame for transmission by the Access Control Machine (ACM) ([6], Section 7). On transmission the frame fields are set using the parameters supplied as specified below, and the Preamble, Start Delimiter, and End Delimiter are added ([6], Section 4).

On receipt of a valid MAC frame by the Receive Machine (RxM) ([6], 7.1.5), an M_UNITDATA.indication primitive is generated, with parameters derived from the frame fields as specified below.

The frame_type parameter is encoded in the FF bits (bit positions 1 and 2) of the frame control field ([6], 4.1.3.1, 4.1.3.2). A bit pattern of 0 1 denotes a user_data_frame, a bit pattern of 0 0 or 1 0 denotes a mac_specific_frame, and a bit pattern of 1 1 denotes a reserved_frame.

The mac_action parameter is encoded in the MMM bits (bit positions 3, 4, and 5) of the frame control field ([6], 4.1.3.2). For user_data_frames these take the values 0 0 0 for request_with_no_response, 0 0 1 for request_with_response, and 0 1 0 for response.

The destination_address parameter is encoded in the destination address field of the MAC frame ([6], 4.1.4.1).

The source_address parameter is encoded in the source address field of the MAC frame ([6], 4.1.4.2).

The mac_service_data_unit parameter is encoded in the MAC Data Unit field ([6], 4.1.5).

The user_priority parameter is encoded in the PPP bits (bit positions 6, 7, and 8) of the frame control field ([6], 4.1.3.2; [6], 5.1.7).

The frame_check_sequence parameter is encoded in the FCS field of the MAC frame ([6], 4.1.6). The FCS is computed as a function of the frame control, destination address, source address, and data fields. If an

M_UNITDATA.request primitive is not accompanied by this parameter, it is calculated in accordance with [6], 4.1.6.

No special action, above that specified for the support of use of the MAC Service by LLC, is required for the support of the MAC Internal Sublayer Service by the token-passing bus access method.

2.5.3 Support by ISO/IEC 8802-5 [7] (Token-Passing Ring). The token-passing ring access method is specified in ISO/IEC 8802-5 [7]. Section 3 of that standard specifies formats and facilities, and Section 4 specifies token-passing ring protocols.

On receipt of an M_UNITDATA.request primitive the local MAC Entity composes a frame using the parameters supplied as specified below, appending the frame control, destination address, source address, and FCS fields to the user data, and enqueueing the frame for transmission on reception of a suitable token ([7], 4.1.1). On transmission, the starting delimiter, access control field, ending delimiter, and frame status fields are added.

On receipt of a valid MAC frame ([7], 4.1.4) that was not transmitted by the Bridge Port's local MAC Entity, with the Routing Information Indicator bit (which occupies the same position in the source address field as does the Group Address bit in the destination address field) set to zero, an M_UNITDATA.indication primitive is generated, with parameters derived from the frame fields as specified below.

The frame_type parameter is encoded in the frame_type bits (FF bits) of the frame control field ([7], 3.2.3.1). A bit pattern of 0 1 denotes a user_data_frame, a bit pattern of 0 0 denotes a mac_specific_frame, and a bit pattern of 1 0 or 1 1 denotes a reserved_frame.

The mac_action parameter only takes the value request_with_no_response and is not explicitly encoded in MAC frames.

The destination_address parameter is encoded in the destination address field of the MAC frame ([7], 3.2.4.1).

The source_address parameter is encoded in the source address field of the MAC frame ([7], 3.2.4.2).

The mac_service_data_unit parameter is encoded in the information field ([7], 3.2.6).

The user_priority parameter associated with user_data_frames is encoded in the YYY bits of the frame control field ([7] 3.2.3).

The frame_check_sequence parameter is encoded in the FCS field of the MAC frame ([7], 3.2.7). The FCS is computed as a function of the frame control, destination address, source address, and information fields. If an M_UNITDATA.request primitive is not accompanied by this parameter, it is calculated in accordance with [7], 3.2.7.

The Address Recognized (A) bits in the Frame Status field of a frame ([7], 3.2.9) may be set to 1 if an M_UNITDATA.indication primitive with frame_type and mac_action parameter values of user_data_frame and request_with_no_response respectively is generated, or if such an indication would be generated if buffering had been available; otherwise the A bits shall not be set except as required by [7].

If the A bits are set to 1, the Frame Copied (C) bits ([7], 3.2.9) may be set to 1 to reflect the availability of receive buffering; otherwise the C bits shall not be set.

In order to support the MAC Internal Sublayer Service, a Token Ring Bridge must be capable of recognizing and removing frames transmitted by itself, even though they can carry a source address different from that of the Bridge Port that transmitted them.

2.5.4 Support by Fibre Distributed Data Interface (FDDI). The FDDI access method is specified in ISO 9314-2 [14]. Clause 6 of that standard specifies Services, and clauses 7 and 8 specify Facilities and Operation, respectively.

On receipt of a valid frame ([14], 8.3.1) that was not transmitted by the Bridge Port's local MAC entity, with the first bit of the source address equal to zero, an M_UNITDATA.indication primitive is generated. The parameters associated with the primitive are derived from the frame fields as specified shortly below.

The Address Recognized (A) indicator in the Frame Status field of the frame ([14], 7.3.8) on the ring from which it was received shall not be set except as required by [14]. The Frame Copied (C) indicator ([14], 7.3.8) may be set if an M_UNITDATA.indication primitive with frame_type and mac_action parameter values of user_data_frame and request_with_no_response, respectively, is generated, if the frame is to be forwarded, and if receive buffering is available. Otherwise, the C indicator shall not be altered except as required by [14].

NOTES: (1) This specification of the setting of the C indicator by MAC Bridges enhances that given in [14] and has been included in the ongoing work of ANSI ASC X3T9.5 and is known as MAC-2. IEEE Std 802.1D does not, however, require all MAC-2 functions or conformance to MAC-2.

(2) A Bridge can be required by [14] to alter the A and/or C indicators when receiving a frame addressed to the Bridge as an FDDI end station, or when receiving a frame associated with the operation of the FDDI MAC.

The parameters associated with the M_UNITDATA.indication that is generated on receipt of a frame now follow:

The frame_type parameter is encoded in the frame format bits (CL, FF, and ZZZZ bits) of the Frame Control field ([14], 7.3.3). The bit pattern 0L01rXXX denotes a user_data_frame (asynchronous LLC frame, where L represents the address length and can be 0 or 1, r is reserved and can be received as 0 or 1, and XXX can range from 000 to 111). All other bit patterns yield a frame_type parameter value of not_user_data_frame.

The mac_action parameter takes only the value request_with_no_response and is not explicitly encoded in MAC frames.

The destination_address parameter is enclosed in the destination address field of the MAC frame ([14], 7.3.4–7.3.4.1).

The source_address parameter is encoded in the source address field of the MAC frame ([14], 7.3.4–7.3.4.2).

The mac_service_data_unit parameter is encoded in the information field ([14], 7.3.5).

The user_priority parameter associated with user_data_frames is encoded in the PPP bits of the frame control field ([14], 7.3.3.4) when the frame is an asynchronously transmitted LLC frame whose frame control field value is 0L010PPP, where L represents the address length ([14], 7.3.3.2).

The frame_check_sequence parameter is encoded in the Frame Check Sequence Field of the MAC frame ([14], 7.3.6). The frame_check_sequence is computed as a function of the frame control, destination address, source address, and information fields.

On receipt of an M_UNITDATA.request primitive, the local MAC entity composes a frame using the parameters supplied as specified above, appending the frame control, destination address, source address, and frame check sequence to the user data, and enqueueing the frame for transmission on reception of a suitable token ([14], 8.3.1). On transmission, the preamble, starting delimiter, ending delimiter, and frame status fields are added.

If an M_UNITDATA.request primitive is not accompanied by a frame check sequence, one is calculated in accordance with [14], 7.3.6.

The bit pattern of the frame control field shall be 0L01rPPP, indicating an asynchronous LLC frame with L representing the address length ([14], 7.3.3.2), r being reserved and set to zero, and PPP indicating the frame's priority ([14], 7.3.3.4).

If the user priority parameter value is specified, it is encoded in the PPP bits and the access priority ([14], 8.1.4) is derived from the token-holding timer THT or otherwise by implementor option. If the user_priority parameter value is unspecified, the PPP bits shall be set to zero and the access priority derived from the THT.

In order to support the MAC Internal Layer Service, an FDDI bridge removes frames transmitted by itself as required by [14], even though they can carry a source address different from that of the bridge port that transmitted them.

3. Principles of Operation

This section establishes the principles and a model of the operation of a Bridge as follows:

- (1) Explains the principal elements of Bridge operation and lists the functions that support these.
- (2) Establishes an architectural model for a Bridge that governs the provision of these functions.
- (3) Provides a model of the operation of a Bridge in terms of Processes and Entities that support the functions.
- (4) Details the addressing requirements in a Bridged Local Area Network and specifies the addressing of Entities in a Bridge.

3.1 Bridge Operation. The principal elements of Bridge operation are

- (1) Relay and filtering of frames.
- (2) Maintenance of the information required to make frame filtering and relaying decisions.
- (3) Management of the above.

3.1.1 Relay. A MAC Bridge relays individual MAC user data frames between the separate MACs of the Bridged Local Area Networks connected to its Ports. The order of frames of given user_priority received on one Port and transmitted on another shall be preserved.

The functions that support the relaying of frames and maintain the Quality of Service supported by the Bridge are

- (1) Frame reception.
- (2) Discard on received frame in error (2.3.2).
- (3) Frame discard if the frame_type is not user_data_frame, or if its mac_action parameter is not request_with_no_response (2.4).
- (4) Frame discard following the application of filtering information.
- (5) Frame discard on transmittable service data unit size exceeded (2.3.8).
- (6) Forwarding of received frames to other Bridge Ports.
- (7) Frame discard to ensure that a maximum bridge transit delay is not exceeded (2.3.6).
- (8) Selection of outbound access priority (2.3.9).
- (9) Mapping of service data units and recalculation of Frame Check Sequence (2.3.7).
- (10) Frame transmission.

3.1.2 Filtering Information. A Bridge filters frames, i.e., does not relay frames received by a Bridge Port to other Ports on that Bridge, in order to prevent the duplication of frames (2.3.4). Frames transmitted between a pair of end stations can be confined to LANs that form a path between those end stations (2.3.10).

The functions that support the use and maintenance of filtering information are

- (1) Permanent configuration of reserved addresses.
- (2) Explicit configuration of static filtering information.
- (3) Automatic learning of dynamic filtering information through observation of Bridged Local Area Network traffic.
- (4) Ageing out of filtering information that has been automatically learned.
- (5) Calculation and configuration of Bridged Local Area Network topology.

3.1.3 Bridge Management. The functions that support Bridge Management control and monitor the provision of the above functions. They are specified in Section 6.

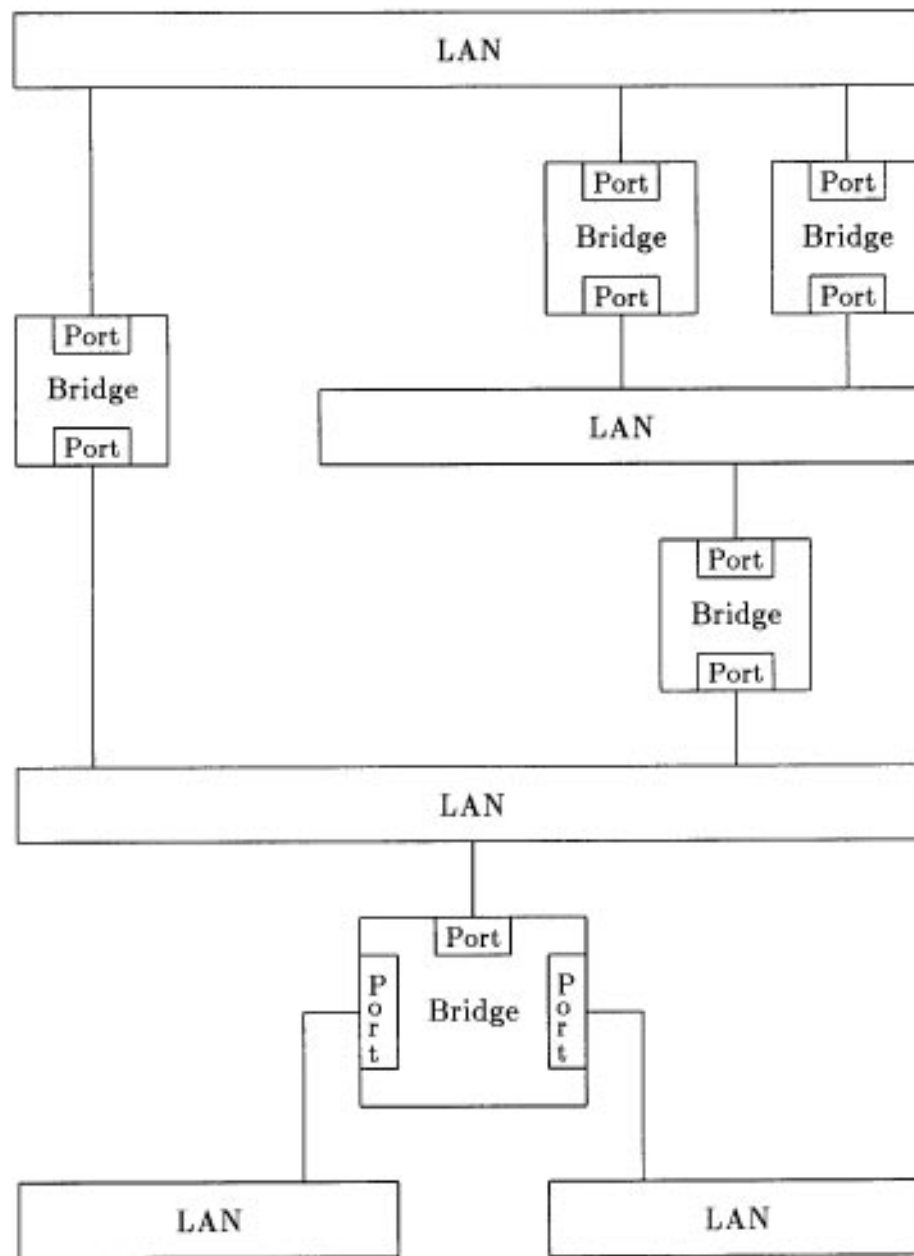


Fig 3-1
A Bridged Local Area Network

3.2 Bridge Architecture. Each Bridge Port receives and transmits frames to and from the LAN to which it is attached using the services provided by the individual MAC Entity associated with that Port. The MAC Entity for each Port handles all the Media Access Method Dependent Functions (MAC protocol and procedures) as specified in the relevant IEEE 802 standard for that MAC technology.

The MAC Relay Entity handles the Media Access Method Independent Functions of relaying frames between Bridge Ports, filtering frames, and learning filtering information.

The Bridge Protocol Entity handles calculation and configuration of Bridged Local Area Network topology.

The MAC Relay Entity uses the Internal Sublayer Service provided by the separate MAC Entities for each Port. This service and its support is described in 2.4 and 2.5. It is not specific to any MAC technology.

The Bridge Protocol Entity and other higher layer protocol users, such as Bridge Management, make use of Logical Link Control procedures. These procedures are provided separately for each Port, and use the MAC Service provided by the individual MAC Entities.

Figures 3-2 and 3-3 illustrate a Bridge and its Ports and the architecture of the Bridge for a Bridge with two Ports. A Bridge may have more than two Ports.

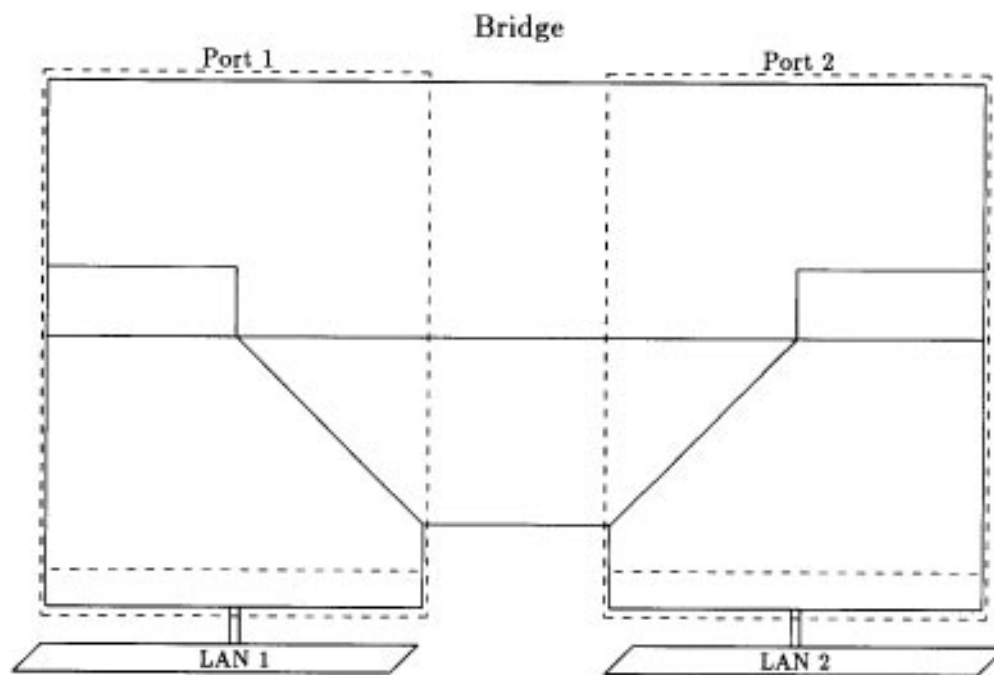


Fig 3-2
Bridge Ports

3.3 Model of Operation. The use, by the MAC Relay Entity, of the Internal Sublayer Service provided by the individual MAC Entities associated with each Bridge Port is specified in 3.5 and 3.6.

Frames are accepted for transmission and delivered on reception to and from Processes and Entities that model the operation of the MAC Relay Entity in a Bridge. These are

- (1) The Forwarding Process (3.7), which forwards received frames that are to be relayed to other Bridge Ports, filtering frames on the basis of information contained in the Filtering Database (3.9) and on the state of the Bridge Ports (3.4).
- (2) The Learning Process (3.8), that, by observing the source addresses of frames received on each Port, updates the Filtering Database (3.9) conditionally on the state of the Port (3.4) on which frames are observed.
- (3) The Filtering Database (3.9), which holds filtering information either explicitly configured by management action or automatically entered by the Learning Process, and which supports queries by the Forwarding Process as to whether frames with given values of the destination MAC address field should be forwarded to a given Port.

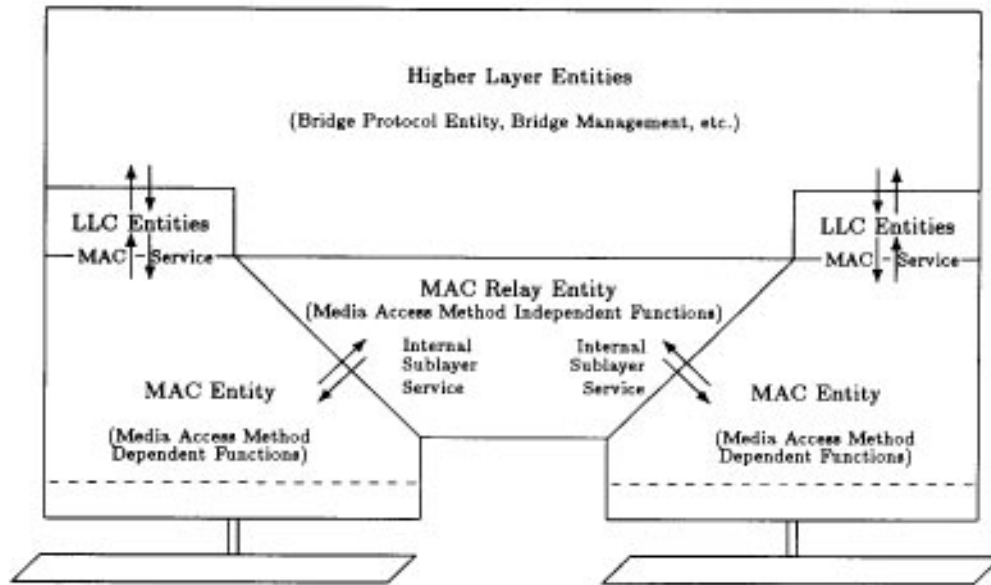


Fig 3-3
Bridge Architecture

Each Bridge Port also functions as an end station providing the MAC Service to LLC that supports

- (1) The Bridge Protocol Entity (3.10), which operates a MAC Sublayer configuration protocol (Section 4) between Bridges, which determines, in part, the state of each Bridge Port (3.4) and its participation in the active topology of the Bridged Local Area Network.
- (2) Other users of LLC, such as protocols providing Bridge Management (3.11).

Each Bridge Port shall support the operation of LLC Type 1 procedures in order to support the operation of the Bridge Protocol Entity. Bridge Ports may support other types of LLC procedures, which may be used by other protocols.

Figure 3-4 illustrates a single instance of frame relay between the Ports of a Bridge with two Ports.

Figure 3-5 illustrates the inclusion of information carried by a single frame, received on one of the Ports of a Bridge with two Ports, in the Filtering Database.

Figure 3-6 illustrates the reception and transmission of Bridge Protocol Data Units by the Bridge Protocol Entity.

3.4 Port State Information. State information associated with each Bridge Port governs its participation in the Bridged Local Area Network. If management permits a Port to participate in frame relay, and if it is capable of doing so, then it is described as active.

This standard specifies the use of a Spanning Tree Algorithm and Protocol, which reduces the topology of the Bridged Local Area Network to a simply connected active topology (Section 4). Subsection 4.4 specifies the Port States associated with that mechanism. Ports that continue to participate in frame relay are described as being in a forwarding state.

The incorporation of end station location information in the Filtering Database by the Learning Process also depends on the active topology. If information associated with frames received on a Port is to be incorporated in the Filtering Database by the Learning Process, then the Port is described as being in a learning state; otherwise, it is in a non-learning state.

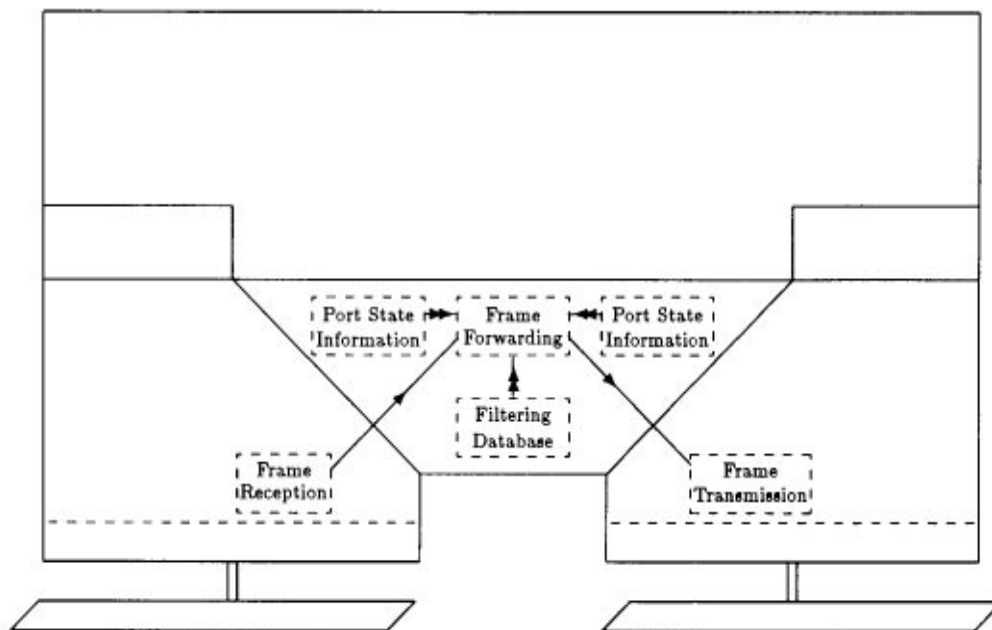


Fig 3-4
Relaying MAC Frames

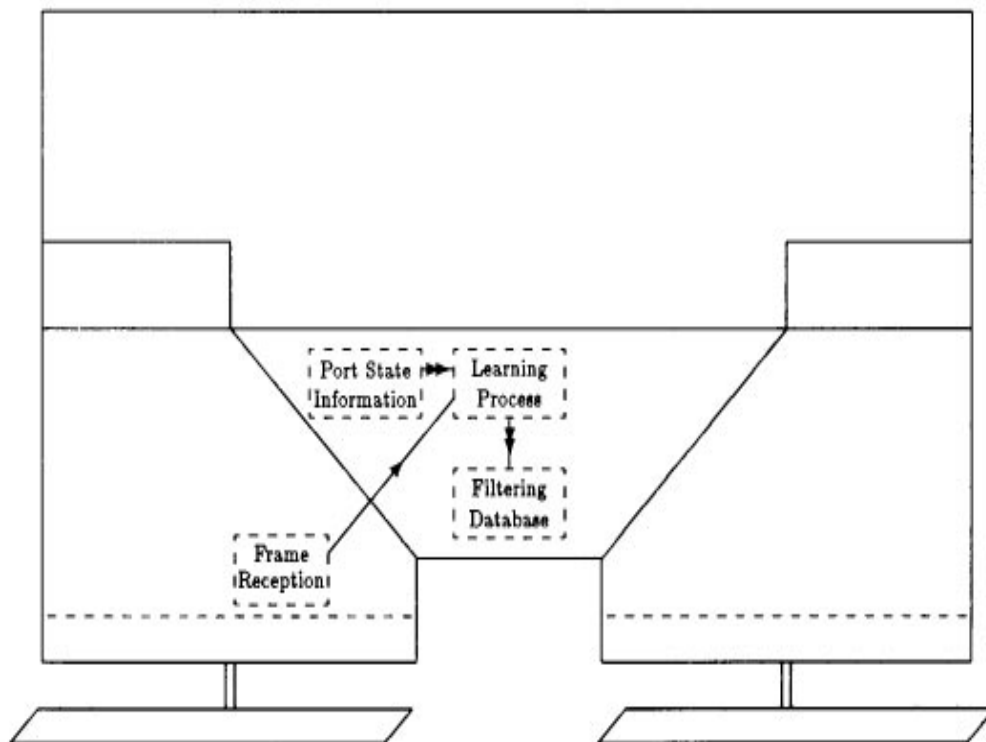


Fig 3-5
Observation of Network Traffic

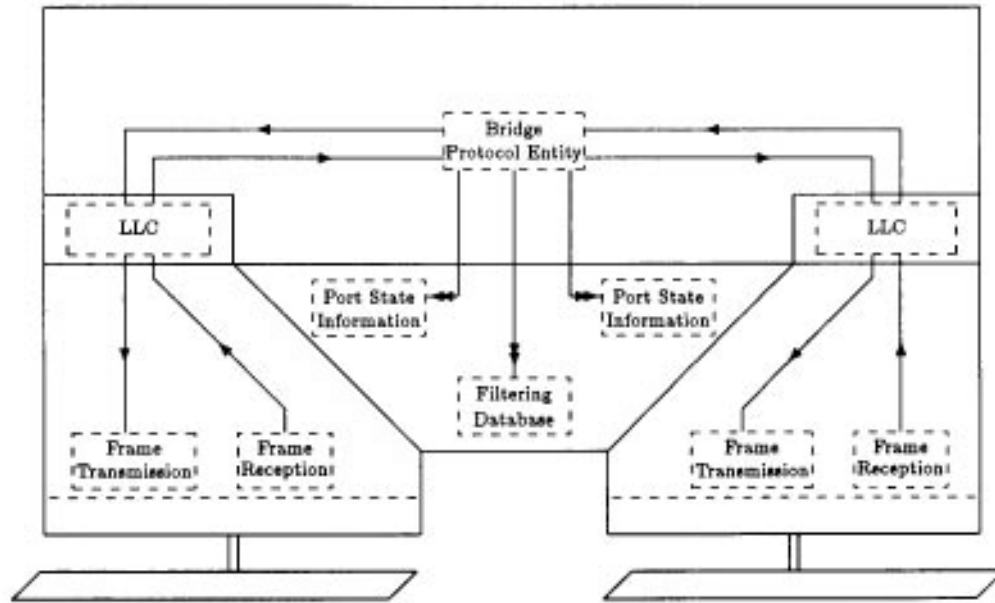


Fig 3-6
Operation of Inter-Bridge Protocol

Figure 3-6 illustrates the operation of the Bridge Protocol Entity which operates the Spanning Tree Algorithm and Protocol, and its modification of Port state information as part of determining the active topology of the Bridged Local Area Network.

Figure 3-5 illustrates the use of the Port state information for a Port receiving a frame, by the Learning Process, in order to determine whether the station location information should be incorporated in the Filtering Database.

Figure 3-4 illustrates the use of the Port state information for a Port receiving a frame, by the Forwarding Process, in order to determine whether the received frame should be relayed through other Ports on the Bridge; and the use of the Port state information for a second Bridge Port in order to determine whether the relayed frame should be forwarded through that Port.

3.5 Frame Reception. The individual MAC Entity associated with each Bridge Port examines all frames transmitted on the LAN to which it is attached.

Frames that are in error as defined by the relevant media access method shall be discarded; this includes frames whose FCS is in error.

All other frames shall be submitted to the Learning Process.

Frames with `M_UNITDATA.indication` primitive `frame_type` and `mac_action` parameter values of `user_data_frame` and `request_with_no_response`, respectively (2.5), are submitted to the Forwarding Process. Frames with other values of `frame_type` and `mac_action` parameters, such as `request_with_response` and response frames, are discarded and shall not be relayed by the Bridge.

Frames addressed to the Bridge Port as an end station, with a `frame_type` of `user_data_frame`, shall be submitted to LLC. Such frames carry either the individual MAC Address of the Port or a group address associated with the Port (3.12) in the destination address field.

Frames relayed to a Bridge Port from other Bridge Ports in the same Bridge, and addressed to that Bridge Port as an end station, shall also be submitted to LLC.

3.6 Frame Transmission. The individual MAC Entity associated with each Bridge Port transmits frames submitted to it by the MAC Relay Entity.

Relayed frames are submitted for transmission by the Forwarding Process. The M_UNITDATA.request primitive associated with such frames conveys the values of the source and destination address fields received in the corresponding M_UNITDATA.indication primitive.

LLC Protocol Data Units are submitted by LLC as a user of the MAC Service provided by the Bridge Port. Frames transmitted to convey such Protocol Data Units carry the individual MAC Address of the Port in the source address field.

Each frame is transmitted subject to the MAC procedures to be observed for that specific IEEE 802 LAN technology. The values of the frame_type and mac_action parameters of the corresponding M_UNITDATA.request primitive shall be user_data_frame and request_with_no_response respectively (2.5).

Frames transmitted following a request by the LLC user of the MAC Service provided by the Bridge Port shall also be submitted to the MAC Relay Entity.

3.7 Frame Forwarding. The Forwarding Process forwards received frames that are to be relayed to other Bridge Ports, filtering frames on the basis of information contained in the Filtering Database and on the state of the Bridge Ports.

3.7.1 Forwarding Conditions. A frame received on a Bridge Port and submitted to the Forwarding Process shall be queued for transmission on each of the other Bridge Ports if, and only if

- (1) The Port on which the frame was received was in a forwarding state (4.4), and
- (2) The Port on which the frame is to be transmitted is in a forwarding state, and
- (3) Either
 - (a) The Filtering Database indicates that frames with this value of the destination MAC address field should be forwarded through the transmission Port (as would happen, for example, if the destination address was not in the database), or
 - (b) The values of the source and destination MAC address fields are the same, and the Bridge is configured to not filter such frames,and
- (4) The Maximum Service Data Unit Size supported by the LAN to which the transmission Port is attached and would not be exceeded.

3.7.2 LLC Duplicate Address Check. A Bridge may either:

- (1) Filter frames whose source and destination MAC address fields have the same value, in order to localize traffic, or
- (2) Forward such frames, in order to support the optional LLC duplicate address check function.

3.7.3 Queued Frames. The Forwarding Process provides storage for queued frames, awaiting an opportunity to submit these for transmission to the individual MAC Entities associated with each Bridge Port. The order of queued frames shall be maintained.

A frame queued by the Forwarding Process for transmission on a Port shall be removed from that queue on submission to the individual MAC Entity for that Port; no further attempt shall be made to transmit the frame on that Port even if the transmission is known to have failed.

A frame queued by the Forwarding Process for transmission on a Port can be removed from that queue, and not subsequently transmitted, if the time for which buffering is guaranteed has been exceeded for that frame.

A frame queued for transmission on a Port shall be removed from that queue, and not subsequently submitted to the individual MAC Entity for that Port, if that is necessary to ensure that the maximum bridge transit delay (2.3.6) will not be exceeded at the time at which the frame would be subsequently transmitted.

A frame queued for transmission on a Port shall be removed from that queue if the associated Port leaves the Forwarding state.

Removal of a frame from a queue for transmission on any particular Port does not of itself imply that it shall be removed from a queue for transmission on any other Port.

3.7.4 Priority Mapping. The Forwarding Process performs the mapping of the priority of forwarded frames (2.3.9). It determines the values of the user_priority and access_priority parameters used to relay frames.

The user_priority parameter in an M_UNITDATA.request primitive (2.5) shall be

- (1) Equal to the value of the user_priority of the corresponding M_UNITDATA.indication primitive, if that was specified; i.e., if the frame was received from a LAN using the token-passing bus, token-passing ring, or FDDI access method; or
- (2) Set to the value of the Outbound User Priority parameter (see below) for the transmission Port, if the value in the corresponding M_UNITDATA.indication primitive was unspecified; i.e., if the frame was received from a LAN using the CSMA/CD access method.

The access_priority parameter in an M_UNITDATA.request primitive (2.5) shall be either

- (a) Set to the value of the Outbound Access Priority parameter (see below) for the transmission Port, or
- (b) Equal to the value of the user priority parameter in the request primitive, or
- (c) For the case of FDDI [14], derived from the THT as a default or otherwise, by implementor option.

The Outbound User Priority and Outbound Access Priority parameters may be set by management. If this capability is provided, the value of the parameters shall be independently settable for each transmission Port, and the Bridge shall have the capability to use the full range of values in the parameter ranges specified in Tables 3-1 and 3-2. If this capability is not provided, the Bridge shall use the default values specified in Tables 3-1 and 3-2.

**Table 3-1
Outbound User Priorities**

Parameter	Recommended or Default Value	Range
Outbound User Priority (ISO/IEC 8802-3 CSMA/CD)	0	0–7
Outbound User Priority (ISO/IEC 8802-4 Token Bus)	0	0–7
Outbound User Priority (ISO/IEC 8802-5 Token Ring)	0	0–7
Outbound User Priority (FDDI)	0	0–7

**Table 3-2
Outbound Access Priorities**

Parameter	Recommended or Default Value	Range
Outbound Access Priority (ISO/IEC 8802-3 CSMA/CD)	0	0–7
Outbound Access Priority (ISO/IEC 8802-4 Token Bus)	0	0–7
Outbound Access Priority (ISO/IEC 8802-5 Token Ring)	4	0–7

Note that the CSMA/CD access method treats all values of access_priority equally and does not signal user_priority. The Outbound User Priority and Outbound Access Priority parameters are still specified for

this access method to allow a consistent approach to the management of Bridge Ports of different MAC types.

3.7.5 FCS Recalculation. Where a frame is being forwarded between two individual MAC Entities of the same IEEE 802 or FDDI LAN type the FCS received in the M_UNITDATA.indication primitive may be supplied in the corresponding M_UNITDATA.request primitive and not recalculated (2.3.7).

Where the LANs are of different types this is not possible, and the FCS is recalculated according to the specific MAC procedures of the transmitting MAC Entity.

3.7.6 Model. Figure 3-4 illustrates the operation of the Forwarding Process in a single instance of frame relay between the Ports of a Bridge with two Ports.

3.8 The Learning Process. The Learning Process observes the source addresses of frames received on each Port and updates the Filtering Database conditionally on the state of the receiving Port.

Frames are submitted to the Learning Process by the individual MAC Entities associated with each Bridge Port as specified in 3.5.

The Learning Process may deduce the path through the Bridged Local Area Network to particular end stations by inspection of the source address field of received frames. It shall create or update a dynamic entry (3.9, 3.9.2) in the Filtering Database, associating the Port on which the frame was received with the MAC address in the source address field of the frame, if and only if

- (1) The Port on which the frame was received is in a state that allows learning (4.4), and
- (2) The source address field of the frame denotes a specific end station, i.e., is not a group address, and
- (3) A static entry (3.9, 3.9.1) for the associated MAC address does not already exist, and
- (4) The resulting number of entries would not exceed the capacity of the Filtering Database.

If the Filtering Database is already filled up to its capacity, but a new entry would otherwise be made, then an existing entry may be removed to make room for the new entry.

Figure 3-5 illustrates the operation of the Learning Process in the inclusion of station location information carried by a single frame, received on one of the Ports of a Bridge, in the Filtering Database.

3.9 The Filtering Database. The Filtering Database holds filtering information that is either explicitly configured by management action or automatically entered by the Learning Process. It supports queries by the Forwarding Process as to whether frames with given values of the destination MAC address field should be forwarded to a given Port.

The Filtering Database shall contain static entries (3.9.1). It shall be capable of containing dynamic entries (3.9.2). Both types of entry shall not exist for a given MAC address: a dynamic entry shall not be created if a static entry for the same MAC address already exists; creation of a static entry shall cause the removal of a dynamic entry for the same address if one exists.

The Filtering Database may be interrogated and updated by management. Such management may be carried out by local or private means, or by use of the remote management capability provided by Bridge Management (3.11) using the operations specified in Section 6.

3.9.1 Static Entries. Static entries may be added to and removed from the Filtering Database under explicit management control. They are not automatically removed by any timeout mechanism.

Static entries specify

- (1) The MAC address for which filtering is specified.
- (2) For each inbound Port on which frames are received, a Port map that specifies for each outbound Port on which frames may be transmitted, whether frames shall be filtered or forwarded to that Port.

The MAC addresses that can be specified shall include group addresses and the broadcast address.

3.9.2 Dynamic Entries. Dynamic entries are created and updated by the Learning Process as described in 3.8. They shall be automatically removed after a specified time has elapsed since the entry was created or last updated. This timing out of entries ensures that end stations that have been moved to a different part of the Bridged Local Area Network will not be permanently prevented from receiving frames. It also

takes account of changes in the active topology of the Bridged Local Area Network which can cause end stations to appear to move from the point of view of a Bridge; i.e., the path to those end stations subsequently lies through a different Bridge Port.

The timeout value, or Ageing Time, after which a dynamic entry is automatically removed, may be set by management (Section 6). A recommended default value for use in IEEE 802 Bridged Local Area Networks is specified in Table 3-3; this is suggested in order to remove the need for explicit setting of the value in most cases. Table 3-3 also specifies a range of applicable values. If the value of Ageing Time can be set by management, the Bridge shall have the capability to use values in the range specified, with a granularity of 1 s.

Table 3-3
Ageing Time Parameter Value

Parameter	Recommended Default Value	Range
Ageing Time	300.0	10.0–1.0 × 10 ⁶

All times are in seconds.

The Spanning Tree Algorithm and Protocol specified in Section 4 includes a procedure for notifying all Bridges in the Bridged Local Area Network of topology changes and specifies a short value for the timeout value which is enforced for a period after any topology change. This procedure allows the normal timeout, operable during periods in which the topology does not change, to be long enough to cope with periods for which addressed end stations do not generate frames themselves, perhaps through being powered down, while not sacrificing the ability of the Bridged Local Area Network to continue to provide a service after automatic reconfiguration.

Dynamic entries specify

- (1) The MAC address for which filtering is specified.
- (2) A Port number.

Frames with the specified destination MAC address shall be forwarded only to the specified Port. A dynamic entry acts like a static entry with a single Port selected in the Port map.

The MAC addresses specified in dynamic entries shall not include group addresses and the broadcast address.

3.9.3 Permanent Database. The Filtering Database contains a Permanent Database which provides fixed storage for static entries. The Filtering Database shall be initialized with the static entries contained in this fixed data store.

Static entries may be added to and removed from the Permanent Database under explicit management control.

3.9.4 Model of Operation. Figure 3-6 illustrates the operation of the Bridge Protocol Entity (3.10), which operates the Spanning Tree Algorithm and Protocol, and its notification of the Filtering Database of changes in active topology signalled by that protocol.

Figure 3-5 illustrates the creation or update of a dynamic entry in the Filtering Database by the Learning Process.

Figure 3-4 illustrates the use of the Filtering Database by the Forwarding Process in a single instance of frame relay between the Ports of a Bridge with two Ports.

3.10 Bridge Protocol Entity. The Bridge Protocol Entity operates the Spanning Tree Algorithm and Protocol.

The Bridge Protocol Entities of Bridges attached, through their Ports, to the same individual LANs in a Bridged Local Area Network, communicate by exchanging Bridge Protocol Data Units (BPDUs).

Figure 3-6 illustrates the operation of the Bridge Protocol Entity including the reception and transmission of frames containing BPDUs, the modification of the state information associated with individual Bridge Ports, and notification of the Filtering Database of changes in active topology.

3.11 Bridge Management. Remote management facilities may be provided by the Bridge.

The facilities provided and the operations that support these are specified in Section 6.

Section 7 specifies the protocol operations, identifiers, and values to be used in realizing these management operations through the use of IEEE Std 802.1B [3].

Bridge Management protocols use the Service provided by the operation of LLC Procedures, which use the MAC Service provided by the Bridged Local Area Network.

3.12 Addressing. All MAC Entities communicating across a Bridged Local Area Network shall use 48-bit addresses, which may be Universally Administered or Locally Administered Addresses, or both.

A Bridge may use

- (1) 48-bit Universally Administered Addresses, or
- (2) 48-bit Locally Administered Addresses, or
- (3) 16-bit Locally Administered Addresses.

The specific MAC address used by every MAC Entity communicating across the Bridged Local Area Network shall be unique in that network in order to specify the addressed station unambiguously.

3.12.1 End Stations. Frames transmitted between end stations using the MAC Service provided by a Bridged Local Area Network carry the MAC address of the source and destination peer end stations in the source and destination address fields of the frames, respectively. The address, or other means of identification, of a Bridge is not carried in frames transmitted between peer users for the purpose of frame relay in the Bridged Local Area Network.

The broadcast address and other group addresses apply to the use of the MAC Service provided by the Bridged Local Area Network as a whole. Frames with such values of the destination address field are, in the absence of explicit management configuration of the Filtering Database (3.9, Section 6), relayed throughout the Bridged Local Area Network.

3.12.2 Bridge Ports. The individual MAC Entity associated with each Bridge Port shall have a separate specific MAC Address. This address is used by the MAC procedures operated by the MAC Entity, if required by the particular Media Access Method employed.

Frames that are received from the LAN to which a Port is attached and which carry a MAC address for the Port in the destination address field are submitted to the MAC Service User (LLC) exactly as for an end station.

3.12.3 Bridge Protocol Entities. Bridge Protocol Entities only receive and transmit BPDUs. These are only received and transmitted from other Bridge Protocol Entities (or in circumstances where two Bridge Ports are connected to the same LAN, to and from themselves).

A Bridge Protocol Entity uses the DL_UNITDATA.request primitive provided by the individual LLC Entities associated with each active Bridge Port to transmit BPDUs. Each BPDU is transmitted on one selected Bridge Port. BPDUs are received through corresponding DL_UNITDATA.indication primitives. The source_address and destination_address parameters of the DL_UNITDATA.request primitive shall both denote the Standard LSAP assigned to the Bridge Spanning Tree Protocol. This identifies the Bridge Protocol Entity among other users of LLC.

Each DL_UNITDATA.request primitive gives rise to the transmission of an LLC UI command PDU which conveys the BPDU in its information field. The source and destination LSAP address fields are set to the values supplied in the request primitive.

The value assigned to the Bridge Spanning Tree Protocol LSAP is given in Table 3-4.¹

Table 3-4
Standard LSAP Assignment

Assignment	Value
Bridge Spanning Tree Protocol	01000010

Code Representation: The least significant bit of the value shown is the left-most. The bits increase in significance from left to right.

This standard defines a Protocol Identifier field, present in all BPDUs (Section 5), which serves to identify different protocols supported by Bridge Protocol Entities, within the scope of the LSAP Assignment. This standard specifies a single value of the Protocol Identifier in Section 5. This value serves to identify BPDUs exchanged between Bridge Protocol Entities operating the Spanning Tree Algorithm and Protocol specified in Section 4. Further values of this field are reserved for future standardization.

A Bridge Protocol Entity that receives a BPDU with an unknown Protocol Identifier shall discard that BPDU.

A Bridge Protocol Entity that operates the Spanning Tree Algorithm and Protocol specified in Section 4 of this standard always transmits BPDUs addressed to all other Bridge Protocol Entities attached to the LAN on which the frame containing the BPDU was transmitted. A group address shall be used in the destination address field to address this group of Entities. This group address shall be configured in the Permanent Database (3.12.6) in order to confine BPDUs to the individual LAN on which they are transmitted.

A 48-bit Universal Address, known as the Bridge Group Address, has been assigned for this purpose. Its value is specified in Table 3-5. Bridges that use 48-bit Universally Administered Addresses shall use this address in the destination address field of all MAC frames conveying BPDUs.

The source address field of MAC frames conveying BPDUs contains the specific MAC Address for the Bridge Port through which the BPDU is transmitted (3.12.2).

3.12.4 Bridge Management Entities. Bridge Management Entities transmit and receive protocol data units using the Service provided by the individual LLC Entities associated with each Bridge Port. Each of these in turn uses the MAC Service, which is provided by the individual MAC Entities associated with that Port and supported by the Bridged Local Area Network as a whole.

As a user of the MAC Service provided by a Bridged Local Area Network, the Bridge Management Entity may be attached to any point in the Bridged Local Area Network. Frames addressed to the Bridge Management Entity will be relayed by Bridges if necessary to reach the LAN to which it is attached.

In order to ensure that received frames are not duplicated, the basic requirement in a single LAN or a Bridged Local Area Network that a unique address be associated with each point of attachment shall be met.

A Bridge Management Entity for a specific Bridge is addressed by one or more specific MAC addresses in conjunction with the higher layer protocol identifier and addressing information. It may share one or more points of attachment to the Bridged Local Area Network with the Ports of the Bridge with which it is associated. It is recommended that it make use of the MAC Service provided by all the MAC Entities associated with each Bridge Port, i.e., that it be reachable through each Bridge Port using frames carrying the specific MAC address of that Port in the destination address field.

This standard specifies a standard group address for public use which serves to convey management requests to the Bridge Management Entities associated with all Bridge Ports attached to a Bridged Local Area Network. A management request that is conveyed in a MAC frame carrying this address value in the

¹The full list of standard LSAP assignments and criteria for assignment is contained in ISO/IEC Draft Technical Report 10178.

destination address field will generally elicit multiple responses from a single Bridge. This address is known as the All LANs Bridge Management Group Address and takes the value specified in Table 3-6.

Table 3-5
Reserved Addresses

Assignment	Value
Bridge Group Address	01-80-C2-00-00-00
Reserved for future standardization	01-80-C2-00-00-01
Reserved for future standardization	01-80-C2-00-00-02
Reserved for future standardization	01-80-C2-00-00-03
Reserved for future standardization	01-80-C2-00-00-04
Reserved for future standardization	01-80-C2-00-00-05
Reserved for future standardization	01-80-C2-00-00-06
Reserved for future standardization	01-80-C2-00-00-07
Reserved for future standardization	01-80-C2-00-00-08
Reserved for future standardization	01-80-C2-00-00-09
Reserved for future standardization	01-80-C2-00-00-0A
Reserved for future standardization	01-80-C2-00-00-0B
Reserved for future standardization	01-80-C2-00-00-0C
Reserved for future standardization	01-80-C2-00-00-0D
Reserved for future standardization	01-80-C2-00-00-0E
Reserved for future standardization	01-80-C2-00-00-0F

Table 3-6
Addressing Bridge Management

Assignment	Value
All LANs Bridge Management Group Address	01-80-C2-00-00-10

3.12.5 Unique Identification of a Bridge. It is necessary for the operation of the Bridge Protocol specified in Section 4, that a single unique identifier be associated with each Bridge. This identifier is derived from a unique MAC address for the Bridge, known as the Bridge Address.

In a Bridged Local Area Network utilizing locally assigned 16-bit addresses, this address shall be unique among all those assigned in the Bridged Local Area Network.

In a Bridged Local Area Network utilizing 48-bit addresses, this address shall be assigned to be globally unique, i.e., it shall be a 48-bit Universally Administered Address.

It is recommended that this address be the specific MAC Address of the lowest numbered Bridge Port (Port 1).

The unique Bridge Identifier used by the Spanning Tree Algorithm and Protocol is derived from the Bridge Address, as specified in 4.5.3 and 5.2.5.

3.12.6 Reserved Addresses. Frames containing any of the group addresses specified in Table 3-5 in their destination address field shall not be relayed by the Bridge. They shall be configured in the Permanent Database. Management shall not provide the capability to remove these addresses from the Permanent or the Filtering Databases. These group addresses are reserved for assignment to standard protocols, according to the criteria for such assignments (IEEE Std 802 [2], 5.5).

Other group addresses may be configured as static entries in the Permanent Database, without the need for explicit initialization through management. Management may provide the capability to remove these addresses from the Permanent or Filtering Database.

4. The Spanning Tree Algorithm and Protocol

The configuration algorithm and protocol described in this section reduce the Bridged Local Area Network topology to a single Spanning Tree.

4.1 Requirements to be Met by the Algorithm. The Spanning Tree Algorithm and its associated Bridge Protocol operate to Support, Preserve, and Maintain the Quality of the MAC Service in all its aspects as discussed in Section 2. In order to perform this function, the algorithm meets the following requirements, each of which is related to the discussion in that section:

- (1) It will configure the active topology of a Bridged Local Area Network of arbitrary topology into a single spanning tree, such that there is at most one data route between any two end stations, eliminating data loops (2.3.3; 2.3.4).
- (2) It will provide for fault tolerance by automatic reconfiguration of the spanning tree topology as a result of Bridge failure or a breakdown in a data path, within the confines of the available Bridged Local Area Network components, and for the automatic accommodation of any Bridge or Bridge Port added to the Bridged Local Area Network without the formation of transient data loops (2.1).
- (3) The entire active topology will stabilize in any sized Bridged Local Area Network. It will, with a high probability, stabilize within a short, known bounded interval in order to minimize the time for which the service is unavailable for communication between any pair of end stations (2.1).
- (4) The active topology will be predictable and reproducible, and may be selected by management of the parameters of the algorithm, thus allowing the application of Configuration Management, following traffic analysis, to meet the goals of Performance Management (2.1; 2.3.10).
- (5) It will operate transparently to the end stations, such that they are unaware of their attachment to a single LAN or a Bridged Local Area Network when using the MAC Service (2.2).
- (6) The communications bandwidth consumed by the Bridges in establishing and maintaining the spanning tree on any particular LAN will be a small percentage of the total available bandwidth and independent of the total traffic supported by the Bridged Local Area Network regardless of the total number of Bridges or LANs (2.3.10).

Additionally, the algorithm and protocol meet the following goals which limit the complexity of Bridges and their configuration:

- (a) The memory requirements associated with each Bridge Port are independent of the number of Bridges and LANs in the Bridged Local Area Network.
- (b) Bridges do not have to be individually configured before being added to the Bridged Local Area Network, other than having their MAC addresses assigned through normal procedures.

4.2 Requirements of the MAC Bridges. In order for the Bridge Protocol to operate, the following are required:

- (1) A unique MAC group address, recognized by all the Bridges within the Bridged Local Area Network, that identifies the Bridge Protocol Entities of all Bridges attached to an individual LAN.
- (2) An identifier for each Bridge, unique within the Bridged Local Area Network.
- (3) A distinct Port identifier for each Bridge Port, that can be assigned independently of the values used in other Bridges.

Values for each of these parameters, or a mechanism for assigning values to them, shall be provided by each Bridge. In the case of MAC Bridges that use 48-bit Universally Administered Addresses, the unique MAC Address that identifies the Bridge Protocol Entities is the Bridge Group Address (3.12.3).

In addition, to allow the configuration of the Spanning Tree active topology to be managed, the following are required:

- (a) A means of assigning the relative priority of each Bridge within the set of Bridges in the Bridged Local Area Network.
- (b) A means of assigning the relative priority of each Port within the set of Ports of an individual Bridge.
- (c) A means of assigning a path cost component to each Port.

These parameters may be set by management.

The unique identifier for each Bridge is derived, in part, from the Bridge Address (3.12.5) and, in part, from a manageable priority component (5.2.5). The relative priority of Bridges is determined by the numerical comparison of the unique identifiers, with the lower numerical value indicating the higher priority identifier.

Part of the identifier for each Port is fixed and is different for each Port on a Bridge, and part is a manageable priority component (5.2.7). The relative priority of Ports is determined by the numerical comparison of the unique identifiers, with the lower numerical value indicating the higher priority identifier.

The path cost associated with each Port may be manageable. Additionally, 4.10.2 recommends default values for Ports attached to LANs of specific MAC types and speeds.

4.3 Overview

4.3.1 The Active Topology and Its Computation. The Spanning Tree Algorithm and Protocol configure a simply connected active topology from the arbitrarily connected components of a Bridged Local Area Network. Frames are forwarded through some of the Bridge Ports in the Bridged Local Area Network and not through others, which are held in a blocking state. At any time, Bridges effectively connect just the LANs to which Ports in a forwarding state are attached. Frames are forwarded in both directions through Bridge Ports that are in a forwarding state. Ports that are in a blocking state do not forward frames in either direction but may be included in the active topology, i.e., be put into a forwarding state if components fail, are removed, or are added.

Figure 2-2 shows an example of a Bridged Local Area Network. Figure 4-1 shows the active topology, i.e., the logical connectivity, of the same Bridged Local Area Network following configuration.

One of the Bridges is known as the Root or the Root Bridge in the Bridged Local Area Network. Each individual LAN has a Bridge Port connected to it that forwards frames from that LAN towards the Root and forwards frames from the direction of the Root onto that LAN. This Port is known as the Designated Port for that LAN, and the Bridge of which it is part is the Designated Bridge for the LAN. The Root is the Designated Bridge for all the LANs to which it is connected. The Ports on each Bridge that are in a forwarding state are the Root Port (that closest to the Root—see below) and the Designated Ports (if there are any).

In Fig 4-1, Bridge 1 has been selected as the Root (though one cannot tell simply by looking at the topology which Bridge is the Root) and is the Designated Bridge for LAN 1 and LAN 2. Bridge 2 is the Designated Bridge for LAN 3 and LAN 4, and Bridge 4 is the Designated Bridge for LAN 5. Figure 4-2 shows the logical tree topology of this configuration of the Bridged Local Area Network.

The stable active topology of a Bridged Local Area Network is determined by

- (1) The unique Bridge Identifiers associated with each Bridge.
- (2) The Path Cost associated with each Bridge Port.
- (3) The Port Identifier associated with each Bridge Port

The Bridge with the highest priority Bridge Identifier is the Root (for convenience of calculation this is the identifier with the lowest numerical value). Every Bridge Port in the Bridged Local Area Network has a Root Path Cost associated with it. This is the sum of the Path Costs for each Bridge Port receiving frames forwarded from the Root on the least cost path to the Bridge. The Designated Port for each LAN is the Bridge Port for which the value of the Root Path Cost is the lowest: if two or more Ports have the same

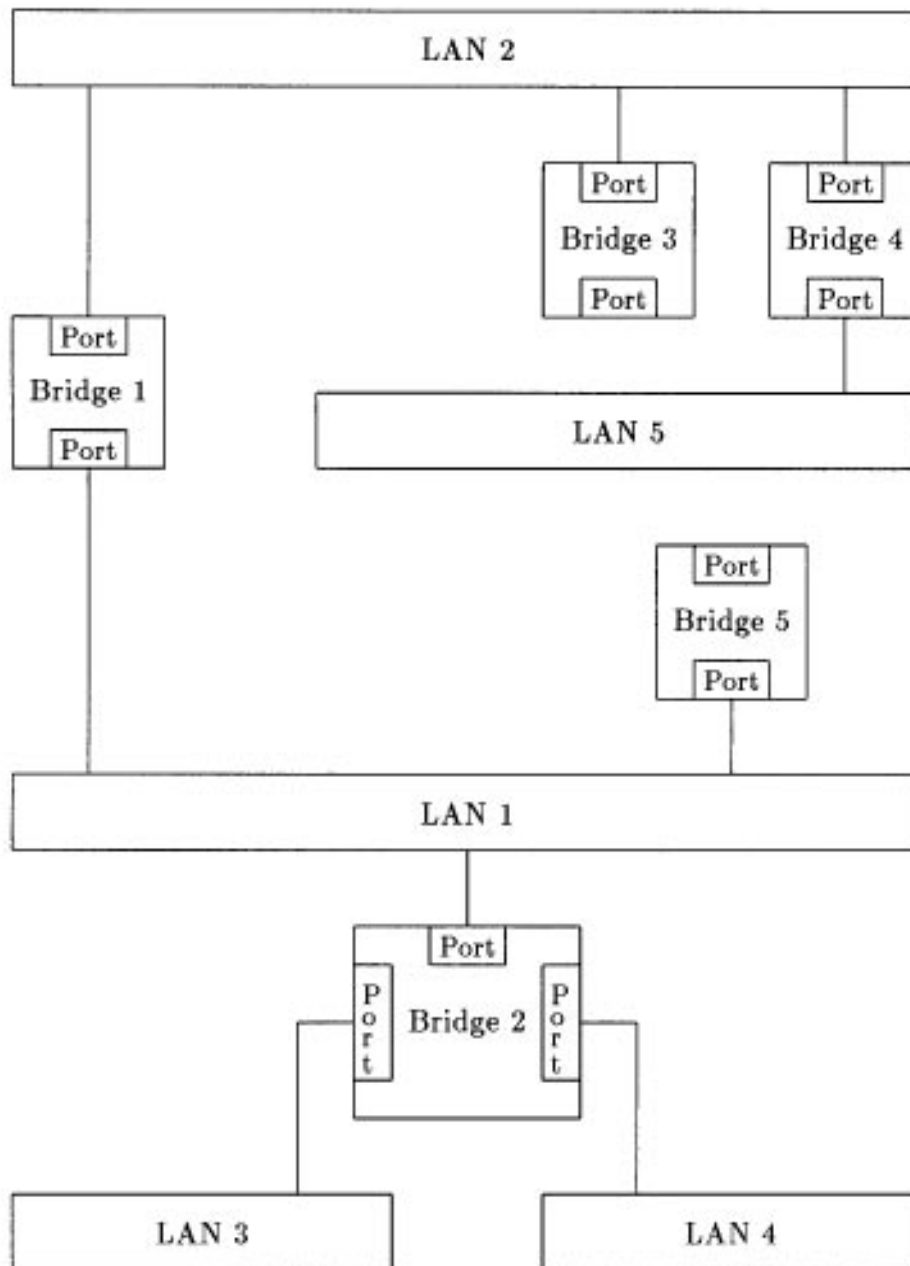


Fig 4-1
Active Topology

value of Root Path Cost, then first the Bridge Identifier of their Bridges and then their Port Identifiers are used as tie- breakers. Thus, a single Bridge Port is selected as the Designated Port for each LAN, the same computation selects the Root Port of a Bridge from amongst the Bridge's own Ports, and the active topology of the Bridged Local Area Network is completely determined.

A component of the Bridge Identifier of each Bridge, and the Path Cost and Port Identifier of each Bridge Port, can be managed, thus allowing a manager to select the active topology of the Bridged Local Area Network.

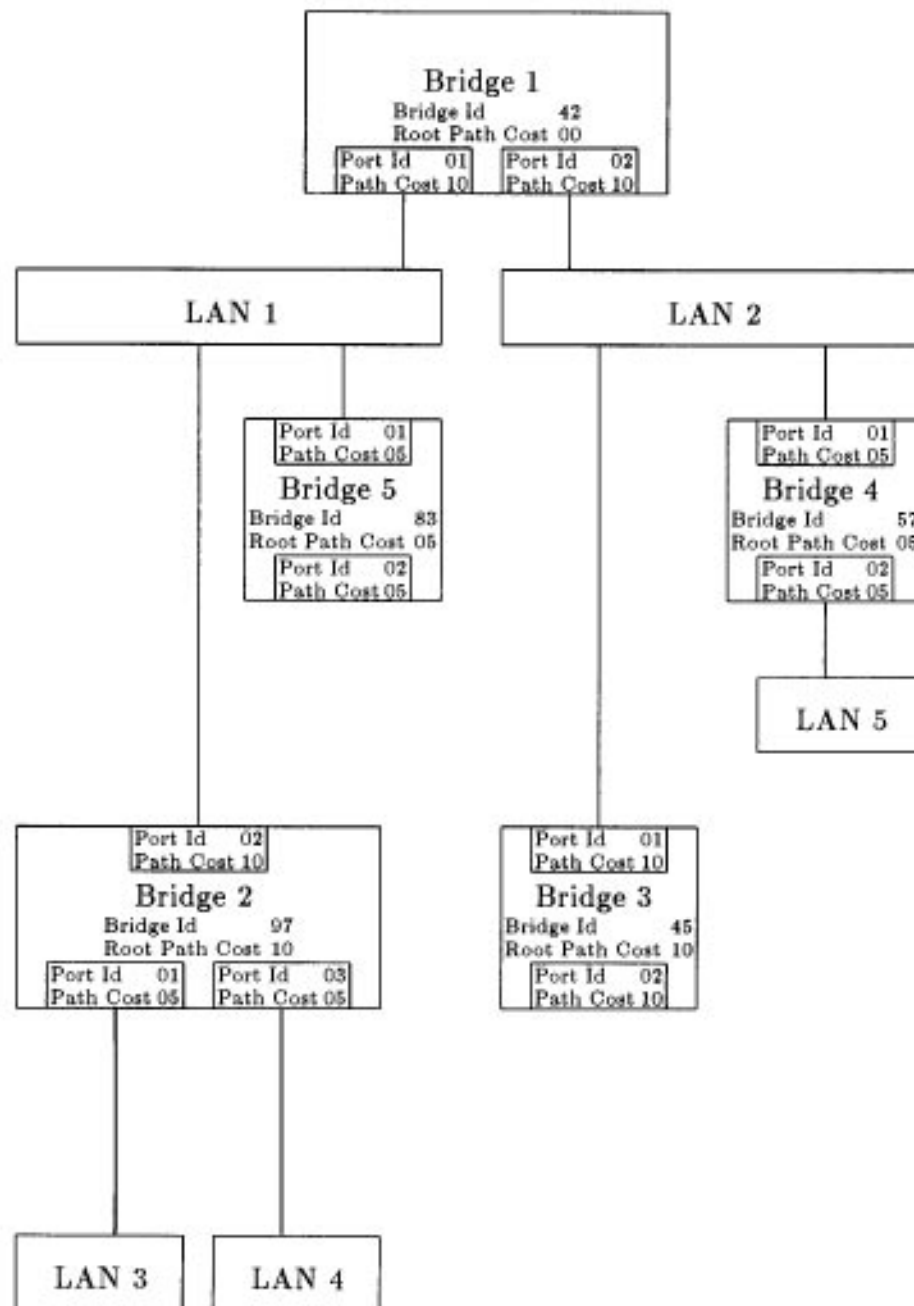


Fig 4-2
Spanning Tree

4.3.2 Propagating the Topology Information. Bridges send a type of Bridge Protocol Data Unit known as a Configuration BPDU to each other in order to communicate and compute the above information. A MAC frame conveying a BPDU carries the Bridge Group Address in the destination address field and is received by all the Bridges connected to the LAN on which the frame is transmitted.

Bridge Protocol Data Units are not directly forwarded by Bridges, but the information in them may be used by a Bridge in calculating its own BPDU to transmit, and may stimulate that transmission. The Con-

figuration BPDUs, which is conveyed between the Bridge Ports attached to a single LAN, is distinguished from the notion of a Configuration Message, which expresses the propagation of the information carried throughout the Bridged Local Area Network.

Each Configuration BPDU contains, among other parameters, the unique identifier of the Bridge that the transmitting Bridge believes to be the Root, the cost of the path to the Root from the transmitting Port, the identifier of the transmitting Bridge, and the identifier of the transmitting Port. This information is sufficient to allow a receiving Bridge to determine whether the transmitting Port has a better claim to be the Designated Port on the LAN on which the Configuration BPDU was received than the Port currently believed to be the Designated Port, and to determine whether the receiving Port should become the Root Port for the Bridge if it is not already.

Timely propagation throughout the Bridged Local Area Network of the necessary information to allow all Bridge Ports to determine their state (blocking or forwarding) is achieved through three basic mechanisms:

- (1) A Bridge that believes itself to be the Root (all Bridges start by believing themselves to be the Root until they discover otherwise); originates Configuration Messages (by transmitting Configuration BPDUs) on all the LANs to which it is attached, at regular intervals.
- (2) A Bridge that receives a Configuration BPDU on what it decides is its Root Port conveying better information (i.e., highest priority Root Identifier, lowest Root Path Cost, highest priority transmitting Bridge and Port), passes that information on to all the LANs for which it believes itself to be the Designated Port.
- (3) A Bridge that receives inferior information on a Port it considers to be the Designated Port on the LAN to which it is attached, transmits its own information in reply for all other Bridges attached to that LAN to hear.

Hence, Spanning Tree paths to the Bridge with highest priority Root Identifier are quickly learned throughout the Bridged Local Area Network, with inferior information about other potential roots and paths being contradicted.

4.3.3 Reconfiguration. To allow for reconfiguration of the Bridged Local Area Network when components are removed or when management changes are made to parameters determining the topology, the topology information propagated throughout the Bridged Local Area Network has a limited lifetime. This is effected by transmitting the age of the information conveyed (the time elapsed since the Configuration Message originated from the Root) in each Configuration BPDU. Every Bridge stores the information from the Designated Port on each of the LANs to which its Ports are connected, and monitors the age of that information.

In normal stable operation, the regular transmission of Configuration Messages by the Root ensures that topology information is not timed out.

If the Bridge times out the information held for a Port, it will attempt to become the Designated Port for the LAN to which that Port is attached, and will transmit protocol information received from the Root on its Root Port on to that LAN.

If the Root Port of the Bridge is timed out, then another Port may be selected as the Root Port. The information transmitted on LANs for which the Bridge is the Designated Bridge will then be calculated on the basis of information received on the new Root Port.

If no record of information from the current Root remains, then the Bridge will reconfigure by claiming to be the Root itself. If the Root has indeed failed, other Bridges will also be timing out protocol information; information as to the best successor and the new topology will rapidly propagate throughout the Bridged Local Area Network. It is also possible that the path to the current Root has changed, perhaps by increasing in cost, and that the reconfiguring Bridge has timed out because it considered more recent information from the Root inferior since it had a higher Root Path Cost. In this latter case, neighboring Bridges will immediately reply to BPDUs transmitted by the aspiring Root.

To ensure that all Bridges in the Bridged Local Area Network share a common understanding of when old information should be timed out, the timeout value is transmitted in all Configuration Messages from the Root. This value takes account of the propagation delays in transmitting and receiving BPDUs on each of the LANs in the Bridged Local Area Network, and thus of propagation of protocol information down the Spanning Tree. To minimize the probability of triggering reconfiguration through the loss of Configuration

Messages, it includes an additional multiple of the time interval at which these are transmitted by the Root.

4.3.4 Changing Port State. Since there are propagation delays in passing protocol information throughout a Bridged Local Area Network, there cannot be a sharp transition from one active topology to another. Topology changes may take place at different times in different parts of the Bridged Local Area Network and to move a Bridge Port directly from non-participation in the active topology to the forwarding state would be to risk having temporary data loops and the duplication and misordering of frames. It is also desirable to allow other Bridges time to reply to inferior protocol information before starting to forward frames.

Bridge Ports must therefore wait for new topology information to propagate throughout the Bridged Local Area Network, and for the frame lifetime of any frames forwarded using the old active topology to expire, before forwarding frames.

During this time it is also desirable to time out station location information in the Filtering Database that may no longer be true and, during the latter part of this interval, to learn new station location information in order to minimize the effect of initial flooding of frames when the Port enters a forwarding state. When the algorithm decides that a Port should be put into the Forwarding State, it is, therefore, first put into a Listening State where it waits for protocol information that suggests it should return to the Blocking State, and for the expiry of a protocol timer that would move it into a Learning State. In the Learning State, it still blocks the forwarding of frames, but learned station location information is included by the Learning Process in the Filtering Database. Finally the expiry of a protocol timer moves it into the Forwarding State where both forwarding of relayed frames and learning of station location information are enabled.

Figure 4-3 shows the transitions between the Port States.

4.3.5 Notifying Topology Changes. In normal stable operation, station location information in the Filtering Database need only change as a consequence of the physical relocation of stations. It may, therefore, be desirable to employ a long ageing time for entries in the Filtering Database, especially as many end stations transmit frames following power-up after relocation which would cause station location information to be relearned.

However, when the active topology of a Bridged Local Area Network reconfigures, end stations may appear to move from the point of view of a Bridge in the network. This is true even if the states of the Ports on that Bridge have not changed. It is necessary for station location to be relearned following a change in the active topology, even if only part of the Bridged Local Area Network has reconfigured.

The Spanning Tree Algorithm and Protocol provide procedures for a Bridge which detects a change in active topology to notify the Root of the change reliably, and for the Root subsequently to communicate the change to all the Bridges. The Bridges then use a short value to ageout dynamic entries in the Filtering Database for a period.

When a Bridge that is not the Root changes the active topology of the Bridged Local Area Network, it transmits a Topology Change Notification BPDU on the LAN to which its Root Port is attached. This transmission is repeated until the Bridge receives an acknowledgment from the Designated Bridge for that LAN. The acknowledgment is carried in a Configuration BPDU, thus the notification will eventually be acknowledged or further reconfiguration will take place. The Designated Bridge passes the notification to, or towards, the Root using the same procedure.

If the Root receives such a notification, or changes the topology itself, it will set a Topology Change flag in all Configuration Messages transmitted for some time. This time is such that all Bridges will receive one or more of the Configuration Messages, or further reconfiguration will take place. While this flag is set, Bridges use the value of Forwarding Delay (the time interval spent in each of the Listening and Learning States) to age out dynamic entries. When the flag is reset again, Bridges revert to using the Filtering Database Ageing Time.