Standard Guide for Digital Communication Protocols for Computerized Systems[1]

1. Scope

1.1 The principal content of this guide provides a road map to implement a communication network applicable to ship and marine computer systems by:

1.1.1 Examining the relationship of digital communication protocols as a network technological infrastructure,

1.1.2 Outlining the basic building blocks of network topologies and transmission techniques associated with the implementation of transmission media in a network environment; and,

1.1.3 Identifying operating system and environments.

1.2 Using the Open System Interconnection (OSI) model, which provides a layered approach to network functionality and evaluation, common network communications protocols are identified and characterized in this guide according to lower and upper layer protocols corresponding to their degree and type of functionality.

1.3 Although it is desirable that network users, designers, and administrators recognize and understand every possible networking protocol, it is not possible to know the intimate details of every protocol specification. Accordingly, this guide is not intended to address fully every hardware and software protocol ever developed for commercial use, which spans a period of about 25 years. Instead, the user of this guide will be introduced to a brief overview of the majority of past and present protocols which may comprise a ship or marine internetwork, to include Local Area Networks (LANs), Wide Area Networks (WANs), and related hardware and software that provide such network interoperability and data transfer.

1.4 While this guide provides an understanding of the wide range of communication protocols, the user is recommended to consult the reference material for acquiring a more comprehensive understanding of individual communication protocols. However, by examining the basic functions of protocols and reviewing the protocol characterization criteria identified in this guide, the user will be more apt to understanding other protocols not mentioned or addressed herein.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1013 Terminology Relating to Computerized Systems (Withdrawn 2000)[3]

2.2 *ANSI Standards:*[4]

X3T9.5 High Speed Local Network

X3.139 Fiber Distributed Data Interface (FDDI) – Token Ring Media Access Control (MAC)

X3.148 Fiber Distributed Data Interface (FDDI)– Token Ring Physical Layer Protocol (PHY)

X3.166 Fiber Distributed Data Interface (FDDI) – Token Ring Physical Layer Medium Dependent (PMD)

X3.172 American National Standard Dictionary for Information Systems

2.3 *IEEE Standards:*[5]

100 Standard Dictionary for Electrical and Electronic Terms

610 Standard Glossary for Software Engineering Terminology

610.7 Standard Glossary of Computer Networking Terminology

802.1 High Level Interface (Internetworking)

802.2 Logical Link Control

802.3 CSMA/CD Medium Access Control

802.4 Token Bus Medium Access Control

802.5 Token Ring Medium Access Control

802.6 Metropolitan Area Networking

802.8 Fiber Optic Technical Advisory Group

802.9 Local and Metropolitan Area Networks: Integrated Services (IS) LAN Interface at the Medium Access Control (MAC) and Physical (PHY) Layers

[1] This guide is under the jurisdiction of ASTM Committee F25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.05 on Computer Applications.

Current edition approved May 1, 2015. Published June 2015. Originally approved in 1996. Last previous edition approved in 2008 as F1757 – 96 (2008). DOI: 10.1520/F1757-96R15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

[5] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331, http://www.ieee.org.

803.5

2.4 *ISO Standards:*[4]

7498 Information Processing Systems–Open Systems Interconnection–Basic Reference Model
9040/9041 Virtual Terminal (VT)
8831/8832 Job Transfer and Manipulation (JTM)
8571/8572 File Transfer Access Management (FTAM)
9595/9596 Common Management Information Service/Protocol (CMIP)
8823 Connection Oriented Presentation Protocol
8327 Connection Oriented Session Protocol
8073 Connection Oriented Transport Protocol
8473 Connectionless Network Service
8208 Packet Level Protocol
8802-2 Logical Link Control
9314-2 FDDI
8802-3 CSMA/CD (Bus)
8802-4 Token Bus
8802-5 Token Ring
7776 Link Access Protocol/Link Access Protocol-Balanced (LAP/LAPB)
7809 High-Level Data Link Control (HDLC)

2.5 *ITU Standards:*[6]

X.25 Packet Level Protocol
X.226 Connection Oriented Presentation Protocol
X.225 Connection Oriented Session Protocol
X.224 Connection Oriented Transport Protocol

2.6 *CCITT Standards:*[7]

V.35
X.21 (BIS) Interface Between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) for Synchronous Operation on Public Data Networks
X.25 Interface Between Data Terminal Equipment (DTE) and Data Circuit Terminating Equipment (DCE) for Terminals Operating in the Packet Mode and Connected Public Data Networks by Dedicated Circuit

2.7 *EIA/TIA Standard:*[7]

232C
568 Commercial Building Telecommunications Wiring Standard (ANSI/EIA/TIA-568-91)

2.8 *Internet Request for Comments (RFCs) Standards:*[8]

RFC 768 User Datagram Protocol (UDP)
RFC 791 Internet Protocol (IP)
RFC 792 Internet Control Message Protocol (CMP)
RFC 793 Transmission Control Protocol (TCP)
RFC 821 Simple Mail Transfer Protocol (SMTP)
RFC 826
RFC 854 TELNET Protocol
RFC 894
RFC 903
RFC 959 File Transfer Protocol (FTP)
RFC 1042
RFC 1157 Simple Network Management Protocol
RFC 1201

3. Terminology

3.1 *Definitions:*

3.1.1 The terminology used in this guide is defined in Terminology E1013, IEEE 610, and ANSI X3.172, with the following additions defined in 3.2.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bridge, n*—a device that interconnects local or remote networks no matter what network protocol that is, TCP/IP or IPX, are involved. Bridges form a single logical network.

3.2.2 *hub, n*—a central location for the attachment of cables from nodes and other network components.

3.2.3 *internetwork, n*—a collection of LANs using different network operating systems that are connected to form a larger network.

3.2.4 *LAN (local area network), n*—a data communication system consisting of a collection of interconnected computers, sharing applications, data and peripherals.

3.2.5 *network operating system (NOS), n*—the software for a network that runs in a file server and control access to files and other resources from multiple users.

3.2.6 *node(s), n*—any intelligent device connected to the network. This includes terminal servers, host computers, and any other devices, such as printers and terminals, that are directly connected to the network.

3.2.7 *protocol, n*—a standard method of communicating over a network.

3.2.8 *repeater, n*—a network device that repeats signals from one cable onto one or more other cables, while restoring signal timing and waveforms.

3.2.9 *router, n*—a device capable of filtering/forwarding packets based upon data link layer information.

3.2.10 *server, n*—a device that stores data for network users and provides network access to that data.

3.2.11 *topology, n*—the arrangement of the nodes and connecting hardware that comprises the network.

3.2.12 *WAN (wide area network), n*—a network using common carrier transmission services for transmission of data over a large geographical area.

4. Significance and Use

4.1 This guide is intended to provide an understanding of the wide range of communication protocols standards, allowing the user to understand better their applicability to shipboard networks and marine platform computerized systems. For computerized networks and systems, communication protocols are necessary for integrating various system devices, providing functionality between dissimilar subnetworks, or for enabling remote connections, either pier side or through geophysical communication technologies.

[6] Available from Electronic Industries Alliance (EIA), 2500 Wilson Blvd., Arlington, VA 22201, http://www.eia.org.

[7] Available from the U.S. Department of Commerce, National Technical Information Service (NTIS), 5285 Port Royal Rd., Springfield, VA 22161, http://www.ntis.gov.

[8] Documents may be obtained by means of anonymous ftp from the hosts:ds.internic.net, directory rfc.

4.2 The wide variety and scope of digital communication protocol standards adds greatly to the complex decision process for specifying compatible protocols for system applications and related devices for the myriad of potential shipboard systems. However, the user must identify the initial networking requirements, so once the network protocols under evaluation are well understood, the decision process should determine the appropriate network protocols. Therefore, this guide is intended to reduce the complexity involved with protocol selection and implementation.

4.3 Network protocols define an agreed, quantifiable entity, or set of rules, by which user computers, system networks, and internetworking devices communicate and exchange information. Communication protocols specify essential networking guidelines, such as physical interface connections, or data format and control operations between two communicating computers. Ship and marine digital communication protocol requirements are no different than their land-based networked counterparts. Both require standardized protocol selection, in various protocol categories, including LAN standards, WAN protocols, LAN/WAN protocols, network management, wiring hub configurations/operations, hardware platforms, operating systems, and network applications.

5. Origin of Protocol Development

5.1 Communication protocol standards have been developed or refined through three separate processes, identified as follows:

5.1.1 *Defacto Protocol Standards*—Acquired widespread use of a popular technique adopted by vendors and developers;

5.1.2 *Dejur Protocol Standards*—Standards making bodies; and,

5.1.3 *Proprietary Protocol Standard*—Private corporation-based protocols with limited interoperability.

5.2 The open standards approach is now the norm, which allows multiple protocol networking solutions to be available, and as a result, proprietary protocols are now becoming obsolete.

6. Local Network Interconnection

6.1 The characteristic of a local network is determined primarily by three factors: transmission medium, topology, and medium access control protocol.

6.1.1 The principal technological elements that determine the nature of a local network are the topology and transmission medium of the network. Together, it determines the type of data that may be transmitted, the speed and efficiency of communications, and the type of applications that a network may support.

6.1.2 Interconnecting a set of local networks is referred to as an internetworking. The local networks are interconnected by devices generically called gateways. Gateways provide a communication path so that data can be exchanged between networks.

6.2 *Topology*—The common topologies used for local networks are star, ring, and bus/tree (see Fig. 1).

6.2.1 *Star Topology*—In a star topology, a central switching element is used to connect all the nodes in the network. The central element uses circuit switching to establish a dedicated path between two stations wishing to communicate (see Fig. 1).

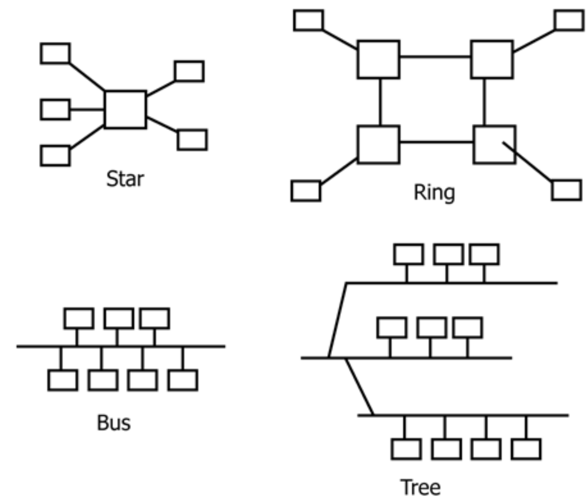


FIG. 1 Local Network Topologies

6.2.2 *Ring Topology*—The ring topology consists of a closed loop, with each node attached to a repeating element. Data circulate around the ring on a series of point-to-point data links between repeaters. A station wishing to transmit waits for its next turn and then sends data out onto the ring in the form of a packet (see Fig. 1).

6.2.3 *Bus/Tree Topology*—The bus or tree topology is characterized by the use of a multipoint medium. The bus is simply a special case of the tree, in which there is only one trunk, with no branches. Because all devices share a common communications medium, only one pair of devices on a bus or tree can communicate at a time. A distributed medium access protocol is used to determine which station may transmit (see Fig. 1).

6.3 *Internetwork Topology*—The common topologies used to support emerging networking topologies requiring the integration of data, video and voice, as well as higher transport bandwidth are backbone, hierarchical, and mesh (see Fig. 2).

6.3.1 *Backbone*—Backbone configurations are used in networking environments in which local networks are connected over high-speed backbone cables. Bridges and routers are used to manage the data passing between interconnected networks and the backbone (see Fig. 2).

6.3.2 *Hierarchial*—In the hierarchial configuration, star-configured hubs are wired to a central hub that handles interhub traffic. Routers and Asynchronous Transfer Mode (ATM) technology provide support to traffic intensive network applications requiring the integration of voice, video, and data (see Fig. 2).

6.3.3 *Mesh*—In mesh configurations, there are at least two pathways to each node. This is a common configuration in emerging high-speed enterprise networks requiring the integration of voice, video, and data. It is composed of internetworking devices, such as bridges, routers, and ATM technology. The internetworking devices provide efficient paths for data to travel from one point to another in this configuration. Mesh networks often are used because of reliability; when one path goes down, another can take over (see Fig. 2).

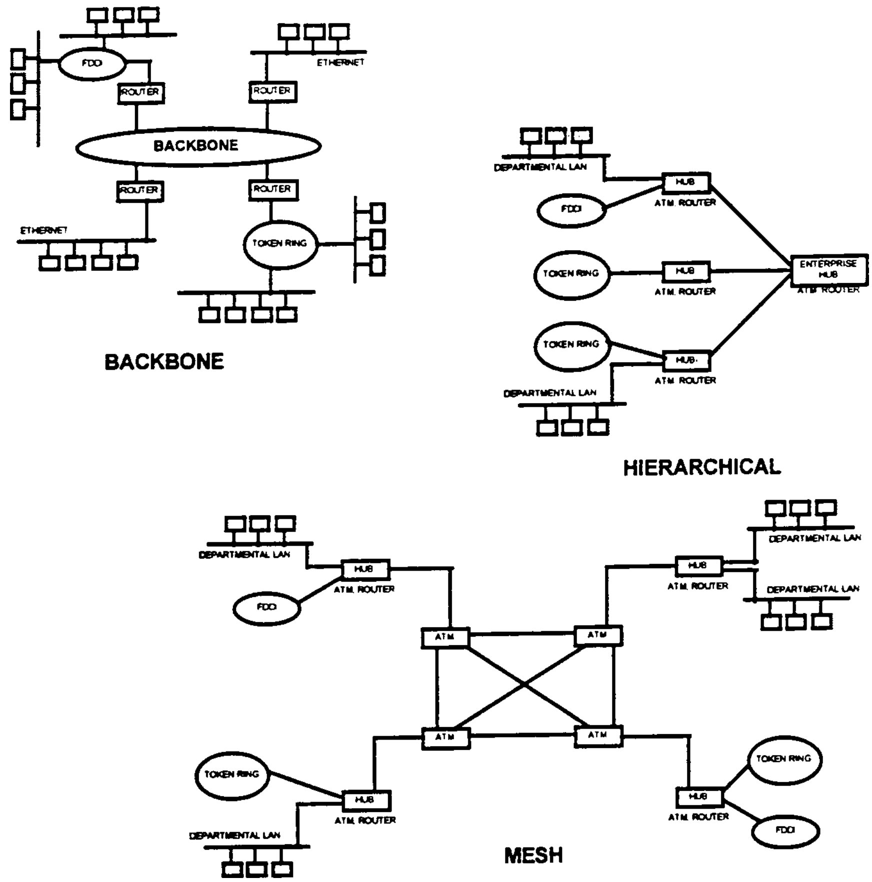


FIG. 2 Internetwork Topology

6.4 *Cabling*—Cabling falls into the following categories: coax, twisted pair, and fiber.

6.4.1 *Coax:*

6.4.1.1 *Thicknet*—The standard Thicknet is IEEE 802.3 10BASE5. It is a 0.4-in. diameter RG 4 50-Ω coaxial cable. It may be up to 500 m in length. A maximum of 100 devices can be attached to this cable.

6.4.1.2 *ThinNet*—The standard for ThinNet is IEEE 802.3 10BASE2. It is a 0.25-in. diameter RG58A/U 50-Ω coaxial cable. It can be up to 185 m in length and have a maximum of 30 devices attached to it. Each device normally is attached at 0.5-m increments via a BNC T-connector. However, devices may be attached to an AUI cable and external transceiver.

6.4.2 *Twisted Pair:*

6.4.2.1 The standard for twisted pair is EIA/TIA-568. It is a 24-AWG telephone wire. The ends of the twisted pair wires are composed of RJ-45 or RJ-11 telephone-style connectors. Each device connects to a network wiring hub which controls or passes the network signal. There are five category ratings for twisted pair wiring, LVL/CAT-1 through LVL/CAT-5.

6.4.2.2 There are two major types of twisted pair: unshielded twisted pair (UTP) and shielded twisted pair (STP). Environmental surroundings dictate what type of twisted pair is used. If the environment is prone to a high degree of electrical interference, STP is used.

6.4.3 *Optical Fiber*—See Table 1.

TABLE 1 Optical Fiber Cabling

Type	Light Source	Bandwidth	Primary Application
Single mode	laser	100 GHz	telephone traffic
Multimode	LED	1-2 GHz	data traffic

6.5 Table 2 provides a generalized comparison of the advantages and disadvantages of the technical characteristics of local networks, using the transmission medium as a frame of reference.

Service Classes of Local Networks and Bandwidth Networks—Computer networks that serve as components of a communication network provide support to a large multitude of service classes (see Table 3).

6.5.1 *Local Area Network (LAN)*—The LAN provides services to support a group of interconnected computers to share applications, data, and peripherals. Bandwidth service is from 1 to 10 Mbps.

6.5.2 *High-Speed Local Area Networks (HSLN)*—The HSLN provides a service in the range of 50 Mbps to 1 Gpbs. There are two key applications for HSLN: backend and backbone networks. A backend HSLN main function is to provide high end-to-end throughput between high-speed devices, such as servers and mass storage devices. A backbone HSLN provides a LAN or WAN that interconnects intermediate systems. Fiber optic cables are used as a transmission medium to internetwork topologies.

TABLE 2 Technical Characteristics of LANS

	Transmission Medium			
Characteristic	twisted pair (UTP, STP)	baseband coaxial cable	broadband coaxial cable	fiber optic cable
Topology	bus, star, or ring	bus or ring	bus or ring	bus, star, or ring
Channels	single channel	single channel	multichannel	single, multichannel
Data rate	normally up to 4 Mbps or 16 Mbps; up to 100 Mbps obtainable	normally 2 to 10 Mbps; up to 100 Mbps obtainable	up to 400 Mbps	up to 1 Gbps
Maximum nodes on net	usually <255	usually <1024	several thousands	several thousands
Major advantages	low cost; may be able to use existing wire	low cost; simple to install	supports voice, data, and video applications simultaneously	supports voice, data, and video applications simultaneously
Major disadvantages	limited bandwidth, requires conduits; low immunity to noise	low immunity to noise	high cost; difficult to install; requires RF modems	cable cost; difficult to splice

TABLE 3 Classes of Local Networks

	Local Area Network	High-Speed Local Network	WAN
Transmission medium	twisted pair, coax, fiber	twisted pair, CATV coax, fiber	public/private data network providers
Topology	bus, tree, ring	backbone, hierarchical, mesh	point-to-point
Transmission speed	1-20 Mbps	50 Mbps - 1 Gbps	56 Kbps - 45.5 Mbps
Switching technique	packet, circuit	packet, circuit	packet, circuit

6.5.3 *Wide Area Network (WAN)*—A network that covers a large geographic area. The differences between WAN and LANs are as follows:

6.5.3.1 *Economic*—WAN services are purchased; LANs are owned.

6.5.3.2 *Technical*—WANs are made up of point-to-point links; LANs are shared-media.

6.6 *Medium Access Control Protocol*—To facilitate the sharing of the transmission among network stations, a proper medium access control scheme must be implemented to control, coordinate, and supervise the access of user information to and from the shared transmission medium:

6.6.1 *LAN*—IEEE 802.3, IEEE 802.4, and IEEE 802.5 (CSMA/CD, token bus, and token ring) LAN protocols.

6.6.2 *HSLN*—IEEE 802.2 (FDDI fiber token ring protocol) or IEEE 802.6 DQDB, ATM.

6.6.3 *WAN*—X.25 Frame Relay, ATM.

6.7 *Internetworking (Gateways and Routers)*—Internetworking is the interconnection and interoperability of small-size local networks into existing networks. A local network should have the capability to support multiple protocols and allow difference environments to operate in parallel. Internetworking devices available for these services are Routers and Gateways.

6.7.1 Routers are devices that implement the network service. Routers are required to support multiple protocol stacks, each with its own routing protocols, and to allow these different environments to operate in parallel.

6.7.2 Gateways are applications specific that connect different architectures. It also provides translation services between different protocols.

6.8 *Types of LANs*—LANs are descriptive in their configuration at two levels: administrative relationship between nodes (stations) and physical and logical relationship among nodes.

6.8.1 *Administrative Relationship Between Nodes (Station)*—LANs are divided into server-based and peer-to-peer LANs. Server-based LAN (client server) controls access to some resource, such as a hard disk or printer, and serves as a hosts for the workstations connected to the server. A workstation request services, such as access to fields or programs on the hard disk or use of a printer, from a server.

6.8.1.1 Servers run the network operating system (NOS) software; workstations run client software that manages the communication between the workstation and the network.

6.8.1.2 Peer-to-peer LANs involve direct communications between computing devices without a dedicated server.

6.8.2 *Physical and Logical Relationship Among Nodes*—This has to do with the manner in how data is transmitted over a network. The physical is concerned with the topology, that is, bus, ring, or star, and logical refers to the method of data transport that is Ethernet, Token Ring, FDDI, ATM, and so forth.

6.9 *Network Operating System (NOS)*—The NOS runs on a server and is responsible for processing requests from workstations, for maintaining the network, and for controlling the services and devices available to users. An NOS may replace the native operating system or run as a program on top of the native operating system. Current NOS available are: NOVELL Netware, WINDOWS NT, LANtastic, BANYAN, IBM LAN Server, LAN Manager, AppleShare/AppleTalk.

6.10 *Operating System (OS)*—Operating systems bring together disparate computing resources and present the user with more convenient abstractions. These resources include devices for processing, storing, and transmitting information:

6.10.1 *DOS (Disk Operating System)*—Single-user operating system for the personal computer (PC).

6.10.2 *Windows 95/NT*—Microsoft windows product replacing Windows 3.1 and Windows for Workgroup 3.11. It provides system monitor utilities, remote access, network e-mail, fax capabilities, and file-and printer-sharing for both Windows-based and Netware-based clients.

6.10.3 *OS/2*—A multicasting operating system originally developed by IBM and Microsoft for use with Intel's microprocessor and IBM's Personal System/2 (PS/2) computers.

6.10.4 *MAC OS*—Apple's Mac operating system.

6.10.5 *UNIX*—A multitasking, multiuser operating system developed by AT&T. This means that more than one user can use the same computer (programs, file system, memory, CPU) by logging in off of different ports (serial, Ethernet, Internet, and so forth).

6.11 *Operating Environments*—Operating environments provide computing flexibility and power to have more than one application active at the same time. They allow users to activate and switch several applications simultaneously.

6.11.1 *Windows 3.1*—This program provides an environment for running 16-bit Windows and DOS applications. It also supports multimedia, true-type fonts, compound documents (OLE), as well as drag-and-stop capabilities.

6.11.2 *Windows for Workgroups*—This program is a LAN-capable version of MS Windows 3.1 environment providing integrated file sharing, electronic mail (Microsoft Mail), and workgroup scheduling (Schedule +) capabilities. Windows for Workgroups 3.11 also supports 32–bit disk and file access.

6.11.3 *Windows 95/NT*—This program provides utilities, protocols, and services for a LAN environment running client software with support for Windows, Windows NT Workstation, Windows for Workgroups, MS-DOS, Macintosh, OS/2, and UNIX.

6.11.4 *X Window System*—A network-based widowing system. It provides an application interface for graphic window displays.

7. OSI Layers of Functionality

7.1 The OSI is a reference model put forth by the International Standards Organization (ISO) for communication between computer equipment and networks partitions computer communication functions into seven layers. Each layer provides a certain kind of service to the next higher layer. This service is provided by communicating with the peer entity in same layer of the remote host using the service provided by the next lower layer. This model explains what each layer does. The model is often used to explain a suite of protocols, not just OSI, to allow computers to share resources across a network (see Table 4).

7.2 The content of each of the first four layers is dictated by the parameters of the network technology, and the upper three by the demands of the application user. As shown in Fig. 3, the lowest four layers, which are physical (1), data link (2), network (3), and transport (4), correspond roughly to protocols used in all networks. Physical distinguishes individual (0,1) bits, data link allows reliable transmission of groups of bits between adjacent computers, network provides safe routing data packets between distant source and distinction computers, and transport lets programs running on different computers exchange sequences of possibly long messages.

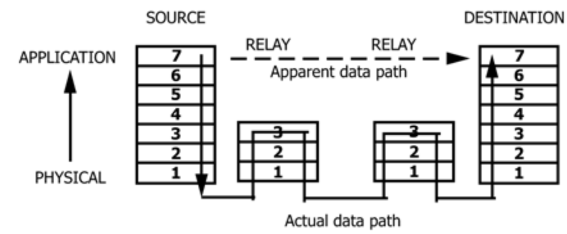


FIG. 3 Protocol Layers in the OSI Model

7.3 The bottom three layers are implemented by communications carrier hardware or by LAN interfaces. Transport software runs on user computers. The highest three layers, session (5), presentation (6), and application (7), are intended to serve the needs of the application or application-specific elements.

7.4 For WANs, the intermediate-node routing function, network layer, is important, but media access is simple, usually a maker of making a leased, dial-up connection or satellite. Conversely, for LANs and MANs, no routing decisions need be made, and the network layer is essentially absent, although the multiaccess protocol can become quite sophisticated.

8. Layers of Interconnection

8.1 The OSI model allows networks to be interconnected at Layers 1 through 3 and 7. Interconnections between LANs and WANs usually occur at Layers 2 through 4 except for protocol conversion between specific applications, such as electronic mail which occur at Layer 7. A generic LAN/WAN interconnection function must operate at the lower OSI layers.

8.2 *Model Structure*—The OSI presents an abstract reference model to describe the computer communications. A layering techniques is used to divide the functions in to distinct yet connected layers. The seven layers can be partitioned into two main infrastructures, the lowest three layers provide internetworking services and the upper four layers are the users of these services. The upper layers, together, provide common network application services. One of the layers, the Transport Layer (4), serves as the boundary between the network-specific elements and the application-specific elements (see Fig. 4):

8.2.1 Lower layer infrastructure providing the end-to-end services responsible for data transfer.

TABLE 4 OSI Layers of Functionality

Layer	Name	Function
7	Application	Provides end-user services, such as application layer file transfers, electronic messages, virtual terminal emulation, remote database access, and network management. The end user interacts with the application user.
6	Presentation	Provides for the representation of information that is communicated between or referred to by application processes.
5	Session	Provides the means to organize and synchronize the dialog between application processes and manage their data.
4	Transport	Provides the transparent transfer of data between systems.
3	Network	Provides routing and relaying through immediate system. In intermediate systems in which there is no application program involved in the communication, the packets are only processed by the lower three layers.
2	Data link	Provides for the transfer of data between directly connected systems and detects any errors in the transfer.
1	Physical	Provides the transparent transmission of bit streams between systems including relaying through different media.

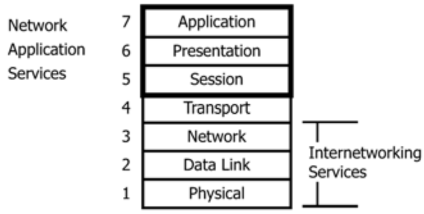


FIG. 4 OSI Model Structure

8.2.2 Upper layer infrastructure providing the application services responsible for information transfer.

8.2.3 Each layer provides a well-defined function. Conceptually, these layers can be considered as performing one of two functions:

8.2.3.1 *Network-Dependent Functions*, lower layer.

8.2.3.2 *Application-Oriented Functions*, upper layer.

8.2.4 Thus when interconnecting networks, communication services are characterized by the following:

8.2.4.1 *Data Link Protocol*—Ethernet, Token Ring, FDDI, and ATM.

8.2.4.2 *Network Protocol*—IP, IPX, TCP, IPVINES, NETBIOS, and NETBEUL.

8.2.4.3 *Higher Level Protocol (NOS)*—Netware, Appletalk, Banyan VINES, Windows NT, IBM OS/2 LAN Manager, and so forth.

8.2.5 A canonical form of a layered communication protocol is illustrated in Fig. 5.

9. Protocol Characterization–Upper Versus Lower Layer Protocols

9.1 The characterization of common network protocols based on the layers of the OSI reference model provides a comparative technique to separate the various communication protocols into two categories. This perspective characterizes communication protocols based on their functionality and operations. By examining the seven layers of the OSI reference model, a lower and upper layer grouping for protocol characterization is developed to provide a better understanding for subsequent protocol selection for shipboard systems. This upper and lower layer characterization perspective is not perfect. Some communications protocols do not correspond exactly to the OSI layers in terms of functionality, while another popular protocol suite similar to the entire OSI network model does not fully correspond exactly to all the OSI layers.

9.2 The communication protocols described in this guide, which are based on the two lowest layers, the data link and physical layers of the OSI model, may differ among themselves with respect to levels of maturity and degree of commercial implementation. These lower layer protocols consists of a mixture of LAN and WAN technology protocols.

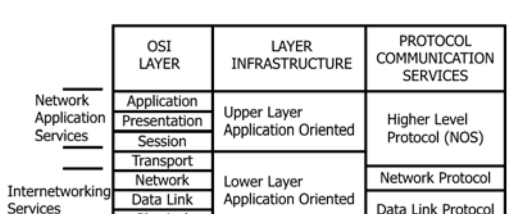


FIG. 5 Characterization of Protocol Grouping

9.3 Upper layer protocols, in contrast, are often found to be families, or suites of protocols, developed as total networking solutions which mainly were developed as proprietary, corporate-based networking schemes. In addition, many upper layer protocols support integration with other upper and lower level protocols, enhancing their popularity and implementation possibilities with dissimilar protocols. Several of these protocols described in this guide were developed by standard groups, although sometimes only portions of the "dejure" protocol suites have been adopted commercially for certain applications.

10. Lower Level Protocols

10.1 The lower level protocols are the standards, specifications, and physical characteristics associated with the implementation of transmission media in a local network environment.

10.1.1 *Ethernet*—Ethernet is based on IEEE 802.3 standards. The standards that define IEEE 802.3 (see Table 5) networks have been given names that follow the form "s type 1." The S refers to the speed of the network in Mbps, type is BASE for baseband and BROAD for broadband, and I refers to the maximum segment length in 100–m multiples. Table 5 shows the operating characteristics of three currently defined IEEE 802.3 networks to Ethernet.

10.1.2 *Token Ring*—Token ring is based on IEEE 802.5 standards. It can be either a 4- or 16-Mbps LAN. Instead of connecting to HUB, the lobe runs connect to either a multistation access unit (MAU) or cable access unit (CAU). A maximum of 260 devices can be connected to a MAU or CAU star-wired ring, depending on the type of cable interface. IBM supports up to 260 devices attached to a MAU via the IBM cabling. With UTP, only 72 can be connected to a MAU and 144 to a CAU. See Table 6.

10.1.3 *Fiber Distributed Data Interface*—FDDI is based on IEEE 802.8 standards. FDDI networks operate at 100 Mbps over either fiber optic or twisted pair transmission media, using a counter-rotating redundant, dual-ring topology. The total length of the dual ring may not exceed 100 km (or 200 KM when wrapped or connected during a fault condition), with a maximum of 500 attached stations.

10.1.4 *X.25 (see Fig. 6)*—X.25 is a packet-switched network not transparent to attached stations, even during the data transfer phase. At a minimum, the network layer protocol must provide a service for transferring data between stations. This service may be either a virtual-circuit service (connection-oriented) or a datagram service (connectionless). Most public networks provide a virtual-circuit service. X.25 encompasses the first three layers of the OSI model.

10.1.4.1 *Layer 1*—The physical layer is concerned with electrical or signalling. It includes standards, such as V.35, X.21(BIS), EIA232C.

10.1.4.2 *Layer 2*—The data link layer manages the transfer of data units called frames from one open system to another. The data link layer specified in X.25 is called LAP-B (Link Access Procedure Balanced).

TABLE 5 Physical Layer Specification[A]

Operational Characteristics	Ethernet	10BASE5	10BASE2	10BASET	10BASEF	100BASET
Operating rate, Mbps	10	10	10	10	10	100
Access protocol	CSMA/CD	CSMA/CD	CSMA/CD	CSMA/CD	CSMA/CD	CSMA/CD
Type of signaling	baseband	baseband	baseband	baseband	baseband	baseband
Data encoding	Manchester	Manchester	Manchester	Manchester	Manchester	Manchester
Max segment length, m	500	500	186	100	1000	100
Stations/segment	100	100	30	12/Hub	—	12/Hub
Medium	50-Ω coaxial	50-Ω coaxial	50-Ω coaxial	twisted pair (UTP, STP)	optical fiber	twisted pair (UTP, STP) optical fiber
Topology	bus	bus	bus	star	bus	star

[A] Based on IEEE 802.3 (CSMA/CD).

TABLE 6 Transmission Speeds

Cable Type	Transmission Speed
IBM Type 1	4 Mbps; lobes can be up to 100 ft 16 Mbps lobes can be up to 500 ft
IBM Type 2	4 Mbps; lobes can be up to 500 ft 16 Mbps; lobes can be up to 164 ft
IBM Type 3	26 Mbps; lobes can be up to 328 ft or 100 m

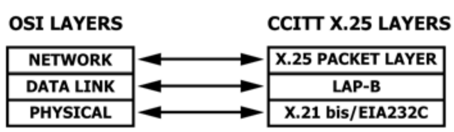


FIG. 6 Layers

10.1.4.3 *Layer 3*—The X.25 Packet Level Protocol (PLP) provides network-routing functions and the multiplexing of simultaneous logical connections over a single physical connection.

10.1.5 *Frame Relay*—Frame relay is a connection-oriented, fast-packet data service, conceptually similar to X.25. Whereas X.25 has three protocol layers and provides a guaranteed, virtual circuit packet delivery service, frame relay has only two layers of protocol (physical and data link layer) and relies on higher-layer protocols for end-to-end message assurance (see Fig. 6).

10.1.5.1 Frame relay is data link layer protocol. Frame relay service is viewed as one of the more versatile packet-switched technologies available for efficiently linking geographically separate organizations. Frame relay generally is deployed in bandwidths from 56 Kbps to about 1.30 Mbps. It can be implemented over dedicated T1-lines, but the widespread application has been toward public networks and ISDN.

10.1.6 *Synchronous Data Link Control*—The SDLC protocol was defined by IBM to facilitate communication over WAN links to IBM hosts in SNA environments. SDLC is the primary serial link protocol for SNA and is a superset of the high-level data link control protocol (HDLC).

10.1.7 *Asynchronous Transfer Mode (ATM)*—ATM is a cell-switching physical layer protocol. The ATM protocol is defined at Layer 1 and part of Layer 2 of the OSI model. It provides virtual circuit connectivity at Layer 2 to reduce the amount of overhead. Therefore, it integrates most other protocols, such as frame relay, SMDS (Switched Multimegabit Data Service), Ethernet, and so forth.

11. Upper Layer Protocols

11.1 Upper layer protocols provide access to and control of the network environment, its applications, and data. The lower layers are used to exchange information.

11.2 *ISO Architecture (see Table 7)*—The ISO protocols are intended to standardize the by-products of network software and hardware development. The seven-layer ISO architectural model includes physical and data link layers that allow other protocol stacks to exist on the same media. OSI protocols include IEEE 802.2, 802.3, 803.5, ANSI FDDI X.21, V.35, X.25, and so forth. OSI also offers both a connectionless and connection-oriented network layer service.

11.3 *TCP/IP*—TCP/IP is a protocol suite. It is termed a suite because it is a family of protocols that can be used independently of each other. TCP/IP is not dependent on any particular

TABLE 7 Upper Layer Protocols

<table>
<tr><td>Application</td><td colspan="2">ISO 9040/9041
VT</td><td>ISO 8831/8832
JTM</td><td>ISO 8571/8572
FTAM</td><td colspan="2">ISO 9595/9596
CMIP</td></tr>
<tr><td>Presentation</td><td colspan="6">ISO 8823/ITU-T X.226
Connection-Oriented Presentation Protocol</td></tr>
<tr><td>Session</td><td colspan="6">ISO 8327/ITU-T X.225
Connection-Oriented Session Protocol</td></tr>
<tr><td>Transport</td><td colspan="6">ISO 8073/ITU-T X.224
Connection-Oriented Transport Protocol</td></tr>
<tr><td>Network</td><td colspan="3">ISO 8473
Connection Less Network Services</td><td colspan="3">ISO 8208/ITU-T X.25
Packet Level Protocol</td></tr>
<tr><td rowspan="2">Data link</td><td colspan="4">ISO 8802-2</td><td rowspan="2">ISO 7776
ITU-T X.25
(LAP/LAPB)</td><td rowspan="2">ISO 7809
HDLC</td></tr>
<tr><td>ISO 9314-2
FDDI</td><td>ISO 8802-3
CSMA/CD (BUS)</td><td>ISO 8802-4
Token Bus</td><td>ISO 8802-5
Token Ring</td></tr>
<tr><td>Physical</td><td colspan="6">Options from EIA , ITU-T, IEEE, and so forth</td></tr>
</table>

physical connection. It was designed to connect subnetworks to larger internetworks. Table 8 shows the TCP/IP layers in relation to the seven layer OSI model.

11.3.1 TCP is a connection-oriented transport layer protocol that uses the connectionless services of IP to ensure the reliable delivery of data. Connection-oriented services establish link between two devices on a LAN. This link stays active for the length of a data transmission and can be closed when the transfer is furnished. With connectionless services, there is no requirement to establish a link between a source and destination device before data transmission can begin. Connectionless services are capable of sending data packets to multiple destinations, while connection-oriented services cannot.

11.3.2 TCP/IP provides important services, such as file transfer, e-mail, and remote login across a large number of distributed client and server systems. TCP/IP was introduced with UNIX, and then it was later incorporated into the IBM environment.

11.3.3 To ensure that multivendor, multiplatform systems could communicate, the original design was based on open system standards. Because of this design, TCP/IP is platform independent in that it operates in a similar manner no matter what the platform. This is synonymous with interoperability, a key strategy for choosing and using protocols.

11.4 *NETWARE IPX/SPX*—Novell Netware protocols comply to the OSI model. The upper five layers provide file and printer sharing and support for various applications, such as electronic mail transfer, database access, and other dedicated NOS services (that is SNA, TCP/IP, Appletalk, and OSI). The Internetwork Packet Exchange (IPX) (see Table 9) is a NetWare protocol used to move data across a Novell network. The IPX packet deals directly with routers to move data across Novell NetWare Internetworks. IPX is a result of Novell's efforts to add new services and features to the original Xerox XNS protocols.

11.4.1 IPX uses the Sequenced Packet Exchange (SPX) rotocol to provide applications with reliable, connection-oriented data transport service. In the OSI model, IPX conforms to the network layer and SPX the transport layer.

11.5 *Systems Network Architecture (SNA)*—SNA is IBM's proprietary networking protocol. SNA was designed to operate at the data link layer of the OSI model. The SNA network is a host-terminal environment because the mainframe acts as a host system, which is accessed by display devices called terminals.

TABLE 9 The Internet Packet Exchange (IPX)

OSI Layer	Netware Protocol Implementation			
Application	Application			
Presentation				
Session				
Transport	Sequential Packet Exchange (SPX)			
Network	(IPX) Internet Packet Exchange			
Data link	Ethernet	Token Ring	FDDI	Others
Physical				

11.6 *Advanced Peer-to-Peer Networking (APPN)*—APPN is IBM's proprietary networking protocol. It is an enhancement to SNA to provide support for distributed applications in IBM networks, such as mainframes, AS/400s, and PS/2s. APPN enables direct communication between users anywhere on the network, a feature SNA could not provide. Much like TCP/IP, APPN resides at Layers 3 and 4 of the OSI model, providing network and transport functionality.

11.7 *Apple Talk*—AppleTalk is an OSI-based, CSMA/CD LAN technology from Apple. It supports Apple's proprietary LocalTalk access method, as well as Ethernet (EtherTalk), and token-ring (TokenTalk). The AppleTalk network manager and the LocalTalk access method are built into all MACs and Laser Writer printers, as well as many third-party devices. AppleTalk can run on PCs, VAXs, and UNIX workstations.

11.7.1 LocalTalk is Apple's LAN access method that uses twisted pair wiring and transmits at 230.4 Kbps. It runs under AppleTalk (see Table 10) and uses a daisy chain topology that connects up to 32 devices at a distance of up to about 1000 ft. LocalTalk can be configured to work in bus, passive, star, and active star topologies.

11.7.2 At Layer 3, the Datagram Delivery Protocol (DDP) provides a connectionless datagram services. At Layer 4, in the AppleTalk architecture, the Name Binding Protocol (NBP) provides name-to-address association. Routing table content is provided by the Routing Table Maintenance Protocol. At Layer 5, the Zone Information Protocol (ZIP) provides means of localizing broadcast traffic.

TABLE 8 TCP/IP Protocol Suite

OSI Layer	Protocol Implementation			
Application	File Transfer	Electronic Mail	Terminal Emulation	Network Management
Presentation Session	File Transfer Protocol (FTP) RFC 959	Simple Mail Transfer-Protocol (SMTP) RFC 821	TELNET Protocol RFC 854	Simple Network Management Protocol RFC 1157
Transport	Transmission Control Protocol RFC 793		User Datagram Protocol (UDP) RFC 768	
Network	Address Resolution ARP RFC 826 RARP RFC 903	Internet Protocol (IP) RFC 791		Internet Control Message Protocol (CMP) RFC 792
Data link	Network interface card: Ethernet, Token Ring, FDDI RFC 894, RFC 1042, RFC 1201			
Physical	Transmission media: LAN, MAN, or WAN			

TABLE 10 LocalTalk LAN Access Method

OSI Layer	AppleTalk Protocol Implementation			
Application	Application			
Presentation				
Session	Zone Information Protocol (ZIP)			
Transport	Routing Table Maintenance Protocol (RTMP) Name Binding Protocol (NBP)			
Network	Datagram Delivery Protocol (DDP)			
Data link	Ethernet	Token Ring	FDDI	Others
Physical				

11.8 *XEROX Network Systems (XNS) (see Table 11)*—The XNS architecture makes two basic assumptions about its users: the Internetwork's underlying LAN technology is Ethernet, and multiple Ethernets exists. The XNS protocol implementation provides five level layers and corresponds closely to the OSI model.

11.8.1 XNS Level 0 defines the transmission media protocols that provide the physical mechanism for packet transport.

11.8.2 XNS Level 1 defines the destination of the datagram (packet), and how it will get there. The Internetwork Datagram Protocol (IDP) is defined, as well as an addressing scheme to designate the various networks, hosts, and sockets through which that packet will originate, traverse, or teminate.

11.8.3 XNS Level 2 provides structures for the stream of datagrams. This level deals with the multitude of issues, such as sequencing, flow control, and retransmissions that are required of the OSI Transport Layer.

11.8.4 XNS Level 3 provides structures for the actual data that was transmitted and also controls various processes. As such, Level 3 covers the OSI session and presentation layers, and is designated the control protocols. XNS Level 4 deals with the various application protocols, similar to the OSI model.

11.9 *DNAs (Digital Network Architecture) DECNet/OSI*—DNA is the architecture, or master plan, for networking. DECNet/OST is an implementation of the architecture that is compliant with the ISO's Open System Interconnection (OSI) Model in both number of layers, as well as layer functionality (see Table 12). DECNet is a proprietary Digital Equipment Corporation (DEC) Protocol. DECNet is a host-to-host (peer-to-peer) communication network. DECNet supports both connectionless and connection-oriented network layers. Both network layers are implemented by OSI protocols.

11.10 *Local Area Transport (LAT)*—LAT is a proprietary Digital Equipment Corporation (DEC) protocol (see Table 13). LAT is a terminal-to-host, or terminal I/O network on an Ethernet. LAT is a lean and mean protocol stack whose only purpose in life is to move terminal I/O as fast as possible between host and terminals and printers. LAT approximately implements Layers 3, 4, and 5. LAT is nonroutable protocol stack, which can only exist on the Ethernet implementation of Layers 1 and 2. LAT is implemented on VAXen, Alpha AXPs, in terminal servers, such as DECservers, and PCs and Macintoshes running PATHWORKS.

TABLE 11 XNS Architecture

OSI Layer	XNS Protocol Implementation				Level
Application	Application				4
Presentation	Control–convention for data structuring and process interaction				3
Session					
Transport	Transport–Interprocess communication primitives				2
Network	Transport–Internet packet format				1
Data link	Ethernet	Leased lines	X.25	Others	0
Physical					

TABLE 12 DNA Architecture

OSI Layer	DECNet Protocol Implementation
Application	User
Presentation	Network management
Session	Network application
Transport	Session control
Network	Routing
Data link	Data link
Physical	Physical

TABLE 13 LAT

OSI Layer	DECNet Protocol Implementation	LAT Protocol Implementation
Application	User	
Presentation	Network management	
Session	Network application	User
Transport	Session control	Slot
Network	Routing	Virtual circuit
Data link	Data link	Data link
Physical	Physical	Physical

11.11 *NetBEUI (Microsoft–proprietary)*—NetBIOS Extended User Interface (NetBEUI) is the native network protocol used by Microsoft's Windows NT and Windows 95. NetBEUI is an enhanced version of NetBIOS protocol used by a network operating system (NOS), such as LAN Manager and LAN server. Systems that use NetBEUI, such as Windows NT, can communicate with other Windows NT systems, as well as workstations running Windows for Workgroups.

11.12 *NetBIOS*—NetBIOS (Network Basic/Input System) is a network protocol designed exclusively for use in LANs. NetBIOS, along with its API, provide support of peer-to-peer network functions and a simple interface for writing network applications. There is no routing layer in NetBIOS. This means that NetBIOS cannot provide internetworking capabilities. Other protocols, such as IP or IPX must be used for internetworking. NetBIOS provides session and transport services (Layers 4 and 5 of the OSI model). This NetBIOS often is used to establish a connection between devices.

12. Fault Tolerance in Communication Networks

12.1 Fault tolerance is achieved using one or more of several forms of redundancy, which is simply the addition of information, resources, or time beyond what is needed for a normal system operation. The redundancy can take one of several forms, including hardware redundancy, software redundancy, information redundancy, and time redundancy.

13. Implementing a Communication Network

13.1 There are many documents and articles that discuss actual network design. Network designers have a definite preference for standard-based solutions, including those for media, protocols, and topologies. Standard-based networking solutions have the aura of optimally conceived technology and the promise of low (commodity) cost and multivendor available networking equipment using common silicon-based implementations. Standards not only imply the preceding desirable features, but also, at least theoretically, guarantee interoperability of equipment from different vendors.

13.2 *Topology Selection Decision Tree*—See Fig. 7.

13.3 *Network Environment Selection Decision Tree*—See Fig. 8, Fig. 9, and Fig. 10.

13.4 *Internetworking (LAN-to-LAN or LAN-to-WAN):*

13.4.1 Identify transport protocols present or supported by LAN-to-LAN or LAN-to-WAN internetwork.

13.4.2 Is the transport protocol(s) identified in 13.3 proprietary?

13.4.3 Identify a common denominator transport protocol to facilitate internetworking: RECOMMENDED: TCP/IP.

13.4.4 Identify basic services to be provided: FILE TRANSFER, ELECTRONIC MAIL, ROUTING, REMOTE ACCESS (Terminal Emulation).

13.4.5 Verify interoperability of NOS: Yes–Use router; No–Use gateway.

14. Keywords

14.1 bus; internetwork; local area network (LAN); network operating system (NOS); operating system (OS); protocol; ring; star; topology; tree; wide area network (WAN)

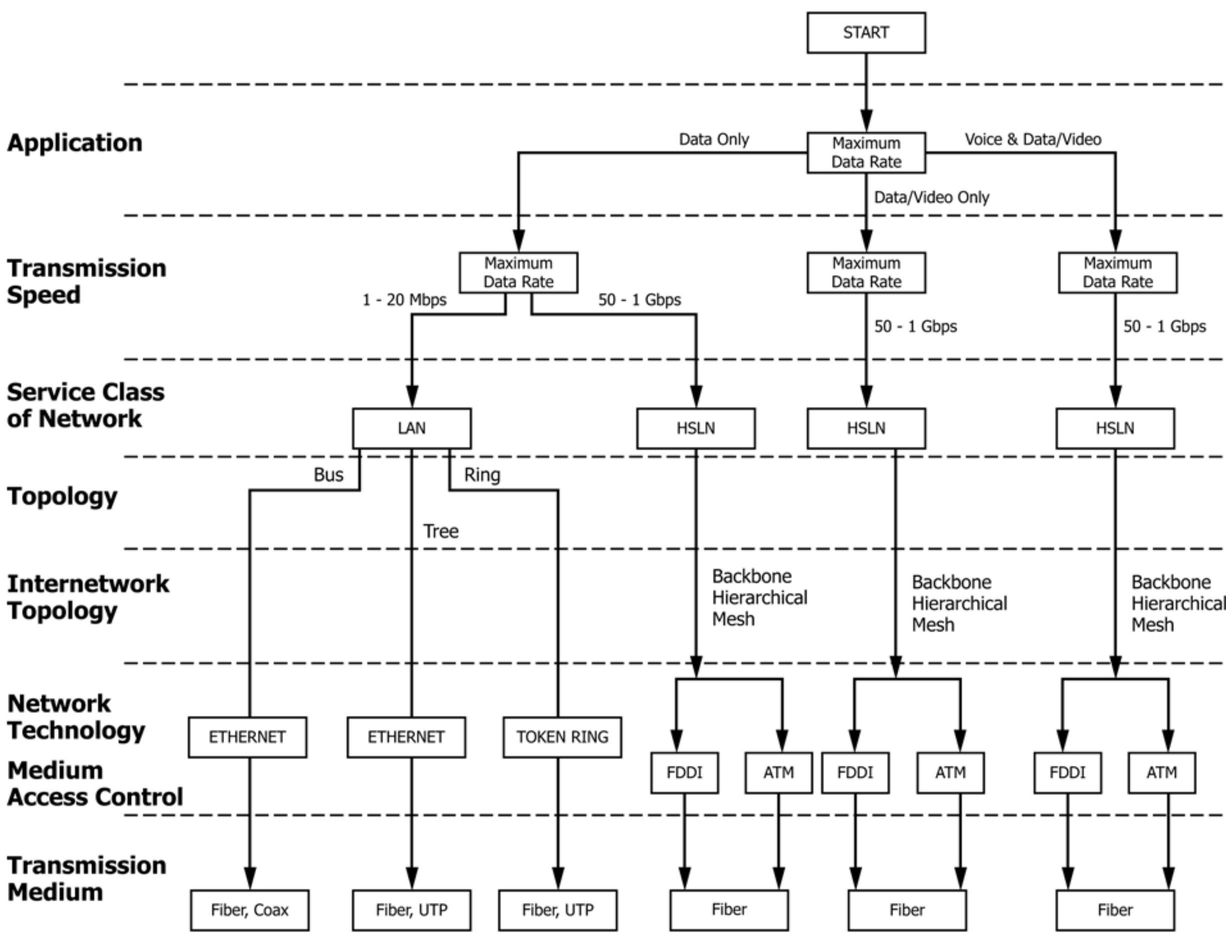
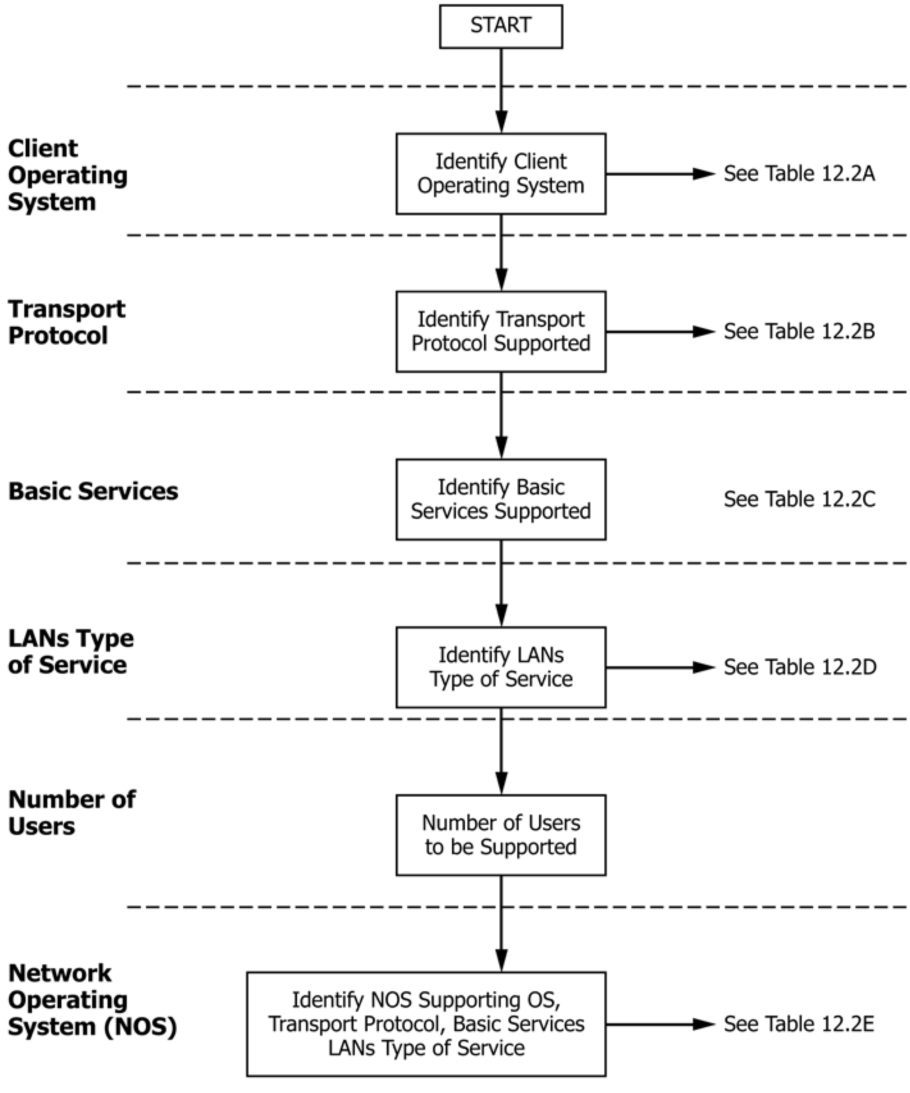


FIG. 7 Topology Selection Decision Tree



CLIENT OS	OS to be Used
DOS	
WINDOWS 3.X	
WINDOWS 95	
WINDOWS NT	
Mac OS	
OS/2	
Others (specify)	

TABLE 12.2A

TRANSPORT PROTOCOL	Protocol to be Used
TCP/IP	
UDP	
DECnet	
AppleTalk	
IPX/SPX	
NetBIOS	
NetBUI	
Others (specify)	

TABLE 12.2B

BASIC SERVICE (BS)	BS to be Used
File Transfer	
Electronic Mail	
Remote Access	
Routing	
Printing	
Database	
Other (specify)	

TABLE 12.2C

FIG. 8 Network Environment Selection Decision Tree (continued in Fig. 9 and Fig. 10)

LANs Type of Service	Type of Service to be Used
Peer-to-Peer	
Server Based	

TABLE 12.2D

Network Operating System (NOS)	Protocol Supported	Basic Network Services	Client OS Support
Novell Netware	IPX, TCP/IP, AppleTalk, OSI	File, Print, Messages, Email	DOS, Mac OS, OS2, UNIX, Windows 3.x, Windows 95/NT
Windows NT	TCP/IP, IPX, AppleTalk, NetBUI	File, Print, Messages, Email	DOS, Mac OS, OS2, UNIX, Windows 3.x, Windows 95/NT
LANtastic	TCP/IP, IPX, NetBIOS	File, Print, Messages, Email	DOS, DEC VAX, OS2, UNIX,
Banyan	TCP/IP, IPX, AppleTalk, NetBUI	File, Print, Messages, Email	DOS, Mac OS, OS2, Windows 3.x, UNIX
LAN Manager	TCP/IP, NetBUI	File, Print, Messages, Email	DOS, OS2, Windows 3.x
IBM LAN Server	TCP/IP, NetBUI	File, Print, Messages, Email	DOS, OS2, Windows 3.x
DEC Pathworks	TCP/IP, AppleTalk	File, Print, Messages, Email	DOS, OS2, Mac OS
Other (specify)			

TABLE 12.2E1 NOS SUPPORT CHART

Network Operating System (NOS)	Type of LAN Service	NOS Client Protocol
Novell Netware	Server-based	IPX/SPX
Windows NT Server	Server-based	NDIS
LANtastic	Peer-to-Peer	NDIS
Windows for Workgroup	Peer-to-Peer	NDIS
Windows 95	Peer-to-Peer	NDIS
UNIX	Server-based or Peer-to-Peer	TCP/IP
Apple Share/Apple Talk	Server-based or Peer-to-Peer	EtherTalk or AppleTalk
The Internet	Peer-to-Peer	TCP/IP
Other (specify)		

TABLE 12.2E2 NOS TYPE OF SERVICE

FIG. 9 Network Environment Selection Decision Tree (continued from Fig. 8)

	Client Operating System	MS Windows 95	IBM OS/2	MS Windows NT	Apple MAC OS
NOS Connectivity	Netware Bindery	YES	YES	YES	must load server NLM
	Netwar NDS	YES	YES	YES	must load MacNDS
	Netware login Scripts	YES	YES	YES	NO
	Windows NT	YES	YES	YES	YES
	Windows 95	YES	YES	YES	NO
	OS/2 LAN Server	YES	YES	YES	YES
	Unix (NFS Server)	some are supported	optional NFS add-on	optional NFS add-on	optional NFS add-on
	LANtastic	possible with real mode drivers	YES	YES	YES
	DEC Pathworks	YES	NO	YES	YES
	AppleTalk	NO	NO	YES	YES
	BANYAN Vines	NO	NO	NO	NO
PEER-TO-PEER SERVICES Client Access	DOS	YES	YES	YES	optional site license
	Windows for Workgroups	YES	YES	YES	optional site license
	Windows 95	YES	YES	YES	YES
	Windows NT Server	YES	YES	YES	YES
	IBM OS/2	YES	YES	YES	NO
	APPLE MACintosh	NO	NO	YES	YES

TABLE 12.2E3 OS FEATURES CHART

FIG. 10 Network Environment Selection Decision Tree (continued from Fig. 8 and Fig. 9)