

Third Edition

Javvin

Network Protocols Handbook

TCP/IP
Ethernet ATM
Frame Relay WAN LAN
MAN WLAN SS7/C7 VOIP Security
VPN SAN VLAN IEEE IETF ISO
ITU-T ANSI Cisco IBM
Apple Microsoft
Novell

Javvin Technologies, Inc.

Table of Contents

Network Communication Architecture and Protocols	1
OSI Network Architecture 7 Layers Model.....	2
TCP/IP Four Layers Architecture Model.....	5
Other Network Architecture Models: IBM SNA.....	7
Network Protocols: Definition and Overview.....	9
Protocols Guide	11
TCP/IP Protocols.....	11
Application Layer Protocols	13
BOOTP: Bootstrap Protocol.....	13
DCAP: Data Link Switching Client Access Protocol.....	14
DHCP: Dynamic Host Configuration Protocol.....	15
DNS: Domain Name System (Service) Protocol.....	16
FTP: File Transfer Protocol.....	17
Finger: User Information Protocol.....	19
HTTP: Hypertext Transfer Protocol.....	20
S-HTTP: Secure Hypertext Transfer Protocol.....	21
IMAP & IMAP4: Internet Message Access Protocol (version 4).....	22
IRC: Internet Relay Chat Protocol.....	24
LDAP: Lightweight Directory Access Protocol (version 3).....	25
MIME (S-MIME): Multipurpose Internet Mail Extensions and Secure MIME.....	26
NAT: Network Address Translation.....	27
NNTP: Network News Transfer Protocol.....	28
NTP: Network Time Protocol.....	29
POP and POP3: Post Office Protocol (version 3).....	30
rlogin: Remote Login to Unix Systems.....	31
RMON: Remote Monitoring MIBs (RMON1 and RMON2).....	32
SLP: Service Location Protocol.....	34
SMTP: Simple Mail Transfer Protocol.....	35
SNMP: Simple Network Management Protocol.....	36

SNMPv1: Simple Network Management Protocol version one.....	37
SNMPv2: Simple Network Management Protocol version two.....	38
SNMPv3: Simple Network Management Protocol version three.....	40
SNTP: Simple Network Time Protocol.....	42
TELNET: Terminal Emulation Protocol of TCP/IP.....	44
TFTP: Trivial File Transfer Protocol.....	45
URL: Uniform Resource Locator.....	46
Whois (and RWhois): Remote Directory Access Protocol.....	47
XMPP: Extensible Messaging and Presence Protocol.....	48
X Window/X Protocol: X Window System Protocol.....	49
Presentation Layer Protocols.....	50
LPP: Lignhtweight Presentation Protocol.....	50
Session Layer Protocols.....	51
RPC: Remote Procedure Call Protocol.....	51
Transport Layer Protocols.....	53
ITOT: ISO Transport Service on top of TCP.....	53
RDP: Reliable Data Protocol.....	54
RUDP: Reliable User Datagram Protocol (Reliable UDP).....	56
TALI: Tekelec's Transport Adapter Layer Interface.....	57
TCP: Transmission Control Protocol.....	58
UDP: User Datagram Protocol.....	60
Van Jacobson: Compressed TCP Protocol.....	61
Network Layer Protocols.....	62
Routing Protocols.....	62
BGP (BGP-4): Border Gateway Protocol.....	62
EGP: Exterior Gateway Protocol.....	63
IP: Internet Protocol (IPv4).....	64
IPv6: Internet Protocol version 6.....	66
ICMP & ICMPv6: Internet Message Control Protocol and ICMP version 6.....	68
IRDP: ICMP Router Discovery Protocol.....	70
Mobile IP: IP Mobility Support Protocol for IPv4 & IPv6.....	71
NARP: NBMA Address Resolution Protocol.....	73
NHRP: Next Hop Resolution Protocol.....	74

OSPF: Open Shortest Path Firest Protocol.....	75
RIP: Routing Information Protocol (RIP2).....	76
RIPng: Routing Information Protocol next generation for IPv6.....	77
RSVP: Resource ReSerVation Protocol.....	78
VRRP: Virtual Router Redundancy Protocol.....	79
Multicasting Protocols.....	80
BGMP: Border Gateway Multicast Protocol.....	80
DVMRP: Distance Vector Multicast Routing Protocol.....	81
IGMP : Internet Group Management Protocol.....	82
MARS: Multicast Address Resolution Server.....	83
MBGP: Multiprotocol BGP.....	84
MOSPF: Multicast Extensions to OSPF.....	86
MSDP: Multicast Source Discovery Protocol.....	87
MZAP: Multicast-Scope Zone Annuncement Protocol.....	88
PGM: Pragmatic General Multicast Protocol.....	89
PIM-DM: Protocol Independent Multicast - Dense Mode.....	90
PIM-SM: Protocol Independent Multicast - Sparse Mode.....	91
MPLS Protocols.....	92
MPLS: Multiprotocol Label Switching.....	92
GMPLS: Generalized Multiprotocol Label Switching.....	94
CR-LDP: Constraint-based LDP.....	95
LDP: Label Distribution Protocol.....	96
RSVP-TE: Resource Reservation Protocol - Traffic Extension.....	97
Data Link Layer Protocols.....	98
ARP and InARP: Address Resolution Protocol and Inverse ARP.....	98
IPCP and IPv6CP: IP Control Protocol and IPv6 Control Protocol.....	99
RARP: Reverse Address Resolution Protocol.....	100
SLIP: Serial Line IP.....	101
Network Security Technologies and Protocols.....	102
AAA Protocols.....	104
Kerberos: Network Authentication Protocol.....	104
RADIUS: Remote Authentication Dial in User Service.....	105

SSH: Secure Shell Protocols	106
Tunneling Protocols	107
L2F: Layer 2 Forwarding Protocol	107
L2TP: Layer 2 Tunneling Protocol	108
PPTP: Point-to-Point Tunneling Protocol	110
Secured Routing Protocols	111
DiffServ: Differentiated Service Architecture	111
GRE: Generic Routing Encapsulation	112
IPSec: Internet Protocol Security Architecture	113
IPSec AH: IPsec Authentication Header	114
IPsec ESP: IPsec Encapsulating Security Payload	115
IPsec IKE: Internet Key Exchange Protocol	116
IPsec ISAKMP: Internet Security Association and Key Management Protocol	117
SSL/TLS: Secure Socket Layer and Transport Layer Security Protocol	118
Other Security Protocols	120
SOCKS v5: Protocol for Sessions Traversal Across Firewall Securely	120
Voice over IP and VOIP Protocols	121
Signalling	123
H.323: ITU-T VOIP Protocols	123
H.225.0: Vall signalling protocols and media stream packetization for packet based multimedia communication systems	125
H.235: Security and encryption for H-series (H.323 and other H.245-based) multimediateminals	127
H.245: Control Protocol for Multimedia Communication	128
Megaco/H.248: Media Gateway Control Protocol	129
MGCP: Media Gateway Control Protocol	130
NCS: Network-Based Call Signaling Protocol	131
RTSP: Real-Time Streaming Protocol	132
SAP: Session Announcement Protocols	134
SDP: Session Description Protocol	135
SIP: Session Initiation Protocol	136
SCCP (Skinny): Cisco Skinny Client Control Protocol	138

T.120: Multipoint Data Conferencing and Real Time Communication Protocols	140
Media/CODEC	142
G.7xx: Audio (Voice) Compression Protocols	142
H.261: Video CODEC for Low Quality Videoconferencing	144
H.263: Video CODEC for Medium Quality Videoconferencing	145
H.264 / MPEG-4: Video CODEC For High Quality Video Streaming	147
RTP: Real-Time Transport Protocol	149
RTCP: RTP Control Protocol	150
Other Protocols	151
COPS: Common Open Policy Service	151
SIGTRAN: Signaling Transport Protocol Stack	152
SCTP: Stream Control Transmission Protocol	154
TRIP: Telephony Routing over IP	155
Wide Area Network and Wan Protocols	156
ATM Protocols	158
ATM: Asynchronous Transfer Mode	158
ATM Layer: Asynchronous Transfer Mode Layer	159
AAL: ATM Adaptation Layers (AAL1, AAL2, AAL3/4, AAL5)	160
ATM UNI: ATM Signaling User-to-Network Interface	163
LANE NNI: ATM LAN Emulation NNI	165
LANE UNI: ATM LAN Emulation UNI	167
MPOA: Multi-Protocol Over ATM	169
ATM PNNI: ATM Private Network-toNetwork Interface	171
Q.2931: ATM Signaling for B-ISDN	172
SONET/SDH: Synchronous Optical Network and Synchronous Digital Hierarchy	174
EoS: Ethernet over SONET/SDH	176
Broadband Access Protocols	178
BISDN: Broadband Integrated Services Digital Network (Broadband ISDN)	178
ISDN: Integrated Services Digital Network	179
LAP-D: ISDN Link Access Protocol-Channel D	181
Q.931: ISDN Network Layer Protocol for Signaling	183
DOCSIS: Data Over Cable Service Interface Specification	184

xDSL: Digital Subscriber Line Technologies (DSL, IDSL, ADSL, HDSL, SDSL, VDSL, G.Lite)•••	185
PPP Protocols•••••	186
PPP: Point-to-Point Protocols•••••	186
BAP: PPP Bandwidth Allocation Protocol(BAP) and BACP: PPP Banwidth Allocation Control Protocol (BACP)•••••	187
BCP: PPP Briding Control Protocol•••••	188
EAP: PPP Extensible Authentication Protocol•••••	189
CHAP: Challenge Handshake Authentication Protocol•••••	190
LCP: PPP Link Control Protocol•••••	191
MP: MultiLink Point to Point Protocol (MultiPPP)•••••	192
PPP NCP: Point to Point Protocol Network Control Protocols•••••	193
PAP: Password Authentication Protocol•••••	194
PoS: Packet over SONET/SDH•••••	195
PPPoA: PPP over ATM AAL5•••••	196
PPPoE: PPP over Ethernet•••••	197
Other WAN Protocols•••••	198
Frame Relay: WAN Protocol for Internetworking•••••	198
LAPF: Link Access Procedure for Frame Mode Services•••••	200
HDLC: High Level Data Link Control•••••	201
LAPB: Link Access Procedure, Balanced•••••	202
X.25: ISO/ITU-T Protocol for WAN Communications•••••	203
Local Area Network and LAN Protocols•••••	205
Ethernet Protocols•••••	206
Ethernet: IEEE 802.3 Local Area Network Protocols•••••	206
Fast Ethernet: 100Mbps Ethernet (IEEE 802.3u)•••••	208
Gigabit (1000 Mbps) Ethernet: IEEE 802.3z (1000Base-X) and 802.3ab (1000 Base-T)•••	209
10 Gigabit Ethernet: The Ethernet Protocol IEEE 802.3ae for LAN, WAN and MAN•••••	211
Virtual LAN Protocols•••••	213
VLAN: Virtual Local Area Network and the IEEE 802.1Q•••••	213
IEEE 802.1P: LAN Layer 2 QoS/CoS Protocol for Traffic Prioritization•••••	215
GARP: Generic Attribute Registration Protocol•••••	217
GMRP: GARP Multicast Registration Protocol•••••	218

GVRP: GARP VLAN Registration Protocol.....	219
Wireless LAN Protocols.....	220
WLAN: Wireless LAN by IEEE 802.11 Protocols.....	220
IEEE 802.11i: WLAN Security Standard.....	222
IEEE 802.1X: EAP over LAN (EAPOL) for LAN/WLAN Authentication and Key Management.....	224
IEEE 802.15 and the Bluetooth: WPAN Communications.....	226
Other Protocols.....	227
FDDI: Fiber Distributed Data Interface.....	227
Token Ring: IEEE 802.5 LAN Protocol.....	228
LLC: Logic Link Control (IEEE 802.2).....	229
SNAP: SubNetwork Access Protocol.....	230
STP: Spanning Tree Protocol (IEEE 802.1D).....	231
Metropolitan Area Network and MAN Protocol.....	233
DQDB: Distributed Queue Dual Bus (Defined in IEEE 802.6).....	234
SMDS: Switched Multimegabit Data Service.....	235
IEEE 802.16: Broadband Wireless MAN Standard (WiMAX).....	237
Storage Area Network and SAN Protocols.....	238
FC & FCP: Fibre Channel and Fibre Channel Protocol.....	240
FCIP: Fibre Channel over TCP/IP.....	241
iFCP: Internet Fibre Channel Protocol.....	243
iSCSI: Internet Small Computer System Interface (SCSI).....	245
iSNS and iSNSP: Internet Storage Name Service and iSNS Protocol.....	247
NDMP: Network Data Management Protocol.....	248
SCSI: Small Computer System Interface.....	250
ISO Protocols in OSI 7 Layers Model.....	252
Application Layer.....	254
ISO ACSE: Association Control Service Element.....	254
ISO CMIP: Common Management Information Protocol.....	256
CMOT: CMIP over TCP/IP.....	258
ISO FTAM: File Transfer Access and Management Protocol.....	259

ISO ROSE: Remote Operations Service Element Protocol.....	260
ISO RTSE: Reliable Transfer Service Element Protocol.....	262
ISO VTP: ISO Virtual Terminal (VT) Protocol.....	263
X.400: Message Handling Service Protocol.....	264
X.500: Directory Access Protocol (DAP).....	266
ASN.1: Abstract Syntax Notation One.....	267
ISO-PP: OSI Presentation Protocol.....	268
ISO-SP: OSI Session Protocol.....	270
ISO-TP: OSI Transport Layer Protocols TP0, TP1, TP2, TP3, TP4.....	271
Network Layer.....	273
CLNP: Connectionless Network Protocol (ISO-IP).....	273
ISO CONP: Connection-Oriented Network Protocol.....	275
ES-IS: End System to Intermediate System Routing Exchange Protocol.....	276
IDRP: Inter-Domain Routing Protocol.....	277
IS-IS: Intermediate System to Intermediate System Routing Protocol.....	278
Cisco Protocols.....	279
CDP: Cisco Discovery Protocol.....	280
CGMP: Cisco Group Management Protocol.....	281
DTP: Cisco Dynamic Trunking Protocol.....	282
EIGRP: Enhanced Interior Gateway Routing Protocol.....	283
HSRP: Hot Standby Router Protocol.....	284
IGRP: Interior Gateway Routing Protocol.....	285
ISL & DISL: Cisco Inter-Switch Link Protocol and Dynamic ISL Protocol.....	286
RGMP: Cisco Router Port Group Management Protocol.....	287
TACACS (and TACACS+): Terminal Access Controller Access Control System.....	288
VTP: Cisco VLAN Trunking Protocol.....	289
XOT: X.25 over TCP Protocol by Cisco.....	291
Novell NetWare and Protocols.....	292
IPX: Internetwork Packet Exchange Protocol.....	294
NCP: NetWare Core Protocol.....	295
NLSP: NetWare Link Services Protocol.....	296

SPX: Sequenced Packet Exchange Protocol.....298

IBM Systems Network Architecture (SNA) and Protocols.....299

 IBM SMB: Server Message Block Protocol.....301

 APPC: Advanced Program to Program Communications (SNA LU6.2).....302

 SNA NAU: Network Accessible Units (PU, LU and CP).....303

 NetBIOS: Network Basic Input Output System.....305

 NetBEUI: NetBIOS Extended User Interface.....306

 APPN: Advanced Peer-to-Peer Networking.....307

 DLSw: Data-Link Switching Protocol.....309

 QLLC: Qualified Logic Link Control.....310

 SDLC: Synchronous Data Link Control.....311

AppleTalk: Apple Computer Protocols Suite.....312

DECnet and Protocols.....314

SS7/C7 Protocols: Signalling System #7 for Telephony316

 BISUP: Broadband ISDN User Part.....318

 DUP: Data User Part.....319

 ISUP: ISDN User Part.....320

 MAP: Mobile Application Part.....322

 MTP2 and MTP3: Message Transfer Part level 2 and level 3.....323

 SCCP: Signalling Connection Control Part of SS7.....325

 TCAP: Transaction Capabilities Application Part.....326

 TUP: Telephone User Part.....328

Other Protocols.....329

 Microsoft CIFS: Common Internet File System.....330

 Microsoft SOAP: Simple Object Access Protocol.....331

 NFS: Network File System.....332

 Xerox IDP: Internet Datagram Protocol.....334

 Toshiba FANP: Flow Attribute Notification Protocol.....335

Appendix	336
Appendix A: TCP and UDP Port Numbers.....	336
Appendix B: Network Protocols Dictionary: From A to Z and 0 to 9.....	339
Appendix C: Major Networking and Telecom Standard Organizations.....	356
Network Protocols Map	357

Table of Figures

Figure 1-1: Communication between computers in a network.....	3
Figure 1-2: Data encapsulation at each layer.....	3
Figure 1-3: Data communication between peer layers.....	4
Figure 1-4: TCP/IP Protocol Stack 4 Layer Model.....	6
Figure 1-5: SNA vs. OSI model.....	8
Figure 1-6: SNA Network Topology.....	8
Figure 1-7: Communication between TP and LU in SNA.....	8
Figure 2-1: RMON Monitoring Layers.....	32
Figure 2-2: Remote Procedure Call Flow.....	51
Figure 2-3: Mobile IP Functional Flow Chart.....	71
Figure 2-4: MPLS protocol stack architecture.....	92
Figure 2-5: GMPLS Protocol Stack Diagram.....	94
Figure 2-6: IPsec Protocol Stack Structure.....	113
Figure 2-7: H.323 Protocol Stack Structure.....	124
Figure 2-8: H.235 – Encryption of media.....	127
Figure 2-9: H.235 – Decryption of media.....	127
Figure 2-10: The relations between MGCP/NCS and other VOIP standards.....	131
Figure 2-11: T.120 Data Conferencing Protocol Structure.....	140
Figure 2-12: SIGTRAN Architecute.....	152
Figure 2-13: SIGTRAN Protocol Stack.....	152
Figure 2-14: EoS Protocol Structure.....	176
Figure 2-15: ATM Reference Model.....	178
Figure 2-16: Packet over SONET/SDH.....	195
Figure 2-17: Encapsulating IP into a SONET/SDH frame.....	195
Figure 2-18: Ethernet protocols.....	206
Figure 2-19: Gigabit Ethernet Protocol Stack.....	209
Figure 2-20: Packet Bursting Mode in Gigabit Ethernet.....	210
Figure 2-21: 10 Gigabit Ethernet Architecture.....	211
Figure 2-22: IEEE 802.11 Protocols.....	220
Figure 2-23: IEEE 802.11i Components.....	222
Figure 2-24: CCMP MPDU Format.....	222

Figure 2-25: CCMP CBC-MAC IV.....	222
Figure 2-26: CCMP CTR.....	222
Figure 2-27: TKIP MPDU Format.....	223
Figure 2-28: IEEE 802.15 (Bluetooth) Protocol Stack.....	226
Figure 2-29: DQDB Architecture.....	234
Figure 2-30: DQDB Cell Format.....	234
Figure 2-31: DQDB cell header.....	234
Figure 2-32: IEEE 802.16 (WiMax) Functional Flow Chart.....	237
Figure 2-33: IEEE 802.16 (WiMax) Protocol Stack.....	237
Figure 2-34: Storage Area Network Architecture.....	238
Figure 2-35: Fibre Channel Protocol.....	240
Figure 2-36: NDMP Functional Components.....	248
Figure 2-37: SCSI Protocol Stack Structure.....	251
Figure 2-38: ISO Protocols in OSI 7 Layers Reference Model.....	252
Figure 2-39: Novell Netware Protocol Stack Architecture.....	293
Figure 2-40: IBM SNA vs. OSI Model.....	300
Figure 2-41: IBM APPN Network Illustration.....	308
Figure 2-42: QLLC Network Architecture.....	310
Figure 2-43: AppleTalk Protocol Stack Architecture.....	313
Figure 2-44: DECnet Protocol Suite Architecture.....	315
Figure 2-45: SS7/C7 Protocol Suite Architecture.....	316
Figure 2-46: SCCP Protocol Structure.....	325
Figure 2-47: TCAP Protocol Structure.....	326
Figure 2-48: Microsoft CIFS Flow Chart.....	330
Figure 3-1: TCP/UDP Port Numbers.....	336

OSI Network Architecture 7 Layers Model

Open Systems Interconnection (OSI) model is a reference model developed by ISO (International Organization for Standardization) in 1984, as a conceptual framework of standards for communication in the network across different equipment and applications by different vendors. It is now considered the primary architectural model for inter-computing and internetworking communications. Most of the network communication protocols used today have a structure based on the OSI model. The OSI model defines the communications process into 7 layers, dividing the tasks involved with moving information between networked computers into seven smaller, more manageable task groups. A task or group of tasks is then assigned to each of the seven OSI layers. Each layer is reasonably self-contained so that the tasks assigned to each layer can be implemented independently. This enables the solutions offered by one layer to be updated without adversely affecting the other layers.

The OSI 7 layers model has clear characteristics at each layer. Basically, layers 7 through 4 deal with end to end communications between data source and destinations, while layers 3 to 1 deal with communications between network devices. On the other hand, the seven layers of the OSI model can be divided into two groups: upper layers (layers 7, 6 & 5) and lower layers (layers 4, 3, 2, 1). The upper layers of the OSI model deal with application issues and generally are implemented only in software. The highest layer, the application layer, is closest to the end user. The lower layers of the OSI model handle data transport issues. The physical layer and the data link layer are implemented in hardware and software. The lowest layer, the physical layer, is closest to the physical network medium (the wires, for example) and is responsible for placing data on the medium.

The specific description for each layer is as follows:

Layer 7: Application Layer

- Defines interface to user processes for communication and data transfer in network
- Provides standardized services such as virtual terminal, file and job transfer and operations

Layer 6: Presentation Layer

- Masks the differences of data formats between dissimilar systems
- Specifies architecture-independent data transfer format
- Encodes and decodes data; encrypts and decrypts data; compresses and decompresses data

Layer 5: Session Layer

- Manages user sessions and dialogues
- Controls establishment and termination of logic links between users
- Reports upper layer errors

Layer 4: Transport Layer

- Manages end-to-end message delivery in network
- Provides reliable and sequential packet delivery through error recovery and flow control mechanisms

- Provides connectionless oriented packet delivery

Layer 3: Network Layer

- Determines how data are transferred between network devices
- Routes packets according to unique network device addresses
- Provides flow and congestion control to prevent network resource depletion

Layer 2: Data Link Layer

- Defines procedures for operating the communication links
- Frames packets
- Detects and corrects packets transmit errors

Layer 1: Physical Layer

- Defines physical means of sending data over network devices
- Interfaces between network medium and devices
- Defines optical, electrical and mechanical characteristics

Information being transferred from a software application in one computer to an application in another proceeds through the OSI layers. For example, if a software application in computer A has information to pass to a software application in computer B, the application program in computer A need to pass the information to the application layer (Layer 7) of computer A, which then passes the information to the presentation layer (Layer 6), which relays the data to the session layer (Layer 5), and so on all the way down to the physical layer (Layer 1). At the physical layer, the data is placed on the physical network medium and is sent across the medium to computer B. The physical layer of computer B receives the data from the physical medium, and then its physical layer passes the information up to the data link layer (Layer 2), which relays it to the network layer (Layer 3), and so on, until it reaches the application layer (Layer 7) of computer B. Finally, the application layer of computer B passes the information to the recipient application program to complete the communication process. The following diagram illustrated this process.

The seven OSI layers use various forms of control information to communicate with their peer layers in other computer systems. This control information consists of specific requests and instructions that are exchanged between peer OSI layers. Headers and Trailers of data at each layer are the two basic forms to carry the control information.

Headers are prepended to data that has been passed down from upper layers. Trailers are appended to data that has been passed down from upper layers. An OSI layer is not required to attach a header or a trailer to data from upper layers.

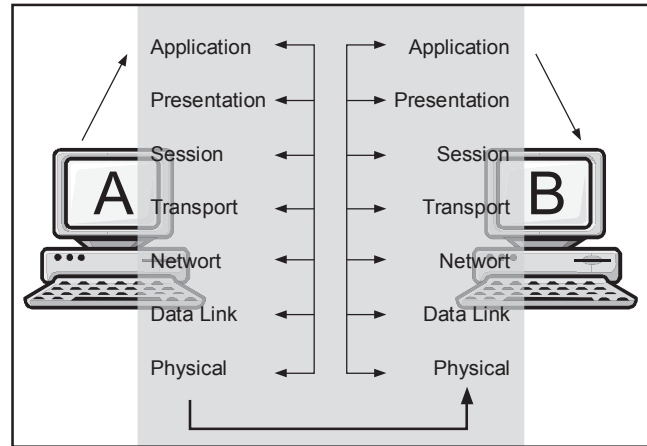


Figure 1-1: Communication between computers in a network

Each layer may add a Header and a Trailer to its Data, which consists of the upper layer's Header, Trailer and Data as it proceeds through the layers. The Headers contain information that specifically addresses layer-to-layer communication. Headers, trailers and data are relative concepts, depending on the layer that analyzes the information unit. For example, the Transport Header (TH) contains information that only the Transport layer sees. All other layers below the Transport layer pass the Transport Header as part of their Data. At the network layer, an information unit consists of a Layer 3 header (NH) and data.

At the data link layer, however, all the information passed down by the network layer (the Layer 3 header and the data) is treated as data. In other words, the data portion of an information unit at a given OSI layer potentially can contain headers, trailers, and data from all the higher layers. This is known as encapsulation.

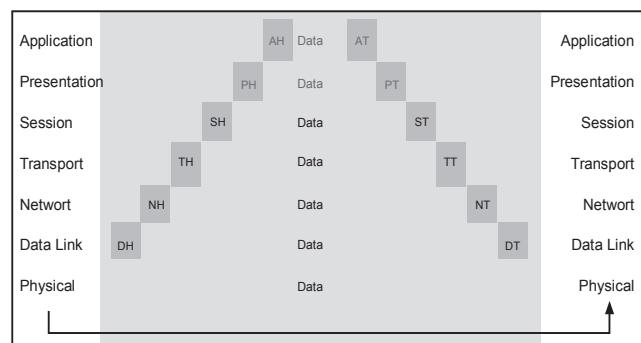


Figure 1-2: Data encapsulation at each layer

For example, if computer A has data from a software application to send to computer B, the data is passed to the application layer. The application layer in computer A then communicates any control information required by the application layer in computer B by prepending a header to the data. The resulting message unit, which includes a header, the data and maybe a trailer, is passed to the presentation layer, which pre-

pend its own header containing control information intended for the presentation layer in computer B. The message unit grows in size as each layer prepends its own header and trailer containing control information to be used by its peer layer in computer B. At the physical layer, the entire information unit is transmitted through the network medium.

The physical layer in computer B receives the information unit and passes it to the data link layer. The data link layer in computer B then reads the control information contained in the header prepended by the data link layer in computer A. The header and the trailer are then removed, and the remainder of the information unit is passed to the network layer. Each layer performs the same actions: The layer reads the header and trailer from its peer layer, strips it off, and passes the remaining information unit to the next higher layer. After the application layer performs these actions, the data is passed to the recipient software application in computer B, in exactly the form in which it was transmitted by the application in computer A.

One OSI layer communicates with another layer to make use of the services provided by the second layer. The services provided by adjacent layers help a given OSI layer communicate with its peer layer in other computer systems. A given layer in the OSI model generally communicates with three other OSI layers: the layer directly above it, the layer directly below it and its peer layer in other networked computer systems. The data link layer in computer A, for example, communicates with the network layer of computer A, the physical layer of computer A and the data link layer in computer B. The following chart illustrates this example.

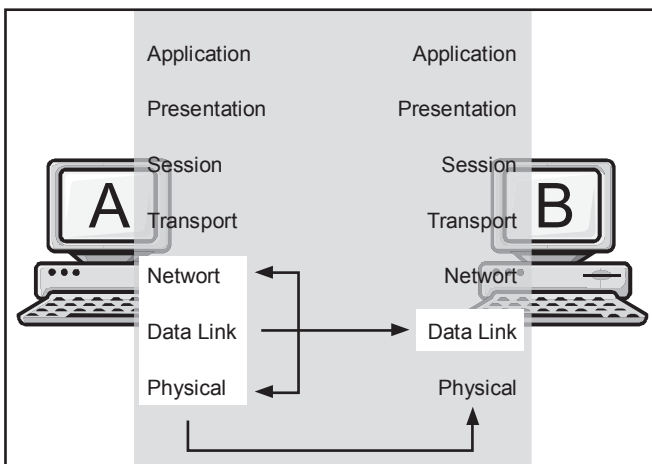


Figure 1-3: Data communication between peer layers

TCP/IP Four Layers Architecture Model

TCP/IP architecture does not exactly follow the OSI model. Unfortunately, there is no universal agreement regarding how to describe TCP/IP with a layered model. It is generally agreed that TCP/IP has fewer levels (from three to five layers) than the seven layers of the OSI model. We adopt a four layers model for the TCP/IP architecture.

TCP/IP architecture omits some features found under the OSI model, combines the features of some adjacent OSI layers and splits other layers apart. The 4-layer structure of TCP/IP is built as information is passed down from applications to the physical network layer. When data is sent, each layer treats all of the information it receives from the upper layer as data, adds control information (header) to the front of that data and then pass it to the lower layer. When data is received, the opposite procedure takes place as each layer processes and removes its header before passing the data to the upper layer.

The TCP/IP 4-layer model and the key functions of each layer is described below:

Application Layer

The Application Layer in TCP/IP groups the functions of OSI Application, Presentation Layer and Session Layer. Therefore any process above the transport layer is called an Application in the TCP/IP architecture. In TCP/IP socket and port are used to describe the path over which applications communicate. Most application level protocols are associated with one or more port number.

Transport Layer

In TCP/IP architecture, there are two Transport Layer protocols. The Transmission Control Protocol (TCP) guarantees information transmission. The User Datagram Protocol (UDP) transports datagram without end-to-end reliability checking. Both protocols are useful for different applications.

Network Layer

The Internet Protocol (IP) is the primary protocol in the TCP/IP Network Layer. All upper and lower layer communications must travel through IP as they are passed through the TCP/IP protocol stack. In addition, there are many supporting protocols in the Network Layer, such as ICMP, to facilitate and manage the routing process.

Network Access Layer

In the TCP/IP architecture, the Data Link Layer and Physical Layer are normally grouped together to become the Network Access layer. TCP/IP makes use of existing Data Link and Physical Layer standards rather than defining its own. Many RFCs describe how IP utilizes and interfaces with the existing data link protocols such as Ethernet, Token Ring, FDDI, HSSI, and ATM. The physical layer, which defines the hardware communication properties, is not often directly interfaced with the TCP/IP protocols in the network layer and above.

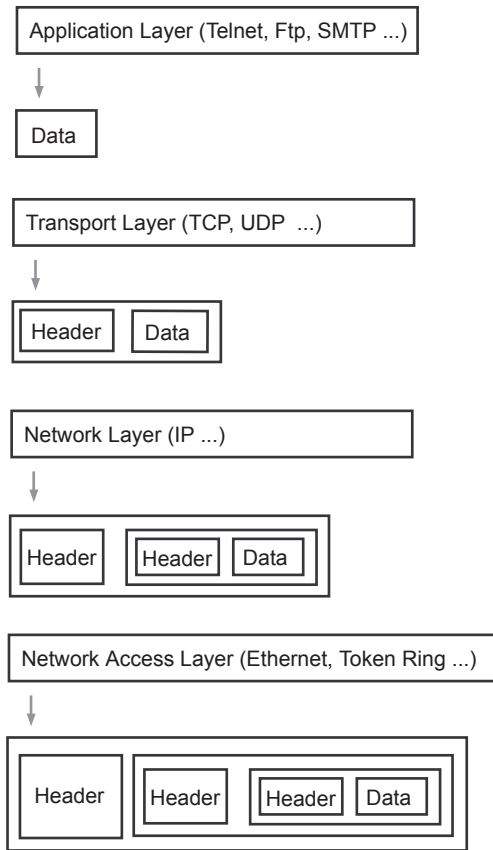


Figure 1-4: TCP/IP Protocol Stack 4 Layer Model

In this book, however, we present TCP/IP protocols into the OSI 7 layers structure for comparison purpose.

Application Layer Protocols

Protocol Name

BOOTP: Bootstrap Protocol

Protocol Description

The Bootstrap Protocol (BOOTP) is an UDP/IP-based protocol which allows a booting host to configure itself dynamically and without user supervision. BOOTP provides a means to notify a host of its assigned IP address, the IP address of a boot server host and the name of a file to be loaded into memory and executed. Other configuration information such as the local subnet mask, the local time offset, the addresses of default routers and the addresses of various Internet servers, can also be communicated to a host using BOOTP.

BOOTP uses two different well-known port numbers. UDP port number 67 is used for the server and UDP port number 68 is used for the BOOTP client. The BOOTP client broadcasts a single packet called a BOOTREQUEST packet that contains the client's physical network address and optionally, its IP address if known. The client could send the broadcast using the address 255.255.255.255, which is a special address called the limited broadcast address. The client waits for a response from the server. If a response is not received within a specified time interval, the client retransmits the request.

The server responds to the client's request with a BOOTREPLY packet. The request can (optionally) contain the 'generic' filename to be booted, for example, 'unix' or 'ethertip'. When the server sends the bootreply, it replaces this field with the fully qualified path name of the appropriate boot file. In determining this name, the server may consult its own database correlating the client's address and filename request, with a particular boot file customized for that client. If the bootrequest filename is a null string, then the server returns a filename field indicating the 'default' file to be loaded for that client.

In the case of clients which do not know their IP addresses, the server must also have a database relating hardware address to IP address. This client IP address is then placed into a field in the bootreply.

BOOTP is an alternative to RARP, which operates at the Data Link Layer for LAN only. BOOTP, a UDP/IP based configuration protocol, provides much more configuration information and allows dynamic configuration for an entire IP network. BOOTP and its extensions became the basis for the Dynamic Host Configuration Protocol (DHCP).

Protocol Structure

8	16	24	32bit
Op	Htype	Hlen	Hops
Xid			
Secs		Flags	
Ciaddr			

Yiaddr
Siaddr
Giaddr
Chaddr (16 bytes)
Sname (64 bytes)
File (128 bytes)
Option (variable)

Op The message operation code. Messages can be either BOOTREQUEST or BOOTREPLY.

Htype The hardware address type.

Hlen The hardware address length.

Xid The transaction ID.

Secs The seconds elapsed since the client began the address acquisition or renewal process.

Flags The flags.

Ciaddr The client IP address.

Yiaddr The "Your" (client) IP address.

Siaddr The IP address of the next server to use in bootstrap.

Giaddr The relay agent IP address used in booting via a relay agent.

Chaddr The client hardware address.

Sname Optional server host name, null terminated string

File Boot file name, null terminated string; generic name or null in DHCPDISCOVER, fully qualified directory-path name in DHCPDISCOVER.

Options Optional parameters field.

Related protocols

IP, UDP, DHCP, RARP

Sponsor Source

BOOTP is defined by IETF (<http://www.ietf.org>) RFC951 and RFC 1542.

Reference

<http://www.javvin.com/protocol/rfc951.pdf>

BOOTSTRAP PROTOCOL (BOOTP)

<http://www.javvin.com/protocol/rfc1542.pdf>

Clarifications and Extensions for the Bootstrap Protocol

<http://www.javvin.com/protocol/rfc2132.pdf>

DHCP Options and BOOTP Vendor Extensions

<http://www.javvin.com/protocol/rfc3396.pdf>

Encoding Long Options in the (DHCPv4)

MPLS Protocols**Protocol Name**

MPLS: Multiprotocol Label Switching

Protocol Description

Multiprotocol Label Switching (MPLS) is an architecture for fast packet switching and routing, which operates independent of the layer 2 and layer 3 protocols. MPLS provides a means to map IP addresses to simple, fixed-length labels used by different packet-forwarding and packet-switching technologies. It interfaces to existing routing and switching protocols, such as IP, ATM, Frame Relay, PPP and Ethernet. High-speed switching of data using MPLS is possible because the fixed-length labels are inserted at the very beginning of the packet or cell and can be used by hardware to switch packets quickly between links. In MPLS, data transmission occurs on Label-Switched Paths (LSPs). LSPs are virtual tunnels, that are formed by a sequence of labels at each and every node along the path from the source to the destination. Martini proposed “two-label” approach in which two labels are prepended at the ingress Label Switch Router (LSR) to carry Protocol Data Unit (PDU) forward across the entire MPLS network and finally removed at the egress LSR. The first label, called a Tunnel Label, decides which LSP will be used to get packets from the ingress LSR to the egress LSR. The second label, called a VC Label, provides Layer 2 forwarding information at egress LSR. Martini method is the most popular way for encapsulating of layer 2 protocols such as Frame Relay, ATM, or Ethernet.

MPLS utilizes existing IP routing protocols such as Border Gateway Protocol (BGP), Resource ReSerVation Protocol (RSVP) and Open Shortest Path First (OSPF), etc. MPLS has also defined a new set of protocols such as LDP, CR-LDP, RSVP-TE for more effective signaling and routing. The industry is developing more new standards such as VPLS, HVPLS and GMPLS, to fully extend its capabilities,

MPLS has mechanisms to manage traffic flows of various granularities for the purpose of traffic management and QoS. Specifically, MPLS provide a rich set of traffic management capabilities in the areas of traffic policing, congestion management, traffic shapping and priority queuing.

In summary, MPLS is designed to address many current network problems such as networks speed, scalability, quality of service (QoS) management and traffic engineering. With its powerful new features and abilities to interface with legacy technologies, MPLS has become a solution for the next generation backbone networks for multiple services such as data, voice and video over the same network.

Generalized MPLS (GMPLS), a newer standard, extends the MPLS capabilities to cover multiple underlay traffic technologies such as TDM, FDM, Fiber, Optical etc. with better management and provisioning schemes. In this section, we focus

on the MPLS framework. Other protocols in the MPLS suite and GMPLS will be discussed in separate documents.

Protocol Structure

MPLS label structure:

	20	23	24	32bit
Label	Exp	S	TTL	

- Label - Label Value carries the actual value of the Label. When a labeled packet is received, the label value at the top of the stack is looked up and the system learns:
 - the next hop to which the packet is to be forwarded;
 - the operation to be performed on the label stack before forwarding; this operation may be to replace the top label stack entry with another, or to pop an entry off the label stack, or to replace the top label stack entry and then to push one or more additional entries on the label stack.
- Exp - Experimental Use: Reserved for experimental use.
- S - Bottom of Stack: This bit is set to one for the last entry in the label stack, and zero for all other label stack entries
- TTL - Time to Live field is used to encode a time-to-live value.

The MPLS architecture protocol family includes:

- MPLS related Routing and Signaling Protocols, such as OSPF, RSVP, IS-IS, BGP, ATM PNNI, etc.
- LDP: Label Distribution Protocol.
- CR-LDP: Constraint-Based LDP
- RSVP-TE: Resource Reservation Protocol – Traffic Engineering

The following figure shows the MPLS protocol stack:

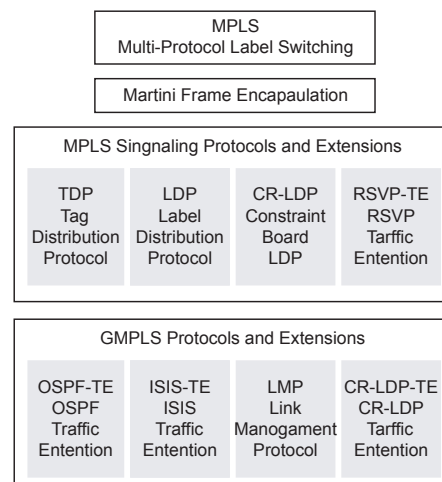


Figure 2-4: MPLS protocol stack architecture

The structure of each protocol will be discussed in separate documents.

Related protocols

LDP, CR-LDP, RSVP-TE, IP, ATM, RSVP, OSPF, GMPLS

Sponsor Source

MPLS is defined by IETF (<http://www.ietf.org>) RFC3031 and RFC 3032.

Reference

<http://www.javvin.com/protocol/rfc3031.pdf>

Multiprotocol Label Switching Architecture

<http://www.javvin.com/protocol/rfc3032.pdf>

MPLS Label Stack Encoding

<http://www.javvin.com/protocol/rfc3443.pdf>

Time To Live (TTL) Processing in Multi-Protocol Label Switching (MPLS) Networks

<http://www.javvin.com/protocol/rfc3036.pdf>

LDP Specification

<http://www.javvin.com/protocol/rfc3209.pdf>

RSVP-TE: Extensions to RSVP for LSP Tunnels

<http://www.javvin.com/protocol/rfc3212.pdf>

Constraint-Based LSP Setup using LDP

<http://www.javvin.com/protocol/rfc3213.pdf>

Applicability Statement for CR-LDP

<http://www.faqs.org/ftp/pub/internet-drafts/draft-martini-l2circuit-encap-mpls-08.txt>

Encapsulation Methods for Transport of Layer 2 Frames Over IP and MPLS Networks

TCP and UDP Port Numbers

Description

TCP and UDP are both transport protocols above the IP layer, which are interfaces between IP and upper-layer processes. TCP and UDP protocol port numbers are designed to distinguish multiple applications running on a single device with one IP address from one another.

Since many network applications may be running on the same machine, computers need something to make sure the correct software application on the destination computer gets the data packets from the source machine, and to make sure replies get routed to the correct application on the source computer. This is accomplished through the use of the TCP or UDP “port numbers”. In the TCP and UDP header, there are “Source Port” and “Destination Port” fields which are used to indicate the message sending process and receiving process identities defined. The combination of the IP address and the port number is called “socket”.

There three port ranges defined by IETF IANA: The Well Known Ports, the Registered Ports, and the Dynamic and/or Private Ports.

- The Well Known Ports are in the range of 0 to 1023, which are assigned by the IANA. In most cases, they can only be used by system (or root) processes or by programs executed by privileged users.
- The Registered Ports are in the range of 1024 to 49151, which are not controlled by IANA. They are commonly used by ordinary user processes or programs executed by ordinary users.
- The Dynamic and/or Private Ports are in the range of 49152 to 65535, which are typically used as source port by a TCP or UDP client, to communicate with a remote TCP or UDP server, using a well-known port as destination port.

Well-Known Ports

Partial TCP UDP Port Numbers (Well-Known Ports)

Port No.	Pro- to- col	Service Name	Aliases	Comment
1	TCP	tcpmux		TCP Port Service Multiplexer
2	TCP/ UDP	com- press- net		Management Utility
3	TCP/ UDP	com- press- net		Compression Process
7	TCP/ UDP	echo		Echo
13	TCP/ UDP	daytime		Daytime
19	TCP/ UDP	char- gen	ttytst source	Character generator
20	TCP	ftp-data		File Transfer
21	TCP	ftp		FTP Control
22	TCP	ssh		SSH remote login protocol
23	TCP	telnet		Telnet
25	TCP	smtp	mail	Simple Mail Transfer
37	TCP/ UDP	Time		Time
39	UDP	RLP	resource	Resource Location Protocol
42	TCP/ UDP	nam- eserver	name	Host Name Server
43	TCP	nic- name	whois	Who Is
49	UDP	TA- CACCS		TACACS: Login Host Protocol
53	TCP/ UDP	domain	DNS	Domain Name Server
67	UDP	bootps	dhcps	Bootstrap Protocol Server
68	UDP	bootpc	dhcpc	Bootstrap Protocol Client
69	UDP	TFTP		Trivial File Transfer Protocol
70	TCP	gopher		Gopher
79	TCP/ UDP	finger		Finger

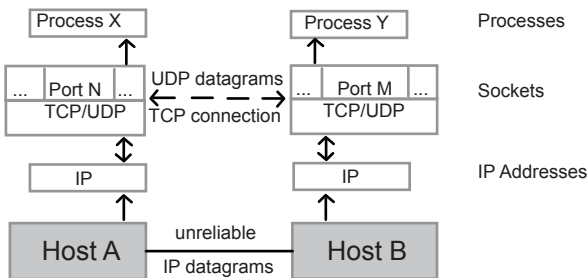


Figure 3-1: TCP/UDP Port Numbers

Network Protocols Handbook

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