NETWORK PROTOCOLS HANDBOOK

网络协议手册

(美) Javvin Technologies, Inc.

清华大学出版社

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内容简介

本书纵观网络协议，阐释和总结了所有常用网络通信协议，包括 TCP/TP，security，VoIP，WAN，LAN，MAN，SAN 等. 本书也囊括了 Cisco，Novell，IBM，Microsoft，Apple 等厂商的网络协议.

这本书可供信息技术和网络专业人员作为参考书和手册，也可供高校相关专业的学生作为参考.

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Preface

We are living in the information technologies(IT) age. The IT provides us many powerful tools that have significantly changed our way of life, work and business operations. Among all the IT advancements, Internet has the most impact on our society in every aspect for the past 20 years. From Internet, people can get instant news, communicate with others, use it as a super-encyclopedia and find anything that they are interested in via search engines at their finger tips; Company can conduct business to business(B2B), business to consumer(B2C), with great efficiency; Government can announce polices, publicize regulations, and provide administrative information and services to the general public. Internet not only provides unprecedented convenience to our daily life, but also opens up new areas of disciplines and commercial opportunities that have boosted overall economy by creating many new jobs. It is reported that Internet will become a $20 trillion industry in the near future.

The Internet has also made significant progress and rapid adoption in China. According to the 14th Statistical Survey Report on the Internet Development in China announced on July 20, 2004 by China Internet Network Information Center (CNNIC), there are about 87 million Internet users as counted by the end of June 2004, in mainland China, second only to the US; There are about 36 million computer hosts; The number of domain names registered under CN is 382 216; The number of "www" websites is 626 600. It should be also noted that China has started its China Next Generation Internet (CNGI) project at the beginning of 2000, right after US and Europe started the similar initiatives. China now is becoming one of the most important and influential members not only in the World Trade Organization, but also within the Internet community.

To build the Internet and many other networks, engineers and organizations around the world have created many technologies over the past 20 years, in which network protocol is one of the key technology areas. After years of development on the communication standards and generations of networking architecture, network communication protocols have become a very complex subject. Various standard organizations have defined many communication protocols and all major vendors have their own proprietary technologies. Yet, people in the industry are continuously proposing and designing new protocols to address new problems in the network communications. It has become a huge challenge for IT and network professionals at all levels to understand the overall picture of communication protocols and to keep up with the pace of its on-going evolutions.

Javvin Company, based on Silicon Valley in California, USA, is a network software provider. This book is one of its contributions to provide an overview of network protocols and to serve as a reference and handbook for IT and network professionals. The book fully explains and reviews all commonly used network communication protocols, including TCP/IP, security, VoIP, WAN, LAN, MAN, SAN and ISO protocols. It also covers Cisco, Novell, IBM, Microsoft, Apple and DEC network protocols. Hundreds of hyperlinks of references for further reading and studies are available in the book. It is an excellent reference for Internet programmers, network professionals and college students who are majoring IT and networking technology. It is also useful for individuals who want to know more details about the technologies underneath the Internet. I highly recommend this book to our readers.

Ke Yan, Ph. D.
Chief Architect of Juniper Networks
Founder of NetScreen Technologies

Table of Contents

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Figures

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Network Communication Architecture and Protocols

A network architecture is a blueprint of the complete computer communication network, which provides a framework and technology foundation for designing, building and managing a communication network. It typically has a layered structure. Layering is a modern network design principle which divides the communication tasks into a number of smaller parts, each part accomplishing a particular sub-task and interacting with the other parts in a small number of well-defined ways. Layering allows the parts of a communication to be designed and tested without a combinatorial explosion of cases, keeping each design relatively simple.

If a network architecture is open, no single vendor owns the technology and controls its definition and development. Anyone is free to design hardware and software based on the network architecture. The TCP/IP network architecture, which the Internet is based on, is such a open network architecture and it is adopted as a worldwide network standard and widely deployed in local area network (LAN), wide area network (WAN), small and large enterprises, and last but not the least, the Internet.

Open Systems Interconnection (OSI) network architecture, developed by International Organization for Standardization(ISO), is an open standard for communication in the network across different equipment and applications by different vendors. Though not widely deployed, the OSI 7-layer model is considered the primary network architectural model for inter-computing and inter-networking communications.

In addition to the OSI network architecture model, there exist other network architecture models by many vendors, such as IBM Systems Network Architecture(SNA), Digital Equipment Corporation's (DEC; now part of HP) Digital Network Architecture (DNA), Apple Computer's AppleTalk, and Novell's NetWare. Actually, the TCP/IP architecture does not exactly match 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.

Network architecture provides only a conceptual framework for communications between computers. The model itself does not provide specific methods of communication. Actual communication is defined by various communication protocols.

OSI Network Architecture 7-Layer Model

Open Systems Interconnection (OSI) model is a reference model developed by ISO 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 inter-networking 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-layer 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 and 5) and lower layers (layers 4, 3, 2, and 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 needs 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 Figure 1-1 illustrated this process.

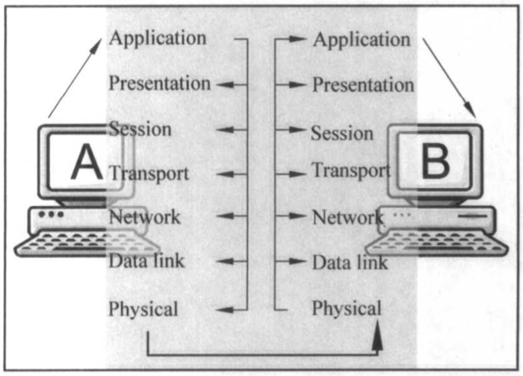

Figure 1-1 Communication between computers in a network

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.

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 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 (see Fig. 1-2).

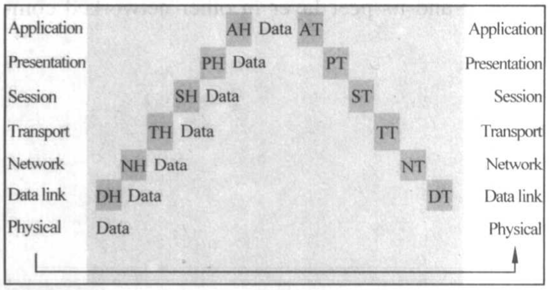

Figure 1-2 Data encapsulation at each layer

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 prepends 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 Figure 1-3 illustrates this example.

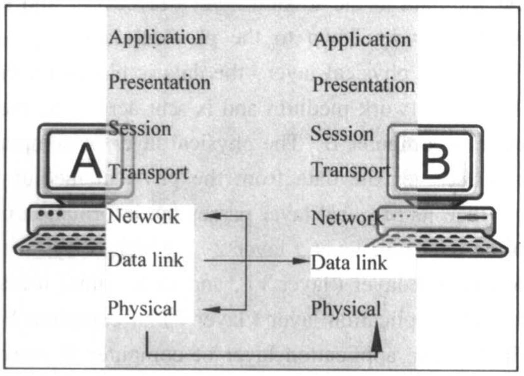

Figure 1-3 Data communication between peer layers

TCP/IP 4-Layer 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 4-layer model for the TCP/IP architecture (see Fig. 1-4).

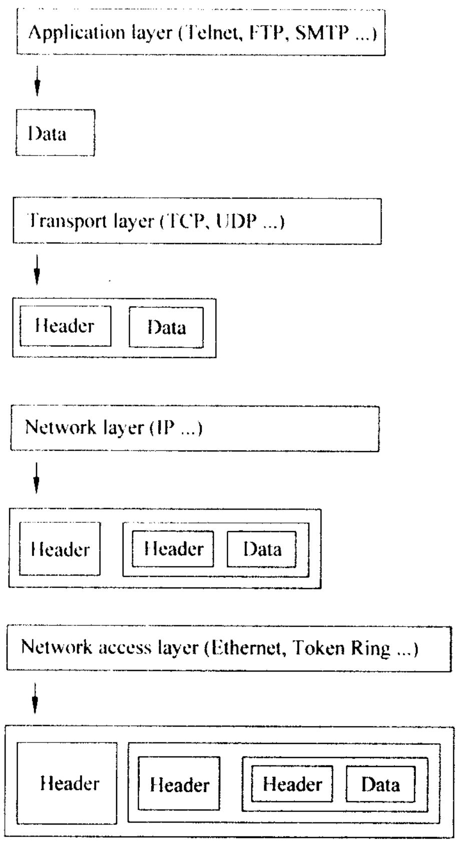

Figure 1-4 TCP/IP protocol stack 4-layer model

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 passes 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 are 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.

Other Network Architecture Models: IBM SNA

In addition to the open architectural models such as the OSI 7-layer model and the TCP/IP architecture model, there exist a few popular vendor specific network communication models, such as IBM Systems Network Architecture (SNA), Digital Equipment Corporation's (DEC, now part of HP) Digital Network Architecture (DNA). We will only provide details on the IBM SNA here.

Although it is now considered a legacy networking architecture, the IBM SNA is still widely deployed. SNA was designed around the host-to-terminal communication model that IBM's mainframes use. IBM expanded the SNA protocol to support peer-to-peer networking. This expansion was deemed Advanced Peer-to-Peer Networking (APPN) and Advanced Program-to-Program Communication (APPC). APPN represents IBM's second-generation SNA. In creating APPN, IBM moved SNA from a hierarchical, mainframe-centric environment to a peer-based networking environment. The heart of APPN is an IBM architecture that supports peer-based communications, directory services, and routing between two or more APPC systems that are not directly attached.

SNA has many similarities with the OSI 7-layer reference model. However, the SNA model has only six layers and it does not define specific protocols for its physical control layer. The physical control layer is assumed to be implemented via other standards. The functions of each SNA component are described as follows:

- Data Link Control (DLC) – defines several protocols, including the Synchronous Data Link Control (SDLC) protocol for hierarchical communication, and the token ring network communication protocol for LAN communication between peers. SDLC provided a foundation for ISO HDSL and IEEE 802.2.
- Path control – performs many OSI network layer functions, including routing and datagram segmentation and reassembly (SAR).
- Transmission control – provides a reliable end-to-end connection service (similar to TCP), as well as encrypting and decrypting services.
- Data flow control – manages request and response processing, determines whose turn it is to communicate, groups messages and interrupts data flow on request.
- Presentation services – specifies data-transformation algorithms that translate data from one format to another, coordinate resource sharing and synchronize transaction operations.
- Transaction services – provides application services in the form of programs that implement distributed processing or management services.

The Figure 1-5 illustrates how the IBM SNA model maps to the ISO OSI reference model.

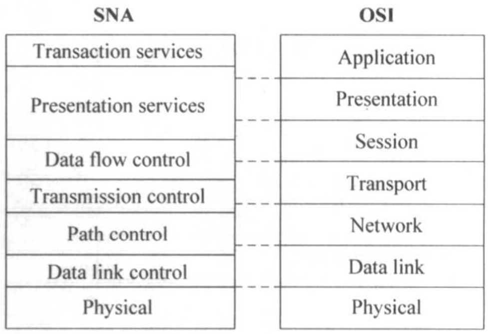

Figure 1-5 SNA vs. OSI model

The Figure 1-6 gives a typical SNA network topology.

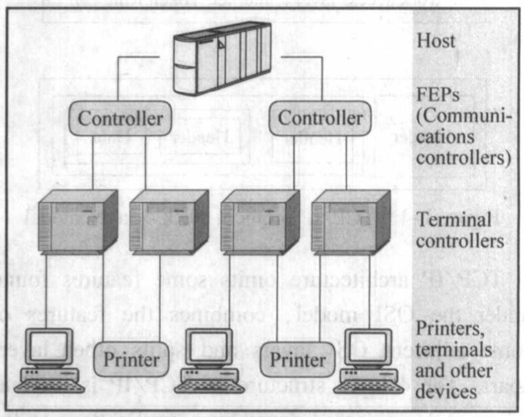

Figure 1-6 SNA network topology

SNA supports the following types of networks:

- A subarea network is a hierarchically organized network consisting of subarea nodes and peripheral nodes. Subarea nodes, such as hosts and communication controllers, handle general network routing. Peripheral nodes,

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