
Delivering Voice over IP Networks

Second Edition

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transport portion based on ATM, POS, MPLS, and Ethernet. Media plane protocols are covered in this chapter; signaling plane protocols are covered in Chapter 7; and QoS protocols are covered in Chapter 8.

This chapter covers the following issues that will play a role in voice over data networks:

- IP and IPv6 [4, 5]
- IP over ATM
- MPLS
- RTP
- Stream Control Transmission Protocol (SCTP)

2.2 Internet Protocol

This section highlights key IP functionality and capabilities.

The Role of the IP

TCP/IP is the name for a family of communications protocols used to support internetting in enterprise and interenterprise applications. Protocols include the Internet Protocol (IP), the Transmission Control Protocol (TCP), the User Datagram Protocol (UDP), and other protocols that support specific tasks, such as transferring files between computers, sending mail, or logging into another computer. TCP/IP protocols are normally deployed in layers, with each layer responsible for a different facet of the communications. Each layer has a different responsibility.

1. The *link layer* (sometimes called the *network interface layer*) normally includes the device driver in the operating system and the corresponding network interface card in the computer. Together they handle all the hardware details of physically interfacing with the cable.
2. The *network layer* (sometimes called the *internet layer*) handles the movement of packets in the network. Routing of packets, for example, takes place here. IP provides the network layer in the TCP/IP protocol suite.
3. The *transport layer* provides a flow of data between two end system hosts for the application layer above. In the Internet protocol suite there are two transport protocols, TCP and UDP. TCP provides a reliable flow of data between two hosts. It is concerned with such things as partitioning the data passed to it from the application into appropriately sized frames for the network layer below, acknowledging received packets, and setting time-outs to

make certain that the other end acknowledges packets that are sent. Because this reliable flow of data is provided by the transport layer, the application layer can ignore all those details. UDP, on the other hand, provides a much simpler service to the application layer. It sends packets of data called *datagrams* from one host to the other, but there is no guarantee that the datagrams will be delivered to the other end. Any desired reliability must be added by the application layer.

4. The *application layer* handles the details of the particular application. There are many common TCP/IP applications that almost every implementation provides:
 - Telnet for remote login
 - The file transfer protocol (FTP)
 - The Simple Mail Transfer Protocol (SMTP) for e-mail
 - The Simple Network Management Protocol (SNMP)
 - Others

In this architecture, TCP is responsible for verifying the correct delivery of data from the sender to the receiver. TCP allows a process on one end system to reliably send a stream of data to a process on another end system. It is connection-oriented: Before transmitting data, participants must establish a connection. Data can be lost in the intermediate networks. TCP adds support to detect lost data and to trigger retransmissions until the data is correctly and completely received.

IP is responsible for relaying packets of data [protocol data units (PDU)] from node to node. IP provides the basis for connectionless best-effort packet delivery service. IP's job is to move—specifically to route—blocks of data over each of the networks that sit between the end systems that want to communicate. IP provides for the carriage of datagrams from a source host to destination hosts, possibly passing through one or more gateways (routers) and networks in the process. An IP protocol data unit (datagram) is a sequence of fields containing a header and a payload. The header information identifies the source, destination, length, and characteristics of the payload contents. The payload is the actual data transported. Both end system hosts and routers in an internet are involved in the processing of the IP headers. The hosts must create and transmit them and process them on receipt; the routers must examine them for the purpose of making routing decisions and modify them (e.g., update some fields in the header) as the IP packets make their way from the source to the destination.

IP protocols are supported over a variety of underlying media, such as ATM, frame relay, dedicated lines, ISDN, Ethernet, DSL, and so forth. As IP networks have become ubiquitous, the business community has become sophisticated about utilizing IP networks as a cost-effective corporate tool, first in data communications and now for other real-time applications. Organizations favor networks based

on IP because of the flexibility and vendor support. IP networks run under the most widely used network operating systems; they are scaleable to a large degree; and they enjoy extensive implementation across product lines (e.g., in the routers, PC clients, server switches, etc.). As noted, a relatively new IP application now in demand is toll-quality, low-bandwidth voice (and fax) transmission over IP networks.

Intranets use the same WWW/HTML/HTTP and TCP/IP technology used for the Internet. When the Internet caught on in the early to mid-1990s, planners were not looking at it as a way to run their businesses. But just as the action of putting millions of computers around the world on the same protocol suite fomented the Internet revolution, so connecting islands of information in a corporation via intranets is now sparking a corporate-based information revolution. Thousands of corporations now have intranets. Across the business world, employees from engineers to office workers are creating their own home pages and sharing details of their projects with the rest of the company.

IP Routing

One of the common ways to interconnect LANs and subnetworks at this time is through the use of *routers*. Routers are found at the boundary points between two logical or physical subnetworks. Routing is a more sophisticated—and, hence, more effective—method of achieving internetworking, as compared to bridging. In theory, a router or, more specifically, a network layer relay, can translate between a subnetwork with a physical layer protocol P1, a data link layer protocol DL1, and a network layer protocol N1 to a subnetwork with a physical layer protocol P2, a data link layer protocol DL2, and a network layer protocol N2. In general, however, a router is used for internetworking two networks or subnetworks that use the same network layer but have different data link layer protocols [6–8] (see Figure 2.2).

Routers have become the fundamental and the predominant building technology for data internetworking; however, ATM technology will likely impact the overall outlook. Routers permit the physical as well as the logical interconnection of two networks. Routers support interconnection of LANs over WANs using traditional as well as new services, including frame relay and ATM. Some routers operate directly over synchronous optical network (SONET). They also are utilized to interconnect dissimilar LANs, such as Token Ring to Ethernet. With the introduction of Layer 2 switching, ATM, and/or MPLS, however, the role of routers in enterprise networks could change slightly. For example, devices enabling connectivity between locations based on router technology may, conceivably, no longer be obligatory elements—but the concept of routing (forwarding frames at the network layer of the protocol model) will certainly continue to exist. In addition, routers work well for traditional data applications, but new broadband video and multimedia applications need different forwarding treatment, higher throughput, and tighter QoS control.

6.2 IP/Internet Background

Network communications can be categorized into two basic types, as implied in Chapter 2: *circuit-switched* (sometimes called connection-oriented) and *packet- or fastpacket-switched* (these can be connectionless or connection-oriented). Circuit-switched networks operate by forming a dedicated connection (circuit) between two points. In packet-switched networks, data to be transferred across a network is segmented into small blocks called *packets* [also called datagrams or protocol data units (PDUs)] that are multiplexed onto high-capacity intermachine connections. A packet, which usually contains a few hundred bytes of data, carries identification that enables the network hardware to know how to send it forward to the specified destination. In frame relay, the basic transfer unit is the data link layer *frame*; in cell relay, this basic unit is the data link layer *cell*. Services such as frame relay and ATM use circuit-switching principles; namely, they use a call setup mechanism similar to that of a circuit-switched (ISDN) call. IP has become the de facto standard connectionless packet network layer protocol for both local area networks (LANs) and wide area networks (WANs). In a connectionless environment there is no call setup. Each packet finds its way across the network independently of the previous one.

Internet Protocol Suite

Chapter 2 provided a basic review of the TCP/IP and UDP/IP suite of networking protocols. TCP/IP is a family of over 100 data communications protocols used in the Internet and in intranets. In addition to the communication functions supported by TCP (end-to-end reliability over a connection-oriented session) and IP (subnetwork-level routing and forwarding in a connectionless manner), the other protocols in the suite support specific application-oriented tasks, for example, transferring files between computers, sending mail, or logging into a remote host. TCP/IP protocols support layered communication, with each layer responsible for a different facet of the communications (as seen in Table 6.2). Some of the VOIP applications utilize TCP, while others utilize RTP and UDP.

The Internet

The same IP technology now used extensively in corporate internets is also used in (and, in fact, originated from) the Internet. The Internet is a global collection of interconnected business, government, and education computer networks—in effect, a network of networks. Recently there has been a near-total commercialization of the Internet, allowing it to be used for pure business applications (the original roots of the Internet were in the research and education arenas). A person at a computer terminal or personal computer equipped with the proper software communicates across the Internet by having the driver place the data in an IP packet and addressing

Table 6.2 Functionality of the TCP/IP Suite Layers

Network interface layer	This layer is responsible for accepting and transmitting IP datagrams. This layer may consist of a device driver (e.g., when the network is a local network to which the machine attaches directly) or of a complex subsystem that uses its own data link protocol.
Network layer (Internet layer)	This layer handles communication from one machine to the other. It accepts a request to send data from the transport layer, along with the identification of the destination. It encapsulates the transport layer data unit in an IP datagram and uses the datagram routing algorithm to determine whether to send the datagram directly onto a router. The internet layer also handles the incoming datagrams and uses the routing algorithm to determine whether the datagram is to be processed locally or be forwarded.
Transport layer	In this layer the software segments the stream of data being transmitted into small data units and passes each packet, along with a destination address, to the next layer for transmission. The software adds information to the packets, including codes that identify which application program sent it, as well as a checksum. This layer also regulates the flow of information and provides reliable transport, ensuring that data arrives in sequence and with no errors.
Application layer	At this level, users invoke application programs to access available services across the TCP/IP internet. The application program chooses the kind of transport needed, which can be either messages or stream of bytes, and passes it to the transport level.

the packet to a particular destination on the Internet. Communications software in routers in the intervening networks between the source and destination networks reads the addresses on packets moving through the Internet and forwards the packets toward their destinations. TCP guarantees end-to-end integrity.

From a thousand or so networks in the mid-1980s, the Internet has grown to an estimated 100 million connected network hosts with about 300 million people having access to it (as of 2001). The majority of these Internet users currently live in the United States or Europe, but the Internet is expected to have ubiquitous global reach over the next few years.

In 1973, ARPA initiated a research program to investigate techniques and technologies for interlinking packet networks of various kinds. The objective was to develop communication protocols that would allow networked computers to communicate transparently across multiple packet networks. The project became very successful and there was increasing demand to use the network, so the government separated military traffic from civilian research traffic, bridging the two by using