

high-speed local area network access, wireless access, and 56 kbps dial-up modem access. ISPs also provide Internet access to content providers, connecting Web sites directly to the Internet. The Internet is all about connecting end systems to each other, so the ISPs that provide access to end systems must also be interconnected. These lower-tier ISPs are interconnected through national and international upper-tier ISPs such as Level 3 Communications, AT&T, Sprint, and NTT. An upper-tier ISP consists of high-speed routers interconnected with high-speed fiber-optic links. Each ISP network, whether upper-tier or lower-tier, is managed independently, runs the IP protocol (see below), and conforms to certain naming and address conventions. We'll examine ISPs and their interconnection more closely in Section 1.3.

End systems, packet switches, and other pieces of the Internet run **protocols** that control the sending and receiving of information within the Internet. The **Transmission Control Protocol (TCP)** and the **Internet Protocol (IP)** are two of the most important protocols in the Internet. The IP protocol specifies the format of the packets that are sent and received among routers and end systems. The Internet's principal protocols are collectively known as **TCP/IP**. We'll begin looking into protocols in this introductory chapter. But that's just a start—much of this book is concerned with computer network protocols!

Given the importance of protocols to the Internet, it's important that everyone agree on what each and every protocol does, so that people can create systems and products that interoperate. This is where standards come into play. **Internet standards** are developed by the Internet Engineering Task Force (IETF)[IETF 2012]. The IETF standards documents are called **requests for comments (RFCs)**. RFCs started out as general requests for comments (hence the name) to resolve network and protocol design problems that faced the precursor to the Internet [Allman 2011]. RFCs tend to be quite technical and detailed. They define protocols such as TCP, IP, HTTP (for the Web), and SMTP (for e-mail). There are currently more than 6,000 RFCs. Other bodies also specify standards for network components, most notably for network links. The IEEE 802 LAN/MAN Standards Committee [IEEE 802 2012], for example, specifies the Ethernet and wireless WiFi standards.

### 1.1.2 A Services Description

Our discussion above has identified many of the pieces that make up the Internet. But we can also describe the Internet from an entirely different angle—namely, as *an infrastructure that provides services to applications*. These applications include electronic mail, Web surfing, social networks, instant messaging, Voice-over-IP (VoIP), video streaming, distributed games, peer-to-peer (P2P) file sharing, television over the Internet, remote login, and much, much more. The applications are said to be **distributed applications**, since they involve multiple end systems that exchange data with each other. Importantly, Internet applications

run on end systems—they do not run in the packet switches in the network core. Although packet switches facilitate the exchange of data among end systems, they are not concerned with the application that is the source or sink of data.

Let's explore a little more what we mean by an infrastructure that provides services to applications. To this end, suppose you have an exciting new idea for a distributed Internet application, one that may greatly benefit humanity or one that may simply make you rich and famous. How might you go about transforming this idea into an actual Internet application? Because applications run on end systems, you are going to need to write programs that run on the end systems. You might, for example, write your programs in Java, C, or Python. Now, because you are developing a distributed Internet application, the programs running on the different end systems will need to send data to each other. And here we get to a central issue—one that leads to the alternative way of describing the Internet as a platform for applications. How does one program running on one end system instruct the Internet to deliver data to another program running on another end system?

End systems attached to the Internet provide an **Application Programming Interface (API)** that specifies how a program running on one end system asks the Internet infrastructure to deliver data to a specific destination program running on another end system. This Internet API is a set of rules that the sending program must follow so that the Internet can deliver the data to the destination program. We'll discuss the Internet API in detail in Chapter 2. For now, let's draw upon a simple analogy, one that we will frequently use in this book. Suppose Alice wants to send a letter to Bob using the postal service. Alice, of course, can't just write the letter (the data) and drop the letter out her window. Instead, the postal service requires that Alice put the letter in an envelope; write Bob's full name, address, and zip code in the center of the envelope; seal the envelope; put a stamp in the upper-right-hand corner of the envelope; and finally, drop the envelope into an official postal service mailbox. Thus, the postal service has its own "postal service API," or set of rules, that Alice must follow to have the postal service deliver her letter to Bob. In a similar manner, the Internet has an API that the program sending data must follow to have the Internet deliver the data to the program that will receive the data.

The postal service, of course, provides more than one service to its customers. It provides express delivery, reception confirmation, ordinary use, and many more services. In a similar manner, the Internet provides multiple services to its applications. When you develop an Internet application, you too must choose one of the Internet's services for your application. We'll describe the Internet's services in Chapter 2.

We have just given two descriptions of the Internet; one in terms of its hardware and software components, the other in terms of an infrastructure for providing services to distributed applications. But perhaps you are still confused as to what the