

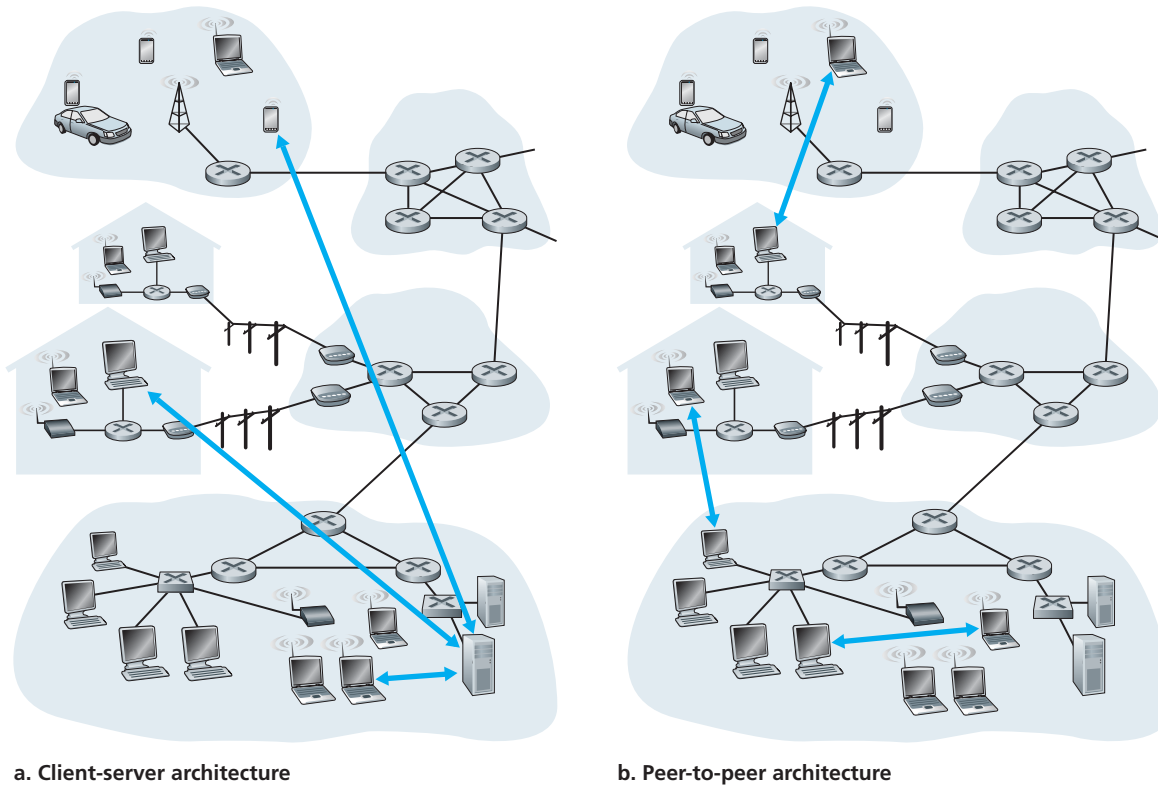
### 2.1.1 Network Application Architectures

Before diving into software coding, you should have a broad architectural plan for your application. Keep in mind that an application's architecture is distinctly different from the network architecture (e.g., the five-layer Internet architecture discussed in Chapter 1). From the application developer's perspective, the network architecture is fixed and provides a specific set of services to applications. The **application architecture**, on the other hand, is designed by the application developer and dictates how the application is structured over the various end systems. In choosing the application architecture, an application developer will likely draw on one of the two predominant architectural paradigms used in modern network applications: the client-server architecture or the peer-to-peer (P2P) architecture

In a **client-server architecture**, there is an always-on host, called the *server*, which services requests from many other hosts, called *clients*. A classic example is the Web application for which an always-on Web server services requests from browsers running on client hosts. When a Web server receives a request for an object from a client host, it responds by sending the requested object to the client host. Note that with the client-server architecture, clients do not directly communicate with each other; for example, in the Web application, two browsers do not directly communicate. Another characteristic of the client-server architecture is that the server has a fixed, well-known address, called an IP address (which we'll discuss soon). Because the server has a fixed, well-known address, and because the server is always on, a client can always contact the server by sending a packet to the server's IP address. Some of the better-known applications with a client-server architecture include the Web, FTP, Telnet, and e-mail. The client-server architecture is shown in Figure 2.2(a).

Often in a client-server application, a single-server host is incapable of keeping up with all the requests from clients. For example, a popular social-networking site can quickly become overwhelmed if it has only one server handling all of its requests. For this reason, a **data center**, housing a large number of hosts, is often used to create a powerful virtual server. The most popular Internet services—such as search engines (e.g., Google and Bing), Internet commerce (e.g., Amazon and e-Bay), Web-based email (e.g., Gmail and Yahoo Mail), social networking (e.g., Facebook and Twitter)—employ one or more data centers. As discussed in Section 1.3.3, Google has 30 to 50 data centers distributed around the world, which collectively handle search, YouTube, Gmail, and other services. A data center can have hundreds of thousands of servers, which must be powered and maintained. Additionally, the service providers must pay recurring interconnection and bandwidth costs for sending data from their data centers.

In a **P2P architecture**, there is minimal (or no) reliance on dedicated servers in data centers. Instead the application exploits direct communication between pairs of intermittently connected hosts, called *peers*. The peers are not owned by the service provider, but are instead desktops and laptops controlled by users, with most of the peers residing in homes, universities, and offices. Because the peers communicate without passing through a dedicated server, the architecture is called peer-to-peer. Many of today's most popular and traffic-intensive applications are based on P2P architectures. These applications include file sharing (e.g., BitTorrent), peer-assisted



**Figure 2.2** ♦ (a) Client-server architecture; (b) P2P architecture

download acceleration (e.g., Xunlei), Internet Telephony (e.g., Skype), and IPTV (e.g., Kankan and PPstream). The P2P architecture is illustrated in Figure 2.2(b). We mention that some applications have hybrid architectures, combining both client-server and P2P elements. For example, for many instant messaging applications, servers are used to track the IP addresses of users, but user-to-user messages are sent directly between user hosts (without passing through intermediate servers).

One of the most compelling features of P2P architectures is their **self-scalability**. For example, in a P2P file-sharing application, although each peer generates workload by requesting files, each peer also adds service capacity to the system by distributing files to other peers. P2P architectures are also cost effective, since they normally don't require significant server infrastructure and server bandwidth (in contrast with clients-server designs with datacenters). However, future P2P applications face three major challenges:

1. *ISP Friendly*. Most residential ISPs (including DSL and cable ISPs) have been dimensioned for “asymmetrical” bandwidth usage, that is, for much more