8.5.2 PGP

Written by Phil Zimmermann in 1991, **Pretty Good Privacy (PGP)** is an e-mail encryption scheme that has become a *de facto* standard. Its Web site serves more than a million pages a month to users in 166 countries [PGPI 2012]. Versions of PGP are available in the public domain; for example, you can find the PGP software for your favorite platform as well as lots of interesting reading at the International PGP Home Page [PGPI 2012]. (A particularly interesting essay by the author of PGP is [Zimmermann 2012].) The PGP design is, in essence, the same as the design shown in Figure 8.21. Depending on the version, the PGP software uses MD5 or SHA for calculating the message digest; CAST, triple-DES, or IDEA for symmetric key encryption; and RSA for the public key encryption.

When PGP is installed, the software creates a public key pair for the user. The public key can be posted on the user's Web site or placed in a public key server. The private key is protected by the use of a password. The password has to be entered every time the user accesses the private key. PGP gives the user the option of digitally signing the message, encrypting the message, or both digitally signing and encrypting. Figure 8.22 shows a PGP signed message. This message appears after the MIME header. The encoded data in the message is $K_A^-(H(m))$, that is, the digitally signed message digest. As we discussed above, in order for Bob to verify the integrity of the message, he needs to have access to Alice's public key.

Figure 8.23 shows a secret PGP message. This message also appears after the MIME header. Of course, the plaintext message is not included within the secret e-mail message. When a sender (such as Alice) wants both confidentiality and integrity, PGP contains a message like that of Figure 8.23 within the message of Figure 8.22.

PGP also provides a mechanism for public key certification, but the mechanism is quite different from the more conventional CA. PGP public keys are certified by a *web of trust.* Alice herself can certify any key/username pair when she believes the

```
-----BEGIN PGP SIGNED MESSAGE-----
Hash:  SHA1
Bob:
Can I see you tonight?
Passionately yours, Alice
-----BEGIN PGP SIGNATURE-----
Version: PGP for Personal Privacy 5.0
Charset:  noconv
yhHJRHhGJGhgg/12EpJ+lo8gE4vB3mqJhFEvZP9t6n7G6m5Gw2
-----END PGP SIGNATURE-----
```

Figure 8.22 ♦ A PGP signed message

```
-----BEGIN PGP MESSAGE-----
Version: PGP for Personal Privacy 5.0
u2R4d+/jKmn8Bc5+hgDsqAewsDfrGdszX68liKm5F6Gc4sDfcXyt
RfdS10juHgbcfDssWe7/K=lKhnMikLo0+1/BvcX4t==Ujk9PbcD4
Thdf2awQfgHbnmKlok8iy6gThlp
-----END PGP MESSAGE
```

Figure 8.23 ♦ A secret PGP message

pair really belong together. In addition, PGP permits Alice to say that she trusts another user to vouch for the authenticity of more keys. Some PGP users sign each other's keys by holding key-signing parties. Users physically gather, exchange public keys, and certify each other's keys by signing them with their private keys.

8.6 Securing TCP Connections: SSL

In the previous section, we saw how cryptographic techniques can provide confidentiality, data integrity, and end-point authentication to a specific application, namely, e-mail. In this section, we'll drop down a layer in the protocol stack and examine how cryptography can enhance TCP with security services, including confidentiality, data integrity, and end-point authentication. This enhanced version of TCP is commonly known as **Secure Sockets Layer (SSL)**. A slightly modified version of SSL version 3, called **Transport Layer Security (TLS)**, has been standardized by the IETF [RFC 4346].

The SSL protocol was originally designed by Netscape, but the basic ideas behind securing TCP had predated Netscape's work (for example, see Woo [Woo 1994]). Since its inception, SSL has enjoyed broad deployment. SSL is supported by all popular Web browsers and Web servers, and it is used by essentially all Internet commerce sites (including Amazon, eBay, Yahoo!, MSN, and so on). Tens of billions of dollars are spent over SSL every year. In fact, if you have ever purchased anything over the Internet with your credit card, the communication between your browser and the server for this purchase almost certainly went over SSL. (You can identify that SSL is being used by your browser when the URL begins with https: rather than http.)

To understand the need for SSL, let's walk through a typical Internet commerce scenario. Bob is surfing the Web and arrives at the Alice Incorporated site, which is selling perfume. The Alice Incorporated site displays a form in which Bob is supposed to enter the type of perfume and quantity desired, his address, and his payment card number. Bob enters this information, clicks on Submit, and

expects to receive (via ordinary postal mail) the purchased perfumes; he also expects to receive a charge for his order in his next payment card statement. This all sounds good, but if no security measures are taken, Bob could be in for a few surprises.

- If no confidentiality (encryption) is used, an intruder could intercept Bob's order and obtain his payment card information. The intruder could then make purchases at Bob's expense.
- If no data integrity is used, an intruder could modify Bob's order, having him purchase ten times more bottles of perfume than desired.
- Finally, if no server authentication is used, a server could display Alice Incorporated's famous logo when in actuality the site maintained by Trudy, who is masquerading as Alice Incorporated. After receiving Bob's order, Trudy could take Bob's money and run. Or Trudy could carry out an identity theft by collecting Bob's name, address, and credit card number.

SSL addresses these issues by enhancing TCP with confidentiality, data integrity, server authentication, and client authentication.

SSL is often used to provide security to transactions that take place over HTTP. However, because SSL secures TCP, it can be employed by any application that runs over TCP. SSL provides a simple Application Programmer Interface (API) with sockets, which is similar and analogous to TCP's API. When an application wants to employ SSL, the application includes SSL classes/libraries. As shown in Figure 8.24, although SSL technically resides in the application layer, from the developer's perspective it is a transport protocol that provides TCP's services enhanced with security services.

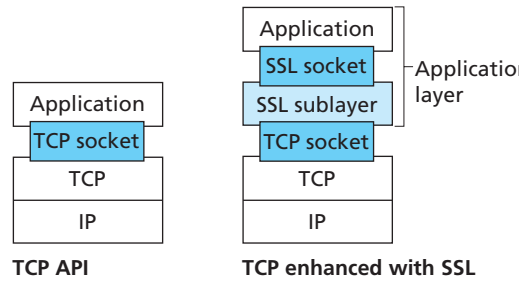

Figure 8.24 ♦ Although SSL technically resides in the application layer, from the developer's perspective it is a transport-layer protocol