

Chapter 13

Digital Signature

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Chapter 13

Objectives

- ☐ To define a digital signature
- ☐ To define security services provided by a digital signature
- ☐ To define attacks on digital signatures
- ☐ To discuss some digital signature schemes, including RSA, ElGamal,
Schnorr, DSS, and elliptic curve
- ☐ To describe some applications of digital signatures

13-1 COMPARISON

Let us begin by looking at the differences between conventional signatures and digital signatures.

Topics discussed in this section:

13.1.1 Inclusion

13.1.2 Verification Method 390

13.1.3 Relationship

13.1.4 Duplicity



13.1.1 Inclusion

A conventional signature is included in the document; it is part of the document. But when we sign a document digitally, we send the signature as a separate document.



13.1.2 Verification Method

For a conventional signature, when the recipient receives a document, she compares the signature on the document with the signature on file. For a digital signature, the recipient receives the message and the signature. The recipient needs to apply a verification technique to the combination of the message and the signature to verify the authenticity.



13.1.3 Relationship

For a conventional signature, there is normally a one-to-many relationship between a signature and documents. For a digital signature, there is a one-to-one relationship between a signature and a message.



13.1.4 Duplicity

In conventional signature, a copy of the signed document can be distinguished from the original one on file. In digital signature, there is no such distinction unless there is a factor of time on the document.

13-2 PROCESS

Figure 13.1 shows the digital signature process. The sender uses a signing algorithm to sign the message. The message and the signature are sent to the receiver. The receiver receives the message and the signature and applies the verifying algorithm to the combination. If the result is true, the message is accepted; otherwise, it is rejected.

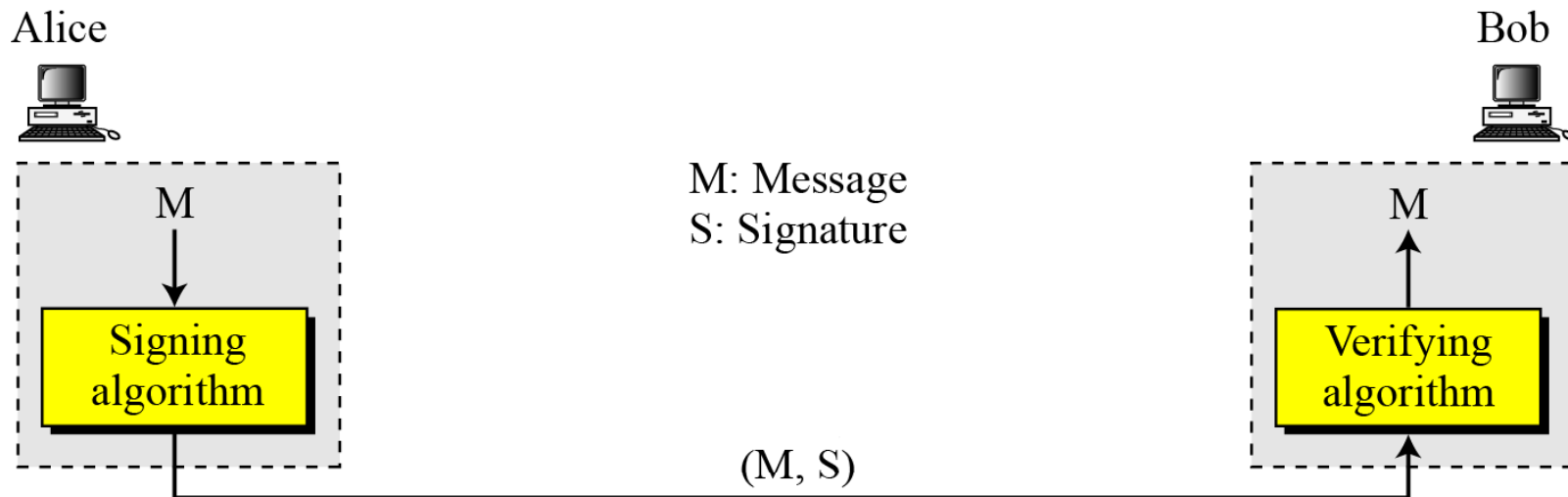
Topics discussed in this section:

13.2.1 Need for Keys

13.2.2 Signing the Digest

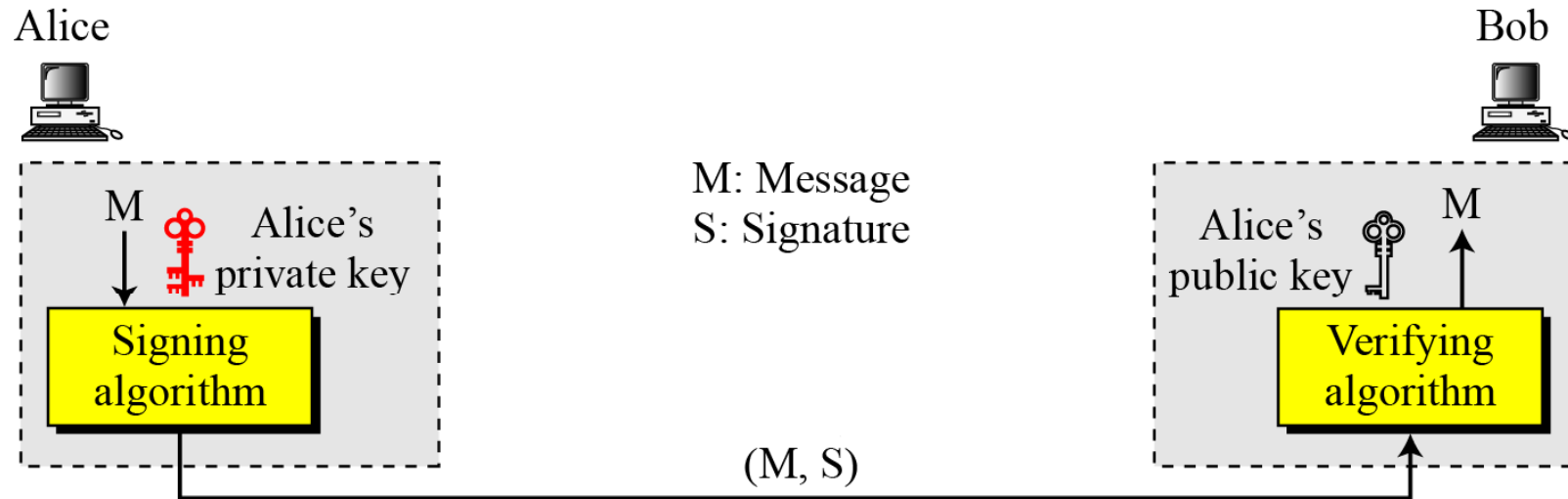
13-2 Continued

Figure 13.1 *Digital signature process*



13.2.1 Need for Keys

Figure 13.2 *Adding key to the digital signature process*



Note

A digital signature needs a public-key system. The signer signs with her private key; the verifier verifies with the signer's public key.



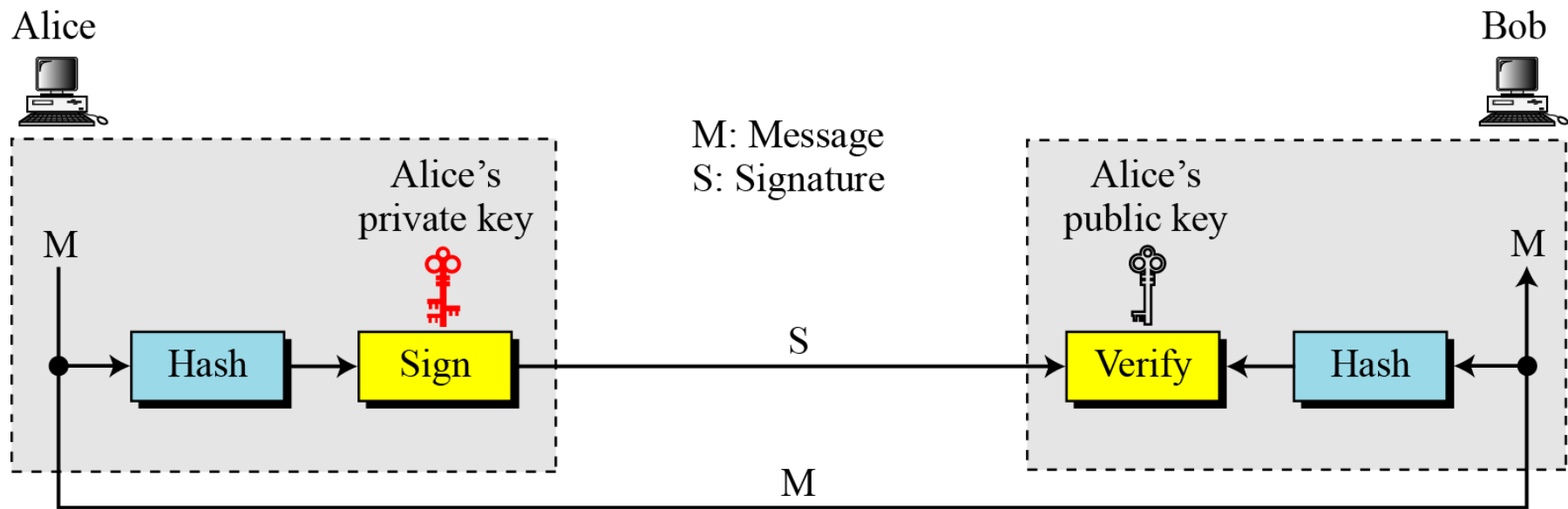
13.2.1 Continued

Note

A cryptosystem uses the private and public keys of the receiver: a digital signature uses the private and public keys of the sender.

13.2.2 Signing the Digest

Figure 13.3 *Signing the digest*



13-3 SERVICES

*We discussed several security services in Chapter 1 including message confidentiality, **message authentication**, message integrity, and **nonrepudiation**. A digital signature can directly provide the last three; for message confidentiality we still need encryption/decryption.*

Topics discussed in this section:

13.3.1 Message Authentication

13.3.2 Message Integrity

13.3.3 Nonrepudiation

13.3.4 Confidentiality



13.3.1 Message Authentication

A secure digital signature scheme, like a secure conventional signature can provide message authentication.

Note

A digital signature provides message authentication.



13.3.2 Message Integrity

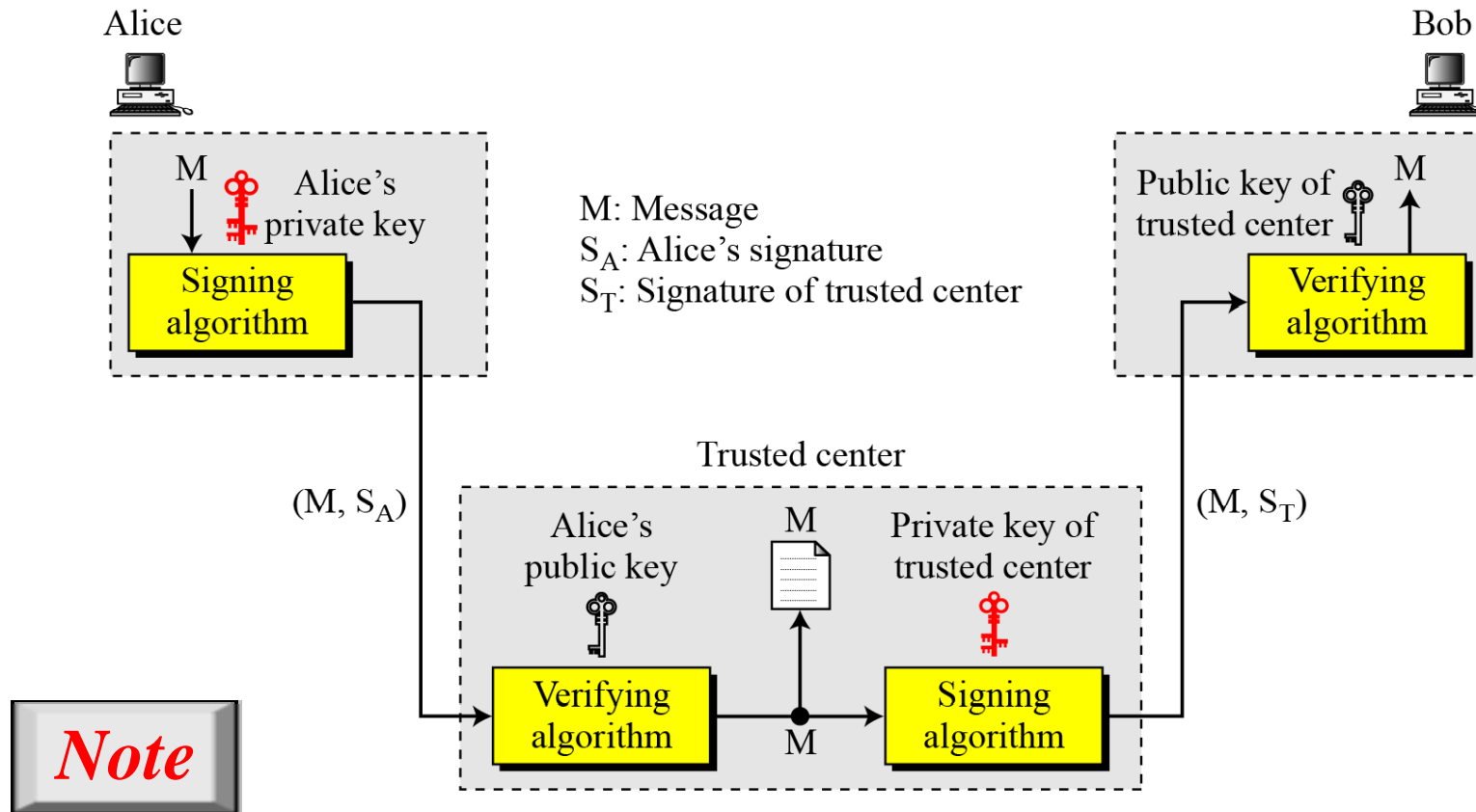
The integrity of the message is preserved even if we sign the whole message because we cannot get the same signature if the message is changed.

Note

A digital signature provides message integrity.

13.3.3 Nonrepudiation

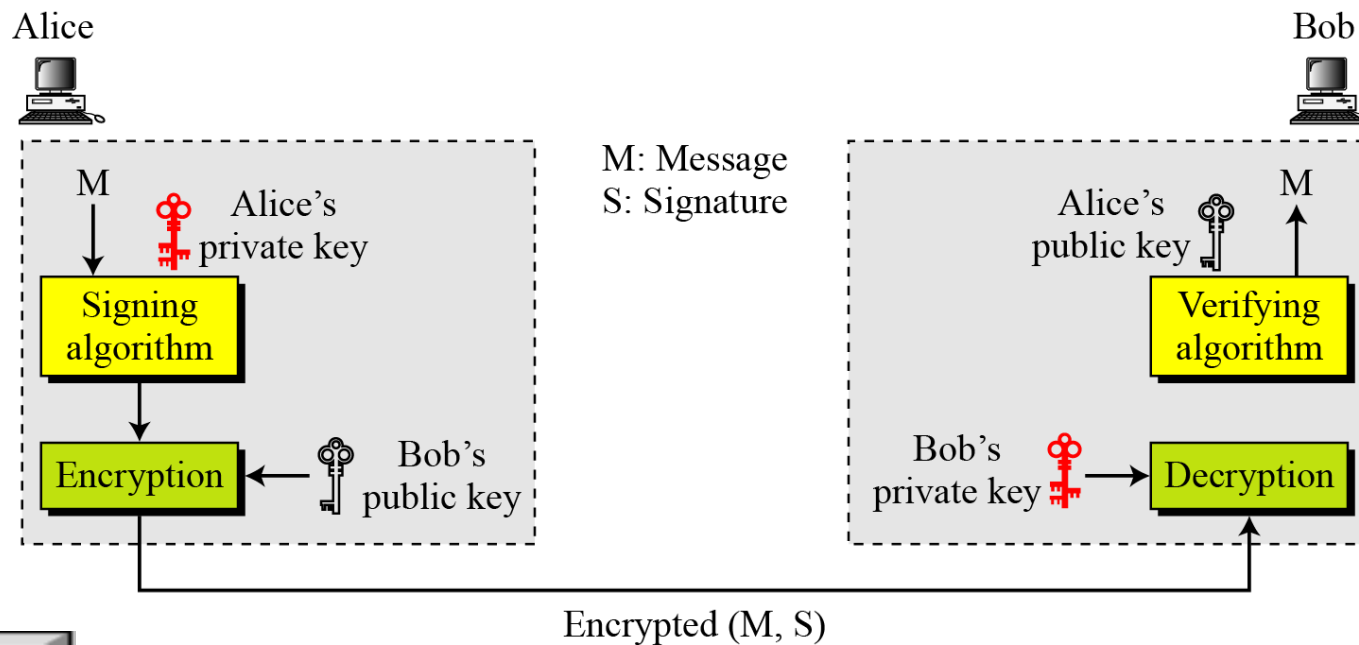
Figure 13.4 *Using a trusted center for nonrepudiation*



Nonrepudiation can be provided using a trusted party.

13.3.4 Confidentiality

Figure 13.5 *Adding confidentiality to a digital signature scheme*



Note

A digital signature does not provide privacy. If there is a need for privacy, another layer of encryption/decryption must be applied.

13-4 ATTACKS ON DIGITAL SIGNATURE

This section describes some attacks on digital signatures and defines the types of forgery.

Topics discussed in this section:

13.4.1 Attack Types

13.4.2 Forgery Types



13.4.1 Attack Types

Key-Only Attack

the attacker is only given the public verification key.

Known-Message Attack

the attacker is given valid signatures for a variety of messages known by the attacker but not chosen by the attacker.

Chosen-Message Attack

the attacker first learns signatures on arbitrary messages of the attacker's choice.



13.4.2 Forgery Types

Existential Forgery

Existential forgery is the creation (by an adversary) of any message/signature pair (m, σ) , where σ was not produced by the legitimate signer.

Selective Forgery

Selective forgery is the creation (by an adversary) of a message/signature pair (m, σ) **where m has been chosen by the adversary prior to the attack.**

13-5 DIGITAL SIGNATURE SCHEMES

Several digital signature schemes have evolved during the last few decades. Some of them have been implemented.

Topics discussed in this section:

- 13.5.1** RSA Digital Signature Scheme
- 13.5.2** ElGamal Digital Signature Scheme
- 13.5.3** Schnorr Digital Signature Scheme
- 13.5.4** Digital Signature Standard (DSS)
- 13.5.5** Elliptic Curve Digital Signature Scheme



13.5.1 Continued

Key Generation

Key generation in the RSA digital signature scheme is exactly the same as key generation in the RSA

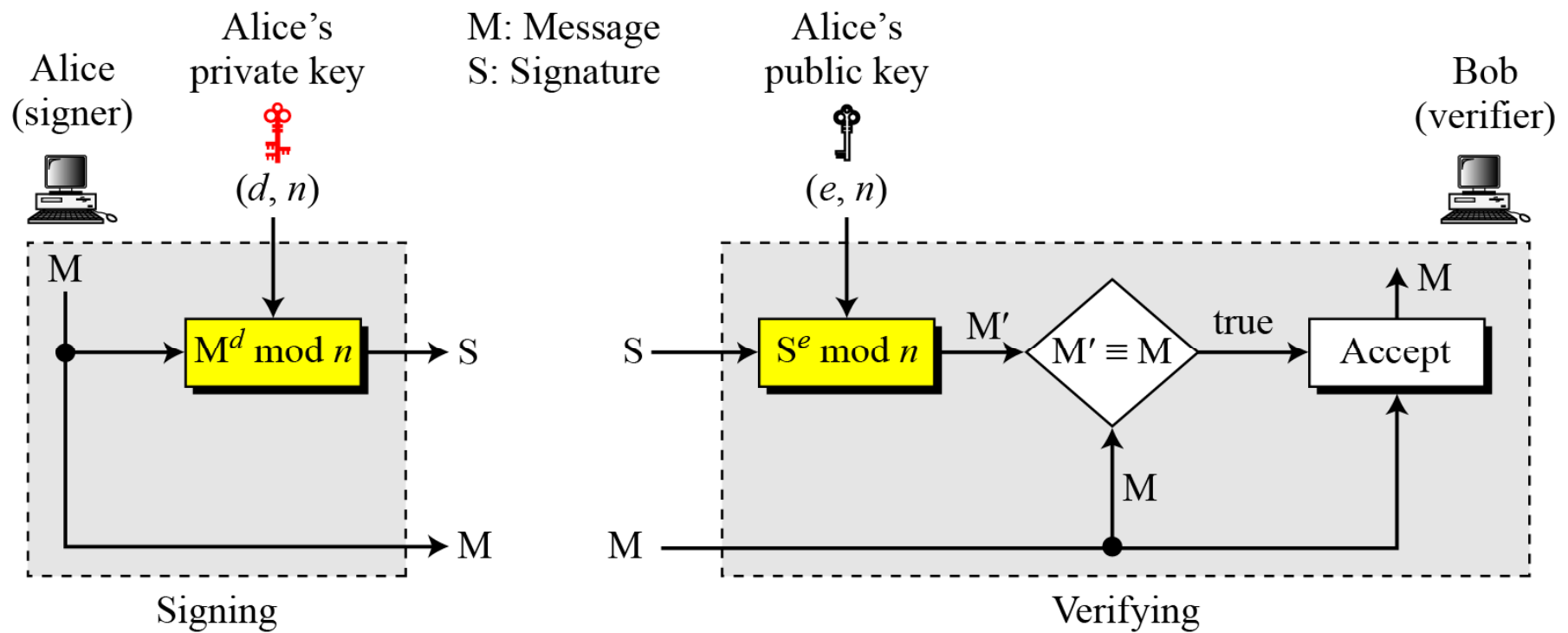
Note

**In the RSA digital signature scheme, d is private;
 e and n are public.**

13.5.1 Continued

Signing and Verifying

Figure 13.7 *RSA digital signature scheme*





13.5.1 Continued

Example 13.1

As a trivial example, suppose that Alice chooses $p = 823$ and $q = 953$, and calculates $n = 784319$. The value of $\phi(n)$ is 782544. Now she chooses $e = 313$ and calculates $d = 160009$. At this point key generation is complete. Now imagine that Alice wants to send a message with the value of $M = 19070$ to Bob. She uses her private exponent, 160009, to sign the message:

$$M: 19070 \rightarrow S = (19070^{160009}) \bmod 784319 = 210625 \bmod 784319$$

Alice sends the message and the signature to Bob. Bob receives the message and the signature. He calculates

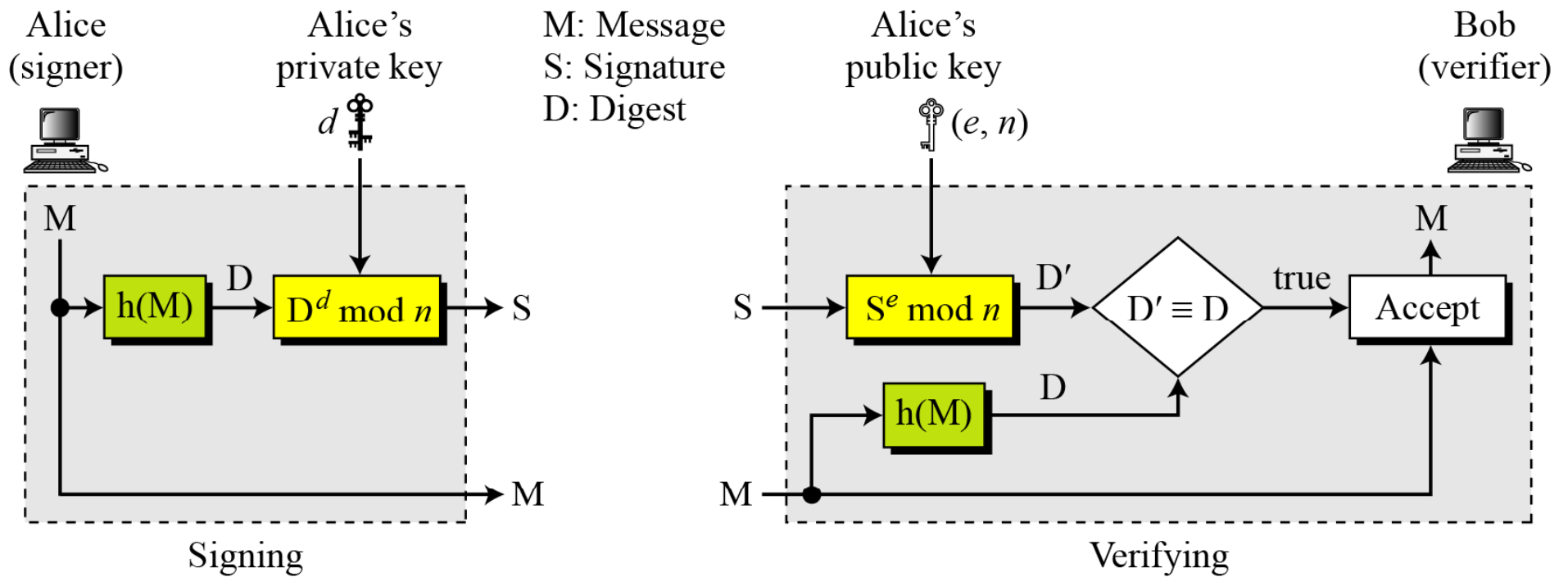
$$M' = 210625^{313} \bmod 784319 = 19070 \bmod 784319 \rightarrow M \equiv M' \bmod n$$

Bob accepts the message because he has verified Alice's signature.

13.5.1 Continued

RSA Signature on the Message Digest

Figure 13.8 *The RSA signature on the message digest*





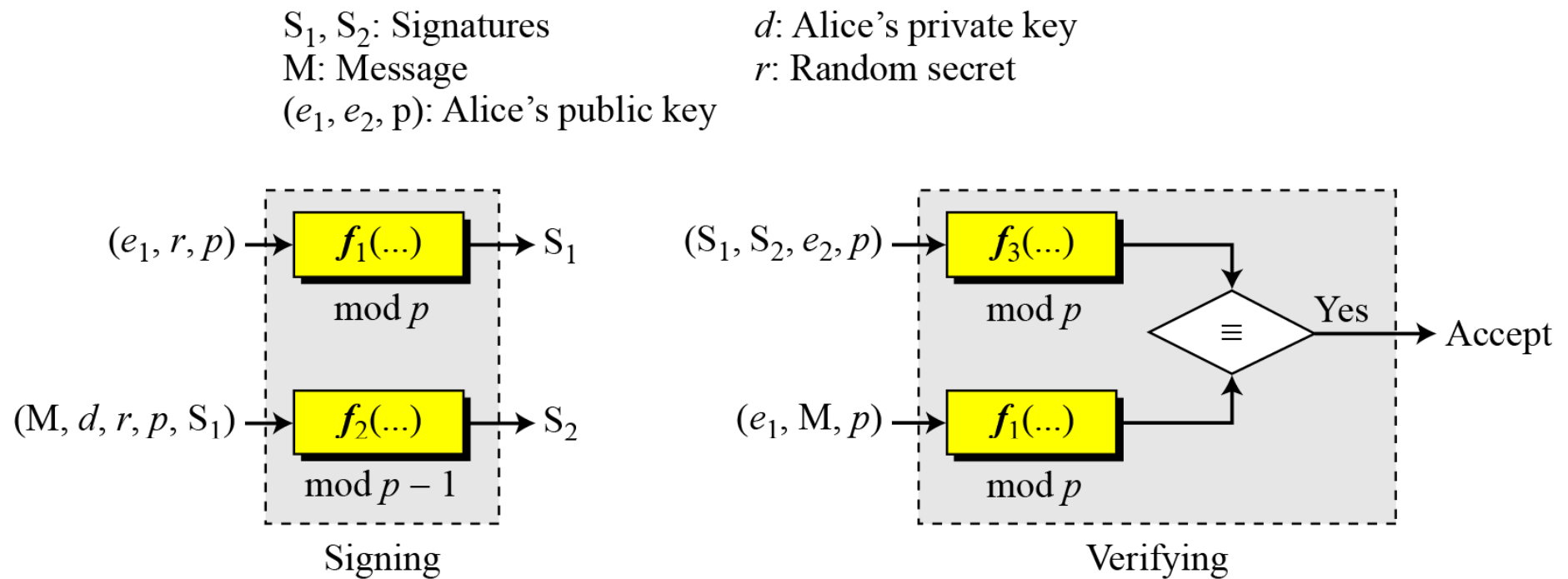
13.5.1 Continued

Note

When the digest is signed instead of the message itself, the susceptibility of the RSA digital signature scheme depends on the strength of the hash algorithm.

13.5.2 ElGamal Digital Signature Scheme

Figure 13.9 *General idea behind the ElGamal digital signature scheme*





13.5.2 Continued

Key Generation

The key generation procedure here is exactly the same as the one used in the cryptosystem.

Note

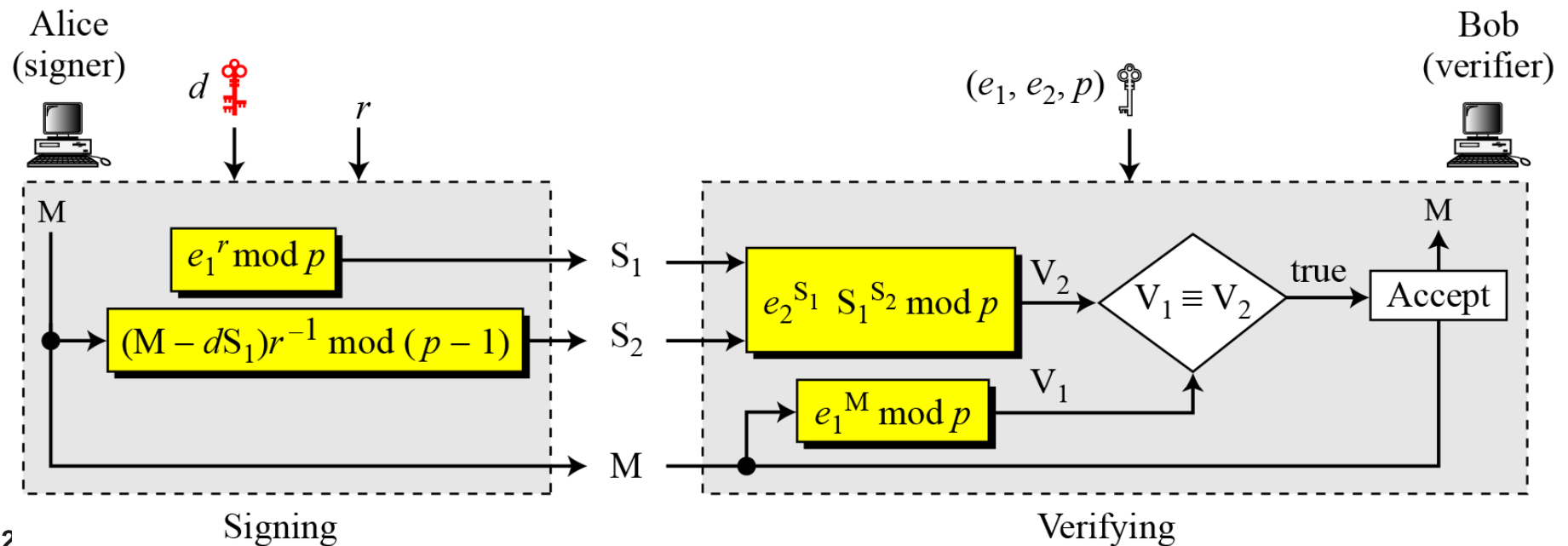
In ElGamal digital signature scheme, (e_1, e_2, p) is Alice's public key; d is her private key.

13.5.2 Continued

Verifying and Signing

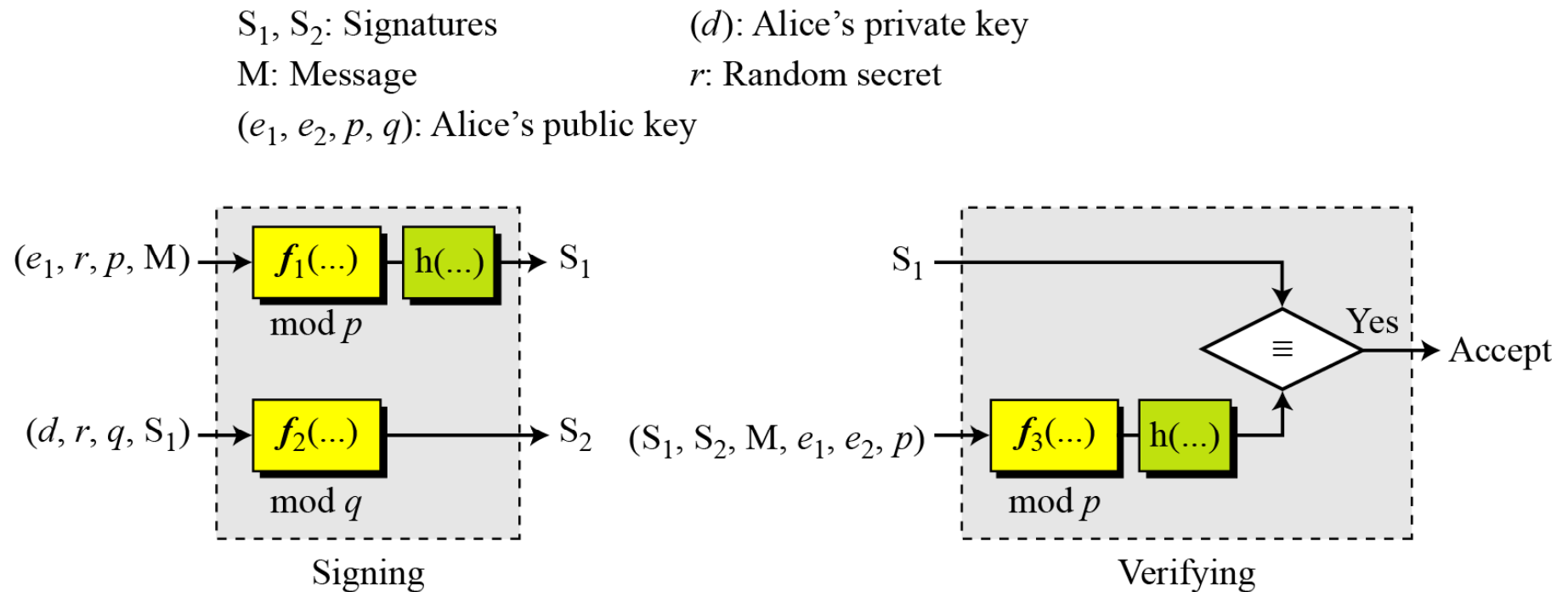
Figure 13.10 *ElGamal digital signature scheme*

M: Message
 S_1, S_2 : Signatures
 V_1, V_2 : Verifications
 r : Random secret
 d : Alice's private key
 (e_1, e_2, p) : Alice's public key



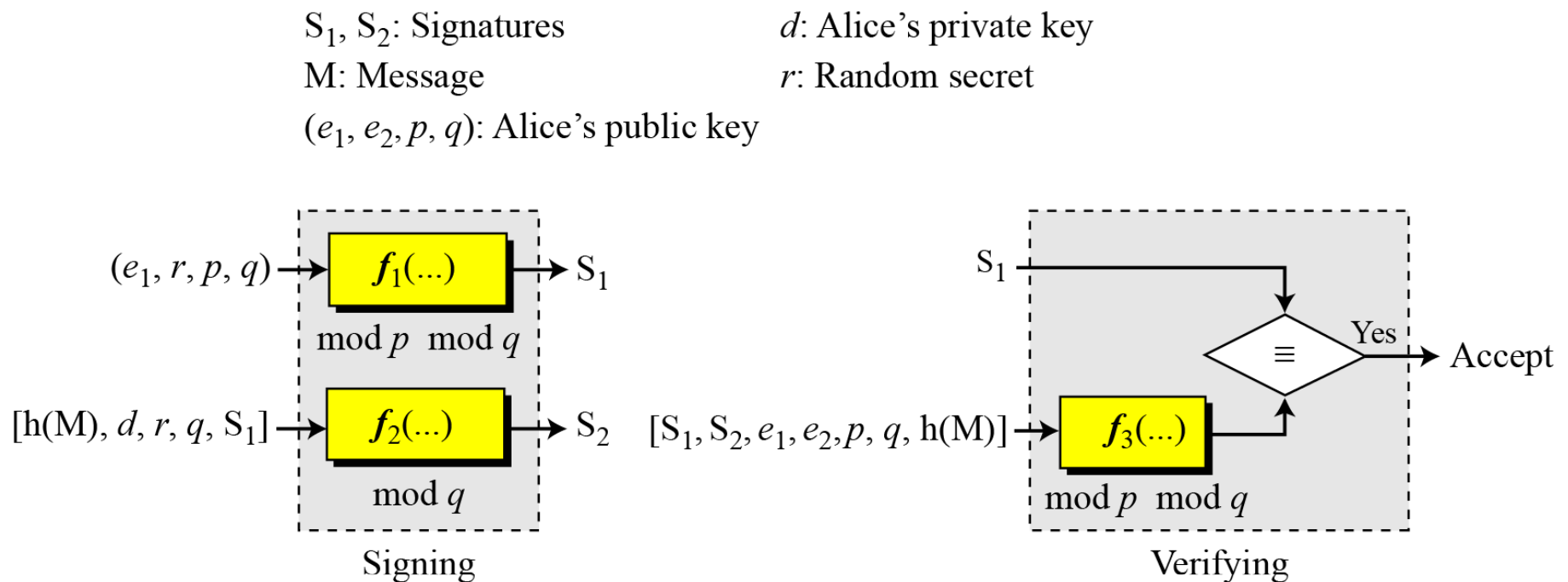
13.5.3 Schnorr Digital Signature Scheme

Figure 13.11 *General idea behind the Schnorr digital signature scheme*



13.5.4 Digital Signature Standard (DSS)

Figure 13.13 *General idea behind DSS scheme*





13.5.4 Continued

DSS Versus RSA

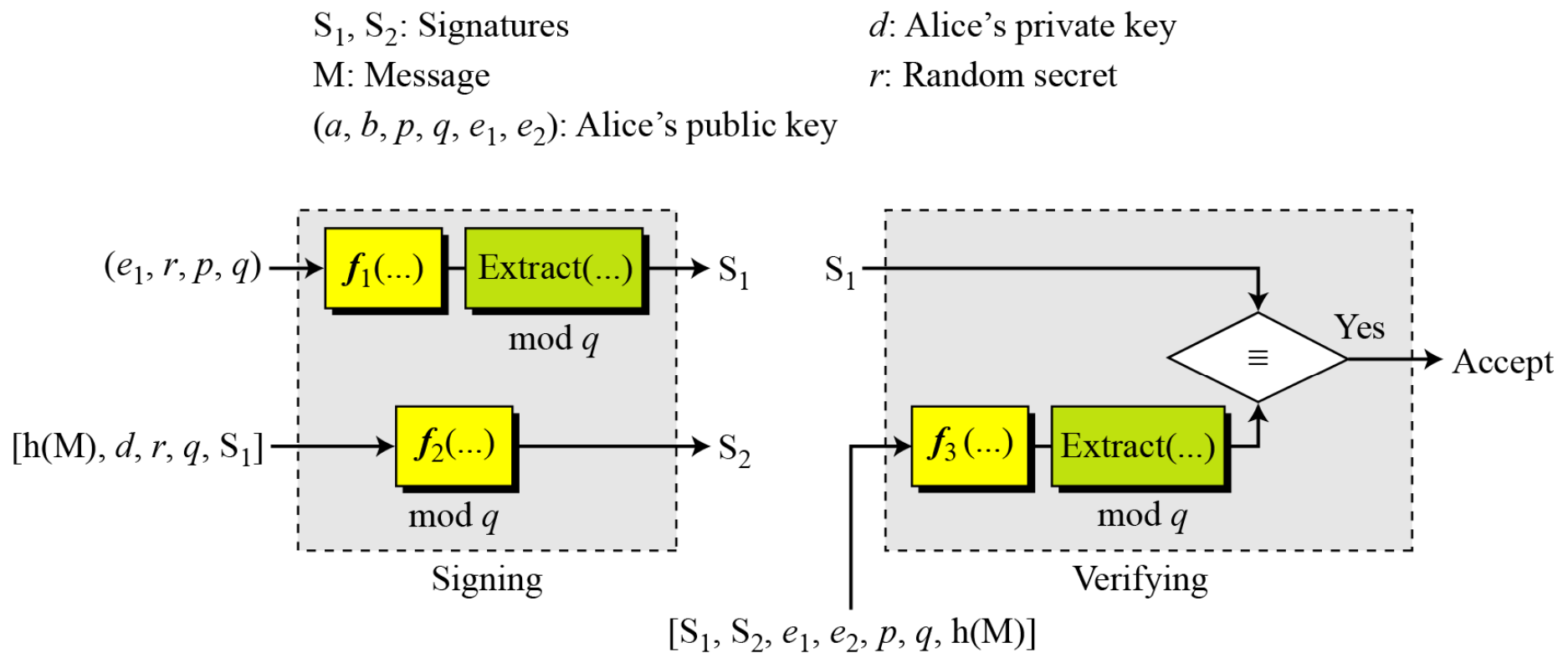
Computation of DSS signatures is faster than computation of RSA signatures when using the same p .

DSS Versus ElGamal

DSS signatures are smaller than ElGamal signatures because q is smaller than p .

13.5.5 Elliptic Curve Digital Signature Scheme

Figure 13.15 *General idea behind the ECDSS scheme*



13-6 VARIATIONS AND APPLICATIONS

This section briefly discusses variations and applications for digital signatures.

Topics discussed in this section:

13.6.1 Variations

13.6.2 Applications



13.6.1 Variations

Time Stamped Signatures

Sometimes a signed document needs to be time stamped to prevent it from being replayed by an adversary. This is called time-stamped digital signature scheme.

Blind Signatures

Sometimes we have a document that we want to get signed without revealing the contents of the document to the signer.