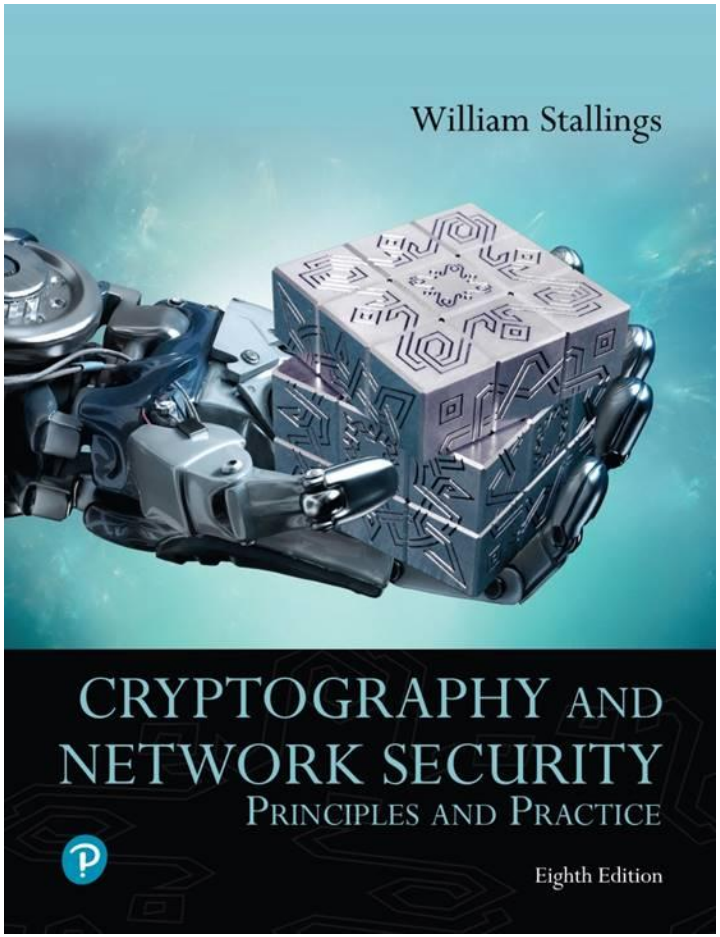
Cryptography and Network Security: Principles and Practice

Eighth Edition

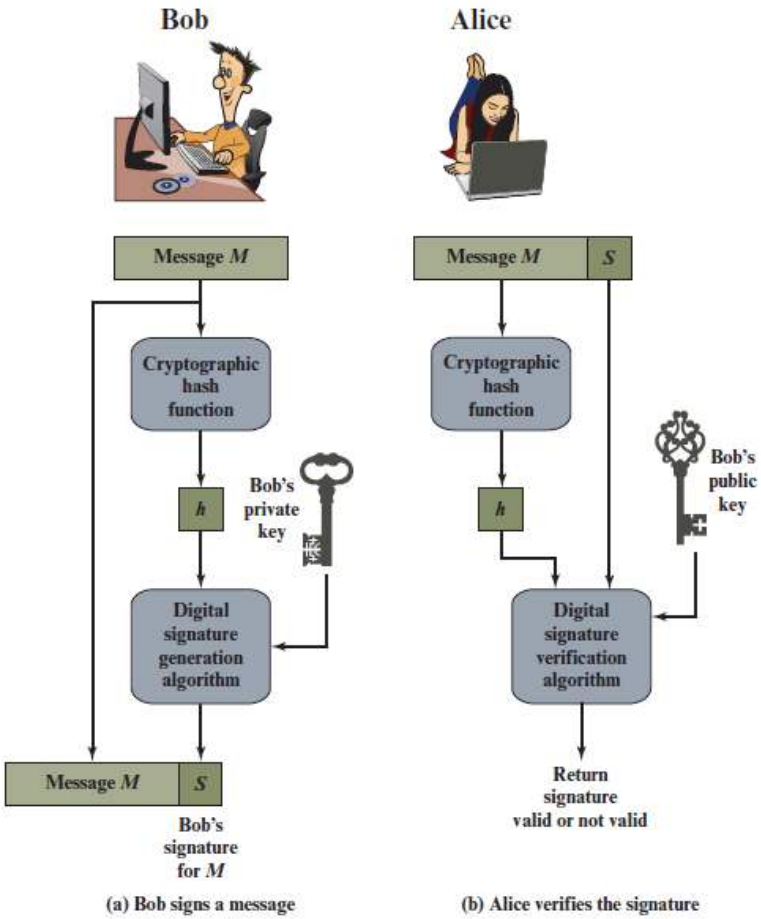


Chapter 13

Digital Signatures

Pearson

Figure 13.1 Simplified Depiction of Essential Elements of Digital Signature Process



Digital Signature Properties

- It must verify the author and the date and time of the signature
- It must authenticate the contents at the time of the signature
- It must be verifiable by third parties to resolve disputes

Attacks

- **Key-only attack**
  - C only knows A's public key
- **Known message attack**
  - C is given access to a set of messages and their signatures
- **Generic chosen message attack**
  - C chooses a list of messages before attempting to break A's signature scheme, independent of A's public key; C then obtains from A valid signatures for the chosen messages
- **Directed chosen message attack**
  - Similar to the generic attack, except that the list of messages to be signed is chosen after C knows A's public key but before any signatures are seen
- **Adaptive chosen message attack**
  - C may request from A signatures of messages that depend on previously obtained message-signature pairs

Forgeries

- **Total break**
  - C determines A's private key
- **Universal forgery**
  - C finds an efficient signing algorithm that provides an equivalent way of constructing signatures on arbitrary messages
- **Selective forgery**
  - C forges a signature for a particular message chosen by C
- **Existential forgery**
  - C forges a signature for at least one message; C has no control over the message

Digital Signature Requirements

- The signature must be a bit pattern that depends on the message being signed
- The signature must use some information unique to the sender to prevent both forgery and denial
- It must be relatively easy to produce the digital signature
- It must be relatively easy to recognize and verify the digital signature
- It must be computationally infeasible to forge a digital signature, either by constructing a new message for an existing digital signature or by constructing a fraudulent digital signature for a given message
- It must be practical to retain a copy of the digital signature in storage

Direct Digital Signature

- Refers to a digital signature scheme that involves only the communicating parties
  - It is assumed that the destination knows the public key of the source
- Confidentiality can be provided by encrypting the entire message plus signature with a shared secret key
  - It is important to perform the signature function first and then an outer confidentiality function
  - In case of dispute some third party must view the message and its signature
- The validity of the scheme depends on the security of the sender's private key
  - If a sender later wishes to deny sending a particular message, the sender can claim that the private key was lost or stolen and that someone else forged his or her signature
  - One way to thwart or at least weaken this ploy is to require every signed message to include a timestamp and to require prompt reporting of compromised keys to a central authority

ElGamal Digital Signature

- Scheme involves the use of the private key for encryption and the public key for decryption
- Global elements are a prime number q and a, which is a primitive root of q
- Use private key for encryption (signing)
- Uses public key for decryption (verification)
- Each user generates their key
  - Chooses a secret key (number): $1 < x_A < q-1$
  - Compute their public key: $y_A = a^{xA} \bmod q$

Schnorr Digital Signature

- Scheme is based on discrete logarithms
- Minimizes the message-dependent amount of computation required to generate a signature
  - Multiplying a $2n$-bit integer with an n-bit integer
- Main work can be done during the idle time of the processor
- Based on using a prime modulus p, with $p - 1$ having a prime factor q of appropriate size
  - Typically p is a 1024-bit number, and q is a 160-bit number

NIST Digital Signature Algorithm

- Published by NIST as Federal Information Processing Standard FIPS 186
- Makes use of the Secure Hash Algorithm (SHA)
- The latest version, FIPS 186-3, also incorporates digital signature algorithms based on RSA and on elliptic curve cryptography

Figure 13.2 Two Approaches to Digital Signatures

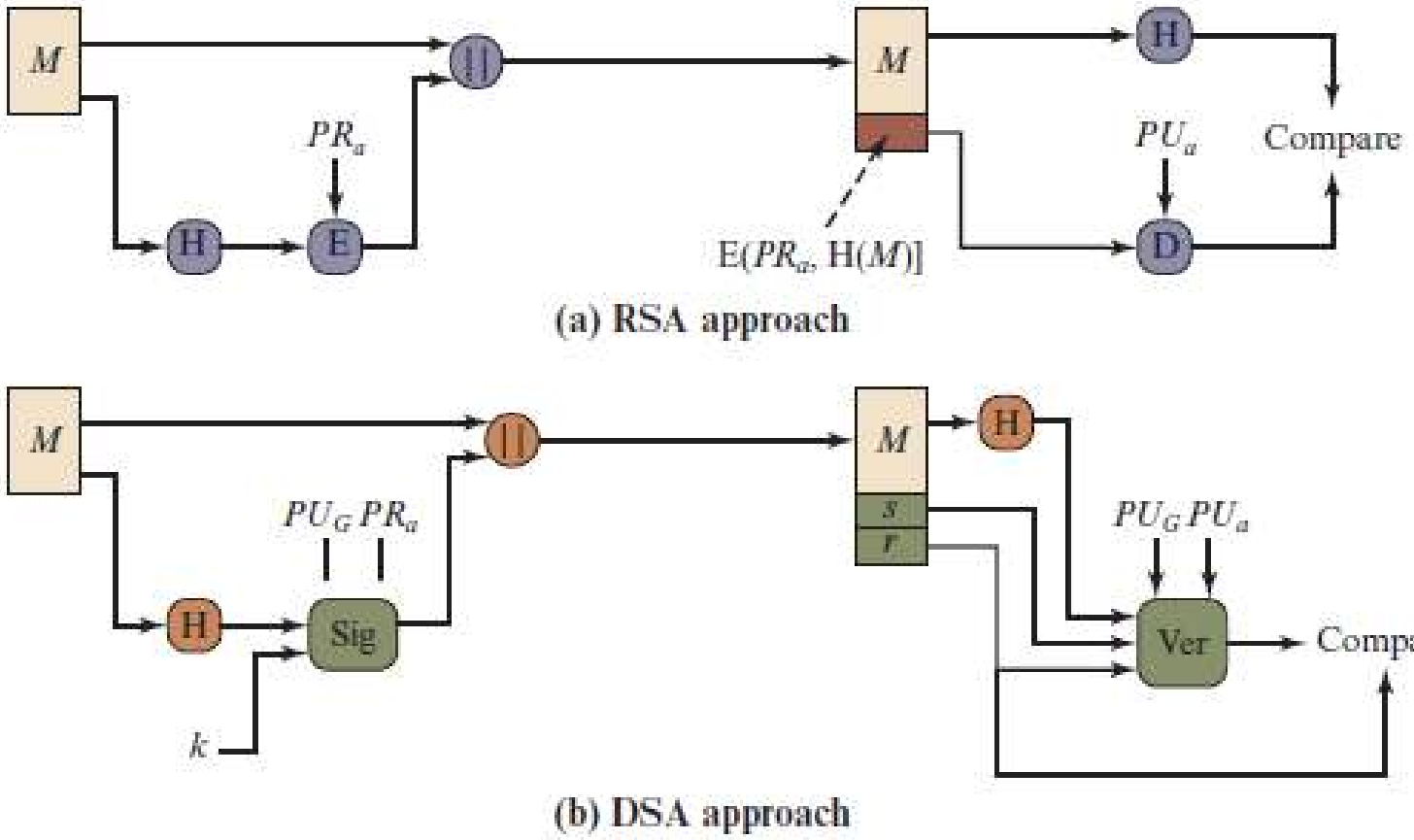


Figure 13.3 The Digital Signature Algorithm (DSA)

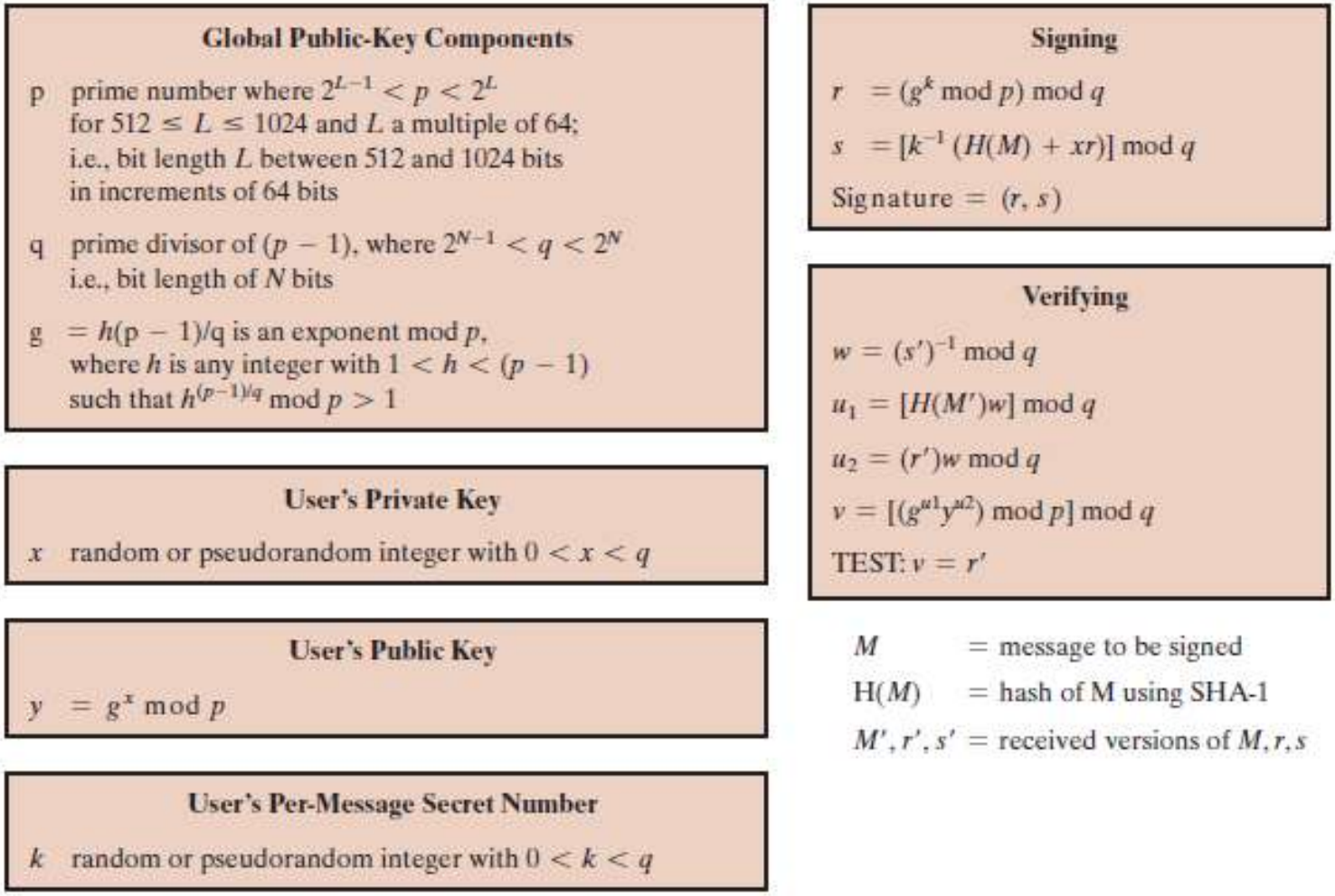
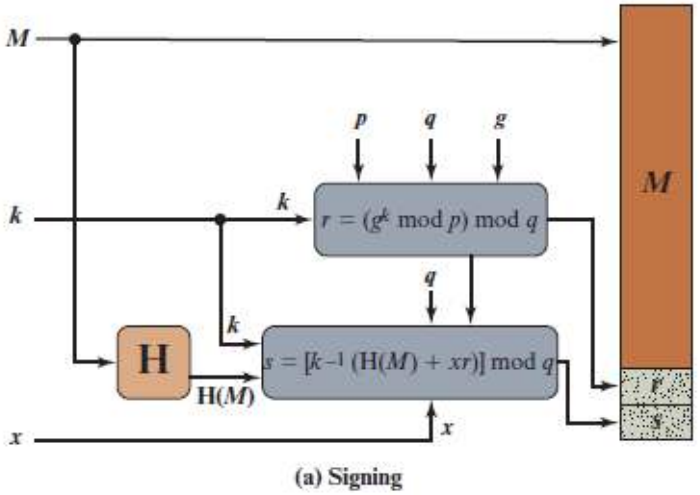
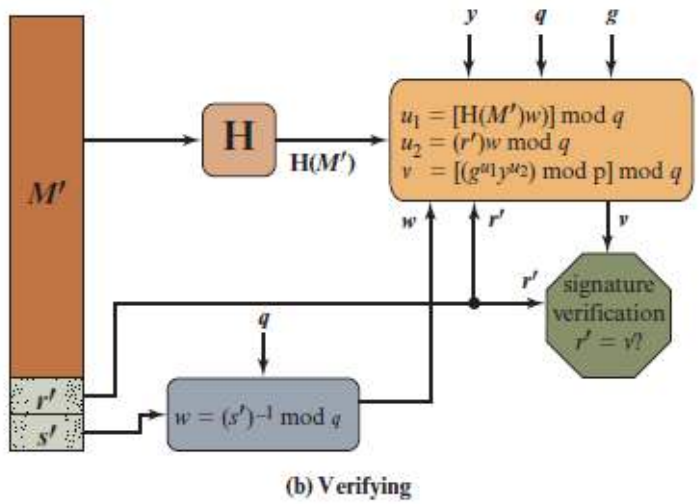


Figure 13.4 DSA Signing and Verifying



(a) Signing

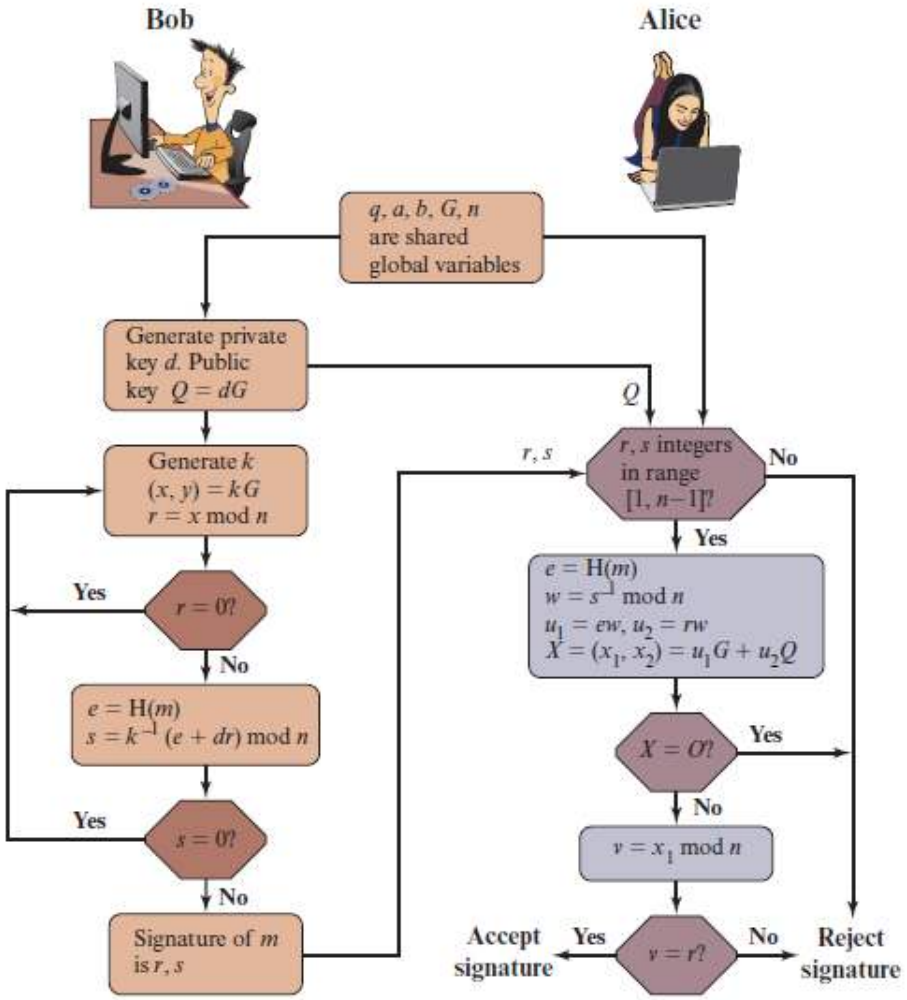


(b) Verifying

Elliptic Curve Digital Signature Algorithm (ECDSA)

- Four elements are involved:
  - All those participating in the digital signature scheme use the same global domain parameters, which define an elliptic curve and a point of origin on the curve
  - A signer must first generate a public, private key pair
  - A hash value is generated for the message to be signed; using the private key, the domain parameters, and the hash value, a signature is generated
  - To verify the signature, the verifier uses as input the signer's public key, the domain parameters, and the integer *s;* the output is a value *v* that is compared to *r* ; the signature is verified if the $v = r$

Figure 13.5 ECDSA Signing and Verifying



RSA-PSS

- RSA Probabilistic Signature Scheme
- Included in the 2009 version of FIPS 186
- Latest of the RSA schemes and the one that RSA Laboratories recommends as the most secure of the RSA schemes
- For all schemes developed prior to PSS it has not been possible to develop a mathematical proof that the signature scheme is as secure as the underlying RSA encryption/decryption primitive
- The PSS approach was first proposed by Bellare and Rogaway
- This approach, unlike the other RSA-based schemes, introduces a randomization process that enables the security of the method to be shown to be closely related to the security of the RSA algorithm itself

Mask Generation Function (MGF)

- Typically based on a secure cryptographic hash function such as SHA-1
  - Is intended to be a cryptographically secure way of generating a message digest, or hash, of variable length based on an underlying cryptographic hash function that produces a fixed-length output

Figure 13.6 RSA-PSS Encoding

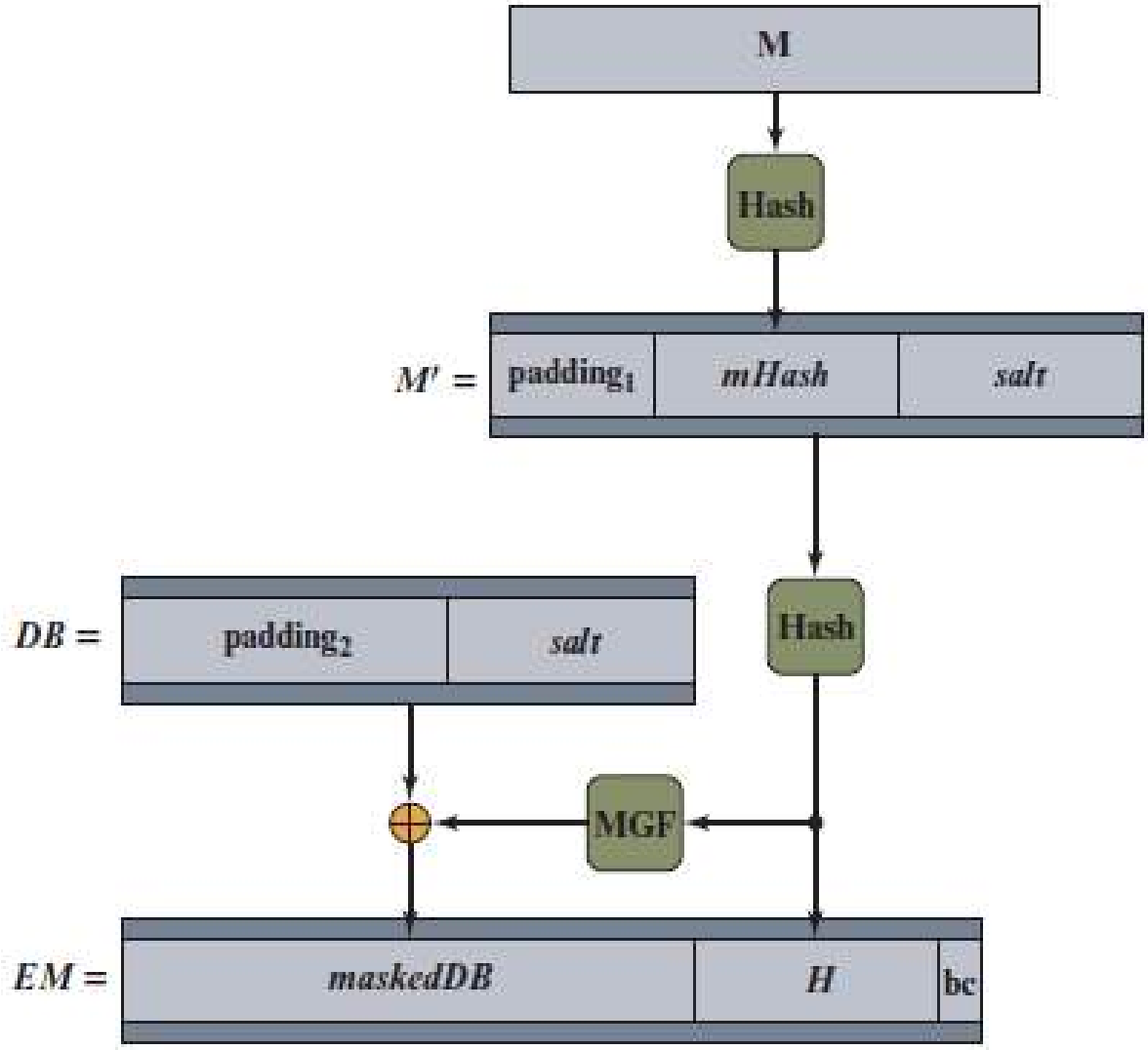
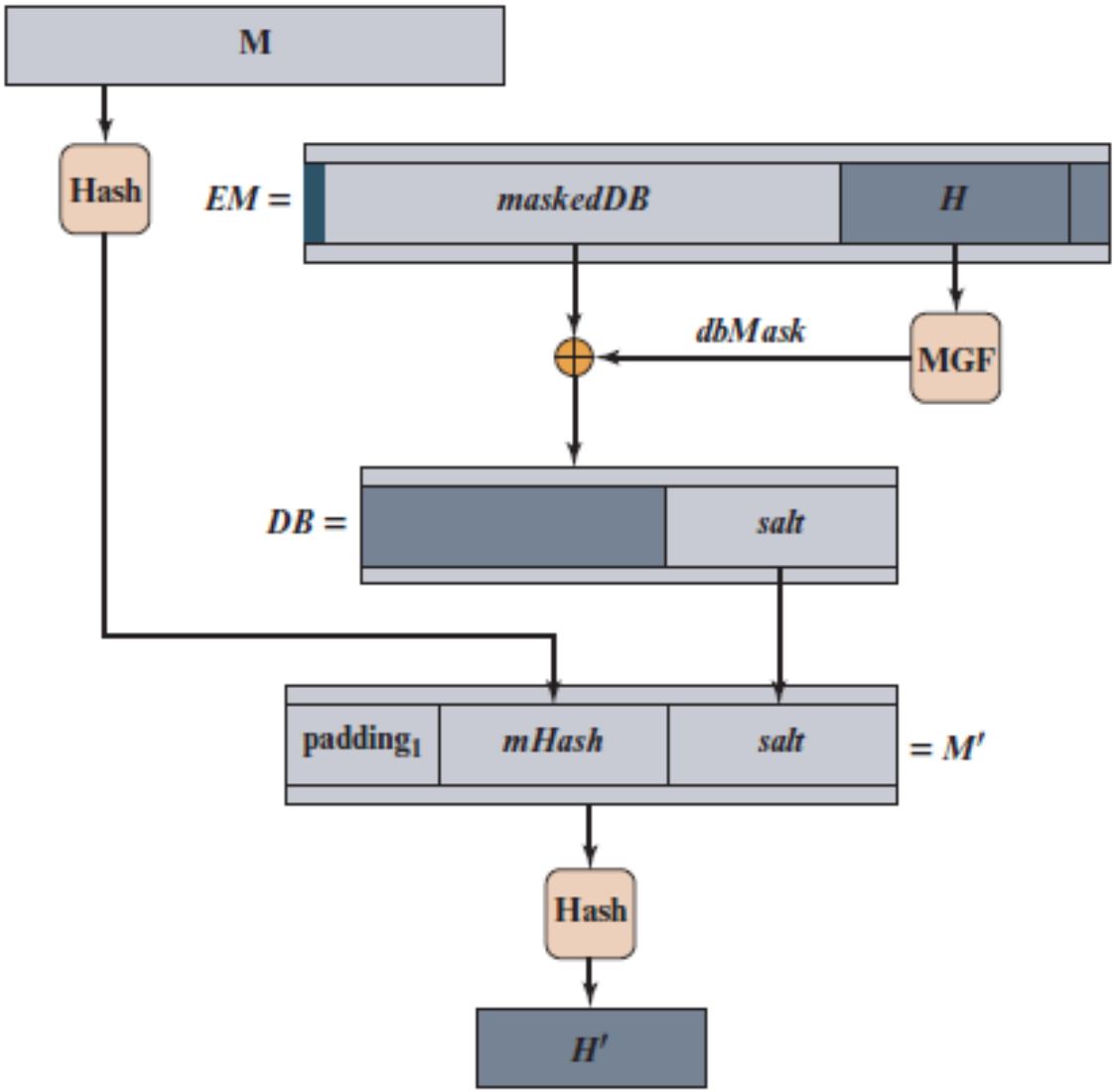


Figure 13.7 RSA-PSS EM Verification



Summary

- Present an overview of the digital signature process
- Understand the ElGamal digital signature scheme
- Understand the Schnorr digital signature scheme
- Understand the NIST digital signature scheme
- Compare and contrast the NIST digital signature scheme with the ElGamal and Schnorr digital signature schemes
- Understand the elliptic curve digital signature scheme
- Understand the RSA-PSS digital signature scheme

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