Cryptography Concepts

Cryptography enables one to secure transactions, communications, and other processes performed in the electronic world. This section deals with cryptography and its associated concepts, which will enable you to understand the advanced topics covered later in this module.

Cryptography

"Cryptography" comes from the Greek words ***kryptos***, meaning "concealed, hidden, veiled, secret, or mysterious," and ***graphia***, meaning "writing"; thus, cryptography is "the art of secret writing."

Cryptography is the practice of concealing information by converting plaintext (readable format) into ciphertext (unreadable format) using a key or encryption scheme. It is the process of converting data into a scrambled code that is encrypted and sent across a private or public network. Cryptography protects confidential data such as email messages, chat sessions, web transactions, personal data, corporate data, e-commerce applications, and many other types of communication. Encrypted messages can, at times, be decrypted by cryptanalysis (code breaking), even though modern encryption techniques are virtually unbreakable.

Types of Cryptography

Cryptography is categorized into two types according to the number of keys employed for encryption and decryption:

- **Symmetric Encryption**

  Symmetric encryption requires that both the sender and the receiver of the message possess the same encryption key. The sender uses a key to encrypt the plaintext and sends the resultant ciphertext to the recipient, who uses the same key (used for encryption) to decrypt the ciphertext into plaintext. Symmetric encryption is also known as secret-key cryptography, as it uses only one secret key to encrypt and decrypt the data. This type of cryptography works well when you are communicating with only a few people.

  Because the sender and receiver must share the key before sending any messages, this technique is of limited use for the Internet, where individuals who have not had prior contact frequently require a secure means of communication. The solution to this problem is asymmetric encryption (public-key cryptography).

Figure 20.2: Symmetric Encryption

- **Asymmetric Encryption**

  The concept of asymmetric encryption (also known as public-key cryptography) was introduced to solve key-management problems. Asymmetric encryption involves both a public key and a private key. The public key is publicly available, whereas the sender keeps the private key secret.

  An asymmetric-key system is an encryption method that uses a key pair comprising a public key available to anyone and a private key held only by the key owner, which helps to provide confidentiality, integrity, authentication, and nonrepudiation in data management.

Asymmetric encryption uses the following sequence to send a message:

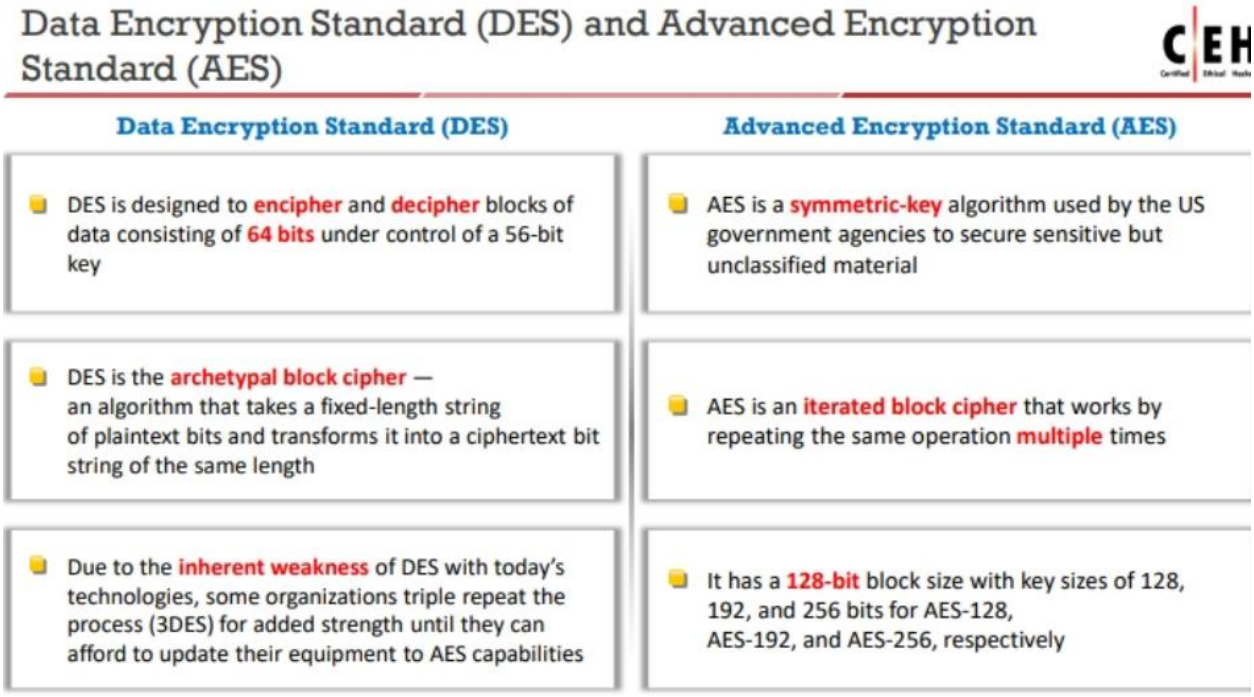
1. An individual finds the public key of the person he or she wants to contact in a directory.
2. This public key is used to encrypt a message that is then sent to the intended recipient.
3. The receiver uses the private key to decrypt the message and reads it.

No one but the holder of the private key can decrypt a message encrypted with the corresponding public key. This increases the security of the information because all communications involve only public keys; the message sender never transmits or shares the private keys. The sender must link public keys with usernames in a secure manner to ensure that individuals claiming to be the intended recipient do not intercept the information. To meet the need for authentication, one can use digital signatures.

Figure 20.3: Asymmetric Encryption

Encryption Algorithms

Encryption is the process of converting readable plaintext into an unreadable ciphertext using a set of complex algorithms that transform the data into blocks or streams of random alphanumeric characters. This section deals with ciphers and various encryption algorithms such as DES, AES, RC4, RC5, RC6, DSA, RSA, MD5, SHA, etc.



Data Encryption Standard (DES)

DES is a standard for data encryption that uses a secret key for both encryption and decryption (symmetric cryptosystem). DES uses a 64-bit secret key, of which 56 bits are generated randomly and the other 8 bits are used for error detection. It uses a data encryption algorithm (DEA), a secret key block cipher employing a 56-bit key operating on 64-bit blocks. DES is the archetypal block cipher—an algorithm that takes a fixed-length string of plaintext bits and transforms it into a ciphertext bit string of the same length. The design of DES allows users to implement it in hardware and use it for single-user encryption, such as to store files on a hard disk in encrypted form.

DES provides 72 quadrillion or more possible encryption keys and chooses a random key for the encryption of each message. Because of the inherent weakness of DES vis-à-vis today's technologies, some organizations use triple DES (3DES), in which they repeat the process three times for added strength until they can afford to update their equipment to AES capabilities.

Triple Data Encryption Standard (3DES)

Eventually, it became obvious that DES would no longer be secure. The U.S. Federal Government began a contest seeking a replacement cryptography algorithm. However, in the meantime, 3DES was created as an interim solution. Essentially, it performs DES three times with three different keys. 3DES uses a "key bundle" that comprises three DES keys, K1, K2, and K3. Each key is a standard 56-bit DES key. It then performs the following process:

DES *encrypt* with K1, DES *decrypt* with K2, DES *encrypt* with K3

There are three options for the keys. In the first option, all three keys are independent and different. In the second option, K1 and K3 are identical. In the third option, all three keys are the same; therefore, you are literally applying the same DES algorithm three times with the same key. The first option is the most secure, while the third is the least secure.

Advanced Encryption Standard (AES)

The Advanced Encryption Standard (AES) is a National Institute of Standards and Technology (NIST) specification for the encryption of electronic data. It also helps to encrypt digital information such as telecommunications, financial, and government data. US government agencies have been using it to secure sensitive but unclassified material.

AES consists of a symmetric-key algorithm: both encryption and decryption are performed using the same key. It is an iterated block cipher that works by repeating the defined steps multiple times. It has a 128-bit block size, with key sizes of 128, 192, and 256 bits for AES-128, AES-192, and AES-256, respectively. The design of AES makes its use efficient in both software and hardware. It works simultaneously at multiple network layers.

AES Pseudocode

Initially, the system copies the cipher input into the internal state and then adds an initial round key. The system transforms the state by iterating a round function in a number of cycles. The number of cycles may vary with the block size and key length. After completing rounding, the system copies the final state into the cipher output.

```
Cipher (byte in [4*Nb], byte out [4*Nb], word w[Nb*(Nr+1)])
begin
  byte state[4, Nb]
  state = in
```

```
  AddRoundKey (state, w)
    for round = 1 step 1 to Nr-1
        SubBytes(state)
        ShiftRows(state)
        MixColumns(state)
        AddRoundKey(state, w+round*Nb)
    end for
  SubBytes(state)
  ShiftRows(state)
  AddRoundKey(state, w+Nr*Nb)
  out = state
end
```