Chapter 2

Conventional Encryption Message Confidentiality

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Outline

- Conventional Encryption Principles
- Conventional Encryption Algorithms
- Cipher Block Modes of Operation
- Location of Encryption Devices
- Key Distribution

Conventional Encryption Principles

- An encryption scheme has five ingredients:
  - Plaintext
  - Encryption algorithm
  - Secret Key
  - Ciphertext
  - Decryption algorithm
- Security depends on the secrecy of the key, not the secrecy of the algorithm

Conventional Encryption Principles

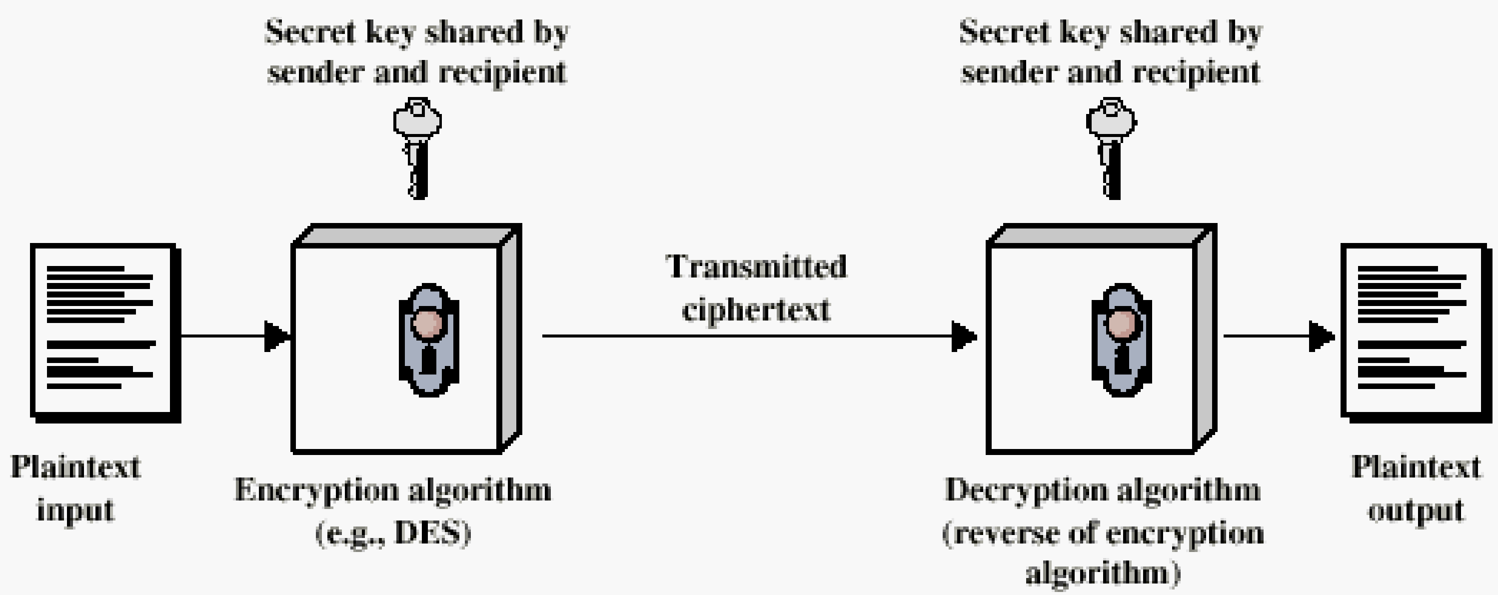


Figure 2.1 Simplified Model of Conventional Encryption

Cryptography

- Classified along three independent dimensions:
  - The type of operations used for transforming plaintext to ciphertext
  - The number of keys used
    - symmetric (single key)
    - asymmetric (two-keys, or public-key encryption)
  - The way in which the plaintext is processed

Average time required for exhaustive key search

Key Size (bits)	Number of Alternative Keys	Time required at 10^6 Decryption/µs
32	$2^{32} = 4.3 \times 10^9$	2.15 milliseconds
56	$2^{56} = 7.2 \times 10^{16}$	10 hours
128	$2^{128} = 3.4 \times 10^{38}$	5.4×10^{18} years
168	$2^{168} = 3.7 \times 10^{50}$	5.9×10^{30} years

Feistel Cipher Structure

- Virtually all conventional block encryption algorithms, including DES have a structure first described by Horst Feistel of IBM in 1973
- The realization of a Fesitel Network depends on the choice of the following parameters and design features (see next slide):

Feistel Cipher Structure

- **Block size:** larger block sizes mean greater security
- **Key Size:** larger key size means greater security
- **Number of rounds:** multiple rounds offer increasing security
- **Subkey generation algorithm:** greater complexity will lead to greater difficulty of cryptanalysis.
- **Fast software encryption/decryption:** the speed of execution of the algorithm becomes a concern

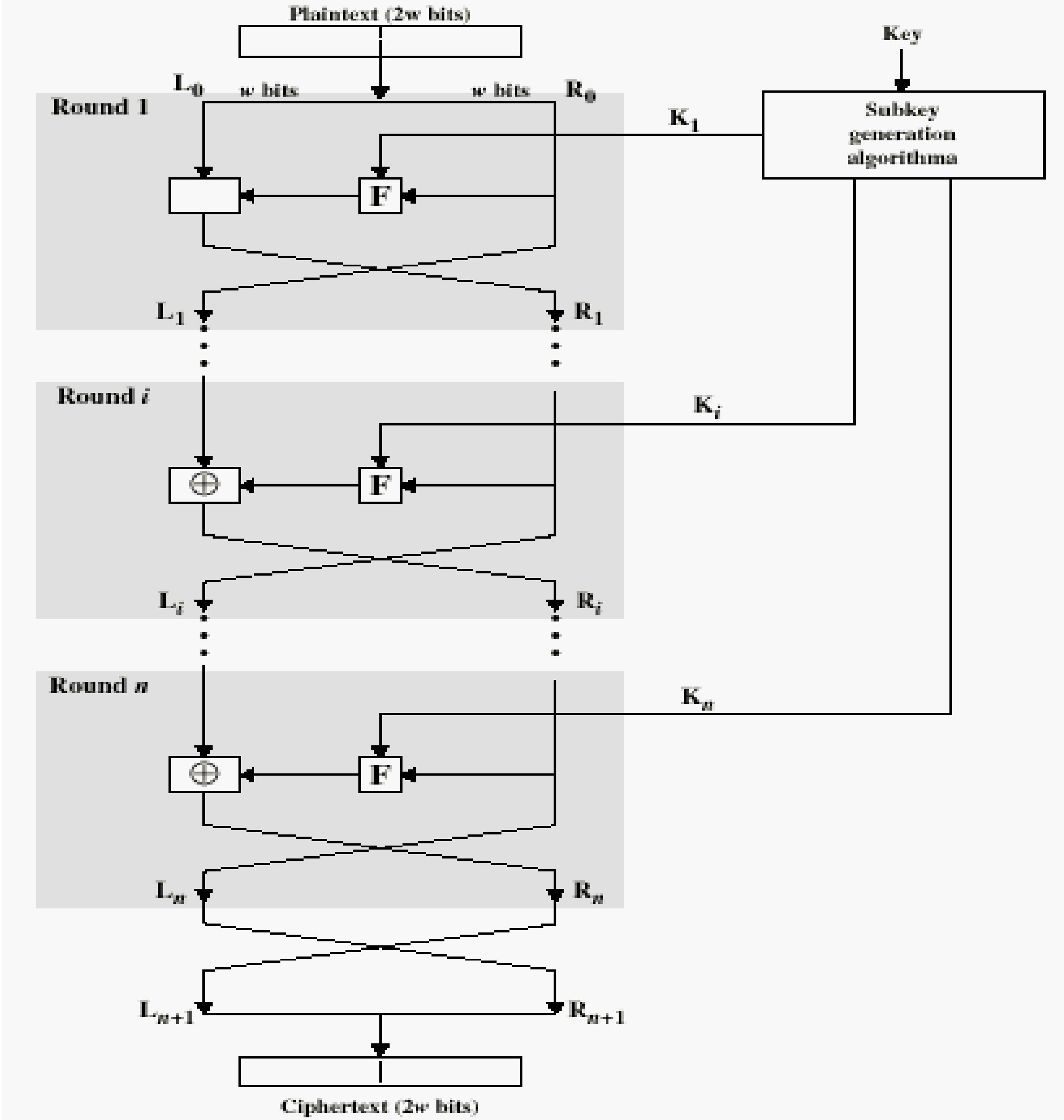


Figure 2.2 Classical Feistel Network

Conventional Encryption Algorithms

- Data Encryption Standard (DES)
  - The most widely used encryption scheme
  - The algorithm is reffered to the Data Encryption Algorithm (DEA)
  - DES is a block cipher
  - The plaintext is processed in 64-bit blocks
  - The key is 56-bits in length

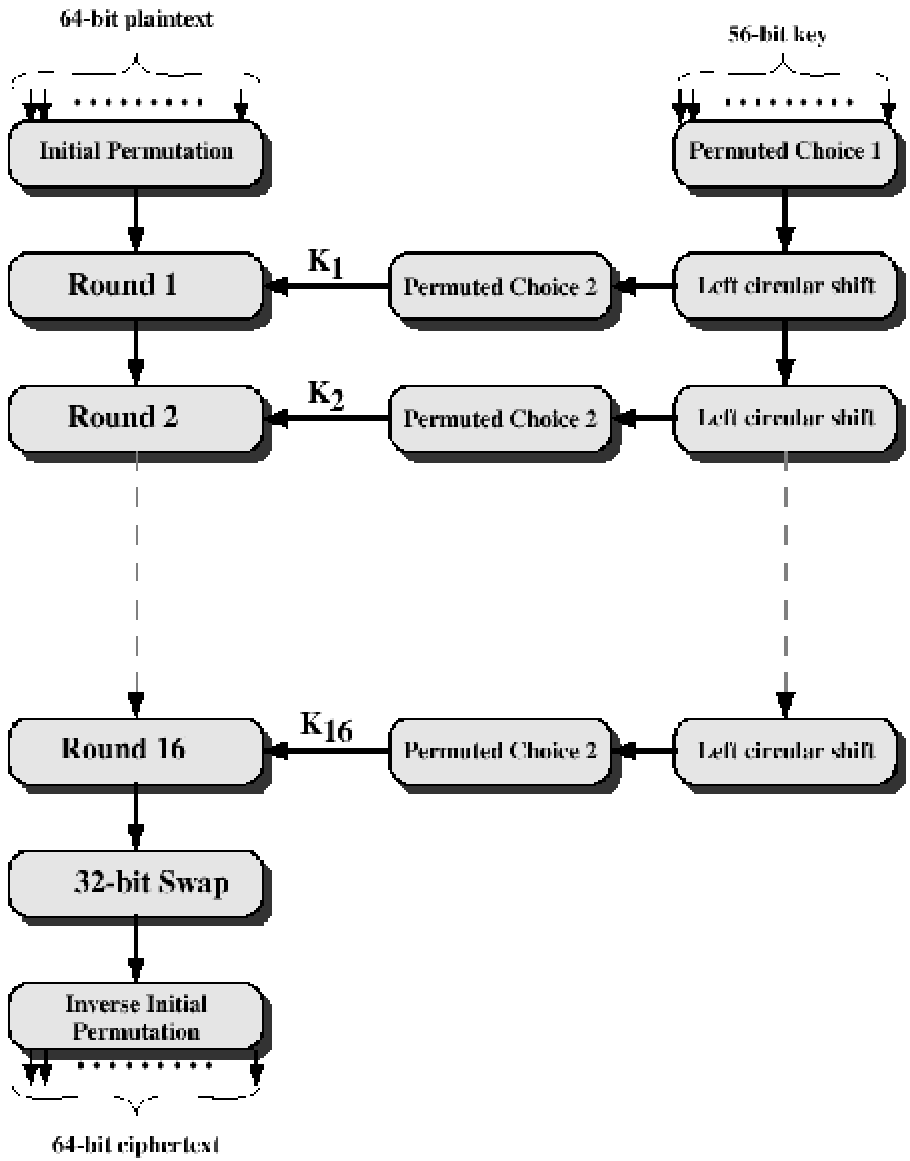


Figure 2.3 General Depiction of DES Encryption Algorithm

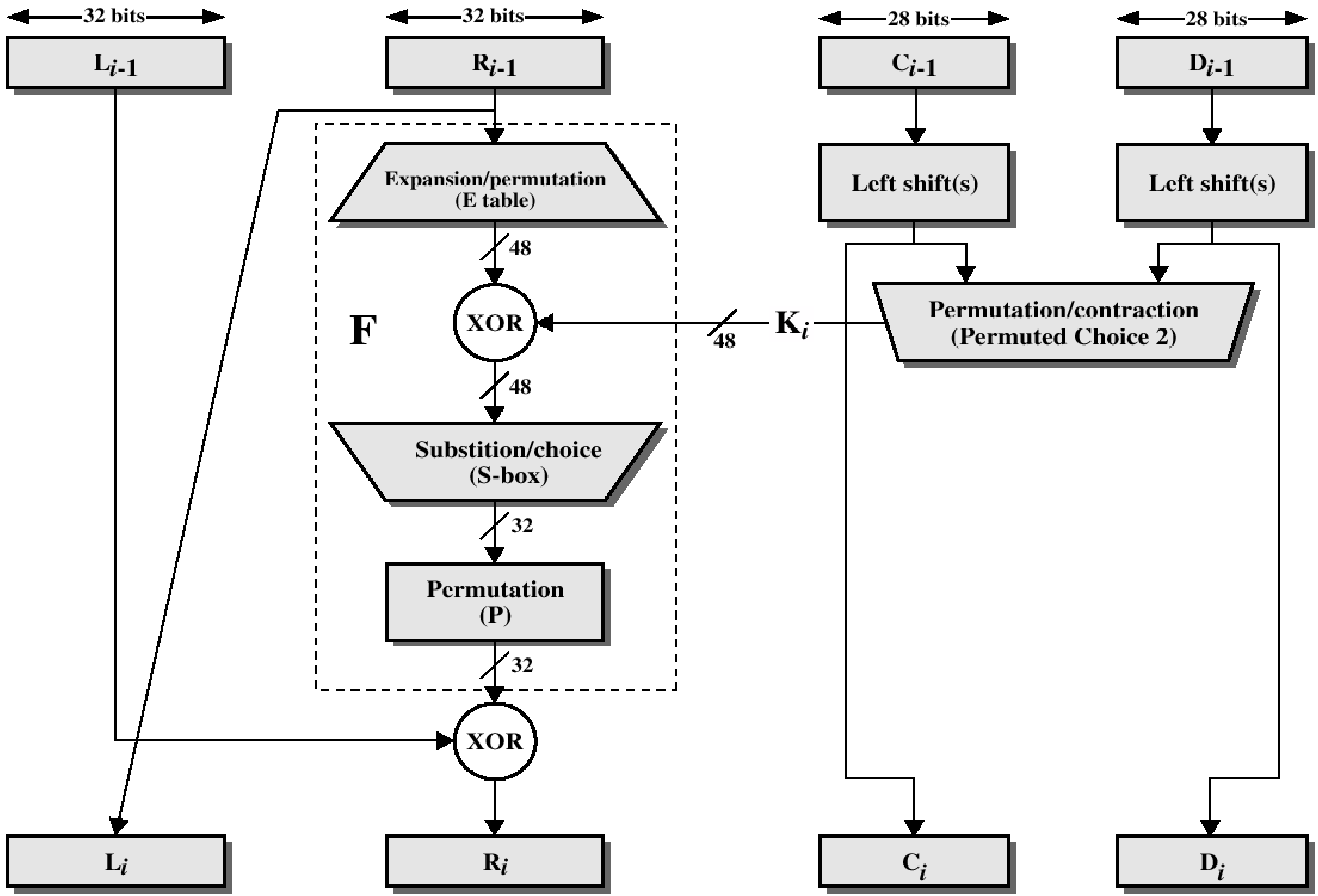
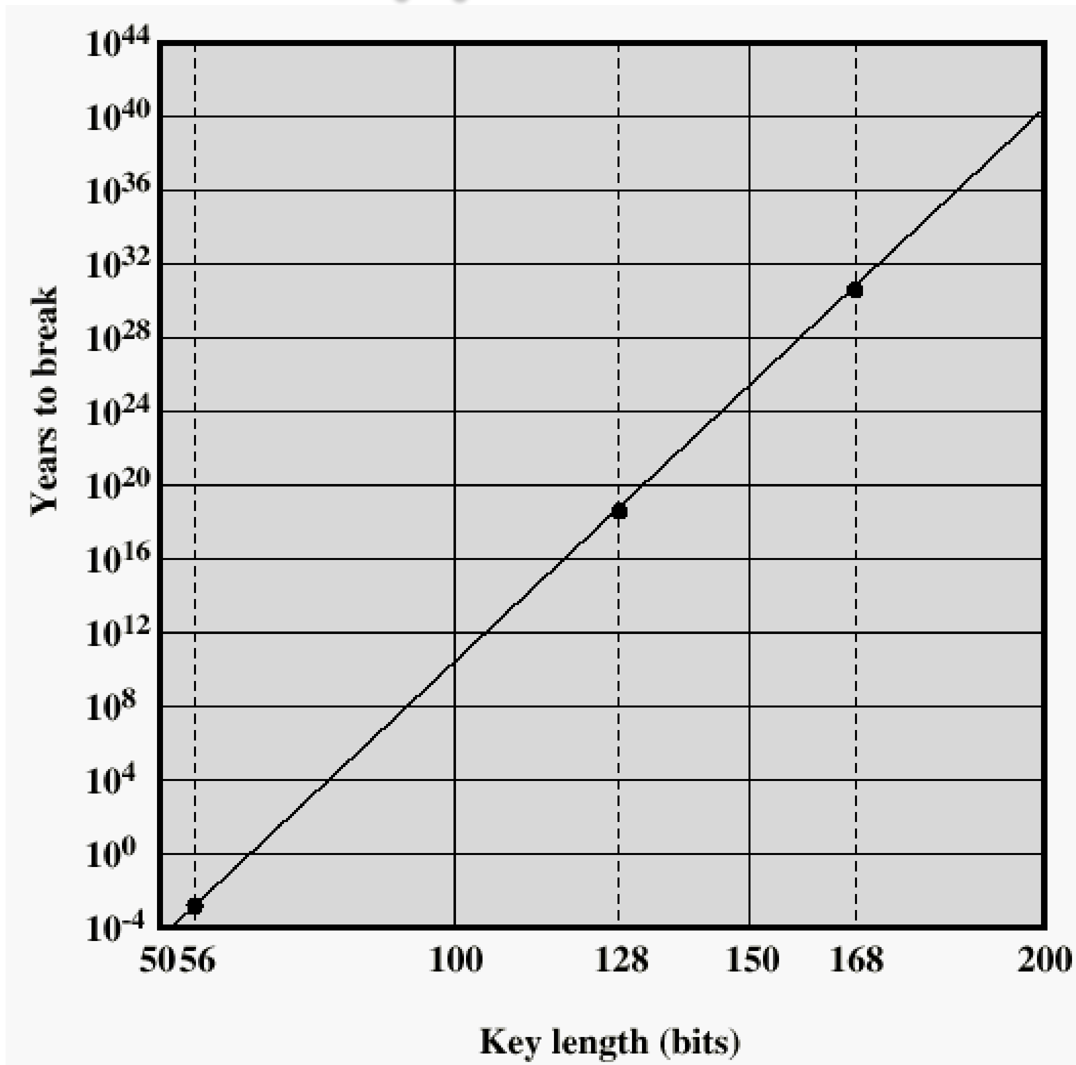


Figure 2.4 Single Round of DES Algorithm

DES

- **The overall processing at each iteration:**
  - $L_i = R_{i-1}$
  - $R_i = L_{i-1} \otimes F(R_{i-1}, K_i)$
- Concerns about:
  - The algorithm and the key length (56-bits)

Time to break a code (10^6 decryptions/µs)



Triple DEA

- Use three keys and three executions of the DES algorithm (encrypt-decrypt-encrypt)

$$C = E_{K3}[D_{K2}[E_{K1}[P]]]$$

  - C = ciphertext
  - P = Plaintext
  - EK[X] = encryption of X using key K
  - DK[Y] = decryption of Y using key K
- Effective key length of 168 bits

Triple DEA

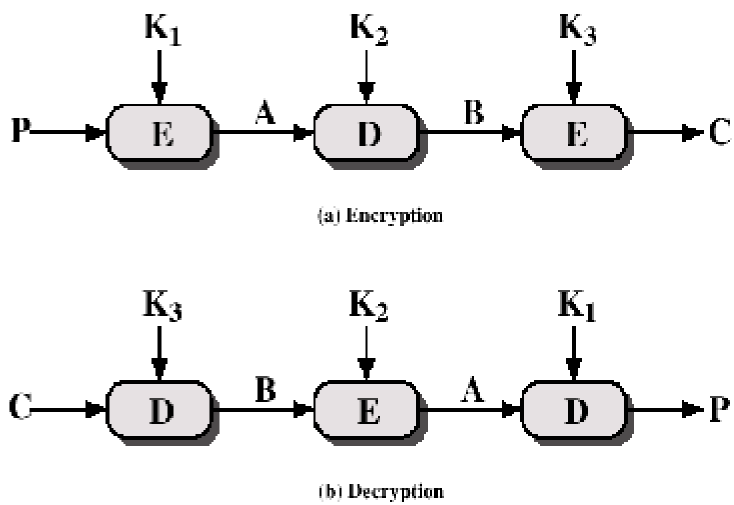


Figure 2.6 Triple DEA

Other Symmetric Block Ciphers

- **International Data Encryption Algorithm (IDEA)**
  - 128-bit key
  - Used in PGP
- **Blowfish**
  - Easy to implement
  - High execution speed
  - Run in less than 5K of memory

Other Symmetric Block Ciphers

- **RC5**
  - Suitable for hardware and software
  - Fast, simple
  - Adaptable to processors of different word lengths
  - Variable number of rounds
  - Variable-length key
  - Low memory requirement
  - High security
  - Data-dependent rotations
- **Cast-128**
  - Key size from 40 to 128 bits
  - The round function differs from round to round

Cipher Block Modes of Operation

- Cipher Block Chaining Mode (CBC)
  - The input to the encryption algorithm is the XOR of the current plaintext block and the preceding ciphertext block.
  - Repeating pattern of 64-bits are not exposed

$$C_i = E_k[C_{i-1} \oplus P_i]$$

$$D_K[C_i] = D_K[E_K(C_{i-1} \oplus P_i)]$$

$$D_K[C_i] = (C_{i-1} \oplus P_i)$$

$$C_{i-1} \oplus D_K[C_i] = C_{i-1} \oplus C_{i-1} \oplus P_i = P_i$$

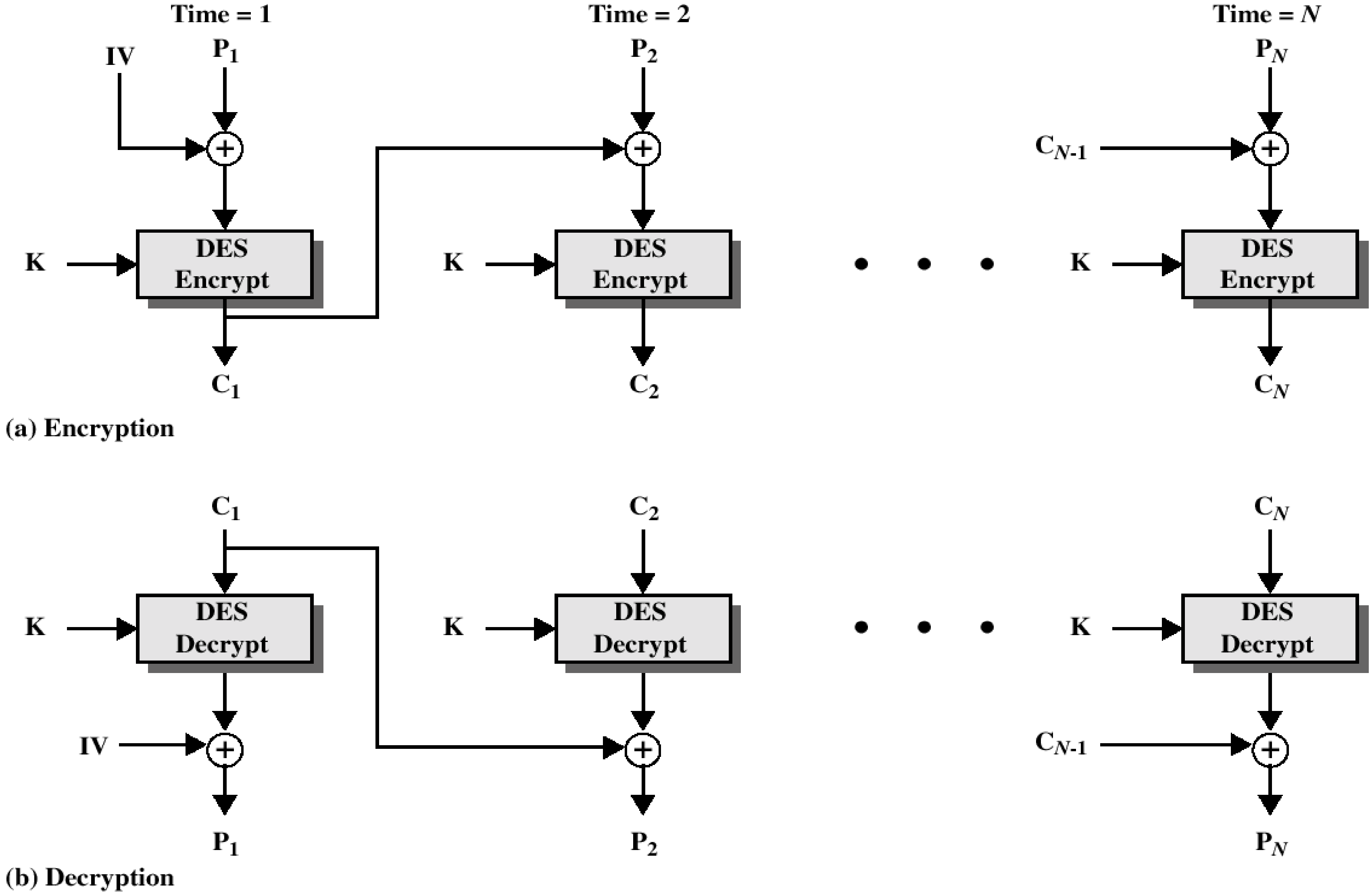


Figure 2.7 Cipher Block Chaining (CBC) Mode

Location of Encryption Device

- **Link encryption:**
  - A lot of encryption devices
  - High level of security
  - Decrypt each packet at every switch
- **End-to-end encryption**
  - The source encrypt and the receiver decrypts
  - Payload encrypted
  - Header in the clear
- **High Security:** Both link and end-to-end encryption are needed (see Figure 2.9)

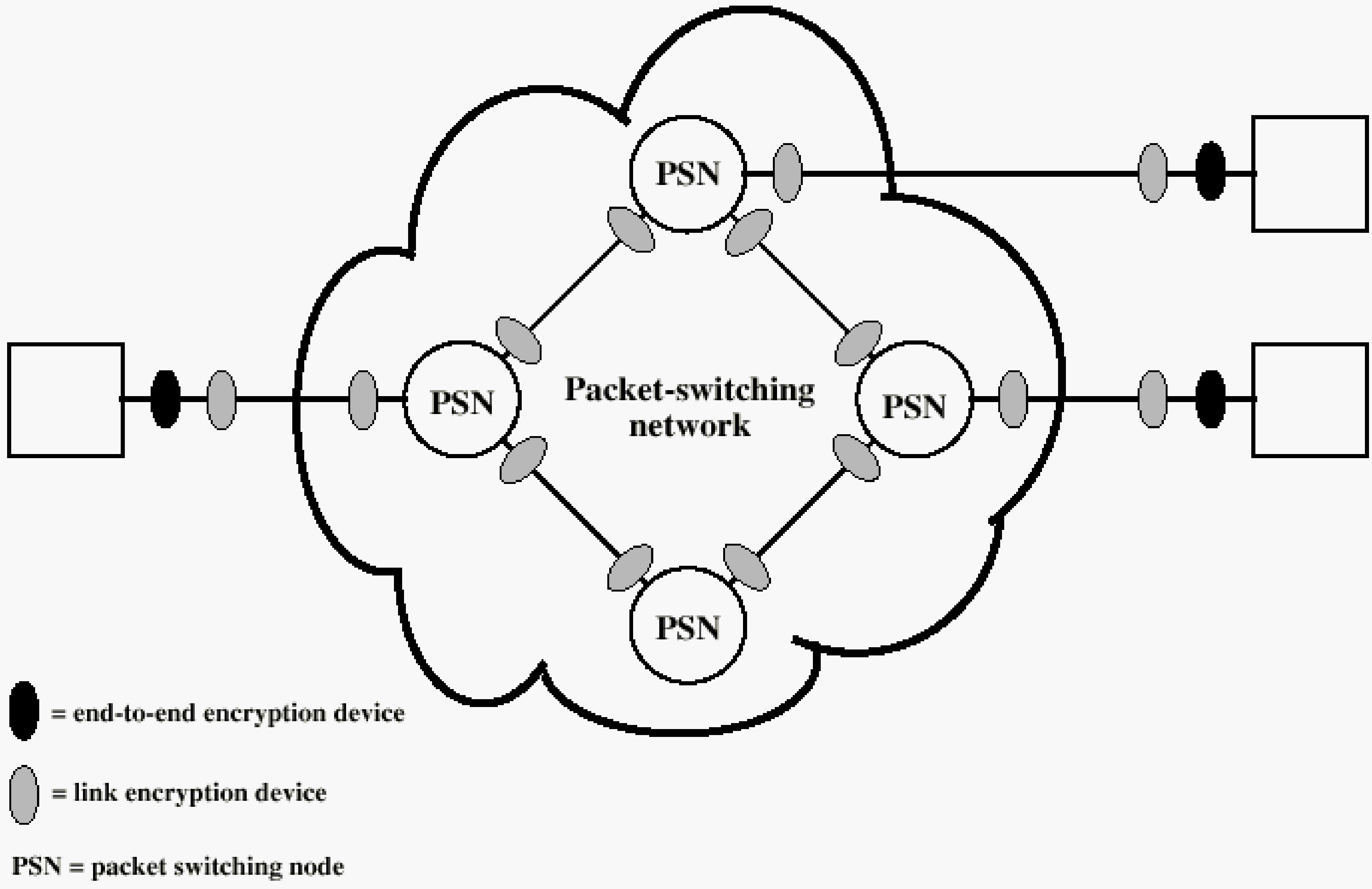


Figure 2.9 Encryption Across a Packet-Switching Network

Key Distribution

1. A key could be selected by A and physically delivered to B.
2. A third party could select the key and physically deliver it to A and B.
3. If A and B have previously used a key, one party could transmit the new key to the other, encrypted using the old key.
4. If A and B each have an encrypted connection to a third party C, C could deliver a key on the encrypted links to A and B.

Key Distribution (See Figure 2.10)

- **Session key:**
  - Data encrypted with a one-time session key.At the conclusion of the session the key is destroyed
- **Permanent key:**
  - Used between entities for the purpose of distributing session keys

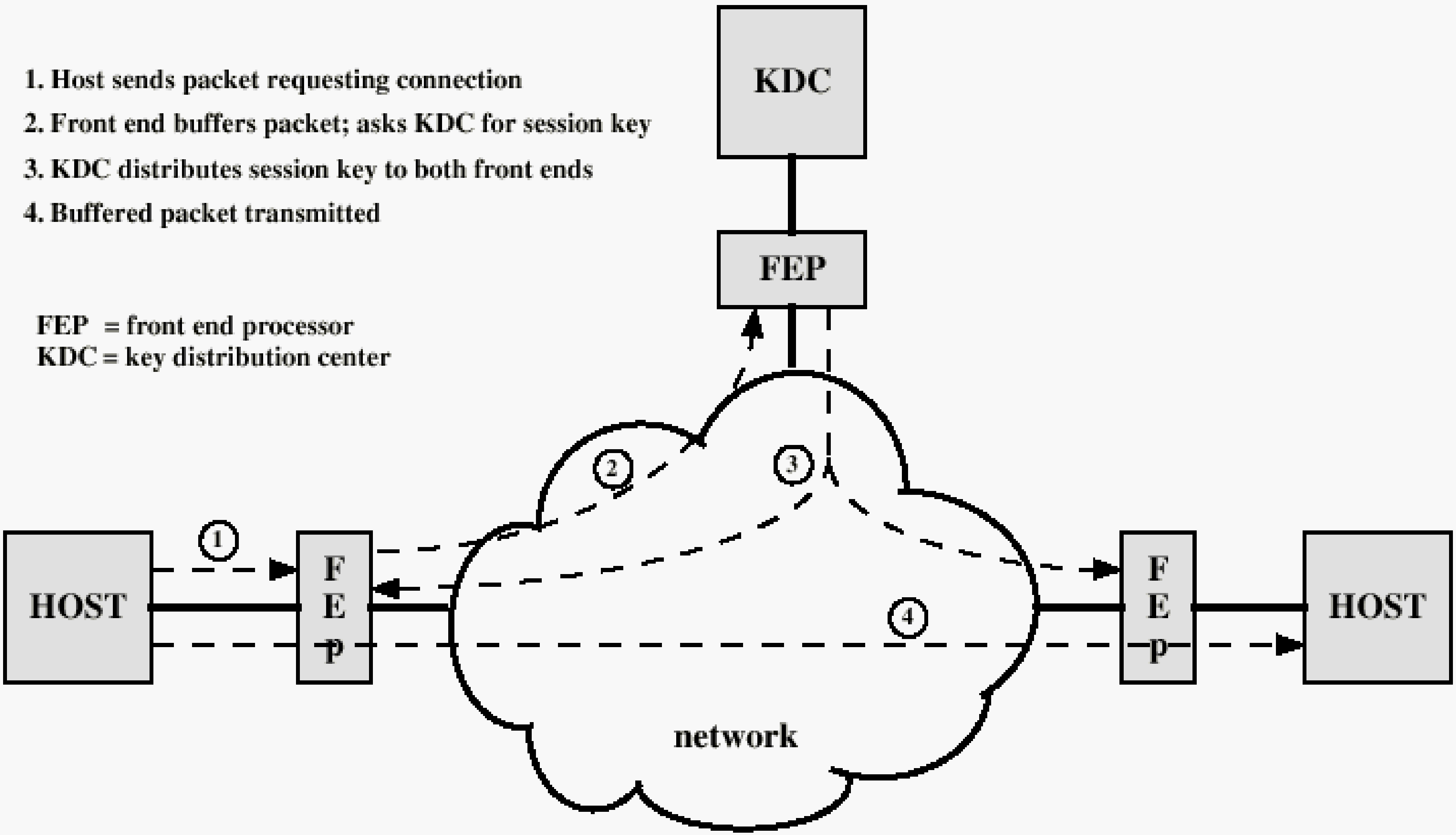


Figure 2.10 Automatic Key Distribution for Connection-Oriented Protocol

Recommended Reading

- Stallings, W. *Cryptography and Network Security: Principles and Practice, 2nd edition*. Prentice Hall, 1999
- Scneier, B. *Applied Cryptography*, New York: Wiley, 1996
- Mel, H.X. Baker, D. *Cryptography Decrypted*. Addison Wesley, 2001