German University in Cairo
Faculty of MET (CSEN 1001 Computer and Network Security Course)
Dr. Amr El Mougy
Reham Ayman
Abdelrahman Osama

Practice Assignment 2

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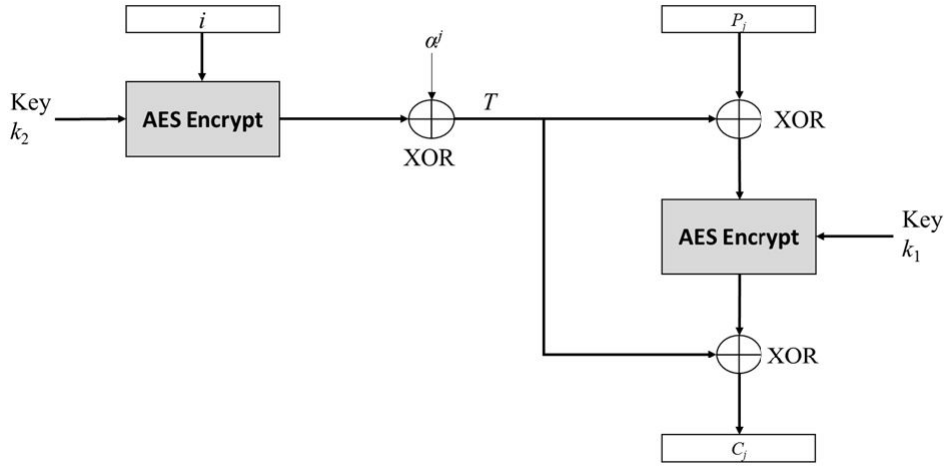
1. The figure below shows the encryption diagram for the AES-XTS mode of encryption, which is used for data storage. In the figure, i, is a 128-bit value known as the tweak that is rarely changed, j is the number of the disk sector to be encrypted, α is a 128-bit fixed value, P_j is the data block in the j^th sector to be encrypted, and C_j is the resulting ciphertext. The system uses two symmetric keys k1 and k2 for the AES blocks.



   (a) Determine the formula for encryption (for calculating C_j).

   (b) Determine the formula for decryption and draw the decryption algorithm.

   (c) If an error occurs in the j block of ciphertext (C_j, how many blocks will be affected in the decryption?

2. Assume a regular cipher block chaining encryption algorithm, which processes blocks of 16 bit length. If the last block is less than 16 bit, it will be padded with zeros on the right. The block cipher encryption consists of only a permutation given with the table below. The key defines how often the permutation is applied on a block. On the other hand, chaining is done using an XOR operation. Encrypt the following plaintext:

   Plain Text: "ROCKNROLL"

   Initialization Vector (IV): 0101 0101 0101 0101
   Permutation table (indexes): 10 3 5 16 7 2 1 12 11 14 8 6 15 9 4 13
   Key: K=1
   Chain Operation: XOR
   Convert letters into 8-bit blocks using ASCII conversion: A = 65, B=66, C=67 ...

3. Let a block cipher with secret key K be chained in the following way:

$$C_i = M_{i-1} \oplus E((M_i \oplus C_{i-1}), K) \text{ for i} > 0$$

Where M_0 and C_0 are fixed public initialization vectors, K is the secret key known to both transmitter and receiver, and E and D represent encryption and decryption, respectively.

1. Determine the equation for decryption and draw the block diagram.
2. Suppose that ciphertext C_j is damaged in transmission, which plaintext blocks will be decrypted incorrectly?

4. (a) Suppose that we use DES in cipher block chaining (CBC) mode. The encryption rule for message M_i, key K and cipher C_i is:

$$C_i = DES(M_i \oplus C_{i-1,K}) \text{ i = 1,2,...}$$

where C_0 is an initial block and $\oplus$ is the XOR operation.

– What is the decryption rule (i.e. what is M_i=.....)? (You can alternatively draw a block diagram).

– Suppose an attacker changes C_i into $C_i' \neq C_i$. How many messages are then decrypted incorrectly?

(b) Suppose that we use DES in counter (CTR) mode. The encryption rule for key K and message M_i, at time i > 0 is

$$C_i = DES(R_i, K) \oplus M_i,\ R_i = R_i + 1$$

where R_0 = some starting value and $\oplus$ is the XOR operation..

– What is the decryption rule (i.e. what is M_i=.....)? (You can alternatively draw a block diagram).

– Suppose an attacker changes C_i into $C_i' \neq C_i$. How many messages are then decrypted incorrectly?

5. Alice and Bob agree to communicate privately via email using a scheme based on RC4, but want to avoid using the same secret key for each transmission. Alice and Bob privately agree on a 128-bit key k. to encrypt a message m, consisting of a string of bits, the following procedure is used:

- Choose a random 80-bit key value v.
- Generate the ciphertext c = RC4(v $\|$ k) $\oplus$ m
- Send the bit string (v $\|$ c)

1. Suppose Alice uses this procedure to send a message m to Bob. Describe how Bob can recover the message m from (v $\|$ c) using k.
2. If an adversary observes several values ($v_1 \| c_1$), ($v_2 \| c_2$)....transmitted between Alice and Bob, how can he/she determine when the same key has been used to encrypt two messages?

6. In a particular system, Alice wishes to send a message, M, to Bob using public key cryptography. Each time, Alice is going to desire to achieve some (or all) the objectives of Confidentiality, Integrity, and Non-repudiation. Alice's public and private keys are denoted by (PU_A, PR_A), while the keys of Bob are denoted by (PU_B, PR_B). An encryption process in this system is denoted by E(K, M), where K is the key (could be a public or private key) and M is the plaintext. For each of the following situations, specify which of these objectives is achieved and explain why.

   (a) Alice sends E(PU_B, M)

   (b) Alice sends E(PR_A, M)

   (c) Alice sends E(PU_B, E(PR_A, M))

   (d) Alice sends E(PR_A, E(PU_B, M))