Information Systems Security
Series 4 : Block Ciphers

October 27th, 2021

Exercice 1 : Linear encryption

Let $EL(k, m)$ be a block cipher linear encryption, with k the key and m the block of the message, with nominal size of 128 bits (blocks of plaintext, blocks of ciphertext, and keys are all 128 bits). Since it's linear, we have :

$$EL(k, (m_1 \oplus m_2)) = EL(k, m_1) \oplus EL(k, m_2)$$

- You are allowed to choose 128 "chosen ciphertexts", i.e., you can choose 128 differents ciphertexts as you want, and obtain for each one the corresponding plaintext.
  By choosing carefully these 128 chosen ciphertexts, show that you can then decipher every cipher you encounter without needing the key.
- Is it a good idea to have a linear encryption system ?

Exercices 2 to 6 : Global Framework

In a block cipher, we work by dividing the plaintext/ciphertext into blocks of fixed size. In this kind of cipher, there is two important choices that impact how the encryption works : the encryption mode, and the encryption fonction.
The encryption mode allows to chain or link different blocks in different ways.
The encryption function is the core of the encryption, and is used many times in different ways depending on which mode is used.

For all following exercices, we will consider :

- **Plaintext P, written as blocks P_i of size 1 byte = 8 bits.**
- **Key K, with a length of 1 byte.**
- **Ciphertext C, as blocks C_i of size 1 byte.**

- **Initial value (if needed) IV, also 1 byte.**
- **Each element may be expressed in hexadecimal. Then, each block is simply written as two hexadecimal characters.**

Exercice 2 : Fonctions d'Encryption pour Chiffrements par Blocs

We consider a block B from the plaintext. We write it as $(B_1B_2)_{16}$. Similarly, we write $K = (K_1K_2)_{16}$ the key, and $E = (E_1E_2)_{16}$ the resulting ciphertext block.

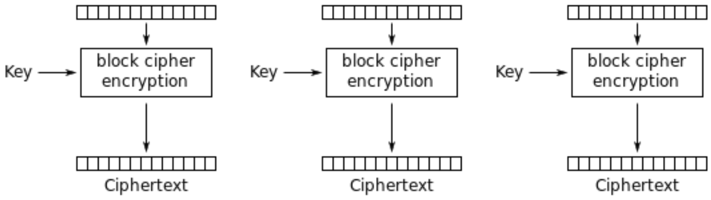
We're proposing the following encryption functions :

1. $E = B \oplus K$
2. $E_i = (B_i + K_i) \mod 16$
3. $E_i = (B_i - 2 * K_i) \mod 16$
4. $E_i = (2 * B_i - K_i) \mod 16$
5. $E_i = (B_i * K_i) \mod 16$
6. $E_i = (7 * B_i + K_i) \mod 16$
7. $E_i = (4 * B_i + K_i) \mod 16$
8. $E_1 = (3 * B_1 + K_2) \mod 16$, $E_2 = (11 * B_2 - K_1) \mod 16$

Which ones of these methods can be used as encryption functions (We are asking which ones can be used, not if they should be or if they are effective) ?
Reminder : If we want to encrypt something, we need to be able to decrypt it.

Exercice 3 : ECB

ECB (Electronic CodeBook) :

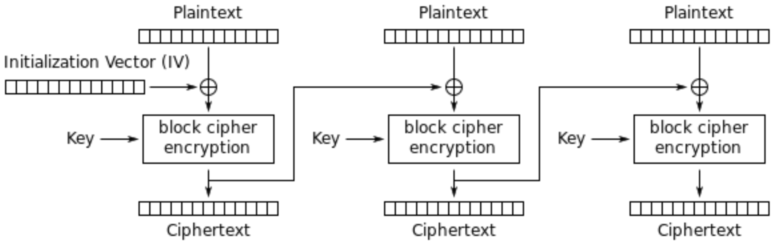


Electronic Codebook (ECB) mode encryption

1. Let $K = (AB)_{16}$, $IV = (AD)_{16}$. Encrypt message $m = (A741BA)_{16}$, with function $E_K(B) = K \oplus B$ and 8 bit blocks.
2. Same question, but with the function $E_K(B_i) = (7 * B_i + K_i) \mod 16$.

Exercice 4 : CBC

CBC (Cipher Block Chaining) :

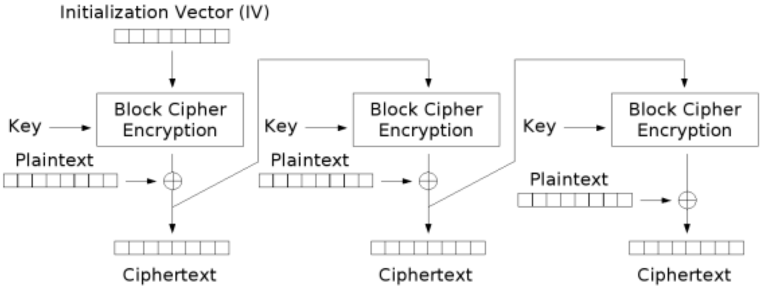


Cipher Block Chaining (CBC) mode encryption

1. Let $K = (AB)_{16}$, $IV = (AD)_{16}$. Encrypt message $m = (A741BA)_{16}$, with function $E_K(B) = B \oplus K$ and 8 bit blocks.
2. Same question, but with encryption function $E_K(B_i) = (7 * B_i + K_i) \mod 16$.

Exercice 5 : CFB

CFB (Cipher FeedBack) :

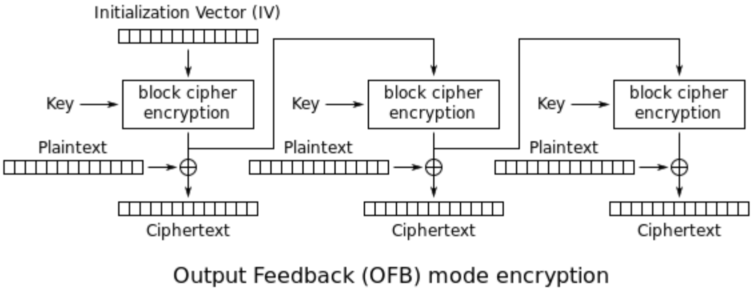


Cipher Feedback (CFB) mode encryption

1. Let $K = (74)_{16}$, $IV = (AA)_{16}$. Encrypt message $m = (2468AC)_{16}$ with function $E_K(B_i) = (7 * B_i + K_i) \mod 16$ and 8 bit blocks.
2. Now, decipher the ciphertext $c = (123456)_{16}$, knowing the encryption was done with the same key, IV and function.

Exercice 6 : OFB

On rappelle le schéma du mode OFB (Output FeedBack) :



1. Let $K = (74)_{16}$, $IV = (AA)_{16}$. Encrypt message $m = (13579B)_{16}$ with function $E_K(B_i) = (11 * B_i + K_i) \mod 16$ and 8 bit blocks.
2. Now, decipher the ciphertext $c = (123456)_{16}$, knowing the encryption was done with the same K, IV and function.