

MIT WORLD PEACE UNIVERSITY

Information and Cybersecurity
Second Year B. Tech, Semester 1

CLASSICAL CRYPTOGRAPHIC TECHNIQUES -
"Fiestal Cipher"

LAB ASSIGNMENT 2

Prepared By

Krishnaraj Thadesar
Cyber Security and Forensics
Batch A1, PA 20

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1 Aim

Write a program using JAVA or Python or C++ to implement Feistel Cipher structure

2 Objectives

To understand the concepts of symmetric key cryptographic system.

3 Theory

3.1 Symmetric Key Cryptography

Symmetric key cryptography is a cryptographic system in which the same key is used for both encryption and decryption. The key is shared between the sender and the receiver. The sender encrypts the message using the key and sends it to the receiver. The receiver decrypts the message using the same key. The key is kept secret and is never sent along with the message.

The most commonly used symmetric key algorithm is the Data Encryption Standard (DES). It uses a 64-bit block size and a 56-bit key. The 64-bit block is divided into two halves of 32-bits each. The key is also divided into two halves of 28-bits each. The first half of the key is used to generate 16 subkeys. Each subkey is 48-bits long. The first 28-bits of the key are shifted left by 1 bit. The first 28-bits of the key are then shifted left by 1 bit. The second 28-bits of the key are shifted left by 1 bit. The second 28-bits of the key are shifted left by 1 bit. This process is repeated for the remaining 16 rounds. The 16 subkeys are then used to encrypt the message.

3.2 Feistel Cipher

Feistel Cipher model is a structure or a design used to develop many block ciphers such as DES. Feistel cipher may have invertible, non-invertible and self invertible components in its design. Same encryption as well as decryption algorithm is used. A separate key is used for each round. However same round keys are used for encryption as well as decryption.

3.3 Feistel Cipher Algorithm

1. Create a list of all the Plain Text characters.
2. Convert the Plain Text to Ascii and then 8-bit binary format.
3. Divide the binary Plain Text string into two halves: left half (L1) and right half (R1)
4. Generate a random binary keys (K1 and K2) of length equal to the half the length of the Plain Text for the two rounds.

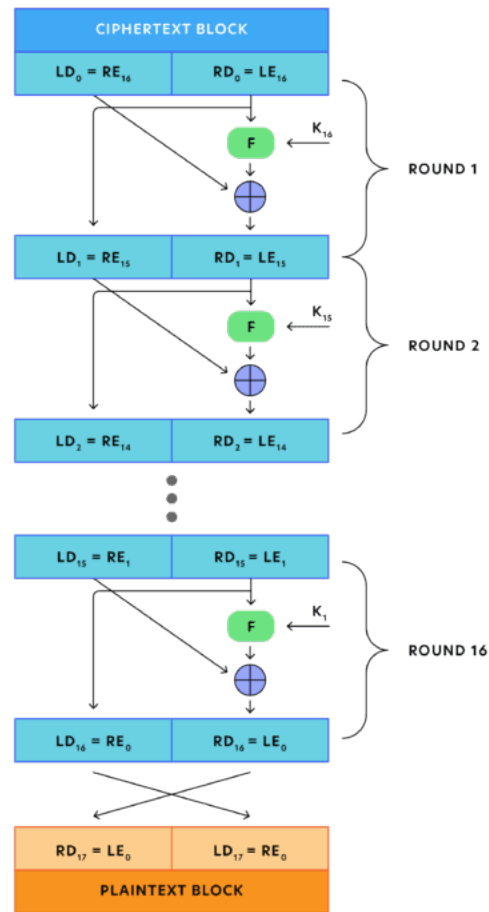


Figure 1: Fiestal Cipher Decryption Method

4 Platform

Operating System: Arch Linux x86-64

IDEs or Text Editors Used: Visual Studio Code

Compilers or Interpreters : Python 3.10.1

5 Input and Output

The plain text, key

[1, 1, 1, 1, 0, 0, 1, 1] [1, 0, 1, 0, 0, 0, 0, 1, 0]

The left and right keys are : [1, 0, 1, 0, 0, 1, 0, 0] [0, 1, 0, 0, 0, 0, 1, 1]

Starting to cipher.

The cipher text is : [0, 1, 0, 0, 0, 0, 0, 1]

6 Code

```
1 # creating the fiester cipher.
2 # Assignment 2
3 # Krishnaraj Thadesar
4 # 10322108888 Batch A1
5
6 ##### Defining Constants #####
7
8 block_size = 8
9
10 binary_to_decimal = {(0, 0): 0, (0, 1): 1, (1, 0): 2, (1, 1): 3}
11
12 PT_IP_8 = [2, 6, 3, 1, 4, 8, 5, 7]
13 PT_IP_8_INV = [4, 1, 3, 5, 7, 2, 8, 6]
14
15 S0_MATRIX = [[1, 0, 3, 2],
16              [3, 2, 1, 0],
17              [0, 2, 1, 3],
18              [3, 1, 3, 2]]
19
20 S1_MATRIX = [
21     [0, 1, 2, 3],
22     [2, 0, 1, 3],
23     [3, 0, 1, 0],
24     [2, 1, 0, 3],
25 ]
26
27 ##### Defining P Boxes #####
28
29 PT_P_10 = [3, 5, 2, 7, 4, 10, 1, 9, 8, 6]
30 PT_P_8 = [6, 3, 7, 4, 8, 5, 10, 9]
31 PT_P_4 = [2, 4, 3, 1]
32 PT_EP = [4, 1, 2, 3, 2, 3, 4, 1]
33
34
35 ##### Functions #####
36
37
38 def shift_left(list_to_shift):
39     """Function to shift bits by 1 to the left
40
41     Args:
42         list_to_shift (list): list of the bunch of binary bits that you wanna
43                                shift to left.
44
45     Returns:
46         list: shifted list.
47     """
48     shifted_list = [i for i in list_to_shift[1:]]
49     shifted_list.append(list_to_shift[0])
50     return shifted_list
51
52 def make_keys(key):
53     """Function to Generate 8 bit K1 and 8 bit K2 from given 10 bit key.
54
55     Args:
```

```
56         key (list): list of 0's and 1's describing the key.
57
58     Returns:
59         (K1, K2): touple containing k1 and k2.
60     """
61     # make key_p10
62     key_P10 = [key[i - 1] for i in PT_P_10]
63
64     # Splitting into lshift and rshift
65     key_P10_left = key_P10[: int(len(key) / 2)]
66     key_P10_right = key_P10[int(len(key) / 2) :]
67
68     # left shifting the key one time
69     key_P10_left_shifted = shift_left(key_P10_left)
70     key_P10_right_shifted = shift_left(key_P10_right)
71
72     # temporarily combining the 2 shifted lists.
73     temp_key = key_P10_left_shifted + key_P10_right_shifted
74     # this gives the first key
75     key_1 = [temp_key[i - 1] for i in PT_P_8]
76
77     # now shifting the key 2 times for both left and right.
78     key_P10_left_shifted = shift_left(key_P10_left_shifted)
79     key_P10_left_shifted = shift_left(key_P10_left_shifted)
80
81     key_P10_right_shifted = shift_left(key_P10_right_shifted)
82     key_P10_right_shifted = shift_left(key_P10_right_shifted)
83
84     temp_key = []
85     temp_key = key_P10_left_shifted + key_P10_right_shifted
86
87     key_2 = [temp_key[i - 1] for i in PT_P_8]
88     # key_1, key_2 = 0, 0
89     return (key_1, key_2)
90
91
92 def function_k(input_text, key):
93
94     # splitting the plain text after applying initial permutation on it.
95     PT_left_after_ip = input_text[: int(len(input_text) / 2)]
96     PT_right_after_ip = input_text[int(len(input_text) / 2) :]
97
98     # Applying Expansion Permutation on the right part of plain text after ip
99     PT_right_after_EP = [PT_right_after_ip[i - 1] for i in PT_EP]
100
101     # xoring the right part of pt after ep with key 1
102     PT_after_XOR_with_key_1 = [x ^ y for x, y in zip(PT_right_after_EP, key)]
103
104     # splitting the xor output of the right part of the plain text after ep.
105     PT_after_XOR_with_key_1_left = PT_after_XOR_with_key_1[
106         : int(len(PT_after_XOR_with_key_1) / 2)
107     ]
108     PT_after_XOR_with_key_1_right = PT_after_XOR_with_key_1[
109         int(len(PT_after_XOR_with_key_1) / 2) :
110     ]
111
112     # getting the row and column number for S0 matrix.
113     row_number_for_S0 = (
114         PT_after_XOR_with_key_1_left[0],
```

```
115     PT_after_XOR_with_key_1_left[-1],
116 )
117
118     col_number_for_S0 = (
119         PT_after_XOR_with_key_1_left[1],
120         PT_after_XOR_with_key_1_left[2],
121     )
122
123     # getting the row and column number for the S1 matrix.
124     row_number_for_S1 = (
125         PT_after_XOR_with_key_1_right[0],
126         PT_after_XOR_with_key_1_right[-1],
127     )
128
129     col_number_for_S1 = (
130         PT_after_XOR_with_key_1_right[1],
131         PT_after_XOR_with_key_1_right[2],
132     )
133
134     # Getting the value from the S0 matrix.
135     S0_value = S0_MATRIX[binary_to_decimal.get(row_number_for_S0)][
136         binary_to_decimal.get(col_number_for_S0)
137     ]
138
139     # getting the value from the S1 matrix.
140     S1_value = S1_MATRIX[binary_to_decimal.get(row_number_for_S1)][
141         binary_to_decimal.get(col_number_for_S1)
142     ]
143
144     # converting the decimal numbers from s box output into binary.
145     S0_value = list(binary_to_decimal.keys())[
146         list(binary_to_decimal.values()).index(S0_value)
147     ]
148     S1_value = list(binary_to_decimal.keys())[
149         list(binary_to_decimal.values()).index(S1_value)
150     ]
151
152     s_box_output = list(S0_value + S1_value)
153
154     # applying P4 to s box output.
155     s_box_output_after_P4 = [s_box_output[i - 1] for i in PT_P_4]
156
157     # xoring the output of sbox after p4 with the left part of the plain text
158     # after ip.
159     fk_xor_output = [x ^ y for x, y in zip(s_box_output_after_P4, PT_left_after_ip)]
160
161     fk_concat_output_8_bit = fk_xor_output + PT_right_after_ip
162
163     return fk_concat_output_8_bit
164
165 def encrypt_fiestal_cipher(plain_text, key_1, key_2):
166     print("Starting to cipher. ")
167
168     # Initial permutation for the plain text
169     plain_text_after_ip = [plain_text[i - 1] for i in PT_IP_8]
170
171     # getting partial output from running f(k) with key 1
```

```
172     output_1_function_k = function_k(plain_text_after_ip, key_1)
173
174     # splitting that output.
175     output_1_function_k_left = output_1_function_k[:4]
176     output_1_function_k_right = output_1_function_k[4:]
177
178     # switching that output.
179     temp = output_1_function_k_right + output_1_function_k_left
180
181     # running function again with switched output from running f(k) with key 2
182     output_2_function_k = function_k(temp, key_2)
183
184     # running IP Inverse on it.
185     cipher_text = [output_2_function_k[i - 1] for i in PT_IP_8_INV]
186
187     return cipher_text
188
189
190 def decrypt_fiestal_cipher(cipher_text, key_1, key_2):
191     print("Starting to Decipher. ")
192
193     # Initial permutation for the cipher text
194     cipher_text_after_ip = [cipher_text[i - 1] for i in PT_IP_8_INV]
195
196     # getting partial output from running f(k) with key 2
197     output_1_function_k = function_k(cipher_text_after_ip, key_2)
198
199     # splitting that output.
200     output_1_function_k_left = output_1_function_k[:4]
201     output_1_function_k_right = output_1_function_k[4:]
202
203     # switching that output.
204     temp = output_1_function_k_right + output_1_function_k_left
205
206     # running function again with switched output from running f(k) with key 1
207     output_2_function_k = function_k(temp, key_1)
208
209     # running IP Inverse on it.
210     deciphered_plain_text = [output_2_function_k[i - 1] for i in PT_IP_8]
211
212     return deciphered_plain_text
213
214
215 def main():
216
217     # this will make the plaintext a list.
218     # plain_text = [int(i) for i in input("Enter the Plain text with spaces: ").
219     split()]
220     # key = [int(i) for i in input("Enter the Key with spaces: ").split()]
221     plain_text = [1, 1, 1, 1, 0, 0, 1, 1]
222     key = [1, 0, 1, 0, 0, 0, 0, 0, 1, 0]
223     print("The plain text, key")
224     print(plain_text, key)
225
226     key_1, key_2 = make_keys(key)
227     print("The left and right keys are : ", key_1, key_2)
228
229     # Generating the Cipher text.
230     cipher_text = encrypt_fiestal_cipher(plain_text, key_1, key_2)
```



```
230     print("The cipher text is : ", cipher_text)
231
232
233 main()
```

Listing 1: "Fiestal Cipher"

7 Conclusion

Thus, learnt about the different kinds of ciphers, classical cryptographic techniques, and how to implement some of them in python.

8 FAQ

1. Differentiate between stream and block ciphers.

- (a) Stream ciphers encrypt the data one bit at a time. Block ciphers encrypt the data in blocks of fixed size.
- (b) Stream ciphers are faster than block ciphers.
- (c) Block ciphers are more secure than stream ciphers.
- (d) Stream ciphers are more suitable for real-time applications.
- (e) Block ciphers are more suitable for bulk data encryption.
- (f) Stream ciphers are more suitable for applications where the data is encrypted and decrypted in a single pass.
- (g) Block ciphers are more suitable for applications where the data is encrypted and decrypted in multiple passes.

2. Write advantages and disadvantages of DES algorithm.

Advantages:

- (a) It is a fast, simple, efficient, and secure algorithm.
- (b) The algorithm has been in use since 1977. Technically, no weaknesses have been found in the algorithm. Brute force attacks are still the most efficient attacks against the DES algorithm.
- (c) DES is the standard set by the US Government. The government recertifies DES every five years, and has to ask for its replacement if the need arises.
- (d) The American National Standards Institute (ANSI) and International Organization for Standardization (ISO) have declared DES as a standard as well. This means that the algorithm is open to the public—to learn and implement.
- (e) DES was designed for hardware; it is fast in hardware, but only relatively fast in software.

Disadvantages:

- (a) Probably the biggest disadvantage of the DES algorithm is the key size of 56-bit. There are chips available that can encrypt and decrypt a million DES operations in a second. A DES cracking machine that can search all the keys in about seven hours is available for 1 million.
- (b) DES can be implemented quickly on hardware. But since it was not designed for software, it is relatively slow on it.
- (c) It has become easier to break the encrypted code in DES as the technology is steadily improving. Nowadays, AES is preferred over DES.
- (d) DES uses a single key for encryption as well as decryption as it is a type of symmetric encryption technique. In case that one key is lost, we will not be able to receive decipherable data at all.

3. Explain block cipher modes of operations.

(a) *Electronic Code Book (ECB)*

- i. ECB mode stands for Electronic Code Block Mode. It is one of the simplest modes of operation. In this mode, the plain text is divided into a block where each block is 64 bits. Then each block is encrypted separately. The same key is used for the encryption of all blocks. Each block is encrypted using the key and makes the block of ciphertext.
- ii. At the receiver side, the data is divided into a block, each of 64 bits. The same key which is used for encryption is used for decryption. It takes the 64-bit ciphertext and, by using the key convert the ciphertext into plain text.
- iii. As the same key is used for all blocks' encryption, if the block of plain text is repeated in the original message, then the ciphertext's corresponding block will also repeat. As the same key used for all block, to avoid the repetition of block ECB mode is used for an only small message where the repetition of the plain text block is less.

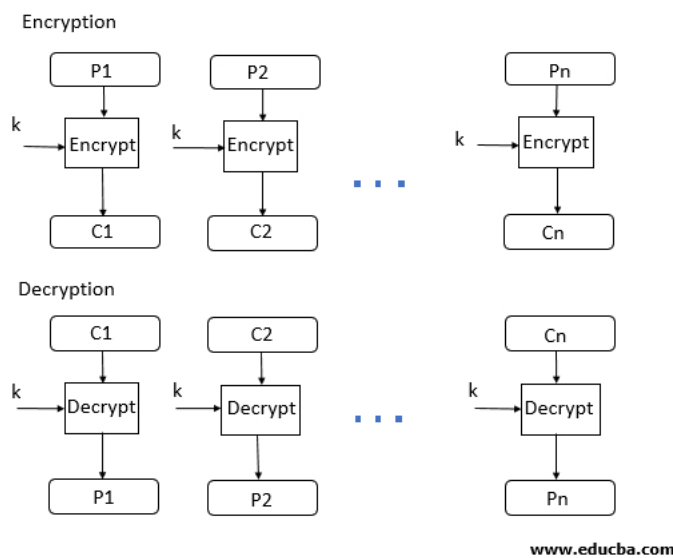


Figure 2: ECB Mode of Operation

(b) *Cipher Block Chaining (CBC)*

- i. CBC Mode stands for Cipher block Mode at the sender side; the plain text is divided into blocks. In this mode, IV(Initialization Vector) is used, which can be a random block of text. IV is used to make the ciphertext of each block unique.
- ii. The first block of plain text and IV is combined using the XOR operation and then encrypted the resultant message using the key and form the first block of ciphertext. The first block of ciphertext is used as IV for the second block of plain text. The same procedure will be followed for all blocks of plain text.
- iii. At the receiver side, the ciphertext is divided into blocks. The first block ciphertext is decrypted using the same key, which is used for encryption. The decrypted result will be XOR with the IV and form the first block of plain text. The second block of ciphertext is also decrypted using the same key, and the result of the decryption will be XOR with the first block of ciphertext and form the second block of plain text. The same procedure is used for all the blocks.

- iv. CBC Mode ensures that if the block of plain text is repeated in the original message, it will produce a different ciphertext for corresponding blocks. Note that the key which is used in CBC mode is the same; only the IV is different, which is initialized at a starting point.

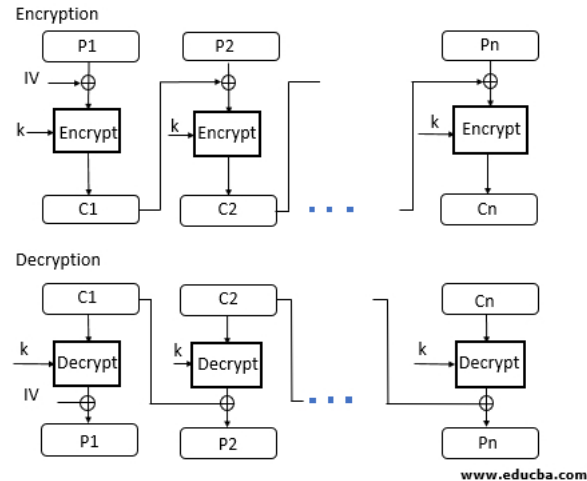


Figure 3: CBC Mode of Operation

(c) Cipher Feedback (CFB)

- i. CFB mode stands for Cipher Feedback Mode. In this mode, the data is encrypted in the form of units where each unit is of 8 bits.
- ii. Like cipher block chaining mode, IV is initialized. The IV is kept in the shift register. It is encrypted using the key and forms the ciphertext.
- iii. Now the leftmost j bits of the encrypted IV are XORed with the plain text's first j bits. This process will form the first part of the ciphertext, and this ciphertext will be transmitted to the receiver.
- iv. Now the bits of IV are shifted left by j bits. Therefore the rightmost j positions of the shift register now have unpredictable data. These rightmost j positions are now filled with the ciphertext. The process will be repeated for all plain text units.

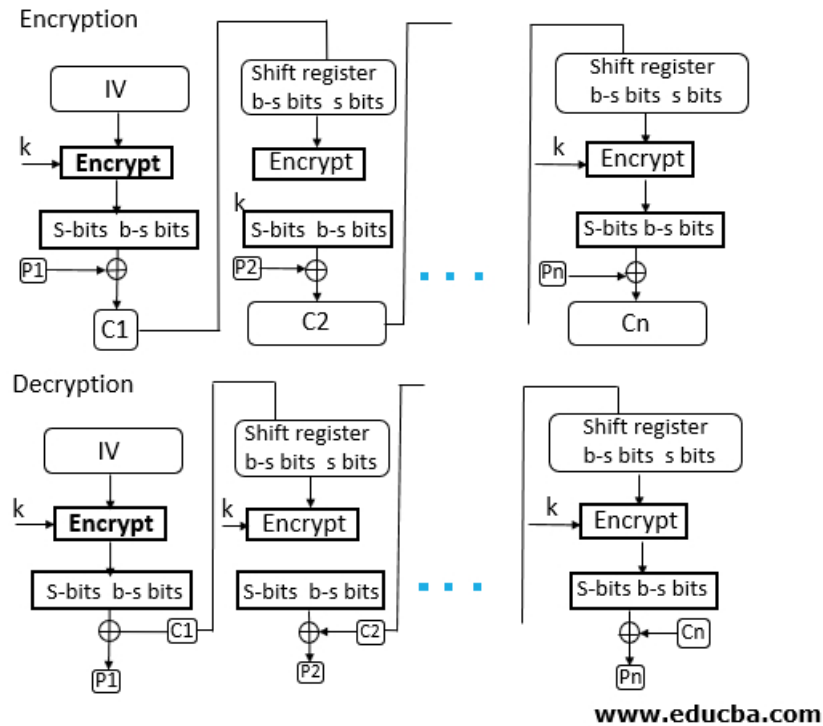


Figure 4: CFB Mode of Operation

(d) *Output Feedback (OFB)*

- OFB Mode stands for output feedback Mode. OFB mode is similar to CFB mode; the only difference is in CFB, the ciphertext is used for the next stage of the encryption process, whereas in OFB, the output of the IV encryption is used for the next stage of the encryption process.
- The IV is encrypted using the key and form encrypted IV. Plain text and leftmost 8 bits of encrypted IV are combined using XOR and produce the ciphertext.
- For the next stage, the ciphertext, which is the form in the previous stage, is used as an IV for the next iteration. The same procedure is followed for all blocks.

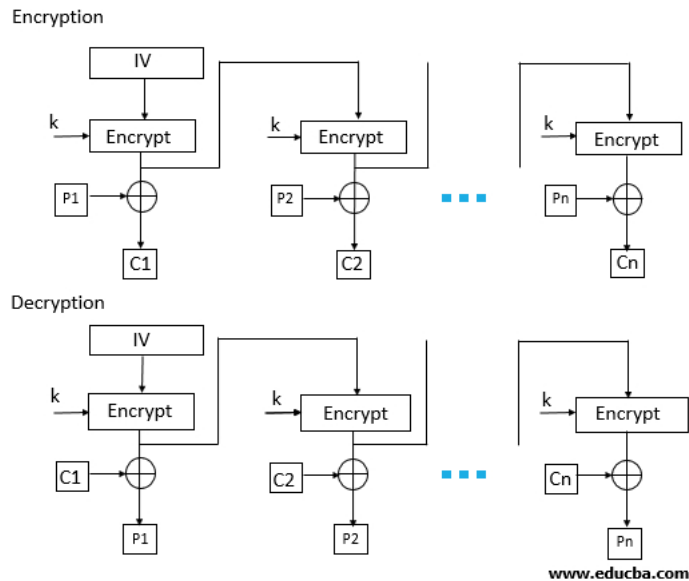


Figure 5: Output Feedback Mode of Operation

(e) Counter (CTR)

- i. CTR Mode stands for counter mode. As the name is counter, it uses the sequence of numbers as an input for the algorithm. When the block is encrypted, to fill the next register next counter value is used.
- ii. For encryption, the first counter is encrypted using a key, and then the plain text is XOR with the encrypted result to form the ciphertext.
- iii. The counter will be incremented by 1 for the next stage, and the same procedure will be followed for all blocks. For decryption, the same sequence will be used. Here to convert ciphertext into plain text, each ciphertext is XOR with the encrypted counter. For the next stage, the counter will be incremented by the same will be repeated for all Ciphertext blocks.

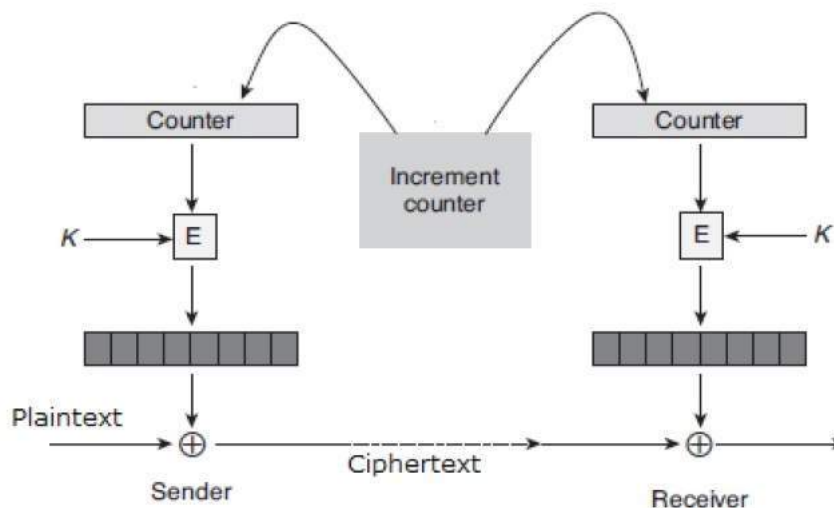


Figure 6: