SNS COLLEGE OF ENGINEERING

Kurumbapalayam (Po), Coimbatore – 641 107

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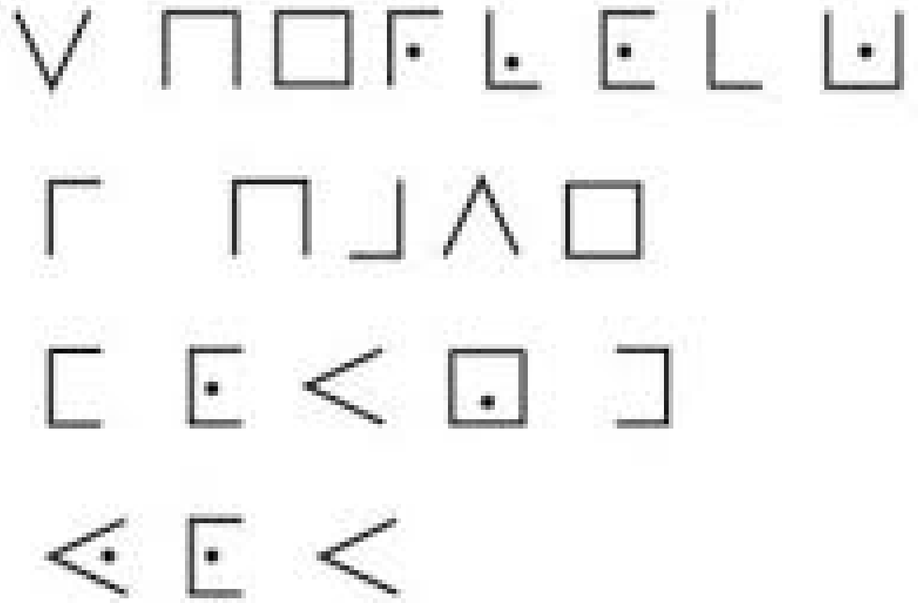
DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

COURSE NAME : 19CS503 Cryptography and Network Security

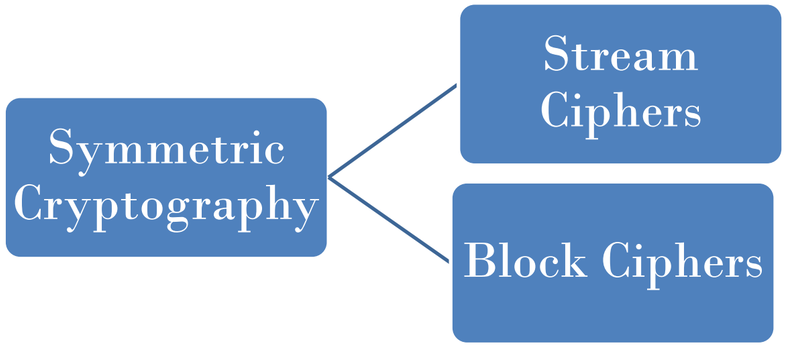
III YEAR /V SEMESTER

Unit 2- SYMMETRIC KEY CRYPTOGRAPHY

Topic : Differential and linear cryptanalysis – Block cipher design principles – Block cipher mode of operation

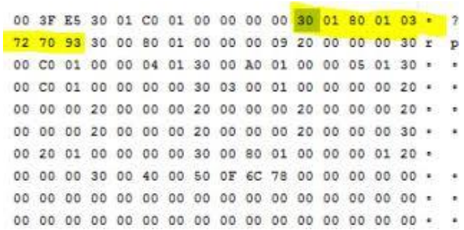


Stream and Block Ciphers



Stream ciphers process messages a bit or byte at a time when en/decrypting

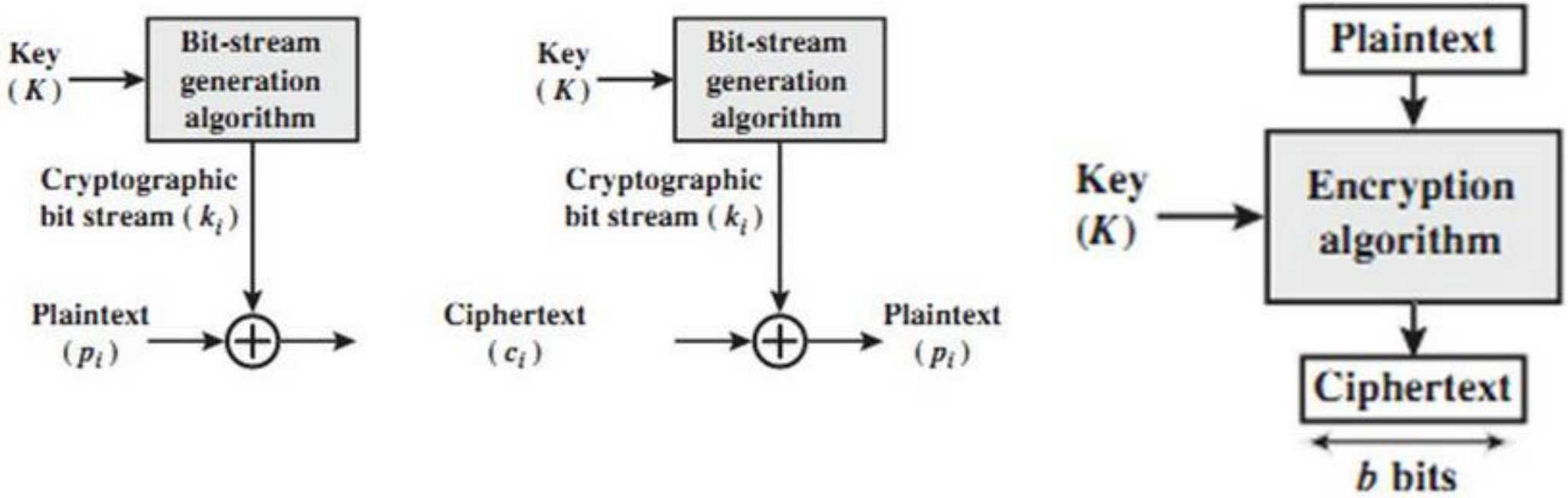
Block ciphers process messages into blocks, each of which is then en/decrypted



Simple substitution is an example of a stream cipher.

Columnar transposition is a block cipher

Stream and Block Ciphers



Block vs Stream Cipher

Block Cipher	Stream Cipher
Block Cipher Converts the plain text into cipher text by taking plain text's block at a time.	Stream Cipher Converts the plaint text into cipher text by taking 1 byte of plain text at a time.
Block cipher uses either 64 bits or more than 64 bits.	While stream cipher uses 8 bits.
The complexity of block cipher is simple.	While stream cipher is more complex.
Block cipher Uses confusion as well as diffusion.	While stream cipher uses only confusion.
In block cipher, reverse encrypted text is hard.	While in stream cipher, reverse encrypted text is easy.
The algorithm modes which are used in block cipher are: ECB (Electronic Code Book) and CBC (Cipher Block Chaining).	The algorithm modes which are used in stream cipher are: CFB (Cipher Feedback) and OFB (Output Feedback).

Feistel Cipher Structure

Reversible Mapping

Plaintext	Ciphertext
00	11
01	10
10	00
11	01

Each time unique ciphertext block is created.

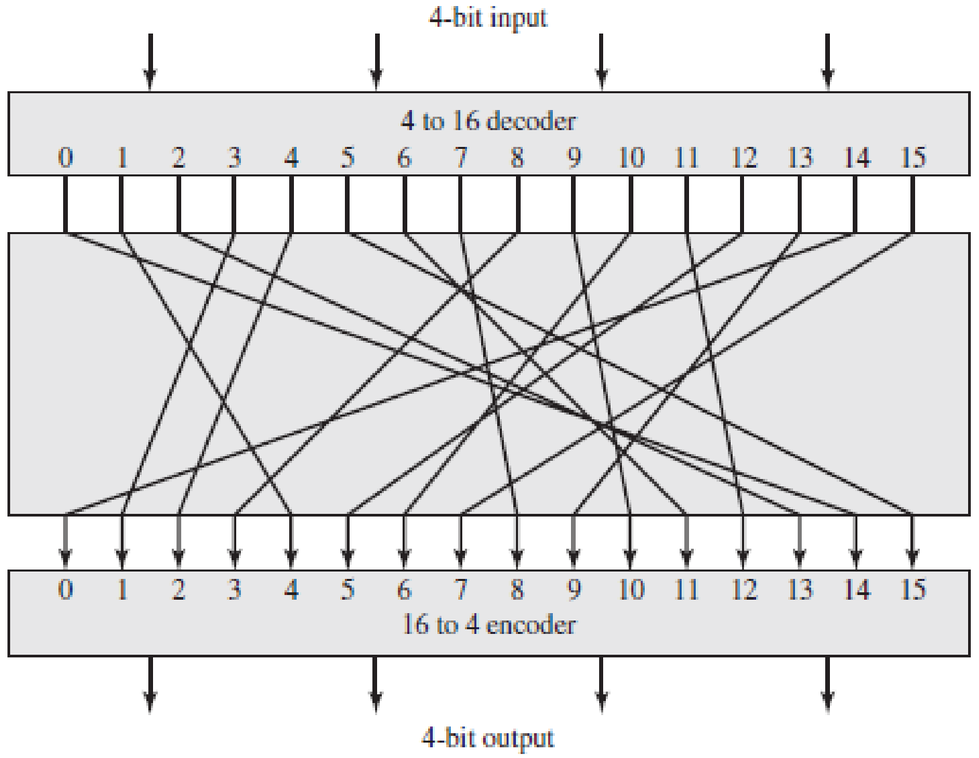
Irreversible Mapping

Plaintext	Ciphertext
00	11
01	10
10	01
11	01

Ciphertext of 01 have been produced by one of two plaintext.

Message Authentication and Digital Signature

- 4-bit input ,16 possible input states - mapped by the substitution cipher - 16 possible output states, 4 ciphertext bits.
- Referred as Ideal Block Cipher
  - Because it allows plaintext-ciphertext mapping for all possible inputs.



key is mapping ; Key length **16 × 4 bits = 64 bits . i.e. concatenate all bits of ciphertext table**

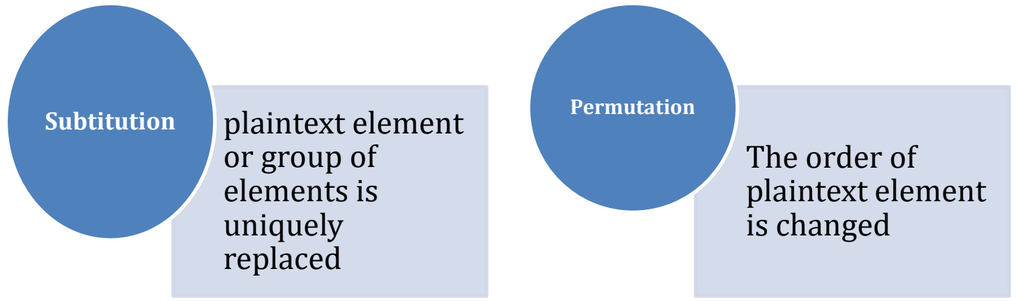
Problems with Ideal Block Cipher

- Small block size
  - equivalent to classical substitution cipher
  - cryptanalysis based on statistical characteristics feasible
- Large block size:
  - key must be very large
  - performance/ implementation problems.

Activity

Feistel Cipher

- Feistel proposed applying two or more simple ciphers in sequence so final result cryptographically stronger than component ciphers
- **n-bit block length; k-bit key length; 2k transformations (rather than 2n !)**
- Feistel cipher alternates: substitutions, transpositions (permutations)



Diffusion and Confusion

- To suppress statistical cryptanalysis

Diffusion	Confusion
• Each plaintext digit affects the value of many ciphertext digits.	• Achieved with the use of complex substitution algorithm

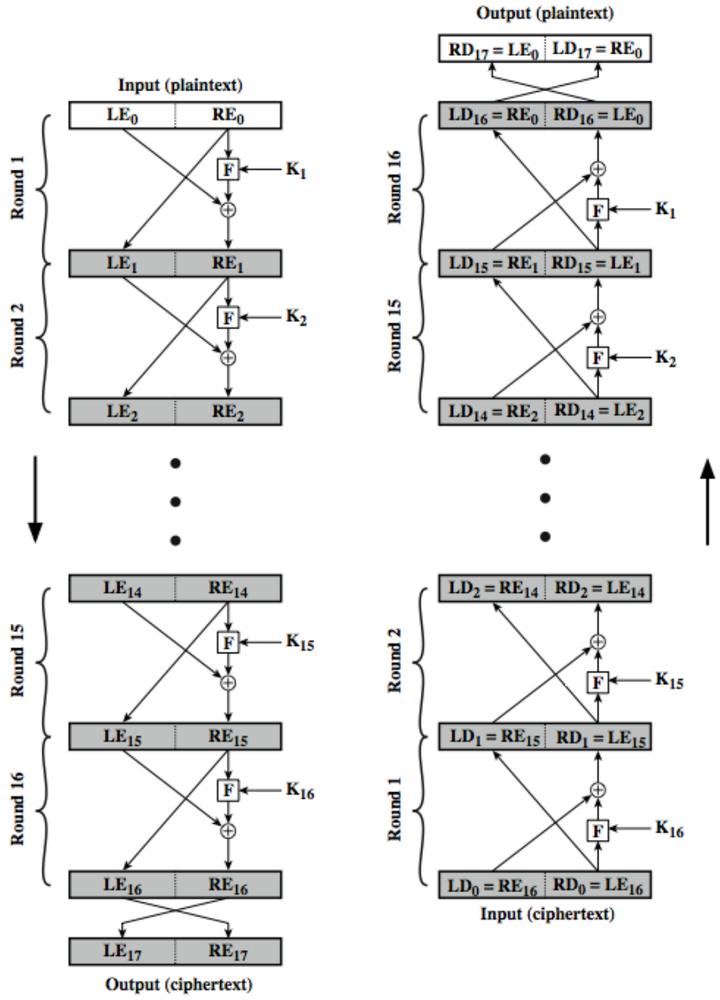
Message M=m1,m2,m3.. of characters encrypted as

$$y_n = \left(\sum_{i=1}^{k} m_{n+i} \right) \bmod 26$$

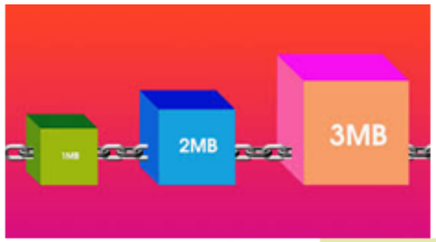
Statistical relationship between the plaintext and ciphertext as complex as possible in order to thwart attempts to deduce the key.

Feistel Cipher Structure

- Left – Hand Side
  - Plaintext 2w bits and Key k
  - L_0 and R_0
  - N rounds of processing
    - (fig has 16 rounds)
  - Subkey K_1
  - Substitution – Left half
  - Round Function F to Right half
  - $F(RE_i,K_{i+1})$
  - Permutation to both halves



Feistel Cipher Design Elements



block size - increasing size improves security, but slows cipher

$y = f(x_i)$

round function - greater complexity can make analysis harder, but slows cipher

key size - increasing size improves security, makes exhaustive key searching harder, but may slow cipher

number of rounds - increasing number improves security, but slows cipher

subkey generation algorithm - greater complexity can make analysis harder, but slows cipher

fast software en/decryption - more recent concern for practical use
ease of analysis - for easier validation & testing of strength

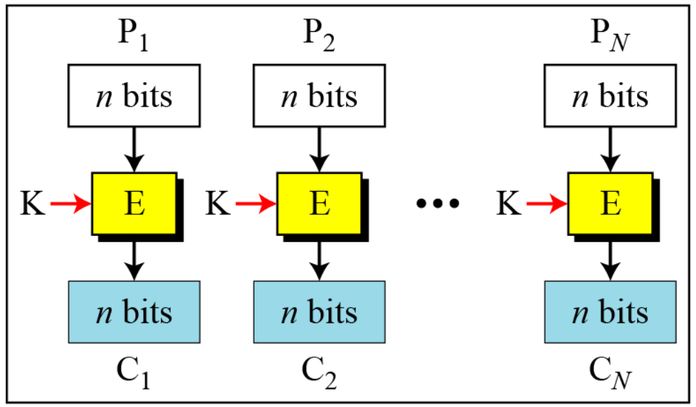
Block Cipher – Modes of operation

Electronic Code Book (ECB)	• Each block encoded independently using the same key.
Cipher Block Chaining (CBC)	• XOR of the next block of plaintext and the preceding block of ciphertext.
Cipher Feedback(CFB)	• pseudorandom output (Preceding ciphertext) XORed with plaintext to produce next unit of ciphertext
Output Feedback (OFB)	• Same as CFB except preceding encryption output, and full blocks are used.
Counter (CTR)	• ORed with an encrypted counter. CTR is incremented for each subsequent block

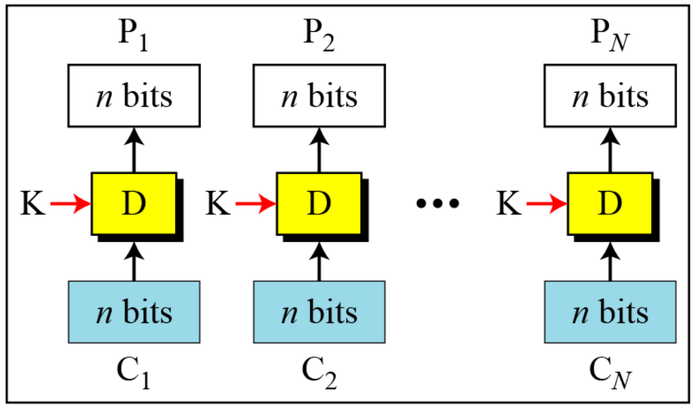
Electronic Code Book (ECB)

ECB	$C_j = E(K, P_j) \quad j = 1, \ldots, N$	$P_j = D(K, C_j) \quad j = 1, \ldots, N$

E: Encryption D: Decryption
P_i: Plaintext block i C_i: Ciphertext block i
K: Secret key



Encryption



Decryption

Application: Secure transmission of single values (e.g., an encryption key)

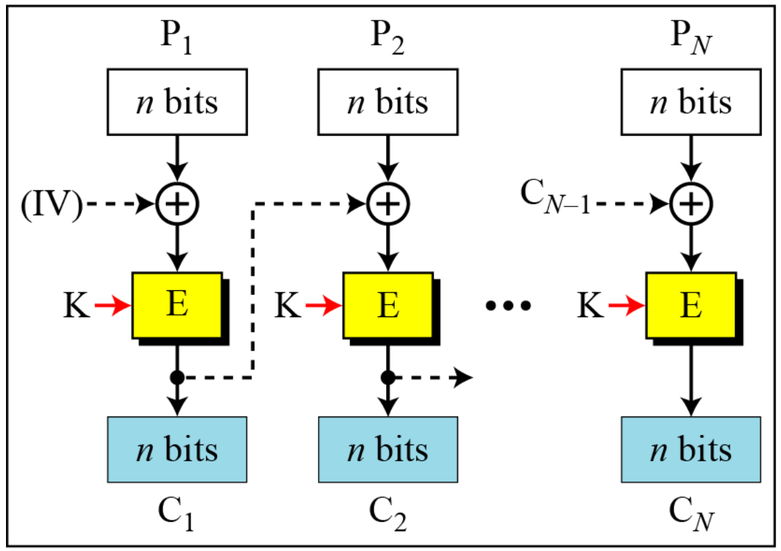
Cipher Block Chaining (CBC)

CBC	$C_1 = \mathrm{E}(K, [P_1 \oplus \mathrm{IV}])$ $C_j = \mathrm{E}(K, [P_j \oplus C_{j-1}])\ j = 2, \ldots, N$	$P_1 = \mathrm{D}(K, C_1) \oplus \mathrm{IV}$ $P_j = \mathrm{D}(K, C_j) \oplus C_{j-1}\ j = 2, \ldots, N$

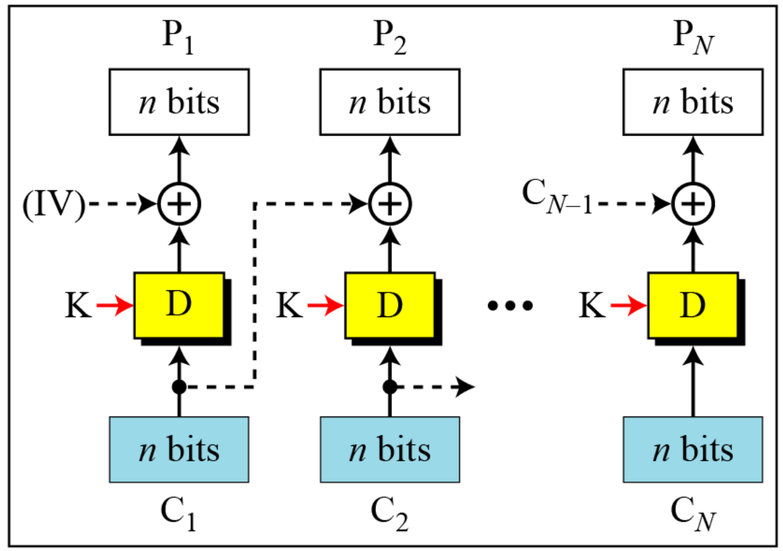
E: Encryption
P_i: Plaintext block i
K: Secret key

D : Decryption
C_i : Ciphertext block i
IV: Initial vector (C_0)

Application: General-purpose block oriented transmission and Authentication



Encryption

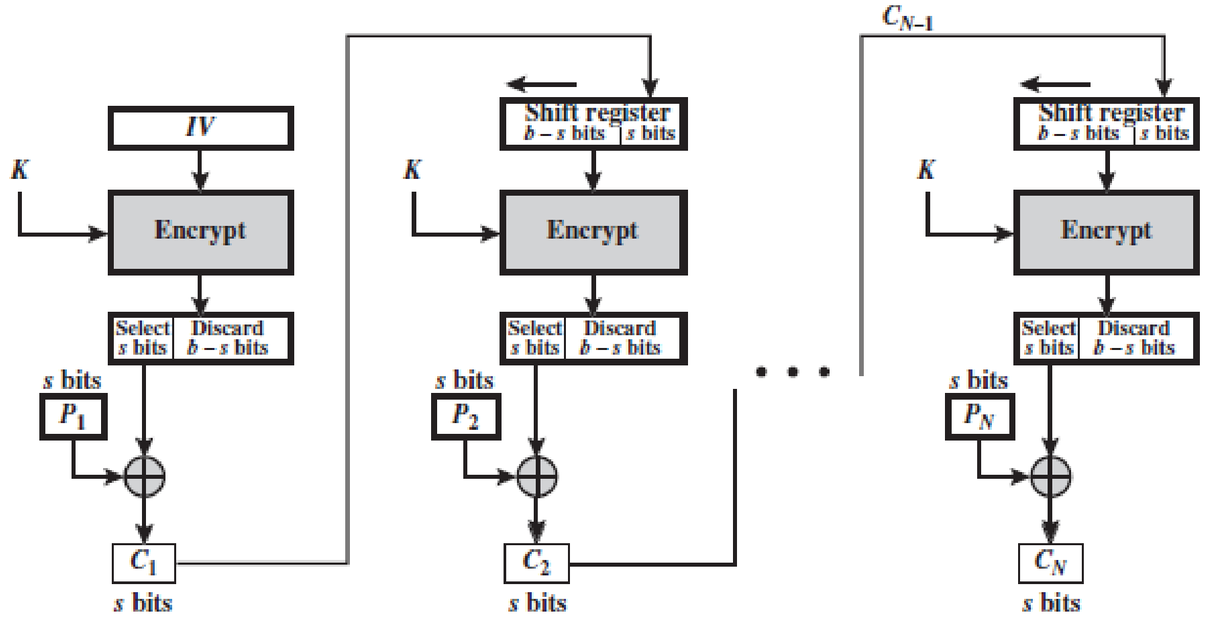


Decryption

Cipher Feedback(CFB)

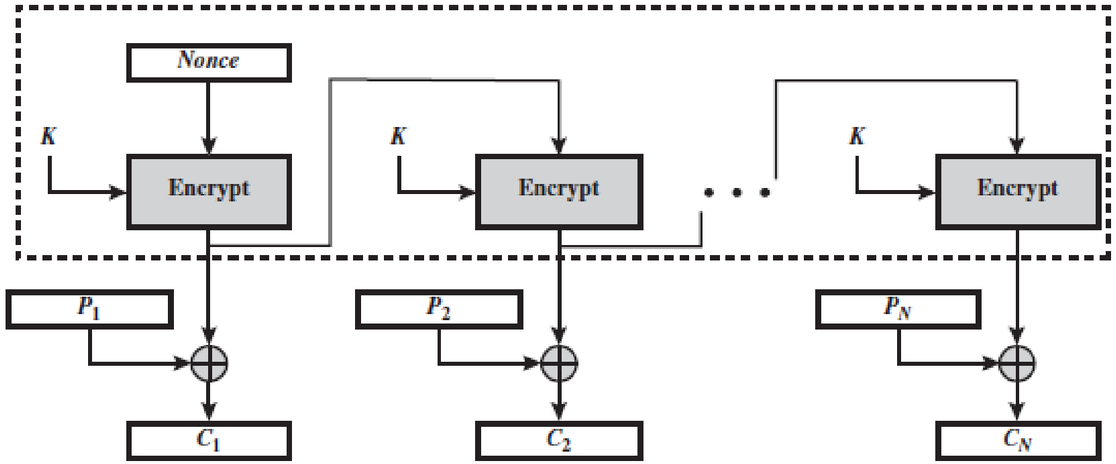
CFB	$I_1 = IV$ $I_j = \text{LSB}_{b-s}(I_{j-1}) \| C_{j-1}$ $\quad j = 2, \ldots, N$ $O_j = \text{E}(K, I_j)$ $\quad j = 1, \ldots, N$ $C_j = P_j \oplus \text{MSB}_s(O_j)$ $\quad j = 1, \ldots, N$	$I_1 = IV$ $I_j = \text{LSB}_{b-s}(I_{j-1}) \| C_{j-1}$ $\quad j = 2, \ldots, N$ $O_j = \text{E}(K, I_j)$ $\quad j = 1, \ldots, N$ $P_j = C_j \oplus \text{MSB}_s(O_j)$ $\quad j = 1, \ldots, N$

Application: General-purpose stream oriented transmission and Authentication



Output FeedBack (OFB)

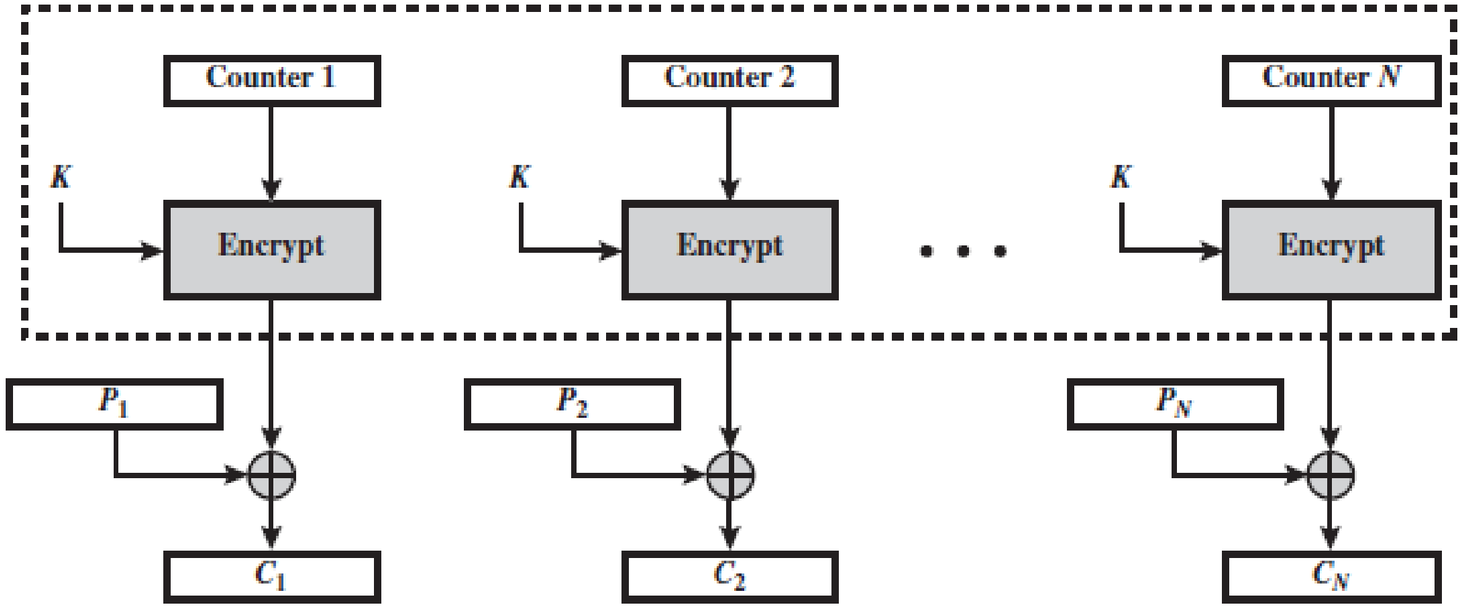
OFB	$I_1 = Nonce$ $I_j = O_{j-1} \quad j = 2, \ldots, N$ $O_j = \mathrm{E}(K, I_j) \quad j = 1, \ldots, N$ $C_j = P_j \oplus O_j \quad j = 1, \ldots, N-1$ $C_N^* = P_N^* \oplus \mathrm{MSB}_u(O_N)$	$I_1 = Nonce$ $I_j = O_{j-1} \quad j = 2, \ldots, N$ $O_j = \mathrm{E}(K, I_j) \quad j = 1, \ldots, N$ $P_j = C_j \oplus O_j \quad j = 1, \ldots, N-1$ $P_N^* = C_N^* \oplus \mathrm{MSB}_u(O_N)$



Application: Stream-oriented transmission over noisy channel (e.g., satellite communication)

Counter (CTR)

CTR	$C_j = P_j \oplus \mathrm{E}(K, T_j) \quad j = 1, \ldots, N-1$ $C_N^* = P_N^* \oplus \mathrm{MSB}_u[\mathrm{E}(K, T_N)]$	$P_j = C_j \oplus \mathrm{E}(K, T_j) \quad j = 1, \ldots, N-1$ $P_N^* = C_N^* \oplus \mathrm{MSB}_u[\mathrm{E}(K, T_N)]$



Application: General-purpose block oriented transmission and Useful for high-speed requirements

Summary

Operation Mode	*Description*	*Type of Result*	*Data Unit Size*
ECB	Each n-bit block is encrypted independently with the same cipher key.	Block cipher	n
CBC	Same as ECB, but each block is first exclusive-ored with the previous ciphertext.	Block cipher	n
CFB	Each r-bit block is exclusive-ored with an r-bit key, which is part of previous cipher text	Stream cipher	$r \leq n$
OFB	Same as CFB, but the shift register is updated by the previous r-bit key.	Stream cipher	$r \leq n$
CTR	Same as OFB, but a counter is used instead of a shift register.	Stream cipher	n

Assessment 1

1 Confusion hides the relationship between the cipher
plaintext.
a) True
b) False

2. The S-Box is used to provide confusion, as it is depe
unknown key.
a) True
b) False

REFERENCES

1. William Stallings, Cryptography and Network Security, 6 th Edition, Pearson Education, March 2013.

THANK YOU