Encrypting
with Block Ciphers

BİL 448/548

Internet Security Protocols

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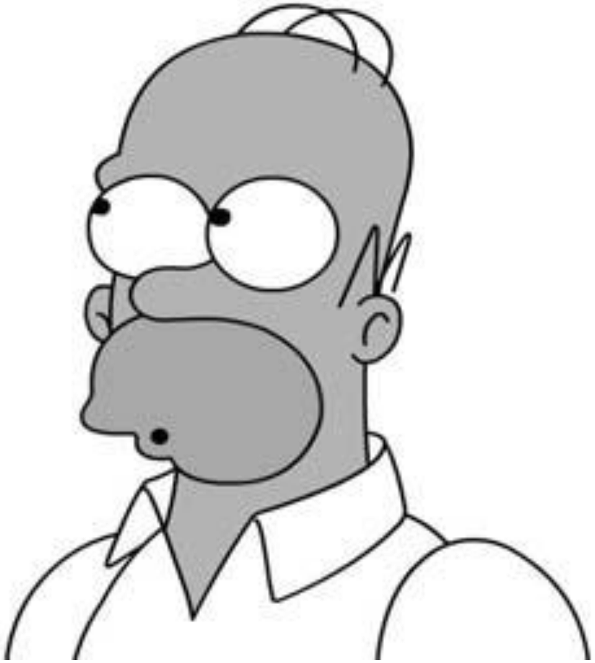
How to Encrypt with a Block Cipher?

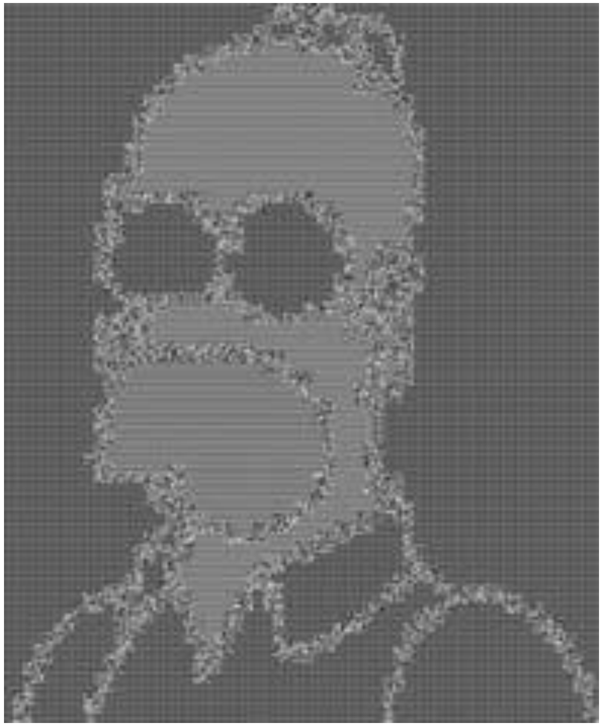
Electronic Codebook (ECB) Mode:

- The naive way.
- The plaintext is divided into blocks P_i , each block is encrypted independently:
  $C_i = E(P_i)$
  $P_i = D(C_i)$
- Problem: Leaks information about identical blocks

An Illustration – The Plaintext



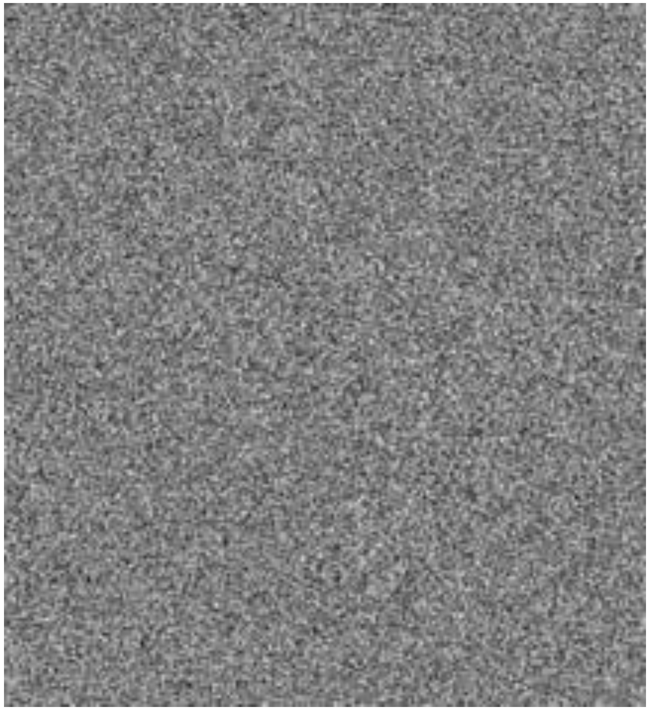
An Illustration – ECB Encrypted



Cipher Block Chaining (CBC)

- Add randomization to the plaintext by mixing with the previous ciphertext:
  $C_i = E(P_i \oplus C_{i-1})$
  $P_i = D(C_i) \oplus C_{i-1}$
- Initialization Vector (IV): used instead of C_0 when encrypting/decrypting the first block.
  (not a secret)
- Most common mode in practice
- Features:
  - Error propagation: 1 wrong bit corrupts 1 block + 1 bit
  - Allows random access to the ciphertext
  - Decryption is parallelizable

An Illustration – CBC Encrypted



Output Feedback (OFB) Mode

- Block cipher is used as the PRNG in a stream cipher.
- A key stream is generated from the output:
  $O_i = E(O_{i-1})$
  $C_i = P_i \oplus O_i$
  $P_i = C_i \oplus O_i$
- IV used for O_0
- Features:
  - Error propagation minimal (bit for bit)
  - Preprocessing possible (may be good for multimedia)
  - Doesn’t allow random access; not parallelizable

Cipher Feedback (CFB) Mode

- A key stream is generated from the ciphertext:

  $O_i = E(C_{i-1})$

  $C_i = P_i \oplus O_i$

  $P_i = C_i \oplus O_i$
- IV used for C_0
- Features:
  - Error propagation: 1 bit + 1 block
  - Allows random access
  - Decryption is parallelizable

Counter (CTR) Mode

- A key stream is generated by encrypting a counter:

  $C_i = P_i \oplus E(IV + i - 1)$

  $P_i = C_i \oplus E(IV + i - 1)$

- Features:
  - Error propagation minimal (bit for bit)
  - Preprocessing possible
  - Allows random access
  - Both encryption and decryption are parallelizable