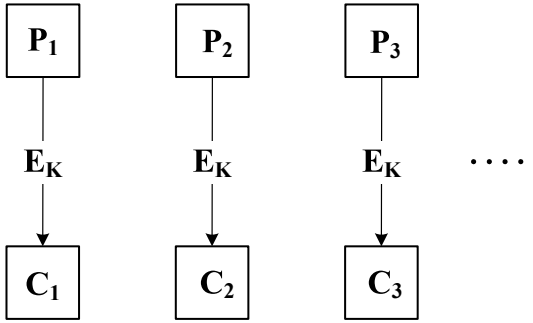
Modes of Operation
(DES and other secret-key block ciphers)

We assume our encryption algorithm is DES, but with minor changes the modes described here apply to other secret-key block ciphers.

The plaintext **P** is divided into 64-bit blocks $\mathbf{P_1}$, $\mathbf{P_2}$, ..., $\mathbf{P_L}$. Corresponding 64-bit blocks of ciphertext **C** are labeled $\mathbf{C_1}$, $\mathbf{C_2}$, ..., $\mathbf{C_L}$.

1. Electronic Codebook (ECB Mode)



$C_j = E_K(P_j)$,

$P_j = D_K(C_j)$

Advantages:

i) Simplest method.

ii) Blocks can be encrypted in parallel.

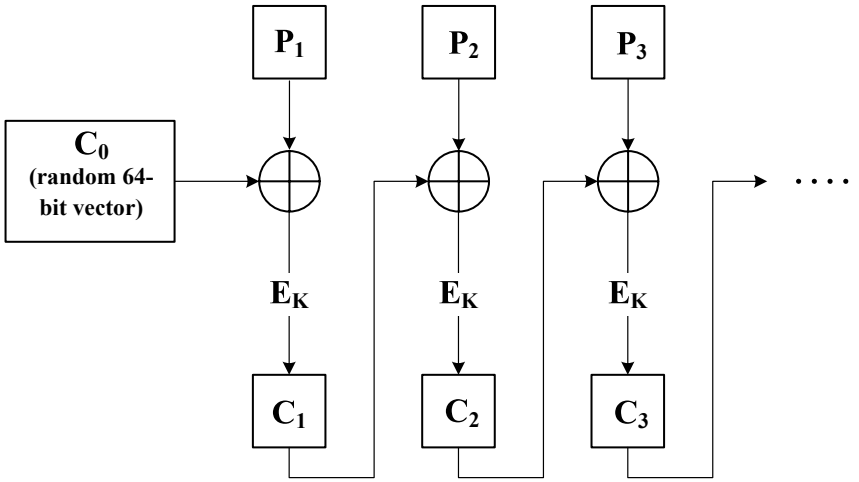
ii) Error in transmitting one ciphertext block causes that block to decrypt incorrectly, but other blocks are not effected.

Disadvantages:

i) Equal plaintext blocks always encrypt to equal ciphertext blocks (until key is changed).

ii) Intruder gaining occasional access to known plaintext might gradually build up a codebook of plaintext-ciphertext pairs, allowing him to (partially) decrypt messages even without the key.

2. Cipher Block Chaining (CBC Mode)



C_0 = a random vector, $C_j = E_K(P_j \oplus C_{j-1})$ for j = 1,2, ...

(Note C_0 is transmitted unencrypted.)

$P_j = D_K(C_j) \oplus C_{j-1}$.

Advantages:

i) Equal plaintext blocks in different positions encrypt to different ciphertext blocks.

ii) Equal plaintext blocks in same position of different texts encrypt to different ciphertext blocks (if a new random C_0 is chosen for each plaintext).

Disadvantages:

i) Blocks cannot be encrypted in parallel.

ii) Errors in transmitting a ciphertext block (a byte) make it impossible to recover the corresponding plaintext block, and *also the next plaintext block*.

3. Cipher Feedback (CFB Mode)

Here we make DES act more like a stream cipher.

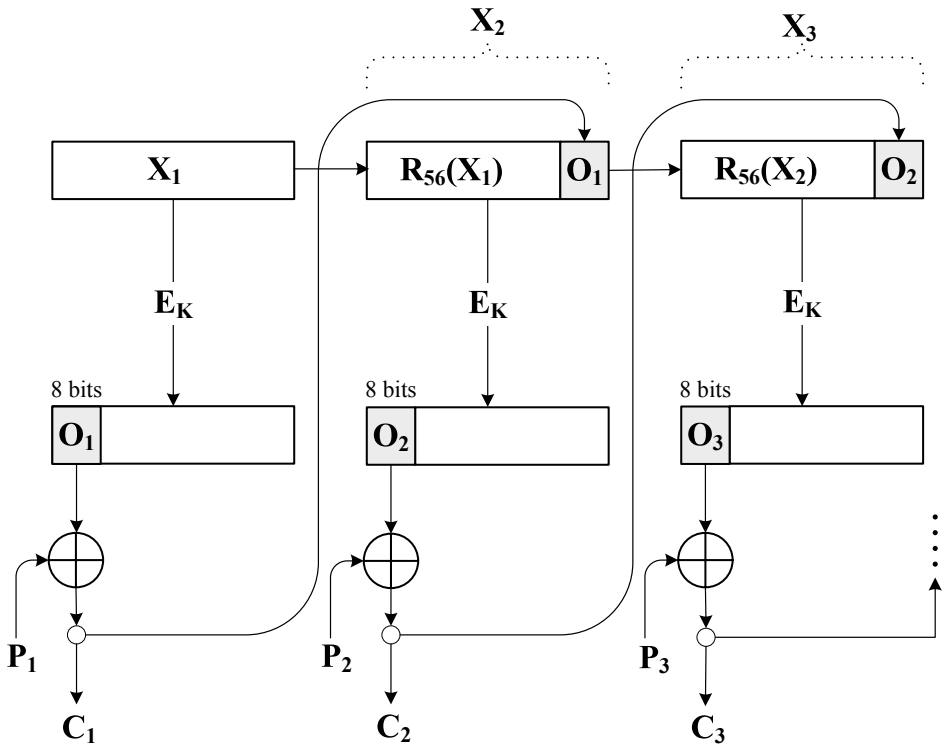
We divide the plaintext and ciphertext into 8-bit blocks $\mathbf{P_1}$, $\mathbf{P_2}$, ..., $\mathbf{P_L}$ and $\mathbf{C_1}$, $\mathbf{C_2}$, ..., $\mathbf{C_L}$ (rather than 64-bit blocks; lengths other than 8 could be used).

We use the notation

$L_8(X)$ = leftmost 8 bits of 64-bit value X.

$R_{56}(X)$ = rightmost 56 bits of 64-bit value X.

An initial 64-bit X_1 is chosen randomly.



Encryption:

X_1 = a random vector,

For j = 1, 2, 3, ...

$O_j = L_8(E_K(X_j))$, $C_j = P_j \oplus O_j$, $X_{j+1} = R_{56}(X_j) \,||\, C_j$.

X_1 is transmitted (unencrypted) along with the ciphertext.

Decryption:

$P_j = C_j \oplus L_8(E_K(X_j))$, $X_{j+1} = R_{56}(X_j) \,||\, C_j$.

Note the decryption function is not used.

Advantages:

i) Each byte (character) of plaintext can be encrypted (or decrypted) as soon as it is available.

iii) Equal plaintext blocks in different positions encrypt to different ciphertext blocks.

ii) Equal plaintext blocks in same position of different texts encrypt to different ciphertext blocks (if a new random initialization vector $\mathbf{X_1}$ is chosen for each plaintext transmitted.)

Disadvantages:

i) Blocks cannot be encrypted in parallel.

ii) Errors in transmitting a ciphertext block (a byte) make it impossible to recover the corresponding plaintext block, and the error propagates, but only for about 8 bytes.