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Safety in Information Technology

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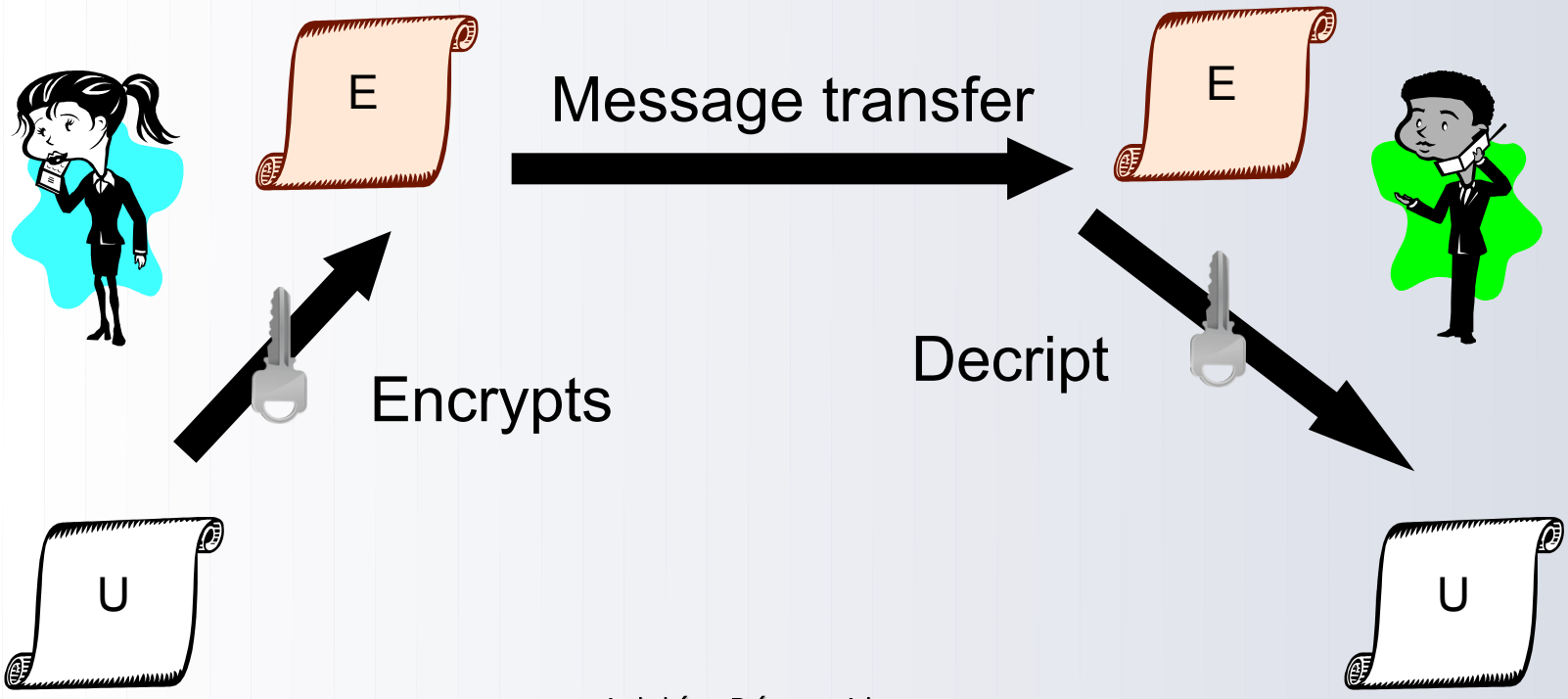
Subject:

Symmetric Cryptograpy – *DES (Data Encryption Standard)*

Editor: Adrián Pérez Alonso, 1.12.2011

Symmetric criptography

The same key is used to encryption of plaintext and decryption of ciphertext



DES (Data Encryption Standard)

1972 - NBS (National Bureau of Standards) needs cipher information

1974 – IBM submitted the Lucifer algorithm

NSA was injustified accused of plant a "back door". But NSA reduce the key size to 128 bits to 56 bits.

1976 – FIPS (Federal Information Processing Standar) choose the final algorithm

Problems with DES?

- The key size is **56bits. Brute force** attack easy
  - Try all posible keys.
  - 1977, Diffie and Hellman proposed a machine (US$20 million) which could find a DES key in 1 day.
  - 1998, the Electronic Frontier Foundation break DES key in less than 3 days
  - 1999, 100.000 PCs working in a network break a DES key in 3 hours, trying 245.000 million keys

Replacement algorithms

- Triple DES (2TDES/3TDES)
- DES-X (XOR & 2 keys)

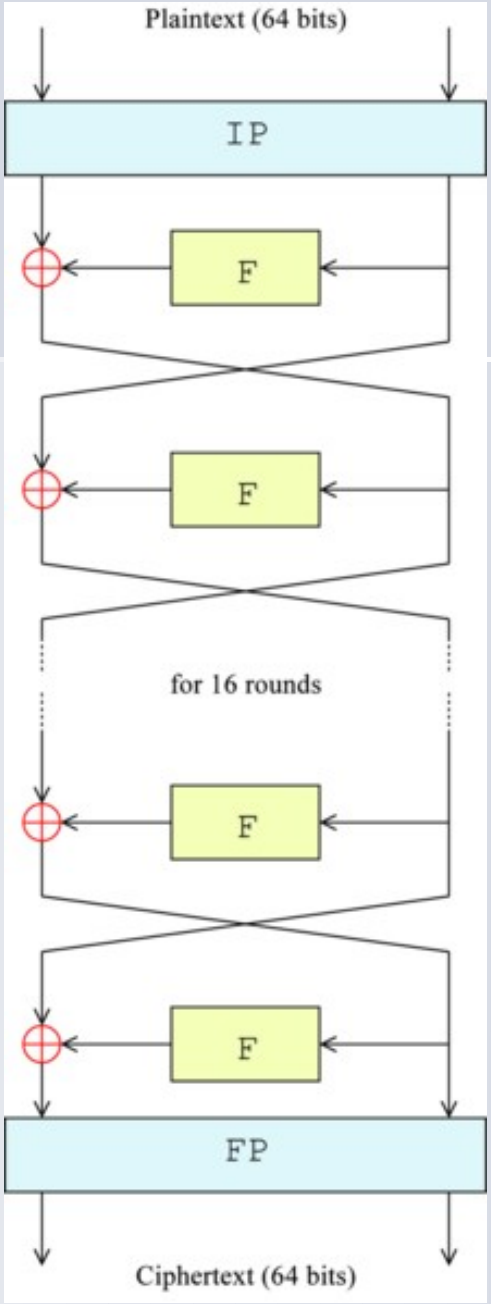
$$(DES - X = K_2 \circ DES_k(M \circ K_1))$$

- AES (Advanced Encryption Standard) (2002, 128-bit key)

DES encryption

- 56-bit key
- Encrypts data using 64-bit blocks and 64-bit key

  (7bitKey+1bitParity) x8 times = 64b
- The main algorithm is repeated **16 times**
- 2 more steps IP and FP

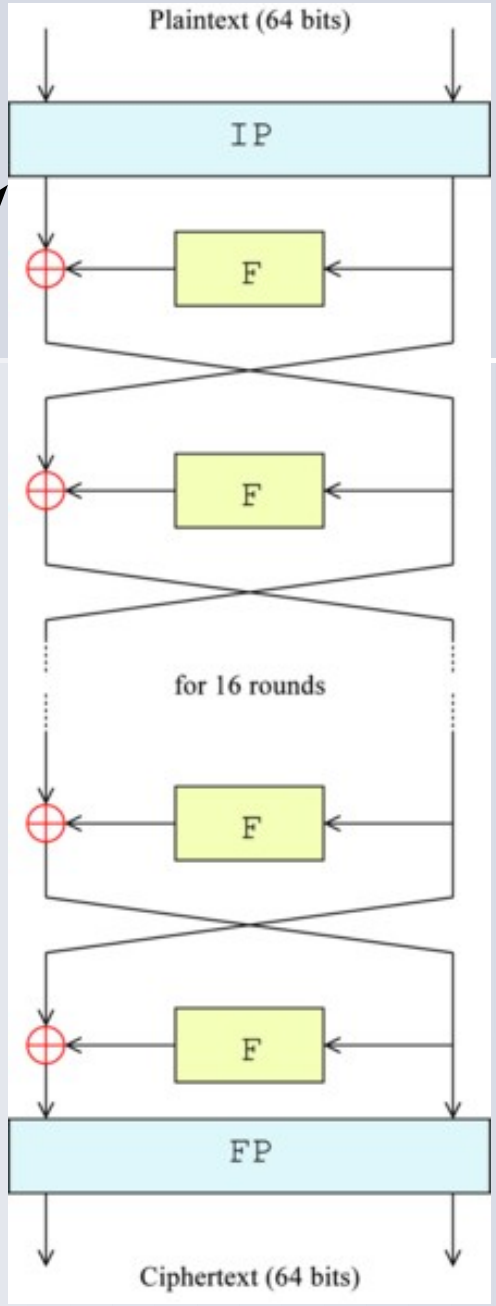


DES encryption

- Initial permutation (get **L0** and **R0** from Half Block)

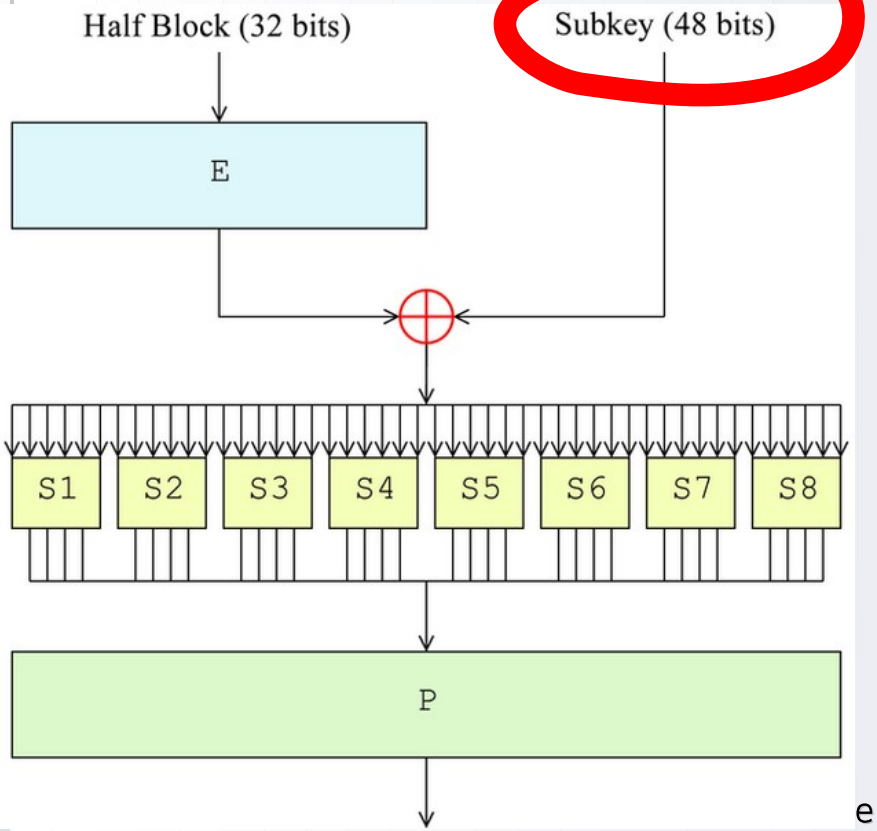
IP

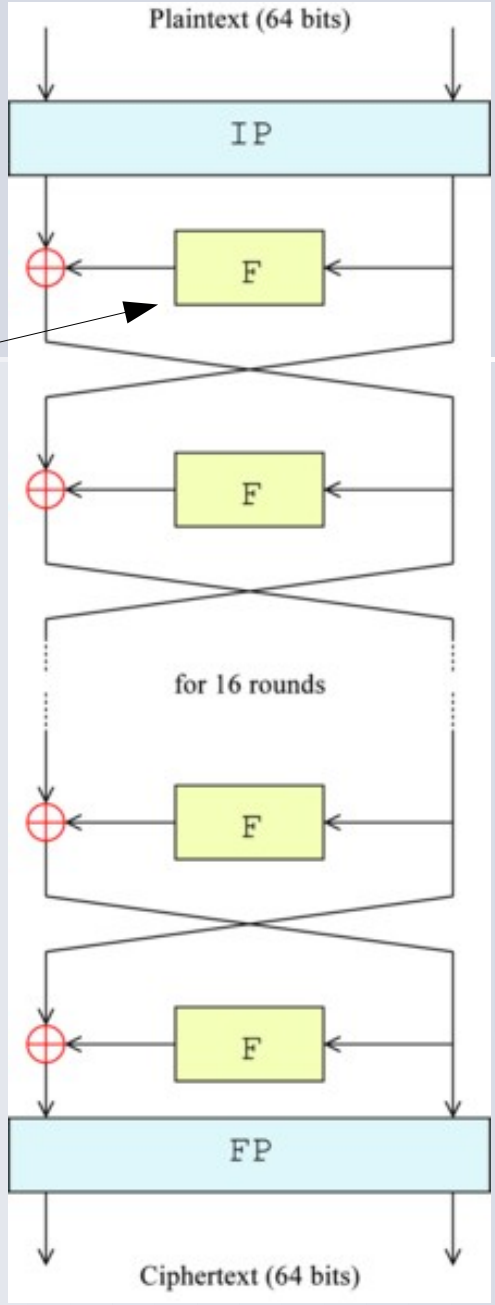
58	50	42	34	26	18	10	2
60	52	44	36	28	20	12	4
62	54	46	38	30	22	14	6
64	56	48	40	32	24	16	8
57	49	41	33	25	17	9	1
59	51	43	35	27	19	11	3
61	53	45	37	29	21	13	5
63	55	47	39	31	23	15	7



DES core Feistel function (f)

- Each iteration





Create 16 subkeys

Iteration Number	Number of Left Shifts
1	1
2	1
3	2
4	2
5	2
6	2
7	2
8	2
9	1
10	2
11	2
12	2
13	2
14	2
15	2
16	1

- AES permute the 64-bit **key** (K) to get another 56-bit Key (K+) using PC-1 table.
- Get the 16 **subkeys** (Kn) using the following (left) schedule of "left shifts"

PC-1

57	49	41	33	25	17	9
1	58	50	42	34	26	18
10	2	59	51	43	35	27
19	11	3	60	52	44	36
63	55	47	39	31	23	15
7	62	54	46	38	30	22
14	6	61	53	45	37	29
21	13	5	28	20	12	4

Create 16 subkeys

- Permute Kn using PC-2 to get the finals **48-bit** subkeys

PC-2

14	17	11	24	1	5
3	28	15	6	21	10
23	19	12	4	26	8
16	7	27	20	13	2
41	52	31	37	47	55
30	40	51	45	33	48
44	49	39	56	34	53
46	42	50	36	29	32

DES core Feistel function (f)

- Apply **f** for each of the 16 iterations:

Ln = Rn-1

Rn = Ln-1 + f(Rn-1,Kn)

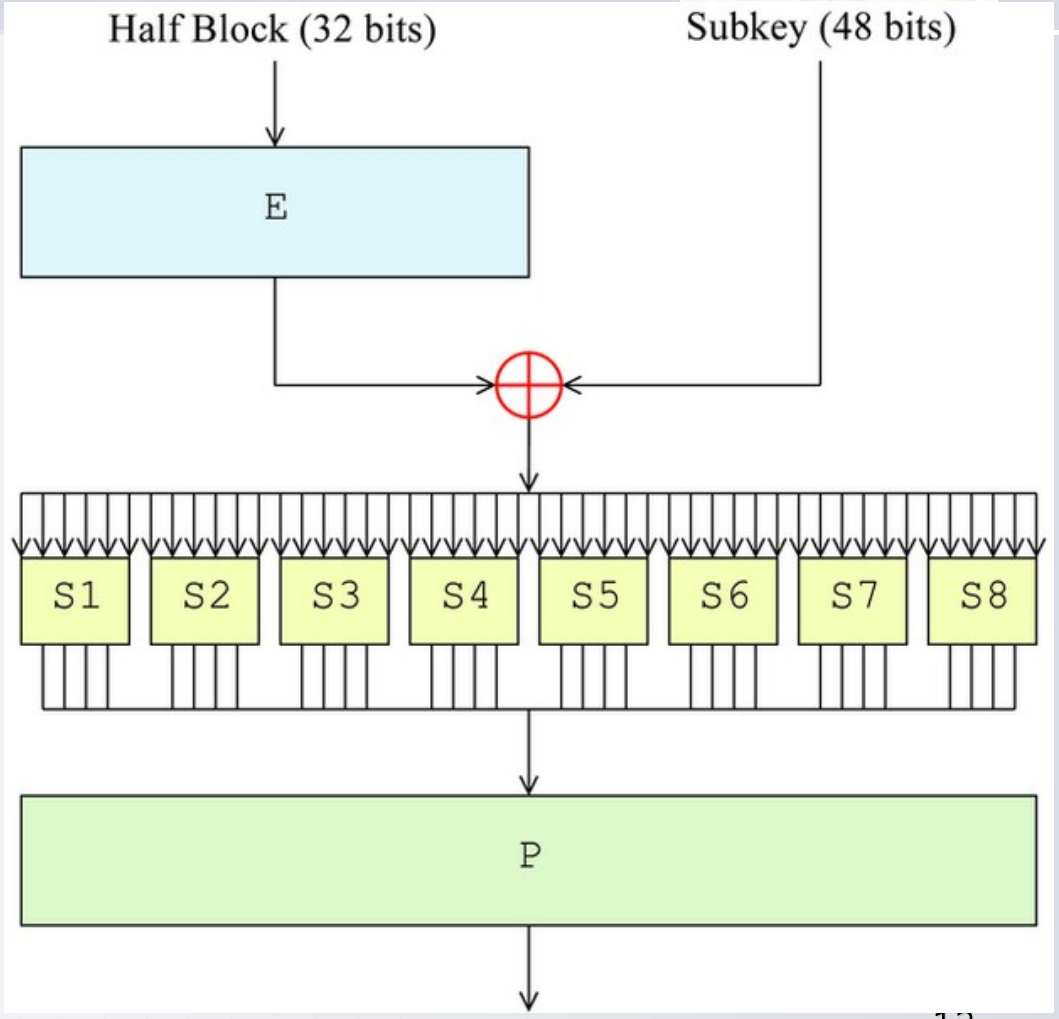
For example:

N=1

K1

L1 = R0

R1 = L0 + f(R0,K1)



DES core Feistel function (f)

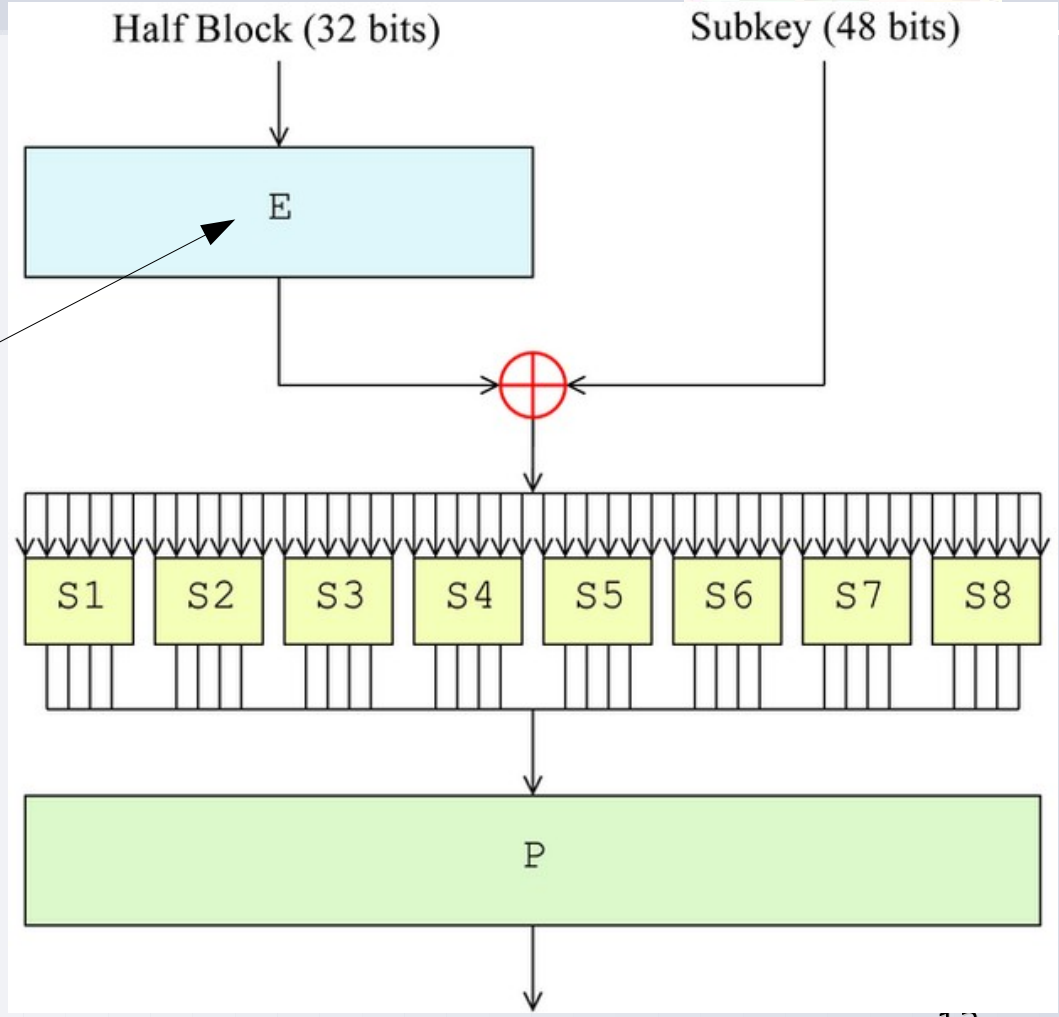
Ln = Rn-1

Rn = Ln-1 + f(Rn-1,Kn)

- First expand **Rn-1** from 32 bits to 48 bits (**E(Rn-1)**)

E BIT-SELECTION TABLE

32	1	2	3	4	5
4	5	6	7	8	9
8	9	10	11	12	13
12	13	14	15	16	17
16	17	18	19	20	21
20	21	22	23	24	25
24	25	26	27	28	29
28	29	30	31	32	1

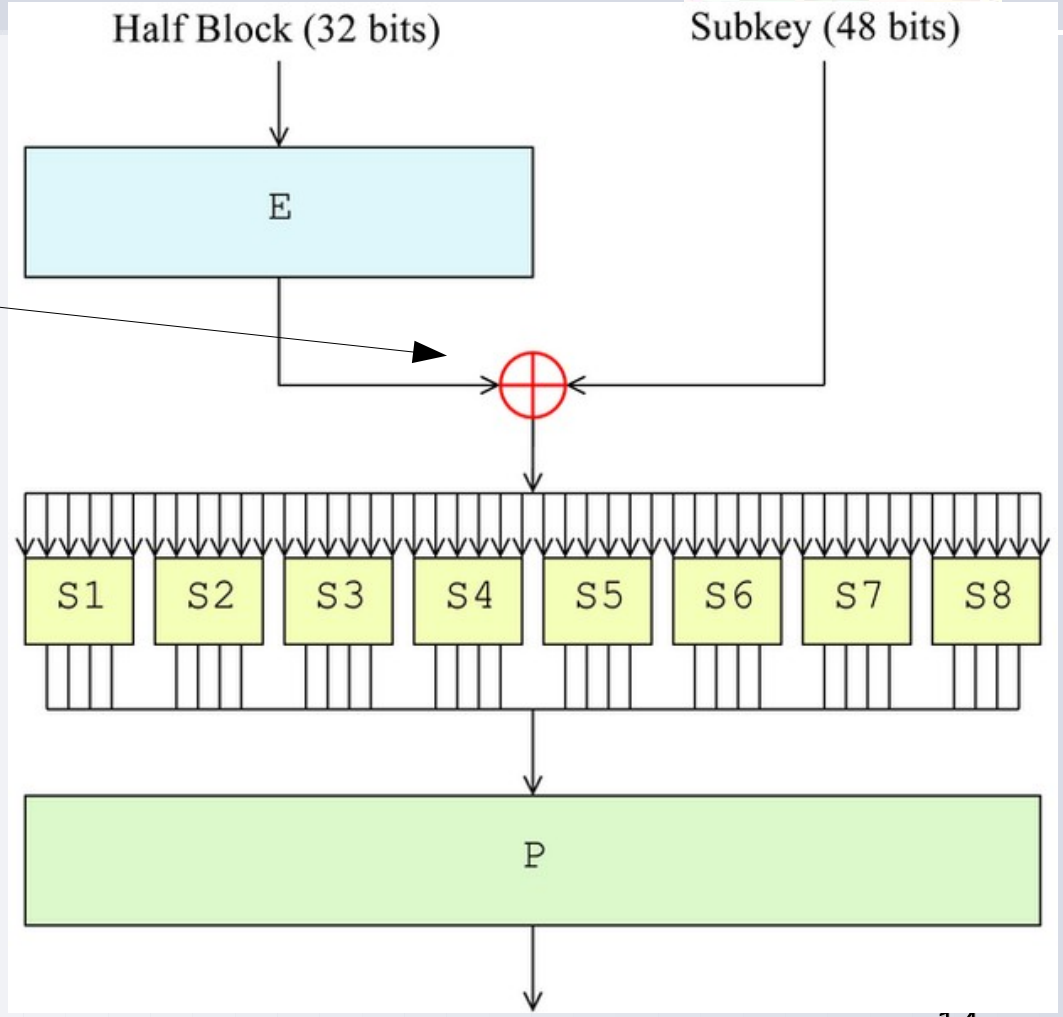


DES core Feistel function (f)

Ln = Rn-1

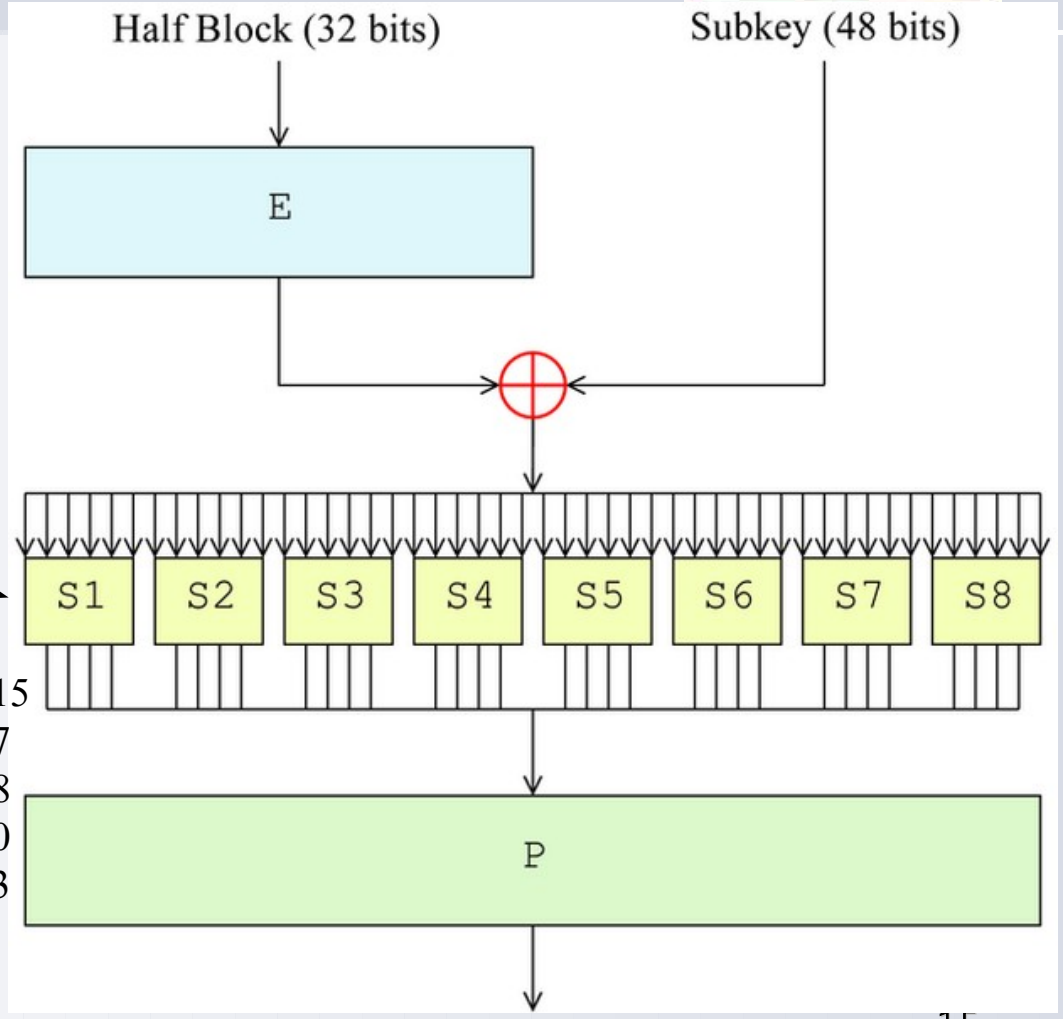
Rn = Ln-1 + f(Rn-1,Kn)

- **Rn-1** XOR **Kn**



DES core Feistel function (f)

- Bi(6bit) is address in S-Box table
- Si(Bi) (4bit) is the number in S-Box table in Bi address



S1

Column Number

Row No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	14	4	13	1	2	15	11	8	3	10	6	12	5	9	0	7
1	0	15	7	4	14	2	13	1	10	6	12	11	9	5	3	8
2	4	1	14	8	13	6	2	11	15	12	9	7	3	10	5	0
3	15	12	8	2	4	9	1	7	5	11	3	14	10	0	6	13

All S-box tables

S1

14	4	13	1	2	15	11	8	3	10	6	12	5	9	0	7
0	15	7	4	14	2	13	1	10	6	12	11	9	5	3	8
4	1	14	8	13	6	2	11	15	12	9	7	3	10	5	0
15	12	8	2	4	9	1	7	5	11	3	14	10	0	6	13

S2

15	1	8	14	6	11	3	4	9	7	2	13	12	0	5	10
3	13	4	7	15	2	8	14	12	0	1	10	6	9	11	5
0	14	7	11	10	4	13	1	5	8	12	6	9	3	2	15
13	8	10	1	3	15	4	2	11	6	7	12	0	5	14	9

S3

10	0	9	14	6	3	15	5	1	13	12	7	11	4	2	8
13	7	0	9	3	4	6	10	2	8	5	14	12	11	15	1
13	6	4	9	8	15	3	0	11	1	2	12	5	10	14	7
1	10	13	0	6	9	8	7	4	15	14	3	11	5	2	12

S4

7	13	14	3	0	6	9	10	1	2	8	5	11	12	4	15
13	8	11	5	6	15	0	3	4	7	2	12	1	10	14	9
10	6	9	0	12	11	7	13	15	1	3	14	5	2	8	4
3	15	0	6	10	1	13	8	9	4	5	11	12	7	2	14

S5

2	12	4	1	7	10	11	6	8	5	3	15	13	0	14	9
14	11	2	12	4	7	13	1	5	0	15	10	3	9	8	6
4	2	1	11	10	13	7	8	15	9	12	5	6	3	0	14
11	8	12	7	1	14	2	13	6	15	0	9	10	4	5	3

S6

12	1	10	15	9	2	6	8	0	13	3	4	14	7	5	11
10	15	4	2	7	12	9	5	6	1	13	14	0	11	3	8
9	14	15	5	2	8	12	3	7	0	4	10	1	13	11	6
4	3	2	12	9	5	15	10	11	14	1	7	6	0	8	13

S7

4	11	2	14	15	0	8	13	3	12	9	7	5	10	6	1
13	0	11	7	4	9	1	10	14	3	5	12	2	15	8	6
1	4	11	13	12	3	7	14	10	15	6	8	0	5	9	2
6	11	13	8	1	4	10	7	9	5	0	15	14	2	3	12

S8

13	2	8	4	6	15	11	1	10	9	3	14	5	0	12	7
1	15	13	8	10	3	7	4	12	5	6	11	0	14	9	2
7	11	4	1	9	12	14	2	0	6	10	13	15	3	5	8
2	1	14	7	4	10	8	13	15	12	9	0	3	5	6	11

DES core Feistel function (f)

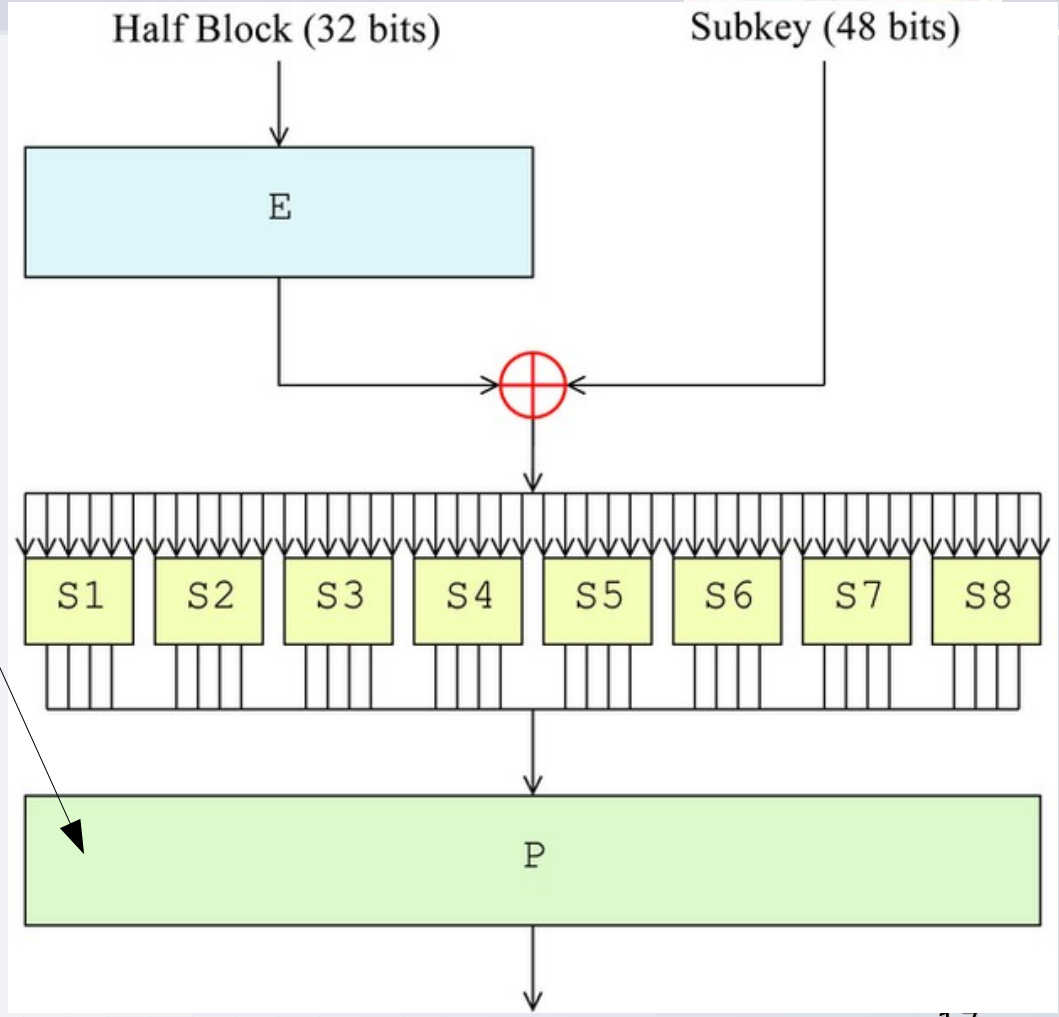
Ln = Rn-1

Rn = Ln-1 + f(Rn-1,Kn)

- Permutation P of the S-box output

P

16	7	20	21
29	12	28	17
1	15	23	26
5	18	31	10
2	8	24	14
32	27	3	9
19	13	30	6
22	11	4	25

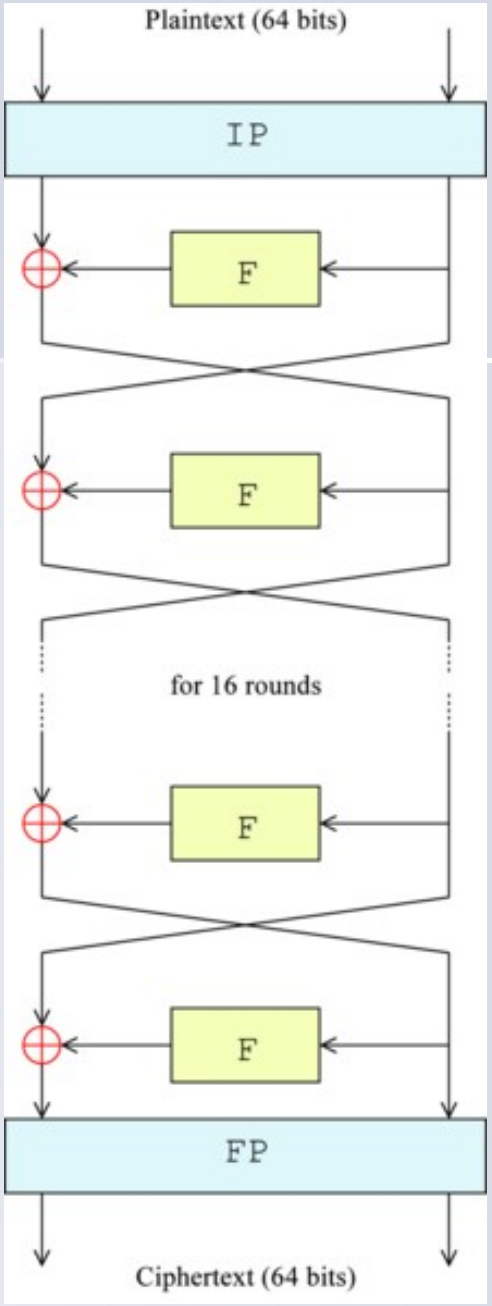


DES encryption

- Apply a final permutation (FP)

FP

40	8	48	16	56	24	64	32
39	7	47	15	55	23	63	31
38	6	46	14	54	22	62	30
37	5	45	13	53	21	61	29
36	4	44	12	52	20	60	28
35	3	43	11	51	19	59	27
34	2	42	10	50	18	58	26
33	1	41	9	49	17	57	25



DES modes of operation

- Electronic Code Book (ECB)

Each 64-bit block is encrypted individually

DES modes of operation

- Chain Block Coding (CBC)
- Cipher Feedback (CFB)

Encrypted ciphertext is XORed with the next plaintext block to be encrypted

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Thanks for your Attention!
Any Questions?

References

- http://www.tropsoft.com/strongenc/des.htm
- http://orlingrabbe.com/des.htm
- http://en.wikipedia.org/wiki/Data_Encryption_Standard