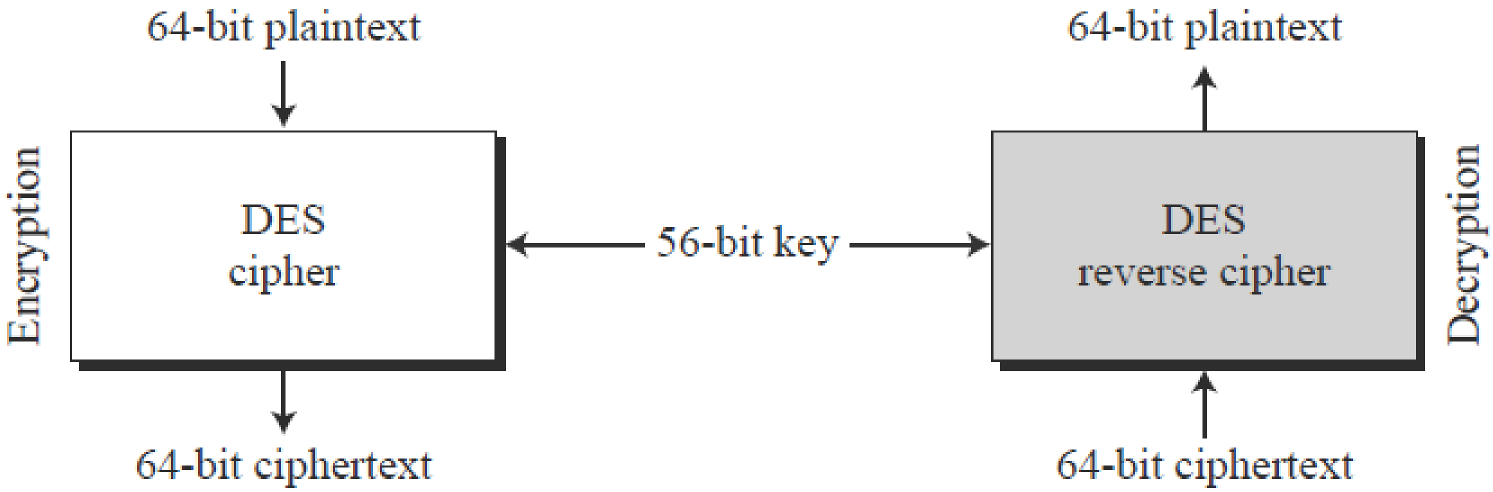
Data Encryption Standard (DES)

The **Data Encryption Standard (DES)** is a symmetric-key block cipher published by the **National Institute of Standards and Technology (NIST).**

In 1973, NIST published a request for proposals for a national symmetric-key cryptosystem. A proposal from IBM, a modification of a project called Lucifer, was accepted as DES. DES was published in the *Federal Register* in March 1975 as a draft of the **Federal Information Processing Standard (FIPS).**

DES is a block cipher, as shown



Encryption and decryption with DES

At the encryption site, DES takes a 64-bit plaintext and creates a 64-bit ciphertext; at the decryption site, DES takes a 64-bit ciphertext and creates a 64-bit block of plaintext. The same 56-bit cipher key is used for both encryption and decryption.

DES STRUCTURE

The encryption process is made of

two permutations (P-boxes),

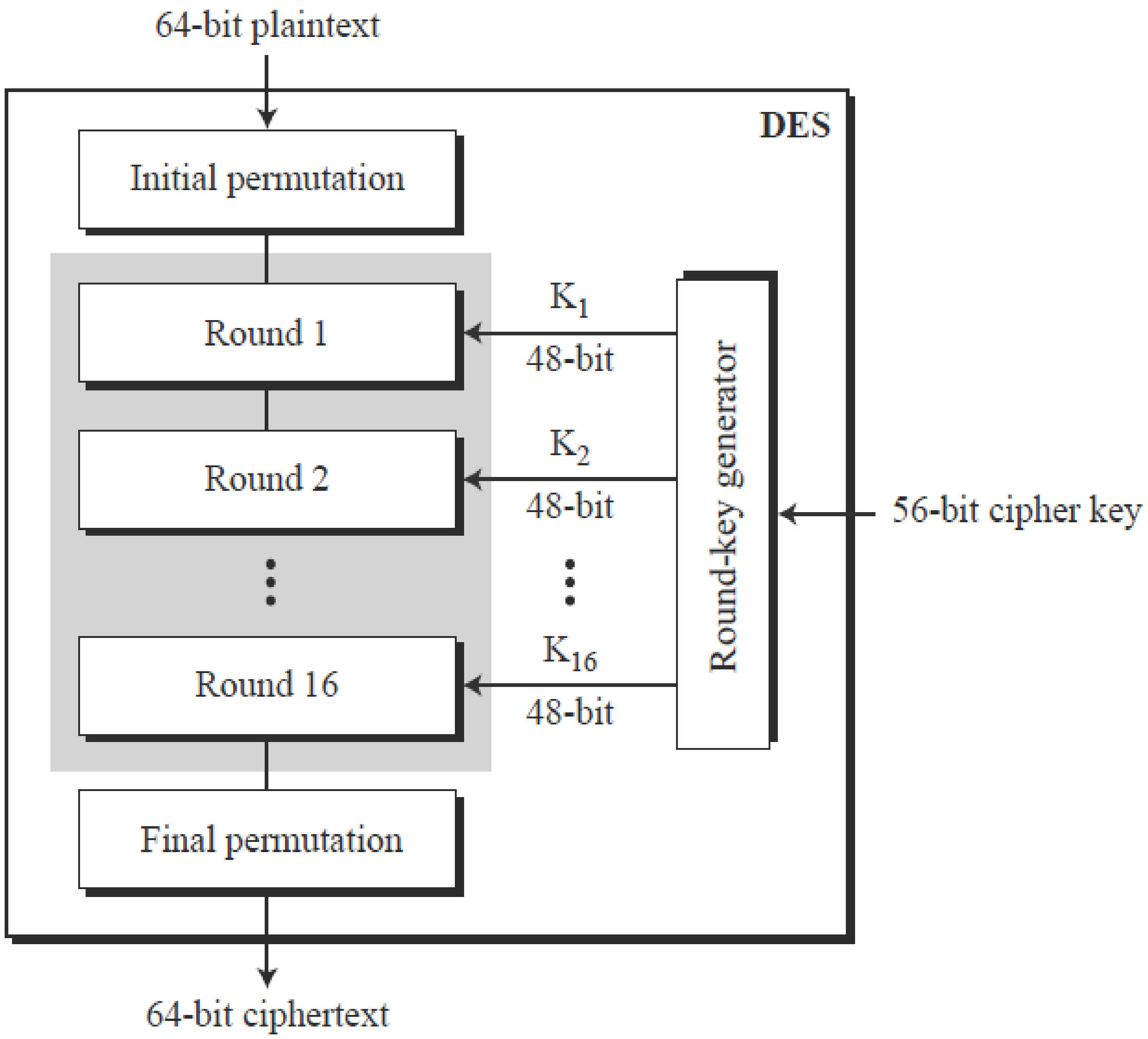
which we call initial and final permutations,

and sixteen Feistel rounds.

Each round uses a different 48-bit round key

generated from the cipher key

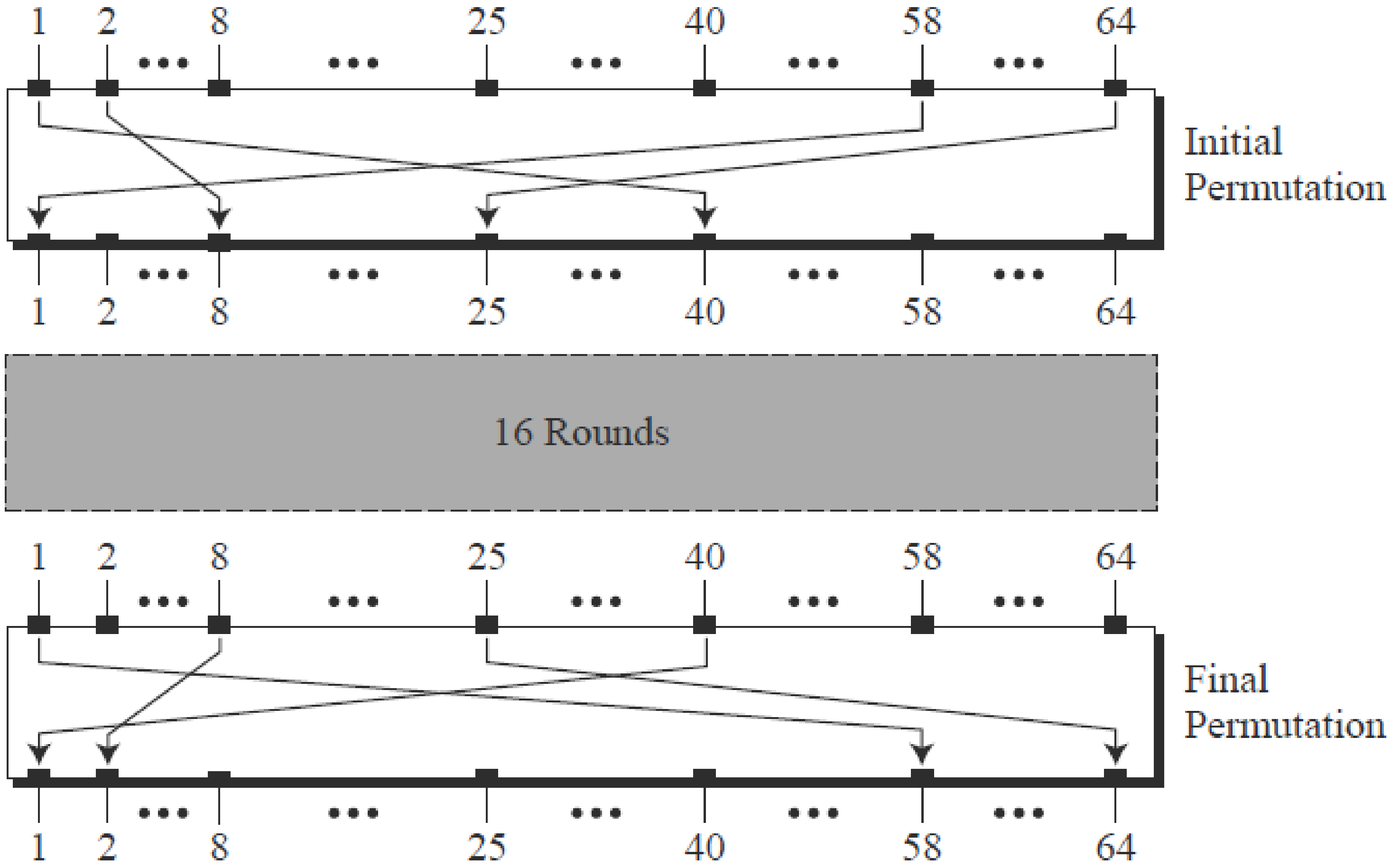
according to a predefined algorithm



General structure of DES

Initial and Final Permutations

Figure shows the initial and final permutations (P-boxes). Each of these permutations takes a 64-bit input and permutes them according to a predefined rule. These permutations are keyless straight permutations that are the inverse of each other.



Initial and final permutation steps in DES

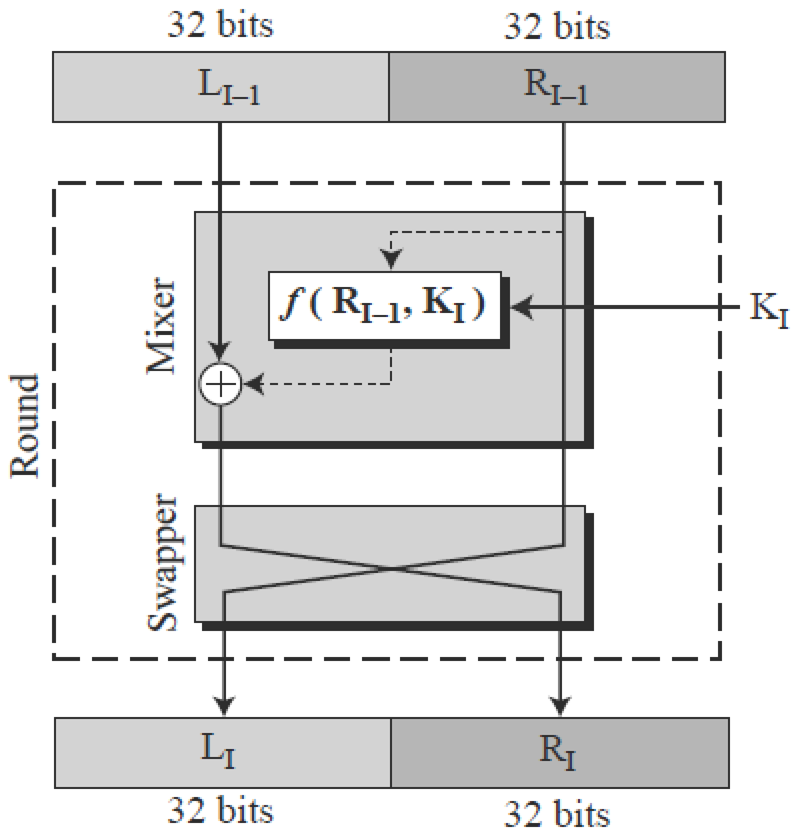
Initial and final permutation tables

Initial Permutation	*Final Permutation*
58 50 42 34 26 18 10 02	40 08 48 16 56 24 64 32
60 52 44 36 28 20 12 04	39 07 47 15 55 23 63 31
62 54 46 38 30 22 14 06	38 06 46 14 54 22 62 30
64 56 48 40 32 24 16 08	37 05 45 13 53 21 61 29
57 49 41 33 25 17 09 01	36 04 44 12 52 20 60 28
59 51 43 35 27 19 11 03	35 03 43 11 51 19 59 27
61 53 45 37 29 21 13 05	34 02 42 10 50 18 58 26
63 55 47 39 31 23 15 07	33 01 41 09 49 17 57 25

The permutation rules for these
P-boxes are shown in Table
Each side of the table can be thought
of as a 64-element array.
as with any permutation table
the value of each element defines
the input port number, and the order (index)
of the element defines the output port number.

Rounds

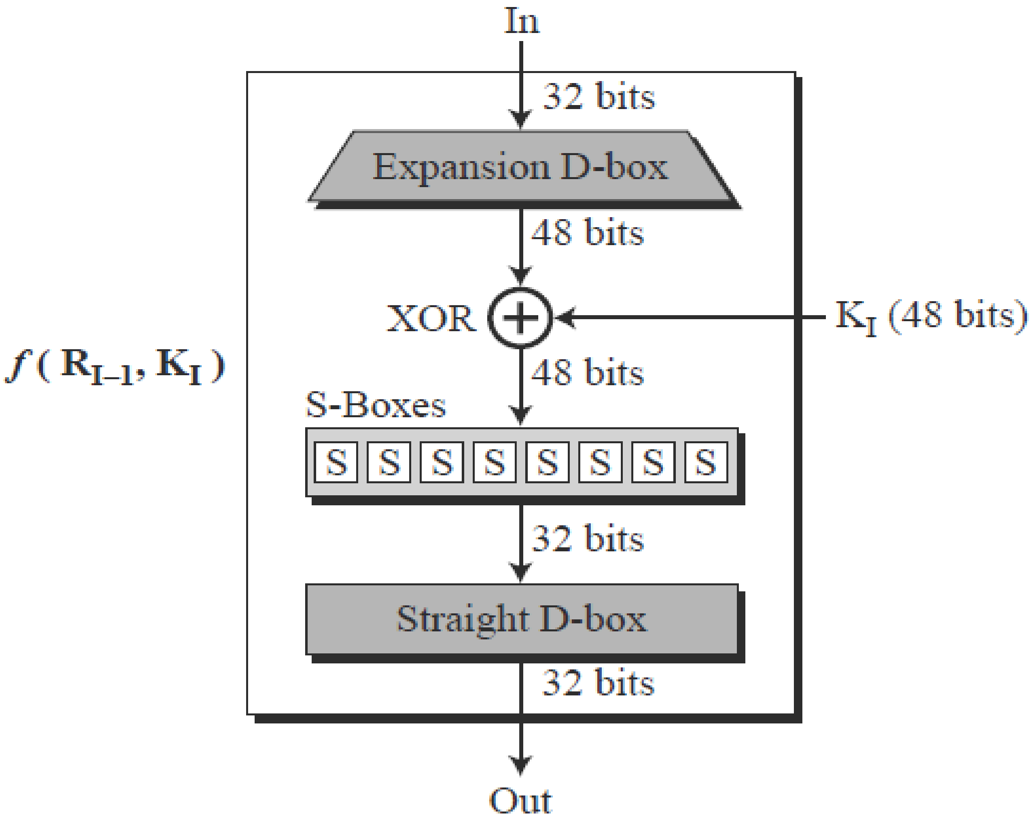
DES uses 16 rounds. Each round of DES is a Feistel cipher,



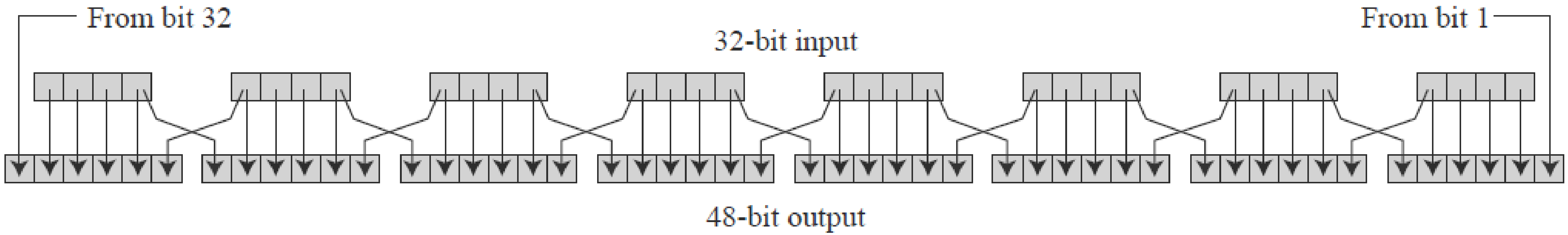
A round in DES (encryption site)

DES Function

The heart of DES is the DES function. The DES function applies a 48-bit key to the rightmost 32 bits (R_{I-1}) to produce a 32-bit output. This function is made up of four sections: an expansion D-box, a whitener (that adds key), a group of S-boxes, and a straight D-box



DES function



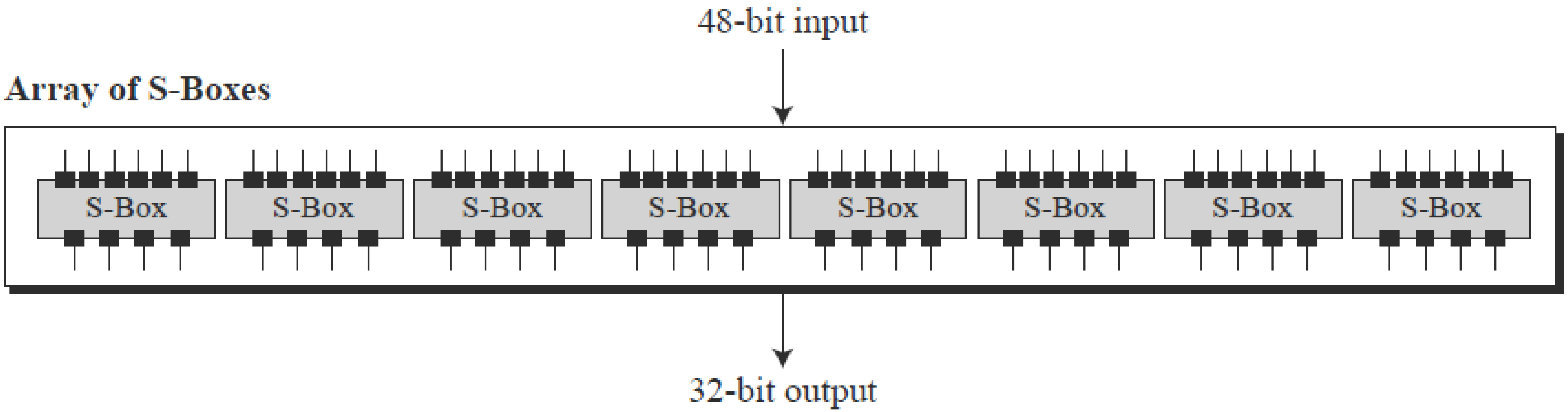
Expansion permutation

Expansion D-box table

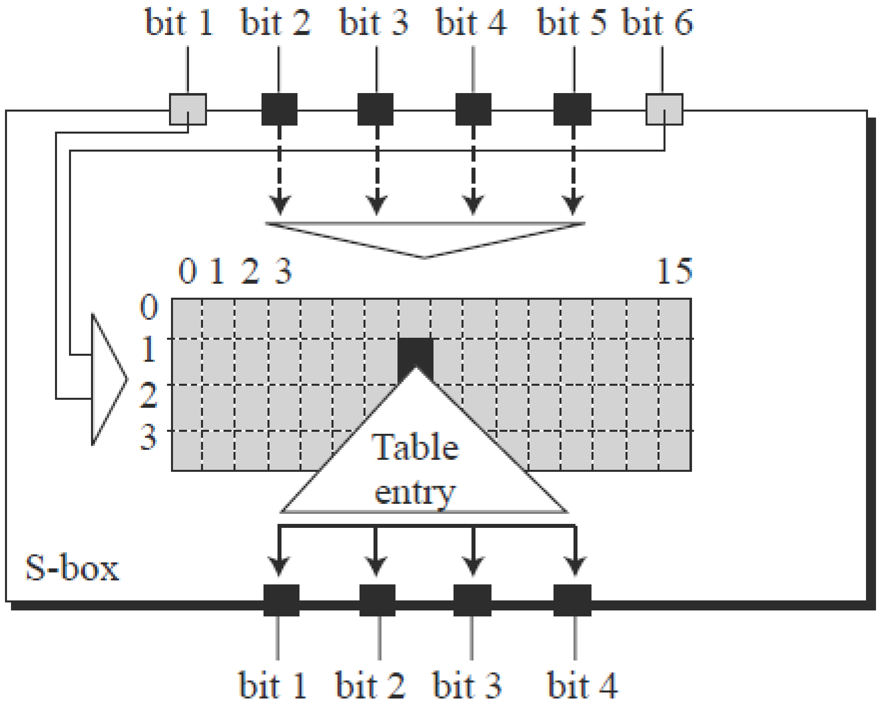
32	01	02	03	04	05
04	05	06	07	08	09
08	09	10	11	12	13
12	13	14	15	16	17
16	17	18	19	20	21
20	21	22	23	24	25
24	25	26	27	28	29
28	29	31	31	32	01

Whitener (XOR) After the expansion permutation, DES uses the XOR operation on the expanded right section and the round key. Note that both the right section and the key are 48-bits in length. Also note that the round key is used only in this operation.

S-Boxes The S-boxes do the real mixing (confusion). DES uses 8 S-boxes, each with a 6-bit input and a 4-bit output.



S-box rule


bit 1
bit 2
bit 3
bit 4
bit 5
bit 6
0 1 2 3
15
0
1
2
3
Table entry
S-box
bit 1
bit 2
bit 3
bit 4