Cryptography & Network Security Lab

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Assignment No. 6

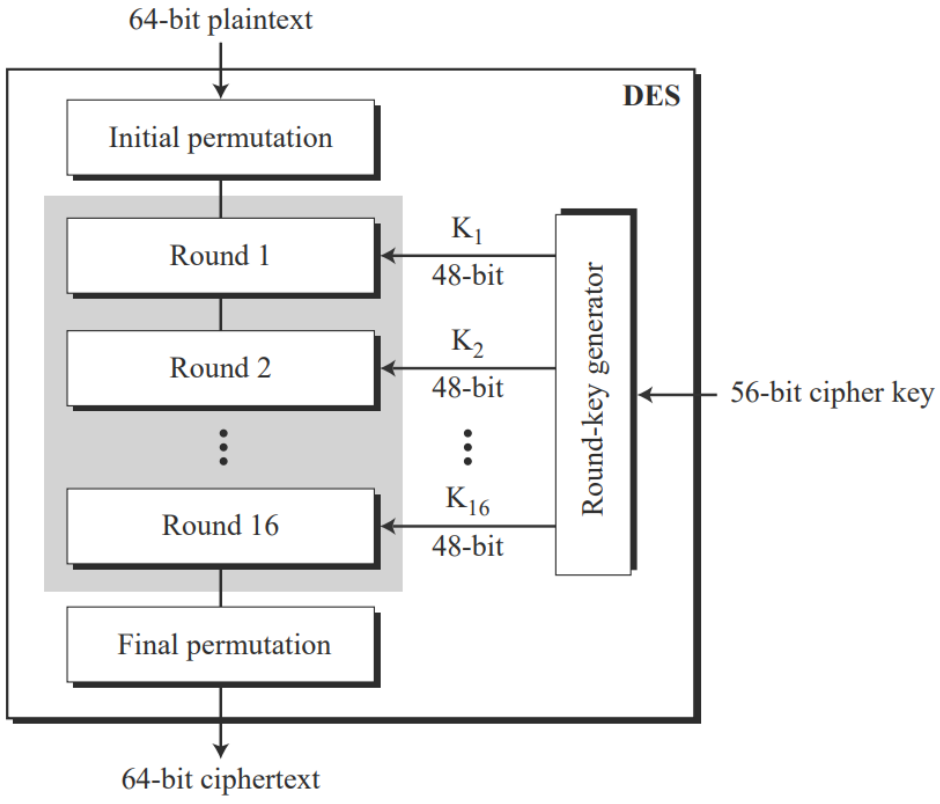
Aim: Implement the DES algorithm

Theory:

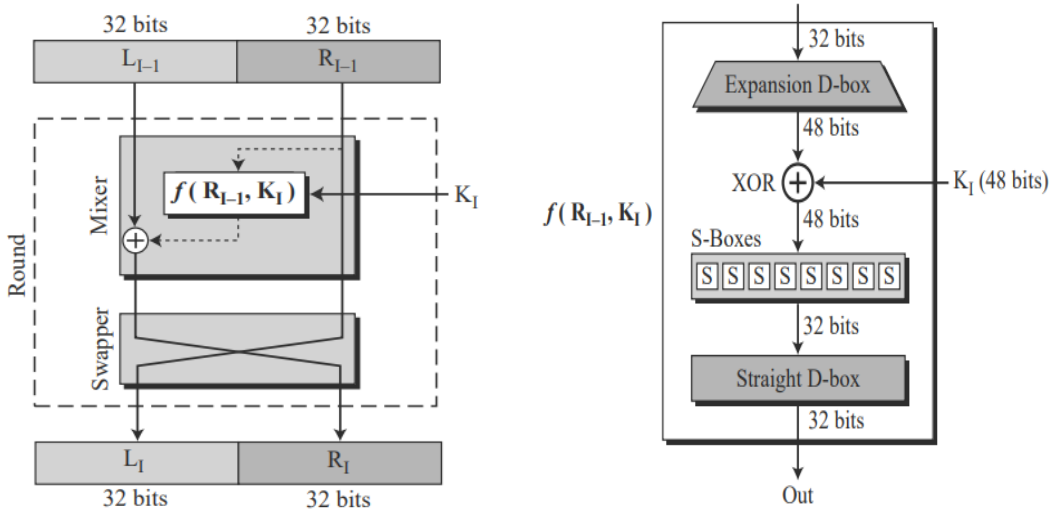
DES is a block cipher and encrypts data in blocks of size of 64 bits each, which means 64 bits of plain text go as the input to DES, which produces 64 bits of ciphertext. The same algorithm and key are used for encryption and decryption, with minor differences. The key length is 56 bits.

DES consists of 16 steps, each of which is called a round. Each round performs the steps of substitution and transposition. Let us now discuss the broad-level steps in DES.

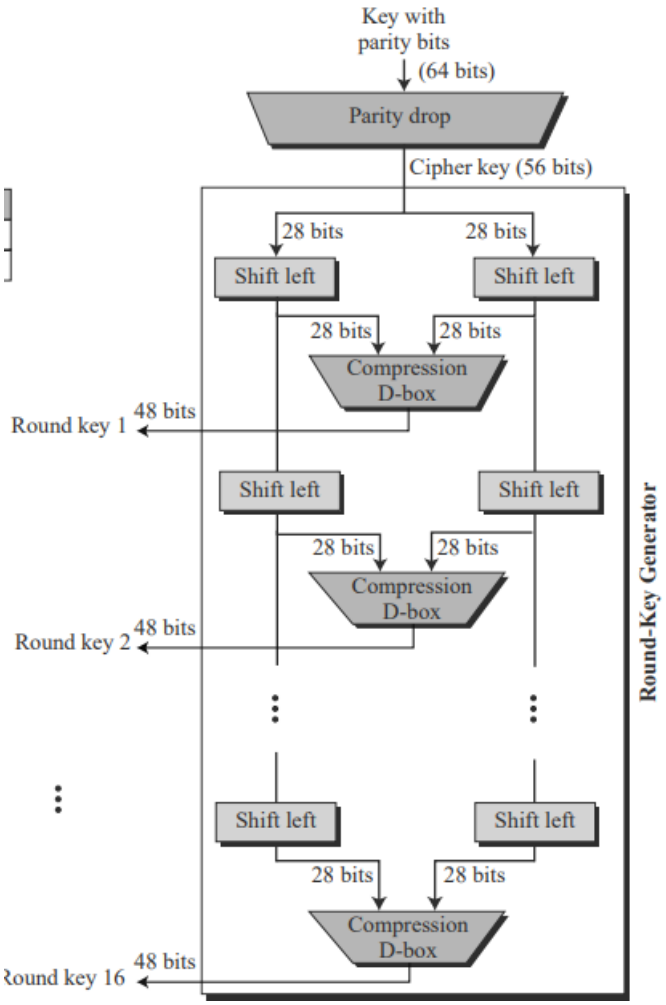
Broad Level Steps In DES



Steps in Each Round In DES



Key Generation Steps:



Code:

```
#include <bits/stdc++.h>
using namespace std;
string round_keys[16];
string pt;

string convertDecimalToBinary(int decimal)
{
    string binary;
    while(decimal != 0) {
        binary = (decimal % 2 == 0 ? "0" : "1") + binary;
        decimal = decimal/2;
    }
    while(binary.length() < 8){
        binary = "0" + binary;
    }
    return binary;
}

int convertBinaryToDecimal(string binary)
{
    int decimal = 0;
    int counter = 0;
    int size = binary.length();
    for(int i = size-1; i >= 0; i--)
    {
        if(binary[i] == '1'){
            decimal += pow(2, counter);
        }
    counter++;
    }
    return decimal;
}
// Function to do a circular left shift by 1
string shift_left_once(string key_chunk){
    string shifted="";
        for(int i = 1; i < 28; i++){
            shifted += key_chunk[i];
        }
        shifted += key_chunk[0];
    return shifted;
}
// Function to do a circular left shift by 2
string shift_left_twice(string key_chunk){
    string shifted="";
```

```
    for(int i = 0; i < 2; i++){
        for(int j = 1; j < 28; j++){
            shifted += key_chunk[j];
        }
        shifted += key_chunk[0];
        key_chunk= shifted;
        shifted ="";
    }
    return key_chunk;
}
// Function to compute xor between two strings
string Xor(string a, string b){
    string result = "";
    int size = b.size();
    for(int i = 0; i < size; i++){
        if(a[i] != b[i]){
            result += "1";
        }
        else{
            result += "0";
        }
    }
    return result;
}
// Function to generate the 16 keys.
void generate_keys(string key){
    // The PC1 table
    int pc1[56] = {
    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
    };
    // The PC2 table
    int pc2[48] = {
    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
    };
```

```
    // 1. Compressing the key using the PC1 table
    string perm_key ="";
    for(int i = 0; i < 56; i++){
        perm_key+= key[pc1[i]-1];
    }
    // 2. Dividing the key into two equal halves
    string left= perm_key.substr(0, 28);
    string right= perm_key.substr(28, 28);
    for(int i=0; i<16; i++){
        // 3.1. For rounds 1, 2, 9, 16 the key_chunks
        // are shifted by one.
        if(i == 0 || i == 1 || i==8 || i==15 ){
            left= shift_left_once(left);
            right= shift_left_once(right);
        }
        // 3.2. For other rounds, the key_chunks
        // are shifted by two
        else{
            left= shift_left_twice(left);
            right= shift_left_twice(right);
        }
        // Combining the two chunks
        string combined_key = left + right;
        string round_key = "";
        // Finally, using the PC2 table to transpose the key bits
        for(int i = 0; i < 48; i++){
            round_key += combined_key[pc2[i]-1];
        }
        round_keys[i] = round_key;
    }

}

string DES(){
    // The initial permutation table
    int initial_permutation[64] = {
    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
    };
    // The expansion table
    int expansion_table[48] = {
    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
    };
    // The substitution boxes. The should contain values
    // from 0 to 15 in any order.
    int substition_boxes[8][4][16]=
    {{
        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
    },
    {
        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
    },
    {
        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
    },
    {
        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
    },
    {
        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
    },
    {
        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
    },
    {
        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
    },
    {
        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
    }};
    // The permutation table
    int permutation_tab[32] = {
    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
    };
    // The inverse permutation table
    int inverse_permutation[64]= {
    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
    };
    //1. Applying the initial permutation
    string perm = "";
    for(int i = 0; i < 64; i++){
        perm += pt[initial_permutation[i]-1];
    }
    // 2. Dividing the result into two equal halves
    string left = perm.substr(0, 32);
    string right = perm.substr(32, 32);
    // The plain text is encrypted 16 times
    for(int i=0; i<16; i++) {
        string right_expanded = "";
        // 3.1. The right half of the plain text is expanded
        for(int i = 0; i < 48; i++) {
            right_expanded += right[expansion_table[i]-1];
    };  // 3.3. The result is xored with a key
        string xored = Xor(round_keys[i], right_expanded);
        string res = "";
        // 3.4. The result is divided into 8 equal parts and passed
        // through 8 substitution boxes. After passing through a
        // substituion box, each box is reduces from 6 to 4 bits.
        for(int i=0;i<8; i++){
```

```
            // Finding row and column indices to lookup the
            // substituition box
            string row1= xored.substr(i*6,1) + xored.substr(i*6 + 5,1);
            int row = convertBinaryToDecimal(row1);
            string col1 = xored.substr(i*6 + 1,1) + xored.substr(i*6 + 2,1) +
xored.substr(i*6 + 3,1) + xored.substr(i*6 + 4,1);;
            int col = convertBinaryToDecimal(col1);
            int val = substition_boxes[i][row][col];
            res += convertDecimalToBinary(val);
        }
        // 3.5. Another permutation is applied
        string perm2 ="";
        for(int i = 0; i < 32; i++){
            perm2 += res[permutation_tab[i]-1];
        }
        // 3.6. The result is xored with the left half
        xored = Xor(perm2, left);
        // 3.7. The left and the right parts of the plain text are swapped
        left = xored;
        if(i < 15){
            string temp = right;
            right = xored;
            left = temp;
        }
    }
    // 4. The halves of the plain text are applied
    string combined_text = left + right;
    string ciphertext ="";
    // The inverse of the initial permuttaion is applied
    for(int i = 0; i < 64; i++){
        ciphertext+= combined_text[inverse_permutation[i]-1];
    }
    //And we finally get the cipher text
    return ciphertext;
}
int main(){
    cout<<"Enter Plain Text: "<<endl;
    string plainText;

    getline(cin,plainText);

    string key;
    cout<<"Enter key (Only first 64 bits are taken)"<<endl;
    getline(cin,key);

    string keyInBinary = "";

    for(int i = 0;i<key.length();i++){
```

```
        keyInBinary+=convertDecimalToBinary(int(key[i]));
    }

    int keyPadd = 64 - keyInBinary.length();

    while(keyPadd>0){
        keyInBinary+="0";
        keyPadd--;
    }

    keyInBinary = keyInBinary.substr(0,64);

    cout<<"Key In Binary Format(64 bits)"<<keyInBinary<<endl;

    string plainTextInBinary = "";

    for(int i  =0;i<plainText.length();i++){
        plainTextInBinary+=convertDecimalToBinary(int(plainText[i]));
    }

    int padd = 64 - plainTextInBinary.length()%64;

    while(padd--){
        plainTextInBinary+='0';
    }
    generate_keys(keyInBinary);
    cout<<"Plain Text length: "<<plainTextInBinary.length()<<endl;
    string decryptedPlainText = "";
    for(int i = 0;i<plainTextInBinary.length();i+=64){
        pt= plainTextInBinary.substr(i,64);
        string apt = pt;

        cout<<"Plain text: "<<pt<<endl;
        // Applying the algo
        string ct= DES();
        cout<<"Ciphertext: "<<ct<<endl;
        int j = 15;
        int k = 0;
        while(j > k)
        {
            string temp = round_keys[j];
            round_keys[j] = round_keys[k];
            round_keys[k] = temp;
            j--;
            k++;
        }
        pt = ct;
        string decrypted = DES();
```

```
        cout<<"Decrypted text:"<<decrypted<<endl;
        // Comapring the initial plain text with the decrypted text

        for(int j = 0;j<decrypted.length();j+=8){
            decryptedPlainText+=char(convertBinaryToDecimal(decrypted.substr(j
,8)));
        }

        if (decrypted == apt){
            cout<<"Plain text encrypted and decrypted successfully."<<endl;
        }
        j = 15;
        k = 0;
        while(j > k)
        {
            string temp = round_keys[j];
            round_keys[j] = round_keys[k];
            round_keys[k] = temp;
            j--;
            k++;
        }
        cout<<endl;
    }

    cout<<"After convertion of bits to characters:
"<<decryptedPlainText<<endl;
    return 0;
}
```

Screenshot:

```
PS C:\Users\Lenovo\Desktop\7th Sem Assignment\CNS> ^C
PS C:\Users\Lenovo\Desktop\7th Sem Assignment\CNS> cd "c:\Users\Lenovo\Desktop\7th Sem Assignment\CNS\" ;
Enter Plain Text:
The killer has left the jail
Enter key (Only first 64 bits are taken)
cid on the way
Key In Binary Format(64 bits)0110001101101001011001000010000001101111011011100010000001110100
Plain Text length: 256
Plain text: 0101010001101000011001010010000001101011011010010110110001101100
Ciphertext: 1010100010111010010011010010101010001001010011001001001101011100
Decrypted text:0101010001101000011001010010000001101011011010010110110001101100
Plain text encrypted and decrypted successfully.

Plain text: 0110010101110010001000000110100001100001011100110010000001101100
Ciphertext: 1001101010100001000100000110010110011011100100110010111001011100
Decrypted text:0110010101110010001000000110100001100001011100110010000001101100
Plain text encrypted and decrypted successfully.

Plain text: 0110010101100110011101000010000001110100011010000110010100100000
Ciphertext: 1001101010111001101110000010111000110000101110111011101110010000
Decrypted text:0110010101100110011101000010000001110100011010000110010100100000
Plain text encrypted and decrypted successfully.

Plain text: 0110101001100001011010010110110000000000000000000000000000000000
Ciphertext: 1001010111010001010010110000100101100111000100011011000100100000
Decrypted text:0110101001100001011010010110110000000000000000000000000000000000
Plain text encrypted and decrypted successfully.

After convertion of bits to characters: The killer has left the jail
PS C:\Users\Lenovo\Desktop\7th Sem Assignment\CNS>
```

Conclusion:

The Des is implemented successfully, the decrypted text is same as the input text.