Cryptography And Network Security Lab

Assignment submission

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Batch: B5

Assignment: 6

Title of assignment: Implementation of DES – Data Encryption Standard

Title:

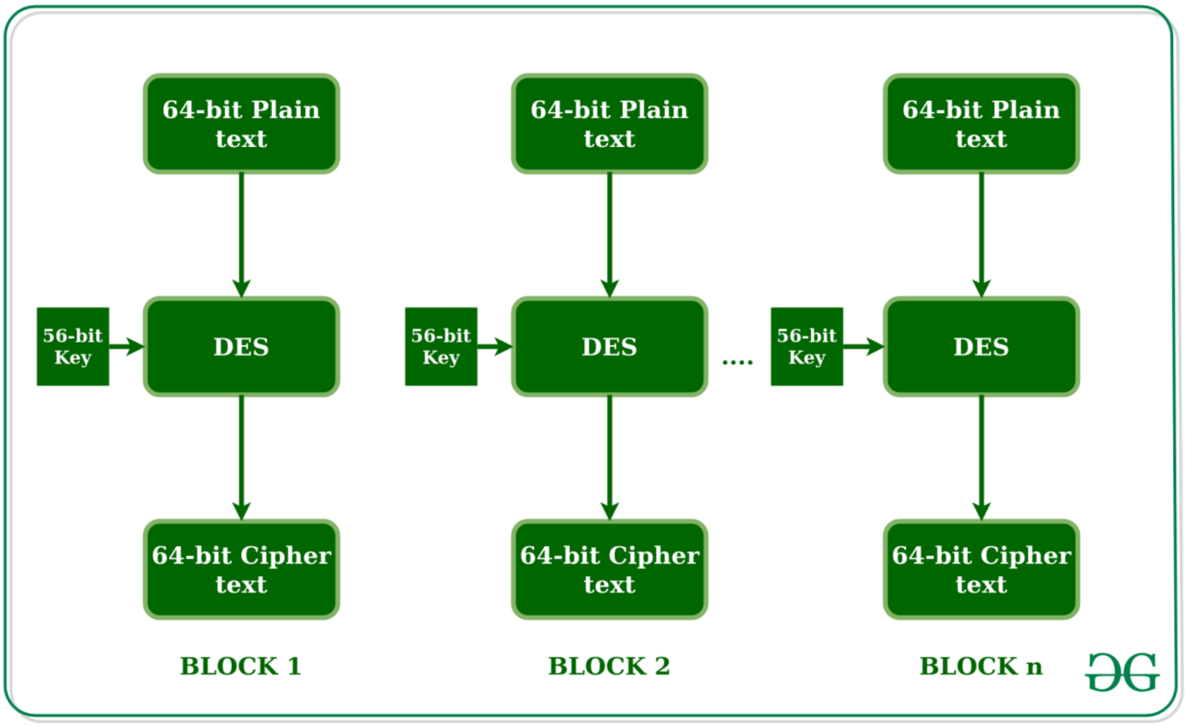
Implementation of Data Encryption Standard

Aim:

To develop and implement the Data Encryption Standard and to do encryption and decryption on the input plaintext

Theory:

- The Data Encryption Standard (DES) is a symmetric key block cipher published by National Institute of Standard and Technology (NIST)
- DES is an implementation of a Feistel Cipher. It uses 16 round Feistel structure.
- DES is a block cipher and encrypts data in blocks of size of 64 bits each
- 64 bits of plain text go as the input to DES, which produces 64 bits of ciphertext.
- Though, key length is 64-bit, DES has an effective key length of 56 bits, since 8 of the 64 bits of the key are not used by the encryption algorithm



- Since DES is based on the Feistel Cipher, all that is required to specify DES is
    - Round function
    - Key schedule
    - Any additional processing – Initial and final permutation

Implementation of Data Encryption Standard

Code:

```
// C++ code for the above approach

#include <bits/stdc++.h>
using namespace std;


string hex2bin(string s)
{
	// hexadecimal to binary conversion
	unordered_map<char, string> mp;
	mp['0'] = "0000";
	mp['1'] = "0001";
	mp['2'] = "0010";
	mp['3'] = "0011";
	mp['4'] = "0100";
	mp['5'] = "0101";
	mp['6'] = "0110";
	mp['7'] = "0111";
	mp['8'] = "1000";
	mp['9'] = "1001";
	mp['A'] = "1010";
	mp['B'] = "1011";
	mp['C'] = "1100";
	mp['D'] = "1101";
	mp['E'] = "1110";
	mp['F'] = "1111";
	string bin = "";
	for (int i = 0; i < s.size(); i++) {
		bin += mp[s[i]];
	}
	return bin;
}
```

```
string bin2hex(string s)
{
	// binary to hexadecimal conversion
	unordered_map<string, string> mp;
	mp["0000"] = "0";
	mp["0001"] = "1";
	mp["0010"] = "2";
	mp["0011"] = "3";
	mp["0100"] = "4";
	mp["0101"] = "5";
	mp["0110"] = "6";
	mp["0111"] = "7";
	mp["1000"] = "8";
	mp["1001"] = "9";
	mp["1010"] = "A";
	mp["1011"] = "B";
	mp["1100"] = "C";
	mp["1101"] = "D";
	mp["1110"] = "E";
	mp["1111"] = "F";
	string hex = "";
	for (int i = 0; i < s.length(); i += 4) {
		string ch = "";
		ch += s[i];
		ch += s[i + 1];
		ch += s[i + 2];
		ch += s[i + 3];
		hex += mp[ch];
	}
	return hex;
}

string permute(string k, int* arr, int n)
{
	string per = "";
```

```
        for (int i = 0; i < n; i++) {
                per += k[arr[i] - 1];
        }
        return per;
}

string shift_left(string k, int shifts)
{
        string s = "";
        for (int i = 0; i < shifts; i++) {
                for (int j = 1; j < 28; j++) {
                        s += k[j];
                }
                s += k[0];
                k = s;
                s = "";
        }
        return k;
}

string xor_(string a, string b)
{
        string ans = "";
        for (int i = 0; i < a.size(); i++) {
                if (a[i] == b[i]) {
                        ans += "0";
                }
                else {
                        ans += "1";
                }
        }
        return ans;
}
string encrypt(string pt, vector<string> rkb,
                        vector<string> rk)
```

```
{
	// Hexadecimal to binary
	pt = hex2bin(pt);

	// Initial Permutation Table
	int initial_perm[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 };
	// Initial Permutation
	pt = permute(pt, initial_perm, 64);
	cout << "After initial permutation: " << bin2hex(pt)
		<< endl;

	// Splitting
	string left = pt.substr(0, 32);
	string right = pt.substr(32, 32);
	cout << "After splitting: L0=" << bin2hex(left)
		<< " R0=" << bin2hex(right) << endl;

	// Expansion D-box Table
	int exp_d[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 };

	// S-box Table
	int s[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 }
};

// Straight Permutation Table
int per[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 };

cout << endl;
for (int i = 0; i < 16; i++) {
        // Expansion D-box
        string right_expanded = permute(right, exp_d, 48);

        // XOR RoundKey[i] and right_expanded
        string x = xor_(rkb[i], right_expanded);

        // S-boxes
        string op = "";
        for (int i = 0; i < 8; i++) {
                int row = 2 * int(x[i * 6] - '0')
                                + int(x[i * 6 + 5] - '0');
                int col = 8 * int(x[i * 6 + 1] - '0')
                                + 4 * int(x[i * 6 + 2] - '0')
                                + 2 * int(x[i * 6 + 3] - '0')
                                + int(x[i * 6 + 4] - '0');
                int val = s[i][row][col];
                op += char(val / 8 + '0');
                val = val % 8;
                op += char(val / 4 + '0');
                val = val % 4;
                op += char(val / 2 + '0');
                val = val % 2;
                op += char(val + '0');
            }
            // Straight D-box
            op = permute(op, per, 32);

            // XOR left and op
            x = xor_(op, left);

            left = x;

            // Swapper
            if (i != 15) {
                swap(left, right);
            }
            cout << "Round " << i + 1 << " " << bin2hex(left)
                << " " << bin2hex(right) << " " << rk[i]
                << endl;
        }

        // Combination
        string combine = left + right;

        // Final Permutation Table
        int final_perm[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 };

        // Final Permutation
        string cipher
            = bin2hex(permute(combine, final_perm, 64));
```

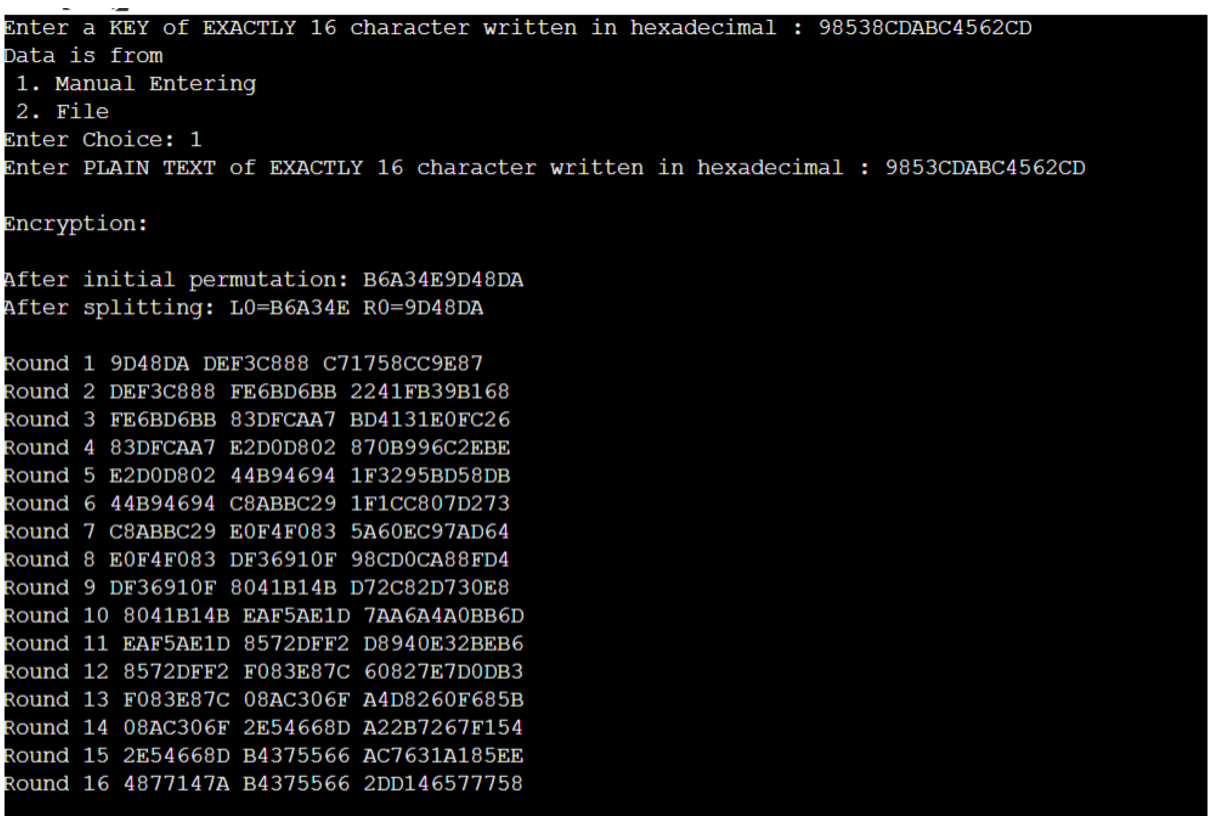
```
	return cipher;
}

// Driver code
int main()
{
	// pt is plain text
	string pt, key;
	/*cout<<"Enter plain text(in hexadecimal): ";
	cin>>pt;
	cout<<"Enter key(in hexadecimal): ";
	cin>>key;*/

//	cout << "Enter PLAIN TEXT of EXACTLY 16 character written in
hexadecimal : ";
//	cin >> pt;

	cout << "Enter a KEY of EXACTLY 16 character written in hexadecimal : ";
	cin>> key;

//	pt = "123456ABCD132536";
//	key = "AABB09182736CCDD";
	// Key Generation

	// Hex to binary
	key = hex2bin(key);

	// Parity bit drop table
	int keyp[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 };
```

```
// getting 56 bit key from 64 bit using the parity bits
key = permute(key, keyp, 56); // key without parity

// Number of bit shifts
int shift_table[16] = { 1, 1, 2, 2, 2, 2, 2, 2,
                        1, 2, 2, 2, 2, 2, 2, 1 };

// Key- Compression Table
int key_comp[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 };

// Splitting
string left = key.substr(0, 28);
string right = key.substr(28, 28);

vector<string> rkb; // rkb for RoundKeys in binary
vector<string> rk; // rk for RoundKeys in hexadecimal
for (int i = 0; i < 16; i++) {
        // Shifting
        left = shift_left(left, shift_table[i]);
        right = shift_left(right, shift_table[i]);

        // Combining
        string combine = left + right;

        // Key Compression
        string RoundKey = permute(combine, key_comp, 48);

        rkb.push_back(RoundKey);
        rk.push_back(bin2hex(RoundKey));
}
```

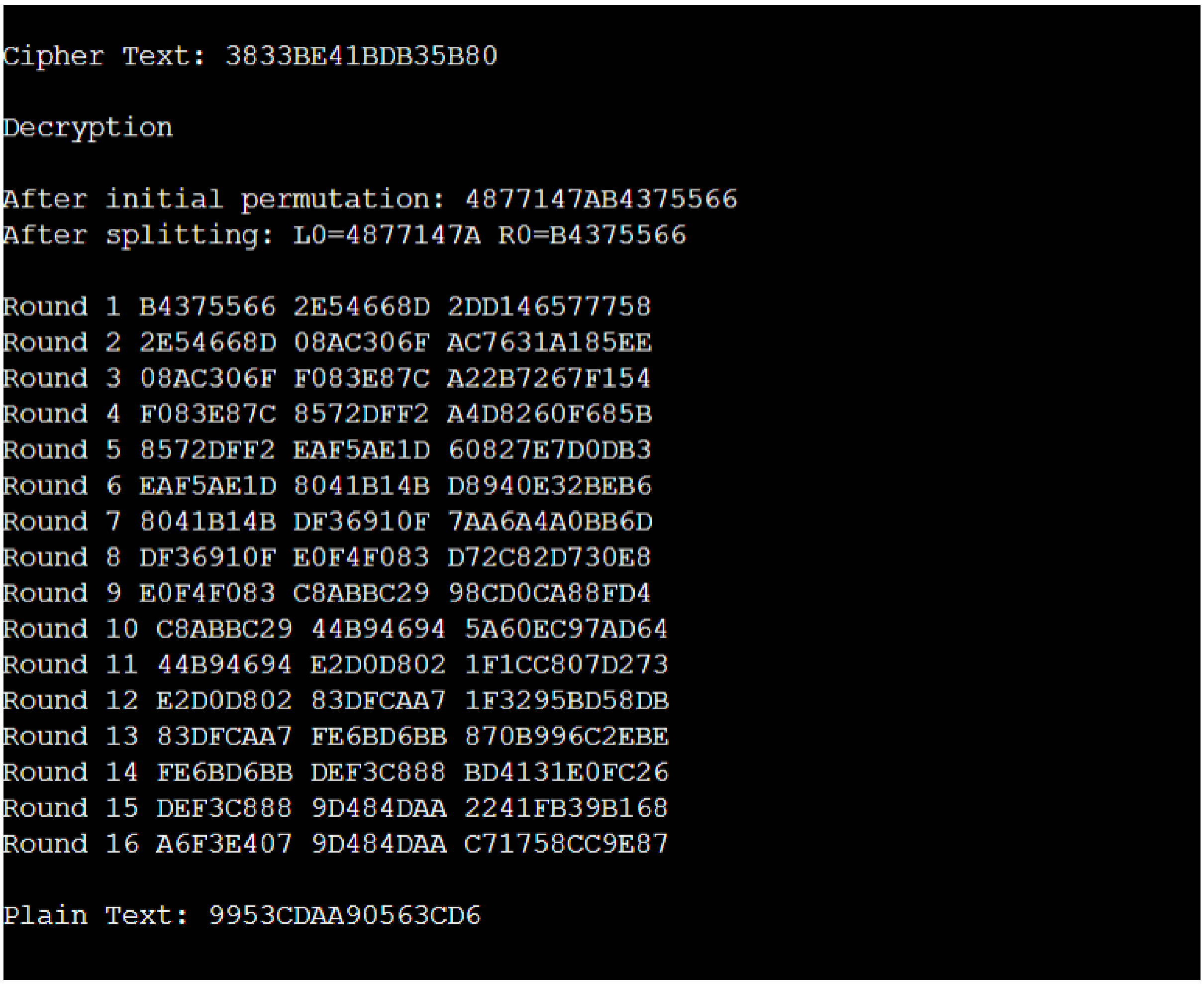
```
        int datachoice;
        cout << "Data is from\n 1. Manual Entering \n 2. File \nEnter Choice: ";
        cin>>datachoice;

        if(datachoice == 1)
        {
                cout << "Enter PLAIN TEXT of EXACTLY 16 character written in
hexadecimal : ";
                cin >> pt;
                string cipher, text;
                cout << "\nEncryption:\n\n";
                cipher = encrypt(pt, rkb, rk);
                cout << "\nCipher Text: " << cipher << endl;

                cout << "\nDecryption\n\n";
                reverse(rkb.begin(), rkb.end());
                reverse(rk.begin(), rk.end());
                text = encrypt(cipher, rkb, rk);
                cout << "\nPlain Text: " << text << endl;
        }

        else
        {
                cout<<"Enter File Name:\n";
//                      cin.ignore();
                string file;
                string str,s;
                cin>>file;
                fstream mf1, mf2;
                mf1.open(file.c_str());
                mf2.open("CipherText.txt",ios_base::out);
                cout << "\nEncryption:\n\n";
                if(!mf1.is_open())
                        cout << "Error while Opening File";
```

```
		while(getline(mf1,str))
		{
			s = encrypt(str, rkb, rk);
			mf2.write(s.data(),s.size());
		}
		mf1.close();
		mf2.close();
		cout<<"File Encrypted\n";


		cout << "\nDecryption\n\n";
		reverse(rkb.begin(), rkb.end());
		reverse(rk.begin(), rk.end());

//		fstream mf3, mf4;
		mf1.open("CipherText.txt");
		mf2.open("PlainText.txt",ios_base::out);
		if(!mf1.is_open())
			cout << "Error while Opening File";
		while(getline(mf1,str))
		{
			s = encrypt(str, rkb, rk);
			mf2.write(s.data(),s.size());
		}
		mf1.close();
		mf2.close();

		cout<<"File Decrypted";

	}

	return 0;
}
```

Output:



```
Enter a KEY of EXACTLY 16 character written in hexadecimal : 98538CDABC4562CD
Data is from
 1. Manual Entering
 2. File
Enter Choice: 1
Enter PLAIN TEXT of EXACTLY 16 character written in hexadecimal : 9853CDABC4562CD

Encryption:

After initial permutation: B6A34E9D48DA
After splitting: L0=B6A34E R0=9D48DA

Round 1 9D48DA DEF3C888 C71758CC9E87
Round 2 DEF3C888 FE6BD6BB 2241FB39B168
Round 3 FE6BD6BB 83DFCAA7 BD4131E0FC26
Round 4 83DFCAA7 E2D0D802 870B996C2EBE
Round 5 E2D0D802 44B94694 1F3295BD58DB
Round 6 44B94694 C8ABBC29 1F1CC807D273
Round 7 C8ABBC29 E0F4F083 5A60EC97AD64
Round 8 E0F4F083 DF36910F 98CD0CA88FD4
Round 9 DF36910F 8041B14B D72C82D730E8
Round 10 8041B14B EAF5AE1D 7AA6A4A0BB6D
Round 11 EAF5AE1D 8572DFF2 D8940E32BEB6
Round 12 8572DFF2 F083E87C 60827E7D0DB3
Round 13 F083E87C 08AC306F A4D8260F685B
Round 14 08AC306F 2E54668D A22B7267F154
Round 15 2E54668D B4375566 AC7631A185EE
Round 16 4877147A B4375566 2DD146577758
```



```
Cipher Text: 3833BE41BDB35B80

Decryption

After initial permutation: 4877147AB4375566
After splitting: L0=4877147A R0=B4375566

Round 1 B4375566 2E54668D 2DD146577758
Round 2 2E54668D 08AC306F AC7631A185EE
Round 3 08AC306F F083E87C A22B7267F154
Round 4 F083E87C 8572DFF2 A4D8260F685B
Round 5 8572DFF2 EAF5AE1D 60827E7D0DB3
Round 6 EAF5AE1D 8041B14B D8940E32BEB6
Round 7 8041B14B DF36910F 7AA6A4A0BB6D
Round 8 DF36910F E0F4F083 D72C82D730E8
Round 9 E0F4F083 C8ABBC29 98CD0CA88FD4
Round 10 C8ABBC29 44B94694 5A60EC97AD64
Round 11 44B94694 E2D0D802 1F1CC807D273
Round 12 E2D0D802 83DFCAA7 1F3295BD58DB
Round 13 83DFCAA7 FE6BD6BB 870B996C2EBE
Round 14 FE6BD6BB DEF3C888 BD4131E0FC26
Round 15 DEF3C888 9D484DAA 2241FB39B168
Round 16 A6F3E407 9D484DAA C71758CC9E87

Plain Text: 9953CDAA90563CD6
```

Conclusion:

The DES satisfies both the desired properties of block cipher. These two properties make cipher very strong.

1) Avalanche effect − A small change in plaintext results in a great change in the ciphertext.
2) Completeness − Each bit of ciphertext depends on many bits of plaintext.