Cryptography & Network Security Lab

PRN: 2019BTECS00021

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Batch: B1

Assignment No. 7

Title: Advanced Encryption Standard

Aim: To Demonstrate Advanced Encryption Standard

Theory:

AES algorithm (Rijndael algorithm) is a symmetric block cipher algorithm. The length of the data packet must be 128 bits, and the length of the key used should be 128, 192 or 256 bits. For three AES algorithms with different key lengths, they are called "AES-128", "AES-192", "AES-256".

Code:

decoding.h

```
/*
this header file implements the algorithm for 128-bit decryption
*/
#include<iostream>
#include "lookup_table_decoding.h"
#include "key_expand.h"
using namespace std;
void decryption(unsigned char * temp,unsigned char * extendedkeys)
```

```
{
    int kp=10;
    while(kp>0)
    {
        //subtract round key
        for(int i=0;i<16;i++)
        {
            temp[i]^=extendedkeys[(kp*16)+i];
        }

        //inverse mix column step
        if(kp<10){
         unsigned char temp2[16];
            for (int i = 0; i < 16; i++)
             {
             temp2[i] = temp[i];
             }

        temp[0] = (unsigned char)lookup14[temp2[0]] ^
lookup11[temp2[1]] ^ lookup13[temp2[2]] ^ lookup9[temp2[3]];
        temp[1] = (unsigned char)lookup9[temp2[0]] ^
lookup14[temp2[1]] ^ lookup11[temp2[2]] ^ lookup13[temp2[3]];
        temp[2] = (unsigned char)lookup13[temp2[0]] ^
lookup9[temp2[1]] ^ lookup14[temp2[2]] ^ lookup11[temp2[3]];
        temp[3] = (unsigned char)lookup11[temp2[0]] ^
lookup13[temp2[1]] ^ lookup9[temp2[2]] ^ lookup14[temp2[3]];

        temp[4] = (unsigned char)lookup14[temp2[4]] ^
lookup11[temp2[5]] ^ lookup13[temp2[6]] ^ lookup9[temp2[7]];
```

```
        temp[5] = (unsigned char)lookup9[temp2[4]] ^
lookup14[temp2[5]] ^ lookup11[temp2[6]] ^ lookup13[temp2[7]];
        temp[6] = (unsigned char)lookup13[temp2[4]] ^
lookup9[temp2[5]] ^ lookup14[temp2[6]] ^ lookup11[temp2[7]];
        temp[7] = (unsigned char)lookup11[temp2[4]] ^
lookup13[temp2[5]] ^ lookup9[temp2[6]] ^ lookup14[temp2[7]];

        temp[8] = (unsigned char)lookup14[temp2[8]] ^
lookup11[temp2[9]] ^ lookup13[temp2[10]] ^ lookup9[temp2[11]];
        temp[9] = (unsigned char)lookup9[temp2[8]] ^
lookup14[temp2[9]] ^ lookup11[temp2[10]] ^ lookup13[temp2[11]];
        temp[10] = (unsigned char)lookup13[temp2[8]] ^
lookup9[temp2[9]] ^ lookup14[temp2[10]] ^ lookup11[temp2[11]];
        temp[11] = (unsigned char)lookup11[temp2[8]] ^
lookup13[temp2[9]] ^ lookup9[temp2[10]] ^ lookup14[temp2[11]];

        temp[12] = (unsigned char)lookup14[temp2[12]] ^
lookup11[temp2[13]] ^ lookup13[temp2[14]] ^ lookup9[temp2[15]];
        temp[13] = (unsigned char)lookup9[temp2[12]] ^
lookup14[temp2[13]] ^lookup11[temp2[14]] ^ lookup13[temp2[15]];
        temp[14] = (unsigned char)lookup13[temp2[12]] ^
lookup9[temp2[13]] ^ lookup14[temp2[14]] ^ lookup11[temp2[15]];
        temp[15] = (unsigned char)lookup11[temp2[12]] ^
lookup13[temp2[13]] ^ lookup9[temp2[14]] ^ lookup14[temp2[15]];
        }
        // Shifts rows right
        unsigned char temp2[16];
        for (int i = 0; i < 16; i++)
         {
```

```
        temp2[i] = temp[i];
         }
         //column one
        temp [0] = temp2[0];
        temp [4] = temp2[4];
        temp [8] = temp2[8];
        temp [12] = temp2[12];
         //column two
        temp [1] = temp2[13];
        temp [5] = temp2[1];
        temp [9] = temp2[5];
        temp [13] = temp2[9];
         //column three
        temp [2] = temp2[10];
        temp [6] = temp2[14];
        temp [10] = temp2[2];
        temp [14] = temp2[6];
        //column four
        temp [3] = temp2[7];
        temp [7] = temp2[11];
        temp [11] = temp2[15];
        temp [15] = temp2[3];

        //substitution bits
        for(int i=0;i<16;i++)
         {
            temp[i]=in_sbox[temp[i]];
         }
         kp--;
```

```
       }

        //subtract round key
        for(int i=0;i<16;i++)
        {
            temp[i]^=extendedkeys[i];
        }

}
```

encoding.h

```
/*
this header file implements the algorithm for 128-bit encryption
*/
#include<iostream>
#include "lookup_table_encoding.h"
#include "key_expand.h"
using namespace std;
void encryption(unsigned char * temp,unsigned char * extendedkeys )
{
    int kp=0;
    for(int i=0;i<16;i++)
    {
        temp[i]^=extendedkeys[i];
    }
    kp++;
    while(kp<11)
    {
```

```
//substitution bits
for(int i=0;i<16;i++)
{
    temp[i]=sbox[temp[i]];
}
//shift row
unsigned char * temp2 = new unsigned char[16];
 for(int i=0;i<16;i++)
 temp2[i]=temp[i];
//1st column
 temp[0]=temp2[0];
 temp[4]=temp2[4];
 temp[8]=temp2[8];
 temp[12]=temp2[12];
 //2nd column
 temp[1]=temp2[5];
 temp[5]=temp2[9];
 temp[9]=temp2[13];
 temp[13]=temp2[1];
 //3rd column
 temp[2]=temp2[10];
 temp[6]=temp2[14];
 temp[10]=temp2[2];
 temp[14]=temp2[6];
 //4th column
 temp[3]=temp2[15];
 temp[7]=temp2[3];
 temp[11]=temp2[7];
 temp[15]=temp2[11];
```

```
        //MIX column
        if(kp<10)
        {
            for (int i = 0; i < 16; i++) {
                temp2[i] = temp[i];
              }
         //1st row
                temp[0] = (unsigned char) lookup2[temp2[0]] ^
lookup3[temp2[1]] ^ temp2[2] ^ temp2[3];
                temp[1] = (unsigned char) temp2[0] ^
lookup2[temp2[1]] ^ lookup3[temp2[2]] ^ temp2[3];
                temp[2] = (unsigned char) temp2[0] ^ temp2[1] ^
lookup2[temp2[2]] ^ lookup3[temp2[3]];
                temp[3] = (unsigned char) lookup3[temp2[0]] ^
temp2[1] ^ temp2[2] ^ lookup2[temp2[3]];
         //2nd row
                temp[4] = (unsigned char)lookup2[temp2[4]] ^
lookup3[temp2[5]] ^ temp2[6] ^ temp2[7];
                temp[5] = (unsigned char)temp2[4] ^
lookup2[temp2[5]] ^ lookup3[temp2[6]] ^ temp2[7];
                temp[6] = (unsigned char)temp2[4] ^ temp2[5] ^
lookup2[temp2[6]] ^ lookup3[temp2[7]];
                temp[7] = (unsigned char)lookup3[temp2[4]] ^
temp2[5] ^ temp2[6] ^ lookup2[temp2[7]];
         //3rd row
                temp[8] = (unsigned char)lookup2[temp2[8]] ^
lookup3[temp2[9]] ^ temp2[10] ^ temp2[11];
```

```
                temp[9] = (unsigned char)temp2[8] ^ 
lookup2[temp2[9]] ^ lookup3[temp2[10]] ^ temp2[11];
                temp[10] = (unsigned char)temp2[8] ^ temp2[9] ^ 
lookup2[temp2[10]] ^ lookup3[temp2[11]];
                temp[11] = (unsigned char)lookup3[temp2[8]] ^ 
temp2[9] ^ temp2[10] ^ lookup2[temp2[11]];
            //4th row
                temp[12] = (unsigned char)lookup2[temp2[12]] ^ 
lookup3[temp2[13]] ^ temp2[14] ^ temp2[15];
                temp[13] = (unsigned char)temp2[12] ^ 
lookup2[temp2[13]] ^ lookup3[temp2[14]] ^ temp2[15];
                temp[14] = (unsigned char)temp2[12] ^ temp2[13] ^ 
lookup2[temp2[14]] ^ lookup3[temp2[15]];
                temp[15] = (unsigned char)lookup3[temp2[12]] ^ 
temp2[13] ^ temp2[14] ^ lookup2[temp2[15]];
           }

           //Add Round Key
            for(int i=0;i<16;i++)
            {
              temp[i]^=extendedkeys[kp*16+i];
            }
            kp++;
    }
}
```

key_expand.h

```
/*
this header file includes algorithm for expanding our key
so that we can use our key foe 10 rounds
*/
#ifndef KEY_EXPAND_H_INCLUDED
#define KEY_EXPAND_H_INCLUDED

// s-box table
unsigned char sbox[256] =
{
    0x63, 0x7C, 0x77, 0x7B, 0xF2, 0x6B, 0x6F, 0xC5, 0x30, 0x01,
0x67, 0x2B, 0xFE, 0xD7, 0xAB, 0x76,
    0xCA, 0x82, 0xC9, 0x7D, 0xFA, 0x59, 0x47, 0xF0, 0xAD, 0xD4,
0xA2, 0xAF, 0x9C, 0xA4, 0x72, 0xC0,
    0xB7, 0xFD, 0x93, 0x26, 0x36, 0x3F, 0xF7, 0xCC, 0x34, 0xA5,
0xE5, 0xF1, 0x71, 0xD8, 0x31, 0x15,
    0x04, 0xC7, 0x23, 0xC3, 0x18, 0x96, 0x05, 0x9A, 0x07, 0x12,
0x80, 0xE2, 0xEB, 0x27, 0xB2, 0x75,
    0x09, 0x83, 0x2C, 0x1A, 0x1B, 0x6E, 0x5A, 0xA0, 0x52, 0x3B,
0xD6, 0xB3, 0x29, 0xE3, 0x2F, 0x84,
    0x53, 0xD1, 0x00, 0xED, 0x20, 0xFC, 0xB1, 0x5B, 0x6A, 0xCB,
0xBE, 0x39, 0x4A, 0x4C, 0x58, 0xCF,
    0xD0, 0xEF, 0xAA, 0xFB, 0x43, 0x4D, 0x33, 0x85, 0x45, 0xF9,
0x02, 0x7F, 0x50, 0x3C, 0x9F, 0xA8,
    0x51, 0xA3, 0x40, 0x8F, 0x92, 0x9D, 0x38, 0xF5, 0xBC, 0xB6,
0xDA, 0x21, 0x10, 0xFF, 0xF3, 0xD2,
    0xCD, 0x0C, 0x13, 0xEC, 0x5F, 0x97, 0x44, 0x17, 0xC4, 0xA7,
0x7E, 0x3D, 0x64, 0x5D, 0x19, 0x73,
    0x60, 0x81, 0x4F, 0xDC, 0x22, 0x2A, 0x90, 0x88, 0x46, 0xEE,
0xB8, 0x14, 0xDE, 0x5E, 0x0B, 0xDB,
    0xE0, 0x32, 0x3A, 0x0A, 0x49, 0x06, 0x24, 0x5C, 0xC2, 0xD3,
0xAC, 0x62, 0x91, 0x95, 0xE4, 0x79,
    0xE7, 0xC8, 0x37, 0x6D, 0x8D, 0xD5, 0x4E, 0xA9, 0x6C, 0x56,
0xF4, 0xEA, 0x65, 0x7A, 0xAE, 0x08,
    0xBA, 0x78, 0x25, 0x2E, 0x1C, 0xA6, 0xB4, 0xC6, 0xE8, 0xDD,
0x74, 0x1F, 0x4B, 0xBD, 0x8B, 0x8A,
    0x70, 0x3E, 0xB5, 0x66, 0x48, 0x03, 0xF6, 0x0E, 0x61, 0x35,
0x57, 0xB9, 0x86, 0xC1, 0x1D, 0x9E,
    0xE1, 0xF8, 0x98, 0x11, 0x69, 0xD9, 0x8E, 0x94, 0x9B, 0x1E,
0x87, 0xE9, 0xCE, 0x55, 0x28, 0xDF,
    0x8C, 0xA1, 0x89, 0x0D, 0xBF, 0xE6, 0x42, 0x68, 0x41, 0x99,
0x2D, 0x0F, 0xB0, 0x54, 0xBB, 0x16
};

// s-box table for decryption
unsigned char in_sbox[256] =
{
    0x52, 0x09, 0x6A, 0xD5, 0x30, 0x36, 0xA5, 0x38, 0xBF, 0x40,
0xA3, 0x9E, 0x81, 0xF3, 0xD7, 0xFB,
    0x7C, 0xE3, 0x39, 0x82, 0x9B, 0x2F, 0xFF, 0x87, 0x34, 0x8E,
0x43, 0x44, 0xC4, 0xDE, 0xE9, 0xCB,
    0x54, 0x7B, 0x94, 0x32, 0xA6, 0xC2, 0x23, 0x3D, 0xEE, 0x4C,
0x95, 0x0B, 0x42, 0xFA, 0xC3, 0x4E,
    0x08, 0x2E, 0xA1, 0x66, 0x28, 0xD9, 0x24, 0xB2, 0x76, 0x5B,
0xA2, 0x49, 0x6D, 0x8B, 0xD1, 0x25,
    0x72, 0xF8, 0xF6, 0x64, 0x86, 0x68, 0x98, 0x16, 0xD4, 0xA4,
0x5C, 0xCC, 0x5D, 0x65, 0xB6, 0x92,
    0x6C, 0x70, 0x48, 0x50, 0xFD, 0xED, 0xB9, 0xDA, 0x5E, 0x15,
0x46, 0x57, 0xA7, 0x8D, 0x9D, 0x84,
    0x90, 0xD8, 0xAB, 0x00, 0x8C, 0xBC, 0xD3, 0x0A, 0xF7, 0xE4,
0x58, 0x05, 0xB8, 0xB3, 0x45, 0x06,
    0xD0, 0x2C, 0x1E, 0x8F, 0xCA, 0x3F, 0x0F, 0x02, 0xC1, 0xAF,
0xBD, 0x03, 0x01, 0x13, 0x8A, 0x6B,
    0x3A, 0x91, 0x11, 0x41, 0x4F, 0x67, 0xDC, 0xEA, 0x97, 0xF2,
0xCF, 0xCE, 0xF0, 0xB4, 0xE6, 0x73,
    0x96, 0xAC, 0x74, 0x22, 0xE7, 0xAD, 0x35, 0x85, 0xE2, 0xF9,
0x37, 0xE8, 0x1C, 0x75, 0xDF, 0x6E,
    0x47, 0xF1, 0x1A, 0x71, 0x1D, 0x29, 0xC5, 0x89, 0x6F, 0xB7,
0x62, 0x0E, 0xAA, 0x18, 0xBE, 0x1B,
    0xFC, 0x56, 0x3E, 0x4B, 0xC6, 0xD2, 0x79, 0x20, 0x9A, 0xDB,
0xC0, 0xFE, 0x78, 0xCD, 0x5A, 0xF4,
    0x1F, 0xDD, 0xA8, 0x33, 0x88, 0x07, 0xC7, 0x31, 0xB1, 0x12,
0x10, 0x59, 0x27, 0x80, 0xEC, 0x5F,
    0x60, 0x51, 0x7F, 0xA9, 0x19, 0xB5, 0x4A, 0x0D, 0x2D, 0xE5,
0x7A, 0x9F, 0x93, 0xC9, 0x9C, 0xEF,
    0xA0, 0xE0, 0x3B, 0x4D, 0xAE, 0x2A, 0xF5, 0xB0, 0xC8, 0xEB,
0xBB, 0x3C, 0x83, 0x53, 0x99, 0x61,
    0x17, 0x2B, 0x04, 0x7E, 0xBA, 0x77, 0xD6, 0x26, 0xE1, 0x69,
0x14, 0x63, 0x55, 0x21, 0x0C, 0x7D
};

// r-con table used in expansion
unsigned char r[256] = {
    0x8d, 0x01, 0x02, 0x04, 0x08, 0x10, 0x20, 0x40, 0x80, 0x1b,
0x36, 0x6c, 0xd8, 0xab, 0x4d, 0x9a,
    0x2f, 0x5e, 0xbc, 0x63, 0xc6, 0x97, 0x35, 0x6a, 0xd4, 0xb3,
0x7d, 0xfa, 0xef, 0xc5, 0x91, 0x39,
    0x72, 0xe4, 0xd3, 0xbd, 0x61, 0xc2, 0x9f, 0x25, 0x4a, 0x94,
0x33, 0x66, 0xcc, 0x83, 0x1d, 0x3a,
    0x74, 0xe8, 0xcb, 0x8d, 0x01, 0x02, 0x04, 0x08, 0x10, 0x20,
0x40, 0x80, 0x1b, 0x36, 0x6c, 0xd8,
    0xab, 0x4d, 0x9a, 0x2f, 0x5e, 0xbc, 0x63, 0xc6, 0x97, 0x35,
0x6a, 0xd4, 0xb3, 0x7d, 0xfa, 0xef,
    0xc5, 0x91, 0x39, 0x72, 0xe4, 0xd3, 0xbd, 0x61, 0xc2, 0x9f,
0x25, 0x4a, 0x94, 0x33, 0x66, 0xcc,
    0x83, 0x1d, 0x3a, 0x74, 0xe8, 0xcb, 0x8d, 0x01, 0x02, 0x04,
0x08, 0x10, 0x20, 0x40, 0x80, 0x1b,
    0x36, 0x6c, 0xd8, 0xab, 0x4d, 0x9a, 0x2f, 0x5e, 0xbc, 0x63,
0xc6, 0x97, 0x35, 0x6a, 0xd4, 0xb3,
    0x7d, 0xfa, 0xef, 0xc5, 0x91, 0x39, 0x72, 0xe4, 0xd3, 0xbd,
0x61, 0xc2, 0x9f, 0x25, 0x4a, 0x94,
    0x33, 0x66, 0xcc, 0x83, 0x1d, 0x3a, 0x74, 0xe8, 0xcb, 0x8d,
0x01, 0x02, 0x04, 0x08, 0x10, 0x20,
    0x40, 0x80, 0x1b, 0x36, 0x6c, 0xd8, 0xab, 0x4d, 0x9a, 0x2f,
0x5e, 0xbc, 0x63, 0xc6, 0x97, 0x35,
    0x6a, 0xd4, 0xb3, 0x7d, 0xfa, 0xef, 0xc5, 0x91, 0x39, 0x72,
0xe4, 0xd3, 0xbd, 0x61, 0xc2, 0x9f,
    0x25, 0x4a, 0x94, 0x33, 0x66, 0xcc, 0x83, 0x1d, 0x3a, 0x74,
0xe8, 0xcb, 0x8d, 0x01, 0x02, 0x04,
    0x08, 0x10, 0x20, 0x40, 0x80, 0x1b, 0x36, 0x6c, 0xd8, 0xab,
0x4d, 0x9a, 0x2f, 0x5e, 0xbc, 0x63,
    0xc6, 0x97, 0x35, 0x6a, 0xd4, 0xb3, 0x7d, 0xfa, 0xef, 0xc5,
0x91, 0x39, 0x72, 0xe4, 0xd3, 0xbd,
    0x61, 0xc2, 0x9f, 0x25, 0x4a, 0x94, 0x33, 0x66, 0xcc, 0x83,
0x1d, 0x3a, 0x74, 0xe8, 0xcb, 0x8d
};

//left shift row by one value
void leftshift(unsigned char * input)
{
    unsigned char temp = input[0];
    input[0] = input[1];
    input[1] = input[2];
    input[2] = input[3];
    input[3] = temp;
}

//function to substitute corresponding values in s-box
void sboxreplace(unsigned char * input)
{
    input[0] = sbox[input[0]];
    input[1] = sbox[input[1]];
    input[2] = sbox[input[2]];
    input[3] = sbox[input[3]];
}

//generating 11 pairs of 128-bits keys
void Key_extenxion(unsigned char originalkey[16], unsigned char
extended[176]) {
    // first key remains same same as original key
    for (int i = 0; i < 16; i++)
    extended[i] = originalkey[i];
   // variables to keep record of keys generated
    int nb = 16;
    int keysgenerated= 1;
    unsigned char tmp[4];

    while (nb < 176) {
        //initially start 4 bits will be same as last 4 generated
bits
        for (int i = 0; i < 4; i++)
            tmp[i] = extended[i + nb - 4];


        // main process for generating keys
        if (nb % 16 == 0)
            {
            leftshift(tmp);
            sboxreplace(tmp);
            tmp[0] ^= r[keysgenerated++];
            }

        for (int i = 0; i < 4; i++)
            {
            extended[nb]= extended[nb - 16] ^ tmp[i];
            nb++;
            }
    }
}
```

```


#endif // KEY_EXPAND_H_INCLUDED
```

lookup_table_decoding.h

```
//Galois Multiplication lookup tables for decryption
unsigned char lookup9[256] =
{

0x00,0x09,0x12,0x1b,0x24,0x2d,0x36,0x3f,0x48,0x41,0x5a,0x53,0x6c,0x65,0x7e,0x77,

0x90,0x99,0x82,0x8b,0xb4,0xbd,0xa6,0xaf,0xd8,0xd1,0xca,0xc3,0xfc,0xf5,0xee,0xe7,

0x3b,0x32,0x29,0x20,0x1f,0x16,0x0d,0x04,0x73,0x7a,0x61,0x68,0x57,0x5e,0x45,0x4c,

0xab,0xa2,0xb9,0xb0,0x8f,0x86,0x9d,0x94,0xe3,0xea,0xf1,0xf8,0xc7,0xce,0xd5,0xdc,

0x76,0x7f,0x64,0x6d,0x52,0x5b,0x40,0x49,0x3e,0x37,0x2c,0x25,0x1a,0x13,0x08,0x01,

0xe6,0xef,0xf4,0xfd,0xc2,0xcb,0xd0,0xd9,0xae,0xa7,0xbc,0xb5,0x8a,0x83,0x98,0x91,

0x4d,0x44,0x5f,0x56,0x69,0x60,0x7b,0x72,0x05,0x0c,0x17,0x1e,0x21,0x28,0x33,0x3a,
0xdd,0xd4,0xcf,0xc6,0xf9,0xf0,0xeb,0xe2,0x95,0x9c,0x87,0x8e,0xb1,0xb8,0xa3,0xaa,
0xec,0xe5,0xfe,0xf7,0xc8,0xc1,0xda,0xd3,0xa4,0xad,0xb6,0xbf,0x80,0x89,0x92,0x9b,
0x7c,0x75,0x6e,0x67,0x58,0x51,0x4a,0x43,0x34,0x3d,0x26,0x2f,0x10,0x19,0x02,0x0b,
0xd7,0xde,0xc5,0xcc,0xf3,0xfa,0xe1,0xe8,0x9f,0x96,0x8d,0x84,0xbb,0xb2,0xa9,0xa0,
0x47,0x4e,0x55,0x5c,0x63,0x6a,0x71,0x78,0x0f,0x06,0x1d,0x14,0x2b,0x22,0x39,0x30,
0x9a,0x93,0x88,0x81,0xbe,0xb7,0xac,0xa5,0xd2,0xdb,0xc0,0xc9,0xf6,0xff,0xe4,0xed,
0x0a,0x03,0x18,0x11,0x2e,0x27,0x3c,0x35,0x42,0x4b,0x50,0x59,0x66,0x6f,0x74,0x7d,
0xa1,0xa8,0xb3,0xba,0x85,0x8c,0x97,0x9e,0xe9,0xe0,0xfb,0xf2,0xcd,0xc4,0xdf,0xd6,
0x31,0x38,0x23,0x2a,0x15,0x1c,0x07,0x0e,0x79,0x70,0x6b,0x62,0x5d,0x54,0x4f,0x46
};
unsigned char lookup11[256] =
{

0x00,0x0b,0x16,0x1d,0x2c,0x27,0x3a,0x31,0x58,0x53,0x4e,0x45,0x74,0x7f,0x62,0x69,

0xb0,0xbb,0xa6,0xad,0x9c,0x97,0x8a,0x81,0xe8,0xe3,0xfe,0xf5,0xc4,0xcf,0xd2,0xd9,

0x7b,0x70,0x6d,0x66,0x57,0x5c,0x41,0x4a,0x23,0x28,0x35,0x3e,0x0f,0x04,0x19,0x12,

0xcb,0xc0,0xdd,0xd6,0xe7,0xec,0xf1,0xfa,0x93,0x98,0x85,0x8e,0xbf,0xb4,0xa9,0xa2,

0xf6,0xfd,0xe0,0xeb,0xda,0xd1,0xcc,0xc7,0xae,0xa5,0xb8,0xb3,0x82,0x89,0x94,0x9f,

0x46,0x4d,0x50,0x5b,0x6a,0x61,0x7c,0x77,0x1e,0x15,0x08,0x03,0x32,0x39,0x24,0x2f,

0x8d,0x86,0x9b,0x90,0xa1,0xaa,0xb7,0xbc,0xd5,0xde,0xc3,0xc8,0xf9,0xf2,0xef,0xe4,

0x3d,0x36,0x2b,0x20,0x11,0x1a,0x07,0x0c,0x65,0x6e,0x73,0x78,0x49,0x42,0x5f,0x54,

0xf7,0xfc,0xe1,0xea,0xdb,0xd0,0xcd,0xc6,0xaf,0xa4,0xb9,0xb2,0x83,0x88,0x95,0x9e,
0x47,0x4c,0x51,0x5a,0x6b,0x60,0x7d,0x76,0x1f,0x14,0x09,0x02,0x33,0x38,0x25,0x2e,

0x8c,0x87,0x9a,0x91,0xa0,0xab,0xb6,0xbd,0xd4,0xdf,0xc2,0xc9,0xf8,0xf3,0xee,0xe5,

0x3c,0x37,0x2a,0x21,0x10,0x1b,0x06,0x0d,0x64,0x6f,0x72,0x79,0x48,0x43,0x5e,0x55,

0x01,0x0a,0x17,0x1c,0x2d,0x26,0x3b,0x30,0x59,0x52,0x4f,0x44,0x75,0x7e,0x63,0x68,

0xb1,0xba,0xa7,0xac,0x9d,0x96,0x8b,0x80,0xe9,0xe2,0xff,0xf4,0xc5,0xce,0xd3,0xd8,

0x7a,0x71,0x6c,0x67,0x56,0x5d,0x40,0x4b,0x22,0x29,0x34,0x3f,0x0e,0x05,0x18,0x13,

0xca,0xc1,0xdc,0xd7,0xe6,0xed,0xf0,0xfb,0x92,0x99,0x84,0x8f,0xbe,0xb5,0xa8,0xa3
};
unsigned char lookup13[256] =
{

0x00,0x0d,0x1a,0x17,0x34,0x39,0x2e,0x23,0x68,0x65,0x72,0x7f,0x5c,0x51,0x46,0x4b,
0xd0,0xdd,0xca,0xc7,0xe4,0xe9,0xfe,0xf3,0xb8,0xb5,0xa2,0xaf,0x8c,0x8
1,0x96,0x9b,

0xbb,0xb6,0xa1,0xac,0x8f,0x82,0x95,0x98,0xd3,0xde,0xc9,0xc4,0xe7,0xe
a,0xfd,0xf0,

0x6b,0x66,0x71,0x7c,0x5f,0x52,0x45,0x48,0x03,0x0e,0x19,0x14,0x37,0x3
a,0x2d,0x20,

0x6d,0x60,0x77,0x7a,0x59,0x54,0x43,0x4e,0x05,0x08,0x1f,0x12,0x31,0x3
c,0x2b,0x26,

0xbd,0xb0,0xa7,0xaa,0x89,0x84,0x93,0x9e,0xd5,0xd8,0xcf,0xc2,0xe1,0xe
c,0xfb,0xf6,

0xd6,0xdb,0xcc,0xc1,0xe2,0xef,0xf8,0xf5,0xbe,0xb3,0xa4,0xa9,0x8a,0x8
7,0x90,0x9d,

0x06,0x0b,0x1c,0x11,0x32,0x3f,0x28,0x25,0x6e,0x63,0x74,0x79,0x5a,0x5
7,0x40,0x4d,

0xda,0xd7,0xc0,0xcd,0xee,0xe3,0xf4,0xf9,0xb2,0xbf,0xa8,0xa5,0x86,0x8
b,0x9c,0x91,

0x0a,0x07,0x10,0x1d,0x3e,0x33,0x24,0x29,0x62,0x6f,0x78,0x75,0x56,0x5
b,0x4c,0x41,
0x61,0x6c,0x7b,0x76,0x55,0x58,0x4f,0x42,0x09,0x04,0x13,0x1e,0x3d,0x3
0,0x27,0x2a,

0xb1,0xbc,0xab,0xa6,0x85,0x88,0x9f,0x92,0xd9,0xd4,0xc3,0xce,0xed,0xe
0,0xf7,0xfa,

0xb7,0xba,0xad,0xa0,0x83,0x8e,0x99,0x94,0xdf,0xd2,0xc5,0xc8,0xeb,0xe
6,0xf1,0xfc,

0x67,0x6a,0x7d,0x70,0x53,0x5e,0x49,0x44,0x0f,0x02,0x15,0x18,0x3b,0x3
6,0x21,0x2c,

0x0c,0x01,0x16,0x1b,0x38,0x35,0x22,0x2f,0x64,0x69,0x7e,0x73,0x50,0x5
d,0x4a,0x47,

0xdc,0xd1,0xc6,0xcb,0xe8,0xe5,0xf2,0xff,0xb4,0xb9,0xae,0xa3,0x80,0x8
d,0x9a,0x97
};
unsigned char lookup14[256] =
{

0x00,0x0e,0x1c,0x12,0x38,0x36,0x24,0x2a,0x70,0x7e,0x6c,0x62,0x48,0x4
6,0x54,0x5a,

0xe0,0xee,0xfc,0xf2,0xd8,0xd6,0xc4,0xca,0x90,0x9e,0x8c,0x82,0xa8,0xa
6,0xb4,0xba,
0xdb,0xd5,0xc7,0xc9,0xe3,0xed,0xff,0xf1,0xab,0xa5,0xb7,0xb9,0x93,0x9
d,0x8f,0x81,

0x3b,0x35,0x27,0x29,0x03,0x0d,0x1f,0x11,0x4b,0x45,0x57,0x59,0x73,0x7
d,0x6f,0x61,

0xad,0xa3,0xb1,0xbf,0x95,0x9b,0x89,0x87,0xdd,0xd3,0xc1,0xcf,0xe5,0xe
b,0xf9,0xf7,

0x4d,0x43,0x51,0x5f,0x75,0x7b,0x69,0x67,0x3d,0x33,0x21,0x2f,0x05,0x0
b,0x19,0x17,

0x76,0x78,0x6a,0x64,0x4e,0x40,0x52,0x5c,0x06,0x08,0x1a,0x14,0x3e,0x3
0,0x22,0x2c,

0x96,0x98,0x8a,0x84,0xae,0xa0,0xb2,0xbc,0xe6,0xe8,0xfa,0xf4,0xde,0xd
0,0xc2,0xcc,

0x41,0x4f,0x5d,0x53,0x79,0x77,0x65,0x6b,0x31,0x3f,0x2d,0x23,0x09,0x0
7,0x15,0x1b,

0xa1,0xaf,0xbd,0xb3,0x99,0x97,0x85,0x8b,0xd1,0xdf,0xcd,0xc3,0xe9,0xe
7,0xf5,0xfb,

0x9a,0x94,0x86,0x88,0xa2,0xac,0xbe,0xb0,0xea,0xe4,0xf6,0xf8,0xd2,0xd
c,0xce,0xc0,
0x7a,0x74,0x66,0x68,0x42,0x4c,0x5e,0x50,0x0a,0x04,0x16,0x18,0x32,0x3c,0x2e,0x20,

0xec,0xe2,0xf0,0xfe,0xd4,0xda,0xc8,0xc6,0x9c,0x92,0x80,0x8e,0xa4,0xaa,0xb8,0xb6,

0x0c,0x02,0x10,0x1e,0x34,0x3a,0x28,0x26,0x7c,0x72,0x60,0x6e,0x44,0x4a,0x58,0x56,

0x37,0x39,0x2b,0x25,0x0f,0x01,0x13,0x1d,0x47,0x49,0x5b,0x55,0x7f,0x71,0x63,0x6d,

0xd7,0xd9,0xcb,0xc5,0xef,0xe1,0xf3,0xfd,0xa7,0xa9,0xbb,0xb5,0x9f,0x91,0x83,0x8d
};
```

lookup_table_encoding.h

```
//Galois Multiplication lookup tables for encryption
unsigned char lookup2[] =
{

0x00,0x02,0x04,0x06,0x08,0x0a,0x0c,0x0e,0x10,0x12,0x14,0x16,0x18,0x1a,0x1c,0x1e,

0x20,0x22,0x24,0x26,0x28,0x2a,0x2c,0x2e,0x30,0x32,0x34,0x36,0x38,0x3a,0x3c,0x3e,
0x40,0x42,0x44,0x46,0x48,0x4a,0x4c,0x4e,0x50,0x52,0x54,0x56,0x58,0x5
a,0x5c,0x5e,

0x60,0x62,0x64,0x66,0x68,0x6a,0x6c,0x6e,0x70,0x72,0x74,0x76,0x78,0x7
a,0x7c,0x7e,

0x80,0x82,0x84,0x86,0x88,0x8a,0x8c,0x8e,0x90,0x92,0x94,0x96,0x98,0x9
a,0x9c,0x9e,

0xa0,0xa2,0xa4,0xa6,0xa8,0xaa,0xac,0xae,0xb0,0xb2,0xb4,0xb6,0xb8,0xb
a,0xbc,0xbe,

0xc0,0xc2,0xc4,0xc6,0xc8,0xca,0xcc,0xce,0xd0,0xd2,0xd4,0xd6,0xd8,0xd
a,0xdc,0xde,

0xe0,0xe2,0xe4,0xe6,0xe8,0xea,0xec,0xee,0xf0,0xf2,0xf4,0xf6,0xf8,0xf
a,0xfc,0xfe,

0x1b,0x19,0x1f,0x1d,0x13,0x11,0x17,0x15,0x0b,0x09,0x0f,0x0d,0x03,0x0
1,0x07,0x05,

0x3b,0x39,0x3f,0x3d,0x33,0x31,0x37,0x35,0x2b,0x29,0x2f,0x2d,0x23,0x2
1,0x27,0x25,

0x5b,0x59,0x5f,0x5d,0x53,0x51,0x57,0x55,0x4b,0x49,0x4f,0x4d,0x43,0x4
1,0x47,0x45,
0x7b,0x79,0x7f,0x7d,0x73,0x71,0x77,0x75,0x6b,0x69,0x6f,0x6d,0x63,0x61,0x67,0x65,

0x9b,0x99,0x9f,0x9d,0x93,0x91,0x97,0x95,0x8b,0x89,0x8f,0x8d,0x83,0x81,0x87,0x85,

0xbb,0xb9,0xbf,0xbd,0xb3,0xb1,0xb7,0xb5,0xab,0xa9,0xaf,0xad,0xa3,0xa1,0xa7,0xa5,

0xdb,0xd9,0xdf,0xdd,0xd3,0xd1,0xd7,0xd5,0xcb,0xc9,0xcf,0xcd,0xc3,0xc1,0xc7,0xc5,

0xfb,0xf9,0xff,0xfd,0xf3,0xf1,0xf7,0xf5,0xeb,0xe9,0xef,0xed,0xe3,0xe1,0xe7,0xe5
};
unsigned char lookup3[] =
{

0x00,0x03,0x06,0x05,0x0c,0x0f,0x0a,0x09,0x18,0x1b,0x1e,0x1d,0x14,0x17,0x12,0x11,

0x30,0x33,0x36,0x35,0x3c,0x3f,0x3a,0x39,0x28,0x2b,0x2e,0x2d,0x24,0x27,0x22,0x21,

0x60,0x63,0x66,0x65,0x6c,0x6f,0x6a,0x69,0x78,0x7b,0x7e,0x7d,0x74,0x77,0x72,0x71,
0x50,0x53,0x56,0x55,0x5c,0x5f,0x5a,0x59,0x48,0x4b,0x4e,0x4d,0x44,0x47,0x42,0x41,

0xc0,0xc3,0xc6,0xc5,0xcc,0xcf,0xca,0xc9,0xd8,0xdb,0xde,0xdd,0xd4,0xd7,0xd2,0xd1,

0xf0,0xf3,0xf6,0xf5,0xfc,0xff,0xfa,0xf9,0xe8,0xeb,0xee,0xed,0xe4,0xe7,0xe2,0xe1,

0xa0,0xa3,0xa6,0xa5,0xac,0xaf,0xaa,0xa9,0xb8,0xbb,0xbe,0xbd,0xb4,0xb7,0xb2,0xb1,

0x90,0x93,0x96,0x95,0x9c,0x9f,0x9a,0x99,0x88,0x8b,0x8e,0x8d,0x84,0x87,0x82,0x81,

0x9b,0x98,0x9d,0x9e,0x97,0x94,0x91,0x92,0x83,0x80,0x85,0x86,0x8f,0x8c,0x89,0x8a,

0xab,0xa8,0xad,0xae,0xa7,0xa4,0xa1,0xa2,0xb3,0xb0,0xb5,0xb6,0xbf,0xbc,0xb9,0xba,

0xfb,0xf8,0xfd,0xfe,0xf7,0xf4,0xf1,0xf2,0xe3,0xe0,0xe5,0xe6,0xef,0xec,0xe9,0xea,

0xcb,0xc8,0xcd,0xce,0xc7,0xc4,0xc1,0xc2,0xd3,0xd0,0xd5,0xd6,0xdf,0xdc,0xd9,0xda,
0x5b,0x58,0x5d,0x5e,0x57,0x54,0x51,0x52,0x43,0x40,0x45,0x46,0x4f,0x4
c,0x49,0x4a,

0x6b,0x68,0x6d,0x6e,0x67,0x64,0x61,0x62,0x73,0x70,0x75,0x76,0x7f,0x7
c,0x79,0x7a,

0x3b,0x38,0x3d,0x3e,0x37,0x34,0x31,0x32,0x23,0x20,0x25,0x26,0x2f,0x2
c,0x29,0x2a,

0x0b,0x08,0x0d,0x0e,0x07,0x04,0x01,0x02,0x13,0x10,0x15,0x16,0x1f,0x1
c,0x19,0x1a
};
```

aes.cpp

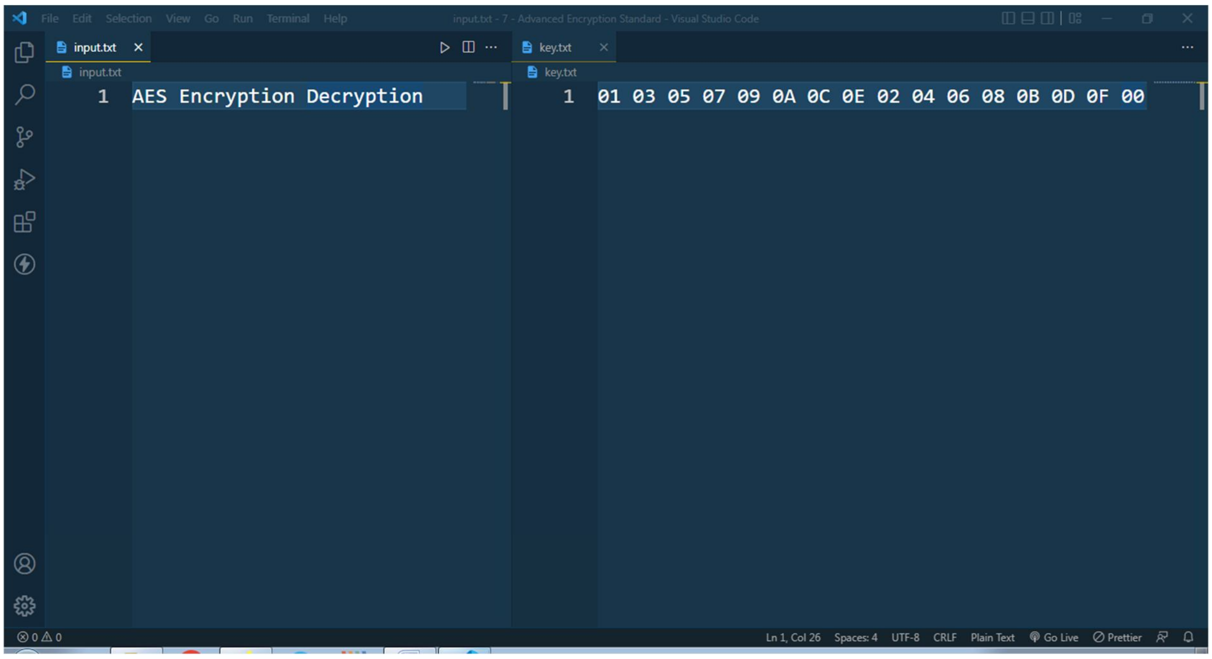
```
#include <iostream>
#include <fstream>
#include <cstring>
#include <sstream>
#include "key_expand.h"
#include "encoding.h"
#include "decoding.h"
#include <typeinfo>
#include <unistd.h>
using namespace std;
int main()
{
    // we will read from file input.txt
    int extendedlength = 0;
    int choice;
    string myText;
label:
    cout << "Welcome to 128 bits AES encryption" << endl;
    cout << endl;
    cout << "Enter you choice " << endl;
    cout << "1- Encoding" << endl;
    cout << "2- Decoding" << endl;
    cin >> choice;

    switch (choice)
    {
    case 1:
    {
        // encryption of text data
        ifstream File;
        string filepath = "encryption.aes";
        // clearing encryption.aes before editing
        File.open(filepath.c_str(), std::ifstream::out |
std::ifstream::trunc);
        if (!File.is_open() || File.fail())
        {
            File.close();
            printf("\nError : failed to erase file content !");
        }
        File.close();
        // reading plain text from input.txt
        fstream newfile;
        newfile.open("input.txt", ios::in); // open a file to
perform read operation using file object
        if (newfile.is_open())
        { // checking whether the file is open
            cout << "Reading plain text from input.txt .........\n";
            usleep(1000);
            string tp;
            cout << "Reading KEY from key.txt ......\n";
            usleep(1000);
            cout << "Now encrypting ....\n";
            usleep(1000);
            cout << "writing encrypted data in encryption.aes ..\n";
            usleep(1000);
            cout << endl;
            while (getline(newfile, tp))
            {
                // read data from file object and put it into
string.
                int messlength = tp.length();
                int extendedlength;
                if ((messlength % 16) != 0)
                {
                    extendedlength = messlength + (16 - (messlength
% 16));
                }
                else
                {
                    extendedlength = messlength;
                }
                unsigned char *encryptedtext = new unsigned
char[extendedlength];
                for (int i = 0; i < extendedlength; i++)
                {
                    if (i < messlength)
                        encryptedtext[i] = tp[i];
                    else
                        encryptedtext[i] = 0;
                }
                // getting key from key.txt
                string k;
                ifstream infile;
                infile.open("key.txt");
                if (infile.is_open())
                {
                    getline(infile, k); // The first line of file
should be the key
                    infile.close();
                }

                else
                    cout << "Unable to open file";

                istringstream tempkey(k);
                unsigned char key[16];
                unsigned int x;
                for (int i = 0; i < 16; i++)
                {
                    tempkey >> hex >> x;
                    key[i] = x;
                }
                // extending key
                unsigned char extendedkeys[176];
                Key_extenxion(key, extendedkeys);

                // encrypting our plain text
                for (int i = 0; i < extendedlength; i += 16)
                {
                    unsigned char *temp = new unsigned char[16];
                    for (int j = 0; j < 16; j++)
                    {
                        temp[j] = encryptedtext[i + j];
                    }
                    encryption(temp, extendedkeys);
                    for (int j = 0; j < 16; j++)
                    {
                        encryptedtext[i + j] = temp[j];
                    }
                }
                // storing our encrypted data in encryption.aes
                ofstream fout; // Create Object of Ofstream
                ifstream fin;
                fin.open("encryption.aes");
                fout.open("encryption.aes", ios::app); // Append
mode

                if (fin.is_open())
                    fout << encryptedtext << "\n"; // Writing data
to file
```

```
                fin.close();
                fout.close();
            }
            cout << "128-bit AES encryption is done sucessfully\n";
            cout << "Data has been appended to file encryption.aes";
            newfile.close(); // close the file object.
        }
        break;
    }

    case 2:
    {
        cout << "Reading encrypted data from encryption.txt
.........\n";
        usleep(1000);
        string tp;
        cout << "Reading KEY from key.txt ......\n";
        usleep(1000);
        cout << "Now Decrypting ....\n";
        usleep(1000);
        cout << "writing decrypted data in outputtext.txt ..\n";
        usleep(1000);
        cout << endl;
        cout << "Following is our decrypted text:- \n";
        // clearing outputtext file
        ifstream File;
        string filepath = "outputtext.txt";
        File.open(filepath.c_str(), std::ifstream::out |
std::ifstream::trunc);
```

```
if (!File.is_open() || File.fail())
{
    File.close();
    printf("\nError : failed to erase file content !");
}
File.close();

ifstream MyReadFile;
MyReadFile.open("encryption.aes", ios::in | ios::binary);
if (MyReadFile.is_open())
{
    while (getline(MyReadFile, myText))
    {
        cout.flush();
        char *x;
        x = &myText[0];
        int messlength = strlen(x);
        char *msg = new char[myText.size() + 1];

        strcpy(msg, myText.c_str());

        int n = strlen((const char *)msg);
        unsigned char *decryptedtext = new unsigned char[n];
        // decrypting our encrypted data
        for (int i = 0; i < n; i++)
        {
            decryptedtext[i] = (unsigned char)msg[i];
        }
        // reading key from key.txt file
```

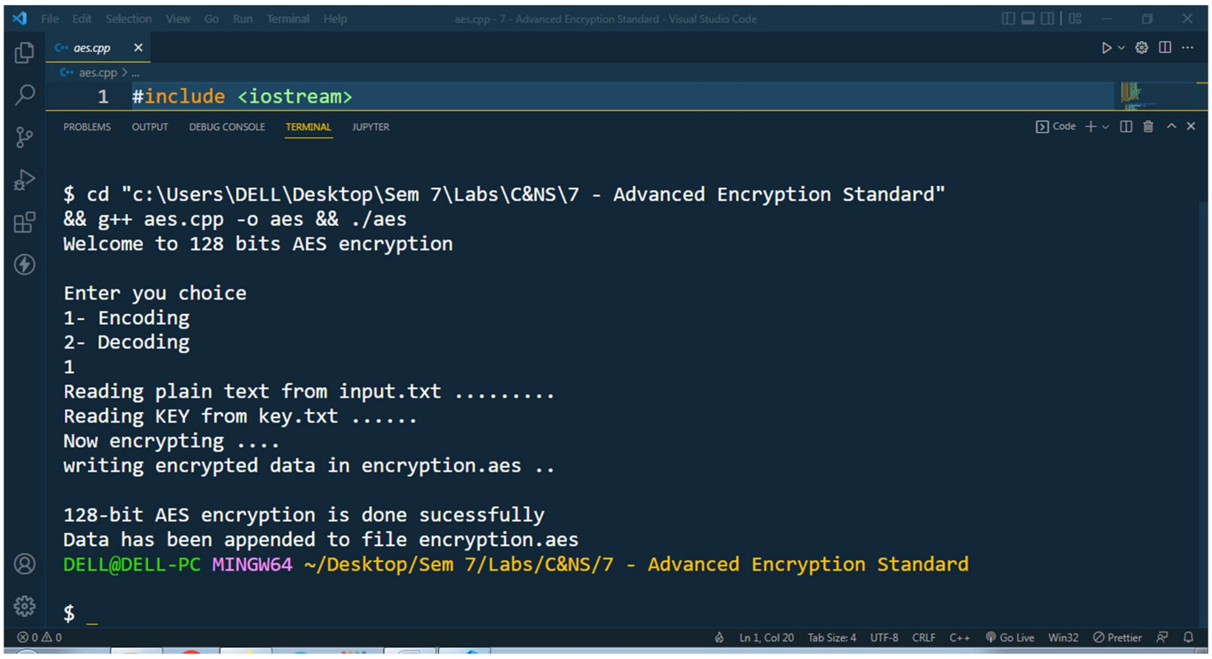
```
                string k;
                ifstream infile;
                infile.open("key.txt");
                if (infile.is_open())
                {
                    getline(infile, k); // The first line of file
should be the key
                    infile.close();
                }

                else
                    cout << "Unable to open file";
                istringstream tempkey(k);
                unsigned char key[16];
                unsigned int x1;
                for (int i = 0; i < 16; i++)
                {
                    tempkey >> hex >> x1;
                    key[i] = x1;
                }
                // extending key
                unsigned char extendedkeys[176];
                Key_extenxion(key, extendedkeys);
                // decrypting our data
                for (int i = 0; i < messlength; i += 16)
                {
                    unsigned char *temp = new unsigned char[16];
                    for (int j = 0; j < 16; j++)
                        temp[j] = decryptedtext[i + j];
                    decryption(temp, extendedkeys);
                    for (int j = 0; j < 16; j++)
                        decryptedtext[i + j] = temp[j];
                }
                // printing our plain text
                for (int i = 0; i < messlength; i++)
                {
                    cout << decryptedtext[i];
                    if (decryptedtext[i] == 0 && decryptedtext[i -
1] == 0)
                        break;
                }
                // storing plain text in outputtext.txt file
                cout << endl;
                ofstream fout; // Create Object of Ofstream
                ifstream fin;
                fin.open("outputtext.txt");
                fout.open("outputtext.txt", ios::app); // Append
mode
                if (fin.is_open())
                    fout << decryptedtext << "\n"; // Writing data
to file

                fin.close();
                fout.close(); // Closing the file
                usleep(500);
            }
        }
        else
        {
            cout << "Can not open input file\n ";
        }
        cout << "\n Data has been appended to file outputtext.txt";
        MyReadFile.close();
        break;
    }
    }
}
```

Output:



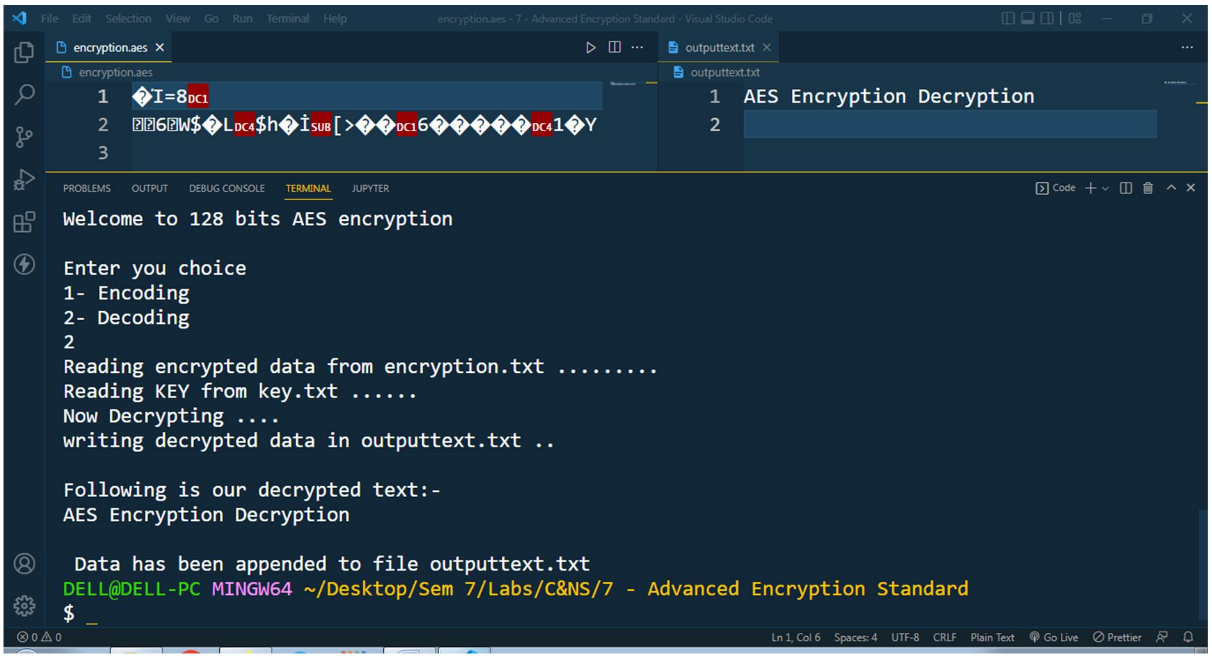
```
AES Encryption Decryption
```

```
01 03 05 07 09 0A 0C 0E 02 04 06 08 0B 0D 0F 00
```



```
#include <iostream>
```

```
$ cd "c:\Users\DELL\Desktop\Sem 7\Labs\C&NS\7 - Advanced Encryption Standard"
&& g++ aes.cpp -o aes && ./aes
Welcome to 128 bits AES encryption

Enter you choice
1- Encoding
2- Decoding
1
Reading plain text from input.txt .........
Reading KEY from key.txt ......
Now encrypting ....
writing encrypted data in encryption.aes ..

128-bit AES encryption is done sucessfully
Data has been appended to file encryption.aes
DELL@DELL-PC MINGW64 ~/Desktop/Sem 7/Labs/C&NS/7 - Advanced Encryption Standard

$ _
```



encryption.aes:

```
�I=8DC1
⍰⍰6⍰W$�LDC4$h�İSUB[>��DC16������DC41�Y
```

outputtext.txt:

```
AES Encryption Decryption
```

```
Welcome to 128 bits AES encryption

Enter you choice
1- Encoding
2- Decoding
2
Reading encrypted data from encryption.txt .........
Reading KEY from key.txt ......
Now Decrypting ....
writing decrypted data in outputtext.txt ..

Following is our decrypted text:-
AES Encryption Decryption

 Data has been appended to file outputtext.txt
DELL@DELL-PC MINGW64 ~/Desktop/Sem 7/Labs/C&NS/7 - Advanced Encryption Standard
$ _
```

Conclusion:

AES instruction set is now integrated into the CPU (offers throughput of several GB/s) to improve the speed and security of applications that use AES for encryption and decryption. Even though it's been 20 years since its introduction we have failed to break the AES algorithm as it is infeasible even with the current technology.