Cryptography & Network Security

PRN - 2019BTECS00026

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Batch - B1

Assignment - 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,
```

```c
    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,
```

```c
    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,0x81,0x96,0x9b,

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

    0x6b,0x66,0x71,0x7c,0x5f,0x52,0x45,0x48,0x03,0x0e,0x19,0x14,0x37,0x3a,0x2d,0x20,

    0x6d,0x60,0x77,0x7a,0x59,0x54,0x43,0x4e,0x05,0x08,0x1f,0x12,0x31,0x3c,0x2b,0x26,

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

    0xd6,0xdb,0xcc,0xc1,0xe2,0xef,0xf8,0xf5,0xbe,0xb3,0xa4,0xa9,0x8a,0x87,0x90,0x9d,

    0x06,0x0b,0x1c,0x11,0x32,0x3f,0x28,0x25,0x6e,0x63,0x74,0x79,0x5a,0x57,0x40,0x4d,

    0xda,0xd7,0xc0,0xcd,0xee,0xe3,0xf4,0xf9,0xb2,0xbf,0xa8,0xa5,0x86,0x8b,0x9c,0x91,

    0x0a,0x07,0x10,0x1d,0x3e,0x33,0x24,0x29,0x62,0x6f,0x78,0x75,0x56,0x5b,0x4c,0x41,

    0x61,0x6c,0x7b,0x76,0x55,0x58,0x4f,0x42,0x09,0x04,0x13,0x1e,0x3d,0x30,0x27,0x2a,

    0xb1,0xbc,0xab,0xa6,0x85,0x88,0x9f,0x92,0xd9,0xd4,0xc3,0xce,0xed,0xe0,0xf7,0xfa,

    0xb7,0xba,0xad,0xa0,0x83,0x8e,0x99,0x94,0xdf,0xd2,0xc5,0xc8,0xeb,0xe6,0xf1,0xfc,

    0x67,0x6a,0x7d,0x70,0x53,0x5e,0x49,0x44,0x0f,0x02,0x15,0x18,0x3b,0x36,0x21,0x2c,

    0x0c,0x01,0x16,0x1b,0x38,0x35,0x22,0x2f,0x64,0x69,0x7e,0x73,0x50,0x5d,0x4a,0x47,

    0xdc,0xd1,0xc6,0xcb,0xe8,0xe5,0xf2,0xff,0xb4,0xb9,0xae,0xa3,0x80,0x8d,0x9a,0x97

};

unsigned char lookup14[256] =

{

    0x00,0x0e,0x1c,0x12,0x38,0x36,0x24,0x2a,0x70,0x7e,0x6c,0x62,0x48,0x46,0x54,0x5a,

    0xe0,0xee,0xfc,0xf2,0xd8,0xd6,0xc4,0xca,0x90,0x9e,0x8c,0x82,0xa8,0xa6,0xb4,0xba,

    0xdb,0xd5,0xc7,0xc9,0xe3,0xed,0xff,0xf1,0xab,0xa5,0xb7,0xb9,0x93,0x9d,0x8f,0x81,

    0x3b,0x35,0x27,0x29,0x03,0x0d,0x1f,0x11,0x4b,0x45,0x57,0x59,0x73,0x7d,0x6f,0x61,

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

    0x4d,0x43,0x51,0x5f,0x75,0x7b,0x69,0x67,0x3d,0x33,0x21,0x2f,0x05,0x0b,0x19,0x17,

    0x76,0x78,0x6a,0x64,0x4e,0x40,0x52,0x5c,0x06,0x08,0x1a,0x14,0x3e,0x30,0x22,0x2c,

    0x96,0x98,0x8a,0x84,0xae,0xa0,0xb2,0xbc,0xe6,0xe8,0xfa,0xf4,0xde,0xd0,0xc2,0xcc,

    0x41,0x4f,0x5d,0x53,0x79,0x77,0x65,0x6b,0x31,0x3f,0x2d,0x23,0x09,0x07,0x15,0x1b,

    0xa1,0xaf,0xbd,0xb3,0x99,0x97,0x85,0x8b,0xd1,0xdf,0xcd,0xc3,0xe9,0xe7,0xf5,0xfb,

    0x9a,0x94,0x86,0x88,0xa2,0xac,0xbe,0xb0,0xea,0xe4,0xf6,0xf8,0xd2,0xdc,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,0x50,0x52,0x54,0x56,0x58,0x5a,0x5c,0x5e,

    0x60,0x62,0x64,0x66,0x68,0x6a,0x6c,0x6e,0x70,0x72,0x74,0x76,0x78,0x7a,0x7c,0x7e,

    0x80,0x82,0x84,0x86,0x88,0x8a,0x8c,0x8e,0x90,0x92,0x94,0x96,0x98,0x9a,0x9c,0x9e,

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

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

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

    0x1b,0x19,0x1f,0x1d,0x13,0x11,0x17,0x15,0x0b,0x09,0x0f,0x0d,0x03,0x01,0x07,0x05,

    0x3b,0x39,0x3f,0x3d,0x33,0x31,0x37,0x35,0x2b,0x29,0x2f,0x2d,0x23,0x21,0x27,0x25,

    0x5b,0x59,0x5f,0x5d,0x53,0x51,0x57,0x55,0x4b,0x49,0x4f,0x4d,0x43,0x41,0x47,0x45,

    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,0x4c,0x49,0x4a,

    0x6b,0x68,0x6d,0x6e,0x67,0x64,0x61,0x62,0x73,0x70,0x75,0x76,0x7f,0x7c,0x79,0x7a,

    0x3b,0x38,0x3d,0x3e,0x37,0x34,0x31,0x32,0x23,0x20,0x25,0x26,0x2f,0x2c,0x29,0x2a,

    0x0b,0x08,0x0d,0x0e,0x07,0x04,0x01,0x02,0x13,0x10,0x15,0x16,0x1f,0x1c,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;
```

```cpp
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];
```

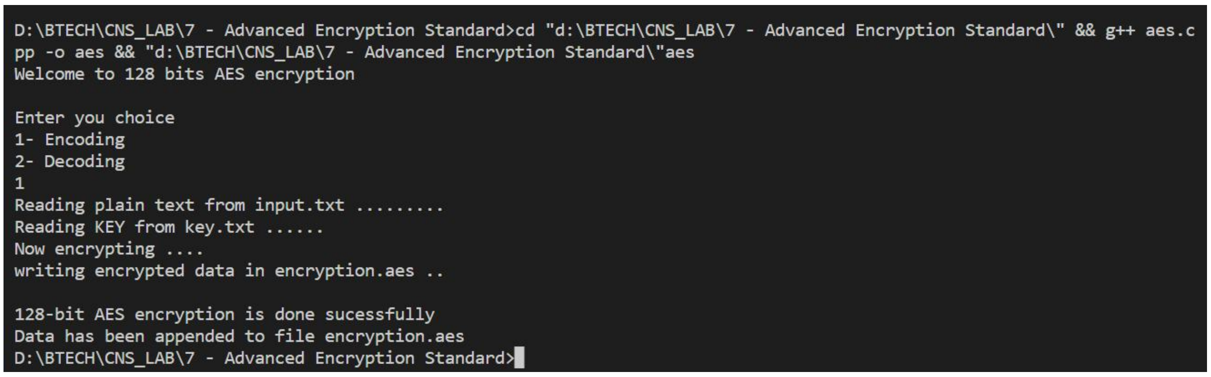
```
                strcpy(msg, myText.c_str());
```

```
                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();

                }
```

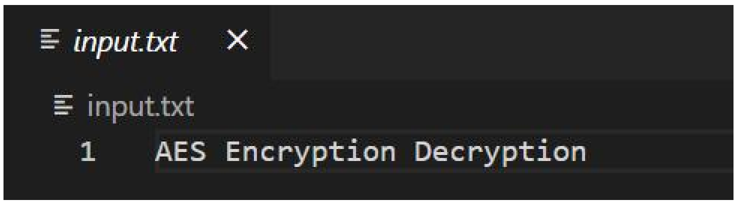
```
else
    cout << "Unable to open file";
istringstream tempkey(k);
unsigned char key[16];
unsigned int x1;
for (int i = 0; i < 16; i++)
{
    tempkey >> hex >> x1;
    key[i] = x1;
}
// extending key
unsigned char extendedkeys[176];
Key_extenxion(key, extendedkeys);
// decrypting our data
for (int 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
```

```cpp
                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;

    }

    }

}
```

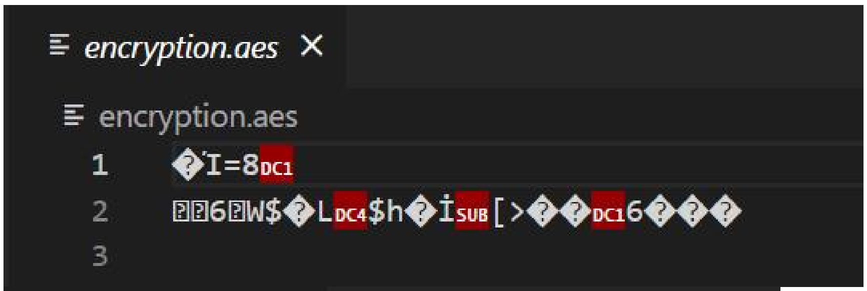
Output:



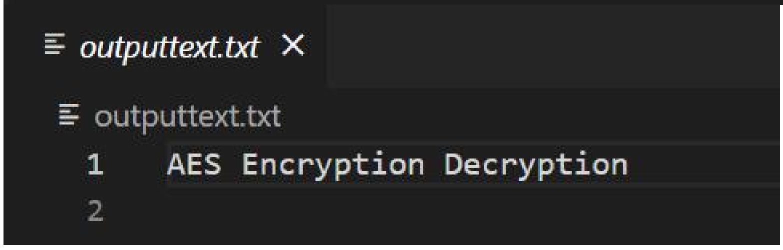
```
D:\BTECH\CNS_LAB\7 - Advanced Encryption Standard>cd "d:\BTECH\CNS_LAB\7 - Advanced Encryption Standard\" && g++ aes.c
pp -o aes && "d:\BTECH\CNS_LAB\7 - Advanced Encryption Standard\"aes
Welcome to 128 bits AES encryption

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
D:\BTECH\CNS_LAB\7 - Advanced Encryption Standard>
```



```
input.txt
AES Encryption Decryption
```



```
encryption.aes
�I=8DC1
▯▯6▯W$�LDC4$h�İSUB[>��DC16���

```



```
outputtext.txt
AES Encryption Decryption

```

<u>Conclusion</u>:

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.