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,
    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,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

```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";
```

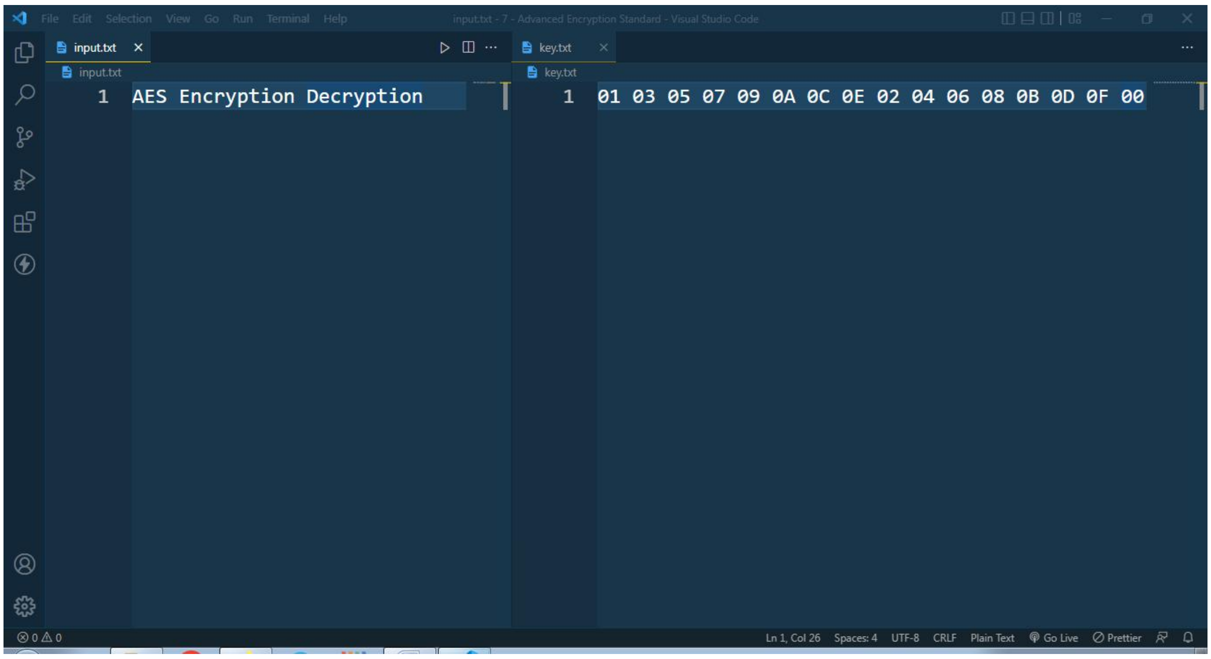
```
// clearing outputtext file
ifstream File;
string filepath = "outputtext.txt";
File.open(filepath.c_str(), std::ifstream::out | std::ifstream::trunc);
if (!File.is_open() || File.fail())
{
   File.close();
   printf("\nError : failed to erase file content !");
}
File.close();

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;
  }
  }
}
```

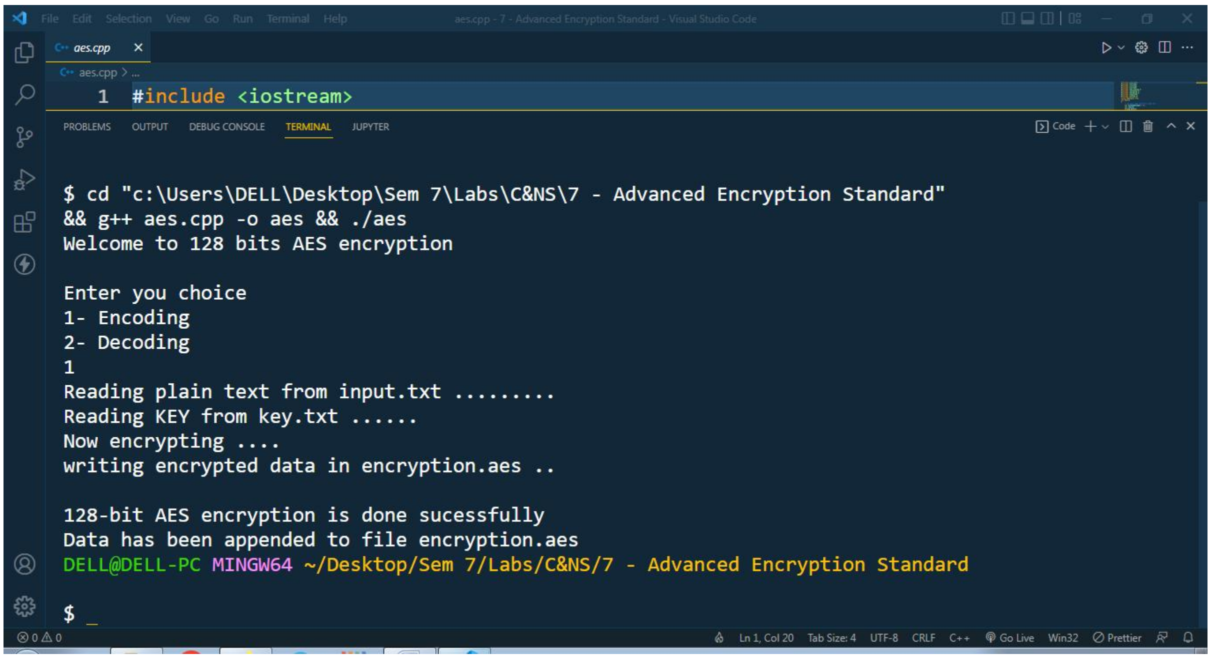
- **Output:**



File Edit Selection View Go Run Terminal Help
input.txt - 7 - Advanced Encryption Standard - Visual Studio Code
input.txt
key.txt
Ln 1, Col 26 Spaces: 4 UTF-8 CRLF Plain Text Go Live Prettier

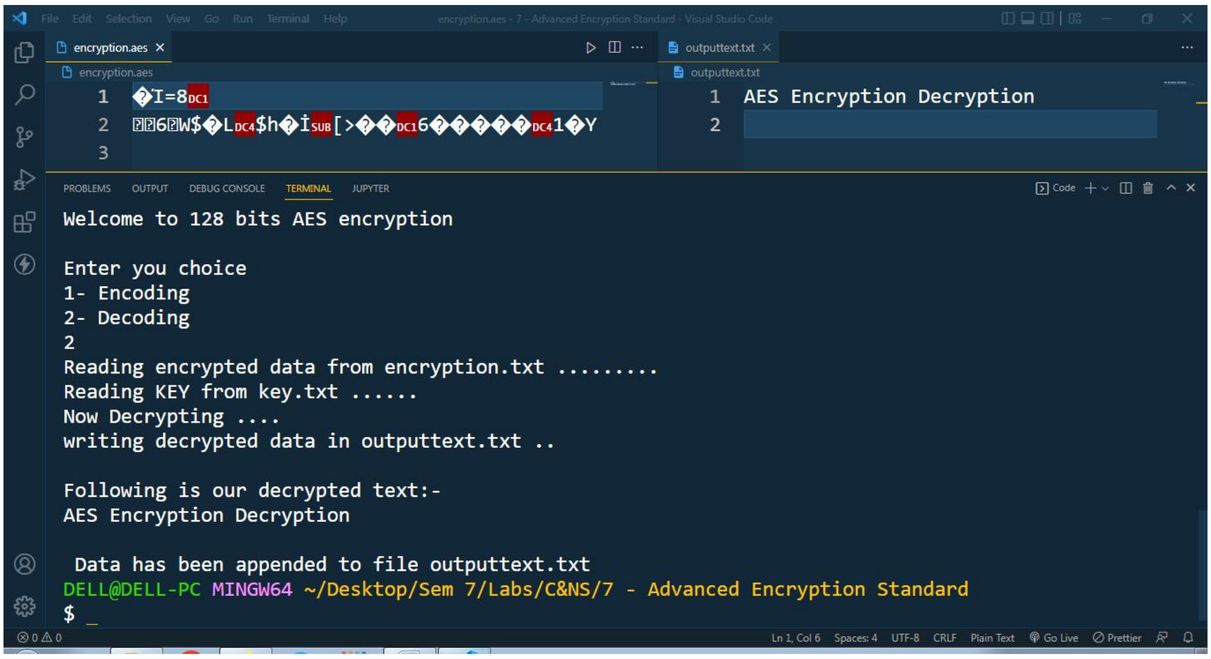
```
AES Encryption Decryption
```

```
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

$ _
```



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

```
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.