Final Year B. Tech., Sem VII 2022-23

Cryptography And Network Security

PRN/ Roll No: 2020BTECS00206

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Assignment No. 7

1. **Aim:**
   To encrypt given plain text using the AES algorithm

2. **Theory:**

The more popular and widely adopted symmetric encryption algorithm likely to be encountered nowadays is the Advanced Encryption Standard (AES). It is found at least six time faster than triple DES.

A replacement for DES was needed as its key size was too small. With increasing computing power, it was considered vulnerable against exhaustive key search attack. Triple DES was designed to overcome this drawback but it was found slow.

The features of AES are as follows −

- Symmetric key symmetric block cipher
- 128-bit data, 128/192/256-bit keys
- Stronger and faster than Triple-DES
- Provide full specification and design details
- Software implementable in C and Java

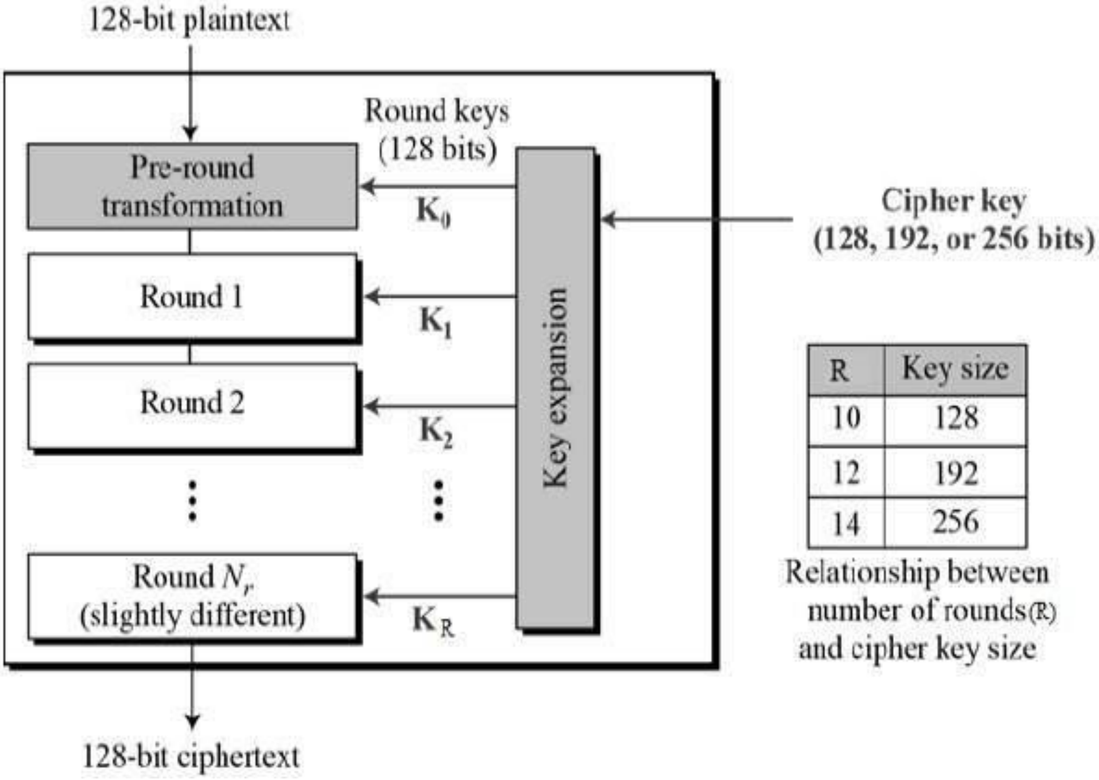
Operation of AES

AES is an iterative rather than Feistel cipher. It is based on 'substitution–permutation network'. It comprises of a series of linked operations, some of which involve replacing inputs by specific outputs (substitutions) and others involve shuffling bits around (permutations).

Interestingly, AES performs all its computations on bytes rather than bits. Hence, AES treats the 128 bits of a plaintext block as 16 bytes. These 16 bytes are arranged in four columns and four rows for processing as a matrix −

Unlike DES, the number of rounds in AES is variable and depends on the length of the key. AES uses 10 rounds for 128-bit keys, 12 rounds for 192-bit keys and 14 rounds for 256-bit keys. Each of these rounds uses a different 128-bit round key, which is calculated from the original AES key.

The schematic of AES structure is given in the following illustration −

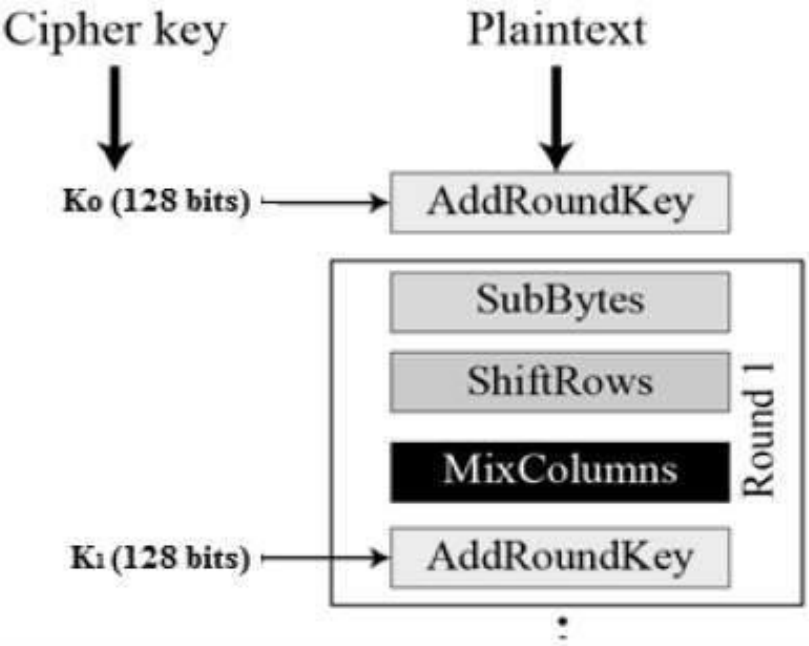


R	Key size
10	128
12	192
14	256

Relationship between number of rounds(R) and cipher key size

Encryption Process

Here, we restrict to description of a typical round of AES encryption. Each round comprise of four sub-processes. The first round process is depicted below −



Byte Substitution (SubBytes)

The 16 input bytes are substituted by looking up a fixed table (S-box) given in design. The result is in a matrix of four rows and four columns.

Shiftrows

Each of the four rows of the matrix is shifted to the left. Any entries that 'fall off' are re-inserted on the right side of row. Shift is carried out as follows −

- First row is not shifted.
- Second row is shifted one (byte) position to the left.
- Third row is shifted two positions to the left.
- Fourth row is shifted three positions to the left.
- The result is a new matrix consisting of the same 16 bytes but shifted with respect to each other.

MixColumns

Each column of four bytes is now transformed using a special mathematical function. This function takes as input the four bytes of one column and outputs four completely new bytes, which replace the original column. The result is another new matrix consisting of 16 new bytes. It should be noted that this step is not performed in the last round.

Addroundkey

The 16 bytes of the matrix are now considered as 128 bits and are XORed to the 128 bits of the round key. If this is the last round then the output is the ciphertext. Otherwise, the resulting 128 bits are interpreted as 16 bytes and we begin another similar round.

Decryption Process

The process of decryption of an AES ciphertext is similar to the encryption process in the reverse order. Each round consists of the four processes conducted in the reverse order −

- Add round key
- Mix columns
- Shift rows
- Byte substitution

Since sub-processes in each round are in reverse manner, unlike for a Feistel Cipher, the encryption and decryption algorithms needs to be separately implemented, although they are very closely related.

3. Code:

```
#include<bits/stdc++.h>

using namespace std;


unsigned char s[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};


// Encryption: Multiply by 2 for MixColumns

unsigned char mul2[] =

    {

        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};


// Encryption: Multiply by 3 for MixColumns

unsigned char mul3[] =

    {

        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};


// Used in KeyExpansion
unsigned char rcon[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};


// Decryption: Inverse Rijndael S-box
unsigned char inv_s[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};


// Decryption: Multiply by 9 for InverseMixColumns

unsigned char mul9[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};


// Decryption: Multiply by 11 for InverseMixColumns

unsigned char mul11[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};


// Decryption: Multiply by 13 for InverseMixColumns

unsigned char mul13[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};
```

```
// Decryption: Multiply by 14 for InverseMixColumns

unsigned char mul14[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};


// Auxiliary function for KeyExpansion
void KeyExpansionCore(unsigned char *in, unsigned char i) {
    // Rotate left by one byte: shift left
    unsigned char t = in[0];
    in[0] = in[1];
    in[1] = in[2];
    in[2] = in[3];
    in[3] = t;

    // S-box 4 bytes
    in[0] = s[in[0]];
    in[1] = s[in[1]];
    in[2] = s[in[2]];
    in[3] = s[in[3]];

    // RCon
    in[0] ^= rcon[i];
}

void KeyExpansion(unsigned char inputKey[16], unsigned char expandedKeys[176]) {
    // The first 128 bits are the original key
    for (int i = 0; i < 16; i++) {
        expandedKeys[i] = inputKey[i];
    }
    int bytesGenerated = 16;  // Bytes we've generated so far
    int rconIteration = 1;    // Keeps track of rcon value
    unsigned char tmpCore[4]; // Temp storage for core

    while (bytesGenerated < 176) {
        /* Read 4 bytes for the core
         * They are the previously generated 4 bytes
         * Initially, these will be the final 4 bytes of the original key
         */
        for (int i = 0; i < 4; i++) {
            tmpCore[i] = expandedKeys[i + bytesGenerated - 4];
        }

        // Perform the core once for each 16 byte key
        if (bytesGenerated % 16 == 0) {
            KeyExpansionCore(tmpCore, rconIteration++);
        }

        for (unsigned char a = 0; a < 4; a++) {
            expandedKeys[bytesGenerated] = expandedKeys[bytesGenerated - 16] ^ tmpCore[a];
            bytesGenerated++;
        }
    }
}

void AddRoundKeyEncrypt(unsigned char *state, unsigned char *roundKey) {
    for (int i = 0; i < 16; i++) {
        state[i] ^= roundKey[i];
    }
}

void SubBytesEncrypt(unsigned char *state) {
    for (int i = 0; i < 16; i++) {
        state[i] = s[state[i]];
    }
}

// Shift left, adds diffusion
void ShiftRowsEncrypt(unsigned char *state) {
    unsigned char tmp[16];

    /* Column 1 */
    tmp[0] = state[0];
    tmp[1] = state[5];
    tmp[2] = state[10];
    tmp[3] = state[15];

    /* Column 2 */
    tmp[4] = state[4];
    tmp[5] = state[9];
    tmp[6] = state[14];
    tmp[7] = state[3];
    /* Column 3 */
    tmp[8] = state[8];
    tmp[9] = state[13];
    tmp[10] = state[2];
    tmp[11] = state[7];

    /* Column 4 */
    tmp[12] = state[12];
    tmp[13] = state[1];
    tmp[14] = state[6];
    tmp[15] = state[11];

    for (int i = 0; i < 16; i++) {
        state[i] = tmp[i];
    }
}

/* MixColumns uses mul2, mul3 look-up tables
 * Source of diffusion
 */
void MixColumns(unsigned char *state) {
    unsigned char tmp[16];

    tmp[0] = (unsigned char)mul2[state[0]] ^ mul3[state[1]] ^ state[2] ^ state[3];
    tmp[1] = (unsigned char)state[0] ^ mul2[state[1]] ^ mul3[state[2]] ^ state[3];
    tmp[2] = (unsigned char)state[0] ^ state[1] ^ mul2[state[2]] ^ mul3[state[3]];
    tmp[3] = (unsigned char)mul3[state[0]] ^ state[1] ^ state[2] ^ mul2[state[3]];
    tmp[4] = (unsigned char)mul2[state[4]] ^ mul3[state[5]] ^ state[6] ^ state[7];
    tmp[5] = (unsigned char)state[4] ^ mul2[state[5]] ^ mul3[state[6]] ^ state[7];
    tmp[6] = (unsigned char)state[4] ^ state[5] ^ mul2[state[6]] ^ mul3[state[7]];
    tmp[7] = (unsigned char)mul3[state[4]] ^ state[5] ^ state[6] ^ mul2[state[7]];

    tmp[8] = (unsigned char)mul2[state[8]] ^ mul3[state[9]] ^ state[10] ^ state[11];
    tmp[9] = (unsigned char)state[8] ^ mul2[state[9]] ^ mul3[state[10]] ^ state[11];
    tmp[10] = (unsigned char)state[8] ^ state[9] ^ mul2[state[10]] ^ mul3[state[11]];
    tmp[11] = (unsigned char)mul3[state[8]] ^ state[9] ^ state[10] ^ mul2[state[11]];

    tmp[12] = (unsigned char)mul2[state[12]] ^ mul3[state[13]] ^ state[14] ^ state[15];
    tmp[13] = (unsigned char)state[12] ^ mul2[state[13]] ^ mul3[state[14]] ^ state[15];
    tmp[14] = (unsigned char)state[12] ^ state[13] ^ mul2[state[14]] ^ mul3[state[15]];
    tmp[15] = (unsigned char)mul3[state[12]] ^ state[13] ^ state[14] ^ mul2[state[15]];

    for (int i = 0; i < 16; i++) {
        state[i] = tmp[i];
    }
}

/* Each round operates on 128 bits at a time
 * The number of rounds is defined in AESEncrypt()
 */
void RoundEncrypt(unsigned char *state, unsigned char *key) {
    SubBytesEncrypt(state);
    ShiftRowsEncrypt(state);
    MixColumns(state);

    AddRoundKeyEncrypt(state, key);

}


void FinalRoundEncrypt(unsigned char *state, unsigned char *key) {

    SubBytesEncrypt(state);

    ShiftRowsEncrypt(state);

    AddRoundKeyEncrypt(state, key);

}


void AESEncrypt(unsigned char *message, unsigned char *expandedKey, unsigned char
*encryptedMessage) {

    unsigned char state[16]; // Stores the first 16 bytes of original message


    for (int i = 0; i < 16; i++) {

        state[i] = message[i];

    }


    int numberOfRounds = 9;


    AddRoundKeyEncrypt(state, expandedKey); // Initial round


    for (int i = 0; i < numberOfRounds; i++) {

        RoundEncrypt(state, expandedKey + (16 * (i + 1)));

    }


    FinalRoundEncrypt(state, expandedKey + 160);
    // Copy encrypted state to buffer
    for (int i = 0; i < 16; i++) {
        encryptedMessage[i] = state[i];
    }
}

// DEcryption
void SubRoundKeyDecrypt(unsigned char *state, unsigned char *roundKey) {
    for (int i = 0; i < 16; i++) {
        state[i] ^= roundKey[i];
    }
}

/* InverseMixColumns uses mul9, mul11, mul13, mul14 look-up tables
 * Unmixes the columns by reversing the effect of MixColumns in encryption
 */
void InverseMixColumnsDecrypt(unsigned char *state) {
    unsigned char tmp[16];

    tmp[0] = (unsigned char)mul14[state[0]] ^ mul11[state[1]] ^ mul13[state[2]] ^ mul9[state[3]];
    tmp[1] = (unsigned char)mul9[state[0]] ^ mul14[state[1]] ^ mul11[state[2]] ^ mul13[state[3]];
    tmp[2] = (unsigned char)mul13[state[0]] ^ mul9[state[1]] ^ mul14[state[2]] ^ mul11[state[3]];
    tmp[3] = (unsigned char)mul11[state[0]] ^ mul13[state[1]] ^ mul9[state[2]] ^ mul14[state[3]];
    tmp[4] = (unsigned char)mul14[state[4]] ^ mul11[state[5]] ^ mul13[state[6]] ^ mul9[state[7]];
    tmp[5] = (unsigned char)mul9[state[4]] ^ mul14[state[5]] ^ mul11[state[6]] ^ mul13[state[7]];
    tmp[6] = (unsigned char)mul13[state[4]] ^ mul9[state[5]] ^ mul14[state[6]] ^ mul11[state[7]];
    tmp[7] = (unsigned char)mul11[state[4]] ^ mul13[state[5]] ^ mul9[state[6]] ^ mul14[state[7]];

    tmp[8] = (unsigned char)mul14[state[8]] ^ mul11[state[9]] ^ mul13[state[10]] ^ mul9[state[11]];
    tmp[9] = (unsigned char)mul9[state[8]] ^ mul14[state[9]] ^ mul11[state[10]] ^ mul13[state[11]];
    tmp[10] = (unsigned char)mul13[state[8]] ^ mul9[state[9]] ^ mul14[state[10]] ^ mul11[state[11]];
    tmp[11] = (unsigned char)mul11[state[8]] ^ mul13[state[9]] ^ mul9[state[10]] ^ mul14[state[11]];

    tmp[12] = (unsigned char)mul14[state[12]] ^ mul11[state[13]] ^ mul13[state[14]] ^ mul9[state[15]];
    tmp[13] = (unsigned char)mul9[state[12]] ^ mul14[state[13]] ^ mul11[state[14]] ^ mul13[state[15]];
    tmp[14] = (unsigned char)mul13[state[12]] ^ mul9[state[13]] ^ mul14[state[14]] ^ mul11[state[15]];
    tmp[15] = (unsigned char)mul11[state[12]] ^ mul13[state[13]] ^ mul9[state[14]] ^ mul14[state[15]];

    for (int i = 0; i < 16; i++) {
        state[i] = tmp[i];
    }
}
```

```
// Shifts rows right (rather than left) for decryption
void ShiftRowsDecrypt(unsigned char *state) {
    unsigned char tmp[16];

    /* Column 1 */
    tmp[0] = state[0];
    tmp[1] = state[13];
    tmp[2] = state[10];
    tmp[3] = state[7];

    /* Column 2 */
    tmp[4] = state[4];
    tmp[5] = state[1];
    tmp[6] = state[14];
    tmp[7] = state[11];

    /* Column 3 */
    tmp[8] = state[8];
    tmp[9] = state[5];
    tmp[10] = state[2];
    tmp[11] = state[15];

    /* Column 4 */
    tmp[12] = state[12];
    tmp[13] = state[9];
    tmp[14] = state[6];
    tmp[15] = state[3];

    for (int i = 0; i < 16; i++) {
        state[i] = tmp[i];
    }
}

/* Perform substitution to each of the 16 bytes
 * Uses inverse S-box as lookup table
 */
void SubBytesDecrypt(unsigned char *state) {
    for (int i = 0; i < 16; i++) { // Perform substitution to each of the 16 bytes
        state[i] = inv_s[state[i]];
    }
}

/* Each round operates on 128 bits at a time
 * The number of rounds is defined in AESDecrypt()
 * Not surprisingly, the steps are the encryption steps but reversed
 */
void RoundDecrypt(unsigned char *state, unsigned char *key) {
    SubRoundKeyDecrypt(state, key);
    InverseMixColumnsDecrypt(state);
    ShiftRowsDecrypt(state);
    SubBytesDecrypt(state);
}
```

```
// Same as RoundDecrypt() but no InverseMixColumns
void InitialRoundDecrypt(unsigned char *state, unsigned char *key) {
    SubRoundKeyDecrypt(state, key);
    ShiftRowsDecrypt(state);
    SubBytesDecrypt(state);
}

/* The AES decryption function
 * Organizes all the decryption steps into one function
 */
void AESDecrypt(unsigned char *encryptedMessage, unsigned char *expandedKey, unsigned char *decryptedMessage) {
    unsigned char state[16]; // Stores the first 16 bytes of encrypted message

    for (int i = 0; i < 16; i++) {
        state[i] = encryptedMessage[i];
    }

    InitialRoundDecrypt(state, expandedKey + 160);

    int numberOfRounds = 9;

    for (int i = 8; i >= 0; i--) {
        RoundDecrypt(state, expandedKey + (16 * (i + 1)));
    }

    SubRoundKeyDecrypt(state, expandedKey); // Final round
    // Copy decrypted state to buffer
    for (int i = 0; i < 16; i++) {
        decryptedMessage[i] = state[i];
    }
}

int main() {

    cout << "AES Algorithm" << endl;
    cout << "Enter 1 for encryption \n 2 for decryption" << endl;
    int choice;
    cin >> choice;
    if (choice == 1) {
        char message[1024];

        cout << "Enter the message to encrypt: ";
        cin.getline(message, sizeof(message));
        cout << message << endl;

        // Pad message to 16 bytes
        int originalLen = strlen((const char *)message);

        int paddedMessageLen = originalLen;

        if ((paddedMessageLen % 16) != 0) {
            paddedMessageLen = (paddedMessageLen / 16 + 1) * 16;
        }

        unsigned char *paddedMessage = new unsigned char[paddedMessageLen];
        for (int i = 0; i < paddedMessageLen; i++) {
            if (i >= originalLen) {
                paddedMessage[i] = 0;
            } else {
                paddedMessage[i] = message[i];
            }
        }

        unsigned char *encryptedMessage = new unsigned char[paddedMessageLen];

        string str;
        ifstream infile;
        infile.open("keyfile", ios::in | ios::binary);

        if (infile.is_open()) {
            getline(infile, str); // The first line of file should be the key
            infile.close();
        }

        else
            cout << "Unable to open file";

        istringstream hex_chars_stream(str);
        unsigned char key[16];
```

```
int i = 0;
unsigned int c;
while (hex_chars_stream >> hex >> c) {
    key[i] = c;
    i++;
}

unsigned char expandedKey[176];

KeyExpansion(key, expandedKey);

for (int i = 0; i < paddedMessageLen; i += 16) {
    AESEncrypt(paddedMessage + i, expandedKey, encryptedMessage + i);
}

cout << "Encrypted message in hex:" << endl;
for (int i = 0; i < paddedMessageLen; i++) {
    cout << hex << (int)encryptedMessage[i];
    cout << " ";
}

cout << endl;

// Write the encrypted string out to file "message.aes"
ofstream outfile;
outfile.open("message.aes", ios::out | ios::binary);
if (outfile.is_open()) {
```

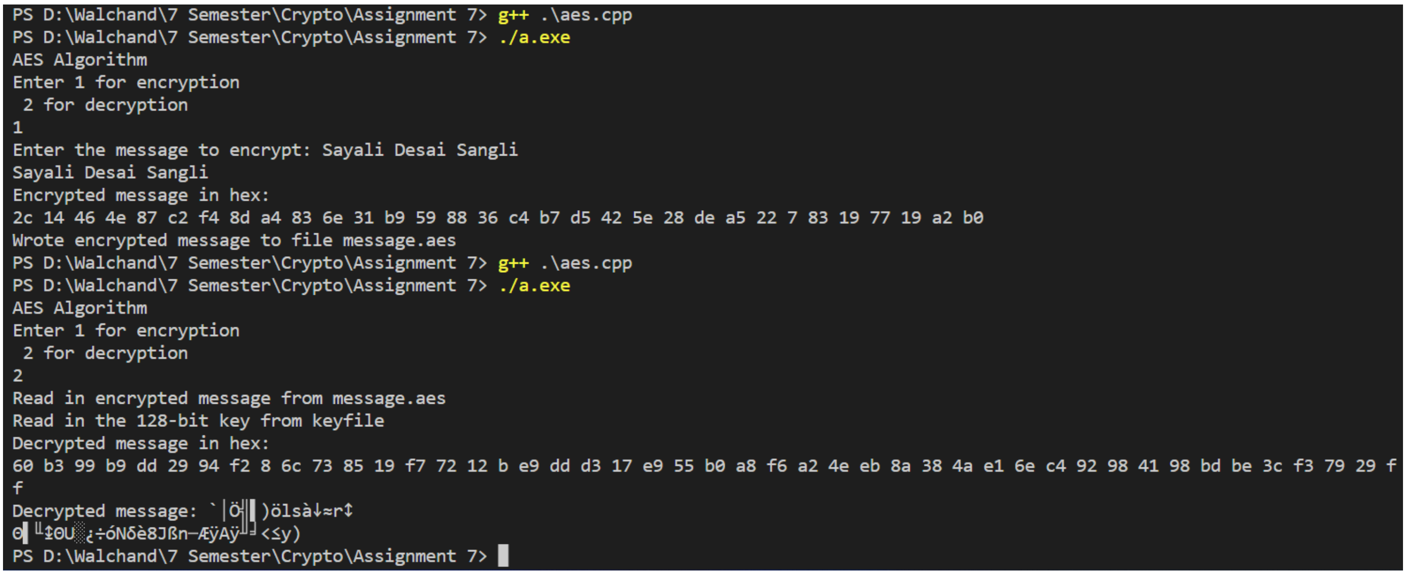
```
            outfile << encryptedMessage;
            outfile.close();
            cout << "Wrote encrypted message to file message.aes" << endl;
        }

        else
            cout << "Unable to open file";

        // Free memory
        delete[] paddedMessage;
        delete[] encryptedMessage;
    } else if (choice == 2) {
        string msgstr;
        ifstream infile;
        infile.open("message.aes", ios::in | ios::binary);

        if (infile.is_open()) {
            getline(infile, msgstr); // The first line of file is the message
            cout << "Read in encrypted message from message.aes" << endl;
            infile.close();
        }

        else
            cout << "Unable to open file";

        char *msg = new char[msgstr.size() + 1];
```

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


int n = strlen((const char *)msg);


unsigned char *encryptedMessage = new unsigned char[n];
for (int i = 0; i < n; i++) {
    encryptedMessage[i] = (unsigned char)msg[i];
}


// Free memory
delete[] msg;


// Read in the key
string keystr;
ifstream keyfile;
keyfile.open("keyfile", ios::in | ios::binary);


if (keyfile.is_open()) {
    getline(keyfile, keystr); // The first line of file should be the key
    cout << "Read in the 128-bit key from keyfile" << endl;
    keyfile.close();
}


else
    cout << "Unable to open file";


istringstream hex_chars_stream(keystr);
```

```
unsigned char key[16];
int i = 0;
unsigned int c;
while (hex_chars_stream >> hex >> c) {
    key[i] = c;
    i++;
}

unsigned char expandedKey[176];

KeyExpansion(key, expandedKey);

int messageLen = strlen((const char *)encryptedMessage);

unsigned char *decryptedMessage = new unsigned char[messageLen];

for (int i = 0; i < messageLen; i += 16) {
    AESDecrypt(encryptedMessage + i, expandedKey, decryptedMessage + i);
}

cout << "Decrypted message in hex:" << endl;
for (int i = 0; i < messageLen; i++) {
    cout << hex << (int)decryptedMessage[i];
    cout << " ";
}
cout << endl;
cout << "Decrypted message: ";
```

```
            for (int i = 0; i < messageLen; i++) {
                cout << decryptedMessage[i];
            }
            cout << endl;
        } else {
            cout << "Invalid choice" << endl;
        }
    }
```

4. Output:



```
PS D:\Walchand\7 Semester\Crypto\Assignment 7> g++ .\aes.cpp
PS D:\Walchand\7 Semester\Crypto\Assignment 7> ./a.exe
AES Algorithm
Enter 1 for encryption
 2 for decryption
1
Enter the message to encrypt: Sayali Desai Sangli
Sayali Desai Sangli
Encrypted message in hex:
2c 14 46 4e 87 c2 f4 8d a4 83 6e 31 b9 59 88 36 c4 b7 d5 42 5e 28 de a5 22 7 83 19 77 19 a2 b0
Wrote encrypted message to file message.aes
PS D:\Walchand\7 Semester\Crypto\Assignment 7> g++ .\aes.cpp
PS D:\Walchand\7 Semester\Crypto\Assignment 7> ./a.exe
AES Algorithm
Enter 1 for encryption
 2 for decryption
2
Read in encrypted message from message.aes
Read in the 128-bit key from keyfile
Decrypted message in hex:
60 b3 99 b9 dd 29 94 f2 8 6c 73 85 19 f7 72 12 b e9 dd d3 17 e9 55 b0 a8 f6 a2 4e eb 8a 38 4a e1 6e c4 92 98 41 98 bd be 3c f3 79 29 f
f
Decrypted message: `│Ö╣▌)ölsà↓≈r↕
Θ▌╚‡ΘU░¿÷óNδè8JßnΓÆÿAÿ╜╛<≤y)
PS D:\Walchand\7 Semester\Crypto\Assignment 7> █
```

5. Conclusion:

Successfully encrypted the given plain text using AES Algorithm.