NETWORK SECURITY AND CRYPTOGRAPHY FUNDAMENTALS

CSE3045

PROJECT REPORT

TITLE: **TEXT ENCRYPTION USING AES ALGORITHM**

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ABSTRACT

Advanced Encryption Standard (AES) algorithm is one of the most common and widely used symmetric block cipher algorithm. This algorithm has its own structure to encrypt and decrypt sensitive data and is applied in hardware and software all over the world. It is extremely difficult for hackers to get the real data when we encrypt using the AES algorithm. To date, there is no evidence to crack this algorithm. AES has the ability to deal with three different key sizes such as AES 128-bit, 192-bit, and 256-bit, and each of these ciphers has a 128-bit block size. In this paper, a text message is given as an input to the AES encryption algorithm which gives an encrypted output. This paper also provides an overview of the AES algorithm.

INTRODUCTION

Internet communication is playing an important role to transfer a large amount of data in various fields. Some of the data might be transmitted through an insecure channel from sender to receiver. Different techniques and methods are being used by private and public sectors to protect sensitive data from intruders because the security of electronic data is a crucial issue. Cryptography is one of the most significant and popular techniques to secure the data from attackers by using two vital processes (ie) Encryption and Decryption. Encryption is the process of encoding data to prevent intruders from reading the original data easily. This stage has the ability to convert the original data (Plaintext) into an unreadable format known as Ciphertext. Decryption is contrary to encryption. It is the process to convert ciphertext into plain text without missing any words in the original text. Encryption is done by the person who is sending the data to the destination, but the decryption is done by the person who is receiving the data. To perform these processes cryptography relies on mathematical calculations along with some substitutions and permutations with or without a key.

Modern cryptography provides confidentiality, integrity, non-repudiation, and authentication. These days, there are several algorithms available to encrypt and decrypt sensitive data which are typically divided into three types. The first one is symmetric cryptography where the same key is used for encryption and decryption of data. The second one is Asymmetric cryptography. This type of cryptography relies on two different keys for encryption and decryption. Finally, the cryptographic hash function which does not need any key and operates in a one-way manner.

The symmetric key is much more effective and faster than Asymmetric. Some of the common symmetric algorithms used is Advanced Encryption Standard (AES), Blowfish, Simplified Data Encryption Standard (S-DES), and 3-DES. The main purpose of this paper is to provide detailed information about Advanced Encryption Standard (AES) algorithm for encryption.

MODULE DESCRIPTION

AES algorithm is of three types i.e. AES-128, AES-192, and AES-256. This classification is done on the basis of the key used in the algorithm for the encryption and the decryption process. The numbers represent the size of the key in bits. This key size determines the security level as the size of the key increases the level of security increases. The AES algorithm uses a round function that is composed of four different byte-oriented transformations.

Each round comprises of 4 steps:

Substitute byte transformation

Shift rows transformation

Mix columns transformation

Add round key transformation

The last round does not have the Mix columns transformation round.

The Substitute byte transformation does the substitution and Shift rows transformation does left shift by 1 byte and Mix columns transformation performs the permutation in the algorithm.

Key Expansion

The AES algorithm takes the Cipher Key, K, and performs a Key Expansion routine to generate a key schedule.

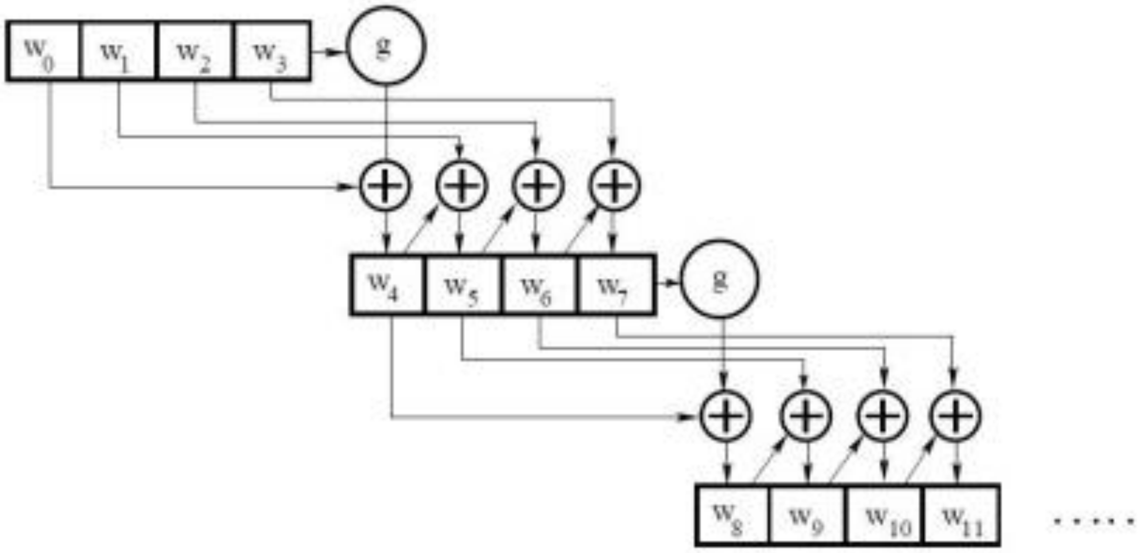
The Key Expansion generates a total of Nb (Nr + 1) words: the algorithm requires an initial set of Nb words, and each of the Nr rounds requires Nb words of key data.

Key Expansion includes the following functions :

RotWord : Takes a word [a0,a1,a2,a3] as input , performs a cyclic permutation, and returns the word [a1,a2,a3,a0]

SubWord : is a function that take a 4-bytes input word and applies the S-box to each of the four bytes to produce and output word.

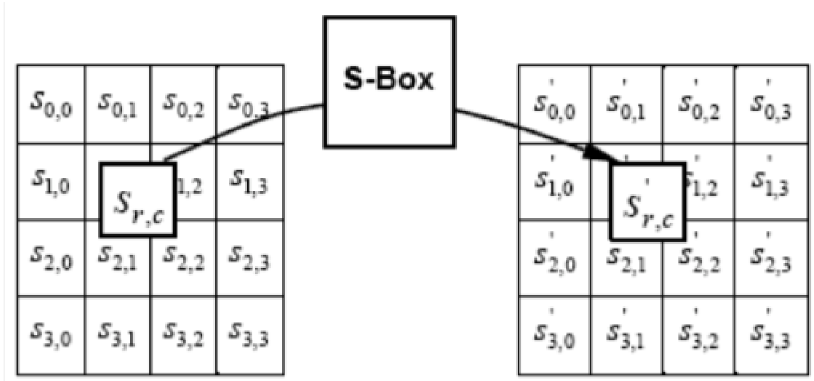
Rcon[i/NK] : contains the values given by [xi-1,{00},{00},{00}], with xi-1 being powers of x (x is denoted as{02}) in the field GF(28).



Substitute Byte Transformation

The byte substitution step consists of replacing each of the 16 bytes in our state matrix (the input) with a byte from a fixed lookup table called an S-box

		y															
		0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f
x	0	63	7c	77	7b	f2	6b	6f	c5	30	01	67	2b	fe	d7	ab	76
	1	ca	82	c9	7d	fa	59	47	f0	ad	d4	a2	af	9c	a4	72	c0
	2	b7	fd	93	26	36	3f	f7	cc	34	a5	e5	f1	71	d8	31	15
	3	04	c7	23	c3	18	96	05	9a	07	12	80	e2	eb	27	b2	75
	4	09	83	2c	1a	1b	6e	5a	a0	52	3b	d6	b3	29	e3	2f	84
	5	53	d1	00	ed	20	fc	b1	5b	6a	cb	be	39	4a	4c	58	cf
	6	d0	ef	aa	fb	43	4d	33	85	45	f9	02	7f	50	3c	9f	a8
	7	51	a3	40	8f	92	9d	38	f5	bc	b6	da	21	10	ff	f3	d2
	8	cd	0c	13	ec	5f	97	44	17	c4	a7	7e	3d	64	5d	19	73
	9	60	81	4f	dc	22	2a	90	88	46	ee	b8	14	de	5e	0b	db
	a	e0	32	3a	0a	49	06	24	5c	c2	d3	ac	62	91	95	e4	79
	b	e7	c8	37	6d	8d	d5	4e	a9	6c	56	f4	ea	65	7a	ae	08
	c	ba	78	25	2e	1c	a6	b4	c6	e8	dd	74	1f	4b	bd	8b	8a
	d	70	3e	b5	66	48	03	f6	0e	61	35	57	b9	86	c1	1d	9e
	e	e1	f8	98	11	69	d9	8e	94	9b	1e	87	e9	ce	55	28	df
	f	8c	a1	89	0d	bf	e6	42	68	41	99	2d	0f	b0	54	bb	16

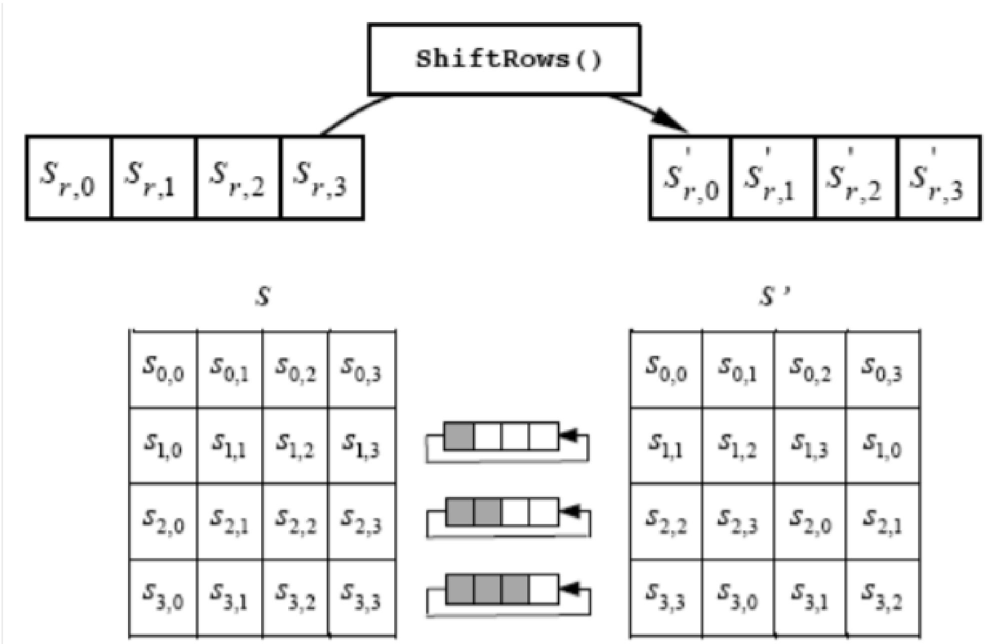


Shift Rows Transformation

Each of the four rows of the matrix is shifted to the left.

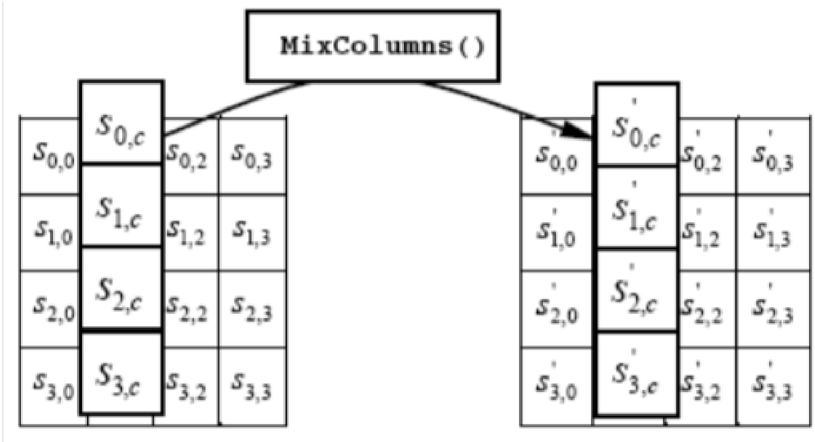
Shift is carried out as follows:

- 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.



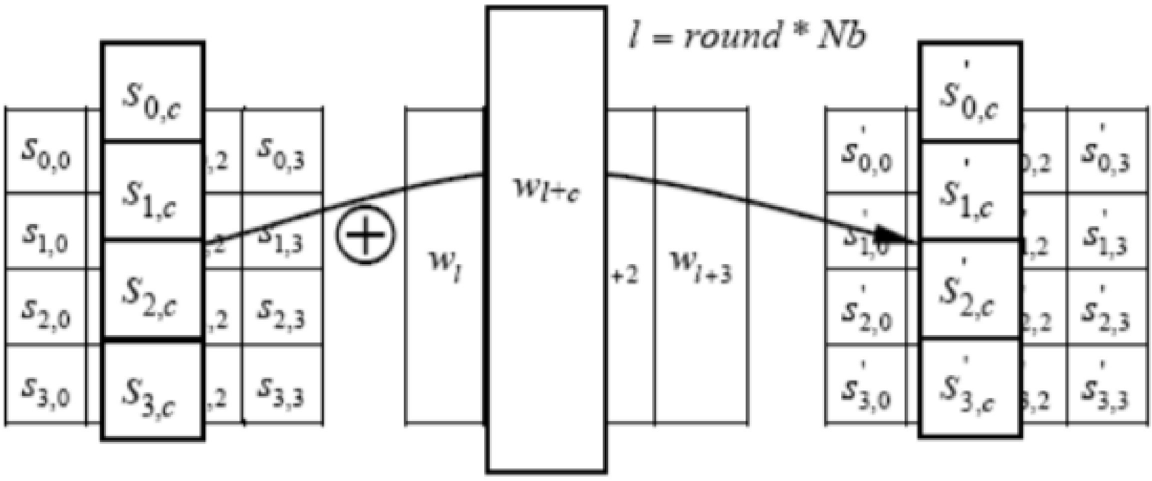
Mix Columns Transformation

This step is basically a matrix multiplication. Each column is multiplied with a specific matrix and thus the position of each byte in the column is changed as a result. It multiplies a constant matrix with each column in the state array to get a new column for the subsequent state array. Once all the columns are multiplied with the same constant matrix, you get your state array for the next step. This particular step is not to be done in the last round.



Add Round Key Transformation

The AddRoundKey operation is the only phase of AES encryption that directly operates on the AES round key. In this operation, the input to the round is XORed with the round key. 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.



SOFTWARE USED:

Jupyter notebook

Jupyter Notebook is a web-based interactive computational environment for creating notebook documents.

LIBRARIES USED:

Tkinter

Tkinter is Python's de-facto standard GUI (Graphical User Interface) package. This framework provides a simple way to create GUI elements using the widgets found in the Tk toolkit.

SOURCE CODE:

Importing tkinter module for GUI creation

```
from tkinter import *
import tkinter as tk
```

'keyExpansion' function :

It produces new 128-bit round keys with the help of Rijndael's key schedule.

The key-expansion routine creates round keys word by word,
where every word is an array of four bytes.

```
def keyExpansion(key,numround,rci,s_box):
    round_const = rci[numround-1]
    gw3 = [key[3][1],key[3][2],key[3][3],key[3][0]] #rotword: lift shift by 1 byte
    for i in range(4):
        u = hex(s_box[int(gw3[i][2],16)][int(gw3[i][3],16)]) #sub_word using s_box
        if(u == "0x0"):
            u = "0x00"
        elif(len(u.lstrip("0x"))<=1):
            u = "0x0"+u.lstrip("0x")
        gw3[i] = u
    a = 1
    b = 1
    if(gw3[0] == "0x00" or gw3[0] == "0x0"):
        a = 0
    else:
        a = int(gw3[0].lstrip("0x"),16)
    x = hex(int(a^int(round_const.lstrip("0x"),16)))
    if(x == "0x0"):
        x = "0x00"
    elif(len(x.lstrip("0x"))<=1):
        x = "0x0"+x.lstrip("0x")
    gw3[0] = x
    w4 = []
    for i in range(4):
        r = 1
        p = 1
        if(gw3[i] == "0x00" or gw3[i] == "0x0"):
            r = 0
        else:
            r = int(gw3[i].lstrip("0x"),16)
        if(key[0][i] == "0x00" or key[0][i] == "0x0"):
            p = 0
        else:
            p = int(key[0][i].lstrip("0x"),16)
        y = hex(r^p)
        if(y == "0x0"):
            y = "0x00"
        elif(len(y.lstrip("0x")) <= 1):
            y = "0x0"+y.lstrip("0x")
        w4.append(y)
```

```
    w5 = []
    w6 = []
    w7 = []
    for i in range(4):
        r = 1
        p = 1
        if(w4[i] == "0x00" or w4[i] == "0x0"):
            r = 0
        else:
            r = int(w4[i].lstrip("0x"),16)
        if(key[1][i] == "0x00" or key[1][i] == "0x0"):
            p = 0
        else:
            p = int(key[1][i].lstrip("0x"),16)
        y = hex(r^p)
        if(y == "0x0"):
            y = "0x00"
        elif(len(y.lstrip("0x")) <= 1):
            y = "0x0"+y.lstrip("0x")
        w5.append(y)
    for i in range(4):
        r = 1
        p = 1
        if(w5[i] == "0x00" or w5[i] == "0x0"):
            r = 0
        else:
            r = int(w5[i].lstrip("0x"),16)
        if(key[2][i] == "0x00" or key[2][i] == "0x0"):
            p = 0
        else:
            p = int(key[2][i].lstrip("0x"),16)
        y = hex(r^p)
        if(y == "0x0"):
            y = "0x00"
        elif(len(y.lstrip("0x")) <= 1):
            y = "0x0"+y.lstrip("0x")
        w6.append(y)
    for i in range(4):
        r = 1
        p = 1
        if(w6[i] == "0x00" or w6[i] == "0x0"):
            r = 0
        else:
            r = int(w6[i].lstrip("0x"),16)
        if(key[3][i] == "0x00" or key[3][i] == "0x0"):
            p = 0
        else:
            p = int(key[3][i].lstrip("0x"),16)
        y = hex(r^p)
        if(y == "0x0"):
            y = "0x00"
        elif(len(y.lstrip("0x")) <= 1):
            y = "0x0"+y.lstrip("0x")
        w7.append(y)
    return [w4,w5,w6,w7]
```

'addRoundKey' Function:

It takes 2 arguments plain text and round key.

It performs XOR between the plain Text and Round key and
returns the plain Text for the next round.

```
def addRoundKey(pt,rk):

    for i in range(4):
        for j in range(4):
            x = 0
            y = 0
            if(pt[j][i] != "0x00"):
                x = int(pt[j][i].lstrip('0x'),16)
            if(rk[j][i] != "0x00"):
                y = int(rk[j][i].lstrip('0x'),16)
            z = hex(x^y)
            if(z == "0x0"):
                z = "0x00"
            elif(len(z.lstrip("0x")) <= 1):
                z = "0x0"+z.lstrip("0x")
            pt[j][i] = z
    return pt
```

'substitute' Function:

The byte substitution replaces each of the 16 bytes in our state matrix (the input)
with a byte from a fixed lookup table called an S-box

```
def substitute(pt,s_box):
    for i in range(4):
        for j in range(4):
            u = hex(s_box[int(pt[i][j][2],16)][int(pt[i][j][3],16)])
            if(u == "0x0"):
                u = "0x00"
            elif(len(u.lstrip("0x"))<=1):
                u = "0x0"+u.lstrip("0x")
            pt[i][j] = u
    return pt
```

In the 'shiftrows' Function:

Each of the rows from plaintext is shifted to the left by a set amount:
Their row number starting with zero.

The top row is not shifted at all, the next row is shifted by one and so on.

```
def shiftRow(pt):
    pt[0][1],pt[1][1],pt[2][1],pt[3][1] = pt[1][1],pt[2][1],pt[3][1],pt[0][1]
    pt[0][2],pt[1][2],pt[2][2],pt[3][2] = pt[2][2],pt[3][2],pt[0][2],pt[1][2]
    pt[0][3],pt[1][3],pt[2][3],pt[3][3] = pt[3][3],pt[0][3],pt[1][3],pt[2][3]
    return pt
```

In 'mixMulCol' function:

Each column is multiplied with a specific matrix and thus the position of each byte in the column is changed as a result.

Once all the columns are multiplied with the same constant matrix, you get your state array for the next step.

This particular step is not to be done in the last round.

```
def mixMulCol(col,mul2,mul3):
    temp = []
    i = mul2[int(col[0][2],16)][int(col[0][3],16)]
    j = mul3[int(col[1][2],16)][int(col[1][3],16)]
    k = int(col[2],16)
    l = int(col[3],16)
    m = hex(i^j^k^l)
    if(m == "0x0"):
        m = "0x00"
    elif(len(m.lstrip("0x")) <= 1):
        m = "0x0"+m.lstrip("0x")
    temp.append(m) #d0

    i = int(col[0],16)
    j = mul2[int(col[1][2],16)][int(col[1][3],16)]
    k = mul3[int(col[2][2],16)][int(col[2][3],16)]
    l = int(col[3],16)
    m = hex(i^j^k^l)
    if(m == "0x0"):
        m = "0x00"
    elif(len(m.lstrip("0x")) <= 1):
        m = "0x0"+m.lstrip("0x")
    temp.append(m) #d1

    i = int(col[0],16)
    j = int(col[1],16)
    k = mul2[int(col[2][2],16)][int(col[2][3],16)]
    l = mul3[int(col[3][2],16)][int(col[3][3],16)]
    m = hex(i^j^k^l)
    if(m == "0x0"):
        m = "0x00"
    elif(len(m.lstrip("0x")) <= 1):
        m = "0x0"+m.lstrip("0x")
    temp.append(m) #d2

    i = mul3[int(col[0][2],16)][int(col[0][3],16)]
    j = int(col[1],16)
    k = int(col[2],16)
    l = mul2[int(col[3][2],16)][int(col[3][3],16)]
    m = hex(i^j^k^l)
    if(m == "0x0"):
        m = "0x00"
    elif(len(m.lstrip("0x")) <= 1):
        m = "0x0"+m.lstrip("0x")
    temp.append(m) #d3
    return temp
```

The 'mixCol' function takes each row from the Plaint Text.

It calls the 'mixMulCol' function by passing row as temp variable, along with the predefined lookup tables mul2 and mul3.

```python
def mixCol(mul2,mul3,pt):
    res = []

    for i in range(4):
        temp = []
        temp.append(pt[i][0])
        temp.append(pt[i][1])
        temp.append(pt[i][2])
        temp.append(pt[i][3])

        res.append(mixMulCol(temp,mul2,mul3))
    return res
```

```python
s_box =[
[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]]

rci =   ["0x01","0x02","0x04","0x08","0x10","0x20","0x40","0x80","0x1B","0x36"]

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]]

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]]
```

'printCipher' function prints cipher text

```
def printCipher(m):
    for i in range(4):
        for j in range(4):
            y = m[i][j]
            if(y == "0x00"):
                y = "00"
            elif(len(y.lstrip("0x")) <= 1):
                y = "0"+y.lstrip("0x")
            else:
                y = y.lstrip("0x")
            print(y.upper(),end=" ")
    print(" ")
```

'pad' Function takes the entry value, checks for the length if it's not 16.
We use a special character '[' to pad and later added it to the entry.
It returns the padded 'entry'

```
def pad(entry):
    if(len(entry)==16):
        return(entry)
    else:
        padded = entry + (16-len(entry)%16)* '['
        return(padded)
```

```
root=tk.Tk()
root.geometry("600x400")
root['bg']='lightblue2'
```

Declaring string variable for storing plaintext and key.

```
plainText_var = tk.StringVar()
key_var = tk.StringVar()
```

Defining a function 'submit' that will get the plaintext and key and display the cipher text.
It calls the other functions in AES process to convert the plaintext to ciphertext.

```
def submit():

    plainText=plainText_var.get()
    plainText= pad(plainText)
    plainText=plainText.encode('UTF-8')

    key= key_var.get()
    key = pad(key)
    key = key.encode('UTF-8')

    plainText_var.set("")
    key_var.set("")

    initialState = []
    initialKey = []
    finalState = []
    total = 0
    for i in range(4):
        temp = []
        temp1 = []
        temp2 = []
        for j in range(4):
            temp2.append(hex(plainText[total]))
            temp.append(hex(plainText[total]))
            temp1.append(hex((key[total])))
            total+=1
        initialState.append(temp)
        initialKey.append(temp1)
        finalState.append(temp2)

    print('PLAIN TEXT:',plainText)
    print('Length of the plain text:',len(plainText))
    print('KEY:',key)
    print('Length of the Key:',len(key))

    initialState = addRoundKey(initialState,initialKey)
    for i in range(1,11):
        initialKey = keyExpansion(initialKey,i,rci,s_box)
        initialState = substitute(initialState,s_box)
        initialState = shiftRow(initialState)

        if(i!=10):
            initialState = mixCol(mul2,mul3,initialState)

        initialState = addRoundKey(initialState,initialKey)

    print("\nOriginal Message")
    printCipher(finalState)
    print("\nThe cipher text is")
    printCipher(initialState)

    message.configure(text=initialState)
```

```
sub_btn=tk.Button(root,text = 'Submit', command = submit,fg="white", bg="tomato",
                  activebackground="pink")

text_label = tk.Label(root, text = 'Plaintext',width = 7,bg="floral white",
                      fg="light salmon",font=('arial',16, 'bold'))

text_entry = tk.Entry(root,textvariable = plainText_var, bg="azure",
                      fg="DodgerBlue4",font=('arial',16,'normal'))

key_label = tk.Label(root, text = 'Key',width =7, bg="floral white",
                     fg="light salmon", font = ('arial',16,'bold'))

key_entry=tk.Entry(root, textvariable = key_var, bg="azure", fg="DodgerBlue4",
                      font = ('arial',16,'normal'))

final_label = tk.Label(root, text = 'Cipher text',bg="floral white",fg="light salmon",
                      font=('arial',16, 'bold'))

message = tk.Label(root, text="" ,bg="azure"  ,fg="DodgerBlue4"  ,width=75  ,height=4 ,
                      font=('arial', 15, ' bold '))

text_label.grid(row=0, column=0)
text_entry.grid(row=0, column=1)
key_label.grid(row=1, column=0)
key_entry.grid(row=1, column=1)
final_label.grid(row=5, column=1)
message.grid(row=5, column=2)
sub_btn.grid(row=2, column=1)

root.title('AES Text Encryption')
root.mainloop()
```

```
PLAIN TEXT: b'network security'
Length of the plain text: 16
KEY: b'1234567812345678'
Length of the Key: 16

Original Message
6E 65 74 77 6F 72 6B 20 73 65 63 75 72 69 74 79

The cipher text is
76 FC E9 0E 80 CB 57 26 D3 0D AC 17 5C 24 B2 75
```

OUTPUT

By entering the plaintext along with the key and clicking on submit in the GUI, we get the encrypted plain text.

CONCLUSION

As you can see the required cipher text is seen, hence we can say the encryption was successful. The Advanced Encryption Technique was implemented successfully using 'Python' language. Various data messages were encrypted using different keys and varying key sizes. The modifications brought about in the code was tested and proved to be accurately encrypting the data messages with even higher security and immunity against the unauthorized users.

REFERENCES

https://csrc.nist.gov/csrc/media/projects/cryptographic-standards-and-guidelines/documents/aes-development/rijndael-ammended.pdf

https://crypto.stackexchange.com/questions/24814/affine-transformation-in-aes-matrix-representation

https://www.commonlounge.com/discussion/e32fdd267aaa4240a4464723bc74d0a5

https://engineering.purdue.edu/kak/compsec/NewLectures/Lecture8.pdf

https://www.password-depot.de/en/know-how/blowfish-and-rijndael.htm

https://www.techtarget.com/searchsecurity/definition/Rijndael

https://blog.finjan.com/rijndael-encryption-algorithm/