Network Security Practical Assignment-2

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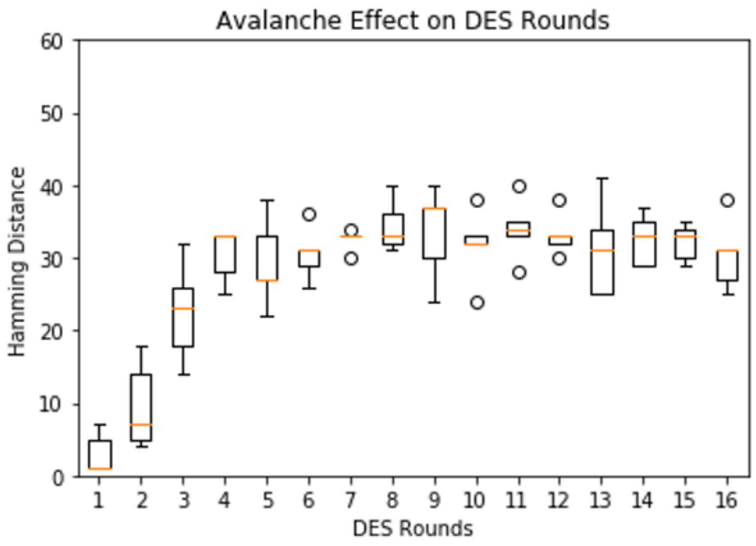
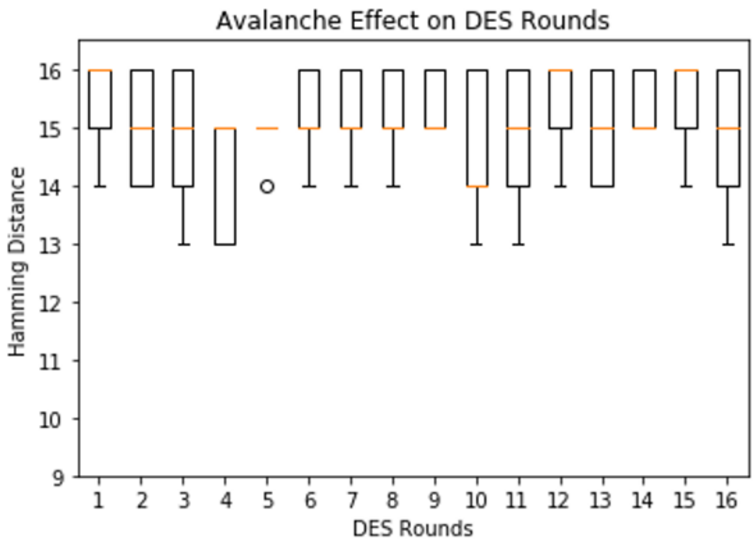
Github Link -
https://github.com/kshitij858/Network-Security/tree/main/Practical%20Assignment%202


Avalanche Effect on DES Rounds
Hamming Distance
DES Rounds


Avalanche Effect on DES Rounds
Hamming Distance
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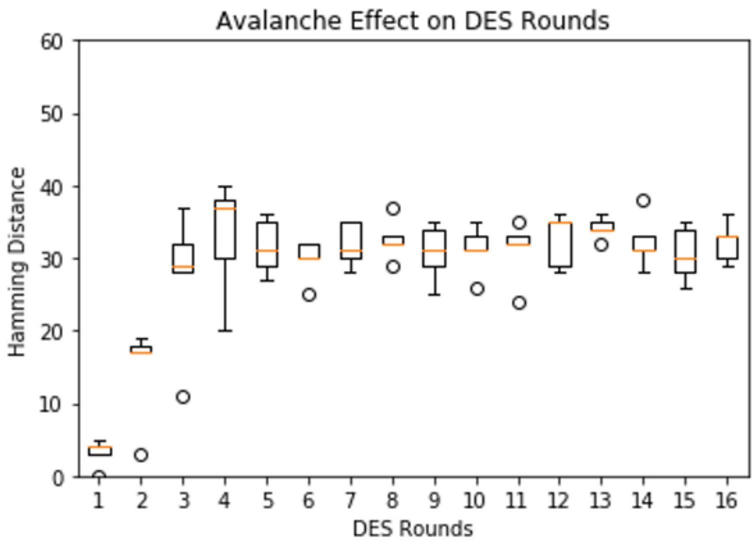
Avalanche Effect on DES Rounds
Hamming Distance
DES Rounds

Code for problem 1:

```
import matplotlib.pyplot as plt

def hex2bin(s):
      mp = {'0' : "0000",
            '1' : "0001",
            '2' : "0010",
            '3' : "0011",
            '4' : "0100",
            '5' : "0101",
            '6' : "0110",
            '7' : "0111",
            '8' : "1000",
            '9' : "1001",
            'A' : "1010",
            'B' : "1011",
            'C' : "1100",
            'D' : "1101",
            'E' : "1110",
            'F' : "1111" }
      bin = ""
      for i in range(len(s)):
            bin = bin + mp[s[i]]
      return bin

def bin2hex(s):
      mp = {"0000" : '0',
            "0001" : '1',
            "0010" : '2',
            "0011" : '3',
            "0100" : '4',
            "0101" : '5',
            "0110" : '6',
            "0111" : '7',
            "1000" : '8',
            "1001" : '9',
            "1010" : 'A',
            "1011" : 'B',
            "1100" : 'C',
            "1101" : 'D',
            "1110" : 'E',
            "1111" : 'F' }
```

```python
    hex = ""
    for i in range(0,len(s),4):
        ch = ""
        ch = ch + s[i]
        ch = ch + s[i + 1]
        ch = ch + s[i + 2]
        ch = ch + s[i + 3]
        hex = hex + mp[ch]

    return hex


def bin2dec(binary):

    binary1 = binary
    decimal, i, n = 0, 0, 0
    while(binary != 0):
        dec = binary % 10
        decimal = decimal + dec * pow(2, i)
        binary = binary//10
        i += 1
    return decimal


def dec2bin(num):
    res = bin(num).replace("0b", "")
    if(len(res)%4 != 0):
        div = len(res) / 4
        div = int(div)
        counter =(4 * (div + 1)) - len(res)
        for i in range(0, counter):
            res = '0' + res
    return res


def permute(k, arr, n):
    permutation = ""
    for i in range(0, n):
        permutation = permutation + k[arr[i] - 1]
    return permutation


def shift_left(k, nth_shifts):
        s = ""
        for i in range(nth_shifts):
              for j in range(1,len(k)):
                    s = s + k[j]
              s = s + k[0]
              k = s
              s = ""
        return k


def xor(a, b):
        ans = ""
        for i in range(len(a)):
              if a[i] == b[i]:
                    ans = ans + "0"
              else:
                    ans = ans + "1"
        return ans


initial_perm = [58, 50, 42, 34, 26, 18, 10, 2,
                        60, 52, 44, 36, 28, 20, 12, 4,
                        62, 54, 46, 38, 30, 22, 14, 6,
                        64, 56, 48, 40, 32, 24, 16, 8,
                        57, 49, 41, 33, 25, 17, 9, 1,
                        59, 51, 43, 35, 27, 19, 11, 3,
                        61, 53, 45, 37, 29, 21, 13, 5,
                        63, 55, 47, 39, 31, 23, 15, 7]


exp_d = [32, 1 , 2 , 3 , 4 , 5 , 4 , 5,
            6 , 7 , 8 , 9 , 8 , 9 , 10, 11,
            12, 13, 12, 13, 14, 15, 16, 17,
            16, 17, 18, 19, 20, 21, 20, 21,
            22, 23, 24, 25, 24, 25, 26, 27,
            28, 29, 28, 29, 30, 31, 32, 1 ]


per = [ 16, 7, 20, 21,
            29, 12, 28, 17,
            1, 15, 23, 26,
            5, 18, 31, 10,
            2, 8, 24, 14,
          32, 27, 3, 9,
          19, 13, 30, 6,
          22, 11, 4, 25 ]


sbox = [[[14, 4, 13, 1, 2, 15, 11, 8, 3, 10, 6, 12, 5, 9, 0, 7],
          [ 0, 15, 7, 4, 14, 2, 13, 1, 10, 6, 12, 11, 9, 5, 3, 8],
          [ 4, 1, 14, 8, 13, 6, 2, 11, 15, 12, 9, 7, 3, 10, 5, 0],
          [15, 12, 8, 2, 4, 9, 1, 7, 5, 11, 3, 14, 10, 0, 6, 13 ]],

          [[15, 1, 8, 14, 6, 11, 3, 4, 9, 7, 2, 13, 12, 0, 5, 10],
                [3, 13, 4, 7, 15, 2, 8, 14, 12, 0, 1, 10, 6, 9, 11, 5],
                [0, 14, 7, 11, 10, 4, 13, 1, 5, 8, 12, 6, 9, 3, 2, 15],
          [13, 8, 10, 1, 3, 15, 4, 2, 11, 6, 7, 12, 0, 5, 14, 9 ]],

          [ [10, 0, 9, 14, 6, 3, 15, 5, 1, 13, 12, 7, 11, 4, 2, 8],
          [13, 7, 0, 9, 3, 4, 6, 10, 2, 8, 5, 14, 12, 11, 15, 1],
          [13, 6, 4, 9, 8, 15, 3, 0, 11, 1, 2, 12, 5, 10, 14, 7],
                [1, 10, 13, 0, 6, 9, 8, 7, 4, 15, 14, 3, 11, 5, 2, 12 ]],

          [ [7, 13, 14, 3, 0, 6, 9, 10, 1, 2, 8, 5, 11, 12, 4, 15],
          [13, 8, 11, 5, 6, 15, 0, 3, 4, 7, 2, 12, 1, 10, 14, 9],
          [10, 6, 9, 0, 12, 11, 7, 13, 15, 1, 3, 14, 5, 2, 8, 4],
                [3, 15, 0, 6, 10, 1, 13, 8, 9, 4, 5, 11, 12, 7, 2, 14] ],

          [ [2, 12, 4, 1, 7, 10, 11, 6, 8, 5, 3, 15, 13, 0, 14, 9],
          [14, 11, 2, 12, 4, 7, 13, 1, 5, 0, 15, 10, 3, 9, 8, 6],
                [4, 2, 1, 11, 10, 13, 7, 8, 15, 9, 12, 5, 6, 3, 0, 14],
          [11, 8, 12, 7, 1, 14, 2, 13, 6, 15, 0, 9, 10, 4, 5, 3 ]],

          [ [12, 1, 10, 15, 9, 2, 6, 8, 0, 13, 3, 4, 14, 7, 5, 11],
          [10, 15, 4, 2, 7, 12, 9, 5, 6, 1, 13, 14, 0, 11, 3, 8],
                [9, 14, 15, 5, 2, 8, 12, 3, 7, 0, 4, 10, 1, 13, 11, 6],
                [4, 3, 2, 12, 9, 5, 15, 10, 11, 14, 1, 7, 6, 0, 8, 13] ],

          [ [4, 11, 2, 14, 15, 0, 8, 13, 3, 12, 9, 7, 5, 10, 6, 1],
          [13, 0, 11, 7, 4, 9, 1, 10, 14, 3, 5, 12, 2, 15, 8, 6],
                [1, 4, 11, 13, 12, 3, 7, 14, 10, 15, 6, 8, 0, 5, 9, 2],
                [6, 11, 13, 8, 1, 4, 10, 7, 9, 5, 0, 15, 14, 2, 3, 12] ],

          [ [13, 2, 8, 4, 6, 15, 11, 1, 10, 9, 3, 14, 5, 0, 12, 7],
                [1, 15, 13, 8, 10, 3, 7, 4, 12, 5, 6, 11, 0, 14, 9, 2],
                [7, 11, 4, 1, 9, 12, 14, 2, 0, 6, 10, 13, 15, 3, 5, 8],
                  [2, 1, 14, 7, 4, 10, 8, 13, 15, 12, 9, 0, 3, 5, 6, 11] ]
]


final_perm = [ 40, 8, 48, 16, 56, 24, 64, 32,
                  39, 7, 47, 15, 55, 23, 63, 31,
                  38, 6, 46, 14, 54, 22, 62, 30,
                  37, 5, 45, 13, 53, 21, 61, 29,
                  36, 4, 44, 12, 52, 20, 60, 28,
                  35, 3, 43, 11, 51, 19, 59, 27,
                  34, 2, 42, 10, 50, 18, 58, 26,
                  33, 1, 41, 9, 49, 17, 57, 25 ]

def encrypt(pt, rkb, rk):
      pt = hex2bin(pt)

      pt = permute(pt, initial_perm, 64)
      l=[]
      left = pt[0:32]
      right = pt[32:64]
      for i in range(0, 16):
            right_expanded = permute(right, exp_d, 48)

            xor_x = xor(right_expanded, rkb[i])

            sbox_str = ""
            for j in range(0, 8):
                  row = bin2dec(int(xor_x[j * 6] + xor_x[j * 6 + 5]))
                  col = bin2dec(int(xor_x[j * 6 + 1] + xor_x[j * 6 + 2] +
xor_x[j * 6 + 3] + xor_x[j * 6 + 4]))
                  val = sbox[j][row][col]
                  sbox_str = sbox_str + dec2bin(val)

            sbox_str = permute(sbox_str, per, 32)

            result = xor(left, sbox_str)
            left = result

            if(i != 15):
                  left, right = right, left
            l.append(left+right)
```

```
        combine = left + right

        cipher_text = permute(combine, final_perm, 64)
        return l

def hd(s,t):
        c=0
        for x,y in zip(s,t):
                if( x !=y ):
                        c=c+1
        return c


pt =
["3510762BCA1D223A","3410762BCA1D623A","1410762BCA1D223A","2410762BCA1D223A
","3C10762BCA1D223A"]
key = "AABB09182736CCDD"
opt = "3410762BCA1D223A"


key = hex2bin(key)


keyp = [57, 49, 41, 33, 25, 17, 9,
                1, 58, 50, 42, 34, 26, 18,
                10, 2, 59, 51, 43, 35, 27,
                19, 11, 3, 60, 52, 44, 36,
                63, 55, 47, 39, 31, 23, 15,
                7, 62, 54, 46, 38, 30, 22,
                14, 6, 61, 53, 45, 37, 29,
                21, 13, 5, 28, 20, 12, 4 ]


key = permute(key, keyp, 56)


shift_table = [1, 1, 2, 2,
                                2, 2, 2, 2,
                                1, 2, 2, 2,
                                2, 2, 2, 1 ]

key_comp = [14, 17, 11, 24, 1, 5,
                        3, 28, 15, 6, 21, 10,
                  23, 19, 12, 4, 26, 8,
                  16, 7, 27, 20, 13, 2,
                  41, 52, 31, 37, 47, 55,
                  30, 40, 51, 45, 33, 48,
                  44, 49, 39, 56, 34, 53,
                  46, 42, 50, 36, 29, 32 ]

left = key[0:28]
right = key[28:56]

rkb = []
rk = []
for i in range(0, 16):

      left = shift_left(left, shift_table[i])
      right = shift_left(right, shift_table[i])

      combine_str = left + right

      round_key = permute(combine_str, key_comp, 48)

      rkb.append(round_key)
      rk.append(bin2hex(round_key))

print("Encryption")
mat=[]
for i in range(16):
  mat.append([])
l3 = encrypt(opt, rkb, rk)
for x in pt:
      l2 = []
      l = encrypt(x, rkb, rk)
      for yy,y in zip(l3,l):
            l2.append(hd(yy,y))
      for i in range(16):
            mat[i].append(l2[i])


print(mat)

plt.boxplot(mat)
plt.title('Avalanche Effect on DES Rounds')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(0,60)
plt.show()
```

Code for problem 2:

```
import matplotlib.pyplot as plt
import numpy as np
def hex2bin(s):
      mp = {'0' : "0000",
            '1' : "0001",
            '2' : "0010",
            '3' : "0011",
            '4' : "0100",
            '5' : "0101",
            '6' : "0110",
            '7' : "0111",
            '8' : "1000",
            '9' : "1001",
            'A' : "1010",
            'B' : "1011",
            'C' : "1100",
            'D' : "1101",
            'E' : "1110",
            'F' : "1111" }
      bin = ""
      for i in range(len(s)):
            bin = bin + mp[s[i]]
      return bin

def bin2hex(s):
      mp = {"0000" : '0',
            "0001" : '1',
            "0010" : '2',
            "0011" : '3',
            "0100" : '4',
            "0101" : '5',
            "0110" : '6',
            "0111" : '7',
            "1000" : '8',
            "1001" : '9',
            "1010" : 'A',
              "1011" : 'B',
              "1100" : 'C',
              "1101" : 'D',
              "1110" : 'E',
              "1111" : 'F' }
        hex = ""
        for i in range(0,len(s),4):
              ch = ""
              ch = ch + s[i]
              ch = ch + s[i + 1]
              ch = ch + s[i + 2]
              ch = ch + s[i + 3]
              hex = hex + mp[ch]

        return hex


def bin2dec(binary):

        binary1 = binary
        decimal, i, n = 0, 0, 0
        while(binary != 0):
              dec = binary % 10
              decimal = decimal + dec * pow(2, i)
              binary = binary//10
              i += 1
        return decimal


def dec2bin(num):
        res = bin(num).replace("0b", "")
        if(len(res)%4 != 0):
              div = len(res) / 4
              div = int(div)
              counter =(4 * (div + 1)) - len(res)
              for i in range(0, counter):
                    res = '0' + res
        return res


def permute(k, arr, n):
        permutation = ""
        for i in range(0, n):
            permutation = permutation + k[arr[i] - 1]
        return permutation


def shift_left(k, nth_shifts):
        s = ""
        for i in range(nth_shifts):
            for j in range(1,len(k)):
                s = s + k[j]
            s = s + k[0]
            k = s
            s = ""
        return k


def xor(a, b):
        ans = ""
        for i in range(len(a)):
            if a[i] == b[i]:
                ans = ans + "0"
            else:
                ans = ans + "1"
        return ans


initial_perm = [58, 50, 42, 34, 26, 18, 10, 2,
                        60, 52, 44, 36, 28, 20, 12, 4,
                        62, 54, 46, 38, 30, 22, 14, 6,
                        64, 56, 48, 40, 32, 24, 16, 8,
                        57, 49, 41, 33, 25, 17, 9, 1,
                        59, 51, 43, 35, 27, 19, 11, 3,
                        61, 53, 45, 37, 29, 21, 13, 5,
                        63, 55, 47, 39, 31, 23, 15, 7]


exp_d = [32, 1 , 2 , 3 , 4 , 5 , 4 , 5,
            6 , 7 , 8 , 9 , 8 , 9 , 10, 11,
            12, 13, 12, 13, 14, 15, 16, 17,
            16, 17, 18, 19, 20, 21, 20, 21,
            22, 23, 24, 25, 24, 25, 26, 27,
            28, 29, 28, 29, 30, 31, 32, 1 ]
```

```
per = [ 16, 7, 20, 21,
        29, 12, 28, 17,
        1, 15, 23, 26,
        5, 18, 31, 10,
        2, 8, 24, 14,
        32, 27, 3, 9,
        19, 13, 30, 6,
        22, 11, 4, 25 ]


sbox = [[[14, 4, 13, 1, 2, 15, 11, 8, 3, 10, 6, 12, 5, 9, 0, 7],
        [ 0, 15, 7, 4, 14, 2, 13, 1, 10, 6, 12, 11, 9, 5, 3, 8],
        [ 4, 1, 14, 8, 13, 6, 2, 11, 15, 12, 9, 7, 3, 10, 5, 0],
        [15, 12, 8, 2, 4, 9, 1, 7, 5, 11, 3, 14, 10, 0, 6, 13 ]],

        [[15, 1, 8, 14, 6, 11, 3, 4, 9, 7, 2, 13, 12, 0, 5, 10],
              [3, 13, 4, 7, 15, 2, 8, 14, 12, 0, 1, 10, 6, 9, 11, 5],
              [0, 14, 7, 11, 10, 4, 13, 1, 5, 8, 12, 6, 9, 3, 2, 15],
        [13, 8, 10, 1, 3, 15, 4, 2, 11, 6, 7, 12, 0, 5, 14, 9 ]],

        [ [10, 0, 9, 14, 6, 3, 15, 5, 1, 13, 12, 7, 11, 4, 2, 8],
        [13, 7, 0, 9, 3, 4, 6, 10, 2, 8, 5, 14, 12, 11, 15, 1],
        [13, 6, 4, 9, 8, 15, 3, 0, 11, 1, 2, 12, 5, 10, 14, 7],
              [1, 10, 13, 0, 6, 9, 8, 7, 4, 15, 14, 3, 11, 5, 2, 12 ]],

        [ [7, 13, 14, 3, 0, 6, 9, 10, 1, 2, 8, 5, 11, 12, 4, 15],
        [13, 8, 11, 5, 6, 15, 0, 3, 4, 7, 2, 12, 1, 10, 14, 9],
        [10, 6, 9, 0, 12, 11, 7, 13, 15, 1, 3, 14, 5, 2, 8, 4],
              [3, 15, 0, 6, 10, 1, 13, 8, 9, 4, 5, 11, 12, 7, 2, 14] ],

        [ [2, 12, 4, 1, 7, 10, 11, 6, 8, 5, 3, 15, 13, 0, 14, 9],
        [14, 11, 2, 12, 4, 7, 13, 1, 5, 0, 15, 10, 3, 9, 8, 6],
              [4, 2, 1, 11, 10, 13, 7, 8, 15, 9, 12, 5, 6, 3, 0, 14],
        [11, 8, 12, 7, 1, 14, 2, 13, 6, 15, 0, 9, 10, 4, 5, 3 ]],

        [ [12, 1, 10, 15, 9, 2, 6, 8, 0, 13, 3, 4, 14, 7, 5, 11],
        [10, 15, 4, 2, 7, 12, 9, 5, 6, 1, 13, 14, 0, 11, 3, 8],
              [9, 14, 15, 5, 2, 8, 12, 3, 7, 0, 4, 10, 1, 13, 11, 6],
              [4, 3, 2, 12, 9, 5, 15, 10, 11, 14, 1, 7, 6, 0, 8, 13] ],

        [ [4, 11, 2, 14, 15, 0, 8, 13, 3, 12, 9, 7, 5, 10, 6, 1],
        [13, 0, 11, 7, 4, 9, 1, 10, 14, 3, 5, 12, 2, 15, 8, 6],
              [1, 4, 11, 13, 12, 3, 7, 14, 10, 15, 6, 8, 0, 5, 9, 2],
                  [6, 11, 13, 8, 1, 4, 10, 7, 9, 5, 0, 15, 14, 2, 3, 12] ],

            [ [13, 2, 8, 4, 6, 15, 11, 1, 10, 9, 3, 14, 5, 0, 12, 7],
                  [1, 15, 13, 8, 10, 3, 7, 4, 12, 5, 6, 11, 0, 14, 9, 2],
                  [7, 11, 4, 1, 9, 12, 14, 2, 0, 6, 10, 13, 15, 3, 5, 8],
                  [2, 1, 14, 7, 4, 10, 8, 13, 15, 12, 9, 0, 3, 5, 6, 11] ]
]


final_perm = [ 40, 8, 48, 16, 56, 24, 64, 32,
                  39, 7, 47, 15, 55, 23, 63, 31,
                  38, 6, 46, 14, 54, 22, 62, 30,
                  37, 5, 45, 13, 53, 21, 61, 29,
                  36, 4, 44, 12, 52, 20, 60, 28,
                  35, 3, 43, 11, 51, 19, 59, 27,
                  34, 2, 42, 10, 50, 18, 58, 26,
                  33, 1, 41, 9, 49, 17, 57, 25 ]

def encrypt(pt, rkb, rk):
      pt = hex2bin(pt)

      pt = permute(pt, initial_perm, 64)
      l=[]
      left = pt[0:32]
      right = pt[32:64]
      for i in range(0, 16):
            right_expanded = permute(right, exp_d, 48)

            xor_x = xor(right_expanded, rkb[i])

            sbox_str = ""
            for j in range(0, 8):
                  row = bin2dec(int(xor_x[j * 6] + xor_x[j * 6 + 5]))
                  col = bin2dec(int(xor_x[j * 6 + 1] + xor_x[j * 6 + 2] +
xor_x[j * 6 + 3] + xor_x[j * 6 + 4]))
                  val = sbox[j][row][col]
                  sbox_str = sbox_str + dec2bin(val)

            sbox_str = permute(sbox_str, per, 32)

            result = xor(left, sbox_str)
            left = result
            if(i != 15):
                left, right = right, left
            l.append(left+right)


        combine = left + right

        cipher_text = permute(combine, final_perm, 64)
        return l

def hd(s,t):
        c=0
        for x,y in zip(s,t):
            if( x !=y ):
                c=c+1
        return c


pt =
["63410762BCA1D223B","52410762BCA1D224A","81210762BCA1D213A","7AB70762BCA1D
323A","B24A9762BCA1A223A"]
key = "AABB09182736CCDD"
opt = "43410762BCA1D223A"


key = hex2bin(key)


keyp = [57, 49, 41, 33, 25, 17, 9,
            1, 58, 50, 42, 34, 26, 18,
            10, 2, 59, 51, 43, 35, 27,
            19, 11, 3, 60, 52, 44, 36,
            63, 55, 47, 39, 31, 23, 15,
            7, 62, 54, 46, 38, 30, 22,
            14, 6, 61, 53, 45, 37, 29,
            21, 13, 5, 28, 20, 12, 4 ]


key = permute(key, keyp, 56)


shift_table = [1, 1, 2, 2,
                    2, 2, 2, 2,
                        1, 2, 2, 2,
                        2, 2, 2, 1 ]

key_comp = [14, 17, 11, 24, 1, 5,
                  3, 28, 15, 6, 21, 10,
                  23, 19, 12, 4, 26, 8,
                  16, 7, 27, 20, 13, 2,
                  41, 52, 31, 37, 47, 55,
                  30, 40, 51, 45, 33, 48,
                  44, 49, 39, 56, 34, 53,
                  46, 42, 50, 36, 29, 32 ]

left = key[0:28]
right = key[28:56]

rkb = []
rk = []
for i in range(0, 16):

      left = shift_left(left, shift_table[i])
      right = shift_left(right, shift_table[i])

      combine_str = left + right

      round_key = permute(combine_str, key_comp, 48)

      rkb.append(round_key)
      rk.append(bin2hex(round_key))

print("Encryption")
mat=[]
for i in range(16):
  mat.append([])

for x in pt:
      l2 = []
      l = encrypt(x, rkb, rk)
      for y in l:
            l2.append(hd(opt,bin2hex(y)))
      for i in range(16):
            mat[i].append(l2[i])
```

```
print(mat)

plt.boxplot(mat)
plt.title('Avalanche Effect on DES Rounds')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(9,16.5)
plt.show()



Code for problem 3:
import matplotlib.pyplot as plt
import numpy as np
def hex2bin(s):
      mp = {'0' : "0000",
            '1' : "0001",
            '2' : "0010",
            '3' : "0011",
            '4' : "0100",
            '5' : "0101",
            '6' : "0110",
            '7' : "0111",
            '8' : "1000",
            '9' : "1001",
            'A' : "1010",
            'B' : "1011",
            'C' : "1100",
            'D' : "1101",
            'E' : "1110",
            'F' : "1111" }
      bin = ""
      for i in range(len(s)):
            bin = bin + mp[s[i]]
      return bin

def bin2hex(s):
      mp = {"0000" : '0',
            "0001" : '1',
            "0010" : '2',
            "0011" : '3',
            "0100" : '4',
            "0101" : '5',
            "0110" : '6',
            "0111" : '7',
            "1000" : '8',
            "1001" : '9',
            "1010" : 'A',
            "1011" : 'B',
            "1100" : 'C',
            "1101" : 'D',
            "1110" : 'E',
            "1111" : 'F' }
      hex = ""
      for i in range(0,len(s),4):
            ch = ""
            ch = ch + s[i]
            ch = ch + s[i + 1]
            ch = ch + s[i + 2]
            ch = ch + s[i + 3]
            hex = hex + mp[ch]

      return hex


def bin2dec(binary):

      binary1 = binary
      decimal, i, n = 0, 0, 0
      while(binary != 0):
            dec = binary % 10
            decimal = decimal + dec * pow(2, i)
            binary = binary//10
            i += 1
      return decimal


def dec2bin(num):
      res = bin(num).replace("0b", "")
      if(len(res)%4 != 0):
            div = len(res) / 4
            div = int(div)
            counter =(4 * (div + 1)) - len(res)
            for i in range(0, counter):
                  res = '0' + res
```

```
    return res


def permute(k, arr, n):
    permutation = ""
    for i in range(0, n):
        permutation = permutation + k[arr[i] - 1]
    return permutation


def shift_left(k, nth_shifts):
    s = ""
    for i in range(nth_shifts):
        for j in range(1,len(k)):
            s = s + k[j]
        s = s + k[0]
        k = s
        s = ""
    return k


def xor(a, b):
    ans = ""
    for i in range(len(a)):
        if a[i] == b[i]:
            ans = ans + "0"
        else:
            ans = ans + "1"
    return ans


initial_perm = [58, 50, 42, 34, 26, 18, 10, 2,
                60, 52, 44, 36, 28, 20, 12, 4,
                62, 54, 46, 38, 30, 22, 14, 6,
                64, 56, 48, 40, 32, 24, 16, 8,
                57, 49, 41, 33, 25, 17, 9, 1,
                59, 51, 43, 35, 27, 19, 11, 3,
                61, 53, 45, 37, 29, 21, 13, 5,
                63, 55, 47, 39, 31, 23, 15, 7]


exp_d = [32, 1 , 2 , 3 , 4 , 5 , 4 , 5,
         6 , 7 , 8 , 9 , 8 , 9 , 10, 11,
            12, 13, 12, 13, 14, 15, 16, 17,
            16, 17, 18, 19, 20, 21, 20, 21,
            22, 23, 24, 25, 24, 25, 26, 27,
            28, 29, 28, 29, 30, 31, 32, 1 ]


per = [ 16, 7, 20, 21,
            29, 12, 28, 17,
            1, 15, 23, 26,
            5, 18, 31, 10,
            2, 8, 24, 14,
            32, 27, 3, 9,
            19, 13, 30, 6,
            22, 11, 4, 25 ]


sbox = [[[14, 4, 13, 1, 2, 15, 11, 8, 3, 10, 6, 12, 5, 9, 0, 7],
            [ 0, 15, 7, 4, 14, 2, 13, 1, 10, 6, 12, 11, 9, 5, 3, 8],
            [ 4, 1, 14, 8, 13, 6, 2, 11, 15, 12, 9, 7, 3, 10, 5, 0],
            [15, 12, 8, 2, 4, 9, 1, 7, 5, 11, 3, 14, 10, 0, 6, 13 ]],

            [[15, 1, 8, 14, 6, 11, 3, 4, 9, 7, 2, 13, 12, 0, 5, 10],
                  [3, 13, 4, 7, 15, 2, 8, 14, 12, 0, 1, 10, 6, 9, 11, 5],
                  [0, 14, 7, 11, 10, 4, 13, 1, 5, 8, 12, 6, 9, 3, 2, 15],
            [13, 8, 10, 1, 3, 15, 4, 2, 11, 6, 7, 12, 0, 5, 14, 9 ]],

            [ [10, 0, 9, 14, 6, 3, 15, 5, 1, 13, 12, 7, 11, 4, 2, 8],
            [13, 7, 0, 9, 3, 4, 6, 10, 2, 8, 5, 14, 12, 11, 15, 1],
            [13, 6, 4, 9, 8, 15, 3, 0, 11, 1, 2, 12, 5, 10, 14, 7],
                  [1, 10, 13, 0, 6, 9, 8, 7, 4, 15, 14, 3, 11, 5, 2, 12 ]],

            [ [7, 13, 14, 3, 0, 6, 9, 10, 1, 2, 8, 5, 11, 12, 4, 15],
            [13, 8, 11, 5, 6, 15, 0, 3, 4, 7, 2, 12, 1, 10, 14, 9],
            [10, 6, 9, 0, 12, 11, 7, 13, 15, 1, 3, 14, 5, 2, 8, 4],
                  [3, 15, 0, 6, 10, 1, 13, 8, 9, 4, 5, 11, 12, 7, 2, 14] ],

            [ [2, 12, 4, 1, 7, 10, 11, 6, 8, 5, 3, 15, 13, 0, 14, 9],
            [14, 11, 2, 12, 4, 7, 13, 1, 5, 0, 15, 10, 3, 9, 8, 6],
                  [4, 2, 1, 11, 10, 13, 7, 8, 15, 9, 12, 5, 6, 3, 0, 14],
            [11, 8, 12, 7, 1, 14, 2, 13, 6, 15, 0, 9, 10, 4, 5, 3 ]],

            [ [12, 1, 10, 15, 9, 2, 6, 8, 0, 13, 3, 4, 14, 7, 5, 11],
            [10, 15, 4, 2, 7, 12, 9, 5, 6, 1, 13, 14, 0, 11, 3, 8],
                  [9, 14, 15, 5, 2, 8, 12, 3, 7, 0, 4, 10, 1, 13, 11, 6],
                  [4, 3, 2, 12, 9, 5, 15, 10, 11, 14, 1, 7, 6, 0, 8, 13] ],

            [ [4, 11, 2, 14, 15, 0, 8, 13, 3, 12, 9, 7, 5, 10, 6, 1],
            [13, 0, 11, 7, 4, 9, 1, 10, 14, 3, 5, 12, 2, 15, 8, 6],
                  [1, 4, 11, 13, 12, 3, 7, 14, 10, 15, 6, 8, 0, 5, 9, 2],
                  [6, 11, 13, 8, 1, 4, 10, 7, 9, 5, 0, 15, 14, 2, 3, 12] ],

            [ [13, 2, 8, 4, 6, 15, 11, 1, 10, 9, 3, 14, 5, 0, 12, 7],
                  [1, 15, 13, 8, 10, 3, 7, 4, 12, 5, 6, 11, 0, 14, 9, 2],
                  [7, 11, 4, 1, 9, 12, 14, 2, 0, 6, 10, 13, 15, 3, 5, 8],
                  [2, 1, 14, 7, 4, 10, 8, 13, 15, 12, 9, 0, 3, 5, 6, 11] ]
]


final_perm = [ 40, 8, 48, 16, 56, 24, 64, 32,
                  39, 7, 47, 15, 55, 23, 63, 31,
                  38, 6, 46, 14, 54, 22, 62, 30,
                  37, 5, 45, 13, 53, 21, 61, 29,
                  36, 4, 44, 12, 52, 20, 60, 28,
                  35, 3, 43, 11, 51, 19, 59, 27,
                  34, 2, 42, 10, 50, 18, 58, 26,
                  33, 1, 41, 9, 49, 17, 57, 25 ]

def encrypt(pt, rkb, rk):
      pt = hex2bin(pt)

      pt = permute(pt, initial_perm, 64)
      l=[]
      left = pt[0:32]
      right = pt[32:64]
      for i in range(0, 16):
            right_expanded = permute(right, exp_d, 48)

            xor_x = xor(right_expanded, rkb[i])

            sbox_str = ""
            for j in range(0, 8):
                  row = bin2dec(int(xor_x[j * 6] + xor_x[j * 6 + 5]))
                  col = bin2dec(int(xor_x[j * 6 + 1] + xor_x[j * 6 + 2] +
xor_x[j * 6 + 3] + xor_x[j * 6 + 4]))
                  val = sbox[j][row][col]
                  sbox_str = sbox_str + dec2bin(val)
            sbox_str = permute(sbox_str, per, 32)

            result = xor(left, sbox_str)
            left = result

            if(i != 15):
                  left, right = right, left
            l.append(left+right)


      combine = left + right

      cipher_text = permute(combine, final_perm, 64)
      return l

def hd(s,t):
      c=0
      for x,y in zip(s,t):
            if( x !=y ):
                  c=c+1
      return c


pt = "4341762BCA1D223A"
okey = "4271A0C2A851A62B"
lkey =
["8271A0C2A851A62B","4771A0C2A851A62B","4211A0C2A851A62B","427100C2A851A62B
","4271A0CDA851A62B"]

mat=[]
for i in range(16):
  mat.append([])

key = hex2bin(okey)

keyp = [57, 49, 41, 33, 25, 17, 9,
    1, 58, 50, 42, 34, 26, 18,
    10, 2, 59, 51, 43, 35, 27,
    19, 11, 3, 60, 52, 44, 36,
    63, 55, 47, 39, 31, 23, 15,
    7, 62, 54, 46, 38, 30, 22,
    14, 6, 61, 53, 45, 37, 29,
    21, 13, 5, 28, 20, 12, 4 ]


key = permute(key, keyp, 56)


shift_table = [1, 1, 2, 2,
        2, 2, 2, 2,
        1, 2, 2, 2,
        2, 2, 2, 1 ]

key_comp = [14, 17, 11, 24, 1, 5,
      3, 28, 15, 6, 21, 10,
      23, 19, 12, 4, 26, 8,
      16, 7, 27, 20, 13, 2,
      41, 52, 31, 37, 47, 55,
      30, 40, 51, 45, 33, 48,
      44, 49, 39, 56, 34, 53,
      46, 42, 50, 36, 29, 32 ]

left = key[0:28]
right = key[28:56]

rkb = []
rk = []
for i in range(0, 16):
  left = shift_left(left, shift_table[i])
  right = shift_left(right, shift_table[i])

  combine_str = left + right

  round_key = permute(combine_str, key_comp, 48)

  rkb.append(round_key)
  rk.append(bin2hex(round_key))
l3 = encrypt(pt, rkb, rk)



for key in lkey:
  key = hex2bin(key)

  keyp = [57, 49, 41, 33, 25, 17, 9,
    1, 58, 50, 42, 34, 26, 18,
    10, 2, 59, 51, 43, 35, 27,
    19, 11, 3, 60, 52, 44, 36,
    63, 55, 47, 39, 31, 23, 15,
    7, 62, 54, 46, 38, 30, 22,
    14, 6, 61, 53, 45, 37, 29,
    21, 13, 5, 28, 20, 12, 4 ]


key = permute(key, keyp, 56)


shift_table = [1, 1, 2, 2,
        2, 2, 2, 2,
        1, 2, 2, 2,
        2, 2, 2, 1 ]

key_comp = [14, 17, 11, 24, 1, 5,
      3, 28, 15, 6, 21, 10,
      23, 19, 12, 4, 26, 8,
      16, 7, 27, 20, 13, 2,
      41, 52, 31, 37, 47, 55,
      30, 40, 51, 45, 33, 48,
      44, 49, 39, 56, 34, 53,
      46, 42, 50, 36, 29, 32 ]

left = key[0:28]
right = key[28:56]

rkb = []
rk = []
for i in range(0, 16):
  left = shift_left(left, shift_table[i])
  right = shift_left(right, shift_table[i])

  combine_str = left + right

  round_key = permute(combine_str, key_comp, 48)

  rkb.append(round_key)
  rk.append(bin2hex(round_key))
l = encrypt(pt, rkb, rk)
l2 = []
```

```
  for yy,y in zip(l3,l):
    l2.append(hd(yy,y))
  for i in range(16):
    mat[i].append(l2[i])



print(mat)

plt.boxplot(mat)
plt.title('Avalanche Effect on DES Rounds')
plt.xlabel('DES Rounds')
plt.ylabel('Hamming Distance')
plt.ylim(0,60)
plt.show()
```