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Homework #2

CSE 7339. Computer System Security

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Please submit under the Homework #2 link on the Assignments page of BlackBoard.
Unless otherwise stated, **PLEASE SHOW ALL WORK.**

Please turn these in using a word processor (such as Word or Excel), instead of hand-written form. **If programming is used to generate a solution, the source code must be included and an output value must be given for EACH sub-question.**
i.e.- 1. a) should have an answer. 1. b) should have a separate answer.

This example problem provides a numerical example of encryption using a **one-round** version of DES.
We will use the following 64-bit pattern for the initial input Key (K_0):
Hex 0123456789ABCDEF

Hexadecimal notation: **0 1 2 3 4 5 6 7 8 9 A B C D E F**

Binary notation: **0000 0001 0010 0011 0100 0101 0110 0111**
1000 1001 1010 1011 1100 1101 1110 1111

We will use a single 64-bit block containing the ASCII text "**MESSAGES"** as the plaintext.

1. Derive the **round 1 key K_1**. This involves the following steps:

   a) Reduce the initial 64-bit key input to the requisite 56-bit key by mapping the bits of the initial key through the Permuted Choice 1 (PC-1) box. (64 bits excluding every 8th bit = 56 bits. These removed 8-bits are sometimes used as parity bits).

   (1100 1100 1010 1010 0000 0000 1111
   1111 1111 1010 1010 1100 1100 0000)$_2$
   = (CCAA00F FFAACC0)$_{16}$

   b) Perform the specified left shift on the 28-bit left and right halves.

   C_0 = **(1100 1100 1010 1010 0000 0000 1111)$_2$**
   D_0 = **(1111 1111 1010 1010 1100 1100 0000)$_2$**

   C_1 = **(1001 1001 0101 0100 0000 0001 1111)$_2$**
   D_1 = **(1111 1111 0101 0101 1001 1000 0001)$_2$**

c) Use the permutation (PC-2) to derive the 48-bit round 1 key $\mathbf{K_1}$.

K_1 = **(0000 1011 0000 0010 0110 0111 1001 1011 0100 1001 1010 0101)$_2$**
= (0B02679B49A5)$_{16}$

2. Use this key to perform the **round 1 encryption** of the plaintext. This involves the following steps:
   a) Convert the Plaintext into binary (i.e.- ASCII "M" = Decimal 77 = Hex 4D = 0100 1101) http://www.asciitable.com/ may help:

   Original plaintext: **MESSAGES**
   Plaintext (hex): **(4D45535341474553)$_{16}$**
   Plaintext (bin): **(0100 1101 0100 0101 0101 0011 0101 0011 0100 0001 0100 0111 0100 0101 0101 0011)$_2$**

   b) Apply the initial permutation and break the plaintext into left and right halves $\mathbf{L_0}$ and $\mathbf{R_0}$.

   Plaintext (bin): **(0100 1101 0100 0101 0101 0011 0101 0011 0100 0001 0100 0111 0100 0101 0101 0011)$_2$**
   IP = **(1111 1111 1000 1100 0110 0011 1111 1111 0000 0000 0000 0000 0000 0001 1010 1100)$_2$**
   L_0 = **(1111 1111 1000 1100 0110 0011 1111 1111)$_2$**
   R_0 = **(0000 0000 0000 0000 0000 0001 1010 1100)$_2$**

   c) Expand $\mathbf{R_0}$ to get $\mathbf{E(R_0)}$.

   R_0 = **(0000 0000 0000 0000 0000 0001 1010 1100)$_2$**
   $E(R_0)$ = **(0000 0000 0000 0000 0000 0000 0000 0000 0011 1101 0101 1000)$_2$**

   d) Calculate $\mathbf{A} = \mathbf{E(R_0)} \oplus \mathbf{K_1}$.

   $E(R_0)$ = **(0000 0000 0000 0000 0000 0000 0000 0000 0011 1101 0101 1000)$_2$**
   K_1 = **(0000 1011 0000 0010 0110 0111 1001 1011 0100 1001 1010 0101)$_2$**
   A = **(0000 1011 0000 0010 0110 0111 1001 1011 0111 0100 1111 1101)$_2$**

   e) Group the 48-bit result **A** into sets of 6 bits and evaluate the corresponding S-box substitutions.

   A_0 = **(0000 1011 0000 0010 0110 0111 1001 1011 0111 0100 1111 1101)$_2$**
   A_1 = **(000010 110000 001001 100111 100110 110111 010011 111101)$_2$**

   S_1 = **(0100)$_2$**
   S_2 = **(0101)$_2$**
   S_3 = **(0011)$_2$**
   S_4 = **(0110)$_2$**
   S_5 = **(1011)$_2$**

S_6 = **$(0111)_2$**
S_7 = **$(0011)_2$**
S_8 = **$(0110)_2$**

f) Concatenate the results of e) to get a 32-bit result **B**.

B = **$(0100\ 0101\ 0011\ 0110\ 1011\ 0111\ 0011\ 0110)_2$**

g) Apply the permutation to get **P(B)**.

P(B) = **$(0010\ 0111\ 0110\ 0010\ 1111\ 0100\ 1011\ 1100)_2$**

h) Calculate $\mathbf{R_1} = \mathbf{P(B)} \oplus \mathbf{L_0}$.

P(B) = **$(0010\ 0111\ 0110\ 0010\ 1111\ 0100\ 1011\ 1100)_2$**
L_0 = **$(1111\ 1111\ 1000\ 1100\ 0110\ 0011\ 1111\ 1111)_2$**
R_1 = **$(1101\ 1000\ 1110\ 1110\ 1001\ 0111\ 0100\ 0011)_2$**
= **$(D8EE9743)_{16}$**

Supplemental Data

PC-1

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

(NOTE: there is no 8, 16, 24, 32, 40, 48, 56, or 64 in PC-1)

PC-2

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

Expansion Permutation (E)

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

Initial Permutation (IP)

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

Final Permutation (IP^{-1})							
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

Permutation (P)							
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

Rotations	
Round number	**Number of left rotations**
1	1
2	1
3	2
4	2
5	2
6	2
7	2
8	2
9	1
10	2
11	2
12	2
13	2
14	2
15	2
16	1

S1																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	14	4	13	1	2	15	11	8	3	10	6	12	5	9	0	7
1	0	15	7	4	14	2	13	1	10	6	12	11	9	5	3	8
2	4	1	14	8	13	6	2	11	15	12	9	7	3	10	5	0
3	15	12	8	2	4	9	1	7	5	11	3	14	10	0	6	13

S2																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	15	1	8	14	6	11	3	4	9	7	2	13	12	0	5	10
1	3	13	4	7	15	2	8	14	12	0	1	10	6	9	11	5
2	0	14	7	11	10	4	13	1	5	8	12	6	9	3	2	15
3	13	8	10	1	3	15	4	2	11	6	7	12	0	5	14	9

S3																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	10	0	9	14	6	3	15	5	1	13	12	7	11	4	2	8
1	13	7	0	9	3	4	6	10	2	8	5	14	12	11	15	1
2	13	6	4	9	8	15	3	0	11	1	2	12	5	10	14	7
3	1	10	13	0	6	9	8	7	4	15	14	3	11	5	2	12

S4																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	7	13	14	3	0	6	9	10	1	2	8	5	11	12	4	15
1	13	8	11	5	6	15	0	3	4	7	2	12	1	10	14	9
2	10	6	9	0	12	11	7	13	15	1	3	14	5	2	8	4
3	3	15	0	6	10	1	13	8	9	4	5	11	12	7	2	14

S5																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1 5
0	2	12	4	1	7	10	11	6	8	5	3	15	13	0	14	9
1	14	11	2	12	4	7	13	1	5	0	15	10	3	9	8	6
2	4	2	1	11	10	13	7	8	15	9	12	5	6	3	0	1 4
3	11	8	12	7	1	14	2	13	6	15	0	9	10	4	5	3

S6																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1 5
0	12	1	10	15	9	2	6	8	0	13	3	4	14	7	5	1 1
1	10	15	4	2	7	12	9	5	6	1	13	14	0	11	3	8
2	9	14	15	5	2	8	12	3	7	0	4	10	1	13	11	6
3	4	3	2	12	9	5	15	10	11	14	1	7	6	0	8	1 3

S7																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1 5
0	4	11	2	14	15	0	8	13	3	12	9	7	5	10	6	1
1	13	0	11	7	4	9	1	10	14	3	5	12	2	15	8	6
2	1	4	11	13	12	3	7	14	10	15	6	8	0	5	9	2
3	6	11	13	8	1	4	10	7	9	5	0	15	14	2	3	1 2

S8																
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1 5
0	13	2	8	4	6	15	11	1	10	9	3	14	5	0	12	7
1	1	15	13	8	10	3	7	4	12	5	6	11	0	14	9	2
2	7	11	4	1	9	12	14	2	0	6	10	13	15	3	5	8
3	2	1	14	7	4	10	8	13	15	12	9	0	3	5	6	1 1