

**CSCI971 Advance Computer Security:
Homework #4**

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Problem 1

First, generate differential table for 3-bit Sbox Table 1 and 5-bit Sbox Table 2;

	0	1	2	3	4	5	6	7
0	8	0	0	0	0	0	0	0
1	0	2	0	2	0	2	0	2
2	0	0	2	2	0	0	2	2
3	0	2	2	0	0	2	2	0
4	0	0	0	0	2	2	2	2
5	0	2	0	2	2	0	2	0
6	0	0	2	2	2	2	0	0
7	0	2	2	0	2	0	0	2

Table 1: Differential distribution table for 3-bit Sbox

We set Table 1 as T1, Table 2 as T2:

We can find some extremum value point. T1(1,1), T1(2,2), T1(4,4), T2(1,1), T2(2,2), T2(4,4), T2(8,8), T2(16,16) with the Probability $1/4$ to maintain its input differential value.

Because only Sbox can contribute to changes to differential value based on probability, the MixRow and BitRot change the differential value in a fixed mode (with the probability of 1). We can just take Sbox into concern.

We can enumerate the input differential value 0x01, 0x02, 0x04, 0x08, 0x10 to the Sbox to get the best probability path.

Then we can find when the p_0 of plaintext is 0x20, we can attack as much as round. The plaintext = 0x20 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 .

We assume Sbox keep its differential value.

Round1

After entering the Sbox, the p_0 state has the probability of $2/8 = 2^{-2}$ to maintain 0x01.

Maintain value probability $P_1 = 1/4 = 2^{-2}$

Round2

We have 0x02 0x10 and 0x01.

Maintain value probability $P_2 = 1/4 * 1/4 = 2^{-4}$

Round3

We have 0x01 0x02 0x04 0x04 0x10 0x02.

Maintain value probability $P_3 = 1/4 * 1/4 * 1/4 * 1/4 = 2^{-8}$

Round4

We have 0x04 0x04 0x01 0x08 0x03=>0x02.

Maintain value probability $P_4 = 1/4 * 1/4 * 1/4 * 1/4 * 1/4 = 2^{-10}$

Round5

We have 0x01 0x0a=>0x01 0x03 0x04 0x1c=>0x02 0x02 0x02 0x02 0x02 0x08 0x02

Maintain value probability $P_5 = 1/4 * 1/8 * 1/8 * 1/4 * 1/8 * (1/4)^4 = 2^{-21}$

Round6

We have 0x10 0x02 0x04 0x02 0x01 0x10 0x14=>0x13 0x01 0x03=>0x01 0x02

Maintain value probability $P_6 = 1/4 * 1/4 * 1/4 * 1/4 * 1/4 * 1/4 * 1/8 * 1/4 * 1/8 * 1/4 = 2^{-24}$

Round7

We have 0x09=>0x07 0x07=>0x07 0x02 0x19=>0x19 0x06=>0x02 0x06=>0x02 0x01 0x02 0x0a=>0x01 0x09=>0x0a 0x08=>0x08

Maintain value probability $P_7 = 1/8 * 1/16 * 1/4 * 1/16 * 1/8 * 1/8 * 1/4 * 1/4 * 1/8 * 1/8 * 1/4 = 2^{-31}$

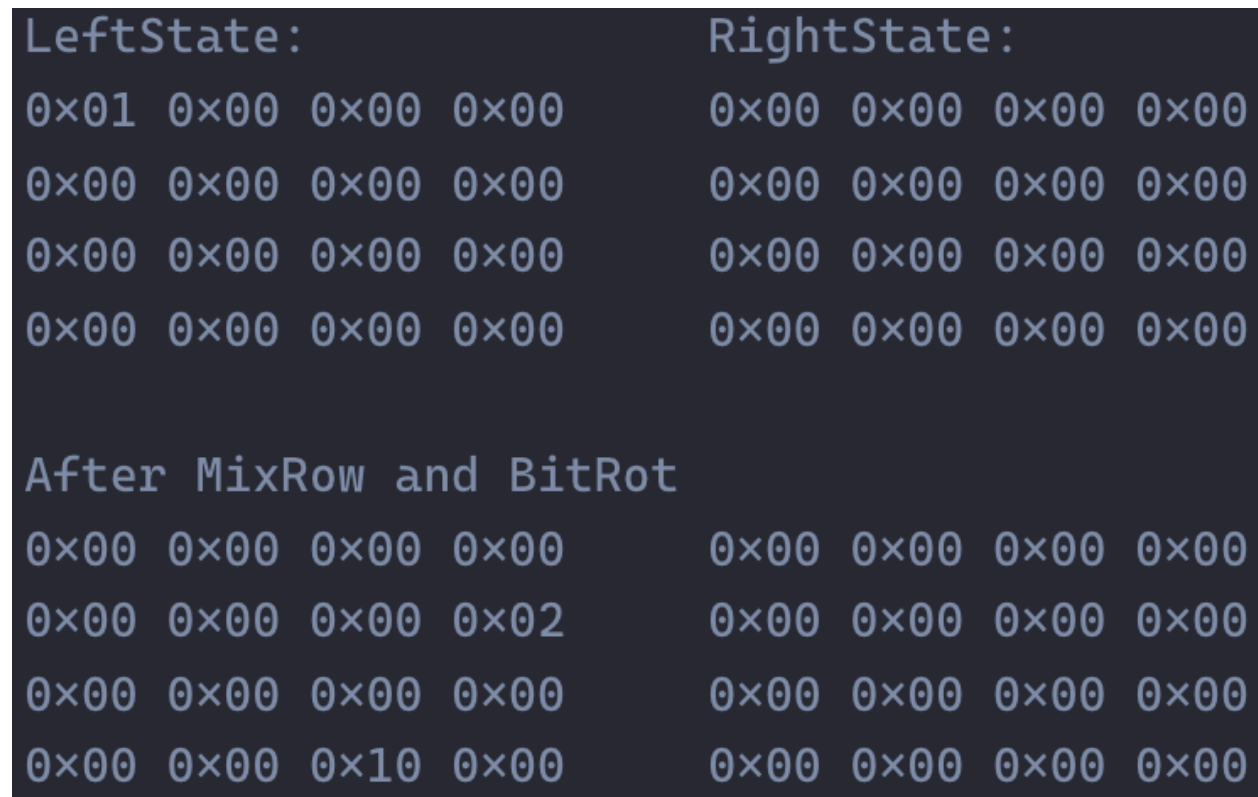


Figure 1: Round 1

Round8

Maintain value probability $P_8 = 1/4 * 1/4 * 1/8 * 1/8 * 1/4 * 1/4 * 1/8 = 2^{-17}$

Round9

Maintain value probability $P_8 = 1/4 * 1/16 * 1/8 * 1/16 * 1/8 * 1/8 * 1/4 * 1/16 * 1/8 * 1/8 * 1/8 * 1/8 * 1/4 = 2^{-39}$

Accumulate Round1 - Round 9 less than 2^{-128} .

So we get to Round 9

```
Round=2:
LeftState:           RightState:
0x00 0x00 0x00 0x00  0x01 0x00 0x00 0x00
0x00 0x00 0x00 0x02  0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00  0x00 0x00 0x00 0x00
0x00 0x00 0x10 0x00  0x00 0x00 0x00 0x00

After MixRow and BitRot
0x00 0x04 0x00 0x00  0x01 0x00 0x00 0x00
0x02 0x04 0x00 0x00  0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00  0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00  0x00 0x00 0x00 0x00
```

Figure 2: Round 2

```
Round=3:
LeftState:           RightState:
0x01 0x04 0x00 0x00  0x00 0x00 0x00 0x00
0x02 0x04 0x00 0x00  0x00 0x00 0x00 0x02
0x00 0x00 0x00 0x00  0x00 0x00 0x00 0x00
0x00 0x00 0x00 0x00  0x00 0x00 0x10 0x00

After MixRow and BitRot
0x04 0x00 0x00 0x00  0x00 0x00 0x00 0x00
0x04 0x00 0x00 0x0a  0x00 0x00 0x00 0x02
0x00 0x00 0x00 0x03  0x00 0x00 0x00 0x00
0x00 0x00 0x11 0x00  0x00 0x00 0x10 0x00
```

Figure 3: Round 3

```
Round=4:
LeftState:           RightState:
0x04 0x00 0x00 0x00  0x01 0x04 0x00 0x00
0x04 0x00 0x00 0x08  0x02 0x04 0x00 0x00
0x00 0x00 0x00 0x03  0x00 0x00 0x00 0x00
0x00 0x00 0x01 0x00  0x00 0x00 0x00 0x00

After MixRow and BitRot
0x00 0x00 0x00 0x00  0x01 0x04 0x00 0x00
0x08 0x18 0x00 0x08  0x02 0x04 0x00 0x00
0x03 0x02 0x02 0x02  0x00 0x00 0x00 0x00
0x00 0x02 0x02 0x00  0x00 0x00 0x00 0x00
```

Figure 4: Round 4

Round=5:

LeftState:

0x01	0x04	0x00	0x00
0x0a	0x1c	0x00	0x08
0x03	0x02	0x02	0x02
0x00	0x02	0x02	0x00

RightState:

0x04	0x00	0x00	0x00
0x04	0x00	0x00	0x08
0x00	0x00	0x00	0x03
0x00	0x00	0x01	0x00

After MixRow and BitRot

0x04	0x00	0x01	0x01	0x04	0x00	0x00	0x00
0x14	0x00	0x10	0x0b	0x04	0x00	0x00	0x08
0x00	0x04	0x00	0x03	0x00	0x00	0x00	0x03
0x02	0x02	0x15	0x02	0x00	0x00	0x01	0x00

Figure 5: Round 5

```
Round=6:
LeftState:           RightState:
0x00 0x00 0x01 0x01  0x01 0x04 0x00 0x00
0x10 0x00 0x10 0x03  0x0a 0x1c 0x00 0x08
0x00 0x04 0x00 0x00  0x03 0x02 0x02 0x02
0x02 0x02 0x14 0x02  0x00 0x02 0x02 0x00

After MixRow and BitRot
0x01 0x06 0x00 0x00  0x01 0x04 0x00 0x00
0x03 0x05 0x01 0x01  0x0a 0x1c 0x00 0x08
0x04 0x04 0x00 0x00  0x03 0x02 0x02 0x02
0x00 0x04 0x08 0x08  0x00 0x02 0x02 0x00
```

Figure 6: Round 6


```
Round=7:
LeftState:           RightState:
0x00 0x02 0x00 0x00  0x00 0x00 0x01 0x01
0x09 0x19 0x01 0x09  0x10 0x00 0x10 0x03
0x07 0x06 0x02 0x02  0x00 0x04 0x00 0x00
0x00 0x06 0x0a 0x08  0x02 0x02 0x14 0x02

After MixRow and BitRot
0x02 0x00 0x07 0x03  0x00 0x00 0x01 0x01
0x10 0x00 0x10 0x05  0x10 0x00 0x10 0x03
0x04 0x04 0x00 0x00  0x00 0x04 0x00 0x00
0x0e 0x02 0x04 0x02  0x02 0x02 0x14 0x02
```

Figure 7: Round 7

```
Round=8:
LeftState:           RightState:
0x02 0x00 0x06 0x02  0x00 0x02 0x00 0x00
0x00 0x00 0x00 0x06  0x09 0x19 0x01 0x09
0x04 0x00 0x00 0x00  0x07 0x06 0x02 0x02
0x0c 0x00 0x10 0x00  0x00 0x06 0x0a 0x08

After MixRow and BitRot
0x02 0x04 0x02 0x06  0x00 0x02 0x00 0x00
0x06 0x04 0x06 0x04  0x09 0x19 0x01 0x09
0x00 0x01 0x01 0x00  0x07 0x06 0x02 0x02
0x00 0x01 0x00 0x08  0x00 0x06 0x0a 0x08
```

Figure 8: Round 8

Round=9:

LeftState:

0x02	0x06	0x02	0x06
0x0f	0x1d	0x07	0x0d
0x07	0x07	0x03	0x02
0x00	0x07	0x0a	0x00

RightState:

0x02	0x00	0x06	0x02
0x00	0x00	0x00	0x06
0x04	0x00	0x00	0x00
0x0c	0x00	0x10	0x00

After MixRow and BitRot

0x00	0x04	0x07	0x03	0x02	0x00	0x06	0x02
0x10	0x0a	0x10	0x19	0x00	0x00	0x00	0x06
0x05	0x05	0x01	0x01	0x04	0x00	0x00	0x00
0x07	0x02	0x07	0x00	0x0c	0x00	0x10	0x00

Figure 9: Round 9

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1	0	8	0	8	0	8	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
2	0	0	8	0	0	0	8	0	0	0	8	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	0	4	0	4	0	4	0	4	0	4	0	4	0	4	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	0	0	0	0	8	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8	0	0	0	
5	0	4	0	4	0	0	0	0	0	0	0	0	0	4	0	4	0	4	0	4	0	0	0	0	0	0	0	0	0	4	0	4	
6	0	0	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0	4	0	
7	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	
8	0	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	0	0	0	0	0	0	0	
9	0	0	0	0	0	0	0	0	4	0	0	4	4	0	0	4	0	0	0	0	0	0	0	0	4	0	0	4	4	0	0	4	
10	0	0	4	4	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	4	4	4	
11	0	4	4	0	0	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	4	4	0	0	
12	0	0	0	0	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	4	4	0	0	
13	0	0	0	0	4	0	0	4	4	0	0	4	0	0	0	0	0	0	0	0	4	0	0	4	4	0	0	4	0	0	0	0	
14	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	
15	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	8	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	4	4	4	4	4	4	0	0	0	0	0	0	0	0	
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	4	4	4	4	0	0	0	0	4	4	
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
20	0	0	0	0	4	0	4	0	0	0	0	0	4	0	4	0	0	0	0	0	0	4	0	4	0	0	0	0	0	4	0	4	
21	0	4	0	4	0	0	0	0	0	0	0	0	0	4	0	4	4	0	4	0	0	0	0	0	0	0	0	0	4	0	4	0	
22	0	0	4	0	4	0	0	0	0	0	4	0	4	0	0	0	0	0	4	0	4	0	0	0	0	0	0	4	0	4	0	0	
23	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0
24	0	0	0	0	0	0	0	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	4	4	0	0	0	0	
25	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	
26	0	0	0	0	0	0	0	0	4	4	0	0	0	0	4	4	4	4	0	0	0	0	4	4	0	0	0	0	0	0	0	0	
27	0	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0	
28	0	0	0	0	2	2	2	2	0	0	0	0	2	2	2	0	0	0	0	2	2	2	2	2	0	0	0	0	2	2	2	2	
29	0	0	0	0	2	2	2	2	2	2	2	2	0	0	0	0	0	0	0	2	2	2	2	2	2	2	2	2	0	0	0	0	
30	0	0	2	2	2	2	0	0	0	0	2	2	2	0	0	0	0	2	2	2	2	2	0	0	0	0	2	2	2	2	0	0	
31	0	2	2	0	2	0	0	2	2	0	0	2	0	2	2	0	2	0	0	2	0	2	2	0	0	2	2	0	2	0	0	2	

Table 2: Differential distribution table for 5-bit Sbox