Hw01

COR (Correlation Attack)

What is COR?

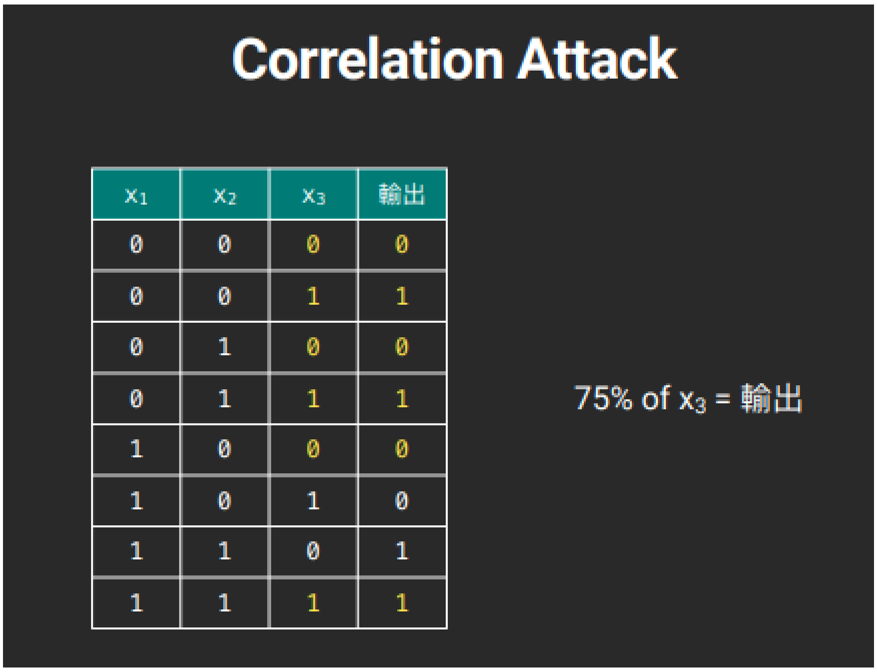
If we use Mixed LFSR to generate bits, and the operation of bits likes this:

```
class MyLFSR:
    ...
    def getbit(self):
        x1 = self.LFSR1.getbit()
        x2 = self.LFSR2.getbit()
        x3 = self.LFSR3.getbit()

        return (x1 & x2) ^ ((not x1) & x3)
    ...
```

The result of Mixed LFSR will be predictable because x2 and x3 have high degrees of similarity with result.

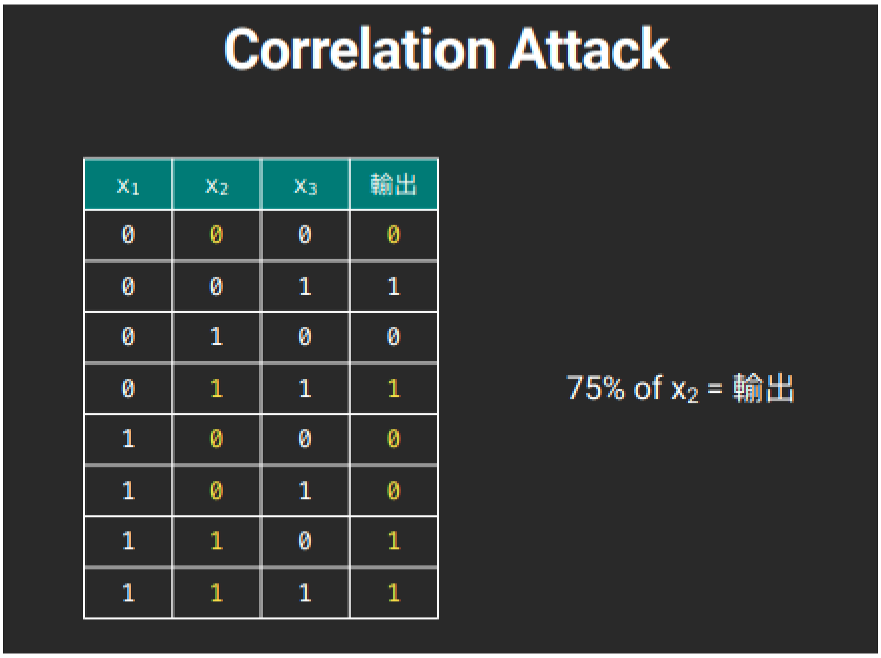
For example: (Images are referred from the handout of TA oalieno)



Correlation Attack

x_1	x_2	x_3	輸出
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

75% of x_3 = 輸出



Correlation Attack

x_1	x_2	x_3	輸出
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	1
1	1	1	1

75% of x_2 = 輸出

By calculation, the probability of degree of similarity between **x2 and output** is about **75%**, and it is about **75%** same when between **x3 and output**.

Attack

Following is my payload:

```
#!/usr/bin/env python3
from functools import reduce
import json
import string

class LFSR:
    def __init__(self, init, feedback):
        self.state = init
        self.feedback = feedback
    def getbit(self):
        nextbit = reduce(lambda x, y: x ^ y, [i & j for i, j in
zip(self.state, self.feedback)])
        self.state = self.state[1:] + [nextbit]
        return nextbit

class MYLFSR:
    def __init__(self, inits):
        inits = [[int(i) for i in f"{int.from_bytes(init, 'big'):016b}"]
for init in inits]
        self.l1 = LFSR(inits[0], [int(i) for i in f'{39989:016b}'])
        self.l2 = LFSR(inits[1], [int(i) for i in f'{40111:016b}'])
        self.l3 = LFSR(inits[2], [int(i) for i in f'{52453:016b}'])
    def getbit(self):
        x1 = self.l1.getbit()
        x2 = self.l2.getbit()
        x3 = self.l3.getbit()
        return (x1 & x2) ^ ((not x1) & x3)
    def getbyte(self):
        b = 0
        for i in range(8):
            b = (b << 1) + self.getbit()
        return bytes([b])

def bytes_to_bits(a):
    return [[int(i) for i in f"{int.from_bytes(init, 'big'):016b}"] for init in [a]]

def corr(a: list, b: list):
    assert len(a) == len(b)
    s = 0
    for i,j in zip(a,b):
        if i == j:
            s += 1
    return s/len(a)

l1_fb = [int(i) for i in f'{39989:016b}']
l2_fb = [int(i) for i in f'{40111:016b}']
l3_fb = [int(i) for i in f'{52453:016b}']

mx = 0
qq = string.printable.encode('utf-8')
FLAG = b''
# l3_fb
for i in qq:
    for j in qq:
        l = LFSR(bytes_to_bits(bytes([i]+[j]))[0], l3_fb)
        guess = [l.getbit() for _ in range(100)]

        tmp = corr(output, guess)
        if mx < tmp:
            print(f"score: {tmp}, val: {i}, {j}, payload: \"{bytes([i]+[j])}\"")
            mx = tmp
            ans = bytes([i] + [j])
FLAG = ans + FLAG
print(FLAG)

mx = 0
# l2_fb
for i in qq:
    for j in qq:
        l = LFSR(bytes_to_bits(bytes([i]+[j]))[0], l2_fb)
        guess = [l.getbit() for _ in range(100)]

        tmp = corr(output, guess)
        if mx < tmp:
            print(f"score: {tmp}, val: {i}, {j}, payload: \"{bytes([i]+[j])}\"")
            mx = tmp
            ans = bytes([i] + [j])
FLAG = ans + FLAG
```

```
print(FLAG)

mx = 0
FLAG = b'  ' + FLAG
# l1_fb
for i in qq:
    for j in qq:
        l = MYLFSR([bytes([i]+[j]), FLAG[2:4], FLAG[4:6]])
        guess = [l.getbit() for _ in range(100)]

        tmp = corr(output, guess)
        if mx < tmp:
            print(f"score: {tmp}, val: {i}, {j}, payload: \"{bytes([i]+[j])}\"")
            mx = tmp
            ans = bytes([i] + [j])
FLAG = ans + FLAG.re
```

Because the feedbacks of l1, l2 and l3 are known, we can easily generate x1, x2 and x3 by given any two bytes as initial value.
So we can only use 256*256 times (2 bytes) to brute force the flag, and because flag is printable and not be `\n`, `\t`, `<space>`, `\r` and `\b`, we can reduce the range of character to 95, using 95*95 times to brute force each block.

For flag[4:6]

When there is 2 bytes making the probability of degree of similarity between x3 and `output.txt` be larger than other 2 bytes (closing 75%), the 2 bytes propably are part of flag.

For flag[2:4]

Same as `flag[4:6]`.

For flag[0:2]

Once we get `flag[2:6]`, all we need to do is brute force 2 bytes, trying to make the probability of degree of similarity between output of **our `MYLFSR` is 100% same as `output.txt`**, then we will get the all flag.

POA (Padding Oracle Attack)

Normally, if plaintext isn't multiple of 16, server will automatically pad it for us.
The padding is usually with `bytes( [n] )*( n = (16 - len(plaintext)%16) )`, but sometimes it will define by user. Like this time, the padding is `bytes( [1] ) + bytes( [0] )*( n = (16 -`

`len(plaintext)%16 - 1) )`.

As we know, the server will print YES if encryption is successfully decrypted, and when:

1. Padding is correct
2. Ciphertext is complete and loseless

, encryption will be successfully decrypted.
We can build a payload which can pass server's padding rule, and **xor with byte** we build to **get decrypt**, then **xor with origin byte** to **get plaintext**.

Pseudo code:

```
for value in range(0, 256): # bytes range
    if pass_padding_rule( origin_cipher[:position_to_brute_force-1] + value + rest_padding ):
        decrypt = 0x80 xor value # when the corresponding part of plaintext is 0x80, rule will be passed
        plaintext = origin_cipher[position_to_brute_force] xor decrypt # decrypt xor with origin byte, and the result is origin plaintext
```

P.S. Split cipher to blocks which size is 16 and use `n-1`th block to POA `n`th block

Attack

Following is my payload:

```
#!/usr/bin/env python3
import os
from Crypto.Cipher import AES
from pwn import *

key = os.urandom(16)
"""
with open('flag', 'rb') as f:
    flag = f.read()
"""
flag = b'CTF{XXXXXXXX}'

class PaddingError(Exception):
    pass

def pad(data):
    padlen = 16 - len(data) % 16
    # 補上 1 + (padlen*8-1) 的 0，並轉成二進位，即為 2^(len*8)
    # padlen = 1 ==> 2^7,   1000 0000
    # padlen = 2 ==> 2^15,  1000 0000 0000 0000
    return data + int('1' + '0' * (padlen * 8 - 1), 2).to_bytes(padlen, 'big')
```

```python
def unpad(data):
    for i in range(len(data) - 1, len(data) - 1 - 16, -1):
        if data[i] == 0x80:
            return data[:i]
        elif data[i] != 0x00:
            raise PaddingError
    raise PaddingError


def xor(a, b):
    return bytes([i^j for i,j in zip(a,b)])

r = remote('140.112.31.97', 30000)
r.recvuntil('cipher = ')
enc = bytes.fromhex(r.recvline().replace(b'\n', b'').decode('utf-8'))
assert len(enc) == 48

def oracle(text):
    r.sendline(text.hex())
    c = r.recvline()
    if b'YES' in c:
        return True
    else:
        return False

flag = b''
for i in range(16, len(enc), 16):
    if i == 32:
        ans = b'\x00\x00\x00\x00\x00\x00\x00\x00' # 第二輪
    else:
        ans = b''
    iv = enc[i-16:i] # e.g. 71e32b962e8eafdd62a9c55a4af44ce5
    block = enc[i:i+16] # e.g 0eb793e55975dca193e8ca93853bb21c
    print(iv.hex(), block.hex())
    for j in range(len(ans),16): # 長度為 16 的 ciphertext
        for k in range(256): # 00 ~ ff
            if bytes([k]) == iv[-j]:
                continue
            payload = iv[:15-j] + bytes([k]) # origin[-j] + 替換的
            # e.g. 71e32b962e8eafdd62a9c55a4af44c 00 for j = 0
            payload += xor(xor(ans, iv[-j:]), bytes( [0]*j )) # 讓後面的幾位數與 block xor 為 00
            # xor(ans, iv[-j:]) 會得到密文 (decrypt)
            payload += block
            if oracle(payload):
                ans = bytes([k ^ 0x80 ^ iv[15-j]]) + ans
                print(ans)
                break
    flag += ans

print(flag)

"""
```

```
71e32b962e8eafdd62a9c55a4af44c e5 ==> 替換成其他的, e.g. 00, 01, ...
如果不是 e5, 則嘗試送 payload 過去確定是否符合標準
使得 dec xor payload 為 0x80
"""
```

The 2th round, we are going to POA the 16~32 block, will get initial answer `b'\x00\x00\x00\x00\x00\x00\x00\x00'` by default, it is because if `b'\x80\x00...\x00'` are origin bytes, server will regard `b'\x00'` as correct answer and response with `'YES'`, the condition passing the rule will increase and payload will becomes more complex.

I also think that 2th block of flag may be padded, so I manually append multiple of `b'\x00'` to initial answer, and finally appending `b'\x00\x00\x00\x00\x00\x00\x00\x00'` to initial answer, server will get me correct flag!