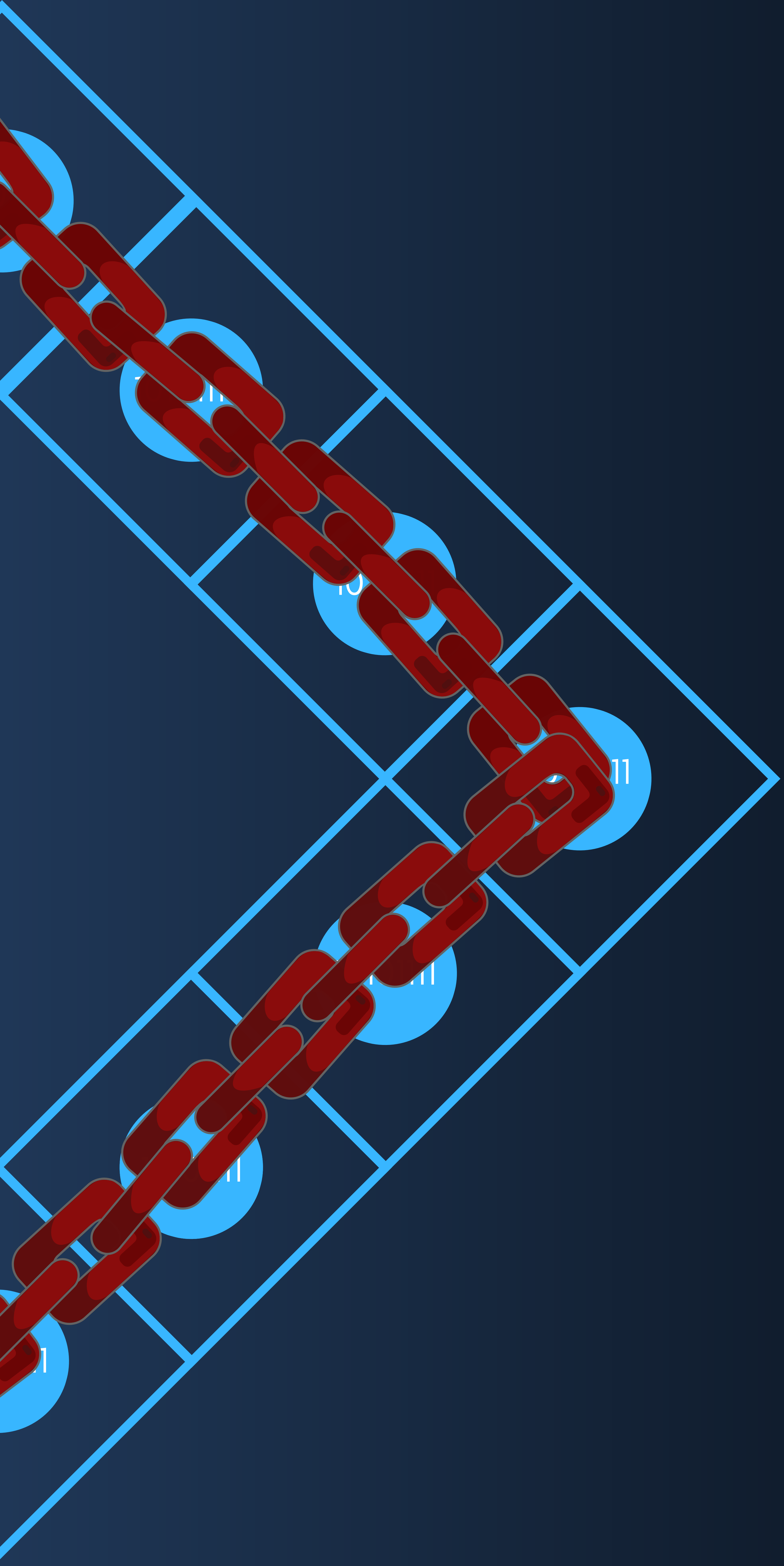


REVIL RANSOMWARE

Malware Analysis Report

tl;dr: I'm no designer, will improve this later

Executive Summary

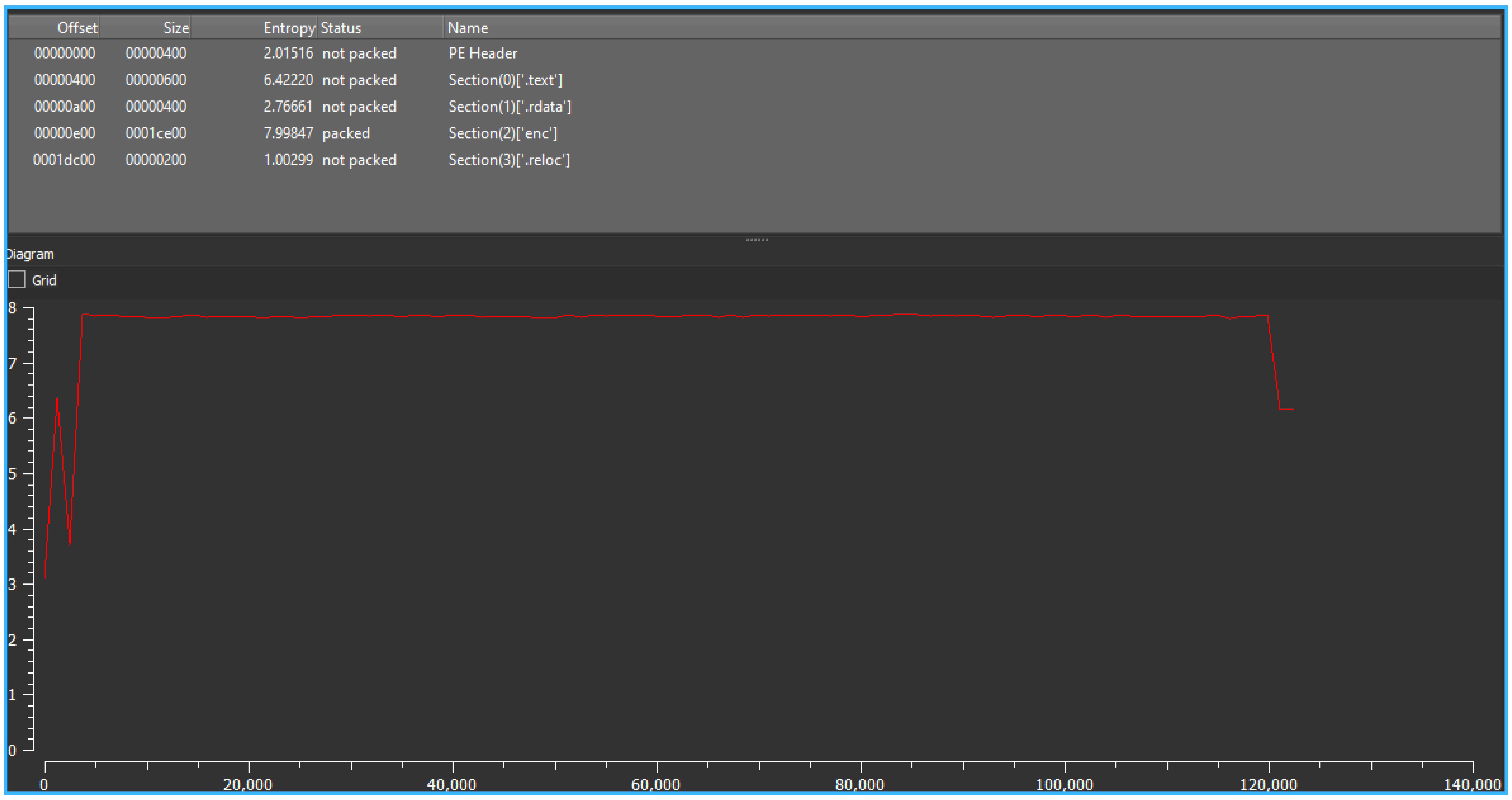
This report examines a sample of the REvil (Sodinokibi) ransomware focusing on its encryption and key generation mechanisms. The ransomware employs AES-CTR and Elliptic-Curve Cryptography (ECC) (Curve25519) to securely encrypt files, making decryption without the attacker's private key impossible.

Introduction

Stage 1

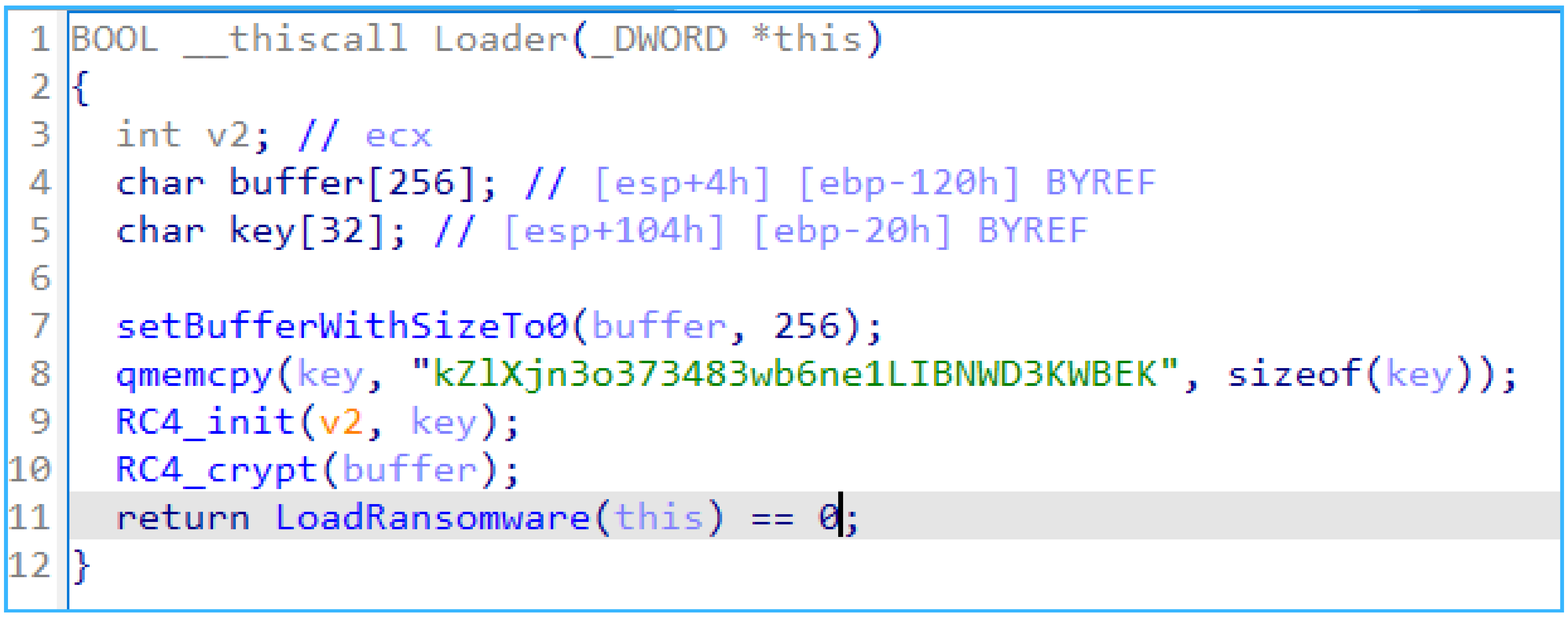
MD5: a4331ff805b0a8f2a2892777c224b65e
SHA256:
329983dc2a23bd951b24780947cb9a6ae3fb80d5ef546e8538dfd9459b176483

This sample of Revil Ransomware consists of 2 stages. First Stage Decrypts the second stage and execute stage 2.
When we look into sections of the malware, we can see that there is unique section called '*enc*'. This section has 7.99 entropy, which is a common indicator for encrypted data.



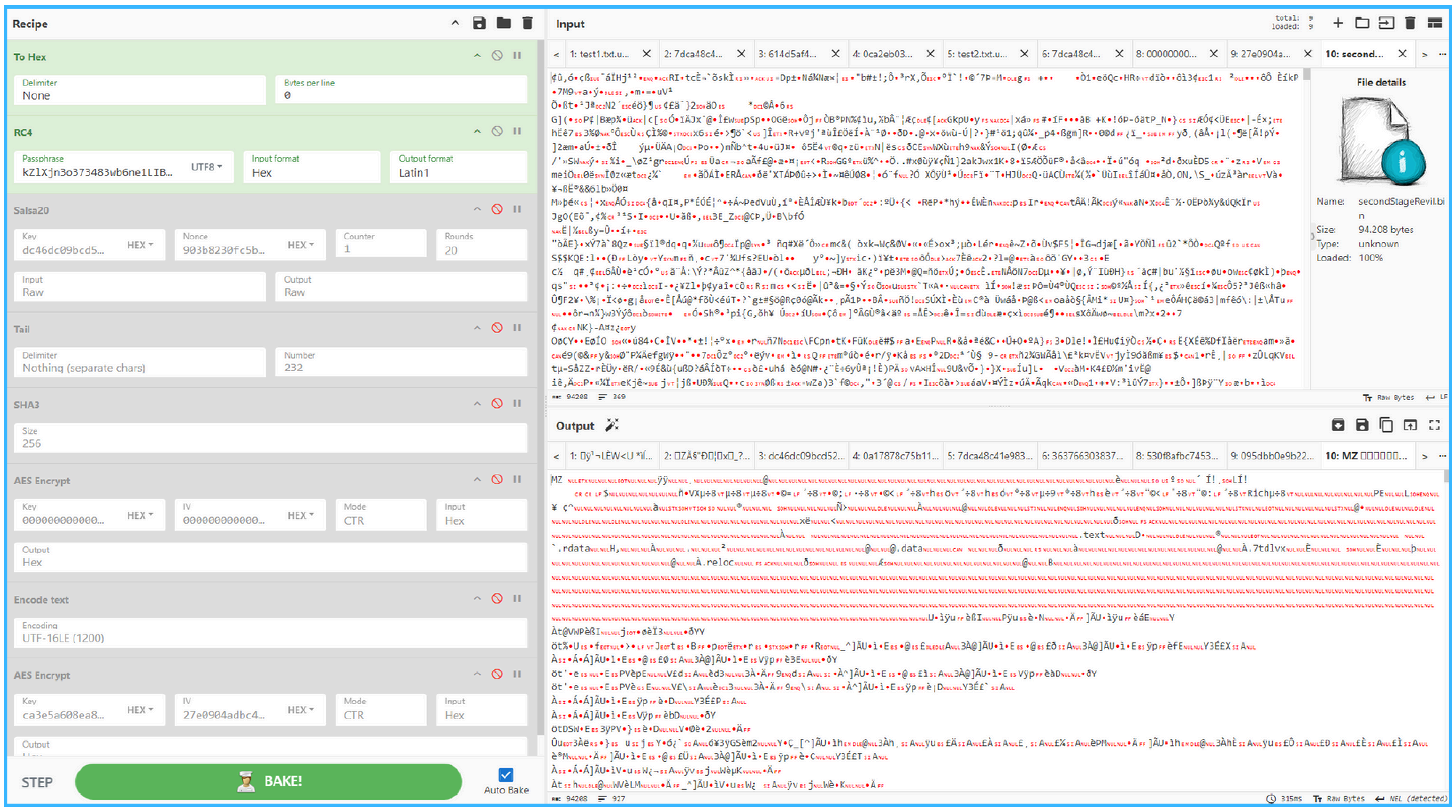
Offset	Size	Entropy	Status	Name
00000000	00000400	2.01516	not packed	PE Header
00000400	00000600	6.42220	not packed	Section(0)['.text']
00000a00	00000400	2.76661	not packed	Section(1)['.rdata']
00000e00	0001ce00	7.99847	packed	Section(2)['enc']
0001dc00	00000200	1.00299	not packed	Section(3)['.reloc']

We can see the general structure of the executable below, After Entry function initializes command line arguments, it calls Loader function. Loader function first initializes the key for encrypted section 'enc', then decrypts it using RC4 encryption algorithm. Both second stage and first stage of the ransomware doesn't use Wincrypt API calls to encrypt or decrypt data, all encryption algorithms are included in the malwares. This makes it harder to recognize encryption algorithms included in the ransomware. After decrypting stage 2 with rc4, LoadRansomware function is called.



```
BOOL __thiscall Loader(_DWORD *this)
{
  int v2; // ecx
  char buffer[256]; // [esp+4h] [ebp-120h] BYREF
  char key[32]; // [esp+104h] [ebp-20h] BYREF

  setBufferWithSizeTo0(buffer, 256);
  qmemcpy(key, "kZlXjn3o373483wb6ne1LIBNWD3KWBEK", sizeof(key));
  RC4_init(v2, key);
  RC4_crypt(buffer);
  return LoadRansomware(this) == 0;
}
```

We can use the rc4 key to obtain second stage of the ransomware



Recipe

To Hex
Delimiter: None
Bytes per line: 0

RC4
Passphrase: kZ1Xjn3o373483wb6ne1LIB… UTF8
Input format: Hex
Output format: Latin1

Salsa20
Key: dc46dc09bcd5… HEX
Nonce: 903b8230fc5b… HEX
Counter: 1
Rounds: 20
Input: Raw
Output: Raw

Tail
Delimiter: Nothing (separate chars)
Number: 232

SHA3
Size: 256

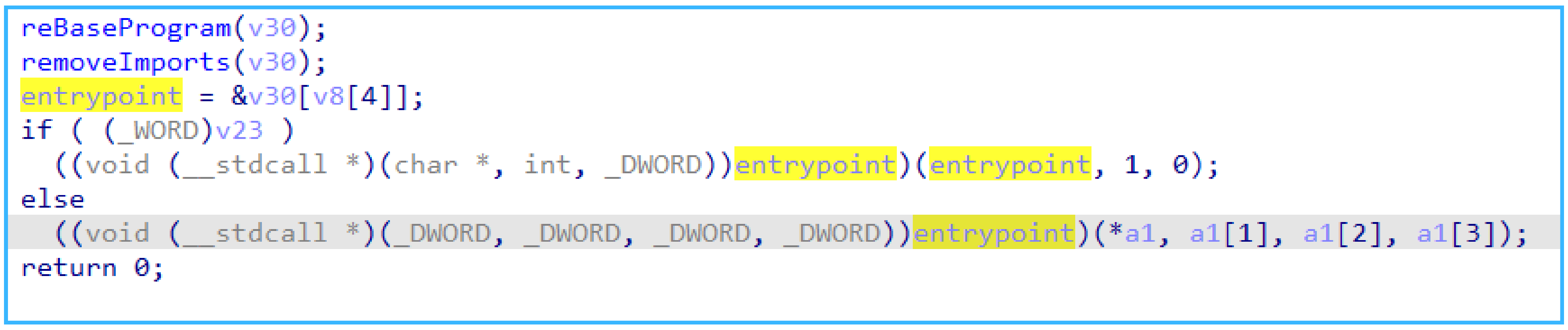
AES Encrypt
Key: 000000000000… HEX
IV: 000000000000… HEX
Mode: CTR
Input: Hex
Output: Hex

Encode text
Encoding: UTF-16LE (1200)

AES Encrypt
Key: ca3e5a608ea8… HEX
IV: 27e0904adbc4… HEX
Mode: CTR
Input: Hex
Output

File details
Name: secondStageRevil.bin
Size: 94,208 bytes
Type: unknown
Loaded: 100%

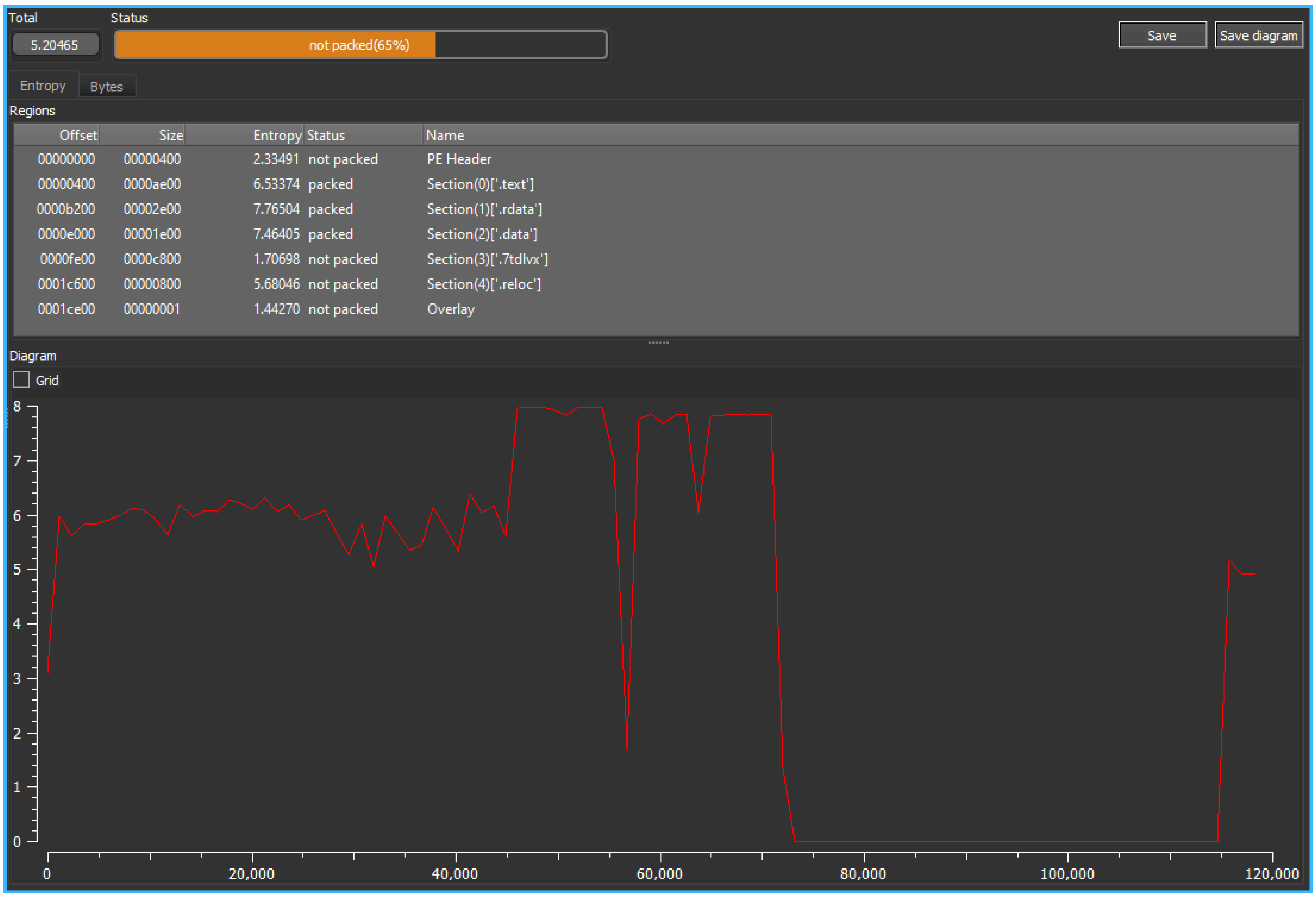
LoadRansomware function first calls *NtAllocateVirtualMemory* and *NtWriteVirtualMemory* functions to allocate and write the decrypted payload, the verifies if the decrypted block is a valid execute pe program. Finally, it rebases the executable and runs it from its entrypoint.



```
reBaseProgram(v30);
removeImports(v30);
entrypoint = &v30[v8[4]];
if ( (_WORD)v23 )
  ((void (__stdcall *)(char *, int, _DWORD))entrypoint)(entrypoint, 1, 0);
else
  ((void (__stdcall *)(_DWORD, _DWORD, _DWORD, _DWORD))entrypoint)(*a1, a1[1], a1[2], a1[3]);
return 0;
```

Stage 2

When we look the second stage, we see *.rdata* and *.data* sections have entropy close to 8 for most of its data, which could indicate most of its data is encrypted. When we investigate the sample further, we confirm that most of this data is encrypted using rc4 encryption algorithm.



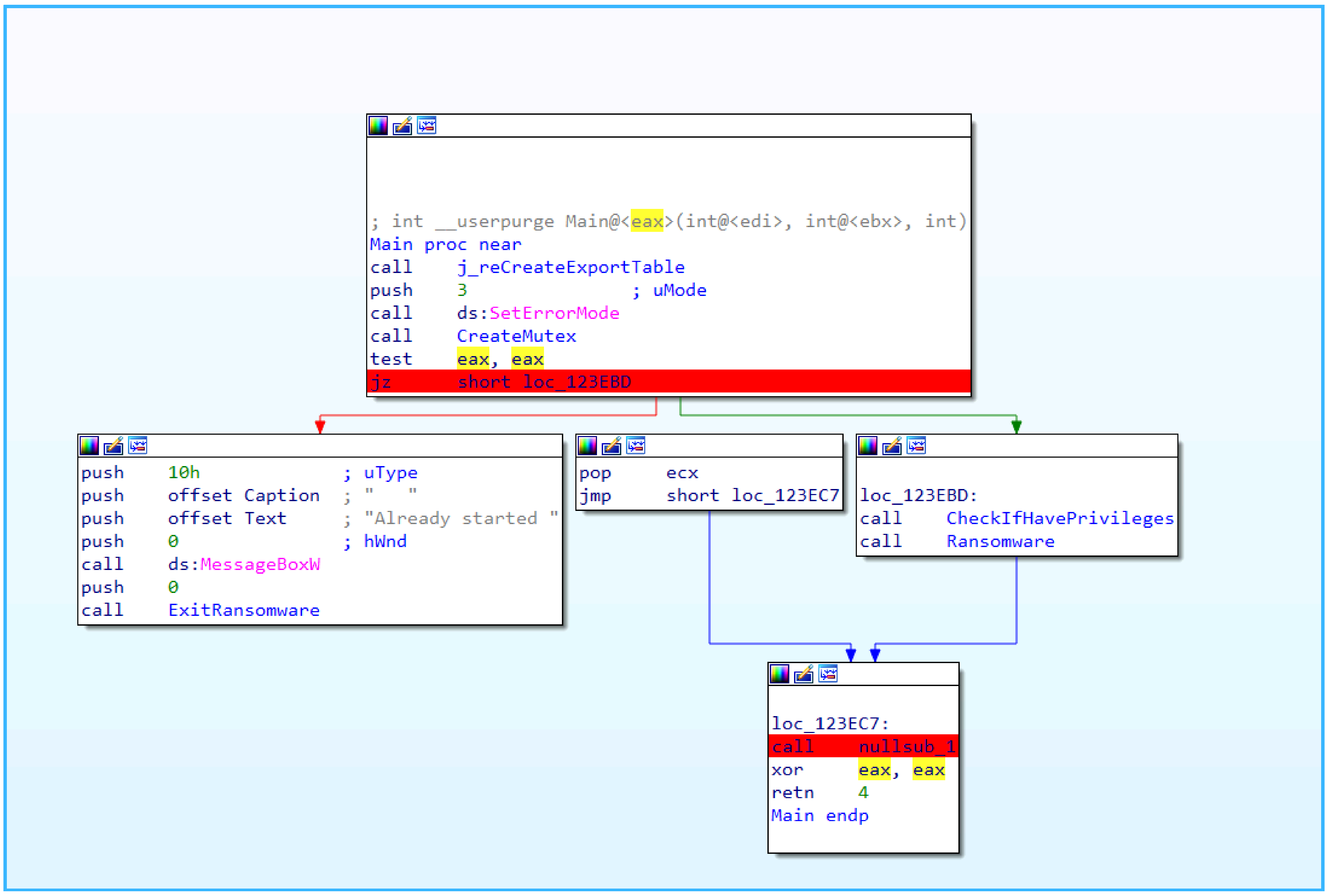
Total 5.20465

Status not packed(65%)

Offset	Size	Entropy	Status	Name
00000000	00000400	2.33491	not packed	PE Header
00000400	0000ae00	6.53374	packed	Section(0)['.text']
0000b200	00002e00	7.76504	packed	Section(1)['.rdata']
0000e000	00001e00	7.46405	packed	Section(2)['.data']
0000fe00	0000c800	1.70698	not packed	Section(3)['.7tdlvx']
0001c600	00000800	5.68046	not packed	Section(4)['.reloc']
0001ce00	00000001	1.44270	not packed	Overlay

Pre-Encryption

We can see the main execution flow of the ransomware below, first it restores its export table using a technique called api hashing. This technique is used to hide import tables in static analysis by recreating imports on runtime by using hashed addresses of the used functions.



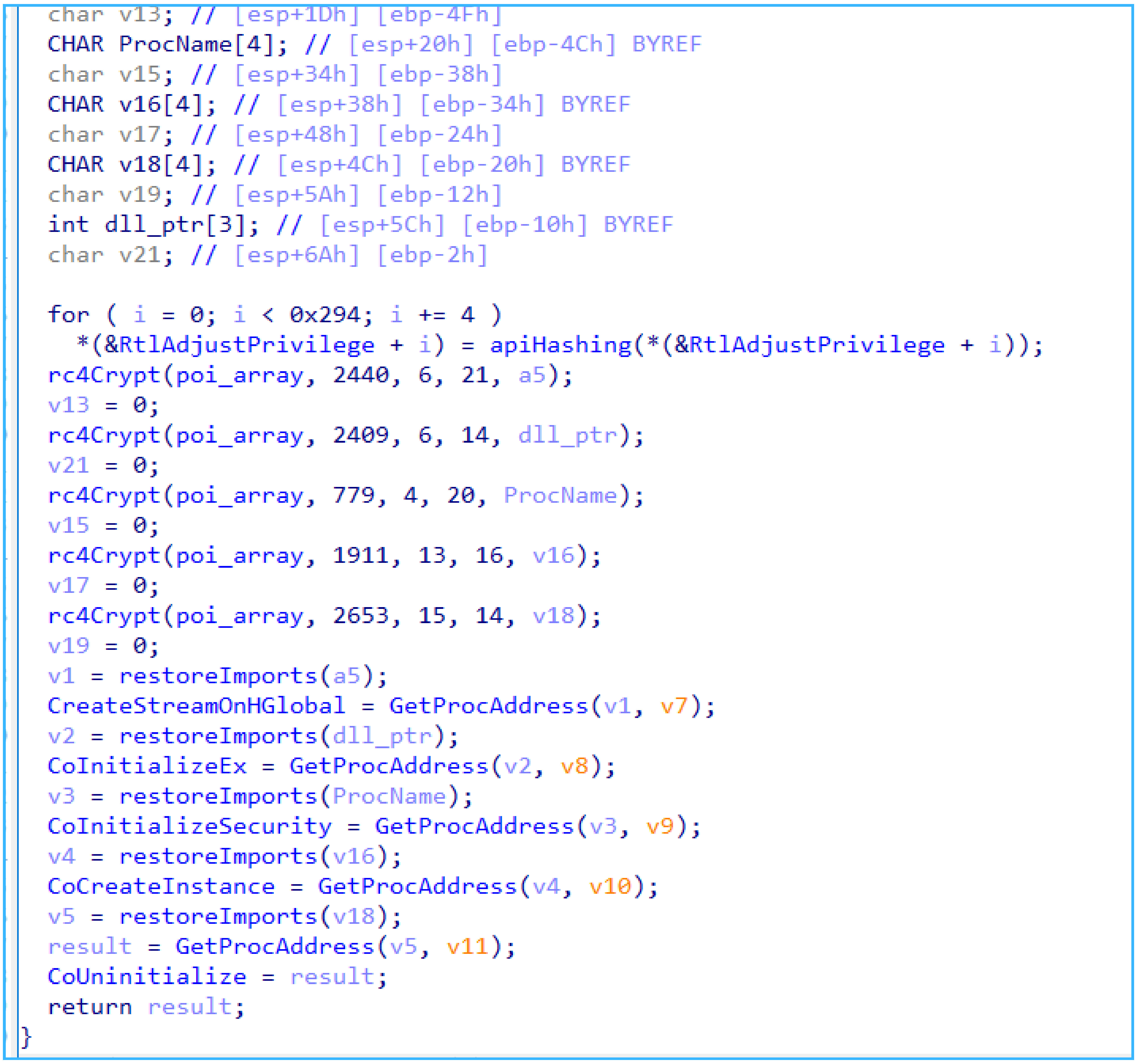
```
; int __userpurge Main@<eax>(int@<edi>, int@<ebx>, int)
Main proc near
call    j_reCreateExportTable
push    3                    ; uMode
call    ds:SetErrorMode
call    CreateMutex
test    eax, eax
jz      short loc_123EBD
```

```
push    10h              ; uType
push    offset Caption   ; "    "
push    offset Text      ; "Already started "
push    0                ; hWnd
call    ds:MessageBoxW
push    0
call    ExitRansomware
```

```
pop     ecx
jmp     short loc_123EC7
```

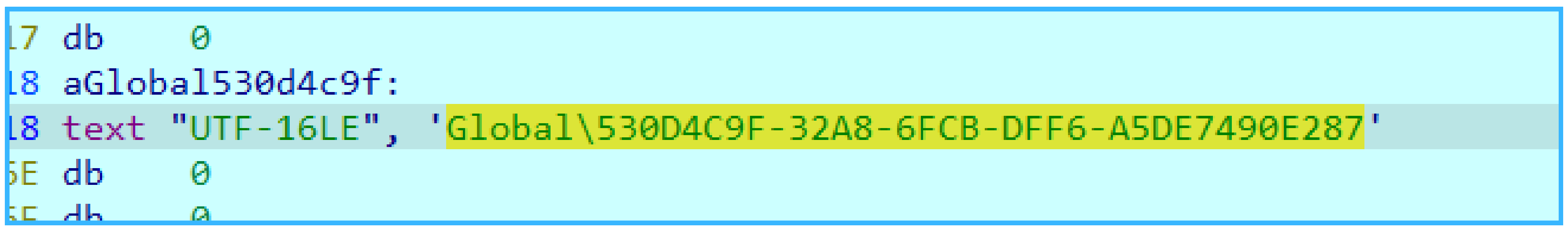
```
loc_123EBD:
call    CheckIfHavePrivileges
call    Ransomware
```

```
loc_123EC7:
call    nullsub_1
xor     eax, eax
retn    4
Main endp
```



```
  char v13; // [esp+1Dh] [ebp-4Fh]
  CHAR ProcName[4]; // [esp+20h] [ebp-4Ch] BYREF
  char v15; // [esp+34h] [ebp-38h]
  CHAR v16[4]; // [esp+38h] [ebp-34h] BYREF
  char v17; // [esp+48h] [ebp-24h]
  CHAR v18[4]; // [esp+4Ch] [ebp-20h] BYREF
  char v19; // [esp+5Ah] [ebp-12h]
  int dll_ptr[3]; // [esp+5Ch] [ebp-10h] BYREF
  char v21; // [esp+6Ah] [ebp-2h]

  for ( i = 0; i < 0x294; i += 4 )
    *(&RtlAdjustPrivilege + i) = apiHashing(*(&RtlAdjustPrivilege + i));
  rc4Crypt(poi_array, 2440, 6, 21, a5);
  v13 = 0;
  rc4Crypt(poi_array, 2409, 6, 14, dll_ptr);
  v21 = 0;
  rc4Crypt(poi_array, 779, 4, 20, ProcName);
  v15 = 0;
  rc4Crypt(poi_array, 1911, 13, 16, v16);
  v17 = 0;
  rc4Crypt(poi_array, 2653, 15, 14, v18);
  v19 = 0;
  v1 = restoreImports(a5);
  CreateStreamOnHGlobal = GetProcAddress(v1, v7);
  v2 = restoreImports(dll_ptr);
  CoInitializeEx = GetProcAddress(v2, v8);
  v3 = restoreImports(ProcName);
  CoInitializeSecurity = GetProcAddress(v3, v9);
  v4 = restoreImports(v16);
  CoCreateInstance = GetProcAddress(v4, v10);
  v5 = restoreImports(v18);
  result = GetProcAddress(v5, v11);
  CoUninitialize = result;
  return result;
}
```

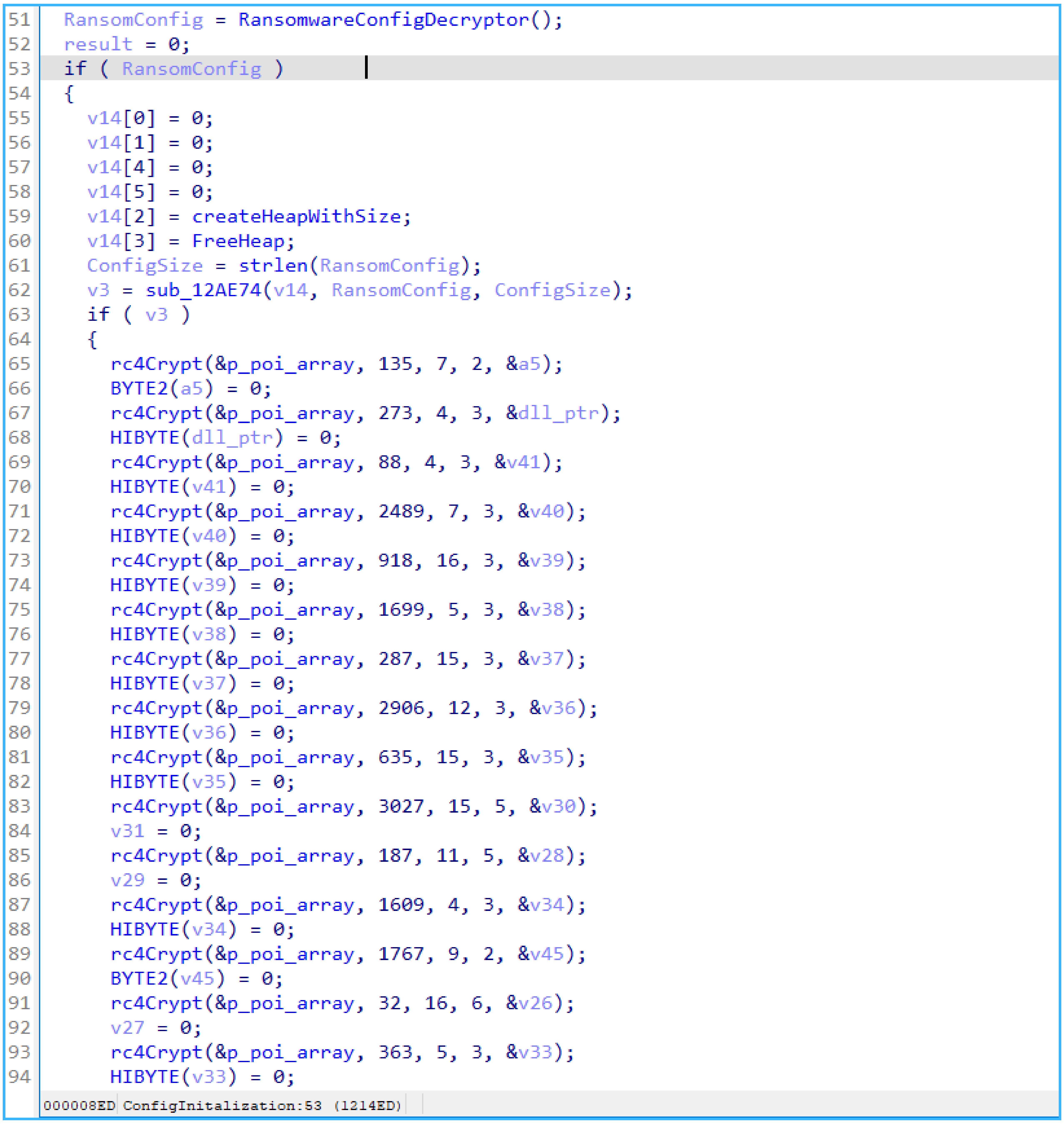
After restoring the import table, the ransomware ensures that only one instance is running by creating a mutex with the name: *Global\530D4C9F-32A8-6FCB-DFF6-A5DE7490E287*. It then checks whether it has been executed with administrator privileges on the target system. If the necessary privileges are not present, the ransomware attempts to re-execute itself with elevated (administrator) rights. This process involves a basic UAC (User Account Control) prompt without any bypass techniques, indicating that the threat actor likely already has administrator access on the systems where the ransomware is deployed.



```
17 db    0
18 aGlobal530d4c9f:
18 text "UTF-16LE", 'Global\530D4C9F-32A8-6FCB-DFF6-A5DE7490E287'
5E db    0
5F db    0
```

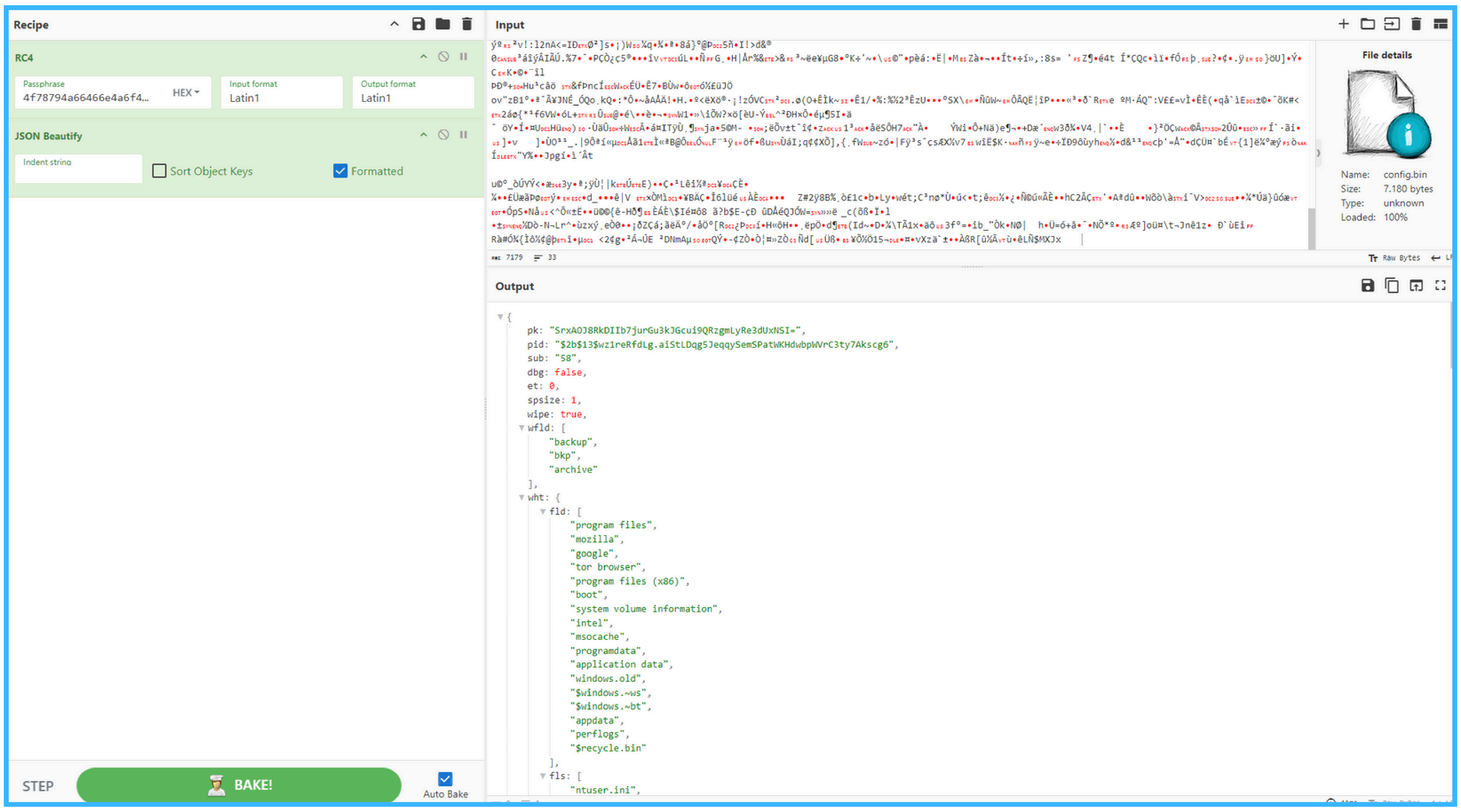
Configuration

After necessary conditions are met, ransomware starts by initializing configuration. Configuration data is stored in the malware as encrypted. Configuration is a Json object, ransomware parses this object to initialize necessary settings, then other settings that is not included in the config is decrypted and initialized.



```
RansomConfig = RansomwareConfigDecryptor();
result = 0;
if ( RansomConfig )
{
  v14[0] = 0;
  v14[1] = 0;
  v14[4] = 0;
  v14[5] = 0;
  v14[2] = createHeapWithSize;
  v14[3] = FreeHeap;
  ConfigSize = strlen(RansomConfig);
  v3 = sub_12AE74(v14, RansomConfig, ConfigSize);
  if ( v3 )
  {
    rc4Crypt(&p_poi_array, 135, 7, 2, &a5);
    BYTE2(a5) = 0;
    rc4Crypt(&p_poi_array, 273, 4, 3, &dll_ptr);
    HIBYTE(dll_ptr) = 0;
    rc4Crypt(&p_poi_array, 88, 4, 3, &v41);
    HIBYTE(v41) = 0;
    rc4Crypt(&p_poi_array, 2489, 7, 3, &v40);
    HIBYTE(v40) = 0;
    rc4Crypt(&p_poi_array, 918, 16, 3, &v39);
    HIBYTE(v39) = 0;
    rc4Crypt(&p_poi_array, 1699, 5, 3, &v38);
    HIBYTE(v38) = 0;
    rc4Crypt(&p_poi_array, 287, 15, 3, &v37);
    HIBYTE(v37) = 0;
    rc4Crypt(&p_poi_array, 2906, 12, 3, &v36);
    HIBYTE(v36) = 0;
    rc4Crypt(&p_poi_array, 635, 15, 3, &v35);
    HIBYTE(v35) = 0;
    rc4Crypt(&p_poi_array, 3027, 15, 5, &v30);
    v31 = 0;
    rc4Crypt(&p_poi_array, 187, 11, 5, &v28);
    v29 = 0;
    rc4Crypt(&p_poi_array, 1609, 4, 3, &v34);
    HIBYTE(v34) = 0;
    rc4Crypt(&p_poi_array, 1767, 9, 2, &v45);
    BYTE2(v45) = 0;
    rc4Crypt(&p_poi_array, 32, 16, 6, &v26);
    v27 = 0;
    rc4Crypt(&p_poi_array, 363, 5, 3, &v33);
    HIBYTE(v33) = 0;
000008ED ConfigInitalization:53 (1214ED)
```

Configuration file contains a whitelist folders and files, debug mode setting, service and process list and other settings that is used in ransomware.



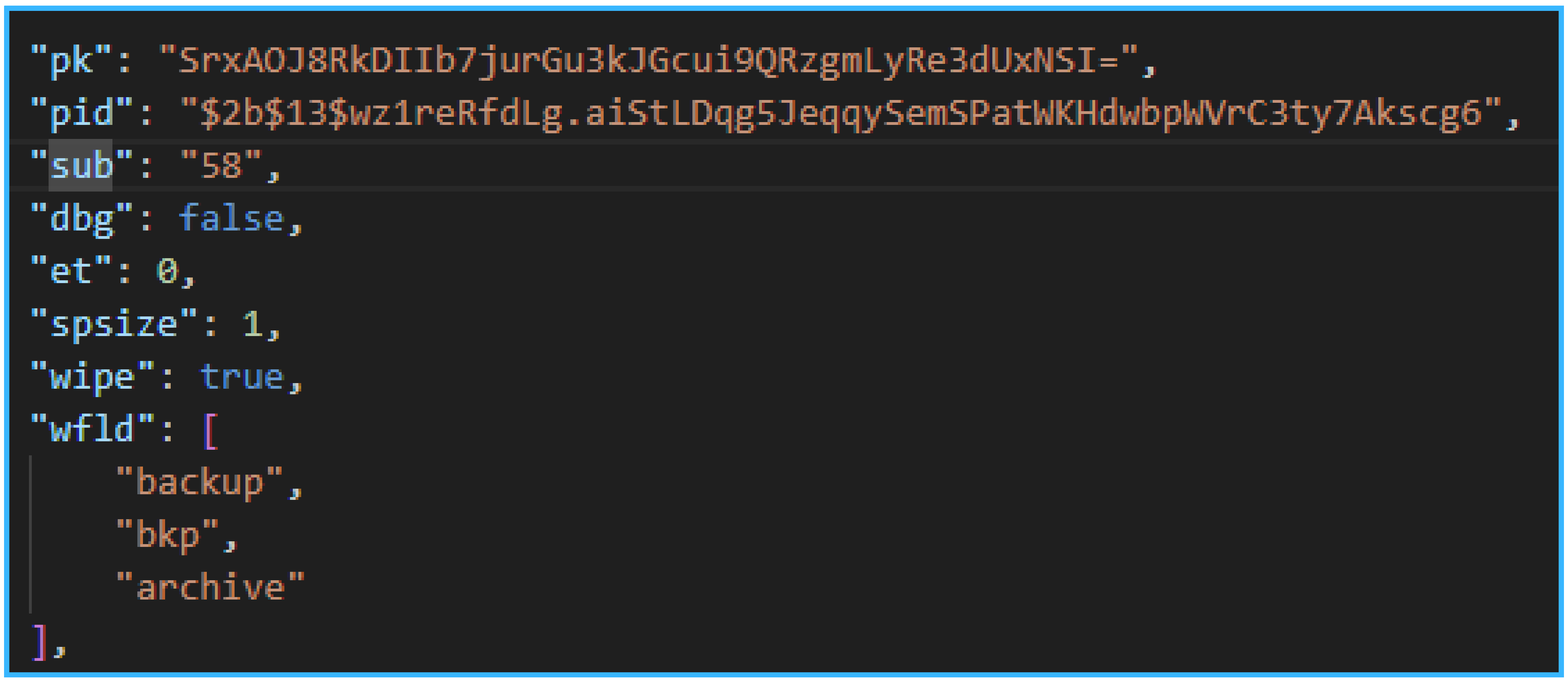
Passphrase: 4f78794a66466e4a6f4... HEX
Input format: Latin1
Output format: Latin1
Indent string
☐ Sort Object Keys
☑ Formatted

Name: config.bin
Size: 7,180 bytes
Type: unknown
Loaded: 100%

7179 33

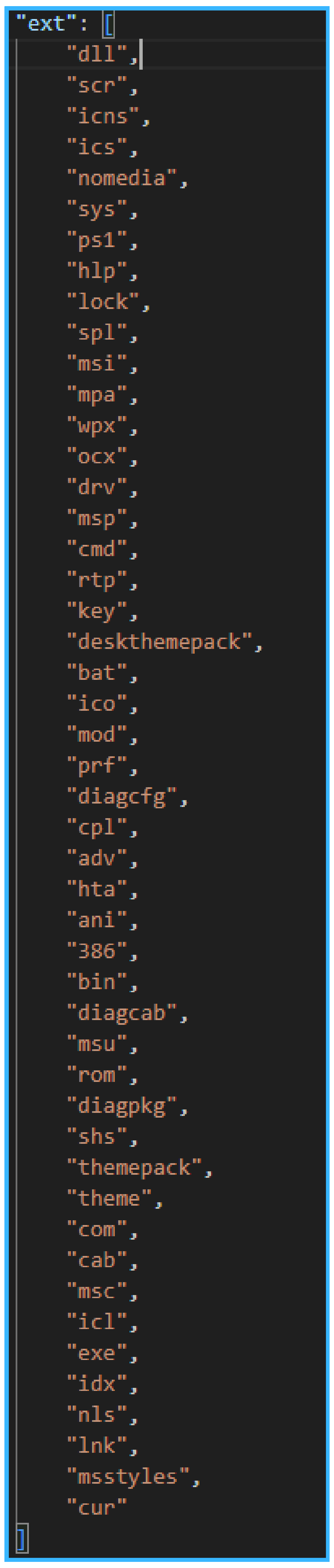
```
{
    pk: "SrxAOJ8RkDIIb7jurGu3kJGcui9QRzgmLyRe3dUxNSI=",
    pid: "$2b$13$wz1reRfdLg.aiStLDqg5JeqqySemSPatWKHdwbpWVrC3ty7Akscg6",
    sub: "58",
    dbg: false,
    et: 0,
    spsize: 1,
    wipe: true,
    wfld: [
        "backup",
        "bkp",
        "archive"
    ],
    wht: {
        fld: [
            "program files",
            "mozilla",
            "google",
            "tor browser",
            "program files (x86)",
            "boot",
            "system volume information",
            "intel",
            "msocache",
            "programdata",
            "application data",
            "windows.old",
            "$windows.~ws",
            "$windows.~bt",
            "appdata",
            "perflogs",
            "$recycle.bin"
        ],
        fls: [
            "ntuser.ini",
```

While some of these settings meanings are still unknown after analysis, we can see that this configuration contains debug mode switch, folders to be wiped, whitelist for folders and files that would corrupt the OS in case of encryption, extensions that won't be meaningful to encrypt, services and processes to stop to achieve maximum efficiency from encryption process, ransom note and ransomware note format.

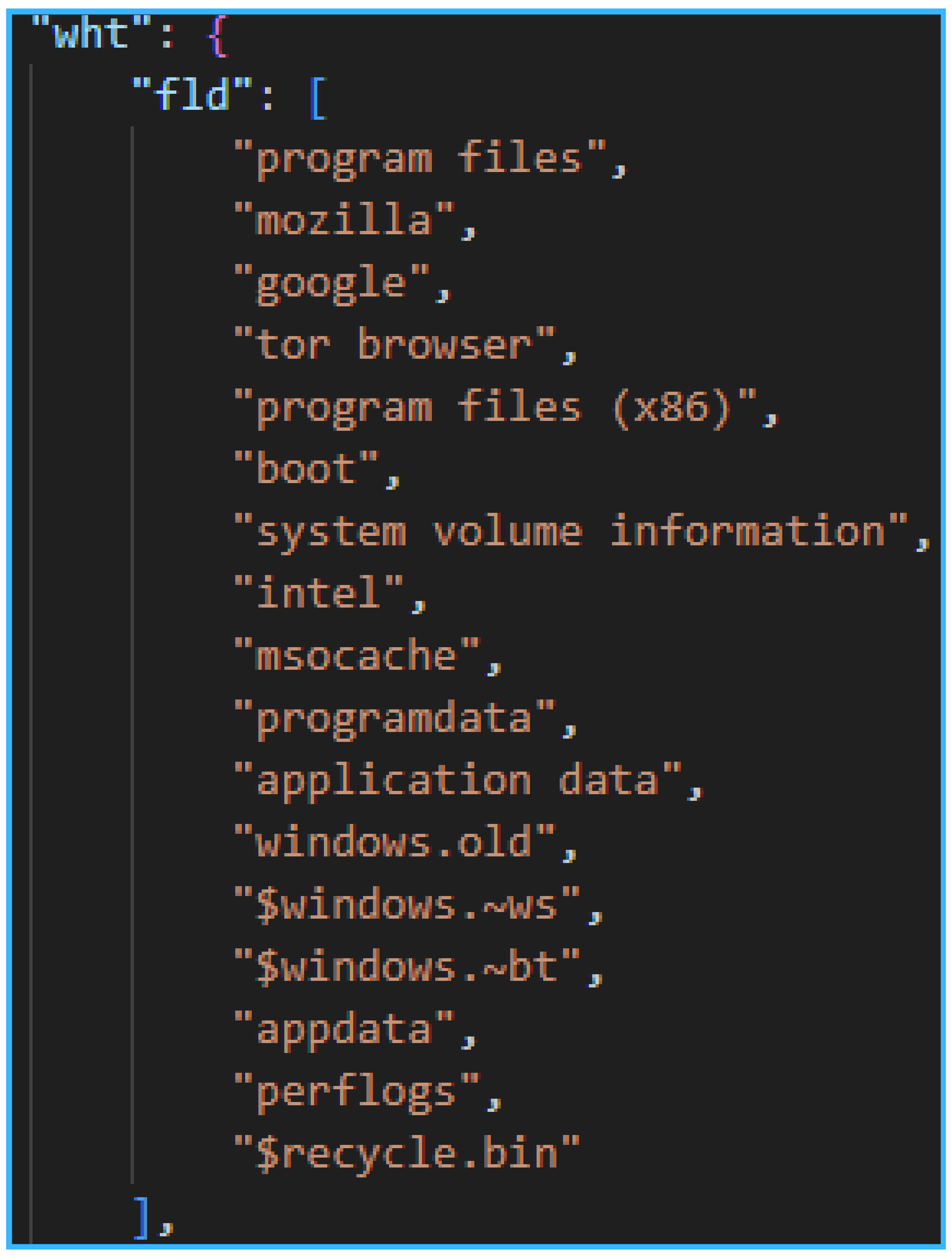


```
"pk": "SrxAOJ8RkDIIb7jurGu3kJGcui9QRzgmLyRe3dUxNSI=",
"pid": "$2b$13$wz1reRfdLg.aiStLDqg5JeqqySemSPatWKHdwbpWVrC3ty7Akscg6",
"sub": "58",
"dbg": false,
"et": 0,
"spsize": 1,
"wipe": true,
"wfld": [
    "backup",
    "bkp",
    "archive"
],
```

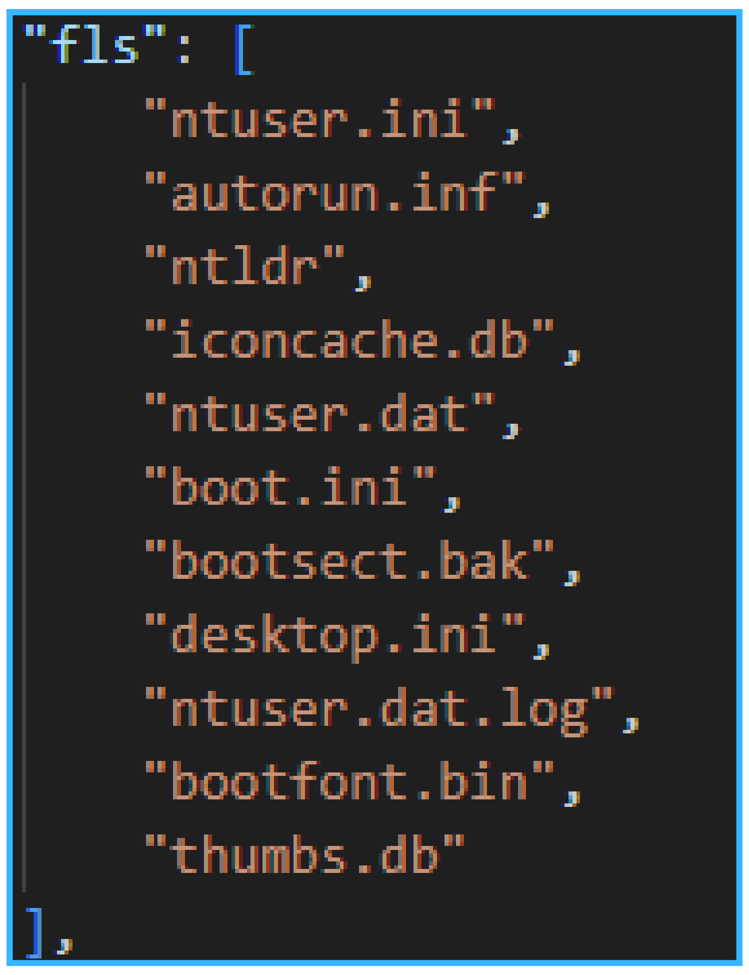
Debug mode setting, wipe setting, wipe folders



```
"ext": [
    "dll",
    "scr",
    "icns",
    "ics",
    "nomedia",
    "sys",
    "ps1",
    "hlp",
    "lock",
    "spl",
    "msi",
    "mpa",
    "wpx",
    "ocx",
    "drv",
    "msp",
    "cmd",
    "rtp",
    "key",
    "deskthemepack",
    "bat",
    "ico",
    "mod",
    "prf",
    "diagcfg",
    "cpl",
    "adv",
    "hta",
    "ani",
    "386",
    "bin",
    "diagcab",
    "msu",
    "rom",
    "diagpkg",
    "shs",
    "themepack",
    "theme",
    "com",
    "cab",
    "msc",
    "icl",
    "exe",
    "idx",
    "nls",
    "lnk",
    "msstyles",
    "cur"
]
```

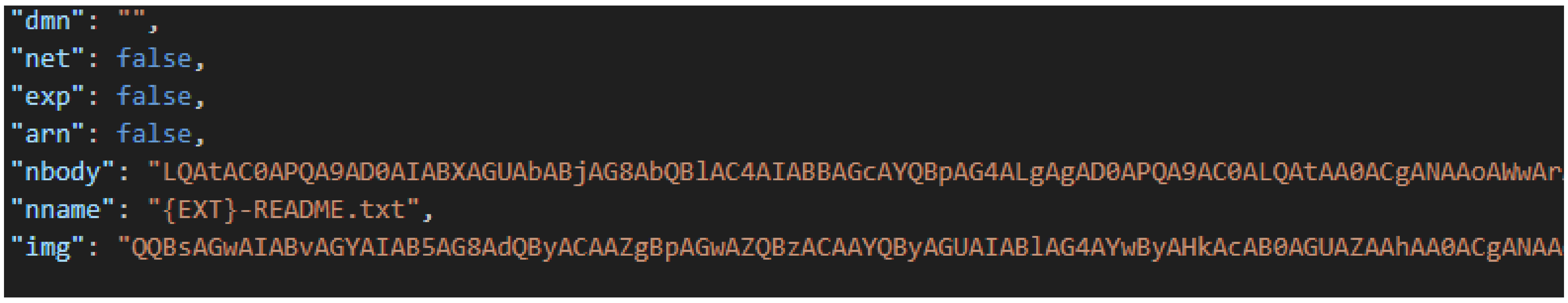


```
"wht": {
    "fld": [
        "program files",
        "mozilla",
        "google",
        "tor browser",
        "program files (x86)",
        "boot",
        "system volume information",
        "intel",
        "msocache",
        "programdata",
        "application data",
        "windows.old",
        "$windows.~ws",
        "$windows.~bt",
        "appdata",
        "perflogs",
        "$recycle.bin"
    ],
```



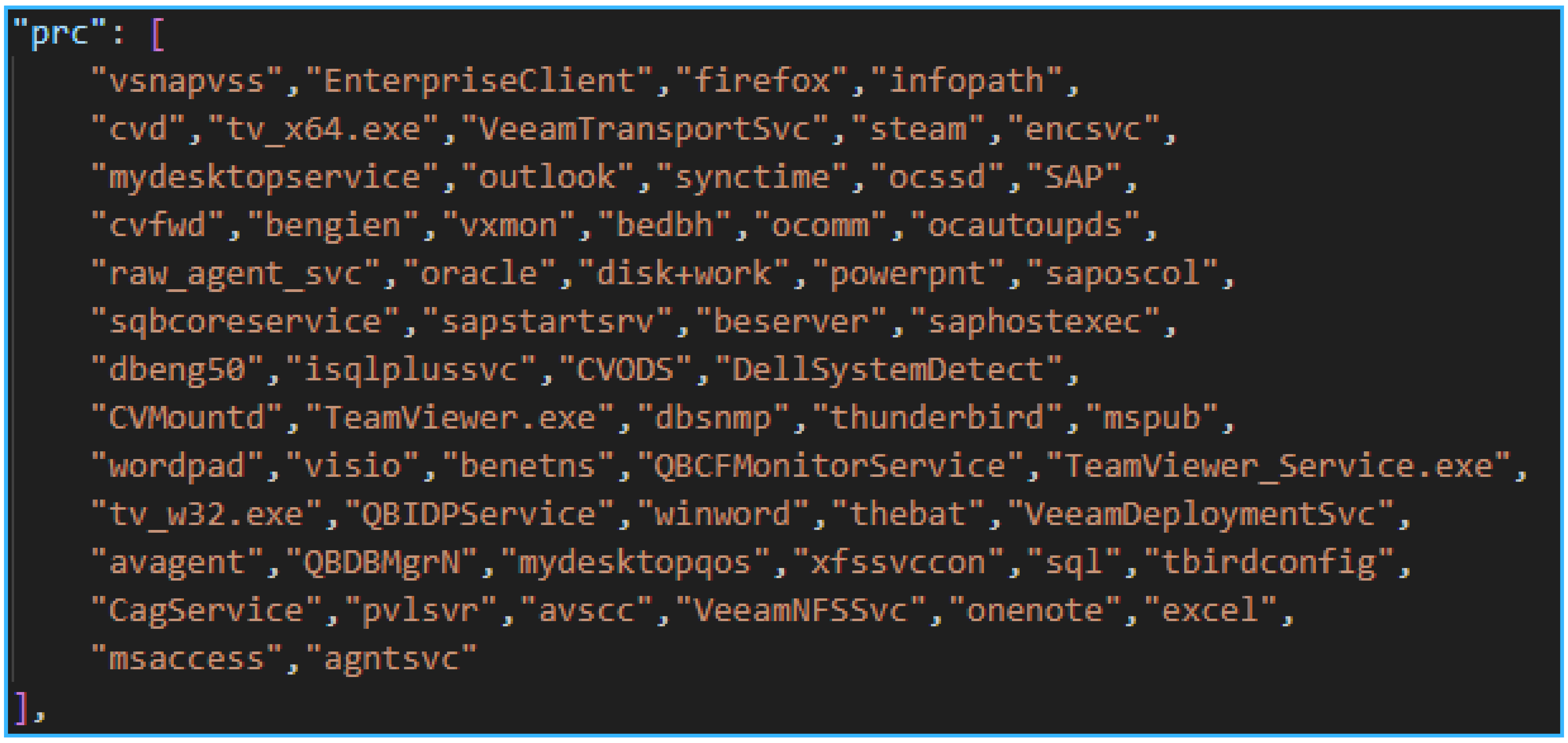
```
"fls": [
    "ntuser.ini",
    "autorun.inf",
    "ntldr",
    "iconcache.db",
    "ntuser.dat",
    "boot.ini",
    "bootsect.bak",
    "desktop.ini",
    "ntuser.dat.log",
    "bootfont.bin",
    "thumbs.db"
],
```

Folders, extensions and files to be whitelisted



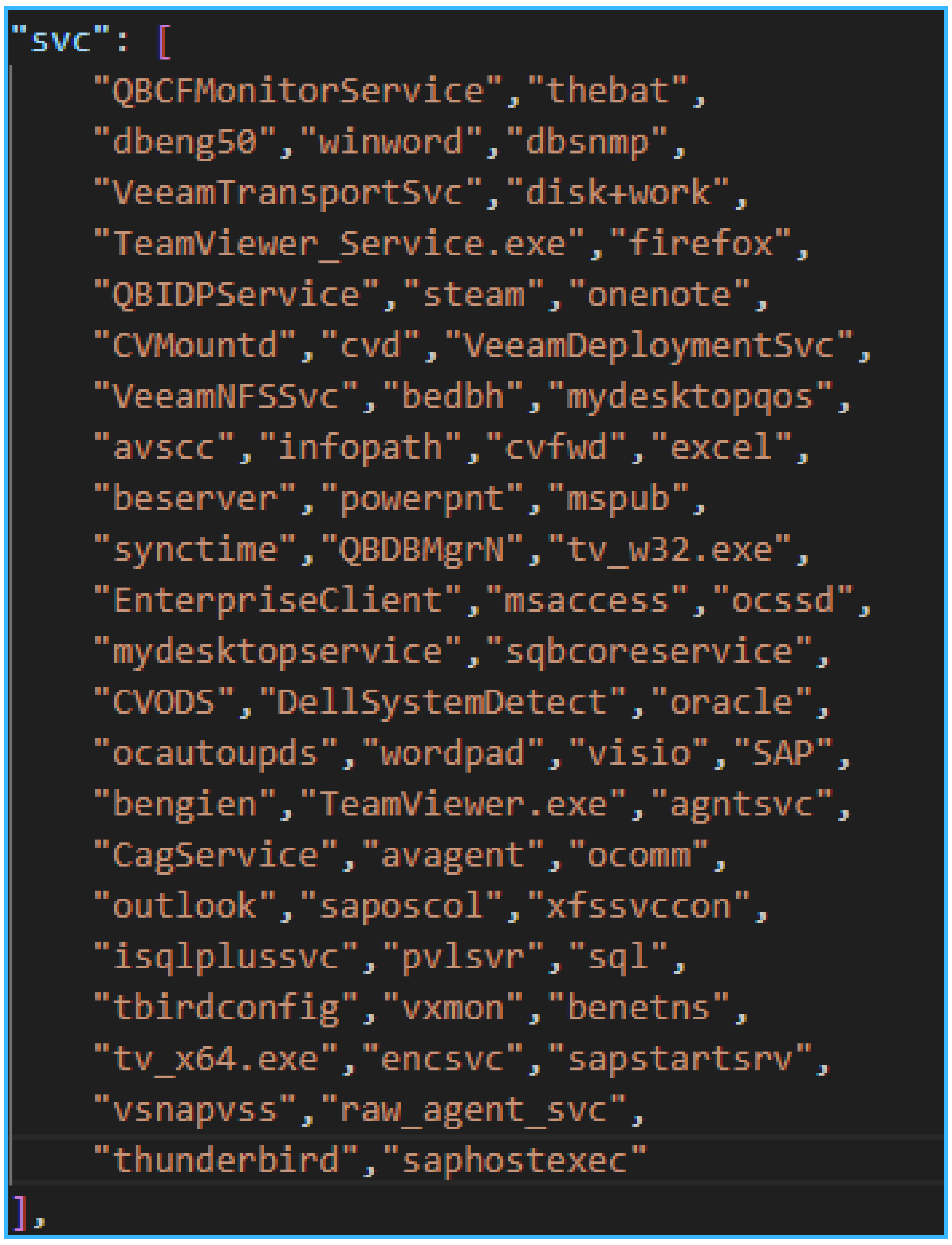
```
"dmn": "",
"net": false,
"exp": false,
"arn": false,
"nbody": "LQAtAC0APQA9AD0AIABXAGUAbABjAG8AbQBlAC4AIABBAGcAYQBpAG4ALgAgAD0APQA9AC0ALQAtAA0ACgANAAoAWwAr
"nname": "{EXT}-README.txt",
"img": "QQBsAGwAIABvAGYAIAB5AG8AdQByACAAZgBpAGwAZQBzACAAYQByAGUAIABlAG4AYwByAHkAcAB0AGUAZAAhAA0ACgANAA
```

Ransomware note, filename format and other settings



```
"prc": [
    "vsnapvss","EnterpriseClient","firefox","infopath",
    "cvd","tv_x64.exe","VeeamTransportSvc","steam","encsvc",
    "mydesktopservice","outlook","synctime","ocssd","SAP",
    "cvfwd","bengien","vxmon","bedbh","ocomm","ocautoupds",
    "raw_agent_svc","oracle","disk+work","powerpnt","saposcol",
    "sqbcoreservice","sapstartsrv","beserver","saphostexec",
    "dbeng50","isqlplussvc","CVODS","DellSystemDetect",
    "CVMountd","TeamViewer.exe","dbsnmp","thunderbird","mspub",
    "wordpad","visio","benetns","QBCFMonitorService","TeamViewer_Service.exe",
    "tv_w32.exe","QBIDPService","winword","thebat","VeeamDeploymentSvc",
    "avagent","QBDBMgrN","mydesktopqos","xfssvccon","sql","tbirdconfig",
    "CagService","pvlsvr","avscc","VeeamNFSSvc","onenote","excel",
    "msaccess","agntsvc"
],
```

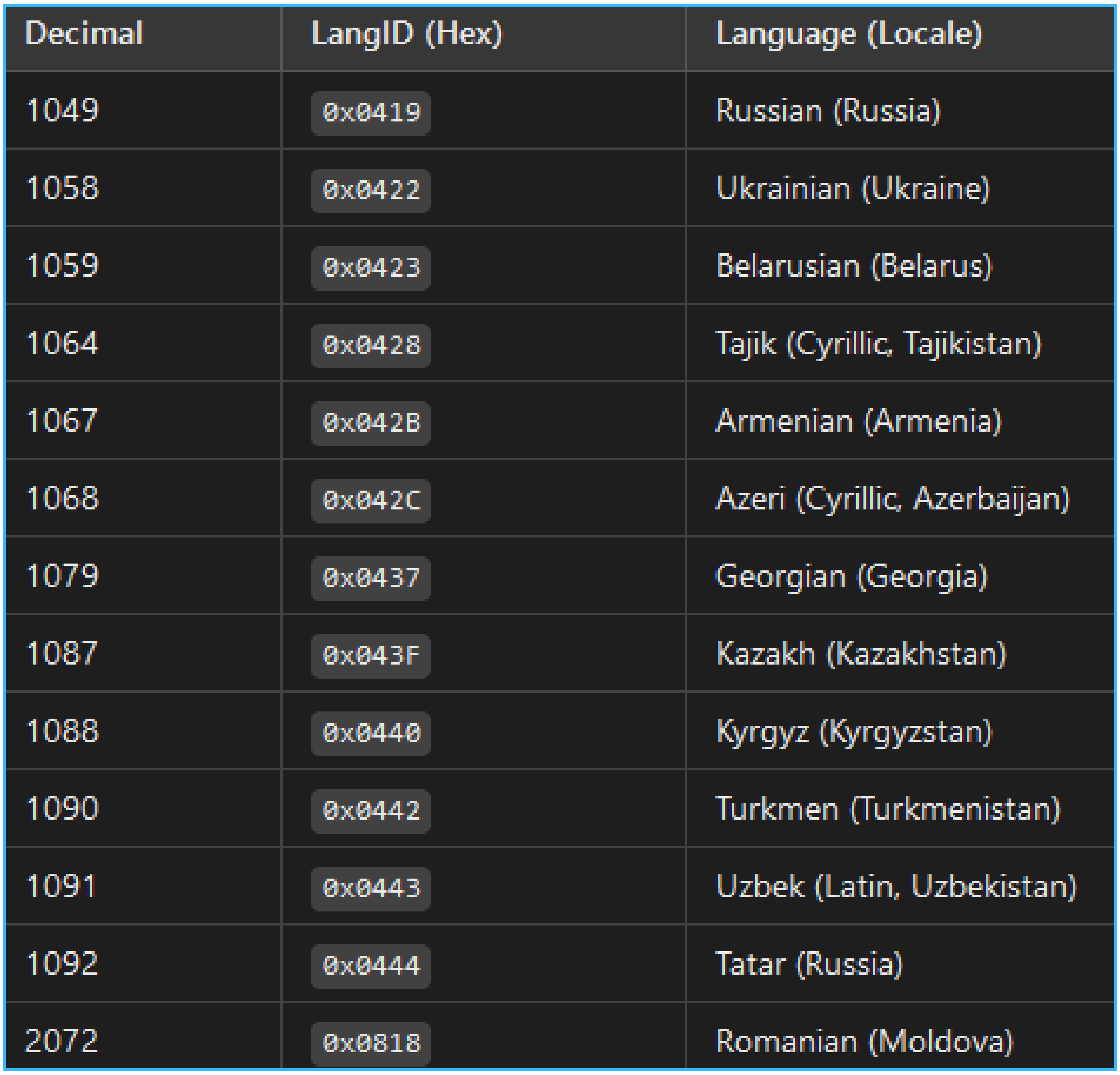
Processes to be killed



```
"svc": [
    "QBCFMonitorService","thebat",
    "dbeng50","winword","dbsnmp",
    "VeeamTransportSvc","disk+work",
    "TeamViewer_Service.exe","firefox",
    "QBIDPService","steam","onenote",
    "CVMountd","cvd","VeeamDeploymentSvc",
    "VeeamNFSSvc","bedbh","mydesktopqos",
    "avscc","infopath","cvfwd","excel",
    "beserver","powerpnt","mspub",
    "synctime","QBDBMgrN","tv_w32.exe",
    "EnterpriseClient","msaccess","ocssd",
    "mydesktopservice","sqbcoreservice",
    "CVODS","DellSystemDetect","oracle",
    "ocautoupds","wordpad","visio","SAP",
    "bengien","TeamViewer.exe","agntsvc",
    "CagService","avagent","ocomm",
    "outlook","saposcol","xfssvccon",
    "isqlplussvc","pvlsvr","sql",
    "tbirdconfig","vxmon","benetns",
    "tv_x64.exe","encsvc","sapstartsrv",
    "vsnapvss","raw_agent_svc",
    "thunderbird","saphostexec"
],
```

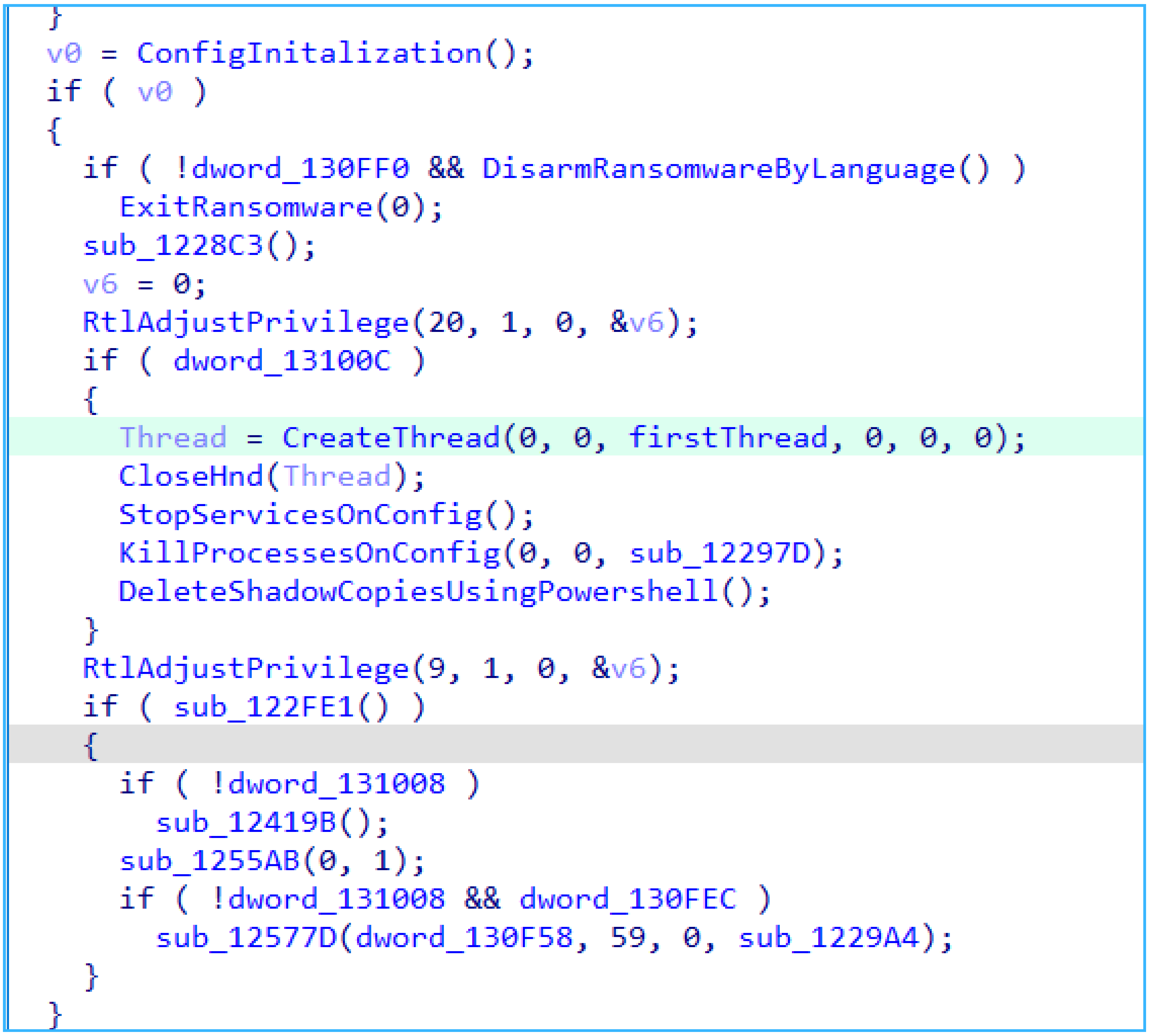
Services to be stopped

After initialization is complete, ransomware first check if the language used in the target system is one of the languages in language whitelist. If the language is on this array ransomware exits directly. This gives us an idea about threat actors origin and motives.



Decimal	LangID (Hex)	Language (Locale)
1049	`0x0419`	Russian (Russia)
1058	`0x0422`	Ukrainian (Ukraine)
1059	`0x0423`	Belarusian (Belarus)
1064	`0x0428`	Tajik (Cyrillic, Tajikistan)
1067	`0x042B`	Armenian (Armenia)
1068	`0x042C`	Azeri (Cyrillic, Azerbaijan)
1079	`0x0437`	Georgian (Georgia)
1087	`0x043F`	Kazakh (Kazakhstan)
1088	`0x0440`	Kyrgyz (Kyrgyzstan)
1090	`0x0442`	Turkmen (Turkmenistan)
1091	`0x0443`	Uzbek (Latin, Uzbekistan)
1092	`0x0444`	Tatar (Russia)
2072	`0x0818`	Romanian (Moldova)

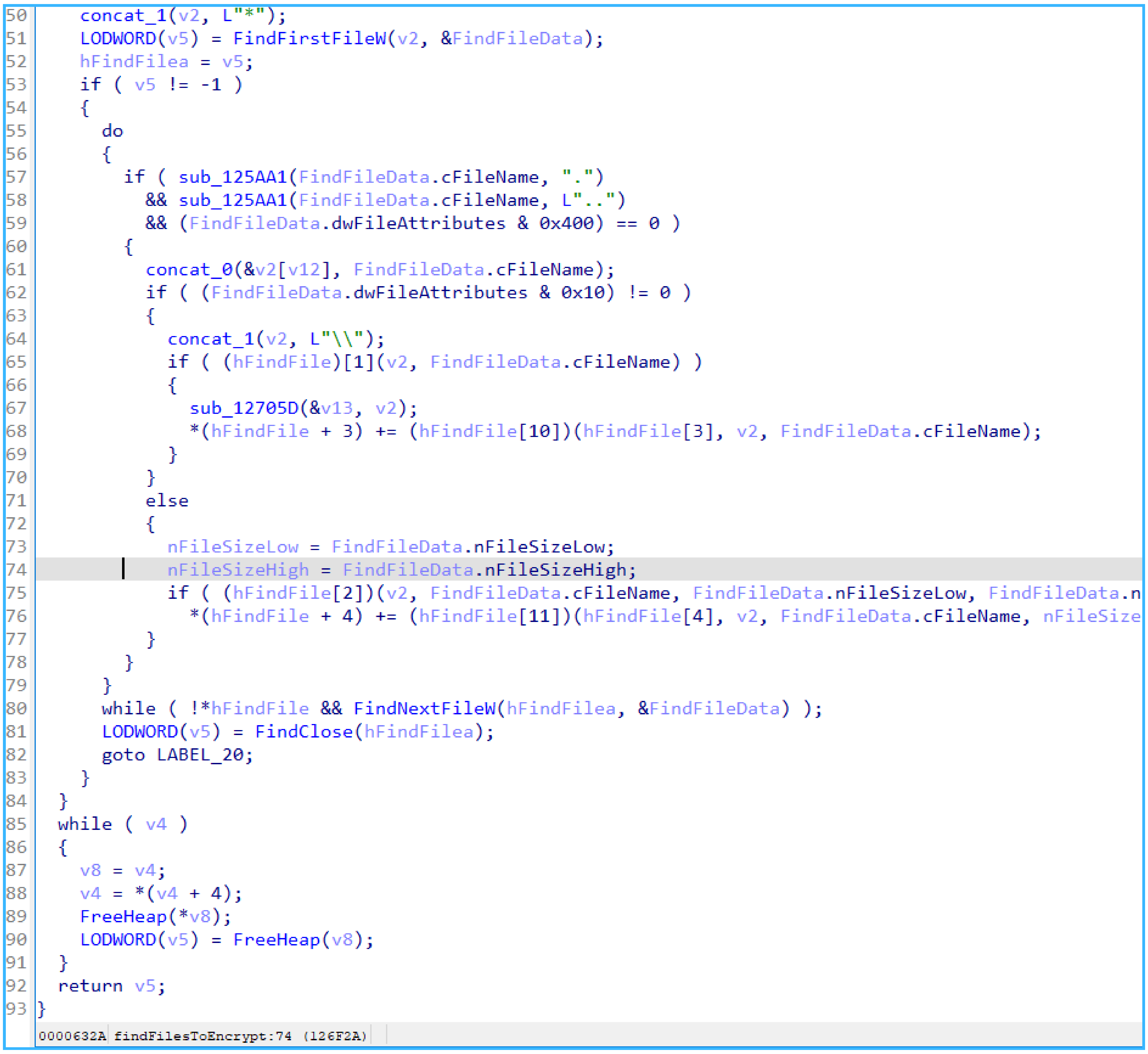
Malware stop services and kill processes found on configuration to make sure when it tries to encrypt files, files opened by these processes and services are accessible to the ransomware. Afterwards, it deletes shadow copies existing on the system to make sure target can't recover their files from copy.



```
  }
  v0 = ConfigInitalization();
  if ( v0 )
  {
    if ( !dword_130FF0 && DisarmRansomwareByLanguage() )
      ExitRansomware(0);
    sub_1228C3();
    v6 = 0;
    RtlAdjustPrivilege(20, 1, 0, &v6);
    if ( dword_13100C )
    {
      Thread = CreateThread(0, 0, firstThread, 0, 0, 0);
      CloseHnd(Thread);
      StopServicesOnConfig();
      KillProcessesOnConfig(0, 0, sub_12297D);
      DeleteShadowCopiesUsingPowershell();
    }
    RtlAdjustPrivilege(9, 1, 0, &v6);
    if ( sub_122FE1() )
    {
      if ( !dword_131008 )
        sub_12419B();
      sub_1255AB(0, 1);
      if ( !dword_131008 && dword_130FEC )
        sub_12577D(dword_130F58, 59, 0, sub_1229A4);
    }
  }
```

Encryption Process

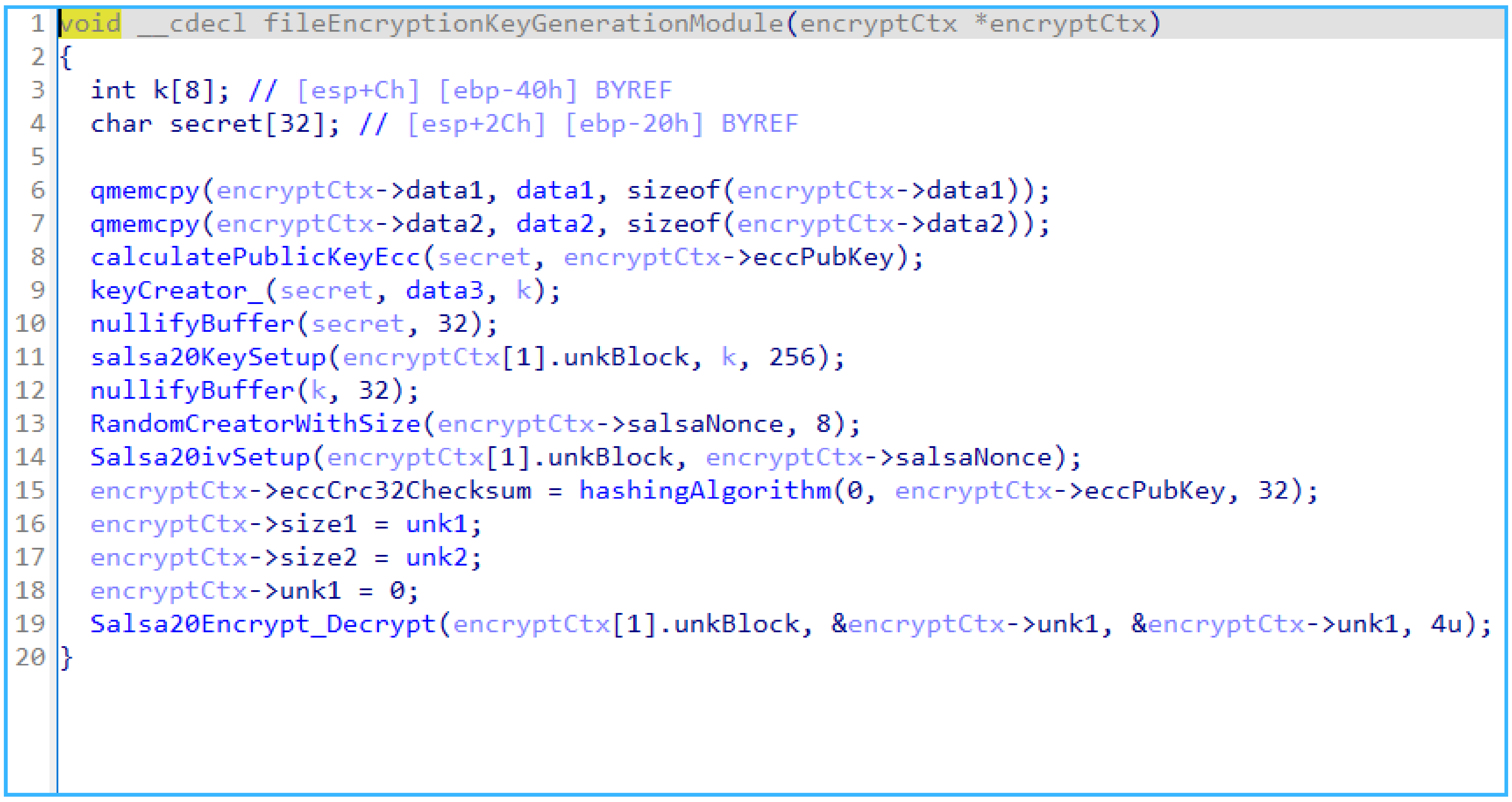
Malware starts encryption process by starting a thread for encrpyting the files, then calls a function that creates keys for each file to be encrypted and writes ransom notes to all folders.



```
    concat_1(v2, L"*");
    LODWORD(v5) = FindFirstFileW(v2, &FindFileData);
    hFindFilea = v5;
    if ( v5 != -1 )
    {
      do
      {
        if ( sub_125AA1(FindFileData.cFileName, ".")
          && sub_125AA1(FindFileData.cFileName, L"..")
          && (FindFileData.dwFileAttributes & 0x400) == 0 )
        {
          concat_0(&v2[v12], FindFileData.cFileName);
          if ( (FindFileData.dwFileAttributes & 0x10) != 0 )
          {
            concat_1(v2, L"\\");
            if ( (hFindFile)[1](v2, FindFileData.cFileName) )
            {
              sub_12705D(&v13, v2);
              *(hFindFile + 3) += (hFindFile[10])(hFindFile[3], v2, FindFileData.cFileName);
            }
          }
          else
          {
            nFileSizeLow = FindFileData.nFileSizeLow;
            nFileSizeHigh = FindFileData.nFileSizeHigh;
            if ( (hFindFile[2])(v2, FindFileData.cFileName, FindFileData.nFileSizeLow, FindFileData.n
              *(hFindFile + 4) += (hFindFile[11])(hFindFile[4], v2, FindFileData.cFileName, nFileSize
          }
        }
      }
      while ( !*hFindFile && FindNextFileW(hFindFilea, &FindFileData) );
      LODWORD(v5) = FindClose(hFindFilea);
      goto LABEL_20;
    }
  }
  while ( v4 )
  {
    v8 = v4;
    v4 = *(v4 + 4);
    FreeHeap(*v8);
    LODWORD(v5) = FreeHeap(v8);
  }
  return v5;
}
```

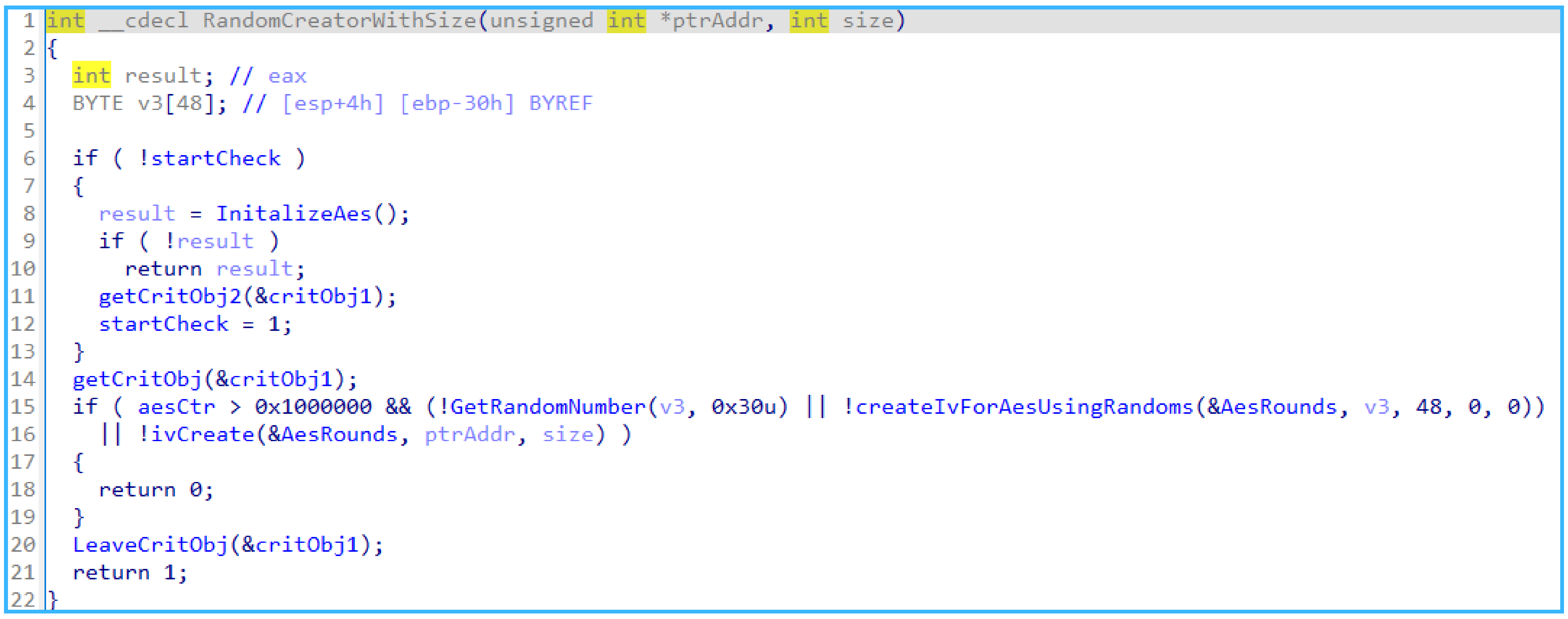
0000632A findFilesToEncrypt:74 (126F2A)

Key generation process can be seen below: Key generation algorithm makes use of Advanced Encryption Standard (AES) algorithm in counter mode and Elliptic curve cryptography with 25519 donna implementation. ECC functions used in the ransomware matches with the code from “*https://github.com/agl/curve25519-donna*” repository, we can assume threat actor copied the code from this repository to reduce of making mistakes in implementation of the encryption algorithm.



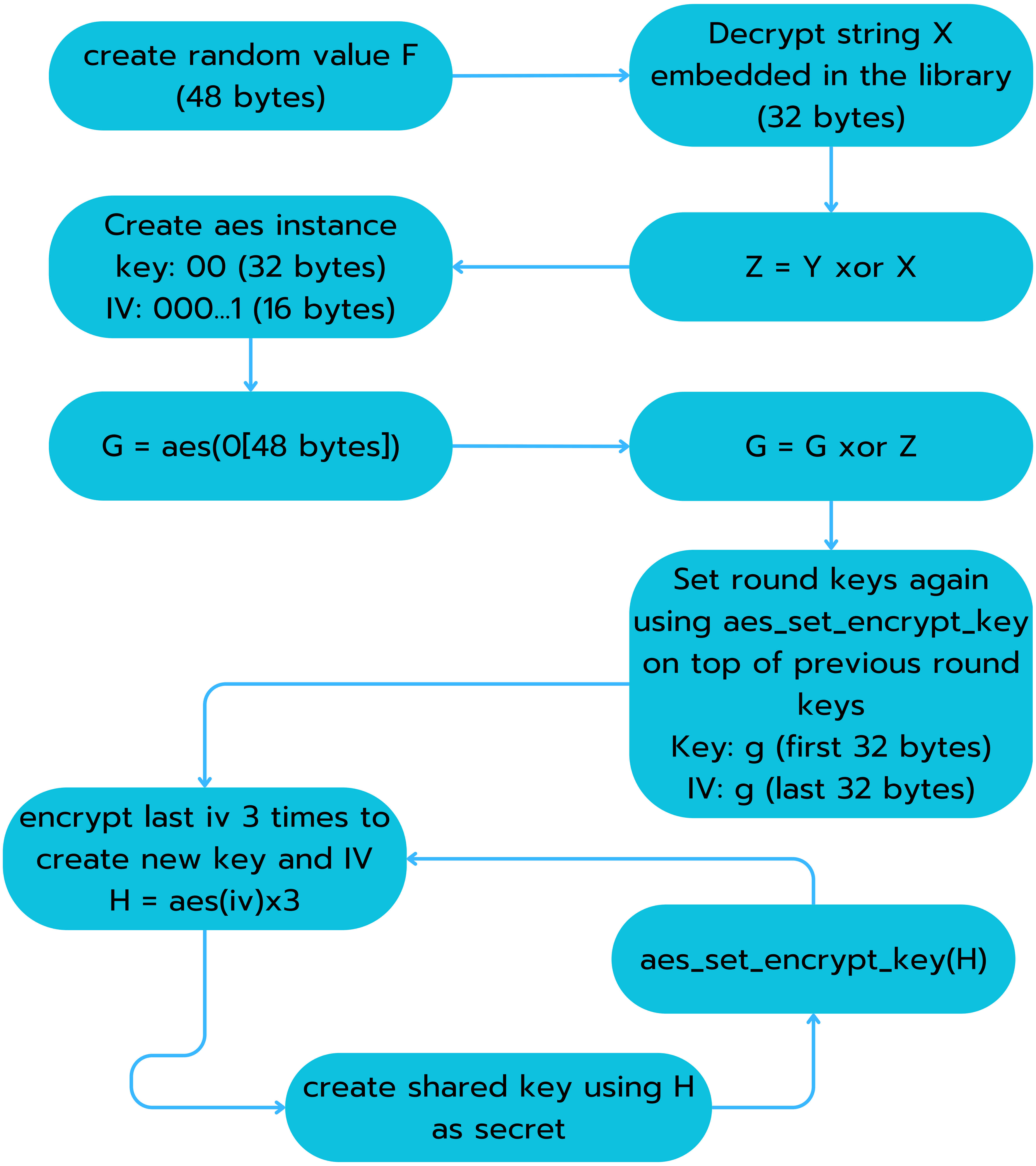
```
void __cdecl fileEncryptionKeyGenerationModule(encryptCtx *encryptCtx)
{
  int k[8]; // [esp+Ch] [ebp-40h] BYREF
  char secret[32]; // [esp+2Ch] [ebp-20h] BYREF

  qmemcpy(encryptCtx->data1, data1, sizeof(encryptCtx->data1));
  qmemcpy(encryptCtx->data2, data2, sizeof(encryptCtx->data2));
  calculatePublicKeyEcc(secret, encryptCtx->eccPubKey);
  keyCreator_(secret, data3, k);
  nullifyBuffer(secret, 32);
  salsa20KeySetup(encryptCtx[1].unkBlock, k, 256);
  nullifyBuffer(k, 32);
  RandomCreatorWithSize(encryptCtx->salsaNonce, 8);
  Salsa20ivSetup(encryptCtx[1].unkBlock, encryptCtx->salsaNonce);
  encryptCtx->eccCrc32Checksum = hashingAlgorithm(0, encryptCtx->eccPubKey, 32);
  encryptCtx->size1 = unk1;
  encryptCtx->size2 = unk2;
  encryptCtx->unk1 = 0;
  Salsa20Encrypt_Decrypt(encryptCtx[1].unkBlock, &encryptCtx->unk1, &encryptCtx->unk1, 4u);
}
```

To create encrpytion keys, Ransomware uses aes in an unconventional way. Ransomware creates a random using an embedded random generator, and if they fail, it uses wincrypt api to generate random keys.



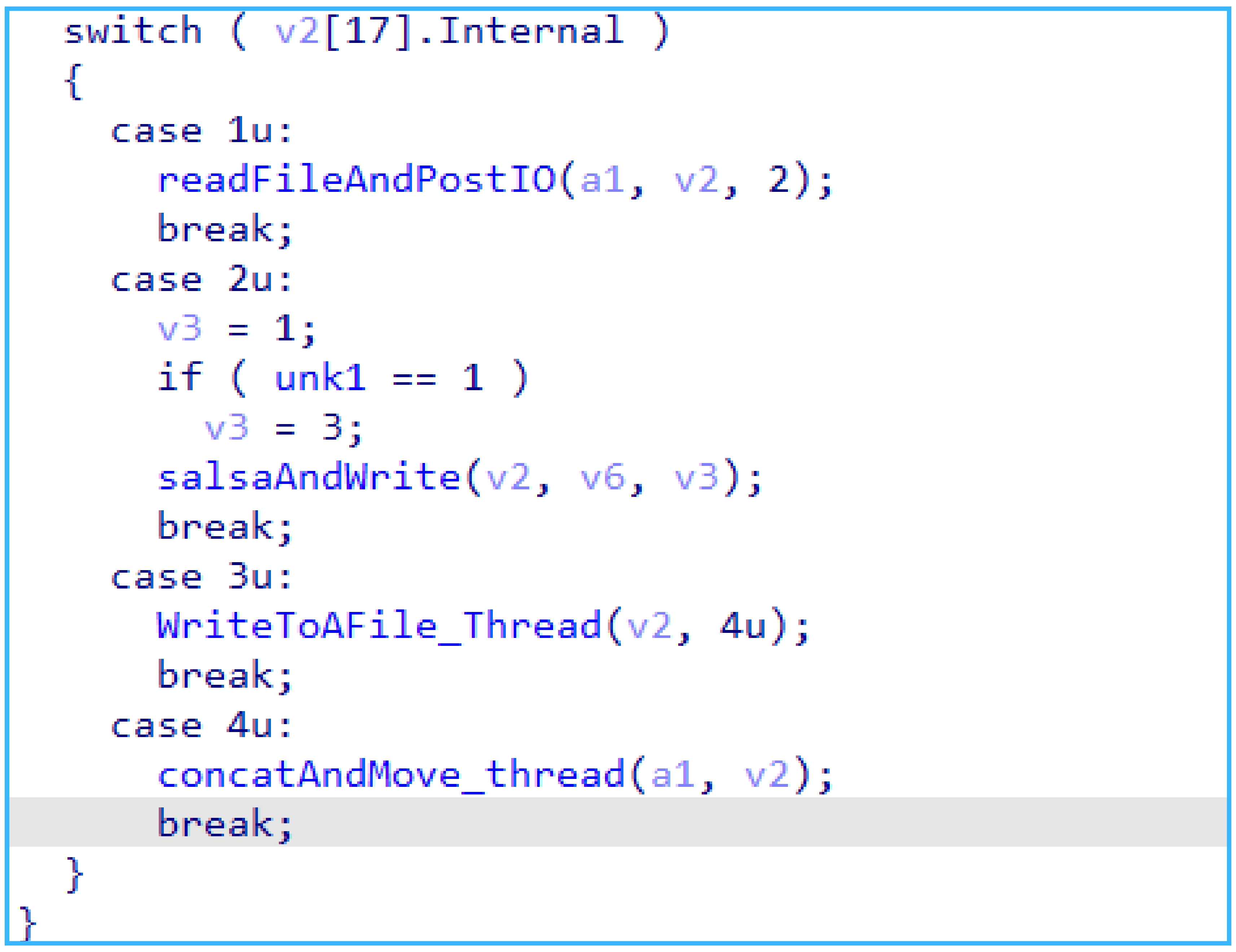
```
int __cdecl RandomCreatorWithSize(unsigned int *ptrAddr, int size)
{
  int result; // eax
  BYTE v3[48]; // [esp+4h] [ebp-30h] BYREF

  if ( !startCheck )
  {
    result = InitalizeAes();
    if ( !result )
      return result;
    getCritObj2(&critObj1);
    startCheck = 1;
  }
  getCritObj(&critObj1);
  if ( aesCtr > 0x1000000 && (!GetRandomNumber(v3, 0x30u) || !createIvForAesUsingRandoms(&AesRounds, v3, 48, 0, 0))
    || !ivCreate(&AesRounds, ptrAddr, size) )
  {
    return 0;
  }
  LeaveCritObj(&critObj1);
  return 1;
}
```

Ransomware does the following operations to generate key:


create random value F (48 bytes)
Decrypt string X embedded in the library (32 bytes)
Z = Y xor X
Create aes instance key: 00 (32 bytes) IV: 000...1 (16 bytes)
G = aes(0[48 bytes])
G = G xor Z
Set round keys again using aes_set_encrypt_key on top of previous round keys Key: g (first 32 bytes) IV: g (last 32 bytes)
encrypt last iv 3 times to create new key and IV H = aes(iv)x3
aes_set_encrypt_key(H)
create shared key using H as secret

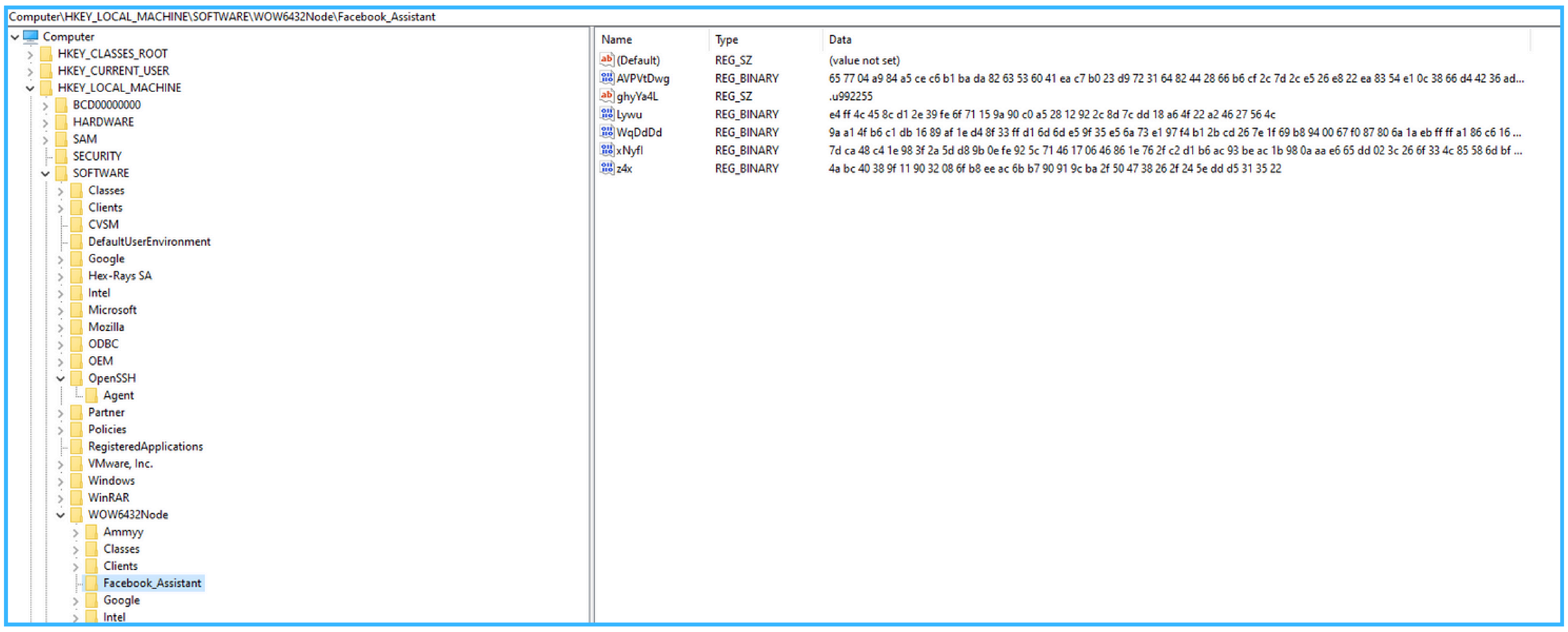
This process is followed on key creation for each file. After random value is created, this value is used as secret for *ECC 25519 donna* impletation. A Shared key is created using ECC and hashed with *sha3-256* before using for *salsa20* encryption. This same process also used to create the nonce for salsa20.

After Key generation for a file is completed, files are encrypted using a thread that accesses files asynchronously to increase encrpytion speed. To encrypt files, ransomware uses *salsa20* encryption algorithm with the key and nonce created before. Some parts of the encryption context is written to end of encrpyted files to provide necessary information for decryption. This information contains, shared key that is generated secret used to encrypt the file, *crc32* hash of this shared key, other information that is asssumed to be used in decryption process and nonce for salsa20 encryption.



```
  switch ( v2[17].Internal )
  {
    case 1u:
      readFileAndPostIO(a1, v2, 2);
      break;
    case 2u:
      v3 = 1;
      if ( unk1 == 1 )
        v3 = 3;
      salsaAndWrite(v2, v6, v3);
      break;
    case 3u:
      WriteToAFile_Thread(v2, 4u);
      break;
    case 4u:
      concatAndMove_thread(a1, v2);
      break;
  }
}
```

Part of the encryption information embedded in files are also written to *HKLM\SOFTWARE\WOW6432Node\Facebook_Assistant* key on 64-bit systems. This information is same in all encrypted files.



Computer\HKEY_LOCAL_MACHINE\SOFTWARE\WOW6432Node\Facebook_Assistant

Name	Type	Data
(Default)	REG_SZ	(value not set)
AVPVtDwg	REG_BINARY	65 77 04 a9 84 a5 ce c6 b1 ba da 82 63 53 60 41 ea c7 b0 23 d9 72 31 64 82 44 28 66 b6 cf 2c 7d 2c e5 26 e8 22 ea 83 54 e1 0c 38 66 d4 42 36 ad...
ghyYa4L	REG_SZ	.u992255
Lywu	REG_BINARY	e4 ff 4c 45 8c d1 2e 39 fe 6f 71 15 9a 90 c0 a5 28 12 92 2c 8d 7c dd 18 a6 4f 22 a2 46 27 56 4c
WqDdDd	REG_BINARY	9a a1 4f b6 c1 db 16 89 af 1e d4 8f 33 ff d1 6d 6d e5 9f 35 e5 6a 73 e1 97 f4 b1 2b cd 26 7e 1f 69 b8 94 00 67 f0 87 80 6a 1a eb ff ff a1 86 c6 16 ...
xNyfl	REG_BINARY	7d ca 48 c4 1e 98 3f 2a 5d d8 9b 0e fe 92 5c 71 46 17 06 46 86 1e 76 2f c2 d1 b6 ac 93 be ac 1b 98 0a aa e6 65 dd 02 3c 26 6f 33 4c 85 58 6d bf ...
z4x	REG_BINARY	4a bc 40 38 9f 11 90 32 08 6f b8 ee ac 6b b7 90 91 9c ba 2f 50 47 38 26 2f 24 5e dd d5 31 35 22

Conclusion

Ransomware uses ECC to keep secret hidden on the endpoint and nullifies any used secrets from the memory after key generation is complete. This key is a public key of an asymmetric encryption algorithm, allowing only holder of the private key to decrypt the secret that is used to generate file encryption key. Usage of the AES in unconventional way reduces the chances of recreation of encryption keys by following same procedures, considering all encryption keys are created in a nested structure. At this moment it does not seems possible to decrypt files without the mentioned private key.