PaaS, or how hackers evade antivirus software

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Positive Technologies

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Malware is one of the main tools of any hacking group. Depending on the level of qualification and the specifics of operation, hackers can use both publicly available tools (such as the Cobalt Strike framework) and their own developments.

Creating a unique set of tools for each attack requires huge resources; therefore, hackers tend to reuse malware in different operations and also share it with other groups. The mass use of the same tool inevitably leads to its getting on the radar of antivirus companies, which, as a result, reduces its efficiency.

To prevent it from happening, hackers use code packing, encryption, and mutation techniques. Such techniques can often be handled by separate tools called crypters or sometimes simply packers. In this article, we will use the example of the RTM banking trojan to discuss which packers attackers can use, how they complicate detection of the malware, and what other malware they can pack.

Packer-as-a-service

A hacker group responsible for RTM distribution regularly sent mass phishing emails with malicious attachments until the end of 2020. Apparently, the attacks were automated.

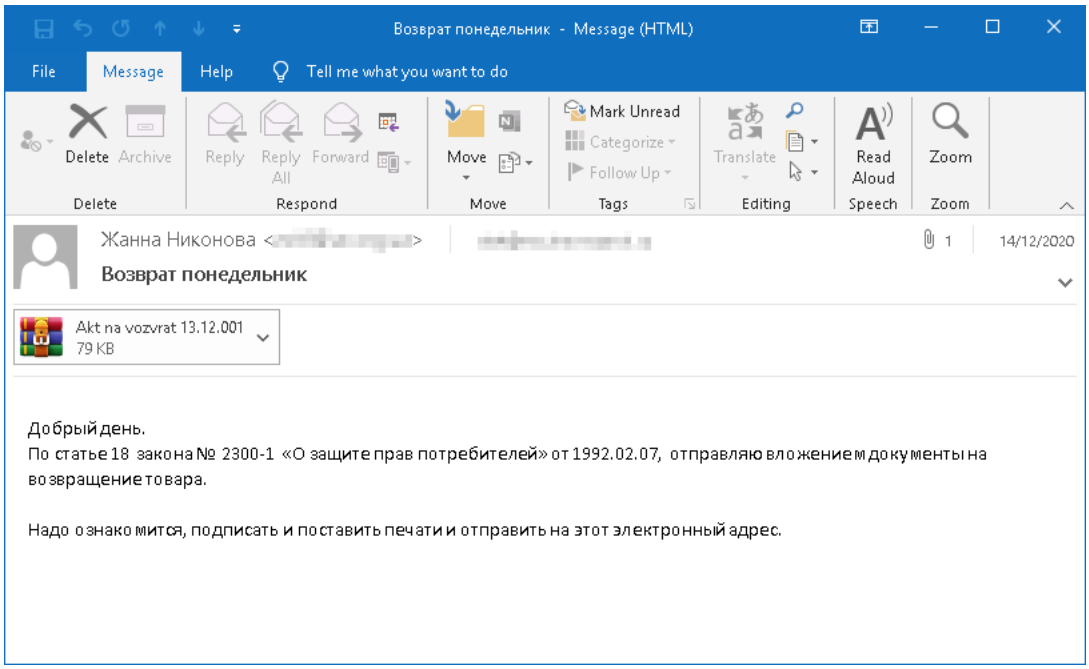


Figure 1. RTM phishing email, December 2020

Each attachment contained files that significantly differed from each other, but the final payload remained almost the same.

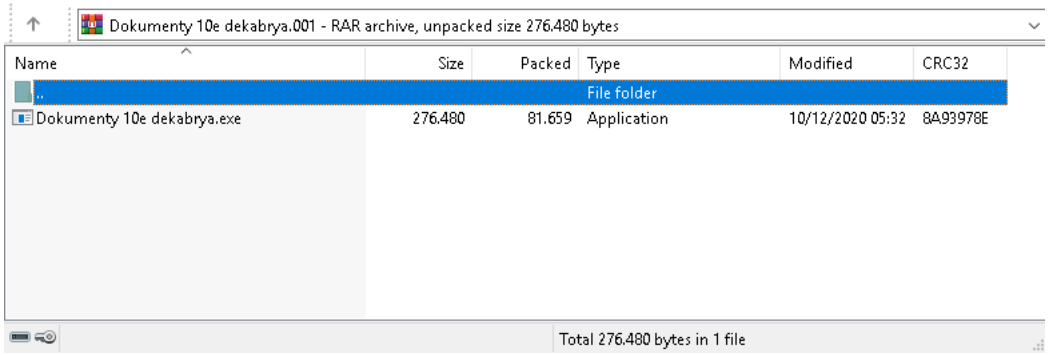


Figure 2. Example of RTM archive

Such feature is a natural consequence of using crypters. Initially, the group behind RTM used its own unique crypter. In 2020, however, the group changed it twice.

When analyzing samples packed in a new way, we detected numerous other malware protected by similar method. Taking into account the fact that packing process is automated, such overlapping with other malware allows us to assume that attackers use the packer-as-a-service model. In this model, packing of malicious files is delegated to a special service managed by a third party.

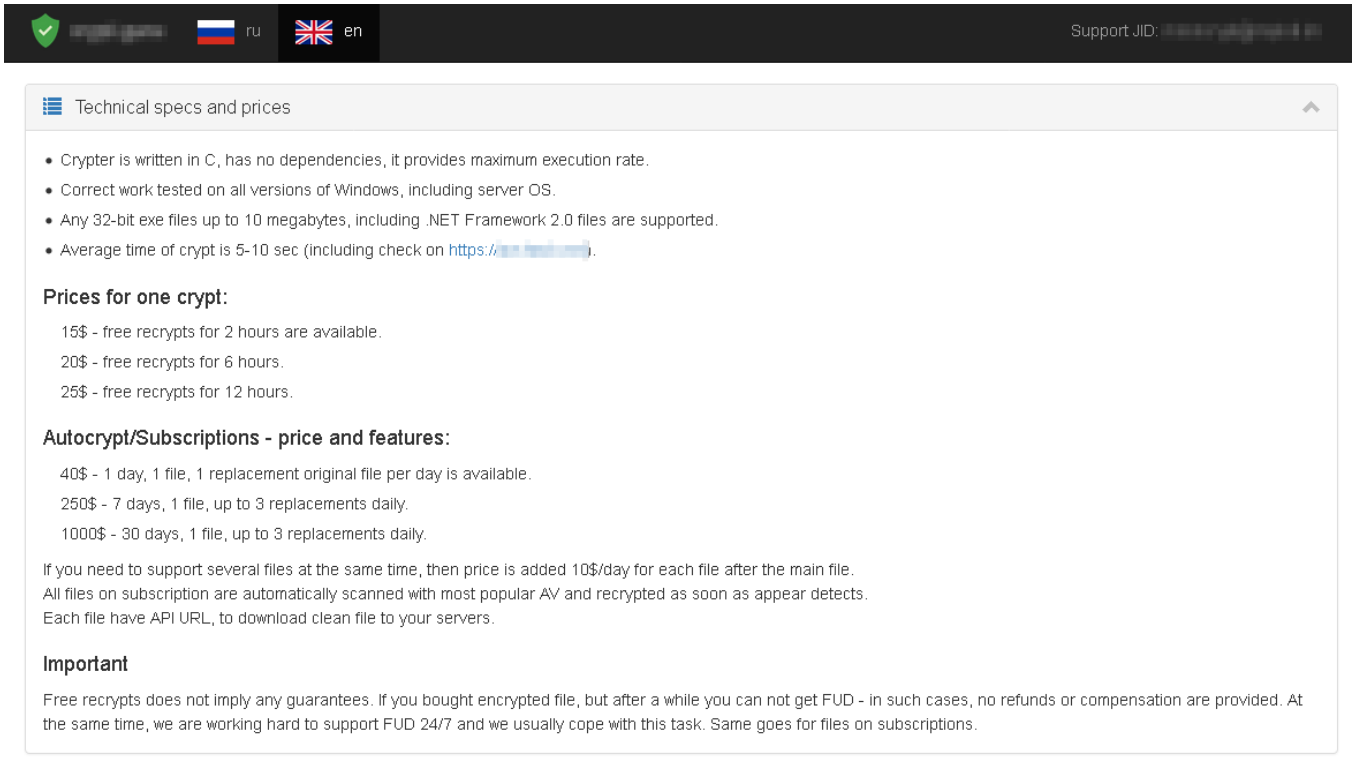


Figure 3. Website of a crypt service

Access to such services can often be found on sale on hacker forums.

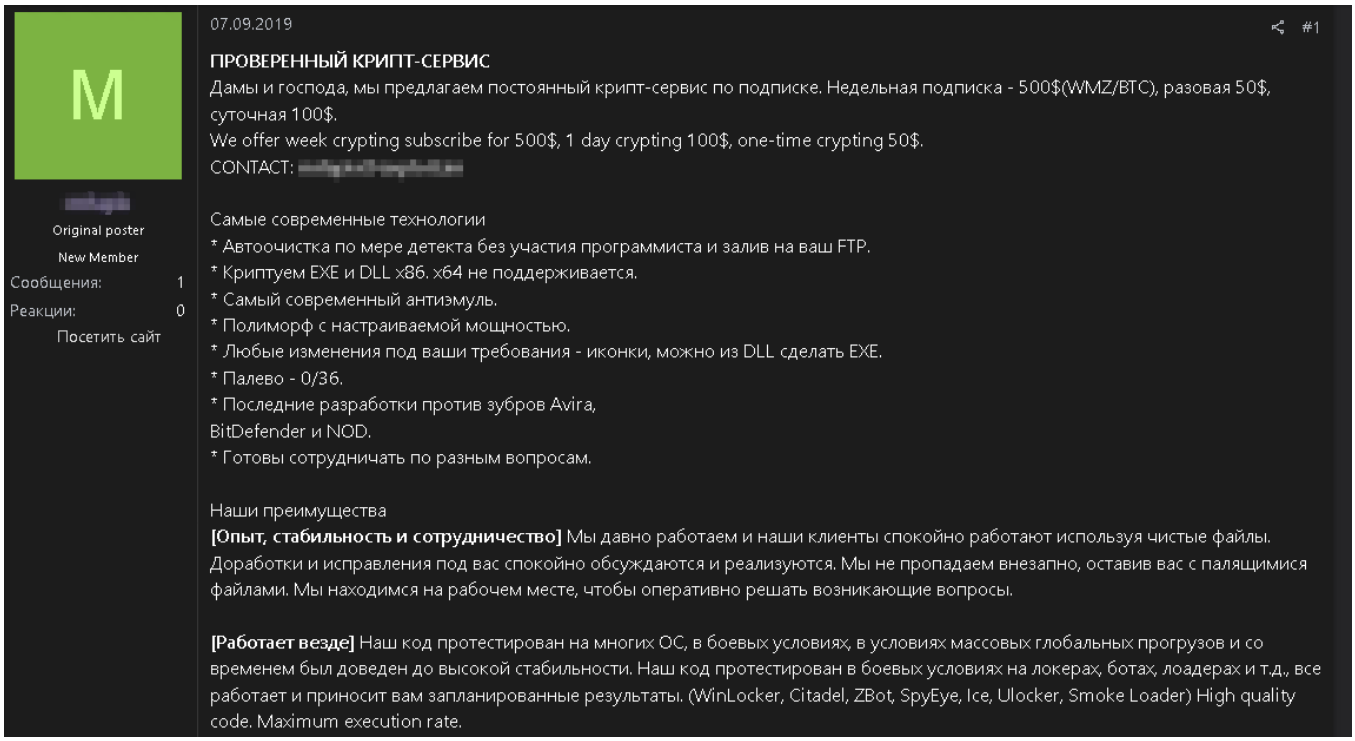


Figure 4. Advertisement of file packing as a service

Later in this article, we will discuss specific examples of crypters used by the RTM group.

Rex3Packer

The first use of this packer by the RTM group that we detected dates back to November 2019. The group started actively using the packer in April–May 2020. Rare uses of the packer for distributing old versions of the RTM trojan were also observed in late January 2021.

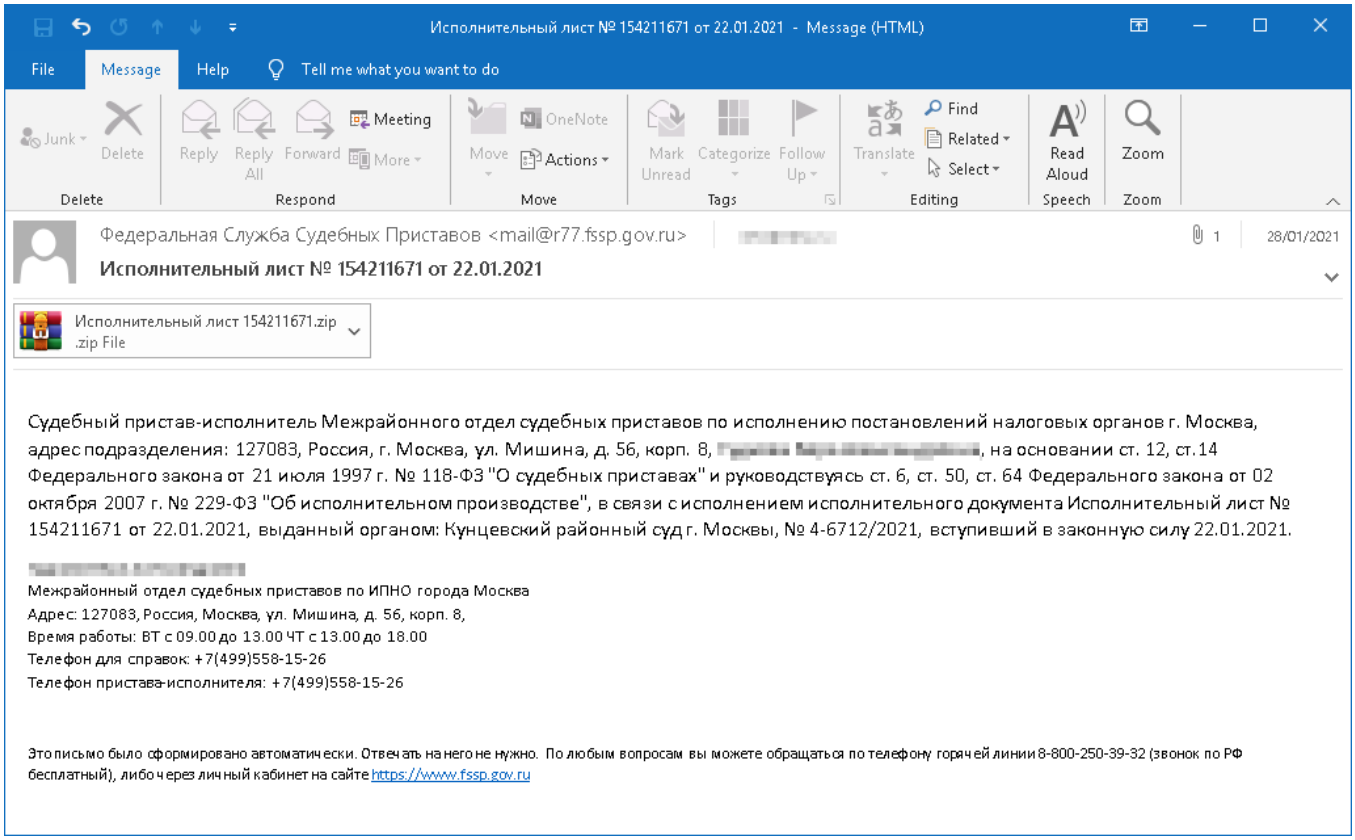


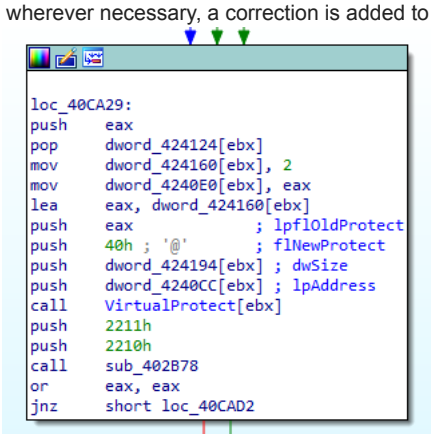
Figure 5. Phishing email by RTM, January 2021

We couldn't associate this packer with any of the publicly described ones, so we named it according to three specifics of its working: **re**cursion, bit **re**verse, and reflective loading of PE files (**re**flection), hence the name **Re**x**3**Packer.

Unpacking algorithm

The overall algorithm for extracting the payload is as follows:

1. A predetermined amount of memory is allocated with read, write, and execute rights using VirtualAlloc.
2. The content of the current process image in the memory is copied to the allocated buffer (in particular, section .text).
3. Control passes to the function inside the buffer.
4. The difference is calculated between the location of data in the buffer and in the PE file image (difference between the addresses in the buffer and virtual addresses in the image). This difference is written to the ebx register. All references to virtual addresses in code are indexed by the content of this register. As a result, wherever necessary, a correction is added to the PE image addresses that allows obtaining the corresponding address in the buffer.



```
loc_40CA29:
push    eax
pop     dword_424124[ebx]
mov     dword_424160[ebx], 2
mov     dword_4240E0[ebx], eax
lea     eax, dword_424160[ebx]
push    eax             ; lpflOldProtect
push    40h ; '@'       ; flNewProtect
push    dword_424194[ebx] ; dwSize
push    dword_4240CC[ebx] ; lpAddress
call    VirtualProtect[ebx]
push    2211h
push    2210h
call    sub_402B78
or      eax, eax
jnz     short loc_40CAD2
```

Figure 6. Calls to functions and variables

   taking into account the correction in the ebx register
5. Another buffer is allocated for packed data.
6. By calling VirtualProtect, RWX rights are assigned to the entire memory region with the PE file image.
7. The packed data is copied to the buffer.
8. The packed data is decoded.
9. The memory region with the PE image is filled with null bytes.
10. The decoded data represents an executable file—the PE payload. This payload is reflectively loaded to where the initial PE image was, and control passes to its entry point.

A specific algorithm for decoding packed data is of special interest to us. In this case, it would be incorrect to compare packing with compression, as the algorithm is such that the size of packed data is always bigger than that of the initial data.

The packed data is preceded by a 16-byte header that contains four 4-byte fields:

- Size of the header
- Size of initial data (PE payload)
- Position in initial data (*) at which they are divided (more details below)
- Encoding mode (1, 2, or 4)

The decoding looks as follows:

1. Inside each byte, bit order is reversed (for example, 10011000 becomes 00011001).
2. Depending on encoding mode (1, 2, 4), data is divided into blocks with N size of 9, 5, or 3 bytes, respectively. The result of the block decoding is N-1 byte (8, 4, or 2).
3. In the first N-1 bytes of the block, some bits are missing: their values always equal zero. To restore the original bytes, the missing bits are extracted from the last byte of the block by using 00000001, 00010001, or 01010101 masks. The mask is shifted for each subsequent byte. As a result, the last byte of the block is composed of the bits extracted from previous bytes and united by the logical operation OR. For example, in mode 4, the last byte is composed of even bits of the block's first byte and odd bits of the block's second byte. As a result of "returning" these bits to the first and second bytes, an original sequence of two bytes is composed.

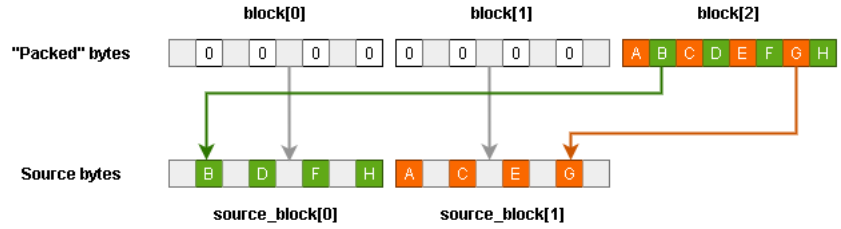


Figure 7. Scheme of obtaining initial bytes in mode 4

4. When bits are restored in all blocks, the obtained data represents the initial PE file divided by two parts at position (*). These parts, in turn, were swapped. The second rearrangement (taking into account the (*) value) allows obtaining the original file.

Obfuscation

To complicate code analysis, various obfuscation techniques are used in the packer:

In between the execution of significant code, various WinAPI functions are called. Their results are saved but not used, and the functions are selected so that not to affect the program operation.

```
58      v21 = v9;
59      if ( !*(&dword_41A5F5 + v7) )
60      {
61        v12 = (*(GetCurrentProcess + v7))();
62        v29 = v13;
63        *(&dword_41A5F5 + v7) = 0;
64        *(&dword_41A5F5 + v7) |= v12;
65        v10 = v29;
66      }
67      if ( !*(&dword_41A681 + v7) )
68      {
69        v14 = (*(GetCursorPos + v7))(v10, &byte_41A382[v7]);
70        v29 = a6;
71        *(&dword_41A681 + v7) = 0;
72        *(&dword_41A681 + v7) ^= v14;
73        a6 = v29;
74      }
```

Figure 8. Calling WinAPI functions

A typical feature of this packer is the presence of cycles (not performing useful operations) implemented via a recursive function.

```
1 int __userpurge sub_40EAA0@<eax>(int a1@<eax>, int a2@<edi>, int a3, int a4)
2 {
3   int v5; // [esp+10h] [ebp+8h]
4
5   v5 = a3 - 1;
6   if ( v5 && a1 != a4 )
7     sub_40EAA0(a1, a2, v5, a4 & (v5 ^ (a2 + v5)));
8   return 0;
9 }
```

Figure 9. Recursive function (sample without junk code)

For further obfuscation, several dozens of randomly generated functions are added to executable file. They may call each other, but none of them obtains control ever.

```
void __userpurge sub_401EB9(int a1@<eax>, int a2@<ebx>, int a3@<esi>, char dl0@<dl>, int a4)
{
  char v5; // dl
  int v6; // [esp+4h] [ebp-8h]
  int v7; // [esp+4h] [ebp-8h]

  if ( a4 == 60091 )
    a1 = 1;
  else
    LOBYTE(a4) = dl0 | a4;
  *(int *)((char *)&dword_460348 + a2) |= 0xFFFFFCA0;
  v5 = dl0 + 1;
  if ( a1 == 20566 )
    v6 &= a3;
  else
    *(int *)((char *)&dword_460348 + a2) -= 143;
  *(int *)((char *)&dword_460348 + a2) ^= a3;
  *(int *)((char *)&dword_460348 + a2) = 1;
  ++*(int *)((char *)&dword_460348 + a2);
  ++*(int *)((char *)&dword_46040C + a2);
  v7 = v6 + 1;
  ++*(int *)((char *)&dword_460348 + a2);
  *(int *)((char *)&dword_46040C + a2) = -1;
  sub_40260C(0, (a3 ^ a4 & v5 & 0xB2) - 114 + 1, 0xFFFFFFFF, a2, *(int *)((char *)&dword_46001C + a2));
  *(int *)((char *)&dword_46040C + a2) = -1;
  ++*(int *)((char *)&dword_460348 + a2);
  *(int *)((char *)&dword_46040C + a2) = *(int *)((char *)&dword_46040C + a2);
  *(int *)((char *)&dword_460348 + a2) ^= 0x7FEu;
  *(int *)((char *)&dword_46040C + a2) = *(int *)((char *)&dword_46040C + a2);
  *(int *)((char *)&dword_46040C + a2) &= ((_BYTE)v7 + (_BYTE)a3 - 1) & 1;
  *(int *)((char *)&dword_46040C + a2) |= 1u;
  *(int *)((char *)&dword_460348 + a2) += ((((v7 - 1115) ^ 0xFFFFFD47) + 261) ^ 0x1FE) - 2493;
}
```

Figure 10. Example of generated function

Usage

In addition to RTM samples, we detected the use of Rex3Packer for packing various malware, mainly originating from the CIS countries. Below is the list with examples of such malware:

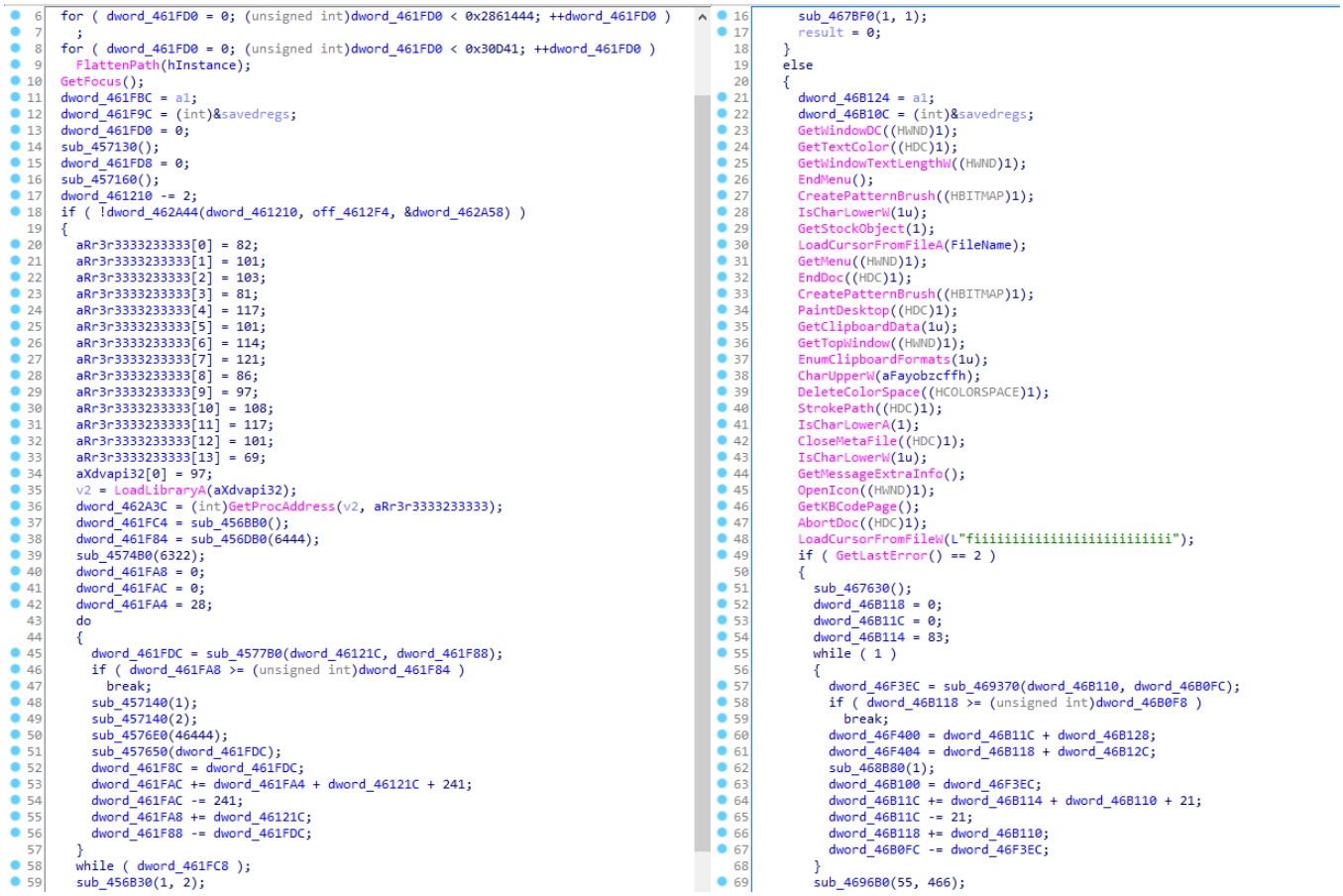
Malware family	SHA256
Phobos Ransomware	6e9c9b72d1bdb993184c7aa05d961e706a57b3becf151ca4f883a80a07fdd955
Zeppelin Ransomware	8d44fdbedd0ec9ae59fad78bdb12d15d6903470eb1046b45c227193b233adda6
Raccoon Stealer	3be91458baa365febafb6b33283b9e1d7e53291de9fec9d3050cd32d98b7a039
KPOT Stealer	9b6af2502547bbf9a64ccfb8889ee25566322da38e9e0ccb86b0e6131a67df1e
Predator The Thief	d1060835793f01d1e137ad92e4e38ef2596f20b26da3d12abcc8372158764a8f
QakBot	18cc92453936d1267e790c489c419802403bb9544275b4a18f3472d2fe6f5dea

We also detected the use of this packer for packing malware samples of the Nemty, Pony, and Amadey families. This is, of course, not an exhaustive list of all cases of using Rex3Packer.

HellowinPacker

In May 2020, RTM started using a new packer and went on using it until the beginning of 2021. We called it HellowinPacker because of the file name "hellowin.wav" we spotted in strings of some samples.

The packer's key feature is two levels of code mutation. The first one significantly changes the unpacking code structure, making samples look different from each other.

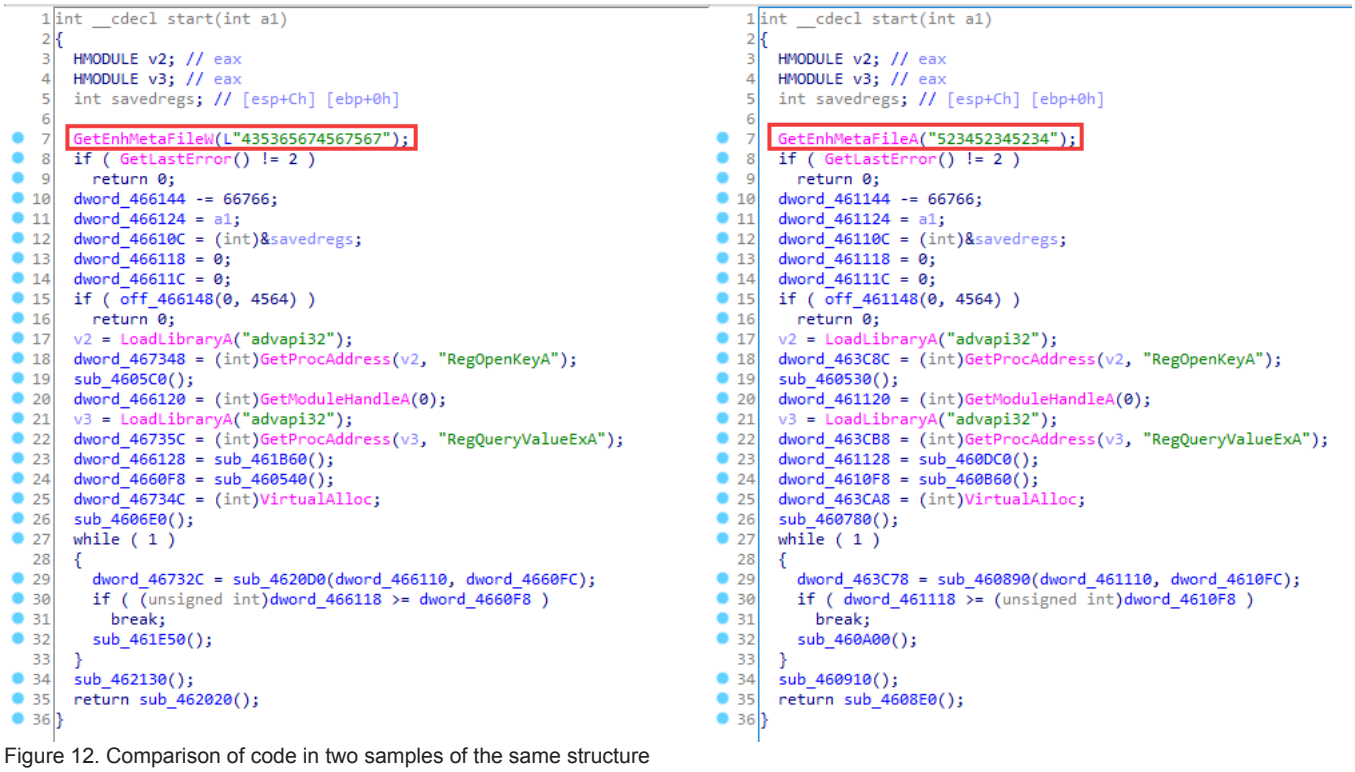


```
for ( dword_461FD0 = 0; (unsigned int)dword_461FD0 < 0x2861444; ++dword_461FD0 )
  ;
for ( dword_461FD0 = 0; (unsigned int)dword_461FD0 < 0x30D41; ++dword_461FD0 )
  FlattenPath(hInstance);
GetFocus();
dword_461FBC = a1;
dword_461F9C = (int)&savedregs;
dword_461FD0 = 0;
sub_457130();
dword_461FD8 = 0;
sub_457160();
dword_461210 -= 2;
if ( !dword_462A44(dword_461210, off_4612F4, &dword_462A58) )
{
  aRr3r3333233333[0] = 82;
  aRr3r3333233333[1] = 101;
  aRr3r3333233333[2] = 103;
  aRr3r3333233333[3] = 81;
  aRr3r3333233333[4] = 117;
  aRr3r3333233333[5] = 101;
  aRr3r3333233333[6] = 114;
  aRr3r3333233333[7] = 121;
  aRr3r3333233333[8] = 86;
  aRr3r3333233333[9] = 97;
  aRr3r3333233333[10] = 108;
  aRr3r3333233333[11] = 117;
  aRr3r3333233333[12] = 101;
  aRr3r3333233333[13] = 69;
  aXdvapi32[0] = 97;
  v2 = LoadLibraryA(aXdvapi32);
  dword_462A3C = (int)GetProcAddress(v2, aRr3r3333233333);
  dword_461FC4 = sub_456BB0();
  dword_461F84 = sub_456DB0(6444);
  sub_4574B0(6322);
  dword_461FA8 = 0;
  dword_461FAC = 0;
  dword_461FA4 = 28;
  do
  {
    dword_461FDC = sub_4577B0(dword_46121C, dword_461F88);
    if ( dword_461FA8 >= (unsigned int)dword_461F84 )
      break;
    sub_457140(1);
    sub_457140(2);
    sub_4576E0(46444);
    sub_457650(dword_461FDC);
    dword_461F8C = dword_461FDC;
    dword_461FAC += dword_461FA4 + dword_46121C + 241;
    dword_461FAC -= 241;
    dword_461FA8 += dword_46121C;
    dword_461F88 -= dword_461FDC;
  }
  while ( dword_461FC8 );
  sub_456B30(1, 2);
  sub_467BF0(1, 1);
  result = 0;
}
else
{
  dword_46B124 = a1;
  dword_46B10C = (int)&savedregs;
  GetWindowDC((HWND)1);
  GetTextColor((HDC)1);
  GetWindowTextLengthW((HWND)1);
  EndMenu();
  CreatePatternBrush((HBITMAP)1);
  IsCharLowerW(1u);
  GetStockObject(1);
  LoadCursorFromFileA(FileName);
  GetMenu((HWND)1);
  EndDoc((HDC)1);
  CreatePatternBrush((HBITMAP)1);
  PaintDesktop((HDC)1);
  GetClipboardData(1u);
  GetTopWindow((HWND)1);
  EnumClipboardFormats(1u);
  CharUpperW(aFayobzcffh);
  DeleteColorSpace((HCOLORSPACE)1);
  StrokePath((HDC)1);
  IsCharLowerA(1);
  CloseMetaFile((HDC)1);
  IsCharLowerW(1u);
  GetMessageExtraInfo();
  OpenIcon((HWND)1);
  GetKBCodePage();
  AbortDoc((HDC)1);
  LoadCursorFromFileW(L"fiiiiiiiiiiiiiiiiiiiiiiiii");
  if ( GetLastError() == 2 )
  {
    sub_467630();
    dword_46B118 = 0;
    dword_46B11C = 0;
    dword_46B114 = 83;
    while ( 1 )
    {
      dword_46F3EC = sub_469370(dword_46B110, dword_46B0FC);
      if ( dword_46B118 >= (unsigned int)dword_46B0F8 )
        break;
      dword_46F400 = dword_46B11C + dword_46B128;
      dword_46F404 = dword_46B118 + dword_46B12C;
      sub_468B80(1);
      dword_46B100 = dword_46F3EC;
      dword_46B11C += dword_46B114 + dword_46B110 + 21;
      dword_46B11C -= 21;
      dword_46B118 += dword_46B110;
      dword_46B0FC -= dword_46F3EC;
    }
    sub_4696B0(55, 466);
```

Figure 11. Comparison of code in two samples of different structure

The example above shows the comparison of samples 5b5f30f7cbd6343efd409f727e656a7039bff007be73a04827cce2277d873aa0 (on the left) and 1f9a8b3c060c2940a81442c9d9c9e36c31ad37aaa7cd61e1d7aec2d86fe1c585 (on the right).

The second level only changes some details, and the code structure remains in general the same. The changes mainly affect assembler instructions and constants that do not impact the program operation. As a result, the code looks almost identical when decompiled.



```
int __cdecl start(int a1)
{
  HMODULE v2; // eax
  HMODULE v3; // eax
  int savedregs; // [esp+Ch] [ebp+0h]

  GetEnhMetaFileW(L"435365674567567");
  if ( GetLastError() != 2 )
    return 0;
  dword_466144 -= 66766;
  dword_466124 = a1;
  dword_46610C = (int)&savedregs;
  dword_466118 = 0;
  dword_46611C = 0;
  if ( off_466148(0, 4564) )
    return 0;
  v2 = LoadLibraryA("advapi32");
  dword_467348 = (int)GetProcAddress(v2, "RegOpenKeyA");
  sub_4605C0();
  dword_466120 = (int)GetModuleHandleA(0);
  v3 = LoadLibraryA("advapi32");
  dword_46735C = (int)GetProcAddress(v3, "RegQueryValueExA");
  dword_466128 = sub_461B60();
  dword_4660F8 = sub_460540();
  dword_46734C = (int)VirtualAlloc;
  sub_4606E0();
  while ( 1 )
  {
    dword_46732C = sub_4620D0(dword_466110, dword_4660FC);
    if ( (unsigned int)dword_466118 >= dword_4660F8 )
      break;
    sub_461E50();
  }
  sub_462130();
  return sub_462020();
}
```

```
int __cdecl start(int a1)
{
  HMODULE v2; // eax
  HMODULE v3; // eax
  int savedregs; // [esp+Ch] [ebp+0h]

  GetEnhMetaFileA("523452345234");
  if ( GetLastError() != 2 )
    return 0;
  dword_461144 -= 66766;
  dword_461124 = a1;
  dword_46110C = (int)&savedregs;
  dword_461118 = 0;
  dword_46111C = 0;
  if ( off_461148(0, 4564) )
    return 0;
  v2 = LoadLibraryA("advapi32");
  dword_463C8C = (int)GetProcAddress(v2, "RegOpenKeyA");
  sub_460530();
  dword_461120 = (int)GetModuleHandleA(0);
  v3 = LoadLibraryA("advapi32");
  dword_463CB8 = (int)GetProcAddress(v3, "RegQueryValueExA");
  dword_461128 = sub_460DC0();
  dword_4610F8 = sub_460B60();
  dword_463CA8 = (int)VirtualAlloc;
  sub_460780();
  while ( 1 )
  {
    dword_463C78 = sub_460890(dword_461110, dword_4610FC);
    if ( dword_461118 >= (unsigned int)dword_4610F8 )
      break;
    sub_460A00();
  }
  sub_460910();
  return sub_4608E0();
}
```

Figure 12. Comparison of code in two samples of the same structure

Just like Rex3Packer, HellowinPacker is actively used by attackers to pack various malware. Note that malware from the same family has the same structure when packed. This lasts for at least some time, after which the structure can change.

All these features coincide with the description of a packing service the access to which is sold on hacker forums:

[Uniqueness] A customer is given a unique crypter that does not depend on other customers. If your files were spotted, your uploads are to blame. We're not looking for 10,000+ customers, we provide correct Premium support and have a very limited number of clients. We make only unique stubs for a customer.

Apparently, each unique crypter has its own structure of generated code. The crypter itself can also mutate code but at a lower level, without changing the program structure. In any case, the significant executable code remains the same.

Unpacking algorithm

One of the first actions in all packed files is an attempt to open the registry key HKEY_CLASSES_ROOT\Interface\{b196b287-bab4-101a-b69c-00aa00341d07} (character case may differ in each particular case) and request a default value. Correct program operation in some modifications of generated code depends on whether these operations are successful.

Interface GUIDs may also differ. Here are some of the possible options:

- {3050f1dd-98b5-11cf-bb82-00aa00bdce0b}
- {aa5b6a80-b834-11d0-932f-00a0c90dcaa9}
- {683130a6-2e50-11d2-98a5-00c04f8ee1c4}
- {c7c3f5a1-88a3-11d0-abcb-00a0c90fffc0}
- {b8da6310-e19b-11d0-933c-00a0c90dcaa9}

The subsequent code obtains the address at which a block of encrypted data is located.

This block starts with a 4-byte number, which stores the size of **initial** data (those that will be obtained after decoding). By calling VirtualAlloc, a memory block of required size with RWX rights is allocated for decrypted data. Encrypted data is copied to the allocated memory by blocks of X bytes each. In the original file, "spaces" of Y byte length are located between these blocks.

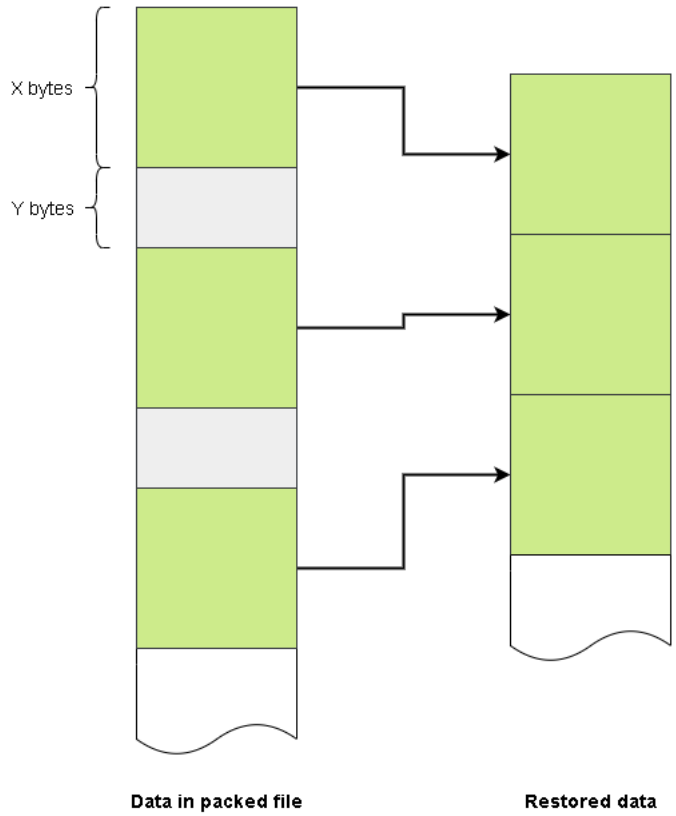


Figure 13. Scheme of data copying in HellowinPacker

Data is then decrypted by 4-byte blocks:

- Each next block is interpreted as an integer (DWORD).
- Index of the first byte in the block is added to the integer.
- An xor operation is executed between the obtained value and the sum of the index and a fixed key (Z number).

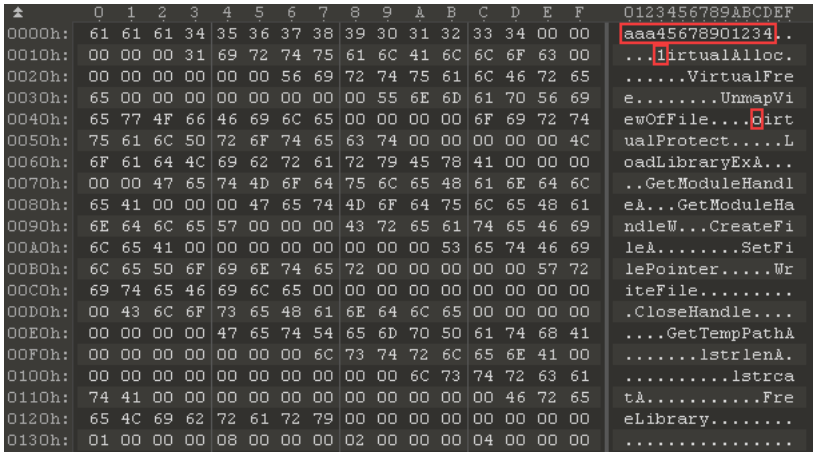
Example of algorithm implementation in Python:

```
def decrypt(data, Z):
    index = 0
    while index < len(data):
        dword = struct.unpack("<I", data[index:index + 4])[0]
        dword = (dword + index) & (2 ** 32 - 1)
        dword = dword ^ (index + Z)
        data[index:index + 4] = struct.pack("<I", dword)
        index += 4
```

Values X, Y, and Z vary depending on a particular packed sample.

The next stage of extracting payload—the shellcode—is located inside the decrypted data. The shellcode takes control when the decryption ends.

The shellcode dynamically loads functions required for its operation. These functions are listed in the "import table" located at the beginning of decrypted data.



	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	0123456789ABCDEF
0000h:	61	61	61	34	35	36	37	38	39	30	31	32	33	34	00	00	aaa45678901234..
0010h:	00	00	00	31	69	72	74	75	61	6C	41	6C	6C	6F	63	00	...1irtualAlloc.
0020h:	00	00	00	00	00	00	56	69	72	74	75	61	6C	46	72	65	......VirtualFre
0030h:	65	00	00	00	00	00	00	00	00	55	6E	6D	61	70	56	69	e........UnmapVi
0040h:	65	77	4F	66	46	69	6C	65	00	00	00	00	6F	69	72	74	ewOfFile....oirt
0050h:	75	61	6C	50	72	6F	74	65	63	74	00	00	00	00	00	4C	ualProtect.....L
0060h:	6F	61	64	4C	69	62	72	61	72	79	45	78	41	00	00	00	oadLibraryExA...
0070h:	00	00	47	65	74	4D	6F	64	75	6C	65	48	61	6E	64	6C	..GetModuleHandl
0080h:	65	41	00	00	00	47	65	74	4D	6F	64	75	6C	65	48	61	eA...GetModuleHa
0090h:	6E	64	6C	65	57	00	00	00	43	72	65	61	74	65	46	69	ndleW...CreateFi
00A0h:	6C	65	41	00	00	00	00	00	00	00	00	53	65	74	46	69	leA........SetFi
00B0h:	6C	65	50	6F	69	6E	74	65	72	00	00	00	00	00	57	72	lePointer.....Wr
00C0h:	69	74	65	46	69	6C	65	00	00	00	00	00	00	00	00	00	iteFile.........
00D0h:	00	43	6C	6F	73	65	48	61	6E	64	6C	65	00	00	00	00	.CloseHandle....
00E0h:	00	00	00	00	47	65	74	54	65	6D	70	50	61	74	68	41	....GetTempPathA
00F0h:	00	00	00	00	00	00	00	6C	73	74	72	6C	65	6E	41	00	.......lstrlenA.
0100h:	00	00	00	00	00	00	00	00	00	00	6C	73	74	72	63	61	..........lstrca
0110h:	74	41	00	00	00	00	00	00	00	00	00	00	00	46	72	65	tA..........Fre
0120h:	65	4C	69	62	72	61	72	79	00	00	00	00	00	00	00	00	eLibrary........
0130h:	01	00	00	00	08	00	00	00	02	00	00	00	04	00	00	00	....

Figure 14. "Import table" in decrypted data

For greater variability, the strings in the "import table" may be partially filled with random symbols. In the example above, the first function name "GetProcAddress" is fully replaced by the string "aaa45678901234", and the names "VirtualAlloc" and "VirtualProtect" are damaged. Right before processing the table, the shellcode restores correct values of all the symbols.

```
71  *(_BYTE *)(v1 + 0x401000) = 'G';
72  v33[1] = 'e';
73  v33[2] = 't';
74  v33[3] = 'P';
75  v33[4] = 'r';
76  v33[5] = 'o';
77  v33[6] = 'c';
78  v33[7] = 'A';
79  v33[8] = 'd';
80  v33[9] = 'd';
81  v33[10] = 'r';
82  v33[11] = 'e';
83  v33[12] = 's';
84  v33[13] = 's';
85  v33[76] = 'V';
86  v33[38] = 'V';
```

Figure 15. Code for restoring damaged names of functions

Payload (this time, it is the PE file) is extracted by the shellcode from the rest of the decrypted data. It is encrypted again by the same algorithm as described above. For Z key, figure 1001 is always used.

When the decryption is finished, the shellcode performs reflective loading of the PE file using the functions imported at the first stage.

Obfuscation

Just like Rex3Packer, HellowinPacker samples call WinAPI functions not related to the main program logic. However, in this case, they are mostly used to complicate behavior analysis and detection in sandboxes. This is also confirmed by the fact that in most cases various functions are called in a row at the very beginning of the program.

```
BOOL __stdcall DllEntryPoint(HINSTANCE hinstDLL, DWORD fdwReason, LPVOID lpReserved)
{
  int v4; // [esp+0h] [ebp-6Ch]
  int savedregs; // [esp+6Ch] [ebp+0h]

  dword_1020E55C = (int)hinstDLL;
  dword_1020E53C = (int)&savedregs;
  GetEnhMetaFileW(L"111");
  if ( GetLastError() != 2 )
    return 0;
  GetEnhMetaFileBits(0, 0, 0);
  if ( GetLastError() != 6 )
    return 0;
  GetMenuContextHelpId((HMENU)1);
  StrokePath((HDC)1);
  GetLastActivePopup((HWND)1);
  GetWindowTextLengthA((HWND)1);
  IsClipboardFormatAvailable(1u);
  DeleteEnhMetaFile((HENHMETAFILE)1);
  GetListBoxInfo((HWND)1);
  GetInputState();
  IsCharLowerW(1u);
  CloseMetaFile((HDC)1);
  GetTextCharset((HDC)1);
  IsMenu((HMENU)1);
  DeleteObject((HGDIOBJ)1);
  GetStretchBltMode((HDC)1);
  IsCharUpperA(1);
  CreateSolidBrush(1u);
  GetObjectType((HGDIOBJ)1);
  GetCapture();
  VkKeyScanW(1u);
  CountClipboardFormats();
```

Figure 16. Entry point in one of the packed libraries

An additional effect of the WinAPI use is the impossibility of detection by a list of imported functions and by imphash.

When working with various numeric values, a certain "arithmetic" obfuscation is often observed: necessary constants are represented as sums or differences of other constants (which in some cases equal zero). To obtain constants, WinAPI functions can also be called, yielding predictable results (for example, 0 in case of failure).

An example of such obfuscation is given on the Figure below: the only goal of this function is to assign the value of the argument *source* to a variable pointed by *target*. In this case, the output of calling GetStockObject(789644) will always equal zero, as the function was given an intentionally incorrect argument.

```
_DWORD *__cdecl sub_401F80(int a1, int source)
{
  int v2; // esi
  _DWORD *result; // eax
  _DWORD *target; // [esp+18h] [ebp+8h]

  target = (_DWORD *)::target;
  GetWindowTextLengthW((HWND)1);
  GetStockObject_0 = (int (__stdcall *)(_DWORD))GetStockObject;
  v2 = (int)GetStockObject(789644) + source + 435766;
  *target += GetStockObject_0(789644) + v2;
  result = target;
  *target -= 435766;
  return result;
}
```

Figure 17. "Arithmetic" obfuscation in the HellowinPacker code

Various mutations are encountered at the assembler level as well: inserting junk code, using opaque predicates, calling functions with unused arguments and repeated calls of the functions, and replacing instructions with their equivalents.

```
xor     eax, eax
jz      loc_401E64

push    4
push    4
call    sub_401710
add     esp, 8
push    4
push    4
call    sub_401710
add     esp, 8
push    4
push    4
call    sub_401710
add     esp, 8
push    4
push    4
call    sub_401710
```

Figure 18. Example of obfuscation at the assembler code level

Usage

HellowinPacker exists at least since 2014 and has been so far used in various mass malware. Here are only a few examples:

Malware family	SHA256
Cerber Ransomware	1e8b814a4bd850fc21690a66159a742bfcec212ccab3c3153a2c54c88c83ed9d
ZLoader	44ede6e1b9be1c013f13d82645f7a9cff7d92b267778f19b46aa5c1f7fa3c10b
Dridex	f5dfbb67b582a58e86db314cc99924502d52ccc306a646da25f5f2529b7bff16
Bunitu	54ff90a4b9d4f6bb2808476983c1a902d7d20fc0348a61c79ee2a9e123054cce
QakBot	c2482679c665dbec35164aba7554000817139035dc12efc9e936790ca49e7854

The packer has been frequently mentioned in reports by other researchers. The earliest mention we found dates back to 2015. In an article about crypters, Malwarebytes experts analyze malware samples that use HellowinPacker. Later, other researchers referred to it as the Emotet packer (1, 2). In 2020, our colleagues from NCC Group called it CryptOne and described how it can be used to pack the WastedLocker ransomware. According to NCC Group, the crypter was also used by the Netwalker, Gozi ISFB v3, ZLoader, and Smokeloader malware families.

Conclusion

Our example of using the crypters shows us how hackers can delegate responsibilities among each other, especially when it comes to mass malware. Developing malicious payload, protecting it from antivirus tools («crypt»), and delivering it to end users—all this can be performed by completely unrelated hackers, and each element of this chain can be offered as a service. This approach lowers the cybercrime entry threshold for technically unskilled criminals: to conduct a mass attack, all they have to do is to provide a necessary amount of money to pay for all the services.

The packers we described are certainly not the only ones that exist on the market. However, they demonstrate the common features of such tools: as a result of their work, an executable file is obtained with obfuscated polymorphic code of the unpacker and a payload encrypted in some way or another. Mutations in code and reuse of the same crypters make static detection of payload almost impossible. However, since the payload is somehow decrypted to the memory and then starts its malicious activity, behavioral analysis using sandboxes (such as PT Sandbox) allows detecting malware and providing accurate verdicts even for packed files. In addition, it should be noted that packers do not affect the interaction of malware with C&C servers in any way. This makes it possible to determine the presence of malware in the network using traffic analysis tools such as PT Network Attack Discovery.

Verdicts of our products

PT Sandbox

- Trojan.Win32.RTM.a
- Trojan.Win32.RTM.b
- Trojan-Banker.Win32.RTM.a
- Trojan-Banker.Win32.RTM.b
- Trojan-Banker.Win32.RTM.c
- Trojan-Banker.Win32.RTM.d
- Trojan-Banker.Win32.RTM.e
- Trojan-Banker.Win32.RTM.f

PT Network Attack Discovery

- REMOTE [PTsecurity] TeamBot/RTM
  sid: 10004412;
- BACKDOOR [PTsecurity] TeamBot/RTM
  sid: 10004415;
- MALWARE [PTsecurity] RTM Banker CnC POST
  sid: 10000765;
- MALWARE [PTsecurity] RTM.N (Redaman)
  sid: 10005556; 10005557;
- MALWARE [PTsecurity] Spy.RTM.AF
  sid: 10005468;

- MALWARE [PTsecurity] Trojan[Banker]/RTM
  sid: 10004855; 10004875;
- MALWARE [PTsecurity] Win32/Spy.RTM.N (Redaman)
  sid: 10003414; 10004754; 10005555;
- PAYLOAD [PTsecurity] RTM.Payload.xor
  sid: 10005585;

IOCs (RTM)

Detection date	Crypter	SHA256	SHA1
19.04.2020	RTM	a4229a54f76815ac30a2a878eadf275e199c82da657dbc5f3fc05fe95603c320	ad22ceb309dd30dc769f6317429
22.04.2020	Rex3Packer	9b88e8143e4452229dac7fdcc3d9281d21390f286c086f09aec410f120dc4325	f881729f6a5ca6fe80f385a2b0f85
13.05.2020	HellowinPacker	43e8ebacfa319ff7d871eef3cc35266cfa7c6f44dd787f27a48311e39727e10f	8a28b75285409c55d5bbeca62e3
28.01.2021	Rex3Packer (2 layers)	fbf5974daee93bf5a2ed1816a4edbb108ceccb264d3e3f72d0aed268dd45e315	2e3352c6341ce57a03aaf2c4fbf4