Malware WinDealer used by LuoYu Attack Group

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During JSAC2021 on 28 January 2021, there was a presentation about an attack group LuoYu, which targets Korean and Japanese organisations since 2014 [1][2]. Recently, JPCERT/CC came across malware WinDealer used by this group. This article introduces some findings of our analysis.

Malware WinDealer overview

WinDealer steals information of an infected PC and sends it to a C2 server as described in Figure 1.

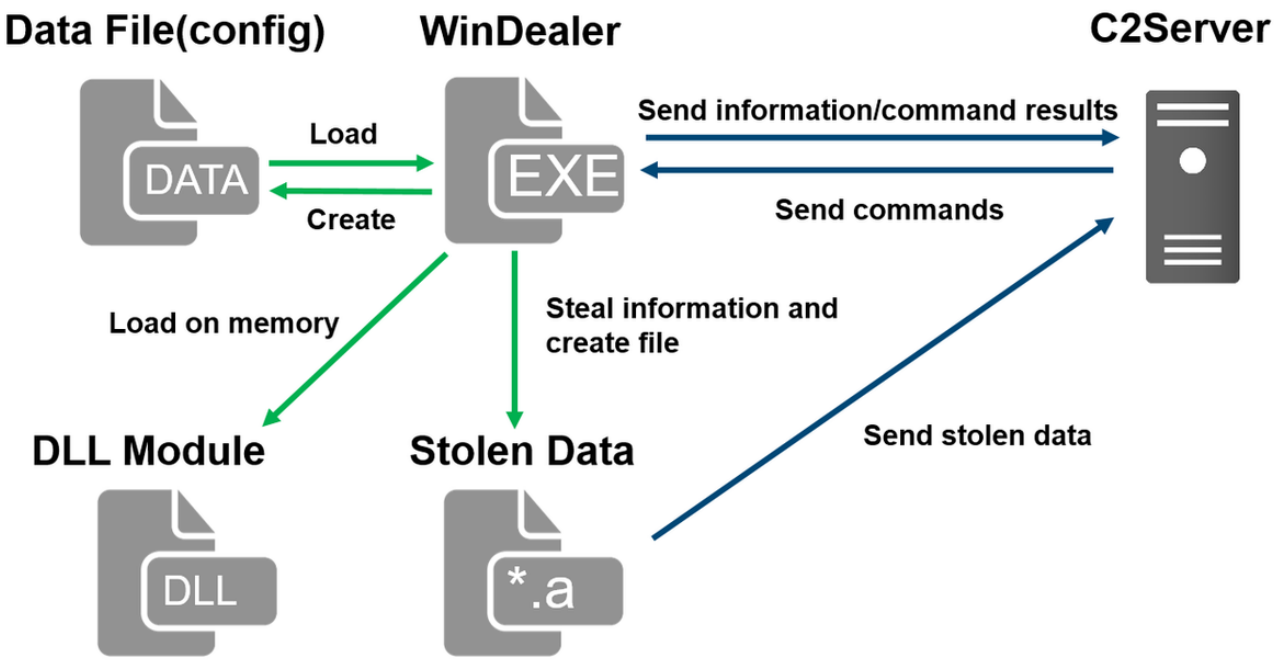


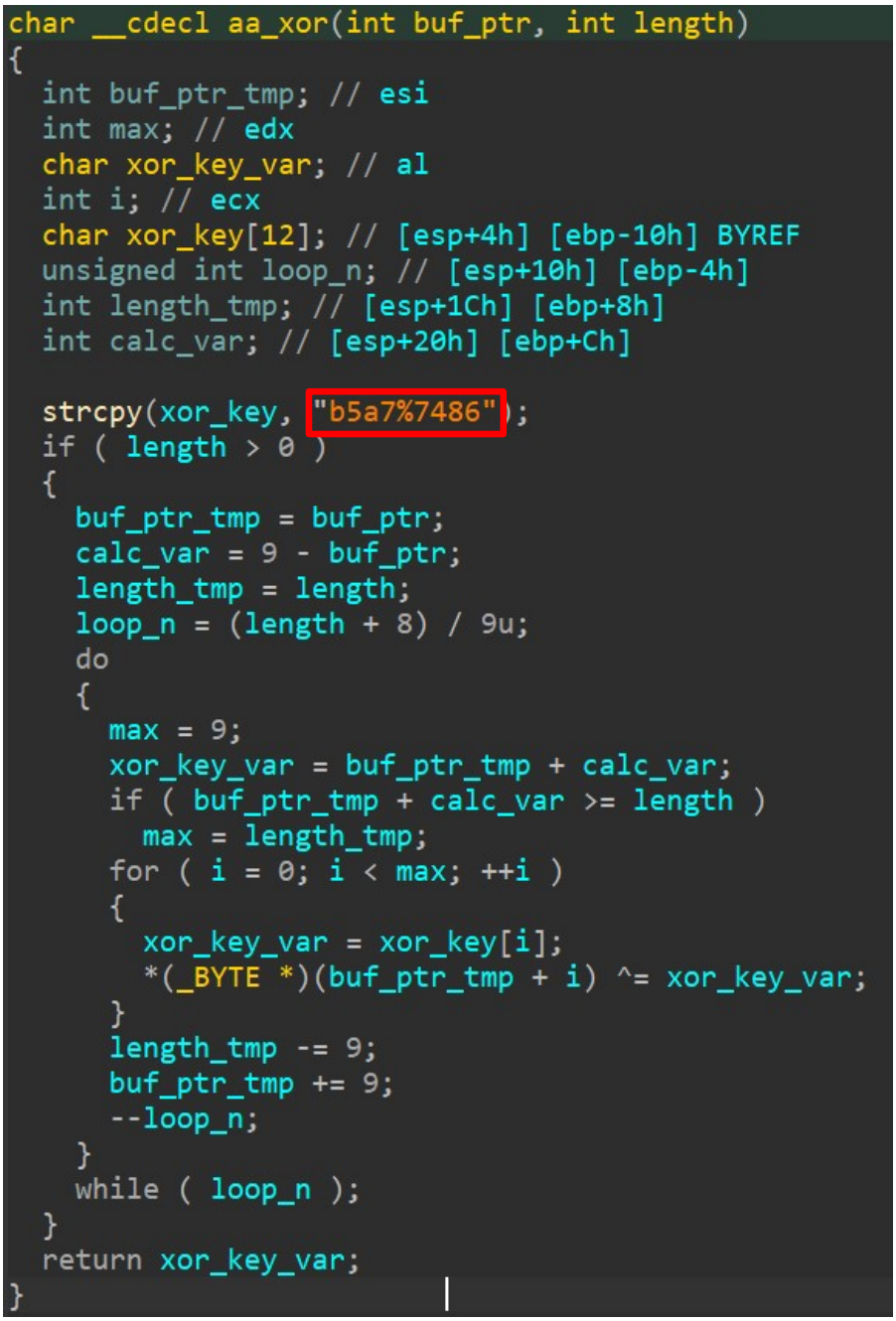
Figure 1： Malware WinDealer behaviour overview

Once launched, the malware reads configuration from a file under C:\ProgramData and loads a DLL module on its memory. It steals information about the victim PC, network configuration and SNS applications etc. and saves them in a file with an ".a" extension under %TEMP%, which is then sent to a C2 server.
The following points will be described in the next sections.

- Read configuration
- Communicate with C2 servers
- Process and send stolen data
- Functions of modules loaded on memory

Read configuration

The malware stores its configuration in several folders under C:\ProgramData and reads it when executed. The contents are encoded based on XOR with its key value "b6a7%7486". Please refer to Appendix A for the configuration file path and its contents. Figure 2 shows a function to decode configuration.



```
char __cdecl aa_xor(int buf_ptr, int length)
{
  int buf_ptr_tmp; // esi
  int max; // edx
  char xor_key_var; // al
  int i; // ecx
  char xor_key[12]; // [esp+4h] [ebp-10h] BYREF
  unsigned int loop_n; // [esp+10h] [ebp-4h]
  int length_tmp; // [esp+1Ch] [ebp+8h]
  int calc_var; // [esp+20h] [ebp+Ch]

  strcpy(xor_key, "b5a7%7486");
  if ( length > 0 )
  {
    buf_ptr_tmp = buf_ptr;
    calc_var = 9 - buf_ptr;
    length_tmp = length;
    loop_n = (length + 8) / 9u;
    do
    {
      max = 9;
      xor_key_var = buf_ptr_tmp + calc_var;
      if ( buf_ptr_tmp + calc_var >= length )
        max = length_tmp;
      for ( i = 0; i < max; ++i )
      {
        xor_key_var = xor_key[i];
        *(_BYTE *)(buf_ptr_tmp + i) ^= xor_key_var;
      }
      length_tmp -= 9;
      buf_ptr_tmp += 9;
      --loop_n;
    }
    while ( loop_n );
  }
  return xor_key_var;
}
```

Figure 2：Function to decode a file storing configuration

Communicate with C2 servers

If the following configuration files exist in the designated folder, WinDealer loads the C2 server information from them and starts communicating.

- C:\ProgramData\ad5f82e8
- C:\ProgramData\1c76cbfe
- C:\ProgramData\9c3b6294

If no such file exists, WinDealer communicates to a random IP address in one of the following ranges (port 6999/UDP or 55556/TCP). It switches to an IP address in the other range at a certain interval.

- 113.62.0.0 - 113.63.255.255
- 111.120.0.0 - 111.123.255.255

Figure 3 shows the malware's communication flow with its C2 server. First, it encrypts an AES key with RSA algorithm and sends to a C2 server. Information stolen from a victim PC is encrypted with this AES key and sent to a C2 server at a certain interval. After that, C2 server sends a command to the victim PC. The malware executes it and sends the result to the C2 server after encryption. Besides the data exchange, the malware also communicates with domains such as www[.]microsoftcom (non-existent at the moment) and icanhazip[.]com.

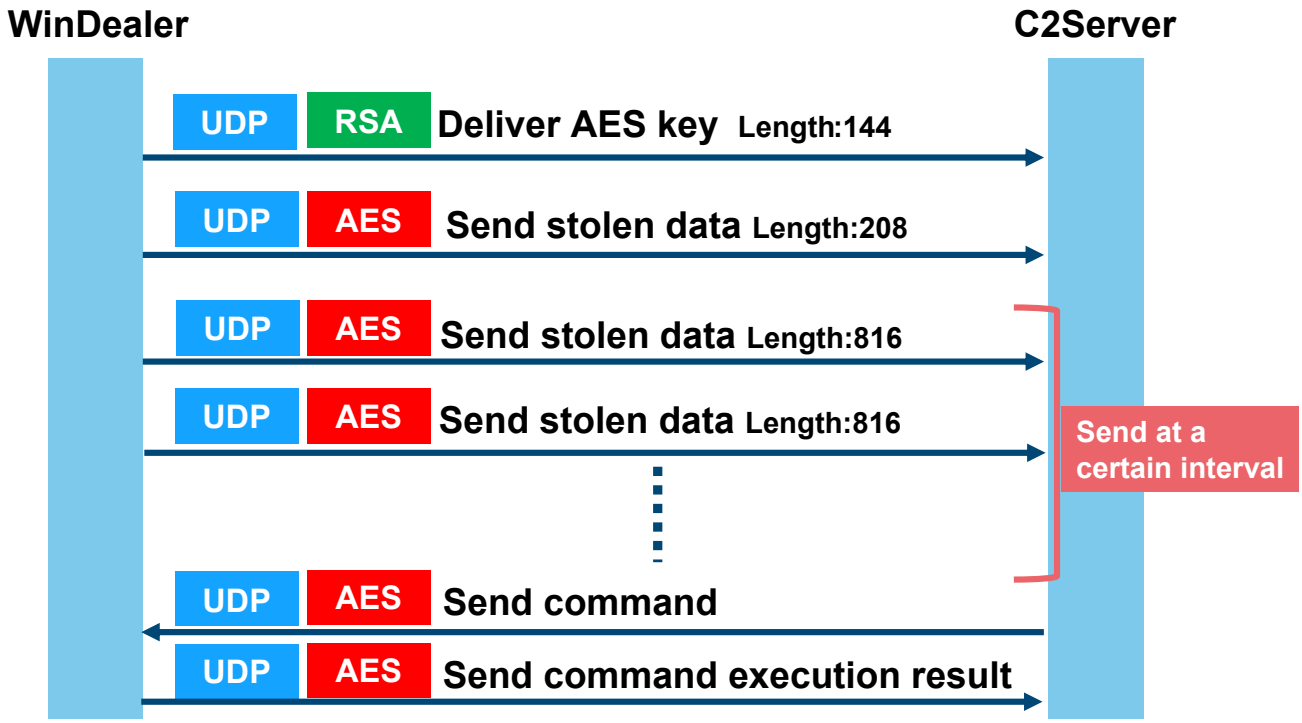


Figure 3: Communication flow with a C2 server

Figure 4 describes the communication contents when delivering an AES key. AES key and its CRC32 checksum value are encrypted with RSA1024bit public key. The public key is hardcoded in the sample, which is also used for other samples as well.

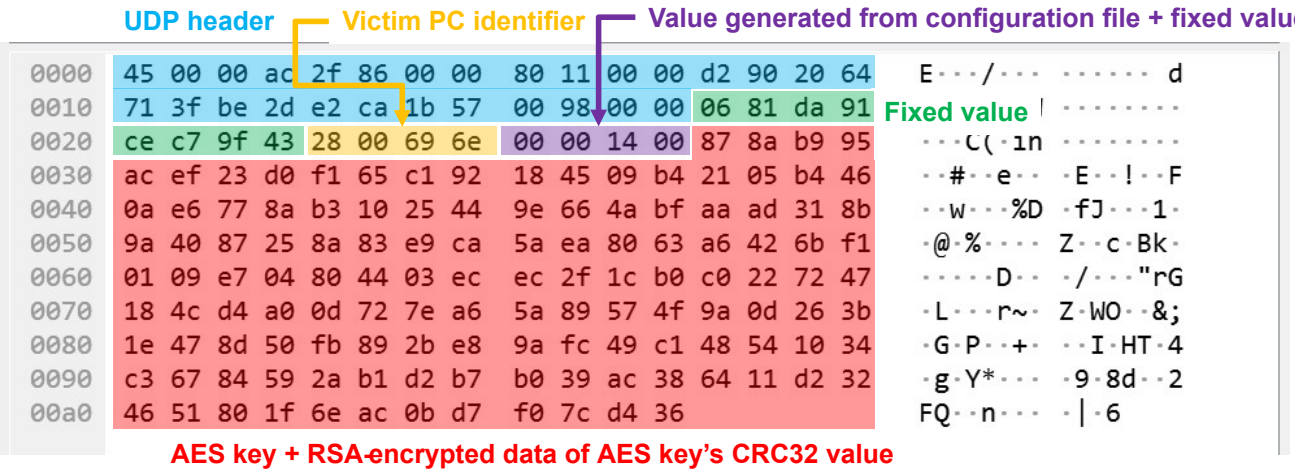


Figure 4： Example of contents sent with AES key

From the second round of communication and onwards, data is encrypted in AES128bit ECB mode based on the AES key which was dynamically generated during the initial communication. Please refer to Appendix B for the details of data format.

Process and send stolen data

WinDealer processes a series of stolen data as ".a" file in a folder under %TEMP%, encrypts it with AES and send it to a C2 server. The flow of event is illustrated in Figure 5. The modules steal and process the data, while WinDealer itself monitors the files under %TEMP%, encrypts the file and sends it to a C2 server.

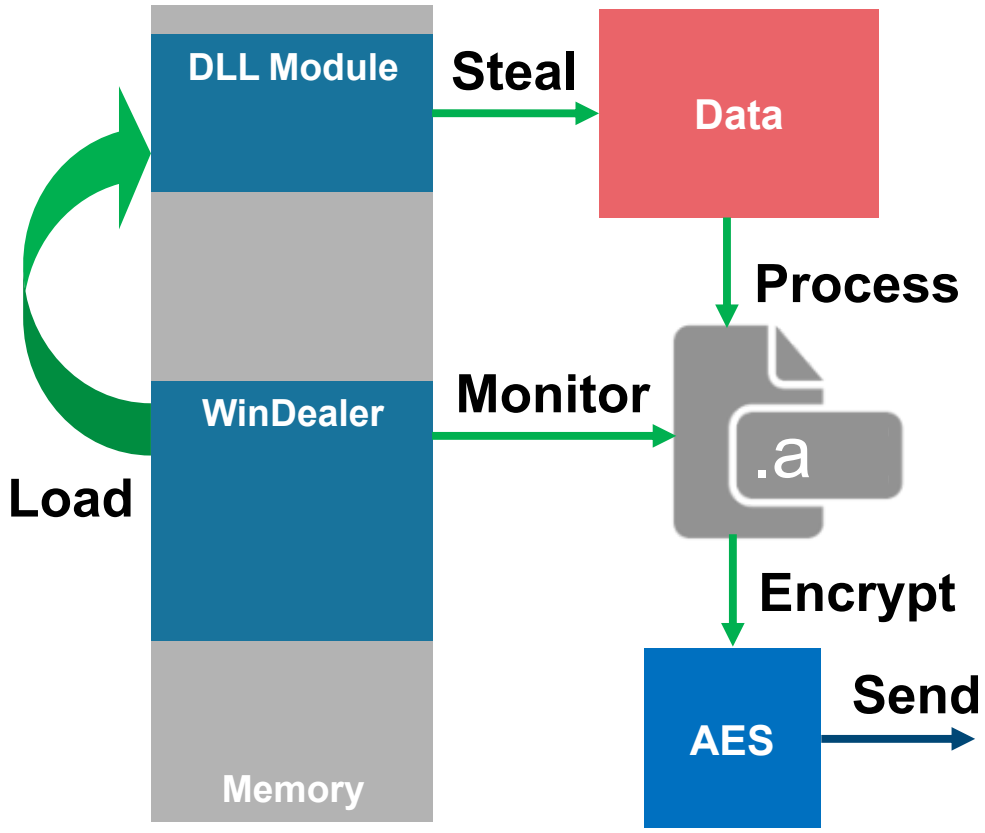


Figure 5：Flow of events by WinDealer and modules

A part of the code for generating ".a" file by a module is as follows (Figure 6):

```
BOOL __cdecl aa_Write_and_RenameFile(
        LPCVOID lpBuffer,
        DWORD nNumberOfBytesToWrite,
        LPCSTR lpFileName,
        char *NewFilename)
{
  HANDLE FileA; // eax
  void *v5; // esi

  FileA = CreateFileA(lpFileName, 0x40000000u, 0, 0, 2u, 0x80u, 0);
  v5 = FileA;
  if ( !FileA || FileA == (HANDLE)-1 )
    return 0;
  aa_WriteFile_via_xor_YYYY(FileA, lpBuffer, nNumberOfBytesToWrite);
  CloseHandle(v5);
  return aa_RenameFile(lpFileName, NewFilename) == 0;
}
```

Figure 6： DLL module's code to generate ".a" file

The stolen data is first stored in a file with an ".t" extension, which is then renamed to ".a". The series of data is stored in different directories based on the data category, and they are taken out when ".a" file is created. Please refer to Appendix E for the details of each directory.
Before writing and reading the files, the data is encoded/decoded by XOR-based function with its key value "YYYY" as in Figure 7.

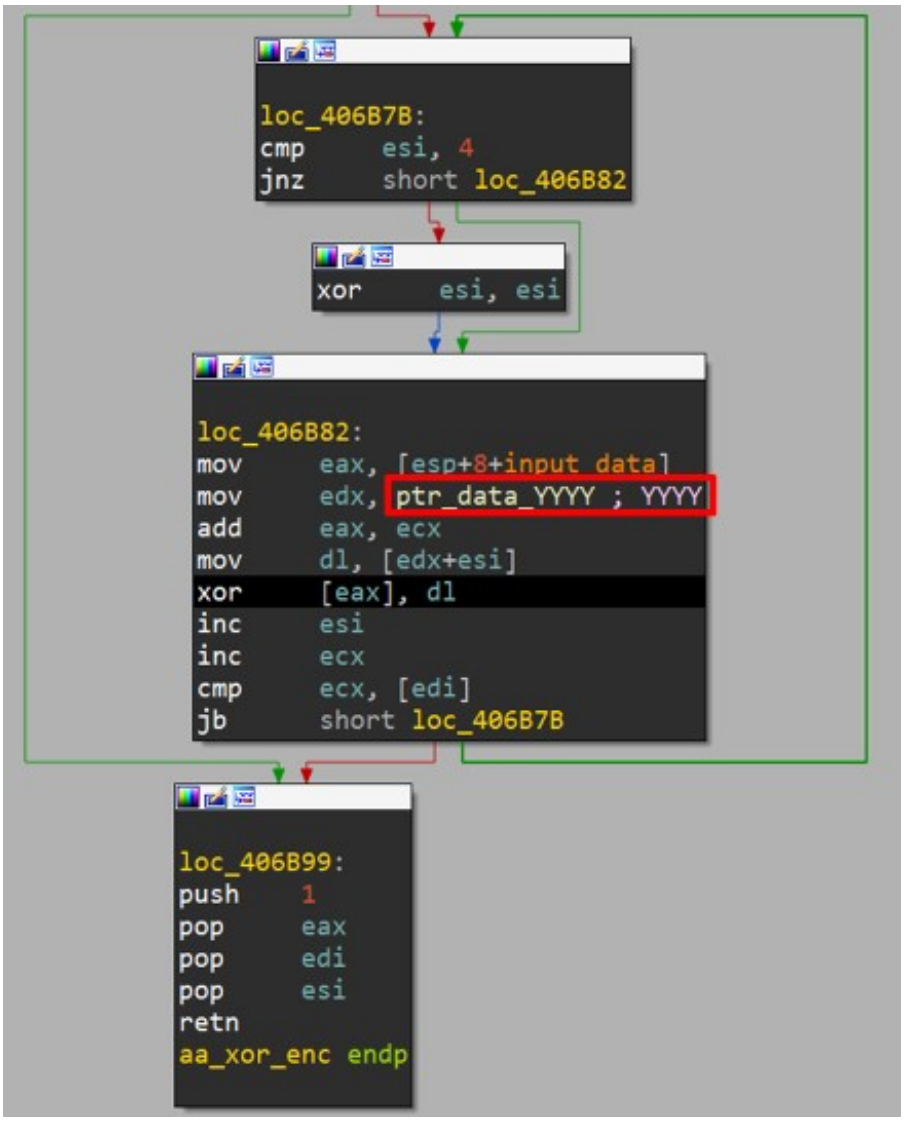


Figure 7：A function for XOR-based encoding when accessing ".a" file

Functions of modules loaded on memory

Once launched, WinDealer loads a DLL module in a PE format (encoded in the sample) on the memory and executes it (Figure 8).

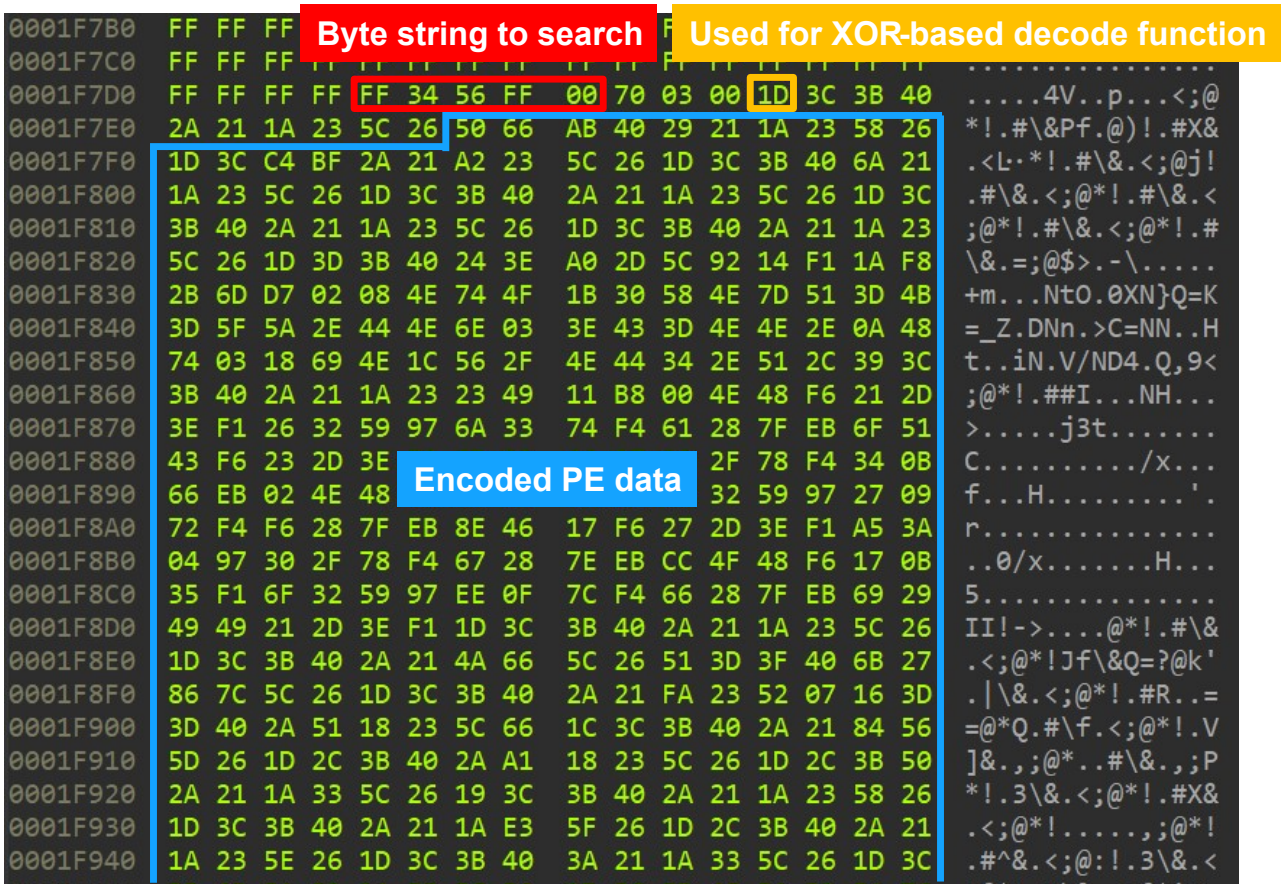


Figure 8： Encoded module data

The malware obtains its file path, searches for a byte string “0xFF3456FF00” and extracts data from its offset 0xE. Using its offset 0x4 value and a XOR-based decode routine (Figure 9), a DLL module is loaded on the memory and then executed.

```
int __thiscall aa_extract_dllimage_via_xor(MODULE_INFO *this, void *destination)
{
  int module_that_point; // ecx
  unsigned int count; // eax
  char *i; // [esp+10h] [ebp+8h]

  if ( !this->current_addr )
    return 0;
  *(_DWORD *)destination = 0;
  memcpy(destination, (const void *)(this->current_addr + this->module_Point), 4u);
  module_that_point = this->module_Point + this->current_addr;
  count = 0;
  for ( i = 0; (unsigned int)i < *(_DWORD *)destination; ++i )
  {
    i[module_that_point + 0xE] ^= *(_BYTE *)(count % 0xA + module_that_point + 4);
    count = (unsigned int)(i + 1);
  }
  return this->module_Point + this->current_addr + 0xE;
}
```

Figure 9： Decoding module

The loaded DLL module is named as “MozillaDll.dll”. There are 3 Export functions as follows:

- AutoGetSystemInfo: Steal data
- GetConfigInfo: Set configuration
- partInitOpt: Set commands

The loaded DLL module monitors the below items, saves related items in a separate file and obtains them to send out to a C2 server.

- Files stored in a USB memory
- Files under Documents, desktop and recycle bin
- Files under folders related to SNS applications

Please see Appendix D for the details of commands that C2 server sends and its contents.

In closing

Besides WinDealer, it has been confirmed that LuoYu uses other kinds of malware that operate in various platforms. We will report if we observe a new type of malware.
For your reference, SHA256 hash values of similar samples are listed in Appendix F.

- Yuma Masubuchi
(Translated by Yukako Uchida)

Reference

[1] “LuoYu” The eavesdropper sneaking in multiple platforms
https://jsac.jpcert.or.jp/archive/2021/pdf/JSAC2021_301_shui-leon_en.pdf

[2] Japan Security Analyst Conference 2021 -3rd Track-
https://blogs.jpcert.or.jp/en/2021/02/jsac2021report1.html

Appendix A WinDealer configuration

Table A：List of configuration

File path	String in malware	Contents
C:\ProgramData\923b5fd7	remark	-

C:\ProgramData\ad5f82e8	remotedomain	Domain name
C:\ProgramData\8fe4c114	password	-
C:\ProgramData\1c76cbfe	remoteip	C2 server IP
C:\ProgramData\9c3b6294	reverseip	C2 server IP (reconfigured)
C:\ProgramData\789406d0	-	Result of connection to a dummy host
C:\ProgramData\c25549fe	otherinfo	-
C:\ProgramData\f46d373b	-	Created when launched
C:\ProgramData\windows.inf	-	-
C:\ProgramData\Destro	-	Name information to register in run key

Appendix B WinDealer Contents of data exchanged

Table B-1： Format of data sent for first communication

Offset	Length (byte)	Contents
0x00	4	0x91DA8106
0x04	4	0x439FC7CE
0x08	4	Victim PC identifier
0x0C	1	Generated based on the contents of a configuration file "789406d0"
0x0D	3	0x001400

0x10	128	AES key + RSA-encrypted data of AES key’s CRC32 value

Table B-2：Format of data sent for second communication onwards

Offset	Length (byte)	Contents
0x00	4	0x91DA8106
0x04	4	0x439FC7CE
0x08	4	Victim PC identifier
0x0C	1	Generated based on the contents of a configuration file "789406d0"
0x0D	1	Type
0x0E	2	0x1400
0x10	1	Length
0x11	1	0x6
0x12	1	remark length
0x13		remark
-	1	0x3
-	1	password length
-	-	password
-	1	0x5

-	1	otherinfo length
-	-	otherinfo
-	-	System information

Table B-3：Format of data received

Offset	Length (byte)	Contents
0x00	4	0x91DA8106
0x04	4	0x439FC7CE
0x0D	1	Commands
0x10	2	command data length
0x12	2	Unused
0x14	2	Unused
0x16	2	Unused
0x18	Command data length	Command data

Appendix C WinDealer List of commands

Table C：List of commands

Value	Parameter string*	Contents
0x06	content-length: 2	uninstall
0x09	content-length, filename, time	Delete files under %TEMP%

0xC	filename, flg	CreateProcess
0x1F	speed	Configure Sleep time
0x2D	filepath	Obtain contents of selected file
0x50	filename, md5	Delete selected file
0x51	filepos,filename, filelen, block, md5	Write on selected file
0x5A	datastate	Write on "C:\ProgramData\windows.inf"
0x5B	-	Perpetuation settings for registries
0x5C	list	Perpetuation after process check
0x5D	yes	Set a value to SType of {HKCU}\\Softwaware\Microsoft
0x5E	otherinfo	Write on "c25549fe"
0x60	headsign, 1, 2	Write on "789406d0"
0x61	reverseip	Write on "9c3b6294"
0x63	-	Obtain configuration
0x64	-	Read time
0x66	remoteip, remark, password	Write on configuration files
0x67	sessionid:	-

0x8F	Hkey, subkey, valuename, classesroot, currentuser, localmachine, users, currentconfig	Execute RegQueryValue
0xAA	pname	Screen capture
0xAB	-	Configuration on screen capture
0xAD	-	Configuration on screen capture

*Parameter string: These strings are parsed from the received command and used as a command parameter

Appendix D List of commands of loaded modules

Table D：List of commands

Value	Parameter string*	Contents
0x02	-	Related to screen capture
0x03	bootdir, filetype	Related to folder/files
0x05	filename, monitortype, begpos, block	Send files
0x07	-	Obtain drive information
0x0A	-	Configure for lnk files
0x0D	-	Execute commands 0xC0, 0xC5, 0xC3, 0xC1, 0xC2, 0xC4, 0xC6
0x12	freq, storetm, quality, type	Configure parameter
0x1E	srhdir, srhcont, srhnum, sessid	-

0x28	filename	Obtain file information
0x29	filefilter, settype, usbfilter, checkdirfilter	Configure parameter for monitoring
0x2A	monitortype, monitorvalue	Obtain files of monitoring results
0x2B	-	-
0x30	-	Write contents such as "c:\windows", "c:\program files" on "~BF24"
0x32	freq, storetm	Configure parameter
0x3E	file	Create jpeg file under %TEMP%
0x65	filename, fileoffset	Obtain contents from selected files and offsets
0x69	filename, delete, yes	Delete selected files
0x7A	cmdtype, command: ,reset, downfile, getmypath, dealmd5	Execute cmd.exe
0x7B	session, command, reset, downfile, exit, getmypath	Execute remote shell
0xC0	-	Write list of processes on "28e4-20a6acec"
0xC1	-	Write list of applications on "28e4-20a6acec"
0xC2	-	Write keyboard information on "28e4-20a6acec"
0xC3	-	Write SNS-related registry contents on "28e4-20a6acec"
0xC4	-	Write configuration of Skype, QQ, WeChat and wangwang on "28e4-20a6acec"

0xC5	-	Write MAC address etc. on "28e4-20a6acec"
0xC6	-	Write network configuration on "28e4-20a6acec"

*Parameter string: These strings are parsed from the received command and used as a command parameter

Appendix E List of generated directories

Table E： List of directory

ID	Path	String in malware
(none)	%TEMP%\\~FEFEFE	-
0x01	%TEMP%\\070a-cf37dcf5	-
0x02	%TEMP%\\d0c8-b9baa92f	audio
0x03	%TEMP%\\~B5D9	keylog
0x04	%TEMP%\\632c-0ef22957	-
0x05	%TEMP%\\8e98-fb8010fb	filelist
0x06	%TEMP%\\7a4a-90e18681	-
0x07	%TEMP%\\d4a5-30d3fff6	-
0x08	%TEMP%\\d4dc-3165f4cf	-
0x09	%TEMP%\\~CE14	monitortype
0x0A	%TEMP%\\~CE2E	-
0x0B	%TEMP%\\~B5BE	skypeaudio

0x0C	%TEMP%\\~B61A	skypeshoot
0x0E	%TEMP%\\5a7e-42ccdb67	-
0x0F	%TEMP%\\~BF24	browser
0x10	%TEMP%\\65ce-731bffbb	md5filter
0x11	%TEMP%\\~BF34	browsercookie
0x12	%TEMP%\\28e4-20a6acec	systeminfo
0x61	%TEMP%\\~FFFE	otherfile
0x62	%TEMP%\\FFFF	otherdata
0x63	%TEMP%\\63ae-a20cf808	-

Appendix F SHA256 hash values of similar samples

EXE

- 1e9fc7f32bd5522dd0222932eb9f1d8bd0a2e132c7b46cfcc622ad97831e6128
- b9f526eea625eec1ddab25a0fc9bd847f37c9189750499c446471b7a52204d5a

DLL

- 0c365d9730a10f1a3680d24214682f79f88aa2a2a602d3d80ef4c1712210ab07
- 2eef273af0c768b514db6159d7772054d27a6fa8bc3d862df74de75741dbfb9c

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Yuma has been engaged in malware analysis and coordination of cyber security incidents in JPCERT/CC Incident Response Group since November 2020.

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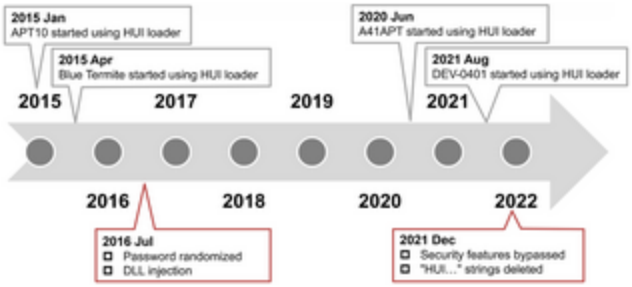
- 

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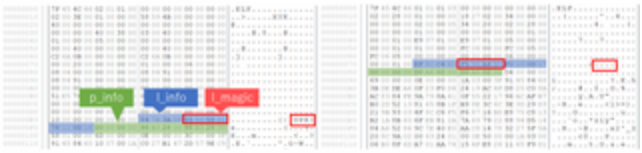
- 
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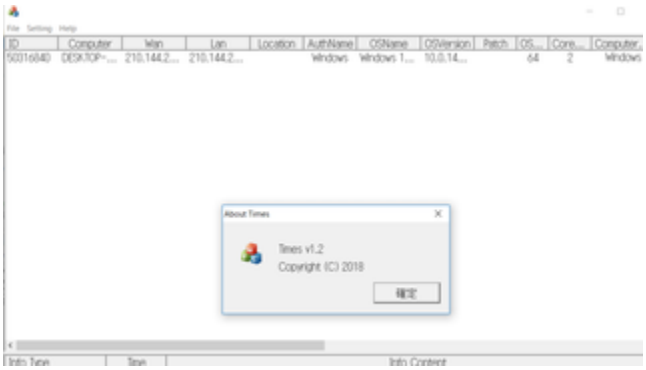
- 

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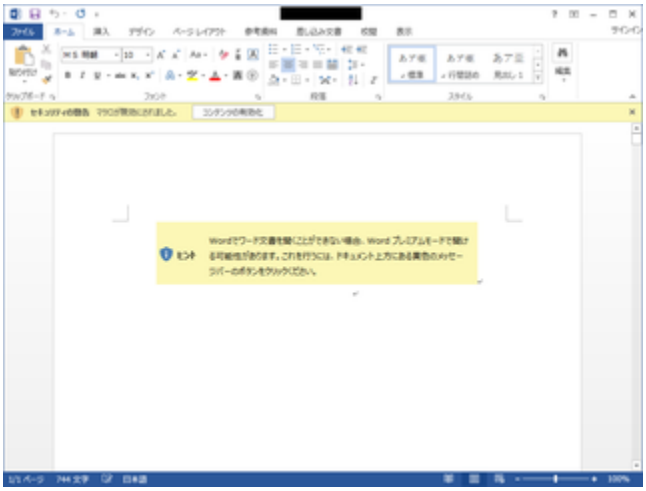
- 
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