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Chaining Vulnerability Scans inTenable IO Using Python

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Chaining Vulnerability Scans in Tenable IO Using Python

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Abstract

Enterprise vulnerability scanning traditionally makes use of multiple scanners, runs scans against targets in a parallel manner for maximum efficiency, and uses substantial amounts of bandwidth. However, a particular scanning use case exists that involves scanning targets in a sequential, or "chained", manner so as to conserve bandwidth. Tenable IO and the Tenable-supported PyTenable library do not currently support chained scanning. Using Tenable IO and a collection of Python scripts, an application by which to scan targets in a chained manner will be presented. Additional features such as the automation of scan creation, deletion and execution will be demonstrated, as well as the use of configuration files to define scans and logging parameters. The culmination of these application features will address and satisfy the use case of deploying chained scans in Tenable IO using Python and the Tenable IO REST API.

1. Introduction

Vulnerability scanning, in the context of information security, is inherently at odds with itself in terms of scanning as many computing assets as possible, and in as many parallel scans as possible, while not consuming all available network bandwidth.

Ideally, vulnerability scans can be run in parallel using multiple scanners to achieve efficiency. This is especially important for densely populated network subnets where scanning windows are perhaps small due to scanning being restricted to off or maintenance hours. However, sometimes a network does not have sufficient bandwidth to accommodate parallel scans. Other times, scanning resources (e.g. scanners) are in short supply and scans cannot be distributed to multiple scanners configured in a scanner group that are able to share the scan load in parallel.

Such use cases lead to the conclusion that running dependent, or chained, scans is a potential solution. As described in his forum post, Steven Weedman inquired of the Tenable IO Forum community: "Is it possible to set up dependent scan triggers in Tenable.IO? I want to chain a series of scans during off-hours. If not, is this a feature that can be requested?" (Weedman, 2020).

The answer to this question resulted in the conclusion, by several posters, that this was not possible using Tenable IO (Gillham, 2020) or PyTenable (Tenable's Python Library) (Holland, 2020). Gillham suggests using the IO API in a Python script (Gillham, 2020), and Holland elaborates on this suggested solution and offers to share a solution upon completion and employer management approval to share the code (Holland, 2020).

The solution to Steven Weedman's question is presented herein as a collection of scripts and configuration files. The original question of how to run dependent scans, referred to as "chained" scans going forward, is specifically addressed. In addition, other useful features are built into the code. One such feature includes being able to query the IO API for customer specific information needed to build the scan configuration file.

Another feature is the automation of scan creation, deletion and execution, either manually or from a cron job, via the Tenable IO API. Incorporation of the Python ArgParse module to present usage information and flag/argument validation, and the

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Python ConfigParser module to parse the scans definition file, are supported features as well. Finally, robust error checking for misconfigured scans in the scan definition file and use of the Python Logging module to log to both STDOUT and log flat-files, is supported.

The code presented here assumes use of Python version 3.7.4 and running said code on Linux or Windows. Some discussion and examples assume Linux is used as the OS for the application deployment (e.g. chmod commands and cron jobs). Windows will respect os.chmod directives in the application code and will set the read-only bit, but not the other bits (docs.python.org, 2020). If running the code on Windows, configure the file and directory permissions and ownership as necessary.

2. Vulnerability Scanning

2.1. What is Vulnerability Scanning?

To avoid any ambiguity or confusion, this paper shall describe vulnerability scanning, or assessment, as: "... a process that identifies and evaluates network vulnerabilities by constantly scanning and monitoring your organization's entire attack surface for risks." (Tenable, 2020).

2.2. What is "Chained" Vulnerability Scanning?

As posed by Steven Weedman in the context of dependent scanning by chaining a series of scans (Weedman, 2020), and rebranded as "chained scanning" (Holland, 2020), "chained" vulnerability scanning is defined as the running, or execution, of a predefined set of vulnerability scans, in order, in a sequential manner, where the scan n+1 runs only after scan n has completed.

2.3. Chained Vulnerability Scanning Use Cases

As described previously, chained vulnerability scanning has several use cases. The first use case would include scanning a low bandwidth network where parallel scanning would result in an unacceptably high usage of available bandwidth. The second use case would be scanning a network where there are insufficient scanning resources for parallel scanning, such as a single scanner (Weedman, 2020). The final use case

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addresses scanning a network where sequential scanning is required, but scheduling scans in IO based upon prior scan times is imprecise due to changing network usage patterns, routine asset additions and deletions, etc (Holland, 2020).

While chained scanning could be applied to external public-facing assets using Tenable's cloud-hosted scanners, herein it is focused on scanning internal assets and networks. However, it's entirely possible to apply this concept to external scans, if desired, by simply using a cloud-hosted scanner or scanner group in the scans config file. One such external scanner would be, for example: "US West Cloud Scanners" (Tenable, 2020).

3. Vulnerability Scanning using the Tenable IO REST API

3.1. What is a REST API

As defined by Margaret Rouse (Rouse, 2020), "A RESTful API is an application program interface (API) that uses HTTP requests to GET, PUT, POST and DELETE data.". Tenable IO, Tenable's cloud-based vulnerability scanning product, utilizes a REST API for configuring customer-specific instances of IO. Specifically, the Tenable IO API allows a customer to create vulnerability scans, delete them, and run (or execute) them by way of API calls using API keys allocated to a user in a specific customer's IO instance. Many other actions can be taken via the API, some of which are described in the next section.

3.2. Tenable IO API Endpoints

An API endpoint is a term used to describe a web-based service that utilizes an API (Application Program Interface) and advertises its service via a URL (RapidAPI, 2020). For example, the Tenable IO API endpoint for creating a scan is:

```
url = "https://cloud.tenable.com/scans"
```

This particular endpoint is described in their IO API Explorer at <https://developer.tenable.com/reference#scans-create> (Tenable, 2020). The IO API explorer is an invaluable reference and tool for using the API and creating automation scripts. Part of its feature set is to allow the user to enter their API keys and test the

endpoint by way of the explorer actually effecting a change in their IO instance. The code used to run the API endpoint command is shown in the selected programming language, as well as the results of the API call (successful or not). What is left to the user is to write the middleware to tie the results from API endpoint calls together into a fully functioning application.

The programming language support is extensive, including but not limited to: Python, cURL, Java, Go, Ruby, and Powershell (Tenable, 2020).

The API endpoints used throughout the code include:

Endpoint Name	Endpoint URL(s)
Folders	url = "https://cloud.tenable.com/folders"
Scanners	url = "https://cloud.tenable.com/scanners" url = "https://cloud.tenable.com/scanners/scanner_id"
Policies	url = "https://cloud.tenable.com/policies"
Tags	url = "https://cloud.tenable.com/tags/values"
Scans	url = "https://cloud.tenable.com/scans" url = "https://cloud.tenable.com/scans/scan_id" url = "https://cloud.tenable.com/scans/scan_id/launch"

Note that the "scanner_id" and "scan_id" in the URLs above are placeholders for the actual scanner ID and scan ID to be passed to the API endpoint call as a variable within scripts.

4. Chained Scanning Using chain.py

4.1. Overview of chain.py Processing

4.1.1. Wrapper script: chain.py

The main, or wrapper, script for the application is called chain.py. This script is the entry point for running the application to create, delete, run and/or query IO for instance information. This script will parse the command line arguments supplied, and if there is an error, report on the error and supply usage information. This is accomplished using the ArgParse module. Usage information can be obtained by using the "-h/--help" option as shown below:

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```

PS C:\Users\Administrator\Desktop\GIAC\chain> python .\chain.py -h
usage: chain.py [-h]
               [--action {create,run,delete,create-run,delete-create,delete-create-run,info}]

optional arguments:
  -h, --help            show this help message and exit
  --action {create,run,delete,create-run,delete-create,delete-create-run,info}

NOTES:
- You cannot delete and then run scans (delete-run), nor create and
then delete scans (create-delete). Similarly, create-delete-run is
not supported.

- The "info" flag will output the folder, scanner, policy, and tag
name:ID dictionaries to log.info to assist in building scan
definitions in the scans.ini file. Run "./chain.py --action info"
to generate this log. The data is also sent to STDOUT, however
it is easier to search/grep from the log.info flat file.

- The create/delete/run scripts all log to log.chain in the logs
subdirectory. The log file is set to rotate when the size reaches
100K bytes, and keeps a history of 5 log files (log.chain.5 being
the oldest and log.chain being the current). Successive
instantiations of the run.py script will also log to log.chain.
The script name is in the log.chain file, such as "create.py" in
the second field (fields delimited by double-colons). Note that
the log.info file is cleared on every run of the
create/delete/run scripts. This is fine as this data is mutable
and should be queried every time a scan in scans.ini is configured
or updated.

```

Figure 1: chain.py -h output

Chain.py performs other actions as listed below:

- Uses the dotenv library (which will likely need to be installed using pip as it's not in the Python standard library) to create environment variables for the API keys from the .env file. More discussion on this topic occurs in section 4.4.
- Creates the subdirectory "logs" in the "chain" directory where chain.py is run from if it doesn't already exist. Then it chmod's the directory 700 (read-write-execute for owner only). This directory will contain two logs files, log.chain and log.info. The log.chain log file will contain all the logs from three scripts that are imported from chain.py: create.py, delete.py, and run.py. The log is created in append mode, and rotates once it reaches 100,000 bytes and saves 5 backup copies before deleting the 6th one in a FIFO manner. The log.info file contains the IO instance specific information needed to build and modify the scan configuration file, scans.ini. See section 4.2 for instructions on building scans.ini. Because this information is mutable within the IO instance, log.info does not rotate and is clobbered every time info.py is run. Every

time log data is written to one of the two logs, the chain.py script will chmod that log file 600 (read-write for owner only) as a means of programmatically ensuring the permissions stay read-write for the owner only.

- The chain.py script will call one or more of the "action" scripts, so called because of the command line flag "--action" that invokes them. These scripts are passed the IO API keys "access_key" and "secret_key" as arguments for use in API calls in their functions. This results in API keys never being written to disk anywhere but the .env file. See section 4.4 for a more comprehensive discussion of API keys and how chain.py secures them.

- The chain.py script, as do all the action scripts, contains logic to prevent them from being invoked directly without arguments. In other words, invoking create.py with the command "./create.py" or "python ./create.py" will result in the script exiting as shown below:

```
PS C:\Users\Administrator\Desktop\GIAC\chain> .\chain.py

ERROR. No arguments supplied when runing the chain.py script.
Run "./chain.py --help" to see usage info.

Exiting...
```

Figure 2: Chain.py output when run without arguments

Proper syntax for running chain.py with the "info" argument is shown in Figure 3 (output redacted):

```
PS C:\Users\Administrator\Desktop\GIAC\chain> python ./chain.py --action info

Running the info.py script

forlder_dict is:
{'DataCenter Scans': 11, 'DMZ Scans': 21}

scanner_dict is:
{'US West Cloud Scanners': 121138, 'ACHESCAN11': 13}

policies_dict is:
{'Internal-Scans': '123-abc', 'DMZ-Scans': '789-xyz'}

tag_dict is:
{'Office:London': 'cbc-123', 'DC:West': 'nmc-897'}

info.py script finished execution

See "log.info" in the logs subdirectory for script output
```

Figure 3: chain.py --info output with redacted data

Python modules from the standard library used in chain.py include:

Module	Intended Use
argparse	Enables use friendly command-line interfaces and parses them (Python.org, 2020)
textwrap	Among other uses, removes common leading whitespace characters from lines in a text string (Python.org, 2012)
os	Enables Python to utilize operation system functionality, such as chmod'ing a file to change its permissions (Python.org, 2020)

Python libraries used in chain.py that may need to be installed include:

Module	Intended Use
dotenv	Reads values from a .env file for use in creating environment variables (Pypi.org, 2020)

4.1.2. Action scripts: run.py, create.py, delete.py, info.py

The action scripts perform as they are named with respect to scans. Create.py creates scans in an automated fashion using the API and the scans.ini config file in its entirety. Delete.py deletes scans based on the names of the scans in scans.ini, and similarly run.py runs the scans based on scan names defined in scans.ini. The info.py script, as mentioned previously and demonstrated in Figure 3 above, queries for the customer specific IO instance information needed to build or update scans.ini. It also queries for the various ID values needed to create a scan and passes that data to create.py. This was implemented to achieve code deduplication between info.py and create.py.

Note that because the four action scripts are imported as modules in the chain.py script, bytecode versions of each are created. These bytecode versions of each script (with the .pyc extension) allow for faster subsequent execution times (Bennett, 2018). Once imported in chain.py, the main function within each action script is called and is passed the API keys as variables that were declared with the value of the environment variables from the .env file as shown below in Figure 4.

```

# Check for --action arguments. Will import
# necessary .py scripts to create .pyc bytecode
# files. Also run fix_perms function to chmod file.
if args.action == 'create':
    import info
    info.main(access_key, secret_key)
    import create
    create.main(access_key, secret_key, info.folder_dict, \
               info.scanner_dict, info.policies_dict, info.tag_dict)
    fix_perms('./logs/log.chain')

elif args.action == 'run':
    import run
    run.main(access_key, secret_key)
    fix_perms('./logs/log.chain')

elif args.action == 'delete':
    import delete
    delete.main(access_key, secret_key)
    fix_perms('./logs/log.chain')

```

Figure 4. Snippet of chain.py showing action scripts being imported as modules

Python modules from the standard library used in create.py, delete.py, and/or run.py include:

Module	Intended Use
Fileconfig	Creates class instances out of config file sections (Pypi.org, 2019)
Configparser	Enables configuration files to be used by Python and easily updated by end users (Python.org, 2020).
Json	Enables encoding and decoding of JSON blobs in Python (Python.org, 2020)
logging	Implements logging for applications that is flexible and works with configuration .ini files (Python.org, 2020)
Re	Enables use of regular expression methods in Python similar those operations found in Perl's regular expressions (Python, 2020)
requests	Enables Python to easily send HTTP requests (Requests: HTTP for Humans, 2020)
Sys	Enables Python to access interpreter variables and functions (Python.org, 2020)
Time	Enables Python to access time-related functions (Python.org, 2020)

Python modules from the standard library used in info.py include:

Module	Intended Use
Fileconfig	Creates class instances out of config file sections (Pypi.org, 2019)
Json	Enables encoding and decoding of JSON blobs in Python (Python.org, 2020)
Logging	Implements logging for applications that is flexible and works with configuration .ini files (Python.org, 2020)
Requests	Enables Python to easily send HTTP requests (Requests: HTTP for Humans, 2020)

4.1.3. Special features: “Clobber” prevention in run.py

The run.py action script has logic to prevent "clobbering". What this means is that when run.py is executed, and is still running its first instantiation, a subsequent execution of the script will not be allowed to execute the same scans a second time. This was implemented to address the following use case:

Assume chain.py was configured to run every hour from a cron job and scan a few high value assets or modestly sized subnets (remember, chained scanning implies scanning at least two assets and/or subnets using at least two scans). Knowing when new vulnerabilities are discovered for any of these assets/subnets is key as they contain critically sensitive data. Such a discovery will be reported via a scheduled report in IO that runs a few minutes after each hour.

If the chained scans that were run at 1200 hours were still running at 1300 hours when run.py was scheduled to execute again, the script will detect a running or pending scan already in progress (via recursive polling of the scan status from the API scans endpoint) and exit. Hence, the scans scheduled to run at 1300 hours will not "clobber" the scans still running from the invocation of run.py at 1200 hours. Doing so would be counter to the very premise of chained scanning, which is running one scan at a time and waiting for it to complete before running the next scan.

Now, this feature is not without imperfections. There are small windows of time where an API call is made to execute scans defined in scans.ini, but the Tenable IO instance has not yet processed the API endpoint request (in the form of an HTTP PUT).

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This results in a race condition. It is an unfortunate byproduct of having a cloud-based server that utilizes a multi-tenant API (meaning multiple customers share the public API engine and are subject to queuing and rate limiting) (Tenable, 2020).

However, `run.py` does provide protection against clobbering a currently running chained scan with another set of scans a majority of the time. Furthermore, logging of any such clobbering prevention, or a lack of clobbering protection having taken place, is logged in the `log.chain` file for postmortem analysis. A demonstration of clobber protection will be presented in section 4.5.

4.2. Building the scans.ini Config File

Scans must be defined in the `scans.ini` file prior to running `create.py`, `delete.py`, and/or `run.py`, and there must be at least two scans defined. There is guidance in the comments along with scan definition examples in `scans.ini` (and is included in its entirety in the Appendix). The fields required for each scan definition are as follows:

Folder name
Scanner, or scanner group, name
Scan policy name
Launch frequency (should always be ON_DEMAND) as <code>chain.py</code> runs manually or via a cron job
Comma-delimited list of email addresses to send scan completion emails to (optional)
Scan description (optional)
Scan name (must be unique)
Comma-delimited list of scan targets (can use IP's, CIDR subnet notation, or both) ***
One or more tag name:value pairs, comma-delimited. If tag name is "Office" and the tag value is "London", the pair is "Office:London". For multiple tag name:value pairs, the format would be: Office:London,Office:Berlin,Servers:Mail There should be no spaces before/after the colons and commas, however the code will remove any that are added by mistake. Spaces in the tag name or value is allowed. For example, these tag name:value pairs are legitimate: Office:New York,Windows Hosts:Mail Servers.***

*** One, or both, of `scan_targets` and `tag_target_pair` must be defined. Conversely, if both are undefined, the script will exit with an error.

Figure 5 shows the format for two scans using our (redacted) instance information from log.info:

```
[Scan1]
folder_name = Adhoc Scans
scanner_name = Datacenter Scanner Group
policy_name = Host Discovery Scan
launch = ON_DEMAND
email = infosec@acme.com
description = Scan created by the chain.py script
scan_name = Discovery Scan: 10.1.1.1 and 10.2.2.2
scan_targets = 10.1.1.1,10.2.2.2
tag_target_pair =

[Scan2]
folder_name = Adhoc Scans
scanner_name = LONSCANNER12
policy_name = Host Discovery Scan
launch = ON_DEMAND
email = infosec@acme.com
description = Scan created by the chain.py script
scan_name = Discovery Scan: London Office
scan_targets =
tag_target_pair = Office:London
```

Figure 5. Sample scans.ini config file

To run three scans, simply add a [Scan3] section and define the parameters as desired. Referring back to Figure 3, note that based on the names in the dictionaries (folder_dict, scanner_dict, etc), the create.py action script will use the names in Figure 5 as the key to obtain the corresponding ID/UUID value in the dictionary. Said another way, if the folder_name for the scans in Figure 5 is "Adhoc Scans", the create.py action script will use that string to obtain the folder_dict ID value of "35". These lookups occur programmatically inside of create.py by importing info.py and returning the dictionaries as parameters at the end of the script for create.py to use. This is reflected in Figure 4, where the create.main function is passed "info.folder_dict" as an argument.

As noted previously, one can define both scan_targets and tag_target_pair. For example, assume [Scan2] is defined to have both scan_targets and tag_target_pair populated as shown below in Figure 6.

```
[Scan2]
folder_name = Adhoc Scans
scanner_name = ACMESCAN11
policy_name = Host Discovery Scan
launch = ON_DEMAND
email = infosec@acme.com
description = Scan created by the chain.py script
scan_name = Discovery Scan: London Office
scan_targets = 10.1.1.1
tag_target_pair = Office:London
```

Figure 6. Sample scans.ini config file with both scan_targets and tag_target_pair defined

This config will run and scan both the 10.1.1.1 IP and the London office using the IPs/subnets defined in that tag.

If neither scan_targets nor tag_target_pair is defined, running `./chain.py --action create` would result in a fatal error as shown below in Figure 7:

```
PS C:\Users\Administrator\Desktop\GIAC\chain> ./chain.py --action create
Running the info.py script
<redacted for brevity>
info.py script finished execution
See "log.info" in the logs subdirectory for script output
Running the create.py script
ERROR on creation of "Discovery Scan: 10.1.1.1". Both text_targets and tag_targets are blank in scans.ini file. At least one must be declared. Fix the scans.ini definition for this scan and run the scan creation again. Exiting the create_scans function...
ERROR: Scan definition in scans.ini is not configured properly
ERROR: (<class 'SystemExit'>, SystemExit(None), <traceback object at 0x0000000003B39188>)
Exiting...
```

Figure 7. Redacted output from chain.py when both scan_targets and tag_target_pair are undefined

It is worth emphasizing that create.py supports use of tags in scan creation. If a tag name has been created called "Office", with the tag value of "London", and has an associated IPv4 rule with all the IP's and/or subnets allocated to the London office, defining each IP/subnet to "scan_targets" in scans.ini is unnecessary. Using the tag is a "single source of truth" within IO and is much more maintainable when creating scans,

reports, etc. for the London office. An example of how this tag would be created in the Tenable IO UI is shown below:

The screenshot shows the 'Create Tag' form in the Tenable IO UI. The form is titled 'Create Tag' and has a close button (X) in the top right corner. It contains the following elements:

- A dropdown menu for 'Office' with 'London' selected.
- A text input field for 'Category Description (optional)'.
- A text input field for 'Value Description (optional)'.
- A checked checkbox labeled 'Apply automatically with rules'.
- A 'Match' dropdown menu set to 'All'.
- A text input field for 'of the following:' containing a rule configuration: 'IPv4 Address' (dropdown), 'is equal to' (dropdown), and '10.1.1.0/24, 10.2.2.0-10.2.2.10q' (text input).

Figure 8. Tag creation in Tenable IO UI

Using tags is the preferred method of defining targets in IO scans, and is supported and encouraged when using `chain.py`. See <https://developer.tenable.com/docs/manage-tag-based-scans-tio> for a full discussion (Tenable, 2020).

4.3. Logging Config File: `logging.ini`

Logging for the application is achieved by using the Python Logging module and a logging configuration file named `logging.ini`. This provides a centralized logging configuration definition and all the flexibility (and complexity) that comes with the `fileConfig` function.

The `logging.ini` file configures three handlers. The first is a `StreamHandler` (for printing script output to `STDOUT` on the console), and the second is a `FileHandler` for `info.py` to print its output to a log file in write mode. The third handler is a `RotatingFileHandler` and is used by the `create.py`, `delete.py` and `run.py` action scripts to

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print to log.chain using append mode. File rotation of log.chain is supported with a setting of 5 backup files each with a max of 100,000 bytes.

This results in each action script only having one logging declaration for each message that gets logged to both STDOUT and a log file. The statements take the form of one of the following, where all the logging statements have the log severity of "INFO" and logger statements that use variables make use of Python f-strings:

```
logger.info('<text to log>')
```

OR

```
logger.info(f'<text to log {variable_name}>')
```

See the Appendix for the full logging.ini config file format. The format of the log files themselves is as follows:

```
<Timestamp> :: <Action Script Name> :: <Severity Level> :: <Message>
```

The contents of log.info is shown below in Figure 9 illustrating this format (redacted and condensed for presentation). For log.info alone, a blank line is placed between the log entries for flat-file readability when using it as a reference to build the scans.ini file.

```
2020-07-06 11:26:07,200 :: info.py :: INFO :: Running the info.py script

2020-07-06 11:26:07,819 :: info.py :: INFO :: folder_dict is:
{'DataCenter Scans': 11, 'DMZ Scans': 21}

2020-07-06 11:26:08,733 :: info.py :: INFO :: scanner_dict is:
{'US West Cloud Scanners': 121138, 'ACMESCAN11': 13}

2020-07-06 11:26:09,460 :: info.py :: INFO :: policies_dict is:
{'Internal-Scans': '123-abc', 'DMZ-Scans': '789-xyz'}

2020-07-06 11:26:10,123 :: info.py :: INFO :: tag_dict is:
{'Office:London': 'cbc-123', 'DC:West': 'nmc-897'}

2020-07-06 11:26:10,163 :: info.py :: INFO :: info.py script finished execution
```

Figure 9. log.info file after running "./chain.py --action info"

The format of log.chain is shown below in Figure 10 (redacted for presentation):

```

2020-07-06 08:18:34,108 :: create.py :: INFO :: Running the create.py script
2020-07-06 08:18:34,111 :: create.py :: INFO :: Creating Discovery Scan: 10.1.1.1 scan
2020-07-06 08:18:34,111 :: create.py :: INFO :: Payload is: {"uuid":"ad629e16-03b6-8c1d-cef6-ef8c9dd3c65e66","setting
s":{"name":"Discovery Scan: 10.1.1.1", "description":"Scan created by the created_chained_scan.py script", "policy_id
":"12", "folder_id":"12", "scanner_id":"12", "text_targets":"10.1.1.1","emails":"infosec@acme.com", "acIs":{"permiss
ions":0,"owner":1, "type":"default"}}}
2020-07-06 08:18:34,739 :: create.py :: INFO :: The scan "Discovery Scan: 10.1.1.1" has been created
2020-07-06 08:18:34,740 :: create.py :: INFO :: Pausing for 1 second before the next API call....
2020-07-06 08:18:35,743 :: create.py :: INFO :: Creating Discovery Scan: 10.2.2.2 scan
2020-07-06 08:18:35,743 :: create.py :: INFO :: Payload is: {"uuid":"ad629e16-03b6-8c1d-cef6-ef4bd260ef5f9e66","setti
ngs":{"name":"Discovery Scan: 10.2.2.2", "description":"Scan created by the created_chained_scan.py script", "policy_
id":"12", "folder_id":"12", "scanner_id":"12", "text_targets":"10.2.2.2/32","emails":"infosec@acme.com", "acIs":{"pe
rmissions":0,"owner":1, "type":"default"}}}
2020-07-06 08:18:36,180 :: create.py :: INFO :: The scan "Discovery Scan: 10.2.2.2" has been created
2020-07-06 08:18:36,180 :: create.py :: INFO :: Pausing for 1 second before the next API call....
2020-07-06 08:18:37,184 :: create.py :: INFO :: Scan creation finished successfully.
2020-07-06 08:18:37,207 :: run.py :: INFO :: Running the run.py script
2020-07-06 08:18:37,940 :: run.py :: INFO :: Number of total scans in IO instance is: 199
2020-07-06 08:18:37,940 :: run.py :: INFO :: Running the following scans in a chained manner,one at at time:
2020-07-06 08:18:37,943 :: run.py :: INFO :: Discovery Scan: 10.1.1.1
2020-07-06 08:18:37,945 :: run.py :: INFO :: Discovery Scan: 10.2.2.2
2020-07-06 08:18:37,950 :: run.py :: INFO :: List of scan ID's that will run in order, one at at time: [5224, 5223]
2020-07-06 08:18:40,904 :: run.py :: INFO :: previous_scan_history_list BEFORE historical run check is: []
2020-07-06 08:18:41,756 :: run.py :: INFO :: NOTE: Null scan history
2020-07-06 08:18:41,760 :: run.py :: INFO :: Running scan for ID 5224 for the first time
2020-07-06 08:18:41,763 :: run.py :: INFO :: Function check_scan_status has been called
2020-07-06 08:18:43,150 :: run.py :: INFO :: Scan ID 5224 still running
2020-07-06 08:21:21,164 :: run.py :: INFO :: Scan ID 5224 still running
2020-07-06 08:21:52,486 :: run.py :: INFO :: Scan completed for scan ID 5224
2020-07-06 08:21:52,486 :: run.py :: INFO :: Function check_scan_status processing has completed
2020-07-06 08:21:55,118 :: run.py :: INFO :: previous_scan_history_list BEFORE historical run check is: []
2020-07-06 08:21:57,200 :: run.py :: INFO :: NOTE: Null scan history
2020-07-06 08:21:57,201 :: run.py :: INFO :: Running scan for ID 5223 for the first time
2020-07-06 08:21:57,204 :: run.py :: INFO :: Function check_scan_status has been called
2020-07-06 08:22:30,702 :: run.py :: INFO :: Scan ID 5223 still running
2020-07-06 08:24:36,497 :: run.py :: INFO :: Scan ID 5223 still running
2020-07-06 08:25:07,855 :: run.py :: INFO :: Scan completed for scan ID 5223
2020-07-06 08:25:07,856 :: run.py :: INFO :: Function check_scan_status processing has completed
2020-07-06 08:25:07,857 :: run.py :: INFO :: Scan execution/running finished successfully.
~

```

Figure 10. log.chain file after running "./chain.py --action create-run"

4.4. Securing API Keys

Storing API keys (also referred to as "secrets") for scripts to run without having to provide them on the command line as an argument is fraught with risk. Let's be clear: API keys are passwords. They are typically complex and of significant length, but passwords nonetheless. There are a number of options for securing API keys, some of which have less inherent risk than others with respect to exposure of the API keys to unauthorized persons or processes. They are discussed below, as well as to why chain.py uses the option that it does.

Requiring the API keys to be read from the command line as an argument results in not having to hardcode the secrets in each script, or a single file that gets parsed by all scripts. However, this results in not being able to run them from a cron job. They must be run manually. Also, the secrets could be written to the user's .bash_history file if supplied as a command line argument (assuming execution occurs on Linux and using the bash shell). A more complicated byproduct of running scans manually could result in logging

the commands via syslog to the SIEM. Now the secrets are in the SIEM, and SIEM logs are not meant to be purged on a one-by-one basis. One option for keeping secrets out of `.bash_history` and SIEM databases is to use the `getpass` module to query for secrets from inside the script at runtime, hence never writing them to disk (only to memory).

However, the inability to cron the script execution remains.

Hardcoding API keys in scripts is the most risky and least palatable of all the options. Hardcoding is when secrets are declared in a single file that gets parsed by scripts, or in every script that utilizes them. With this option, the importing of secrets into a GitHub or other repo along with code is a significant risk that could lead to them being exposed to unauthorized persons. Also, the secrets rely upon the file permissions of the script file(s), which may not always be as restrictive as they should and need to be.

Storing secrets in a "dot file", such as `.env`, and then using a Python library like `dotenv` to create environment variables is still hard coding secrets. However, there's some mitigating controls that makes this more palatable than hard coding secrets in scripts. This is the option that `chain.py` uses.

First off, `chain.py` `chmod`'s the `.env` file `600` (read-write for owner only). This mitigation uses file permissions to keep the file from being viewed by unauthorized users. Then `chain.py` `chmod`s `.env` `600` every time it is invoked, regardless of what the permissions are currently set to. While this is most likely an unnecessary action after the first time the file's permissions are set, it does provide a programmatic way to change the permissions to the correct setting should a user ever change them to a more permissive state on purpose or by accident.

Secondly, if a GitHub repo is created for the code, a `.gitignore` file can be created and configured so the `.env` file does not get inserted into the repo (FreeCodeCamp, 2020). By creating environment variables and then passing those environment variables as arguments to the main function of the action scripts from `chain.py`, secrets are never written to disk anywhere but the `.env` file. For additional security, the environment variables can be "unset" (or deleted) at the end of any action script execution (Pypi.org, 2020).

The final potential option to be briefly discussed here is using a password vault, such as Hashicorp Vault (HashiCorp, 2020) or CyberArk AAM (CyberArk, 2020). This is the ideal and most secure option. However, this option requires a license for commercial use of these enterprise tools, and the configuration of them is beyond the scope of the topic being presented here.

4.5. Using chain.py

Using chain.py, addressed previously in demonstrating other aspects of the scripts such as logging, is addressed formally and in its entirety here. There are a combination of action script command variations supported by chain.py. These include:

Command	Result
<code>./chain.py --action info</code>	Obtain IO instance data and write to STDOUT and log.info
<code>./chain.py --action create</code>	Create scans defined in scans.ini and write to STDOUT and log.chain
<code>./chain.py --action delete</code>	Delete scans defined in scans.ini and write to STDOUT and log.chain
<code>./chain.py --action run</code>	Run scans defined in scans.ini and write to STDOUT and log.chain
<code>./chain.py --action create-run</code>	Create and then run scans defined in scans.ini and write to STDOUT and log.chain
<code>./chain.py --action delete-create-run</code>	Delete, create, and run scans defined in scans.ini and write to STDOUT and log.chain
<code>./chain.py --action delete-create</code>	Delete and create scans defined in scans.ini and write to STDOUT and log.chain
<code>./chain.py -h</code> <code>./chain.py --help</code>	Print usage information of chain.py to STDOUT

Note: The following arguments to chain.py are not supported as they are either unnecessary or nonsensical: create-delete, delete-run, run-create-delete, run-delete, and run-delete-create.

As briefly discussed in section 4.1.3, chain.py works, at a high level, by parsing scans.ini to obtain all parameters needed to create scans, or just the scan names required to either run or delete scans. To run or delete scans, the run.py and delete.py action

scripts (when called by `chain.py`) lookup the scan ID's (based on the scan names from `scans.ini`) and use the API scans endpoint to delete or run the scan.

The chaining functionality occurs only in `run.py`. The create and delete action scripts also run sequentially and one at a time, as each scan is created or deleted based upon a single API call to the scans endpoint with a single unique scan ID value. However, `create.py` and `delete.py` have no specific chaining logic in their code.

Based on scan names parsed from `scans.ini` and the scan ID's associated with the scan names, `run.py` builds a Python list of the ID's. For the first scan ID in the list, `run.py` launches the scan using that ID with the scans API endpoint. Then `run.py` calls the `check_scan_status` function to poll the status of the scan using the scan ID. If the scan status is "pending" or "running", `run.py` sleeps for 30 seconds in an infinite while-loop inside the `check_scan_status` function. When the scan status is marked as "completed" by the API, `run.py` breaks out of the while-loop, exits the `check_scan_status` function, and launches the next scan in the list based on the scan ID list's second index value.

The "clobber" protection is effected by keeping track of the scan status values for each scan in a separate list. If any status is "pending" or "running", a second instantiation of `run.py` is terminated. Consider Figure 11 below:

```

1) 2020-07-06 08:18:37,207 :: run.py :: INFO :: Running the run.py script
2) 2020-07-06 08:18:37,940 :: run.py :: INFO :: Number of total scans in IO instance is: 199
3) 2020-07-06 08:18:37,940 :: run.py :: INFO :: Running the following scans in a chained manner,one at at time:
4) 2020-07-06 08:18:37,943 :: run.py :: INFO :: Discovery Scan: 10.1.1.1
5) 2020-07-06 08:18:37,945 :: run.py :: INFO :: Discovery Scan: 10.2.2.2
6) 2020-07-06 08:18:37,950 :: run.py :: INFO :: List of scan ID's that will run in order, one at at time: [5224, 5223]
7) 2020-07-06 08:18:40,904 :: run.py :: INFO :: previous_scan_history_list BEFORE historical run check is: []
8) 2020-07-06 08:18:41,756 :: run.py :: INFO :: NOTE: Null scan history
9) 2020-07-06 08:18:41,760 :: run.py :: INFO :: Running scan for ID 5224 for the first time
10) 2020-07-06 08:18:41,763 :: run.py :: INFO :: Function check_scan_status has been called
11) 2020-07-06 08:18:43,150 :: run.py :: INFO :: Scan ID 5224 still running
12) 2020-07-06 08:18:43,150 :: run.py :: INFO :: Scan ID 5224 still running
13) 2020-07-06 08:19:04,240 :: run.py :: INFO :: Running the run.py script
14) 2020-07-06 08:19:04,947 :: run.py :: INFO :: Number of total scans in IO instance is: 199
15) 2020-07-06 08:19:04,947 :: run.py :: INFO :: Running the following scans in a chained manner,one at at time:
16) 2020-07-06 08:19:04,948 :: run.py :: INFO :: Discovery Scan: 10.1.1.1
17) 2020-07-06 08:19:04,950 :: run.py :: INFO :: Discovery Scan: 10.2.2.2
18) 2020-07-06 08:19:04,950 :: run.py :: INFO :: List of scan ID's that will run in order, one at at time: [5224, 5223]
19) 2020-07-06 08:19:08,956 :: run.py :: INFO :: History status for scan_id 5224 is:pending
20) 2020-07-06 08:19:08,957 :: run.py :: INFO :: previous_scan_history_list BEFORE historical run check is: ['pending']
21) 2020-07-06 08:19:08,958 :: run.py :: INFO :: Scan for ID 5224 is pending, already running or a second instantiation
of this script is trying to run before the previous one finished
22) 2020-07-06 08:19:08,959 :: run.py :: INFO :: previous_scan_history_list AFTER historical run check is: ['pending']
23) 2020-07-06 08:19:08,960 :: run.py :: INFO :: Exiting....

```

Figure 11. Demonstration of clobber protection by running a second instantiation of `run.py` while the first instantiation is still executing

On lines (1) through (12) `run.py` was executed via the command `./chain.py --action run` based upon the log message (note the `"run.py"` string in each log entry). The prior history status for these two scans was, as shown on lines (8) and (9), `[]` or `"Null"`. This means these scans had not run previously and had no history in the IO instance backend. Tenable IO keeps a scan's history for as long as that scan is defined (or in other words, until it's deleted from the IO instance).

Line (13) shows the command to execute `run.py` was issued again from another shell (or cron job) that caused `run.py` to execute while the first instantiation was still running. Then `run.py` detected that the first scan (Discovery Scan: 10.1.1.1) with scan ID 5224 from the first invocation of `run.py` was still pending on line (19).

The second instantiation of `run.py` then checked the status of all the scans that were launched sequentially in the first `run.py` execution on line (20). The result was `"['pending']"`, as scan ID 5224 was still queued to run, and scan ID 5223 was waiting to be launched when 5224 finished. Ignore the fact that scan ID 5224 was queued to run before 5223, it's not relevant that the scan ID's run in numerical order, only that they run one at time and in the order as defined in the Python list on line (6).

Line (21) indicates the second instantiation of `run.py` detected the scan for ID 5224 was still pending, running or a second instantiation. The first and third of those three possibilities was true, and hence the second instantiation of `run.py` terminated itself at that point as indicated on line (23).

4.6. Processing Quirks in `chain.py`

There are some processing quirks to using `chains.py` to delete and create scans while updating `scans.ini` between executions.

Assume `scans.ini` is configured to create scans for 10.1.1.1 and 10.2.2.2 and place them in the "DataCenter Scans" folder with scans names reflecting their IP address (e.g. Discovery Scan: 10.1.1.1). Then `./chain.py --action create` is executed to create the scans in IO. Next `scans.ini` is updated to create scans 10.3.3.3 and 10.4.4.4 and place them in "DataCenter Scans" (replacing 10.1.1.1 and 10.2.2.2. in the config file with 10.3.3.3 and 10.4.4.4). Again, `./chain.py --action create` is executed to create the scans in IO. Finally, `./chain.py --action delete` is executed to delete the scans.

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Which scans get deleted? Only 10.3.3.3 and 10.4.4.4, as the `delete.py` script reads the scan names to be deleted from the `scans.ini` file, looks up their scan ID in the `scans_dict` dictionary, and then uses the scan API endpoint to delete them. So what's left in the "DataCenter Scans" folder are the scans for 10.1.1.1 and 10.2.2.2.

Why was `chain.py` implemented this way? The reasoning is that there might be scans in the "DataCenter Scans" folder that were not created by the `chain.py` script. Deleting all scans in the "DataCenter Scans" folder could result in some scans having to be recreated and the history of those scans being purged from the IO instance.

To prevent this quirk from occurring, delete scans before modifying `scans.ini` and creating scans with different names, if applicable. Worst case, if a number of scans were created after iterations of modifying `scans.ini` and running `chain.py`, go into the IO web UI and select the scans to delete and move them to the trash. Then empty the trash. This deletes the scan resource and its ID from the IO backend (which means if any of these scripts are recreated, their history will be NULL and their scan ID will almost surely change, which will be reflected in the `log.chain` log file).

If this quirk wasn't a concern and the application user simply wanted every scan to be deleted from a specific folder every time the `delete.py` script was executed, `delete.py` could be modified to do so. Simply obtain a list of all scans from the API scans endpoint to obtain the scan ID's. Then query the scan details for each scan based on the Scan ID from the API scans endpoint. Next, parse out the scans IDs for all scans that live in the folder "DataCenter Scans", for example, and place them in a Python list (or tuple). Each scan may then be deleted based on its scan ID from IO, one at time in a loop, using the API scans endpoint.

5. Conclusion

With `chain.py` and its associated actions scripts (`create.py`, `delete.py`, `run.py`, and `info.py`) efficient scan creation, deletion and chained running/executing can be accomplished using Tenable IO. Having a library of scans defined in `scans.ini` for specific folder, scanner, and policy combinations would allow the application to automate all scan creations. Some scans could be `ON_DEMAND`, such as the chained scans that would run from a scheduled (cron) job. Other scans could be scheduled to run directly from IO itself and not be chained. Just a few script modifications would be required to pass the additional parameters to the scan creation function. Remember, `chain.py`'s modular action scripts `create.py`, `delete.py`, and `run.py` operate independently from each other. Creating a script using `chain.py` is not coupled to running or deleting chained scans.

It bears acknowledging that the Tenable-supported `PyTenable` library provides a framework to enable scan creation/deletion/execution automation as well, with just a little bit of middleware code written to tie various methods together. However, `PyTenable` does not support chained scanning and clobber prevention like `chain.py` does. Further, utilizing `PyTenable` would abstract much of the programmatic interaction with the IO API endpoints. This would be counter to gaining as much experience with Python scripting and Tenable IO API automation as possible, which is the point of this paper.

A link to the GitHub repo containing all the code mentioned above is located at the end of the Appendix. A few assumptions and required steps to configure the application are listed below, as well as in `README.md` in the repo:

- The code was written on and for both Windows and Linux using Python 3.7.4.
- Make sure all necessary modules and libraries are installed, including the `dotenv` library (with all other modules required being resident in the standard Python library).
- Create and populate the `.env` file in the "chain" subdirectory of the cloned/forked repo with the API keys. The contents of the `.env` file is shown below, with stub values for the API keys there for replacement.

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```
ACCESS_KEY=<access_key>  
SECRET_KEY=<secret_key>
```

Replace <access_key> and <security_key> with the corresponding user API keys from IO. Then chmod the file 600 (chmod 600 ./env) if using Linux. For Windows, set the repo file and directory permissions and ownership as required to protect the .env file at a minimum.

- Run "./chain --action info" and use the information in log.info in the logs subdirectory to configure scans.ini. As many scans can be defined as desired, but there needs to be at least two defined.
- Run chain.py either manually or from cron, or both, as necessary.

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Appendix

Scans.ini Config File

```
#####
#
#### Config file for scan creation
#
#### See: https://wiki.python.org/moin/ConfigParserExamples
####      https://docs.python.org/2/library/configparser.html
#
#####
#
### Fields described in order below.
###
### Run the command './chain.py -a info' to get a listing of folder names,
### scanner names, policy names, and tag names.
###
### These all print out in the form of dictionaries, with the ID or UUID as the
### value and the name as the key. Use the key (or name) of these below in your
### scan definition. This of course assumes that folder, scanners, policies and
### tags have already been created in IO. Examples are below you can use as
### templates.
#
# - folder name
# - scanner or scanner group name
# - scan policy name
# - launch frequency (should always be ON_DEMAND) as chain.py runs manually
#   or via a cron job
# - comma-delimited list of email addresses to send scan completion emails
#   to (optional)
# - scan description (optional)
# - scan name (must be unique)
# - comma-delimited list of scan targets (can use IP's, CIDR subnet
#   notation, or both)
# - One or more tag name:value pairs, comma-delimited. If tag name is
#   "Office" and the tag value is "London", the pair is "Office:London". For
#   multiple tag name:value pairs, the format would be:
#
#   Office:London,Office:Berlin,Servers:Mail
#
# There should be no spaces before/after the colons and commas, however
# the code will remove any that are added by mistake. Spaces in the tag
# name or value is OK. For example, these tag name:value pairs are
# legitimate:
#
#   Office:New York,Windows Hosts:Mail Servers
### NOTE: At least one of scan_targets and tag_target_pair must be declared, or both.
#####
#
```

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```

#
# Example 1:
#   [Scan1]
#   folder_name = Adhoc Scans
#   scanner_name = Datacenter Scanner Group
#   policy_name = Host Discovery Scan
#   launch = ON_DEMAND
#   email = infosec@acme.com
#   description = Scan created by the chain.py script
#   scan_name = Discovery Scan: 10.1.1.1 and 10.2.2.2
#   scan_targets = 10.1.1.1,10.2.2.2
#   tag_target_pair =
#
# Example 2:
#   [Scan2]
#   folder_name = Adhoc Scans
#   scanner_name = LONSCANNER12
#   policy_name = Host Discovery Scan
#   launch = ON_DEMAND
#   email = infosec@acme.com
#   description = Scan created by the chain.py script
#   scan_name = Discovery Scan: London Office
#   scan_targets =
#   tag_target_pair = Office:London
#
# Example 3:
#   [Scan3]
#   folder_name = Adhoc Scans
#   scanner_name = LONSCANNER12
#   policy_name = Internal Safe Scan
#   launch = ON_DEMAND
#   email = infosec@acme.com,server_team@acme.com
#   description = Scan created by the chain.py script
#   scan_name = Vuln Scan: London and Berlin Offices, and 10.1.1.1/32
#   scan_targets = 10.1.1.1/32
#   tag_target_pair = Office:London,Office:Berlin
#####
#

[Scan1]

[Scan2]

#[Scan3]

```

Logging.ini Config File

```
#####
### Logging configuration file
#####
[loggers]
keys=root,info,create,delete,run

[handlers]
keys=stream_handler,file_handler,rotating_file_handler

[formatters]
keys=formatter_stream,formatter_file_info,formatter_file_create-delete-run

[logger_root]
level=INFO
handlers=stream_handler

[logger_info]
level=INFO
handlers=file_handler
propagate=0
qualname=info

[logger_create]
level=INFO
handlers=rotating_file_handler
propagate=0
qualname=create

[logger_delete]
level=INFO
handlers=rotating_file_handler
propagate=0
qualname=delete

[logger_run]
level=INFO
handlers=rotating_file_handler
propagate=0
qualname=run

[handler_stream_handler]
class=StreamHandler
level=INFO
formatter=formatter_stream
args=(sys.stdout,)

[handler_file_handler]
class=FileHandler
level=INFO
formatter=formatter_file_info
# write to log.info in write mode. Note that log gets cleared when
```

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```
# create/run/delete scripts execute and log to log.chain.  
# This is fine as the info data is mutable.  
args=( './logs/log.info', 'w'  
  
[handler_rotating_file_handler]  
class=handlers.RotatingFileHandler  
level=INFO  
formatter=formatter_file_create-delete-run  
# write to log.chain in append mode, maxBytes=100000, backupCount=5,  
# encoding=None delay=False  
args=( './logs/log.chain', 'a', 100000, 5, None, False)  
  
[formatter_formatter_stream]  
# Add a line return so STDOUT is more easily read  
format=  
%(message)s  
  
[formatter_formatter_file_info]  
format=%(asctime)s :: %(name)s.py :: %(levelname)-4s :: %(message)s  
  
[formatter_formatter_file_create-delete-run]  
format=%(asctime)s :: %(name)s.py :: %(levelname)-4s :: %(message)s
```

GitHub Repo with Chain.py Application Source Code

<https://github.com/jeff-a-holland/Chain.py-Tenable-IO-Chained-Scanning-Application>



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