Second Report - Traffic Analysis

Project developed within the scope of ***Security in Network Communication*** course, at *University of Aveiro* under the orientation of professor *Paulo Salvador*.

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Tools

Sentinel Analysis

For this project a traffic analysis tool called **Sentinel**, complete with a *Command Line Interface* (CLI) was developed in order to streamline the analysis of traffic.

At the moment of this report, Sentinel allows highly specific and precise metric measurements, such as:

- Search for possible **exfiltration**.
- Search for possible **botnet and C&C** communication.
- **Volume** of connection **per destination**.
- **Hourly** connection **volume**.

Architecture

This tool was developed in **Python** version 3.11.2 and **Poetry**, which is a tool for dependency management and packaging. It allows for declaration of libraries in a project and it will manage (install/update) this dependencies automatically. Poetry offers a lockfile to ensure repeatable installs, and can build a project for distribution.

Installation

Sentinel is publicly available at PyPi and it is recommended that the installation is done using Pipx, however, it is **NOT** absolutely necessary.

```
pipx install sentinel-analysis
```

Running

After installing, the tool can be called from any terminal session with the `sentinel` command.

```
$ sentinel -h
usage: sentinel [-h] --data DATA -gi GI -gin GIN [-dx DATAEXFILTRATION] [-
bn BOTNET] [-cv] [-td] [-q] [-p]

Traffic analysis tool.

options:
  -h, --help            show this help message and exit
  --data DATA           Path to datafile to analyze
  -gi GI                Geolocation IP database
  -gin GIN              Geolocation IP database with nameserver
  -dx DATAEXFILTRATION, --dataExfiltration DATAEXFILTRATION
                        Threshold percentage for outliers in
upload/download byte amount. Example '-dx 90' will return the top 10%
  -bn BOTNET, --botnet BOTNET
                        Detecting possible botnet communication in
specified networks, or all networks. Example '-bn 192.168.1.0/24' will
search P2P communication within that network
  -cv, --countryVolume  Measures the connection volume per country
  -td, --trafficDistribution
                        Generates a graph illustrating the hourly
distribution of the volume of connections during a day
  -q, --quiet           Suppress stdout
  -o, --outfileMd       Export to markdown file
```

Options

There are multiple options for processing, and each one is only executed if explicitly called. There are however, **three** mandatory parameters that **must be provided**.

- **data** - *Required* - Path to the *paquet* file containing the traffic capture to be analyses.
- **gi** - *Required* - Path to the *dat* file containing the IP geolocation database.
- **gin** - *Required* - PAth to the *dat* file containing the IP geolocation of nameservers database.

Some **anomalous** behavior can be searched for by using the following options:

- **dx** - By specifying an integer between 0 and 100, the user is filtering for flows above the download over upload percentile of all the connections in the session.
- **bn** - The user can specify in which subnet to look for P2P communication, which can indicate the presence of a botnet. If 0.0.0.0/0 is used, it will search in all subnets found.

For getting a general overview of the traffic, two commands are also available:

- **cv** - Measures the number of connection per country of destination.
- **td** - Measures the traffic hourly volume distribution.

Traffic Analysis

Now we will perform an overall analysis of a traffic capture file with all of the options selected and analyze the data recovered, as well as inspecting how the calculations for each of the metric in performed.

The code presented next demonstrates a comprehensive set of SIEM rules specifically tailored to detect and combat two major security threats: data exfiltration and botnets. These rules have been meticulously crafted to analyze network traffic patterns, monitor system logs, and identify anomalous behaviors indicative of data exfiltration attempts. By leveraging these SIEM rules, organizations can effectively safeguard their sensitive data from unauthorized exfiltration and combat the growing menace of botnets, ensuring a resilient and secure computing environment.

Sentinel will be called with the following manner:

```
sentinel --data ../dataset4/data4.parquet -gi ../GeoIP_DBs/GeoIP.dat -gin
../GeoIP_DBs/GeoIPASNum.dat -cv -td -dx 90 -bn 192.168.104.0/24 -o
```

Note that the only option not selected is `--quiet` as it would suppress all *stdout*.

Note also that the flag `-o` is selected, what this does is creates a markdown file at the end of the analysis with all of the generated data. This can be useful for posterior archiving.

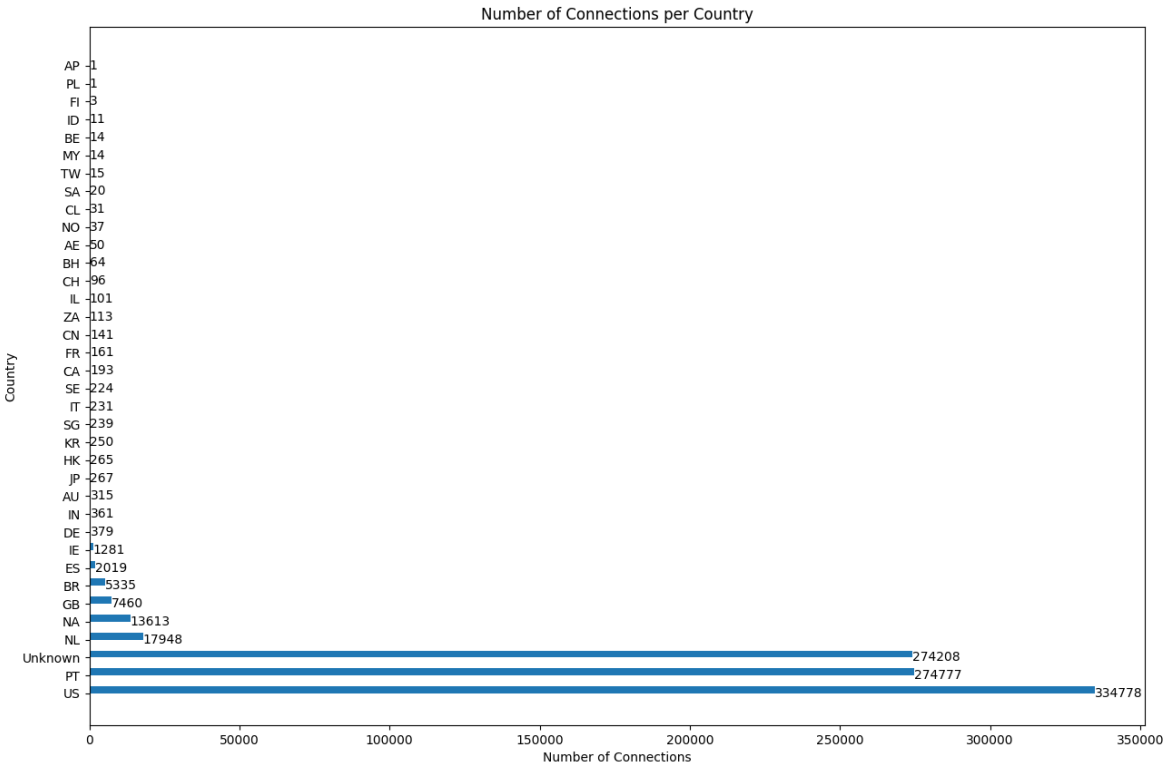
Country connection volume

The objective of this measurement is simply to understand **which country are more targeted as connection destinations** and which country has **downloaded more data**. When executed, it produces the following output at the console,

```
[!] Calculate the country of origin of the destination IPs and the
connection volume for each country. Generating a PNG with the bar graph.

         dst_ip   down_bytes
          count          sum
country
US       334778  39621538092
PT       274777  26423827803
         274208  15754974807
NL        17948   1728071763
NA        13613   1310943454
GB         7460    717314962
BR         5335    512859364
ES         2019    196188082
IE         1281    118558649
...
```

and generates the following graph as a PNG image.



Code

```
def countryVolume():
    ...
    # Analyses of destination countries connection volume
    countries = data
    countries["country"] = countries["dst_ip"].apply(
        lambda ip: gi.country_code_by_addr(ip)
    )

    # Associates each country with it's number of connection and the total
    #  data downloads by it. For normal flows they should be directly
proportional
    volume = countries.groupby(["country"]).agg(
        {"dst_ip": ["count"], "down_bytes": ["sum"]}
    )

    # Sorting the DataFrame by dst_ip column in descending order
    volume = volume.sort_values(("dst_ip", "count"), ascending=False)

    printq(volume)
    ...
```

Hourly traffic distribution

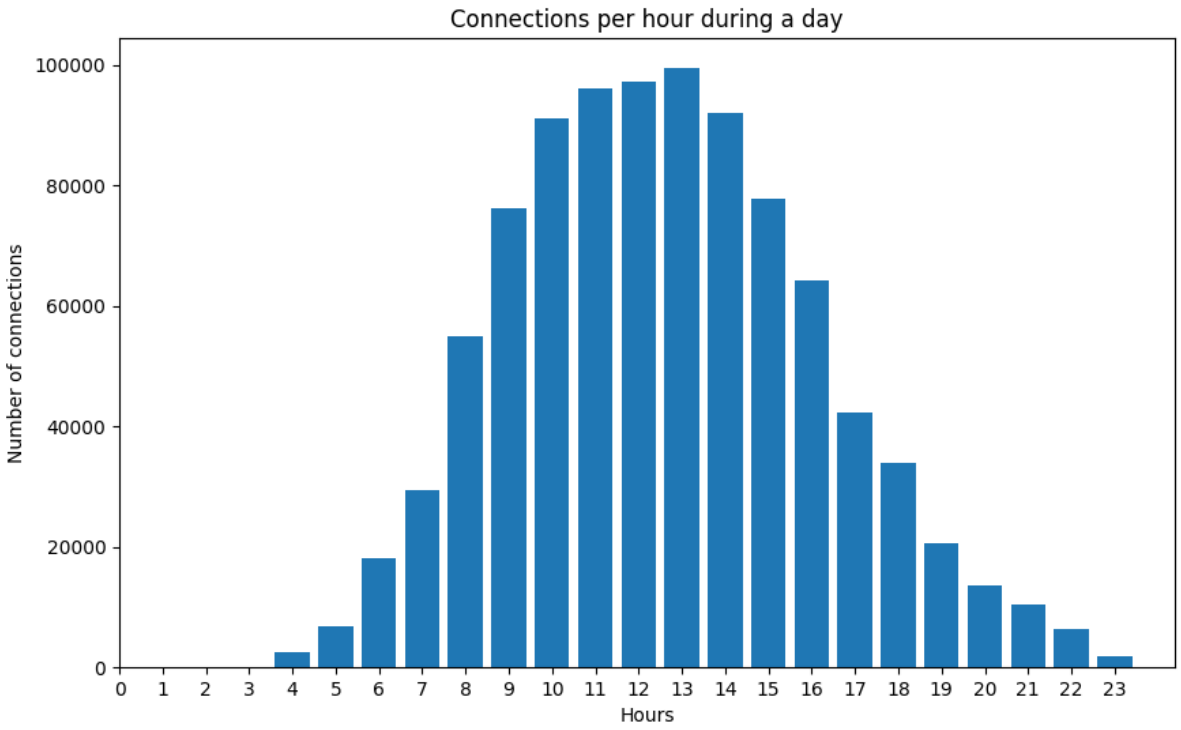
The objective of this measurement is to understand the **time of the day** in which there is a **higher volume of connections**.

hen executed, it produces the following output at the console,

```
[!] Distribution of connection volume during the day.

hour
4      2439
5      6845
6     18117
7     29313
8     55071
9     76117
10    91050
11    96017
12    97340
13    99522
14    92054
15    77853
16    64196
...
```

and generates the following graph as a PNG image.



Code

```
def trafficDistribution():
    ...
    traffic = data
    traffic["hour"] = pd.to_datetime(traffic["timestamp"] / 100.0,
unit="s").dt.hour
    hourly = traffic["hour"].value_counts().sort_index()
    fig, ax = plt.subplots(figsize=(10, 6))
    ax.bar(hourly.index, hourly.values)
    ax.set_xlabel("Hours")
    ax.set_ylabel("Number of connections")
    ax.set_title("Connections per hour during a day")
    ax.set_xticks(range(24))

    filepath = "connectionsxhour"
    fig.savefig(fname=filepath)

    printq(hourly)
    ...
```

Data exfiltration

For data exfiltration analysis we focused on the fact that although the amount of downloaded data is usually larger that the uploaded data, if the service is the same for all of the clients during the session, the ratio of this two values should (if normal behaviour is considered) be similar for all the clients.

If a particular client demonstrates a particular large ratio of downloads over uploads, this might indicate that it is extracting large amount of data, possibly with malicious intent.

This is the generated output at the console,

```
[!] IPs above the 90 percentile of the downloads over uploads in this
session.

              src_ip  down_bytes  up_bytes      ratio
110  192.168.104.200    14778895   1415961  10.437360
116  192.168.104.206    53495023   5195056  10.297295
64   192.168.104.159   324226107  32356733  10.020360
144   192.168.104.44    98180581   9977423   9.840274
131   192.168.104.31   259857369  26500446   9.805773
174   192.168.104.74   385717683  39392101   9.791752
184   192.168.104.84   193031076  19880947   9.709350
90   192.168.104.182   609527835  63089225   9.661362
...
```

Code

```
def dataExfiltration(percentage):
    percentage = 1 - (percentage / 100)

    # Calculate the total downloaded and uploaded bytes per IP
    ratios = data.groupby(["src_ip"], as_index=False)[["down_bytes",
"up_bytes"]].sum()

    # Calculate the ratio between downloaded and uploaded bytes
    ratios["ratio"] = ratios["down_bytes"] / ratios["up_bytes"]

    # Sort by ratio
    ratios = ratios.sort_values(["ratio"], ascending=False)

    # Top outliers base on percentage
    outliers = ratios.head(int(len(ratios) * percentage))

    printq(outliers)
```

Botnet communication

It is not usual for devices within the same network in a corporate environment to engage in *peer-to-peer* communication, if soo, this may indicate that botnets, C&C or horizontal traversal may be taking place within the network.

This is the generated output at the console when the botnet detection algorithm is executed,

```
[!] Flows between internal host to common destinations in the same subnet
(192.168.104.0/24), may indicate the existence of a internal botnet.

            dst_ip                                                src_ip
frequency
1  192.168.104.224  [192.168.104.82, 192.168.104.63, 192.168.104.2...
0.008091
3  192.168.104.231  [192.168.104.82, 192.168.104.63, 192.168.104.2...
0.007870
2  192.168.104.230  [192.168.104.82, 192.168.104.63, 192.168.104.2...
0.005934
5  192.168.104.234  [192.168.104.82, 192.168.104.63, 192.168.104.2...
0.005923
0  192.168.104.222  [192.168.104.82, 192.168.104.63, 192.168.104.2...
0.005816
4  192.168.104.232  [192.168.104.82, 192.168.104.63, 192.168.104.2...
0.005724
```

Code

```
def botnet(subnet):
    subnet = ipaddress.IPv4Network(subnet)

    # Filter to src_ip for desired subnet
    same_subnet = data
    same_subnet["src_ip"] = same_subnet["src_ip"].astype(str)

    # Filter to src_ip and dst_ip in the same desired subnet
    same_subnet = same_subnet.loc[
        (data["src_ip"].apply(lambda x: ipaddress.IPv4Address(x) in
subnet))
        & (data["dst_ip"].apply(lambda x: ipaddress.IPv4Address(x) in
subnet))
    ]

    # Associates each dst_ip with a set of IPs and a set of timestamps
    same_subnet = same_subnet.groupby(["dst_ip"], as_index=False).agg(
        {"src_ip": list, "timestamp": list}
    )

    # Calculate the frequency of the communications
    def frequency(comms, period):
        return len(comms) / (period[-1] - period[0])

    same_subnet["frequency"] = same_subnet.apply(
        lambda x: frequency(x.src_ip, x.timestamp), axis=1
    )

    # Clean non relevant series
    same_subnet = same_subnet.drop(["timestamp"], axis=1)

    # Clean repeated IPs
    same_subnet["src_ip"] = same_subnet["src_ip"].apply(lambda x:
list(set(x)))

    # Order
    same_subnet = same_subnet.sort_values(["frequency"], ascending=False)

    printq(same_subnet)
    ...
```

Conclusion anf final thoughts

In summary, the project report focuses on the development of a software solution capable of analyzing traffic captures to detect data exfiltration and botnet communication. The software utilizes advanced algorithms to scan network traffic, identify patterns associated with these threats, and promptly alert security teams. By addressing these critical security concerns, the project offers an effective means of safeguarding sensitive data and proactively mitigating potential risks.

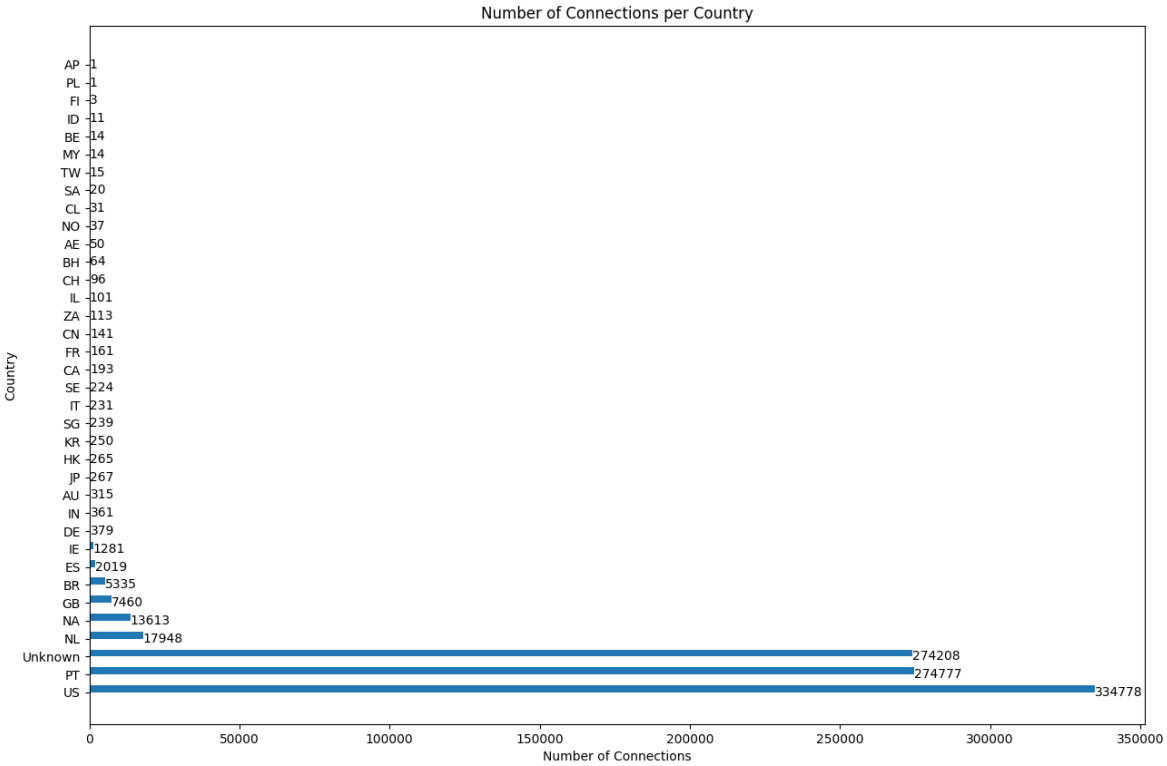
As an additional feature, **Sentinel is also capable of automatically generating markdown files with the data generated**. The content of this test execution analyzed in this report was converted to PDF and appended to this report.

Sentinel traffic report

This report was automatically generated at **2023-06-25 21:01:06.788283** by the **Sentinel** service.

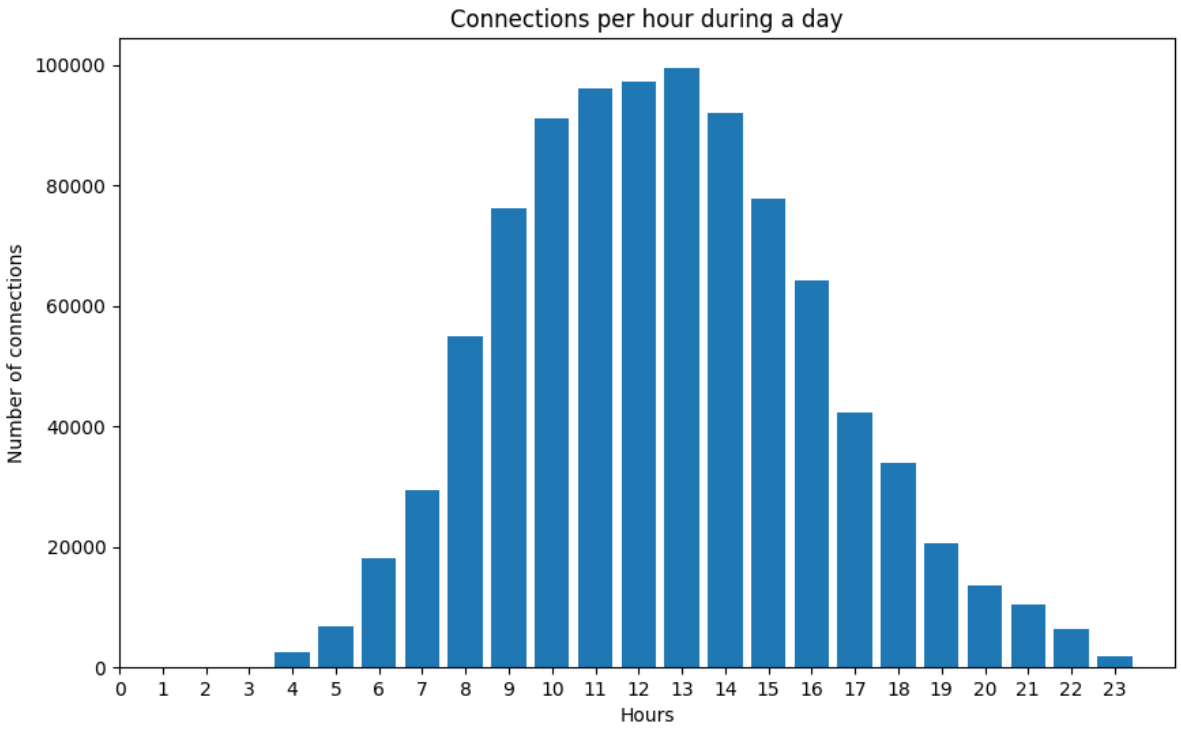
Connection volume by country

The correlation between connection volume and country of destination can be viewed in the graphic bellow.



Connection volume per hour

This graph ilustrates the number of connection per hour during a day



Alerts Detected

Alert - nº 0

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.200	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
14778895	1415961

Alert - nº 1

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.206	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
53495023	5195056

Alert - nº 2

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.159	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
324226107	32356733

Alert - nº 3

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.44	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
98180581	9977423

Alert - nº 4

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.31	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
259857369	26500446

Alert - nº 5

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.74	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
385717683	39392101

Alert - nº 6

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.84	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
193031076	19880947

Alert - nº 7

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.182	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
609527835	63089225

Alert - nº 8

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.61	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
180286154	18757183

Alert - nº 9

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.48	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
119473876	12433702

Alert - nº 10

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.196	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
171209567	17843063

Alert - nº 11

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.80	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
451710050	47183733

Alert - nº 12

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.39	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
342444522	35770433

Alert - nº 13

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.86	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
454187871	47468009

Alert - nº 14

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.15	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
270917065	28330074

Alert - nº 15

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.96	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
410205007	42922223

Alert - nº 16

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.210	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
227739990	23856747

Alert - nº 17

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.14	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
493350116	51688074

Alert - nº 18

Traffic generated by a possible **exfiltration**.

Details

IP Address	Origin	DNS name
192.168.104.98	Unknown	Unknown

Flow shows a ratio of downloaded bytes over uploaded bytes above the **90 percentile** for downloads over uploads in this session.

Downloaded bytes	Uploaded bytes
291560827	30572242

Alert - nº 19

Traffic generated by a possible **botnet**.

Details

IP Address	Origin	DNS name
192.168.104.224	Unknown	Unknown

Flows between internal host to common destinations in the same subnet, may indicate the existance of a internal botnet.

Subnet	Rate of communications (per second)	Number of peers in the network
192.168.104.0/24	0.0081	199

Alert - nº 20

Traffic generated by a possible **botnet**.

Details

IP Address	Origin	DNS name
192.168.104.231	Unknown	Unknown

Flows between internal host to common destinations in the same subnet, may indicate the existance of a internal botnet.

Subnet	Rate of communications (per second)	Number of peers in the network
192.168.104.0/24	0.0079	199

Alert - nº 21

Traffic generated by a possible **botnet**.

Details

IP Address	Origin	DNS name
192.168.104.230	Unknown	Unknown

Flows between internal host to common destinations in the same subnet, may indicate the existance of a internal botnet.

Subnet	Rate of communications (per second)	Number of peers in the network
192.168.104.0/24	0.0059	199

Alert - nº 22

Traffic generated by a possible **botnet**.

Details

IP Address	Origin	DNS name
192.168.104.234	Unknown	Unknown

Flows between internal host to common destinations in the same subnet, may indicate the existance of a internal botnet.

Subnet	Rate of communications (per second)	Number of peers in the network
192.168.104.0/24	0.0059	199

Alert - nº 23

Traffic generated by a possible **botnet**.

Details

IP Address	Origin	DNS name
192.168.104.222	Unknown	Unknown

Flows between internal host to common destinations in the same subnet, may indicate the existance of a internal botnet.

Subnet	Rate of communications (per second)	Number of peers in the network
192.168.104.0/24	0.0058	199

Alert - nº 24

Traffic generated by a possible **botnet**.

Details

IP Address	Origin	DNS name
192.168.104.232	Unknown	Unknown

Flows between internal host to common destinations in the same subnet, may indicate the existance of a internal botnet.

Subnet	Rate of communications (per second)	Number of peers in the network
192.168.104.0/24	0.0057	199