SC18 Network Research Exhibition: Publishable Submission

Automated Tensor Analysis for Deep Network Visibility

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Abstract

We will demonstrate a usable and scalable network security workflow based on ENSIGN, a high-performance data analytics tool based on tensor decompositions, that can analyze huge volumes of network data and provide actionable insights into the network. The enhanced workflow provided by ENSIGN assists in identifying actors who craft their actions to subvert signature-based detection methods and automates much of the labor intensive forensic process of connecting isolated incidents into a coherent attack profile. This approach complements traditional workflows that focus on highlighting individual suspicious activities.

ENSIGN uses advanced tensor decomposition algorithms to decompose network data with multiple metadata attributes into components that capture multimodal network patterns and behaviors. This enables easier identification of anomalies and suspicious patterns and simpler analysis of large, complex patterns. We will apply ENSIGN over the network security logs available through the SCinet network stack to provide deep visibility into network behaviors/trends including, but not limited to, port scans, network mapping attempts, scans targeting specific services, SSH brute forcing, NTP amplification attacks, DNS amplification DDoS attacks, and obfuscated data exfiltration using DNS and ICMP tunneling.

Goals

At SC15 and SC16 NRE, we successfully demonstrated ENSIGN [1] on offline network data feeds provided by R-Scope network appliances [2]. Specifically, we demonstrated how ENSIGN separated normal and off-normal traffic patterns in a way that led to the discovery of indicators consistent with, and in some cases prior to, human analyst discovery (e.g., a distributed takeover attack on a vendor booth and a suspected ICMP-based data exfiltration) [3]. At SC17 NRE, we introduced an initial version of a streaming analysis capability to improve the timeliness of previously demonstrated offline analysis of network metadata [4].

At SC18 NRE, our overall objective is to demonstrate the effectiveness of ENSIGN in an operational cyber security setup to extract anomalous patterns of network traffic, detect suspicious behaviors, and provide actionable insights into the network. With mature development of ENSIGN and associated tools over the last year, our specific research objectives at SC18 NRE are the following:

- Demonstrate the use of **user-friendly cyber utility tools** built on top of ENSIGN to report suspicious behaviors and attacks disrupting the operation and performance of SCinet.
- Demonstrate **advanced streaming analysis** capability in ENSIGN to improve the timeliness of detection of malicious and anomalous behaviors.
- Demonstrate and validate the capability of ENSIGN to provide deep network visibility by **analyzing diverse network security logs** that are available from the SCinet network security stack.
- Optionally, demonstrate the capability of ENSIGN for **automated clustering and classification** of patterns-of-activity in SCinet network data.
- Optionally, demonstrate the results of **advanced anomaly detection** techniques in ENSIGN to identify and isolate anomalous network behaviors/patterns.

Planned Experiments at SCinet

We divide the experiments and activities that we plan to do at SCinet into two major categories, namely, operational and research. The operational activities will be closely tied to the NOC security activities. The research activities will be optional and will be done based on the availability of personnel and network resources that are free after being used for the operational activities.

Operational Activities

1. Static network data analysis

We will use highly-scalable static tensor analysis methods to analyze large batches of offline network data collected by R-Scope and stored in the form of Bro network logs. We have multiple tensor decomposition methods that are suited for analyzing network data. These methods have varied degrees of tradeoff between "interpretability" of the tensor analysis output and time needed to complete the tensor analysis. We will run two of these static tensor methods that we have extensively tested, in parallel, to provide more robust analysis of the network data.

Expected outcome:

- Separate normal and off-normal traffic patterns
- Discovery of indicators related to suspicious traffic patterns (port scans, network mapping attempts, scans targeting specific services, SSH brute forcing, NTP amplification attacks, DNS amplification DDoS attacks, and more)
- Discovery of indicators of obfuscated behaviors with potential malicious intent (data exfiltration using DNS, ICMP tunneling, and more)

2. Streaming network data analysis

We will use advanced streaming tensor decompositions [5] (a prototype of which we tested at SC17 SCinet) to analyze small batches of network logs (as opposed to waiting for accumulation of large batches of network logs) as soon as they are made available by R-Scope. We will start with "hourly" batches for the streaming analysis and we will dynamically adjust the batch size as needed during the experiments.

Expected outcome:

- Identify new network patterns, if any, that appear in the new data stream
- Identify how already-seen patterns have changed or evolved after the new data stream
- Discovery of indicators of suspicious traffic patterns and obfuscated behaviors close to their onset

3. Using and testing cyber utility tools

We have developed cyber utility tools to operate on top of the ENSIGN tensor analysis engine with the primary objective of facilitating the usability of ENSIGN. Specifically, we have developed utility tools to query, process, and present the mathematically sophisticated raw tensor analysis output in a network analyst friendly format. We have also developed tools that will parse the tensor output to check for the occurence of specific (most common) network patterns such as beaconing, network mapping, and port scanning.

We will use, test, and dynamically enhance these tools as needed by running them on the output generated by the static and streaming tensor decompositions (described above).

4. Analyzing a variety of network logs

We have extensively used the Bro `conn.log` and `dns.log` in our experiments at past SCinets. This year, in addition to `conn.log` and `dns.log`, we will be including Bro `files.log`, `http.log`, and `ssl.log` in our tensor-based network analysis. In addition to individually using these logs for analysis, we will also be trying to correlate activities and patterns across all these logs. This will improve the process of connecting isolated (but related) incidents spread across different logs.

Research activities

1. Automated clustering and classification

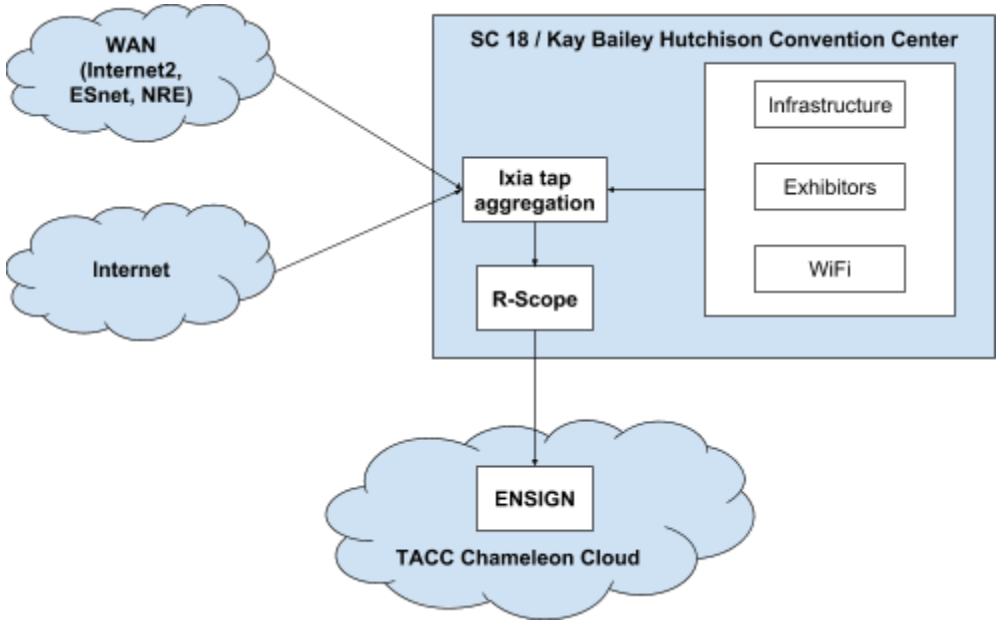
As an optional research activity, we plan to exercise our recently developed technique for automated clustering and classification of the tensor analysis output based on topic modeling [6]. This automation technique is expected to substantially increase the usability of the tool by reducing the cognitive load of the analysts. This activity needs computational resources that may contend with the resources need for the operational activities and hence it is planned as an optional activity.

2. Advanced anomaly detection

As a second optional research activity, we plan, in the context of effective cyber analysis, to experiment with advanced anomaly detection approaches around ENSIGN for which we have a working prototype implementation. These methods are aimed at easily separating off-normal traffic patterns from normal traffic patterns and also effectively extracting off-normal traffic patterns with "very low strength of presence" without them being dispersed within high volume traffic patterns or dropped from the tensor analysis output.

Network Resources

We will install and operate ENSIGN from a compute node in the TACC Chameleon Cloud. The compute node will have an Intel Haswell processor with 48 cores and 128 GB RAM. We will be installing and running Ubuntu 16.04 OS on the compute node. The primary source that will feed ENSIGN with the network logs from SCinet network security stack will be R-Scope. R-Scope will provide Zeek (Bro) logs to the ENSIGN node through SCP file transfer. The diagram describing the network workflow of ENSIGN is shown below.



References

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