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Performance analysis of automated attack graph generation software

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

PERFORMANCE ANALYSIS OF AUTOMATED ATTACK GRAPH GENERATION SOFTWARE

by

James J. Cullum

December 2006

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The current generation of network vulnerability detection software uses databases of known vulnerabilities and scans target networks for these weaknesses. The results can be voluminous and difficult to assess. Thus, the success of this technology has created a need for software to aid in network vulnerability analysis. Although research has shown the effectiveness of automated attack graph generation tools in displaying potential attack paths in a network, research involving the performance of these tools has been limited. Using empirical testing, we have collected quantitative data using CAULDRON, an attack graph generation tool developed at George Mason University, on a collection of simulated networks. By defining our model to include sets of nodes, which allow connectivity from all nodes to all nodes in the set; the number of nodes present in each set, the number of connections between sets; and the number of vulnerabilities per node as our variables, we are able to observe the performance impact on CAULDRON of connectivity and the increased presence of vulnerabilities in our networks. The effect of these variables on processing time and memory usage is presented and can be used as a metric to assess the scalability of this tool within various customer environments.

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PERFORMANCE ANALYSIS OF AUTOMATED ATTACK GRAPH GENERATION SOFTWARE

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requirements for the degree of

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The current generation of network vulnerability detection software uses databases of known vulnerabilities and scans target networks for these weaknesses. The results can be voluminous and difficult to assess. Thus, the success of this technology has created a need for software to aid in network vulnerability analysis. Although research has shown the effectiveness of automated attack graph generation tools in displaying potential attack paths in a network, research involving the performance of these tools has been limited. Using empirical testing, we have collected quantitative data using CAULDRON, an attack graph generation tool developed at George Mason University, on a collection of simulated networks. By defining our model to include sets of nodes, which allow connectivity from all nodes to all nodes in the set; the number of nodes present in each set, the number of connections between sets; and the number of vulnerabilities per node as our variables, we are able to observe the performance impact on CAULDRON of connectivity and the increased presence of vulnerabilities in our networks. The effect of these variables on processing time and memory usage is presented and can be used as a metric to assess the scalability of this tool within various customer environments.

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I. INTRODUCTION

A. MOTIVATION

Network vulnerability scanners have become common tools used to help network administrators discover and patch security holes that exist on enterprise networks. Although analysis of vulnerability reports can be accomplished with little effort on smaller networks, analysis of larger networks can be more difficult due to size and the potential for error. Depending on the extent of a security breach and the data that has been compromised, errors in vulnerability analysis have the potential to be costly. Network vulnerability scanners, which helped administrators learn which vulnerabilities exist on their networks, have created a new problem regarding how to manage, interpret, and visualize the data contained in vulnerability reports.

Network vulnerability analysis tools were conceptualized to automate the analysis of vulnerability reports allowing administrators to better assess their network security posture. By displaying the results of analysis in the form of an *attack graph*, all known attack paths from an attacker to a target are succinctly depicted, and a response strategy can be more easily created.

The creation of network vulnerability analysis tools has spawned additional concerns. One concern that this new genre of network security tool has raised is whether these tools represent an approach that will scale to use in large enterprises as indicated by the amount of time and resources required to perform analysis. Performance analysis is required to help identify factors that have the largest influence on performance. This thesis examines one automated network vulnerability analysis tool, CAULDRON, and subjects it to a variety of performance tests in an attempt to identify whether it is suitable for use on large-scale enterprise networks.

B. PURPOSE

Research undertaken to measure the performance of existing network vulnerability analysis tools has been limited and has focused on the amount of time required to analyze fully connected networks as the number of nodes varied; however, other network variables and measurements should be examined, such as the effects of the degree of vulnerability on memory usage. Using CAULDRON as the subject, an experiment consisting of six phases was developed to answer the following questions:

- What characteristics of the data significantly affect performance of CAULDRON?
- What functions of CAULDRON are most significantly impacted by increased load?
- Using observed performance as a measurement, how well does CAULDRON scale with respect to increased load?

Using the results of this experiment as a metric, we hope that CAULDRON's potential customers will be able to determine the suitability of CAULDRON for real world use, and that CAULDRON's developers can use our findings to determine where optimizations should be made.

C. THESIS ORGANIZATION

The thesis is organized as follows:

- This chapter (Chapter I) provided an introduction by describing the motivation and purpose of the thesis. Network vulnerability analysis software was briefly introduced and CAULDRON was chosen for experimentation.
- In Chapter II, background research was undertaken to examine the capabilities of the CAULDRON tool, and the input models required of CAULDRON. A survey of network vulnerability analysis tools was performed to compare CAULDRON with similar tools.
- Chapter III discussed the experiment to test performance of CAULDRON. The experiment was divided into six phases. The chapter also discusses configuration, modifications and scripting necessary to conduct the experiment.
- Chapter IV analyzed the results collected during experimentation by phase.
- Chapter V concludes with a summary and suggestions for future work.
- The appendices include the system configuration in Appendix A. Appendix B contains bash scripts and describes modifications made to the source code to support the experiment. Finally, Appendix C contains data collected during experimentation.

D. SUMMARY

In this chapter, the motivation for studying network vulnerability analysis software was examined, and the purpose for measuring performance of attack graph generation software was discussed, followed by a presentation of the thesis's organization. Chapter II, continues with background research of CAULDRON and similar software used to automate the process of analyzing network vulnerabilities.

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II. BACKGROUND

A. CAULDRON DESCRIPTION

Combinatorial Analysis Utilizing Logical Dependencies Residing on Networks (CAULDRON) is an ongoing project developed and supported by George Mason University (GMU). CAULDRON uses externally provided network vulnerability scan reports of a given network as well as exploit models and detailed attack scenarios to automatically generate attack graphs depicting all known combinations of vulnerabilities that could be systematically exploited by an attacker to reach an attack goal on that network [Jaj03]. The version of CAULDRON examined in this paper and used during experimentation is version 2.6.

While there are currently many network vulnerability scanners that can detect the presence of vulnerabilities on individual systems, these tools are inadequate in that the vulnerabilities are considered in isolation and do not take into account vulnerability interdependencies or network connectivity [Rit02]. A holistic approach must be taken when analyzing vulnerabilities on one's network, in order to accurately assess the extent to which the network is vulnerable. While a single vulnerability may provide an attacker access to one system, the presence of vulnerabilities on multiple systems may provide the attacker with multiple attack paths over which compromised systems can be used to launch further attacks. Furthermore, due to the complexity involved, human analysis of network vulnerability scan reports requires expert knowledge, is labor intensive, and is often error-prone [Jaj03]. By automating the task of analysis and by considering system vulnerabilities in combination rather than in isolation, CAULDRON is able to determine how an attacker could systematically compromise a network in order to reach his attack goal [Noe02][Jaj03].

In addition to being able to aid in the construction of attack graphs based on vulnerability scans, CAULDRON is able to correlate Intrusion Detection System (IDS) events with the attack graphs. These correlated results can be used to better distinguish attacks in progress from false alarms, and also provide context to attacks in order to determine where a response should be directed [Noe04]. CAULDRON also allows for customization on several levels of increasing complexity. At the simplest level, a user could modify the network, attack scenario, or exploit database models input to CAULDRON by making changes to the model's extensible markup language (XML) code. For more advanced customization, changes can be made to not only these inputs but also to CAULDRON's source code, included with the utility, which allows the user to modify the functionality of CAULDRON. Given the different uses of CAULDRON and the flexibility given to the user, it could prove to be an interesting and useful tool for assessing the security posture of one's network.

B. CAULDRON ABSTRACT MODEL

This section examines the abstract model used by CAULDRON to create the attack graph. Figure 2-1 depicts a high-level abstraction of the inputs required and the output produced by CAULDRON.

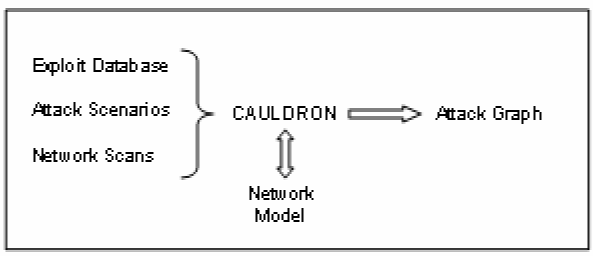

Figure 2-1. CAULDRON Engine Inputs and Output

1. Exploit Modeling

As depicted in Figure 2-1, a database of exploit models is required prior to running CAULDRON. The *exploit model* is an abstract representation of the *pre-conditions* necessary for a single system vulnerability to be exploited and the *post-conditions* that result after the exploit has been run. An exploit's pre-conditions describe a vulnerability, connections, and user privileges that must be present to exploit the vulnerability [Rit02]. The post-conditions describe the changes to the system that result from the exploit, which are then applied to update CAULDRON's internal network model. For example, in the updated network model, the attacker may be able to obtain more information about the network, and/or obtain elevated user rights [Rit02]. By modeling multiple exploits, it is possible to represent how an attacker could chain the post-conditions of one exploit to the pre-conditions of another exploit to construct a complex attack. Figure 2-2 depicts the exploit model used by CAULDRON.

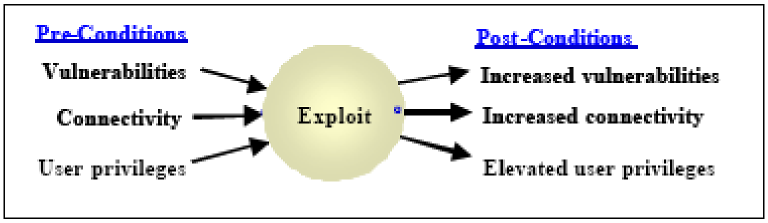

Figure 2-2. Exploit Model (From Ref. Rit02)

Analysis from various sources is required to create a new exploit model. A vulnerability, and a known exploit of that vulnerability, must exist. Vulnerabilities are derived from reports published by vulnerability gathering services such as ISS, XForce, Nessus, Symantec, or eEye Retina. These reports also may provide information about conditions required to exploit vulnerabilities. An initial database of exploit models is provided with the CAULDRON tool and is updated regularly by researchers at GMU. The same database can also be customized by the end user utilizing instructions provided in the customization manual included with CAULDRON.

2. Network Scanning

Another element required to run CAULDRON is a set of network vulnerability scans of the target network. CAULDRON is capable of accepting reports produced by Nessus and eEye Retina vulnerability scans. Network vulnerability scans must be conducted in advance of running CAULDRON in order to model hosts that are running vulnerable services. If planned correctly, these scans can also show connectivity rules being enforced by filtering routers or firewalls [Rit02]. By conducting a vulnerability scan through the firewall as well as behind the firewall, as depicted in Figure 2-3 and Figure 2-4, it is possible to model the attacker's knowledge of the network prior to the initial attack, as well as any knowledge gained after hosts residing behind the firewall have been compromised.

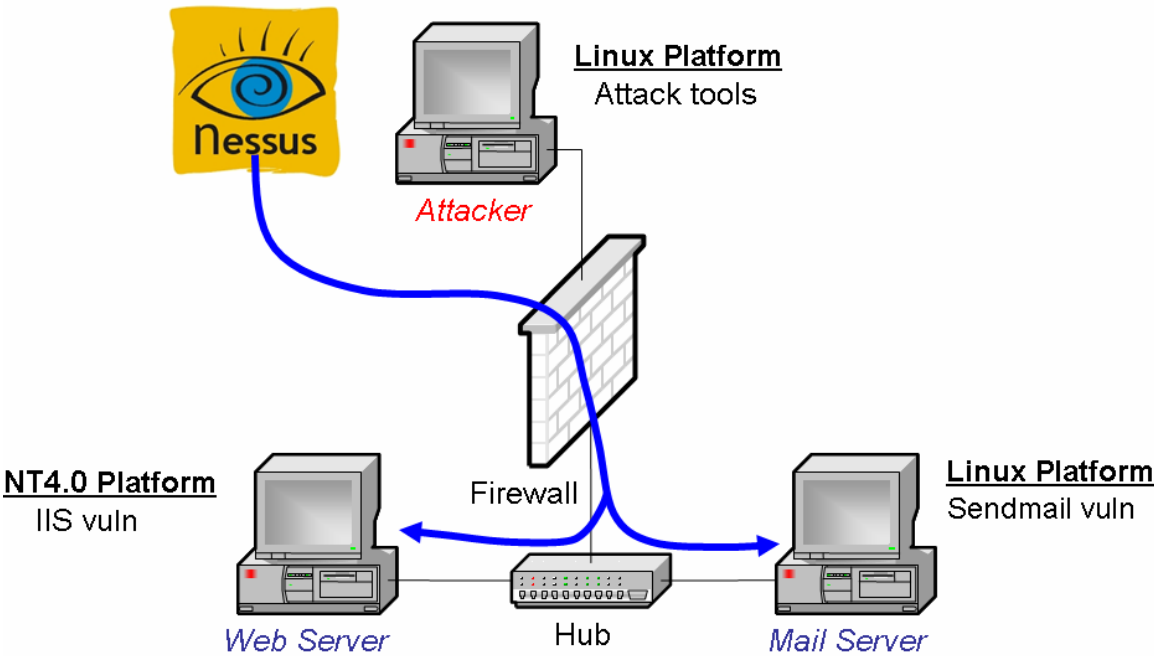

Figure 2-3. Attacker's initial knowledge of the network

An external scan targeting machines inside the firewall will yield a network vulnerability report revealing only vulnerable services that are allowed to pass through the firewall. In the example depicted in Figure 2-3, an initial scan initiated by the attacker reveals vulnerabilities in the Internet Information Services (IIS) service on the machine labeled Web Server, and in the Sendmail service on the machine labeled Mail Server. Although other vulnerable services may be present on either machine, the firewall prevents this information from being known to the attacker.

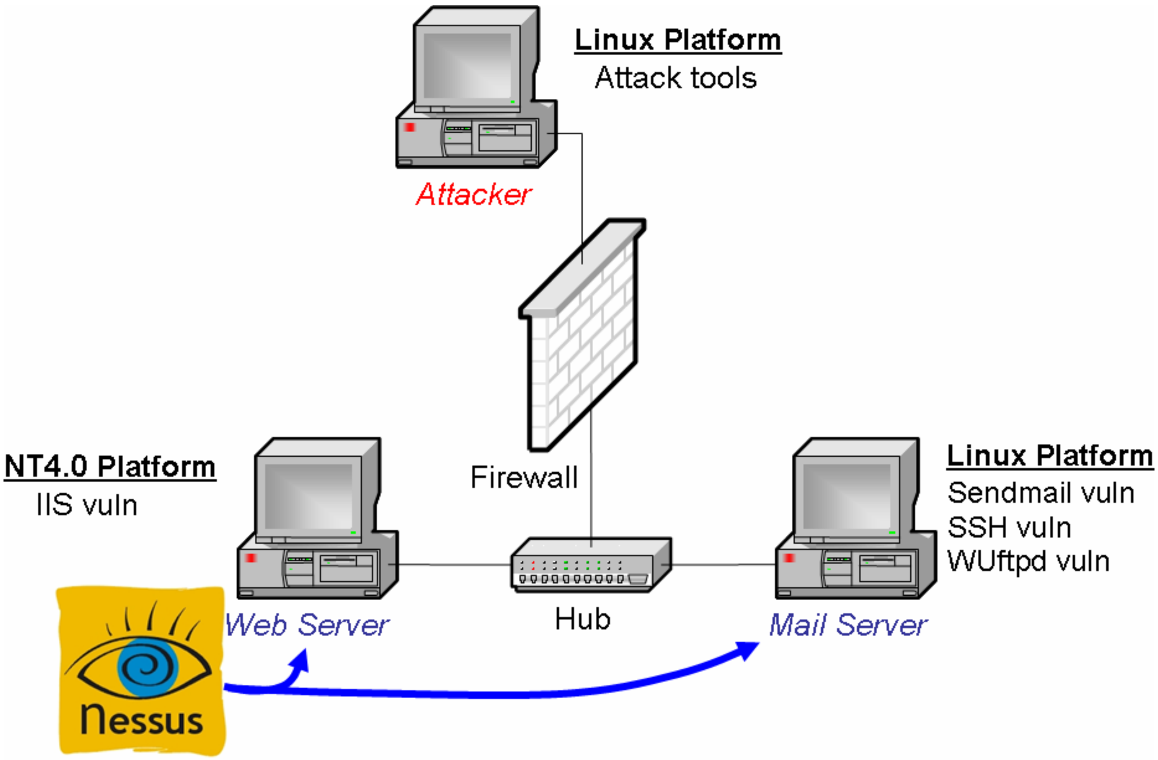

Figure 2-4. Attacker's knowledge after a host has been compromised

As depicted in Figure 2-4, a second scan conducted inside the firewall, shows the same vulnerabilities present from the initial scan, as well as a SSH service vulnerability and a WUftpd service vulnerability that can be exploited once an attacker has bypassed the firewall. The same technique depicted in Figures 2-3 and 2-4 must be applied whenever a personal firewall, network firewall, filtering router, or any other device that limits connectivity between nodes is encountered on a network.

Once the network has been scanned for vulnerabilities, the vulnerability reports are loaded into CAULDRON, which then creates a network model based on vulnerability and connectivity information derived from the vulnerability reports. Network hardening and other changes to the network model can be made by making modifications to the model's XML code as directed by CAULDRON's customization manual.

3. Attack Scenario

The user-defined attack scenario identifies the attacker and target nodes as well as the initial capabilities of the attacker and capabilities the attacker desires to obtain from the target. Capabilities of both the attacker and the target are represented in terms of access level and user privilege. The *access level* represents the ability to transfer files and execute code. *User privilege* is the privilege level at which the attacker's toolkit and vulnerable services are run for each machine. It can be represented as either root level or normal user privileges, which are respectively notated within CAULDRON as superuser and user. The attack scenario is defined manually within the CAULDRON graphical user interface (GUI) using user-selectable lists to assign the attacker, target, user privileges, and access levels. From this input, CAULDRON produces an XML data file for its own use. Existing attack scenarios can be edited using the GUI or by making changes directly to the XML file by following instructions provided in CAULDRON's customization manual.

4. Attack Graph

After entering the exploit models, network scans and attack scenario, when invoked, CAULDRON generates an attack graph and displays it for the user. An attack graph depicts all attack paths between the specified attacker and the target that result in the goal conditions specified in the attack scenario and that are known to the exploit model. The vertices of the attack graph represent exploits and security conditions, and are connected by edges which represent dependencies [Jaj03]. The attack graph is formed by chaining the post-conditions of exploits to pre-conditions of other reachable exploits.

As one might imagine, in larger networks in which each node might contain multiple vulnerabilities, interpreting an attack graph may become a daunting task. CAULDRON makes use of hierarchical aggregation techniques to simplify this task [Noe04*]. Through the use of aggregation techniques, CAULDRON can automatically summarize attack graphs, providing the user with a less complex visual representation. This allows the user the ability to manage attack graph detail rather than overload the user with all possible attack paths in a single view. Figure 2-5 and 2-6 depict the same network using non-aggregated and aggregated attack graphs to illustrate how this technique results in simplified and subsequently easier to understand attack graphs.

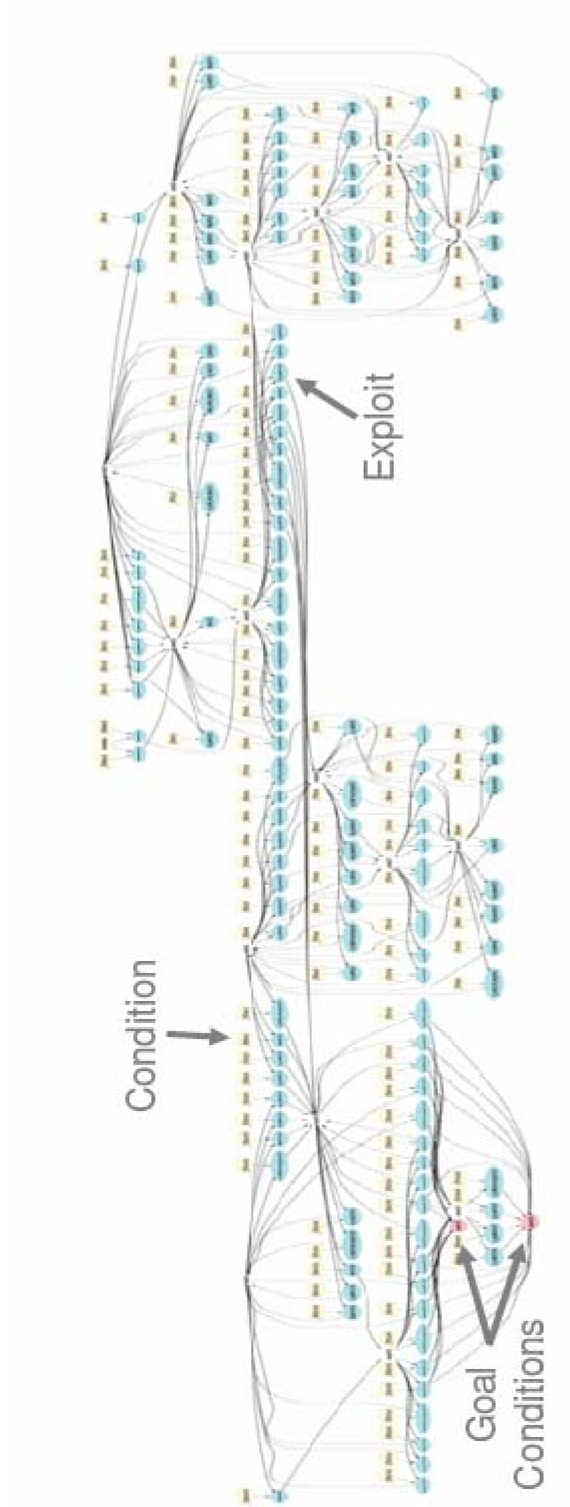

Figure 2-5. Non-aggregated attack graph (From Ref. Noe04*)

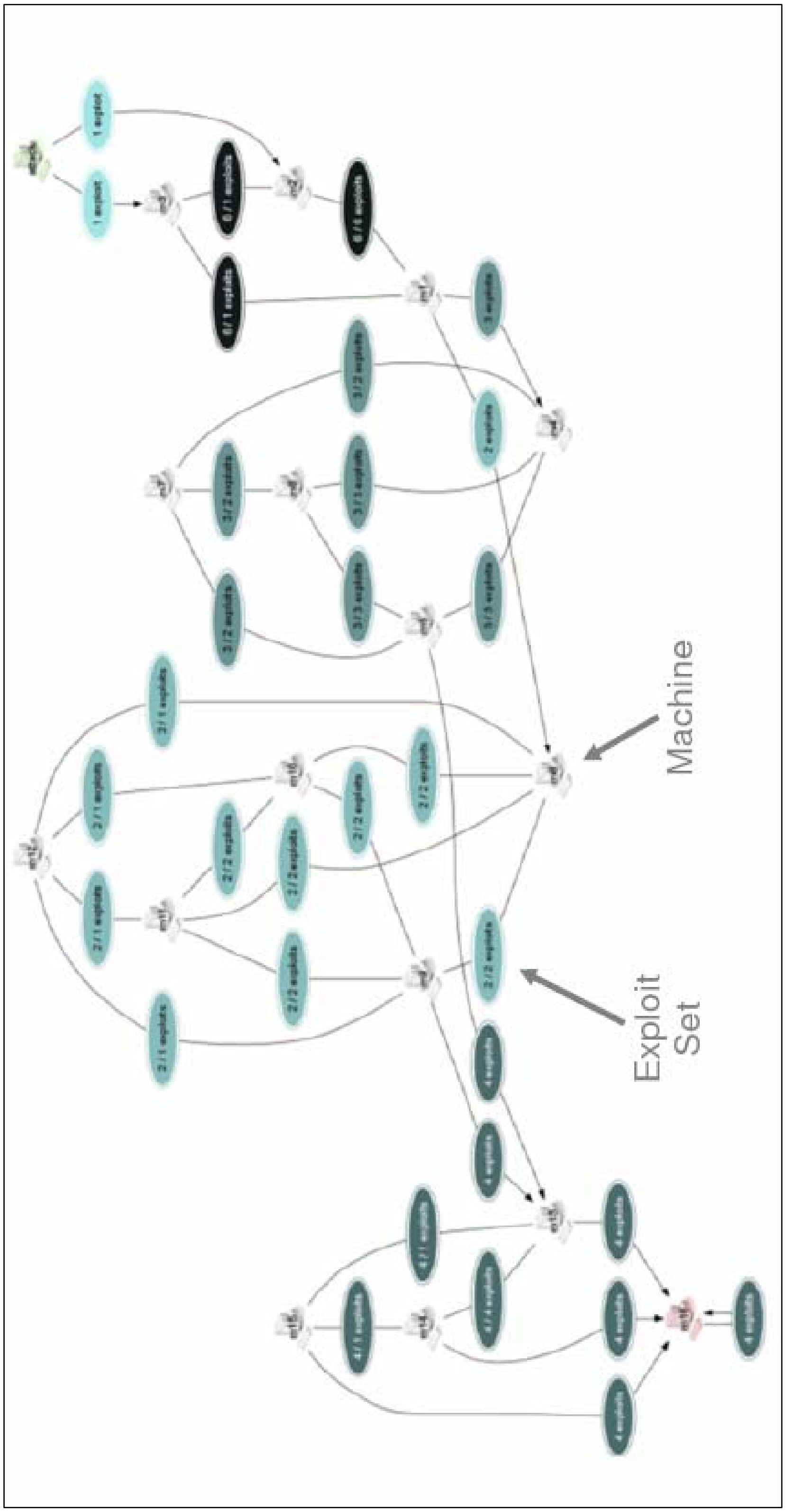

Figure 2-6. Aggregated Attack Graph (From Ref. Noe04*)

C. SURVEY OF AUTOMATED ATTACK GRAPH GENERATION TOOLS

In addition to ongoing work being done on CAULDRON, there are several other independent efforts underway to develop tools which can automatically generate attack graphs. This section examines recent development efforts to automate the process of building attack graphs.

1. CMU - Attack Graph Toolkit

The "Attack Graph Toolkit", created by researchers at Carnegie Mellon University, uses *model checking* to model network security. Through the use of model checking, an automatic technique for formally verifying finite-state reactive systems, attack graphs can be generated that match an attacker's capabilities with respect to the current state of the network in an attempt to identify all possible attack paths to the target node rather than paths from one particular attacker [She04]. This system is similar to CAULDRON in that it accepts Nessus vulnerability reports as input in order to gain information about the network's topology and network vulnerabilities, and it also requires the manual creation of exploit models based on vulnerability gathering services. It differs in that it can interface with host based vulnerability scanners such as MITRE Corporation's Outpost and Lockheed Martin's ANGI systems to display vulnerabilities which might not be visible to a network scanner, and uses a model checker rather than a custom application to perform analysis [She04]. Unfortunately, one problem with this approach is scalability. Although the model checking approach is capable of creating graphs that depict a large number of possible network states, it may have trouble completing computation. For example, a three host network with five vulnerabilities was reported to require five seconds to graph, while an increase to an eight node network with eight vulnerabilities required nearly three hours [Lip05].

2. MIT Lincoln Laboratory – NetSPA

Network Security Planning Architecture (NetSPA) is another automated attack graph generation tool being worked on by researchers from MIT Lincoln Laboratory. NetSPA generates attack graphs that show all possible paths from a particular attacker to all reachable nodes; in contrast, CAULDRON performs this step and performs further analysis to eliminate all reachable nodes that cannot reach the goal node. NetSPA uses the same general types of inputs as CAULDRON. In order to run, NetSPA requires the connectivity rules of the network, Nessus network vulnerabilities reports, and a database of pre-conditions and post-conditions for each vulnerability. The first requirement is generated by importing firewall and router rules into the utility rather than gathering information from Nessus scans; however, it should be noted that the importation of router rules has not been implemented to date, and currently importation of firewall configuration files is limited to Sidewinder and Checkpoint firewalls [Lip05*]. NetSPA also seeks to remove the manual entry of an exploit database by automatically gathering this information from vulnerability descriptions used by Nessus and vulnerability gathering services such as the Mitre CVE dictionary, and the NIST ICAT database [Lip05*]. In a report produced by Lincoln Laboratory, NetSPA was tested on a variety of simulated networks to show how its performance scaled. Figure 2-7 shows how overall processing times scaled on fully interconnected networks using a single processor Pentium 4 1.80-GHz machine with 1024 MB PC 133 SDRAM, and running Microsoft Windows XP [Lip05*]. Despite favorable performance results, until the interpretation of router and firewall configuration files is completed, real world deployment of NetSPA may be limited.

% Rootable	Total Hosts	Overall Time	Reachability and AG Generation	AG Analysis
5.00	500	3.41	0.02	0
5.00	1,000	6.58	0.09	0.05
5.00	2,000	13.25	0.3	0.16
5.00	4,000	28.28	1.16	0.63
5.00	8,000	60.05	4.55	2.47
5.00	16,000	145.34	18.25	9.83
5.00	32,000	383.8	73.06	44.67
5.00	64,000	1163.45	292	216.17
5.00	128,000	3877.16	1165.77	834.28

Figure 2-7. Simulation of a flat network with a variable number of hosts (From Ref. Lip05*)

3. Skybox - Skybox View

Skybox View is a commercially available tool developed by Skybox Security that can automatically generate attack graphs through the use of host-based agents, management interfaces, and an analysis server located on the target network [Sky06]. This product is similar to CAULDRON in that it requires a database of exploits and probing prior to analysis to discover which vulnerabilities are present on each host. It differs from CAULDRON because it requires that Skybox View probe live networks and must be connected to live networks during its analysis phase, while CAULDRON relies on data collected by network vulnerability scanners and has the ability to be run on a standalone computer air-gapped from the target network. Although no performance details were available from Skybox, an examination of recent patents submitted by Skybox identified the algorithmic complexity of the product as n^4, where n represents the number of nodes present on the network [Lip05].

D. SUMMARY

This chapter has provided an introduction to CAULDRON, including an overview of the software, a high level view of the inputs and outputs required, and a survey of ongoing projects similar in nature to CAULDRON. Chapter III examines the setup of an experiment designed to test the performance of CAULDRON, as well as tools required to implement the experiment.

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III. EXPERIMENT SETUP

In this chapter, we describe the resources, tools and setup used to test CAULDRON's performance. Initial research, conducted by GMU, measured performance scalability of combinatorial analysis; however, all tests were conducted on fully connected networks, used model checking to analyze the models, and recorded only the processing times per test [Noe02]. Although, initial testing provided clues regarding how well a combinatorial analysis approach would scale, more testing was needed to determine the performance requirements and limitations of the CAULDRON approach. In our experiment, we measure the performance impact of heap size, network size, connectivity within the network, the number of vulnerabilities per node, and the size of the exploit database. This chapter covers a description of the performance measurements that were recorded, a high-level view of the experiment, and a description of the implementation required to conduct the experiment.

A. PERFORMANCE MEASUREMENTS

The experiment comprises of a series of tests that will be examined in greater detail in Chapter III, Section B. This section examines the performance measurements that were recorded for each experiment.

1. Runtime

The first performance measurement that was recorded for each test was the amount of time required by CAULDRON's analysis engine to complete certain tasks during attack graph analysis. Time measurements were recorded for the following tasks:

- Initialization runtime – The amount of time required to read input files, and determine which exploits were applicable to the network model.
- Analysis runtime – The amount of time required to run CAULDRON's attack graph analysis algorithm.
- Forward Chaining Algorithm – The amount of time required to run the first half of CAULDRON's attack graph analysis algorithm.
- Backward Chaining Algorithm – The amount of time required to run the second half of CAULDRON's attack graph analysis algorithm.
- Total runtime – The amount of time required to read input files, perform attack graph analysis, and write results to the attack graph output file.

2. Physical Memory Usage

The second performance measurement for each test was the maximum amount of physical memory in use by CAULDRON. This measured the maximum size of CAULDRON's working set for each test. The *working set* is the smallest set of memory referenced by a process required for efficient execution [Den68]. Since the number of memory pages in physical memory grows and shrinks depending on the demands of the process and availability of memory in the system, the maximum size was recorded for each test to determine if a correlation existed between characteristics of the input models and the amount of physical memory required.

3. Virtual Memory Usage

The third, and final, performance measurement that was recorded was the maximum amount of virtual memory used by CAULDRON per test. *Virtual memory* is a memory management technique where the operating system swaps memory pages from secondary storage into physical memory as needed while presenting the memory as a contiguous block to the application [Den70]. The use of virtual memory allows the operating system to manage the use of physical memory between running processes and keeps memory management transparent to the processes running.

B. HIGH-LEVEL EXPERIMENT DESCRIPTION

An experiment was designed to test how performance varied as changes were made to CAULDRON's inputs. The experiment was divided into five phases, with each phase designed to measure specific characteristics of the input models. This section provides a high-level overview of each phase of the experiment.

1. Heap Size

The initial phase of the experiment examined the role of the Java Virtual Machine (JVM) heap size on the variability of performance measurements. Since CAULDRON is implemented in Java, all active memory objects are stored in Java's memory heap. As objects are no longer needed, Java's garbage collector frees heap memory so that new objects can be created. The size of the heap, which fluctuates as objects are added and removed, determines the frequency and duration of garbage collection. CAULDRON includes a configuration file, *cauldron.exe.vmoptions*, to define the JVM's heap size boundaries. The initial heap size is defined by the *–Xms* option, and the maximum heap size is defined by the –*Xmx* option. According to an article written by Sun Microsystems, Inc. regarding tuning garbage collection in Java,

> Setting –Xms and –Xmx to the same value increases predictability by removing the most important sizing decision from the virtual machine. On the other hand, the virtual machine can't compensate if you make a poor choice [Sun03].

Under the assumption that performance predictability is greatest when initial and maximum heap sizes are equal, the first phase of the experiment was conducted to test the hypothesis that a sufficiently sized heap is necessary to reduce the variability of performance measurements. This phase of the experiment consisted of setting the initial and maximum heap sizes equal to each other and incrementing the heap size from 128MB to 1GB. Each test was repeated 50 times using the same network model, attack scenario, and exploit database. Before proceeding to the next phase of the experiment, the variability of the performance measurements was analyzed, and the heap size that resulted in the least performance variability was selected for use in the remainder of the experiment.

2. Network Size

The second phase of the experiment used fully connected network models and measured how performance scaled as the number of nodes varied. Results from the original scalability experiment described above showed that execution time scaled polynomially, with respect to the number of nodes, and that results could not be computed for networks containing more than 50 nodes when using 512 MB of physical memory [Noe02]. This phase of the experiment examined whether performance limitations encountered by using formal model checking would be present in CAULDRON, and measured how execution times scale on our implementation. Each node contained in the network had a single vulnerability and a corresponding exploit associated with it. The tests varied network size from 2 to 100 nodes and each test was repeated five times in order to verify that results were not significantly affected by performance variability.

3. Connectivity within the Network

The third phase of the experiment examined how performance measurements scaled when the number of nodes on the network was held constant and modifications were made to connectivity restrictions between nodes. In order to model connectivity restrictions, network models were created using four variables.

The first variable was the number of fully connected sets of nodes that was present within the network model. A *fully connected node-set* is a collection of nodes in which every node has at least one vulnerable service that can be exploited, and where every node is allowed full connectivity to all services present within the same node-set. The presence of multiple fully connected node-sets in the network model allowed the emulation of networks in which connectivity was restricted due to the presence of firewalls or filtering routers, devices commonly found on real-world networks.

The second variable was the number of nodes present per fully connected node-set. One decision that had to be made was whether to create a variable to represent the size of each fully connected node-set individually or to require that all node-sets be a uniform size and define the size using one variable. Although it was possible to represent the size of each node-set individually, which would provide a more realistic network model, the amount of data collected and the time required to analyze the combinations of different sized node-sets would have been overwhelming. Hence, the number of nodes per node-set was always uniform.

The third variable that was examined was the number of connections that were allowed between fully connected node-sets in the network model. A connection between fully connected node-sets allows a node belonging to one set to exploit a vulnerable service offered by a node belonging to another node-set. By allowing connections between node-sets in the network model, it was possible to define connectivity in the model ranging from no connectivity to full connectivity between every node. The individual connections between node-sets were randomized. Connections between node-sets were selected pseudo-randomly using the first four bytes of Cygwin's /dev/urandom to seed the random generator for each test. Connections were generated by selecting a node and service that would be exploited and a node which would connect to the service.

Each connection was verified to assure that its nodes belonged to unique node-sets. After all connection pairs were generated, duplicates were removed, and replaced with new connections until the target number was achieved and all connection pairs were unique.

To test the hypothesis that the presence of connectivity restrictions would significantly impact performance, this phase of the experiment was conducted by varying the number of node-sets and node-set size, such that the total number of nodes remained constant. Since selection of connections occurs at random, multiple tests were conducted for each number of connections between node-sets to allow the generation of variants network models. Analysis of the variants of each test is expected to reveal how arrangements of connections between node-sets affect performance measurements. To verify the accuracy of results that were collected, each variant network model was tested five times.

4. Vulnerabilities per Node

The fourth phase of the experiment measured how performance of CAULDRON varied with respect to the number of vulnerabilities per node. It was necessary to decide whether or not to represent the number of vulnerabilities per node with a variable for each node, or to make the number of vulnerabilities per node a uniform size for all nodes. Although it was possible to create a variable to represent the number of vulnerabilities present on a per-node basis, which would have provided a more realistic network model, the amount of data collected and the time required to analyze the performance measurements for combinations of vulnerabilities per node would have been overwhelming. Instead, vulnerability counts were uniform across all nodes for each test. Tests were conducted using a fully connected network, and each vulnerability and exploit pair was only used once. Each network model was run through CAULDRON and performance measurements were recorded. Each test was repeated five times in order to verify the accuracy of results due to expected performance variability.

5. Size of the Exploit Database

The fifth, and final, phase of the experiment measured how performance of CAULDRON scaled as exploits were added to the exploit database. Since CAULDRON must search the exploit database to locate exploits that are relevant to the network model, it was assumed that an increase in the number of exploits to be searched might result in an increase in the amount of time and resources required to do so. In this phase of the experiment, the network model and attack scenarios remain unchanged, and exploits were added to the exploit database such that the exploits added were not present in the network model, but caused the size of the search space to increase. Each test was repeated five times in order to verify the accuracy of results due to expected performance variability.

C. IMPLEMENTATION DESCRIPTION

This section discusses the implementation used for the series of experiments described in the previous section, as well as the rationale behind implementation specific decisions.

1. Environment

All experiments were conducted on a standalone Dell Dimension 5150 3.2 GHz personal computer containing 2GB of memory and running the Microsoft Windows XP SP2 operating system. The computer was not connected to the LAN in order to avoid the possibility that network administration operations might interfere with tests, and to reduce the possibility that all or part of the CAULDRON source code might be unknowingly copied to another machine residing on the network or the Internet.

Since a large amount of research has already been conducted regarding how to optimize the performance of Windows, a configuration guide was consulted to determine an optimal configuration [Bla03]. The configuration used is included as Appendix A, along with a listing of all services that are available, and the services that are enabled by default. Services were disabled incrementally until a minimal, but sufficient, configuration was reached. Using this approach, it was assumed that the operating system was running the minimum amount of services required to support itself, CAULDRON, and the tools necessary for data collection. It was assumed that this should help to reduce measurement noise.

2. File Naming Convention and Experiment Organization

A file naming convention was established to identify the different types of models, and to identify the values of variables used for each test. Each network model file was named using the following schema:

<exploits>_<sets>_<nodes>_<connections>_<vulnerabilities>_<variant>_net.xml

Table 3-1 below describes the purpose of each code used in the network schema.

Table 3-1. Naming Convention for Network Models and Attack Scenarios

Name	Description
<exploits>	Number of additional exploits added to the exploit database
<sets>	Number of fully connected node-sets present in the network model
<nodes>	Number of nodes per fully connected node-set
<connections>	Number of connections between fully connected node-sets
<vulnerabilities>	Number of vulnerabilities per node
<variant>	Number that distinguishes tests where the number of connections between node-sets were the same but whose actual connection pairs differ

Each attack scenario file generated was named using the following schema and used the same naming convention described in Table 3-1:

<exploits>_<sets>_<nodes>_<connections>_<vulnerabilities>_<variant>_config.xml

Each exploit database file was named using the following schema and used the naming convention described in Table 3-2:

exploits_<exploits>.xml

Table 3-2. Naming Convention for Exploit Databases

Name	Description
<exploits>	Number of additional exploits added to the exploit database

To keep the phases of the experiment organized, a separate directory was created to contain each phase of the experiment. While input files were stored inside the directory created for each phase, output files were stored in a sub-directory that was created to contain results for each test repetition.

3. Simulation of Models

One implementation decision required for this experiment was whether to collect data from a production real-world network, a simulated network, or a network setup in a laboratory. Collection of data from a production real-world environment would provide real-world evidence of how CAULDRON performs on live networks; however, publication of results obtained from the experiment could become problematic since that would involve revealing a real-world network's vulnerabilities to the public. Alternatively, data could be collected from a test laboratory that was setup for the purpose of this experiment; however, this approach was also problematic due to the large amount of time required to configure hardware and software, and validate that the network was setup correctly. By simulating the networks and constructing the network model files by hand, it was possible to avoid all the issues mentioned above.

4. Contents of the Exploit Database

Another implementation decision required for this experiment was whether the exploit database should contain real-world or simulated exploit models. Although a real-world test case would use a database containing real exploit models, the database contained a mixture of exploits containing simple and complex pre-conditions and whose post-conditions, in regard to access level and user privilege, were not uniform. Since it was unknown if the selection of exploits with differing pre- and post-conditions might impact performance, a database of exploit models was generated such that every exploit had pre-conditions defined by a connection, a unique vulnerability, along with uniform access level and user privileges. Each post-condition had uniform access level and user privileges.

5. Required Tools

To perform measurements, automate control of the experiment, and to generate tests based on the variables defined in the previous subsection, additional software was required. The subsections that follow examine the roles of additional tools required for the experiment.

a. Cygwin

Cygwin is a Linux-like environment for Windows that consists of a Linux API emulation layer that provides Linux functionality and a collection of tools which provide a Linux look and feel [Cyg06]. For this experiment, Cygwin was installed as a part of the test environment in order to take advantage of string processing tools such as *awk*, *grep*, and *sed* which could be used along with bash scripts to generate the input models required for testing. In addition, the same tools aided in the automation of the experiment, and retrieval of performance data that was stored in output files.

b. Windows Performance Monitor

The Windows Performance Monitor is a performance benchmarking tool that is included with the Microsoft Windows XP operating system. For this experiment, the Windows Performance Monitor was used to measure the peak working set, and the amount of virtual memory allocated exclusively to CAULDRON. Results from the Windows Performance Monitor were stored to separate files for each phase of the experiment.

Since each log file contained the results for multiple tests, it was necessary to find a way to associate results collected by the Windows Performance Monitor with the results stored in CAULDRON's attack graph output files. To accomplish this, the process ID for each test was recorded in the summary data for each attack graph output file and the Windows Performance Monitor was configured to log the process ID for each test. A script was developed that would match process IDs between Windows Performance Monitor log files and CAULDRON attack graph output files. In the event that two CAULDRON processes used the same process ID, the system time was used to distinguish which results belonged to which test. Performance measurements were collected at one-second intervals, the shortest interval allowed by the Windows Performance Monitor.

c. Bash Scripts

Bash scripts were created to accomplish specialized tasks during experimentation. Bash is a common Unix shell program, also implemented in Cygwin, that provides a scripting interface. Scripts were grouped into three categories based on their functionality. Scripts were designed that would generate the input models required for testing, automate the control of the experiment, and collect data from output files once the tests had completed. All bash scripts created for the experiment are provided in Appendix B. The following paragraphs provide greater detail about each category of script.

The first group of scripts was created to generate the input files required for each test in the experiment. Scripts were created to generate input files based on the inputs defined in Chapter III, Section B. To create the input files, two scripts were run. The first script generated the exploit database and required two inputs. The first input defined the number of exploits that defined the base size of the exploit database. The second input defined the number of additional exploits that were added to the database. The second script generated the network model and the attack scenario and required six inputs: the number of fully connected node-sets, the number of nodes per node-set, the number of connections allowed between node-sets, the number of vulnerabilities per node, the number of additional exploits contained in the exploit database, and the number of network models to create.

The second group of scripts was created to automate each phase of the experiment. Each phase of the experiment had an automation script that ran each test sequentially.

The final group of scripts was created to collect results from the output files. This group of scripts was necessary because performance data was stored in separate locations for each experiment. One script was necessary to combine the results stored by the Windows Performance Monitor with results stored in the attack graph output files. By providing the script with the location of the Windows Performance Monitor log file, and placing the script in a directory that contains one or more CAULDRON attack graph output files, a resulting output file was created.

6. Modifications to CAULDRON

In order to perform the large amount of testing needed and to collect the resulting data, it became evident that automation of the experiment would be desirable. Thus customization of the CAULDRON source code was necessary. Modifications to the source code were made such that the program would accept command line input, terminate after analyzing the attack graph, collect and report the amount of time required to complete the initialization phase, the forward chaining algorithm, and the backward chaining algorithm during attack graph analysis, and record the process ID of CAULDRON within the summary output contained within the attack graph output file.

To demonstrate the performance impact of the modifications to CAULDRON, additional experimentation was conducted using the modified version of CAULDRON and an unmodified version of CAULDRON where the network, attack scenario, and exploit database were held constant. The results of the experiment will be discussed in Chapter IV. After changes were made to CAULDRON's source code, CAULDRON was rebuilt using instructions included in its customization manual. The remainder of this subsection provides more detail about changes that were made to CAULDRON's source code.

a. Command Line Interface

Automation of the experiment required the ability to load an attack scenario into CAULDRON without having to manually do so with the graphical user interface (GUI). To accomplish this, CAULDRON's source code was modified to accept command line input containing the absolute path of an attack scenario file. The following shows how CAULDRON could be executed to automatically load an attack scenario.

```
$c:/CAULDRON/CAULDRON.exe c:/cauldron_topologies/0_1_32_0_1_1_config.xml
```

b. Program Termination after Attack Graph Analysis

Another requirement necessary for experiment automation was the ability for CAULDRON to terminate upon generation of the attack graph. Normally, after attack graph analysis has completed, CAULDRON displays the attack graph and then enters a waiting state while the user decides whether to examine results in greater detail, load a new attack scenario, or terminates the program. Since the experiment was designed to measure performance during attack graph analysis, displaying the attack graph is unnecessary. In the modified version of CAULDRON, the program terminates after attack graph analysis if an attack scenario file is provided as a command line argument.

c. Runtime Measurements

Next, it was necessary to create additional timers within CAULDRON to measure the time required to perform initialization, the forward chaining, and the backward chaining algorithms and report the results. By default, CAULDRON measures the time required to analyze the attack graph, and reports that measurement in a summary tag contained within the attack graph output file. The timing functions that were created during modification were modeled after timing functions already in place in the unmodified version. The timer was started before each algorithm and stopped at the end of the algorithm. Modification was made to the summary report to include the additional performance measurements.

d. Process ID

Finally, it was necessary to modify CAULDRON so that it would record its own process ID in the summary report contained in the attack graph output file. This modification was necessary so that it would be possible to identify tests that were contained in the Windows Performance Monitor log files. CAULDRON was modified to make an external call to *ps*, a tool which provides information about all processes that are currently running on the operating system, to locate the process ID of CAULDRON, after attack graph analysis has completed. The value obtained from the external call is then written to the attack graph output file.

D. SUMMARY

This chapter examined the performance measurements, the experiment design, and describes the implementation used to conduct the CAULDRON performance experiment. The first section examined which performance measurements are of interest for this experiment. The second section provided a high-level view of the experimental variables and how the experiment would be conducted. The third section provided details of the implementation that was used to conduct the experiment and the rationale behind the implementation. After performing the experiment, performance measurements were collected. Chapter IV contains an analysis of the performance measurements that were collected for the experiment.

IV. ANALYSIS

In this chapter, we analyzed the output from each phase of the experiment described in the previous chapter to obtain a better understanding of how changes to the input models affect CAULDRON's performance. This chapter examines the impact of the heap size, CAULDRON modifications, network size, connectivity, vulnerabilities per node, and the exploit database size on CAULDRON's analysis time and memory usage.

A. PHASE I: HEAP SIZE

Prior to performing experiments to measure how time and memory usage scaled, an effort was made to reduce background noise in the environment. One environment variable that could add uncertainty was the initial and maximum heap size settings [Sun03]. Although it is known that predictability would increase by setting the initial and maximum heap sizes equal to one another, it was unclear how large the heap should be and whether the value assigned could add consistency of the performance measurements. Phase I of the experiment was designed to find an acceptable heap size to be used in the remainder of the experiment. To measure consistency, the standard deviation was computed for the performance measurements described in Chapter III, Section A. An acceptable heap size was selected, using the standard deviation of the forward pass algorithm times, private bytes, and working set as selection criteria.

This phase was conducted using a fully connected network model containing 60 nodes, and an exploit database containing 1500 unique exploit models. Each node on the network contained a unique vulnerability that mapped to a unique exploit model contained in the exploit database. The attack scenario was identical for each test. The initial and maximum heap sizes, contained in cauldron.exe.vmoptions, were set equal to one another and were changed in 128MB increments using a bash script. The values ranged from 128MB to 1024MB. Each test was repeated 50 times for each heap size in order to account for background noise. The data collected for Phase I can be found in Appendix C Section A; Figure 4-1 shows the standard deviations of the data.

Heap Size	Analysis Time (s)	Total Time (s)	Forward Pass Time (s)	Backward Pass Time (s)	Initialization Time (s)	Private Bytes (B)	Working Set (B)
128MB	1.268	1.285	1.243	0.00	0.00	37947	973653
256MB	1.478	1.497	1.442	0.00	0.00	43931	1157584
384MB	0.683	0.677	0.686	0.00	0.00	45387	262488
512MB	0.641	0.642	0.523	0.00	0.00	40496	791833
640MB	2.267	2.265	2.235	0.00	0.00	45166	382100
768MB	0.440	0.444	0.407	0.00	0.00	41833	250799
896MB	0.226	0.253	0.212	0.00	0.00	35777	637181
1024MB	0.305	0.319	0.303	0.00	0.00	46904	731437

Table 4-1. Standard Deviations per measurement and heap size observed during the heap size experiment.

1. Observations

The smallest heap sizes, 128MB and 256MB, exhibited higher standard deviations, and hence less predictability. Although it was not clear why the smaller heap sizes resulted in lower predictability, it is possible that this was caused by garbage collection and compaction, activities of java, which may have been necessary due to limited heap size. It is also unclear why a 640MB heap size had the highest variability for time measurements. This is especially peculiar since 512MB and 768MB heap sizes appeared to be significantly more predictable. Heap sizes that were 768MB and larger provided more predictable outcomes in our implementation.

2. Conclusions

Since all heap sizes larger than 768MB displayed the highest predictability, it was determined that any of these values would be an acceptable choice for the remainder of the experiment. A heap size of 768MB was selected since its standard deviation was lowest in memory measurements and was low for time measurements as well.

B. PHASE II: MODIFICATIONS TO CAULDRON

Changes were made to the CAULDRON source code in an effort to aid data collection and automate the experiment; however, it was unclear whether these changes would significantly impact the performance of CAULDRON and consequently any measurements recorded in experiments using the modified version. Phase II of the experiment was conducted to determine how changes made to CAULDRON affected performance.

Phase II of the experiment was conducted using a fully connected network model containing 60 nodes, and an exploit database containing 1500 unique exploit models. As in Phase I, each node on the network contained a unique vulnerability that mapped to a unique exploit model contained in the exploit database. The attack scenario was identical for each test. The variable in Phase II of the experiment was the version of CAULDRON used. Each test was repeated five times to help reduce background noise. Each test was terminated after analysis had completed and the attack graph output file was created. The data collected for this phase of experimentation is contained in Appendix C Section B.

1. Observations

In this phase, accurate measurement of the private bytes and working set required a clear determination of the point at which attack graph analysis stopped and attack graph visualization began, because the modified version was designed to terminate prior to visualization, while the unmodified version ran until the user intervened. This affected measurements because memory usage was recorded only for the analysis phase in the modified version, and was recorded for the analysis phase and the visualization phase in the unmodified version. To compensate, we approximated the time at which attack graph visualization began and removed the records collected after that time in the unmodified CAULDRON data. This time was based on the file modification time attribute of CAULDRON's attack graph output files.

A Student's t-Test was performed on analysis time, total time, private bytes, and working set measurements to determine whether the version of CAULDRON was likely to have an impact on the data collected. For analysis time, total time and working set, the student's t-Test rejected the null hypothesis with greater than 99% confidence that there was no difference between the means for each data set. Since the Student's t-Test failed to reject the null hypothesis for the private byte measurement, it appears that the version of CAULDRON used has no effect on this measurement.

Visual inspection of analysis time and total time measurements show that the modified version of CAULDRON is about two seconds slower than the unmodified version. Although it was expected that changes to CAULDRON would have a slight impact on performance due to the addition of timers within the analysis algorithm, it was expected that modifications would be unnoticeable. The Student's t-Test showed that working set data was influenced by the version of CAULDRON used, but it is unclear whether changes to the source code or approximations to compensate for attack graph visualization were responsible for changes in the size of the working set.

2. Conclusions

It was concluded that the changes made to CAULDRON did have an impact on time measurements and size of the working set. While changes to the source code were noticeable by measuring working set size, analysis time, and total time; the size of the changes were insignificant. In all cases where the Student's t-Test indicated a likely influence on data collected, these changes were less than one percent.

C. PHASE III: NETWORK SIZE

Phase III of this experiment was conducted to measure how performance scaled on a fully connected network model as the number of nodes increased. This phase was conducted in a manner similar to the scalability experiment conducted on the Topological Vulnerability Assessment (TVA) tool, a predecessor to CAULDRON, by GMU [Noe02].

This phase of experimentation was conducted using network models constructed with a variable number of nodes ranging from 2-100 nodes, and an exploit database containing 1500 unique exploit models. Each node possessed a single vulnerability that mapped to a unique exploit model contained in the exploit database. The attack scenario was created such that the first node was the attacker and the last node was the target. Each test was repeated five times to allow for background noise. The data collected for this phase is contained in Appendix C Section C.

1. Observations

Curve fitting analysis of the data was conducted to determine how well CAULDRON scaled during this phase of the experiment. Observations made during analysis were then used to draw conclusions about how the number of nodes present in the network model affects the performance of CAULDRON.

Plots of the analysis time, total time, and forward pass time measurements, showed that each measurement scaled similarly as the number of nodes increased. From this observation it was concluded that the amount of time required to complete the forward pass algorithm is the dominant factor in analysis of the network model. Attempts to fit the data showed that a fourth order polynomial was the lowest ordered polynomial equation that provided an acceptable fit to the data; however, it was observed that the third and fourth order terms were very small. Figures 4-1, 4-2, and 4-3 show how the analysis, total, and forward pass time measurements scaled as well as the fit equations that were used.

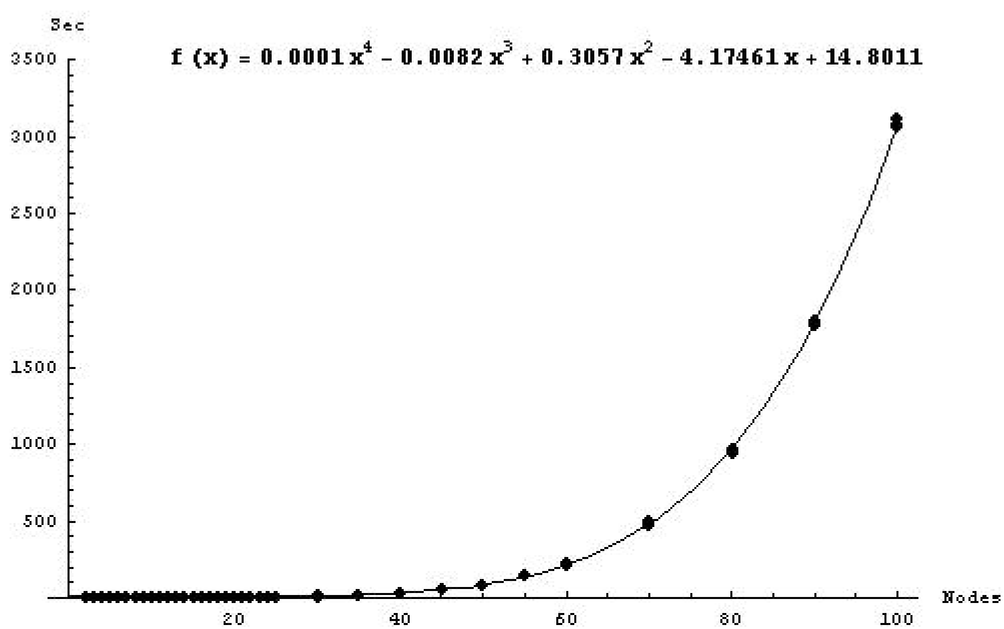

Figure 4-1. Time required to complete the Forward Pass Algorithm

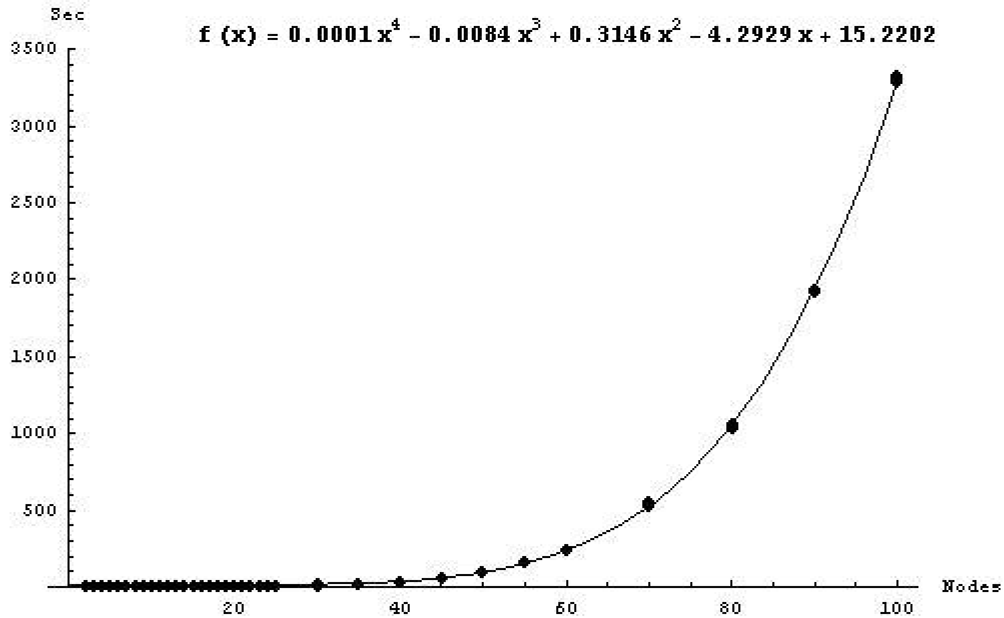

Figure 4-2. Time required to complete the Analysis Algorithm

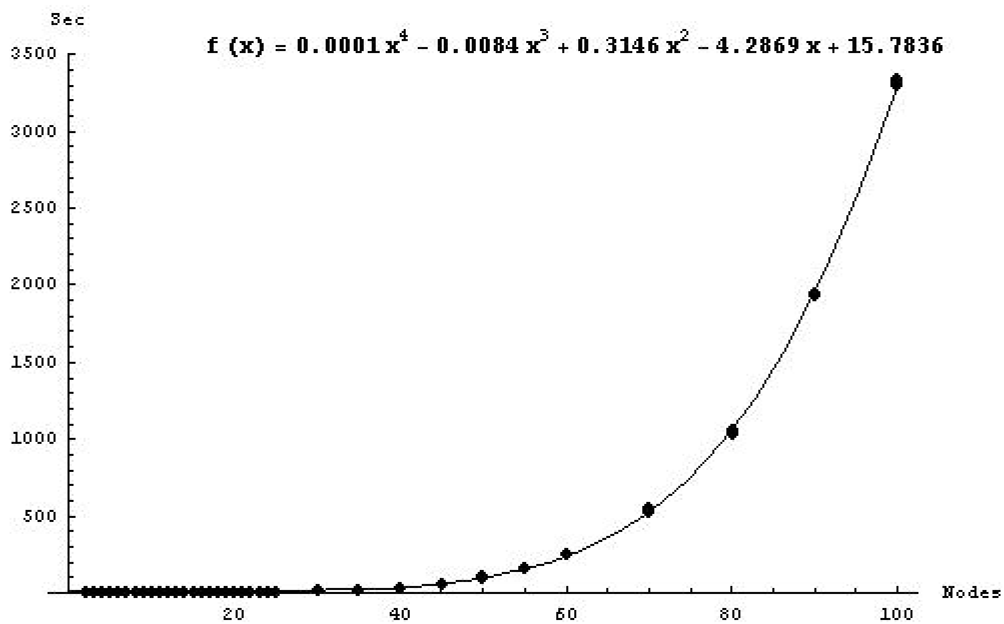

Figure 4-3. Total Time required to Analyze

After plotting the times measured to complete the backward pass algorithm, attempts to curve fit the data revealed that a third order polynomial provided a reasonable fit for the data obtained; however, the second and third order terms were very small. In comparison to the amount of time required to run the forward pass algorithm, the time required to run the backward pass algorithm was negligible. Since the purpose of the backward pass algorithm was to remove nodes from the attack graph which could not reach the target node and all nodes on the network were capable of directly accessing the target node, it is not surprising that this portion of analysis did not take much time to complete. Figure 4-4 shows the amount of time required to run the backward pass algorithm as nodes were added to the network.

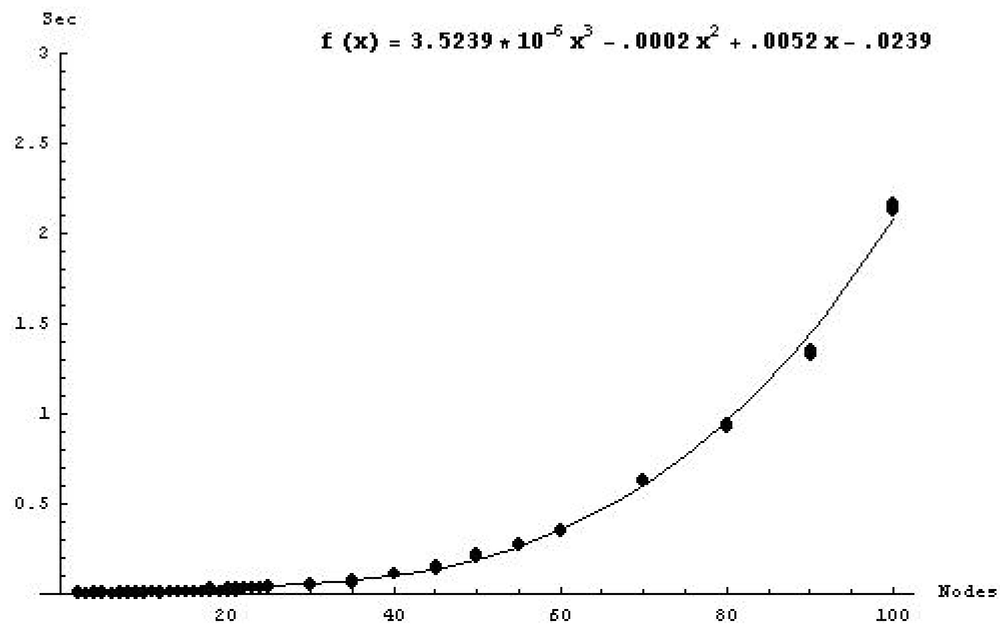

Figure 4-4. Time required to complete the Backward Pass Algorithm

As shown in Figure 4-5, the amount of time required to complete initialization appears to scale linearly as the number of nodes are increased. Using the fit equation, which was calculated after removing one outlier, it was observed that it would require at least 250 nodes to raise initialization time by one second.

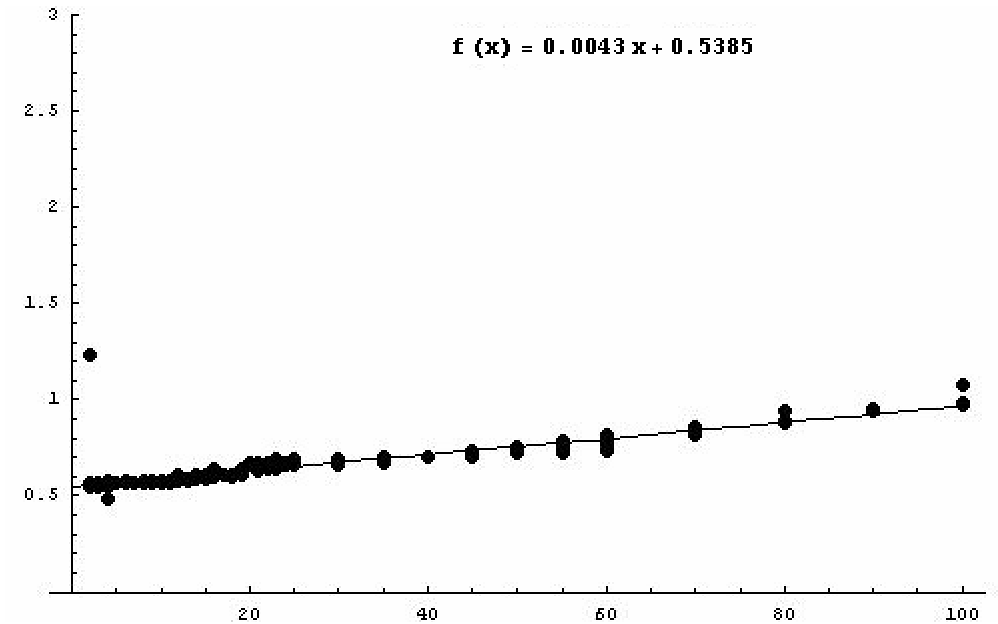

Figure 4-5. Time required to complete the Initialization Algorithm

Analysis of the data collected for private bytes indicates that the number of private bytes used does not scale as nodes are increased. Although a curve fit of the data suggested that private bytes scaled linearly, the slope of the line was shallow enough to cast doubt whether virtual memory requirements scaled at all. Either way, it appears that the impact of adding nodes to the network is negligible in terms of the private bytes allocated to the CAULDRON process.

As the number of nodes increase on the network, a larger working set was requested by CAULDRON as shown by the graph in Figure 4-6. Although the size of CAULDRON's working set was large for this phase of the experiment, this did not cause any problems due to the combination of the large amount of physical memory present on the system, and low memory requirements of processes running concurrently. The size of the working set requested by CAULDRON appears to scale as a third order polynomial when physical memory is abundant. As the working set grows larger, and the amount of free memory decreases, it is expected that the working set would be trimmed so that the operating system can allow all services enough memory. Although this was not encountered in our tests, it is expected that performance of CAULDRON would degrade as swapping is required to bring pages in and out of secondary storage. An examination of the graph contained in Figure 4-6 shows that working set measurements obtained from network models containing a low number of nodes exhibited greater unpredictability than those containing a greater number of nodes. Since the network models containing a low number of nodes required smaller amounts of time to run, and working set measurements were completed in one second intervals, it is possible that working set measurements were taken while CAULDRON was loading and that analysis was complete before the next scheduled measurement could be obtained.

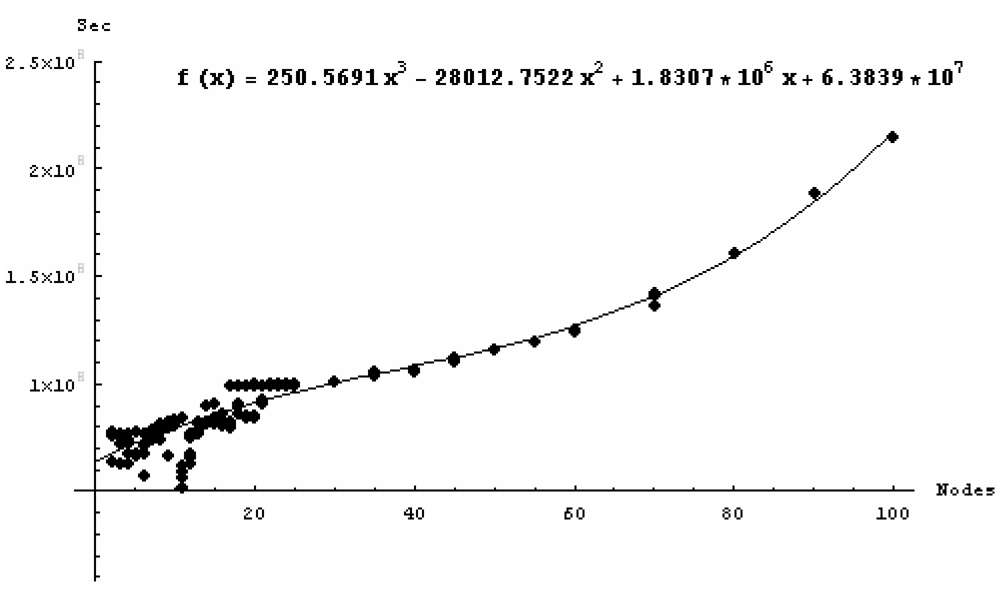

Figure 4-6. Working Set Size as Network Size Grows

2. Conclusions

The number of nodes present on a network appears to play a significant role in how well performance of CAULDRON scales. The time required to perform the forward pass of the analysis algorithm appears to be the most significant factor in the time required to complete analysis. Although the fit equation obtained was a fourth order polynomial, the higher order terms were very small, just as in the TVA experiment, the equation scaled considerably better, which is probably due to a combination of faster hardware and the use of a customized application, as an analysis engine, rather than a formal model checker.

D. PHASE IV: CONNECTIVITY

Phase IV of this experiment was conducted to measure how performance scaled on networks where the total number of nodes remained constant, but connectivity between nodes was changed. This phase was conducted using network models that consisted of 60 nodes, and varied the number of node-sets and the number of nodes per node-set such that network size remained constant, but connectivity allowed on the network was varied. This phase also had an exploit database containing 1500 unique exploit models. Each node contained one vulnerability that mapped to a unique exploit model contained in the exploit database. The attack scenario was created such that the first node was the attacker and the last node was the target. Connections between node-sets were generated at random, and multiple networks were generated in an attempt to identify characteristics of a network which impacted performance. Each test was repeated five times to reduce background noise. The data collected for this phase is contained in Appendix C Section D.

1. Observations

An examination of the data collected revealed that the forward pass algorithm required the most time during analysis to complete for each test. Although the amount of time required to analyze each network model varied, some factors appear to hold for most of the network models that were used during experimentation. The size of the node-set, the number of node-sets that are reachable, and the number of connections allowed in the model appear to have the largest effect on performance.

The size of the node-set appears to have the largest impact on the amount of time required to perform analysis. Although it is uncertain if a linear fit would always retain accuracy, Figure 4-7 shows that the amount of time required to analyze the network model appears to scale linearly as the size of the node-set grows assuming that no connections are allowed between node-sets and that the total number of nodes present on the network remains constant. Using this information, it appears that the size of the node-set belonging to the attacker has a significant effect on the amount of time required to perform analysis.

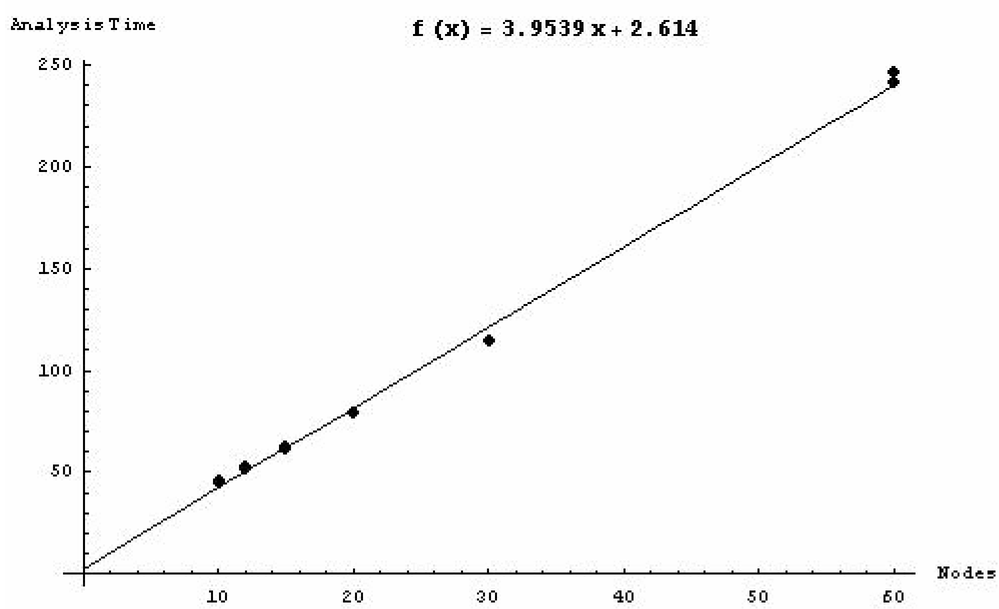

Figure 4-7. Time required to perform analysis as the attacker's node-set size increases

An examination of the network models tested and the amount of time necessary to perform analysis revealed that analysis time also depends on the number of node-sets that are reachable from the attacking node, and the number of connections present in the network model. Figure 4-7 contains a graph which depicts how performance was observed to scale as more connections were added to network models containing five node-sets containing twelve nodes apiece. Stratifications in the amount of time required to perform analysis were observed depending primarily on the number of node-sets that were reachable from the node-set containing the attacker. The lowest strata on the graph shows the amount of time required to complete analysis when no connections existed between the attacker's node-set and other node-sets, while the highest strata shows the amount of time required when the attacker is able to attack all nodes present in all node-sets.

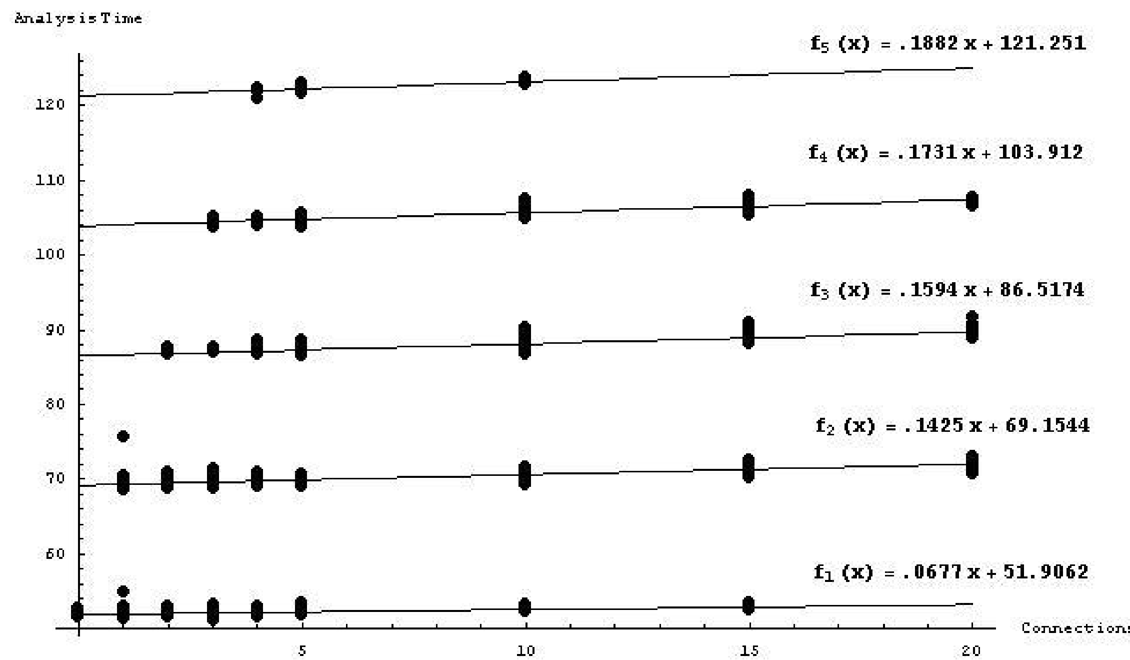

Figure 4-8. Stratifications in time required to perform analysis

By comparing analysis times collected from fully connected network models with those collected from network models which limited connectivity, it appears that the fully connected network model requires more time to analyze. While the fully connected network model containing 60 nodes required approximately 240 seconds to analyze, networks containing node-sets which constrained connectivity exhibited significantly better performance depending upon the degree of connectivity allowed between node-sets.

The amount of time required to perform the backward pass algorithm was small for all tests that were run. Although the backward pass algorithm required more time on networks in which nodes could be trimmed from the final attack graph, the amount of time required to perform this task was relatively small. The backward pass algorithm never required more than 1.1 seconds to complete on any of the network models tested in this phase of the experiment.

The time required to perform initialization, the amount of private bytes used, and size of the working set requested by CAULDRON did not appear to be significantly affected by changes to connectivity allowed on the network.

2. Conclusions

After analyzing the data, it appears that analysis time is influenced by the size of the attacker's node-set, the number of node-sets that are reachable from the attacking node, and the number of connections that are present in the network model. Although the same amount of memory is required on networks which restrict connectivity, it appears that network models which restrict connectivity require less analysis time than models which employ full connectivity, and that, like fully connected network models, the majority of analysis time is spent running the forward pass algorithm.

E. PHASE V: VULNERABILITIES PER NODE

Phase V of the experiment was conducted to measure how performance scaled as the number of vulnerabilities per node increased. This phase was conducted using a fully connected network model that consisted of 60 nodes, and varied the number of vulnerabilities present per node. This phase had an exploit database containing 1500 unique exploit models. Each node contained one or more vulnerabilities that mapped to unique exploit models contained in the exploit database. The attack scenario was identical for each test, and each test was repeated five times to account for background noise. The data collected for this phase of the experiment is contained in Appendix C Section E.

1. Observations

Curve fitting analysis of the data was conducted to determine how well performance scaled during this phase of the experiment and to examine how performance might scale if each node contained more than five vulnerabilities. The results of this analysis were then used to draw conclusions about how the number of vulnerabilities present per node in the network model affected performance.

The analysis time, total time, and forward pass time measurements appear to scale similar to one another just as in previous phases of experimentation. Each measurement appears to scale as a second order polynomial, with the amount of time required to complete the forward pass algorithm requiring the most analysis time. Figures 4-9, 4-10, and 4-11 show how the analysis, total, and forward pass time measurements scaled as well as the fit equations that were used for the data collected.

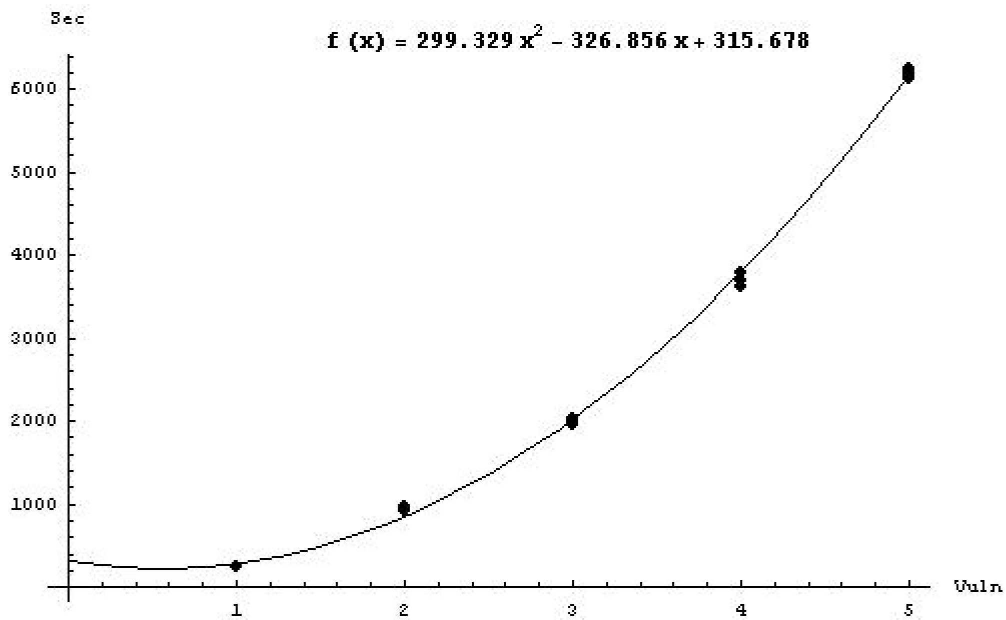

Figure 4-9. Analysis time required as the number of vulnerabilities per node scaled

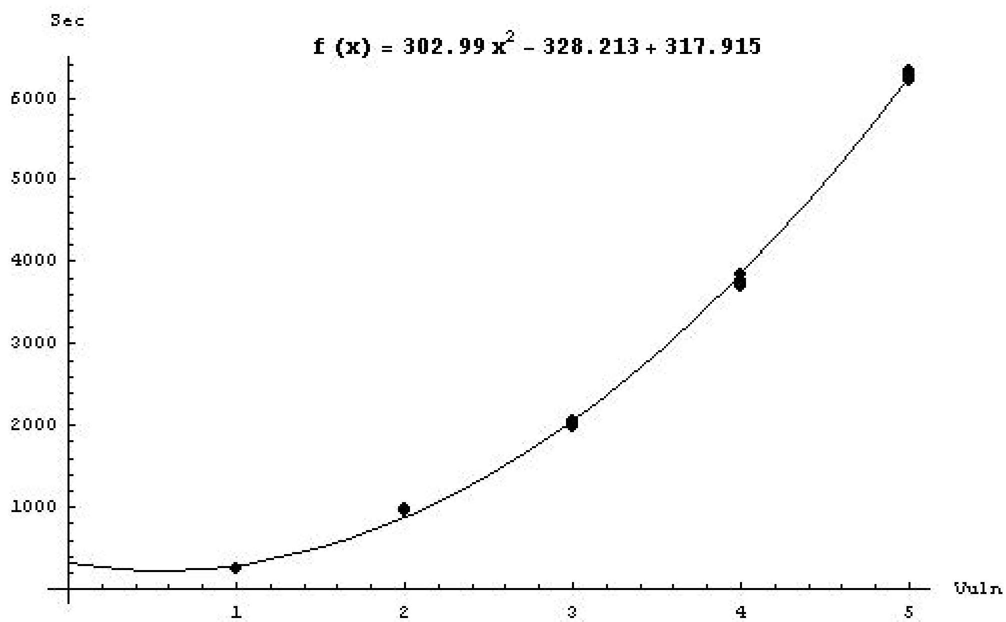

Figure 4-10. Total time to complete tests as the number of vulnerabilities per node scaled

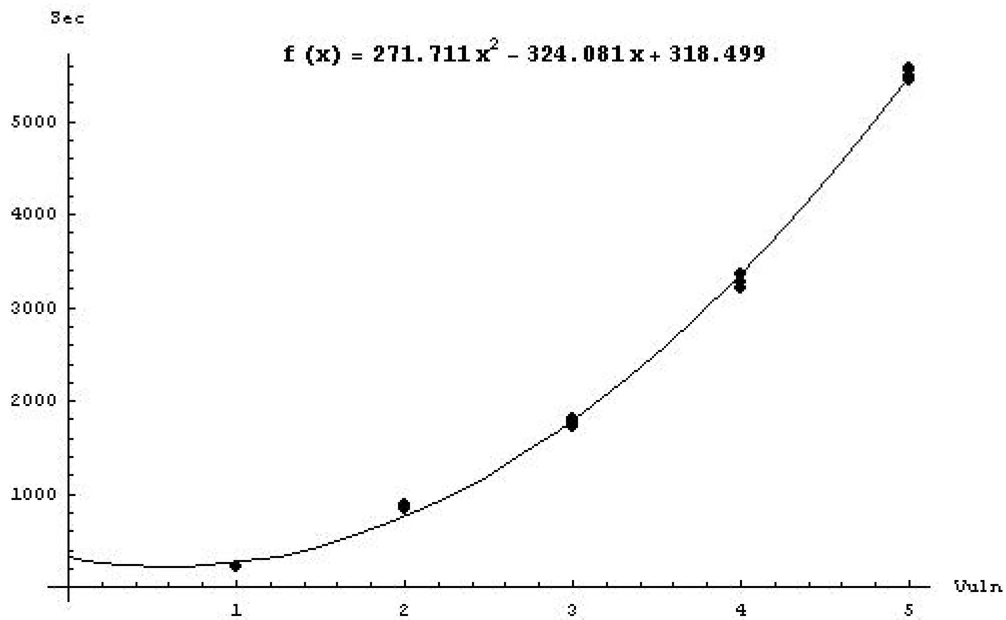

Figure 4-11. Time to complete the forward algorithm as the number of vulnerabilities per node varied

The time required to perform the backward pass algorithm was small for each test. When each node possessed one vulnerability, approximately 0.360 seconds was required to perform the backward pass algorithm, compared to approximately six seconds when each node possessed five vulnerabilities. It was unclear from the number of points that were sampled if the backward pass algorithm scaled linearly or in a higher order manner; however, in comparison to the amount of time required to execute the forward path algorithm, the amount of time required to execute the backward path algorithm seems insignificant. The small times encountered during execution were expected, since the algorithm did not need to trim nodes to form the final attack graph.

The amount of time required to perform initialization was small for each test but appeared to scale linearly with a very shallow slope, and seemed insignificant in comparison with to the amount of time required to perform the forward pass algorithm. Although the amount of time required to perform initialization did increase as more vulnerabilities were added to each node, little more than a second was required to initialize the 60 node network containing five vulnerabilities per node.

Examination of the private bytes measurements recorded during experimentation revealed that the total amount of private bytes did not seem to be affected as the number of vulnerabilities per node increased. The total size of pages belonging to the working set scaled linearly as more vulnerabilities were present per node. Although the size of the working set grew by approximately 50MB when all nodes present on the network gained an additional vulnerability, the effect exhibited on working set size seemed small when compared to prior phases of experimentation.

2. Conclusions

Although a real-world network would not likely contain such a high number of vulnerabilities per node, for all nodes present on the network, this phase of experimentation provided an indication of how performance might scale as the number of vulnerabilities per node increased. The number of vulnerabilities present per node appears to have a considerable effect on analysis time, most notably in the amount of time required to execute the forward path algorithm. The impact of multiple vulnerabilities per node on memory requirements seems small.

F. PHASE VI: EXPLOIT DATABASE

Phase VI of the experiment was conducted to measure how performance scaled as the number of exploit models contained in the exploit database increased. This phase of experimentation was conducted using a fully connected network model that consisted of 60 nodes, and varied the number of exploit models present in the exploit database. The smallest exploit database contained 1500 unique exploit models and the largest exploit database contained 31,500 unique exploit models. Each node contained a unique vulnerability that could be mapped to a unique exploit model contained in the exploit database. The attack scenario was identical for each test, and each test was repeated five times to reduce background noise. The data collected for this phase of the experiment is contained in Appendix C Section F.

1. Observations

Curve fitting analysis of the data was conducted to determine how well performance scaled as exploit models were added to the exploit database and to examine how performance might scale if more exploit models had been added to the exploit database. Observations made during analysis were then used to draw conclusions about how the number of exploit models in the exploit database affects the performance of CAULDRON.

The analysis time, total time, and forward pass time measurements appear to scale linearly as more exploit models are added to the exploit database; however, the slope was very shallow. In order to raise the total time required by one second, it was necessary to add 5000 exploits to the exploit database. Data collected appears to indicate that the number of models in the exploit seem to have a minor impact on the time required to perform the forward pass algorithm, and subsequently impact the amount of time required to run the complete analysis of the network. Figure 4-12 shows how analysis times scaled as more exploit models were added to the exploit database.

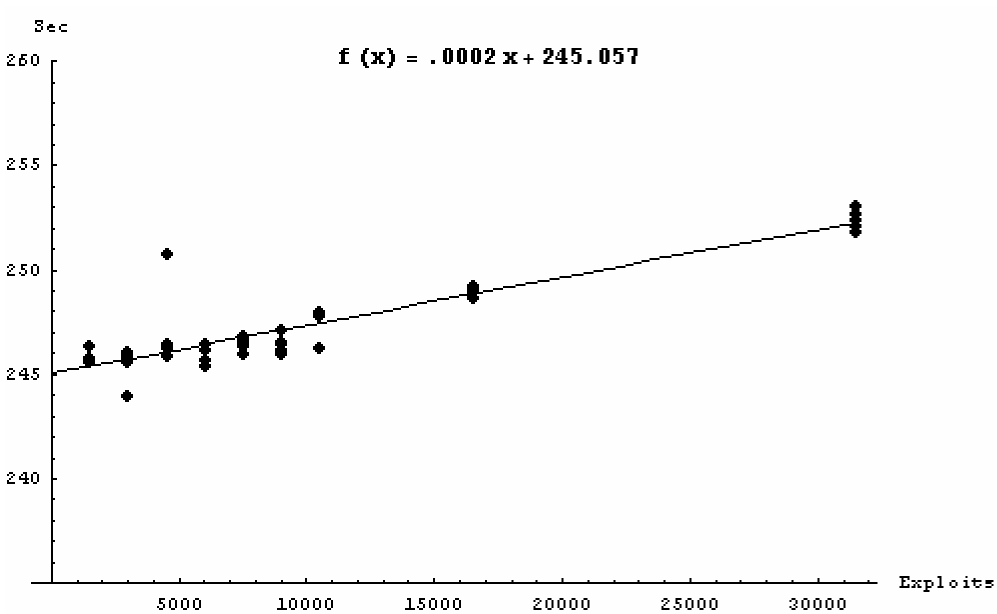

Figure 4-12.   Analysis time as the exploit models were added to the exploit database

The amount of time required to perform initialization appears to scale linearly as more exploit models are added to the exploit database. The slope appears to be approximately the same as that determined for the forward pass algorithm, analysis and total time measurements. It was expected that the amount of time required for initialization would be affected by an increase in exploit database size because analysis of the initialization function indicated that the exploit database would be examined to locate only those exploit models relevant to the network model. Figure 4-13 shows how initialization time scales as more exploit models are added to the exploit database.

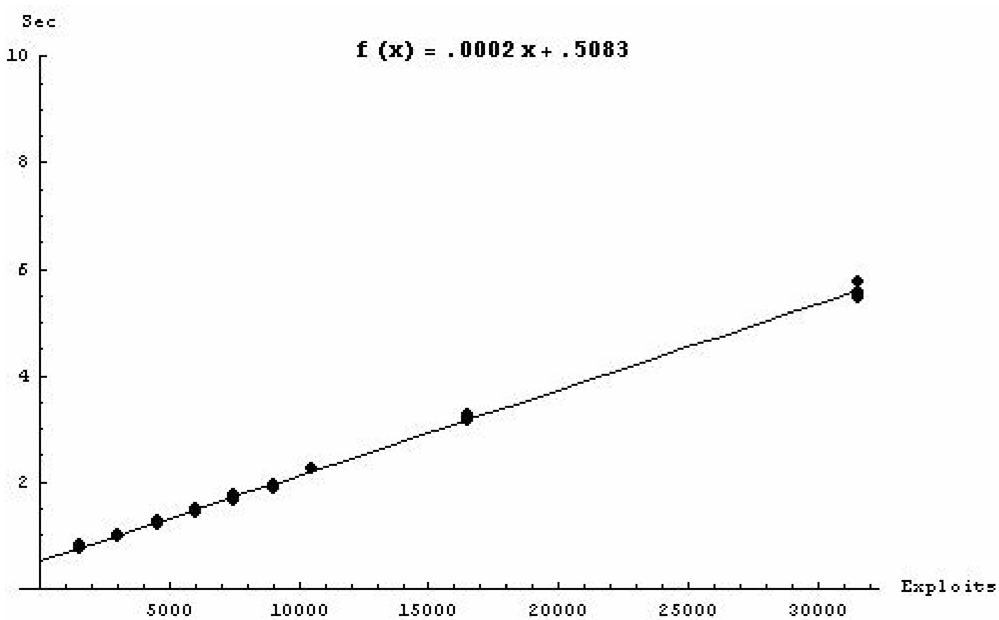

Figure 4-13. Time required to perform initialization as size of the exploit database grows

The time required to perform the backward pass algorithm, and the size of private bytes did not appear to scale as exploit models were added to the exploit database.

As a larger number of exploits are added to the exploit database, the size of the working set appeared to scale linearly with a shallow slope as exploit models are added to the exploit database, as shown in Figure 4-14. Each additional exploit added to the model appears to require approximately 1852 additional bytes of memory. Although initially, a linear fit did not seem accurate, as the exploit database grew larger, a linear fit appeared acceptable. Interestingly, the addition of 30,000 exploits to the original exploit database size of 1500 exploits only raised the working set by 60MB.

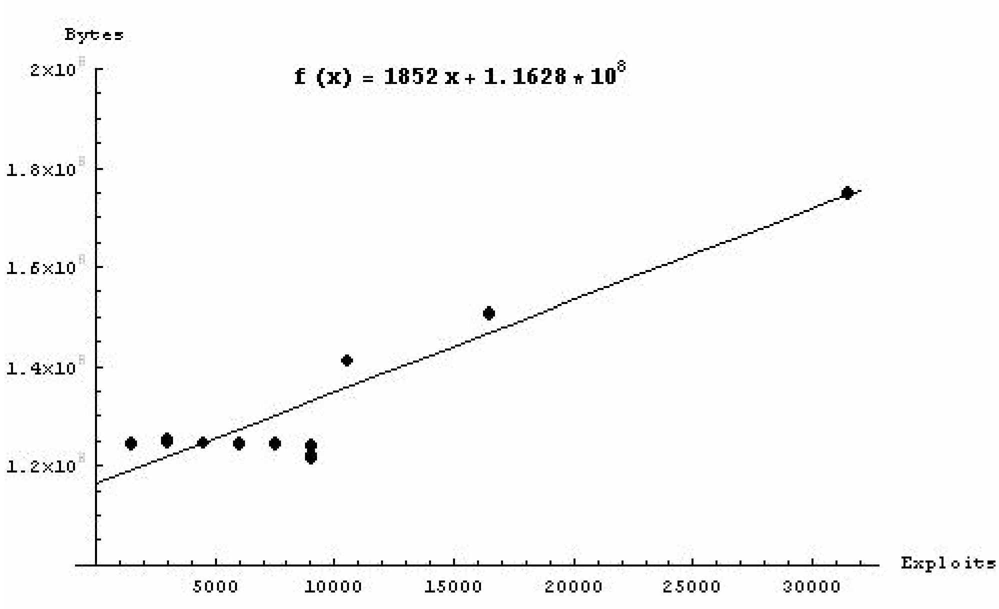

Figure 4-14. Working set size as exploits are added to the exploit database

2. Conclusions

The number of exploit models present in the exploit database does not appear to have a significant effect on the amount of time required to analyze network models or on the amount of memory needed by CAULDRON to complete these tasks. The system used during experimentation appeared to have sufficient resources to complete testing in a reasonable amount of time without causing a strain on system resources.

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V. CONCLUSION

A. SUMMARY

CAULDRON is one software solution in an emerging class of network vulnerability analysis tools that aims to assist network security efforts through automated analysis of vulnerability reports and generation of network attack graphs. CAULDRON's analysis engine requires network vulnerability scans of the target network; an exploit database, which is provided and regularly updated by researchers at GMU; and an attack scenario. By planning network vulnerability scans such that firewall rules can be captured, and by creating attack scenarios to represent possible attack launch points and possible targets on one's network, CAULDRON can generate attack graphs that depict how an attacker could systematically compromise the network to reach his attack goals. Customization options are available to allow the user to define new exploits, add custom exploit behavior, and change the behavior of the analysis engine. A survey of the domain of attack graph analysis tools examined similar research efforts and documented similarities and differences between these efforts and CAULDRON.

An experiment consisting of six phases was designed to measure time and memory consumption as changes were made to CAULDRON's inputs. A test environment was set up to run CAULDRON and collect measurements. Unnecessary services were stopped to reduce background noise, and bash scripts were used to create network models, exploit databases, and attack scenarios, as well as to control the experiment and to organize results. Modifications were made to CAULDRON's uncompiled source code to allow for additional time measurements, to help automate the experiment, and to collect results. The first phase of the experiment examined whether the size of the JVM heap affected variability in performance measurements. The second phase of the experiment was designed to measure whether modifications made to CAULDRON to support the experiment had an impact on performance. The remaining four phases of the experiment were designed to measure aspects of CAULDRON's performance using the tools created to facilitate the experiment. The third phase measured the performance impact measured by adding nodes to the network model and compared those results to those that were collected using TVA, CAULDRON's predecessor. The fourth phase measured how changes in network connectivity affected performance. Phase five varied the number of vulnerabilities per node, and the number of exploit models in the exploit database were varied in phase six.

Analysis of the results collected during experimentation showed that larger heap sizes appear to exhibit less variability than smaller heap sizes, and that changes made to CAULDRON appear to have a noticeable but small effect on performance measurements. As more nodes were added to a fully connected network model, it appeared that analysis time scaled as a fourth order polynomial with negligible fourth and third order terms and that memory usage scaled as a third order polynomial. During connectivity experiments, it was found that analysis time appeared to scale linearly when the size of the node-set containing the attacker was increased, and that the number of nodes reachable from the attacking node had a pronounced effect on the amount of time required to analyze a network, with the number of connections between nodes appearing to have a small effect on analysis time. The connectivity of the network did not appear to affect memory use. As the number of vulnerabilities per node increased, the amount of time required for analysis appeared to scale as a second order polynomial, and working set size appeared to scale linearly. Finally, the size of the exploit database did not appear to have a significant effect on analysis time, and had a small effect on the amount of memory required. For all tests, it appears that the amount of time required to perform the forward pass algorithm had the greatest influence on analysis time.

B. FUTURE WORK

Analysis of performance measurements helped determine characteristics of input models which had the most impact on performance; however, additional research questions were also raised. This section discusses future research which could be undertaken to improve performance, as well as additional analysis that could help provide more information regarding performance scalability of CAULDRON.

- Although experimentation and analysis helped to clarify which model characteristics tested had the most effect on analysis time and memory usage, all nodes in the network model possessed a unique vulnerability-exploit pair. It is uncertain how performance would have scaled if all nodes possessed the same vulnerability-exploit pair. Experiments ranging from completely heterogeneous to completely homogeneous vulnerability-exploit pairs would be informative.

- Algorithm analysis was attempted to determine whether measurements obtained agreed with observations recorded; however, this effort was abandoned due to code complexity and time constraints. An analysis effort would be useful to determine if observations agree with the algorithm, and would help explain the observed results.
- In each of the experiments, all exploit models were constructed such that the pre-conditions of an exploit consisted of a connection, an access level, a user privilege, and a vulnerability identifier. CAULDRON is capable of creating exploit models which consist of additional pre-conditions; however, it is unknown what effect the inclusion of more complex exploit models will have on performance.
- Observations from each experiment indicate that the forward pass algorithm required the most time to complete for each test. It would seem that any efforts to improve CAULDRON performance would need to focus on the efficiency of this algorithm. An analysis of the forward pass algorithm would provide insight to whether the algorithm could be improved or if a better approach exists.

C. CONCLUSION

As a result of our experiment, several conclusions were drawn using the initial questions posed in Chapter I. First, in regards to which characteristics of the data effect performance of CAULDRON, we found that the network size, degree of network connectivity, and the degree of vulnerabilities per node appear to effect performance significantly. Secondly, in regards to what functions of CAULDRON are most significantly impacted by increased load, we found that the forward pass algorithm requires the most time to analyze as the load was increased. Finally, considering that performance scaled no worse than polynomially, often with negligible higher order terms, the results of our analysis indicate that CAULDRON scales reasonably well with respect to load.

Using the results of our study, we believe that customers can gain a better understanding of CAULDRON's capabilities and limitations, while developers can gain insight into areas that may require further development. CAULDRON and the domain of network vulnerability analysis tools it represents appear to be an exciting emerging technology that can be used to analyze network security and protect network resources.

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APPENDIX A. SYSTEM CONFIGURATION

This appendix contains a list of services that were running on the test environment.

Display Name	Process Name	DEFAULT Pro	Test Environment
Alerter	svchost.exe *	Disabled *	Disabled
Application Layer Gateway Service	alg.exe	Manual	Disabled
Application Management	svchost.exe	Manual	Manual
Automatic Updates	svchost.exe	Automatic	Disabled
Background Intelligent Transfer Service	svchost.exe	Manual	Disabled
ClipBook	clipsrv.exe	Disabled *	Disabled
COM+ Event System	svchost.exe	Manual	Disabled
COM+ System Application	dllhost.exe	Manual	Disabled
Computer Browser	svchost.exe	Automatic	Disabled
Cryptographic Services	svchost.exe	Automatic	Disabled
DCOM Server Process Launcher *	svchost.exe *	Automatic *	Disabled *
DHCP Client	svchost.exe	Automatic	Disabled
Distributed Link Tracking Client	svchost.exe	Automatic	Disabled
Distributed Transaction Coordinator	msdtc.exe	Manual	Disabled
DNS Client	svchost.exe	Automatic	Disabled
Error Reporting Service	svchost.exe	Automatic	Disabled
Event Log	**services**.exe	Automatic	Automatic
Fast User Switching Compatibility	svchost.exe	Manual	Disabled
Fax Service	fxssvc.exe	Not Installed	Not Installed
FTP Publishing Service	inetinfo.exe	Not Installed	Not Installed
HTTP SSL *	svchost.exe *	Manual *	Disabled *
Help and Support	svchost.exe	Automatic	Disabled
Human Interface Device Access	svchost.exe	Disabled	Disabled
IIS Admin	inetinfo.exe	Not Installed	Not Installed
IMAPI CD-Burning COM Service	imapi.exe	Manual	Disabled
Indexing Service	cisvc.exe	Manual	Disabled
IPSEC Services	lsass.exe	Automatic	Disabled
IPv6 Helper Service *	svchost.exe *	Not Installed *	Not Installed *
Logical Disk Manager	svchost.exe	Automatic	Disabled

Display Name	Process Name	DEFAULT Pro	Test Environment
Logical Disk Manager Administrative Service	dmadmin.exe	Manual	Disabled
Message Queuing	mqsvc.exe	Not Installed	Not Installed
Message Queuing Triggers	mqtgsvc.exe	Not Installed	Not Installed
Messenger	**services**.exe	Disabled *	Disabled
MS Software Shadow Copy Provider	dllhost.exe	Manual	Disabled
Net Logon	lsass.exe	Manual *	Disabled
NetMeeting Remote Desktop Sharing	mnmsrvc.exe	Manual	Disabled
Network Connections	svchost.exe	Manual	Disabled
Network DDE	netdde.exe	Disabled *	Disabled
Network DDE DSDM	netdde.exe	Disabled *	Disabled
Network Location Awareness (NLA)	svchost.exe	Manual	Disabled
Network Provisioning Service *	svchost.exe *	Manual *	Disabled *
Peer Name Resolution *	svchost.exe *	Not Installed *	Not Installed *
Peer Networking *	svchost.exe *	Not Installed *	Not Installed *
Peer Networking Group Authentication *	svchost.exe *	Not Installed *	Not Installed *
Peer Networking Identity Manager *	svchost.exe *	Not Installed *	Not Installed *
NT LM Security Support Provider	lsass.exe	Manual	Disabled
Performance Logs and Alerts	smlogsvc.exe	Manual	Disabled
Plug and Play	**services**.exe	Automatic	Automatic
Portable Media Serial Number Service *	svchost.exe *	Manual *	Disabled
Print Spooler	spoolsv.exe	Automatic	Disabled
Protected Storage	lsass.exe	Automatic	Disabled
QoS RSVP	rsvp.exe	Manual	Disabled
Remote Access Auto Connection Manager	svchost.exe	Manual	Disabled
Remote Access Connection Manager	svchost.exe	Manual	Disabled
Remote Desktop Help Session Manager	sessmgr.exe	Manual	Disabled
Remote Procedure Call (RPC)	svchost.exe	Automatic	Automatic

Display Name	Process Name	DEFAULT Pro	Test Environment
Remote Procedure Call (RPC) Locator	locator.exe	Manual	Disabled
Remote Registry Service	svchost.exe	Automatic	Disabled
Removable Storage	svchost.exe	Manual	Disabled
RIP Listener	svchost.exe	Not Installed	Not Installed
Routing and Remote Access	svchost.exe	Disabled *	Disabled
Secondary Logon	svchost.exe	Automatic	Disabled
Security Accounts Manager	lsass.exe	Automatic	Disabled
Security Center *	svchost.exe *	Automatic *	Disabled *
Server	svchost.exe	Automatic	Disabled
Shell Hardware Detection	svchost.exe	Automatic	Disabled
Simple Mail Transport Protocol (SMTP)	inetinfo.exe	Not Installed	Not Installed
Simple TCP/IP Services	tcpsvcs.exe	Not Installed	Not Installed
Smart Card	SCardSvr.exe	Manual	Disabled
SNMP Service	snmp.exe	Not Installed	Not Installed
SNMP Trap Service	snmptrap.exe	Not Installed	Not Installed
SSDP Discovery Service	svchost.exe	Manual	Disabled
System Event Notification	svchost.exe	Automatic	Disabled
System Restore Service	svchost.exe	Automatic	Disabled
Task Scheduler	svchost.exe	Automatic	Disabled
TCP/IP NetBIOS Helper Service	svchost.exe	Automatic	Disabled
TCP/IP Printer Server	tcpsvcs.exe	Not Installed	Not Installed
Telephony	svchost.exe	Manual	Disabled
Telnet	tlntsvr.exe	Manual	Disabled
Terminal Services	svchost.exe	Manual	Disabled
Themes	svchost.exe	Automatic	Disabled
Uninterruptible Power Supply	ups.exe	Manual	Disabled
Universal Plug and Play Device Host	svchost.exe	Manual	Disabled
Volume Shadow Copy	vssvc.exe	Manual	Disabled
WebClient	svchost.exe	Automatic	Disabled
Windows Audio	svchost.exe	Automatic	Automatic
Windows Firewall / Internet Connection Sharing *	svchost.exe *	Automatic	Disabled
Windows Image Acquisition (WIA)	svchost.exe	Manual	Disabled
Windows Installer	msiexec.exe	Manual	Manual

Display Name	Process Name	DEFAULT Pro	Test Environment
Windows Management Instrumentation	svchost.exe	Automatic	Automatic
Windows Management Instrumentation Driver Extension	svchost.exe	Manual	Disabled
Windows Time	svchost.exe	Automatic	Disabled
Wireless Zero Configuration	svchost.exe	Automatic	Disabled
WMI Performance Adapter	wmiapsrv.exe	Manual	Disabled
Workstation	svchost.exe	Automatic	Automatic
World Wide Web Publishing *	inetinfo.exe *	Not Installed	Not Installed

Table A-1. Service Configuration for the test environment (After Ref. [Bla03].)

APPENDIX B. BASH SCRIPTS AND SOURCE MODIFICATIONS

This appendix contains bash scripts used during experimentation as well as changes to CAULDRON's source code. Changes to CAULDRON's source code were documented by using Cygwin's *diff* utility.

A. BASH SCRIPTS

1. Model Creation

The following scripts were used to generate input models for the experiment. The first six scripts were called from the Cygwin command line by the user. The remaining scripts were called upon by the first scripts and were not executed directly.

heapsize_setup.sh

```
./exploit_gen.sh 0 1500 > c:\/CAULDRON_topologies\exploits_1500.xml

for ((i=1;i<=5;i++))
do
  mkdir "trial_"$i
done

for ((i=1;i<=50;i++))
do
  ./experiment_setup.sh 0 1 50 0 1 $i
done
```

mod_vs_unmod_setup.sh

```
./exploit_gen.sh 0 1500 > c:\/CAULDRON_topologies\exploits_1500.xml
mkdir mod
mkdir unmod

for ((i=1; i<=5;i++))
do
  ./experiment_setup.sh 0 1 60 0 1 $i
done
```

network_size_setup.sh

```
./exploit_gen.sh 0 1500 > c:\/CAULDRON_topologies\exploits_1500.xml

for ((i=1;i<=5;i++))
do
  mkdir "trial_"$i
done
```

```
for ((i=2;i<=25;i++))
do
  ./experiment_setup.sh 0 1 $i 0 1 1
done

for ((i=30;i<=60;i+=5))
do
  ./experiment_setup.sh 0 1 $i 0 1 1
done

for ((i=70;i<=100;i+=10))
do
  ./experiment_setup.sh 0 1 $i 0 1 1
done
```

connectivity_setup.sh

```
./exploit_gen.sh 0 1500 > c:\/CAULDRON_topologies\exploits_1500.xml
for ((i=1;i<=5;i++))
do
  mkdir "trial_"$i
done

./experiment_setup.sh 0 1 60 0 1 1
./experiment_setup.sh 0 2 30 0 1 1
./experiment_setup.sh 0 3 20 0 1 1
./experiment_setup.sh 0 4 15 0 1 1
./experiment_setup.sh 0 5 12 0 1 1
./experiment_setup.sh 0 6 10 0 1 1

./experiment_setup.sh 0 5 12 1 1 50
./experiment_setup.sh 0 5 12 2 1 50
./experiment_setup.sh 0 5 12 3 1 50
./experiment_setup.sh 0 5 12 4 1 50
./experiment_setup.sh 0 5 12 5 1 50
./experiment_setup.sh 0 5 12 10 1 50
./experiment_setup.sh 0 5 12 15 1 50
./experiment_setup.sh 0 5 12 20 1 50
```

vulnerability_setup.sh

```
./exploit_gen.sh 0 1500 > c:\/CAULDRON_topologies\exploits_1500.xml
for ((i=1;i<=5;i++))
do
  mkdir "trial_"$i
done
for ((i=1;i<=5;i++))
do
  ./experiment_setup.sh 0 1 60 0 $i 1
done
```

exploit_setup.sh

```
for ((i=0;i<=9000;i+=1500))
do
  ./experiment_setup.sh $i 1 60 0 1 1
done

./experiment_setup.sh 15000 1 60 0 1 1
./experiment_setup.sh 30000 1 60 0 1 1
```

experiment_setup.sh

```
# $1 - Max number of irrelevant exploits
# $2 - Max number of sets
# $3 - Max number of nodes per set
# $4 - Max number of conns
# $5 - Max number of vulnerabilities per node
# $6 - Max number of trials

echo "$1 $2 $3 $4 $5"
for ((i=1;i<=$6;i++))
do
  ./attack_scenario_gen.sh $1 $2 $3 $4 $5 $i >
"$1""_$2""_$3""_$4""_$5""_$i"_config.xml
  ./network_gen.sh $1 $2 $3 $4 $5
   mv "$1""_$2""_$3""_$4""_$5"_x_net.xml
"$1""_$2""_$3""_$4""_$5""_$i"_net.xml
   mv "$1""_$2""_$3""_$4""_$5"_x_pairs.txt
"$1""_$2""_$3""_$4""_$5""_$i"_pairs.txt

done
```

attack_scenario_gen.sh

```
# $1 Number of irrelevant exploits
# $2 Number of sets
# $3 Number of nodes
# $4 Number of connections
# $5 Number of vulnerabilities per node
# $6 Trial #

the_path=`pwd | sed 's/\/cygdrive\/C/C:/g'`

echo -e "<?xml version=\"1.0\"?>"
echo -e "<TVAConfiguration name =\"$1_$2_$3_$4_$5_$6\" author=\"Jason
Cullum\" date_created=\"`date +\"%m/%d/%Y %T\"`\"
xmlns=\"gmu://csis.notadomain/nsTVA_CONFIG\">"
echo -e "\t<attacker mach_id=\"Node1\" access=\"execute\"
privilege=\"superuser\"/>"
echo -e "\t<goals>"
let "target=$2*$3"
echo -e "\t\t<goal mach_id=\"Node$target\" access=\"execute\"
privilege=\"superuser\"/>"
echo -e "\t</goals>"
echo -e "\t<datafiles
output_file=\"$the_path/$1_$2_$3_$4_$5_$6_out.xml\">"
```

```
echo -e
"\t\t<input_file>$the_path/$1_$2_$3_$4_$5_$6_net.xml</input_file>"
echo -e "\t</datafiles>"
echo -e "<statistics startTime=\"06/13/2004 14:49:33\"
endTime=\"06/13/2004 15:59:34\" elapsedTime=\"0.391\"
processingTime=\"0.180\"/>"
echo -e "</TVAConfiguration>"
```

connection_gen.sh

```
# $1 - Number of Sets
# $2 - Number of Nodes/Set
# $3 - Number of Connections between sets
# $4 - Number of Vulnerabilities per node

#seed the random generator
SEED=$(head -c4 /dev/urandom | OD -t u4 | awk '{print $2}')
RANDOM=$SEED

#setup a connection across sets
#choose a node that will initiate connection
for ((i=1; i<=$3; i++))
do
  #CAULDRON will not graph an attack from Target to another machine
  #for this reason, we are removing the Target machineas a possible
attacker

  #Select the node initiating connection
  fromNode=$RANDOM;let "fromNode%=($1*$2-1)"
  ((fromNode++))

  toNode=0

  while ((toNode==0))
  do
    #choose a node/vulnberability for the attacker to exploit
    vulnerability=$RANDOM

    #we want to attack any node except the attacker.
    #choose a random number between #of vulns and #sets * #nodes per
set
    let "vulnerability%=(($1*$2*$4)-$4)"
    ((vulnerability+=$4+1))

    #find which node possesses this vulnerability
    ((toNode=($vulnerability-1)/$4+1))

    #test to make sure nodes are not in same set
    ((fromSet=(($fromNode-1)/$2)+1))
    ((toSet=(($toNode-1)/$2)+1))

    #make sure that fromSet and toSet are unique, if not generate a new
toNode
    if (($fromSet==$toSet))
    then
      toNode=0
```

```
    fi

  done

  echo $fromNode,$vulnerability,$toNode

done
```

exploit_gen.sh

```
# $1 - number of irrelevant exploits/vulnerabilities
# $2 - number of relevant exploits/vulnerabilities

FILLERCOUNT=1

echo -e "<?xml version=\"1.0\" encoding=\"UTF-8\"?>"
echo -e "<exploits>"

for ((j=1;j<=$2;j++))
do
  for ((i=0;i<$1/$2;i++))
  do
    echo -e "\t<exploit name=\"Filler$FILLERCOUNT\">"
    echo -e "\t\t<preconditions>"
    echo -e "\t\t\t<access access=\"execute\" machine=\"attack\"/>"
    echo -e "\t\t\t<connection from=\"attack\" to=\"victim\">"
    echo -e "\t\t\t\t<vuln vid=\"vuln.id.Filler.$FILLERCOUNT\">"
    echo -e "\t\t\t\t\t<external_ids>"
    echo -e "\t\t\t\t\t\t<external_id source=\"ext_source\"
id=\"ext_source_filler_id.$FILLERCOUNT\"/>"
    echo -e "\t\t\t\t\t</external_ids>"
    echo -e "\t\t\t\t</vuln>"
    echo -e "\t\t\t</connection>"
    echo -e "\t\t</preconditions>"
    echo -e "\t\t<postconditions>"
    echo -e "\t\t\t<access access=\"execute\" machine=\"victim\"/>"
    echo -e "\t\t\t<privilege privilege=\"superuser\"
machine=\"victim\"/>"
    echo -e "\t\t</postconditions>"
    echo -e "\t</exploit>"
    ((FILLERCOUNT++))
  done

  echo -e "\t<exploit name=\"exploit.$j\">"
  echo -e "\t\t<preconditions>"

  echo -e "\t\t\t<access access=\"execute\" machine=\"attack\"/>"
  echo -e "\t\t\t<connection from=\"attack\" to=\"victim\">"
  echo -e "\t\t\t\t<vuln vid=\"vuln.id.$j\">"
  echo -e "\t\t\t\t\t<external_ids>"
  echo -e "\t\t\t\t\t\t<external_id source=\"ext_source\"
id=\"ext_id.$j\"/>"
  echo -e "\t\t\t\t\t</external_ids>"
  echo -e "\t\t\t\t</vuln>"
  echo -e "\t\t\t</connection>"
  echo -e "\t\t</preconditions>"
```

```
  echo -e "\t\t<postconditions>"
  echo -e "\t\t\t<access access=\"execute\" machine=\"victim\"/>"
  echo -e "\t\t\t<privilege privilege=\"superuser\"
machine=\"victim\"/>"
  echo -e "\t\t</postconditions>"
  echo -e "\t</exploit>"
done
echo -e "</exploits>"
```

network_gen.sh

```
# $1 - number of irrelevant exploits
# $2 - number of sets
# $3 - number of nodes per set
# $4 - number of connections between sets
# $5 - number of vulnerabilities per node


numPairs=0
pairs="0,0";
#echo "Generating Connection Pairs"
#Generate connection pairs (node->node+vulnerability)


((numConns =$4))
if (($numConns > ($2 * $3 - $3) * $2 * $3 * $5))
then
  ((numConns  = ($2 * $3 - $3) * $2 * $3 * $5))

fi
if (($numConns == $4))
then
while (($numPairs != $4))
do
  pairs=`./connection_gen.sh $2 $3 $4 $5 | sort -n | sed 's/$/ /g'|
uniq | tr -d "\012"`
  numPairs=`echo $pairs | wc -w`
done
fi

#echo "Connection Pairs Complete"
if ((`ls "set_$1""_$2""_$3""_0_$5"_x_net.xml | grep . -c`!=1))
then
  ./network_base_gen.sh $2 $3 $5> "set_$1""_$2""_$3""_0_$5"_x_net.xml
fi

echo $pairs > $1_$2_$3_$4_$5_x_pairs.txt

cp "set_$1""_$2""_$3""_0_$5""_x_"net.xml
"$1""_$2""_$3""_$4""_$5"_x_net.xml

if ((numConns== $4))
then

next_connection_pair=`echo $pairs | gawk '{print $1}'`
```

```
next_connection_fromNode=`echo $next_connection_pair | gawk -F, '{print
$1}'`
next_connection_toVulnerability=`echo $next_connection_pair | gawk -F,
'{print $2}'`
next_connection_toNode=`echo $next_connection_pair | gawk -F, '{print
$3}'`

((next_connection_fromNode++))

cat "$1""_$2""_$3""_$4""_$5"_x_net.xml | sed "s/$/#/g" | tr -d "\012" >
"$1""_$2""_$3""_$4""_$5"_x_temp_net.xml

mv "$1""_$2""_$3""_$4""_$5"_x_temp_net.xml
"$1""_$2""_$3""_$4""_$5"_x_net.xml

while (($numPairs!=0))
do
  cat "$1_""$2_""$3_""$4_""$5"_x_net.xml | sed
"s/<\/machine>#\t<machine
mach_id=\"Node$next_connection_fromNode\">/\t\t<connection
to_machine=\"Node$next_connection_toNode\">#\t\t\t<vuln
vid=\"vuln.id.$next_connection_toVulnerability\">#\t\t\t<external_ids>#
\t\t\t\t<external_id source=\"ext_source\"
id=\"ext_id.$next_connection_toVulnerability\"\/>#\t\t\t<\/external_ids
>#\t\t\t<\/vuln>#\t\t<\/connection>#<\/machine>#\t<machine
mach_id=\"Node$next_connection_fromNode\">/g" >
"$1""_$2""_$3""_$4""_$5"_x_temp_net.xml
  mv "$1""_$2""_$3""_$4""_$5"_x_temp_net.xml
"$1""_$2""_$3""_$4""_$5"_x_net.xml

  ((output_fromNode=$next_connection_fromNode-1))
  #((output_toNode=$next_connection_toNode-1))

  echo
$output_fromNode,$next_connection_toNode,$next_connection_toVulnerabili
ty

  pairs=`echo $pairs | sed "s/^$next_connection_pair[ ]*//g"`
  next_connection_pair=`echo $pairs | gawk '{print $1}'`
  next_connection_fromNode=`echo $next_connection_pair | gawk -F,
'{print $1}'`
  next_connection_toVulnerability=`echo $next_connection_pair | gawk -
F, '{print $2}'`
  next_connection_toNode=`echo $next_connection_pair | gawk -F, '{print
$3}'`


  ((next_connection_fromNode++))
  ((numPairs--))
done

cat "$1""_$2""_$3""_$4""_$5"_x_net.xml | sed "s/#/\n/g" >
"$1""_$2""_$3""_$4""_$5"_x_temp_net.xml
```

```
mv "$1""_$2""_$3""_$4""_$5"_x_temp_net.xml
"$1""_$2""_$3""_$4""_$5"_x_net.xml

fi
```

network_base_gen.sh

```
# $1 - number of sets
# $2 - number of nodes per set
# $3 - number of vulnerabilities per node

echo -e "<?xml version=\"1.0\"?>"
echo -e "<network>"
for ((i=1;i<=$1;i++))
do
  for ((j=1;j<=$2;j++))
  do
    let "fromNode=$j+($i-1)*$2"
    echo -e "\t<machine mach_id=\"Node$fromNode\">"

    for ((k=1;k<=$2;k++))
    do

      let "toNode=$k+($i-1)*$2"
      echo -e "\t\t<connection to_machine=\"Node$toNode\">"

      for ((l=1;l<=$3;l++))
      do
        ((vuln_id=($toNode-1)*$3+$l))
        echo -e "\t\t\t<vuln vid=\"vuln.id.$vuln_id\">"
        echo -e "\t\t\t<external_ids>"
        echo -e "\t\t\t\t<external_id source=\"ext_source\"
id=\"ext_id.$vuln_id\"/>"
        echo -e "\t\t\t</external_ids>"
        echo -e "\t\t\t</vuln>"

      done

      echo -e "\t\t</connection>"
    done

    echo -e "\t</machine>"
  done

done
echo -e "</network>"
```

2. Experiment Automation

The following scripts were used to automate the experiment. Each script was called by the user from the Cygwin command line.

automate_heapsize.sh

```
cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
"s/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\exploits_1500
.xml/g" > c:/progra~1/modified_CAULDRON/lib/tva.tmp
    mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties


for ((i=128;i<=1024;i+=128))
do
  #set the start/max heapsize
  echo "-Xms"$i"M" >
c:/progra~1/modified_CAULDRON/cauldron.exe.vmoptions
  echo "-Xmx"$i"M" >>
c:/progra~1/modified_CAULDRON/cauldron.exe.vmoptions

  for ((j=1;j<=50;j++))
  do
    echo "Heapsize $i:Test $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/baseline/heap_size/0_1_50_0_1_$j""_config.xml"
  done

  mv *out* ./trial_$i/
done
```

automate_mod.sh

```
cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
"s/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\exploits_1500
.xml/g" > c:/progra~1/modified_CAULDRON/lib/tva.tmp
    mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties

for ((i=1;i<=5;i++))
do
  echo "Run $i"
  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/mod_vs_unmod/0_1_60_0_1_$i""_config.xml"

done
  mv *out* ./mod/
```

automate_network_size.sh

```
cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
"s/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\exploits_1500
.xml/g" > c:/progra~1/modified_CAULDRON/lib/tva.tmp
    mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties

for ((i=1;i<=5;i++))
do
  for ((j=2;j<=25;j++))
  do
    echo "$i:Trial 0_1_$j""_0_1_1"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/1_set_scaling/0_1_$j""_0_1_1_config.xml"
  done

  for ((j=30;j<=60;j+=5))
  do
    echo "$i:Trial 0_1_$j""_0_1_1"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/1_set_scaling/0_1_$j""_0_1_1_config.xml"
  done

  for ((j=70;j<=100;j+=10))
  do
    echo "$i:Trial 0_1_$j""_0_1_1"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/1_set_scaling/0_1_$j""_0_1_1_config.xml"
  done

  mv *out* ./trial_$i/
done
```

automate_connectivity.sh

```
cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
"s/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\exploits_1500
.xml/g" > c:/progra~1/modified_CAULDRON/lib/tva.tmp
    mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties

for ((i=1;i<=5;i++))
do
  echo "Run $i"
  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/0_conn/0_1_60_0_1_1_config.xml"
  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/0_conn/0_2_30_0_1_1_config.xml"
  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/0_conn/0_3_20_0_1_1_config.xml"
  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/0_conn/0_4_15_0_1_1_config.xml"
  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/0_conn/0_5_12_0_1_1_config.xml"
  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/0_conn/0_6_10_0_1_1_config.xml"
```

```
  mv *out* ./trial_$i/
done

for ((i=1;i<=5;i++))
do
  echo "$i:Trial 0_5_12_1_1"
  for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_1_$j""_config.x
ml"
  done

  for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_2_$j""_config.x
ml"
  done

for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_3_$j""_config.x
ml"
  done

for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_4_$j""_config.x
ml"
  done


for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_5_$j""_config.x
ml"
  done
```

```
for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_10_$j""_config.
xml"
  done


for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_15_$j""_config.
xml"
  done


for ((j=1;j<=50;j++))
  do
    echo "Variant $j"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/60_node_network/1_conn/0_5_12_1_20_$j""_config.
xml"
  done


  mv *out* ./trial_$i/
done
```

automate_vulnerability.sh

```
cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
"s/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\exploits_1500
.xml/g" > c:/progra~1/modified_CAULDRON/lib/tva.tmp
    mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties

for ((i=1;i<=5;i++))
do
  for ((j=1;j<=5;j++))
  do
    echo "$i:Trial 0_1_60_0_$j""_1"
    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/vulnerabilities/0_1_60_0_$j""_1_config.xml"
  done

  mv *out* ./trial_$i/
done
```

automate_exploit.sh

```
for ((i=1;i<=5;i++))
do
  for ((j=0;j<=9000;j+=1500))
  do
    echo "$i:Trial $j"
    cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
"s/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\/exploit_db\/
exploits_$j"".xml/g" > c:/progra~1/modified_CAULDRON/lib/tva.tmp
    mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties

    c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/exploit_db/$j""_1_60_0_1_1_config.xml"
  done

  echo "$i:Trial 15000"
  cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
's/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\/exploit_db\/
exploits_15000.xml/g' > c:/progra~1/modified_CAULDRON/lib/tva.tmp
  mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties

  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/exploit_db/15000_1_60_0_1_1_config.xml"

  echo "$i:Trial 30000"
  cat c:/progra~1/modified_CAULDRON/lib/tva.properties | sed
's/^EXPLOIT_FILE=.*$/EXPLOIT_FILE=c:\/CAULDRON_topologies\/exploit_db\/
exploits_30000.xml/g' > c:/progra~1/modified_CAULDRON/lib/tva.tmp
  mv c:/progra~1/modified_CAULDRON/lib/tva.tmp
c:/progra~1/modified_CAULDRON/lib/tva.properties

  c:/progra~1/modified_CAULDRON/CAULDRON.exe
"c:/CAULDRON_topologies/exploit_db/30000_1_60_0_1_1_config.xml"

  mv *out* ./trial_$i/
done
```

3. Data collection

The last script was used to automate the collection of data. Each script was called by the user from the Cygwin command line.

merge.sh

```
# $1 Performance Monitor Log

# Remove blank lines from performance log
cat $1 | sed 's/^\"(PDH.*$//g' | sed 's/^.*" "$//g' | grep "^\".*" >
temp_log.csv

exec < temp_log.csv

read line
```

```
((old_pid=`echo $line | gawk -F"\",\"" '{print $3}'`))
time=`echo $line | gawk -F"\"" '{print $2}'`

((new_pid=-1))
((max_private_bytes=0))
((max_working_set=0))
while read line
do
  ((new_pid=`echo $line | gawk -F"\",\"" '{print $3}'`))
  ((private_bytes=`echo $line | gawk -F"\",\"" '{print $4}'`))
  ((working_set=`echo $line | gawk -F"\",\"" '{print $5}' | egrep -o -e
"[0-9]+"`))

  if (($old_pid == $new_pid && $private_bytes > $max_private_bytes))
  then
    ((max_private_bytes=$private_bytes))
  fi

  if (($old_pid == $new_pid && $working_set > $max_working_set))
  then
    ((max_working_set=$working_set))
  fi

  if (($old_pid != $new_pid))
  then
    echo $time,$old_pid,$max_private_bytes,$max_working_set >>
perfmon_results.txt
    ((old_pid=$new_pid))
    ((max_private_bytes=$private_bytes))
    ((max_working_set=$working_set))
    time=`echo $line | gawk -F"\"" '{print $2}'`
  fi
done

echo $time,$old_pid,$max_private_bytes,$max_working_set >>
perfmon_results.txt



ls `find | grep out` -1 -t -r > list.txt
exec < list.txt
while read line
do
cat $line | grep "\/Summary" | gawk -F" " '{print
$4":"$5":"$6":"$7":"$8":"$9}' | gawk -F":" '{print
$2","$4","$6","$8","$10","$12","$14}' | sed 's/<\/Summary>,//g' >>
cauldron_results.txt
done

counter=1
exec < cauldron_results.txt
while read line
do
  perfmon_line=`grep -n . perfmon_results.txt | grep "^$counter:" | sed
"s/^$counter://g"`
```

```
  echo $line,$perfmon_line >> outfile.csv
  ((counter++))
done
```

B. CAULDRON SOURCE CODE

cauldron_tree/tva/src/java/org/csis/tva/gui/Gui.java

```
4,7d3
> import javax.swing.JInternalFrame;
> import java.io.File;
> import java.lang.Boolean;
> import org.csis.tva.gui.context.tva.TVAContext;
18,22d13
>     File cl_file = null;
>     if (args.length > 0)
>     {
>       cl_file = new File(args[0]);
>     }
29,62d19
>
>
>     if (cl_file != null)
>     {
>       TVAContext context = new TVAContext(cl_file);
>       context._clFileUsed=true;
>       context.apaStart();
>      }
>
```

cauldron_tree/tva/src/java/org/csis/tva/gui/context/TVAContext.java

```
26a27,28
> import java.lang.Boolean;
>
149a152,153
>   public Boolean _clFileUsed = false;
>
535a540,542
>
>     if (_clFileUsed == true)
>       System.exit(0);
```

cauldron_tree/tva/src/java/org/csis/tva/model/TVAConfig.java

```
40c40,49
<
---
>
>     protected long _startInitTime;
>     protected long _endInitTime;
>
>     protected long _startForwardTime;
>     protected long _endForwardTime;
>
>     protected long _startReverseTime;
>     protected long _endReverseTime;
>
```

```
97a107,118
>
>     _startInitTime = System.currentTimeMillis();
>     _endInitTime = System.currentTimeMillis();
>
>
>     _startForwardTime = System.currentTimeMillis();
>     _endForwardTime = System.currentTimeMillis();
>
>     _startReverseTime = System.currentTimeMillis();
>     _endReverseTime = System.currentTimeMillis();
>
>
256a278,288
>     public void setStartInitTime(long start){ _startInitTime = start;
}
>     public void setEndInitTime(long end){ _endInitTime = end; }
>
>
>     public void setStartForwardTime(long start){ _startForwardTime =
start; }
>     public void setEndForwardTime(long end){ _endForwardTime = end; }
>
>     public void setStartReverseTime(long start){ _startReverseTime =
start; }
>     public void setEndReverseTime(long end){ _endReverseTime = end; }
>
>
265a298,300
>     public long queryElapsedInitTime(){ return _endInitTime -
_startInitTime; }
>     public long queryElapsedForwardTime(){ return _endForwardTime -
_startForwardTime; }
>     public long queryElapsedReverseTime(){ return _endReverseTime -
_startReverseTime; }
```

cauldron_tree/tva/src/java/org/csis/tva/AttackPathAnalyzer/AttackPathAnalyzer.java

```
9a10
> import java.io.*;
88a90,91
>     _config.setStartInitTime(System.currentTimeMillis());
>
103a107,109
>
>     _config.setEndInitTime(System.currentTimeMillis());
>
161a168
>         _config.setStartForwardTime(System.currentTimeMillis());
163a171
>         _config.setEndForwardTime(System.currentTimeMillis());
170a179,180
>
>         _config.setStartReverseTime(System.currentTimeMillis());
172a183
```

```
>          _config.setEndReverseTime(System.currentTimeMillis());
176a188
>
177a190,191
>
>
183a198,199
>
>          _config.setStartForwardTime(System.currentTimeMillis());
185a202
>          _config.setEndForwardTime(System.currentTimeMillis());
192a210
>          _config.setStartReverseTime(System.currentTimeMillis());
194a213
>          _config.setEndReverseTime(System.currentTimeMillis());
203a223
>
574a595,597
>
>
>
950a974,982
>        Runtime rt = Runtime.getRuntime();
>        String command[] = {"sh","-c","ps -W | grep -i cauldron | gawk
'{print $4}'"};
>        Process proc = rt.exec(command);
>
>        InputStreamReader isr = new
InputStreamReader(proc.getInputStream());
>        BufferedReader    br  = new BufferedReader(isr);
>
>        String pid = br.readLine();
>
959c991,999
<            + (_config.queryElapsedTime() / 1000.0));
---
>            + (_config.queryElapsedTime() / 1000.0)
>            + "  ForwardTraversal:"
>            + (_config.queryElapsedForwardTime() / 1000.0)
>            + "  BackwardTraversal:"
>            + (_config.queryElapsedReverseTime() / 1000.0)
>            + "  ProcessID:"
>            + pid
>            + "  InitializationTime:"
>            + (_config.queryElapsedInitTime() / 1000.0));
```

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APPENDIX C. EXPERIMENT DATA

A. HEAP SIZE

This section contains data collected during Phase I of the experiment.

128 MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
97.297	100.031	86.25	0.203	0.719	164597760	65785856
96.781	99.469	86.125	0.219	0.704	164622336	65626112
97.031	99.75	85.985	0.219	0.703	164556800	65626112
97.172	99.891	86.157	0.218	0.719	164675584	65785856
97.266	99.969	86.234	0.219	0.703	164585472	65744896
97.343	100.063	86.329	0.218	0.735	164610048	65667072
97.234	99.953	86.187	0.219	0.719	164573184	65650688
99.921	102.672	88.844	0.218	0.719	164642816	68288512
97.484	100.391	86.375	0.219	0.719	164634624	65712128
97.125	99.843	86.157	0.218	0.703	164601856	65699840
97.204	99.938	86.156	0.219	0.703	164605952	65744896
97.469	100.188	86.453	0.218	0.719	164638720	65638400
97.437	100.125	86.437	0.203	0.687	164671488	65773568
97.609	100.328	86.485	0.219	0.703	164585472	65499136
97.156	99.906	86.109	0.219	0.734	164655104	65765376
97.203	99.922	86.187	0.204	0.719	164638720	65654784
97.469	100.203	86.234	0.219	0.703	164601856	65642496
97.36	100.062	86.313	0.218	0.703	164597760	65609728
97.406	100.141	86.328	0.219	0.719	164601856	65662976
97.265	99.969	86.219	0.203	0.719	164704256	68370432
97.328	100.016	86.297	0.219	0.704	164675584	65826816
97.234	99.938	86.187	0.219	0.719	164589568	65622016
97.172	99.875	86.141	0.203	0.703	164700160	65658880
97.328	100.063	86.297	0.218	0.719	164646912	65765376
97.36	100.079	86.328	0.219	0.704	164618240	65765376
97.078	99.813	86.11	0.218	0.719	164597760	65732608
97.485	100.188	86.437	0.219	0.703	164589568	65613824
97.391	100.094	86.328	0.219	0.719	164589568	65695744
97.297	100.015	86.453	0.219	0.718	164659200	65720320
97.422	100.125	86.406	0.219	0.719	164642816	65830912
97.094	99.812	86.063	0.203	0.718	164610048	65638400
100.532	103.234	89.469	0.203	0.718	164691968	68329472
97.125	99.828	86.125	0.219	0.719	164597760	65691648
101.188	103.906	90.078	0.219	0.718	164581376	68272128
101.265	103.984	90.156	0.219	0.719	164548608	68202496
97.141	99.89	86.094	0.218	0.718	164618240	65720320
97.156	99.86	86.188	0.203	0.704	164597760	65761280
97.062	99.781	86.156	0.219	0.719	164589568	65691648

97.187	99.891	86.141	0.219	0.719	164663296	65662976
97.469	100.172	86.406	0.219	0.718	164589568	65609728
97.344	100.125	86.344	0.218	0.719	164655104	65646592
100.281	103.203	89.234	0.219	0.719	164585472	65630208
97.078	99.781	86.063	0.219	0.703	164548608	65691648
100.828	103.578	89.75	0.219	0.735	164593664	68280320
100.984	103.813	89.875	0.219	0.719	164593664	68427776
97.203	99.937	86.187	0.219	0.734	164605952	65593344
97.469	100.172	86.438	0.203	0.703	164601856	65691648
100.093	102.812	89.062	0.204	0.719	164667392	68308992
97.672	100.407	86.64	0.219	0.719	164638720	65564672
97.234	99.953	86.188	0.219	0.719	164597760	65757184

Table B-1. Performance measurements with a 128MB Heap.

256 MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
101.093	104.063	89.828	0.234	0.735	299560960	76484608
99.922	102.64	88.969	0.218	0.718	299556864	76484608
98.172	100.859	87.203	0.218	0.703	299589632	76394496
97.187	99.86	86.25	0.204	0.688	299511808	73875456
97.297	99.985	86.281	0.219	0.687	299511808	74006528
100.5	103.219	89.469	0.203	0.719	299544576	76435456
96.843	99.531	86	0.219	0.688	299499520	73842688
100.437	103.141	89.531	0.219	0.719	299552768	76357632
96.781	99.454	85.937	0.219	0.688	299520000	73814016
98.172	100.89	87.172	0.219	0.734	299614208	76480512
96.891	99.578	86.078	0.203	0.687	299503616	73805824
100.313	103.016	89.328	0.219	0.719	299552768	76365824
97.204	99.906	86.281	0.219	0.718	299483136	76308480
99.703	102.375	88.797	0.219	0.703	299495424	76382208
100.265	102.953	89.25	0.219	0.703	299560960	76492800
97.188	99.843	86.25	0.219	0.687	299446272	73728000
97.015	99.719	86.453	0.218	0.719	299470848	73793536
97.875	100.594	86.937	0.219	0.719	299556864	76386304
100.187	102.89	89.219	0.219	0.703	299610112	76451840
100.89	103.578	89.969	0.219	0.719	299581440	76349440
100.312	103.234	89.485	0.219	0.719	299560960	76361728
97.812	100.5	86.875	0.203	0.719	299569152	76259328
98.468	101.14	87.437	0.219	0.703	299663360	76500992
99.266	101.984	88.265	0.219	0.718	299552768	76468224
97.062	99.719	86.109	0.219	0.688	299466752	73846784
100.437	103.125	89.375	0.218	0.719	299593728	76443648
97.109	99.781	86.172	0.219	0.671	299503616	73760768
100.328	103.063	89.375	0.203	0.735	299560960	76390400
102.391	105.109	91.453	0.219	0.718	299520000	76443648
97.937	100.75	86.984	0.203	0.703	299560960	76439552
99.984	102.687	89.016	0.218	0.719	299548672	76308480

98.766	101.453	87.782	0.203	0.703	299552768	76394496
97.968	100.765	86.875	0.219	0.719	299503616	76464128
97.281	99.984	86.312	0.203	0.703	299511808	73920512
97.984	100.687	87.032	0.203	0.703	299577344	76357632
98.453	101.141	87.484	0.219	0.719	299581440	76369920
97.234	99.921	86.281	0.203	0.687	299470848	73936896
97.75	100.453	86.735	0.218	0.718	299556864	76218368
96.75	99.422	85.938	0.203	0.687	299458560	73760768
98.032	100.719	87.063	0.218	0.703	299569152	76505088
98.297	101	87.296	0.219	0.719	299565056	76394496
98.313	101.016	87.36	0.219	0.719	299548672	76361728
97.079	99.75	86.156	0.204	0.672	299524096	73863168
97.984	100.937	87.094	0.203	0.719	299552768	76390400
100.312	103.031	89.281	0.203	0.719	299466752	76398592
100.406	103.078	89.11	0.218	0.703	299569152	76378112
97.031	99.703	86.062	0.219	0.672	299528192	73969664
97.953	100.656	87.015	0.219	0.719	299540480	76349440
100.235	102.938	89.422	0.219	0.719	299577344	76447744
100.016	102.703	89.015	0.219	0.703	299548672	76390400

Table B-2. Performance measurements with a 256MB Heap.

384 MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
97.438	100.187	86.344	0.219	0.718	434688000	86048768
98.469	101.157	87.61	0.218	0.703	434622464	85831680
97.141	99.844	86.297	0.219	0.703	434618368	85979136
97.313	100.031	86.453	0.219	0.734	434626560	86061056
97.266	100.015	86.375	0.219	0.718	434565120	86155264
97.188	99.891	86.344	0.203	0.703	434692096	85430272
97.437	100.125	86.563	0.219	0.704	434708480	85856256
97.265	99.984	86.375	0.234	0.719	434634752	86134784
97.922	100.641	87.032	0.234	0.734	434765824	86085632
97.219	99.953	86.36	0.218	0.718	434679808	86552576
97.078	99.797	86.11	0.265	0.718	434704384	86130688
97.031	99.718	86.156	0.234	0.703	434638848	85872640
97.11	99.812	86.235	0.218	0.718	434671616	86106112
97.062	99.828	86.235	0.234	0.75	434704384	85209088
97.078	99.797	86.171	0.219	0.719	434683904	85843968
100.188	102.875	89.328	0.219	0.703	434704384	86220800
97.391	100.094	86.437	0.219	0.719	434601984	86020096
97.078	100.016	86.234	0.219	0.719	434720768	85995520
97	99.735	86.141	0.219	0.735	434614272	85786624
97.063	99.75	86.156	0.219	0.703	434651136	86147072
97.594	100.297	86.75	0.218	0.719	434585600	85512192
97.109	99.829	86.235	0.218	0.704	434692096	86192128
98.094	100.844	87.203	0.218	0.75	434655232	85831680
97.265	99.984	86.407	0.218	0.719	434683904	85606400

97.282	99.969	86.359	0.219	0.703	434765824	86126592
97.375	100.156	86.515	0.219	0.734	434634752	85839872
97.219	99.89	86.328	0.203	0.703	434626560	86188032
99.718	102.406	88.891	0.219	0.703	434683904	85786624
99.812	102.562	88.89	0.235	0.75	434634752	85721088
97.204	99.953	86.328	0.219	0.703	434647040	86142976
97.187	99.922	86.312	0.219	0.719	434606080	86208512
97.094	100.016	86.219	0.234	0.719	434630656	85774336
97.297	100	86.453	0.219	0.703	434700288	85889024
97.422	100.141	86.546	0.219	0.735	434675712	85893120
96.937	99.657	86.016	0.219	0.704	434630656	86339584
97.266	99.953	86.343	0.219	0.703	434634752	86155264
97.328	100.047	86.469	0.219	0.704	434683904	85966848
97.453	100.14	86.579	0.218	0.703	434585600	86183936
97.313	100.047	86.5	0.219	0.734	434647040	85790720
97.312	100	86.469	0.203	0.703	434622464	86212608
97.422	100.11	86.516	0.218	0.703	434647040	85811200
97.766	100.484	86.86	0.234	0.734	434659328	85549056
97.563	100.281	86.703	0.219	0.718	434675712	85512192
97.234	99.937	86.359	0.219	0.703	434745344	86294528
97.297	100.016	86.438	0.234	0.719	434593792	85856256
97.172	99.875	86.235	0.234	0.703	434618368	86188032
97.328	100.203	86.438	0.234	0.765	434589696	85925888
97.36	100.063	86.5	0.219	0.703	434638848	85737472
97.047	99.75	86.219	0.203	0.687	434655232	86286336
97.156	99.907	86.265	0.219	0.75	434638848	85684224

Table B-3. Performance measurements with a 384MB Heap.

512 MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
97.391	100.156	86.407	0.203	0.718	569663488	95174656
97.344	100.078	86.5	0.219	0.703	569700352	97841152
99.438	102.172	87.547	0.266	0.703	569561088	97734656
97.688	100.406	86.843	0.219	0.703	569606144	97591296
97.203	99.954	86.297	0.234	0.704	569663488	95170560
97.797	100.703	86.969	0.219	0.687	569602048	97759232
97.891	100.625	87.094	0.203	0.703	569663488	97837056
97.828	100.547	86.984	0.219	0.703	569606144	97583104
101.047	103.75	89.375	0.25	0.703	569671680	97890304
97.312	100.031	86.484	0.219	0.687	569606144	97902592
97.609	100.328	86.766	0.218	0.687	569602048	97869824
97.86	100.594	87.125	0.219	0.703	569610240	97542144
97.578	100.297	86.75	0.203	0.719	569667584	97722368
97.844	100.578	87.078	0.234	0.703	569626624	97521664
97.766	100.453	86.906	0.219	0.687	569737216	97644544
98.562	101.281	87.75	0.218	0.703	569614336	97759232
97.75	100.469	86.891	0.218	0.703	569667584	97783808

98.672	101.484	87.875	0.219	0.719	569618432	97824768
97.703	100.422	86.843	0.219	0.704	569618432	97632256
97.704	100.422	86.86	0.219	0.703	569606144	97759232
97.938	100.64	87.078	0.219	0.687	569573376	97751040
96.953	99.671	86.125	0.219	0.703	569700352	95170560
98.235	100.953	87.422	0.219	0.687	569614336	97841152
98.015	100.765	87.203	0.219	0.703	569606144	97890304
97.438	100.125	86.594	0.234	0.687	569708544	97759232
97.609	100.328	86.781	0.203	0.687	569663488	97918976
97.484	100.187	86.641	0.203	0.703	569659392	97828864
97.375	100.094	86.813	0.219	0.703	569577472	97894400
97.156	99.86	86.563	0.203	0.704	569655296	95182848
97.828	100.578	87	0.219	0.703	569614336	97546240
97.516	100.234	86.672	0.219	0.688	569659392	97935360
97.922	100.656	87.219	0.218	0.703	569602048	97775616
97.703	100.453	86.906	0.219	0.688	569716736	97841152
97.953	100.891	87.14	0.219	0.703	569659392	97837056
97.61	100.328	86.813	0.219	0.703	569659392	97673216
97.735	100.469	87.047	0.219	0.703	569602048	97624064
97.984	100.687	87.172	0.203	0.687	569729024	97988608
97.812	100.563	87.078	0.25	0.704	569597952	97685504
97.828	100.563	87.109	0.219	0.688	569614336	97546240
97.953	100.657	87.203	0.218	0.688	569630720	97918976
97.844	100.578	87.016	0.203	0.688	569655296	97517568
98.719	101.438	87.891	0.219	0.703	569622528	97783808
97.297	100.016	86.5	0.219	0.687	569671680	97792000
98.515	101.265	87.687	0.219	0.703	569602048	97792000
97.5	100.187	86.718	0.204	0.687	569651200	97746944
98.063	100.781	87.344	0.218	0.687	569618432	97767424
97.265	100.141	86.422	0.219	0.704	569651200	95203328
97.781	100.485	86.921	0.219	0.688	569618432	97628160
97.547	100.25	86.703	0.218	0.703	569675776	97972224
98.468	101.203	87.765	0.203	0.688	569610240	97886208

Table B-4. Performance measurements with a 512MB Heap.

640MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
100.843	103.797	89.985	0.203	0.766	701890560	107241472
101.765	104.531	90.921	0.204	0.735	701960192	107032576
102.125	104.891	91.546	0.204	0.719	701894656	107278336
101.563	104.328	90.734	0.203	0.734	701931520	107417600
102.234	105.016	91.313	0.203	0.735	701927424	107438080
101.109	103.891	90.297	0.203	0.735	701857792	107356160
100.11	102.875	89.546	0.204	0.734	701865984	107429888
102.609	105.407	91.797	0.203	0.735	701972480	107483136
101.531	104.313	90.704	0.218	0.75	701984768	107503616
102.031	104.828	91	0.203	0.75	702005248	107544576

109.86	112.641	99	0.203	0.719	701911040	107298816
102.062	104.844	91.25	0.203	0.719	701960192	107302912
102.016	104.766	91.156	0.219	0.734	701947904	107335680
102.203	105	91.375	0.203	0.734	701906944	107384832
102.938	105.719	92.109	0.203	0.719	701960192	107044864
101.578	104.344	90.671	0.235	0.734	701865984	107376640
99.578	102.359	88.765	0.219	0.734	701874176	107442176
101.406	104.188	90.625	0.219	0.719	702005248	107356160
101.188	103.969	90.625	0.204	0.75	701976576	107311104
100.265	103.032	89.438	0.203	0.735	701820928	107401216
101.968	104.735	91.125	0.234	0.735	701865984	107290624
102.282	105.078	91.453	0.203	0.734	701956096	107339776
101.734	104.516	91.094	0.203	0.735	701902848	107216896
101.593	104.359	90.75	0.219	0.75	701964288	107593728
107.922	110.704	96.985	0.203	0.735	701923328	107048960
107.328	110.078	96.421	0.219	0.734	701943808	107470848
101.969	104.719	91.172	0.219	0.735	701919232	107294720
101.422	104.188	90.844	0.203	0.735	701988864	107347968
101.953	104.719	91.094	0.203	0.735	701923328	107290624
103.828	106.61	93.016	0.203	0.735	701906944	107167744
102.109	104.89	91.141	0.219	0.734	701906944	107307008
102.219	105	91.39	0.203	0.734	701931520	107302912
98.719	101.5	87.921	0.204	0.735	701865984	107433984
102.219	105	91.407	0.218	0.734	701972480	107442176
102.141	104.938	91.312	0.219	0.719	702009344	107429888
101.656	104.422	90.828	0.218	0.734	702005248	107343872
101.656	104.437	91.031	0.203	0.75	701956096	107581440
102.344	105.11	91.641	0.218	0.735	701947904	107380736
108.547	111.329	97.61	0.203	0.735	701952000	107327488
100.61	103.406	89.781	0.219	0.735	701898752	107364352
102.391	105.172	91.562	0.203	0.735	701960192	107470848
97.328	100.078	86.531	0.203	0.718	701878272	104796160
102.015	104.86	91.188	0.218	0.735	701956096	107298816
106.188	108.953	95.25	0.218	0.734	701947904	107331584
102.5	105.266	91.641	0.219	0.735	701902848	107024384
98.891	101.672	88.078	0.203	0.75	701878272	107425792
100.906	103.687	90.062	0.219	0.719	701960192	107388928
102.266	105.046	91.468	0.204	0.718	701964288	107384832
101.797	104.563	90.922	0.203	0.719	701997056	107339776
102.297	105.094	91.454	0.218	0.766	701919232	107307008

Table B-5. Performance measurements with a 640MB Heap.

768 MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
97.125	99.922	86.39	0.219	0.734	836907008	115634176
96.922	99.735	86.375	0.204	0.735	836964352	115617792
96.75	99.547	85.953	0.219	0.719	836907008	115597312
97.265	100.078	86.469	0.219	0.75	836952064	115757056
97.625	100.406	86.687	0.219	0.734	836853760	115396608
96.813	99.609	86.266	0.219	0.719	836964352	115781632
96.844	99.625	86.047	0.218	0.719	836943872	115384320
97.906	100.688	87.078	0.219	0.719	836931584	115671040
96.891	99.672	86.312	0.219	0.719	836960256	115113984
97.718	100.516	86.907	0.203	0.735	836919296	115675136
97.078	99.843	86.234	0.204	0.718	836931584	115798016
97.953	100.75	87.156	0.219	0.719	836866048	115453952
97.062	99.828	86.328	0.219	0.719	836915200	115646464
96.937	99.719	86.14	0.203	0.703	837013504	115773440
97	99.766	86.437	0.219	0.719	836907008	114757632
97.281	100.047	86.485	0.203	0.719	836972544	115785728
97.188	100.172	86.375	0.219	0.718	836911104	115793920
97.031	99.828	86.187	0.219	0.735	836923392	115286016
97.25	100.016	86.453	0.219	0.719	836972544	115355648
96.859	99.625	86.015	0.219	0.719	836931584	115564544
97.016	99.797	86.203	0.219	0.719	836935680	115814400
97.969	100.75	87.172	0.219	0.718	836870144	115683328
97.172	99.953	86.375	0.219	0.718	837001216	115650560
97.282	100.078	86.344	0.203	0.734	836960256	115589120
98	100.781	87.25	0.203	0.719	836866048	115707904
97.25	100.016	86.468	0.204	0.719	837005312	115671040
98.156	101.094	87.36	0.218	0.719	836874240	115740672
97.656	100.453	86.828	0.219	0.735	836870144	115142656
97.765	100.547	86.844	0.219	0.719	836866048	115761152
97.047	99.828	86.265	0.219	0.719	836911104	115752960
98.641	101.406	87.797	0.218	0.703	836956160	115634176
97.797	100.547	86.953	0.219	0.719	836857856	115437568
97.265	100.062	86.5	0.219	0.719	836923392	115384320
97.11	99.907	86.281	0.204	0.75	836907008	115494912
97.157	99.953	86.344	0.219	0.734	836943872	115748864
97.5	100.266	86.672	0.218	0.703	836939776	115122176
97.89	100.688	86.969	0.219	0.735	836874240	115773440
97.828	100.61	86.39	0.219	0.719	836915200	115101696
98.016	100.782	87.094	0.218	0.719	836878336	115752960
97.25	100.031	86.407	0.218	0.719	836964352	115593216
98	100.781	87.141	0.234	0.719	836866048	115826688
97.578	100.36	86.782	0.218	0.735	836886528	115736576
98.016	100.797	87.234	0.219	0.719	836857856	115847168
97.453	100.235	86.516	0.219	0.735	836919296	115470336
96.891	99.657	86.187	0.219	0.719	836931584	115662848

97.188	99.969	86.39	0.204	0.719	836972544	115073024
97.296	100.062	86.438	0.219	0.719	836923392	115802112
97.11	99.922	86.297	0.203	0.719	836894720	115154944
97.843	100.625	86.969	0.219	0.704	836861952	115752960
96.984	99.75	86.172	0.203	0.719	836907008	115740672

Table B-6. Performance measurements with a 768MB Heap.

896 MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
97.344	100.125	86.531	0.219	0.734	971907072	126218240
97.234	100.031	86.422	0.218	0.734	971821056	126504960
97.203	100	86.359	0.25	0.734	971894784	126312448
97.407	100.188	86.578	0.219	0.734	971952128	125964288
97.312	100.109	86.39	0.219	0.719	971845632	125915136
97.094	99.906	86.266	0.218	0.75	971857920	126177280
97.187	99.985	86.391	0.219	0.735	971853824	126205952
97.688	100.469	86.625	0.219	0.719	971911168	124657664
97.406	100.203	86.61	0.219	0.735	971853824	126824448
98.313	101.406	87.5	0.234	0.765	971857920	126746624
97.203	100.016	86.406	0.219	0.75	971919360	126763008
97.234	100.031	86.437	0.203	0.734	971911168	126775296
97.218	100.016	86.375	0.219	0.735	971886592	126771200
97.375	100.188	86.547	0.203	0.735	971894784	126607360
97.312	100.14	86.469	0.203	0.75	971853824	126574592
97.469	100.297	86.656	0.219	0.766	971915264	124825600
97.156	99.938	86.313	0.219	0.735	971874304	126238720
97.39	100.234	86.546	0.219	0.765	971894784	124899328
97.265	100.078	86.422	0.219	0.734	971911168	125984768
97.281	100.093	86.438	0.219	0.75	971911168	125173760
97.421	100.235	86.578	0.219	0.735	971837440	127078400
97.187	99.985	86.359	0.203	0.735	971882496	124805120
97.266	100.047	86.297	0.218	0.734	971849728	126754816
97.656	100.453	86.89	0.219	0.734	971878400	126472192
97.297	100.093	86.438	0.219	0.75	971816960	126947328
97.282	100.093	86.422	0.219	0.75	971907072	126558208
97.563	100.343	86.703	0.219	0.734	971853824	126033920
97.219	100.094	86.421	0.219	0.75	971902976	126017536
97.812	100.625	86.547	0.219	0.75	971829248	127000576
97.015	99.828	86.235	0.203	0.735	971902976	124604416
97.578	100.39	86.765	0.219	0.734	971915264	126730240
97.234	100.063	86.39	0.219	0.766	971849728	126775296
97.453	100.25	86.578	0.235	0.735	971853824	126033920
97.187	100	86.375	0.219	0.719	971890688	126447616
97.406	100.234	86.579	0.218	0.75	971874304	126287872
97.157	99.953	86.344	0.219	0.734	971956224	126234624
97.156	99.953	86.297	0.218	0.734	971915264	126291968
97.109	99.938	86.25	0.219	0.734	971911168	126259200

97.187	100.015	86.375	0.219	0.75	971956224	126115840
97.469	100.281	86.781	0.204	0.734	971862016	125075456
97.125	99.938	86.375	0.235	0.735	971862016	125935616
97.219	100.047	86.391	0.218	0.734	971902976	125976576
97.11	99.937	86.25	0.203	0.719	971952128	126164992
97.625	100.453	86.781	0.219	0.734	971915264	126595072
97.578	100.406	86.781	0.219	0.734	971829248	126926848
97.141	100	86.344	0.218	0.734	971890688	126849024
97.469	100.297	86.437	0.219	0.75	971829248	126271488
97.219	100.031	86.406	0.219	0.75	971857920	126484480
97.219	100.062	86.391	0.218	0.734	971898880	126234624
97.047	99.86	86.391	0.218	0.719	971890688	126746624

Table B-7. Performance measurements with an 896MB Heap.

1024 MB Heap

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
97.422	100.156	86.328	0.203	0.656	1106726912	134512640
97.688	100.594	86.766	0.218	0.703	1106829312	132734976
97.593	100.344	86.625	0.204	0.688	1106767872	134971392
98	100.875	87.125	0.203	0.75	1106919424	136519680
97.047	99.797	86.078	0.219	0.656	1106817024	135233536
97.266	100.032	86.141	0.203	0.672	1106857984	135323648
97.187	99.954	86.203	0.203	0.657	1106911232	135233536
97.531	100.282	86.531	0.203	0.656	1106800640	135155712
97.718	100.531	86.829	0.218	0.656	1106878464	134168576
97.25	100.016	86.265	0.219	0.656	1106853888	134877184
97.359	100.141	86.359	0.203	0.672	1106833408	134541312
97.391	100.172	86.391	0.218	0.687	1106821120	133591040
97.188	99.921	86.203	0.219	0.671	1106862080	134586368
97.11	99.875	86.109	0.203	0.656	1106812928	135122944
97.203	99.984	86.203	0.203	0.672	1106833408	135131136
97.265	100.046	86.265	0.219	0.688	1106853888	135114752
97.187	99.953	86.265	0.219	0.672	1106870272	135254016
97.469	100.234	86.531	0.219	0.672	1106853888	134516736
97.343	100.141	86.312	0.219	0.688	1106776064	134533120
97.015	99.766	86.016	0.219	0.656	1106849792	135196672
97.094	99.844	86.172	0.219	0.672	1106866176	135270400
97.297	100.234	86.297	0.203	0.703	1106862080	135319552
97.265	100.031	86.344	0.218	0.656	1106788352	135213056
97	99.75	86.015	0.204	0.656	1106870272	133242880
97.203	99.938	86.172	0.203	0.672	1106731008	134516736
97.485	100.219	86.516	0.203	0.672	1106808832	133529600
98.391	101.203	87.39	0.219	0.656	1106849792	133337088
97.859	100.641	86.828	0.219	0.671	1106878464	134877184
97.235	99.953	86.234	0.219	0.656	1106853888	135053312
97.922	100.718	86.89	0.219	0.703	1106857984	133042176
96.859	99.594	85.86	0.219	0.656	1106767872	134828032

97.078	99.875	86.062	0.219	0.687	1106763776	135233536
97.485	100.25	86.485	0.218	0.671	1106833408	134942720
97.469	100.219	86.515	0.204	0.672	1106792448	134553600
97.078	99.828	86.047	0.203	0.656	1106788352	135217152
97.281	100.094	86.297	0.219	0.688	1106882560	135192576
97.172	99.938	86.172	0.219	0.672	1106812928	135200768
97.203	99.953	86.187	0.219	0.672	1106812928	135168000
97.422	100.312	86.344	0.218	0.656	1106767872	134549504
97.172	100.109	86.203	0.219	0.703	1106857984	134574080
96.953	99.719	86	0.219	0.656	1106767872	135143424
97.187	99.938	86.219	0.218	0.672	1106870272	135270400
97.281	100.047	86.375	0.219	0.672	1106804736	135139328
96.812	99.734	86.062	0.219	0.672	1106923520	135233536
97	99.735	86.016	0.219	0.656	1106821120	133595136
97.219	99.953	86.25	0.219	0.656	1106866176	134483968
97.234	99.968	86.187	0.219	0.656	1106788352	134844416
97.187	100.172	86.172	0.203	0.656	1106771968	134553600
97.094	99.843	86.172	0.234	0.671	1106874368	135016448
97.844	100.609	86.781	0.219	0.672	1106767872	133300224

Table B-8. Performance measurements with a 1024MB Heap.

B. MODIFICATIONS TO CAULDRON

This section contains data collected during Phase II of the experiment.

<u>Modified Source Code</u>

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
242.765	246.953	219.453	0.36	0.766	836915200	124518400
241.062	245.297	217.735	0.359	0.797	836870144	124506112
241.781	246.016	218.484	0.344	0.797	836911104	124592128
242.812	247.36	219.391	0.359	0.75	836882432	124604416
241.094	245.64	217.765	0.36	0.75	836911104	124514304

Table B-9. Performance measurements using the modified version of CAULDRON.

<u>Unmodified Source Code</u>

Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
240.016	244.078	N/A	N/A	N/A	8.38E+08	3.58E+08
240.218	244.313	N/A	N/A	N/A	8.38E+08	3.58E+08
240.438	244.485	N/A	N/A	N/A	8.39E+08	3.59E+08
240.594	244.625	N/A	N/A	N/A	8.39E+08	3.59E+08
239.765	243.844	N/A	N/A	N/A	8.39E+08	3.59E+08

Table B-10. Performance measurements using the unmodified version of CAULDRON.

C. NETWORK SIZE

This section contains data collected during Phase III of the experiment. The following table show how performance measurements scaled as network size varied on a fully connected network.

Number of Nodes	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
2	0	1.25	0	0	1.234	8.37E+08	76840960
3	0.015	0.578	0	0	0.563	8.37E+08	76177408
4	0.031	0.562	0.031	0	0.484	8.37E+08	74280960
5	0.031	0.609	0.016	0	0.562	8.37E+08	77524992
6	0.062	0.656	0.047	0	0.578	8.37E+08	77164544
7	0.062	0.656	0.047	0.015	0.562	8.37E+08	78532608
8	0.109	0.688	0.063	0	0.563	8.37E+08	81498112
9	0.125	0.734	0.094	0.015	0.578	8.37E+08	80728064
10	0.157	0.766	0.094	0.015	0.578	8.37E+08	83152896
11	0.172	0.797	0.141	0.016	0.578	8.37E+08	84246528
12	0.219	0.859	0.157	0.015	0.578	8.36E+08	63094784
13	0.297	0.968	0.219	0.016	0.593	8.37E+08	76447744
14	0.359	1.047	0.281	0.016	0.61	8.37E+08	82214912
15	0.453	1.156	0.344	0.016	0.61	8.37E+08	81502208
16	0.562	1.313	0.453	0.015	0.61	8.37E+08	80764928
17	0.703	1.468	0.547	0.015	0.609	8.37E+08	98893824
18	0.859	1.641	0.687	0.016	0.594	8.37E+08	86179840
19	1.109	1.891	0.86	0.015	0.61	8.37E+08	98902016
20	1.36	2.219	1.078	0.016	0.656	8.37E+08	99450880
21	1.703	2.547	1.328	0.031	0.625	8.37E+08	90701824
22	2.078	2.937	1.64	0.031	0.656	8.37E+08	99139584
23	2.516	3.406	2	0.031	0.656	8.37E+08	99127296
24	3.015	3.953	2.406	0.031	0.672	8.37E+08	99401728
25	3.672	4.625	2.984	0.031	0.656	8.37E+08	99770368
30	8.281	9.422	6.953	0.047	0.672	8.37E+08	1.01E+08
35	17.234	18.625	14.719	0.078	0.672	8.37E+08	1.04E+08
40	32.328	34.125	28	0.109	0.703	8.37E+08	1.06E+08
45	57.765	60.047	50.719	0.156	0.735	8.37E+08	1.1E+08
50	96.875	99.796	86.031	0.219	0.718	8.37E+08	1.16E+08
55	155.859	159.343	139.703	0.266	0.781	8.37E+08	1.19E+08
60	240.859	245.078	217.516	0.359	0.75	8.37E+08	1.25E+08
70	522.313	528.938	477.14	0.625	0.813	8.37E+08	1.36E+08
80	1046.797	1055.813	966.594	0.937	0.875	8.37E+08	1.61E+08
90	1929.593	1942.078	1793.063	1.359	0.953	8.37E+08	1.89E+08
100	3284.656	3301.75	3067.031	2.172	0.985	8.37E+08	2.15E+08
2	0.016	0.562	0	0.016	0.546	8.37E+08	76394496
3	0.016	0.594	0	0	0.562	8.37E+08	75386880
4	0.015	0.609	0.015	0	0.578	8.36E+08	63102976
5	0.031	0.593	0.016	0.015	0.562	8.36E+08	67014656
6	0.063	0.657	0.047	0	0.578	8.36E+08	67465216
7	0.078	0.657	0.062	0	0.563	8.36E+08	73768960

8	0.094	0.688	0.063	0	0.563	8.36E+08	73773056
9	0.125	0.718	0.093	0	0.562	8.36E+08	66732032
10	0.156	0.766	0.109	0.016	0.579	8.37E+08	83304448
11	0.187	0.797	0.125	0.015	0.578	8.36E+08	62357504
12	0.234	0.907	0.172	0.016	0.61	8.36E+08	76701696
13	0.297	0.968	0.203	0.016	0.593	8.37E+08	81838080
14	0.36	1.062	0.281	0.016	0.594	8.37E+08	90333184
15	0.453	1.172	0.344	0.016	0.594	8.37E+08	91025408
16	0.562	1.313	0.453	0.016	0.61	8.37E+08	86368256
17	0.688	1.453	0.547	0.016	0.609	8.37E+08	82153472
18	0.875	1.657	0.688	0.015	0.61	8.37E+08	98918400
19	1.093	1.906	0.844	0.016	0.625	8.37E+08	84336640
20	1.39	2.25	1.11	0.015	0.657	8.37E+08	84213760
21	1.703	2.531	1.328	0.032	0.641	8.37E+08	99536896
22	2.109	2.984	1.657	0.031	0.672	8.37E+08	99368960
23	2.532	3.469	2.031	0.031	0.687	8.37E+08	99782656
24	3.031	3.969	2.422	0.032	0.672	8.37E+08	99844096
25	3.625	4.579	2.922	0.031	0.657	8.37E+08	99389440
30	8.391	9.5	7.016	0.047	0.656	8.37E+08	1.01E+08
35	17.187	18.594	14.641	0.078	0.687	8.37E+08	1.05E+08
40	32.797	34.594	28.484	0.109	0.703	8.37E+08	1.06E+08
45	57.796	60.031	50.828	0.156	0.719	8.37E+08	1.1E+08
50	97.672	100.453	86.875	0.219	0.75	8.37E+08	1.16E+08
55	155.875	159.422	139.719	0.281	0.719	8.37E+08	1.19E+08
60	240.922	245.141	217.61	0.343	0.781	8.37E+08	1.25E+08
70	528.015	534.359	483.36	0.64	0.828	8.37E+08	1.42E+08
80	1032.203	1041.266	952.078	0.937	0.891	8.37E+08	1.61E+08
90	1933.234	1945.813	1796.343	1.344	0.954	8.37E+08	1.89E+08
100	3300.157	3317.172	3083.453	2.125	1.078	8.37E+08	2.15E+08
2	0.015	0.562	0	0	0.547	8.36E+08	63717376
3	0.016	0.579	0.016	0	0.563	8.36E+08	71872512
4	0.016	0.563	0.016	0	0.547	8.36E+08	72093696
5	0.032	0.61	0.016	0	0.563	8.37E+08	77451264
6	0.063	0.64	0.047	0	0.562	8.37E+08	77008896
7	0.079	0.656	0.047	0	0.562	8.37E+08	77254656
8	0.094	0.672	0.078	0	0.563	8.37E+08	77651968
9	0.125	0.735	0.094	0.016	0.562	8.37E+08	79970304
10	0.141	0.75	0.11	0.015	0.563	8.37E+08	80482304
11	0.188	0.797	0.125	0.015	0.578	8.36E+08	56528896
12	0.234	0.859	0.172	0	0.578	8.36E+08	67358720
13	0.281	0.953	0.219	0.015	0.578	8.37E+08	77598720
14	0.359	1.047	0.281	0.016	0.594	8.37E+08	81428480
15	0.469	1.156	0.359	0.016	0.594	8.37E+08	84160512
16	0.562	1.313	0.437	0.016	0.61	8.37E+08	83685376
17	0.688	1.469	0.547	0.016	0.61	8.37E+08	81473536
18	0.875	1.656	0.687	0.016	0.609	8.37E+08	90247168
19	1.11	1.937	0.859	0.016	0.64	8.37E+08	99491840
20	1.359	2.218	1.078	0.031	0.656	8.37E+08	99819520
21	1.704	2.562	1.328	0.031	0.671	8.37E+08	92540928

22	2.172	3.031	1.703	0.031	0.64	8.37E+08	99426304
23	2.5	3.391	2	0.032	0.641	8.37E+08	99090432
24	3.016	3.938	2.422	0.031	0.656	8.37E+08	99217408
25	3.625	4.609	2.938	0.031	0.687	8.37E+08	99434496
30	8.25	9.391	6.922	0.046	0.687	8.37E+08	1.01E+08
35	17.313	18.734	14.796	0.079	0.703	8.37E+08	1.04E+08
40	32.797	34.61	28.437	0.11	0.703	8.37E+08	1.07E+08
45	57.75	59.953	50.75	0.156	0.703	8.37E+08	1.12E+08
50	97.422	100.172	86.578	0.218	0.719	8.37E+08	1.16E+08
55	155.813	159.281	139.562	0.266	0.781	8.37E+08	1.19E+08
60	240.781	245.031	217.672	0.344	0.734	8.37E+08	1.24E+08
70	521.672	527.984	476.64	0.625	0.828	8.37E+08	1.36E+08
80	1031.109	1040.109	951.109	0.953	0.875	8.37E+08	1.61E+08
90	1930.61	1943.094	1793.985	1.343	0.938	8.37E+08	1.89E+08
100	3289.547	3306.516	3071.829	2.14	0.969	8.37E+08	2.15E+08
2	0	0.578	0	0	0.562	8.37E+08	77881344
3	0.015	0.594	0.015	0	0.563	8.36E+08	62926848
4	0.032	0.594	0	0.016	0.562	8.36E+08	67227648
5	0.032	0.609	0.032	0	0.562	8.36E+08	67665920
6	0.062	0.641	0.047	0	0.563	8.36E+08	71180288
7	0.062	0.656	0.047	0	0.562	8.37E+08	78618624
8	0.094	0.703	0.063	0	0.578	8.37E+08	80482304
9	0.141	0.734	0.093	0	0.578	8.37E+08	82243584
10	0.157	0.75	0.109	0	0.562	8.37E+08	82567168
11	0.188	0.781	0.141	0.016	0.562	8.35E+08	51752960
12	0.218	0.875	0.171	0.016	0.578	8.36E+08	66064384
13	0.297	0.953	0.219	0.015	0.578	8.37E+08	78807040
14	0.359	1.047	0.281	0.015	0.594	8.37E+08	82862080
15	0.453	1.141	0.344	0.016	0.594	8.37E+08	84094976
16	0.562	1.344	0.437	0.016	0.641	8.37E+08	83312640
17	0.687	1.453	0.532	0.015	0.61	8.37E+08	79917056
18	0.875	1.656	0.672	0.031	0.609	8.37E+08	90480640
19	1.11	1.891	0.859	0.016	0.609	8.37E+08	99258368
20	1.375	2.25	1.093	0.032	0.672	8.37E+08	99508224
21	1.703	2.547	1.328	0.032	0.641	8.37E+08	91136000
22	2.109	2.969	1.656	0.032	0.641	8.37E+08	99831808
23	2.5	3.391	1.985	0.031	0.657	8.37E+08	99299328
24	3.031	4.016	2.438	0.031	0.657	8.37E+08	99733504
25	3.656	4.61	2.938	0.047	0.672	8.37E+08	99135488
30	8.391	9.547	7.032	0.046	0.687	8.37E+08	1.01E+08
35	17.266	18.656	14.718	0.078	0.687	8.37E+08	1.04E+08
40	32.531	34.312	28.188	0.109	0.703	8.37E+08	1.06E+08
45	57.797	60.016	50.828	0.14	0.703	8.37E+08	1.1E+08
50	97.61	100.39	86.797	0.203	0.734	8.37E+08	1.16E+08
55	155.594	159.016	139.422	0.281	0.734	8.37E+08	1.19E+08
60	242.203	246.516	218.813	0.359	0.813	8.37E+08	1.25E+08
70	541.375	547.703	496.235	0.625	0.828	8.37E+08	1.41E+08
80	1051.985	1061.187	972.938	0.922	0.937	8.37E+08	1.61E+08
90	1915.172	1927.953	1778.516	1.343	0.937	8.37E+08	1.89E+08

100	3327.438	3344.375	3110.781	2.141	0.984	8.37E+08	2.15E+08
2	0	0.578	0	0	0.547	8.37E+08	78254080
3	0.015	0.578	0	0	0.547	8.37E+08	76849152
4	0.031	0.594	0	0	0.563	8.37E+08	76435456
5	0.031	0.61	0.031	0	0.563	8.37E+08	77922304
6	0.063	0.657	0.047	0	0.578	8.36E+08	57298944
7	0.079	0.656	0.047	0	0.562	8.37E+08	78925824
8	0.094	0.688	0.063	0.015	0.578	8.37E+08	80347136
9	0.125	0.718	0.078	0.016	0.562	8.37E+08	81707008
10	0.156	0.75	0.11	0.015	0.563	8.37E+08	81956864
11	0.188	0.813	0.125	0.015	0.578	8.36E+08	58769408
12	0.234	0.875	0.172	0.016	0.594	8.36E+08	75272192
13	0.282	0.953	0.219	0.016	0.593	8.37E+08	82030592
14	0.36	1.031	0.282	0.015	0.593	8.37E+08	90320896
15	0.469	1.156	0.344	0.015	0.593	8.37E+08	90787840
16	0.578	1.312	0.438	0.015	0.594	8.37E+08	83726336
17	0.704	1.453	0.547	0.016	0.609	8.37E+08	82694144
18	0.86	1.64	0.672	0.015	0.609	8.37E+08	99155968
19	1.094	1.906	0.859	0.016	0.625	8.37E+08	85385216
20	1.36	2.219	1.078	0.016	0.656	8.37E+08	85389312
21	1.718	2.563	1.344	0.016	0.657	8.37E+08	99545088
22	2.078	2.953	1.64	0.031	0.641	8.37E+08	99397632
23	2.563	3.453	2.047	0.031	0.656	8.37E+08	99168256
24	3.016	3.937	2.407	0.031	0.656	8.37E+08	1E+08
25	3.625	4.594	2.938	0.031	0.672	8.37E+08	99221504
30	11.516	12.641	10.11	0.062	0.672	8.37E+08	1.01E+08
35	17.407	18.828	14.89	0.063	0.703	8.37E+08	1.04E+08
40	32.438	34.235	28.094	0.109	0.704	8.37E+08	1.07E+08
45	58	60.235	51.032	0.156	0.719	8.37E+08	1.12E+08
50	97.547	100.328	86.766	0.218	0.719	8.37E+08	1.16E+08
55	155.921	159.375	139.75	0.281	0.766	8.37E+08	1.19E+08
60	241.61	245.797	218.141	0.359	0.75	8.37E+08	1.24E+08
70	547.656	554.156	502.281	0.641	0.859	8.37E+08	1.42E+08
80	1025.641	1034.703	945.672	0.937	0.875	8.37E+08	1.61E+08
90	1915.343	1927.891	1778.656	1.328	0.938	8.37E+08	1.89E+08
100	3280.234	3297.141	3064.64	2.157	0.969	8.37E+08	2.15E+08

Table B-11. Performance measurements as network size varied on a fully connected network.

D. CONNECTIVITY

This section contains data collected during Phase IV of the experiment. The first table contains measurements obtained as the attacker's node-set varied in size and did not allow connections to other node-sets. The second table contains measurements obtained as the number of connections increased on the network, allowing the attacker to connect to other node-sets.

<u>0 Connections</u>

Number of Node-sets	Number of Nodes	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1	60	246.203	251.078	223.047	0.344	1.437	8.37E+08	1.28E+08
1	60	241.719	246.25	218.375	0.359	0.75	8.37E+08	1.25E+08
1	60	241.157	245.375	217.828	0.344	0.765	8.37E+08	1.24E+08
1	60	241.563	245.766	218.11	0.359	0.735	8.37E+08	1.24E+08
1	60	241.125	245.344	217.672	0.36	0.75	8.37E+08	1.24E+08
2	30	114.218	114.937	114.063	0.015	0.719	8.37E+08	1.14E+08
2	30	114.407	115.125	114.266	0.016	0.703	8.37E+08	1.14E+08
2	30	114.328	115.047	114.203	0	0.719	8.37E+08	1.14E+08
2	30	166.75	167.453	166.516	0.016	0.703	8.37E+08	1.14E+08
2	30	114.641	115.359	114.5	0.016	0.718	8.37E+08	1.14E+08
3	20	79.5	80.188	79.438	0	0.688	8.37E+08	1.14E+08
3	20	79.609	80.297	79.547	0	0.688	8.37E+08	1.14E+08
3	20	79.594	80.282	79.516	0	0.688	8.37E+08	1.14E+08
3	20	79.547	80.234	79.469	0.015	0.687	8.37E+08	1.14E+08
3	20	79.562	80.25	79.5	0	0.672	8.37E+08	1.14E+08
4	15	61.813	62.516	61.781	0	0.688	8.37E+08	1.14E+08
4	15	62.75	63.422	62.703	0	0.672	8.37E+08	1.14E+08
4	15	62.593	63.265	62.531	0.015	0.672	8.37E+08	1.14E+08
4	15	61.891	62.578	61.828	0.016	0.687	8.37E+08	1.14E+08
4	15	62.375	63.078	62.329	0	0.703	8.37E+08	1.14E+08
5	12	51.703	52.375	51.656	0	0.657	8.37E+08	1.14E+08
5	12	52.484	53.156	52.453	0	0.672	8.37E+08	1.14E+08
5	12	51.812	52.5	51.781	0	0.672	8.37E+08	1.14E+08
5	12	52.781	53.468	52.735	0	0.687	8.37E+08	1.14E+08
5	12	51.765	52.437	51.719	0	0.672	8.37E+08	1.14E+08
6	10	45.109	45.781	45.062	0	0.672	8.37E+08	1.14E+08
6	10	44.906	45.578	44.875	0	0.672	8.37E+08	1.15E+08
6	10	45.359	46.031	45.328	0	0.656	8.37E+08	1.14E+08
6	10	44.328	44.984	44.281	0	0.656	8.37E+08	1.14E+08
6	10	44.641	45.313	44.625	0	0.656	8.37E+08	1.14E+08

Table B-12. Performance measurements as the attacker's node set was scaled.

5 Node-Sets with 12 Nodes per Node-set

Performance measurements as more node-sets became reachable from the attacker's node-set.

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
0	51.703	52.375	51.656	0	0.657	836853760	114298880
0	52.484	53.156	52.453	0	0.672	836882432	113987584
0	51.812	52.5	51.781	0	0.672	836931584	113872896
0	52.781	53.468	52.735	0	0.687	836923392	114208768
0	51.765	52.437	51.719	0	0.672	836931584	113782784
1	51.812	52.5	51.781	0	0.688	836947968	113790976
1	51.907	52.579	51.875	0	0.672	836972544	113754112
1	69.703	70.375	69.671	0	0.672	837029888	113664000
1	51.61	52.282	51.579	0	0.672	836857856	113999872
1	52.125	52.813	52.078	0.016	0.688	836878336	114016256
1	51.687	52.375	51.656	0	0.688	836968448	113709056
1	69.812	70.484	69.781	0	0.672	836927488	113700864
1	69.813	70.485	69.782	0	0.672	836956160	113709056
1	51.906	52.593	51.86	0	0.687	836935680	113754112
1	51.735	52.406	51.703	0	0.671	837025792	113741824
1	51.5	52.188	51.453	0	0.688	836919296	113795072
1	52.172	52.844	52.141	0	0.672	836988928	113627136
1	52.063	52.735	52.032	0	0.672	836947968	113565696
1	52.125	52.813	52.094	0	0.688	836882432	114061312
1	51.765	52.437	51.734	0	0.672	836919296	113659904
1	69.094	69.766	69.047	0.016	0.672	836927488	113831936
1	52.063	52.734	52.031	0	0.671	836976640	113840128
1	51.828	52.516	51.781	0	0.688	836894720	114171904
1	68.922	69.593	68.89	0	0.671	836857856	113987584
1	51.89	52.578	51.859	0	0.688	836833280	113876992
1	51.766	52.438	51.719	0	0.672	836927488	113729536
1	51.969	52.641	51.938	0	0.672	837025792	113795072
1	52.547	53.218	52.515	0	0.671	836972544	113590272
1	51.781	52.453	51.75	0	0.672	836984832	114593792
1	52.562	53.265	52.531	0	0.688	836882432	113672192
1	52	52.688	51.969	0	0.688	836886528	114057216
1	51.672	52.344	51.64	0	0.672	836980736	113881088
1	69.234	69.922	69.187	0	0.688	836964352	113815552
1	51.687	52.375	51.64	0	0.688	836923392	113664000
1	51.891	52.578	51.86	0	0.687	836976640	113733632
1	51.937	52.609	51.891	0	0.672	836939776	113979392
1	52.422	53.109	52.39	0	0.671	836976640	113737728
1	51.812	52.468	51.781	0	0.656	836968448	113774592
1	69.203	69.906	69.171	0	0.703	836890624	114282496

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1	68.782	69.469	68.75	0	0.672	836968448	113864704
1	52.344	53.016	52.297	0	0.672	836927488	113831936
1	51.812	52.5	51.781	0	0.688	836870144	114565120
1	51.954	52.625	51.922	0	0.671	836976640	113971200
1	51.609	52.281	51.578	0	0.672	836968448	113930240
1	52.375	53.079	52.344	0	0.704	836923392	113672192
1	52.109	52.797	52.078	0	0.688	836972544	113762304
1	69.125	69.813	69.094	0	0.688	836931584	113831936
1	69.219	69.891	69.188	0	0.672	836956160	113635328
1	52.172	52.844	52.14	0	0.672	837033984	113688576
1	51.812	52.484	51.781	0	0.672	836890624	114278400
1	51.61	52.281	51.578	0	0.671	836960256	113864704
1	51.875	52.562	51.843	0	0.687	836886528	114028544
1	51.641	52.328	51.609	0	0.687	836915200	113659904
1	69.109	69.891	68.859	0.032	0.672	836927488	116490240
1	51.687	52.391	51.656	0	0.704	836907008	113795072
1	51.875	52.547	51.844	0	0.672	836902912	113659904
1	51.984	52.656	51.938	0	0.672	836972544	113782784
1	69.406	70.094	69.375	0	0.688	836923392	113864704
1	51.75	52.438	51.719	0	0.688	836927488	113803264
1	75.531	76.188	75.484	0	0.657	836939776	113725440
1	52.172	52.875	52.14	0.016	0.688	837021696	113557504
1	68.969	69.657	68.922	0	0.688	837005312	113770496
1	70.469	71.141	70.422	0.016	0.672	836882432	114294784
1	52.312	52.984	52.281	0	0.672	836960256	113836032
1	52.062	52.75	52.016	0	0.688	836968448	113737728
1	51.906	52.593	51.875	0	0.687	836947968	113745920
1	51.875	52.547	51.844	0	0.672	836980736	113844224
1	51.719	52.39	51.672	0	0.671	836853760	114077696
1	51.891	52.578	51.86	0	0.687	836874240	114159616
1	51.843	52.531	51.797	0.015	0.688	836964352	113713152
1	69.281	69.968	69.25	0	0.672	836923392	113889280
1	52.125	52.797	52.093	0	0.672	836988928	113586176
1	51.937	52.625	51.906	0	0.688	836882432	114368512
1	69.125	69.796	69.093	0	0.671	836956160	113639424
1	51.891	52.579	51.86	0	0.688	836923392	113754112
1	51.938	52.625	51.907	0	0.687	836972544	113750016
1	51.89	52.562	51.843	0	0.672	836931584	113684480
1	51.953	52.656	51.922	0	0.688	836947968	113754112
1	51.968	52.64	51.937	0	0.672	836988928	113786880
1	51.796	52.468	51.765	0	0.672	836919296	113795072
1	51.812	52.5	51.781	0	0.688	836952064	113696768
1	52.344	53	52.297	0	0.656	836927488	113840128
1	69	69.688	68.969	0	0.656	836853760	114147328
1	51.703	52.375	51.656	0	0.672	836952064	113643520
1	52.187	52.875	52.156	0	0.688	836915200	113946624
1	52.031	52.718	51.985	0	0.687	836972544	113909760

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1	51.766	52.453	51.718	0.016	0.687	836907008	113754112
1	51.781	52.453	51.75	0	0.672	836874240	114036736
1	69.953	70.625	69.906	0	0.672	836976640	113618944
1	69.094	69.797	69.063	0	0.687	836964352	114036736
1	51.922	52.61	51.891	0	0.688	836894720	114012160
1	51.734	52.422	51.703	0	0.688	836980736	113725440
1	51.86	52.579	51.829	0	0.719	836874240	113983488
1	52.11	52.797	52.063	0	0.687	836931584	113872896
1	52.172	52.844	52.141	0	0.672	836923392	113688576
1	52.156	52.828	52.125	0	0.672	836915200	114032640
1	69	69.672	68.969	0	0.672	836907008	113659904
1	69.453	70.125	69.422	0	0.672	837029888	113659904
1	52.14	52.797	52.109	0	0.657	836911104	113700864
1	51.718	52.422	51.671	0	0.688	836886528	113885184
1	52.125	52.813	52.094	0	0.672	836923392	113872896
1	51.953	52.625	51.922	0	0.672	836968448	113840128
1	52.015	52.687	51.984	0	0.672	837038080	113856512
1	69.75	70.547	69.484	0.047	0.703	836890624	114114560
1	53.078	53.75	53.047	0	0.672	836980736	113754112
1	52.187	52.859	52.156	0	0.672	836968448	113569792
1	51.781	52.469	51.734	0	0.688	836927488	113926144
1	69.141	69.828	69.093	0.016	0.672	836866048	114167808
1	51.937	52.609	51.906	0	0.672	836927488	113876992
1	52.266	52.938	52.235	0	0.672	836972544	113594368
1	52.39	53.078	52.344	0	0.688	836882432	114061312
1	68.781	69.485	68.766	0	0.688	836898816	113750016
1	70.375	71.047	70.329	0.015	0.672	836931584	113897472
1	51.859	52.531	51.828	0	0.672	836960256	113631232
1	51.969	52.672	51.938	0	0.703	836923392	113786880
1	51.875	52.547	51.829	0	0.672	836915200	113852416
1	52.078	52.75	52.032	0.015	0.672	836927488	113692672
1	51.75	52.422	51.719	0	0.672	836886528	114110464
1	51.969	52.672	51.953	0	0.672	836886528	113954816
1	51.828	52.531	51.797	0	0.703	836915200	113631232
1	69.203	69.89	69.171	0	0.687	836943872	113766400
1	52.094	52.765	52.062	0	0.671	837009408	113659904
1	51.922	52.61	51.891	0	0.688	836931584	113709056
1	68.86	69.532	68.828	0	0.672	837103616	116477952
1	52	52.687	51.954	0	0.687	836976640	113872896
1	51.781	52.453	51.75	0	0.672	836902912	113659904
1	51.875	52.563	51.844	0	0.688	836927488	113725440
1	51.609	52.281	51.563	0	0.672	836919296	113676288
1	51.765	52.437	51.734	0	0.672	836890624	114130944
1	52.125	52.813	52.094	0	0.672	836968448	113737728
1	51.969	52.641	51.938	0	0.656	836927488	113811456
1	51.969	52.641	51.922	0.016	0.672	837009408	113700864
1	69.641	70.328	69.593	0	0.687	836980736	113631232

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1	51.875	52.547	51.828	0	0.672	836898816	113651712
1	51.86	52.531	51.828	0	0.671	836923392	113803264
1	51.594	52.281	51.563	0	0.687	836968448	113737728
1	51.61	52.297	51.562	0.016	0.687	836927488	113782784
1	51.937	52.625	51.891	0	0.688	836882432	114176000
1	69.14	69.828	69.11	0.015	0.672	836968448	113770496
1	69.062	69.75	69.031	0	0.688	836878336	114245632
1	51.781	52.469	51.766	0	0.672	836947968	113840128
1	51.734	52.422	51.703	0	0.688	836919296	113717248
1	52.219	52.906	52.187	0	0.687	836857856	114016256
1	51.813	52.5	51.782	0	0.687	836874240	113983488
1	51.891	52.563	51.86	0	0.672	836919296	113815552
1	51.656	52.344	51.625	0	0.688	836976640	113909760
1	69.453	70.125	69.406	0	0.672	836972544	113889280
1	69.735	70.422	69.687	0.016	0.687	836968448	113700864
1	52.593	53.265	52.562	0	0.672	836911104	113676288
1	52.438	53.109	52.406	0	0.671	836935680	113647616
1	51.796	52.484	51.765	0	0.688	836915200	113713152
1	51.86	52.547	51.828	0	0.672	836980736	114036736
1	52.078	52.75	52.047	0	0.672	836907008	113696768
1	69.421	70.187	69.172	0.031	0.672	836870144	113913856
1	52.234	52.922	52.219	0	0.672	836939776	113770496
1	52.203	52.891	52.172	0	0.688	836870144	114098176
1	51.688	52.344	51.656	0	0.656	836939776	113856512
1	69.015	69.687	68.968	0	0.672	836956160	113709056
1	51.938	52.625	51.891	0.016	0.687	836907008	113942528
1	52	52.688	51.969	0	0.688	836911104	113819648
1	51.984	52.672	51.937	0	0.688	836894720	113803264
1	69.297	69.969	69.266	0	0.672	836931584	113840128
1	68.938	69.61	68.907	0	0.672	836968448	113868800
1	51.407	52.094	51.375	0	0.687	836874240	114163712
1	51.844	52.531	51.812	0	0.687	836935680	113889280
1	52.25	52.922	52.187	0	0.672	836874240	113999872
1	51.75	52.422	51.719	0	0.672	836976640	113815552
1	51.813	52.485	51.765	0	0.672	837005312	113696768
1	51.766	52.453	51.718	0	0.687	836907008	113807360
1	51.828	52.516	51.797	0	0.688	836886528	114245632
1	69.297	69.985	69.266	0	0.688	836907008	113811456
1	51.875	52.547	51.812	0	0.672	836915200	113639424
1	51.657	52.344	51.625	0	0.687	836923392	113672192
1	69.359	70.047	69.312	0	0.688	836857856	114307072
1	51.812	52.484	51.781	0	0.672	836886528	114167808
1	51.641	52.313	51.61	0	0.672	837021696	113680384
1	51.813	52.5	51.782	0	0.672	836976640	113885184
1	52.703	53.391	52.672	0	0.688	836911104	113565696
1	52.141	52.829	52.11	0	0.688	836923392	113713152
1	51.922	52.594	51.891	0	0.656	836980736	113848320

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1	51.906	52.578	51.859	0	0.672	836931584	113737728
1	51.828	52.5	51.797	0	0.657	836956160	113717248
1	69.422	70.094	69.391	0	0.672	836882432	114028544
1	51.609	52.297	51.578	0.016	0.688	836898816	113631232
1	51.922	52.61	51.891	0	0.672	836837376	114204672
1	51.766	52.453	51.735	0	0.687	836927488	113819648
1	52.406	53.078	52.36	0	0.672	836927488	116355072
1	54.906	55.578	54.875	0	0.672	837009408	113631232
1	69.969	70.641	69.921	0.016	0.672	836923392	114032640
1	69.141	69.813	69.11	0	0.672	836861952	114003968
1	51.703	52.406	51.672	0	0.688	836890624	113831936
1	51.813	52.5	51.781	0	0.687	836866048	114204672
1	51.906	52.578	51.875	0	0.672	836886528	114208768
1	51.938	52.609	51.906	0	0.671	836833280	114122752
1	52.046	52.734	52.015	0	0.688	836882432	114171904
1	51.703	52.39	51.672	0	0.687	836947968	113909760
1	68.937	69.625	68.906	0	0.688	836878336	114176000
1	68.969	69.657	68.938	0	0.688	836919296	113778688
1	51.985	52.657	51.954	0	0.672	836915200	113643520
1	51.75	52.438	51.735	0	0.672	837009408	113881088
1	52.079	52.766	52.031	0	0.687	836976640	114008064
1	51.688	52.375	51.657	0	0.687	836874240	114139136
1	51.782	52.468	51.75	0	0.671	836968448	113848320
1	69.641	70.422	69.391	0.031	0.688	836968448	114532352
1	51.844	52.532	51.813	0	0.688	836882432	114008064
1	51.687	52.359	51.656	0	0.672	836874240	114151424
1	51.89	52.562	51.859	0	0.672	836866048	113950720
1	68.828	69.516	68.797	0	0.688	836878336	114065408
1	51.985	52.688	51.953	0	0.688	836976640	113713152
1	52.219	52.906	52.188	0	0.687	836947968	113795072
1	51.984	52.688	51.953	0	0.704	836972544	113876992
1	68.89	69.578	68.859	0	0.688	836919296	114044928
1	68.625	69.296	68.593	0	0.671	836980736	113807360
1	51.875	52.547	51.844	0	0.672	836972544	113868800
1	52.063	52.75	52.015	0.016	0.687	836902912	113790976
1	51.703	52.391	51.672	0	0.672	836886528	113991680
1	52.015	52.687	52	0	0.656	836931584	113733632
1	51.891	52.563	51.844	0	0.672	837005312	113725440
1	51.968	52.656	51.922	0	0.688	836935680	113745920
1	51.609	52.281	51.563	0.015	0.672	836878336	113750016
1	69.078	69.765	69.047	0	0.687	836878336	114020352
1	52.296	52.968	52.265	0	0.672	836886528	113762304
1	51.859	52.562	51.812	0	0.703	836919296	113721344
1	68.906	69.593	68.875	0	0.671	836980736	114085888
1	51.594	52.281	51.562	0	0.687	836927488	113807360
1	52.032	52.703	52	0	0.671	836980736	113700864
1	51.953	52.625	51.907	0	0.672	836968448	114106368

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1	52.047	52.719	52	0	0.672	836853760	114171904
1	52.172	52.875	52.125	0	0.687	836845568	113991680
1	51.593	52.265	51.578	0	0.656	836947968	113807360
1	52.063	52.75	52.032	0	0.687	836927488	113868800
1	52.328	53	52.297	0	0.672	836861952	113938432
1	70.141	70.813	70.094	0.016	0.672	836816896	114089984
1	51.625	52.297	51.594	0	0.672	836972544	113913856
1	51.656	52.344	51.609	0	0.688	836972544	113733632
1	52.016	52.703	51.984	0	0.687	836964352	113700864
1	51.719	52.407	51.688	0	0.672	836874240	114253824
1	51.969	52.641	51.938	0	0.672	836882432	114184192
1	68.922	69.61	68.891	0	0.688	836964352	113721344
1	69.344	70.015	69.312	0	0.671	836964352	113549312
1	51.828	52.515	51.797	0	0.687	836956160	113881088
1	51.985	52.672	51.938	0	0.687	836894720	113901568
1	51.704	52.375	51.672	0	0.671	836898816	113618944
1	51.766	52.453	51.734	0	0.687	836923392	113885184
1	51.562	52.234	51.516	0.015	0.672	836976640	113885184
1	51.875	52.562	51.844	0	0.687	836886528	114176000
1	69.032	69.719	69	0	0.687	836935680	114237440
1	68.969	69.641	68.938	0	0.672	836878336	114266112
1	52.016	52.688	51.985	0	0.672	836894720	113876992
1	51.766	52.438	51.734	0	0.672	836956160	113717248
1	52.094	52.781	52.062	0	0.687	836837376	114069504
1	51.688	52.36	51.641	0	0.672	836960256	113729536
1	52.485	53.172	52.454	0	0.687	836919296	114266112
1	69.531	70.312	69.266	0.047	0.672	836964352	113782784
1	51.562	52.234	51.531	0	0.672	836972544	113827840
2	51.765	52.453	51.75	0	0.672	836923392	113721344
2	52.422	53.203	52.141	0.062	0.688	836972544	114434048
2	51.844	52.516	51.813	0	0.672	836923392	113778688
2	51.907	52.579	51.875	0	0.672	836825088	114225152
2	51.906	52.609	51.875	0	0.687	836947968	113848320
2	51.968	52.64	51.937	0	0.672	836997120	113987584
2	51.984	52.656	51.953	0	0.672	836890624	113922048
2	52.078	52.75	52.031	0	0.672	836882432	114081792
2	52.25	52.937	52.219	0	0.687	836976640	113790976
2	52.36	53.141	52.093	0.047	0.687	836861952	114155520
2	52.125	52.812	52.094	0	0.687	836886528	114094080
2	51.625	52.297	51.594	0	0.672	836947968	113664000
2	51.719	52.407	51.672	0	0.688	836878336	113954816
2	69.157	69.844	69.125	0.016	0.672	836915200	113692672
2	51.969	52.656	51.937	0	0.687	836841472	114102272
2	69.265	69.937	69.219	0	0.672	836976640	113885184
2	69.453	70.141	69.438	0	0.672	836927488	113754112
2	70.922	71.609	70.891	0	0.687	836964352	113967104
2	51.875	52.547	51.843	0	0.672	836866048	114229248

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
2	69.203	69.875	69.172	0	0.672	836886528	114012160
2	51.781	52.453	51.75	0	0.672	836878336	113737728
2	51.938	52.625	51.891	0.016	0.687	836964352	114016256
2	69.516	70.266	69.25	0.031	0.656	836939776	114540544
2	51.969	52.657	51.938	0	0.688	836915200	113635328
2	51.968	52.656	51.937	0	0.688	836923392	113967104
2	51.968	52.625	51.937	0	0.657	836972544	113811456
2	52.125	52.797	52.078	0	0.672	836841472	114122752
2	51.859	52.531	51.828	0	0.672	836931584	113803264
2	52.14	52.828	52.109	0	0.672	836915200	113729536
2	69.438	70.125	69.407	0	0.687	836874240	114180096
2	51.796	52.484	51.765	0	0.688	836878336	114020352
2	69.547	70.235	69.516	0	0.688	836853760	116670464
2	86.75	87.516	86.453	0.078	0.672	836927488	114511872
2	70.157	70.829	70.125	0.016	0.657	837017600	113614848
2	52.11	52.797	52.079	0	0.687	836874240	114085888
2	51.984	52.671	51.953	0	0.687	836919296	113664000
2	51.859	52.531	51.828	0	0.672	836968448	113692672
2	51.937	52.625	51.906	0	0.688	836976640	113868800
2	68.969	69.641	68.938	0	0.672	836886528	114323456
2	69.219	69.922	69.188	0	0.703	836931584	113958912
2	68.969	69.657	68.938	0	0.688	836882432	114180096
2	68.938	69.625	68.89	0.016	0.672	836976640	113721344
2	52.297	52.953	52.266	0	0.656	836972544	113664000
2	52.078	52.765	52.046	0	0.687	836976640	113963008
2	51.938	52.61	51.907	0	0.672	836947968	113700864
2	51.875	52.563	51.828	0.016	0.688	836882432	114352128
2	52.141	52.828	52.109	0	0.687	836943872	113799168
2	52.109	52.781	52.078	0	0.672	836829184	113954816
2	51.64	52.328	51.609	0	0.688	836911104	115691520
2	69.5	70.266	69.234	0.031	0.672	836878336	113721344
2	52.015	52.687	51.984	0	0.672	836968448	113725440
2	52.515	53.297	52.219	0.078	0.688	836919296	113700864
2	52.078	52.766	52.047	0	0.688	836972544	113610752
2	52.031	52.703	52	0	0.672	836968448	113901568
2	51.891	52.594	51.859	0	0.688	836890624	114126848
2	51.781	52.469	51.75	0	0.688	836972544	113766400
2	51.859	52.531	51.828	0	0.672	836997120	113737728
2	52.266	52.938	52.234	0	0.672	836882432	113922048
2	51.906	52.593	51.875	0.015	0.672	836964352	113639424
2	52.469	53.25	52.218	0.032	0.672	836890624	114757632
2	52.047	52.734	52.015	0	0.687	836882432	114143232
2	51.937	52.625	51.891	0.015	0.688	836935680	113741824
2	51.766	52.438	51.734	0	0.672	836882432	114065408
2	69.093	69.781	69.062	0	0.672	836870144	114229248
2	52.078	52.765	52.047	0	0.687	836919296	114421760
2	69.985	70.657	69.953	0	0.672	836980736	113762304

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
2	69.109	69.797	69.078	0	0.688	836968448	113758208
2	70.203	70.875	70.156	0.016	0.672	836931584	113659904
2	52.828	53.515	52.797	0	0.687	836927488	113836032
2	69.344	70.031	69.297	0.016	0.687	836919296	113623040
2	51.984	52.656	51.953	0	0.672	836874240	114110464
2	51.922	52.61	51.891	0	0.688	836919296	113729536
2	70.766	71.547	70.516	0.047	0.672	837021696	114458624
2	52.047	52.735	52.016	0	0.688	836931584	113741824
2	51.86	52.532	51.829	0	0.672	836919296	113709056
2	51.907	52.579	51.859	0	0.672	836890624	114008064
2	51.922	52.578	51.891	0	0.656	836861952	113655808
2	51.953	52.625	51.922	0	0.672	836939776	113795072
2	52.125	52.828	52.078	0.016	0.703	836960256	113790976
2	69.328	70.016	69.297	0	0.688	836976640	113733632
2	52.063	52.75	52.031	0	0.687	836911104	113713152
2	69.313	69.969	69.266	0	0.656	836931584	113664000
2	87.406	88.204	87.125	0.078	0.688	836878336	114769920
2	69.859	70.531	69.812	0.016	0.672	836980736	113782784
2	52	52.688	51.969	0	0.672	836911104	113917952
2	52.594	53.282	52.563	0	0.688	836874240	113688576
2	52.297	52.984	52.266	0	0.672	836882432	114159616
2	51.844	52.515	51.812	0	0.671	836886528	114143232
2	69.297	69.985	69.266	0	0.688	836870144	113819648
2	69.328	70	69.297	0	0.672	836960256	113827840
2	69.719	70.407	69.688	0	0.688	836968448	113598464
2	69.188	69.875	69.14	0.016	0.687	836968448	113836032
2	51.797	52.485	51.766	0	0.688	836972544	113778688
2	52.016	52.703	51.968	0	0.672	836964352	113844224
2	52.25	52.922	52.203	0	0.672	836988928	113741824
2	52.797	53.454	52.766	0	0.657	836976640	113635328
2	51.797	52.484	51.765	0	0.687	836972544	113938432
2	51.953	52.64	51.922	0	0.687	836919296	113659904
2	51.984	52.672	51.937	0	0.672	836874240	114069504
2	70.141	70.921	69.891	0.031	0.687	836857856	113913856
2	51.859	52.531	51.813	0	0.672	836923392	113856512
2	53	53.781	52.703	0.078	0.687	836972544	114049024
2	52.047	52.734	52.016	0	0.687	836919296	113664000
2	51.781	52.469	51.75	0	0.688	836911104	113774592
2	52	52.703	51.968	0	0.703	836874240	114126848
2	51.875	52.578	51.844	0	0.672	836968448	113827840
2	52.375	53.062	52.344	0	0.687	836931584	113954816
2	51.828	52.5	51.781	0	0.672	836943872	113852416
2	51.844	52.531	51.813	0	0.687	836919296	113876992
2	52.172	52.954	51.922	0.031	0.688	836857856	113864704
2	52.39	53.078	52.359	0	0.672	836968448	113709056
2	51.89	52.578	51.844	0	0.688	836968448	113844224
2	51.766	52.437	51.734	0	0.671	836902912	113799168

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
2	69.625	70.313	69.594	0	0.688	836968448	113725440
2	52.078	52.75	52.047	0	0.672	836976640	113876992
2	69.562	70.234	69.531	0	0.672	837001216	113594368
2	69.203	69.875	69.156	0.015	0.672	836964352	113766400
2	69.047	69.735	69.016	0	0.672	836923392	113934336
2	52.031	52.703	52	0	0.672	836874240	114237440
2	70.407	71.094	70.359	0	0.672	836898816	113811456
2	51.921	52.609	51.89	0	0.688	836960256	113836032
2	52	52.688	51.937	0.016	0.688	836976640	113766400
2	69.688	70.469	69.422	0.031	0.687	836861952	114253824
2	51.985	52.672	51.937	0.016	0.687	836947968	113844224
2	52.515	53.203	52.469	0	0.688	836968448	113557504
2	51.828	52.516	51.797	0	0.672	836968448	113655808
2	52	52.672	51.969	0	0.656	836976640	113758208
2	51.781	52.453	51.735	0	0.672	836886528	113954816
2	52.203	52.891	52.188	0	0.672	836866048	113946624
2	69.719	70.391	69.688	0	0.672	837013504	113639424
2	51.969	52.656	51.937	0	0.672	836952064	113807360
2	69.219	69.875	69.172	0	0.656	836947968	113713152
2	87.609	88.375	87.313	0.078	0.672	836882432	114118656
2	69.672	70.36	69.641	0	0.672	836923392	113975296
2	52	52.672	51.953	0.016	0.672	836882432	114081792
2	52.125	52.812	52.093	0	0.687	836923392	113684480
2	51.812	52.5	51.781	0	0.672	836874240	114147328
2	52.063	52.734	52.031	0	0.671	836923392	113770496
2	69.187	69.875	69.156	0	0.656	836952064	113840128
2	69.453	70.125	69.422	0	0.672	836976640	113999872
2	69.172	69.859	69.14	0	0.687	836841472	113958912
2	69.312	70.016	69.265	0.016	0.704	836935680	113885184
2	52.141	52.828	52.11	0	0.687	836878336	114208768
2	52.031	52.719	52	0	0.688	836960256	113664000
2	51.984	52.656	51.953	0	0.656	836964352	113860608
2	51.797	52.485	51.766	0	0.688	836878336	113987584
2	52.375	53.047	52.343	0	0.672	836972544	113717248
2	52.11	52.782	52.078	0	0.672	836964352	113700864
2	52.109	52.797	52.078	0	0.672	836976640	113602560
2	70.781	71.547	70.531	0.031	0.672	837038080	113635328
2	52.11	52.797	52.079	0	0.687	836964352	113696768
2	52.937	53.719	52.641	0.078	0.688	836886528	114987008
2	51.828	52.516	51.797	0	0.688	836874240	114176000
2	52.328	53	52.281	0	0.672	836976640	113606656
2	51.844	52.5	51.813	0	0.656	836935680	113819648
2	51.906	52.594	51.875	0	0.688	836960256	113733632
2	51.875	52.547	51.844	0	0.672	836882432	113905664
2	51.969	52.656	51.953	0	0.672	836882432	113987584
2	51.954	52.61	51.922	0	0.656	836882432	113946624
2	52.109	52.891	51.844	0.046	0.688	836956160	114655232

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
2	52.063	52.735	52.016	0	0.672	836849664	114110464
2	52.422	53.078	52.39	0	0.656	836976640	113721344
2	51.704	52.391	51.672	0	0.687	836878336	113958912
2	69.14	69.843	69.094	0.015	0.703	836968448	113958912
2	51.75	52.422	51.703	0	0.672	836919296	113664000
2	69.172	69.859	69.125	0.016	0.687	836878336	113909760
2	68.953	69.625	68.922	0	0.672	836907008	115908608
2	69.282	69.954	69.25	0	0.672	836956160	113864704
2	51.89	52.562	51.859	0	0.672	836972544	113799168
2	69.312	69.984	69.297	0	0.672	836833280	114094080
2	52.032	52.719	52	0	0.687	836861952	113967104
2	52.203	52.875	52.171	0	0.672	836866048	114008064
2	70.125	70.89	69.875	0.031	0.671	836886528	113827840
2	51.875	52.563	51.844	0	0.688	836972544	114049024
2	51.968	52.64	51.937	0	0.672	836866048	114102272
2	51.922	52.594	51.891	0	0.672	836882432	114089984
2	51.953	52.625	51.922	0	0.672	836927488	113844224
2	52.172	52.86	52.141	0	0.688	836898816	113721344
2	51.89	52.562	51.859	0	0.672	836964352	113651712
2	69.11	69.797	69.094	0	0.672	836931584	113741824
2	51.907	52.578	51.859	0.016	0.671	836886528	114147328
2	69.047	69.719	69.016	0	0.672	836915200	113659904
2	86.75	87.547	86.469	0.078	0.703	836874240	114135040
2	69.281	69.968	69.25	0	0.671	836874240	114397184
2	52.031	52.688	52	0	0.657	836964352	113913856
2	51.89	52.594	51.859	0	0.672	836919296	113684480
2	52.187	52.875	52.141	0	0.688	836886528	114176000
2	52.016	52.703	51.985	0	0.687	836968448	113803264
2	69.891	70.563	69.86	0	0.672	837009408	113770496
2	68.985	69.672	68.938	0	0.672	836915200	113676288
2	69.125	69.796	69.078	0.015	0.671	836878336	114200576
2	69.063	69.766	69.016	0	0.703	836931584	113745920
2	51.875	52.547	51.844	0	0.672	836861952	113975296
2	52.016	52.687	51.984	0	0.671	836952064	113696768
2	52.25	52.938	52.203	0	0.672	836947968	113680384
2	52.031	52.719	52.016	0	0.672	836907008	114085888
2	52.391	53.078	52.36	0	0.687	836997120	113758208
2	52.016	52.719	52	0	0.688	836882432	113942528
2	52.109	52.781	52.078	0	0.672	837013504	113885184
2	69.484	70.266	69.234	0.032	0.672	836886528	114622464
2	52.235	52.938	52.219	0	0.688	836882432	114192384
2	52.578	53.359	52.281	0.078	0.687	836923392	113836032
2	52.031	52.703	52	0	0.672	837033984	113692672
2	51.782	52.469	51.734	0	0.687	836960256	113782784
2	51.75	52.406	51.703	0	0.656	836882432	113881088
2	51.937	52.625	51.891	0	0.672	836919296	113766400
2	51.828	52.515	51.812	0	0.671	836919296	113807360

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
2	52.047	52.75	52	0.016	0.687	836923392	113803264
2	52.047	52.735	52.016	0	0.688	836927488	114016256
2	52.125	52.906	51.875	0.031	0.687	836943872	113950720
2	52.031	52.687	52	0	0.656	836943872	113815552
2	52.172	52.86	52.125	0.016	0.688	836911104	113770496
2	51.985	52.657	51.954	0	0.672	836964352	113795072
2	69.094	69.766	69.063	0	0.672	836919296	113655808
2	52.047	52.703	52.016	0	0.656	836964352	113709056
2	69.578	70.266	69.547	0	0.656	836968448	113569792
2	68.922	69.594	68.891	0	0.672	836972544	113631232
2	69.062	69.734	69.015	0	0.672	836907008	113655808
2	51.953	52.625	51.922	0	0.672	836866048	113963008
2	69.36	70.047	69.328	0	0.687	836964352	113688576
2	52.344	53.032	52.313	0	0.688	836923392	113713152
2	51.938	52.625	51.891	0	0.687	836931584	113901568
2	69.406	70.172	69.156	0.032	0.672	836837376	114933760
2	52.344	53.047	52.312	0	0.703	836972544	113897472
2	51.656	52.344	51.625	0	0.688	836984832	113795072
2	52.203	52.891	52.156	0	0.688	836956160	113848320
2	52.031	52.719	52	0	0.688	836931584	113696768
2	51.781	52.453	51.75	0	0.672	836972544	113852416
2	52.172	52.844	52.125	0	0.672	836972544	113876992
2	69.141	69.797	69.078	0.016	0.656	836980736	113983488
2	51.922	52.594	51.891	0	0.672	836886528	113872896
2	69.203	69.891	69.172	0	0.672	836902912	114036736
2	86.859	87.625	86.578	0.063	0.672	836870144	113684480
2	69.187	69.875	69.172	0	0.672	836816896	113860608
2	51.954	52.641	51.922	0	0.687	836927488	113672192
2	52.031	52.718	52	0	0.687	836952064	113750016
2	52.156	52.844	52.109	0	0.688	836829184	114212864
2	51.953	52.641	51.922	0	0.688	836874240	114216960
2	69.532	70.204	69.5	0	0.672	836968448	113790976
2	68.75	69.438	68.703	0.016	0.688	836882432	114212864
2	69.265	69.953	69.25	0	0.672	836927488	113942528
2	69.219	69.906	69.172	0	0.687	836923392	113823744
2	52.125	52.797	52.094	0	0.672	837009408	113680384
2	52.64	53.297	52.609	0	0.657	837009408	113774592
2	51.797	52.484	51.766	0	0.687	836902912	113786880
2	52.234	52.922	52.219	0	0.672	836960256	113655808
2	51.703	52.375	51.687	0	0.672	836952064	116453376
2	52.297	52.984	52.266	0	0.687	836964352	114020352
2	52.032	52.719	52	0	0.687	836878336	113913856
2	69.516	70.297	69.266	0.047	0.672	836870144	116260864
3	52.016	52.688	51.985	0	0.672	836866048	113926144
3	69.125	69.796	69.078	0.015	0.671	836923392	113876992
3	52.172	52.86	52.141	0	0.688	836931584	113713152
3	52.469	53.141	52.438	0	0.672	836976640	113623040

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
3	52	52.688	51.953	0	0.688	836882432	113979392
3	69.453	70.125	69.422	0	0.672	836882432	114434048
3	87.015	87.828	86.562	0.078	0.688	836874240	113913856
3	51.969	52.64	51.937	0	0.671	836972544	113885184
3	104.516	105.312	104.188	0.109	0.703	836923392	113901568
3	52.344	53.109	52.094	0.031	0.672	836857856	114020352
3	52.125	52.797	52.078	0	0.672	836902912	114348032
3	68.937	69.625	68.906	0	0.688	836911104	113651712
3	52.078	52.766	52.047	0	0.672	836857856	114323456
3	70.188	70.922	70.047	0.031	0.672	837017600	113627136
3	69.39	70.078	69.359	0	0.688	836976640	113823744
3	52.453	53.141	52.422	0	0.672	837029888	113655808
3	69.781	70.547	69.531	0.032	0.672	836911104	114536448
3	69.547	70.234	69.516	0	0.687	836894720	113799168
3	69.5	70.187	69.468	0	0.687	836980736	113844224
3	52.688	53.454	52.437	0.031	0.672	837009408	113893376
3	51.688	52.359	51.656	0	0.671	836915200	113635328
3	51.782	52.454	51.75	0	0.657	836952064	113881088
3	69.656	70.328	69.61	0	0.672	837013504	113971200
3	104.234	104.937	104.203	0	0.703	836882432	114065408
3	51.75	52.421	51.718	0	0.671	836952064	114020352
3	52.296	53.078	52.047	0.031	0.672	836947968	114749440
3	52.406	53.078	52.375	0	0.672	837025792	113651712
3	52.329	53.016	52.297	0	0.687	836960256	113635328
3	52.125	52.797	52.094	0	0.672	836943872	113713152
3	52.485	53.156	52.422	0	0.671	836870144	113975296
3	51.953	52.656	51.922	0	0.703	836972544	113831936
3	51.859	52.531	51.813	0.015	0.672	836882432	114339840
3	52.25	52.937	52.234	0	0.672	836923392	113672192
3	52.094	52.766	52.063	0	0.672	836964352	113836032
3	104.141	104.922	103.813	0.109	0.687	836874240	115015680
3	52.329	53.016	52.297	0	0.687	836919296	113799168
3	52.016	52.703	51.969	0	0.672	837013504	113946624
3	52.219	52.891	52.172	0	0.672	836927488	113565696
3	51.813	52.485	51.782	0	0.672	836882432	113987584
3	70.125	70.89	69.86	0.031	0.656	837029888	113901568
3	70.172	70.953	69.828	0.11	0.687	836861952	114864128
3	51.938	52.61	51.89	0	0.672	836820992	113901568
3	69.266	69.953	69.219	0	0.687	836976640	113766400
3	52.282	52.969	52.234	0	0.687	836902912	113774592
3	69.406	70.094	69.375	0	0.688	836927488	114061312
3	52.156	52.828	52.125	0	0.672	836968448	113614848
3	103.937	104.719	103.61	0.109	0.688	836919296	114454528
3	51.984	52.656	51.953	0	0.672	836976640	113819648
3	52.125	52.797	52.094	0	0.672	836980736	113786880
3	51.656	52.328	51.625	0	0.672	836878336	113975296
3	52.015	52.719	51.984	0	0.704	836927488	114106368

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
3	69.078	69.75	69.047	0	0.672	836968448	113594368
3	52.079	52.75	52.031	0	0.671	836878336	113934336
3	51.844	52.532	51.813	0	0.688	836964352	113668096
3	52.297	52.984	52.266	0	0.672	836952064	113688576
3	69.235	69.922	69.203	0	0.672	836919296	113688576
3	87.344	88.14	86.89	0.078	0.671	836988928	113852416
3	51.75	52.422	51.719	0	0.672	836890624	114286592
3	104.312	105.094	103.984	0.11	0.688	836943872	114663424
3	52.063	52.843	51.813	0.031	0.687	836861952	114180096
3	51.969	52.656	51.937	0	0.687	836927488	113770496
3	69.25	69.953	69.219	0	0.687	836952064	113643520
3	51.86	52.547	51.828	0	0.687	836947968	116363264
3	69.532	70.281	69.39	0.032	0.687	836882432	114126848
3	69.281	69.953	69.235	0.015	0.672	836927488	113856512
3	51.906	52.609	51.875	0	0.687	836960256	113704960
3	69.734	70.515	69.485	0.031	0.671	836968448	114036736
3	69.375	70.047	69.344	0	0.672	836976640	113713152
3	69.234	69.922	69.203	0	0.688	836882432	114188288
3	52.578	53.36	52.313	0.047	0.688	836874240	114188288
3	52.297	52.984	52.25	0	0.672	836997120	113684480
3	52	52.672	51.969	0	0.672	836923392	113786880
3	69.156	69.844	69.125	0	0.688	836972544	113770496
3	103.985	104.672	103.938	0	0.687	836898816	113987584
3	52.141	52.829	52.11	0	0.688	836882432	114212864
3	52.375	53.157	52.11	0.031	0.672	836878336	114159616
3	51.938	52.625	51.89	0	0.687	837066752	116338688
3	51.938	52.609	51.89	0.016	0.671	836866048	116568064
3	52.016	52.688	51.985	0	0.672	836968448	113831936
3	51.921	52.609	51.875	0.015	0.672	836911104	113733632
3	51.984	52.656	51.938	0	0.672	836931584	113840128
3	52.422	53.094	52.406	0	0.657	836984832	113766400
3	52.172	52.844	52.141	0	0.656	836988928	113901568
3	51.968	52.671	51.953	0	0.687	836886528	114061312
3	104.093	104.875	103.782	0.109	0.672	836886528	113762304
3	52.172	52.859	52.141	0	0.687	836919296	113594368
3	52.078	52.75	52.016	0.015	0.672	836980736	113930240
3	51.985	52.657	51.953	0	0.672	836861952	114118656
3	52.687	53.359	52.656	0	0.672	836960256	115236864
3	70.016	70.782	69.766	0.031	0.672	837013504	113623040
3	69.594	70.375	69.266	0.125	0.688	836849664	114237440
3	51.578	52.25	51.531	0	0.672	836976640	113569792
3	69.36	70.063	69.329	0	0.703	836915200	116232192
3	51.687	52.359	51.656	0	0.656	836902912	113823744
3	69.484	70.171	69.438	0.015	0.687	836915200	113651712
3	51.984	52.656	51.937	0	0.672	836943872	113807360
3	104.079	104.843	103.75	0.109	0.671	836964352	114688000
3	51.968	52.64	51.922	0	0.672	836874240	114036736

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
3	51.984	52.656	51.953	0	0.672	836915200	114282496
3	52.39	53.093	52.359	0	0.703	836972544	114003968
3	51.719	52.422	51.687	0	0.688	836972544	113897472
3	69.234	69.922	69.203	0	0.688	836861952	114241536
3	51.89	52.578	51.859	0	0.688	836870144	114098176
3	51.875	52.547	51.828	0	0.672	836960256	113823744
3	52.125	52.812	52.093	0	0.687	836931584	113766400
3	70.797	71.454	70.766	0	0.657	836976640	113676288
3	87.172	87.969	86.719	0.078	0.672	836943872	113684480
3	51.891	52.563	51.859	0	0.672	836878336	113922048
3	104.219	104.984	103.891	0.109	0.672	836870144	116723712
3	52.547	53.312	52.297	0.031	0.671	836984832	114282496
3	52.062	52.75	52.031	0	0.688	836878336	114065408
3	69.641	70.313	69.594	0	0.672	837009408	113758208
3	52.109	52.781	52.078	0	0.672	836902912	113647616
3	71.328	72.062	71.188	0.031	0.672	836927488	113725440
3	69.297	70	69.266	0	0.687	836882432	114270208
3	51.782	52.454	51.734	0	0.672	836911104	113696768
3	69.328	70.094	69.078	0.031	0.672	836968448	113741824
3	69.704	70.375	69.657	0	0.656	836960256	113569792
3	69.484	70.156	69.453	0	0.672	836931584	113704960
3	52.266	53.032	52.016	0.031	0.672	836923392	113672192
3	51.953	52.625	51.922	0	0.672	836874240	114061312
3	52.032	52.719	52	0	0.672	836923392	113635328
3	69.312	70	69.281	0	0.688	836960256	113696768
3	103.985	104.672	103.953	0	0.687	836993024	114044928
3	51.891	52.562	51.859	0	0.671	836976640	113856512
3	52.625	53.39	52.359	0.047	0.671	836972544	113627136
3	52.562	53.266	52.531	0	0.688	836935680	113868800
3	51.985	52.657	51.953	0	0.672	836947968	113659904
3	52.734	53.406	52.703	0	0.672	836878336	114413568
3	51.672	52.344	51.64	0	0.672	836956160	113688576
3	52.656	53.328	52.625	0	0.672	836911104	116273152
3	51.828	52.515	51.781	0.015	0.687	836927488	113655808
3	52.188	52.875	52.157	0	0.687	836927488	113668096
3	52.656	53.313	52.625	0	0.657	837013504	113790976
3	105.078	105.86	104.75	0.109	0.688	836861952	114065408
3	52.078	52.75	52.047	0	0.672	836874240	114221056
3	52.296	52.968	52.265	0	0.672	836972544	113963008
3	51.829	52.5	51.797	0	0.671	836890624	113922048
3	52.14	52.828	52.094	0	0.688	836927488	113958912
3	69.36	70.125	69.094	0.031	0.672	836960256	113614848
3	69.718	70.5	69.391	0.125	0.688	836911104	114487296
3	51.859	52.546	51.828	0	0.687	836964352	113922048
3	69.969	70.657	69.938	0	0.688	836907008	113823744
3	52.234	52.906	52.203	0	0.672	836861952	113602560
3	69.781	70.453	69.75	0	0.672	836980736	113717248

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
3	51.875	52.562	51.844	0	0.672	836976640	113844224
3	104.937	105.703	104.594	0.11	0.672	836960256	113594368
3	52.438	53.109	52.406	0	0.671	836956160	113577984
3	52.297	52.984	52.266	0.015	0.687	836972544	113737728
3	52.563	53.25	52.516	0	0.687	836931584	113680384
3	52.11	52.797	52.078	0	0.687	836886528	113987584
3	69.407	70.063	69.36	0	0.656	836956160	113741824
3	52.328	53.016	52.297	0	0.688	836902912	113713152
3	52.265	52.953	52.219	0	0.688	837009408	113651712
3	51.812	52.5	51.781	0	0.688	836833280	113610752
3	68.985	69.656	68.953	0	0.671	836878336	114036736
3	87.281	88.109	86.828	0.079	0.703	836882432	114978816
3	52.282	52.954	52.25	0	0.672	836935680	113856512
3	105.125	105.906	104.797	0.125	0.687	836997120	113647616
3	52.391	53.172	52.125	0.047	0.687	836870144	113975296
3	52	52.672	51.969	0	0.672	836882432	113954816
3	68.859	69.547	68.828	0	0.688	836857856	113668096
3	52.11	52.782	52.047	0	0.672	837021696	113823744
3	69.329	70.062	69.187	0.031	0.671	836972544	114610176
3	69.828	70.484	69.797	0	0.656	837021696	113647616
3	52.344	53.016	52.297	0.016	0.672	836915200	113635328
3	69.985	70.765	69.735	0.031	0.687	836931584	113844224
3	69.406	70.078	69.375	0.015	0.656	836976640	113606656
3	69.141	69.829	69.109	0.016	0.672	836919296	113725440
3	52.734	53.5	52.469	0.047	0.672	836976640	113618944
3	52.5	53.171	52.453	0.015	0.671	836988928	113852416
3	51.922	52.594	51.891	0	0.672	836907008	113991680
3	69.984	70.672	69.938	0.015	0.688	837025792	113819648
3	104.656	105.328	104.609	0	0.672	837029888	113659904
3	52.172	52.86	52.125	0.016	0.688	836886528	113655808
3	52.313	53.093	52.063	0.031	0.687	836943872	113971200
3	51.969	52.656	51.922	0	0.671	836849664	114180096
3	51.89	52.578	51.859	0	0.672	836947968	113836032
3	52.75	53.422	52.718	0	0.672	836972544	113598464
3	53	53.672	52.969	0.015	0.657	836972544	113725440
3	52.438	53.11	52.406	0	0.672	837021696	113631232
3	51.969	52.656	51.938	0	0.672	836878336	113971200
3	52.375	53.047	52.328	0	0.672	836968448	113545216
3	51.875	52.547	51.828	0	0.656	836927488	113750016
3	104.406	105.187	104.094	0.109	0.672	836964352	113774592
3	52.203	52.875	52.172	0	0.672	836849664	114200576
3	52	52.672	51.953	0	0.656	836972544	113754112
3	51.891	52.563	51.859	0	0.672	836882432	114216960
3	52.313	53	52.282	0	0.687	836968448	114098176
3	70.032	70.781	69.75	0.047	0.656	836952064	116178944
3	69.938	70.718	69.61	0.109	0.687	836972544	114450432
3	52.891	53.563	52.86	0	0.672	837021696	113651712

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
3	70.328	71.016	70.297	0	0.688	836984832	113852416
3	51.922	52.594	51.875	0	0.672	836939776	113795072
3	69.344	70.016	69.297	0	0.672	836874240	113983488
3	51.906	52.578	51.875	0	0.672	836878336	113885184
3	104.125	104.891	103.797	0.125	0.656	836976640	113795072
3	52.266	52.938	52.235	0	0.672	836915200	113635328
3	52.406	53.078	52.375	0	0.656	836960256	116187136
3	51.969	52.641	51.938	0	0.672	836919296	113836032
3	52.266	52.953	52.235	0	0.687	836829184	113659904
3	69.203	69.891	69.172	0	0.688	836878336	114020352
3	52.297	52.984	52.265	0	0.687	837017600	116076544
3	52.125	52.812	52.078	0.016	0.687	836997120	113635328
3	51.922	52.625	51.875	0	0.703	836923392	114966528
3	69.531	70.218	69.515	0	0.672	836878336	114028544
3	87.719	88.516	87.266	0.078	0.672	836943872	114069504
3	52.781	53.453	52.75	0	0.672	837009408	113815552
3	103.719	104.5	103.39	0.11	0.672	836882432	115097600
3	51.047	51.813	50.797	0.031	0.672	836968448	113577984
3	52.984	53.672	52.938	0	0.688	836931584	113573888
3	69.36	70.032	69.312	0.016	0.657	836976640	113885184
3	51.844	52.516	51.828	0	0.672	836964352	113741824
3	69.797	70.516	69.641	0.031	0.672	836866048	114024448
3	69.172	69.859	69.14	0	0.687	836939776	113803264
3	51.828	52.515	51.797	0.015	0.672	836927488	113836032
3	69.703	70.469	69.421	0.047	0.672	836968448	114606080
3	69.047	69.719	69	0	0.672	836890624	114221056
3	69.157	69.844	69.109	0	0.672	837017600	113840128
3	52.859	53.641	52.61	0.031	0.672	836931584	113799168
3	52.281	52.953	52.25	0	0.657	836943872	113569792
3	52.016	52.688	51.985	0	0.672	836927488	113909760
3	69.422	70.094	69.391	0	0.672	836964352	113807360
3	104.407	105.079	104.375	0	0.672	836812800	114143232
3	52.047	52.719	52.015	0	0.672	836931584	113704960
3	52.094	52.875	51.828	0.047	0.688	836964352	114487296
3	52.485	53.157	52.453	0	0.672	836923392	113872896
3	52.266	52.922	52.235	0	0.656	836870144	114286592
3	51.828	52.516	51.797	0	0.688	836976640	113868800
3	52.125	52.797	52.094	0	0.672	836988928	113594368
3	52.047	52.719	52.016	0	0.672	836898816	113676288
3	51.828	52.5	51.781	0	0.672	836915200	116416512
3	52.125	52.813	52.094	0	0.688	836849664	114130944
3	51.828	52.5	51.796	0	0.672	836882432	113975296
3	104.843	105.609	104.516	0.109	0.672	836902912	114659328
3	53.328	54	53.296	0	0.672	836837376	113668096
3	52.265	52.937	52.219	0	0.672	836972544	113700864
3	52.5	53.172	52.469	0	0.656	836947968	113545216
3	51.922	52.593	51.89	0	0.671	836894720	114348032

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
3	69.734	70.5	69.469	0.047	0.672	836968448	114044928
3	70.281	71.062	69.953	0.125	0.687	837001216	116232192
3	51.828	52.5	51.796	0	0.672	836972544	113639424
3	69.484	70.156	69.453	0	0.672	836915200	113688576
3	52	52.672	51.953	0	0.672	836812800	114135040
3	69.063	69.765	69.032	0	0.687	836902912	114032640
3	52.063	52.735	52.032	0	0.672	836915200	113659904
3	104.078	104.875	103.75	0.125	0.687	836878336	115044352
3	51.765	52.453	51.734	0	0.688	836919296	113643520
3	52.61	53.297	52.578	0	0.687	836886528	114225152
3	52.047	52.719	52.016	0	0.672	836956160	113946624
4	69.625	70.312	69.579	0.015	0.687	836927488	113737728
4	69.907	70.594	69.859	0.016	0.687	836976640	113623040
4	69.75	70.438	69.719	0	0.688	836972544	113840128
4	70.453	71.25	69.921	0.157	0.672	836980736	114438144
4	69.469	70.141	69.406	0.016	0.672	836878336	114077696
4	70.922	71.61	70.891	0	0.672	836952064	113713152
4	69.766	70.578	69.25	0.14	0.687	837009408	113823744
4	120.922	121.688	120.563	0.14	0.672	836882432	114651136
4	69.704	70.484	69.453	0.031	0.672	836968448	113737728
4	87.562	88.313	87.266	0.078	0.657	836972544	113594368
4	69.359	70.062	69.328	0	0.703	836886528	113934336
4	51.968	52.64	51.922	0	0.672	836927488	113618944
4	52.141	52.828	52.093	0.016	0.687	836976640	113885184
4	51.921	52.593	51.875	0.015	0.672	836907008	113602560
4	69.672	70.359	69.64	0	0.687	836882432	114241536
4	87.093	87.859	86.781	0.11	0.672	836988928	114532352
4	86.61	87.297	86.578	0	0.687	836861952	113926144
4	52.484	53.156	52.453	0	0.672	836927488	113827840
4	53.094	53.766	53.063	0	0.672	836882432	114200576
4	69.656	70.328	69.625	0	0.672	836882432	114204672
4	69.313	69.985	69.25	0.016	0.672	836882432	114245632
4	69.375	70.047	69.344	0	0.672	836927488	114286592
4	69.562	70.344	69.312	0.032	0.688	836849664	114728960
4	69.297	69.984	69.25	0.016	0.687	836976640	113688576
4	52.094	52.782	52.062	0	0.672	836952064	113704960
4	70.156	70.938	69.89	0.047	0.688	836890624	114782208
4	86.828	87.64	86.375	0.078	0.672	836919296	114044928
4	52.219	52.891	52.172	0	0.672	836861952	116699136
4	70	70.781	69.766	0.031	0.672	836960256	113651712
4	70.547	71.234	70.515	0	0.687	836857856	114114560
4	52.094	52.781	52.078	0	0.687	836927488	113659904
4	51.687	52.375	51.656	0	0.688	836874240	114176000
4	69.547	70.235	69.516	0	0.688	836927488	113721344
4	69.953	70.75	69.438	0.14	0.672	836976640	114073600
4	52.609	53.296	52.563	0	0.687	836952064	113647616
4	69.656	70.422	69.375	0.063	0.672	836886528	113594368

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
4	52.266	52.953	52.218	0	0.672	836870144	114245632
4	69.562	70.25	69.516	0.015	0.688	836878336	114130944
4	104.922	105.75	104.406	0.125	0.688	837021696	114434048
4	70.422	71.25	69.938	0.125	0.687	836972544	114049024
4	86.922	87.719	86.485	0.062	0.672	836943872	113696768
4	69.219	69.89	69.187	0	0.671	836878336	114163712
4	69.734	70.421	69.688	0	0.687	836874240	114016256
4	52.391	53.062	52.359	0	0.671	836968448	113545216
4	52.265	52.953	52.234	0	0.688	836956160	113803264
4	52.031	52.719	52.016	0	0.672	836919296	113709056
4	70.297	71.063	70.016	0.047	0.672	836915200	114507776
4	88.11	88.922	87.687	0.063	0.687	837021696	113623040
4	52.312	53	52.266	0.015	0.688	836927488	113750016
4	69.25	69.921	69.218	0	0.671	836919296	113672192
4	69.641	70.313	69.61	0	0.672	837021696	113795072
4	69.875	70.562	69.844	0	0.687	836882432	114085888
4	69.281	69.953	69.25	0	0.672	836976640	113872896
4	69.734	70.531	69.219	0.141	0.672	836919296	114130944
4	69.968	70.64	69.937	0	0.672	836956160	116154368
4	69.282	69.969	69.25	0	0.672	836870144	114204672
4	69.828	70.625	69.313	0.14	0.672	836976640	114647040
4	121.781	122.562	121.422	0.156	0.672	836902912	114003968
4	69.609	70.39	69.36	0.031	0.687	837025792	113778688
4	86.953	87.719	86.657	0.078	0.672	836878336	114900992
4	69.782	70.469	69.734	0.016	0.687	836886528	114151424
4	52.734	53.39	52.703	0	0.656	836968448	113557504
4	52.047	52.735	52.016	0	0.688	836964352	113680384
4	51.843	52.515	51.797	0	0.672	836968448	113676288
4	69.219	69.906	69.188	0	0.687	836902912	113737728
4	87.156	87.953	86.828	0.125	0.687	836886528	114675712
4	86.968	87.656	86.922	0	0.688	836907008	113700864
4	52.391	53.078	52.359	0	0.687	836952064	113545216
4	52.125	52.797	52.078	0.016	0.672	836882432	114089984
4	69.406	70.078	69.375	0	0.672	836911104	113647616
4	69.766	70.438	69.719	0	0.672	836902912	113786880
4	69.485	70.172	69.453	0	0.687	836997120	113659904
4	69.719	70.5	69.468	0.032	0.687	836915200	113684480
4	69.406	70.078	69.375	0	0.672	836882432	113930240
4	51.921	52.625	51.89	0	0.704	836874240	114200576
4	69.625	70.406	69.375	0.032	0.671	836898816	114188288
4	86.797	87.594	86.375	0.078	0.656	836870144	114831360
4	52.266	52.969	52.25	0	0.672	836874240	114016256
4	69.735	70.516	69.468	0.047	0.687	836923392	114483200
4	69.063	69.735	69.032	0	0.672	836878336	114102272
4	52.141	52.828	52.11	0	0.672	836911104	113647616
4	52.078	52.766	52.031	0	0.688	836911104	113762304
4	69.438	70.125	69.407	0	0.687	836980736	113745920

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
4	70.375	71.187	69.859	0.141	0.687	836972544	114442240
4	52.031	52.703	52	0	0.672	836878336	113926144
4	70.093	70.859	69.797	0.078	0.672	836931584	114491392
4	52.484	53.171	52.453	0	0.687	837009408	113577984
4	70.875	71.547	70.828	0	0.672	836861952	114200576
4	104.25	105.078	103.719	0.141	0.687	836894720	114270208
4	70.125	70.937	69.625	0.125	0.672	836886528	114638848
4	87.625	88.438	87.187	0.063	0.688	836878336	114429952
4	69.25	69.921	69.218	0	0.671	836964352	113721344
4	70	70.672	69.968	0	0.672	836927488	113475584
4	52.656	53.328	52.625	0	0.672	836857856	113840128
4	52.063	52.75	52.016	0.016	0.687	836902912	116322304
4	52.062	52.734	52.031	0	0.672	836972544	113750016
4	70.297	71.078	70.031	0.031	0.687	836972544	113664000
4	87.375	88.172	86.938	0.062	0.672	836935680	113733632
4	52.078	52.75	52.047	0	0.672	836878336	113934336
4	69.281	69.953	69.25	0	0.672	836947968	113651712
4	69.375	70.046	69.343	0	0.671	836923392	113795072
4	69.891	70.594	69.843	0.016	0.703	837005312	113655808
4	69.109	69.797	69.078	0	0.688	836943872	113692672
4	69.875	70.688	69.359	0.141	0.688	836931584	114102272
4	69.719	70.422	69.672	0	0.703	836878336	114417664
4	69.5	70.172	69.453	0.016	0.672	837025792	113754112
4	69.969	70.782	69.453	0.141	0.688	836935680	114585600
4	122.281	123.031	121.922	0.141	0.656	837017600	114675712
4	70.375	71.172	70.125	0.031	0.688	836878336	113594368
4	87.297	88.078	87	0.078	0.672	836870144	114151424
4	69.562	70.25	69.516	0	0.688	836984832	113754112
4	51.859	52.546	51.828	0	0.671	836882432	113737728
4	51.954	52.641	51.938	0	0.687	836845568	114098176
4	52.203	52.891	52.156	0	0.688	836870144	113897472
4	69.25	69.922	69.203	0.015	0.672	836927488	113684480
4	87.5	88.265	87.172	0.109	0.672	836923392	114143232
4	86.656	87.344	86.61	0	0.688	836866048	113922048
4	52.375	53.062	52.329	0.015	0.672	836841472	114196480
4	52.375	53.047	52.344	0	0.672	836964352	113786880
4	69.469	70.157	69.438	0	0.688	836927488	113758208
4	69.781	70.469	69.735	0	0.688	836976640	113876992
4	70.047	70.719	70.016	0	0.672	836931584	114049024
4	69.86	70.641	69.578	0.047	0.687	836931584	113938432
4	69.969	70.641	69.937	0	0.672	836931584	113721344
4	51.813	52.5	51.781	0	0.687	836923392	113717248
4	69.672	70.469	69.422	0.047	0.688	836923392	113725440
4	87.015	87.828	86.562	0.094	0.688	836923392	114421760
4	51.984	52.688	51.953	0	0.672	836972544	113774592
4	69.484	70.266	69.25	0.032	0.672	836972544	113659904
4	69.687	70.359	69.641	0.015	0.672	836894720	113958912

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
4	52.094	52.781	52.062	0	0.687	836874240	113979392
4	51.938	52.609	51.906	0	0.671	836960256	113942528
4	69.375	70.047	69.328	0	0.672	836972544	113745920
4	70.359	71.172	69.844	0.14	0.688	836870144	114143232
4	51.719	52.406	51.687	0	0.687	836919296	113635328
4	70.688	71.453	70.391	0.078	0.672	837021696	113831936
4	52.406	53.093	52.375	0	0.687	836911104	113643520
4	69.265	69.921	69.234	0	0.656	836878336	114044928
4	104.515	105.328	103.984	0.141	0.672	836898816	114679808
4	70.281	71.094	69.797	0.125	0.672	836976640	114327552
4	88.5	89.297	88.063	0.062	0.656	836935680	113987584
4	69.235	69.922	69.203	0	0.687	836857856	114302976
4	69.672	70.344	69.641	0	0.672	836878336	113967104
4	51.937	52.609	51.891	0	0.672	836976640	113655808
4	51.969	52.656	51.922	0	0.687	836870144	114307072
4	52.016	52.688	51.969	0.016	0.656	837017600	113913856
4	69.578	70.344	69.312	0.047	0.672	836931584	113729536
4	87.516	88.313	87.078	0.062	0.672	836915200	113709056
4	52.547	53.219	52.515	0	0.672	836935680	113709056
4	69.421	70.093	69.375	0	0.672	836866048	114122752
4	69.922	70.594	69.891	0	0.672	836964352	113688576
4	69.75	70.422	69.719	0	0.672	836980736	113700864
4	70.078	70.75	70.047	0	0.672	836984832	113860608
4	70.172	71	69.656	0.141	0.672	836882432	114630656
4	70.141	70.844	70.109	0	0.688	836923392	113631232
4	69.609	70.281	69.563	0	0.672	836927488	113848320
4	70.047	70.86	69.547	0.141	0.688	836931584	113885184
4	122.406	123.187	122.063	0.156	0.656	836980736	113754112
4	69.718	70.5	69.469	0.031	0.688	836915200	114524160
4	86.984	87.75	86.688	0.078	0.656	836853760	113979392
4	69.531	70.219	69.5	0	0.672	836968448	113848320
4	51.985	52.657	51.938	0	0.672	836923392	113750016
4	52.375	53.063	52.344	0	0.688	836874240	113979392
4	52.078	52.75	52.047	0	0.672	837005312	113721344
4	69.344	70.016	69.297	0	0.672	836870144	114151424
4	87.469	88.25	87.14	0.11	0.687	836890624	114221056
4	86.734	87.422	86.719	0	0.672	836857856	114241536
4	52.078	52.766	52.047	0	0.672	836861952	116002816
4	51.813	52.485	51.766	0	0.672	836935680	113651712
4	69.265	69.937	69.219	0.015	0.672	836878336	114225152
4	69.796	70.484	69.765	0	0.688	836886528	114155520
4	69.391	70.063	69.36	0	0.672	836964352	113594368
4	69.516	70.281	69.25	0.047	0.671	836837376	114204672
4	69.219	69.891	69.172	0	0.672	836898816	113684480
4	52.25	52.922	52.203	0	0.672	836956160	113963008
4	69.515	70.297	69.25	0.047	0.688	836915200	114667520
4	87.266	88.047	86.813	0.078	0.656	836935680	114581504

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
4	52.406	53.078	52.375	0	0.672	836882432	113971200
4	70.172	70.937	69.906	0.047	0.656	836890624	113979392
4	69.188	69.891	69.157	0	0.703	836919296	113831936
4	52.094	52.797	52.063	0	0.688	836861952	113995776
4	51.969	52.656	51.922	0	0.687	836915200	113823744
4	69.266	69.938	69.218	0	0.672	836964352	113680384
4	70.484	71.281	69.969	0.14	0.672	836898816	114200576
4	51.984	52.672	51.938	0	0.672	836976640	113848320
4	69.859	70.61	69.578	0.062	0.657	837009408	114024448
4	52.063	52.766	52.047	0	0.688	836841472	114323456
4	69.375	70.047	69.344	0	0.672	836927488	113750016
4	103.968	104.781	103.438	0.125	0.672	836923392	114110464
4	70.64	71.453	70.157	0.125	0.672	836882432	114331648
4	87.235	88.047	86.797	0.062	0.672	836874240	114319360
4	69.437	70.093	69.406	0	0.656	836931584	113717248
4	69.297	69.985	69.25	0.016	0.688	836960256	113840128
4	52.094	52.781	52.062	0	0.687	836894720	114212864
4	52.063	52.734	52.031	0	0.671	836980736	113971200
4	52.093	52.781	52.062	0	0.688	836878336	114061312
4	69.89	70.656	69.625	0.047	0.672	836935680	114061312
4	87.156	87.938	86.719	0.062	0.657	836923392	113934336
4	52.094	52.766	52.063	0	0.672	836972544	115732480
4	69.266	69.969	69.235	0	0.703	836907008	113811456
4	69.109	69.797	69.078	0	0.672	836972544	113745920
4	70.172	70.828	70.141	0	0.656	837021696	113618944
4	69.453	70.125	69.422	0	0.672	836886528	114049024
4	69.859	70.656	69.359	0.141	0.672	837009408	114495488
4	69.703	70.391	69.672	0	0.672	836972544	113717248
4	69.906	70.578	69.875	0	0.672	836964352	113594368
4	70	70.813	69.5	0.141	0.688	836882432	114626560
4	121.969	122.735	121.594	0.156	0.672	836886528	115019776
4	69.547	70.328	69.281	0.047	0.688	836976640	114622464
4	86.906	87.672	86.625	0.078	0.672	836886528	114106368
4	69.36	70.032	69.328	0	0.672	836935680	113774592
4	52.062	52.734	52.031	0	0.672	837058560	116494336
4	52.093	52.765	52.062	0	0.672	836890624	114028544
4	52.531	53.203	52.5	0	0.672	836964352	113725440
4	69.625	70.297	69.578	0.016	0.672	836882432	113926144
4	87.703	88.485	87.375	0.109	0.688	837021696	114524160
4	86.703	87.39	86.657	0.015	0.687	836960256	113713152
4	52.218	52.922	52.187	0	0.688	836956160	115163136
4	52.093	52.765	52.078	0	0.656	836923392	113709056
4	69.266	69.953	69.219	0.016	0.672	836882432	114294784
4	69.609	70.281	69.578	0	0.672	836878336	114237440
4	69.469	70.141	69.438	0	0.672	837013504	113639424
4	69.828	70.594	69.578	0.031	0.672	836919296	113684480
4	69.328	70.015	69.282	0.015	0.687	836968448	113745920

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
4	52	52.672	51.969	0	0.672	836976640	113885184
4	69.89	70.64	69.609	0.047	0.656	837005312	113586176
4	86.938	87.75	86.485	0.078	0.687	837001216	114376704
4	52.047	52.718	52	0	0.671	836915200	113602560
4	70.016	70.781	69.75	0.047	0.672	836882432	114163712
4	69.141	69.813	69.094	0	0.672	836878336	114532352
4	52.031	52.719	52	0	0.688	836927488	113700864
4	53.109	53.797	53.078	0	0.688	836956160	113852416
4	69.828	70.515	69.797	0	0.687	836915200	113643520
4	70.515	71.328	70	0.141	0.672	836874240	113909760
4	52.25	52.937	52.218	0	0.687	836988928	113741824
4	69.719	70.5	69.421	0.079	0.687	836878336	114171904
4	52.813	53.5	52.781	0	0.687	836980736	113582080
4	69.578	70.25	69.531	0	0.672	836952064	113762304
4	105.188	106	104.672	0.125	0.656	837009408	114503680
4	70.5	71.297	70	0.125	0.672	836980736	114323456
4	87.235	88.047	86.796	0.063	0.687	836820992	116355072
4	69.844	70.516	69.812	0	0.672	836980736	113623040
4	69.406	70.11	69.359	0.016	0.688	836972544	113782784
4	52	52.687	51.969	0	0.687	836870144	114126848
4	52.14	52.843	52.109	0	0.703	836923392	113635328
4	52.047	52.734	52.015	0	0.687	836923392	113909760
4	69.578	70.344	69.329	0.031	0.672	836923392	114098176
4	87.063	87.86	86.625	0.063	0.672	836960256	114528256
4	52.281	52.953	52.25	0	0.672	837017600	113606656
4	69.359	70.047	69.312	0.016	0.672	836931584	113664000
5	69.188	69.86	69.156	0	0.672	836882432	114008064
5	122.453	123.281	121.672	0.203	0.672	837001216	114331648
5	52.172	52.844	52.141	0	0.672	836911104	113635328
5	52.157	52.844	52.125	0	0.687	836878336	114012160
5	52.11	52.782	52.078	0	0.672	836972544	113774592
5	104.782	105.563	104.468	0.11	0.672	836980736	113799168
5	88.5	89.359	87.766	0.156	0.688	836878336	114958336
5	87.187	88	86.734	0.079	0.672	836927488	113790976
5	52.203	52.875	52.14	0	0.672	836947968	113737728
5	104.141	104.828	104.11	0	0.687	836964352	113602560
5	52.188	52.875	52.157	0	0.687	836886528	114360320
5	104.281	105.047	104	0.078	0.672	836870144	114896896
5	70.031	70.813	69.796	0.032	0.672	836972544	113750016
5	70.687	71.5	69.953	0.141	0.672	836931584	114700288
5	52.234	52.922	52.203	0	0.672	836874240	114114560
5	52.656	53.359	52.625	0	0.703	837013504	113741824
5	52.141	52.797	52.094	0	0.656	836960256	113647616
5	52.078	52.766	52.047	0	0.688	836853760	116654080
5	52.64	53.312	52.609	0	0.672	836968448	113594368
5	52.625	53.313	52.578	0	0.688	836960256	113463296
5	70.203	70.968	69.875	0.109	0.656	836976640	113831936

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
5	52.516	53.187	52.484	0	0.671	836972544	113700864
5	87.047	87.735	87	0	0.688	836923392	113782784
5	52.484	53.172	52.453	0	0.672	836993024	113709056
5	52.266	52.953	52.219	0	0.687	836923392	113840128
5	70.562	71.343	70.031	0.157	0.656	836976640	114352128
5	69.953	70.734	69.656	0.079	0.672	836927488	113860608
5	104.719	105.562	103.922	0.218	0.671	836882432	114806784
5	121.985	122.781	121.406	0.187	0.687	836968448	114098176
5	69.922	70.594	69.875	0.016	0.672	837013504	113639424
5	69.922	70.609	69.891	0	0.687	836927488	113688576
5	87.546	88.359	86.969	0.203	0.688	836874240	113803264
5	87.062	87.828	86.734	0.11	0.672	836923392	113614848
5	52.719	53.391	52.672	0	0.672	836968448	113815552
5	69.281	69.953	69.25	0	0.672	836952064	113672192
5	69.468	70.156	69.437	0	0.688	836964352	113860608
5	104.984	105.828	104.188	0.218	0.688	836943872	114561024
5	52.391	53.079	52.375	0	0.672	836923392	113627136
5	52.219	52.906	52.172	0	0.687	836870144	113795072
5	86.531	87.219	86.5	0	0.688	836993024	113770496
5	52.578	53.25	52.547	0	0.672	836972544	113598464
5	69.187	69.859	69.156	0	0.672	836902912	113647616
5	52.281	52.953	52.25	0	0.672	836956160	113684480
5	52.344	53.125	52.078	0.047	0.688	836907008	113627136
5	51.937	52.609	51.891	0	0.672	836886528	113897472
5	86.813	87.485	86.766	0.016	0.672	837021696	113778688
5	52.188	52.86	52.141	0	0.672	836870144	113582080
5	69.453	70.125	69.422	0	0.672	836943872	113770496
5	104.86	105.657	104.344	0.141	0.657	836980736	114036736
5	105.297	106.156	104.25	0.218	0.671	836923392	114225152
5	69.234	69.922	69.203	0	0.672	836874240	113905664
5	121.922	122.75	121.109	0.203	0.672	836960256	114778112
5	52.156	52.844	52.125	0	0.688	836923392	114069504
5	52.359	53.031	52.328	0	0.672	836898816	113639424
5	53.094	53.766	53.062	0	0.672	836976640	113594368
5	104.985	105.765	104.672	0.125	0.672	836972544	114692096
5	87.938	88.797	87.234	0.141	0.688	836878336	114372608
5	87.391	88.219	86.937	0.094	0.687	836902912	113885184
5	51.969	52.641	51.937	0	0.672	836976640	113717248
5	103.797	104.484	103.766	0	0.687	836907008	113872896
5	52.328	53.016	52.297	0	0.688	836952064	113549312
5	104.656	105.438	104.36	0.078	0.672	836943872	113876992
5	69.703	70.468	69.453	0.031	0.672	836964352	114638848
5	70.781	71.609	70.063	0.14	0.672	836993024	114012160
5	52.188	52.875	52.141	0	0.672	836919296	113655808
5	51.937	52.625	51.906	0	0.688	836976640	113840128
5	52.063	52.75	52.047	0	0.672	837009408	113655808
5	52.063	52.735	52.032	0	0.672	836968448	113999872

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
5	52.359	53.047	52.328	0	0.688	836915200	113823744
5	52.219	52.906	52.172	0	0.687	836976640	113774592
5	70.063	70.828	69.734	0.109	0.671	836931584	113971200
5	51.984	52.656	51.953	0	0.672	836972544	113913856
5	88	88.703	87.953	0.015	0.703	836866048	113643520
5	52.281	52.953	52.25	0	0.672	836841472	114122752
5	52.031	52.703	51.985	0	0.672	836960256	113668096
5	70	70.812	69.484	0.141	0.671	836886528	114274304
5	69.828	70.61	69.515	0.078	0.672	836964352	114532352
5	105.672	106.515	104.875	0.219	0.687	836927488	114524160
5	122.875	123.656	122.282	0.187	0.656	836976640	114057216
5	69.563	70.25	69.532	0	0.687	836886528	113999872
5	69.64	70.312	69.609	0	0.672	837087232	117010432
5	87.735	88.562	87.171	0.188	0.687	836853760	114376704
5	87.421	88.172	87.094	0.109	0.657	836972544	113881088
5	52.031	52.703	51.984	0.016	0.672	836968448	113954816
5	69.359	70.047	69.328	0	0.688	836968448	113930240
5	69.563	70.25	69.532	0	0.687	836923392	114036736
5	105.235	106.078	104.422	0.218	0.687	837005312	114733056
5	52.141	52.813	52.109	0	0.672	836923392	113676288
5	52.063	52.75	52.015	0	0.687	836878336	113917952
5	86.656	87.328	86.625	0	0.657	836886528	113979392
5	52.297	52.969	52.25	0	0.672	836907008	113610752
5	69.187	69.859	69.156	0	0.672	836927488	114106368
5	51.922	52.594	51.875	0	0.672	837013504	113897472
5	52.953	53.718	52.687	0.047	0.672	836980736	114515968
5	52.015	52.703	51.969	0	0.688	836972544	113668096
5	86.891	87.578	86.844	0.016	0.687	836972544	114061312
5	52.188	52.891	52.156	0	0.688	836980736	113913856
5	69.406	70.078	69.375	0	0.672	836853760	113999872
5	104.687	105.484	104.187	0.125	0.672	836907008	114778112
5	105.344	106.235	104.281	0.235	0.672	836927488	114688000
5	69.313	70	69.297	0	0.672	836902912	113971200
5	121.782	122.609	121	0.203	0.671	836956160	114884608
5	51.984	52.656	51.953	0	0.672	836882432	113975296
5	52.109	52.797	52.062	0.016	0.672	836931584	113930240
5	51.906	52.593	51.875	0	0.687	836890624	114237440
5	105.578	106.36	105.25	0.11	0.672	836972544	113770496
5	87.359	88.187	86.641	0.14	0.672	836947968	113958912
5	87.188	87.985	86.719	0.078	0.672	836902912	114008064
5	52.109	52.781	52.078	0	0.672	836886528	114229248
5	105.547	106.235	105.484	0.016	0.688	836968448	113770496
5	51.89	52.578	51.859	0	0.672	836890624	115515392
5	104.406	105.172	104.125	0.078	0.672	836923392	113807360
5	69.437	70.203	69.172	0.047	0.657	836919296	113963008
5	70.485	71.328	69.765	0.141	0.687	836956160	114630656
5	52.156	52.828	52.125	0	0.672	836972544	113684480

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
5	52.204	52.891	52.172	0	0.687	836943872	113696768
5	52.469	53.141	52.438	0	0.672	836972544	113627136
5	52.078	52.75	52.032	0	0.672	836927488	113836032
5	52.234	52.906	52.203	0	0.672	836874240	113991680
5	51.954	52.641	51.906	0.016	0.687	836898816	113704960
5	69.797	70.578	69.469	0.109	0.688	836952064	113704960
5	52.188	52.86	52.156	0	0.672	836988928	113917952
5	87.25	87.922	87.203	0	0.672	836997120	113606656
5	52.218	52.89	52.187	0	0.672	836812800	113729536
5	52.578	53.266	52.547	0	0.688	836874240	114085888
5	70.235	71.063	69.719	0.141	0.672	836943872	114544640
5	69.625	70.422	69.328	0.078	0.688	836960256	113958912
5	104.578	105.422	103.797	0.203	0.688	836952064	114085888
5	122.062	122.875	121.5	0.188	0.688	836923392	114446336
5	69.594	70.266	69.562	0	0.672	836972544	113709056
5	69.219	69.907	69.188	0	0.688	836923392	113610752
5	87.375	88.172	86.797	0.203	0.672	836964352	114171904
5	87.125	87.891	86.797	0.125	0.672	836968448	114524160
5	52.078	52.766	52.047	0	0.688	836911104	113758208
5	69.547	70.25	69.516	0	0.688	836923392	113864704
5	69.141	69.828	69.109	0	0.672	836964352	113713152
5	104.453	105.281	103.641	0.219	0.672	836923392	114167808
5	52.078	52.75	52.047	0	0.672	836972544	113819648
5	51.922	52.594	51.875	0.016	0.672	836952064	113856512
5	86.922	87.61	86.891	0	0.688	836861952	114081792
5	52.391	53.063	52.344	0	0.672	836952064	113557504
5	69.266	69.938	69.25	0	0.672	836939776	113819648
5	51.969	52.672	51.937	0	0.703	836923392	113700864
5	52.547	53.328	52.282	0.046	0.687	836907008	113659904
5	52.281	52.968	52.25	0	0.687	836956160	113684480
5	87.328	87.985	87.281	0	0.657	836972544	113582080
5	51.844	52.531	51.797	0	0.687	836894720	113897472
5	69.859	70.547	69.828	0	0.688	836960256	113672192
5	104.5	105.312	104	0.125	0.687	836947968	114171904
5	104.766	105.625	103.718	0.219	0.672	836968448	114184192
5	69.218	69.906	69.187	0	0.688	836976640	113811456
5	122.093	122.922	121.312	0.203	0.672	836972544	114847744
5	52.078	52.75	52.031	0	0.672	836882432	113901568
5	52.063	52.735	52.032	0	0.672	836972544	113762304
5	51.985	52.672	51.953	0	0.687	836882432	113655808
5	105.578	106.36	105.25	0.109	0.688	836980736	114614272
5	87.375	88.219	86.641	0.156	0.657	836964352	114663424
5	87.406	88.219	86.953	0.078	0.688	836952064	114577408
5	52.125	52.797	52.094	0	0.672	836972544	114036736
5	104.359	105.047	104.313	0.015	0.688	836927488	113893376
5	52.031	52.718	52.015	0	0.672	836886528	114065408
5	105.047	105.829	104.75	0.078	0.688	836923392	113672192

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
5	69.828	70.578	69.578	0.031	0.656	836952064	113876992
5	70.422	71.25	69.703	0.141	0.672	836915200	114229248
5	52.5	53.187	52.453	0	0.687	837001216	113790976
5	52.781	53.453	52.735	0.015	0.672	837013504	113586176
5	52.375	53.031	52.344	0	0.656	837025792	113655808
5	52.36	53.032	52.329	0	0.672	836878336	113926144
5	52	52.672	51.954	0	0.672	836972544	113987584
5	52.344	53.031	52.313	0	0.687	836874240	114216960
5	69.813	70.579	69.484	0.125	0.657	836886528	114511872
5	52.391	53.062	52.359	0	0.671	836878336	114130944
5	87.078	87.75	87.031	0.015	0.672	836878336	114262016
5	52.203	52.875	52.172	0	0.672	836968448	113782784
5	52.125	52.797	52.094	0	0.672	836861952	113926144
5	70.266	71.094	69.75	0.14	0.672	836943872	114425856
5	69.593	70.391	69.297	0.078	0.688	836882432	114315264
5	104.656	105.484	103.859	0.219	0.672	836829184	113938432
5	121.703	122.484	121.125	0.187	0.672	836890624	115036160
5	69.484	70.172	69.469	0	0.688	836878336	114126848
5	69.406	70.063	69.359	0	0.657	836878336	114356224
5	87.25	88.062	86.672	0.203	0.687	836878336	115073024
5	86.796	87.578	86.485	0.109	0.672	836886528	114425856
5	52.11	52.782	52.079	0	0.672	836911104	113840128
5	69.203	69.89	69.172	0	0.672	836861952	113942528
5	69.578	70.266	69.563	0	0.672	836919296	113627136
5	104.735	105.563	103.922	0.219	0.672	836984832	114597888
5	53.406	54.109	53.375	0	0.703	836972544	113696768
5	52	52.688	51.953	0	0.688	836878336	113737728
5	86.984	87.656	86.953	0	0.672	836984832	113819648
5	52.328	53.015	52.297	0	0.687	836857856	114130944
5	69.75	70.422	69.719	0	0.657	836976640	113623040
5	51.922	52.594	51.875	0.016	0.672	836878336	114069504
5	52.671	53.453	52.406	0.047	0.688	836960256	114552832
5	52.14	52.812	52.109	0	0.672	836935680	113774592
5	87.734	88.437	87.703	0	0.672	836870144	114262016
5	52.125	52.797	52.094	0	0.672	836927488	113876992
5	70.5	71.187	70.468	0	0.687	836861952	114237440
5	104.235	105.062	103.734	0.141	0.672	836960256	114176000
5	105.078	105.938	104.015	0.219	0.672	836980736	114241536
5	69.5	70.187	69.469	0	0.687	836927488	113876992
5	123.032	123.875	122.25	0.203	0.687	836993024	114761728
5	52.516	53.188	52.468	0	0.657	836980736	113557504
5	52.328	53	52.297	0	0.672	836972544	113889280
5	52.453	53.125	52.422	0	0.672	836972544	113774592
5	104.453	105.234	104.125	0.11	0.672	837013504	114622464
5	87.375	88.219	86.641	0.156	0.688	836964352	114573312
5	87.343	88.156	86.89	0.079	0.672	836952064	114409472
5	52.297	52.969	52.266	0	0.657	836968448	113819648

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
5	104.485	105.188	104.437	0.016	0.688	836923392	114114560
5	52.187	52.891	52.156	0	0.704	836870144	113983488
5	104.531	105.313	104.234	0.078	0.688	836894720	114675712
5	69.969	70.75	69.718	0.032	0.672	836943872	113688576
5	69.969	70.812	69.266	0.141	0.687	836919296	114909184
5	52.156	52.844	52.125	0	0.688	836866048	114245632
5	52.046	52.718	52	0	0.672	836972544	113881088
5	52.047	52.703	52	0	0.656	836886528	114454528
5	52.266	52.953	52.235	0	0.687	837025792	113868800
5	52.016	52.688	51.969	0	0.672	836902912	113848320
5	52.078	52.75	52.047	0	0.672	836874240	114372608
5	69.985	70.75	69.657	0.109	0.672	836919296	113676288
5	52.141	52.828	52.109	0	0.672	836882432	113954816
5	86.781	87.453	86.735	0	0.672	836931584	113704960
5	52.265	52.937	52.234	0	0.672	836968448	113745920
5	52.797	53.469	52.766	0	0.672	836980736	113602560
5	70.187	70.984	69.656	0.141	0.672	836849664	114126848
5	69.922	70.688	69.61	0.078	0.672	836976640	114540544
5	104.813	105.656	104.015	0.203	0.687	836988928	114343936
5	122.813	123.625	122.25	0.187	0.687	836886528	115204096
5	69.515	70.187	69.469	0.015	0.672	836841472	113995776
5	69.593	70.281	69.562	0	0.672	836866048	113963008
5	86.953	87.765	86.375	0.203	0.672	836935680	113946624
5	86.984	87.765	86.672	0.109	0.672	836870144	114249728
5	52.391	53.063	52.359	0	0.672	836878336	113926144
5	69.375	70.062	69.328	0	0.671	836952064	113639424
5	69.468	70.156	69.422	0	0.688	836866048	114122752
5	105.453	106.282	104.656	0.219	0.672	837017600	114143232
5	52.328	53	52.297	0	0.672	836927488	113696768
5	52.672	53.328	52.64	0	0.656	836976640	113586176
5	86.969	87.64	86.937	0	0.671	836960256	113971200
5	52.187	52.859	52.156	0	0.672	836878336	114089984
5	69.203	69.875	69.156	0.015	0.672	836927488	114212864
5	52.109	52.781	52.063	0	0.672	836931584	113831936
5	52.515	53.281	52.25	0.031	0.672	836878336	114790400
5	52.562	53.234	52.531	0	0.672	836980736	113614848
5	87.516	88.188	87.468	0.016	0.672	837001216	113917952
5	52.234	52.906	52.187	0	0.672	836861952	114126848
5	69.375	70.078	69.343	0.016	0.687	836968448	114085888
5	104.032	104.829	103.515	0.141	0.672	836886528	114262016
5	105.031	105.891	103.969	0.219	0.672	836927488	114544640
10	88.156	88.968	87.328	0.234	0.672	836866048	114806784
10	106.688	107.5	106.265	0.063	0.671	836939776	114008064
10	88.843	89.609	88.515	0.125	0.672	836886528	114003968
10	69.641	70.329	69.61	0	0.672	836931584	116219904
10	88.141	88.984	87.328	0.234	0.687	836874240	114196480
10	106.047	106.875	105.328	0.125	0.671	836960256	114241536

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
10	88.156	88.953	87.641	0.125	0.672	836911104	114167808
10	105.844	106.688	104.75	0.235	0.672	836878336	115056640
10	69.813	70.5	69.765	0	0.687	836874240	114114560
10	87.437	88.219	87.109	0.11	0.688	836964352	113987584
10	106.141	107.032	105.11	0.187	0.688	837009408	114323456
10	52.89	53.562	52.859	0	0.672	836993024	113647616
10	87.344	88.016	87.312	0	0.672	837017600	113696768
10	86.703	87.484	86.391	0.094	0.687	836931584	114610176
10	71.078	71.86	70.578	0.109	0.657	836976640	113831936
10	70.078	70.765	70.047	0	0.672	836874240	113958912
10	105.516	106.391	104.453	0.219	0.687	836878336	114622464
10	88.078	88.906	87.625	0.079	0.703	836976640	114233344
10	71.406	72.219	70.688	0.125	0.672	837001216	114118656
10	71.016	71.828	70.437	0.203	0.687	836968448	114499584
10	105.281	106.125	104.578	0.125	0.688	836919296	114642944
10	52.562	53.25	52.531	0	0.688	837017600	113614848
10	105.984	106.86	104.938	0.203	0.688	836841472	115064832
10	53.188	53.875	53.14	0	0.687	836882432	114118656
10	122.938	123.766	122.235	0.125	0.672	836980736	114372608
10	106.203	107.047	105.5	0.109	0.688	836898816	114823168
10	104.875	105.719	104.188	0.093	0.688	836976640	114151424
10	88.031	88.844	87.5	0.14	0.672	836947968	114024448
10	88.484	89.344	87.453	0.188	0.672	836927488	114126848
10	87.984	88.812	87.282	0.093	0.672	836972544	114200576
10	52.391	53.063	52.36	0	0.672	836878336	113881088
10	88.344	89.171	87.61	0.125	0.687	836968448	114479104
10	87.375	88.219	86.687	0.094	0.688	836911104	114233344
10	105.765	106.61	104.969	0.203	0.688	836968448	115638272
10	106.156	107.015	105.094	0.218	0.672	836972544	114163712
10	69.906	70.594	69.875	0	0.672	836968448	113995776
10	88	88.844	87.281	0.125	0.688	836886528	114302976
10	107.359	108.156	106.813	0.172	0.672	837025792	113831936
10	52.36	53.047	52.344	0	0.672	836956160	113823744
10	71.203	72.078	70.171	0.172	0.687	836861952	114122752
10	87.781	88.625	86.969	0.219	0.657	836890624	114737152
10	70.562	71.359	70.047	0.125	0.672	836968448	114188288
10	105.235	106.047	104.437	0.188	0.656	836923392	114577408
10	123.328	124.188	122.234	0.234	0.672	837009408	114225152
10	105.829	106.672	105.109	0.141	0.687	836964352	114921472
10	52.219	52.891	52.188	0	0.672	836972544	113754112
10	70.703	71.547	70.016	0.094	0.688	836968448	114528256
10	70.766	71.609	70.047	0.109	0.687	836968448	114085888
10	88.343	89.015	88.297	0	0.672	837013504	113553408
10	105.25	106.047	104.89	0.141	0.687	836952064	114077696
10	88.156	89	87.344	0.218	0.688	836915200	113909760
10	105.875	106.672	105.438	0.062	0.672	837025792	114139136
10	88.032	88.812	87.703	0.125	0.687	836882432	114913280

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
10	69.734	70.422	69.703	0	0.688	836857856	113938432
10	87.922	88.734	87.078	0.234	0.656	836878336	114278400
10	105.719	106.562	105	0.125	0.687	836956160	114565120
10	87.828	88.641	87.313	0.125	0.657	836853760	114135040
10	106.156	107.016	105.078	0.235	0.672	836980736	114122752
10	71.266	71.938	71.235	0	0.672	836907008	114511872
10	87.657	88.421	87.328	0.109	0.671	836939776	113840128
10	105.578	106.453	104.546	0.188	0.687	836927488	114700288
10	52.594	53.266	52.563	0	0.672	836976640	114126848
10	87.047	87.735	87	0.016	0.688	836923392	113934336
10	87.406	88.203	87.094	0.094	0.688	836947968	113774592
10	70.203	71.047	69.734	0.078	0.704	836890624	114442240
10	69.203	69.89	69.172	0	0.687	836866048	113995776
10	106.219	107.093	105.157	0.218	0.687	836878336	114667520
10	88.125	88.938	87.671	0.063	0.688	836968448	114515968
10	70.484	71.329	69.796	0.125	0.656	836956160	114102272
10	70.719	71.516	70.141	0.203	0.672	836980736	113958912
10	105.421	106.25	104.703	0.125	0.672	836972544	114167808
10	52.672	53.36	52.641	0	0.688	836960256	113889280
10	105.813	106.687	104.765	0.203	0.671	836874240	114753536
10	52.562	53.234	52.515	0	0.672	836849664	114147328
10	123.032	123.875	122.297	0.125	0.687	836972544	114118656
10	105.218	106.032	104.5	0.125	0.657	836972544	114573312
10	105.031	105.875	104.344	0.094	0.672	836874240	114950144
10	87.625	88.437	87.094	0.141	0.687	836964352	114434048
10	88.094	88.953	87.063	0.187	0.656	836931584	114642944
10	88.125	88.969	87.438	0.109	0.672	836976640	114126848
10	52.734	53.406	52.703	0	0.672	836919296	113737728
10	89.657	90.5	88.937	0.125	0.687	837025792	114028544
10	88.375	89.188	87.672	0.109	0.672	836968448	114315264
10	105.547	106.391	104.75	0.203	0.687	836837376	114393088
10	105.719	106.594	104.656	0.234	0.657	836976640	114675712
10	70.5	71.156	70.469	0	0.656	837013504	113651712
10	88.265	89.109	87.547	0.125	0.672	836907008	114532352
10	104.89	105.719	104.328	0.188	0.688	836886528	114278400
10	52.453	53.14	52.422	0	0.672	836972544	113704960
10	71.547	72.391	70.5	0.188	0.672	837025792	114507776
10	88.329	89.156	87.515	0.219	0.671	836968448	114438144
10	70.625	71.422	70.094	0.125	0.672	836972544	114110464
10	105.75	106.594	104.953	0.204	0.672	836968448	114110464
10	123.25	124.11	122.156	0.219	0.672	836968448	114331648
10	106.188	107.016	105.485	0.125	0.672	836943872	113971200
10	52.375	53.046	52.343	0	0.671	837029888	113844224
10	70.39	71.219	69.703	0.109	0.672	836915200	114077696
10	70.75	71.593	70.047	0.11	0.672	836788224	115073024
10	87.203	87.906	87.157	0.015	0.703	836915200	113651712
10	105	105.75	104.625	0.156	0.656	836882432	114270208

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
10	88.375	89.203	87.547	0.219	0.671	836882432	114483200
10	105.141	105.954	104.703	0.063	0.688	836972544	114561024
10	87.594	88.359	87.265	0.11	0.671	836931584	113995776
10	71.235	71.907	71.203	0	0.672	836935680	113704960
10	88.516	89.359	87.704	0.234	0.687	836919296	114130944
10	105.172	106	104.453	0.125	0.672	837021696	114556928
10	88.422	89.25	87.906	0.125	0.688	836874240	114405376
10	105.765	106.641	104.672	0.234	0.672	836976640	114307072
10	69.75	70.437	69.703	0	0.687	837021696	113844224
10	87.531	88.313	87.203	0.11	0.688	836894720	114348032
10	105.437	106.313	104.391	0.187	0.688	836915200	114360320
10	52.797	53.484	52.765	0	0.687	836870144	113975296
10	86.953	87.625	86.907	0	0.656	837021696	113799168
10	87.86	88.64	87.532	0.109	0.687	836878336	114286592
10	70.454	71.266	69.968	0.079	0.687	836874240	114806784
10	69.937	70.625	69.906	0	0.688	836919296	113676288
10	105.281	106.156	104.234	0.204	0.672	836927488	114151424
10	87.765	88.578	87.312	0.063	0.672	836931584	114593792
10	70.61	71.453	69.906	0.125	0.687	836915200	114212864
10	70.594	71.391	70.015	0.203	0.672	836947968	113950720
10	105.203	106.031	104.485	0.125	0.672	836927488	114278400
10	52.609	53.281	52.578	0	0.656	836960256	113799168
10	107.469	108.328	106.422	0.203	0.672	836886528	114495488
10	52.359	53.031	52.313	0	0.672	836927488	113655808
10	122.843	123.656	122.094	0.125	0.672	836882432	114941952
10	105.109	105.922	104.406	0.109	0.672	836972544	114044928
10	105.578	106.437	104.891	0.093	0.687	836874240	114896896
10	87.796	88.609	87.281	0.141	0.688	836943872	113909760
10	88.687	89.547	87.656	0.172	0.672	836976640	114659328
10	87.812	88.641	87.125	0.094	0.672	836866048	114651136
10	52.828	53.5	52.797	0	0.672	836968448	113643520
10	88.438	89.265	87.719	0.125	0.687	836972544	114601984
10	87.812	88.641	87.125	0.094	0.688	837115904	116404224
10	105.437	106.282	104.657	0.203	0.672	836866048	114458624
10	106.453	107.328	105.375	0.235	0.687	836878336	114565120
10	70.031	70.703	69.984	0.016	0.672	836972544	113852416
10	88.671	89.485	87.953	0.125	0.657	837013504	113909760
10	105.328	106.125	104.766	0.171	0.672	836984832	114102272
10	52.828	53.5	52.797	0	0.672	836972544	113782784
10	71.093	71.953	70.078	0.172	0.656	836935680	114184192
10	87.781	88.61	86.954	0.234	0.672	836919296	114507776
10	70.313	71.14	69.812	0.125	0.657	836968448	114573312
10	105.484	106.328	104.687	0.188	0.688	836919296	114290688
10	123.844	124.703	122.765	0.219	0.687	836882432	114589696
10	105.187	106	104.469	0.125	0.656	836927488	114057216
10	52.75	53.422	52.719	0	0.672	836972544	113958912
10	70.938	71.765	70.25	0.093	0.671	836968448	114159616

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
10	70.64	71.469	69.922	0.109	0.672	836939776	114626560
10	86.969	87.641	86.938	0	0.672	836960256	113717248
10	106.031	106.844	105.656	0.157	0.703	836915200	115101696
10	88.25	89.094	87.422	0.234	0.688	836997120	114143232
10	105.047	105.86	104.61	0.062	0.688	836886528	114765824
10	90.156	90.937	89.828	0.125	0.672	836931584	113983488
10	69.922	70.594	69.891	0	0.672	836882432	113995776
10	88.469	89.312	87.657	0.218	0.687	836894720	114061312
10	105.766	106.61	105.047	0.125	0.688	836972544	114667520
10	87.64	88.453	87.109	0.125	0.688	836874240	114704384
10	105.828	106.703	104.734	0.234	0.687	836923392	114221056
10	70.375	71.047	70.328	0.016	0.672	837009408	113651712
10	87.812	88.578	87.485	0.109	0.672	836976640	114597888
10	107.047	107.906	106	0.203	0.656	836960256	114122752
10	52.422	53.125	52.39	0	0.687	836931584	113680384
10	87.235	87.906	87.203	0	0.671	836964352	113786880
10	87.922	88.703	87.594	0.109	0.687	836923392	114499584
10	70.64	71.469	70.172	0.078	0.672	836919296	114008064
10	70.188	70.875	70.141	0	0.687	836956160	113766400
10	105.672	106.547	104.609	0.219	0.672	836964352	114192384
10	87.953	88.765	87.5	0.063	0.687	836907008	114405376
10	70.688	71.531	69.984	0.125	0.671	836964352	114122752
10	71.625	72.438	71.047	0.203	0.672	836894720	114573312
10	105.515	106.36	104.813	0.125	0.688	837001216	114515968
10	52.562	53.234	52.531	0	0.672	836857856	113930240
10	105.532	106.422	104.484	0.203	0.687	836878336	114618368
10	52.469	53.14	52.437	0	0.671	836857856	116527104
10	122.766	123.609	122.031	0.125	0.687	836952064	114700288
10	105.562	106.422	104.859	0.125	0.687	836923392	114266112
10	105.172	106	104.469	0.109	0.672	836915200	114515968
10	88.609	89.437	88.094	0.14	0.687	836911104	114159616
10	88.157	89	87.094	0.188	0.671	836939776	114610176
10	88.25	89.078	87.547	0.109	0.671	836931584	114515968
10	52.531	53.219	52.5	0	0.672	836923392	113790976
10	87.563	88.39	86.843	0.125	0.671	836972544	114270208
10	88.39	89.218	87.703	0.094	0.672	836947968	116011008
10	105.437	106.282	104.641	0.203	0.688	836956160	114196480
10	105.672	106.547	104.578	0.235	0.688	836960256	114868224
10	70.421	71.078	70.375	0	0.657	837021696	113987584
10	88.625	89.485	87.906	0.125	0.704	836870144	114458624
10	105.625	106.422	105.062	0.188	0.672	836898816	114548736
10	52.578	53.25	52.546	0	0.672	836878336	113901568
10	70.828	71.703	69.813	0.172	0.672	837021696	114458624
10	88.157	89	87.343	0.219	0.687	836968448	114380800
10	71.219	72.062	70.703	0.11	0.703	836952064	114647040
10	105.641	106.469	104.844	0.203	0.657	836972544	114397184
10	123.109	123.984	122.047	0.219	0.687	836931584	114720768

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
10	105.656	106.5	104.938	0.125	0.688	836878336	114200576
10	52.485	53.156	52.453	0	0.671	836874240	113745920
10	71.281	72.094	70.594	0.093	0.657	837005312	114020352
10	70.828	71.688	70.125	0.109	0.688	836968448	114548736
10	87.984	88.656	87.938	0.015	0.672	836993024	113655808
10	105.093	105.891	104.734	0.156	0.688	836898816	113934336
10	87.922	88.734	87.094	0.234	0.672	836972544	114618368
10	104.984	105.781	104.532	0.062	0.672	836882432	113885184
10	88	88.765	87.688	0.109	0.641	836968448	113852416
10	69.546	70.25	69.515	0	0.704	836911104	113664000
10	88.032	88.86	87.218	0.219	0.672	836972544	114454528
10	105.703	106.531	104.985	0.14	0.672	837009408	114118656
10	88.563	89.36	88.047	0.125	0.672	836980736	113610752
10	105.547	106.421	104.468	0.235	0.671	836952064	114704384
10	69.593	70.281	69.562	0	0.688	836874240	114110464
10	87.61	88.39	87.282	0.109	0.687	836915200	113848320
10	105.687	106.563	104.641	0.187	0.688	836927488	114810880
10	52.484	53.156	52.453	0	0.672	836972544	113786880
10	86.969	87.641	86.922	0	0.672	836890624	114008064
10	87.687	88.453	87.359	0.11	0.672	836919296	113651712
10	70.844	71.656	70.36	0.093	0.672	837021696	114053120
10	69.937	70.609	69.906	0	0.672	836947968	113688576
10	105.406	106.281	104.344	0.218	0.672	836874240	114700288
10	88	88.812	87.547	0.063	0.687	836964352	114077696
10	70.75	71.594	70.031	0.125	0.688	836882432	115052544
10	70.937	71.75	70.359	0.188	0.688	836952064	114155520
10	105.437	106.281	104.719	0.125	0.688	836919296	114024448
10	52.578	53.25	52.531	0.016	0.672	836968448	113803264
10	105.64	106.516	104.594	0.203	0.672	836976640	114728960
10	52.906	53.593	52.875	0	0.672	836984832	113872896
10	123.031	123.859	122.328	0.125	0.672	836882432	114647040
10	105.047	105.875	104.344	0.109	0.656	836968448	114757632
10	105.468	106.313	104.781	0.094	0.688	836931584	114356224
10	87.704	88.5	87.187	0.141	0.671	836874240	114282496
10	88.5	89.344	87.469	0.172	0.672	836866048	114941952
10	87.625	88.469	86.938	0.109	0.672	836952064	114466816
10	52.453	53.125	52.422	0	0.672	836960256	113643520
10	88.687	89.532	87.969	0.125	0.688	836919296	113922048
10	87.61	88.422	86.921	0.094	0.672	836931584	114655232
10	105.14	105.953	104.344	0.203	0.672	836964352	114081792
10	105.422	106.281	104.344	0.234	0.672	836976640	114233344
10	71.344	72.031	71.297	0	0.671	836960256	113569792
10	88.235	89.078	87.515	0.125	0.687	836960256	114036736
10	106.375	107.188	105.812	0.188	0.688	836915200	114167808
10	52.297	52.969	52.25	0	0.672	836907008	113631232
10	70.985	71.844	69.954	0.187	0.672	836976640	114450432
10	88.203	89.062	87.39	0.235	0.687	836964352	114540544

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
10	70.61	71.422	70.093	0.125	0.672	836931584	114204672
10	105.75	106.593	104.969	0.187	0.672	837001216	114044928
10	123.062	123.906	121.984	0.219	0.672	836968448	114368512
10	105.313	106.141	104.578	0.125	0.687	836878336	114212864
10	52.25	52.921	52.218	0	0.656	836829184	113901568
10	70.359	71.218	69.688	0.093	0.687	836947968	114364416
10	70.719	71.563	70.015	0.11	0.672	836927488	114589696
10	87.25	87.922	87.218	0	0.672	836878336	114143232
10	105.609	106.406	105.25	0.156	0.687	836984832	114827264
15	72.359	73.234	71.282	0.218	0.687	836947968	114159616
15	70.297	70.969	70.266	0	0.672	836968448	113745920
15	71.828	72.688	70.766	0.187	0.672	836964352	114692096
15	88.969	89.844	87.906	0.203	0.688	836886528	114597888
15	106.094	106.938	105.281	0.219	0.688	836931584	114155520
15	52.672	53.359	52.625	0	0.687	836857856	114176000
15	107.235	108.125	106.172	0.203	0.672	836956160	114434048
15	71.719	72.578	70.672	0.188	0.672	836923392	114470912
15	88.594	89.453	87.547	0.188	0.672	836919296	114212864
15	52.5	53.203	52.469	0	0.688	836861952	113790976
15	88.875	89.75	87.797	0.203	0.687	836886528	115085312
15	107.031	107.891	105.969	0.203	0.672	836964352	114122752
15	89.485	90.36	88.438	0.187	0.672	836927488	114700288
15	71.032	71.906	69.984	0.187	0.672	836882432	114622464
15	71.859	72.719	70.828	0.172	0.656	837013504	114028544
15	71.578	72.438	70.532	0.187	0.672	836972544	114249728
15	71.937	72.828	70.86	0.218	0.687	836882432	114294784
15	88.859	89.75	87.797	0.203	0.688	836931584	114683904
15	71.297	72.172	70.234	0.188	0.688	836927488	114561024
15	88.078	88.891	87.375	0.094	0.672	836952064	113922048
15	70.359	71.094	70.141	0.093	0.688	836947968	113819648
15	70.844	71.672	70.328	0.14	0.687	836902912	114647040
15	106.766	107.656	105.735	0.187	0.672	836853760	115232768
15	71.594	72.484	70.531	0.204	0.687	836923392	114507776
15	71.625	72.485	70.594	0.172	0.672	836935680	114159616
15	88.719	89.578	87.64	0.204	0.672	836952064	114663424
15	71.109	71.953	70.375	0.125	0.671	836915200	114106368
15	71.547	72.422	70.5	0.188	0.672	836972544	114585600
15	71.719	72.609	70.672	0.188	0.703	836956160	114208768
15	106.766	107.625	105.734	0.172	0.671	836890624	114851840
15	53.078	53.844	52.797	0.047	0.672	836923392	113786880
15	106.265	107.125	105.234	0.188	0.672	836882432	114712576
15	71.484	72.375	70.453	0.172	0.687	836923392	114176000
15	90.891	91.75	89.813	0.218	0.656	836960256	114184192
15	89.5	90.375	88.5	0.14	0.671	836968448	114216960
15	71.343	72.219	70.281	0.203	0.672	837005312	114094080
15	106.781	107.641	105.703	0.203	0.672	836911104	114597888
15	89.172	90.031	88.125	0.172	0.672	836931584	114741248

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
15	89.047	89.938	88	0.172	0.672	836927488	114081792
15	71.172	72.047	70.093	0.203	0.687	836898816	114163712
15	89.156	90.047	88.125	0.172	0.688	836911104	114180096
15	89.312	90.172	88.25	0.203	0.672	836837376	114393088
15	70.922	71.734	70.343	0.204	0.687	836972544	114184192
15	71.015	71.844	70.344	0.11	0.656	836927488	114507776
15	71.5	72.375	70.453	0.187	0.688	836927488	114491392
15	89.109	89.985	88.063	0.187	0.688	836988928	114532352
15	71.562	72.438	70.531	0.157	0.688	836960256	114262016
15	71.437	72.328	70.344	0.234	0.687	836919296	114057216
15	71.843	72.719	70.812	0.172	0.688	836882432	114835456
15	71.453	72.297	70.64	0.219	0.672	836968448	114081792
15	71.344	72.219	70.266	0.219	0.688	836874240	114286592
15	70.313	70.985	70.266	0.016	0.672	836927488	114012160
15	72.125	72.984	71.062	0.204	0.672	836972544	114286592
15	88.672	89.531	87.609	0.203	0.671	837005312	114139136
15	105.844	106.687	105.032	0.218	0.687	836907008	114491392
15	52.594	53.266	52.563	0	0.672	836956160	113668096
15	106.578	107.437	105.516	0.187	0.672	836861952	116674560
15	71.266	72.125	70.219	0.172	0.672	836935680	114204672
15	88.547	89.406	87.484	0.203	0.672	836976640	114180096
15	52.89	53.578	52.844	0.015	0.688	836915200	113647616
15	89.813	90.688	88.75	0.203	0.672	837017600	114085888
15	106.718	107.579	105.672	0.187	0.657	836976640	114524160
15	88.609	89.485	87.562	0.188	0.688	836931584	114077696
15	71.359	72.234	70.313	0.203	0.687	836947968	114192384
15	71.203	72.063	70.172	0.172	0.672	837013504	114163712
15	71.75	72.625	70.703	0.172	0.688	836874240	114774016
15	71.562	72.438	70.485	0.218	0.688	836882432	114429952
15	90.032	90.89	88.968	0.204	0.671	836976640	114094080
15	71.329	72.187	70.265	0.188	0.671	836874240	114327552
15	88.515	89.344	87.812	0.094	0.688	836960256	114114560
15	71.156	71.891	70.938	0.093	0.688	836853760	114360320
15	70.625	71.438	70.11	0.14	0.672	836878336	114241536
15	107.906	108.781	106.86	0.187	0.687	836988928	114761728
15	72.062	72.938	71	0.203	0.672	837013504	113942528
15	71.5	72.359	70.485	0.171	0.672	836968448	114741248
15	88.766	89.625	87.703	0.203	0.672	836960256	114147328
15	70.86	71.672	70.125	0.125	0.672	836861952	114933760
15	71.734	72.61	70.688	0.187	0.688	836964352	114171904
15	71.578	72.453	70.531	0.188	0.672	836898816	114573312
15	107.234	108.094	106.219	0.156	0.672	837005312	114163712
15	53.437	54.218	53.172	0.031	0.672	837021696	114544640
15	106.594	107.453	105.547	0.187	0.672	836931584	114995200
15	72.171	73.031	71.125	0.172	0.672	837025792	114434048
15	88.922	89.797	87.828	0.219	0.688	836886528	114704384
15	88.313	89.172	87.313	0.14	0.672	836968448	113995776

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
15	72.078	72.953	71.016	0.187	0.688	836894720	114302976
15	106.437	107.312	105.375	0.203	0.672	836870144	114507776
15	88.844	89.719	87.796	0.172	0.687	836882432	114425856
15	88.985	89.859	87.938	0.187	0.687	836907008	114679808
15	71.312	72.188	70.266	0.187	0.688	836972544	114577408
15	89.406	90.266	88.375	0.172	0.672	836886528	114909184
15	89.141	90.016	88.078	0.187	0.687	836956160	114716672
15	71	71.812	70.422	0.203	0.687	836976640	113999872
15	70.813	71.672	70.125	0.093	0.687	836964352	114499584
15	71.328	72.219	70.296	0.188	0.672	836931584	114421760
15	88.859	89.765	87.828	0.188	0.703	836997120	114053120
15	71.578	72.453	70.547	0.172	0.688	836964352	114540544
15	71.562	72.422	70.5	0.219	0.672	836911104	114290688
15	72.609	73.485	71.594	0.172	0.672	836849664	114368512
15	71.25	72.078	70.437	0.219	0.672	836894720	114499584
15	71.297	72.172	70.234	0.219	0.687	836956160	114626560
15	70.625	71.297	70.578	0.016	0.672	836980736	113647616
15	71.719	72.609	70.671	0.188	0.672	836947968	114700288
15	88.719	89.578	87.656	0.203	0.672	836857856	114974720
15	106.312	107.172	105.484	0.235	0.704	836960256	114569216
15	52.781	53.453	52.734	0	0.672	836931584	114122752
15	107.328	108.203	106.281	0.188	0.688	836927488	114278400
15	71.344	72.218	70.297	0.188	0.687	836886528	114442240
15	89.547	90.406	88.485	0.187	0.672	836931584	114118656
15	52.782	53.469	52.75	0	0.687	836833280	114208768
15	88.703	89.578	87.64	0.203	0.687	836931584	114130944
15	106.282	107.156	105.234	0.188	0.687	836915200	114397184
15	89.25	90.141	88.187	0.188	0.672	836964352	114216960
15	71.047	71.922	69.984	0.203	0.687	836874240	114507776
15	71.578	72.438	70.547	0.172	0.672	836972544	114221056
15	72.094	72.938	71.046	0.188	0.656	837017600	113950720
15	71.625	72.5	70.547	0.218	0.671	836931584	114253824
15	89.25	90.109	88.188	0.203	0.672	836923392	114192384
15	72.016	72.875	70.968	0.204	0.671	836984832	114044928
15	88.531	89.343	87.828	0.094	0.656	836968448	114085888
15	70.891	71.641	70.688	0.093	0.688	836976640	114499584
15	70.594	71.422	70.094	0.14	0.672	836960256	114098176
15	107.703	108.578	106.641	0.203	0.672	836882432	114479104
15	72.204	73.078	71.109	0.234	0.671	836939776	114077696
15	71.109	71.985	70.078	0.172	0.688	836890624	114679808
15	88.75	89.625	87.703	0.203	0.672	836902912	114581504
15	71.203	72.062	70.485	0.125	0.687	836931584	114569216
15	72.266	73.14	71.203	0.187	0.671	836988928	114532352
15	71.5	72.375	70.468	0.172	0.671	836988928	114544640
15	106.438	107.312	105.422	0.172	0.671	836972544	114397184
15	53.047	53.797	52.766	0.031	0.656	836968448	114626560
15	106.594	107.469	105.563	0.187	0.688	836931584	114348032

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
15	71.36	72.218	70.328	0.172	0.671	836829184	114577408
15	88.953	89.844	87.875	0.219	0.672	836972544	114638848
15	88.656	89.515	87.656	0.141	0.672	836956160	114147328
15	71.266	72.125	70.187	0.203	0.671	836915200	114106368
15	105.937	106.797	104.875	0.203	0.672	836952064	114831360
15	89.031	89.907	87.984	0.188	0.688	836878336	114475008
15	89.438	90.297	88.391	0.188	0.672	837009408	114671616
15	71.734	72.609	70.672	0.188	0.687	836861952	114532352
15	89.328	90.218	88.297	0.156	0.687	836956160	114339840
15	89.016	89.89	87.937	0.203	0.687	836915200	114429952
15	71.016	71.828	70.438	0.203	0.687	836935680	114589696
15	70.828	71.672	70.125	0.094	0.672	836874240	114462720
15	71.75	72.625	70.719	0.172	0.671	836935680	114696192
15	88.563	89.422	87.516	0.187	0.672	836960256	114442240
15	71.609	72.469	70.594	0.172	0.672	836902912	114102272
15	71.5	72.375	70.422	0.219	0.672	836931584	114212864
15	71.469	72.328	70.437	0.172	0.671	836956160	114651136
15	71.188	72.047	70.375	0.218	0.703	836816896	114397184
15	71.422	72.281	70.344	0.203	0.672	836976640	114569216
15	70.563	71.25	70.532	0	0.687	836956160	115445760
15	71.734	72.609	70.672	0.203	0.672	836927488	114343936
15	88.75	89.61	87.687	0.188	0.672	836927488	114634752
15	105.469	106.312	104.656	0.219	0.671	836874240	114900992
15	52.625	53.313	52.594	0	0.688	836952064	113885184
15	106.39	107.25	105.344	0.187	0.672	836964352	114327552
15	71.25	72.11	70.204	0.187	0.672	836947968	114188288
15	88.703	89.563	87.641	0.203	0.672	836927488	114130944
15	52.735	53.407	52.704	0	0.672	836931584	113803264
15	88.594	89.485	87.531	0.203	0.672	836960256	114110464
15	106.906	107.766	105.86	0.187	0.672	836919296	114819072
15	89.062	89.937	88.015	0.188	0.672	836874240	114348032
15	71.75	72.625	70.671	0.204	0.687	836956160	114343936
15	71.625	72.484	70.593	0.172	0.671	836874240	114401280
15	72.406	73.266	71.375	0.172	0.672	837013504	114077696
15	71.781	72.656	70.688	0.234	0.687	836870144	114479104
15	90.171	91.031	89.094	0.203	0.672	837013504	114483200
15	71.375	72.266	70.312	0.188	0.687	836923392	114069504
15	88.609	89.437	87.922	0.093	0.672	836886528	114626560
15	70.671	71.39	70.453	0.109	0.672	836980736	113913856
15	70.89	71.687	70.359	0.141	0.672	836972544	114204672
15	106.343	107.219	105.297	0.187	0.688	836915200	114356224
15	71.453	72.312	70.39	0.204	0.672	836927488	114114560
15	71.766	72.625	70.719	0.172	0.672	836931584	114524160
15	88.469	89.343	87.422	0.203	0.671	836960256	114397184
15	70.828	71.672	70.11	0.125	0.687	836939776	113983488
15	71.578	72.422	70.516	0.188	0.656	836956160	114696192
15	71.625	72.5	70.578	0.188	0.688	836886528	114356224

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
15	106.359	107.219	105.344	0.172	0.672	836829184	114225152
15	53.063	53.859	52.797	0.031	0.703	836931584	114561024
15	105.968	106.828	104.937	0.172	0.672	836919296	114978816
15	71.546	72.422	70.515	0.188	0.688	836972544	114462720
15	89.344	90.203	88.281	0.219	0.657	836984832	114335744
15	89.75	90.625	88.75	0.141	0.672	836976640	114171904
15	71.219	72.078	70.157	0.203	0.672	836960256	114192384
15	106.031	106.906	104.969	0.203	0.688	836972544	114290688
15	88.828	89.703	87.782	0.172	0.672	836972544	114769920
15	89.688	90.562	88.625	0.172	0.687	836935680	114155520
15	72.375	73.234	71.313	0.203	0.672	837009408	114061312
15	88.797	89.657	87.781	0.156	0.672	836874240	114688000
15	88.938	89.812	87.875	0.203	0.687	836911104	114245632
15	71.031	71.844	70.437	0.204	0.672	836923392	114073600
15	71.156	71.984	70.453	0.094	0.672	836976640	114425856
15	71.297	72.171	70.25	0.188	0.687	836972544	114511872
15	89.578	90.422	88.531	0.188	0.657	837029888	114081792
15	71.406	72.281	70.375	0.172	0.687	836878336	114577408
15	71.125	71.985	70.063	0.219	0.672	836841472	114466816
15	71.875	72.734	70.828	0.187	0.672	836964352	114503680
15	71.531	72.36	70.719	0.219	0.672	836980736	114012160
15	71.218	72.078	70.125	0.203	0.672	836886528	115003392
15	70.468	71.156	70.422	0.015	0.688	836988928	113897472
15	71.859	72.719	70.797	0.188	0.672	836943872	114044928
15	89.079	89.937	88.015	0.203	0.671	836919296	114143232
15	106.672	107.515	105.859	0.219	0.687	836956160	114098176
15	53.062	53.734	53.015	0	0.672	836890624	113897472
15	107.766	108.64	106.703	0.188	0.687	836968448	114237440
15	70.953	71.828	69.922	0.188	0.687	836960256	114065408
15	88.953	89.813	87.89	0.203	0.672	837005312	114556928
15	53.047	53.734	53.016	0	0.687	836878336	114044928
15	89	89.875	87.922	0.203	0.672	836976640	114049024
15	106.797	107.672	105.735	0.187	0.687	836882432	114753536
15	89.063	89.953	88.016	0.187	0.687	836870144	115281920
15	72.172	73.031	71.094	0.203	0.672	837025792	113963008
15	71.562	72.406	70.531	0.156	0.672	836866048	114794496
15	72.359	73.235	71.313	0.187	0.688	836976640	114388992
15	71.546	72.406	70.453	0.219	0.672	836878336	114597888
15	88.875	89.75	87.813	0.203	0.656	836972544	114798592
15	71.453	72.343	70.391	0.203	0.687	836927488	114405376
15	88.531	89.359	87.844	0.094	0.672	836874240	114180096
15	71.094	71.829	70.875	0.094	0.688	836964352	114577408
15	70.766	71.578	70.235	0.14	0.671	836923392	113954816
15	106.828	107.687	105.766	0.203	0.672	836878336	114753536
15	71.938	72.812	70.875	0.218	0.671	837013504	113938432
15	71.39	72.266	70.359	0.172	0.688	837005312	114110464
15	89.266	90.125	88.219	0.188	0.672	836931584	114597888

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
15	71.187	72.016	70.453	0.125	0.672	837021696	113942528
15	71.297	72.172	70.234	0.187	0.687	836902912	114044928
15	71.719	72.594	70.688	0.171	0.672	837001216	114360320
15	106.328	107.187	105.297	0.172	0.672	836878336	114532352
15	52.938	53.703	52.688	0.031	0.656	836878336	114855936
15	106.125	106.984	105.078	0.188	0.672	836972544	114196480
15	71.438	72.296	70.406	0.172	0.671	836853760	114184192
15	89	89.875	87.922	0.219	0.672	836915200	114106368
15	88.969	89.844	87.968	0.141	0.687	836878336	114663424
15	71.656	72.531	70.594	0.203	0.672	836976640	114274304
15	108.047	108.906	106.985	0.203	0.672	836952064	114163712
15	89.172	90.031	88.141	0.171	0.672	836894720	114573312
15	89.391	90.25	88.344	0.188	0.672	836927488	114204672
15	71.703	72.579	70.641	0.187	0.688	836968448	114610176
15	89.203	90.062	88.172	0.172	0.672	836919296	114790400
15	89.344	90.235	88.281	0.204	0.672	836947968	114585600
15	71.359	72.156	70.782	0.203	0.672	836923392	114638848
15	70.782	71.61	70.093	0.094	0.672	836956160	114081792
15	71.656	72.531	70.61	0.187	0.671	836931584	114696192
15	90.891	91.766	89.843	0.188	0.657	836915200	114118656
15	71.172	72.047	70.157	0.171	0.672	837013504	114176000
15	71.422	72.281	70.344	0.218	0.672	836968448	114307072
15	71.672	72.547	70.625	0.172	0.688	836960256	114692096
15	71.735	72.578	70.922	0.219	0.687	836878336	114671616
20	71.594	72.453	70.578	0.141	0.672	836878336	114405376
20	89.516	90.39	88.469	0.172	0.687	836956160	114688000
20	72.422	73.296	71.375	0.187	0.671	837001216	114388992
20	71.563	72.437	70.515	0.156	0.672	836882432	114466816
20	71.656	72.515	70.64	0.141	0.672	836923392	114225152
20	89	89.891	87.937	0.188	0.688	836927488	114155520
20	107.078	107.969	106.046	0.172	0.687	836849664	114712576
20	72.125	72.984	71.125	0.125	0.672	836964352	114577408
20	89.266	90.125	88.266	0.141	0.672	836976640	114630656
20	88.984	89.859	87.906	0.203	0.688	836968448	114716672
20	72.203	73.078	71.156	0.172	0.687	836984832	114089984
20	106.546	107.391	105.484	0.188	0.657	836927488	114704384
20	70.797	71.453	70.75	0.016	0.656	836972544	113872896
20	89.235	90.109	88.187	0.172	0.672	837165056	116482048
20	89.812	90.687	88.75	0.188	0.672	836980736	114032640
20	72.047	72.906	70.969	0.188	0.671	836907008	114122752
20	72.109	72.969	71.032	0.203	0.672	836915200	114089984
20	106.859	107.75	105.86	0.14	0.687	836968448	114745344
20	89.438	90.296	88.422	0.14	0.671	836907008	114442240
20	89.516	90.36	88.515	0.125	0.656	836866048	114388992
20	72.204	73.062	71.187	0.125	0.671	837013504	114061312
20	72.625	73.485	71.546	0.204	0.672	837029888	114089984
20	71.547	72.422	70.484	0.203	0.672	836947968	114843648

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
20	71.875	72.735	70.812	0.188	0.672	836980736	114159616
20	71.734	72.594	70.672	0.187	0.672	836956160	114606080
20	71.797	72.671	70.75	0.172	0.687	836947968	114163712
20	72.047	72.922	71.047	0.125	0.688	836853760	114372608
20	72.578	73.453	71.516	0.203	0.672	836931584	113930240
20	90.047	90.922	89.016	0.156	0.687	836882432	114499584
20	89.594	90.469	88.593	0.141	0.687	836878336	114171904
20	71.719	72.609	70.687	0.172	0.672	836861952	114712576
20	89.157	89.985	88.453	0.093	0.672	836935680	114679808
20	89.14	90.031	88.047	0.219	0.688	836976640	114118656
20	89.843	90.719	88.797	0.172	0.688	836960256	114184192
20	71.625	72.5	70.547	0.203	0.688	836870144	114405376
20	71.532	72.39	70.5	0.172	0.671	836878336	114749440
20	89.953	90.828	88.922	0.156	0.688	836866048	114589696
20	107.718	108.594	106.703	0.141	0.688	836968448	114565120
20	72.141	73.031	71.032	0.234	0.687	836968448	114565120
20	90.109	90.985	89.094	0.141	0.672	837021696	114548736
20	71.875	72.75	70.813	0.187	0.687	836829184	114700288
20	72.406	73.25	71.344	0.187	0.656	837017600	114085888
20	71.64	72.5	70.547	0.219	0.672	836919296	114466816
20	90.25	91.109	89.172	0.203	0.672	837021696	114659328
20	71.782	72.657	70.734	0.187	0.672	836886528	114155520
20	71.969	72.828	70.906	0.188	0.672	836927488	115027968
20	71.922	72.781	70.875	0.187	0.672	836861952	114892800
20	72.5	73.343	71.469	0.156	0.672	837111808	116457472
20	71.75	72.625	70.671	0.204	0.672	836878336	114495488
20	90.719	91.578	89.672	0.172	0.672	836874240	114929664
20	71.75	72.609	70.719	0.156	0.672	836919296	114122752
20	90.532	91.39	89.484	0.172	0.671	836952064	114696192
20	72.218	73.11	71.172	0.172	0.704	836874240	114860032
20	71.812	72.688	70.781	0.156	0.688	836952064	114397184
20	71.359	72.219	70.36	0.125	0.672	836988928	114212864
20	88.969	89.844	87.891	0.203	0.672	836943872	114155520
20	107.594	108.469	106.547	0.172	0.688	836907008	114368512
20	71.828	72.703	70.829	0.125	0.657	836952064	114159616
20	89.844	90.703	88.828	0.14	0.671	836907008	114671616
20	89.141	90	88.063	0.203	0.672	836935680	114200576
20	72.016	72.89	70.969	0.188	0.687	836886528	114364416
20	107.391	108.25	106.328	0.188	0.672	836931584	114167808
20	71.407	72.094	71.359	0.016	0.687	836947968	113766400
20	89.188	90.062	88.14	0.172	0.687	836947968	114229248
20	89.187	90.047	88.109	0.204	0.672	836907008	114176000
20	72.078	72.953	71.016	0.187	0.688	836866048	114917376
20	71.671	72.531	70.594	0.203	0.672	836972544	114171904
20	106.75	107.61	105.766	0.141	0.672	836866048	114896896
20	91.61	92.484	90.593	0.141	0.671	837005312	114118656
20	90.078	90.922	89.063	0.141	0.656	837009408	114130944

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
20	71.766	72.641	70.766	0.141	0.672	836968448	114184192
20	72.14	73	71.047	0.203	0.672	836972544	114302976
20	71.891	72.781	70.844	0.188	0.671	836837376	114429952
20	72.812	73.688	71.75	0.188	0.672	836935680	114176000
20	71.922	72.797	70.875	0.172	0.672	837017600	114237440
20	72.125	72.985	71.063	0.172	0.672	836980736	114511872
20	72.546	73.422	71.531	0.125	0.688	836902912	114360320
20	71.875	72.766	70.812	0.188	0.687	836960256	114458624
20	89.281	90.125	88.25	0.156	0.657	836972544	114540544
20	89.281	90.172	88.282	0.14	0.703	836882432	114929664
20	72.032	72.89	70.968	0.188	0.671	836915200	114737152
20	88.75	89.593	88.047	0.094	0.687	836919296	114200576
20	89.438	90.297	88.344	0.219	0.672	836902912	114130944
20	88.954	89.828	87.906	0.172	0.671	836911104	114413568
20	71.828	72.718	70.766	0.203	0.687	836964352	114122752
20	72.406	73.281	71.375	0.157	0.687	836874240	115064832
20	91.625	92.516	90.594	0.156	0.688	836927488	114200576
20	107.172	108.031	106.172	0.141	0.672	836861952	114819072
20	71.875	72.735	70.782	0.218	0.672	836947968	114155520
20	90.062	90.922	89.031	0.141	0.672	837013504	114069504
20	72.39	73.25	71.328	0.188	0.672	836968448	114130944
20	71.906	72.797	70.844	0.203	0.688	836947968	114106368
20	71.765	72.625	70.703	0.203	0.656	836964352	114294784
20	89.593	90.469	88.531	0.188	0.688	836931584	114733056
20	72.281	73.141	71.219	0.187	0.672	836976640	114425856
20	72.296	73.156	71.234	0.188	0.657	836976640	114368512
20	72.172	73.047	71.094	0.203	0.687	836927488	114581504
20	71.843	72.703	70.812	0.157	0.672	836968448	114167808
20	71.562	72.453	70.485	0.203	0.703	836878336	115007488
20	89.375	90.25	88.328	0.172	0.688	836849664	115216384
20	71.812	72.688	70.797	0.141	0.688	836890624	114454528
20	89.516	90.406	88.485	0.172	0.687	836960256	114688000
20	72.328	73.188	71.234	0.204	0.672	837005312	114466816
20	71.797	72.656	70.766	0.156	0.688	836837376	114544640
20	71.875	72.735	70.86	0.14	0.656	836825088	114597888
20	89.156	90.031	88.094	0.188	0.687	836968448	114655232
20	107.469	108.344	106.406	0.172	0.672	836927488	114679808
20	71.843	72.703	70.828	0.141	0.672	836915200	114151424
20	89.437	90.282	88.422	0.14	0.657	836931584	114700288
20	89.672	90.547	88.594	0.203	0.672	836976640	114266112
20	72.093	72.984	71.047	0.172	0.703	836968448	114688000
20	107.469	108.344	106.422	0.172	0.688	836923392	114200576
20	70.64	71.328	70.61	0.015	0.672	836956160	113688576
20	89.875	90.75	88.828	0.172	0.688	836972544	114733056
20	89.5	90.375	88.438	0.187	0.672	837013504	114094080
20	72.516	73.375	71.454	0.187	0.672	836972544	114020352
20	72.046	72.922	70.984	0.188	0.688	837005312	114061312

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
20	107.219	108.094	106.219	0.141	0.672	836927488	114257920
20	89.593	90.469	88.578	0.141	0.672	836972544	114163712
20	89.61	90.469	88.594	0.141	0.672	836968448	114892800
20	72.546	73.422	71.531	0.141	0.688	836878336	114647040
20	71.781	72.656	70.703	0.204	0.687	836919296	114569216
20	71.718	72.578	70.656	0.188	0.672	836927488	114204672
20	71.625	72.484	70.578	0.172	0.672	836927488	114135040
20	71.735	72.594	70.672	0.188	0.672	836882432	114688000
20	72.032	72.906	70.968	0.188	0.687	836939776	114769920
20	71.907	72.781	70.906	0.125	0.687	836968448	114286592
20	72.532	73.391	71.437	0.219	0.672	836923392	114143232
20	89.344	90.219	88.328	0.141	0.672	836915200	114085888
20	89.704	90.562	88.703	0.14	0.671	836956160	114499584
20	71.703	72.578	70.657	0.187	0.672	836833280	114647040
20	88.969	89.813	88.266	0.093	0.688	836886528	114565120
20	89.39	90.25	88.297	0.219	0.672	836968448	114237440
20	89.672	90.547	88.625	0.172	0.688	836964352	114188288
20	72.125	73	71.062	0.203	0.672	836968448	114016256
20	71.875	72.719	70.844	0.156	0.656	836882432	114929664
20	89.235	90.109	88.203	0.156	0.672	836861952	114692096
20	107	107.875	106	0.141	0.672	836927488	114937856
20	71.875	72.734	70.781	0.219	0.672	836960256	114147328
20	89.469	90.344	88.454	0.14	0.672	836927488	114126848
20	71.922	72.797	70.859	0.187	0.687	836927488	114262016
20	71.953	72.828	70.875	0.203	0.688	837001216	114716672
20	71.813	72.687	70.735	0.203	0.687	836956160	114266112
20	88.922	89.797	87.859	0.187	0.657	836972544	114495488
20	71.89	72.75	70.844	0.187	0.672	836972544	114688000
20	71.922	72.797	70.86	0.187	0.672	836915200	114094080
20	71.593	72.469	70.531	0.188	0.672	836952064	114122752
20	72.109	72.985	71.063	0.172	0.672	836968448	114085888
20	71.688	72.547	70.609	0.188	0.672	836972544	114614272
20	89.36	90.234	88.313	0.156	0.687	836927488	114581504
20	72.016	72.875	70.985	0.171	0.672	836923392	114606080
20	90.391	91.265	89.36	0.156	0.687	836911104	114774016
20	72.172	73.016	71.109	0.187	0.656	836976640	114520064
20	71.875	72.766	70.844	0.156	0.704	836968448	114176000
20	71.609	72.5	70.609	0.125	0.672	836984832	114577408
20	90.531	91.406	89.484	0.188	0.656	837021696	114450432
20	107.359	108.235	106.297	0.188	0.688	836968448	114765824
20	71.782	72.656	70.765	0.141	0.687	836964352	114253824
20	88.86	89.734	87.843	0.141	0.671	836919296	114491392
20	90	90.875	88.922	0.203	0.688	836939776	114794496
20	72.641	73.5	71.593	0.172	0.671	836980736	114032640
20	107.172	108.031	106.125	0.187	0.671	836935680	114671616
20	70.578	71.25	70.547	0	0.672	836870144	114081792
20	89.297	90.156	88.25	0.172	0.671	836964352	114245632

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
20	89.031	89.906	87.953	0.203	0.688	836907008	114515968
20	71.922	72.781	70.843	0.172	0.672	836911104	114106368
20	71.75	72.61	70.687	0.203	0.672	836878336	114987008
20	106.922	107.813	105.922	0.14	0.672	836853760	115212288
20	89.937	90.797	88.938	0.125	0.672	837021696	114098176
20	90.172	91.032	89.156	0.14	0.672	836988928	114098176
20	71.859	72.735	70.844	0.125	0.688	836919296	114556928
20	71.578	72.469	70.5	0.203	0.672	836952064	114073600
20	72.265	73.125	71.203	0.188	0.672	837013504	114049024
20	71.609	72.468	70.562	0.172	0.672	836972544	114241536
20	72.344	73.219	71.282	0.203	0.672	836927488	114044928
20	72.14	73	71.063	0.203	0.672	836968448	114159616
20	71.593	72.453	70.594	0.125	0.672	836878336	115134464
20	72.282	73.141	71.187	0.219	0.672	836919296	114536448
20	89.672	90.531	88.656	0.156	0.672	836927488	114278400
20	89.266	90.172	88.281	0.125	0.687	836911104	114106368
20	72.656	73.516	71.609	0.172	0.672	836853760	114110464
20	88.828	89.656	88.125	0.094	0.672	836886528	114368512
20	90.312	91.172	89.219	0.219	0.672	837001216	114257920
20	89.984	90.844	88.938	0.172	0.656	836984832	114810880
20	71.766	72.625	70.688	0.203	0.672	836915200	114110464
20	71.687	72.547	70.64	0.172	0.672	836956160	114765824
20	89.234	90.093	88.203	0.172	0.672	836878336	114982912
20	107.234	108.094	106.235	0.14	0.672	836874240	114548736
20	71.969	72.844	70.875	0.219	0.688	836931584	114225152
20	89.984	90.844	88.969	0.14	0.672	836947968	114405376
20	71.641	72.5	70.579	0.187	0.672	836931584	115023872
20	73.094	73.968	72.032	0.187	0.687	836931584	114167808
20	71.828	72.688	70.75	0.203	0.672	836976640	114651136
20	89.25	90.125	88.188	0.187	0.688	836972544	114843648
20	71.813	72.687	70.734	0.203	0.672	836964352	114159616
20	71.953	72.844	70.891	0.188	0.703	836923392	114606080
20	71.921	72.797	70.875	0.187	0.672	836894720	114278400
20	71.797	72.656	70.766	0.156	0.672	836886528	114581504
20	71.687	72.578	70.641	0.203	0.672	836919296	114155520
20	90.141	91	89.093	0.172	0.672	837017600	114065408
20	71.703	72.563	70.688	0.141	0.672	836886528	114335744
20	90.484	91.344	89.437	0.172	0.672	837001216	114065408
20	72.86	73.719	71.797	0.188	0.672	837021696	114118656
20	72.203	73.078	71.187	0.157	0.688	836857856	114475008
20	71.734	72.609	70.719	0.125	0.687	836878336	114610176
20	90.11	90.969	89.031	0.188	0.672	836927488	114233344
20	107.828	108.672	106.782	0.172	0.656	837017600	114802688
20	71.656	72.516	70.656	0.141	0.672	836976640	114171904
20	88.953	89.812	87.937	0.141	0.672	836956160	114634752
20	89.89	90.766	88.812	0.203	0.688	836915200	114102272
20	72.031	72.907	70.969	0.187	0.672	836919296	114077696

Number of connections	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
20	106.781	107.656	105.734	0.188	0.672	836927488	114720768
20	70.797	71.468	70.765	0	0.671	836907008	113704960
20	89.859	90.735	88.813	0.172	0.688	836935680	114749440
20	89.453	90.312	88.375	0.203	0.672	836943872	114614272
20	72	72.875	70.953	0.172	0.672	836915200	114106368
20	71.734	72.593	70.656	0.203	0.672	836886528	114937856
20	107.25	108.093	106.25	0.141	0.656	836976640	114601984
20	89.563	90.422	88.531	0.141	0.672	836972544	114155520
20	89.844	90.718	88.828	0.141	0.687	836956160	114733056
20	71.812	72.688	70.813	0.125	0.672	836935680	114118656
20	72.016	72.875	70.938	0.203	0.672	836878336	114642944
20	71.797	72.656	70.719	0.203	0.672	836886528	114155520
20	72.391	73.25	71.328	0.188	0.672	836972544	114065408
20	71.641	72.5	70.578	0.187	0.671	837013504	114663424
20	71.828	72.688	70.781	0.172	0.672	836972544	114245632
20	71.516	72.39	70.515	0.125	0.687	836956160	114872320
20	72.469	73.328	71.39	0.203	0.671	836952064	114360320
20	90.078	90.937	89.063	0.14	0.672	836972544	114741248
20	89.406	90.281	88.407	0.14	0.687	836976640	114671616
20	71.89	72.765	70.828	0.188	0.672	836968448	114118656
20	90.594	91.453	89.907	0.093	0.687	836898816	114716672
20	89.515	90.406	88.422	0.218	0.672	836837376	114896896
20	90.078	90.938	89.016	0.188	0.672	836972544	114573312
20	72.687	73.562	71.625	0.203	0.672	836964352	114073600
20	71.718	72.593	70.672	0.157	0.672	836923392	114597888
20	90.094	90.953	89.032	0.171	0.671	836874240	114528256
20	107.047	107.922	106.063	0.125	0.672	836943872	114298880
20	71.781	72.672	70.688	0.218	0.672	836874240	114896896
20	89.532	90.39	88.5	0.156	0.671	836947968	116445184
20	72	72.86	70.938	0.172	0.672	836988928	114692096
20	72.171	73.047	71.078	0.203	0.688	836915200	114597888
20	71.859	72.719	70.766	0.218	0.672	836874240	114106368
20	89.734	90.609	88.672	0.188	0.672	836988928	114601984
20	72.843	73.703	71.781	0.188	0.672	836919296	114122752
20	71.422	72.281	70.36	0.187	0.672	836972544	114229248
20	71.828	72.703	70.766	0.188	0.672	837009408	114446336
20	71.922	72.796	70.89	0.157	0.671	836927488	114221056
20	71.657	72.531	70.578	0.203	0.672	836870144	114864128
20	89.984	90.86	88.922	0.172	0.672	836972544	114880512

Table B-13. Performance measurements as more node-sets are reachable from the attacker's node-set.

E. VULNERABILITIES

This section contains data collected during Phase V of the experiment.

Number of vulnerabilities per node	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1	241.625	246.375	218.266	0.359	0.734	836943872	124551168
2	935.344	950.797	837.172	1.187	0.859	836866048	159498240
3	1963.39	1995.172	1725.219	2.688	0.953	836816896	208551936
4	3703.718	3758.36	3273.391	4.218	1.016	836837376	273076224
5	6243.734	6329.125	5571.344	6	1.047	836808704	325521408
1	242.078	246.281	218.735	0.359	0.781	836853760	124444672
2	945.062	959.891	845.453	1.188	0.891	836866048	159465472
3	2034.453	2065.656	1796.547	2.672	0.937	836911104	208588800
4	3705.031	3759.984	3275.281	4.188	1.016	836808704	273006592
5	6129.594	6224.328	5456.844	5.969	1.047	836853760	325509120
1	242.297	246.484	218.938	0.359	0.75	836857856	124473344
2	965.359	979.578	865.297	1.188	0.875	836968448	159711232
3	2006.797	2037.906	1769.313	2.765	0.953	836788224	208568320
4	3794.657	3849.157	3364	4.187	1	836890624	273039360
5	6254.656	6339.531	5582.5	6	1.062	836812800	325480448
1	241.532	245.75	218.156	0.359	0.797	836915200	124448768
2	982.328	996.485	881.968	1.188	0.875	836988928	159518720
3	2042.218	2073.313	1804.625	2.688	0.938	836886528	208699392
4	3786.985	3841.656	3356.781	4.172	1.015	836816896	273002496
5	6224.188	6309.531	5551	5.984	1.062	836849664	325496832
1	242.453	246.625	219.203	0.344	0.766	836911104	124485632
2	963.047	977.297	864.422	1.203	0.875	836870144	159510528
3	1998.953	2030.078	1761.468	2.735	0.953	836808704	208556032
4	3635.234	3690.25	3204.719	4.188	1	836947968	273043456
5	6168.562	6254.469	5496.313	6.015	1.047	836861952	325505024

Table B-14. Performance measurements as nodes contain more vulnerabilities.

F. EXPLOIT DATABASE SIZE

This section contains data collected during Phase VI of the experiment.

Number of exploits	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
1500	241.313	245.547	217.875	0.344	0.765	836911104	124530688
3000	241.5	246.094	217.907	0.359	0.985	836825088	125333504
4500	241.125	245.844	217.75	0.344	1.266	836923392	124563456
6000	241.547	246.5	218.234	0.344	1.438	836947968	124301312
7500	241.625	246.797	218.219	0.359	1.719	836919296	124661760
9000	241.813	247.172	218.656	0.344	1.906	836980736	122159104
10500	241.89	247.782	218.812	0.359	2.266	836956160	141385728
16500	242.031	248.672	218.734	0.36	3.188	836923392	150667264
31500	242.86	252.109	219.313	0.359	5.765	836714496	174931968
1500	241.469	245.656	218.093	0.36	0.75	836927488	124493824
3000	241.531	245.953	218.078	0.359	0.984	836886528	125255680
4500	241.218	245.89	217.922	0.343	1.219	837001216	124653568
6000	240.828	245.704	217.563	0.359	1.438	836964352	124641280
7500	241.375	246.531	218	0.359	1.672	836997120	124391424
9000	240.438	245.937	217.125	0.359	1.968	836874240	124325888
10500	242.094	247.875	218.828	0.359	2.265	836952064	141361152
16500	242.641	249.25	219.328	0.359	3.156	836825088	150863872
31500	243.375	252.406	220.046	0.375	5.562	836771840	174989312
1500	242.157	246.344	218.734	0.36	0.75	836882432	124616704
3000	241.312	245.797	218.016	0.344	1.032	836870144	125386752
4500	246.047	250.75	222.671	0.36	1.234	836902912	124620800
6000	240.469	245.359	217.375	0.344	1.453	837001216	124514304
7500	241.61	246.781	218.172	0.359	1.672	836902912	124522496
9000	241.079	246.422	217.718	0.36	1.875	836915200	121901056
10500	240.547	246.266	217.172	0.375	2.266	836907008	141348864
16500	242.5	249.125	219.344	0.343	3.156	836825088	150855680
31500	244.094	253.032	220.657	0.359	5.485	836726784	174919680
1500	241.64	245.828	218.203	0.36	0.75	836886528	124608512
3000	239.485	243.922	216.172	0.359	1	836915200	125222912
4500	241.656	246.297	218.203	0.375	1.203	836956160	124571648
6000	241.203	246.171	217.89	0.36	1.5	836907008	124719104
7500	240.782	245.953	217.422	0.375	1.703	836898816	124649472
9000	241.172	246.562	217.765	0.36	1.906	836972544	121405440
10500	242.204	247.891	218.906	0.36	2.25	837001216	141168640
16500	242.235	249.125	218.968	0.344	3.281	836804608	150917120
31500	243.657	252.656	220.422	0.359	5.531	836734976	175005696
1500	241.328	245.579	217.969	0.36	0.813	836878336	124428288
3000	241.125	245.594	217.796	0.36	1	837009408	124858368
4500	241.813	246.468	218.281	0.359	1.218	836964352	124571648
6000	241.266	246.172	217.968	0.344	1.453	836902912	124641280
7500	241.171	246.359	217.922	0.375	1.766	836976640	124411904

Number of exploits	Analysis Time (s)	Total Time (s)	Forward Pass (s)	Backward Pass (s)	Initialization (s)	Private Bytes (B)	Working Set (B)
9000	240.766	246.141	217.469	0.359	1.906	836861952	124125184
10500	242.25	247.984	219.172	0.359	2.266	836911104	141451264
16500	242.344	248.953	219.047	0.36	3.156	836935680	150810624
31500	242.765	251.828	219.5	0.375	5.594	836759552	174698496

Table B-15. Performance measurements as the exploit database grew larger.

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