PERFSONAR
LAB SERIES

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Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Lab 1: Configuring Administrative Information
Using perfSONAR Toolkit GUI

Document Version: 06-14-2019

Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Overview

This lab provides an introduction to perfSONAR Toolkit. It shows how to configure the administrative information of a perfSONAR node using the Graphical User Interface (GUI).

Objectives

By the end of this lab, the user will:

1. Understand perfSONAR GUI.
2. Access to perfSONAR Toolkit GUI.
3. Configure the administrative information.
4. Visualize the administrative information of a perfSONAR node.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled as perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.
Lab 1: Configuring Administrative Information Using perfSONAR Toolkit GUI

Lab settings

The information in Table 1 provides the credentials to access to perfSONAR nodes.

Table 1. Credentials to access perfSONAR1, perfSONAR2 and perfSONAR3.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

This lab is organized as follows:

1. Section 1: Introduction.
2. Section 2: Configuring Administrative Information.

1 Introduction

Networks are designed to support diverse mixtures of hardware and protocols, especially in large collaborations. Interoperability takes precedence in most cases, along with local control and policy being preserved. Reason that, actions taken by one organization can affect the performance of users in another organization. A global monitoring framework is required to reliably discover and mitigate these issues. Monitoring within a single domain is a common and accepted practice but cross-domain performance monitoring is difficult to do with traditional tools.

perfSONAR is a tool which offers web services-based infrastructure from collecting and diagnosing network performance. perfSONAR makes it possible to diagnose problems on networks quickly and easily, providing a collection of tools for performing and sharing end-to-end network measurements.perfSONAR is used to diagnose performance issues such as latency, achievable bandwidth, packet loss, and many others. While perfSONAR is currently focused on reporting network metrics, it is designed to be flexible enough to handle new metrics from technologies as middleware or monitoring.

The perfSONAR project is currently deployed in over 1,700 locations around the world. Its main feature relies on network troubleshooting. perfSONAR has been developed through an international collaboration led by Internet2, ESnet, Indiana University, and GÉANT.
The perfSONAR Toolkit Graphical User Interface (GUI) is a fully enclosed measurement infrastructure packaged as a Linux distribution. perfSONAR Toolkit GUI belongs to the visualization layer, as shown in the figure 2. In this lab, the user will configure the administrative information using perfSONAR Toolkit GUI.

![Figure 2. perfSONAR layers.](image)

## 2 Configuring administrative information

The perfSONAR Toolkit GUI allows the user to enter contact and location information about a perfSONAR node. Once the perfSONAR Toolkit is installed and it is booted for the first time, the first step consists on adding a user with the privileges to edit and manage the administrative information.

### 2.1 Adding a web user

The perfSONAR Toolkit provides utilities for adding, deleting and modifying user’s privileges to access the web interface. All of these tasks can be done through the perfSONAR command-line interface (CLI).

**Step 1.** In the topology, click on perfSONAR1 and enter the username `admin` and password `admin`. Note that the password will not be displayed while typing it.
Step 2. In order to create a new user, type the command displayed down below. If a password is required, type **admin** as password.

```
sudo /usr/lib/perfsonar/scripts/nptoolkit-configure.py
```

Step 3. Select **Manage Web Users** typing **2** and then hit **Enter** to proceed.

Step 4. Select **Add a new user** typing **1** and then hit **Enter** to proceed.

Step 5. Type **admin** as the username and **admin** as the password, the user will be required twice to enter the password. Notice that the password will not be displayed while typing it. In the future, the user can change the password running the same script and selecting option **3**.
2.2 Accessing the administrative information interface

**Step 1.** On the Client host, open web browser located on the desktop.

**Step 2.** On the address bar, type the IP address of perfSONAR1 Toolkit node *which is 192.168.1.10*. The user will see the perfSONAR Toolkit web interface.

2.3 Filling up administrative information
In this section the user will fill out a form with the corresponding administrative information. Note that the information provided in this section is just for training purposes, and it is valid only for this lab. The user may change this information depending on the characteristics of the node.

**Step 1.** Click on edit.

Step 2. The user will be given an authentication screen. Type `admin` as the **User Name** and `admin` as the **Password** then, click on **OK**.

Step 3. In this step the user will fill a form with the administrative information. This information may change depending on the organization, administrator information, and location of the node. Fill the form with the following information:

- **Organization Name**: The name of the organization to which this host belongs.
• **Administrator Name:** The full name of a person to contact about this host.

• **Administrator email:** The email address where correspondence regarding this host may be sent. Since this e-mail address should be used only for communication related to the operations of the specific node, it is highly recommended that a role or group e-mail address is used instead of a personal one.

• **City:** The city where the host resides.

• **Country:** The country where the host resides.

• **State/Province:** The state, province or other country-specific region where the host resides. May be the 2-letter abbreviation if applicable.

• **ZIP/Postal Code:** The postal code of the location where the host resides.

• **Latitude:** The latitude of the host as a decimal number between -90 and 90. Note that if you are in the southern hemisphere, this value should be negative.

• **Longitude:** The longitude of the host as a decimal number between -180 and 180. Note that if the node is in the western hemisphere, this value should be negative.

---

**Step 4.** Click on the check box in order to agree to the perfSONAR Policy.
Lab 1: Configuring Administrative Information Using perfSONAR Toolkit GUI

Step 5. Click *Save* to apply the changes.

Step 6. After applying the changes, the user will see the administrative information on the public dashboard. To see this information, click on *View public dashboard*. 

Step 7. The user can verify the given information on the public dashboard of perfSONAR Toolkit.

2.4 Adding node metadata

The perfSONAR project maintains a graphical interface to the services directory of all perfSONAR nodes. The node metadata are tags that can be used to describe a host in the global node directory page. There are two types of metadata tags:

- **Node Role**: It describes the node roles in the domain. It helps potential users of this node to recognize the place of node installation in the domain of the owner. The user can select multiple roles for a node.
- **Node Access Policy**: It is used to indicate the access policy for a node. These policies could be: public access node, private with no access, R&E only, or with limited access. The user can select only one Access Policy for a node.
Step 1. Click on Edit, if the user is required to authenticate, type admin as the username and admin as password.

![PerfSONAR Toolkit GUI](image)

Step 2. In order to add a Node Role, under Metadata, click on the field Node Role. A drop-down list shows with possible values. Click on Test Host value to select it. The user can repeat this step to add more tags.

![Metadata](image)

Step 3. In order to add a Node Access Policy, under Metadata, click in the field Node Access Policy. A drop-down list shows with possible values. Click on a R&E Only.
Step 4. The user may also add a descriptive note in *Access Policy Notes* field which is a human readable text that can optionally be added to help further describe the access policy.

Step 5. Click *Save* to apply the changes.

2.5 Adding a community

*Communities* are self-defined tags that can be used as a means to search for a host on the Global node directory page. There are two ways to select from existing communities, either by selecting from the list of existing communities or by typing the known community (note that communities are case-sensitive).

Step 1. Under *Communities*, click the field *Select communities*. A list will be shown with existing communities. Select one, for example *ESNet*. 
Step 2. The user can also create a community tag clicking on Add a Community. An entry box will be displayed.

Step 3. Write the community name. For example, type UofSC and then click on Add.

Step 4. Click on the checkbox to agree with perfSONAR policy.
Step 5. Click on **Save** to apply the changes.

Step 6. Click on **View public dashboard**.

Step 7. The user can verify the given information on the public dashboard of perfSONAR Toolkit.
This concludes Lab 1.

References

PERFSONAR

Lab 2: perfSONAR Metrics and Tools

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Overview

This lab introduces the reader to network metrics using perfSONAR tools. It also explains how to use perfSONAR tools to measure the parameters that can affect the performance of networks.

Objectives

By the end of this lab, the user will:

1. Understand about network metrics.
2. Perform measurement test using perfSONAR tools.
3. Comprehend measurement results.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled as perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.
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The information in Table 1 provides the credentials to access to perfSONAR nodes.

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</tr>
<tr>
<td>perfSONAR2</td>
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<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
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</tbody>
</table>

Lab roadmap

1. Section 1: Introduction.
2. Section 2: Throughput Measurement Tools.
4. Section 4: Trace Tools.

1 Introduction

The only effective way to qualify and quantify the usage and behavior of a network is performing measurement tests. Knowing the network behavior is critical to diagnose network problems and performance issues. Metrics are quantitative and qualitative way to verify if a network achieves a desired behavior. Network managers are interested to measure the performance or availability of services. Therefore, the most typical metrics are connectivity, latency, packet loss rate, bandwidth and throughput. These metrics are introduced as follows:

- **Connectivity**: It determines whether two hosts can establish a connection between each other through the network.
- **Latency**: It is the time it takes for a packet to arrive from the source node to the destination host. Latency is also referred as network delay and can be measured in one-way or two-way latency. Two-way delay is also known as Round-Trip Time (RTT).
- **Packet loss rate**: It is the rate at which packets are being lost in their transit from the source to the destination host. Packets being lost means that the packet does not arrive to the intended destination.
• **Bandwidth**: Depending on the context, the term is used to describe either the physical link capacity in terms of signaling or the maximum actual data rate of a specific network link or a path can transfer.

• **Throughput**: It is a measure for amount of data being transferred across a link or network at a certain time.

**Figure 2.** perfSONAR layers\(^5\).

perfSONAR tools provide the test to measure network metrics. These tools can be combined to provide a picture of the capabilities of a network. This lab is aimed to provide a brief description about the tools used by perfSONAR to run throughput, latency and trace measurements. These tests are delivered by the *Tools* layer as shown in the figure 2. In the following sections the user will use the tools available in the *Tool* layer to run throughput, latency and trace tests.

### 2 Throughput measurement tools

In this section the user will run measurement tests using *iperf3* and *nuttcp*. By default, perfSONAR uses *iperf3*. These tools are used by perfSONAR to measure the throughput. First, the user will run throughput tests using *iperf3* commands. Secondly, the user will measure the throughput using *nuttcp* commands. Finally, there is a brief analysis about the differences between the *tools*.

#### 2.1 *iperf3*

*iperf3* is a real-time network throughput measurement tool. It is an open source and cross-platform client-server application that can be used to measure the throughput between the two end devices. Typical *iperf3* output contains a time-stamped report of the amount of data transferred and the measured throughput.
The user interacts with *iperf3* using the `iperf3` command. The basic *iperf3* syntax used on both the client and the server is as follows:

```
iperf3 [-s|-c] [options]
```

**Step 1.** Open perfSONAR1 and enter the username `admin` and password `admin`. Note that the password will not be displayed while typing it.

**Step 2.** To launch *iperf3* in server mode, run the command `iperf3 -s` in perfSONAR1 command line. The parameter `-s` in the command above indicates that the host is configured as a server. Now, the server is listening on port 5201 waiting for incoming connections.

**Step 3.** Open perfSONAR2 and enter the username `admin` and password `admin`. Note that the password will not be displayed while typing it.

**Step 4.** Now to launch *iperf3* in client mode, run the command `iperf3 -c 192.168.1.10` in perfSONAR2 node. The parameter `-c` in command above indicates that the host is
configured as an `iperf3` client. The parameter `192.168.1.10` is the IP address of the server in this case, perfSONAR1 node.

Once the test is completed, a summary report on both the client and the server is displayed containing the following data:

- **ID**: identification number of the connection.
- **Interval**: time interval to periodically report throughput. By default, the time interval is 1 second.
- **Transfer**: how much data was transferred in each time interval.
- **Bitrate**: the measured throughput in each time interval.
- **Retr**: the number of TCP segments retransmitted in each time interval. This field increases when TCP segments are lost in the network due to congestion or corruption.
- **Cwnd**: indicates the congestion windows size in each time interval. TCP uses this variable to limit the amount of data the TCP client can send before receiving the acknowledgement of the sent data.

The summarized data, which starts after the last dashed line, shows the total amount of transferred data 6.87 GBytes and the throughput 5.89 Gbps. Note that the results may vary.

**Step 5.** In order to stop the server, go back to perfSONAR1 CLI and press `Ctrl+c`. The user will see the throughput results in the server side too. The summarized data on the server is similar to the client side and must be interpreted in the same way.

### 2.2 Nuttcp

`nuttcp` is a network performance measurement tool intended for use by network and system managers. Its most basic usage is to determine the raw TCP/UDP network layer throughput by transferring memory buffers from a source system across an interconnecting network to a destination system, either transferring data for a specified
time interval, or alternatively transferring a specified number of bytes. In addition to reporting the achieved network throughput, `nuttcp` also provides additional useful information related to the data transfer such as user, system, and wall-clock time, transmitter and receiver CPU utilization, and loss percentage for UDP transfers.

The user interacts with `nuttcp` using the `nuttcp` command. The basic `nuttcp` syntax used on both the client and the server is as follows:

```
nuttcp [options] dest_IP
```

**Step 1.** To launch `nuttcp` in server mode, run the command `nuttcp -S` in perfSONAR1 CLI as shown in the figure below.

```
nuttcp -S
```

**Step 2.** To launch `nuttcp` in client mode, run the command shown below in perfSONAR2 CLI. The parameter `-i1` indicates the time interval for the results will be every 1 second. The parameter `192.168.1.10` is the IP address of the server perfSONAR1.

```
nuttcp -i1 192.168.1.10
```

Once the test is completed, a summary report just on the client. Each line contains the following data:

- **Transferred Data:** how much data was transferred in each time interval.
- **Time Interval:** how long it takes between each transferred data.
- **Bitrate:** the measured throughput in in each time interval.
- **Retransmissions:** the number of TCP segments retransmitted in each time interval. This field increases when TCP segments are lost in the network due to congestion or corruption.
- **Congestion Window:** indicates the congestion windows size in each time interval. TCP uses this variable to limit the amount of data the TCP client can send before receiving the acknowledgement of the sent data.
Lab 2: perfSONAR Metrics and Tools

The summarized data indicate that 6485.4513 MBytes where transferred in 10.04 seconds. This is equivalent to 5416.6847 Mbps. The results also show the CPU usage which in this case is 22% for either the transmitter (TX) and the receiver (RX). The number of retransmissions is 1053, the mean size of congestion windows is 684 KBytes and the Round-Trip Time (RTT) is 0.31ms.

**Step 3.** To stop the server, go back to perfSONAR1 CLI and type the command `pkill nuttcp`.

The main differences between `iperf3` and `nuttcp` are that `nuttcp` also measures the CPU usage and Round-Trip Time (RTT). However, in `nuttcp` the user only sees the test report in the client side.

### 3 Latency measurement tools

perfSONAR uses `ping` and `owping` to measure the latency. By default, perfSONAR uses `ping` to measure the latency. In the following sections, the user will measure the latency using `ping` command. Then, the user will use `owping` command. Finally, there is a brief analysis about the differences between the tools.

#### 3.1 Ping

The `ping` command sends Internet Control Message Protocol (ICMP) echo request messages to the destination computer and waiting for a response. The number of messages returned to the requester is a key factor to measure the round-trip time and the packet loss. perfSONAR uses this tool to measure both. In addition, this command is also useful to test the connectivity. The basic syntax of `ping` is as follows:

```
ping [options] dest_IP
```

**Step 1.** In order to run a `ping` test, in perfSONAR1 CLI, type the command shown below. The parameter `-c 10` indicates how many packets are going to be sent to the destination host. The destination IP address is `192.168.2.10`.

```
ping -c 10 192.168.2.10
```
The result above indicates that all ten packets were received successfully by perfSONAR2 node (192.168.2.10) (0% packet loss) and that the minimum, mean, maximum, and standard deviation of the Round-Trip Time (RTT) were 0.367, 0.393, 0.442 and 0.028 milliseconds respectively.

**Step 2.** In order to run a ping test, in perfSONAR1 CLI, type the command shown below. The parameter `-c 10` indicates how many packets are going to be sent to the destination host. The destination IP address is 192.168.3.10.

```bash
ping -c 10 192.168.3.10
```

The result above indicates that all ten packets were received successfully by perfSONAR3 node (192.168.3.10) (0% packet loss) and that the minimum, mean, maximum, and standard deviation of the round-trip time (RTT) were 0.458, 0.539, 0.632 and 0.055 milliseconds respectively.

### 3.2 Owping

The *owping* is a command line client application and a policy daemon used to determine one-way latencies between hosts. With roundtrip-based measurements, it is hard to isolate the direction in which congestion is experienced. One-way measurements solve this problem and make the direction of congestion immediately apparent. Since traffic can be asymmetric at many sites that are primarily producers or consumers of data, this
Lab 2: perfSONAR Metrics and Tools

allows for more informative measurements. One-way measurements allow the user to better isolate the effects of specific parts of a network on the treatment of traffic.

The basic syntax of *owping* is as follows:

```
owping [options] dest_IP
```

**Step 1.** In perfSONAR1 command line type the command shown below. The destination IP address is **192.168.2.10**. The results are going to be displayed after approximately 12.9 seconds.

```
nowping 192.168.2.10
```

The figure above indicates results from perfSONAR1 (**192.168.1.10**) to perfSONAR2 (**192.168.2.10**). The source and destination ports number are 9278 and 9680 respectively. All packets were received successfully by perfSONAR2 node (**192.168.2.10**) (0% packet loss). The minimum, median and maximum one-way latency values were 0.129, 0.4 and 137 milliseconds respectively. The one-way jitter is 1.7 milliseconds, it takes 1 hop to reach the destination consistently, which means there no other way get that destination. Finally, there is not packet reordering.

The test result from perfSONAR2 (**192.168.2.10**) to perfSONAR1 (**192.168.1.10**) are similar to the previous one. In this case, the source and destination ports are 9311 and 8997 respectively. All packets were received successfully by perfSONAR1 node (**192.168.1.10**) (0% packet loss). The minimum, median and maximum one-way latency values were 0.0925, 0.3 and 167 milliseconds respectively. The one-way jitter is 0.1 milliseconds, it takes 1 hop to reach out the destination and there is not packet reordering.
Step 2. In perfSONAR1 command line type the command shown below. The destination IP address is 192.168.3.10. The results are going to be displayed after approximately 12.9 seconds.

```
$ owping 192.168.3.10
```

![Command output](image)

The results shown above are similar to the previous one. In this case, test results are from perfSONAR1 (192.168.1.10) to perfSONAR3 (192.168.3.10). The source and destination ports number are 9930 and 9460 respectively. All packets were received successfully by perfSONAR3 node (192.168.3.10) (0% packet loss). The minimum, median and maximum one-way latency values were 0.19, 0.5, 41.3 milliseconds. The one-way jitter is 0.1 milliseconds, it takes 2 hops to reach out the destination and there is not packet reordering.

By the other hand, test results from perfSONAR3 (192.168.3.10) to perfSONAR1 (192.168.1.10) are like the first one. In this case, the source and destination ports number are 9943 and 8938 respectively. All packets were received successfully by perfSONAR1 node (192.168.1.10) (0% packet loss). The minimum, median and maximum one-way latency values were 0.144, 0.4, 14.5 milliseconds respectively. The one-way jitter is 0.1 milliseconds, it takes 2 hops to reach out the destination and there is not packet reordering.

4 Trace test

Trace tests are networking tools which allow to discover the path a data packet takes to go from a source node to a destination node. The trace tools which perfSONAR uses are traceroute, tracepath and paris-tracepath. In this section, the user will run trace tests using these tools. By default, perfSONAR uses traceroute.
4.1 Traceroute

Traceroute displays the path that a packet took as it traveled through the network. It also displays times which are the response times that occurred at each stop along the route. If there is a connection problem or latency connecting to a site, it will be perceived analyzing these times. The user will be able to identify which of the hops along the route may cause a problem³.

The basic syntax of traceroute is as follows:

```
traceroute[options] dest_IP
```

**Step 1.** In perfSONAR1 command line type the command shown below. The IP address of the destination is 192.168.2.10.

```
traceroute 192.168.2.10
```

In the figure above, there are several rows divided into columns on the report. Each row represents a hop along the route. In each hop, the packet gets its next set of directions. Each row is divided into five columns. A sample row is shown below:

<table>
<thead>
<tr>
<th>HOP NUMBER</th>
<th>IP ADDRESS</th>
<th>RTT 1</th>
<th>RTT 2</th>
<th>RTT 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192.168.1.1</td>
<td>0.373 ms</td>
<td>0.252 ms</td>
<td>0.182 ms</td>
</tr>
<tr>
<td>2</td>
<td>192.168.2.10</td>
<td>0.439 ms</td>
<td>0.407 ms</td>
<td>0.302 ms</td>
</tr>
</tbody>
</table>

- **HOP NUMBER:** It represents the number of the hop along the route. In this case, it takes two hops to reach out the destination.
- **IP ADDRESS:** The second column has the IP address of the destination; the previous hop has the IP address of the router. If it is available, the domain name will also be listed.
- **RTT Columns:** The next three columns display the round-trip time (RTT) for the packet to reach that point and return to the source host. This measure is listed in milliseconds. There are three columns because the traceroute sends three separate signal packets. This is to display consistency, or a lack thereof, in the route.

**Step 2.** In perfSONAR1 command line type the command shown below. The IP address of the destination is 192.168.3.10.

```
traceroute 192.168.3.10
```
In the figure above, there are several rows divided into columns on the report. Each row represents a hop along the route. In each hop, the packet gets its next set of directions. Each row is divided into five columns. A sample row is shown below:

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<th>IP ADDRESS</th>
<th>RTT 1</th>
<th>RTT 2</th>
<th>RTT 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192.168.1.1</td>
<td>0.383 ms</td>
<td>0.286 ms</td>
<td>0.228 ms</td>
</tr>
<tr>
<td>2</td>
<td>192.168.2.2</td>
<td>0.557 ms</td>
<td>0.551 ms</td>
<td>0.525 ms</td>
</tr>
<tr>
<td>3</td>
<td>192.168.3.10</td>
<td>0.677 ms</td>
<td>0.649 ms</td>
<td>0.631 ms</td>
</tr>
</tbody>
</table>

- **HOP NUMBER**: It represents the number of the hop along the route. In this case, it takes three hops to reach out the destination.
- **IP ADDRESS**: The second column has the IP address of the destination; the previous hop has the IP address of the router. If it is available, the domain name will also be listed.
- **RTT Columns**: The next three columns display the round-trip time (RTT) for the packet to reach that point and return to the source host. This measure is listed in milliseconds. There are three columns because the traceroute sends three separate signal packets. This is to display consistency, or a lack thereof, in the route.

### 4.2 Tracepath

This tool traces a path from the source to destination discovering the Maximum Transmission Unit (MTU) along this path. It uses UDP port or some random port. The difference with **traceroute** is that this tool includes less options and it is not required to be a superuser to run the tests.

The basic syntax of **tracepath** is as follows:

```
tracepath[options] dest_IP
```

**Step 1.** In perfSONAR1 command line type the command. The IP address of the destination is **192.168.2.10**.

```
tracepath 192.168.2.10
```
The first column shows the hop number, the second column shows the IP address or Domain name. The third column shows the Round-Trip Time (RTT) for the packet to reach that point and return to the source host. At the end a resume is displayed, in this case the user will see the Path MTU.

Step 2. In perfSONAR1 command line type the command. The IP address of the destination is 192.168.3.10.

```
tracepath 192.168.3.10
```

Similarly, the first column shows the hop number, the second column shows the IP address or Domain name. The third column shows the round-trip time (RTT) for the packet to reach that point and return to the source host. At the end a resume is displayed, in this case the user will see the Path MTU.

### 4.3 Paris traceroute

Paris traceroute is a new version of the traceroute network diagnosis tool. It addresses problems caused by load balancers with the initial traceroute implementation. By controlling the flow identifier of the probes, it is able to follow accurate paths in networks with load balancers. It is also able to find all the load balanced paths to the destination. Finally, it complements its output with information extracted from the received packets, allowing a more precise analysis of the discovered paths. Paris traceroute, by controlling packet header contents, obtains a more precise picture of the actual routes that packets follow.

To exemplify this idea, a topology is presented in the leftmost portion of figure 3, where A is a router that balances load across two paths, via routers B or C. The middle figure illustrates what the result might show with classic traceroute. The figure on the right is the result using Paris traceroute.
The basic syntax of traceroute is as follows:

```
paris-traceroute [options] dest_IP
```

**Step 1.** In perfSONAR1 command line type the command shown below. The IP address of the destination is 192.168.2.10. The user may be required to authenticate, in that case type `admin` as the password, notice that the password will not be displayed while typing it.

```
sudo paris-traceroute 192.168.2.10
```

Notice that it is not possible to prove the concept of Paris traceroute in the current lab topology.

The results of Paris-traceroute test are interpreted in the same way of traceroute test. In the figure above, there are several rows divided into columns on the report. These results are reordered in the table below. Each row represents a hop along the route. In each hop, the packet gets its next set of directions. Each row is divided into five columns. A sample row is shown below:

<table>
<thead>
<tr>
<th>HOP NUMBER</th>
<th>IP ADDRESS</th>
<th>RTT 1</th>
<th>RTT 2</th>
<th>RTT 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192.168.1.1</td>
<td>1.076 ms</td>
<td>1.074 ms</td>
<td>1.076 ms</td>
</tr>
<tr>
<td>2</td>
<td>192.168.2.10</td>
<td>0.319 ms</td>
<td>0.306 ms</td>
<td>0.301 ms</td>
</tr>
</tbody>
</table>
Lab 2: perfSONAR Metrics and Tools

- **HOP NUMBER**: It represents the number of the hop along the route. In this case, it takes two hops to reach out the destination.

- **IP ADDRESS**: The second column has the IP address of the destination; the previous hop has the IP address of the router. If it is available, the domain name will also be listed.

- **RTT Columns**: The next three columns display the round-trip time (RTT) for the packet to reach that point and return to the source host. This measure is listed in milliseconds. There are three columns because the traceroute sends three separate signal packets. This is to display consistency, or a lack thereof, in the route.

**Step 2.** In perfSONAR1 command line type the command shown below. The IP address of the destination is **192.168.3.10** The user may be required to authenticate, in that case type **admin** as the password, notice that the password will not be displayed while typing it.

```
sudo paris-traceroute 192.168.3.10
```

The results should be interpreted as the traceroute tool. In the figure above, there are several rows divided into columns on the report. Each row represents a hop along the route. In each hop, the packet gets its next set of directions. Each row is divided into five columns. A sample row is shown below:

<table>
<thead>
<tr>
<th>HOP NUMBER</th>
<th>IP ADDRESS</th>
<th>RTT 1</th>
<th>RTT 2</th>
<th>RTT 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192.168.1.1</td>
<td>1.028 ms</td>
<td>1.023 ms</td>
<td>1.022 ms</td>
</tr>
<tr>
<td>2</td>
<td>192.168.2.2</td>
<td>0.357 ms</td>
<td>10.135 ms</td>
<td>10.136 ms</td>
</tr>
<tr>
<td>3</td>
<td>192.168.3.10</td>
<td>0.489 ms</td>
<td>0.470 ms</td>
<td>0.465 ms</td>
</tr>
</tbody>
</table>

- **HOP NUMBER**: It represents the number of the hop along the route. In this case, it takes three hops to reach out the destination.

- **IP ADDRESS**: The second column has the IP address of the destination; the previous hope has the IP address of the router. If it is available, the domain name will also be listed.

- **RTT Columns**: The next three columns display the round-trip time (RTT) for the packet to reach that point and return to the source host. This measure is listed in milliseconds. There are three columns because the traceroute sends three separate signal packets. This is to display consistency, or a lack thereof, in the route.

This concludes Lab 2.
References

PERFSONAR

Lab 3: Configuring Regular Tests Using perfSONAR Graphical User Interface

Document Version: 06-14-2019

Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Overview

This lab introduces the reader to perfSONAR Toolkit. At the end of this lab, the user will configure regular tests using perfSONAR Toolkit Graphical User Interface (GUI) in a Wide Area Network (WAN).

Objectives

By the end of this lab, the user will:

1. Configure regular test using perfSONAR GUI.
2. Store measurement data.
3. Set the parameters of the tests.
4. Conduct regular tests and measure the performance on a WAN.
5. Visualize the measurement results.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.

![Lab topology diagram]

Figure 1. Lab topology.
Lab settings

The information in Table 1 provides the credentials to access to perfSONAR nodes and the Client host.

Table 1. Credentials to access perfSONAR1, perfSONAR2 and perfSONAR3.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

This lab is organized as follows:

1. Section 1: Introduction.
2. Section 2: Configuring regular tests.
3. Section 3: Configuring R1 and R2 to emulate a Wide Area Network (WAN).

1 Introduction

perfSONAR toolkit brings a web user interface to configure, manage and display test results as throughput, latency and packet loss. A core function of the perfSONAR Toolkit is to run regularly scheduled network measurements. The user can define the tests through the toolkit’s graphical user interface (GUI).

perfSONAR Toolkit GUI is component the visualization layer as shown in the figure 2. perfSONAR includes many other utilities responsible for visualizing the measurement results. The user can configure regular tests using perfSONAR Toolkit GUI. In general, the user will not invoke any tools directly but, instead use the graphical user interface to execute them. perfSONAR Toolkit GUI interacts with the archiving layer which at the same time interacts with the scheduling layer that is responsible on deliver the requested test.
2 Configuring regular tests

perfSONAR Toolkit provides the tools to run regularly scheduled network measurements. The user can define the tests which run through the toolkit’s web interface. In this section the user will access the web user interface to run the measurement and storage of tests such as throughput, one-way ping and loss.

2.1 Accessing the web user interface

Step 1. On the Client host, open web browser located on the desktop.
Step 2. On the address bar, type 192.168.2.10. That is the IP address of perfSONAR2 toolkit node. The user will see the perfSONAR toolkit web interface.

2.2 Configuring throughput test

Step 1. In the section Test Results, click on Configure Test.

Step 2. In this step, the user could be required to authenticate. Type admin as the username, and admin as the password.
Step 3. Click on + Test to access to the test configuration form.

Step 4. A drop-down list shows to choose the test type. Select Throughput to proceed with the configuration.

Step 5. A new window will appear prompting the user for the parameters of the test. Type the Test name/description as Throughput Test.
Step 6. Select the interface *ens32*, notice that the perfSONAR2 node IP address will be displayed at the interface.

Step 7. Set *Time between tests* to 1, and *Units* to *minutes*. and the duration of each test will be 20 seconds.
In a production network, the time interval between tests is around 1 hour however, the user will set the interval between tests to 1 minute in order to have the results propagated.

**Step 8.** Scroll down until *Test members* section. In *Hostname/IP* type the IP address of perfSONAR1 node *192.168.1.10*. In the *Host description* type perfSONAR1.
**Step 9.** Click on *Add host* to save the changes

**Step 10.** Similarly, in *Hostname/IP* type the IP address of perfSONAR3 node *192.168.3.10*. In the *Host description* type perfSONAR3.
Step 11. Click on Add host to save the changes.

Step 12. In order to save the changes, click on OK.
Step 13. To save the test click on Save.

Step 14. Click on View public dashboard to get back to main page and see the throughput results.
Step 15. After 3 minutes the data will be propagated thus, refresh the browser and scroll down until the Test Result section.

The result above indicates the throughput is 4.72 Gbps, when the source is 192.168.2.10 and the destination is 192.168.3.10. Then, when the source is 192.168.2.10 and the destination is 192.168.3.10, the throughput is 4.79 Gbps. Notice that the latency and loss results are not available. Note that the results may vary.

2.3 Configuring latency and packet loss tests

Step 1. In the section Test Results, click on Configure Test. In this step, the user could be required to login. If that case, type admin as the username, and admin as the password.
Step 2. Click on +Test to access to the test configuration form.

Step 3. A drop-down list shows to choose the test type. Select One-way latency to proceed with the configuration.

Step 5. A new window will appear prompting the user for the parameters of the test. Type the Test name/description as Latency Test.

Step 6. Select the interface ens32, notice that the perfSONAR2 node IP address will be displayed at the interface.
Lab 3: Configuring Regular Tests Using perfSONAR Graphical User Interface

Step 7. Scroll down until Test members section. In Hostname/IP type the IP address of perfSONAR1 node 192.168.1.10. In the Host description type perfSONAR1.

Step 8. Click on Add host to save the changes
**Step 10.** Similarly, in **Hostname/IP** type the IP address of perfSONAR3 node **192.168.3.10**. In the **Host description** type perfSONAR3.

**Step 11.** Click on **Add host** to save the changes.
Step 12. In order to save the changes, click on OK.

Step 13. To save the test click on Save.
Step 14. Click on View public dashboard to get back to main page and see the throughput results.

Step 15. After 3 minutes the data will be propagated thus, refresh the browser and scroll down until the Test Result section.
The result above indicates that the throughput, latency and loss are 3.08 Gbps, 1.96 ms and 0% respectively, when the source is 192.168.2.10 and the destination is 192.68.1.10. When the source is 192.168.1.10 and the destination is 192.168.2.10, the throughput is not available yet, the latency and loss are 2.69 ms and 0% respectively. In the next row, when the source is 192.168.2.10 and the destination is 192.68.3.10, the results of the throughput, latency and loss are 2.45 Gbps, 13.8 ms and 0% respectively. On the other row, when the source is 192.168.3.10 and the destination is 192.168.2.10, the throughput, latency and loss are 1.37 Gbps, -7.49 ms and 0% respectively. Note that the results may vary.

3 Configuring R1 and R2 to emulate a Wide Area Network (WAN)

In this section, the user will modify the routers R1 and R2 in order to emulate a WAN using Network Emulator (NETEM) commands. The first modification consists in adding delay to the routers interface and, the second one consists in adding packet loss. At the end the user will visualize on the web interface how these changes affect the performance of the network.

3.1 Adding delay to interface connecting to network 192.168.2.0/24

In this section, the user will add a 50ms delay to the router R1 and router R2 using NETEM commands.

Step 1. On the topology, click on R1 and enter the username root and password as password. Note that the password will not be displayed while typing it.
Step 2. To identify the interface connected to the network 192.168.2.0/24, in R1 command line, type the command `ifconfig`. This command displays information related to the network interfaces in the local device.

The output of the `ifconfig` command indicates that R1 has three interfaces. The interface `ens37` connects R1 to the network 192.168.2.0/24 and is configured with the IP address 192.168.2.1. Thus, this interface must be used for emulation.

Step 3. In order to add a 50ms delay, in R1 CLI type the following command:

```
sudo tc qdisc add dev ens37 root netem delay 50ms
```

Step 4. On the topology, click on R2 and enter the username `root` and `password` as password. Note that the password will not be displayed while typing it.
Step 5. To identify the interface connected to the network 192.168.2.0/24, in R2 command line, type the command `ifconfig`. This command displays information related to the network interfaces in the local device.

The output of the `ifconfig` command indicates that R2 has two interfaces. The interface `ens37` connects R2 to the network `192.168.2.0/24`. Thus, this interface must be used for emulation.

Step 6. In order to add a 50ms delay, in R2 command line type the command:

```
sudo tc qdisc add dev ens37 root netem delay 50ms
```

Step 7. After 3 minutes the data will be propagated thus, refresh the browser and scroll down until the Test Result section.
The results of the throughput, latency and loss are 1.63 Gbps, 31.3ms and 0% respectively, when the source is 192.168.2.10 and the destination is 192.68.3.10. On the other hand, when the source is 192.168.3.10 and the destination is 192.168.2.10, the throughput, latency and loss are 1.48 Gbps, 20.3ms and 0% respectively. Note that the results may vary.

### 3.2 Adding packet loss to interface connecting to network 192.168.2.0/24

In this section, the user will add a 40% packet loss to the routers R1 and R2 using Network Emulator (NETEM) command line.

Notice that 40% of loss is unrealistic for real WANs. This value is used in order to have the data propagated during this lab.

**Step 1.** Open R2 and enter the username `root` and password as `password`. Note that the password will not be displayed while typing it.

**Step 2.** To identify the interface connected to the network 192.168.2.0/24, in R1 command line, type the command `ifconfig`. This command displays information related to the network interfaces in the local device.
The output of the `ifconfig` command indicates that R1 has also three interfaces with the same names. The interface `ens37` connects R1 to the network 192.168.2.0/24. Thus, this interface must be used for emulation.

**Step 3.** In order to add 40% packet loss, in R1 command line type:

```
sudo tc qdisc change dev ens37 root netem delay 50ms loss 40%
```

**Step 4.** Open R2 and enter the username `root` and password as `password`. Note that the password will not be displayed while typing it.

**Step 5.** To identify the interface connected to the network 192.168.2.0/24, in R2 command line, type the command `ifconfig`. This command displays information related to the network interfaces in the local device.
Notice that the interface ens37 is connected to the network 192.168.2.0/24.

**Step 6.** In order to add a 40% packet loss, type in R2 command line, type:

```
sudo tc qdisc change dev ens37 root netem delay 50ms loss 40%
```

**Step 7.** Go back to the Client host to see how these changes affect the performance.

The results of the throughput, latency and loss are 1.23 Gbps, 72.4ms and 61.667% respectively, when the source is 192.168.2.10 and the destination is 192.68.3.10. On the
other hand, when the source is \textit{192.168.3.10} and the destination is \textit{192.168.2.10}, the throughput, latency and loss are 1.26 Gbps, -24.9ms and 42.389\% respectively.

This concludes Lab 3.

\textbf{References}

PERFSONAR

Lab 4: Configuring Regular Tests Using pScheduler CLI Part I

Document Version: 06-14-2019

Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Overview

This lab introduces the reader to pScheduler commands, and how to use the default and specific tools to run latency, throughput and trace tests. It demonstrates how to invoke the pScheduler command to properly run a measurement test using the available tools.

Objectives

By the end of this lab, the user will:

1. Understand pScheduler commands.
2. Measure latency using owamp, twamp and ping tools.
3. Run throughput tests using iperf3 and nuttcp tools.
4. Use traceroute, tracepath and paris-tracecoute tools to identify the hops from a source to a destination.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.
Lab settings

The information in Table 1 provides the credentials to access to perfSONAR nodes.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

This lab is organized as follows:

1. Section 1: Introduction.
2. Section 2: Latency tests.
3. Section 3: Throughput tests.
4. Section 4: Trace Tests.

1 Introduction

pScheduler is responsible for managing the execution of network measurements, or more generally tasks, in perfSONAR. When the user wants to run a network measurement on perfSONAR, it is performed through pScheduler command-line. pScheduler is part of the scheduling layer, as it is shown in the figure 2. The scheduling layer is responsible for:

- Finding time-slots to run the tools while avoiding scheduling conflicts that would negatively impact results.
- Executing the tools and gathering results.
- Sending to the results to the archiving layer (if needed).
pScheduler handles the coordination, execution and optionally storage of the task requested. Many of the tools pScheduler executes could be run independently of pScheduler. However, pScheduler provides additional features that the tool by itself does not provide. These features are listed below:

- **Measurement Integrity**: pScheduler maintains a schedule of all measurements to be run and will not allow any measurements to run simultaneously if doing so would adversely affect the result in a significant way. For instance, it will not run two throughput tests at the same time as the competition for resources could affect the results of each. In contrast, it will run latency tests in the background as the low resource consumption does not significantly affect results of parallel tests.

- **Simplified Coordination**: In addition to simplifying coordination during task execution, pScheduler will contact each end device and handle bringing up any daemons as required. It also has a plug-in architecture that allows for sending the result elsewhere, such as a long-term storage system, as well the measurement completes.

- **Access Control**: pScheduler has a limits system that allows the definition of rules about who can run what type of measurements and other rules such as how long a test can run, and which tests are allowed to run in a specific node.

- **Diagnostics**: pScheduler provides the tools to visualize the schedule. It specifies when a task ran, is running or will run. Additionally, it keeps for some amount of time information about the outcome, including whether the result was a failure or not, which can be useful for diagnosing issues within a network.

In addition to these foundational features, pScheduler allows plug-ins for new tests, tools and archivers to be written. This means that pScheduler allows extensions to
perform new type of measurements or other functions, as well as the ability to have their results sent to new types of storage and/or analysis tools.

In this lab, the user will run latency, throughput and trace tests using pScheduler command-line interface (CLI). These tests include, latency, throughput and traceroute measurements.

1.1 The pScheduler command

The user interacts with perfSONAR using `pscheduler` command. The pScheduler command is the primary way for the command-line to create new pScheduler tasks. The basic syntax is as follows:

```
pscheduler command [args] (1)
```

- **pscheduler**: command used to interact with perfSONAR.
- **command**: describes the type of test that will be performed. These commands could be task commands or administrative and diagnosis commands, and each command has its own lists of arguments **args**. The task commands are listed as follows:

  - **task**: give pScheduler a task that consists of making one or more measurements.
  - **result**: fetch and display the results of a single, previously-concluded run by its URL.
  - **watch**: attach to a task identified by URL and show run results as they become available.
  - **cancel**: stop any future runs of a task.

The following commands are for diagnosis and administrative:

  - **ping**: determine if pScheduler is running on a host.
  - **clock**: check and compare the clocks on pScheduler hosts.
  - **debug**: Enable debugging on the internal part of pScheduler.
  - **diags**: Produce a diagnostic dump for the perfSONAR team to use in resolving problems.

For more information about pScheduler tasks, diagnosis, and administrative commands, the user can get access to the help by typing on the perfSONAR command-line:

```
pscheduler -help
```

To get more details about a specific command, using the format of the command (1) type:

```
pscheduler [command] --help
```

2 Latency tests
In this section, the user will run latency measurement tests using pScheduler tools. pScheduler uses One-Way Ping (OWPING), Two-Way Ping (TWPING) and Round-Trip Time (RTT) to measure the latency as shown in the tools layer in figure 2. First, the user will run a latency test using the default configuration then, the user will specify a tool to run a latency test.

2.1 One-way ping

In this part, the user will run a latency test between perfSONAR1 (192.168.1.10) and perfSONAR2 (192.168.2.10). The default tool used to perform this measurement is one-way ping (owping), as shown in figure 2. The user interacts with pScheduler using command-line interface (CLI).

Step 1. On the topology, click on perfSONAR1 then, enter the username admin and password admin. Note that the password will not be displayed while typing it. Proceed similarly with perfSONAR2 and perfSONAR3.

Step 2. In perfSONAR1 command line, follow command format (1) and type:

```
pscheduler task latency --source 192.168.1.10 --dest 192.168.2.10
```

- **pscheduler**: command to interact with perfSONAR.
- **task**: pScheduler command to specify a measurement test.
- **latency**: test type.
- **--source**: specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
- **--dest**: destination node, in this case it is the perfSONAR2 node (192.168.2.10).
The default tool used by pScheduler to run the default test is one-way ping (owping) tool. The task is scheduled, and the results are shown below. There are three sections in the report:

- **Packet Statistics**: It shows a summary of the number of sent and received packets, as well as the number packet lost, duplicated and reordered. The Packet Statistics of the last test is shown in the table 2.
- **One-way Latency Statistics**: It summarizes the One-way Latency Statistics as shown in the table 3 and a Histogram of the delay values.
- **TTL Statistics**: It shows the time-to-live statistics. The results are shown in the table 4, where the values do not vary.

In order to navigate through the result summary, press **Shift+Page Up** to scroll up and **Shift+Page Down** to scroll down.
Table 2. Packet Statistics.

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet Sent</td>
<td>100</td>
</tr>
<tr>
<td>Packet Received</td>
<td>100</td>
</tr>
<tr>
<td>Packet Lost</td>
<td>0</td>
</tr>
<tr>
<td>Packet Duplicated</td>
<td>0</td>
</tr>
<tr>
<td>Packet Reordered</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 3. One-way Latency Statistics.

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay Median</td>
<td>1.33ms</td>
</tr>
<tr>
<td>Delay Minimum</td>
<td>1.26ms</td>
</tr>
<tr>
<td>Delay Maximum</td>
<td>2.03ms</td>
</tr>
<tr>
<td>Delay Mean</td>
<td>1.34ms</td>
</tr>
<tr>
<td>Delay Median</td>
<td>1.36ms</td>
</tr>
<tr>
<td>Delay 25th Percentile</td>
<td>1.38ms</td>
</tr>
<tr>
<td>Delay 75th Percentile</td>
<td>1.36ms</td>
</tr>
<tr>
<td>Max Clock Error</td>
<td>6.75ms</td>
</tr>
</tbody>
</table>

Common Jitter Measurements:
- P50 - P75: 0.19 ms
- Variance: 0.01 ms
- Std Deviation: 0.09 ms

Histogram:
- 1.25 ms: 4 packets
- 1.27 ms: 7 packets
- 1.29 ms: 2 packets
- 1.30 ms: 8 packets
- 1.31 ms: 9 packets
- 1.32 ms: 0 packets
- 1.33 ms: 8 packets
- 1.34 ms: 6 packets
- 1.35 ms: 9 packets
- 1.36 ms: 12 packets
- 1.37 ms: 7 packets
- 1.39 ms: 5 packets
- 1.40 ms: 1 packets
- 1.41 ms: 2 packets
- 1.43 ms: 1 packets
- 1.44 ms: 1 packets
- 1.52 ms: 1 packets
- 1.61 ms: 1 packets
- 2.03 ms: 1 packets

TTL Statistics

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTL Median</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL Minimum</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL Maximum</td>
<td>224.00</td>
</tr>
<tr>
<td>TTL Mean</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL Mode</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL 25th Percentile</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL 75th Percentile</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL 95th Percentile</td>
<td>254.00</td>
</tr>
</tbody>
</table>

Histogram:
- 254: 100 packets

No further runs scheduled.
2.2 Two-way ping

In the following steps, the user will specify a tool to run a two-way ping (`twping`) test between perfSONAR1 (192.168.1.10) and perfSONAR2 (192.168.2.10) using pscheduler command-line.

**Step 1.** In perfSONAR1 command line, follow command format (1) and type:

```
pscheduler task --tool twping latency --source 192.168.1.10 --dest 192.168.2.10
```

- `pscheduler`: command to interact with perfSONAR.
- `task`: pScheduler command to specify a measurement test.
- `--tool`: command to specify the tool.
- `twping`: tool for two-way ping measurement.
- `latency`: test type.
- `--source`: specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
• `--dest`: the destination node, in this case it is the perfSONAR2 node (192.168.2.10).

In this case, the user specifies two-way ping (`twping`) as the tool to run the measurement test. The task is scheduled, and the results are shown below. The report format is like the latency report.

In order to navigate through the result summary, press `Shift+Page Up` to scroll up and `Shift+Page Down` to scroll down.
Lab 4: Configuring Regular Tests Using pScheduler CLI Part I

Table 5. Packet Statistics.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Packet Sent</td>
<td>100 packets</td>
</tr>
<tr>
<td>Packet Received</td>
<td>100 packets</td>
</tr>
<tr>
<td>Packet Lost</td>
<td>0 packets</td>
</tr>
<tr>
<td>Packet Duplicated</td>
<td>0 packets</td>
</tr>
<tr>
<td>Packet Reordered</td>
<td>0 packets</td>
</tr>
</tbody>
</table>

Table 6. One-way Latency Statistics.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay Median</td>
<td>1.99ms</td>
</tr>
<tr>
<td>Delay Minimum</td>
<td>1.92ms</td>
</tr>
<tr>
<td>Delay Maximum</td>
<td>2.21ms</td>
</tr>
<tr>
<td>Delay Mean</td>
<td>2.00ms</td>
</tr>
<tr>
<td>Delay Mode</td>
<td>1.99ms</td>
</tr>
</tbody>
</table>

Common Jitter Measurements:
- P50 – P50: 0.88 ms
- P75 – P25: 0.94 ms
- Variance: 0.00 ms
- Std Deviation: 0.05 ms

Histogram:
- 1.92 ms: 1 packets
- 1.93 ms: 3 packets
- 1.94 ms: 3 packets
- 1.95 ms: 7 packets
- 1.96 ms: 16 packets
- 1.97 ms: 8 packets
- 1.98 ms: 11 packets
- 1.99 ms: 16 packets
- 2.00 ms: 14 packets
- 2.01 ms: 0 packets
- 2.02 ms: 4 packets
- 2.03 ms: 2 packets
- 2.05 ms: 2 packets
- 2.06 ms: 4 packets
- 2.07 ms: 3 packets
- 2.13 ms: 2 packets
- 2.14 ms: 1 packets
- 2.21 ms: 1 packets

TTL Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TTL Median</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL Minimum</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL Maximum</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL Mean</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL Mode</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL 75th Percentile</td>
<td>254.00</td>
</tr>
<tr>
<td>TTL 95th Percentile</td>
<td>254.00</td>
</tr>
</tbody>
</table>

Histogram:
- 254: 100 packets

No further runs scheduled.
2.3 Round-Trip Time (RTT)

In this part, the user will run a Round-Trip Time (RTT) test between perfSONAR1 (192.168.1.10) and perfSONAR2 (192.168.2.10) of the given topology, see figure 1. First, the user is going to type a pScheduler command to run a test in perfSONAR1 command-line, then the user will repeat the same test in perfSONAR3 (192.168.3.10) command-line.

**Step 1.** In perfSONAR1 command line, follow command format (1) and type:

```
pscheduler task rtt --source 192.168.1.10 --dest 192.168.2.10
```

- **pscheduler**: command to interact with perfSONAR.
- **task**: pScheduler command to specify a measurement test.
- **rtt**: test type.
- **--source**: it specifies where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
- **--dest**: destination node, in this case it is the perfSONAR2 node (192.168.2.10).
The result above indicates that all five packets were received successfully by perfSONAR2 node (192.168.2.10) (0% packet loss) and that the minimum, mean, maximum, and standard deviation of the Round-Trip Time (RTT) were 0.290, 0.347, 0.376 and 0.032 milliseconds respectively.

3 Throughput tests

In this section, the user will run throughput measurement tests using pScheduler tools. These tools are iperf, iperf3 and nuttcp as shown in the tools layer in the figure 2. First, the user will run a throughput test using the default configuration then, the user will specify a tool to run a latency test.

3.1 iPerf3

The following throughput test is between perfSONAR1 node (192.168.1.10) and perfSONAR2 node (192.168.2.10). The tool used to run the default test is iperf3.

Step 1. In perfSONAR1 command line, follow the command format (1) and type:

```bash
pscheduler task throughput --source 192.168.1.10 --dest 192.168.2.10
```

- `pscheduler`: command to interact with perfSONAR.
- `task`: pScheduler command.
- `throughput`: test type.
- `--source`: specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
- `--dest`: destination node, in this case it is the perfSONAR2 node (192.168.2.10).
Shortly after starting the test submission, the user will see that the tool used to run the test is iperf3. The results above list the throughput every second (Interval), the number of retransmissions (Retransmits) and current windows size. At the end, it is summarized the time interval when the test took place, in this case from 0 seconds to 10 seconds, the throughput is 8.20 Gbps and the number of retransmissions is 2070.

3.2 Nuttcp

The following throughput test is between perfSONAR1 node (192.168.1.10) and perfSONAR2 node (192.168.2.10). The tool used to this test is nuttcp.

Step 1. In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler task --tool nuttcp throughput --source 192.168.1.10 --dest 192.168.2.10 -i1
```

- **pscheduler**: command to interact with perfSONAR.
- **task**: pScheduler command.
- **--tool**: command to specify the tool.
- **nuttcp**: tool used to run the test.
- **throughput**: test type.
- **--source**: specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
- **--dest**: destination node, in this case it is the perfSONAR2 node (192.168.2.10).
- **i1**: indicates the interval is 1 second.
The results above indicate that the test did not failed. After that it is shown the nuttcp command used to run the task from local host or perfSONAR1 node (192.168.1.10). The summarized data indicates that 8133.3174 MB were transferred in 10.03 seconds. This is equivalent to 6800.8015 Mbps. The results also show the CPU usage, which in this case is 20% for the transmitter (TX) and 24% for the receiver (RX). The number of retransmissions is 1052, the congestion windows size is 951 KB, and the Round-Trip Time (RTT) is 0.31ms. In addition, it is shown the nuttcp command used to run the server in perfSONAR2 node (192.168.2.10). Finally, there is a report indicating that there is not any error from perfSONAR2 node.

In order to navigate through the result summary, press **Shift+Page Up** to scroll up or **Shift+Page Down** to scroll down.

4 Trace tests
In this section, the user will run trace measurement tests using pScheduler tools. These tools are *traceroute*, *tracepath* and *paris-traceroute* as shown in the tools layer in the figure 2. First, the user will run a trace test using the default configuration then, then the user will specify a tool to run a latency test.

### 4.1 Traceroute

*Traceroute* measures the path that a packet took as it traveled around the Internet to the website. It also displays the response times that occurred at each stop along the route. If there is a connection problem or latency connecting to a site, it will show up in these response times. The user will be able to identify which of the hops along the route may cause a problem.

**Step 1.** In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler task trace --source 192.168.1.10 --dest 192.168.3.10
```

Shortly after submitting the test, the default tool used to run the test is *traceroute*. In the figure above, there are several rows divided into columns on the report. Each row represents a hop along the route. In each hop, the packet gets its next set of directions. Each row is divided into five columns. A sample row is shown below:

<table>
<thead>
<tr>
<th>HOP NUMBER</th>
<th>IP ADDRESS</th>
<th>RTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192.168.1.1</td>
<td>0.2 ms</td>
</tr>
<tr>
<td>2</td>
<td>192.168.2.2</td>
<td>0.9 ms</td>
</tr>
<tr>
<td>3</td>
<td>192.168.3.10</td>
<td>0.9 ms</td>
</tr>
</tbody>
</table>

- **HOP NUMBER**: It represents the number of the hop along the route. In this case, it takes two hops to reach the destination.
- **IP ADDRESS**: The second column has the IP address of the destination; the previous hop has the IP address of the router. If it is available, the domain name will also be listed.
Lab 4: Configuring Regular Tests Using pScheduler CLI Part I

- **RTT**: The next column displays the Round-Trip Time (RTT) for the packet to reach that point and return to the source host. This measure is listed in milliseconds.

### 4.2 Tracepath

*Tracepath* traces a path from the source to destination, discovering the Maximum Transmission Unit (MTU) along this path. It uses UDP port or some random port. The difference from *traceroute* is that this tool includes less options and the user is not required to be a superuser to run the tests. pScheduler allows the selection of the tool *tracepath* using the `--tool` command.

**Step 1.** In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler task --tool tracepath trace --source 192.168.1.10 --dest 192.168.3.10
```

The first column shows the hop number, the second column shows the IP address or Domain name. The third column shows the Round-Trip Time (RTT) for the packet to reach that point and return to the source host. The last column shows the Maximum Transmission Unit (MTU) size.

<table>
<thead>
<tr>
<th>HOP NUMBER</th>
<th>IP ADDRESS</th>
<th>RTT</th>
<th>MTU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192.168.1.1</td>
<td>0.148 ms</td>
<td>1500 bytes</td>
</tr>
<tr>
<td>2</td>
<td>192.168.2.2</td>
<td>0.389 ms</td>
<td>1500 bytes</td>
</tr>
<tr>
<td>3</td>
<td>192.168.3.10</td>
<td>1.4 ms</td>
<td>1500 bytes</td>
</tr>
</tbody>
</table>

### 4.3 Paris traceroute

Paris traceroute is a new version of the *traceroute* network diagnosis tool. It addresses problems caused by load balancers with the initial traceroute implementation. By controlling the flow identifier of the probes, it can follow accurate paths in networks with load balancers. It is also able to find all the load balanced paths to the destination. Finally, it complements its output with information extracted from the received packets, allowing
a more precise analysis of the discovered paths. Paris traceroute, by controlling packet header contents, obtains a more precise picture of the actual routes that packets follow. The user can select `paris-traceroute` tool using `pScheduler` command.

**Step 1.** In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler task --tool paris-traceroute trace --source 192.168.1.10 --dest 192.168.3.10
```

Notice that it is not possible to prove the idea of Paris traceroute in the current lab topology.

After the task is submitted, the user can see that the tool selected is `paris-traceroute`. The results of Paris-traceroute test are interpreted in the same way of traceroute test. In the figure above, there are several rows divided into columns on the report. These results are reordered in the table below. Each row represents a hop along the route. In each hop, the packet gets its next set of directions. Each row is divided into five columns. A sample row is shown below:

<table>
<thead>
<tr>
<th>HOP NUMBER</th>
<th>IP ADDRESS</th>
<th>RTT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192.168.1.1</td>
<td>0.241 ms</td>
</tr>
<tr>
<td>2</td>
<td>192.168.2.2</td>
<td>0.343 ms</td>
</tr>
<tr>
<td>3</td>
<td>192.168.3.10</td>
<td>4.515 ms</td>
</tr>
</tbody>
</table>

- **HOP NUMBER**: It represents the number of the hop along the route. In this case, it takes two hops to reach out the destination.
- **IP ADDRESS**: The second column has the IP address of the destination; the previous hop has the IP address of the router. If it is available, the domain name will also be listed.
- **RTT Columns**: The next three columns display the Round-Trip Time (RTT) for the packet to reach that point and return to the source host. This measure is listed in milliseconds. There are three columns, because the traceroute sends three separate signal packets. This is to display consistency, or a lack thereof, in the route.
This concludes Lab 4.

References

PERFSONAR

Lab 5: Configuring Regular Tests Using pScheduler CLI Part II

Document Version: 06-14-2019

Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Overview

This lab continues the description of pScheduler commands, and how to use it to run measurement tests between perfSONAR nodes. This lab is focused on running a pScheduler task from other nodes, repeating, exporting and importing tasks. In addition, the tools to visualize the schedule are presented. Finally, the user will learn about the procedure to cancel a task.

Objectives

By the end of this lab, the user will:

1. Understand pScheduler commands.
2. Run tasks from other perfSONAR nodes.
3. Repeat a specific task.
5. Use the visualization tools.
6. Cancel a specific task.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.

![Lab topology diagram](image_url)
Lab settings

The information in Table 1 provides the credentials to access to perfSONAR nodes.

Table 1. Credentials to access perfSONAR1, perfSONAR2 and perfSONAR3.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

The lab includes the following tasks:

1. Section 1: Introduction.
2. Section 2: Running tasks from other perfSONAR nodes.
3. Section 3: Repeating tasks.
4. Section 4: Exporting and importing tasks.
5. Section 5: Viewing the schedule.

1 Introduction

pScheduler is responsible for managing the execution of network measurements, or more generally tasks, in perfSONAR. When the user wants to run a network measurement on perfSONAR, it is performed through pScheduler command-line. pScheduler is part of the scheduling layer, as it is shown in the figure 2. The scheduling layer is responsible for:

- Finding timeslots to run the tools while avoiding scheduling conflicts that would negatively impact results.
- Executing the tools and gathering results.
- Sending to the results to the archiving layer (if needed).
pScheduler handles the coordination, execution and optionally storage of the task requested. Many of the tools pScheduler executes could be run independently of pScheduler. However, pScheduler provides additional features that the tools by itself does not provide. These features are listed below:

- **Measurement Integrity**: pScheduler maintains a schedule of all measurements to be run and will not allow any measurements to run simultaneously, if doing so, it would adversely affect the result in a significant way. For instance, it will not run two throughput tests at the same time as the competition for resources could affect the results of each. In contrast, it will run latency tests in the background as the low resource consumption does not significantly affect results of parallel tests.

- **Simplified Coordination**: In addition to simplify coordination during task execution, pScheduler will contact each end device and handle bringing up any daemons as required. It also has a plug-in architecture that allows to send the result elsewhere, such as a long-term storage system, as well the measurement completes.

- **Access Control**: pScheduler has a limits system that allows the definition of rules about who can run what type of measurements and other rules as how long a test can run, and which tests can run in a specific node.

- **Diagnostics**: pScheduler provides the tools to visualize the schedule. It specifies when a task ran, runs or will run. Additionally, it keeps for some amount of time information about the outcome, including whether the result was a failure or not, which can be useful for diagnosing issues with in a network.

In addition to these foundational features, pScheduler allows plug-ins for new tests, tools and archivers to be written. This means that pScheduler allows extensions to perform new type of measurements or other functions as well as to have their results sent to new types of storage and/or analysis tools.
1.1 The pScheduler command

The user interacts with perfSONAR using `pscheduler` command. The pScheduler command is the primary way from the command-line to create new pScheduler tasks. The basic syntax is as follows:

```
pscheduler command [args] (1)
```

- **pscheduler**: command used to interact with perfSONAR.
- **command**: it describes the type of test that will be performed, these commands could be task commands or administrative and diagnosis commands, each command has its lists of arguments `args`. The task commands are listed as follows:

  - **task**: give pScheduler a task that consists of making one or more measurements.
  - **result**: fetch and display the results of a single, previously-concluded run by its URL.
  - **watch**: attach to a task identified by URL and show run results as they become available.
  - **cancel**: stop any future runs of a task.

  - The following commands are for diagnosis and administrative:
    - **ping**: determine if pScheduler is running on a host.
    - **clock**: checks and compare the clocks on pScheduler hosts.
    - **debug**: Enable debugging on the internal part of pScheduler.
    - **diags**: Produce a diagnostic dump for the perfSONAR team to use in resolving problems.

For more information about pScheduler tasks, diagnosis and administrative commands, the user get access to the help typing on the perfSONAR command-line:

```
pscheduler --help
```

To get more details about a specific command, using the format of the command (1) type:

```
pscheduler [command] --help
```

2 Running tasks from other perfSONAR nodes

pScheduler determines where to submits a task based on the test parameters. Where a task needs to be submitted is called the lead participant. For many tests run by perfSONAR, a `--source` switch which specifies where the test should originate and is also the lead participant. In this section the user will run a throughput test using pScheduler commands.
This test will be submitted by perfSONAR1 node (192.168.1.10), however, the tests will run between perfSONAR2 (192.168.2.10) and perfSONAR3 (192.168.3.10) nodes.

**Step 1.** On the topology, click on perfSONAR1 then, enter the username admin and password admin. Note that the password will not be displayed while typing it. Proceed similarly with perfSONAR2 and perfSONAR3 nodes.

```
CentOS Linux 7 (Core)  
Kernel 3.10.0-957.1.3.el7.x86_64 on an x86_64  

dersonar1 login: admin  
Password: 
Last login: Wed Jan 30 15:14:47 on tty1 
Welcome to the perfSONAR Toolkit v4.1.5-1.el7  
You may create accounts to manage this host through the web interface by running the following as root:  
/usr/lib/perfsonar/scripts/mpkt-toolkit-configure.py  
The web interface should be available at:  
https://[Host address]/toolkit 
[admin@perfsonar1 ~]$  
```

**Step 2.** In perfSONAR1 command line, follow command format (1) and type:

```
pscheduler task throughput --source 192.168.2.10 --dest 192.168.3.10  
```

- **pscheduler:** is the command to interact with perfSONAR.
- **task:** is a pScheduler command to specify a measurement test.
- **throughput:** specifies the test.
- **--source:** is to specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10)
- **--dest:** is the destination node, in this case is the perfSONAR3 node (192.168.3.10).
Shortly after starting the test submission, the user will see that the tool used to run the test is iperf3. The results above, lists the throughput every second (Interval), the number of retransmissions (Retransmits) and current windows size. At the end, it is summarized the time interval when the test took place, in this case form 0 seconds to 10 seconds, the throughput is 6.66 Gbps and the number of retransmissions is 1535.

In this example, the command above is run on perfSONAR1 node (192.168.1.10), then the node will submit the task to perfSONAR2 node (192.168.2.10) and the test will be run between perfSONAR2 (192.168.2.10) and perfSONAR3 (192.168.3.10).

3 Repeating tasks

A task can be configured to run periodically. In this section, it is shown step by step how to repeat throughput and RTT tasks using pScheduler command. First the user will configure pScheduler to run a throughput task every 30 seconds. Then, the user will run an RTT task every 45 seconds. Any pScheduler task can be configured to run repeatedly by adding options to the task command:

- `--start TIMESTAMP`: it runs the first iteration of the task at `TIMESTAMP`.
- `--repeat DURATION`: Repeat runs at intervals of `DURATION`.
- `--max-runs N`: Allow the task to run up to `N` times.
- `--until TIMESTAMP`: Repeat runs of the task until `TIMESTAMP`.
- `--slip DURATION`: Allow the start of each run to be as much as `DURATION` later than their ideal scheduled time. If the environment variable `PSCHEDULER_SLIP` is
present, its value will be used as a default. Failing that, the default will be PT5M. Notice that the slip value also applies to non-repeating tasks.

- **--sliprand**: Randomly choose a timeslot within the allowed slip instead of choosing earliest available.

**Step 1.** In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler task --repeat PT20M --max-runs 10 rtt --dest 192.168.2.10
```

- **pscheduler**: is the command to interact with perfSONAR.
- **--repeat PT20M**: is a pScheduler command that configure the task to be repeated every 20 minutes.
- **task**: is a pScheduler command to specify a measurement test.
- **throughput**: is the test type.
- **--dest**: is the destination node, in this case it is perfSONAR2 node (192.168.2.10). Notice that the source node is not explicit, this means that the source node is perfSONAR1 (192.168.1.10).

The figure above shows the first measurement of the round-trip time. Notice that the task is going to be repeated 10 times in 20 minutes.

**Step 2.** To return to the CLI, press **Ctrl+C**. Notice that the task will keep running.

**4 Exporting and importing tasks to JSON**

The user can export a pScheduler task to a Java Script Object Notation (JSON) file. The JSON version of a task specification can be sent to the standard output without scheduling using the **--export** command.

**Step 1.** In perfSONAR1 command line, follow the command format (1) and type:
Lab 5: Configuring Regular Tests Using pScheduler CLI Part 2

```
pscheduler task --repeat PT3M --export throughput --source 192.168.1.10 --dest 192.168.2.10 > my_test_1
```

- `pscheduler`: is the command to interact with perfSONAR.
- `task`: is a pScheduler command to specify a measurement test.
- `--repeat PT3M`: is a pScheduler command that configure the task to be repeated every 3 minutes.
- `--export`: is to indicate that the task will not be executed but stored.
- `throughput`: is the test type.
- `--source`: is to specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
- `--dest`: is the destination node, in this case it is perfSONAR2 node (192.168.2.10).
- `> my_test_1`: is to create a file where the task is going to be stored.

Step 2. In order to visualize the file, type `cat my_test_1`. A JSON file will be displayed. This file contents a pScheduler task, however this task is not running. Notice also that the task might be invalid because tasks are not validated until they are submitted for scheduling.

Step 3. A JSON file that was previously exported or generated elsewhere can be imported using the `--import` command. In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler task --import my_test_1
```

- `pscheduler`: is the command to interact with perfSONAR.
- `task`: is a pScheduler command to specify a measurement test.
- `my_test_1`: is the file that contains the task.
Step 4. To return to the CLI, press `Ctrl+C`. Notice that the task will keep running.

5 Viewing the schedule

In this section, it is presented two visualization tools, pScheduler monitor and pScheduler schedule. The tests scheduled in the last section still running. The user will use pScheduler commands to visualize the schedule.

5.1 pScheduler monitor

The `pscheduler monitor` command provides top-like output of what the schedule is doing in near real time. It takes the following form:

Step 1. In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler monitor
```

The user will see the scheduled tests. These tests have a status depending on whether they have already run or are still waiting to do so. Possible status values are:

- **Pending**: This run is scheduled to execute at some point in the future.
Lab 5: Configuring Regular Tests Using pScheduler CLI Part 2

- **On Deck**: This run is scheduled to execute and will begin execution very soon.
- **Running**: This run is in the middle of execution.
- **Cleanup**: This run completed execution and is doing some final operations.
- **Finished**: The run has already executed and finished successfully.
- **Overdue**: The run was scheduled to execute at a certain time in the past but did not. It may get executed soon if it is not beyond a certain threshold.
- **Missed**: The run was scheduled but did not execute at its given time. This can happen if the scheduler was not running at the allotted time or the task was paused.
- **Failed**: The run failed to complete for some reason.
- **Non-Starter**: The run could not be scheduled because there were no timeslots that could accommodate the constraints.
- **Canceled**: The task was cancelled before the run was executed.

<table>
<thead>
<tr>
<th>2019-05-07T14:25:24+01:00</th>
<th>pScheduler Monitor</th>
<th>perfsonar1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finished</td>
<td>trace --dest 192.168.3.10 --source 192.168.1.10</td>
<td></td>
</tr>
<tr>
<td>Finished</td>
<td>trace --dest 192.168.3.10 --source 192.168.1.10</td>
<td></td>
</tr>
<tr>
<td>Finished</td>
<td>throughput --dest 192.168.3.10</td>
<td></td>
</tr>
<tr>
<td>Finished</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Finished</td>
<td>rtt --dest 192.168.2.10</td>
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<tr>
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<tr>
<td>Finished</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Running</td>
<td>throughput --source 192.168.1.10 --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Finished</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
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<tr>
<td>Finished</td>
<td>rtt --dest 192.168.2.10</td>
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<tr>
<td>Finished</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>On Deck</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Pending</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Pending</td>
<td>throughput --source 192.168.1.10 --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Pending</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Pending</td>
<td>throughput --source 192.168.1.10 --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Pending</td>
<td>rtt --dest 192.168.2.10</td>
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<td>Pending</td>
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<td>rtt --dest 192.168.2.10</td>
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<td>Pending</td>
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<td>Pending</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
<tr>
<td>Pending</td>
<td>rtt --dest 192.168.2.10</td>
<td></td>
</tr>
</tbody>
</table>

**Step 2.** To exit from pScheduler monitor, press Ctrl+C.

### 5.2 pScheduler schedule

The `pscheduler schedule` command asks pScheduler to fetch scheduled task runs from the past, present or future and display them as text.

**Step 1.** In perfSONAR1 command line, follow the command format (1) and type:
Step 2. To exit from pScheduler schedule, press \texttt{Ctrl+C}.

6 Canceling tasks

So far there are two pscheduler tasks running. In this section, the user will cancel the scheduled Round-Trip Time (RTT) and throughput tasks which are running.

Step 1. In perfSONAR1 command line, follow the command format (1) and type:

\begin{verbatim}
pscheduler schedule --filter-test rtt
\end{verbatim}

The user will see the scheduled task for Round-Trip Time (RTT) measurement.
Step 2. In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler cancel https://localhost/pscheduler/tasks/[url]
```

Replace `[url]` with the first three characters of the last task URL. In this example, the first three characters of the task is `631`, these characters may vary then, press Tab key to autocomplete the following characters. Press Enter to cancel the task.

![Example Command]

Step 3. In perfSONAR1 command line, type the command `pscheduler monitor` to visualize the schedule.

![Scheduler Monitor]

The user will notice that all the Round-Trip Time (RTT) tasks are finished and there are not more tasks like this scheduled.

Step 4. In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler schedule --filter-test throughput
```

The user will see the scheduled task for round-trip time (RTT) tests.
Step 5. In perfSONAR1 command line, follow the command format (1) and type:

```
pscheduler cancel https://localhost/pscheduler/tasks/[url]
```

Replace `[url]` with the first three characters of the last task URL. In this example, the first three characters of the task is `f44`, these characters may vary then, press Tab key to autocomplete the following characters. Press Enter to cancel the task.

Step 6. In perfSONAR1 command line, type the command `pscheduler monitor` to visualize the schedule.
The user will notice that all the tasks are finished and there are not more tasks scheduled.

This concludes lab 5.

References

PERFSONAR

Lab 6: Bandwidth-delay Product and TCP Buffer Size

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Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Overview

This lab explains the Bandwidth-Delay Product (BDP) in Wide Area Networks (WAN) and how to perform TCP Tuning in a perfSONAR node to modify the buffer size. Throughput measurements are also conducted in this lab to verify the buffer size configuration using pScheduler commands.

Objectives

By the end of this lab, the user will:

1. Understand Bandwidth-Delay Product (BDP).
2. Define TCP window size.
3. TCP window size calculation.
4. Change buffer size with `sysctl`.
5. Emulate WAN using NETEM commands.
6. Visualize the results on pScheduler report.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (*Lubuntu*). The Client host is used to access perfSONAR graphical user interface.
Lab settings

The information in Table 1 provides the credentials to access to perfSONAR nodes.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

The lab includes the following tasks:

1. Section 1: Introduction.
2. Section 2: Emulating 2 Gbps high-latency WAN.
3. Section 3: BDP and buffer size experiments.
4. Section 4: Modifying the buffer size and throughput test.

1 Introduction

1.1 TCP buffers

Consider Figure 1, which shows a data transfer between a sender and a receiver. At the sender side, TCP receives data from the application layer and places it in the TCP buffer. Typically, TCP fragments the data in the buffer into Maximum Segment Size (MSS) units and passes the newly formed segments (application-layer data plus TCP header) to the network layer. In this example, the MSS is 100 bytes. A segment stored in the TCP send buffer will only be removed from the buffer when a corresponding acknowledgement is received. If the send buffer is full, TCP blocks the application from sending new data. Each segment carries a sequence number, which is the byte-stream number of the first byte in the segment. The corresponding acknowledgement (Ack) carries the number of the next expected byte (e.g., Ack-101 acknowledges bytes 1-100, carried by the first segment).

At the receiver side, TCP receives data from the network layer and places it into the TCP receive buffer. TCP delivers the data in order to the application layer. The implication here is that bytes contained in a segment, say segment 2 (bytes 101-200), cannot be delivered to the application layer before the bytes contained in segment 1 (bytes 1-100) are
delivered to the application layer. At any given time, the TCP receiver indicates to the TCP sender how many bytes the latter can send. This reflects how much free buffer space is available at the receiver.

![TCP send and receive buffers diagram](image)

**Figure 1. TCP send and receive buffers.**

### 1.2 Bandwidth-delay product

In many Wide Area Networks (WANs) connecting geographically separated locations, the Round-Trip Time (RTT), which is the time it takes for a small packet to travel from sender to receiver and then back to the sender, is dominated by the propagation delay. Long RTTs along with TCP buffer size can have important implications for the efficiency of the bandwidth utilization and throughput. As an example, consider a 10 Gbps WAN with a 50-millisecond RTT. Assume that the TCP send and receive buffer sizes are set to 1 Mbyte (1 Mbyte = 1024² bytes = 1,048,576 bytes = 1,048,576 · 8 bits = 8,388,608 bits). At 10 Gbps, this number of bits is approximately transmitted in:

\[
T_{tx} = \frac{\text{# bits}}{\text{transmission rate}} = \frac{8,388,608}{10 \cdot 10^9} = 0.84 \text{ milliseconds.}
\]

I.e., if at \( t = 0 \) the TCP sender starts transmitting, at \( t = 0.84 \) milliseconds the content in TCP send buffer has been completely sent. At this point, TCP must wait for the corresponding acknowledgements, which will only start arriving at \( t = 50 \) milliseconds. This means that the sender only uses 0.84/50 or 1.68% of the available bandwidth.

The solution to that above problem lies in allowing the sender to continuously transmit segments until the corresponding acknowledgments arrive back. Note that the first acknowledgement arrives after RTT = 50 milliseconds. The number of bits that can be transmitted in this time period is given by bandwidth of the channel in bits per second multiplied by the RTT. This quantity is referred to as the Bandwidth-Delay Product (BDP). For the above example, the buffer size must be greater than or equal to the BDP:

\[
\text{TCP buffer size} \geq \text{BDP} = (10 \cdot 10^9)(50 \cdot 10^{-3}) = 500,000,000 \text{ bits} = 62,500,000 \text{ bytes.}
\]

The first factor \( (10 \cdot 10^9) \) is the bandwidth; the second factor \( (50 \cdot 10^{-3}) \) is the RTT. For practical purposes/configuration, the TCP buffer can be also expressed in Mbytes (1
Mbyte = 1024² bytes) or Gbytes (1 Gbyte = 1024³ bytes). The above expression, in Mbytes, is:

\[ \text{TCP buffer size} \geq 62,500,000 \text{ bytes} = 59.6 \text{ Mbytes} \approx 60 \text{ Mbytes}. \]

1.3 Practical observations on setting TCP buffer size

*Linux systems configuration.* When configuring the buffer size in Linux systems, it is important to note that Linux assumes that half of the send/receive TCP buffers are used for internal kernel structures. Thus, only half of the buffer size is used to store segments. This implies that if a TCP connection requires certain buffer size, then the administrator must configure the buffer size equals to twice the bandwidth-delay product. For the previous example, the TCP buffer size must be:

\[ \text{TCP buffer size} \geq 2 \cdot BDP = 2 \cdot 60 \text{ Mbytes} = 120 \text{ Mbytes}. \]

*Packet loss scenarios.* TCP provides a reliable, in-order delivery service. In this context, reliability means that bytes successfully received must be acknowledged. The sender will only release (free the memory) a segment stored in its TCP send buffer after it receives the corresponding acknowledgement. In-order delivery means that the receiver only delivers bytes to the application layer in sequential order. This has some performance implications, as illustrated next. Consider Figure 2, which shows a TCP receive buffer. Assume that the segment carrying bytes 101-200 was lost in transit. Although the receiver has successfully received bytes 301-900, they cannot be delivered to the application layer until bytes 101-200 are received. Note that the receive buffer may become full, thus preventing the reception of additional bytes beyond byte 900. Thus, the sender will be blocked, and the bandwidth will be underutilized (eventually, the sender will retransmit the segment 101-200).

To fully utilize the available bandwidth, the TCP send and receive buffer must be large enough to prevent such situation.

1.4 TCP window size calculated value
The receiver must constantly communicate with the sender to indicate how much free buffer space is available in the TCP receive buffer. This information is carried in a TCP header field called window size. The window size has a maximum value of 65,535 bytes, as the header value allocated for the window size is two bytes long ($2^{16}-1 = 65,535$). However, this value is not large enough for high-bandwidth high-latency networks. Therefore, *TCP window scale option* was standardized in RFC 1323. By using this option, the calculated window size may be increased up to a maximum value of 1,073,725,440 bytes.

When advertising its window, a device also advertises the *scale factor* (multiplier) that will be used throughout the session. The TCP window size is calculated as follows:

\[
\text{Scaled TCP}_{\text{Win}} = \text{TCP}_{\text{Win}} \cdot \text{Scaling Factor}
\]

Consider the following example. For an advertised TCP window of 2,049 and a scale factor of 512, then the final window size is 1,049,088 bytes. Figure 3 displays a packet inspected in Wireshark protocol analyzer for this numerical example.

- Flags: 0x010 (ACK)
- Window size value: 2049
- [Calculated window size: 1049088]
- [Window size scaling factor: 512]

Figure 3. Window Scaling in Wireshark.

### 1.5 Zero window

When the TCP buffer is full, a window size of zero is advertised to inform the other end that it cannot receive any more data. When a client sends a TCP Window of zero, the server will pause its data transmission, and waits for the client to recover. Once the client is recovered, it digests data and informs the server to resume the transmission by setting again the TCP Window.

### 2 Emulating 2 Gbps high-latency WAN

In this section, the user will emulate a high-latency WAN by introducing a 100ms delay to the network. Specifically, the user will set 50ms delay to the router R1 and 50ms delay to router R2 using Network Emulator (NETEM) commands. Additionally, the bandwidth between perfSONAR1 and perfSONAR3 nodes will be set to 2 Gbps using Token Bucket Filter (TBF). In order to verify, the user will run a throughput test using pScheduler commands.

**Step 1.** On the topology, click on router R1 and enter the username `root` and `password` as password. Note that the password will not be displayed while typing it.
Step 2. To identify the interface connected to the network 192.168.2.0/24, in router R1 command line, type the command `ifconfig`. This command displays information related to the network interfaces in the local device.

```
R1 login: root
Password:
```

The output of the `ifconfig` indicates that router R1 has three interfaces. The interface `ens37` connects router R1 to the network 192.168.2.0/24. Thus, this interface must be used for emulation.

Step 3. In order to add a 50ms delay, in router R1 CLI type the following command:

```
sudo tc qdisc add dev ens37 root handle 1: netem delay 50ms
```

Step 4. In order to set the bandwidth, type the command shown below. This command sets the bandwidth to 2 Gbps on router R1 `ens37` interface. The `tbf` parameters are the following:
• **rate:** 2gbit
• **burst:** 500,000
• **limit:** 50,000,000

```bash
sudo tc qdisc add dev ens37 parent 1: handle 2: tbf rate 2gbit burst 500000 limit 50000000
```

**Step 5.** On the topology, click on R2 and enter the username `root` and password as password. Note that the password will not be displayed while typing it.

```
CentOS Linux 7 (Core)
Kernel 4.19.1-1.el7.elrepo.x86_64 on an x86_64

R2 login: root
Password:
```

**Step 6.** To identify the interface connected to the network **192.168.2.0/24**, in R2 command line, type the command `ifconfig`. This command displays information related to the network interfaces in the local device.

```
[root@R2 ~]# ifconfig
ens37: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.2.2 netmask 255.255.255.0 broadcast 192.168.2.255
    ether 00:50:56:ae:e5:dc txqueuelen 1000 (Ethernet)
    RX packets 1013392352 bytes 1408674532723 (1.3 TiB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 121711195 bytes 28937957450 (2.6 TiB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

ens37: flags=4163<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 192.168.2.2 netmask 255.255.255.0 broadcast 192.168.2.255
    ether 00:50:56:ae:e5:dc txqueuelen 1000 (Ethernet)
    RX packets 121313763 bytes 179953633195 (1.6 TiB)
    RX errors 0 dropped 10 overruns 0 frame 0
    TX packets 101666899 bytes 2402663209617 (2.1 TiB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 468 bytes 37528 (36.6 KiB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 468 bytes 37528 (36.6 KiB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
[root@R2 ~]#
```

The output of the `ifconfig` command indicates that R2 has two interfaces. The interface `ens37` connects R2 to the network 192.168.2.0/24. Thus, this interface must be used for emulation.

**Step 7.** In order to add a 50ms delay, in R2 command line type the command:
**Step 8.** To verify if the parameters where applied, on the topology, click on perfSONAR1 node and login entering the username `admin` and password `admin`. Note that the password will not be displayed while typing it.

```bash
sudo tc qdisc add dev ens37 root netem delay 50ms
```

**Step 9.** In perfSONAR1 command line, type the following command to verify if the delay was applied:

```
pscheduler task rtt --source 192.168.1.10 --dest 192.168.3.10
```

- `pscheduler` is the command to interact with perfSONAR.
- `task` is a pScheduler command.
- `rtt` is the test type.
- `--source` is to specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
- `--dest` is the destination node, in this case it is perfSONAR3 (192.168.3.10).
The result above indicates that all five packets were received successfully (0% packet loss) and that the minimum, average, maximum, and standard deviation of the Round-Trip Time (RTT) were 100.53, 100.59, 100.761 and 0.217 milliseconds, respectively. The output above verifies that delay was injected successfully, as the RTT is approximately 100ms.

**Step 10.** To verify the throughput, in perfSONAR1 command line, type the following command:

```
pscheduler task throughput --source 192.168.1.10 --dest 192.168.3.10
```

- `pscheduler` is the command to interact with perfSONAR.
- `task` is a pScheduler command.
- `throughput` is the test type.
- `--source` is to specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
- `--dest` is the destination node, in this case it is perfSONAR3 (192.168.3.10).

Notice the measured throughput now is around 950 Mbps, which is different than the value assigned in the `tbf` rule. In the following section, the user will modify the send and receive TCP buffer size in order to achieve 2 Gbps bandwidth.

### 3 BDP and buffer size experiments

In a connection-oriented protocol such as TCP, BDP plays an important role as it represents the amount of buffering required on both senders and receivers (transmitting
end-hosts). In connections that have a small BDP (either because the link has a low bandwidth or because the latency is small), buffers are usually small. However, in high-bandwidth high-latency networks, where the BDP is large, a larger buffer is required to achieve the maximum theoretical bandwidth.

3.1 Window size in sysctl

In this section, the user will set different values the corresponding sysctl keys, which is used for dynamically changing parameters in the Linux operating system. It allows users to modify kernel parameters dynamically without rebuilding the Linux kernel.

The sysctl key for the receive window size is `net.ipv4.tcp_rmem` and the send window size is `net.ipv4.tcp_wmem`.

**Step 1.** To read the current receiver window size value of perfSONAR1 node, type the following command:

```
sysctl net.ipv4.tcp_rmem
```

```
admin@perfsonar1 ~$ sysctl net.ipv4.tcp_rmem
net.ipv4.tcp_rmem = 4096 87380 33554432
```

**Step 2.** To read the current send window size value of perfSONAR1 node, type the following command:

```
sysctl net.ipv4.tcp_wmem
```

```
admin@perfsonar1 ~$ sysctl net.ipv4.tcp_wmem
net.ipv4.tcp_wmem = 4096 65536 33554432
```

The returned values of both keys `net.ipv4.tcp_rmem` and `net.ipv4.tcp_wmem` are measured in bytes. The first number represents the minimum buffer size used by each TCP socket. The middle one is the default buffer which is allocated when applications create a TCP socket. The last one is the maximum receive buffer that can be allocated for a TCP socket. Note that similar results are displayed in perfSONAR2 and perfSONAR3. For simplicity, in this section is just shown the values on perfSONAR1 node.

The default values used by in perfSONAR nodes are:

- Minimum: 4,096
- Default: 65,536
- Maximum: 33,554,432

Note that the maximum value is 32 Mbytes. However, to achieve the maximum throughput, it is necessary to set the send and receive TCP buffer size to at least twice
Bandwidth-Delay Product ($2 \cdot BDP$). In the previous test (2 Gbps, 100ms delay), the buffer size was not modified on end-hosts namely, perfSONAR1 and perfSONAR3 nodes.

The BDP for the above test is:

$$BDP = (2 \cdot 10^9) \cdot (100 \cdot 10^{-3}) = 200,000,000 \text{ bits} = 25,000,000 \text{ bytes} \approx 25 \text{ Mbytes}.$$ 

Note that twice BDP is around 50 Mbytes thus, this value is significantly greater than the maximum buffer size (32 Mbytes), and therefore, the pipe is not getting filled, which leads to network resources underutilization (see section 1.3).

4 Modifying buffer size and throughput test

This section repeats the throughput test after modifying the buffer size on perfSONAR1 and perfSONAR3 nodes according to the formula described above. This test assumes the same network parameters introduced in the previous test therefore, the bandwidth is limited to 2 Gbps and the RTT (delay or latency) is 100ms. The send and receive buffer sizes should be set to at least $2 \cdot BDP$. Use 25 Mbytes value for the BDP instead of 25,000,000 bytes ($1 \text{ Mbyte} = 1024^2 \text{ bytes}$).

$$BDP = 25 \text{ Mbytes} = 25 \cdot 1024^2 \text{ bytes} = 26,214,400 \text{ bytes}$$

TCP buffer size $= 2 \cdot BDP = 2 \cdot 26,214,400 \text{ bytes} = 52,428,800 \text{ bytes}$

Step 1. To change the TCP receive-window size value, type the following command on perfSONAR1 CLI. If a password is required, type admin as the password. Note that the password will not be displayed while typing it. The values set are: 4,096 (minimum), 65,536 (default) and 52,428,800 (maximum, calculated by doubling the BDP).

```
sudo sysctl -w net.ipv4.tcp_rmem='4096 65536 52428800'
```

The returned values are measured in bytes. 4,096 represents the minimum buffer size that is used by each TCP socket. 65,536 is the default buffer which is allocated when applications create a TCP socket. 52,428,800 is the maximum receive buffer that can be allocated for a TCP socket.

Step 2. To change the current send-window size value, type the following command on perfSONAR1 CLI. The values set are: 4,096 (minimum), 65,536 (default) and 52,428,800 (maximum, calculated by doubling the BDP).

```
sudo sysctl -w net.ipv4.tcp_wmem='4096 65536 52428800'
```
Step 3. To verify if the parameters were applied, on the topology, click on perfSONAR3 node and login entering the username admin and password admin. Note that the password will not be displayed while typing it.

```
CentOS Linux 7 (Core)
Kernel 3.10.0-957.1.3.el7.x86_64 on an x86_64

perfsonar3 login: admin
Password:
Last login: Wed Jan 30 16:55:14 on tty1
Welcome to the perfSONAR Toolkit v4.1.5-1.el7

You may create accounts to manage this host through the web interface by running the following as root:
/usr/lib/perfsonar/scripts/ntoolkit-configure.py

The web interface should be available at:
https://host address1/toolkit
```

Step 4. To change the TCP receive-window size value, type the following command on perfSONAR1 CLI, if a password is required, type admin as password. Note that the password will not be displayed while typing it. The values set are: 4,096 (minimum), 65,536 (default) and 52,428,800 (maximum, calculated by doubling the BDP).

```
sudo sysctl -w net.ipv4.tcp_rmem='4096 65536 52428800'
```

The returned values are measured in bytes. 4,096 represents the minimum buffer size that is used by each TCP socket. 65,536 is the default buffer which is allocated when applications create a TCP socket. 52,428,800 is the maximum receive buffer that can be allocated for a TCP socket.

Step 5. To change the current send-window size value, type the following command on perfSONAR1 CLI. The values set are: 4,096 (minimum), 65,536 (default) and 52,428,800 (maximum, calculated by doubling the BDP).

```
sudo sysctl -w net.ipv4.tcp_wmem='4096 65536 52428800'
```

Step 6. To verify the if after the configuration the throughput is achieved, go back to perfSONAR1 CLI and type the following command:

```
pscheduler task throughput --source 192.168.1.10 --dest 192.168.3.10
```

* `pscheduler` is the command to interact with perfSONAR.
* `task` is a pScheduler command.
• `throughput` is the test type.
• `--source` is to specify where the test should originate, in this case it is perfSONAR1 node (192.168.1.10).
• `--dest` is the destination node, in this case it is perfSONAR3 (192.168.3.10).

Note that the measured throughput now is approximately 2 Gbps, which is similar to the value assigned in the `tbf` rule (2 Gbps).

This concludes Lab 6.

References

Lab 7: Configuring Regular Tests Using a pSConfig Template

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Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Overview

This lab presents a template framework for describing and configuring pScheduler tasks known as pSConfig. The lab describes the steps to create and interpret the parts of a pSConfig template. The user will use this template to run regular test in a perfSONAR node.

Objectives

By the end of this lab, the user will:

1. Understand the structure of pSConfig template.
2. Create a pSConfig configuration file.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.

![Lab topology diagram]

Figure 1. Lab topology.

Lab settings
Lab 7: Configuring Tasks using pSConfig Template

The information in Table 1 provides the credentials to access to perfSONAR nodes.

Table 1. Credentials to access perfSONAR1, perfSONAR2 and perfSONAR3.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

The lab includes the following tasks:

1. Section 1: Introduction.
2. Section 2: The pSConfig file structure.
4. Section 4: Running the pSConfig pScheduler Agent.
5. Section 5: Viewing Scheduled Tasks.

1 Introduction

The perfSONAR Configuration (pSConfig) is a template-based setup for describing and configuring a topology of tasks. A task is defined as a measurement test to be performed using pScheduler. The topology defines how multiple tasks are interrelated. Overall, the goal of pSConfig is to simplify the scheduling of such tasks as well as maintenance of visualization components when managing more than one perfSONAR node.

The basic pSConfig workflow is shown in Figure 2 and consists of three key steps:

1. A template file is defined using the machine-readable JavaScript Object Notation (JSON) file format to describe the task topology of the perfSONAR hosts.
2. This file is then published to the web where it is read by an agent to perform specific operations.
3. Agents read the pSConfig template. An agent is a software that reads one or more pSConfig templates and uses the information to perform a specific function. The pScheduler agent which reads template files and submits related measurement tests to pScheduler and, the MaDDash agent, which reads template files to generate dashboard in order display the measurement results. Overall this lab focuses on the first step of building a sample JSON template file.
In this lab, the user will understand how the file is created. Secondly, the user will publish the template in order to be accessible by any node in the topology. Then, the template will be read by an agent. Finally, the user will verify the tasks using pScheduler monitor.

2 The pSConfig file structure

Basically, a pSConfig file has six components: addresses, groups, tests, archives, schedules and tasks. These components are put all together to perform measurement tests. In this section all these components are explained. For that purpose, there is available a pSConfig template in perfSONAR2 node. The user will not modify this file during the lab. This file will be useful to explain the structure of pSConfig template. In addition, this template will be used by an agent to run measurement test in the current lab topology.

Step 1. In order to visualize the pSConfig template, open perfSONAR2 and enter the username admin and password admin. Note that the password will not be displayed while typing it.
Step 2. After login, type the command shown below, a pSCConfig template will be displayed. Use the arrows to scroll up/down into the file.

```
nano /home/template.json
```
The address is the most basic unit of a template. An address is a collection of properties that act as the unit of input to a task. This address is not necessarily connected to an interface or host. It is simply an object with properties. The figure 3 illustrates the idea.

![Figure 3: Representation of three addresses](image)

Each shape has certain properties such as the form and the color. In pSConfig these properties can be used when constructing a task.

**Step 1.** In perfSONAR2 type `nano /home/template.json`, a pSConfig template will be displayed.

**Step 2.** Go to the line 17. To see the actual line number press `Ctrl+C`.

```json
"addresses": {
  "perfSONAR1": { "address": "192.168.1.10" },
  "perfSONAR2": { "address": "192.168.2.10" },
  "perfSONAR3": { "address": "192.168.3.10" }
},
```

In this configuration file these addresses are specified with the names and IP addresses of perfSONAR1, perfSONAR2 and perfSONAR3.

### 2.2 Groups

A group describes the way to combine addresses when building the list of tasks. All groups have a type that provides the base for how addresses are combined. Currently, pSConfig support three group types.

#### 2.2.1 Mesh

The first group type is *mesh*. A group of type mesh pairs every address against every other address in the group. A mesh group is shown in the figure 4. Notice that the three addresses are paired in six groups.
The user could visualize the group configuration following the next steps:

**Step 1.** In perfSONAR2 type `nano /home/template.json`, a pSConfig template will be displayed.

**Step 2.** Go to the line 22. To see the actual line number press `Ctrl+C`.

```json
"groups": {
  "loss_group": {
    "type": "mesh",
    "addresses": [
      { "name": "perfSONAR1" },
      { "name": "perfSONAR2" },
      { "name": "perfSONAR3" }
    ]
  },
  "throughput_group": {
    "type": "mesh",
    "addresses": [
      { "name": "perfSONAR1" },
      { "name": "perfSONAR2" },
      { "name": "perfSONAR3" }
    ]
  }
},
```

The user will see there are two groups, `loss_group` and `throughput_group`. The group type for both is `mesh` and the nodes involved in these groups are perfSONAR1, perfSONAR2 and perfSONAR3.

### 2.2.2 Disjoint

The second group type is `disjoint`. A group of type disjoint pairs every address in one group (Group A) with every address in another group (Group B). Both groups can have one or
more addresses. A mesh group is shown in the figure 5. Notice that the three addresses are paired in four groups.

![Figure 5: Disjoint group](image)

The pSconfig template of this lab does not provide an example for this type of group. However, a JSON object for this type of group is described below.

```json
{
  "type": "disjoint",
  "a-addresses": [
    {"name": "circle1"}
  ],
  "b-addresses": [
    {"name": "circle2"},
    {"name": "circle3"}
  ]
}
```

### 2.2.3 List

The final group type is called list. A group of type list returns each address independently. It is the only current type that does not pair addresses. Instead, it just generates a one-dimensional list of addresses. The figure 5 illustrate a list group type.

![Figure 6: List group](image)

The pSconfig template of this lab does not provide an example for this type of group. However, a JSON object for this type of group is described below.

```json
{
  "type": "list",
}
```
2.3 Tests

Test objects define the parameters of the job to be carried out by the task. These parameters are interpreted by the agent and then it is delivered to pScheduler to run the task.

Step 1. In perfSONAR2 type `nano /home/template.json`, a pSConfig template will be displayed.

Step 2. Go to the line 41. To see the actual line number press `Ctrl+C`.

The user will see there are two tests, `throughput_test` and `loss_test`. The specification for the `throughput_test` is given by the source and destination addresses. The value of these keys are `address[0]` and `address[1]` respectively. These values represent the addresses in the group pairs. Finally, the duration of the test is specified with the key `duration`, in this case the value is `PT10S` which means the test duration will last 10 seconds. The `loss_test` uses the toll `rtt` to measure the packet loss ratio. The specification indicates that the source and destination addressed will be taken also from each group pair.

2.4 Schedule

Schedule objects tell the agent how often a task will be scheduled and how long the test is going to inactive after each run. Schedule objects are borrowed directly from pScheduler.

Step 1. In perfSONAR2 type `nano /home/template.json`, a pSConfig template will be displayed.
**Step 2.** Go to the line 61. To see the actual line number press Ctrl+C.

```json
"schedules": {
  "schedule_PT2M": {
    "repeat": "PT2M",
    "sliprand": true,
    "slip": "PT2M"
  }
}
```

In the pSConfig template is defined one schedule named `schedule_PT2M` which will tell a task using it to run on a random interval between every 2-4 minutes. The `repeat` property is an ISO8601 duration telling a task that uses it to repeat at least every two minutes. The slip says that it can run up to 2 minutes later than that (i.e. 4 minutes). Finally, `sliprand` tells it to randomly choose an interval between those two values for each run. This is commonly done to prevent tests from bunching together at the beginning of a time interval.

### 2.5 Archives

Archive objects are optional components of the template that tell agents where the results of the described tasks are to be stored. Archive objects at a minimum have an archiver field that indicates the type of archive and a data field containing archive-specific parameters. Archive objects in pSConfig are taken directly from pScheduler.

**Step 1.** In perfSONAR2 type `nano /home/template.json`, a pSConfig template will be displayed.

**Step 2.** Go to the line 6. To see the actual line number press Ctrl+C.

```json
"archives": {
  "esmond_archive_1": {
    "archiver": "esmond",
    "data": {
      "measurement-agent": "v. scheduled_by_address %",
      "url": "https://192.168.2.10/esmond/perfsonar/archive/"
    }
  }
}
```

The archiver tag `esmond_archive_1` that can be referenced in other areas of the template. The archiver type is ESNet Monitoring Daemon (*esmond*). This definition also uses the template variable `% scheduled_by_address %` which is replaced with an address property associated with the address object representing the agent that will schedule the task. The *url* key specify the location to store the measurement data. In this case, the data will be stored in perfSONAR2 node.

### 2.6 Tasks

A task is a job to do consisting of a test to be carried out, scheduling information and other options. A task in pSConfig means the same thing as a task in pScheduler. Template
variables allow pSConfig to access properties of the task components listed in the previous sections to connect the various pieces of the task together. Figure 7 shows representation of a task definition.

The squares represent the two addresses (source and destination) defined in a test. In this figure, those addresses are represented by colors. After the test definition, it is scheduled according to the parameters in the schedule object. Finally, the results are stored into an archiver, this feature is optional.

Step 1. In perfSONAR2 type `nano /home/template.json`, a pSConfig template will be displayed.

Step 2. Go to the line 69. To see the actual line number press `Ctrl+C`.

```
"tasks": {
  "throughput_task": {
    "group": "throughput_group",
    "test": "throughput_test",
    "schedule": "schedule_PT2M",
    "archives": [ "esmond_archives_1" ],
    "meta": {
      "display-name": "Throughput Test"
    }
  },
  "loss_task": {
    "group": "loss_group",
    "test": "loss_test",
    "schedule": "schedule_PT2M",
    "archives": [ "esmond_archives_1" ],
    "meta": {
      "display-name": "Loss Test"
    }
  }
}
```

In this object, there are two tasks, one for throughput measurements tagged as `throughput_task` and another for packet loss measurements tagged as `loss_task`. The group attribute is referred to `throughput_group` and `loss_group` specified before in the group object. The schedule and archiver have the same key values for both tasks. Finally, a metadata key is specified with the name of each task, those values are identifier. At this point, the template describes the task topology and can be published to be accessed by all perfSONAR node in the topology.
Step 3. Press \( \text{Ctrl} + \text{X} \) to close the window. The user could repeat the previous steps anytime along this lab.

3 Publishing a pSConfig template

In this section, the user will verify the pSConfig file and the it will be published. It is necessary to publish this template to make it accessible to all perfSONAR nodes in the topology.

Step 1. To check the syntax, in perfSONAR2 command line type the command shown below. If the JSON file syntax is correct, the user will see the script on the screen.

```
jq . /home/template.json
```

```
{
  "meta": {
    "display-name": "perfSONAR Lab"
  },
  "archives": {
    "esmond_archive_1": {
      "archive": "esmond",
      "data": {
        "measurement-agent": "%(scheduled_by_address)s"
      },
      "url": "https://192.168.2.10/esmond/perfsonar/archive/"
    }
  },
  "addresses": {
    "perfSONAR1": {
      "address": "192.168.1.10"
    },
    "perfSONAR2": {
      "address": "192.168.2.10"
    },
    "perfSONAR3": {
      "address": "192.168.3.10"
    }
  },
  "groups": {
    "loss_group": {
      "type": "mesh",
      "addresses": {
        "name": "perfSONAR1"
      },
      "name": "perfSONAR2"
    }
  }
}
```

Step 2. To publish the file, type the following command:

```
sudo psconfig publish /home/template.json
```

Type `admin` as the password, notice that the password will not be displayed while typing it.
Now the template is published in https://192.168.2.10/psconfig/template.json, and can be accessed by perfSONAR1, perfSONAR2 and perfSONAR3 nodes.

At this point, the user has configured MaDDash server. In this section, perfSONAR1 and perfSONAR3 nodes, are going to run the pSConfig agent published on https://192.168.2.10/psconfig/template.json.

4 Running the pSConfig pScheduler Agent

The role of the pSConfig pScheduler Agent is to read pSConfig templates and generate a set of pScheduler tasks. The figure 8 describes this role.

The process depicted in the figure 8 includes the following steps:

- Read the configured templates.
- Determine the pScheduler tasks to schedule.
- Communicate with the appropriate pScheduler servers to ensure the tasks are created.

These steps are completed whenever one of the following events occur:
• The agent starts.
• The default local configuration file remains unchanged within a certain time period. By default, this value is 1 minute.
• If no changes, on a configurable interval after the start of the last run. By default, these steps are run every 1 hour.

Step 1. On the topology click on perfSONAR1 node and login typing `admin` as the username and `admin` as the password.

Step 2. To run the pSConfig Agent in perfSONAR1 node, type the following command:

```
sudo psconfig remote add “https://192.168.2.10/pconfig/template.json”
```

If required, type `admin` as the password.

At this point the pConfig template is run by a pScheduler agent. Notice that the pSConfig template is published in perfSONAR2 node and the task are running in perfSONAR1.

5 Viewing Scheduled Tasks

Step 1. In order to visualize the tasks defined in the pSConfig template, on perfSONAR1 command line type `pscheduler monitor` to visualize the ongoing tests.

The user will see a screen with the schedule of tests. These tests have a status depending on whether they have already run or are still waiting to do so. Possible status values are:
• **Pending**: This run is scheduled to execute at some point in the future.
• **On Deck**: This run is scheduled to execute and will begin execution very soon.
• **Running**: This run is in the middle of execution.
• **Cleanup**: This run completed execution and is doing some final operations.
• **Finished**: The run has already executed and finished successfully,
• **Overdue**: The run was scheduled to execute at a certain time in the past but did not. It may get executed soon if it is not beyond a certain threshold.
• **Missed**: The run was scheduled but did not execute at its given time. This can happen if the scheduler was not running at the allotted time or the task was paused.
• **Failed**: The run failed to complete for some reason.
• **Non-Starter**: The run could not be scheduled because there were no timeslots that could accommodate the constraints.
• **Canceled**: The task was cancelled before the run was executed.

The results above indicate that several round-trip time test rtt and throughput tests are running approximately each 2 minutes. The user will see the status, the source and the destination IP addresses. In addition, the duration of the rtt test is shown besides it.

**Step 2.** To exit from pScheduler monitor, press `Ctrl+c`.

This concludes Lab 7.
References

PERFSONAR

Lab 8: perfSONAR Monitoring and Debugging Dashboard

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Overview

This lab presents the perfSONAR Monitoring and Debugging Dashboard (MaDDash). This tool is aimed to collect large amounts of measurement data and display them in a two-dimensional grid referred to as a dashboard.

Objectives

By the end of this lab, the user will:

1. Configure MaDDash in order to visualize regular tests.
2. Run pSConfig agents on perfSONAR nodes.
3. Configure a central measurement archive.
4. Check the grids using MaDDash administrator web interface.
5. Visualize the measurement data on the dashboard.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.

Lab settings
The information in Table 1 provides the credentials to access to perfSONAR nodes and the Client host.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

This lab includes the following tasks:

1. Section 1: Introduction.
2. Section 2: Configuring MaDDash server.
3. Section 3: Configuring perfSONAR nodes.
4. Section 4: Checking the grids.
5. Section 5: Visualizing the dashboard.

1 Introduction

In scientific collaboration environments, computational and instrumentalational resources are often physically distributed over the Wide Area Networks (WAN). Collaborators work remotely in different centers and require access to instruments. As a large number of data flows move between centers, data visualization becomes an important tool in facilitating network monitoring.

The Monitoring and Debugging Dashboard (MaDDash) is a software package for perfSONAR. It collects and presents two-dimensional monitoring data as a set of grids referred to as a dashboard. Many monitoring systems emphasize one-dimensional graphs, however network managers can face difficulties presenting the measurement data as complexity increases. Therefore, MaDDash provides the tools to create, configure and synchronize tests which are running on multiple hosts. These results can then be accessed using a REST API which provides the building blocks for components such as the included web interface that presents the data as a set of grids.
MaDDash is a part of the visualization layer, as shown in the figure 2. It can run a pSConfig template and can retrieve the measurement data of other perfSONAR nodes through the ESnet Monitoring Daemon (Esmond), which is a system for collecting, storing, visualizing and analyzing large sets of timeseries data.

![Figure 2. perfSONAR layers](image)

## 2 Configuring MaDDash server

In this section the user will configure a MaDDash server in order run and collect measurement data. First, the user will open firewall to allow http/https traffic. Second, the user will publish a pSConfig template to run the measurement tests in the server and the other nodes. Then, it is shown how to configure the central measurement archive. Finally, the user will run a pSConfig MaDDash agent.

### 2.1 Allow http and https traffic to MaDDash server

In order to provide access the server, it is necessary to open the firewall to allow http/https traffic.

**Step 1.** Login to perfSONAR2 typing the username `admin` and password `admin`. Note that the password will not be displayed while typing it.
Step 2. To allow traffic through the http port (80) type the command shown below. The user will be required to enter the password as `admin`. Notice that the password will not be displayed while typing it.

```
sudo firewall-cmd --permanent --add-port=80/tcp
```

Step 3. Similarly, to allow traffic through the https port (443) type the command shown below.

```
sudo firewall-cmd --permanent --add-port=443/tcp
```

Step 4. To apply the changes, type the following command:

```
sudo firewall-cmd --reload
```

### 2.2 Publishing pSConfig agent

In this lab, the user is provided a template. This template is a pSConfig archive which runs pScheduler tasks. It is necessary to publish this template to make it accessible to all perfSONAR nodes.
Step 1. In the directory `/home/`, the user will find the pSConfig agent `template.json`, which runs pScheduler tasks. To check for errors, type the command shown below. If the JSON file syntax is correct, the user will see the script echoed on the screen.

```
jq . /home/template.json
```

Step 2. To publish the template, type the command shown below. The script will be available at `https://192.168.2.10/psconfig/template.json`.

```
sudo psconfig publish /home/template.json
```

Now, the pSConfig template is published and can be accessed by perfSONAR1 and perfSONAR3 nodes.

2.3 Configuring central measurement archive

Each host will collect measurement data specified in the pSConfig template. This measurement data will be stored into a centralized database, the ESnet Monitoring Daemon (esmond). Esmond is a system for collecting, storing, visualizing and analyzing
large sets of timeseries data. In order to store measurement data, each host needs to authenticate to the Central Measurement Archive esmond.

To allow each node to store its measurement data, the user will use the following command format:

```
sudo /usr/sbin/esmond_manage add_user_ip_address admin <IP_ADDRESS>
```

- `sudo`: enables the execution of the command with higher security privileges.
- `/usr/sbin/esmond_manage`: is the route to the script to register a perfSONAR node.
- `add_user_ip_address`: is a script which allows a perfSONAR node to have access to the central measurement archive and store its measurement data.
- `admin`: is the administrator password.
- `<IP_ADDRESS>`: is the IP address of the perfSONAR node to be registered.

**Step 1.** To allow perfSONAR1 node to store its measurement data, in perfSONAR2 CLI type the command shown below. The user will be required to enter the password as `admin`. Notice that the password will not be displayed while typing it.

```
sudo /usr/sbin/esmond_manage add_user_ip_address admin 192.168.1.10
```

**Step 2.** To allow perfSONAR2 node to store its measurement data, in perfSONAR2 CLI type the following command:

```
sudo /usr/sbin/esmond_manage add_user_ip_address admin 192.168.2.10
```
Step 3. To allow perfSONAR3 node to store its measurement data, in perfSONAR2 CLI type the following command:

```
sudo /usr/sbin/esmond_manage add_user_ip_address admin 192.168.3.10
```
2.4 Running pSConfig MaDDash agent

The role of the pSConfig MaDDash agent is to read pSConfig templates and generate a set of grids to be displayed by MaDDash.

**Step 1.** In perfSONAR2 command line type the command shown below to publish the MaDDash agent at the given URL.

```
sudo psconfig remote add "https://192.168.2.10/psconfig/template.json"
```

**Step 2.** Now, perfSONAR2 node is collecting measurement data specified in the pSConfig template. To proceed, the user will restart Apache Cassandra database typing the command shown below:

```
sudo systemctl restart cassandra
```

**Step 3.** In order to restart MaDDash server, type the following command:

```
sudo systemctl restart maddash-server
```

**Step 4.** To restart MaDDash agent, type the following command:

```
sudo systemctl restart psconfig-maddash-agent
```

**Step 5.** At this point MaDDash web interface is set up and running. To check it, go to the topology and login to the Client host and open the web browser.
Step 7. In order to access to the dashboard, type the following URL https://192.168.2.10/maddash-webui/. If the web server is running, the user will see the MaDDash web user interface.

3 Configuring perfSONAR nodes

At this point, the MaDDash server has been configured. In this section, the user will configure perfSONAR1 and perfSONAR3 nodes in order to run the pSConfig agent published on https://192.168.2.10/psconfig/template.json.

Step 1. On the topology click on perfSONAR1 node and login typing admin as the username and admin as the password.
Step 2. To add a remote pSConfig template on perfSONAR1, type the command shown below. The user will be required to enter the password as admin. Notice that the password will not be displayed while typing it.

```
sudo psconfig remote add --configure-archives
"https://192.168.2.10/psconfig/template.json"
```

Step 3. On the topology, click on perfSONAR3 node and login with typing admin as the username and admin as the password.

Step 4. To add a remote pSConfig template on perfSONAR3 type the command shown below. The user will be required to enter the password as admin. Notice that the password will not be displayed while typing it.

```
sudo psconfig remote add --configure-archives
"https://192.168.2.10/psconfig/template.json"
```

4 Checking the grids

At this point, the MaDDash server is running and collecting data. It takes time to have the measurement data propagated and displayed on the grid. To avoid waiting, the user will access the MaDDash Administrator Web Interface. The administrator web interface allows privileged users to perform special operations on the dashboard. The allowed operations are:

- Re-scheduling a check to run at a certain time.
- Scheduling an event, such as a maintenance window, that may impact check results.
- Viewing and canceling existing events.

The steps that follow describe how to reschedule a check event. This check event will propagate measurement data on the dashboard immediately.
Step 1. On the Client host, click on Dashboards > perfSONAR Lab. The user will see the dashboard, but in this case the measurement data is not displayed because by default it needs time to be propagated and visualized on the dashboard.

Step 2. To display the measurement data on the dashboard immediately, the user will modify the Server Settings to schedule a Check. To proceed, click on Settings > Server Settings.

Step 3. The user will be required to authenticate. To proceed type username admin and password admin.

Step 4. The user will see the Administrator Web Interface. Click on Reschedule Check. This will force the dashboard to show the measurement data as sooner than it would otherwise.
Step 5. Select the grid name as *perfSONAR Lab – Throughput*.

Step 6. To apply the configuration, click on *Schedule*.

Step 7. Select the grid name as *perfSONAR Lab – Loss Test*. 
Step 8. To apply the configuration, click on Schedule.

5 Visualizing the dashboard

Step 1. In order to access the dashboard, type the following URL https://192.168.2.10/maddash-webui/. If the web server is running, the user will see MaDDash web user interface.

Step 2. In the Web User Interface select Dashboard > perfSONAR Lab
Step 3. The user will see the Throughput and Loss Dashboards which are from perfSONAR1, perfSONAR2 and perfSONAR3 nodes. To visualize the results in a timing graph, the user can click on any green square and the browser will open a new tab. On the Throughput dashboard, click on square located on first row and third column to visualize the results of the throughput test between perfSONAR1 and perfSONAR3 nodes.

Step 4. In this graph the results collected since the pScheduler agents started are shown, and the user can visualize the throughput when the source is 192.168.1.10 and the destination is 192.168.3.10. To adjust the time range, select an appropriate value on Report range to see the results with more detail. The throughput graph shows bidirectional throughput, failures and retransmissions on the same plot. Below, the timing graph of the packet loss and latency are displayed.
6 Adding packet loss to interface connecting to network 192.168.2.0/24

In this section, the user will add a 10% packet loss to the router R1 and router R2 using Network Emulator (NETEM) commands. This change will affect the performance of the network. The user will see the effects on the dashboard.

**Step 1.** Open router R2 and enter the username `root` and password `password`. Note that the password will not be displayed while typing it.

```
CentOS Linux 7 (Core)
Kernel 4.19.1-1.el7.elrepo.x86_64 on an x86_64

R2 login: root
Password:
```

**Step 2.** Identify the interfaces which are connected to the network 192.168.2.0/24 on router R2. In router R2 command line, type the command `ifconfig`. This command displays information related to the network interfaces in the local device.
Notice that the interface `ens37` is connected to the network `192.168.2.0/24`.

**Step 3.** In order to add a 10% packet loss, `sudo` in router R2 command line, type the following command:

```
sudo tc qdisc add dev ens37 root netem loss 10%
```

**Step 4.** Wait for at least 2 minutes to get the data propagated to the dashboard, then go to the administrator web interface. In order to access the dashboard, type the following URL `https://192.168.2.10/maddash-webui/`.

**Step 5.** In the Web User Interface select `Settings > Server Settings`. 
Step 6. The user may be required to authenticate. To proceed type username admin and password admin.

Step 7. The user will see the Administrator Web Interface. Click on Reschedule Check. This will force the dashboard to show the measurement data as sooner than it would otherwise.

Step 8. Select the grid name as perfSONAR Lab – Loss Test.
Step 9. To apply the configuration, click on Schedule and wait 1 minute to enter again to MaDDash web interface http://192.168.2.10/maddash-webui.

Step 10. In order to access the dashboard, type the following URL https://192.168.2.10/maddash-webui/. If the web server is running, the user will see MaDDash web user interface.

Step 11. In the Web User Interface select Dashboard > perfSONAR Lab
Step 12. The user will see the Throughput and Loss Dashboards which are from perfSONAR1, perfSONAR2 and perfSONAR3 nodes. Now the user will see that the loss rate between perfSONAR3 and the other nodes are affected.

Step 13. To visualize the results in a timing graph, the user can click on any green square and the browser will open a new tab. On the Loss dashboard, click on the square located on third row and first column to visualize the results of the throughput test between perfSONAR3 and perfSONAR1 nodes.
This graph shows the results collected since the pScheduler agents started, the user can visualize the throughput when the source is 192.168.3.10 and the destination is 192.168.1.10. To adjust the time range, select an appropriate value on Report range to see the results with more detail. Bidirectional throughput, failures and retransmissions are shown on the same plot.

This concludes Lab 8.

References

Lab 9: pSConfig Web Administrator

Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
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Overview

This lab presents how to create and publish pSConfig templates using pSConfig Web Administrator (PWA). This tool is a web-based user interface for perfSONAR administrators to define and publish pSConfig templates, which automates tests executed by test nodes, and provides topology information to various services, such as MadDash.

Objectives

By the end of this lab, the user will:

1. Understand PWA architecture.
2. Create host groups.
3. Define tests specifications.
4. Configure test parameters.
5. Publish pSConfig archive.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.

Figure 1. Lab topology.
Lab settings

The information in Table 1 provides the credentials to access to perfSONAR nodes and the Client host.

Table 1. Credentials to access perfSONAR1, perfSONAR2, perfSONAR3 and Client.

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Lab roadmap

This lab includes the following tasks:

1. Section 1: Introduction.
2. Section 2: Configuring hosts.
3. Section 3: Configuring host groups.
4. Section 4: Setting test specifications.
5. Section 5: Configuring pSConfig output.

1 Introduction

pSConfig Web Administrator (PWA) is a web-based user interface for perfSONAR administrators to define and publish pSConfig configuration files. The output automates tests executed by test nodes, and provides topology information to various services, such as MaDDash.

In addition to providing a user-friendly interface for creating pSConfig file, PWA allows multiple users to collaborate on the configuration of tests specifications, host groups, and configs. Users can be designated super-admins or normal users, depending on how much access they need. It is also possible to allow users to edit some configuration files, but not others.
The architecture shown in the figure 2, assumes the names of the instances as pwa-admin1, pwa-pub1, nginx mongodb, sca-auth and postfix. The user can modify and add more publishers (pwa-pub), to improve publisher performance, if needed.

Figure 2. PWA architecture

PWA is deployed using a series of docker containers some are PWA-specific and provided by the perfSONAR project. In this lab the user will use PWA interface to create a pSConfig file. This file groups perfSONAR nodes to run pScheduler tasks specified by the user. The output is published in order to accessible by all the nodes.

Table 2. Description the containers.

<table>
<thead>
<tr>
<th>Container</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>pwa-admin</td>
<td>PWA UI and API</td>
</tr>
<tr>
<td>pwa-pub</td>
<td>It is used for publishing Configs defined in PWA</td>
</tr>
<tr>
<td>sca-auth</td>
<td>Authentication module used by the GUI</td>
</tr>
<tr>
<td>nginx</td>
<td>Web server, used as a proxy to access the PWA and SCA components</td>
</tr>
<tr>
<td>mongodb</td>
<td>MongoDB, used by pwa-admin and pwa-pub</td>
</tr>
<tr>
<td>postfix</td>
<td>It is used to run a mail server in another docker container</td>
</tr>
</tbody>
</table>

1.1 PWA overview
The pSConfig Web Admin (PWA) is provides the tools for managing pSConfig configuration files. In order to generate and publish a pSConfig file, the user goes through three parts:

- **Host Group**: A group of hosts that are user-selected that all can perform a certain type of test.
- **Test spec**: Test configuration for a test to run; this can include tool and test parameters, scheduling configuration, etc.
- **Config**: In the context of PWA, a Config is an actual test configuration that brings together Host Groups and Testspecs to generate a pSConfig output. The user can use this to configure meshes or other topologies.

## 2 Configuring hosts

In this section, the user will configure the host information. The *Hosts* form displays a list of all perfSONAR nodes and services loaded from configured Lookup Service (sLS) data sources or defined manually (ad-hoc hosts). In this lab, the user will configure ad-hoc hosts. These hosts are perfSONAR1, perfSONAR2 and perfSONAR3. In order to proceed, the user must login the Web User Interface.

### 2.1 Accessing the web user interface

**Step 1.** On the Client host and open web browser.

**Step 2.** On the address bar, type the URL *https://192.168.1.10:8443*.
Step 3. The user will be given an authentication screen. Type `admin` as the Username and `admin` as the Password. Click on Login.

2.2 Adding hosts to the directory

Step 1. On the left part of the web interface, click on Hosts.

Step 2. A form will be displayed. On left side, it is displayed the list with all the public perfSONAR nodes. On the right side, it is shown all the information about the selected node. In this lab, the user will define the configuration of each host. To proceed, click on New host.
Step 3. A form will be shown up on the right side. The fields must be completed with the following information:

- **Hostname**: This label is used to identify the host on the Global Lookup Service (GLS). For this lab, complete this field with the IP addresses of perfSONAR1 (192.168.1.10), perfSONAR2 (192.168.2.10) and perfSONAR3 (192.168.3.10).
- **Site Name**: The name of the site, typically this comes from the GLS. Complete this information typing perfSONAR Lab.
- **Host Description**: This information will be displayed in MaDDash as the row/column labels. Add a brief description about the host.
- **toolkit_url**: This is the URL that links back to the toolkit instance on MaDDash matrix view. Complete this entry with the IP addresses of perfSONAR1, perfSONAR2 and perfSONAR3 respectively.

In the figure below, it is given the configuration of perfSONAR1 node (192.168.1.10). Complete the form with the information shown below, then click on *Create* to save the configuration.
Step 4. Scroll down to add information about the measurement archive (MA). In this lab, perfSONAR2 node is configured to store the measurement data collected by each node. Check the box Use local MA and complete the field Local MA URL with the IP address of perfSONAR2 (192.168.2.10), then click on Update to save the configuration.

Step 5. Click again on New host to add information about perfSONAR2 node (192.168.2.10). Complete the form with the information shown below and click on Create to save the configuration.
Step 6. Scroll down to add information about the measurement archive (MA). In this lab, perfSONAR2 node is configured to store the measurement data collected by each node. Check the box Use local MA, then complete the field Local MA URL with the IP address of perfSONAR2 (192.168.2.10), then click on Update to save the configuration.

Step 7. Click again on New host to add information about perfSONAR3 node (192.168.3.10). Complete the form with the information shown below and click on Create to save the configuration.
Step 8. Scroll down to add information about the measurement archive (MA). In this lab, perfSONAR2 node is configured to store the measurement data collected by each node. Check the box Use local MA, then complete the field Local MA URL with the IP address of perfSONAR2 (192.168.2.10), then click on Update to save the configuration.

3 Configuring host groups

A host group is a logical grouping of perfSONAR nodes. The user may reuse a single host group for multiple configuration files. In this section the user will configure two groups of perfSONAR nodes. Both groups include perfSONAR1, perfSONAR2 and perfSONAR3. The first group is for throughput tests, and the second group is for latency measurements.

3.1 Configuring Throughput Group

Step 1. On the left part of the web interface, click on Host Groups.
Step 2. Click on *New hostgroup*.

Step 3. Write *group1* as the name. This name will be a tag to identify the host group during the test configuration.
Step 4. Click on Service Type. A list will be displayed, select Throughput.

Step 5. On Hosts field, type the IP address of perfSONAR1 node (192.168.1.10) to search for the host configured on the last section. A list will be displayed, select 192.168.1.10 to add the node to the group.
Step 6. Repeat the previous step but now, complete the form with perfSONAR2 (192.168.2.10) and perfSONAR3 (192.168.3.10) IP addresses. Then, click on Create to save the configuration.

3.2 Configuring latency group

Step 1. In order to create a new group, click again on New hostgroup.
Step 2. Write *group2* as the name. This will be a tag to identify the host group during the test configuration.

Step 3. Click on *Service Type*. A list will be displayed, select *Latency*. 
Step 4 As in the previous section, on the *Hosts* field, type the IP address of perfSONAR1 node (192.168.1.10) to search for the host configured on the last section. A list will be displayed, select 192.168.1.10 to add the node to the group. In addition, add perfSONAR2 (192.168.2.10) and perfSONAR3 (192.168.3.10) IP addresses. Then, click on *Create* to save the configuration.

4 Setting test specifications

The test specification is a set of parameters used by a particular test service. Instead of defining such parameters for each test, the user can define and use them in one or more configuration definitions. In this section the user will configure the tests specification for the host groups created on the last section. The first test specification is for throughput test which corresponds to the group1. The second test specification is for the latency test which corresponds to the group2.
4.1 Configuring throughput test specification

**Step 1.** On the left part of the web browser, click on `Testspec`.

![Image of Testspec page with New testspec button highlighted]

**Step 2.** Click on `New testspec`.

![Image of Testspec page with New testspec button highlighted]

**Step 3.** Type `Throughput_Test` in the `Name` field.
Step 4. Click on Service Type, a list will be displayed. Select Throughput in order to configure a throughput test.

Step 5. A parameter box will be displayed after selecting the Service Type. The user will see different set of test parameters. Below each parameter is shown the description of each field. In this lab, the user will use the default configuration. Click on Create to save the configuration.
4.2 Configuring latency test specification

Step 1. Click on New Testspec.

Step 2. Type Latency_Test in the Name field.
**Step 3.** Click on *Service Type*, a list will be displayed. Select *Latency* in order to configure a *Latency* test.

**Step 4.** A parameter box will be displayed after selecting the *Service Type*. The user will see different set of test parameters. Below each parameter is shown the description of each field. Select *twamp* as the *Tool*. 
Step 5. On the *Schedule Type*, select the second option as shown in the figure below.

Step 6. Click on *Create* to save the *Configuration*. 
5 Creating pSConfig output

Once the Host Groups and Test Specs are defined, it is possible now to create pSConfig file by combining those entities. Under the Config section, the user will see a list of Configs defined and their basic information. The links displayed next to the Config name is the actual Config URLs that users can download and subscribe on various perfSONAR services. To edit, or see more detail for each Config, click on the Config name in the Configs column.

Step 1. In order to define a configuration file, click on New config.

Step 2. The Config URL shows the url where the configuration file will be published once the configuration is finished. Complete the entry box typing config1.
Step 3. Type *Configuration_1* as the *Name*.

Step 6. In the description box, add a brief description about the configuration file. This field is optional.
Step 7. The perfSONAR2 node is configured as the Measurement Archive (MA). This node collects the measurement data of all perfSONAR node. Type the IP address of perfSONAR2 in order to configure it as the MA.

5.1 Adding throughput test

Step 1. To proceed, click on Add New Test. A configuration box will be displayed below.
Step 2. Type **Throughput Test** as the **Test Name**.

Step 3. Click on **Service Type**, a list will be displayed, select **Throughput**.
Step 4. Scroll down and click Host Group A, a list will be displayed, select group1. The user will see the IP addresses of the three nodes involved in the test.

Step 5. Click on Testspec, a list will be displayed, select Throughput Test.
Step 6. Click on Create to save the changes.

5.2 Adding latency test

Step 1. To configure the latency test, click again on Add New Test.

Step 2. Type Latency Test as the Test Name.
Step 3. Click of Service Type, select Latency from the list.

Step 4. Scroll down and click Host Group A, a list will be displayed, select group2. The user will see the IP addresses of the three nodes involved in the test.
Step 5. Click of Testspec, a list will be displayed, select Latency_Test.

Step 6. Click on Create to save the configuration.
6 Visualizing the measurement data using pScheduler monitor

At this point, the user has created and published a pSConfig file. This file is accessible from the perfSONAR nodes on the topology. In this section the user will run the pSConfig archive using a pScheduler agent. First, the user will login to perfSONAR2 node and add the configuration file. Secondly, the user will see the test schedule using pScheduler monitor.

**Step 1.** On the topology, click on perfSONAR2 and enter the username **admin** and password **admin**. Note that the password will not be displayed while typing it.

**Step 2.** To run the pSConfig template type the following command:

```bash
sudo psconfig remote add --configure-archives "https://192.168.1.10:8443/pub/config/config1?format=psconfig"
```

The user will be required to enter the password as **admin**.
Step 3. After a minute, type the command `pscheduler monitor`. The user will see the scheduled tasks through pScheduler monitor. Notice that the latency task is running twice each hour, and the throughput test once every four hours.

Step 4. To exit from pScheduler monitor, press `Ctrl+c`.

This concludes Lab 9.

References

PERFSONAR

Lab 10: Configuring pScheduler Limits

Document Version: 06-14-2019

Award 1829698
“CyberTraining CIP: Cyberinfrastructure Expertise on High-throughput Networks for Big Science Data Transfers”
Lab 10: Configuring pScheduler Limits

Overview

This lab introduces the reader to pScheduler limits configuration file. The lab describes the components and the syntax of the configuration file how to configure it in order to apply rules to the tests between perfSONAR nodes in the topology.

Objectives

By the end of this lab, the user will:

1. Understand the concept of pScheduler limits.
3. Verify the impact on pScheduler test after modifying the limits configuration file.

Lab topology

Figure 1 illustrates the topology used for this lab. The topology includes three perfSONAR nodes labeled perfSONAR1, perfSONAR2, perfSONAR3 and a Client host. The perfSONAR nodes run a Linux CentOS 7, and the Client runs a lightweight Linux distribution (Lubuntu). The Client host is used to access perfSONAR graphical user interface.

Lab settings

The information in Table 1 provides the credentials to access to perfSONAR nodes.
### Lab roadmap

This lab includes the following tasks:

1. Section 1: Introduction.
2. Section 2: Sample limits files.
3. Section 3: Applying perfSONAR limits files.

### 1 Introduction

The perfSONAR toolkit provides a detailed framework for network performance measurement across single and multiple network domains\(^1\). An integral component of this solution is the pScheduler tool which is responsible for executing desired network performance tests, also termed as tasks. In particular, pScheduler runs on a server and can either be called using a graphical user interface (GUI), command line input (CLI), or through an application programmer interface (API).

Now perfSONAR users can request a wide range of end-to-end monitoring tests through pScheduler, e.g., such as latency, throughput, loss, etc. However, in general, system and network administrators will want to control various aspects of such user-initiated tests, i.e., as per policy, resource limitations, timing constraints, etc. To accommodate such needs, the perfSONAR framework also provides the ability to control who can run tasks, the types of tasks allowed, and their associated parameter ranges\(^2\). Specifically, this control is implemented through a limits configuration file. Hence this lab focuses on the contents of this file and how to modify it to achieve desired perfSONAR operation. Note that the default limits configuration file in the perfSONAR installation is also available in the toolkit sources\(^3\).

#### 1.1 Overview of perfSONAR limits Files

<table>
<thead>
<tr>
<th>Device</th>
<th>IP Address</th>
<th>Account</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>perfSONAR1</td>
<td>192.168.1.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR2</td>
<td>192.168.2.10</td>
<td>admin</td>
<td>admin</td>
</tr>
<tr>
<td>perfSONAR3</td>
<td>192.168.3.10</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>
The perfSONAR limits configuration file uses JavaScript Object Notation (JSON) notation and is named limits.conf. This file is located in the /etc/pscheduler directory and is read by pScheduler to determine the validity of user task requests. Namely, the pScheduler server checks and applies the latest instance of this file for any new requests and also regularly checks for updates every 15 seconds. Any changes to the limits.conf file are also tracked in a log file, generally located in the /var/log/pscheduler.log file.

The pScheduler limits file plays a very important role in verifying user requests. Otherwise the pScheduler system will simply accept all requests in case of missing and/or improper limits.conf files. As a result, it is important to make sure that the limits file is properly checked for validity before being installed for use by pScheduler. This particular step can also be done through the pScheduler validate-limits command, as applied subsequently. Overall, the limits configuration file contains a single JSON object with several attribute-value pairs given by:

```json
{
   "#: "Skeletal pScheduler limit configuration",
   " identifiers": [ ... ],
   " classifiers": [ ... ],
   " rewrite": [ ... ],
   " limits": [ ... ],
   " applications": [ ... ]
}
```

### 1.2 Identifiers

The first part of the verification process is to identify who is actually requesting the performance measurement task. Hence the identifiers component of the limits file contains identifier objects with several attribute fields including name (string containing a unique identifier name), description (string describing identifier), type (string indicating what method to determine if requester should be identified in a category), data (JSON object containing type object specific data), and invert (optional boolean value to invert identification after evaluation). In particular, the type and its associated data field can support a range of identification strategies, e.g., using hints about the requester, pre-specified classless inter-domain routing (CIDR) IPv4 or IPv6 address lists, downloaded CIDR IP address lists from a website, list of non-bogon IP addresses (to prevent malicious dark web activities), reverse IP address resolution, using jq scripts, or local identifiers.

### 1.3 Classifiers

The second part of the verification process groups the identifiers into broader categories. Hence the classifiers component of the limits files contains classifier objects with several attribute fields including name (string containing a unique identifier name), description (string describing identifier), and identifiers (string array listing identifiers to be part of classifier). In many cases requesters are classified as friendlies or hostiles.
1.4 Rewrite

The third part of the verification process allows the pScheduler system to make changes to requested tasks. These changes are specified in *rewrite* attribute pair and done using jq scripts. In particular, these scripts call a set functions after initial validation but before limit enforcement (Section 2.4). Overall, the *rewrite* attribute can be used to implement a variety of actions/modifications, e.g., enforce tests from specific interfaces, throttle bandwidth rates, enforce minimum durations, etc.

1.5 Limits

The fourth part of the verification process determines whether or not the requested test parameters fall within acceptable ranges. Hence the limits component of the limits file contains limits objects with several attribute fields including *name* (string containing a unique identifier name), *description* (string describing identifier), *clone* (string naming other limit to be used as a starting point), *type* (type of limit to be checked), *data* (JSON object containing *type*-specific data), and *invert* (optional boolean value to invert identification after evaluation). Note that these attributes are very similar to the identifier’s attributes (detailed in Section 2.1). Overall, each limit is individually evaluated and passed or failed. Namely, the *type* field of a limits object can be passed or failed using various strategies, i.e., explicit pass or fail, use of jq scripts to evaluate test parameters, checking of run times or ranges, comparing parameters versus a template of acceptable values, and comparing against a list of acceptable test types.

1.6 Applications

The fifth part of the verification process determines if the test parameters make it permissible, and this check is done by using a set of limit applications. Namely, each classifier is tied to a set of conditions which must be passed. Hence the applications component of the limits files contains *limit application* objects with several attribute fields including *description* (string describing identifier), *classifier* (string naming classifier to which application should be applied), *apply* (array of limit requirements), *invert* (boolean value to invert application result after evaluation), and *stop-on-failure* (boolean value indicating if failure to pass application should prompt further application list evaluations). These application limits are evaluated sequentially, and a task is only run it if passes all of them (or if it passes subsequent application list checks if *stop-on-failure* is false).

2 Sample limits files

Overall, the limits configuration file lets pScheduler exercise a very broad range of control over user task requests. However, providing an exhaustive set of examples to detail every possible verification option is clearly not feasible here. Instead, three sample limit files are used to highlight different components of the pScheduler limits framework. In
particular, these files are located in the /home/admin directory and named as limits-1.conf, limits-2.conf, and limits-3.conf. These files are now discussed further.

**Step 1.** Open perfSONAR2 and enter the username admin and password admin. Note that the password will not be displayed while typing it.

```
CentOS Linux 7 (Core)
Kernel 3.10.0-957.1.3.el7.x86_64 on an x86_64

perfsomar2 login: admin
Password: ...
Welcome to the perfSONAR Toolkit v4.1.5-1.el7
You may create accounts to manage this host through the web interface by running the following as root:

~usr/lib/perfsonar/scripts/nptoolkit-configure.py
The web interface should be available at:
https://(host address)/toolkit
'shrt-cli status' timed out
```

**Step 2.** On the perfSONAR2 host go to the directory containing the sample limits files by directly typing the command:

```
cd /home/admin
```

**Step 3.** To ensure the correct directory, enter the `ls` command to verify that the three sample limits files are listed:

```
ls
```

**Step 4.** Now open the first limits file, limits-1.conf, in order to inspect its contents. Type the following command:

```
nano limits-1.conf
```

This JSON file contains an identifiers component (object array) with a several objects, one of which is an object with the name attribute defined as certain-group. This particular object is subsequently used to identify the subnet which cannot run tasks on perfSONAR2.
Additionally, the limits-1.conf file also contains a classifiers component (object array) with an object whose name attribute is defined as hostiles. This particular object also has an identifiers attribute defined as (the above-defined) “certain-group”, i.e., to prevent identifiers in this group from running tasks on perfSONAR2.

```
"classifiers": {
  "name": "hostiles",
  "description": "Identifiers we find unfriendly",
  "identifiers": ["certain-group"]
}
```

**Step 5.** To close the current file type Ctrl+x. Next, open the second limits file, limits-2.conf, by typing the following command:

```
nano limits-2.conf
```

This file contains an identifiers component (object array) with two objects with their name attributes set to perfSONAR1 and perfSONAR2, respectively. Specifically, both of these objects define their type attributes as ip-cidr-list and related data attributes as a cidrs object array (containing two IP addresses, i.e., 192.168.1.10 and 192.168.3.10).

```
"identifiers": [
  {
    "name": "perfSONAR1",
    "description": "Requests coming from perfSONAR1",
    "type": "ip-cidr-list",
    "data": {
      "cidrs": ["192.168.1.10"]
    }
  },
  {
    "name": "perfSONAR3",
    "description": "Requests coming from perfSONAR3",
    "type": "ip-cidr-list",
    "data": {
      "cidrs": ["192.168.3.10"]
    }
  }
]
```

Using the above, the limits-2.conf file also includes a classifier component (object array) with two objects with their name attributes set to friendlies and hostiles, respectively. Specifically, the first object contains an identifiers attribute listing IP address(es) that can send requests to perfSONAR2 (in this case only perfSONAR3 is allowed). Meanwhile, the second object contains an identifiers attribute listing IP address(es) who cannot send requests to perfSONAR2 (in this case only perfSONAR1 is not allowed).
Step 6. Finally, exit the nano editor as before by typing `Ctrl+x`. Then open the third limits file, `limits-3.conf`, by typing the following command:

```
nano limits-3.conf
```

This file contains a limits component (object array) with a single object with the name attribute set to `throughput-default-time`. Furthermore, the data attribute here defines another object with a limit attribute (object) specifying the upper and lower run time durations for throughput tasks, i.e., 5 seconds and 15 seconds, respectively.

```
"name": "throughput-default-time",
"description": "Throughput time limits",
"type": "test",
"data": {
  "test": "throughput",
  "limit": {
    "duration": {
      "range": {
        "lower": "PT5S",
        "upper": "PT15S"
      }
    }
  }
}
```

Step 7. Exit the nano editor as before by typing `Ctrl+x`.

### 3 Applying perfSONAR limits files

The three sample limits files detailed in Section 3 are now used to test and verify the capabilities of pScheduler limits framework.

#### 3.1 Testing the first limits configuration file (limits-1.conf)

Step 1. In perfSONAR2, go to the local file directory containing the three sample limit configuration files typing the following command:
Step 2. Type the command `ls` to ensure that all three template files are listed in the directory.

Step 3. The pScheduler limits file is located in the local directory `/etc/pscheduler` and called `limits.conf`, i.e., `/etc/pscheduler/limits.conf`. Now pScheduler can only recognize a limits file with this particular name. Hence in order to test the first limit configuration file, `limits-1.conf` must be copied from `/home/admin` and renamed into the `/etc/pscheduler` directory. To do this, type the command in the `/home/admin` directory, i.e., to create a renamed copy:

```
cp limits-1.conf limits.conf
```

Step 4. To verify that the copy succeeded, type `ls`.

Step 5. Next, move the copied `limits.conf` file to the pScheduler directory `/etc/pscheduler`. To do this, type the command shown below and enter the password `admin`:

```
sudo mv limits.conf /etc/pscheduler
```

Step 6. To ensure the file was properly moved, type `ls` to make sure that the `limits.conf` is no longer in the current `/home/admin` directory:

Step 7. Now return to the main directory by entering the following command:

```
cd ~
```
Step 8. Since the pScheduler limits.conf file has just been changed, it is important to verify that it is still valid by using the pScheduler validate-limits command. To verify this, type the command shown below and note the output. If the configuration is valid, the output should display Limit configuration is valid.

```
pscheduler validate-limits
```

Step 9. As detailed in Section 3, the limits-1.conf file is designed to block perfSONAR1 and perfSONAR3 from running tasks on perfSONAR2. However, these limits should not prevent perfSONAR1 from running a task on perfSONAR3 or vice versa. In order to test these restrictions, try to schedule a throughput task to perfSONAR2 by typing command shown below. This task will fail.

```
pscheduler task throughput --source 192.168.1.10 --dest 192.168.2.10
```

Step 10. Next, verify that the rule also applies to perfSONAR3 by typing the command shown below. This task request will also fail.

```
pscheduler task throughput --source 192.168.3.10 --dest 192.168.2.10
```
Step 11. Finally, verify that perfSONAR1 and perfSONAR3 can still schedule tasks between themselves. To verify this, type the command shown below. This task request should succeed and display throughput results.

```bash
pscheduler task throughput --source 192.168.3.10 --dest 192.168.1.10
```

### 3.2 Testing second limits configuration file (limits-2.conf)

**Step 1.** In perfSONAR2, go to the local file directory containing the 3 sample limit configuration files. Namely, type the command shown below.

```bash
cd /home/admin
```
Step 2. Copy the contents of limits-2.conf into a file titled limits.conf by entering the following command:

```
cp limits-2.conf limits.conf
```

Step 3. Move this new limit file into the /etc/pscheduler directory by entering the command. Enter the password admin when prompted.

```
sudo mv limits.conf /etc/pscheduler
```

Step 4. Now return to the main directory again by entering the following command:

```
cd ~
```

Step 5. Check the validity of the limits file once again by using the command shown below. The output should read limit configuration is valid.

```
pscheduler validate-limits
```

Step 6. As detailed in Section 3 the limits-2.conf file is designed to block any requests from perfSONAR1 but allow requests from perfSONAR3. In order to test these restrictions, try to schedule a throughput task to perfSONAR2 by typing the command shown below. This task request should fail based upon the specified limits.

```
pscheduler task throughput --source 192.168.1.10 --dest 192.168.2.10
```
Step 7. Next, verify that perfSONAR3 is still able to run tasks to perfSONAR2. Specifically, type the command shown below. This task request should succeed and display throughput results.

```
pscheduler task throughput --source 192.168.3.10 --dest 192.168.2.10
```

3.3 Testing third limits configuration file (limits-3.conf)

Step 1. In perfSONAR2, go to the local file directory containing the 3 sample limit configuration files. Type the following command.

```
cd /home/admin
```
Step 2. Copy the contents of limits-3.conf into a file named limits.conf by entering the following command.

```
cp limits-3.conf limits.conf
```

Step 3. Move this new limit file into the /etc/pscheduler directory by entering the command shown below. Enter the password `admin` when prompted.

```
sudo mv limits.conf /etc/pscheduler
```

Step 4. Now return to the main directory again by entering the following command:

```
cd ~
```

Step 5. Check the validity of the limits file once again by using the command shown below. The output should read `Limit configuration is valid`.

```
pscheduler validate-limits
```

Step 6. As detailed in Section 3, the limits-3.conf file is designed to restrict the maximum duration of throughput tasks to 15 seconds. Hence any request to schedule such a task for 20 seconds should fail. In order to test this restriction, try to schedule a 20 second throughput task to perfSONAR2 by typing in the command shown below. This task request should fail based upon the specified duration limit. In perfSONAR1, type the following command:

```
pscheduler task throughput --source 192.168.1.10 --dest 192.168.2.10 -t 20
```
Step 7. Meanwhile, a request to schedule throughput tasks with durations of 15 seconds or less should be successful. In order to test this bound, try to schedule a 15 second throughput task to perfSONAR2 by typing in the command shown below. This task request should succeed and display throughput results.

```
pscheduler task throughput --source 192.168.1.10 --dest 192.168.2.10 -t 15
```

This concludes Lab 10.
References