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Photon OS 3.0

Photon OS Documentation

The Photon OS Documentation provides information about how to install, configure, and use VMware Photon OS™.

Product version: 3.0

This documentation applies to all 3.0.x releases.

Intended Audiences

This information is intended for Photon OS developers.

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Photon OS Administration Guide

Introduction

This guide describes the fundamentals of administering Photon OS, the open-source minimalist Linux operating system from VMware that is optimized for cloud computing platforms, VMware vSphere deployments, and applications native to the cloud.

The guide covers the basics of managing packages, controlling services with systemd, setting up networking, initializing Photon OS with cloud-init, running Docker containers, and working with other technologies, such as Kubernetes. The guide also includes a section to get you started using Photon OS quickly and easily.

Photon OS is a Linux container host optimized for vSphere and cloud-computing platforms such as Amazon Elastic Compute and Google Compute Engine. As a lightweight and extensible operating system, Photon OS works with the most common container formats, including Docker, Rocket, and Garden. Photon OS includes a yum-compatible, package-based lifecycle management system called tdnf.

When used with development tools and environments such as VMware Fusion, VMware Workstation, HashiCorp (Vagrant and Atlas), and production runtime environments (vSphere, vCloud Air), Photon OS lets you seamlessly migrate container-based applications from development to production. With a small footprint and fast boot and run times, Photon OS is optimized for cloud computing and cloud applications.

There are two versions of Photon OS: a minimal version and a full version.

The minimal version of Photon OS is lightweight container host runtime environment best suited to managing and hosting containers. The minimal version contains just enough packaging and functionality to manage and modify containers while remaining a fast runtime environment. The minimal version is ready to work with appliances.

The full version of Photon OS includes additional packages to help you customize the system and create containerized applications. For running containers, the full version is excessive. The full version is targeted at helping you create, develop, test, and package an application that runs a container.

Two characteristics of Photon OS stand out: It manages services with systemd and it manages packages with an open source, yum-compatible package manager called tdnf, for Tiny DNF.

By using systemd, Photon OS adopts a contemporary Linux standard to manage system services. Photon OS bootstraps the user space and concurrently starts services with systemd. The systemctl utility controls services on Photon OS. For example, instead of running the /etc/init.d/ssh script to stop and start the OpenSSH server on a init.d-based Linux system, you run the following systemctl commands on Photon OS:

```
systemctl stop sshd
```

```
systemctl start sshd
```

Tdnf keeps the operating system as small as possible while preserving yum's robust package-management capabilities. On Photon OS, tdnf is the default package manager for installing new packages. It is a C implementation of DNF package manager.

Examining the Packages in the SPECS Directory on Github

The SPECS directory of the GitHub website for Photon OS contains all the packages that can appear in Photon OS repositories:

https://github.com/vmware/photon/tree/master/SPECS

To see the version of a package, in the SPECS directory, click the name of the subdirectory of the package that you want to examine, and then click the `.spec` filename in the subdirectory. For example, the version of OpenJDK, which contains the openjre package that installs the Java class library and the javac Java compiler, looks like this:

```
%define _use_internal_dependency_generator 0
Summary:    OpenJDK
Name:        openjdk
Version:    1.8.0.72
Release:    1%{?dist}
License:    GNU GPL
URL:        https://openjdk.java.net
Group:        Development/Tools
Vendor:        VMware, Inc.
Distribution:   Photon
AutoReqProv:     no
Source0:    http://anduin.linuxfromscratch.org/files/BLFS/OpenJDK-%{version}/OpenJDK-%{version}-
x86_64-bin.tar.xz
%define sha1 OpenJDK=0c705d7b13f4e22611d2da654209f469a6297f26
%description
The OpenJDK package installs java class library and javac java compiler.

%package    -n openjre
Summary:    Jave runtime environment
AutoReqProv:     no
%description    -n openjre
It contains the libraries files for Java runtime environment
#%global __requires_exclude ^libgif.*$
#%filter_from_requires ^libgif.*$...
...
```

Looking at the Differences Between the Minimal and the Full Version

The minimal version of Photon OS contains about 50 packages. As it is installed, the number of packages increases to nearly 100 to fulfill dependencies. The full version of Photon OS adds several hundred packages to those in the minimal version to deliver a more fully featured operating system.

You can view a list of the packages that appear in the minimal version by examining the following file:

https://github.com/vmware/photon/blob/master/common/data/packages_minimal.json

You can view a list of the packages that appear in the full version by examining the following file:

https://github.com/vmware/photon/blob/master/common/data/packages_full.json

If the minimal or the full version of Photon OS does not contain a package that you want, you can of course install it with tdnf, which appears in both the minimal and full versions of Photon OS by default. In the full version of Photon OS, you can also install packages by using yum.

One notable difference between the two versions of Photon OS pertains to OpenJDK, the package that contains not only the Java runtime environment (openjre) but also the Java compiler (javac). The OpenJDK package appears in the full but not the minimal version of Photon OS. To add support for Java programs to the minimal version of Photon OS, install the Java packages and their dependencies:

```
tdnf install openjdk
Installing:
openjre     x86_64    1.8.0.92-1.ph1    95.09 M
openjdk     x86_64    1.8.0.92-1.ph1    37.63 M
```

NOTE: openjdk and openjre are available as openjdk8 and openjre8 in Photon OS 2.0

Alater section covers tdnf.

The Root Account and the `sudo` and `su` Commands

This guide assumes that you are logged in to Photon OS with the root account and running commands as root. The sudo program comes with the full version of Photon OS. On the minimal version, you must install sudo with tdnf if you want to use it. As an alternative to installing sudo on the minimal version, you can switch users as needed with the `su` command to run commands that require root privileges.

Getting Started with Photon OS 2.0

NOTE: This section applies to Photon OS w.0 only.

To get started with Photon OS 2.0, refer to the installation instructions for your target environment:

- Running Photon OS on VMware vSphere
- Running Photon OS on VMware Fusion
- Running Photon OS on VMware Workstation
- Running Photon OS on Amazon EC2
- Running Photon OS on Google Compute Engine
- Running Photon OS on Microsoft Azure

Note: If you want to upgrade an existing Photon 1.0 VM, refer to the instructions in Upgrading to Photon OS 2.0.

Quick Start for Photon OS 1.0

NOTE: This section applies to Photon OS 1.0 only.

This section helps you get Photon OS up and running quickly and easily. There are several ways to deploy Photon OS for free within a matter of minutes:

- Obtain the ISO from Bintray and use it to create a virtual machine running Photon OS.
- Install the OVA for the minimal version of Photon OS in VMware vSphere.
- Rapidly deploy the OVA for the minimal version of Photon OS in VMware Workstation 12 Pro.

Obtaining the ISO from Bintray and Creating a Photon OS VM in VMware Workstation

The full version of Photon OS installs from an ISO in VMware Workstation and other hypervisors in a matter of minutes. Photon OS is a free download from the Bintray web site.

This section demonstrates how to create a virtual machine running Photon OS in VMware Workstation 12 Pro. If you are using a different hypervisor, the example set by this section should help you install it in your system. For instructions on how to install Photon OS from an ISO in VMware vSphere, see Installing Photon OS on VMware vSphere from an ISO Image.

1. Go to the following Bintray URL and download the ISO for the general availability release of Photon OS:

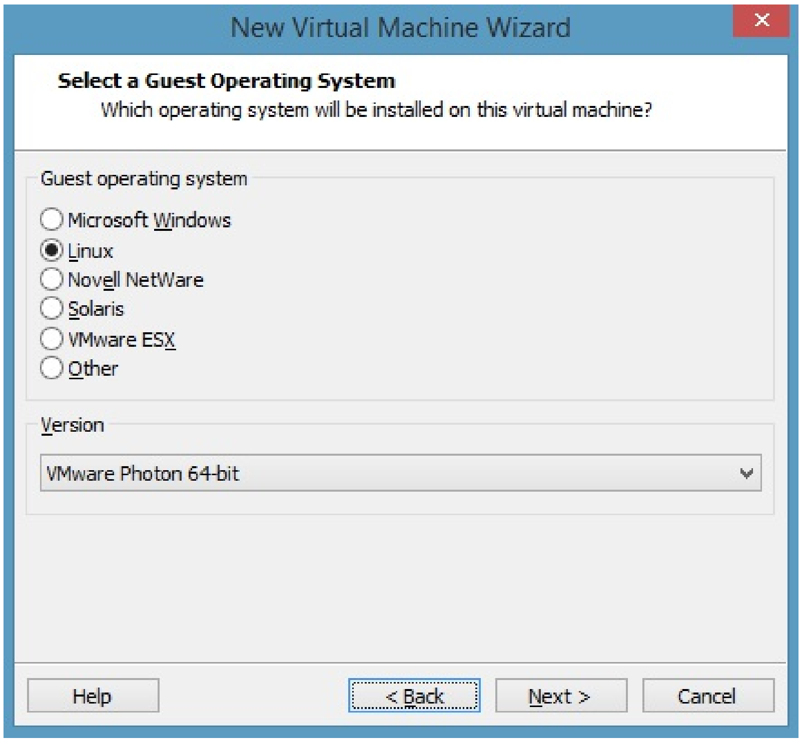
   https://bintray.com/vmware/photon/iso/view

2. In VMware Workstation, type Ctrl+N to create a new virtual machine.

3. In the New Virtual Machine Wizard, select `Typical`, and then click `Next`.

4. Select `Installer disk image file (iso)`, click `Browse` to locate the Photon OS ISO that you downloaded from Bintray, and then click `Next`.

5. For the guest operating system, select `Linux`. From the `Version` drop-down menu, select `VMware Photon 64-bit`. If you have an older version of VMware Workstation and Photon does not appear in the list, select `Other Linux 3.x kernel 64-bit`.



6. Click `Next` through the remaining dialog boxes of the wizard, either accepting the default settings, which is recommended, or making the changes that you want, and then click `Finish`.

7. Power on the virtual machine and, in the Workstation window containing Photon, press Enter to start the installation.

8. During disk setup, the installer might ask you to confirm that this will erase the disk. If so, accept the default value of `yes` by hitting your Enter key.
9. Select the installation that you want. For this example, choose `Photon Full` by using the tab key to move to Photon Full and then hitting the space bar to select it. Press Enter to install it.
10. Either accept the default hostname that Photon provides or type the name that you want. Press Enter to continue.
11. Type the root password. Photon OS requires the root password to be a complex string containing no common words or names.

The installation typically completes in about 150 seconds for the full version and in less than 30 seconds for the minimal version. After the installation finishes, boot the system and log in as root with your root password.

To connect to Photon OS by SSH, see the section on permitting root login with SSH below.

You can also build an ISO containing Photon OS from its source code on GitHub by following the instructions in the document on building Photon OS.

Installing the OVA for the Minimal Version in vSphere

You can download the OVA for the minimal version of Photon OS from Bintray and deploy it in vSphere in a matter of seconds. Here's how:

Download the OVA for the minimal version of Photon OS from the following URL:

```
https://bintray.com/vmware/photon/ova
```

To install the OVA in vSphere, on the `File` menu, click `Deploy OVF Template`, and then click `Browse` to locate the image that you downloaded. Move through the `Deploy OVF Template` dialog boxes by clicking `Next` to accept the default settings, and then click `Finish`.

In vSphere Client, turn on the power of the Photon OS virtual machine and open a console to it.

The default password for the root account is `changeme`, and you must change it when you first login. For security, Photon OS forbids common dictionary words for the root password.

There are other options for installing Photon OS in vSphere, such as building an ISO from the source code. For more information about the versions of Photon and their installation options, see Running Photon OS on vSphere.

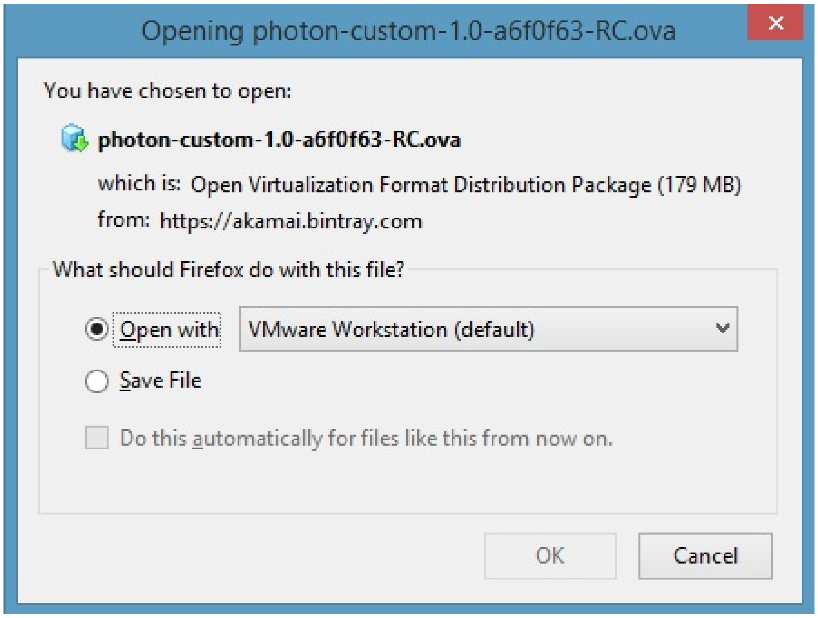
Rapidly Deploying the Photon OS OVA in VMware Workstation 12 Pro

Here's how to rapidly deploy the OVA for Photon in VMware Workstation 12 Pro by using an up-to-date version of Firefox. The procedure in other browsers or another version of Workstation might be different.

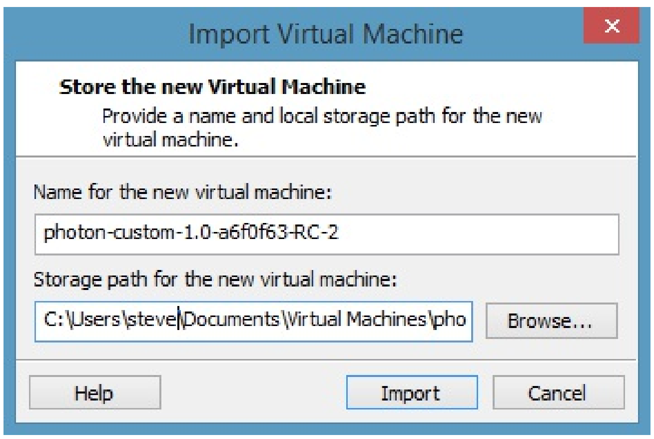
In Firefox, download the OVA for the minimal version of Photon OS from this URL:

```
https://bintray.com/vmware/photon/ova
```

In the download dialog box, select `Open with VMware Workstation (default)`, like this:



In the Workstation Import dialog box, click Import.



Workstation creates a virtual machine from the Photon OS OVA template in a few seconds. In Workstation, power on the virtual machine and log in as root with the initial password of `changeme`.

Photon OS then prompts you to change the root password.

Root Password Rules

When you first log on a new Photon OS machine, you must set the root password to a complex string containing no common words or names. Photon OS rejects a root password that contains simplistic patterns, common words, or words derived from the name of your account. The rules apply only to the root password, not other user and group accounts.

Permitting Root Login with SSH

The full version of Photon OS prevents root login with SSH by default. To permit root login over SSH, open `/etc/ssh/sshd_config` with the vim text editor and set `PermitRootLogin` to `yes`.

Vim is the default text editor available in both the full and minimal versions of Photon OS. (Nano is also in the full version.) After you modify the SSH daemon's configuration file, you must restart the sshd daemon for the changes to take effect. Example:

```
vim /etc/ssh/sshd_config

# override default of no subsystems
```

```
Subsystem       sftp    /usr/libexec/sftp-server

# Example of overriding settings on a per-user basis
#Match User anoncvs
#       X11Forwarding no
#       AllowTcpForwarding no
#       PermitTTY no
#       ForceCommand cvs server
PermitRootLogin yes
UsePAM yes
```

Save your changes in vim and then restart the sshd daemon:

```
systemctl restart sshd
```

You can then connect to the Photon OS machine with the root account over SSH:

```
steve@ubuntu:~$ ssh root@198.51.100.131
```

PXE Boot

Photon OS works with the Preboot Execution Environment, or PXE, to boot by retrieving software from a PXE server over a network connection. For instructions on how to set Photon OS to boot from a PXE server, see Network PXE Boot.

Kickstart

Photon OS supports kickstart for unattended installations through a CD-ROM or an HTTP server. On Photon OS, kickstart can set the hostname, password, run post-installation scripts, and add public keys for SSH. See Kickstart Support.

Checking the Version and Build Number

To check the version and build number of Photon OS, concatenate `/etc/photon-release`. Example:

```
cat /etc/photon-release
VMware Photon Linux 1.0
PHOTON_BUILD_NUMBER=a6f0f63
```

The build number in the results maps to the commit number on the VMware Photon OS GitHub commits page.

Tiny DNF for Package Management

On Photon OS, Tiny DNF, for Tiny Dandified Yum, is the default package manager for installing new packages. It is a C implementation of DNF package manager. The standard syntax for `tdnf` commands is the same as that for DNF:

```
tdnf [options] <command> [<arguments>...]
```

You can view its help information like this:

```
tdnf --help
tdnf -h
```

Photon OS 1.0 only: In the minimal version of Photon OS, tdnf serves as the sole package manager to streamline the operating system. The full version of Photon OS includes yum, a common utility that checks for, downloads, and automatically installs RPM packages. On the minimal version of Photon OS, you can install yum by using tdnf if you are unconcerned with the size of the operating system: `tdnf install yum`

Configuration Files and Repositories

The main configuration files reside in /etc/tdnf/tdnf.conf. The configuration file looks like this:

```
cat /etc/tdnf/tdnf.conf
[main]
gpgcheck=1
installonly_limit=3
clean_requirements_on_remove=true
repodir=/etc/yum.repos.d
cachedir=/var/cache/tdnf
```

The cache files for data and metadata reside in /var/cache/tdnf.

The repositories appear in /etc/yum.repos.d/ with `.repo` file extensions:

```
ls /etc/yum.repos.d/
lightwave.repo
photon-extras.repo
photon-iso.repo
photon-updates.repo
photon.repo
```

Note: Photon OS 1.0 (only) also includes the lightwave.repo.

You can list the the repositories by using the `tdnf repolist` command. Tdnf filters the results with `enabled`, `disabled`, and `all`. Running the command without specifying an argument returns the enabled repositories:

```
tdnf repolist
repo id            repo name                               status
photon-updates     VMware Photon Linux 2.0(x86_64)Updates  enabled
photon-extras      VMware Photon Extras 2.0(x86_64)        enabled
photon             VMware Photon Linux 2.0(x86_64)         enabled
```

Note: Photon OS 1.0 (only) also includes the lightwave repository.

The photon-iso.repo, however, does not appear in the list of repositories because it is unavailable on the virtual machine from which these examples are taken. Photon-iso.repo is the default repository; it points to /media/cdrom. The contents of photon-iso.repo look like this:

```
cat /etc/yum.repos.d/photon-iso.repo
[photon-iso]
name=VMWare Photon Linux 2.0(x86_64)
baseurl=file:///mnt/cdrom/RPMS
gpgkey=file:///etc/pki/rpm-gpg/VMWARE-RPM-GPG-KEY
gpgcheck=1
enabled=0
skip_if_unavailable=True
```

The local cache is populated with data from the repository:

```
ls -l /var/cache/tdnf/photon
total 8
drwxr-xr-x 2 root root 4096 May 18 22:52 repodata
d-wxr----t 3 root root 4096 May  3 22:51 rpms
```

You can clear the cache to help troubleshoot a problem, but keep in mind that doing so might slow the performance of tdnf until the cache becomes repopulated with data. Here is how to clear the cache:

```
tdnf clean all
Cleaning repos: photon photon-extras photon-updates lightwave
```

```
Cleaning up everything
```

The command purges the repository data from the cache:

```
ls -l /var/cache/tdnf/photon
total 4
d-wxr----t 3 root root 4096 May  3 22:51 rpms
```

Options for Commands

You can add the following options to `tdnf` commands. If the option to override a configuration is unavailable in a command, consider adding it to the configuration file, /etc/tdnf/tdnf.conf.

```
OPTION                     DESCRIPTION
--allowerasing             Allow erasing of installed packages to resolve dependencies
--assumeno                 Answer no for all questions
--best                     Try the best available package versions in transactions
--debugsolver              Dump data aiding in dependency solver debugging info.
--disablerepo=<repoid>     Disable specific repositories by an id or a glob.
--enablerepo=<repoid>      Enable specific repositories
-h, --help                 Display help
--refresh                  Set metadata as expired before running command
--nogpgcheck               Skip gpg check on packages
--rpmverbosity=<debug level name>
                           Debug level for rpm
--version                  Print version and exit
-y, --assumeyes            Answer yes to all questions
-q, --quiet                Quiet operation
```

Here is an example that adds the short form of the `assumeyes` option to the install command:

```
tdnf -y install gcc
Upgrading:
gcc     x86_64    5.3.0-1.ph1     91.35 M
```

Commands

check: Checks for problems in installed and available packages for all enabled repositories. Command has no arguments. You can use `--enablerepo` and `--disablerepo` to control the repos used. Supported in Photon OS 2.0 (only).

check-local: This command resolves dependencies by using the local RPMs to help check RPMs for quality assurance before publishing them. To check RPMs with this command, you must create a local directory and place your RPMs in it. The command, which includes no options, takes the path to the local directory containing the RPMs as its argument. The command does not, however, recursively parse directories; it checks the RPMs only in the directory that you specify. For example, after creating a directory named `/tmp/myrpms` and placing your RPMs in it, you can run the following command to check them:

```
tdnf check-local /tmp/myrpms
Checking all packages from: /tmp/myrpms
Found 10 packages
Check completed without issues
```

check-update: This command checks for updates to packages. It takes no arguments. The `tdnf list updates` command performs the same function. Here is an example of the `check update` command:

```
tdnf check-update
rpm-devel.x86_64     4.11.2-8.ph1     photon
yum.noarch          3.4.3-3.ph1     photon
```

clean: This command cleans up temporary files, data, and metadata. It takes the argument `all`. Example:

```
tdnf clean all
Cleaning repos: photon photon-extras photon-updates lightwave
Cleaning up everything
```

distro-sync: This command synchronizes the machine's RPMs with the latest version of all the packages in the repository. Abridged example:

```
tdnf distro-sync

Upgrading:
zookeeper                              x86_64        3.4.8-2.ph1               3.38 M
yum                                    noarch        3.4.3-3.ph1               4.18 M

Total installed size: 113.01 M

Reinstalling:
zlib-devel                             x86_64        1.2.8-2.ph1             244.25 k
zlib                                   x86_64        1.2.8-2.ph1             103.93 k
yum-metadata-parser                    x86_64        1.1.4-1.ph1              57.10 k

Total installed size: 1.75 G

Obsoleting:
tftp                                   x86_64        5.2-3.ph1                32.99 k

Total installed size: 32.99 k
Is this ok [y/N]:
```

downgrade: This command downgrades the package that you specify as an argument to the next lower package version. Example:

```
tdnf downgrade boost
Downgrading:
boost                                  x86_64        1.56.0-2.ph1              8.20 M
Total installed size: 8.20 M
Is this ok [y/N]:y
Downloading:
boost                                   2591470    100%
Testing transaction
Running transaction
Complete!
```

To downgrade to a version lower than the next one, you must specify it by name, epoch, version, and release, all properly hyphenated. Example:

```
tdnf downgrade boost-1.56.0-2.ph1
```

erase: This command removes the package that you specify as an argument. Example:

```
tdnf erase vim
Removing:
vim                                    x86_64        7.4-4.ph1                 1.94 M
Total installed size: 1.94 M
Is this ok [y/N]:
```

You can also erase multiple packages:

```
tdnf erase docker cloud-init
```

info: This command displays information about packages. It can take the name of a package. Or it can take one of the following arguments: all, available, installed, extras, obsoletes, recent, upgrades. Examples:

```
tdnf info ruby
tdnf info obsoletes
tdnf info upgrades
```

install: This command takes the name of a package as its argument. It then installs the package and its dependencies. Examples:

```
tdnf install kubernetes
```

You can also install multiple packages:

```
tdnf install python-curses lsof audit gettext chkconfig ntsysv bindutils
     wget gawk irqbalance lvm2 cifs-utils c-ares distrib-compat
```

list: This command lists the packages of the package that you specify as the argument. The command can take one of the following arguments: all, available, installed, extras, obsoletes, recent, upgrades.

```
tdnf list updates
```

The list of packages might be long. To more easily view it, you can concatenate it into a text file, and then open the text file in a text editor:

```
tdnf list all > pkgs.txt
vi pkgs.txt
```

makecache: This command updates the cached binary metadata for all known repositories. Example:

```
tdnf makecache
Refreshing metadata for: 'VMware Lightwave 1.0(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)Updates'
Refreshing metadata for: 'VMware Photon Extras 1.0(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)'
Metadata cache created.
```

provides: This command finds the packages that provide the package that you supply as an argument. Examples:

```
tdnf provides docker
docker-1.11.0-1.ph1.x86_64 : Docker
Repo     : photon
docker-1.11.0-1.ph1.x86_64 : Docker
Repo     : @System
```

reinstall: This command reinstalls the packages that you specify. If some packages are unavailable or not installed, the command fails. Example:

```
tdnf reinstall docker kubernetes

Reinstalling:
kubernetes                          x86_64       1.1.8-1.ph1            152.95 M
docker                              x86_64       1.11.0-1.ph1            57.20 M

Total installed size: 210.15 M
```

remove: This command removes a package. When removing a package, tdnf by default also removes dependencies that are no longer used if they were was installed by tdnf as a dependency without being explicitly requested by a user. You can modify the dependency removal by changing the `clean_requirements_on_remove` option in /etc/tdnf/tdnf.conf to `false`.

```
tdnf remove packagename
```

search: This command searches for the attributes of packages. The argument can be the names of packages, as this example testifies:

```
tdnf search docker kubernetes
docker : Docker
docker : Docker
docker-debuginfo : Debug information for package docker
docker : Docker
kubernetes : Kubernetes cluster management
kubernetes : Kubernetes cluster management
kubernetes-debuginfo : Debug information for package kubernetes
kubernetes : Kubernetes cluster management
```

The argument of the search command can also be a keyword or a combination of keywords and packages:

```
tdnf search terminal bash
rubygem-terminal-table : Simple, feature rich ascii table generation library
ncurses : Libraries for terminal handling of character screens
mingetty : A minimal getty program for virtual terminals
ncurses : Libraries for terminal handling of character screens
ncurses : Libraries for terminal handling of character screens
bash : Bourne-Again SHell
bash-lang : Additional language files for bash
bash-lang : Additional language files for bash
bash : Bourne-Again SHell
bash-debuginfo : Debug information for package bash
bash : Bourne-Again SHell
bash-lang : Additional language files for bash
```

upgrade: This command upgrades the package or packages that you specify to an available higher version that tdnf can resolve. If the package is already the latest version, the command returns `Nothing to do`. Example:

```
tdnf upgrade boost

Upgrading:
boost                                 x86_64        1.60.0-1.ph1              8.11 M

Total installed size: 8.11 M
Is this ok [y/N]:y

Downloading:
boost                                  2785950    100%
Testing transaction
Running transaction

Complete!
```

You can also run the `upgrade` command with the `refresh` option to update the cached metadata with the latest information from the repositories. The following example refreshes the metadata and then checks for a new version of tdnf but does not find one, so tdnf takes no action:

```
tdnf upgrade tdnf --refresh
Refreshing metadata for: 'VMware Lightwave 1.0(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)Updates'
Refreshing metadata for: 'VMware Photon Extras 1.0(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)'
```

```
Nothing to do.
```

upgrade-to: This command upgrades to the version of the package that you specify. Example:

```
tdnf upgrade-to ruby2.3
```

The commands and options of tdnf are, at present, a subset of those of dnf. For more help with `tdnf` commands, see the DNF documentation.

Adding a New Repository

With Photon OS, you can add a new repository from which tdnf installs packages. To do so, you create a repository configuration file with a `.repo` extension and place it in /etc/yum.repos.d. The repository can be on either the Internet or a local server containing your in-house applications.

Be careful if you add a repository that's on the Internet: Installing packages from untrusted or unverified sources might put the security, stability, or compatibility of your system at risk. It might also make your system harder to maintain.

On Photon OS, the existing repositories appear in /etc/yum.repos.d:

```
ls /etc/yum.repos.d/
lightwave.repo
photon-extras.repo
photon-iso.repo
photon-updates.repo
photon.repo
```

Looking at one of the `.repo` files reveals the format and information that a new repository configuration file should contain:

```
cat /etc/yum.repos.d/lightwave.repo
[lightwave]
name=VMware Lightwave 1.0(x86_64)
baseurl=https://dl.bintray.com/vmware/lightwave
gpgkey=file:///etc/pki/rpm-gpg/VMWARE-RPM-GPG-KEY
gpgcheck=1
enabled=1
skip_if_unavailable=True
```

The minimal information needed to establish a repository is an ID and human-readable name of the repository and its base URL. The ID, which appears in square brackets, must be one word that is unique amoung the system's repositories; in the example above, it is `[lightwave]`.

The `baseurl` is a URL for the repository's repodata directory. For a repository on a local server that can be accessed directly or mounted as a file system, the base URL can be a file referenced by `file://`. Example:

```
baseurl=file:///server/repo/
```

The `gpgcheck` setting specifies whether to check the GPG signature. The `gpgkey` setting furnishes the URL for the repository's ASCII-armored GPG key file. Tdnf uses the GPG key to verify a package if its key has not been imported into the RPM database.

The `enabled` setting tells tdnf whether to poll the repository. If `enabled` is set to `1`, tdnf polls it; if it is set to `0`, tdnf ignores it.

The `skip_if_unavailable` setting instructs tdnf to continue running if the repository goes offline.

Other options and variables can appear in the repository file. The variables that go with some of the options can reduce future changes to the repository configuration files. There are variables to replace the value of the version of the package and to replace the base architecture. For more information, see the man page for yum.conf on the full version of Photon OS: `man yum.conf`

Here is an example of how to add a new repository for a local server that tdnf polls for packages:

```
cat > /etc/yum.repos.d/apps.repo << "EOF"
[localapps]
name=Local In-House Applications(x86_64)
baseurl=file:///appserver/apps
enabled=1
skip_if_unavailable=True
EOF
```

Because this new repository resides on a local server, make sure the Photon OS machine can connect to it by, for instance, mounting it.

After establishing a new repository, you must run the following command to update the cached binary metadata for the repositories that tdnf polls. Example:

```
tdnf makecache
Refreshing metadata for: 'VMware Lightwave 1.0(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)Updates'
Refreshing metadata for: 'VMware Photon Extras 1.0(x86_64)'
Refreshing metadata for: 'Local In-House Applications(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)'
Metadata cache created.
```

Adding the Dev Repository to Get New Packages from the GitHub Dev Branch

If you want to try out new packages or the latest versions of existing packages as they are merged into the dev branch of the Photon OS GitHub site, you can add the dev repository to your repository list. Here's how:

On your Photon OS machine, run the following command as root to create a repository configuration file named `photon-dev.repo`, place it in /etc/yum.repos.d, and concatenate the repository's information into the file:

```
cat > /etc/yum.repos.d/photon-dev.repo << "EOF"
[photon-dev]
name=VMware Photon Linux Dev(x86_64)
baseurl=https://dl.bintray.com/vmware/photon_dev_$basearch
gpgkey=file:///etc/pki/rpm-gpg/VMWARE-RPM-GPG-KEY
gpgcheck=1
enabled=1
skip_if_unavailable=True
EOF
```

After establishing a new repository, you must run the following command to update the cached binary metadata for the repositories that tdnf polls:

```
tdnf makecache
```

Managing Services with systemd

Photon OS manages services with systemd. By using systemd, Photon OS adopts a contemporary Linux standard to bootstrap the user space and concurrently start services--an architecture that differs from traditional Linux systems such as SUSE Linux Enterprise Server.

A traditional Linux system contains an initialization system called SysVinit. With SLES 11, for instance, SysVinit-style init programs control how the system starts up and shuts down. Init implements system runlevels. A SysVinit runlevel defines a state in which a process or service runs.

In contrast to a SysVinit system, systemd defines no such runlevels. Instead, systemd uses a dependency tree of targets to determine which services to start when. Combined with the declarative nature of systemd commands, systemd targets reduce the amount of code needed to run a command, leaving you with code that is easier to maintain and probably faster to execute. For an overview of systemd, see systemd System and Service Manager and the man page for systemd.

On Photon OS, you should manage services with systemd and its command-line utility for inspecting and controlling the system, `systemctl`, not the deprecated commands of init.d.

The following sections present a brief overview of useful systemctl commands and options for examining and managing the state of systemd services. For more information, see the index of all the systemd man pages, including systemctl, at the following URL:

https://www.freedesktop.org/software/systemd/man/

Viewing Services

To view a description of all the active, loaded units, execute the systemctl command without any options or arguments:

```
systemctl
```

To see all the loaded, active, and inactive units and their description, run this command:

```
systemctl --all
```

To see all the unit files and their current status but no description, run this command:

```
systemctl list-unit-files
```

The `grep` command filters the services by a search term, a helpful tactic to recall the exact name of a unit file without looking through a long list of names. Example:

```
systemctl list-unit-files | grep network
org.freedesktop.network1.busname           static
dbus-org.freedesktop.network1.service      enabled
systemd-networkd-wait-online.service       enabled
systemd-networkd.service                   enabled
systemd-networkd.socket                    enabled
network-online.target                      static
network-pre.target                         static
network.target                             static
```

Controlling Services

To control services on Photon OS, you use systemctl. For example, instead of running the /etc/init.d/ssh script to stop and start the OpenSSH server on a init.d-based Linux system, you run the following systemctl commands on Photon OS:

```
systemctl stop sshd
systemctl start sshd
```

The systemctl tool includes a range of commands and options for inspecting and controlling the state of systemd and the service manager; for more information, see the systemctl man page.

Creating a Startup Service

This section shows you how to create a systemd startup service that changes the maximum transmission unit, or MTU, of the default Ethernet connection, eth0.

First, concatenate the following block of code into a file:

```
cat << EOF >> /lib/systemd/system/eth0.service
[Unit]
```

```
Description=Network interface initialization
After=local-fs.target network-online.target network.target
Wants=local-fs.target network-online.target network.target

[Service]
ExecStart=/bin/ifconfig eth0 mtu 1460 up
Type=oneshot

[Install]
WantedBy=multi-user.target
EOF
```

Second, set the service to auto-start when the system boots:

```
cd /lib/systemd/system/multi-user.target.wants/
ln -s ../eth0.service eth0.service
```

Disabling the Photon OS httpd.service

If your application or appliance includes its own HTTP server, you should turn off and disable the HTTP server that comes with Photon OS so that it does not conflict with your own HTTP server.

To stop it and disable it, run the following commands as root:

```
systemctl stop httpd.service
systemctl disable httpd.service
```

Auditing System Events with auditd

Because Photon OS emphasizes security, the Linux auditing service, auditd, is enabled and active by default on the full version of Photon OS:

```
systemctl status auditd
* auditd.service - Security Auditing Service
   Loaded: loaded (/usr/lib/systemd/system/auditd.service; enabled; vendor preset: enabled)
   Active: active (running) since Fri 2016-04-29 15:08:50 UTC; 1 months 9 days ago
 Main PID: 250 (auditd)
   CGroup: /system.slice/auditd.service
           `-250 /sbin/auditd -n
```

To help improve security, the auditd service can monitor file changes, system calls, executed commands, authentication events, and network access. After you implement an audit rule to monitor an event, the `aureport` tool generates reports to display information about the events.

You can, for instance, use the auditctl utility to set a rule that monitors the sudoers file for changes:

```
auditctl -w /etc/sudoers -p wa -k sudoers_changes
```

This rule specifies that the auditd service watch (`-w`) the /etc/sudoers file to log permissions changes (`p`) to the write access (`w`) or attributes (`a`) of the file and to identify them in logs as `sudoers_changes` . The auditing logs appear in /var/log/audit/audit.log. You can list the auditing rules like this:

```
auditctl -l
-w /etc/sudoers -p wa -k sudoers_changes
```

For more information on the Linux Audit Daemon, see its man page on Photon OS:

```
man auditd
```

For more information on setting auditing rules and options with auditctl, see its man page:

```
man auditctl
```

For more information on viewing reports on audited events, see the aureport man page:

```
man aureport
```

Analyzing systemd Logs with journalctl

The journalctl tool queries the contents of the systemd journal. For help troubleshooting systemd, two journalctl queries are particularly useful: showing the log entries for the last boot and showing the log entries for a systemd service unit.

This command displays the messages that systemd generated during the last time the machine started:

```
journalctl -b
```

This command reveals the messages for only the systemd service unit specified by the `-u` option, which is auditd in the following example:

```
journalctl -u auditd
```

For more information, see the journalctl man page by running this command on Photon OS: `man journalctl`

Migrating Scripts to systemd

Although systemd maintains compatibility with init.d scripts, you should, as a best practice, adapt the scripts that you want to run on Photon OS to systemd to avoid potential problems. Such a conversion standardizes the scripts, reduces the footprint of your code, makes the scripts easier to read and maintain, and improves their robustness on a systemd system.

Managing the Network Configuration

The network service, which is enabled by default, starts when the system boots. You manage the network service by using systemd commands, such as systemd-networkd, systemd-resolvd, and networkctl. You can check its status of the network service by running the following command:

```
systemctl status systemd-networkd
```

Here is a healthy result of the command:

```
* systemd-networkd.service - Network Service
   Loaded: loaded (/usr/lib/systemd/system/systemd-networkd.service; enabled; vendor preset: enabled)
   Active: active (running) since Fri 2016-04-29 15:08:51 UTC; 6 days ago
     Docs: man:systemd-networkd.service(8)
 Main PID: 291 (systemd-network)
   Status: "Processing requests..."
   CGroup: /system.slice/systemd-networkd.service
           `-291 /lib/systemd/systemd-networkd
```

Because Photon OS relies on systemd to manage services, you should employ the systemd suite of commands, not deprecated init.d commands or other deprecated commands, to manage networking.

Using the Photon Management Daemon

The Photon Management Daemon (PMD) that ships with Photon OS 2.0 provides the remote management of a Photon instance via several APIs: a command line client (pmd-cli), a REST API, and a Python API. The PMD provides the ability to manage network interfaces, packages, firewalls, users, and user groups.

Installing the pmd Package

The pmd package is included with your Photon OS 2.0 distribution. To make sure that you have the latest version, you can run:

```
# tdnf install pmd
# systemctl start pmd
```

Available APIs

pmd-cli

The pmd-cli utility enables Photon customers to invoke API requests securely on local and remote servers. For details, see Photon Management Daemon Command-line Interface (pmd-cli).

PMD REST API

The PMD REST API is an openapi 2.0 specification. Once the pmd package is installed, you can use a Swagger UI tool to browse the REST API specifications (/etc/pmd/restapispec.json). You can also browse it using the copenapi_cli tool that comes with the pmd package:

```
# copenapi_cli --apispec /etc/pmd/restapispec.json
```

For more information about the copenapi_cli tool, refer to github.com/vmware/copenapi.

PMD Python API

Python3 is included with your Photon OS 2.0 distribution. PMD Python interfaces are available for python3 (pmd-python3) and python2 (pmd-python2). You can use tdnf to ensure that the latest version is installed:

```
# tdnf install pmd-python3
# systemctl start pmd
```

To navigate the help documentation for the pmd Python packages:

```
# python3
>>> import pmd
>>> net = pmd.server().net
>>> help(pmd)
```

To show help text for individual interfaces:

```
>>> help(pmd.server().net)
>>> help(pmd.server().pkg)
>>> help(pmd.server().firewall)
>>> help(pmd.server().user)
```

For details about the network commands, see also the Network Configuration Manager - Python API.

PMD C Documentation

PMD C APIs are defined in the header files (pmd_fwmgmt.h, pmd_netmgr.h, pmd_pkgmgmt.h, pmd_usermgmt.h) that are stored in the following location:

```
[https://github.com/vmware/pmd/tree/master/include](https://github.com/vmware/pmd/tree/master/include)
```

For details about the network commands, see also the Network Configuration Manager - C API.

Using the Network Configuration Manager

The Network Configuration Manager library that ships with Photon OS 2.0 provides a collection of C, Python, and CLI APIs that simplify common onfiguration tasks for:

- interfaces
- IP addresses (IPv4 and IPv6 addresses)
- routes
- DNS server and domain settings
- DHCP DUID and IAID settings
- NTP server settings
- service management
- object parameters (interfaces and files)

For additional details, see:

- **CLI** - see the `-net` commands in the Photon Management Daemon Command-line Interface (pmd-cli)
- **C APIs** - Network Configuration Manager - C API
- **Python APIs** - Network Configuration Manager - Python API

Use `ip` and `ss` Commands Instead of `ifconfig` and `netstat`

Although the `ifconfig` command and the `netstat` command work on Photon OS, VMware recommends that you use the `ip` or `ss` commands. The `ipconfig` and `netstat` commands are deprecated.

For example, instead of running `netstat` to display a list of network interfaces, run the `ss` command. Similarly, to display information for IP addresses, instead of running `ifconfig -a`, run the `ip addr` command. Examples:

```
USE THIS IPROUTE COMMAND     INSTEAD OF THIS NET-TOOL COMMAND
ip addr                     ifconfig -a
ss                            netstat
ip route                     route
ip maddr                     netstat -g
ip link set eth0 up         ifconfig eth0 up
ip -s neigh                   arp -v
ip link set eth0 mtu 9000    ifconfig eth0 mtu 9000
```

Using the `ip route` version of a command instead of the net-tools version often provides more complete, accurate information on Photon OS, as the following example demonstrates:

```
ip neigh
198.51.100.2 dev eth0 lladdr 00:50:56:e2:02:0f STALE
198.51.100.254 dev eth0 lladdr 00:50:56:e7:13:d9 STALE
198.51.100.1 dev eth0 lladdr 00:50:56:c0:00:08 DELAY

arp -a
? (198.51.100.2) at 00:50:56:e2:02:0f [ether] on eth0
? (198.51.100.254) at 00:50:56:e7:13:d9 [ether] on eth0
? (198.51.100.1) at 00:50:56:c0:00:08 [ether] on eth0
```

Configuring Network Interfaces

Network configuration files for systemd-networkd reside in /etc/systemd/network and /usr/lib/systemd/network. Example:

```
root@photon-rc [ ~ ]# ls /etc/systemd/network/
99-dhcp-en.network
```

By default, when Photon OS starts, it creates a DHCP network configuration file, or rule, which appears in /etc/systemd/network, the highest priority directory for network configuration files with the lowest priority filename:

```
cat /etc/systemd/network/99-dhcp-en.network
[Match]
Name=e*

[Network]
DHCP=yes
```

Network configuration files can also appear in the system network directory, /usr/lib/systemd/network, as the results of the following search illustrate:

```
root@photon-rc [ ~ ]# updatedb
root@photon-rc [ ~ ]# locate systemd/network
/etc/systemd/network
/etc/systemd/network/99-dhcp-en.network
/usr/lib/systemd/network
/usr/lib/systemd/network/80-container-host0.network
/usr/lib/systemd/network/80-container-ve.network
/usr/lib/systemd/network/99-default.link
root@photon-rc [ ~ ]#
```

As you can see, the /usr/lib/systemd/network directory contains several network configuration files. Photon OS applies the configuration files in the lexicographical order specified by the file names without regard for the network configuration directory in which the file resides unless the file name is the same. Photon OS processes files with identical names by giving precedence to files in the /etc directory over the other directory. Thus, the settings in /etc/systemd/network override those in /usr/lib/systemd/network. Once Photon OS matches an interface in a file, Photon OS ignores the interface if it appears in files processed later in the lexicographical order.

Each .network file contains a matching rule and a configuration that Photon OS applies when a device matches the rule. You set the matching rule and the configuration as sections containing vertical sets of key-value pairs according to the information at https://www.freedesktop.org/software/systemd/man/systemd.network.html.

To configure Photon OS to handle a networking use case, such as setting a static IP address or adding a name server, you create a configuration file with a `.network` extension and place it in the /etc/systemd/network directory.

After you create a network configuration file with a `.network` extension, you must run the `chmod` command to set the new file's mode bits to `644`. Example:

```
chmod 644 10-static-en.network
```

For Photon OS to apply the new configuration, you must restart the `systemd-networkd` service by running the following command:

```
systemctl restart systemd-networkd
```

For information about network configuration files, their processing order, and their matching rules, sections, and keys, see https://www.freedesktop.org/software/systemd/man/systemd.network.html.

For information about creating virtual network device files (`.netdev`), see https://www.freedesktop.org/software/systemd/man/systemd.netdev.html.

Setting a Static IP Address

Before you set a static IP address, obtain the name of your Ethernet link by running the following command:

```
networkctl
IDX LINK             TYPE               OPERATIONAL SETUP
  1 lo               loopback           carrier     unmanaged
  2 eth0             ether              routable    configured
```

In the results of the command, you can see the name of an Ethernet link, `eth0`.

To create a network configuration file that systemd-networkd uses to establish a static IP address for the eth0 network interface, execute the following command as root:

```
cat > /etc/systemd/network/10-static-en.network << "EOF"

[Match]
Name=eth0

[Network]
Address=198.51.0.2/24
Gateway=198.51.0.1
EOF
```

Change the new file's mode bits by running the `chmod` command:

```
chmod 644 10-static-en.network
```

Apply the configuration by running the following command:

```
systemctl restart systemd-networkd
```

For more information, see the man page for systemd-networkd: `man systemd.network`

Turning Off DHCP

By default, when Photon OS first starts, it creates a DHCP network configuration file, or rule, which appears in /etc/systemd/network, the highest priority directory for network configuration files with the lowest priority filename: cat /etc/systemd/network/99-dhcp-en.network [Match] Name=e*

```
[Network]
DHCP=yes
```

To turn off DHCP for all Ethernet interfaces, change the value of `DHCP` from `yes` to `no`, save the changes, and then restart the `systemd-networkd` service:

```
systemctl restart systemd-networkd
```

If you create a configuration file with a higher priority filename (e.g. `10-static-en.network`), it is not necessary but still recommended to turn off DHCP.

Adding a DNS Server

Photon OS resolves domain names, IP addresses, and network names for local applications by using systemd-resolved. The systemd-resolved daemon automatically creates and maintains the /etc/resolv.conf file, into which systemd-resolved places the IP address of the DNS server. You should therefore never modify the /etc/resolv.conf file.

(If you want to implement a local resolver like bind instead of systemd-resolved, stop the systemd-resolved service and disable it.)

If you open the default /etc/resolv.conf file after you deploy Photon OS, it looks like this:

```
root@photon-rc [ ~ ]# cat /etc/resolv.conf
# This file is managed by systemd-resolved(8). Do not edit.
#
# Third party programs must not access this file directly, but
# only through the symlink at /etc/resolv.conf. To manage
# resolv.conf(5) in a different way, replace the symlink by a
# static file or a different symlink.

nameserver 198.51.100.2
```

To add a DNS server to your static network configuration file, insert a DNS key into the Network section of, in this example, /etc/systemd/network/10-eth0-static.network and set it to the IP address of your DNS server:

```
[Match]
Name=e*

[Network]
Address=198.51.0.2/24
Gateway=198.51.0.1
DNS=198.51.0.1
```

Another way of adding a DNS server is to modify /etc/systemd/resolved.conf--a method that can be particularly useful when your machine is working with DHCP. For more information, see https://www.freedesktop.org/software/systemd/man/resolved.conf.html.

You can optionally activate the local DNS stub resolver of systemd-resolved by adding `dns` and `resolve` to /etc/nsswitch.conf. To do so, make a backup copy of /etc/nsswitch.conf and then execute the following command as root:

```
sed -i 's/^hosts.*$/hosts: files resolve dns/' /etc/nsswitch.conf
```

For more information on the systemd-resolved service, see https://www.freedesktop.org/software/systemd/man/systemd-resolved.service.html.

Setting Up Networking for Multiple NICs

If your machine contains multiple NICs, you should, as a best practice, create a .network configuration file for each network interface. The following scenario demonstrates how to set one wired network interface to use a static IP address and another wired network interface to use a dynamic IP address obtained through DHCP. Keep in mind that the following configurations are examples: You must change the IP addresses and other information to match your network and requirements.

First, create the .network file for the static Ethernet connection in /etc/systemd/network. Abest practice is to match the exact name of the network interface, which is in this example eth0. This example file also includes a DNS server for the static IP address. As a result, the configuration sets the UseDNS key to false in the DHCP column so that Photon OS ignores the DHCP server for DNS for this interface.

```
cat > /etc/systemd/network/10-eth0-static-en.network << "EOF"
[Match]
Name=eth0

[Network]
Address=10.137.20.11/19
Gateway=10.137.23.253
DNS=10.132.71.1

[DHCP]
UseDNS=false
EOF
```

Second, create the .network file for the second network interface, which is named eth1 in this example. This configuration file sets the eth1 interface to an IP address from DHCP and sets DHCP as the source for DNS lookups. Setting the DHCP key to `yes` acquires an IP address for IPv4 and IPv6. To acquire an IP address for IPv4 only, set the DHCP key to `ipv4`.

```
cat > /etc/systemd/network/50-eth1-dhcp-en.network << "EOF"

[Match]
Name=eth1

[Network]
DHCP=yes

[DHCP]
UseDNS=true
EOF
```

Combining DHCP and Static IP Addresses with IPv4 and IPv6

This section presents examples that demonstrate how to combine DHCP and static IP addresses with both IPv4 and IPv6.

Here's how to use DHCP to allocate both IPv4 and IPv6 addresses:

```
[Network]
DHCP=yes
```

Here's how to use DHCP to allocate only IPv4 addresses:

```
[Network]
DHCP=ipv4
```

Here's how to use DHCP to allocate only IPv6 addresses:

```
[Network]
DHCP=ipv6
```

Here's how to use DHCP for IPv4 addresses and static IP addresses for IPv6 addresses:

```
[Network]
DHCP=ipv4
Address=fd00::1/48
Gateway=fd00::252
```

Here's how to use DHCP for IPv6 addresses and static IP addresses for IPv4:

```
[Network]
DHCP=ipv6
Address=10.10.10.1/24
Gateway=10.10.10.253
```

Here's how to use static IP addresses for both IPv4 and IPv6:

```
[Network]
DHCP=ipv6
Address=10.10.10.1/24
Gateway=10.10.10.253
Address=fd00::1/48
Gateway=fd00::252
```

Clearing the Machine ID of a Cloned Instance for DHCP

Photon OS uses the contents of `/etc/machine-id` to determine the DHCP unique identifier (duid) that is used for DHCP requests. If you use a Photon OS instance as the base system for cloning to create additional Photon OS instances, you should clear the machine-id with this command:

```
echo -n > /etc/machine-id
```

With the value cleared, systemd regenerates the machine-id and, as a result, all DHCP requests will contain a unique duid.

Using Predictable Network Interface Names

On a virtual machine running Photon OS, just as on a bare-metal machine, the Ethernet network interface name might shift from one device to another if you add or removed a card and reboot the machine. A device named `eth2`, for example, might become `eth1` after a NIC is removed and the machine is restarted.

You can prevent interface names from reordering by turning on predictable network interface names. The naming schemes that Photon OS uses can then assign fixed, predictable names to network interfaces even after cards or other firmware are added or removed and the system is restarted. With predictable network interface names enabled, you can select among several options to assign persistent names to network interfaces:

- Apply the `slot` name policy to set the name of networking devices in the `ens` format with a statically assigned PCI slot number.
- Apply the `mac` name policy to set the name of networking devices in the `enx` format a unique MAC address.
- Apply the `path` name policy to set the name of networking devices in the `enpXsY` format derived from a device connector's physical location.

(Although Photon OS also supports the `onboard` name policy to set in the `eno` format the name of networking devices from index numbers given by the firmware, the `onboard` policy might result in nonpersistent names.)

The option that you choose depends on your use case and your unique networking requirements. If, for instance, you clone clones virtual machines in a use case that requires the MAC addresses to be different from one another but the interface name to be the same, you should consider using `ens` to keep the slot the same after reboots.

Alternatively, if the cloning function supports it and it works for your use case, you can use `enx` to set a MAC address, which also persists after reboots.

Here's how to turn on predictable network interface names.

First, make a backup copy of the following file in case you need to restore it later:

```
cp /boot/grub/grub.cfg /boot/grub/grub.cfg.original
```

Second, to turn on predictable network interface names, edit `/boot/grub/grub.cfg` to remove the following string:

```
net.ifnames=0
```

The string appears near the bottom of the file in the `menuentry` section:

```
menuentry "Photon" {
    linux "/boot/"$photon_linux root=$rootpartition net.ifnames=0 $photon_cmdline
    if [ "$photon_initrd" ]; then
        initrd "/boot/"$photon_initrd
    fi
}
# End /boot/grub2/grub.cfg
```

Edit out `net.ifnames=0`, but make no other changes to the file, and then save it.

Third, specify the types of policies that you want to use for predictable interface names by modifying the `NamePolicy` option in `/lib/systemd/network/99-default.link`. Here's what the file looks like:

```
cat /lib/systemd/network/99-default.link
[Link]
NamePolicy=kernel database
MACAddressPolicy=persistent
```

To use the `ens` or `enx` option, the `slot` policy or the `mac` policy can be added to the space-separated list of policies that follow the `NamePolicy` option in the default link file, `/lib/systemd/network/99-default.link`. The order of the policies matters: Photon OS applies the policy listed first before proceeding to the next policy if the first one fails. Example:

```
/lib/systemd/network/99-default.link
[Link]
NamePolicy=slot mac kernel database
MACAddressPolicy=persistent
```

With the name policy specified in the above example, it's possible that you could still end up with an Ethernet-style interface name if the two previous policies, `slot` and `mac`, fail.

For information on setting name policies, see systemd.link--network device configuration.

Inspecting the Status of Network Links with `networkctl`

The `networkctl` command shows information about network connections that helps you configure networking services and troubleshoot networking problems. You can, for example, progressively add options and arguments to the `networkctl` command to move from general information about network connections to specific information about a network connection.

Running `networkctl` without options defaults to the list command:

```
networkctl
IDX LINK             TYPE               OPERATIONAL SETUP
  1 lo               loopback           carrier     unmanaged
  2 eth0             ether              routable    configured
  3 docker0          ether              routable    unmanaged
 11 vethb0aa7a6      ether              degraded    unmanaged
 4 links listed.
```

Running `networkctl` with the status command displays information that looks like this; you can see that there are active network links with IP addresses for not only the Ethernet connection but also a Docker container.

```
root@photon-rc [ ~ ]# networkctl status
*      State: routable
     Address: 198.51.100.131 on eth0
              172.17.0.1 on docker0
              fe80::20c:29ff:fe55:3ca6 on eth0
              fe80::42:f0ff:fef7:bd81 on docker0
              fe80::4c84:caff:fe76:a23f on vethb0aa7a6
     Gateway: 198.51.100.2 on eth0
         DNS: 198.51.100.2
```

You can then add a network link, such as the Ethernet connection, as the argument of the status command to show specific information about the link:

```
root@photon-rc [ ~ ]# networkctl status eth0
* 2: eth0
       Link File: /usr/lib/systemd/network/99-default.link
    Network File: /etc/systemd/network/99-dhcp-en.network
            Type: ether
           State: routable (configured)
```

```
            Path: pci-0000:02:01.0
          Driver: e1000
      HW Address: 00:0c:29:55:3c:a6 (VMware, Inc.)
             MTU: 1500
         Address: 198.51.100.131
                  fe80::20c:29ff:fe55:3ca6
         Gateway: 198.51.100.2
             DNS: 198.51.100.2
        CLIENTID: ffb6220feb00020000ab116724f520a0a77337
```

And you can do the same thing with the Docker container:

```
networkctl status docker0
* 3: docker0
       Link File: /usr/lib/systemd/network/99-default.link
    Network File: n/a
            Type: ether
           State: routable (unmanaged)
          Driver: bridge
      HW Address: 02:42:f0:f7:bd:81
             MTU: 1500
         Address: 172.17.0.1
                  fe80::42:f0ff:fef7:bd81
```

In the example above, it is OK that the state of the Docker container is unmanaged; Docker handles managing the networking for the containers without using systemd-resolved or systemd-networkd. Instead, Docker manages the container's connection by using its bridge drive.

For more information about `networkctl` commands and options, see https://www.freedesktop.org/software/systemd/man/networkctl.html.

Turning on Network Debugging

You can set `systemd-networkd` to work in debug mode so that you can analyze log files with debugging information to help troubleshoot networking problems. The following procedure turns on network debugging by adding a drop-in file in /etc/systemd to customize the default systemd configuration in /usr/lib/systemd.

First, run the following command as root to create a directory with this exact name, including the `.d` extension:

```
mkdir -p /etc/systemd/system/systemd-networkd.service.d/
```

Second, run the following command as root to establish a systemd drop-in unit with a debugging configuration for the network service:

```
cat > /etc/systemd/system/systemd-networkd.service.d/10-loglevel-debug.conf << "EOF"
[Service]
Environment=SYSTEMD_LOG_LEVEL=debug
EOF
```

You must reload the systemctl daemon and restart the systemd-networkd service for the changes to take effect:

```
systemctl daemon-reload
systemctl restart systemd-networkd
```

Verify that your changes took effect:

```
systemd-delta --type=extended
```

View the log files by running this command:

```
journalctl -u systemd-networkd
```

When you are finished debugging the network connections, turn debugging off by deleting the drop-in file:

```
rm /etc/systemd/system/systemd-networkd.service.d/10-loglevel-debug.conf
```

Mounting a Network File System

To mount a network file system, Photon OS requires nfs-utils. The nfs-utils package contains the daemon, userspace server, and client tools for the kernel Network File System, or NFS. The tools include mount.nfs, umount.nfs, and showmount.

The nfs-utils package is installed by default in the full version of Photon OS but not in the minimal version. To install nfs-utils in the minimal version, run the following command as root:

```
tdnf install nfs-utils
```

For instructions on how to use nfs-utils to share files over a network, see Photon OS nfs-utils.

Installing the Packages for tcpdump and netcat with tdnf

The minimal version of Photon OS leaves out several useful networking tools to keep the operating system lean. Tcpdump, for example, is absent in the minimal version but available in the repository. The minimal version does, however, include the iproute2 tools by default.

Tcpdump captures and analyzes packets on a network interface. On Photon OS, you install tcpdump and its accompanying package libpcap, a C/C++ library for capturing network traffic, by using tdnf, Photon's command-line package manager:

```
tdnf install tcpdump
```

Netcat, a tool for sending data over network connections with TCP or UDP, appears in neither the minimal nor the full version of Photon OS. But since netcat furnishes powerful options for analyzing, troubleshooting, and debugging network connections, you might want to install it. To do so, run the following command:

```
tdnf install netcat
```

Cloud-Init on Photon OS

The minimal and full versions of Photon OS include the cloud-init service as a built-in component. Cloud-init is a set of Python scripts that initialize cloud instances of Linux machines. The cloud-init scripts configure SSH keys and run commands to customize the machine without user interaction. The commands can set the root password, create a hostname, configure networking, write files to disk, upgrade packages, run custom scripts, and restart the system.

There are several ways in which you can deploy Photon OS with cloud-init, including the following:

- As a stand-alone Photon machine
- In Amazon Elastic Compute Cloud, called EC2
- In the Google cloud through the Google Compute Engine, or GCE
- In a VMware Vsphere private cloud

When a cloud instance of Photon OS starts, cloud-init requires a data source. The data source can be an EC2 file for Amazon's cloud platform, a seed.iso for a stand-alone instance of Photon OS, or the internal capabilities of a system for managing virtual machines, such as VMware vSphere or vCenter. Cloud-init also includes data sources for OpenStack, Apache CloudStack, and OVF. The data source comprises two parts:

1. Metadata
2. User data

The metadata gives the cloud service provider instructions on how to implement the Photon OS machine in the cloud infrastructure. Metadata typically includes the instance ID and the local host name.

The user data contains the commands and scripts that Photon OS executes when it starts in the cloud. The user data commonly takes the form of a shell script or a YAML file containing a cloud configuration. The cloud-init documentation contains information about the types of data sources and the formats for metadata and user data.

On Photon OS, cloud-init is enabled and running by default. You can check its status like this:

```
systemctl status cloud-init
```

The Photon OS directory that contains the local data and other resources for cloud-init is here:

```
/var/lib/cloud
```

Photon OS stores the logs for cloud-init in the following file:

```
/var/log/cloud-init.log
```

The following sections demonstrate how to use cloud-init to customize a stand-alone Photon OS machine, instantiate a Photon OS machine in the Amazon EC2 cloud, and deploy a virtual machine running Photon OS in vSphere. Each section uses a different combination of the available options for the metadata and the user data that make up the data source. Specifications, additional options, and examples appear in the cloud-init documentation.

Creating a Stand-Alone Photon Machine with cloud-init

Cloud-init can customize a Photon OS virtual machine by using the `nocloud` data source. The nocloud data source bundles the cloud-init metadata and user data into a ISO that acts as a seed when you boot the machine. This seed.iso delivers the metadata and the user data without requiring a network connection.

Here's how customize a Photon OS VM with a nocloud data source:

First, create the metadata file with the following lines in the YAML format and name it `meta-data`:

```
instance-id: iid-local01
local-hostname: cloudimg
```

Second, create the user data file with the following lines in YAML and name it user-data:

```
#cloud-config
hostname: testhost
packages:
 - vim
```

Third, generate the ISO that will serve as the seed; the ISO must have the volume ID set to `cidata`. In this example, the ISO is generated on an Ubuntu 14.04 computer containing the files named `meta-data` and `user-data` in the local directory:

```
genisoimage -output seed.iso -volid cidata -joliet -rock user-data meta-data
```

The ISO now appears in the current directory:

```
steve@ubuntu:~$ ls
meta-data seed.iso user-data
```

Optionally, you can check the ISO that you generated on Ubuntu by transferring the ISO to the root directory of your Photon OS machine and then running the following command:

```
cloud-init --file seed.iso --debug init
```

After running the cloud-init command above, check the cloud-init log file:

```
more /var/log/cloud-init.log
```

Finally, attach the ISO to the Photon OS virtual machine as a CD-ROM and reboot it so that the changes specified by seed.iso take effect. In this case, cloud-init sets the hostname and adds the vim package.

Customizing a Photon OS Machine on EC2

This section illustrates how to upload an `ami` image of Photon OS to Amazon Elastic Compute Cloud (EC2) and customize the Photon OS machine by using cloud-init with an EC2 data source. The Amazon machine image version of Photon OS is available as a free download on Bintray:

```
https://bintray.com/vmware/photon/
```

The cloud-init service is commonly used on EC2 to configure the cloud instance of a Linux image. On EC2, for example, cloud-init typically sets the `.ssh/authorized_keys` file to let you log in with a private key from another computer--that is, a computer besides the workstation that you are already using to connect with the Amazon cloud. The cloud-config user-data file that appears in the following example contains abridged SSH authorized keys to show you how to set them.

Working with EC2 requires Amazon accounts for both AWS and EC2 with valid payment information. If you execute the following examples, you will be charged by Amazon. You will need to replace the `<placeholders>` for access keys and other account information in the examples with your account information.

The following code assumes you have installed and set up the Amazon AWS CLI and the EC2 CLI tools, including `ec2-ami-tools`. See Installing the AWS Command Line Interface and Setting Up the Amazon EC2 Command Line Interface Tools on Linux. Also see Setting Up the AMI Tools.

EC2 requires an SSH key and an RSA certificate. The code in the examples assumes that you have created SSH keys as well as an RSA user signing certificate and its corresponding private RSA key file.

Here's a code example that shows how to upload the Photon OS `.ami` image to the Amazon cloud and configure it with cloud-init. The correct virtualization type for Photon OS is `hvm`.

```
$ mkdir bundled
$ tar -zxvf ./photon-ami.tar.gz
$ ec2-bundle-image -c ec2-certificate.pem -k ec2-privatekey.pem -u <EC2 account id>  --arch x86_64 --image photon-ami.raw --destination ./
bundled/
$ aws s3 mb s3://<bucket-name>
$ ec2-upload-bundle --manifest ./bundled/photon-ami.manifest.xml --bucket <bucket-name> --access-key <Account Access Key> --secret-key <Ac
count Secret key>
$ ec2-register <bucket-name>/photon-ami.manifest.xml --name photon-ami --architecture x86_64 --virtualization-type hvm
```

In the following command, the `--user-data-file` option instructs cloud-init to import the cloud-config data in `user-data.txt`. The next command assumes you have created the keypair called `mykeypair` and the security group photon-sg as well as uploaded the user-data.txt file; see the EC2 documentation.

```
$ ec2-run-instances <ami-ID> --instance-type m3.medium -g photon-sg --key mykeypair --user-data-file user-data.txt
```

You can now describe the instance to see its ID:

```
$ ec2-describe-instances
```

And you can run the following command to obtain its public IP address, which you can use to connect to the instance with SSH:

```
$ aws ec2 describe-instances --instance-ids <instance-id> --query 'Reservations[*].Instances[*].PublicIpAddress' --output=text
$ ec2-describe-images
```

Important: When you are done, run the following commands to terminate the machine. Because Amazon charges you while the host is running, make sure to shut it down:

```
$ ec2-deregister <ami-image-identifier>
$ ec2-terminate-instances <instance-id>
```

Here are the contents of the user-data.txt file that cloud-init applies to the machine the first time that it boots up in the cloud:

```
#cloud-config
hostname: photon-on-01
groups:
- cloud-admins
- cloud-users
users:
- default
- name: photonadmin
   gecos: photon test admin user
   primary-group: cloud-admins
   groups: cloud-users
   lock-passwd: false
   passwd: vmware
- name: photonuser
   gecos: photon test user
   primary-group: cloud-users
   groups: users
   passwd: vmware
packages:
- vim
ssh_authorized_keys:
 - ssh-rsa MIIEogIBAAKCAQEAuvHKAjBhpwuomcUTpIzJWRJAe71JyBgAWrwqyN1Mk5N+c9X5
Ru2fazFA7WxQSD1KyTEvcuf8JzdBfrEJ0v3/nT2x63pvJ8fCl6HRkZtHo8zRu8vY
KYTZS/sdvM/ruubHfq1ldRpgtYSqbkykoe6PCQIDAQABAoIBAEgveQtjVzHDhLTr
rmwJmO316ERfkQ/chLaElhi9qwYJG/jqlNIISWFyztqD1b3fxU6m5MOBIujh7Xpg
... ec3test@example.com
```

Now check the cloud-init output log file on EC2 at `/var/log/cloud-init-output.log`.

For more information on using cloud-init user data on EC2, see Running Commands on Your Linux Instance at Launch.

An article on the Photon OS GitHub wiki demonstrates how to get Photon OS up and running on EC2 and run a containerized application in the Docker engine. See Running Photon OS on Amazon Elastic Cloud Compute.

With Photon OS, you can also build cloud images on Google Compute Engine and other cloud providers; see Compatible Cloud Images.

Running a Photon OS Machine on GCE

Photon OS comes in a preconfigured image ready for Google Cloud Engine. This section demonstrates how to create a Photon OS instance on Google Cloud Engine with and without cloud-init user data.

This section assumes that you have set up a GCE account and, if you try the examples, are ready to pay Google for its cloud services. The GCE-ready version of Photon OS, however, comes for free. It is, in the parlance of Google cloud services, a private image. You can freely download it without registration from Bintray:

```
https://bintray.com/vmware/photon/gce/view
```

The GCE-ready image of Photon OS contains packages and scripts that prepare it for the Google cloud to save you time as you implement a compute cluster or develop cloud applications. The GCE-ready version of Photon OS adds the following packages to the packages installed with the minimal version:

```
sudo, tar, which, google-daemon, google-startup-scripts,
kubernetes, perl-DBD-SQLite, perl-DBIx-Simple, perl, ntp
```

In addition to a GCE account, the following examples require the gcloud command-line tool; see https://cloud.google.com/compute/docs/gcloud-compute.

Here are the commands to create an instance of Photon OS from the Photon GCE image without using cloud-init. In the following commands, you must replace `<bucket-name>` with the name of your bucket. You also need to replace the path to the Photon GCE tar file.

```
$ gcloud compute instances list
$ gcloud compute images list
$ gcloud config list
$ gsutil mb gs://<bucket-name>
$ gsutil cp <path-to-photon-gce-image.tar.gz> gs://<bucket-name>/photon-gce.tar.gz
$ gcloud compute images create photon-gce-image --source-uri gs://<bucket-name>/photon-gce.tar.gz
$ gcloud compute instances create photon-gce-vm --machine-type "n1-standard-1" --image photon-gce-image
$ gcloud compute instances describe photon-gce-vm
```

Now, to create a new instance of a Photon OS machine and configure it with a cloud-init user data file, replace the `gcloud compute instances create` command in the example above with the following command. Before running this command, you must upload your user-data file to Google's cloud infrastructure and replace `<path-to-userdata-file>` with its path and file name.

```
gcloud compute instances create photon-gce-vm --machine-type "n1-standard-1" --image photon-gce-vm --metadata-from-file=user-data=<path-to
-userdata-file>
```

You can also add a cloud-init user-data file to an existing instance of a Photon OS machine on GCE:

```
gcloud compute instances add-metadata photon-gce-vm --metadata-from-file=user-data=<path-to-userdata-file>
```

Docker Containers

Photon OS includes the open source version of Docker. With Docker, Photon OS becomes a Linux run-time host for containers--that is, a Linux cloud container. A container is a process that runs on the Photon OS host with its own isolated application, file system, and networking.

On Photon OS, the Docker daemon is enabled by default. To view the status of the daemon, run this command:

```
systemctl status docker
```

Docker is loaded and running by default on the full version of Photon OS. On the minimal version, it is loaded but not running by default, so you have to start it:

```
systemctl start docker
```

To obtain information about Docker, run this command as root:

```
docker info
```

After you make sure that docker is enabled and started, you can, for example, run the following docker command as root to create a container running Ubuntu 14.04 with an interactive terminal shell:

```
docker run -i -t ubuntu:14.04 /bin/bash
```

Photon OS also enables you to run a docker container that, in turn, runs Photon OS:

```
docker run -i -t photon /bin/bash
```

Kubernetes

The full version of Photon OS includes Kubernetes so you can manage clusters of containers. For more information, see Running Kubernetes on Photon OS.

Installing Sendmail

Before you install Sendmail, you should set the fully qualified domain name (FQDN) of your Photon OS machine.

Neither the full nor the minimal version of Photon OS installs Sendmail by default. When you install Sendmail, it provides Photon OS with a systemd service file that typically enables Sendmail. If, however, the service is not enabled after installation, you must enable it.

Sendmail resides in the Photon extras repository. You can install it with `tdnf` after setting the machine's FQDN. Here's how:

First, check whether the machine's FQDN is set by running the `hostnamectl status` command:

```
    hostnamectl status
  Static hostname: photon-d9ee400e194e
        Icon name: computer-vm
          Chassis: vm
       Machine ID: a53b414142f944319bd0c8df6d811f36
          Boot ID: 1f75baca8cc249f79c3794978bd82977
   Virtualization: vmware
 Operating System: VMware Photon/Linux
           Kernel: Linux 4.4.8
     Architecture: x86-64
```

In the results above, the FQDN is not set; the Photon OS machine has only a short name. If the FQDN were set, the hostname would be in its full form, typically with a domain name.

If the machine does not have an FQDN, set one by running `hostnamectl set-hostname new-name`, replacing `new-name` with the FQDN that you want. Example:

```
 hostnamectl set-hostname photon-d9ee400e194e.corp.example.com
```

The `hostnamectl status` command now shows that the machine has an FQDN:

```
root@photon-d9ee400e194e [ ~ ]# hostnamectl status
   Static hostname: photon-d9ee400e194e.corp.example.com
         Icon name: computer-vm
           Chassis: vm
        Machine ID: a53b414142f944319bd0c8df6d811f36
           Boot ID: 1f75baca8cc249f79c3794978bd82977
    Virtualization: vmware
  Operating System: VMware Photon/Linux
            Kernel: Linux 4.4.8
```

```
      Architecture: x86-64
```

Next, install Sendmail:

```
tdnf install sendmail
```

Make sure it is enabled:

```
systemctl status sendmail
```

Enable Sendmail if it's disabled and then start it:

```
systemctl enable sendmail
systemctl start sendmail
```

Fixing Sendmail If Installed Before an FQDN Was Set

If Sendmail is behaving improperly or if it hangs during installation, it is likely that an FQDN is not set. Take the following corrective action.

First, set an FQDN for your Photon OS machine.

Then, run the following commands in the order below:

```
echo $(hostname -f) > /etc/mail/local-host-names

cat > /etc/mail/aliases << "EOF"
    postmaster: root
    MAILER-DAEMON: root
    EOF

/bin/newaliases

cd /etc/mail

m4 m4/cf.m4 sendmail.mc > sendmail.cf

chmod 700 /var/spool/clientmqueue

chown smmsp:smmsp /var/spool/clientmqueue
```

Changing the Locale

You can change the locale if the default locale, shown below by running the `localectl` command, fails to fulfill your requirements:

```
localectl
System Locale: LANG=en_US.UTF-8
   VC Keymap: n/a
  X11 Layout: n/a
```

To change the locale, choose the languages that you want from `/usr/share/locale/locale.alias`, add them to `/etc/locale-gen.conf`, and then regenerate the locale list by running the following command as root:

```
locale-gen.sh
```

Finally, run the following command to set the new locale, replacing the example (`en_US.UTF-8`) with the locale that you want:

```
localectl set-locale LANG="en_US.UTF-8" LC_CTYPE="en_US.UTF-8"
```

The Default Security Policy of Photon OS

Default Firewall Settings

The design of Photon OS emphasizes security. On the minimal and full versions of Photon OS, the default security policy turns on the firewall and drops packets from external interfaces and applications. As a result, you might need to add rules to iptables to permit forwarding, allow protocols like HTTP, and open ports. In other words, you must configure the firewall for your applications and requirements.

The default iptables settings on the full version look like this:

```
iptables --list
Chain INPUT (policy DROP)
target     prot opt source               destination
ACCEPT     all  --  anywhere             anywhere
ACCEPT     all  --  anywhere             anywhere             ctstate RELATED,ESTABLISHED
ACCEPT     tcp  --  anywhere             anywhere             tcp dpt:ssh

Chain FORWARD (policy DROP)
target     prot opt source               destination

Chain OUTPUT (policy DROP)
target     prot opt source               destination
ACCEPT     all  --  anywhere             anywhere
```

To find out how to adjust the settings, see the man page for iptables.

Although the default iptables policy accepts SSH connections, the `sshd` configuration file on the full version of Photon OS is set to reject SSH connections. See Permitting Root Login with SSH.

If you are unable to ping a Photon OS machine, one of the first things you should do is check the firewall rules. Do they allow connectivity for the port and protocol in question? You can supplement the `iptables` commands by using `lsof` commands to, for instance, see the processes listening on ports:

```
lsof -i -P -n
```

Default Permissions and umask

The umask on Photon OS is set to `0027`.

When you create a new file with the `touch` command as root, the default on Photon OS is to set the permissions to `0640` --which translates to read-write for user, read for group, and no access for others. Here's an example:

```
touch newfile.md
stat newfile.md
  File: 'newfile.md'
  Size: 0               Blocks: 0          IO Block: 4096   regular empty file
Device: 801h/2049d      Inode: 316454      Links: 1
Access: (0640/-rw-r-----)  Uid: (    0/    root)   Gid: (    0/    root)
```

When you create a directory as root, Photon OS sets the permissions to `0750`:

```
mkdir newdir
stat newdir
  File: 'newdir'
  Size: 4096            Blocks: 8          IO Block: 4096   directory
```

```
Device: 801h/2049d      Inode: 316455      Links: 2
Access: (0750/drwxr-x---)  Uid: (    0/    root)   Gid: (    0/    root)
```

Because the `mkdir` command uses the umask to modify the permissions placed on newly created files or directories, you can see `umask` at work in the permissions of the new directory: Its default permissions are set at 0750 after the umask subtracts 0027 from the full set of open permissions, 0777.

Similarly, a new file begins as 0666, which you could see if you were to set umask to 0000. But because umask is set by default to 0027, a new file's permissions are set to 0640.

So be aware of the default permissions on the directories and files that you create. Some system services and applications might require permissions other than the default. The systemd network service, for example, requires user-defined configuration files to be set to 644, not the default of 640. Thus, after you create a network configuration file with a `.network` extension, you must run the `chmod` command to set the new file's mode bits to `644`. Example:

```
chmod 644 10-static-en.network
```

For more information on permissions, see the man pages for `stat`, `umask`, and `acl`.

Disabling TLS 1.0 to Improve Transport Layer Security

Photon OS includes GnuTLS to help secure the transport layer. GnuTLS is a library that implements the SSL and TLS protocols to secure communications.

On Photon OS, SSL 3.0, which contains a known vulnerability, is disabled by default.

However, TLS 1.0, which also contains known vulnerabilities, is enabled by default.

To turn off TLS 1.0, make a directory named `/etc/gnutls` and then in `/etc/gnutls` create a file named `default-priorities`. In the `default-priorities` file, specify GnuTLS priority strings that remove TLS 1.0 and SSL 3.0 but retain TLS 1.1 and TLS 1.2.

After adding a new `default-priorities` file or after modifying it, you must restart all applications, including SSH, with an open TLS session for the changes to take effect.

Here is an example of a `default-priorities` file that contains GnuTLS priorities to disable TLS 1.0 and SSL 3.0:

```
cat /etc/gnutls/default-priorities
SYSTEM=NONE:!VERS-SSL3.0:!VERS-TLS1.0:+VERS-TLS1.1:+VERS-TLS1.2:+AES-128-CBC:+RSA:+SHA1:+COMP-NULL
```

This example priority string imposes system-specific policies. The NONE keyword means that no algorithms, protocols, or compression methods are enabled, so that you can enable specific versions individually later in the string. The example priority string then specifies that SSL version 3.0 and TLS version 1.0 be removed, as marked by the exclamation point. The priority string then enables, as marked by the plus sign, versions 1.1 and 1.2 of TLS. The cypher is AES-128-CBC. The key exchange is RSA. The MAC is SHA1. And the compression algorithm is COMP-NULL.

On Photon OS, you can verify the system-specific policies in the `default-priorities` file as follows.

Concatenate the `default-priorities` file to check its contents:

```
root@photon-rc [ ~ ]# cat /etc/gnutls/default-priorities
SYSTEM=NONE:!VERS-SSL3.0:!VERS-TLS1.0:+VERS-TLS1.1:+VERS-TLS1.2:+AES-128-CBC:+RSA:+SHA1:+COMP-NULL
```

Run the following command to check the protocols that are enabled for the system:

```
root@photon-rc [ /etc/gnutls ]# gnutls-cli --priority @SYSTEM -l
Cipher suites for @SYSTEM
TLS_RSA_AES_128_CBC_SHA1                              0x00, 0x2f      SSL3.0
```

```
Certificate types: none
Protocols: VERS-TLS1.1, VERS-TLS1.2
Compression: COMP-NULL
Elliptic curves: none
PK-signatures: none
```

For information about the GnuTLS priority strings, see https://gnutls.org/manual/html_node/Priority-Strings.html.

For information about the vulnerability in SSL 3.0, see SSL 3.0 Protocol Vulnerability and POODLE Attack.

For information about the vulnerabilities in TLS 1.0, see Guidelines for the Selection, Configuration, and Use of Transport Layer Security (TLS) Implementations.

Working with Repositories and Packages

The design of Photon OS simplifies life-cycle management and improves the security of packages. Photon OS seeks to reduce the burden and complexity of managing clusters of Linux machines by providing curated package repositories and by securing packages with GPG signatures.

Photon OS Package Repositories

The default installation of Photon OS includes four yum-compatible repositories plus the repository on the Photon OS ISO when it's available in a CD-ROM drive:

```
ls /etc/yum.repos.d/
lightwave.repo
photon-extras.repo
photon-iso.repo
photon-updates.repo
photon.repo
```

The Photon ISO repository (`photon-iso.repo`) contains the installation packages for Photon OS. All the packages that Photon builds and publishes reside in the RPMs directory of the ISO when it is mounted. The RPMs directory contains metadata that lets it act as a yum repository. Mounting the ISO gives you all the packages corresponding to a Photon OS build. If, however, you built Photon OS yourself from the source code, the packages correspond only to your build, though they will typically be the latest. In contrast, the ISO that you obtain from the Bintray web site contains only the packages that are in the ISO at the point of publication. As a result, the packages may no longer match those on Bintray, which are updated regularly.

The main Photon OS repository (`photon.repo`) contains all the packages that are built from the ISO or from another source. This repository points to a static batch of packages and spec files at the point of a release.

The updates repository (`photon-updates.repo`) is irrelevant to a major release until after the release is installed. Thereafter, the updates repository holds the updated packages for that release. The repository, that is, points to updates for the installed version, such as a version of Kubernetes that supersedes the version installed during the major release.

The Photon extras repository (`photon-extras.repo`) holds Likewise Open, an open source authentication engine, and other VMware software that you can add to Photon OS for free. Photon OS supports but does not build the packages in the extras repository. Similarly, the Lightwave repository (`lightwave.repo`) contains the packages that make up the VMware Lightwave security suite for cloud applications, including tools for identity management, access control, and certificate management.

Examining Signed Packages

Photon OS signs its packages and repositories with GPG signatures to bolster security. The GPG signature uses keyed-hash authentication method codes, typically the SHA1 algorithm and an MD5 checksum, to simultaneously verify the integrity and authentication of a package. Akeyed-hash message authentication code combines a cryptographic hash function with a secret cryptographic key.

In Photon OS, GPG signature verification automatically takes place when you install or update a package with the default package manager, tdnf. The default setting in the tdnf configuration file for checking the GPG is set to `1`, for true:

```
cat /etc/tdnf/tdnf.conf
[main]
gpgcheck=1
installonly_limit=3
clean_requirements_on_remove=true
repodir=/etc/yum.repos.d
cachedir=/var/cache/tdnf
```

On Photon OS, you can view the key with which VMware signs packages by running the following command:

```
rpm -qa gpg-pubkey*
```

The command returns the GPG public key:

```
gpg-pubkey-66fd4949-4803fe57
```

Once you have the name of the key, you can view information about the key with the `rpm -qi` command, as the following abridged output demonstrates:

```
rpm -qi gpg-pubkey-66fd4949-4803fe57
Name        : gpg-pubkey
Version     : 66fd4949
Release     : 4803fe57
Architecture: (none)
Install Date: Thu Jun 16 11:51:39 2016
Group       : Public Keys
Size        : 0
License     : pubkey
Signature   : (none)
Source RPM  : (none)
Build Date  : Tue Apr 15 01:01:11 2008
Build Host  : localhost
Relocations : (not relocatable)
Packager    : VMware, Inc. -- Linux Packaging Key -- <linux-packages@vmware.com>
Summary     : gpg(VMware, Inc. -- Linux Packaging Key -- <linux-packages@vmware.                        com>)
Description :
-----BEGIN PGP PUBLIC KEY BLOCK-----
Version: rpm-4.11.2 (NSS-3)
mI0ESAP+VwEEAMZylR8dOijUPNn3He3GdgM/kOXEhn3uQl+sRMNJUDm1qebi2D5b ...
```

If you have one of the RPMs from Photon OS on another Linux system, such as Ubuntu, you can check the status of the SHA and MD5 for the package to verify that it has not been tampered with:

```
rpm -K /home/steve/workspace/photon/stage/SRPMS/kubernetes-1.1.8-4.ph1.src.rpm
/home/steve/workspace/photon/stage/SRPMS/kubernetes-1.1.8-4.ph1.src.rpm: sha1 md5 OK
```

And then you can view the SHA1 digest and the MD5 digest by running the following command:

```
rpm -Kv /home/steve/workspace/photon/stage/SRPMS/kubernetes-1.1.8-4.ph1.src.rpm
/home/steve/workspace/photon/stage/SRPMS/kubernetes-1.1.8-4.ph1.src.rpm:
Header SHA1 digest: OK (89b55443d4c9f67a61ae0c1ec9bf4ece2d6aa32b)
        MD5 digest: OK (51eee659a8730e25fd2a52aff9a6c2c2)
```

The above examples show that the Kubernetes package has not been tampered with.

Building a Package from a Source RPM

This section describes how to install and build a package on the full version of Photon OS from the package's source RPM. You obtain the source RPMs that Photon OS uses from Bintray:

https://bintray.com/vmware/photon

To build a package from its source RPM, or SRPM, Photon OS requires the following packages:

- rpmbuild. This package is installed by default on the full version of Photon OS, so you should not have to install it.
- gcc. This package is also installed by default on the full version of Photon OS, so you should not have to install it.
- make, Cmake, automake, or another make package, depending on the package you are trying to install and build from its source RPM. Cmake is installed by default on Photon OS. You can install other make packages if need be by using tdnf or yum.

Another requirement is a local unprivileged user account other than the root account. You should build RPMs as an unprivileged user. Do not build a package as root--building an RPM with the root account might damage your system.

If you are building a package on a virtual machine running Photon OS in VMware vSphere, VMware Workstation, or VMware Fusion, take a snapshot of your virtual machine before building the package.

VMware recommends that you install and build packages from their source RPMs on the full version of Photon OS. Do not use the minimal version to work with source RPMs.

Here's how to install and build an example package--sed, in this case--from its source RPM on Photon OS with an unprivileged account.

First, check whether rpmbuild is installed by running the following command:

```
rpmbuild --version
```

If it is not installed, install it by running the following command as root:

```
tdnf install rpm-build
```

Second, create the directories for building RPMs under your local user account's home directory (not under root):

```
mkdir -p ~/rpmbuild/{BUILD,RPMS,SOURCES,SPECS,SRPMS}
```

Next, create a .rpmmacros file under your home directory and override the default location of the RPM building tree with the new one. This command overwrites an existing .rpmmacros file. Before running the following command, make sure you do not already have a .rpmmacros file; if a .rpmmacros file exists, back it up under a new name in case you want to restore it later.

```
echo '%_topdir %(echo $HOME)/rpmbuild' > ~/.rpmmacros
```

Now place the source RPM file that you want to install and build in the /tmp directory.

To install the source file, run the following command with your unprivileged user account, replacing the sed example source RPM with the name of the one that you want to install:

```
rpm -i /tmp/sed-4.2.2-2.ph1.src.rpm
```

The above command unpacks the source RPM and places its .spec file in your ~/rpmbuild/SPECS directory. In the next step, the rpmbuild tool uses the .spec file to build the RPM.

To build the RPM, run the following commands with your unprivileged user account. Again, replace the sed.spec example file with the name of the .spec file that you want to build.

```
cd ~/rpmbuild/SPECS
rpmbuild -ba sed.spec
```

If successful, the rpmbuild -ba command builds the RPM and generates an RPM package file in your ~/rpmbuild/RPMS/x86_64 directory. Example:

```
ls RPMS/x86_64/
sed-4.2.2-2.x86_64.rpm  sed-debuginfo-4.2.2-2.x86_64.rpm  sed-lang-4.2.2-2.x86_64.rpm
```

The rpmbuild command also generates a new SRPM file and saves it in your ~/rpmbuild/SRPMS directory. Example:

```
ls SRPMS/
sed-4.2.2-2.src.rpm
```

If the rpmbuild command is unsuccessful with an error that it cannot find a library, you must install the RPMs for the library that your source RPM depends on before you can successfully build your source RPM. Iterate through installing the libraries that your source RPM relies on until you can successfully build it.

To install the RPM, run the following command with your unprivileged user account:

```
rpm -i RPMS/x86_64/sed-4.2.2-2.x86_64.rpm
```

Compiling C++ Code on the Minimal Version of Photon OS

As a minimalist Linux run-time environment, the minimal version of Photon OS lacks the packages that you need to compile the code for a C++ program. For example, without the requisite packages, trying to compile the file containing the following code with the `gcc` command will generate errors:

```
#include <stdio.h>
int main()
{
return 0;
}
```

The errors look something like this:

```
gcc test.c
-bash: gcc: command not found
tdnf install gcc -y
gcc test.c
test.c:1:19: fatal error: stdio.h: No such file or directory
compilation terminated.
```

To enable the minimal version of Photon OS to preprocess, compile, assemble, and link C++ code, you must install the following packages as root with tdnf:

- gcc
- glibc-devel
- binutils

Here's the `tdnf` command to install these packages:

```
tdnf install gcc glibc-devel binutils
```

References

- Photon OS Troubleshooting Guide.

The following technical articles and guides appear in the Photon OS wiki:

- FAQ
- Running Photon OS on vSphere
- Running Photon OS on Fusion
- Install and Configure a Swarm Cluster with DNS Service on Photon OS
- Install and Configure a Production Ready Mesos Cluster on Photon OS
- Install and Configure Marathon for Mesos Cluster on Photon OS
- Install and Configure DCOS CLI for Mesos
- Install and Configure Mesos DNS on a Mesos Cluster

Photon OS Linux Troubleshooting Guide

Introduction

This guide describes the fundamentals of troubleshooting problems on Photon OS. An open-source minimalist Linux operating system from VMware, Photon OS is optimized for cloud computing platforms, VMware vSphere deployments, virtual appliances, and applications native to the cloud.

This guide covers the basics of troubleshooting systemd, packages, network interfaces, services such as SSH and Sendmail, the file system, and the Linux kernel. The guide includes a quick tour of the tools that you can use for troubleshooting and provides examples along the way. The guide also demonstrates how to access the system's log files.

For information on how to install and manage Photon OS, see the Photon OS Administration Guide.

Systemd and TDNF

Two characteristics of Photon OS stand out: It manages services with systemd, and it manages packages with its own open source, yum-compatible package manager called tdnf, for Tiny DNF.

By using systemd, Photon OS adopts a contemporary Linux standard to bootstrap the user space and concurrently start services--an architecture that differs from traditional Linux systems such as SUSE Linux Enterprise Server 11.

A traditional Linux system contains an initialization system called SysVinit. With SLES 11, for instance, SysVinit-style init programs control how the system starts up and shuts down. Init implements system runlevels. A SysVinit runlevel defines a state in which a process or service runs. In contrast to a SysVinit system, systemd defines no such runlevels. Instead, systemd uses a dependency tree of *targets* to determine which services to start when.

Because the systemd commands differ from those of an init.d-based Linux system, a section later in this guide illustrates how to troubleshoot by using systemctl commands instead of init.d-style commands.

Tdnf keeps the operating system as small as possible while preserving yum's robust package-management capabilities. On Photon OS, tdnf is the default package manager for installing new packages. Since troubleshooting with tdnf differs from using yum, a later section of this guide describes how to solve problems with packages and repositories by using tdnf commands.

The Root Account and the `sudo` and `su` Commands

This guide assumes that you are logged in to Photon OS with the root account and running commands as root. The sudo program comes with the full version of Photon OS. On the minimal version, you must install sudo with tdnf if you want to use it. As an alternative to installing sudo on the minimal version, you can switch users as needed with the `su` command to run commands that require root privileges.

Checking the Version and Build Number

To check the version and build number of Photon OS, concatenate `/etc/photon-release`. Example:

```
cat /etc/photon-release
VMware Photon Linux 1.0
PHOTON_BUILD_NUMBER=a6f0f63
```

The build number in the results maps to the commit number on the VMware Photon OS GitHub commits page.

General Best Practices

When troubleshooting, you should follow some general best practices:

- **Take a snapshot.** Before you do anything to a virtual machine running Photon OS, take a snapshot of the VM so that you can restore it if need be.
- **Make a backup copy.** Before you change a configuration file, make a copy of the original in case you need to restore it later; example: `cp /etc/tdnf/tdnf.conf /etc/tdnf/tdnf.conf.orig`
- **Collect logs.** Save the log files associated with a Photon OS problem; you or others might need them later. Include not only the log files on the guest but also the `vmware.log` file on the host; `vmware.log` is in the host's directory that contains the VM.
- **Know what's in your toolbox.** Glance at the man page for a tool before you use it so that you know what your options are. The options can help focus the command's output on the problem you're trying to solve.
- **Understand the system.** The more you know about the operating system and how it works, the better you can troubleshoot.

Logs on Photon OS

On Photon OS, all the system logs except the installation log and the cloud-init log are written into the systemd journal. The `journalctl` command queries the contents of the systemd journal.

The installation log files and the cloud-init log files reside in `/var/log`. If Photon OS is running on a virtual machine in a VMware hypervisor, the log file for the VMware tools (vmware-vmsvc.log) also resides in `/var/log`.

Troubleshooting Progression

If you encounter a problem running an application or appliance on Photon OS and you suspect it involves the operating system, you can troubleshoot by proceeding as follows.

First, check the services running on Photon OS:

```
systemctl status
```

Second, check your application's log files for clues. (For VMware applications, see Location of Log Files for VMware Products.)

Third, check the service controller or service monitor for your application or appliance.

Fourth, check the network interfaces and other aspects of the network service with `systemd-network` commands.

Fifth, check the operating system's log files:

```
journalctl
```

Next, run the following commands to view all services according to the order in which they were started:

```
systemd-analyze critical-chain
```

Finally, if the previous steps have not revealed enough information to isolate the problem, turn to the troubleshooting tool that you think is most likely to help with the issue at hand. You could, for example, use `strace` to identify the location of the failure. See the list of troubleshooting tools on Photon OS in a later section.

Solutions to Common Problems

This section describes solutions to problems that you're likely to encounter.

Resetting a Lost Root Password

Here's how to reset a lost root password.

First, restart the Photon OS machine or the virtual machine running Photon OS. When the Photon OS splash screen appears as it restarts, type the letter `e` to go to the GNU GRUB edit menu. Be quick about it: Because Photon OS reboots so quickly, you won't have much time to type `e`. Remember that in vSphere and Workstation, you might have to give the console focus by clicking in its window before it will register input from the keyboard.

Second, in the GNU GRUB edit menu, go to the end of the line that starts with `linux`, add a space, and then add the following code exactly as it appears below:

```
rw init=/bin/bash
```

After you add this code, the GNU GRUB edit menu should look exactly like this:

Now type `F10`.

At the command prompt, type `passwd` and then type (and re-enter) a new root password that conforms to the password complexity rules of Photon OS. Remember the password.

Next, type the following command:

```
umount /
```

Finally, type the following command. You must include the `-f` option to force a reboot; otherwise, the kernel enters a state of panic.

```
reboot -f
```

This sequence of commands should look like this:

After the Photon OS machine reboots, log in with the new root password.

Fixing Permissions on Network Config Files

If you, as the root user, create a new network configuration file on Photon OS, the network service might be unable to process it until you set the file's mode bits to `644`.

If you query the journal with `journalctl -u systemd-networkd`, you might see the following error message along with an indication that the network service did not start:

```
could not load configuration files. permission denied
```

The permissions on the network files are the likely cause of this problem. Without the correct permissions, networkd-systemd cannot parse and apply the settings, and the network configuration that you created will not be loaded.

After you create a network configuration file with a `.network` extension, you must run the `chmod` command to set the new file's mode bits to `644`. Example:

```
chmod 644 10-static-en.network
```

For Photon OS to apply the new configuration, you must restart the `systemd-networkd` service by running the following command:

```
systemctl restart systemd-networkd
```

Permitting Root Login with SSH

The full version of Photon OS prevents root login with SSH by default. To permit root login over SSH, open `/etc/ssh/sshd_config` with the vim text editor and set `PermitRootLogin` to `yes`.

Vim is the default text editor available in both the full and minimal versions of Photon OS. (Nano is also in the full version.) After you modify the SSH daemon's configuration file, you must restart the sshd daemon for the changes to take effect. Example:

```
vim /etc/ssh/sshd_config

# override default of no subsystems
Subsystem       sftp    /usr/libexec/sftp-server

# Example of overriding settings on a per-user basis
#Match User anoncvs
```

```
#       X11Forwarding no
#       AllowTcpForwarding no
#       PermitTTY no
#       ForceCommand cvs server
PermitRootLogin yes
UsePAM yes
```

Save your changes in vim and then restart the sshd daemon:

```
systemctl restart sshd
```

You can then connect to the Photon OS machine with the root account over SSH:

```
steve@ubuntu:~$ ssh root@198.51.100.131
```

Fixing Sendmail If Installed Before an FQDN Was Set

If Sendmail is behaving improperly or if it hangs during installation, it is likely that an FQDN is not set. Take the following corrective action.

First, set an FQDN for your Photon OS machine.

Then, run the following commands in the order below:

```
echo $(hostname -f) > /etc/mail/local-host-names

cat > /etc/mail/aliases << "EOF"
    postmaster: root
    MAILER-DAEMON: root
    EOF

/bin/newaliases

cd /etc/mail

m4 m4/cf.m4 sendmail.mc > sendmail.cf

chmod 700 /var/spool/clientmqueue

chown smmsp:smmsp /var/spool/clientmqueue
```

Common Troubleshooting Tools on Photon OS

This section describes tools that can help troubleshoot problems. These tools are installed by default on the full version of Photon OS. On the minimal version of Photon OS, you may have to install a tool before you can use it.

There is a manual, or man page, on Photon OS for all the tools covered in this section. The man pages provide more information about each tool's commands, options, and output. To view a tool's man page, on the Photon OS command line, type `man` and then the name of the tool. Example:

```
man strace
```

Some of the examples in this section are marked as abridged with ellipsis (`...`).

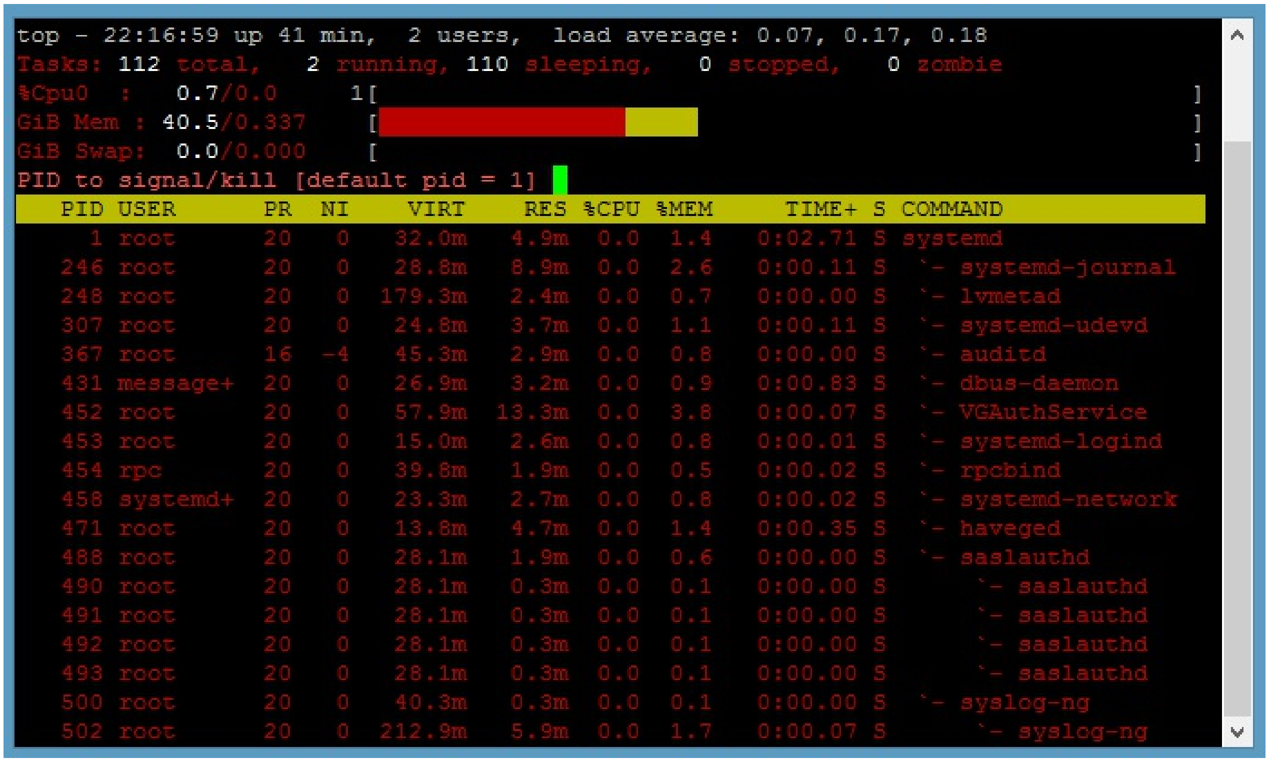
Top

Photon OS includes the Top tool to monitor system resources, workloads, and performance. It can unmask problems caused by processes or applications overconsuming CPUs, time, or RAM.

To view a textual display of resource consumption, run the `top` command:

```
top
```

In Top, you can kill a runaway or stalled process by typing `k` followed by its process ID (PID).



If the percent of CPU utilization is consistently high with little idle time, there might be a runaway process overconsuming CPUs. Restarting the service might solve the problem.

A handy trick while troubleshooting an unknown issue is to run Top in the background by using batch mode to write its output to a file in order to collect data about performance:

```
top d 120 b >> top120second.output
```

For a list of options that filter top output and other information, see the man page for Top.

ps

The `ps` tool shows the processes running on the machine. The `ps` tool derives flexibility and power from its options, all of which are covered in the tool's Photon OS man page:

```
man ps
```

Here are several popular invocations of `ps` for troubleshooting.

Show processes by user:

```
ps aux
```

Show processes and child processes by user:

```
ps auxf
```

Show processes containing the string `ssh` :

```
ps aux | grep ssh
```

Show processes and the command and options with which they were started:

```
ps auxww
```

Example abridged output:

```
ps auxww
USER       PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root         1  0.0  0.9  32724  3300 ?        Ss   07:51   0:32 /lib/systemd/systemd --switched-root --system --deserialize 22
```

netstat

The `netstat` command can identify bottlenecks causing performance issues. It lists network connections, listening sockets, port information, and interface statistics for different protocols. Examples:

```
netstat --statistics
netstat --listening
```

find

The `find` command can be a useful starting point to troubleshoot a Photon OS machine that has stopped working. The following command, for example, lists the files in the root directory that have changed in the past day:

```
    find / -mtime -1
```

See the `find` manual. Take note of the security considerations listed in the `find` manual if you are using `find` to troubleshoot an appliance running on Photon OS.

Locate

The `locate` command is a fast way to find files and directories when all you have is a keyword. Similar to `find` and part of the same `findutils` package preinstalled on the full version of Photon OS by default, the `locate` command finds file names in the file names database. Before you can use `locate` accurately, you should update its database:

```
updatedb
```

Then you can run `locate` to quickly find a file, such as any file name containing `.network` , which can be helpful to see all the system's `.network` configuration files; abridged example:

```
locate .network
/etc/dbus-1/system.d/org.freedesktop.network1.conf
/etc/systemd/network/10-dhcp-en.network
/usr/lib/systemd/network/80-container-host0.network
/usr/lib/systemd/network/80-container-ve.network
/usr/lib/systemd/system/busnames.target.wants/org.freedesktop.network1.busname
/usr/lib/systemd/system/dbus-org.freedesktop.network1.service
/usr/lib/systemd/system/org.freedesktop.network1.busnname
/usr/share/dbus-1/system-services/org.freedesktop.network1.service
```

The `locate` command is also a quick way to see whether a troubleshooting tool is installed on Photon OS. Examples:

```
locate strace
/usr/bin/strace
/usr/bin/strace-graph
/usr/bin/strace-log-merge
/usr/share/man/man1/strace.1.gz
/usr/share/vim/vim74/syntax/strace.vim

locate traceroute
```

The `strace` tool is there but `traceroute` is not. You can, however, quickly install `traceroute` from the Photon OS repository:

```
tdnf install traceroute
```

df

The `df` command reports the disk space available on the file system. Because running out of disk space can lead an application to fail, a quick check of the available space makes sense as an early troubleshooting step:

```
df -h
```

The `-h` option prints out the available and used space in human-readable sizes. After checking the space, you should also check the number of available inodes. Too few available inodes can lead to difficult-to-diagnose problems:

```
df -i
```

md5sum and sha256sum

`md5sum` calculates 128-bit MD5 hashes--a message digest, or digital signature, of a file--to uniquely identify a file and verify its integrity after file transfers, downloads, or disk errors when the security of the file is not in question. Photon OS also includes `sha256sum`, which is the preferred method of calculating the authenticity of a file to prevent tampering when security is a concern. Photon OS also includes `shasum`, `sha1sum`, `sha384sum`, and `sha512sum`. See the man pages for `md3sum`, `sha256sum`, and the other SHA utilities.

`md5sum` can help troubleshooting installation issues by verifying that the version of Photon OS being installed matches the version on the Bintray download page. If, for instance, bytes were dropped during the download, the checksums will not match. Try downloading it again.

strace

The `strace` utility follows system calls and signals as they are executed so that you can see what an application, command, or process is doing. `strace` can trace failed commands, identify where a process obtains its configuration, monitor file activity, and find the location of a crash.

By tracing system calls, `strace` can help troubleshoot a broad range of problems, including issues with input-output, memory, interprocess communication, network usage, and application performance.

For troubleshooting a problem that gives off few or no clues, the following command displays every system call:

```
strace ls -al
```

With strace commands, you can route the output to a file to make it easier to analyze:

```
strace -o output.txt ls -al
```

`strace` can reveal the files that an application is trying to open with the `-eopen` option. This combination can help troubleshoot an application that is failing because it is missing files or being denied access to a file it needs. If, for example, you see "No such file or directory" in the results of `strace -eopen`, something might be wrong:

```
strace -eopen sshd
open("/usr/lib/x86_64/libpam.so.0", O_RDONLY|O_CLOEXEC) = -1 ENOENT (No such file or directory)
open("/usr/lib/libpam.so.0", O_RDONLY|O_CLOEXEC) = 3
```

In the results above, it's OK that the first file is missing because it is found in the next line. In other cases, the application might be unable to open one of its configuration files or reading the wrong one. If the results say "permission denied" for one of the files, check the permissions of the file with `ls -l` or `stat`.

When troubleshooting with `strace`, you can include the process ID in its commands. Here's an example of how to find a process ID:

```
ps -ef | grep apache
```

And you can then use `strace` to examine the file a process is working with:

```
strace -e trace=file -p 1719
```

A similar command can trace network traffic:

```
strace -p 812 -e trace=network
```

If an application is crashing, use `strace` to trace the application and then analyze what happens right before the application crashes.

You can also trace the child processes that an application spawns with the fork system call, and you can do so with systemctl commands that start a process to identify why an application crashes immediately or fails to start:

```
strace -f -o output.txt systemctl start httpd
```

Here's another example. If journalctl is showing that networkd is failing, you can run strace to help determine why:

```
strace -o output.txt systemctl restart systemd-networkd
```

And then grep inside the results for something, such as *exit* or *error*:

```
grep exit output.txt
```

Maybe the results indicate systemd-resolved is going wrong, and you can then strace it, too:

```
strace -f -o output.txt systemctl restart systemd-resolved
```

file

The `file` command determines the file type, which can help troubleshoot problems when an application mistakes one type of file for another, leading it to misbehave. Example:

```
file /usr/sbin/sshd
/usr/sbin/sshd: ELF 64-bit LSB shared object, x86-64, version 1 (SYSV), dynamically linked, interpreter /lib64/ld-linux-x86-64.so.2, for G
NU/Linux 2.6.32, stripped
```

stat

The `stat` command can help troubleshoot problems with files or the file system by showing the last date it was modified and other information. Example:

```
stat /dev/sda1
File: '/dev/sda1'
Size: 0               Blocks: 0          IO Block: 4096   block special file
Device: 6h/6d   Inode: 6614        Links: 1     Device type: 8,1
Access: (0660/brw-rw----)  Uid: (    0/    root)   Gid: (    8/    disk)
Access: 2016-09-02 12:23:56.135999936 +0000
Modify: 2016-09-02 12:23:52.879999981 +0000
Change: 2016-09-02 12:23:52.879999981 +0000
Birth: -
```

On Photon OS, `stat` is handy to show permissions for a file or directory in both their absolute octal notation and their read-write-execute abbreviation; truncated example:

```
chmod 777 tester.md
stat tester.md
  File: 'tester.md'
  Size: 0               Blocks: 0          IO Block: 4096   regular empty file
Device: 801h/2049d      Inode: 316385      Links: 1
Access: (0777/-rwxrwxrwx)  Uid: (    0/    root)   Gid: (    0/    root)
```

watch

The `watch` utility runs a command at regular intervals so you can observe how its output changes over time. `watch` can help dynamically monitor network links, routes, and other information when you are troubleshooting networking or performance issues. Examples:

```
watch -n0 --differences ss
watch -n1 --differences ip route
```

Here's another example with a screenshot of the command's output. This command monitors the traffic on your network links. The highlighted numbers are updated every second so you can see the traffic fluctuating:

```
watch -n1 --differences ip -s link show up
```

```
Every 1.0s: ip -s link show up                    Thu Sep 22 20:41:00 2016

1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN mode
 DEFAULT group default qlen 1
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    RX: bytes  packets  errors  dropped overrun mcast
    304304952  1041779  0       0       0       0
    TX: bytes  packets  errors  dropped carrier collsns
    304304952  1041779  0       0       0       0
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state
 UP mode DEFAULT group default qlen 1000
    link/ether 00:0c:29:bf:0c:65 brd ff:ff:ff:ff:ff:ff
    RX: bytes  packets  errors  dropped overrun mcast
    762811835  551398   0       0       0       0
    TX: bytes  packets  errors  dropped carrier collsns
    16352679   52289    0       0       0       0
```

vmstat and fdisk

The `vmstat` tool displays statistics about virtual memory, processes, block input-output, disks, and CPU activity. This tool can help diagnose performance problems, especially system bottlenecks.

Its output on a Photon OS virtual machine running in VMware Workstation 12 Pro without a heavy load looks like this:

```
vmstat
procs -----------memory---------- ---swap-- -----io---- -system-- ------cpu-----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0   5980  72084 172488    0    0    27    44  106  294  1  0 98  1  0
```

What do all these codes mean? They are explained in the vmstat man page.

If `r`, the number of runnable processes, is higher than 10, the machine is under stress; consider intervening to reduce the number of processes or to distribute some of the processes to other machines. In other words, the machine has a bottleneck in executing processes.

If `cs`, the number of context switches per second, is really high, there may be too many jobs running on the machine.

If `in`, the number of interrupts per second, is relatively high, there might be a bottleneck for network or disk IO.

You can investigate disk IO further by using vmstat's `-d` option to report disk statistics; abridged example on a machine with little load:

```
vmstat -d
disk- ------------reads------------ ------------writes----------- -----IO------
       total merged sectors      ms  total merged sectors      ms    cur    sec
ram0       0      0       0       0      0      0       0       0      0      0
ram1       0      0       0       0      0      0       0       0      0      0
loop0      0      0       0       0      0      0       0       0      0      0
loop1      0      0       0       0      0      0       0       0      0      0
sr0        0      0       0       0      0      0       0       0      0      0
sda    22744    676  470604   12908  72888  24949  805224  127692      0    130
```

The `-D` option summarizes disk statistics:

```
vmstat -D
           26 disks
            2 partitions
        22744 total reads
          676 merged reads
       470604 read sectors
        12908 milli reading
        73040 writes
        25001 merged writes
       806872 written sectors
       127808 milli writing
            0 inprogress IO
          130 milli spent IO
```

You can also get statistics about a partition. First, run the `fdisk -l` command to list the machine's devices. Then run `vmstat -p` with the name of a device to view its stats:

```
fdisk -l
Disk /dev/ram0: 4 MiB, 4194304 bytes, 8192 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 4096 bytes
I/O size (minimum/optimal): 4096 bytes / 4096 bytes
...
Device        Start      End  Sectors Size Type
/dev/sda1      2048 16771071 16769024   8G Linux filesystem
/dev/sda2  16771072 16777182     6111   3M BIOS boot

vmstat -p /dev/sda1
sda1          reads   read sectors  writes    requested writes
```

```
              22579     473306      78510     866088
```

See the vmstat man page for more options.

lsof

The `lsof` command lists open files. And this tool's definition of an open file is quite broad--directories, libraries, streams, domain sockets, and Internet sockets are all considered files, making `lsof` broadly applicable as a mid-level troubleshooting tool to identify the files a process is using. Because a Linux system like Photon OS uses files to do its work, you can run `lsof` as root to see how the system is using them and to see how an application works.

If, for example, you cannot unmount a disk because it is in use, you can run `lsof` to identify the files on the disk that are being used. Here's an example showing what's using the root directory:

```
lsof /root
COMMAND    PID USER   FD   TYPE DEVICE SIZE/OFF   NODE NAME
bash       879 root  cwd    DIR    8,1     4096 262159 /root
bash      1265 root  cwd    DIR    8,1     4096 262159 /root
sftp-serv 1326 root  cwd    DIR    8,1     4096 262159 /root
gdb       1351 root  cwd    DIR    8,1     4096 262159 /root
bash      1395 root  cwd    DIR    8,1     4096 262159 /root
lsof      1730 root  cwd    DIR    8,1     4096 262159 /root
```

You can do the same with an application or virtual appliance by running `lsof` with the user name or process ID of the app. Here's an example that lists the open files used by the Apache HTTP Server:

```
lsof -u apache
```

Running the command with the `-i` option lists all the open network and Internet files, which can help troubleshoot network problems:

```
lsof -i
```

See the Unix socket addresses of a user like *zookeeper*:

```
lsof -u zookeeper -U
```

And here's an example that shows the processes running on Ports 1 through 80:

```
lsof -i TCP:1-80
COMMAND  PID   USER   FD   TYPE DEVICE SIZE/OFF NODE NAME
httpd    403   root    3u  IPv6  10733      0t0  TCP *:http (LISTEN)
httpd    407 apache    3u  IPv6  10733      0t0  TCP *:http (LISTEN)
httpd    408 apache    3u  IPv6  10733      0t0  TCP *:http (LISTEN)
httpd    409 apache    3u  IPv6  10733      0t0  TCP *:http (LISTEN)
sshd     820   root    3u  IPv4  11336      0t0  TCP *:ssh (LISTEN)
sshd     820   root    4u  IPv6  11343      0t0  TCP *:ssh (LISTEN)
sshd    1258   root    3u  IPv4  48040      0t0  TCP 198.51.100.143:ssh->198.51.100.1:49759 (ESTABLISHED)
sshd    1319   root    3u  IPv4  50866      0t0  TCP 198.51.100.143:ssh->198.51.100.1:51054 (ESTABLISHED)
sshd    1388   root    3u  IPv4  56438      0t0  TCP 198.51.100.143:ssh->198.51.100.1:60335 (ESTABLISHED)
```

You can also inspect the files opened by a process ID. Here's a truncated example that queries the files open by the systemd network service:

```
lsof -p 1917
COMMAND    PID            USER   FD      TYPE             DEVICE SIZE/OFF   NODE NAME
systemd-n 1917 systemd-network  cwd       DIR                8,1     4096      2 /
systemd-n 1917 systemd-network  txt       REG                8,1   887896 272389 /usr/lib/systemd/systemd-networkd
```

```
systemd-n 1917 systemd-network  mem       REG                8,1   270680 262267 /usr/lib/libnss_files-2.22.so
systemd-n 1917 systemd-network    0r      CHR                1,3      0t0   5959 /dev/null
systemd-n 1917 systemd-network    1u     unix 0x0000000000000000      0t0  45734 type=STREAM
systemd-n 1917 systemd-network    3u  netlink                         0t0   6867 ROUTE
systemd-n 1917 systemd-network    4u     unix 0x0000000000000000      0t0  45744 type=DGRAM
systemd-n 1917 systemd-network    9u  netlink                         0t0  45754 KOBJECT_UEVENT
systemd-n 1917 systemd-network   12u  a_inode               0,11        0   5955 [timerfd]
systemd-n 1917 systemd-network   13u     IPv4             104292      0t0    UDP 198.51.100.143:bootpc
```

fuser

The `fuser` command identifies the process IDs of processes using files or sockets. The term *process* is, in this case, synonymous with *user*. To identify the process ID of a process using a socket, run `fuser` with its namespace option and specify `tcp` or `udp` and the name of the process or port. Examples:

```
fuser -n tcp ssh
ssh/tcp:              940  1308
fuser -n tcp http
http/tcp:             592   594   595   596
fuser -n tcp 80
80/tcp:               592   594   595   596
```

ldd

By revealing the shared libraries that a program depends on, `ldd` can help troubleshoot an application that is missing a library or finding the wrong one.

If, for example, you find output that says "file not found," check the path to the library.

```
ldd /usr/sbin/sshd
linux-vdso.so.1 (0x00007ffc0e3e3000)
libpam.so.0 => (file not found)
libcrypto.so.1.0.0 => /usr/lib/libcrypto.so.1.0.0 (0x00007f624e570000)
```

You can also use the `objdump` command to show dependencies for a program's object files; example:

```
objdump -p /usr/sbin/sshd | grep NEEDED
```

gdb

The gdb tool is the GNU debugger. It lets you peer inside a program while it executes or when it crashes so that you can catch bugs on the fly. The gdb tool is typically used to debug programs written in C and C++. On Photon OS, gdb can help you determine why an application crashed. See the man page for gdb for instructions on how to run it. For an extensive example on how to use gdb to troubleshoot Photon OS running on a VM when you cannot login to Photon OS, see the section on troubleshooting boot and logon problems.

Other Troubleshooting Tools Installed by Default

The following troubleshooting tools are included in the full version of Photon OS:

- `grep` searches files for patterns.
- `ping` tests network connectivity.
- `strings` displays the characters in a file to identify its contents.
- `lsmod` lists loaded modules.
- `ipcs` shows data about the inter-process communication (IPC) resources to which a process has read access--typically, shared memory segments, message queues, and semaphore arrays.
- `nm` lists symbols from object files.

- `diff` compares files side by side. Useful to compare two configuration files when one version works and the other doesn't.

Installing More Tools from Repositories

You can install several troubleshooting tools from the Photon OS repositories by using the default package management system, `tdnf`.

If a tool you need is not installed, the first thing you should do is search the repositories to see whether it's available. The traceroute tool, for example, is not installed by default. Here's how to search for it in the repositories:

```
tdnf search traceroute
traceroute : Traces the route taken by packets over an IPv4/IPv6 network
```

The results of the above command show that traceroute exists in the repository. You install it with `tdnf`:

```
tdnf install traceroute
```

Additional tools are not installed by default but are in the repository for instant installation with `tdnf`:

- `net-tools`: networking tools.
- `ltrace`: tool for intercepting and recording dynamic library calls. It can identify the function an application was calling when it crashed, making it useful for debugging.
- `nfs-utils`: client tools for the kernel Network File System, or NFS, including showmount; installed by default in the full version of Photon OS but not in the minimal version.
- `pcstat`: A tool that inspects which pages of a file or files are being cached by the Linux kernel.
- `sysstat` and `sar`: Utilities to monitor system performance and usage activity. Installing sysstat also installs sar.
- `systemtap` and `crash`: The systemtap utility is a programmable instrumentation system for diagnosing problems of performance or function. Installing systemtap also installs crash, which is a kernel crash analysis utility for live systems and dump files.
- `dstat`: versatile tool for viewing and analyzing statistics about system resources.

The `dstat` tool, for example, can help troubleshoot system performance. The tool shows a live, running list of statistics about system resources:

```
dstat
You did not select any stats, using -cdngy by default.
----total-cpu-usage---- -dsk/total- -net/total- ---paging-- ---system--
usr sys idl wai hiq siq| read  writ| recv  send|  in   out | int   csw
  1   0  98   1   0   0|4036B   42k|   0     0 |   0     0 |  95   276
  1   0  98   1   0   0|   0    64k|  60B  940B|   0     0 | 142   320
  1   1  98   0   0   0|   0    52k|  60B  476B|   0     0 | 149   385
```

Linux Troubleshooting Tools Not on Photon OS

The following Linux troubleshoot tools are neither installed on Photon OS by default nor available in the Photon OS repositories:

- iostat
- telnet (use SSH instead)
- Iprm
- hdparm
- syslog (use journalctl instead)
- ddd
- ksysmoops
- xev
- GUI tools (because Photon OS has no GUI)

Systemd

Photon OS manages services with systemd and its command-line utility for inspecting and controlling the system, `systemctl`, not the deprecated commands of init.d. For example, instead of running the /etc/init.d/ssh script to stop and start the OpenSSH server on a init.d-based Linux system, you control the service by running the following systemctl commands on Photon OS:

```
systemctl stop sshd
systemctl start sshd
```

For an overview of systemd, see systemd System and Service Manager and the man page for systemd. The systemd man pages are listed at https://www.freedesktop.org/software/systemd/man/.

Viewing Services

To view a description of all the active, loaded units, execute the systemctl command without any options or arguments:

```
systemctl
```

To see all the loaded, active, and inactive units and their description, run this command:

```
systemctl --all
```

To see all the unit files and their current status but no description, run this command:

```
systemctl list-unit-files
```

The `grep` command filters the services by a search term, a helpful tactic to recall the exact name of a unit file without looking through a long list of names. Example:

```
systemctl list-unit-files | grep network
org.freedesktop.network1.busname           static
dbus-org.freedesktop.network1.service      enabled
systemd-networkd-wait-online.service       enabled
systemd-networkd.service                   enabled
systemd-networkd.socket                    enabled
network-online.target                      static
network-pre.target                         static
network.target
```

Using Systemd Commands Instead of Init.d Commands

Basic system administration commands on Photon OS differ from those on operating systems that use SysVinit. Since Photon OS uses systemd instead of SysVinit, you must use systemd commands to manage services.

For example, to list all the services that you can manage on Photon OS, you run the following command instead of `ls /etc/rc.d/init.d/`:

```
systemctl list-unit-files --type=service
```

Similarly, to check whether the `sshd` service is enabled, on Photon OS you run the following command instead of `chkconfig sshd`:

```
systemctl is-enabled sshd
```

The `chkconfig --list` command that shows which services are enabled for which runlevel on a SysVinit computer becomes substantially different on Photon OS because there are no runlevels, only targets:

```
ls /etc/systemd/system/*.wants
```

You can also display similar information with the following command:

```
systemctl list-unit-files --type=service
```

Here is a list of some of the systemd commands that take the place of SysVinit commands on Photon OS:

```
USE THIS SYSTEMD COMMAND     INSTEAD OF THIS SYSVINIT COMMAND
systemctl start sshd         service sshd start
systemctl stop sshd         service sshd stop
systemctl restart sshd         service sshd restart
systemctl reload sshd         service sshd reload
systemctl condrestart sshd     service sshd condrestart
systemctl status sshd         service sshd status
systemctl enable sshd         chkconfig sshd on
systemctl disable sshd         chkconfig sshd off
systemctl daemon-reload        chkconfig sshd --add
```

Analyzing System Logs with journalctl

The journalctl tool queries the contents of the systemd journal. On Photon OS, all the system logs except the installation log and the cloud-init log are written into the systemd journal.

If called without parameters, the `journalctl` command shows all the contents of the journal, beginning with the oldest entry. To display the output in reverse order with new entries first, include the `-r` option in the command:

```
journalctl -r
```

The `journalctl` command includes many options to filter its output. For help troubleshooting systemd, two journalctl queries are particularly useful: showing the log entries for the last boot and showing the log entries for a systemd service unit. This command displays the messages that systemd generated during the last time the machine started:

```
journalctl -b
```

This command reveals the messages for only the systemd service unit specified by the `-u` option, which in the following example is the auditing service:

```
journalctl -u auditd
```

You can look at the messages for systemd itself or for the network service:

```
journalctl -u systemd
journalctl -u systemd-networkd
```

Example:

```
root@photon-1a0375a0392e [ ~ ]# journalctl -u systemd-networkd
-- Logs begin at Tue 2016-08-23 14:35:50 UTC, end at Tue 2016-08-23 23:45:44 UTC. --
Aug 23 14:35:52 photon-1a0375a0392e systemd[1]: Starting Network Service...
Aug 23 14:35:52 photon-1a0375a0392e systemd-networkd[458]: Enumeration completed
Aug 23 14:35:52 photon-1a0375a0392e systemd[1]: Started Network Service.
Aug 23 14:35:52 photon-1a0375a0392e systemd-networkd[458]: eth0: Gained carrier
Aug 23 14:35:53 photon-1a0375a0392e systemd-networkd[458]: eth0: DHCPv4 address 198.51.100.1
```

```
Aug 23 14:35:54 photon-1a0375a0392e systemd-networkd[458]: eth0: Gained IPv6LL
Aug 23 14:35:54 photon-1a0375a0392e systemd-networkd[458]: eth0: Configured
```

For more information, see journalctl or the journalctl man page by running this command: `man journalctl`

Inspecting Services with `systemd-analyze`

The `systemd-analyze` command reveals performance statistics for boot times, traces system services, and verifies unit files. It can help troubleshoot slow system boots and incorrect unit files. See the man page for a list of options. Examples:

```
systemd-analyze blame

systemd-analyze dump
```

Networking

Managing the Network Configuration

The network service, which is enabled by default, starts when the system boots. You manage the network service by using systemd commands, such as systemd-networkd, systemd-resolvd, and networkctl. You can check its status of the network service by running the following command:

```
systemctl status systemd-networkd
```

Here is a healthy result of the command:

```
* systemd-networkd.service - Network Service
   Loaded: loaded (/usr/lib/systemd/system/systemd-networkd.service; enabled; vendor preset: enabled)
   Active: active (running) since Fri 2016-04-29 15:08:51 UTC; 6 days ago
     Docs: man:systemd-networkd.service(8)
 Main PID: 291 (systemd-network)
   Status: "Processing requests..."
   CGroup: /system.slice/systemd-networkd.service
           `-291 /lib/systemd/systemd-networkd
```

Because Photon OS relies on systemd to manage services, you should employ the systemd suite of commands, not deprecated init.d commands or other deprecated commands, to manage networking.

Use `ip` and `ss` Commands Instead of `ifconfig` and `netstat`

Although the `ifconfig` command and the `netstat` command work on Photon OS, VMware recommends that you use the `ip` or `ss` commands. The `ifconfig` and `netstat` commands are deprecated.

For example, instead of running `netstat` to display a list of network interfaces, consider running the `ss` command. Similarly, to display information for IP addresses, instead of running `ifconfig -a`, run the `ip addr` command. Examples:

```
USE THIS IPROUTE COMMAND     INSTEAD OF THIS NET-TOOL COMMAND
ip addr                     ifconfig -a
ss                            netstat
ip route                     route
ip maddr                     netstat -g
ip link set eth0 up         ifconfig eth0 up
ip -s neigh                   arp -v
ip link set eth0 mtu 9000    ifconfig eth0 mtu 9000
```

Using the `ip route` version of a command instead of the net-tools version often provides more complete, accurate information on Photon OS, as the following example demonstrates:

```
ip neigh
198.51.100.2 dev eth0 lladdr 00:50:56:e2:02:0f STALE
198.51.100.254 dev eth0 lladdr 00:50:56:e7:13:d9 STALE
198.51.100.1 dev eth0 lladdr 00:50:56:c0:00:08 DELAY

arp -a
? (198.51.100.2) at 00:50:56:e2:02:0f [ether] on eth0
? (198.51.100.254) at 00:50:56:e7:13:d9 [ether] on eth0
? (198.51.100.1) at 00:50:56:c0:00:08 [ether] on eth0
```

Important: If you modify an IPv6 configuration or add an IPv6 interface, you must restart `systemd-networkd`. Traditional methods of using `ifconfig` commands will be inadequate to register the changes. Run the following command instead:

```
systemctl restart systemd-networkd
```

Inspecting the Status of Network Links with `networkctl`

The `networkctl` command shows information about network connections that helps you configure networking services and troubleshoot networking problems. You can, for example, progressively add options and arguments to the `networkctl` command to move from general information about network connections to specific information about a network connection.

Running `networkctl` without options defaults to the list command:

```
networkctl
IDX LINK             TYPE               OPERATIONAL SETUP
  1 lo               loopback           carrier     unmanaged
  2 eth0             ether              routable    configured
  3 docker0          ether              routable    unmanaged
 11 vethb0aa7a6      ether              degraded    unmanaged
 4 links listed.
```

Running `networkctl` with the status command displays information that looks like this; you can see there are active network links with IP addresses for not only the Ethernet connection but also a Docker container.

```
root@photon-rc [ ~ ]# networkctl status
*      State: routable
     Address: 198.51.100.131 on eth0
              172.17.0.1 on docker0
              fe80::20c:29ff:fe55:3ca6 on eth0
              fe80::42:f0ff:fef7:bd81 on docker0
              fe80::4c84:caff:fe76:a23f on vethb0aa7a6
     Gateway: 198.51.100.2 on eth0
         DNS: 198.51.100.2
```

You can then add a network link, such as the Ethernet connection, as the argument of the status command to show specific information about the link:

```
root@photon-rc [ ~ ]# networkctl status eth0
* 2: eth0
       Link File: /usr/lib/systemd/network/99-default.link
    Network File: /etc/systemd/network/10-dhcp-en.network
            Type: ether
           State: routable (configured)
            Path: pci-0000:02:01.0
          Driver: e1000
      HW Address: 00:0c:29:55:3c:a6 (VMware, Inc.)
             MTU: 1500
         Address: 198.51.100.131
```

```
                  fe80::20c:29ff:fe55:3ca6
         Gateway: 198.51.100.2
             DNS: 198.51.100.2
        CLIENTID: ffb6220feb00020000ab116724f520a0a77337
```

And you can do the same thing with the Docker container:

```
networkctl status docker0
* 3: docker0
       Link File: /usr/lib/systemd/network/99-default.link
    Network File: n/a
            Type: ether
           State: routable (unmanaged)
          Driver: bridge
      HW Address: 02:42:f0:f7:bd:81
             MTU: 1500
         Address: 172.17.0.1
                  fe80::42:f0ff:fef7:bd81
```

In the example above, it is OK that the state of the Docker container is unmanaged; Docker handles managing the networking for the containers without using systemd-resolved or systemd-networkd. Instead, Docker manages the container's connection by using its bridge drive.

For more information about `networkctl` commands and options, see https://www.freedesktop.org/software/systemd/man/networkctl.html.

Turning on Network Debugging

You can set `systemd-networkd` to work in debug mode so that you can analyze log files with debugging information to help troubleshoot networking problems. The following procedure turns on network debugging by adding a drop-in file in /etc/systemd to customize the default systemd configuration in /usr/lib/systemd.

First, run the following command as root to create a directory with this exact name, including the `.d` extension:

```
mkdir -p /etc/systemd/system/systemd-networkd.service.d/
```

Second, run the following command as root to establish a systemd drop-in unit with a debugging configuration for the network service:

```
cat > /etc/systemd/system/systemd-networkd.service.d/10-loglevel-debug.conf << "EOF"
[Service]
Environment=SYSTEMD_LOG_LEVEL=debug
EOF
```

You must reload the systemctl daemon and restart the systemd-networkd service for the changes to take effect:

```
systemctl daemon-reload
systemctl restart systemd-networkd
```

Verify that your changes took effect:

```
systemd-delta --type=extended
```

View the log files by running this command:

```
journalctl -u systemd-networkd
```

When you are finished debugging the network connections, turn debugging off by deleting the drop-in file:

```
rm /etc/systemd/system/systemd-networkd.service.d/10-loglevel-debug.conf
```

Installing the Packages for tcpdump and netcat with tdnf

The minimal version of Photon OS leaves out several useful networking tools to keep the operating system lean. Tcpdump, for example, is absent in the minimal version but available in the repository. The minimal version does, however, include the iproute2 tools by default.

Tcpdump captures and analyzes packets on a network interface. On Photon OS, you install tcpdump and its accompanying package libpcap, a C/C++ library for capturing network traffic, by using tdnf, Photon's command-line package manager:

```
tdnf install tcpdump
```

Netcat, a tool for sending data over network connections with TCP or UDP, appears in neither the minimal nor the full version of Photon OS. But since netcat furnishes powerful options for analyzing, troubleshooting, and debugging network connections, you might want to install it. To do so, run the following command:

```
tdnf install netcat
```

Checking Firewall Rules

The design of Photon OS emphasizes security. On the minimal and full versions of Photon OS, the default security policy turns on the firewall and drops packets from external interfaces and applications. As a result, you might need to add rules to iptables to permit forwarding, allow protocols like HTTP, and open ports. In other words, you must configure the firewall for your applications and requirements.

The default iptables settings on the full version look like this:

```
iptables --list
Chain INPUT (policy DROP)
target     prot opt source               destination
ACCEPT     all  --  anywhere             anywhere
ACCEPT     all  --  anywhere             anywhere             ctstate RELATED,ESTABLISHED
ACCEPT     tcp  --  anywhere             anywhere             tcp dpt:ssh

Chain FORWARD (policy DROP)
target     prot opt source               destination

Chain OUTPUT (policy DROP)
target     prot opt source               destination
ACCEPT     all  --  anywhere             anywhere
```

To find out how to adjust the settings, see the man page for iptables.

Although the default iptables policy accepts SSH connections, the `sshd` configuration file on the full version of Photon OS is set to reject SSH connections. See Permitting Root Login with SSH.

If you are unable to ping a Photon OS machine, one of the first things you should do is check the firewall rules. Do they allow connectivity for the port and protocol in question? You can supplement the `iptables` commands by using `lsof` to, for instance, see the processes listening on ports:

```
lsof -i -P -n
```

Netmgr

If you are running a VMware appliance on Photon OS and the VAMI module has problems or if there are networking issues, you can use the Photon OS `netmgr` utility to inspect the networking settings. Make sure, in particular, that the IP addresses for the DNS server and other infrastructure are correct. Use `tcpdump` to analyze the issues.

If you get an error code from netmgr, it is a standard Unix error code--enter it into a search engine to obtain more information.

File System

This section covers troubleshooting the file system.

Checking Disk Space

One of the first simple steps to take when you're troubleshooting is to check how much disk space is available by running the `df` command:

```
df -h
```

Adding a Disk and Partitioning It

If the `df` command shows that the file system is indeed nearing capacity, you can add a new disk on the fly and partition it to increase capacity.

First, add a new disk. You can, for example, add a new disk to a virtual machine by using the VMware vSphere Client. After adding a new disk, check for the new disk by using `fdisk`; see the section on `fdisk` below. In the following example, the new disk is named `/dev/sdb`:

```
fdisk -l
Device        Start      End  Sectors Size Type
/dev/sda1      2048 16771071 16769024   8G Linux filesystem
/dev/sda2  16771072 16777182     6111   3M BIOS boot

Disk /dev/sdb: 1 GiB, 1073741824 bytes, 2097152 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
```

After you confirm that Photon OS registers the new disk, you can partition it with the `parted` wizard. The command to partition the disk on Photon OS is as follows:

```
parted /dev/sdb
```

And then you use the parted wizard to create it (see the man page for `parted` for more information):

```
mklabel gpt
mkpart ext3 1 1024
```

Then you must create a file system on the partition:

```
mkfs -t ext3 /dev/sdb1
```

Make a directory where you will mount the new file system:

```
mkdir /newdata
```

Finally, open `/etc/fstab` and add the new file system with the options that you want:

```
#system mnt-pt  type    options dump    fsck
/dev/sda1       /       ext4    defaults,barrier,noatime,noacl,data=ord$
/dev/cdrom      /mnt/cdrom      iso9660 ro,noauto       0       0
/dev/sdb1       /newdata        ext3    defaults        0        0
```

Mount it for now:

```
mount /newdata
```

Check your work:

```
df -h
Filesystem      Size  Used Avail Use% Mounted on
/dev/root       7.8G  4.4G  3.1G  59% /
devtmpfs        172M     0  172M   0% /dev
tmpfs           173M     0  173M   0% /dev/shm
tmpfs           173M  664K  172M   1% /run
tmpfs           173M     0  173M   0% /sys/fs/cgroup
tmpfs           173M   36K  173M   1% /tmp
tmpfs            35M     0   35M   0% /run/user/0
/dev/sdb1       945M  1.3M  895M   1% /newdata
```

Expanding Disk Partition

If you need more space, you can expand the last partition of your disk after resizing the disk. In the examples we are assuming `sda` as disk device.

After the disk is resized in the virtual machine, it's necessary to tell the system to recognize the new disk ending boundary without rebooting:

```
echo 1 > /sys/class/block/sda/device/rescan
```

You will need to install the parted package to resize the disk partition, which is not available by default. Just run the following command to install it: `tdnf install parted`.

```
# parted /dev/sda
GNU Parted 3.2
Using /dev/sda
Welcome to GNU Parted! Type 'help' to view a list of commands.
```

List all partitions available to fix the GPT and check the last partition number:

```
(parted) print

Warning: Not all of the space available to /dev/sda appears to be used, you can
fix the GPT to use all of the space (an extra 4194304 blocks) or continue with
the current setting?
Fix/Ignore?
```

Press `f` to fix the GPT layout.

```
Model: VMware Virtual disk (scsi)
Disk /dev/sda: 34.4GB
Sector size (logical/physical): 512B/512B
Partition Table: gpt
Disk Flags:

Number  Start   End     Size    File system  Name  Flags
1      1049kB  3146kB  2097kB                     bios_grub
```

```
2      3146kB  8590MB  8587MB  ext4
```

In this case we have the partition `2` as last, then we extend the partition to 100% of the remaining size:

```
(parted) resizepart 2 100%
```

Finally, expand the filesystem to the new size:

```
resize2fs /dev/sda2
resize2fs 1.42.13 (17-May-2015)
Filesystem at /dev/sda2 is mounted on /; on-line resizing required
old_desc_blocks = 1, new_desc_blocks = 2
The filesystem on /dev/sda2 is now 8387835 (4k) blocks long.
```

The new space is already available in the system:

```
df -h
Filesystem      Size  Used Avail Use% Mounted on
/dev/root        32G  412M   30G   2% /
devtmpfs       1001M     0 1001M   0% /dev
tmpfs          1003M     0 1003M   0% /dev/shm
tmpfs          1003M  252K 1003M   1% /run
tmpfs          1003M     0 1003M   0% /sys/fs/cgroup
tmpfs          1003M     0 1003M   0% /tmp
tmpfs           201M     0  201M   0% /run/user/0
```

fdisk

The `fdisk` command manipulates the disk partition table. You can, for example, use `fdisk` to list the disk partitions so that you can identify the root Linux file system. Here is an truncated example showing `/dev/sda1` to be the root Linux partition:

```
fdisk -l
Disk /dev/ram0: 4 MiB, 4194304 bytes, 8192 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 4096 bytes
I/O size (minimum/optimal): 4096 bytes / 4096 bytes
...
Disk /dev/sda: 8 GiB, 8589934592 bytes, 16777216 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: gpt
Disk identifier: 3CFA568B-2C89-4290-8B52-548732A3972D

Device        Start      End  Sectors Size Type
/dev/sda1      2048 16771071 16769024   8G Linux filesystem
/dev/sda2  16771072 16777182     6111   3M BIOS boot
```

Remember the `fdisk -l` command--it will be used later in a section that demonstrates how to reset a lost root password.

fsck

The Photon OS file system includes btrfs and ext4. The default root file system is ext4, which you can see by looking at the file system configuration file, `/etc/fstab`:

```
cat /etc/fstab
#system mnt-pt  type    options dump    fsck
/dev/sda1       /       ext4    defaults,barrier,noatime,noacl,data=ordered     1       1
/dev/cdrom      /mnt/cdrom      iso9660 ro,noauto       0       0
```

The `1` in the fifth column, under `fsck`, indicates that fsck checks the file system when the system boots.

You can manually check the file system by using the file system consistency check tool, `fsck`, after you unmount the file system. You can also perform a read-only check without unmounting it:

```
fsck -nf /dev/sda1
fsck from util-linux 2.27.1
e2fsck 1.42.13 (17-May-2015)
Warning!  /dev/sda1 is mounted.
Warning: skipping journal recovery because doing a read-only filesystem check.
Pass 1: Checking inodes, blocks, and sizes
Pass 2: Checking directory structure
Pass 3: Checking directory connectivity
Pass 4: Checking reference counts
Pass 5: Checking group summary information
Free blocks count wrong (1439651, counted=1423942).
Fix? no
Free inodes count wrong (428404, counted=428397).
Fix? no
/dev/sda1: 95884/524288 files (0.3% non-contiguous), 656477/2096128 blocks
```

The inodes count is probably off because the file system is mounted and in use. To fix problems, you must first unmount the file system and then run fsck again:

```
umount /dev/sda1
umount: /: target is busy
        (In some cases useful info about processes that
         use the device is found by lsof(8) or fuser(1).)
```

So check it with `lsof`:

```
lsof | grep ^jbd2/sd
jbd2/sda1   99                root  cwd       DIR                8,1     4096          2 /
jbd2/sda1   99                root  rtd       DIR                8,1     4096          2 /
jbd2/sda1   99                root  txt   unknown                                        /proc/99/exe
```

The file system is indeed in use. What troubleshooting tool would you use next to further explore the applications or processes that are using the file system?

Fixing File System Errors When fsck Fails

A potential issue is that when `fsck` runs during startup, it finds a problem that prevents the system from fully booting until you fix the issue by running fsck manually. This kind of a problem can occur when Photon OS is the operating system for a VM running an appliance.

If fsck fails when the computer boots and an error message says to run fsck manually, you can troubleshoot by restarting the VM, altering the GRUB edit menu to enter emergency mode before Photon OS fully boots, and running fsck.

1. Take a snapshot of the virtual machine.
2. Restart the virtual machine running Photon OS.
3. When the Photon OS splash screen appears as it restarts, type the letter `e` to go to the GNU GRUB edit menu. Be quick about it: Because Photon OS reboots so quickly, you won't have much time to type `e`. Remember that in VMware vSphere or VMware Workstation Pro, you might have to give the console focus by clicking in its window before it will register input from the keyboard.
4. In the GNU GRUB edit menu, go to the end of the line that starts with `linux`, add a space, and then add the following code exactly as it appears below:

   `systemd.unit=emergency.target`
5. Type `F10`.

6. In the bash shell, run one of the following commands to fix the file system errors, depending on whether `sda1` or `sda2` represents the root file system:

   `e2fsck -y /dev/sda1`

   or

   `e2fsck -y /dev/sda2`

7. Restart the virtual machine.

Packages

On Photon OS, tdnf is the default package manager. The standard syntax for `tdnf` commands is the same as that for DNF and Yum:

```
tdnf [options] <command> [<arguments>...]
```

The main configuration files reside in `/etc/tdnf/tdnf.conf`. The repositories appear in `/etc/yum.repos.d/` with `.repo` file extensions. For more information, see the Photon OS Administration Guide.

The cache files for data and metadata reside in `/var/cache/tdnf`. The local cache is populated with data from the repository:

```
ls -l /var/cache/tdnf/photon
total 8
drwxr-xr-x 2 root root 4096 May 18 22:52 repodata
d-wxr----t 3 root root 4096 May  3 22:51 rpms
```

You can clear the cache to help troubleshoot a problem, but keep in mind that doing so might slow the performance of tdnf until the cache becomes repopulated with data. Cleaning the cache can remove stale information. Here is how to clear the cache:

```
tdnf clean all
Cleaning repos: photon photon-extras photon-updates lightwave
Cleaning up everything
```

Some tdnf commands can help you troubleshoot problems with packages:

`makecache`: This command updates the cached binary metadata for all known repositories. You can run it after you clean the cache to make sure you are working with the latest repository data as you troubleshoot. Example:

```
tdnf makecache
Refreshing metadata for: 'VMware Lightwave 1.0(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)Updates'
Refreshing metadata for: 'VMware Photon Extras 1.0(x86_64)'
Refreshing metadata for: 'VMware Photon Linux 1.0(x86_64)'
Metadata cache created.
```

`tdnf check-local`: This command resolves dependencies by using the local RPMs to help check RPMs for quality assurance before publishing them. To check RPMs with this command, you must create a local directory and place your RPMs in it. The command, which includes no options, takes the path to the local directory containing the RPMs as its argument. The command does not, however, recursively parse directories; it checks the RPMs only in the directory that you specify. For example, after creating a directory named `/tmp/myrpms` and placing your RPMs in it, you can run the following command to check them:

```
tdnf check-local /tmp/myrpms
Checking all packages from: /tmp/myrpms
Found 10 packages
Check completed without issues
```

`tdnf provides`: This command finds the packages that provide the package that you supply as an argument. If you are used to a package name for another system, you can use `tdnf provides` to find the corresponding name of the package on Photon OS. Example:

```
tdnf provides docker
docker-1.11.0-1.ph1.x86_64 : Docker
Repo     : photon
docker-1.11.0-1.ph1.x86_64 : Docker
Repo     : @System
```

For a file, you must provide the full path. Here's an example:

```
tdnf provides /usr/include/stdio.h
glibc-devel-2.22-8.ph1.x86_64 : Header files for glibc
Repo     : photon
glibc-devel-2.22-8.ph1.x86_64 : Header files for glibc
Repo     : @System
```

Here's an example that shows you how to find the package that provides a pluggable authentication module, which you might need to find if the system is mishandling passwords.

```
tdnf provides /etc/pam.d/system-account
shadow-4.2.1-7.ph1.x86_64 : Programs for handling passwords in a secure way
Repo     : photon
shadow-4.2.1-8.ph1.x86_64 : Programs for handling passwords in a secure way
Repo     : photon-updates
```

Additional commands appear in the Photon OS Administration Guide.

If you find a package that is installed but is not working, try re-installing it; example:

```
tdnf reinstall shadow
Reinstalling:
shadow     x86_64     4.2.1-7.ph1   3.85 M
```

Kernel Problems and Boot and Login Problems

Kernel Overview

Photon OS 1.0 uses Linux kernel version 4.4. Troubleshooting kernel problems starts with `dmesg`. The `dmesg` command prints messages from the kernel ring buffer. The following command, for example, presents kernel messages in a human-readable format:

```
dmesg --human --kernel
```

To examine kernel messages as you perform actions, such as reproducing a problem, in another terminal, you can run the command with the `--follow` option, which waits for new messages and prints them as they occur:

```
dmesg --human --kernel --follow
```

The kernel buffer is limited in memory size. As a result, the kernel cyclically overwrites the end of the information in the buffer from which dmesg pulls information. The systemd journal, however, saves the information from the buffer to a log file so that you can access older information. To view it, run the following command:

```
journalctl -k
```

If need be, you can check the modules that are loaded on your Photon OS machine by running the `lsmod` command; truncated example:

```
lsmod
Module                  Size  Used by
vmw_vsock_vmci_transport    28672  1
vsock                  36864  2 vmw_vsock_vmci_transport
coretemp               16384  0
hwmon                  16384  1 coretemp
crc32c_intel           24576  0
hid_generic            16384  0
usbhid                 28672  0
hid                   106496  2 hid_generic,usbhid
xt_conntrack           16384  1
iptable_nat            16384  0
nf_conntrack_ipv4      16384  2
nf_defrag_ipv4         16384  1 nf_conntrack_ipv4
nf_nat_ipv4            16384  1 iptable_nat
nf_nat                 24576  1 nf_nat_ipv4
iptable_filter         16384  1
ip_tables              24576  2 iptable_filter,iptable_nat
```

Boot Process Overview

When a Photon OS machine boots, the BIOS initializes the hardware and uses a boot loader to start the kernel. After the kernel starts, systemd takes over and boots the rest of the operating system.

More specifically, the BIOS checks the memory and initializes the keyboard, the screen, and other peripherals. When the BIOS finds the first hard disk, the boot loader--GNU GRUB 2.02--takes over. From the hard disk, GNU GRUB loads the master boot record (MBR) and initializes the root partition of the random-access memory by using initrd. The device manager, udev, provides initrd with the drivers it needs to access the device containing the root file system. Here's what the GNU GRUB edit menu looks like in Photon OS with its default commands to load the boot record and initialize the RAM disk:

At this point, the Linux kernel in Photon OS, which is kernel version 4.4.8, takes control. Systemd kicks in, initializes services in parallel, mounts the rest of the file system, and checks the file system for errors.

Blank Screen on Reboot

If the Photon OS kernel enters a state of panic during a reboot and all you see is a blank screen, note the name of the virtual machine running Photon OS and then power off the VM.

In the host, open the `vmware.log` file for the VM. When a kernel panics, the guest VM prints the entire kernel log in `vmware.log` in the host's directory containing the VM. This log file contains the output of the `dmesg` command from the guest, and you can analyze it to help identify the cause of the boot problem.

Here's an example. After searching for `Guest:` in the following abridged `vmware.log`, this line appears, identifying the root cause of the reboot problem:

```
2016-08-30T16:02:43.220-07:00| vcpu-0| I125: Guest:
<0>[1.125804] Kernel panic - not syncing:
VFS: Unable to mount root fs on unknown-block(0,0)
```

Further inspection finds the following lines:

```
2016-08-30T16:02:43.217-07:00| vcpu-0| I125: Guest:
<4>[    1.125782] VFS: Cannot open root device "sdc1" or unknown-block(0,0): error -6
2016-08-30T16:02:43.217-07:00| vcpu-0| I125: Guest:
<4>[    1.125783] Please append a correct "root=" boot option;
here are the available partitions:
2016-08-30T16:02:43.217-07:00| vcpu-0| I125: Guest:
<4>[    1.125785] 0100            4096 ram0  (driver?)
...
0800         8388608 sda  driver: sd
2016-08-30T16:02:43.220-07:00| vcpu-0| I125: Guest:
```

```
<4>[    1.125802]   0801         8384512 sda1 611e2d9a-a3da-4ac7-9eb9-8d09cb151a93
2016-08-30T16:02:43.220-07:00| vcpu-0| I125: Guest:
<4>[    1.125803]   0802            3055 sda2 8159e59c-b382-40b9-9070-3c5586f3c7d6
```

In this unlikely case, the GRUB configuration points to a root device named `sdc1` instead of the correct root device, `sda1`. You can fix the problem by restoring the GRUB GNU edit screen and the GRUB configuration file (`/boot/grub/grub.cfg`) to their original configurations.

Investigating Strange Behavior

If you rebooted to address strange behavior before the reboot of if you encountered strange behavior during the reboot but have reached the shell, you should analyze what happened since the previous boot. Start broad by running the following command to check the logs:

```
journalctl
```

Next, run the following command to look at what happened since the penultimate reboot:

```
journalctl --boot=-1
```

Then look at the log from the reboot:

```
journalctl -b
```

If need be, examine the logs for the kernel:

```
journalctl -k
```

Check which kernel is in use:

```
uname -r
```

The kernel version of Photon OS in the full version is 4.4.8. The kernel version of in the OVA version is 4.4.8-esx. With the ESX version of the kernel, some services might not start. Run this command to check the overall status of services:

```
systemctl status
```

If a service is in red, check it:

```
systemctl status service-name
```

Start it if need be:

```
systemctl start service-name
```

If looking at the journal and checking the status of services gets you nowhere, run the following `systemd-analyze` commands to examine the boot time and the speed with which services start.

```
systemd-analyze time
systemd-analyze blame
systemd-analyze critical-chain
```

Keep in mind that the output of these commands might be misleading because one service might just be waiting for another service to finish initializing.

Investigating the Guest Kernel When You Cannot Log On

If a VM running Photon OS and an application or virtual appliance is behaving so oddly that, for example, you cannot log on to the machine, you can still troubleshoot by extracting the kernel logs from the guest's memory and analyzing them with `gdb`.

This advanced troubleshooting method works when you are running Photon OS as the operating system for an application or appliance on VMware Workstation, Fusion, or ESXi. This approach assumes that the virtual machine running Photon OS is functioning normally.

This troubleshooting method has the following requirements:

- Root access to a Linux machine other than the one you are troubleshooting. It can be another Photon OS machine, Ubuntu, or another Linux variant.
- The `vmss2core` utility from VMware. It is installed by default in VMware Workstation and some other VMware products. If your system doesn't already contain it, you can download it for free from https://labs.vmware.com/flings/vmss2core.
- A local copy of the Photon OS ISO of the exact same version and release number as the Photon OS machine that you are troubleshooting.

The process to use this troubleshooting method varies by environment. The examples in this section assume that the troublesome Photon OS virtual machine is running in VMware Workstation 12 Pro on a Microsoft Windows 8 Enterprise host. The examples also use an additional, fully functional Photon OS virtual machine running in Workstation.

You can, however, use other hosts, hypervisors, and operating systems--but you will have to adapt the example process below to them. Directory paths, file names, and other aspects might be different on other systems.

Overview

The process to apply this troubleshooting method goes like this: On a local computer, you open a file on the Photon OS ISO that contains Linux debugging information. Then you suspend the troublesome Photon OS VM and extract the kernel memory logs from the VMware hypervisor running Photon OS.

Next, you use the vmss2core tool to convert the memory logs into core dump files. The vmss2core utility converts VMware checkpoint state files into formats that third-party debugging tools understand. It can handle both suspend (.vmss) and snapshot (.vmsn) checkpoint state files (hereafter referred to as a *vmss file*) as well as monolithic and non-monolithic (separate .vmem file) encapsulation of checkpoint state data. See Debugging Virtual Machines with the Checkpoint to Core Tool.

Finally, you prepare to run the gdb tool by using the debug info file from the ISO to create a `.gdbinit` file, which you can then analyze with the gdb shell on your local Linux machine.

All three components must be in the same directory on a Linux machine.

Process

First, obtain a local copy of the Photon OS ISO of the exact same version and release number as the Photon OS machine that you are troubleshooting and mount the ISO on a Linux machine (or open it on a Windows machine):

```
mount /mnt/cdrom
```

Second, locate the following file. (If you opened the Photon OS ISO on a Windows computer, copy the following file to the root folder of a Linux machine.)

```
/RPMS/x86_64/linux-debuginfo-4.4.8-6.ph1.x86_64.rpm
```

Third, on a Linux machine, run the following `rpm2cpio` command to convert the RPM file to a cpio file and to extract the contents of the RPM to the current directory:

```
rpm2cpio /mnt/cdrom/RPMS/x86_64/linux-debuginfo-4.4.8-6.ph1.x86_64.rpm | cpio -idmv
```

From the extracted files, copy the following file to your current directory:

```
cp usr/lib/debug/lib/modules/4.4.8/vmlinux-4.4.8.debug .
```

Run the following command to download the dmesg functions that will help extract the kernel log from the coredump:

```
wget https://github.com/vmware/photon/blob/master/tools/scripts/gdbmacros-for-linux.txt
```

Move the file as follows:

```
mv gdbmacros-for-linux.txt .gdbinit
```

Next, switch to your host machine so you can get the kernel memory files from the VM. Suspend the troublesome VM and locate the `.vmss` and `.vmem` files in the virtual machine's directory on the host. Example:

```
C:\Users\tester\Documents\Virtual Machines\VMware Photon 64-bit (7)>dir
 Volume in drive C is Windows
 Directory of C:\Users\tester\Documents\Virtual Machines\VMware Photon 64-bit
 (7)
09/20/2016  12:22 PM    <DIR>          .
09/20/2016  12:22 PM    <DIR>          ..
09/19/2016  03:39 PM       402,653,184 VMware Photon 64-bit (7)-f6b070cd.vmem
09/20/2016  12:11 PM         5,586,907 VMware Photon 64-bit (7)-f6b070cd.vmss
09/20/2016  12:11 PM     1,561,001,984 VMware Photon 64-bit (7)-s001.vmdk
...
09/20/2016  12:11 PM           300,430 vmware.log
...
```

Now that you have located the `.vmss` and `.vmem` files, convert them to one or more core dump files by using the vmss2core tool that comes with Workstation. Here is an example of how to run the command. Be careful with your pathing, escaping, file names, and so forth--all of which might be different from this example on your Windows machine.

```
C:\Users\shoenisch\Documents\Virtual Machines\VMware Photon 64-bit (7)>C:\"Program Files (x86)\VMware\VMware Workstation"\vmss2core.exe "V
Mware Photon 64-bit (7)-f6b070cd.vmss" "VMware Photon 64-bit (7)-f6b070cd.vmem"
```

The result of this command is one or more files with a `.core` extension plus a digit. Truncated example:

```
C:\Users\tester\Documents\Virtual Machines\VMware Photon 64-bit (7)>dir
 Directory of C:\Users\tester\Documents\Virtual Machines\VMware Photon 64-bit(7)
09/20/2016  12:22 PM       729,706,496 vmss.core0
```

Copy the `.core` file or files to the your current directory on the Linux machine where you so that you can analyze it with gdb.

Run the following `gdb` command to enter the gdb shell attached to the memory core dump file. You might have to change the name of the `vmss.core` file in the example to match your `.core` file:

```
gdb vmlinux-4.4.8.debug vmss.core0

GNU gdb (GDB) 7.8.2
Copyright (C) 2014 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. ...
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
```

```
Find the GDB manual and other documentation resources online at: <http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from vmlinux-4.4.8.debug...done.
warning: core file may not match specified executable file.
[New LWP 12345]
Core was generated by `GuestVM'.
Program terminated with signal SIGSEGV, Segmentation fault.
#0  0xffffffff813df39a in insb (count=0, addr=0xffffc90000144000, port=<optimized out>)
    at arch/x86/include/asm/io.h:316
316     arch/x86/include/asm/io.h: No such file or directory.
(gdb)
```

In the results above, the *(gdb)* of the last line is the prompt of the gdb shell. You can now analyze the core dump by using commands like `bt` (to perform a backtrace) and `dmesg` (to view the Photon OS kernel log and see Photon OS kernel error messages).

Kernel Log Replication with VProbes

Replicating the Photon OS kernel logs on the VMware ESXi host is an advanced but powerful method of troubleshooting a kernel problem. This method is applicable when the virtual machine running Photon OS is hanging or inaccessible because, for instance, the hard disk has failed.

There is a prerequisite, however: You must have preemptively enabled the VMware VProbes facility on the VM before a problem rendered it inaccessible. You must also create a VProbes script on the ESXi host, but you can do that after the fact.

Although the foresight to implement these prerequisites might limit the application of this troubleshooting method for production systems, the method can be particularly useful in analyzing kernel issues when testing an application or appliance that is running on Photon OS.

There are two similar ways in which you can replicate the Photon OS kernel logs on ESXi by using VProbes. The first modifies the VProbes script so that it works only for the VM that you set; it uses a hard-coded address. The second uses an abstraction instead of a hard-coded address so that the same VProbes script can be used for any VM on an ESXi host that you have enabled for VProbe and copied its kernel symbol table (kallsyms) to ESXi.

For more information on VMware VProbes, see VProbes: Deep Observability Into the ESXi Hypervisor and the VProbes Programming Reference.

Using VProbes Script with a Hard-Coded Address

Here's how to set a VProbe for an individual VM:

First, power off the VM so that you can turn on the VProbe facility. Edit the `.vmx` configuration file for the VM. The file resides in the directory that contains the VM in the ESXi data store. Add the following line of code to the `.vmx` file and then power the VM on:

```
vprobe.enable = "TRUE"
```

When you edit the `.vmx` file to add the above line of code, you must first turn off the VM--otherwise, your changes will not persist.

Second, obtain the kernel log_store function address by connecting to the VM with SSH and running the following commands as root. (Photon OS uses the `kptr_restrict` setting to place restrictions on the kernel addresses exposed through `/proc` and other interfaces. This setting hides exposed kernel pointers to prevent attackers from exploiting kernel write vulnerabilities. When you are done using VProbes, you should return `kptr_restrict` to the original setting of `2` by rebooting.)

```
echo 0 > /proc/sys/kernel/kptr_restrict
grep log_store /proc/kallsyms
```

The output of the `grep` command will look similar to the following string. The first set of characters (without the `t`) is the log_store function address:

```
ffffffff810bb680 t log_store
```

Third, connect to the ESXi host with SSH so that you can create a VProbes script. Here's the template for the script; `log_store` in the first line is a placeholder for the VM's log_store function address:

```
GUEST:ENTER:log_store {
   string dst;
   getgueststr(dst, getguest(RSP+16) & 0xff, getguest(RSP+8));
   printf("%s\n", dst);
}
```

On the ESXi host, create a new file, add the template to it, and then change `log_store` to the function address that was the output from the grep command on the VM.

You must add a `0x` prefix to the function address. In this example, the modified template looks like this:

```
GUEST:ENTER:0xffffffff810bb680 {
   string dst;
   getgueststr(dst, getguest(RSP+16) & 0xff, getguest(RSP+8));
   printf("%s\n", dst);
}
```

Save your VProbes script as `console.emt` in the `/tmp` directory. (The file extension for VProbe scripts is `.emt`.)

While still connected to the ESXi host with SSH, run the following command to obtain the ID of the virtual machine that you want to troubleshoot:

```
vim-cmd vmsvc/getallvms
```

This command lists all the VMs running on the ESXi host. Find the VM you want to troubleshoot in the list and make a note of its ID.

Finally, run the following command to print all the kernel messages from Photon OS in your SSH console; replace `<VM ID>` with the ID of your VM:

```
vprobe -m <VM ID> /tmp/console.emt
```

When you're done, type `Ctrl-C` to stop the loop.

A Reusable VProbe Script Using the kallsyms File

Here's how to create one VProbe script and use for all the VMs on your ESXi host.

First, power off the VM and turn on the VProbe facility on each VM that you want to be able to analyze. Add `vprobe.enable = "TRUE"` to the VM's `.vmx` configuration file. See the instructions above.

Second, power on the VM, connect to it with SSH, and run the following command as root:

```
echo 0 > /proc/sys/kernel/kptr_restrict
```

Third, connect to the ESXi host with SSH to create the following VProbes script and save it as `/tmp/console.emt`:

```
GUEST:ENTER:log_store {
   string dst;
   getgueststr(dst, getguest(RSP+16) & 0xff, getguest(RSP+8));
   printf("%s\n", dst);
}
```

Fourth, from the ESXi host, run the following command to copy the VM's `kallsyms` file to the `tmp` directory on the ESXi host:

```
scp root@<vm ip address>:/proc/kallsyms /tmp
```

While still connected to the ESXi host with SSH, run the following command to obtain the ID of the virtual machine that you want to troubleshoot:

```
vim-cmd vmsvc/getallvms
```

This command lists all the VMs running on the ESXi host. Find the VM you want to troubleshoot in the list and make a note of its ID.

Finally, run the following command to print all the kernel messages from Photon OS in your SSH console; replace `<VM ID>` with the ID of your VM. When you're done, type `Ctrl-C` to stop the loop.

```
vprobe -m <VM ID> -k /tmp/kallysyms /tmp/console.emt
```

You can use a directory other than `tmp` if you want.

Performance Issues

Performance issues can be difficult to troubleshoot because so many variables play a role in overall system performance. Interpreting performance data often depends on the context and the situation. To better identify and isolate variables and to gain insight into performance data, you can use the troubleshooting tools on Photon OS to diagnose the system.

If you have no indication what the cause of a performance degradation might be, start by getting a broad picture of the system's state. Then look for clues in the data that might point to a cause. The systemd journal is a useful place to start.

The `top` tool can unmask problems caused by processes or applications overconsuming CPUs, time, or RAM. If the percent of CPU utilization is consistently high with little idle time, for example, there might be a runaway process. Restart it.

The `netstat --statistics` command can identify bottlenecks causing performance issues. It lists interface statistics for different protocols.

If `top` and `netstat` reveal no clues, run the `strace ls -al` to view every system call.

The following `watch` command can help dynamically monitor a command to help troubleshoot performance issues:

```
watch -n0 --differences <command>
```

You can, for example, combine `watch` with the `vmstat` command to dig deeper into statistics about virtual memory, processes, block input-output, disks, and CPU activity. Are there any bottlenecks?

Another option is to use the `dstat` utility. It shows a live, running list of statistics about system resources.

In addition, `systemd-analyze` , which reveals performance statistics for boot times, can help troubleshoot slow system boots and incorrect unit files.

The additional tools that you select depend on the clues that your initial investigation reveals. The following tools can also help troubleshoot performance: `sysstat` , `sar` , `systemtap` , and `crash` .