Linux Stacks for Intel® SGX

2021.07.28 Release

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Introduction

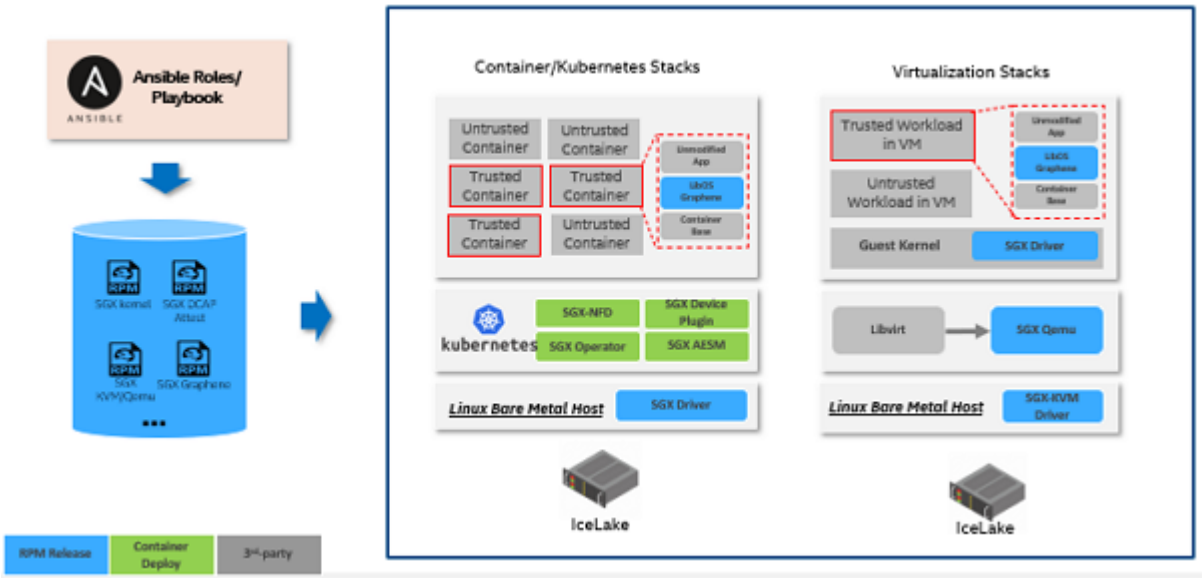
This document introduces the setup and deployment of the Linux* Stacks for Intel® SGX on a 3rd Generation Intel® Xeon® Scalable Processors server.

Note: You can find more detail about SGX (Software Guard Extension) at Intel® Software Guard Extension

The cloud stacks include:

- Virtualization stack: KVM based virtualization environment to run an SGX enclave workload in a VM guest. The Libvirt/ QEMU* components act as the orchestrator.
- Containers Stack: A container based Kubernetes* environment to run an SGX enclave workload in a container. Kubernetes is the orchestrator for the SGX device plugin.

The stack components are packaged into RPMs and are delivered via an RPM repository server. This document introduces the setup for development and Ansible* deployment for mass provisioning in the cloud environment.



Note: The Stacks are presently implemented only for the CentOS 8.4, RHEL 8.3 and RHEL 8.4 Operating Systems

Prerequisites

NOTE: The following configurations are for reference only; please use the updated platform configurations from the Intel® Software Guard Extensions SDK for Linux* documentation.

Memory DIMM Configurations

On 3rd Generation Intel® Xeon® Scalable Processors platforms, the SGX supported memory configuration is shown as follows:

IMC#	IMC0				IMC1				IMC2				IMC3			
Channel	Chan 0 (A)		Chan 1 (B)		Chan 0 (C)		Chan 1 (D)		Chan 0 (E)		Chan 1 (F)		Chan 0 (G)		Chan 1 (H)	
DDR4	Slot0	Slot1	Slot0	Slot1	Slot0	Slot1	Slot0	Slot1	Slot0	Slot1	Slot0	Slot1	Slot0	Slot1	Slot0	Slot1
8	DDR4		DDR4		DDR4		DDR4		DDR4		DDR4		DDR4		DDR4	
12	DDR4	DDR4	DDR4		DDR4	DDR4	DDR4		DDR4	DDR4	DDR4		DDR4	DDR4	DDR4	
16	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4	DDR4

BIOS Setup

Ensure the following BIOS settings are set as shown:

- TME enable:

  ```
  Advanced → Socket Configuration → Processor Configuration → TME, MK-TME, TDX → Total Memory Encryption → Enable
  ```

  NOTE: SGX will be visible only if TME is enabled.

- Disable UMA-Based Clustering (Otherwise SGX will be grayed out):

  ```
  Advanced → Socket Configuration → Common RefCode Configuration → UMA-Based Clustering → Disable
  ```

- Enable SGX:

  ```
  Advanced → Socket Configuration → Processor Configuration → SW Guard Extensions(SGX) → Enable
  ```

- Disable Patrol scrub (Only `LCC & HCC`):

  ```
  Advanced → Socket Configuration → Memory RAS Configuration → Patrol Scrub → Disable
  ```

- Disable Mirroring:

  ```
  Advanced → Socket Configuration → Memory RAS Configuration → Mirror Mode → Disable
  ```

- Enable Memory ECC

Software Stack Components

All software components are based on Open Source licensed software, installed from one of the public DNF repositories: `https://download.01.org/intelsgxstack/2021-07-28/centos`.

Component	Package Name	Description
kernel-5.13.4-1	kvm-sgx-kernel	Kernel for KVM host
linux-sgx-sdk-2.14	linux-sgx-sdk	SGX SDK/PSW
qemu-sgx-v6.0.0-rc5	qemu-kvm	QEMU KVM with SGX compatible with kernel-5.13.4
graphene-1.2-rc1	graphene	Graphene LibOS

`https://download.01.org/intelsgxstack/2021-07-28/rhel`

Component	Package Name	Description
kernel-5.13.4-1	kvm-sgx-kernel	Kernel for KVM host
linux-sgx-sdk-2.14	linux-sgx-sdk	SGX SDK/PSW
qemu-sgx-6.0.0-rc5	qemu-kvm	QEMU KVM with SGX compatible with kernel-5.13.4
graphene-1.2-rc1	graphene	Graphene LibOS

NOTE:

- The kernel will create SGX device node names:
    - /dev/sgx_enclave
    - /dev/sgx_provision

  For compatibility with legacy node names, create a udev rules file such as 10-sgx.rules:

```
SUBSYSTEM=="misc",KERNEL=="enclave",MODE="0666"
SUBSYSTEM=="misc",KERNEL=="provision",GROUP="sgx_prv",MODE="0660"
SUBSYSTEM=="misc",KERNEL=="sgx_enclave",MODE="0666",SYMLINK+="sgx/enclave"
SUBSYSTEM=="misc",KERNEL=="sgx_provision",GROUP="sgx_prv",MODE="0660",SYMLINK+="sgx/provision"
```

Manual Setup for Development

Download *intelsgxstack.repo*

Based on your OS, download the file *intelsgxstack.repo* from `https://download.01.org/intelsgxstack/2021-07-28/centos` or `https://download.01.org/intelsgxstack/2021-07-28/rhel` and copy it to the folder */etc/yum.repos.d*. More details here.

SGX SDK

Install the SDK:

```
sudo dnf install linux-sgx-sdk
```

This installs the SGX-SDK in the default folder */opt/intel/sgxsdk*. Sample code is installed under the */opt/intel/sgxsdk/SampleCode* directory with read-only permissions for normal users. Each user should make separate copies to modify, build, and experiment with the sample codes.

Note: To be able to run the code samples you need to have these packages installed:

```
sudo dnf install libsgx-launch libsgx-urts
```

It is also recommended to source the SDK environment:

```
source /opt/intel/sgxsdk/environment
```

SGX Development User Setup

The first step is to verify we have SGX legacy nodes and correct ownership:

```
$ sudo ls -al /dev/sgx*
crw-rw-rw-. 1 root root    10, 126 May  7 15:47 /dev/sgx_enclave
crw-rw----. 1 root sgx_prv 10, 125 May  7 15:47 /dev/sgx_provision

/dev/sgx:
total 0
drwxr-xr-x.  2 root root   80 May  7 15:47 .
drwxr-xr-x. 21 root root 3040 May  7 15:47 ..
lrwxrwxrwx.  1 root root   14 May  7 15:47 enclave -> ../sgx_enclave
lrwxrwxrwx.  1 root root   16 May  7 15:47 provision -> ../sgx_provision
```

If we do not have the group `sgx_prv` and the node names `/dev/sgx/enclave` and `/dev/sgx/provision`, we need to create them. Users that are members of the group `sgx_prv` do not need to run SGX applications with root privileges.

```
sudo groupadd sgx_prv
```

Next, create the file /etc/udev/rules.d/10-sgx.rules and reload the udev rules:

```
$ cat /etc/udev/rules.d/10-sgx.rules
SUBSYSTEM=="misc",KERNEL=="enclave",MODE="0666"
SUBSYSTEM=="misc",KERNEL=="provision",GROUP="sgx_prv",MODE="0660"
SUBSYSTEM=="misc",KERNEL=="sgx_enclave",MODE="0666",SYMLINK+="sgx/enclave"
SUBSYSTEM=="misc",KERNEL=="sgx_provision",GROUP="sgx_prv",MODE="0660",SYMLINK+="sgx/provision"

udevadm trigger
```

To be able to run and/or develop SGX based applications as a non-privileged user, follow these steps:

Create a user account and add the user to desired groups:

```
sudo useradd <user>
sudo passwd <user>
sudo usermod -aG wheel,sgx_prv <user>
```

Finally, log out and log in as the new user.

Graphene

Prerequisite: kernel with SGX support.

This release contains several graphene RPMs built from the repository: https://github.com/oscarlab/graphene Although the Graphene project is not currently suitable for production, we provide the Graphene RPMs to allow testing and evaluation on CentOS/RHEL platforms without any out-of-tree drivers.

To install:

```
sudo dnf install graphene graphene-tools
```

You can view the SGX information by issuing the following command:

```
is_sgx_available
```

Production blockers: https://github.com/oscarlab/graphene/issues/1544

Gaphene Busybox

Graphene busybox demonstrates how to distribute packaged Graphene based applications. To run busybox with Graphene as an example application, please follow the steps below.

NOTE: *The following steps are applicable to CentOS. Other distributions may require modified steps.*

1. Verify your user account meets the conditions as described in *SGX Development User Setup*.
2. Install several pre-requisites:

   ```
   sudo dnf install epel-release nss-mdns binutils python3
   ```

3. Install graphene-busybox. This will install the busybox binary, the manifest file, and it will sign the application:

   ```
   sudo dnf install graphene-busybox
   ```

4. Change directory to the location where the graphene-busybox files were installed:

   ```
   cd /usr/lib64/graphene-busybox
   ```

5. Run some Busybox commands within an SGX enclave:

   Example: List available commands:

   ```
   graphene-sgx busybox sh
   ```

   Example: Get Busybox kernel version

   ```
   graphene-sgx busybox uname -a
   ```

   Example: Run the Busybox shell within an SGX enclave:

   ```
   graphene-sgx busybox sh
   ```

   A shell should be running within an SGX enclave. You can run any busybox shell command at this point. To exit, hit Ctrl+C or type the exit command.

   There is no shell prompt displayed in the busybox shell. Just go ahead and type various commands (ls, uname, busybox, etc.) after you see the line: `error: Using insecure argv source. Graphene will continue application execution, but this configuration must not be used in production!`

KVM Stack

Setup the SGX KVM host

You can install KVM SGX kernel manually via:

```
sudo dnf install kernel
```

This will install the latest kernel, which in this case should be the kernel-5.13.4. This kernel supports KVM SGX.

If planning to install Virtual Machines (VMs), you will also need to install QEMU with SGX support:

```
sudo dnf install qemu-kvm
```

Create SGX VM

To install Virtual Machines, you will generally need to follow the instructions from here.

There is no need to configure/build the kernel nor QEMU, as this has already been done. However, make sure your /etc/libvirt/qemu.conf contains:

```
cgroup_device_acl = [
 "/dev/null", "/dev/full", "/dev/zero",
 "/dev/random", "/dev/urandom",
 "/dev/ptmx", "/dev/kvm", "/dev/kqemu",
 "/dev/rtc","/dev/hpet", "/dev/sgx_vepc", "/dev/sgx_provision"
]
```

QEMU needs to read and write to the /dev/sgx_vepc device, which is owned by root with file mode 600. This means you must configure QEMU to run as root. In order to do that also ensure /etc/libvirt/qemu.conf contains:

```
user = "root"
```

You may need to manually install bridged network named `br0` bridging the Ethernet device on the KVM host computer if you plan on creating Virtual Machines and make them accessible from outside of the host computer. You can find details on setting up bridged networks in Linux here.

Kubernetes Stack

Install SGX kernel on a Kubernetes host

A Kubernetes host can be a virtual machine (VM) or a bare metal host with SGX support. Since SGX in-kernel driver is already integrated in the 5.11+ kernel, simply install the latest kernel with:

```
sudo dnf install kernel
```

Install *kubeadm*

Follow the instructions from here to install kubeadm. Then create a Kubernetes master or slave to join an existing Kubernetes cluster.

Install NFD, SGX device plugin

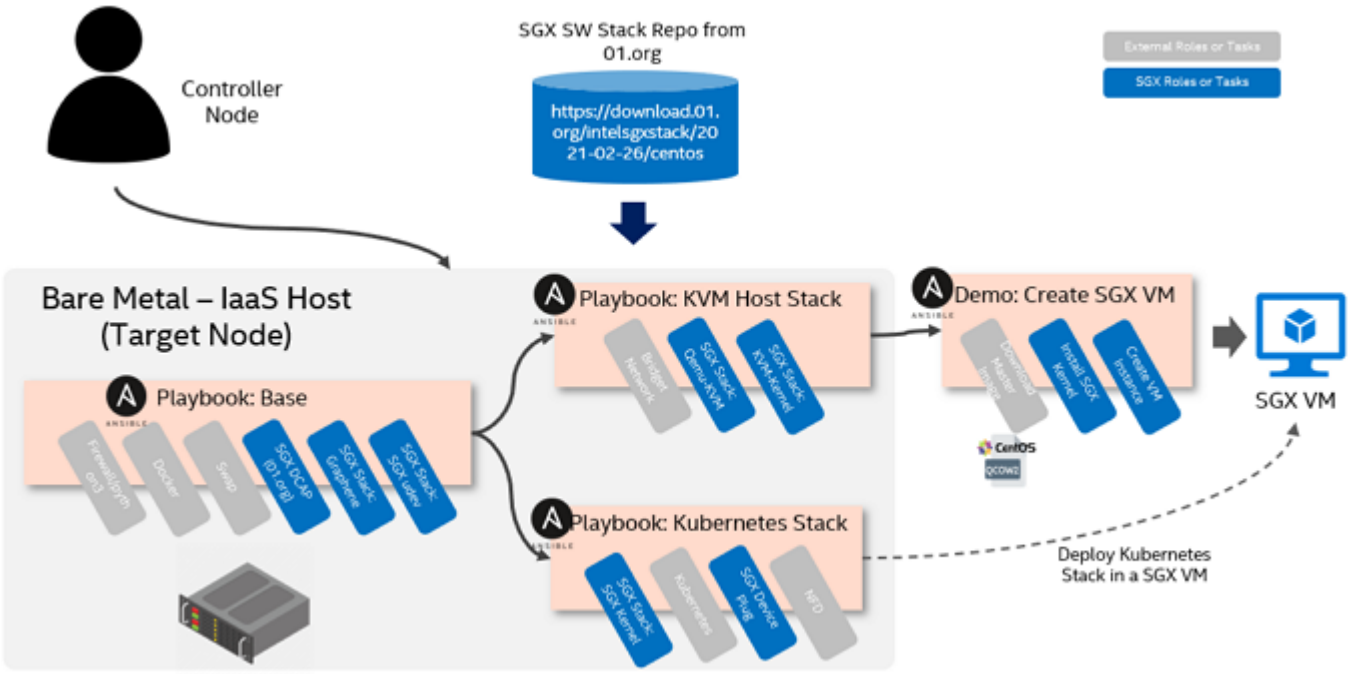
Follow the instructions from here for installing device plugins.

Ansible Mass Deployment

To facilitate the mass deployment in data center, this guide leverages Ansible. Ansible is an IT automation tool that can configure systems, deploy software, and orchestrate more advanced IT tasks. Please get familiar with the "Ansible concepts" from the official documentation.

High Level Flow

The ansible playbooks are running from the controller node within the same network as the target node, and the whole deployment workflow is as follows:



There are two types of playbook:

- Stack playbooks (in stacks directory)

  Deploy KVM host or Kubernetes stacks on target bare metal node. The base playbook provides some common configurations or installations for both stacks. The Kubernetes stack could also be deployed in an SGX VM.

- Demo playbooks (in demos directory).

Assumptions & Limitations

- *The target node has been provisioned with CentOS or RHEL via OS mass provisioning tool. Only releases 8.3/8.4 are supported.*
- *The target node could be the 3rd Generation Intel® Xeon® Scalable Processors server or later platform with SGX enabled in BIOS.*

Prerequisites

Please read the Prerequisites for both controller node and managed nodes.

Download the compressed file for ansible roles/playbooks from https://download.01.org/intelsgxstack/2021-07-28/sgx-cloud-stack-deploy.tar.bz2, and extract it on the control node.

```
tar xjvf sgx-cloud-stack-deploy.tar.bz2
```

Run Ansible in Docker on controller node

Prerequisites: Docker is installed on the controller node and the user is a member of the *docker* group.

The *docker-playbook.sh* script allows you to run ansible-playbook from a docker container. The container `ansible-playbook` will be built at the initial running of *docker-playbook.sh*. You can also use the following command to re-generate the container:

```
./docker-playbook.sh rebuild
```

NOTE: Container runs as user `sgxdev`. If you see errors such as:

```
docker: Error response from daemon: OCI runtime create failed:
container_linux.go:348: starting container process caused "chdir to
cwd (\"/home/sgxdev/deployment\") set in config.json failed:
permission denied": unknown.
ERRO[0000] error waiting for container: context canceled:_
```

Please make sure the folder you are running the shell script from has sufficient permissions:

```
chmod o+rx .
```

Setup an SSH account on the target managed nodes

The managed nodes are network devices (and/or servers) you manage with Ansible. Managed nodes are also sometimes called "hosts". You do not need to install any software on the target managed nodes beyond setting up an SSH account via `ssh-copy-id <user@target_node_address>`.

For example, to set up an SSH account on a target node called `node1.some-cluster.com`:

- On the target managed node, create an admin user:

  ```
  sudo adduser sgxdev
  sudo usermod -aG wheel sgxdev
  sudo passwd sgxdev
  ```

- On the control node, setup SSH passwordless login:

  ```
  # If you already have an ssh key, you can skip the ssh-keygen command

  ssh-keygen
  ssh-copy-id sgxdev@node1.some-cluster.com
  ```

- Verify SSH based passwordless login:

  ```
  ssh sgxdev@node1.some-cluster.com ls
  ```

  NOTE: For the ssh-copy-id command to work the managed node has to have SSH password authentication enabled, this can be verified by running:

  ```
  sudo cat /etc/ssh/sshd_config | grep PasswordAuthentication
  ```

  NOTE: Passwordless login does not mean passwordless sudo privileges. For that, on each managed node you need to include the line "%sgxdev ALL=(ALL) NOPASSWD: ALL" in the file /etc/sudoers via `visudo`. Alternatively, on each managed node create a separate file with the line and place the file in the folder /etc/sudoers.d.

  ```
  sudo bash -c 'echo "%sgxdev ALL=(ALL) NOPASSWD: ALL" > /etc/sudoers.d/sgxdev'
  ```

  NOTE: Please refer to the Ansible document check your SSH connections for detail.

Define the inventory

Inventories are commonly formatted in either INI or YAML.

On the control node, create an inventory file in the default location:

```
sudo mkdir -p /etc/ansible
echo <name-or-ip-of-my-system> | sudo tee /etc/ansible/hosts
```

Please refer to the Ansible document How to build your inventory.

Config Variables

Variables are passed into the playbooks or roles via options "-e". Please evaluate the variables in all new or existing roles or playbooks carefully. The following table gives the variables most often used for deploying SGX cloud stacks.

name	value	default value	applicable stack	note
`net_ethernet_dev`	The name string of bridge slave ethernet interface	`enp1s0`	kvm-host	Setup bridge network `br0` on `net_ethernet_dev`, ***Note: Please check the interface name on your target managed node.***
`sgx_repo_file_url`	URL of repo file to be used for deployment	`https://download.01.org/intelsgxstack/2021-07-28/centos/intelsgxstack.repo` or `https://download.01.org/intelsgxstack/2021-07-28/rhel/intelsgxstack.repo`	all	Specify a different DNF Repo URL if needed.
`k8s_role`	`master|slave`	`master`	Kubernetes	If deploying the master node, the NFD and SGX device plugins will be installed. If deploying slave nodes, please specify the `kubernetes_join_command` to join the cluster.
`kubernetes_join_command`	The join command string for slave nodes	empty	Kubernetes slave	Create with: `kubeadm token create --print-join-command` as admin.
`k8s_username`	Non-root user account name	`k8s_master`	Kubernete master	
`k8s_password`	Non-root user accout password	`k8s_master`	Kubernetes master	
`k8s_web_ui_create`	Create Kubernetes Web Dashboard	`true`	Kubernetes master	
`k8s_web_ui_manifest_file`	Web Dashboard version to create	https://raw.githubusercontent.com/kubernetes/dashboard/v2.2.0/aio/deploy/recommended.yaml	Kubernetes master	
`k8s_web_ui_enable_skip_login`	Allow read-only login to Dashboard without user credentials	`true`	Kubernetes master	
`k8s_web_ui_banner`	Optionally displayed banner	`Kubernetes with SGX support`	Kubernetes master	

Config Variables for Virtual Machines Creation

Variable	Description	Default
`vm_action`	Create or destroy action, one of [`create`|`destroy`]	`create`
`vm_location`	The directory of VM image on the KVM host	`/var/lib/libvirt/images/`
`vm_image`	The file name of VM image on the KVM host	`CentOS-8-GenericCloud-8.4.2105-20210603.0.x86_64.qcow2`
`vm_image_url`	The remote download URL for VM image	`https://cloud.centos.org/centos/8/x86_64/images/CentOS-8-GenericCloud-8.4.2105-20210603.0.x86_64.qcow2`
`vm_os_variant`	VM os variant. Should be one of reported by "osinfo-query os" [^1]	`centos8`
`vm_root_password`	The root password for demo VM image	`Intelinux123`
`vm_resize_partition`	Disk partition to resize [^2]	`/dev/sda1`
`vm_kernel`	Linux kernel for VMs [^3]	`kernel`
`vm_guests`	List of VM configurations	See below "VM Template"
`vm_repo_file_url`	URL of an additional repo file to be used to install packages to VM (optional)	None
`vm_no_log`	Keep sensitive values out of logs	`true`
`copy_host_files`	Copy files from Host to VMs [^4]	empty
`sm_username`	User name (ID) for RHEL subscription manager [^5]	None
`sm_password`	User password for RHEL subscription manager [^5]	None

[^1]: Currently suported values are: `centos8`, `rhel8.3` and `rhel8.4`

[^2]: EFI based images typically need `/dev/sda3`

[^3]: If `vm_kernel` is specified as an empty string, no new kernel is installed in VMs.

[^4]: Implemented via `virt-customize --copy-in`, for details see https://libguestfs.org/virt-customize.1.html

[^5]: Values for username/password obtained by subscribing to Red Hat at https://www.redhat.com

Variables for vm_guests

Name	Description	Default	Notes
`name`	domain name of the VM	must be specified	compulsory, if domain already exists then new VM creation is ignored
`hostname`	hostname of the VM	must be specified	compulsory
`memory_kib`	amount of RAM for VM	must be specified	compulsory, no checks for overcommitment
`vcpu`	number of CPUs	2	no checks for overcommitment
`qcow_disk_file`	disk file name	`name`.qcow2	
`disk_size`	disk size in GB	none	Shrinking of an image is ignored. No resizing of VM image if `disk_size` not defined
`mac_address`	MAC address of VM	'52:54:00:xx:yy:zz' with xx:yy:zz randomized	
`autostart`	start VM automatically after host reboot	`yes`	optional
`running`	start VM after VM created	`yes`	optional
`epc_size`	SGX EPC size	`512M`	
`customize_extra`	commands to pass to `virt-customize`	empty	optionally customize individual VMs (create users, ssh access,...) [^6]

[^6] See the complete list of available commands here: https://libguestfs.org/virt-customize.1.html

VM Template

```
vm_guests:
  - name : vm01
    hostname : 'test-vm01'
    memory_kib: 16777216
    vcpu: 4
    qcow_disk_file: 'test-vm01.qcow2'
    mac_address: '52:54:00:c5:9e:e6'
    autostart: 'yes'
    epc_size: '256M'
    disk_size: '12G'
  - name : vm02
    hostname : 'test-vm02'
    memory_kib: 16777216
    vcpu: 8
    qcow_disk_file: 'test-vm02.qcow2'
    mac_address: '52:54:00:c5:9e:e7'
    autostart: 'no'
    epc_size: '512M'
    disk_size: '20G'
```

Deploy the KVM host virtualization stack

- Guest VMs use the bridge network on the KVM host; the bridge will be created by the playbook on top of the host's Ethernet interface. By default it uses the value “enp1s0”, if your network device name is different, you must specify it via the net_ethernet_dev variable. For example:

  ```
  ./docker-playbook.sh -i inventory/nodes stacks/kvm-host.yml -e "net_ethernet_dev=<host-ethernet-device-name>"
  ```

- The default user that will be used by the playbook is "`sgxdev`", if want to use a different user, please specify via "-u <user>":

```
./docker-playbook.sh -i inventory/nodes -u <user> stacks/kvm-host.yml  -e "net_ethernet_dev=<host-ethernet-
        device-name>"
```

NOTE: Whether using the user `sgxdev` or other, please make sure the `<user>` exists on managed node and is part of `sudo` group. Ansible playbooks need to run with administrator privilege, so either use `-K` for password prompt or modify sudoers for passwordless sudo. Note that -K can only be used when managing a single node, or all managed nodes use identical sudo password for `<user>` . Read more details in the Ansible Documentation.

- By default, the SGX RPM packages will be downloaded from one of the public repositories, based on the OS installed on managed nodes. This address can be customized via variable the `sgx_repo_file_url`:

```
./docker-playbook.sh -i inventory/nodes stacks/kvm-host.yml \
-e "net_ethernet_dev=<host-ethernet-device-name>" \
-e 'sgx_repo_file_url="https://my-dnf-server-address.com/my-repo-file.repo"'
```

Deploy Kubernetes stack

The Kubernetes stack can be deployed via the stacks/kubernetes.yml playbook:

```
./docker-playbook.sh stacks/kubernetes.yml
```

By default, the command will setup a Kubernetes master node with SGX and the NFD (Node Feature Discovery) device plugin. By default it will also install web-ui dashboard,

The playbook also supports setting up a Kubernetes slave node and joining it into an existing Kubernetes cluster via a customized join command, for example:

```
ansible-playbook stacks/kubernetes.yml -e "k8s_role=slave" \
-e 'kubernetes_join_command="kubeadm join 10.239.85.45:6443 \
--token 1ddbem.v1tikqrbutr6sq7e \
--discovery-token-ca-cert-hash sha256:b02cba3d2c98aebbd0f26be97af19fee68ae3fcb1f2f2a04b684160f534edb32"'
```

NOTE: The parameter `kubernetes_join_command` will not work with *./docker-playbook.sh* when running `ansible-playbook` tool within docker. Please either run `ansible-playbook` on the controller node directly without docker or modify the `kubernetes_join_command` in *stacks/kubernetes.yml* without passing via command line. Another option is to use *./docker-playbook.sh* and pass `kubernetes_join_command` via a playbook file. See the file *demos/join-k8-master.yml* for an example.

In the deployment of the slave node, it will assume SGX and the NFD (Node Feature Discovery) device plugin were already installed. Refer to the SGX plugin documentation for more information.

After the SGX node has joined the cluster, the NFD device plugin will discover the `SGX` and `SGXLC` features.

Demos and utilities

Create/Destroy SGX VM

Two playbooks are provided to demonstrate creation of virtual machines:

demos/create-sgx-vms-centos8.yml
demos/create-sgx-vms-rhel8.3.yml
demos/create-sgx-vms-rhel8.4.yml

The number of VMs, host names, memory sizes, vCPU counts, EPC sizes, root password and other options can be customized by editing the playbook files. You need to provide repository file for the SGX kernel. This can be done either by providing URL of the repository or by copying the repository file from the KVM host to the VMs via "copy_host_files". It is safer to provide the URL, this is demonstarted below.

Example command to create CentOS Virtual Machines on KVM host:

```
./docker-playbook.sh demos/create-sgx-vms-centos8.yml
 -e "vm_repo_file_url=https://download.01.org/intelsgxstack/2021-07-28/centos/intelsgxstack.repo"
```

Example command to destroy all VMs created by the file *demos/create-sgx-vms-centos8.yml*:

```
./docker-playbook.sh demos/create-sgx-vms-centos8.yml -e "vm_action=destroy"
```

It is slightly more complex to create RHEL virtual machines: you also need to provide RHEL credentials. The credentials are obtained via registration/subscription to RHEL. The playbook file assumes the cloud image file is already placed in the host folder as specified by "vm_location". (Defaults to_/var/lib/libvirt/images_.) Otherwise, you need to provide URL of the image. Beware that Red Hat provided download URLs expire quickly, so you may need to host the downloaded cloud image yourself.

Example command to create RHEL8.4 Virtual Machines on KVM host:

```
./docker-playbook.sh demos/create-sgx-vms-rhel8.4.yml
   -e "vm_repo_file_url=https://download.01.org/intelsgxstack/2021-07-28/rhel/intelsgxstack.repo"
   -e "sm_username=<my_rhelusername>" -e "sm_password=<my_rhelpassword>"
```

The virtual machines will be registered with Red Hat, as can be verified by viewing https://access.redhat.com/management/systems

Example command to destroy all VMs created by the file *demos/create-sgx-vms-rhel8.4.yml*:

```
./docker-playbook.sh demos/create-sgx-vms-rhel8.4.yml -e "vm_action=destroy"
```

The virtual machines will be un-registered from Red Hat, as can be verified by viewing https://access.redhat.com/management/systems

Create/Destroy SGX VM ready to be managed by Ansible

A playbook that demonstrates creation of VMs with user `sgxdev` with passwordless ssh connection and passwordless sudo privileges. All you need to do is provide your own public ssh key. The playbook also demonstrates how to install additional packages. Edit the playbook file *demos/create-sgx-k8s-vms.yml* with your public ssh key and run the playbook:

```
./docker-playbook.sh demos/create-sgx-k8s-vms.yml
```

NOTE: *The virtual machines created at this point are simple cloud images, with no Kubernetes software deployed. The Kubernetes deployment will be demonstrated in the next step.*

Destroy all created VMs:

```
./docker-playbook.sh demos/create-sgx-k8s-vms.yml -e "vm_action=destroy"
```

Create/Destroy Kubernetes cluster using virtual machines

Once you have successfully created virtual machines using *demos/create-sgx-k8s-vms.yml*, it is fairly easy to set up a simple Kubernetes cluster. The first step is to create two inventory files *host-k8s-master* and *host-k8s-workers* containing IP addresses of our virtual machines (use IP addresses as reported by the VMs creation):

```
$ cat host-k8-master
10.165.56.228 ansible_user=sgxdev

$ cat host-k8-workers
10.165.56.229 ansible_user=sgxdev
10.165.59.10  ansible_user=sgxdev
```

Next, deploy the Kubernetes master. The deployment will also create a default account for a user "*k8s_master*" with the password "*k8s_master*". You can override the default account values and specify your own values.

```
./docker-playbook.sh -i host-k8-master stacks/kubernetes.yml \
-e "k8s_username=joe" -e "k8s_password=intelsgx" \
-e "sgx_repo_file_url=https://download.01.org/2021-07-28/centos/intelsgxstack.repo"
```

The deployment will print out the Kubernetes join command. We will need it later.

At this point you can query the cluster. This can be done via command line interface from a terminal or via web ui dashboard.

Terminal:

Log into k8_vm_master (use IP address as reported for the k8_vm_master).

Example:

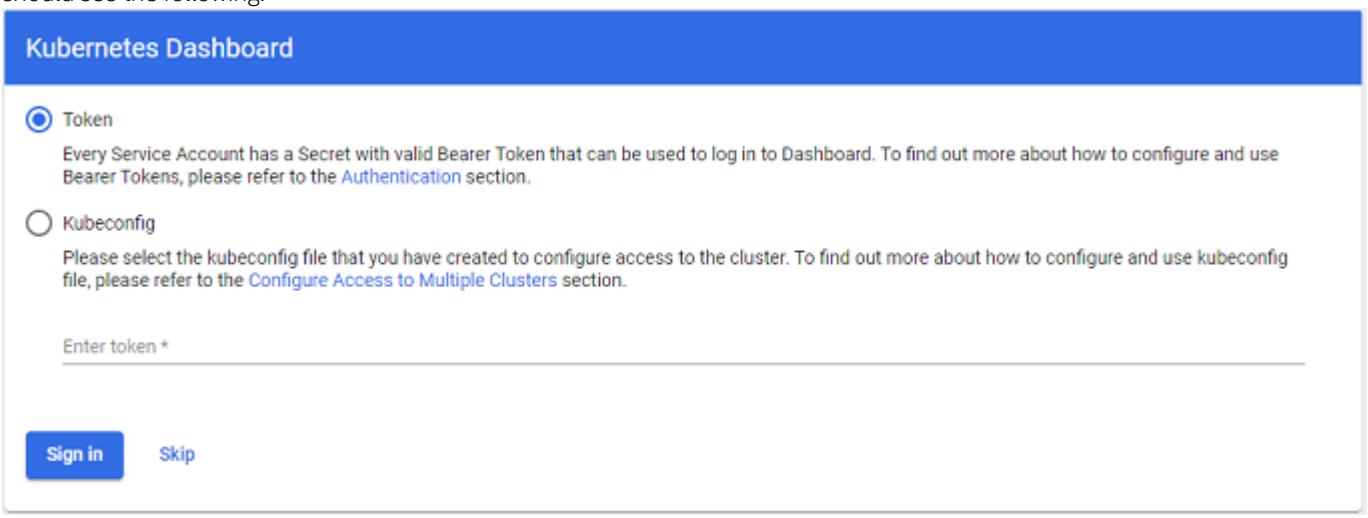
```
ssh joe@10.165.56.228
password: intelsgx

[joe@k8s-vm-master ~]$ kubectl get nodes
NAME            STATUS   ROLES    AGE     VERSION
k8s-vm-master   Ready    master   2m19s   v1.20.4
```

WEB UI:

After the Kubernetes master is deployed, the playbook will display URL for Kubernetes Web Dashboard and administartor login token, similar to the following:

```
"Login to dashboard UI:"
    "https://10.165.59.82:31217/#/login"
    "Admin login token:"
       "eyJhbGciOiJSUzI1NiIsImtpZCI6Ijl4QXhZT ... "
```

Paste in the provided dashboard URL in a browser (you will encounter some warnings due to unknown certificates) and you should see the following:

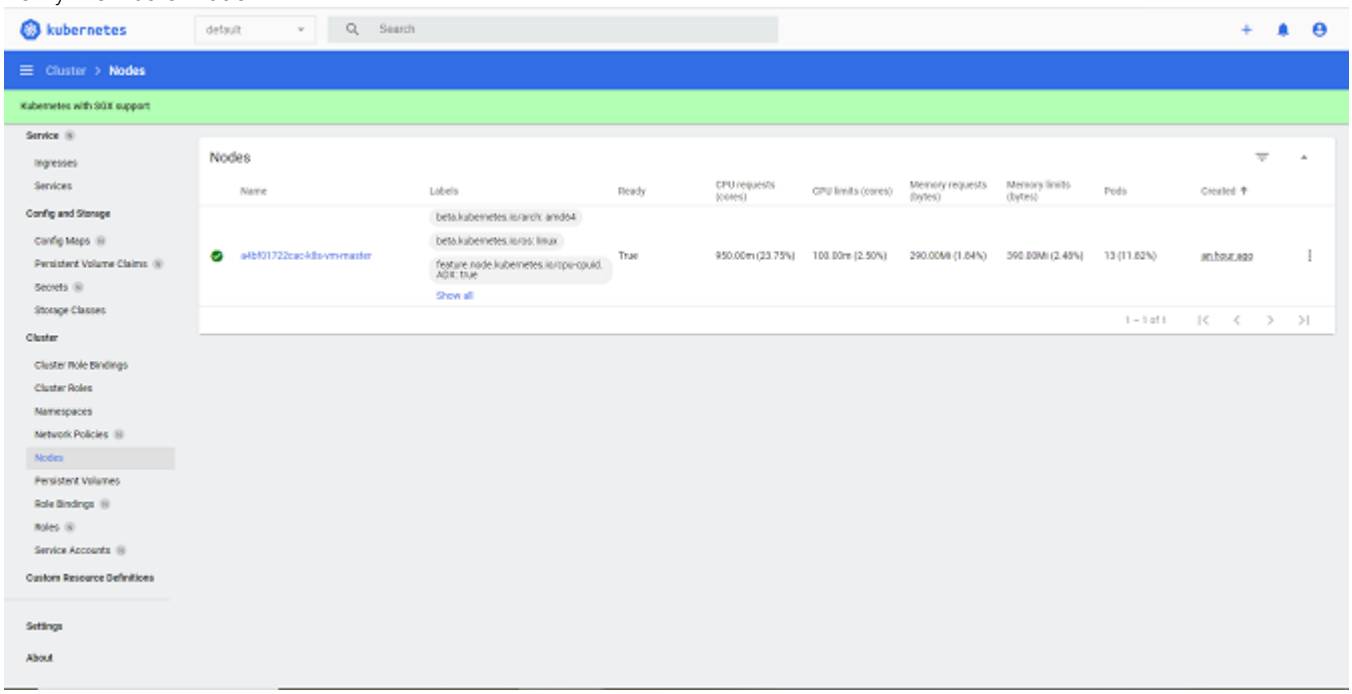


To sign in as administrator, paste in the login token. You can use `Skip` for view-only dashboard mode.

NOTE You can also generate the admin login token manually using the command:

```
kubectl -n kubernetes-dashboard get secret \
$(kubectl -n kubernetes-dashboard get sa/admin-user -o jsonpath="{.secrets[0].name}") \
-o go-template="{{.data.token | base64decode}}"
```

Verify the master node:



NOTE: *The join command init token can expire. You can obtain a fresh token by logging into Kubernetes master VM and issuing the command "kubeadm token create --print-join-command".*

NOTE: *Due to the format of the join command string, we cannot pass the* `kubernetes_join_command` *on the command line using Docker deployment, hence we have to resort to editing the playbook file.*

Next step is to edit the playbook *stacks/kubernetes.yml* and enter the value for *kubernetes_join_command:* by entering the join command reported by the Kubernetes master deployment.

Now we are ready to deploy all worker nodes:

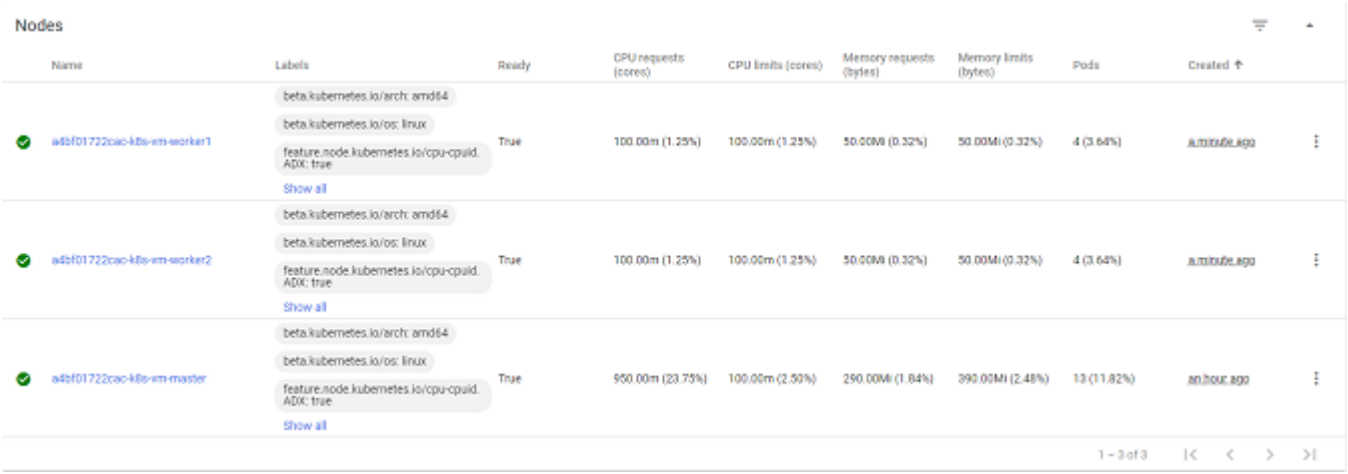
```
./docker-playbook.sh stacks/kubernetes.yml -i host-k8-workers \
-e "k8s_role=slave" \
-e "sgx_repo_file_url=https://download.01.org/2021-07-28/centos/intelsgxstack.repo"
```

Now let's query the cluster again. This time we should also see the worker nodes.

Example:

```
[joe@k8s-vm-master ~]$ kubectl get nodes
NAME             STATUS   ROLES    AGE     VERSION
k8s-vm-master    Ready    master   16m     v1.20.4
k8s-vm-worker1   Ready    <none>   2m40s   v1.20.4
k8s-vm-worker2   Ready    <none>   2m40s   v1.20.4

[joe@k8s-vm-master ~]$  kubectl get pods --show-labels
NAME                    READY   STATUS    RESTARTS   AGE     LABELS
intel-sgx-plugin-cjpkq   1/1     Running   0          16m     app=intel-sgx-plugin,controller-revision-
        hash=5d667c9f7d,pod-template-generation=1

intel-sgx-plugin-rw97l   1/1     Running   0          2m55s   app=intel-sgx-plugin,controller-revision-
        hash=5d667c9f7d,pod-template-generation=1

intel-sgx-plugin-slfp2   1/1     Running   0          2m55s   app=intel-sgx-plugin,controller-revision-
        hash=5d667c9f7d,pod-template-generation=1
```

NOTE: *You can use the dashboard to view the new nodes.*



Cleanup hosts

Use the following playbook to do a partial cleanup for SGX stack deployment:

```
./docker-playbook.sh demos/cleanup-hosts.yml
```

The playbook will not uninstall any kernel. You can customize the cleanup by editing the script file *files/cleanup-hosts.sh*.

ATTENTION: This will remove docker installation on all managed nodes.

Show the IP address for all VMs

Use the following playbook to show the IP address for all VMs on all managed nodes:

```
./docker-playbook.sh demos/show-vm-ip-address.yml
```

Verify the VMs were created and are running

You can verify that the VMs were created successfully and are running by running the following command from the managed node:

```
sudo virsh list --all
```

Known Issues

1. Kubernetes stacks fail to be deployed

If the managed node is the type of master role, run `kubeadm reset default` to clean up the previous Kubernetes deployment. If the managed node is the type of slave role, make sure the `kubernetes_join_command` was provided.

2. Fail pass `kubernetes_join_command` via `-e` when using `docker-playbook.sh`

When deploying the SGX stack to a Kubernetes slave node, the join command line need be passed via `-e`. It will fail if using `docker-playbook.sh` which is running `ansible-playbook` in docker. There are three workarounds below, either one should work:

- Run `ansible-playbook` on the controller node directly instead of `docker-playbook.sh`. However, this requires installation of Ansible and all dependencies like Dockerfile does for `docker-playbook`.
- Modify the `kubernetes_join_command` in `stacks/kubernetes.yml` instead of passing it via `-e`.
- Run a playbook file with an explicit join command initialized to the desired value. See *demos/join-k8-master.yml* as an example.

3. Red Hat does not show host names of registered virtual machines

You can check your registered RHEL systems at https://access.redhat.com/management/systems. You will see all your registered virtual machines, however they may be showing the name `(none)`. To be able to identify the virtual machines by their host names, you need to re-register each virtual machine with the credentials obtained from Red Hat registration:

```
subscription-manager register --username=<username> --password=<password> --auto-attach --force
```

Additional Information

Visit us at https://01.org/intel-sgx-stacks/

Connect with us on the Linux Stacks for Intel® SGX mailing list to keep up to date on releases and features!

You can sign up here:

https://lists.01.org/postorius/lists/intel-sgx-stacks.lists.01.org/

Or email us at intel-sgx-stacks@lists.01.org.

Statement