

Smart Data Transaction for CPS R7 Installation Guide

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Introduction

This guide provides instructions for installing and configuring the Smart Data Transaction for CPS blueprint, and also includes recommended hardware and software requirements for the blueprint. The guide describes a minimal installation of the blueprint consisting of a single "master" node and two "edge" nodes, with directions on how the number of nodes can be modified as needed.

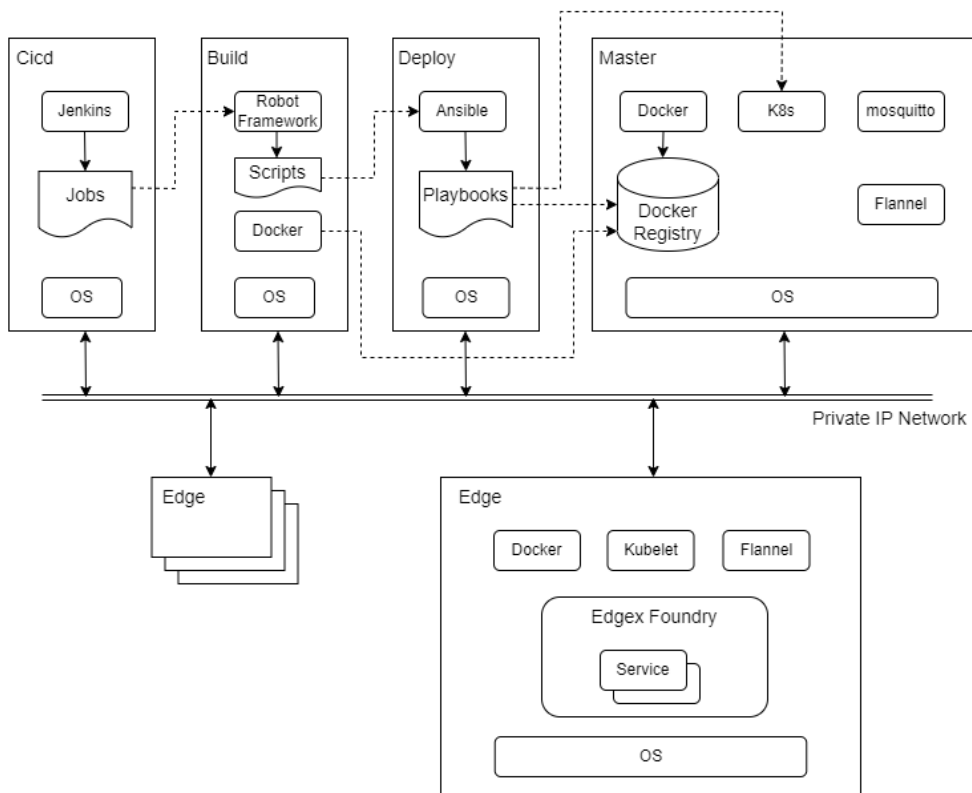
How to Use This Document

This document assumes the reader is familiar with basic UNIX command line utilities and [Kubernetes](#). Familiarity with [Ansible](#) and [Docker](#) may also be useful. To interact with the EdgeX micro-services in a running setup, use the APIs as described in the [EdgeX documentation](#). Sensor data and camera data can be observed through the MQTT broker mosquitto and its command line utility `mosquitto_sub`.

Start by reviewing the deployment architecture and requirements in the following sections, then follow the steps in the Installation section to set up the software and start it running. Confirm the services are functioning as expected by following the instructions in the Verifying the Setup section. The later sections in this document describe other tasks that can be performed on a running setup, alternate configuration options, and how to shut down and uninstall the software.

Deployment Architecture

The diagram below shows the major components and relationships in a deployment of this blueprint.



Deployment, as well as other tasks such as starting and stopping the cluster, is coordinated through a set of Ansible playbooks. (Ansible playbooks are a system used by the Ansible tool for describing the desired state of a system. In many ways they are similar to shell scripts. For more details see the Ansible documentation.) The playbooks are run by the deploy node and build node, and they execute commands on the deploy node, the master node, the build node, and in some cases on the edge nodes. Once the nodes are set up, most activity is carried out by Kubernetes. Kubernetes is configured by the playbooks and told to start or stop services on the edge nodes. These services are run in containers, and the images for these containers are stored in a local Docker registry. There are containers for the Kubernetes components themselves, plus Flannel (a component which provides networking inside the Kubernetes cluster), EdgeX Foundry services, and four custom services (sync-app, image-app, device-lora and device-camera) built using the EdgeX SDKs.

Note that the build node and the deploy node and the master node can be the same host or virtual machine.

The camera nodes are not shown in the above diagram as they are not envisioned as being connected to the network, and are not configured by the playbooks from the deploy node. See the Camera Nodes section of Installation for an example of how camera nodes may be setup.

Pre-Installation Requirements

Hardware Requirements

The table below shows the recommended minimum specifications for the hardware in the testing installation. It is possible that lower spec hardware could be used for many of the nodes.

	Master/Deploy/Build/CICD	Edge	Camera
Platform	VM running on commercial grade PC	NVidia Jetson Nano	H.View HV-500E6A
CPU	x86-64, Intel i5 or similar	ARM 64bit Cortex-A57	N/A
Cores	2	4	N/A
RAM	4 GB	2 GB	N/A
Storage	128 GB Hard Disk space	32 GB SD Card	N/A (SD card optional)
Network	1x Ethernet	1x Ethernet	1x Ethernet
Other	N/A	LoRa dongle (LRA-1)* *Used in R6 configuration	ONVIF (Profile S, Profile T) supporting IP camera

At a minimum one node is required for the master and deploy and build and cicd roles together, and at least two edge nodes and two camera nodes. The testing installation contains eight nodes(one deploy node, one master node, one build node, one cicd node, two edge nodes, two camera nodes).

Network Requirements

All nodes are expected to have IP connectivity to one another during installation and normal operation, with the exception of the camera nodes. In the installation described here, all the nodes are connected to a private wired network operating at 100Mbps or better. However, there are no strict bandwidth or latency requirements.

During initial software installation all of the nodes will require access to the internet to download required software packages. Once the required software packages are installed and the docker registry is started, only the deploy node and build node will need further access to the internet (unless, of course, software packages need to be changed or updated). The deploy node will need to access the internet when pulling upstream images to install in the docker registry. The build node will need to access the internet when building docker images for custom services. Of course, if external tools are going to be used to access the collected data through the MQTT broker (Mosquitto), those tools will need network access to the master node.

When the edge node services are started, images will be downloaded from the docker registry on the master node to the edge nodes, so bandwidth may be a consideration if, for example, the edge nodes are accessed over a mobile network.

Software Prerequisites

The list below shows the required software for each node type prior to beginning the installation process.

- CICD node
 - Ubuntu 20.04
- Build node
 - Ubuntu 20.04
- Deploy node
 - Ubuntu 20.04
 - Ansible 2.12.5
- Master node
 - Ubuntu 20.04
- Edge node
 - Ubuntu 20.04
- Camera node
 - N/A (pre-installed)

Note that Ansible 2.9.6 is installed from the regular Ubuntu repository on Ubuntu 20.04, but needs to be upgraded from the Ansible repository to support the `kubernetes.core` collection used by this blueprint.

Additional Installed Software Packages

Note that the installation process will install several more software packages through Ansible playbooks. These are listed below for reference. Packages included by default in an install of Ubuntu 20.04 server are not included. The version numbers are those that are available/installed at the time of writing by the Ansible playbooks on Ubuntu 20.04.

- CICD node
 - make 4.2.1, build-essential 12.8, python3-pip 20.0.2, default-jre 2:1.11-72
 - Jenkins 2.332.3
- Build node
 - make 4.2.1, build-essential 12.8, python3-pip 20.0.2, default-jre 2:1.11-72
 - Robot Framework 6.0
 - Docker (docker.io) 20.10.12
 - Go 1.16.10
- Deploy node
 - make 4.2.1, build-essential 12.8, python3-pip 20.0.2
 - Ansible 2.12.5
 - Ansible collections `community.docker`, `kubernetes.core`, `community.crypto`
- Master node
 - Docker (docker.io) 20.10.12
 - python3-pip 20.0.2
 - Python packages `cryptography` and `kubernetes`
 - mosquitto 2.0.15, mosquitto-clients 2.0.15
 - Kubernetes (kubectl, kubelet, kubeadm) 1.22.9
 - Flannel 0.17.0, flannel-cni-plugin 1.0.1 (Note: These are containers installed via Kubernetes through a config file)
- Edge node
 - Docker (docker.io) 20.10.12
 - Kubernetes (kubelet, kubeadm) 1.22.9 (kubectl may be installed for debugging purposes)

Installation

Setting Up the Deploy Node

The deploy node will coordinate all other installation and operations, so it needs to be set up first. In the test installation, the deploy node is a VM running on a x86 PC, with Ubuntu Linux 20.04 installed. In addition, the [Ansible](#) tool must be installed. The Ansible tool provided in the Ubuntu software repository is a slightly older version which needs to be upgraded, but it is sufficient to execute the `setup_deploy.yml` playbook, which will install the newer version of Ansible and other tools required on the deploy node. But before running that playbook you need to configure a few things described in the section below.

The playbooks for use on the deploy node are stored in the `deploy/playbook` directory of the source repository. These playbooks refer to other files in the source code, so the entire directory tree should be copied onto the deploy node. The easiest way to do this is by cloning the git repository directly as shown below:

```
git clone repository-url
```

Note, using the `--depth=1` option can save some disk space if you don't need to modify the source code.

The git command will create a directory in the directory where it is run named after the repository. Inside the new directory will be the `deploy/playbook` directory. Unless noted otherwise, the commands below should be run in that directory.

Node and Cluster Configuration

Before running the `setup_deploy.yml` playbook, two hosts files need to be modified.

Modify the hosts file in the `deploy/playbook` directory with the host names and IP addresses of the master, build, cicc, and edge nodes.

```
all:
  hosts:
  children:
    deploy:
      hosts:
        localhost:
    master:
      hosts:
        sdt-master: # hostname of master node
    edge_nodes:
      hosts:
        jet03: # hostname of first edge node
        ip: 192.168.2.27 # IP address of first edge node
        lora_id: 1
        jet04: # hostname of second edge node
        ip: 192.168.2.29 # IP address of second edge node
        lora_id: 4
      vars:
        ansible_user: edge
        ansible_ssh_private_key_file: ~/.ssh/edge
    build:
      hosts:
        sdt-build: # hostname of build node
        ip: 192.168.10.203 # IP address of build node
    cicc:
      hosts:
        sdt-cicc: # hostname of cicc node
        ip: 192.168.10.200 # IP address of cicc node
```

Modify the host names and IP addresses of the master, build, cicc and deploy nodes in the `cicc/playbook/hosts` file.

```

all:
  hosts:
    localhost:
    arm-build:
      ansible_host: erc01
      ansible_user: edge
      ansible_ssh_private_key_file: ~/.ssh/edge
      ansible_become_password: password
  children:
    master:
      hosts:
        sdt-master: # hostname of master node
    build:
      hosts:
        sdt-build: # hostname of build node
        ip: 192.168.10.203 # ip address of build node
      vars:
        ansible_user: sdt-admin
        ansible_ssh_private_key_file: ~/.ssh/lfedge_build
    cicd:
      hosts:
        sdt-cicd: # hostname of cicd node
        ip: 192.168.10.200 # ip address of cicd node
      vars:
        ansible_user: sdt-admin
        ansible_ssh_private_key_file: ~/.ssh/lfedge_cicd
    deploy:
      hosts:
        sdt-deploy: # hostname of deploy node
        ip: 192.168.10.231 # ip address of deploy node

```

In the file `master.yml` in the `deploy/playbook/group_vars/all` directory, set the `master_ip` value to the IP address of the master node. Note that this is required even if the master node is the same as the deploy node.

```
master_ip: 192.168.2.16
```

Set Up the Deploy Node

The account which runs the deploy playbooks will need to be able to use `sudo` to execute some commands with super-user permissions. The following command can be used (by root or another user which already has super-user permissions) to enable the use of `sudo` for a user:

```
sudo usermod -aG sudo username
```

After setting IP addresses and node names in the `master.yml` and `hosts` files, you can run the `setup_deploy.yml` playbook using the command below.

```
ansible-playbook -i ./hosts setup_deploy.yml --ask-become-pass
```

This will add the node names and addresses to the deploy node's `/etc/hosts` file as well as upgrade the version of Ansible if necessary. It will also install Ansible collections `community.docker`, `kubernetes.core`, and `community.crypto`, required by the other Ansible playbooks in this blueprint.

Ansible will be installed using root permissions on the deploy node, so supply the `sudo` password (by default the user's password) when prompted for the "become" password.

Preparing the Master Node

If the master node is not on the same host as the deploy node, the user that runs the deploy playbooks must have an account on the master host under the same name, and that account must have `sudo` privileges like the account on the deploy node (see above). Also, the account should have password-less SSH login configured. See the description of configuring password-less login for the edge node administrator account in the [Preparing Edge Nodes](#) section.

The following command will prepare the master node for use:

```
ansible-playbook -i ./hosts master_install.yml --ask-become-pass
```

This playbook requires the password for `sudo` on the master node (the "become" password).

It will perform the following initialization tasks:

- Make sure there are entries for the `cicd`, `build`, `master` and `edge` node names in `/etc/hosts`
- Install required software packages including `Docker`, `Kubernetes`, `pip`, and `mosquitto`
- Install Python packages used by other playbooks (`kubernetes` and `cryptography`)
- Make sure the user can run `Docker` commands
- Prepare basic configuration for `Docker` and `Kubernetes`
- Set up a user name and password for the MQTT service

Note, you can customize the MQTT user name and password using the `mqtt_user` and `mqtt_pwd` variables in the `docker/playbook/group_vars/all/mqtt.yml` file. By default the user name is "edge" and the password "edgemqtt". These credentials must be used if you want to, for example, use the `mosquitto_sub` command to monitor incoming MQTT messages from the edge nodes.

Master Node Kubernetes Requirements

Kubernetes' initialization tool `kubeadm` requires that swap be disabled on nodes in the cluster. Turn off swap on the master mode by editing the `/etc/fstab` file (using `sudo`) and commenting out the line with "swap" as the third parameter:

```
# /swap.img none swap sw 0 0
```

In addition, if you have proxy settings `kubeadm` will warn that you should disable the proxy for cluster IP addresses. The default cluster IP ranges `10.96.0.0/12` and `10.244.0.0/16` should be added to the `no_proxy` and `NO_PROXY` variables in `/etc/environment` if necessary.

```
no_proxy=localhost,127.0.0.0/8,192.168.2.0/24,10.96.0.0/12,10.244.0.0/16,*.local,*.fujitsu.com
NO_PROXY=localhost,127.0.0.0/8,192.168.2.0/24,10.96.0.0/12,10.244.0.0/16,*.local,*.fujitsu.com
```

Creating the Docker Registry

This blueprint sets up a private Docker registry on the master node to hold all the images which will be downloaded to the edge nodes. The following command will start the registry. This command also creates and installs a cryptographic key that is used to identify the registry to the edge nodes.

```
ansible-playbook -i ./hosts start_registry.yml --ask-become-pass
```

Once this command has been run the registry will run as a service and will automatically restart if the master node reboots for some reason. If you need to stop the registry or clear its contents, see the instructions in the Stopping and Clearing the Docker Registry section of the Uninstall Guide.

Note that if you stop and restart the registry new keys will be generated and you will need to run the `edge_install.yml` playbook again to copy them to the edge nodes.

Populating the Registry

The following command will download the required images from their public repositories and store copies in the private repository:

```
ansible-playbook -i ./hosts pull_upstream_images.yml
```

Note that this process can take some time depending on the speed of the internet connection from the master node.

If the version of Kubernetes or Flannel changes you will need to populate the registry with updated images using the above command again. Note that you can force Kubernetes to use a specific patch version by editing the `deploy/playbook/k8s/config.yml` file and adding the line `kubernetesVersion: v1.22.9` (with the version you require) under the the `kind: ClusterConfiguration` line, and running the `master_install.yml` playbook again. (You can also make the same change to `~/lfdedge/config.yml` directly to avoid having to run `master_install.yml` again.)

Populating the registry will leave extra copies of the downloaded images on the master node. You can remove these using the following command (the images will remain in the private registry):

```
ansible-playbook -i ./hosts clean_local_images.yml
```

Preparing Edge Nodes

Add an administrative account to all the edge nodes. This account will be used by the deploy node when it needs to run commands directly on the edge nodes (e.g. for installing base software, or for joining or leaving the cluster). The following commands run on each edge node will add a user account named "edge" and add it to the group of users with `sudo` privileges.

```
sudo adduser edge
sudo usermod -aG sudo edge
```

Note, if you use an administrative account with a different name, change the variable `ansible_user` in the `edge_nodes` group in the `deploy/playbook/hosts` file to match the user name you are using.

In the file `secret` in the `deploy/playbook/group_vars/edge_nodes` directory, set the edge node admin user's `sudo` password.

The deploy node needs to log in via SSH to the edge nodes using a cryptographic key (rather than a password), so that a password does not need to be provided for every command. Run the following command on the deploy node to create a key called "edge" for the administrative user.

```
ssh-keygen -t ed25519 -f ~/.ssh/edge
```

The parameter `~/ssh/edge` is the name and location of the private key file that will be generated. If you use a different name or location, change the `ansible_ssh_private_key_file` variable for the `edge_nodes` group in `deploy/playbook/hosts` to match.

Once the key files have been created, the following command can be run from the deploy node to copy the key to each edge node so a password will not be required for each login. (The administrative user's password will be requested when running this command.)

```
ssh-copy-id -i ~/.ssh/edge.pub edge@nodename
```

After the administrative account has been created, the following command will perform initial setup on all edge nodes configured in the `deploy/playbook/hosts` file:

```
ansible-playbook -i ./hosts edge_install.yml
```

The playbook will perform the following initialization tasks:

- Make sure there is an entry for the master node in `/etc/hosts`
- Install required software packages including Docker and kubelet
- Make sure the user can run Docker commands
- Configure Docker, including adding the certificates to secure access to the private registry

Edge Node Kubernetes Requirements

Like the master node, swap should be disabled and the cluster IP address ranges should be excluded from proxy processing if necessary.

Note that on the Jetson Nano hardware platform has a service called `nvzramconfig` that acts as swap and needs to be disabled. Use the following command to disable it:

```
sudo systemctl disable nvzramconfig.service
```

Preparing the Build Node

The deploy node needs to log in via SSH to the build node and the cicd node using a cryptographic key (rather than a password), so that a password does not need to be provided for every command. Run the following command on the deploy node to create a key called "lfedge_build" for the administrative user to log in to the build node.

```
ssh-keygen -t rsa -b 2048 -f ~/.ssh/lfedge_build
```

The parameter `~/.ssh/lfedge_build` is the name and location of the private key file that will be generated. If you use a different name or location, change the `ansible_ssh_private_key_file` variable for the build group in `cicd/playbook/hosts` to match.

Once the key files have been created, the following command can be run from the deploy node to copy the key to build node so a password will not be required for each login. (The administrative user's password will be requested when running this command.)

```
ssh-copy-id -i ~/.ssh/lfedge_build.pub sdt-admin@nodename
```

Note, if you use an administrative account with a different name, change the variable `ansible_user` in the build group in the `cicd/playbook/hosts` file to match the user name you are using.

After the configuration of private key, the following command will prepare the build node for use:

```
ansible-playbook -i ./hosts setup_build.yml --ask-become-pass
```

The playbook will perform the following initialization tasks:

- Make sure there are entries for the master and deploy nodes in `/etc/hosts`
- Install required software packages including Docker and Go and Robot Framework
- Make sure the user can run Docker commands
- Configure Docker, including adding the certificates to secure access to the private registry

Preparing the CICD Node

The deploy node needs to log in via SSH to the cicd node using a cryptographic key (rather than a password), so that a password does not need to be provided for every command. Run the following command on the deploy node to create a key called "lfedge_cicd" for the administrative user to log in to the cicd node.

```
ssh-keygen -t rsa -b 2048 -f ~/.ssh/lfedge_cicd
```

The parameter `~/.ssh/lfedge_cicd` is the name and location of the private key file that will be generated. If you use a different name or location, change the `ansible_ssh_private_key_file` variable for the cicd group in `cicd/playbook/hosts` to match.

Once the key files have been created, the following command can be run from the deploy node to copy the key to build node so a password will not be required for each login. (The administrative user's password will be requested when running this command.)

```
ssh-copy-id -i ~/.ssh/lfedge_cicd.pub sdt-admin@nodename
```

Note, if you use an administrative account with a different name, change the variable `ansible_user` in the cicd group in the `cicd/playbook/hosts` file to match the user name you are using.

After the configuration of private key, the following command will prepare the cicd node for use:

```
ansible-playbook -i ./hosts setup_cicd.yml --ask-become-pass
```

The playbook will perform the following initialization tasks:

- Make sure there is an entry for the build node in `/etc/hosts`
- Install required software packages including Jenkins

Building the Custom Services

At this time, images for the four custom services, `sync-app`, `image-app`, `device-lora` and `device-camera`, need to be built from source and pushed to the private Docker registry. (In the future these images should be available on Docker Hub or another public registry.) Use the following playbooks from the `cicd/playbook` directory on the deploy node to do so.

Note, limited by base image [NVIDIA L4T CUDA](#) which only supports arm architecture, so custom service `image-app` also only supports arm architecture. Other custom services support both arm64 and amd64 architectures.

This command executed on the deploy node will build local docker images of the custom microservices:

```
ansible-playbook -i ./hosts build_images.yml
```

The build command can take some time, depending on connection speed and the load on the deploy host, especially the compilation of cross-compiled images.

This command executed on the deploy node will push the images to the private registry:

```
ansible-playbook -i ./hosts push_images.yml
```

At time of writing this step will also create some workaround images required to enable EdgeX security features in this blueprint's Kubernetes configuration. Hopefully, these images will no longer be needed once fixes have been made upstream.

Starting the Cluster

With the base software installed and configured on the master and edge nodes, the following command executed on the deploy node will start the cluster:

```
ansible-playbook -i ./hosts init_cluster.yml --ask-become-pass
```

This command only starts the master node in the Kubernetes cluster. The state of the master node can be confirmed using the `kubectl get node` command on the master node.

```
sdt-admin@sdt-master:~$ kubectl get node
NAME      STATUS    ROLES                  AGE     VERSION
master    Ready     control-plane,master   3d5h    v1.22.9
```

Adding Edge Nodes to the Cluster

Once the cluster is initialized, the following command executed on the deploy node will add all the configured edge nodes to the cluster:

```
ansible-playbook -i ./hosts join_cluster.yml
```

The `kubectl get nodes` command on the master node can be used to confirm the state of the edge nodes.

```
sdt-admin@sdt-master:~$ kubectl get node
NAME      STATUS    ROLES                  AGE     VERSION
jet03     Ready     <none>                 3d5h    v1.22.9
jet04     Ready     <none>                 3d5h    v1.22.9
master    Ready     control-plane,master   3d5h    v1.22.9
```

Starting EdgeX

Before starting EdgeX services, you need to do the following configuration first.

- Modify the file `edgex.yml` in the `deploy/playbook/group_vars/all` directory to decide which services will be started. For details, please refer to the section [Enabling and Disabling Optional Services](#) below.
- If the custom service `device-camera` will be started, set the `camera_ip` value to the IP address of the camera node in the `deploy\playbook\host_vars\jet03.yml` file and the `deploy\playbook\host_vars\jet04.yml` file.
- If you are using different host names of the edge nodes, change the file name of files in the `deploy\playbook\host_vars` directory, and change `destination_host` value in the files in the `deploy\playbook\host_vars` directory.

After all configurations are completed, the following command executed on the deploy node will start the EdgeX services on the edge nodes:

```
ansible-playbook -i ./hosts edgex_start.yml
```

You can confirm the status of the EdgeX microservices using the `kubectl get pod` command on the master node. (EdgeX micro-service containers are grouped into one Kubernetes "pod" per node.)

```
sdt-admin@sdt-master:~$ kubectl get pod
NAME                                READY   STATUS    RESTARTS      AGE
edgex-jet03-7f9644bb7d-gklvb       22/22   Running   18 (3d5h ago)  3d5h
edgex-jet04-749647459c-drpzb       22/22   Running   18 (3d5h ago)  3d5h
```


Note, during initialization of the services you may see some containers restart one or more times. This is part of the timeout and retry behavior of the services waiting for other services to complete initialization and does not indicate a problem.

Camera Nodes

Consult the installation instructions for the H.View HV-500E6A hardware.

Readings received from Camera nodes should appear in the `core-data` database and be possible to monitor using the `edgex-events-nodename` channel. For example, the following command run on the master node should show the readings arriving at an edge node named "jet03":

```
mosquitto_sub -t edgex-events-jet03 -u edge -P edgmqtt
```

Verifying the Setup

Test cases for verifying the blueprint's operation are provided in the `cicd/tests` directory. These are [Robot Framework](#) scripts which can be executed using the robot tool.

Before using the playbook scripts in the `cicd/tests` directory, modify the `common.resource` file in the `cicd/tests/` directory according to your environment. The content to be changed is the part annotated with '#' below.

```
*** Settings ***
Library SSHLibrary
Library String

*** Variables ***
${HOME} /home/sdt-admin # host directory of deploy node
${DEPLOY_HOST} sdt-deploy # hostname of deploy node
${DEPLOY_USER} sdt-admin # username of deploy node
${DEPLOY_KEY} ${HOME}/.ssh/lfedge_deploy # private key in build node to access deploy node
${DEPLOY_PWD} password
${PLAYBOOK_PATH} lf-edge/deploy/playbook # playbook path of deploy node
${EDGE_HOST1} jet03 # hostname of edge node#1
${EDGE_HOST2} jet04 # hostname of edge node#2
${EDGE_USER} edge # username of edge node
${EDGE_KEY} ${HOME}/.ssh/edge # private key in deploy node to access edge node

*** Keywords ***
.....
.....
```

Note, if there is no private key(`${DEPLOY_KEY}`) on the build node, use command `ssh-keygen` to create the private key, and use the command `ssh-copy-id` to copy the key to the destination node.(Please refer to the section [Preparing Edge Nodes](#) above for detailed usage of command `ssh-keygen` and `ssh-copy-id`.)

Developer Guide and Troubleshooting

EdgeX Service Configuration UI

The configuration parameters of EdgeX micro-services can be accessed through a Consul server on each edge node. The UI is accessible at the address `http://node-address:8500/ui`. The node address is automatically assigned by Kubernetes and can be confirmed using the `kubectl get node -o wide` command on the master node.

In order to access the configuration UI a login token is required. This can be acquired using the `get-consul-ac1-token.sh` script in the `edgex` directory. Execute it as follows and it will print out the Consul access token:

```
get-consul-ac1-token.sh pod-name
```

The `pod-name` parameter is the name of the EdgeX pod running on the node. This can be obtained with the `kubectl get pod` command on the master node. The name of the pod will be shown in the first column of the output, and will be "edgex-*nodename*-..."

Access the UI address through a web browser running on the master node, and click on the "log in" button in the upper right. You will be prompted to enter the access token. Copy the access token printed by the `get-consul-ac1-token.sh` script into the text box and press enter to log in to the UI. See the [EdgeX documentation](#) and [Consul UI documentation](#) for more information.

EdgeX API Access

The EdgeX micro-services each support REST APIs which are exposed through an API gateway running on `https://node-address:8443`. The REST APIs are documented in the [EdgeX documentation](#), and they are mapped to URLs under the API gateway address using path names based on the names of each micro-service. So, for example, the `core-data` service's ping interface can be accessed through `https://node-address:8443/core-data/api/v2/ping`. A partial list of these mappings can be found in the [EdgeX introduction to the API gateway](#).

Note that the blueprint does not automatically generate signed certificates for the API gateway, so the certificate it uses by default will cause warnings if accessed using a web browser and require the `-k` option if using the `curl` tool.

There is more information about the API gateway in the [EdgeX documentation](#).

Enabling and Disabling Optional Services

Five EdgeX micro-services can be enabled and disabled using variables in the `deploy/playbook/group_vars/all/edgex.yml` file. Set the variable to `true` to enable the micro-service the next time the `edgex_start.yml` playbook is run. Set the variable to `false` to disable that micro-service. The micro-service controlling variables are listed below:

- `device_virtual`: Enable or disable the [device-virtual](#) service, provided by EdgeX Foundry, used for testing.
- `device_lora`: Enable or disable the `device-lora` service, one of the custom services provided by this blueprint, which provides support for receiving readings and sending commands to remote sensors over LoRa low-power radio links.
- `sync_app`: Enable or disable the `sync-app` application service, the other custom service provided by this blueprint, which provides a way to forward sensor data to other edge nodes.
- `device-camera`: Enable or disable the `device-camera` service, provided by EdgeX Foundry, and modified by this blueprint, which provides support for receiving readings and sending commands to remote cameras.
- `image-app`: Enable or disable the `sync-app` service, the other custom service provided by this blueprint, which provides support for analyzing and comparing images received from the edge nodes

Debugging Failures

Consult the sections under Troubleshooting for commands to debug failures. In particular, using the `kubectl` commands described in Accessing Logs, and changing the log levels of services using the configuration UI described above, which can change the logging level of running services, can be useful.

Reporting a Bug

Contact the Smart Data Transaction for CPS mailing list at sdt-blueprint@lists.akraino.org to report potential bugs or get assistance with problems.

Uninstall Guide

Stopping EdgeX

The EdgeX services can be stopped on all edge nodes using the `edgex_stop.yml` playbook. (It is not currently possible to stop and start the services on individual nodes.)

```
ansible-playbook -i ./hosts edgex_stop.yml
```

Confirm that the services have stopped using the `kubectl get pod` command on the master node. It should show no pods in the default namespace.

After stopping the EdgeX services it is possible to restart them using the `edgex_start.yml` playbook as usual. Note, however, that the pod names and access tokens will have changed.

Removing Edge Nodes

The edge nodes can be removed from the cluster using the following command:

```
ansible-playbook -i ./hosts delete_from_cluster.yml
```

This command should be run before stopping the cluster as described in the following section, in order to provide a clean shutdown. It is also possible to re-add the edge nodes using `join_cluster.yml`, perhaps after editing the configuration in the `hosts` file.

Stopping Kubernetes

Kubernetes can be stopped by running the following command. Do this after all edge nodes have been removed.

```
ansible-playbook -i ./hosts reset_cluster.yml --ask-become-pass
```

Stopping and Clearing the Docker Registry

If you need to stop the private Docker registry service for some reason, use the following command:

```
ansible-playbook -i ./hosts stop_registry.yml
```

With the registry stopped it is possible to remove the registry entirely. This will recover any disk space used by images stored in the registry, but means that `pull_upsteam_images.yml`, `build_images.yml`, and `push_images.yml` will need to be run again.

```
ansible-playbook -i ./hosts remove_registry.yml
```

Uninstalling Software Components

Installed software components can be removed with `sudo apt remove package-name`. See the list of installed software components earlier in this document. Python packages (cryptography and kubernetes) can be removed with the `pip uninstall` command.

Ansible components installed with ansible-galaxy (community.docker, kubernetes.core, community.crypto) can be removed by deleting the directories under `~/ansible/collections/ansible_collections` on the deploy node.

Removing Configuration and Temporary Data

This blueprint stores configuration and data in the following places. When uninstalling the software, these folders and files can also be removed, if present, on the master, build and edge nodes.

- Master node:
 - `~/lfdge`
 - `/opt/lfdge`
 - `/etc/mosquito/conf.d/edge.conf`
 - `/usr/share/keyrings/kubernetes-archive-keyring.gpg`
- Edge node:
 - `/opt/lfdge`
 - `/etc/docker/certs.d/master:5000/registry.crt`
 - `/usr/local/share/ca-certificates/master.crt`
 - `/etc/docker/daemon.json`
 - `/usr/share/keyrings/kubernetes-archive-keyring.gpg`
- Build node:
 - `/etc/profile.d/go.sh`
 - `/usr/local/go`
 - `~/edgexfoundry`
 - `/usr/local/go1.16.10.linux-amd64.tar.gz`

Troubleshooting

Confirming Node and Service Status

The `kubectl` command can be used to check the status of most cluster components. `kubectl get node` will show the health of the master and edge nodes, and `kubectl get pod` will show the overall status of the EdgeX services. The `kubectl describe pod pod-name` command can be used to get a more detailed report on the status of a particular pod. The EdgeX configuration UI, described in the section EdgeX Service Configuration UI above, also shows the result of an internal health check of all EdgeX services on the node.

Accessing Logs

The main tool for accessing logs is `kubectl logs`, run on the master node. This command can be used to show the logs of a running container:

```
kubectl logs -c container-name pod-name
```

It can also be used to check the logs of a container which has crashed or stopped:

```
kubectl logs --previous -c container-name pod-name
```

And it can be used to stream the logs of a container to a terminal:

```
kubectl logs -c container-name pod-name -f
```

The container names can be found in the output of `kubectl describe pod` or in the `edgex/deployments/edgex.yml` file (the names of the entries in the containers list).

For the rare cases when the Kubernetes log command does not work, it may be possible to use the `docker log` command on the node you wish to debug.

Maintenance

Stopping and Restarting EdgeX Services

As described in the Uninstall Guide subsection Stopping EdgeX, the EdgeX services can be stopped and restarted using the `edgex_stop.yml` and `edgex_start.yml` playbooks.

Stopping and Restarting the Kubernetes Cluster

Similar to stopping and restarting the EdgeX services, the whole cluster can be stopped and restarted by stopping EdgeX, removing the edge nodes, stopping Kubernetes, starting Kubernetes, adding the edge nodes, and starting EdgeX again:

```
ansible-playbook -i ./hosts edgex_stop.yml

ansible-playbook -i ./hosts delete_from_cluster.yml

ansible-playbook -i ./hosts reset_cluster.yml --ask-become-pass

ansible-playbook -i ./hosts init_cluster.yml --ask-become-pass

ansible-playbook -i ./hosts join_cluster.yml

ansible-playbook -i ./hosts edgex_start.yml
```

Adding and Removing Edge Nodes

Edge nodes can be added and removed by stopping the cluster, editing the `deploy/playbook/hosts` file, and adding or removing host files in the `deploy/playbook/host_vars` directory. The `master_install.yml` and `edge_install.yml` playbooks need to be run again to update `/etc/hosts` and certificates on any added nodes.

Updating the Software

Running `setup_deploy.yml`, `setup_build.yml`, `setup_cicd.yml`, `master_install.yml`, and `edge_install.yml` playbooks can be used to update software packages if necessary. Note that Kubernetes is specified to use version 1.22 to avoid problems that might arise from version instability, but it should be possible to update if so desired.

Rebuilding Custom Services

The custom services can be rebuilt by running the `build_images.yml` playbook in `cicd/playbook`. After successfully building a new version of a service, use `push_images.yml` to push the images to the private Docker registry. The source for the services is found in `edgex/sync-app`, `edgex/image-app`, `edgex/device-camera`, and `edgex/device-lora`.

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The synchronization application, image application, device camera service and LoRa device service are linked with other packages/components when compiled, which are each covered by their own licenses, listed below. Other components downloaded and installed during the blueprint's installation process are covered by their own licenses.

Synchronization Application

The synchronization application is linked with the following packages when compiled:

Package	License Type	License URL
bitbucket.org/bertimus9/systemstat	MIT	https://bitbucket.org/bertimus9/systemstat/src/0eeff89b0690/LICENSE
github.com/armon/go-metrics	MIT	https://github.com/armon/go-metrics/blob/f0300d1749da/LICENSE
github.com/cenkalti/backoff	MIT	https://github.com/cenkalti/backoff/blob/v2.2.1/LICENSE
github.com/diegoholiveira/jsonlogic	MIT	https://github.com/diegoholiveira/jsonlogic/blob/ab7989be08b9/LICENSE
github.com/eclipse/paho.mqtt.golang	BSD-3-Clause	https://github.com/eclipse/paho.mqtt.golang/blob/v1.3.5/LICENSE
github.com/edgexfoundry/app-functions-sdk-go/v2	Apache-2.0	https://github.com/edgexfoundry/app-functions-sdk-go/blob/v2.1.0/LICENSE

github.com/edgexfoundry/app-functions-sdk-go/v2/internal/etm	MIT	https://github.com/edgexfoundry/app-functions-sdk-go/blob/v2.1.0/internal/etm/LICENSE
github.com/edgexfoundry/go-mod-bootstrap/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-bootstrap/blob/v2.1.0/LICENSE
github.com/edgexfoundry/go-mod-configuration/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-configuration/blob/v2.1.0/LICENSE
github.com/edgexfoundry/go-mod-core-contracts/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-core-contracts/blob/v2.1.0/LICENSE
github.com/edgexfoundry/go-mod-messaging/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-messaging/blob/v2.1.0/LICENSE
github.com/edgexfoundry/go-mod-registry/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-registry/blob/v2.1.0/LICENSE
github.com/edgexfoundry/go-mod-secrets/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-secrets/blob/v2.1.0/LICENSE
github.com/fatih/color	MIT	https://github.com/fatih/color/blob/v1.9.0/LICENSE.md
github.com/fxamacker/cbor/v2	MIT	https://github.com/fxamacker/cbor/blob/v2.3.0/LICENSE
github.com/go-kit/kit/log	MIT	https://github.com/go-kit/kit/blob/v0.11.0/LICENSE
github.com/go-logfmt/logfmt	MIT	https://github.com/go-logfmt/logfmt/blob/v0.5.0/LICENSE
github.com/go-playground/locales	MIT	https://github.com/go-playground/locales/blob/v0.14.0/LICENSE
github.com/go-playground/universal-translator	MIT	https://github.com/go-playground/universal-translator/blob/v0.18.0/LICENSE
github.com/go-playground/validator/v10	MIT	https://github.com/go-playground/validator/blob/v10.9.0/LICENSE
github.com/go-redis/redis/v7	BSD-2-Clause	https://github.com/go-redis/redis/blob/v7.3.0/LICENSE
github.com/gomodule/redigo	Apache-2.0	https://github.com/gomodule/redigo/blob/v2.0.0/LICENSE
github.com/google/uuid	BSD-3-Clause	https://github.com/google/uuid/blob/v1.3.0/LICENSE
github.com/gorilla/mux	BSD-3-Clause	https://github.com/gorilla/mux/blob/v1.8.0/LICENSE
github.com/gorilla/websocket	BSD-2-Clause	https://github.com/gorilla/websocket/blob/v1.4.2/LICENSE
github.com/hashicorp/consul/api	MPL-2.0	https://github.com/hashicorp/consul/blob/api/v1.9.1/api/LICENSE
github.com/hashicorp/errwrap	MPL-2.0	https://github.com/hashicorp/errwrap/blob/v1.0.0/LICENSE
github.com/hashicorp/go-cleanhttp	MPL-2.0	https://github.com/hashicorp/go-cleanhttp/blob/v0.5.1/LICENSE
github.com/hashicorp/go-hclog	MIT	https://github.com/hashicorp/go-hclog/blob/v0.12.0/LICENSE
github.com/hashicorp/go-immutable-radix	MPL-2.0	https://github.com/hashicorp/go-immutable-radix/blob/v1.0.0/LICENSE
github.com/hashicorp/go-multierror	MPL-2.0	https://github.com/hashicorp/go-multierror/blob/v1.1.1/LICENSE
github.com/hashicorp/go-rootcerts	MPL-2.0	https://github.com/hashicorp/go-rootcerts/blob/v1.0.2/LICENSE
github.com/hashicorp/golang-lru/simplelru	MPL-2.0	https://github.com/hashicorp/golang-lru/blob/v0.5.0/LICENSE
github.com/hashicorp/serf/coordinate	MPL-2.0	https://github.com/hashicorp/serf/blob/v0.9.5/LICENSE
github.com/leodido/go-urn	MIT	https://github.com/leodido/go-urn/blob/v1.2.1/LICENSE
github.com/matttn/go-colorable	MIT	https://github.com/matttn/go-colorable/blob/v0.1.6/LICENSE
github.com/matttn/go-isatty	MIT	https://github.com/matttn/go-isatty/blob/v0.0.12/LICENSE
github.com/mitchellh/consulstructure	MIT	https://github.com/mitchellh/consulstructure/blob/56fdc4d2da54/LICENSE
github.com/mitchellh/copystructure	MIT	https://github.com/mitchellh/copystructure/blob/v1.0.0/LICENSE
github.com/mitchellh/mapstructure	MIT	https://github.com/mitchellh/mapstructure/blob/v1.1.2/LICENSE
github.com/mitchellh/reflectwalk	MIT	https://github.com/mitchellh/reflectwalk/blob/v1.0.0/LICENSE
github.com/pebbe/zmq4	BSD-2-Clause	https://github.com/pebbe/zmq4/blob/v1.2.7/LICENSE.txt
github.com/pelletier/go-toml	Apache-2.0	https://github.com/pelletier/go-toml/blob/v1.9.4/LICENSE
github.com/x448/float16	MIT	https://github.com/x448/float16/blob/v0.8.4/LICENSE
golang.org/x/crypto/sha3	BSD-3-Clause	https://cs.opensource.google/go/x/crypto/+a769d52b:LICENSE
golang.org/x/net	BSD-3-Clause	https://cs.opensource.google/go/x/net/+a5a99cb3:LICENSE

golang.org/x/sys	BSD-3-Clause	https://cs.opensource.google/go/x/sys/+e5e7981a:LICENSE
golang.org/x/text	BSD-3-Clause	https://cs.opensource.google/go/x/text/+v0.3.6:LICENSE

LoRa Device Service

The LoRa device service is linked with the following packages when compiled:

Package	License Type	License URL
bitbucket.org/bertimus9/systemstat	MIT	https://bitbucket.org/bertimus9/systemstat/src/master/LICENSE
github.com/armon/go-metrics	MIT	https://github.com/armon/go-metrics/blob/master/LICENSE
github.com/cenkalti/backoff	MIT	https://github.com/cenkalti/backoff/blob/master/LICENSE
github.com/eclipse/paho.mqtt.golang	BSD-3-Clause	https://github.com/eclipse/paho.mqtt.golang/blob/master/LICENSE
github.com/edgexfoundry/device-sdk-go/v2	Apache-2.0	https://github.com/edgexfoundry/device-sdk-go/blob/master/v2/LICENSE
github.com/edgexfoundry/go-mod-bootstrap/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-bootstrap/blob/master/v2/LICENSE
github.com/edgexfoundry/go-mod-configuration/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-configuration/blob/master/v2/LICENSE
github.com/edgexfoundry/go-mod-core-contracts/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-core-contracts/blob/master/v2/LICENSE
github.com/edgexfoundry/go-mod-messaging/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-messaging/blob/master/v2/LICENSE
github.com/edgexfoundry/go-mod-registry/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-registry/blob/master/v2/LICENSE
github.com/edgexfoundry/go-mod-secrets/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-secrets/blob/master/v2/LICENSE
github.com/fatih/color	MIT	https://github.com/fatih/color/blob/master/LICENSE.md
github.com/fxamacker/cbor/v2	MIT	https://github.com/fxamacker/cbor/blob/master/v2/LICENSE
github.com/go-kit/kit/log	MIT	https://github.com/go-kit/kit/blob/master/log/LICENSE
github.com/go-logfmt/logfmt	MIT	https://github.com/go-logfmt/logfmt/blob/master/LICENSE
github.com/google/uuid	BSD-3-Clause	https://github.com/google/uuid/blob/master/LICENSE
github.com/go-playground/locales	MIT	https://github.com/go-playground/locales/blob/master/LICENSE
github.com/go-playground/universal-translator	MIT	https://github.com/go-playground/universal-translator/blob/master/LICENSE
github.com/go-playground/validator/v10	MIT	https://github.com/go-playground/validator/blob/master/v10/LICENSE
github.com/go-redis/redis/v7	BSD-2-Clause	https://github.com/go-redis/redis/blob/master/v7/LICENSE
github.com/gorilla/mux	BSD-3-Clause	https://github.com/gorilla/mux/blob/master/LICENSE
github.com/gorilla/websocket	BSD-2-Clause	https://github.com/gorilla/websocket/blob/master/LICENSE
github.com/hashicorp/consul/api	MPL-2.0	https://github.com/hashicorp/consul/blob/master/api/LICENSE
github.com/hashicorp/errwrap	MPL-2.0	https://github.com/hashicorp/errwrap/blob/master/LICENSE
github.com/hashicorp/go-cleanhttp	MPL-2.0	https://github.com/hashicorp/go-cleanhttp/blob/master/LICENSE
github.com/hashicorp/go-hclog	MIT	https://github.com/hashicorp/go-hclog/blob/master/LICENSE
github.com/hashicorp/go-immutable-radix	MPL-2.0	https://github.com/hashicorp/go-immutable-radix/blob/master/LICENSE
github.com/hashicorp/golang-lru/simplelru	MPL-2.0	https://github.com/hashicorp/golang-lru/blob/master/simplelru/LICENSE
github.com/hashicorp/go-multierror	MPL-2.0	https://github.com/hashicorp/go-multierror/blob/master/LICENSE
github.com/hashicorp/go-rootcerts	MPL-2.0	https://github.com/hashicorp/go-rootcerts/blob/master/LICENSE
github.com/hashicorp/serf/coordinate	MPL-2.0	https://github.com/hashicorp/serf/blob/master/coordinate/LICENSE
github.com/leodido/go-urn	MIT	https://github.com/leodido/go-urn/blob/master/LICENSE
github.com/mattn/go-colorable	MIT	https://github.com/mattn/go-colorable/blob/master/LICENSE

github.com/mattn/go-isatty	MIT	https://github.com/mattn/go-isatty/blob/master/LICENSE
github.com/mitchellh/consulstructure	MIT	https://github.com/mitchellh/consulstructure/blob/master/LICENSE
github.com/mitchellh/copystructure	MIT	https://github.com/mitchellh/copystructure/blob/master/LICENSE
github.com/mitchellh/mapstructure	MIT	https://github.com/mitchellh/mapstructure/blob/master/LICENSE
github.com/mitchellh/reflectwalk	MIT	https://github.com/mitchellh/reflectwalk/blob/master/LICENSE
github.com/OneOfOne/xxhash	Apache-2.0	https://github.com/OneOfOne/xxhash/blob/master/LICENSE
github.com/pebbe/zmq4	BSD-2-Clause	https://github.com/pebbe/zmq4/blob/master/LICENSE.txt
github.com/pelletier/go-toml	Apache-2.0	https://github.com/pelletier/go-toml/blob/master/LICENSE
github.com/tarm/serial	BSD-3-Clause	https://github.com/tarm/serial/blob/master/LICENSE
github.com/x448/float16	MIT	https://github.com/x448/float16/blob/master/LICENSE
golang.org/x/crypto/sha3	BSD-3-Clause	https://pkg.go.dev/golang.org/x/crypto/sha3?tab=licenses
golang.org/x/net	BSD-3-Clause	https://pkg.go.dev/golang.org/x/net?tab=licenses
golang.org/x/sys	BSD-3-Clause	https://pkg.go.dev/golang.org/x/sys?tab=licenses
golang.org/x/text	BSD-3-Clause	https://pkg.go.dev/golang.org/x/text?tab=licenses
gopkg.in/yaml.v3	MIT	https://github.com/go-yaml/yaml/blob/v3/LICENSE

Image Application

The image application is linked with the following packages when compiled:

Package	License Type	License URL
bitbucket.org/bertimus9/systemstat	MIT	https://bitbucket.org/bertimus9/systemstat/src/0eeff89b0690/LICENSE
github.com/armon/go-metrics	MIT	https://github.com/armon/go-metrics/blob/f0300d1749da/LICENSE
github.com/cenkalti/backoff	MIT	https://github.com/cenkalti/backoff/blob/v2.2.1/LICENSE
github.com/diegoholiveira/jsonlogic	MIT	https://github.com/diegoholiveira/jsonlogic/blob/ab7989be08b9/LICENSE
github.com/eclipse/paho.mqtt.golang	BSD-3-Clause	https://github.com/eclipse/paho.mqtt.golang/blob/v1.3.5/LICENSE
github.com/edgexfoundry/app-functions-sdk-go/v2	Apache-2.0	https://github.com/edgexfoundry/app-functions-sdk-go/blob/v2.2.0/LICENSE
github.com/edgexfoundry/app-functions-sdk-go/v2/internal/etm	MIT	https://github.com/edgexfoundry/app-functions-sdk-go/blob/v2.2.0/internal/etm/LICENSE
github.com/edgexfoundry/go-mod-bootstrap/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-bootstrap/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-configuration/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-configuration/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-core-contracts/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-core-contracts/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-messaging/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-messaging/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-registry/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-registry/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-secrets/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-secrets/blob/v2.2.0/LICENSE
github.com/fatih/color	MIT	https://github.com/fatih/color/blob/v1.9.0/LICENSE.md
github.com/fxamacker/cbor/v2	MIT	https://github.com/fxamacker/cbor/blob/v2.4.0/LICENSE
github.com/go-kit/log	MIT	https://github.com/go-kit/log/blob/v0.2.0/LICENSE
github.com/go-logfmt/logfmt	MIT	https://github.com/go-logfmt/logfmt/blob/v0.5.1/LICENSE
github.com/go-playground/locales	MIT	https://github.com/go-playground/locales/blob/v0.14.0/LICENSE
github.com/go-playground/universal-translator	MIT	https://github.com/go-playground/universal-translator/blob/v0.18.0/LICENSE

github.com/go-playground/validator/v10	MIT	https://github.com/go-playground/validator/blob/v10.10.1/LICENSE
github.com/go-redis/redis/v7	BSD-2-Clause	https://github.com/go-redis/redis/blob/v7.3.0/LICENSE
github.com/golang/protobuf	BSD-3-Clause	https://github.com/golang/protobuf/blob/v1.5.2/LICENSE
github.com/gomodule/redigo/redis	Apache-2.0	https://github.com/gomodule/redigo/blob/v1.8.8/LICENSE
github.com/google/uuid	BSD-3-Clause	https://github.com/google/uuid/blob/v1.3.0/LICENSE
github.com/gorilla/mux	BSD-3-Clause	https://github.com/gorilla/mux/blob/v1.8.0/LICENSE
github.com/gorilla/websocket	BSD-2-Clause	https://github.com/gorilla/websocket/blob/v1.4.2/LICENSE
github.com/hashicorp/consul/api	MPL-2.0	https://github.com/hashicorp/consul/blob/api/v1.9.1/api/LICENSE
github.com/hashicorp/errwrap	MPL-2.0	https://github.com/hashicorp/errwrap/blob/v1.0.0/LICENSE
github.com/hashicorp/go-cleanhttp	MPL-2.0	https://github.com/hashicorp/go-cleanhttp/blob/v0.5.1/LICENSE
github.com/hashicorp/go-hclog	MIT	https://github.com/hashicorp/go-hclog/blob/v0.12.0/LICENSE
github.com/hashicorp/go-immutable-radix	MPL-2.0	https://github.com/hashicorp/go-immutable-radix/blob/v1.0.0/LICENSE
github.com/hashicorp/go-multierror	MPL-2.0	https://github.com/hashicorp/go-multierror/blob/v1.1.1/LICENSE
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github.com/mitchellh/copystructure	MIT	https://github.com/mitchellh/copystructure/blob/v1.0.0/LICENSE
github.com/mitchellh/mapstructure	MIT	https://github.com/mitchellh/mapstructure/blob/v1.1.2/LICENSE
github.com/mitchellh/reflectwalk	MIT	https://github.com/mitchellh/reflectwalk/blob/v1.0.0/LICENSE
github.com/pebbe/zmq4	BSD-2-Clause	https://github.com/pebbe/zmq4/blob/v1.2.7/LICENSE.txt
github.com/pelletier/go-toml	Apache-2.0	https://github.com/pelletier/go-toml/blob/v1.9.4/LICENSE
github.com/rcrowley/go-metrics	BSD-2-Clause-FreeBSD	https://github.com/rcrowley/go-metrics/blob/3113b8401b8a/LICENSE
github.com/spiffe/go-spiffe/v2	Apache-2.0	https://github.com/spiffe/go-spiffe/blob/v2.0.0/v2/LICENSE
github.com/x448/float16	MIT	https://github.com/x448/float16/blob/v0.8.4/LICENSE
github.com/zeebo/errs	MIT	https://github.com/zeebo/errs/blob/v1.2.2/LICENSE
gocv.io/x/gocv	Apache-2.0	https://github.com/hybridgroup/gocv/blob/v0.31.0/LICENSE.txt
golang.org/x/crypto	BSD-3-Clause	https://cs.opensource.google/go/x/crypto/+v0.1.0/LICENSE
golang.org/x/net	BSD-3-Clause	https://cs.opensource.google/go/x/net/+v0.1.0/LICENSE
golang.org/x/sys/unix	BSD-3-Clause	https://cs.opensource.google/go/x/sys/+v0.1.0/LICENSE
golang.org/x/text	BSD-3-Clause	https://cs.opensource.google/go/x/text/+v0.4.0/LICENSE
google.golang.org/genproto/googleapis/rpc/status	Apache-2.0	https://github.com/googleapis/go-genproto/blob/37a418bb8959/LICENSE
google.golang.org/grpc	Apache-2.0	https://github.com/grpc/grpc-go/blob/v1.48.0/LICENSE
google.golang.org/protobuf	BSD-3-Clause	https://github.com/protocolbuffers/protobuf-go/blob/v1.28.1/LICENSE
gopkg.in/square/go-jose.v2	Apache-2.0	https://github.com/square/go-jose/blob/v2.4.1/LICENSE
gopkg.in/square/go-jose.v2/json	BSD-3-Clause	https://github.com/square/go-jose/blob/v2.4.1/json/LICENSE

Camera Device Service

The camera device service is linked with the following packages when compiled:

Package	License Type	License URL
bitbucket.org/bertimus9/systemstat	MIT	https://bitbucket.org/bertimus9/systemstat/src/v0.5.0/LICENSE
github.com/OneOfOne/xxhash	Apache-2.0	https://github.com/OneOfOne/xxhash/blob/v1.2.8/LICENSE
github.com/armon/go-metrics	MIT	https://github.com/armon/go-metrics/blob/f0300d1749da/LICENSE
github.com/cenkalti/backoff	MIT	https://github.com/cenkalti/backoff/blob/v2.2.1/LICENSE
github.com/eclipse/paho.mqtt.golang	EPL-2.0	https://github.com/eclipse/paho.mqtt.golang/blob/v1.4.1/LICENSE
github.com/edgexfoundry/device-camera-go	Apache-2.0	https://github.com/edgexfoundry/device-camera-go/blob/HEAD/LICENSE
github.com/edgexfoundry/device-sdk-go/v2	Apache-2.0	https://github.com/edgexfoundry/device-sdk-go/blob/v2.2.1-dev.10/LICENSE
github.com/edgexfoundry/go-mod-bootstrap/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-bootstrap/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-configuration/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-configuration/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-core-contracts/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-core-contracts/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-messaging/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-messaging/blob/v2.2.1-dev.5/LICENSE
github.com/edgexfoundry/go-mod-registry/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-registry/blob/v2.2.0/LICENSE
github.com/edgexfoundry/go-mod-secrets/v2	Apache-2.0	https://github.com/edgexfoundry/go-mod-secrets/blob/v2.2.0/LICENSE
github.com/faceterteam/onvif4go	MIT	https://github.com/faceterteam/onvif4go/blob/v0.4.0/LICENSE
github.com/fatih/color	MIT	https://github.com/fatih/color/blob/v1.9.0/LICENSE.md
github.com/fxamacker/cbor/v2	MIT	https://github.com/fxamacker/cbor/blob/v2.4.0/LICENSE
github.com/go-kit/log	MIT	https://github.com/go-kit/log/blob/v0.2.0/LICENSE
github.com/go-logfmt/logfmt	MIT	https://github.com/go-logfmt/logfmt/blob/v0.5.1/LICENSE
github.com/go-playground/locales	MIT	https://github.com/go-playground/locales/blob/v0.14.0/LICENSE
github.com/go-playground/universal-translator	MIT	https://github.com/go-playground/universal-translator/blob/v0.18.0/LICENSE
github.com/go-playground/validator/v10	MIT	https://github.com/go-playground/validator/blob/v10.10.1/LICENSE
github.com/go-redis/redis/v7	BSD-2-Clause	https://github.com/go-redis/redis/blob/v7.3.0/LICENSE
github.com/golang/protobuf	BSD-3-Clause	https://github.com/golang/protobuf/blob/v1.5.2/LICENSE
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github.com/hashicorp/go-cleanhttp	MPL-2.0	https://github.com/hashicorp/go-cleanhttp/blob/v0.5.1/LICENSE
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github.com/hashicorp/golang-lru/simplelru	MPL-2.0	https://github.com/hashicorp/golang-lru/blob/v0.5.0/LICENSE
github.com/hashicorp/serf/coordinate	MPL-2.0	https://github.com/hashicorp/serf/blob/v0.9.5/LICENSE
github.com/leodido/go-urn	MIT	https://github.com/leodido/go-urn/blob/v1.2.1/LICENSE

github.com/mattn/go-colorable	MIT	https://github.com/mattn/go-colorable/blob/v0.1.6/LICENSE
github.com/mattn/go-isatty	MIT	https://github.com/mattn/go-isatty/blob/v0.0.12/LICENSE
github.com/mitchellh/consulstructure	MIT	https://github.com/mitchellh/consulstructure/blob/56fdc4d2da54/LICENSE
github.com/mitchellh/copystructure	MIT	https://github.com/mitchellh/copystructure/blob/v1.0.0/LICENSE
github.com/mitchellh/mapstructure	MIT	https://github.com/mitchellh/mapstructure/blob/v1.1.2/LICENSE
github.com/mitchellh/reflectwalk	MIT	https://github.com/mitchellh/reflectwalk/blob/v1.0.0/LICENSE
github.com/pebbe/zmq4	BSD-2-Clause	https://github.com/pebbe/zmq4/blob/v1.2.7/LICENSE.txt
github.com/pelletier/go-toml	Apache-2.0	https://github.com/pelletier/go-toml/blob/v1.9.5/LICENSE
github.com/rcrowley/go-metrics	BSD-2-Clause-FreeBSD	https://github.com/rcrowley/go-metrics/blob/3113b8401b8a/LICENSE
github.com/spiffe/go-spiffe/v2	Apache-2.0	https://github.com/spiffe/go-spiffe/blob/v2.0.0/v2/LICENSE
github.com/x448/float16	MIT	https://github.com/x448/float16/blob/v0.8.4/LICENSE
github.com/zeebo/errs	MIT	https://github.com/zeebo/errs/blob/v1.2.2/LICENSE
golang.org/x/crypto	BSD-3-Clause	https://cs.opensource.google/go/x/crypto/+e495a2d5/LICENSE
golang.org/x/net	BSD-3-Clause	https://cs.opensource.google/go/x/net/+69e39bad/LICENSE
golang.org/x/sync/semaphore	BSD-3-Clause	https://cs.opensource.google/go/x/sync/+036812b2/LICENSE
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golang.org/x/text	BSD-3-Clause	https://cs.opensource.google/go/x/text/+v0.3.7/LICENSE
google.golang.org/genproto/googleapis/rpc/status	Apache-2.0	https://github.com/googleapis/go-genproto/blob/3a66f561d7aa/LICENSE
google.golang.org/grpc	Apache-2.0	https://github.com/grpc/grpc-go/blob/v1.42.0/LICENSE
google.golang.org/protobuf	BSD-3-Clause	https://github.com/protocolbuffers/protobuf-go/blob/v1.27.1/LICENSE
gopkg.in/square/go-jose.v2	Apache-2.0	https://github.com/square/go-jose/blob/v2.4.1/LICENSE
gopkg.in/square/go-jose.v2/json	BSD-3-Clause	https://github.com/square/go-jose/blob/v2.4.1/json/LICENSE
gopkg.in/yaml.v3	MIT	https://github.com/go-yaml/yaml/blob/v3.0.1/LICENSE

References

- EdgeX Foundry Documentation (release 2.1): <https://docs.edgexfoundry.org/2.1/>

Definitions, Acronyms and Abbreviations

- CPS: [Cyber-Physical System](#)
- MQTT: A lightweight, publish-subscribe network protocol designed for connecting remote devices, especially when there are bandwidth constraints. (MQTT is not an acronym.)