DevOps

Caltech | Center for Technology & Management Education

Post Graduate Program in DevOps

simplilearn

Security

Learning Objectives

By the end of this lesson, you'll be able to:

- Implement Docker Security and Default Engine Security
- Describe the process of signing an image
- Create the MKE client bundles
- Illustrate the significance of Roles and Secrets

Docker Security

Docker Security

Docker security prevents a compromised container from consuming a large amount of resources for disrupting service or performing malicious activities.

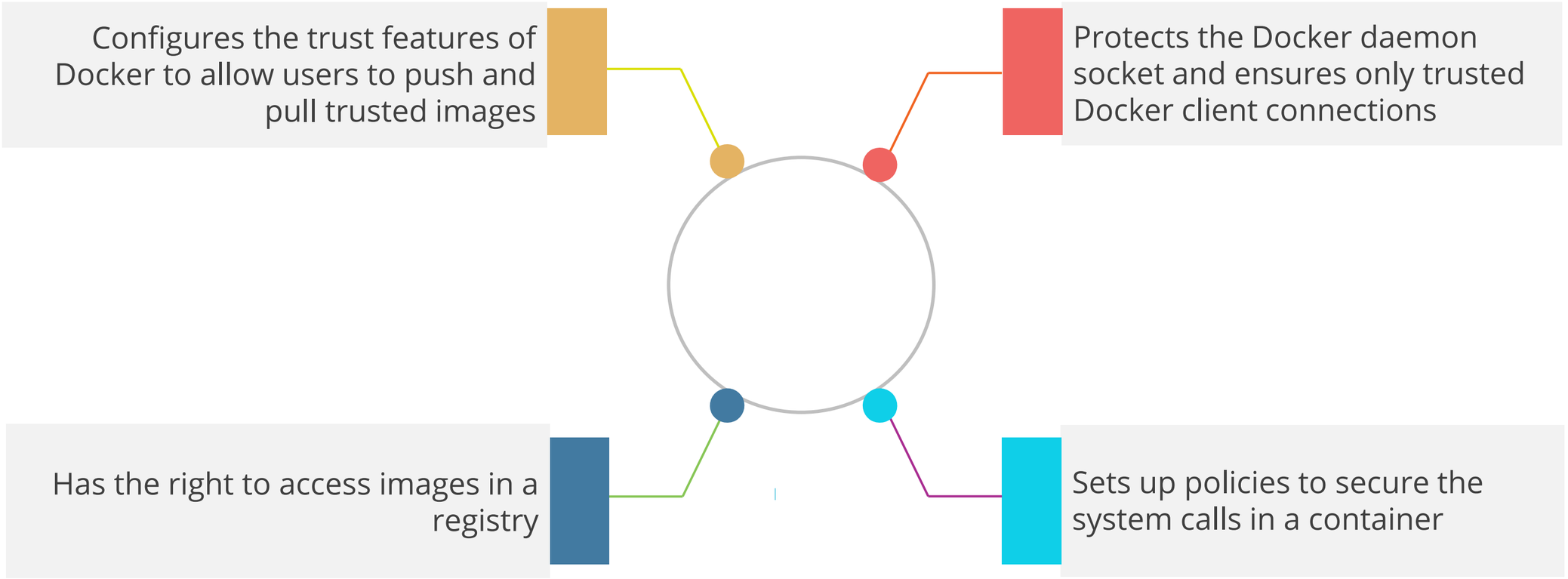
The kernel's intrinsic security and support for namespaces and cgroups

The vulnerable surface on the Docker daemon

The container configuration profile's loopholes

The kernel's *hardening* security features and how they interact with containers

Default Engine Security



Namespace

Docker creates namespaces in the container to provide the isolated workspace.

Docker Engine uses namespaces such as the following on Linux:

- **The pid namespace**: Isolates the process ID
- **The net namespace**: Manages network interfaces (**net**: Networking)
- **The ipc namespace**: Manages access to IPC resources (**ipc**: InterProcess Communication)
- **The mnt namespace**: Manages filesystem mount points (**mnt**: Mount)
- **The uts namespace**: Isolates kernel and version identifiers (**uts**: Unix Timesharing System)

Kernel Namespace

Docker containers are similar to Linux containers, and they have similar security features.

- Namespaces provide the first and most straightforward form of isolation.
- Each aspect of a container runs in a separate namespace and its access is limited to that namespace.
- Each container also gets its own network stack, meaning that a container doesn't get privileged access to the sockets or interfaces of another container.

Control Groups

Docker Engine on Linux relies on a technology called control groups (cgroups). They are a key component of Linux Containers.

Key features of control groups:

- Limit an application to a particular collection of resources
- Allow Docker Engine to share available container hardware resources and enforce limitations and constraints as an option
  For example, the user can restrict the available space to a specific container
- Implement resource accounting

Control Groups

Key features of control groups:

- Provide many useful metrics
- Ensure that each container gets its fair share of memory, CPU, and disk I/O
- Ensure that a single container cannot bring the system down by exhausting one of the resources

Docker Daemon

Docker Daemon Attack Surface

It helps the Docker to allow the user to share a directory between the Docker host and a guest container. It also allows the user to do so without limiting the access rights of the container.

Additional features of Docker Daemon:

- Running containers (and applications) with Docker implies running the Docker daemon.
- This daemon requires root privileges unless you opt in to rootless mode (experimental). The user should be aware of some important details:
  - Only trusted users should be allowed to control your Docker daemon
  - The daemon is potentially vulnerable to inputs, such as image loading from either disk with docker load or from the network with docker pull

Linux Kernel Capabilities

Linux Kernel Capabilities

Docker runs the containers with certain restricted capabilities by default. This means the root capabilities are not provided to all processes operating inside a container.

For instance, it is possible to:

- Deny all **mount** operations
- Deny access to raw sockets
- Deny access to some filesystem operations, like creating new device nodes, changing the owner of files, or altering attributes
- Deny module loading

Docker Content Trust

Docker Content Trust

Docker Content Trust (DCT) provides the ability to use digital signatures for data from remote Docker registries that are sent and received.

Image Tags and DCT:

An individual image record has the following identifier:
[REGISTRY_HOST[:REGISTRY_PORT]/]REPOSITORY[:TAG]

- A particular image **REPOSITORY** can have multiple tags.
- DCT is associated with the **TAG** portion of an image.

Docker Content Trust

Docker Content Trust Keys

Trust for an image tag is managed using signing keys. A key set is created when an operation using DCT is first invoked. A key set consists of the following classes of keys:

- An offline key that is the root of DCT for an image tag
- Repository or tagging keys that sign tags
- Server-managed keys, such as the timestamp key, which provides freshness security guarantees for the repository

Docker Content Trust

Sign Images with Docker Content Trust

- The user can use the **$docker** trust command syntax to sign and push a container image within the Docker CLI
- A prerequisite for signing an image is a Docker Registry with an attached Notary server like the Docker Hub or Mirantis Secure Registry
- The user will need a delegation key pair to sign a Docker File

Docker Content Trust

Runtime Enforcement with DCT

Docker Content Trust within the Mirantis Container Runtime (MCR) prevents a user from using a container image from an unknown source, as well as prevents a user from building a container image from an unknown source.

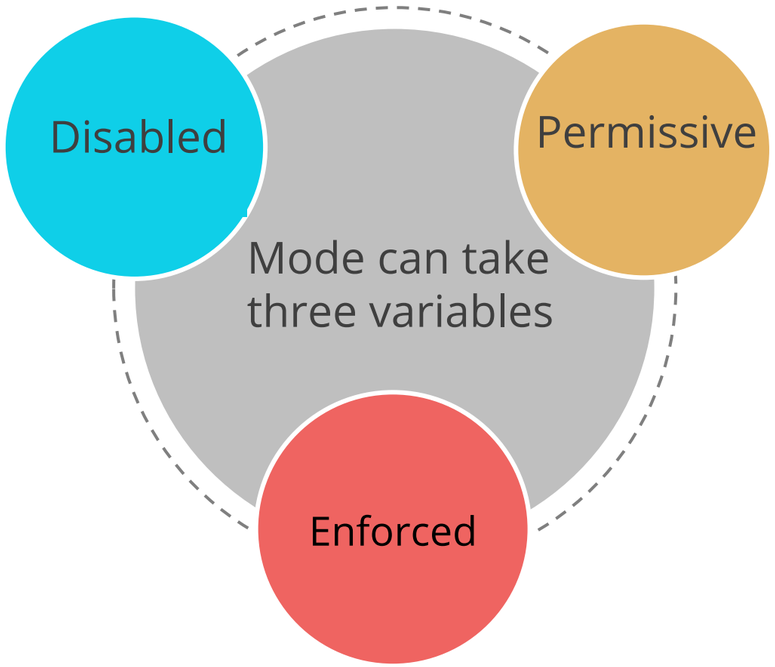
Engine Signature Verification prevents the following:

- *$ docker container run* of an unsigned or altered image
- *$ docker pull* of an unsigned or altered image
- *$ docker build* where there is no FROM image signed or scratched

Docker Content Trust

Enabling DCT within the Docker Enterprise Engine

- DCT is controlled by *daemon.json* that is the configuration file of MCR
- The content-trust flag is based on a mode variable instructing the engine whether to implement signed images. The trust-pinning variable tells the engine what sources to trust.



Docker Content Trust Signature Verification

It is a feature that allows the Docker Engine to run signed images.

How is it implemented?

- Built directly into the *dockerd* binary
- Configured in the *dockerd* configuration file

Docker Content Trust Signature Verification

Advantages

- Allows to pull out and run repositories signed with a user-specified root key
- Trust-pinning can be configured in daemon.json to allow this function
- Provides administrators with more information to implement and perform image signature validation with the CLI

Sign an Image

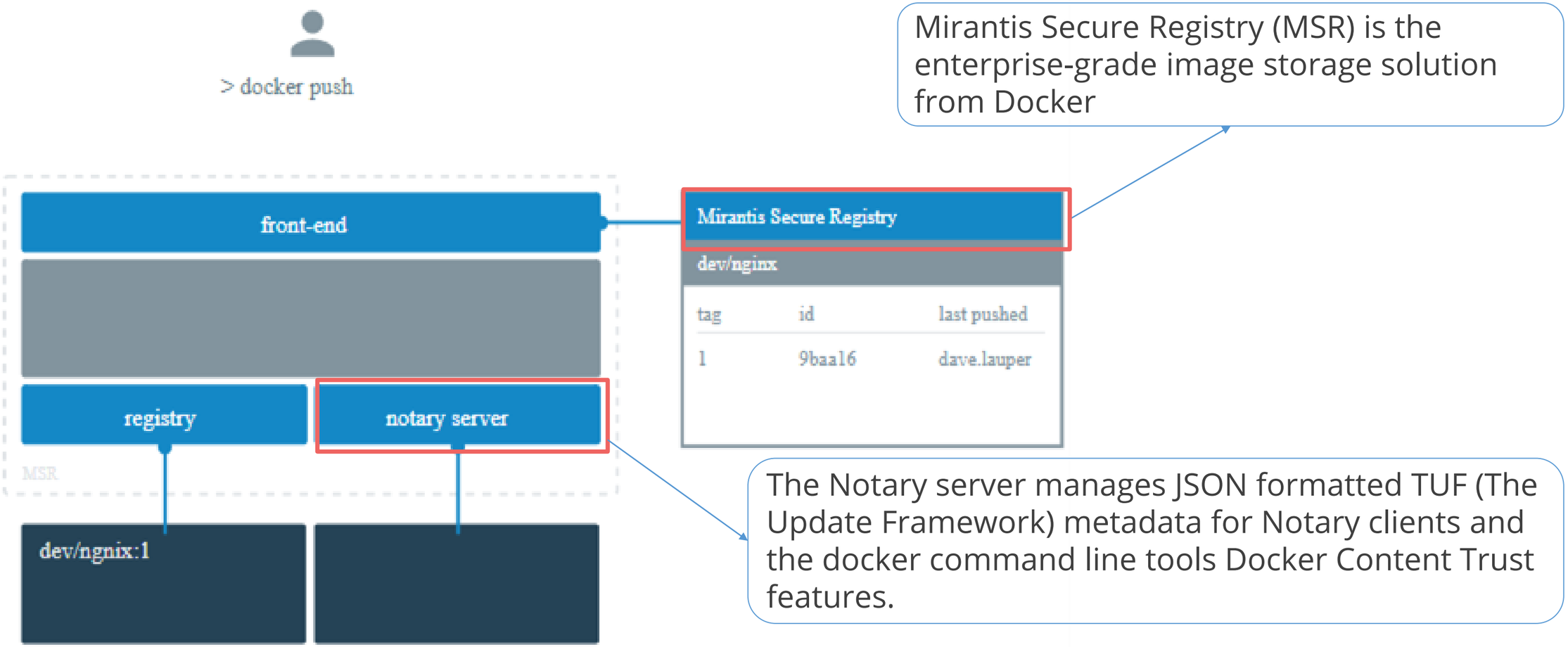
Sign an Image

- The user can configure the Docker CLI client to sign the images that the user pushes to DTR. This allows whoever pulls the image to validate if they are getting the image that is created, or a forged one.

- To sign an image, the user can run:
  export DOCKER_CONTENT_TRUST=1
  docker push <dtr-domain>/<repository>/<image>:<tag>

- The above command pushes the image to DTR and creates trust metadata. It also creates public and private key pairs to sign the trust metadata and push that metadata to the Notary Server internal to DTR.

Sign an Image



Mirantis Secure Registry (MSR) is the enterprise-grade image storage solution from Docker

The Notary server manages JSON formatted TUF (The Update Framework) metadata for Notary clients and the docker command line tools Docker Content Trust features.

Source: https://docs.mirantis.com/containers/v3.1/dockeree-products/msr/msr-user/manage-images/sign-images/sign-an-image.html

Sign Images That MKE Can Trust

MKE prevents untrusted images from being deployed on a cluster. Users can use this feature by signing the MSR images with the private keys of the MKE users to tie them back to MKE.

To sign images in a way that MKE trusts them, user needs to:

1. Download a client bundle for the user account they want to use for signing the images
1. Add the user's private key to their machine's trust store
1. Initialize trust metadata for the repository
1. Delegate signing for that repository to the MKE user
1. Sign the image

Vulnerabilities

Docker image security best practices:

- Prefer minimal base images
- Sign and verify images to mitigate MITM attack
- Find, fix, and monitor for open source vulnerabilities
- Don’t leak sensitive information to docker images
- Create a dedicated user with minimal permissions
- Use fixed tags for immutability
- Use **COPY** instead of **ADD**
- Use labels for metadata
- Use multi-stage builds for small secure images
- Use a linter

Scan Images for Vulnerabilities

MSR can scan images in the repositories using Docker Security Scanning, to verify that they are free from known security vulnerabilities or exposures.

Docker Security Scan process:

- Scans run either on demand when you click the **Start a Scan** link or **Scan** button, or automatically on any docker push to the repository
- MSR scans both Linux and Windows images, but by default Docker doesn't push foreign image layers for Windows images so MSR won't be able to scan them
- If you want MSR to scan your Windows images, *configure Docker to always push image layers <pull-and-push-images>*, and it will scan the non-foreign layers

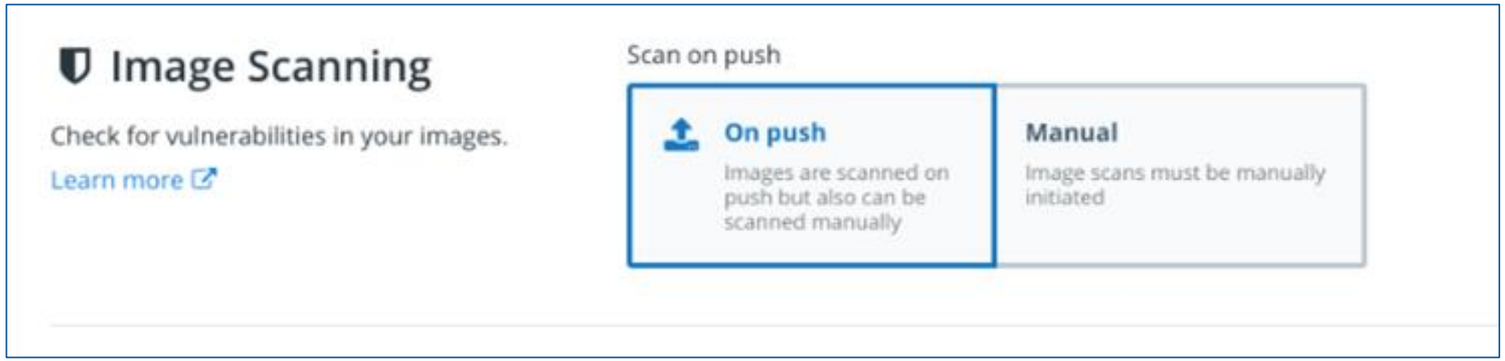
Scan Images for Vulnerabilities

Security scan on push

Docker Security Scanning runs automatically on docker push to an image repository by default.

Manual Scanning

Manual Scanning can start scanning images manually in repositories to which the user has write access.



Source: https://docs.mirantis.com/containers/v3.1/dockeree-products/msr/msr-user/manage-images/scan-images-for-vulnerabilities.html

MKE Client Bundle

MKE Client Bundle

A client bundle is a group of certificates downloadable directly from the MKE web UI. It contains a private and public key pair that authorizes requests in MKE and also contains utility scripts that can be used to configure client tools.

Admin user certificate bundles:
Allow the running of docker commands on the Docker Engine of any node

User certificate bundles:
Only allow running docker commands through an MKE controller node

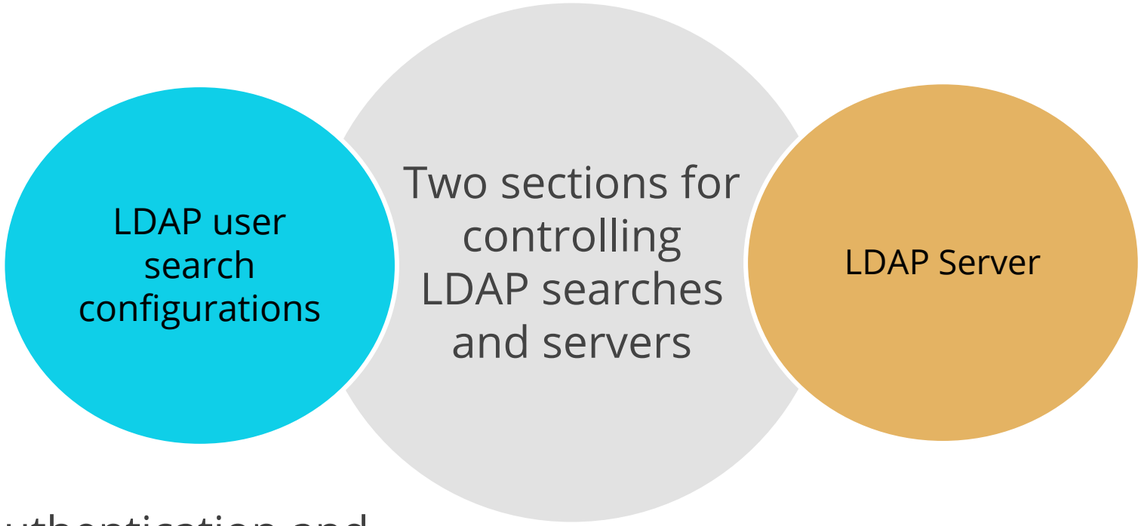
UCP Client Bundles

Integrate MKE with LDAP

MKE integrates with LDAP (Lightweight Directory Access Protocol) directory services to manage users and groups from an organization's directory, and automatically propagate that information to MKE and MSR.

- Users can control how MKE integrates with LDAP by creating user searches
- User can specify multiple search configurations
- User can also specify multiple LDAP servers for integration
- Searches start with the **Base DN**, which is the *distinguished name* of the node in the LDAP directory tree where the search starts looking for users

Integrate MKE with LDAP



Authentication and Authorization section where a user specifies search parameters

Section where a user specifies the URL of an LDAP server

Integrate MKE with LDAP

1. MKE creates a set of search results by iterating over each of the user search configs, in the order that you specify
2. MKE chooses an LDAP server from the list of domain servers by considering the Base DN from the user search config and selecting the domain server that has the longest domain suffix match
3. If no domain server has a domain suffix that matches the Base DN from the search config, MKE uses the default domain server
4. MKE combines the search results into a list of users and creates MKE accounts for them. If the Just-In-Time User Provisioning option is set, user accounts are created only when users first login

Configure the LDAP Integration

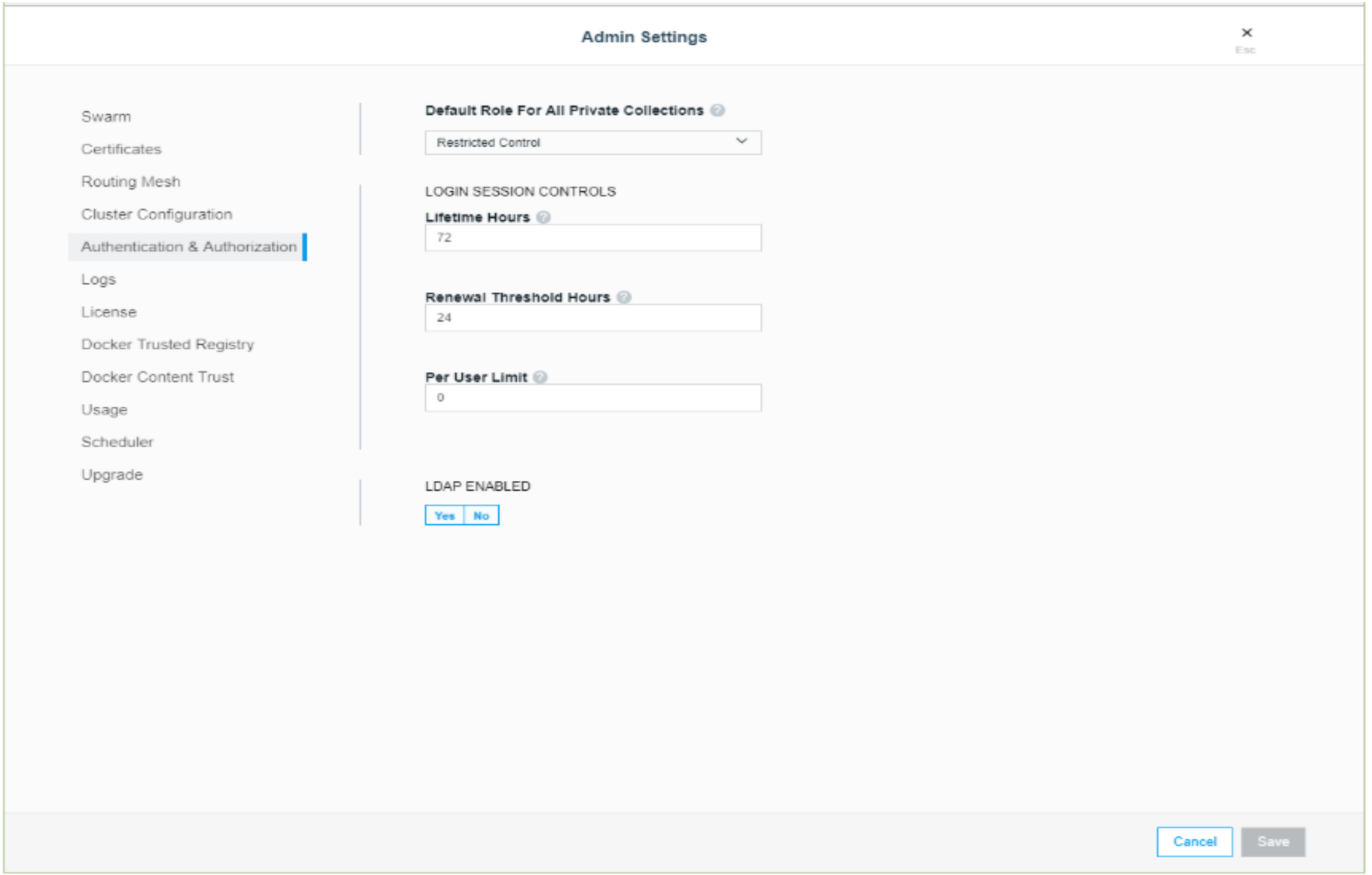
To configure MKE to create and authenticate users by using an LDAP directory:

1. Go to the MKE web interface and navigate to the **Admin Settings** page

1. Click **Authentication & Authorization** to select the method used to create and authenticate users

1. In the **LDAP Enabled** section, click **Yes**

Configure the LDAP Integration



LDAP Enabled

Default role for all private collections:

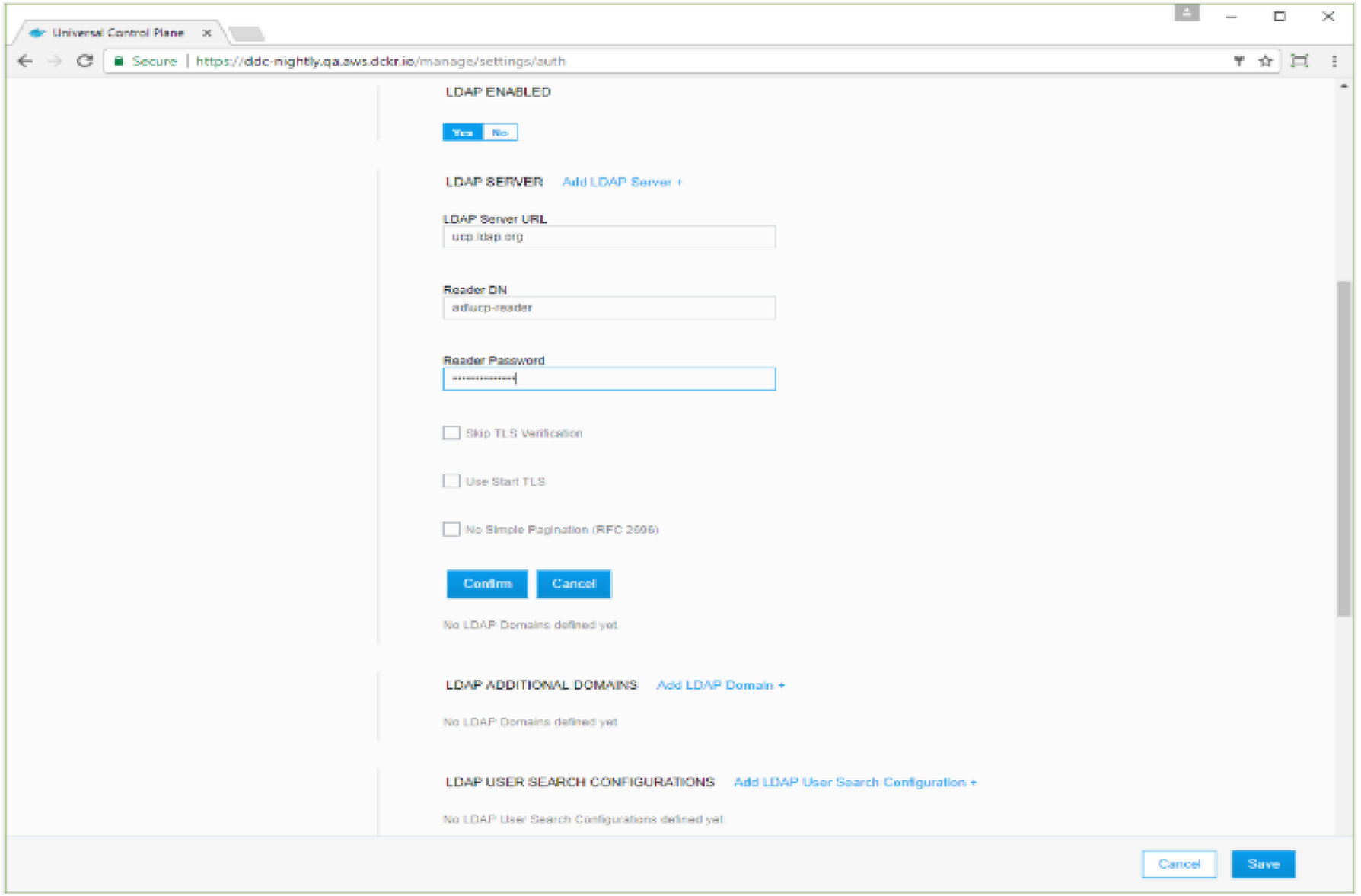
Use this setting to change the default permissions of new users. Click the dropdown to select the permission level that MKE assigns by default to the private collections of new users.

LDAP enabled:

Click **Yes** to enable integrating MKE users and teams with LDAP servers.

Source: https://docs.docker.com/datacenter/ucp/2.2/guides/admin/configure/external-auth/

LDAP Enabled

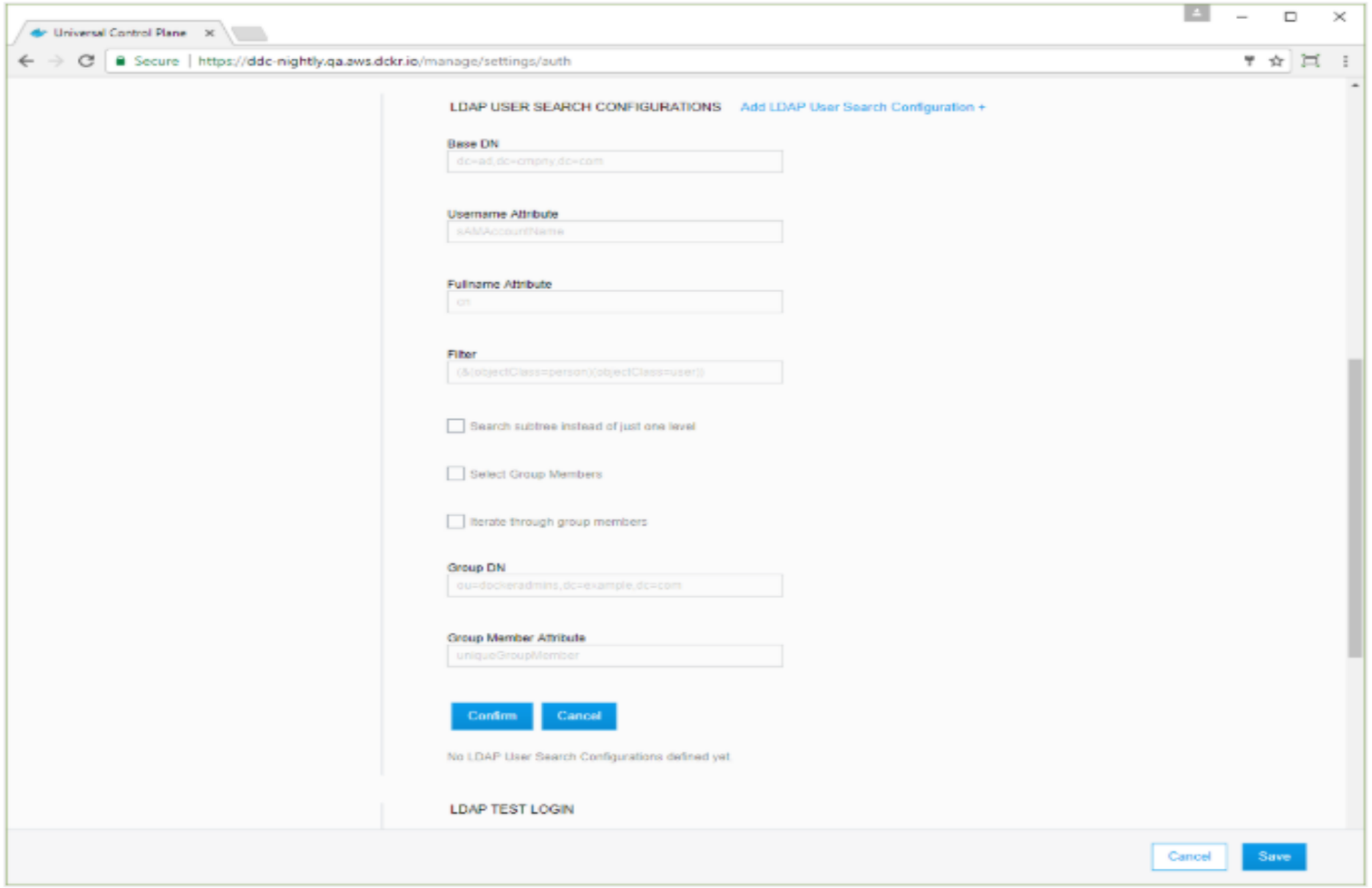


LDAP Server

Field	Description
LDAP server URL	The URL where the LDAP server can be reached
Reader DN	The distinguished LDAP account name used in the LDAP server to search for entries. This should be a read-only client of LDAP as a best practice.
Reader password	The password of the account used for searching entries in the LDAP server
Use Start TLS	The connection can be authenticated/encrypted only after connecting to the LDAP server over TCP
Skip TLS verification	The LDAP server certificate will be verified using TLS
No simple pagination	The LDAP server doesn't support pagination
Just-in-Time User Provisioning	The user can create user accounts only when they log in for the first time

LDAP User Search Configurations

To configure more user search queries, click **Add LDAP User Search Configuration** again.



LDAP User Search Configurations

Field	Description
Base DN	The distinguished name of the node in the directory tree where the search should start looking for users
Username attribute	The LDAP attribute to use as username on MKE. A valid username is no longer than 100 characters and does not contain any unprintable characters, whitespace characters, or any of the following characters: / \ [ ] : ; | = , + * ? < > ' ".
Full name attribute	The LDAP attribute to use as the user's full name for display purposes
Filter	The LDAP search filter used to find users
Search subtree instead of just one level	The LDAP can be performed by searching on a single level of the LDAP tree, or searching through the full LDAP tree starting at the Base DN
Select Group Members	This feature is helpful if the LDAP server does not support **memberOf** search filters

LDAP User Search Configurations

Field	Description
Iterate through group members	This option searches for users by first iterating over the target group's membership, making a separate LDAP query for each member if **Select Group Members** is selected.
Group DN	This specifies the distinguished name of the group from which to select users if **Select Group Members** is selected.
Group Member Attribute	The value of this group attribute corresponds to the distinguished names of the members of the group if **Select Group Members** is selected.

LDAP Test Login

Field	Description
Username	An LDAP username for testing authentication to this application. This value corresponds with the **Username Attribute** specified in the **LDAP user search configurations** section.
Password	The user's password is used to authenticate (BIND) to the directory server.

Before the user saves the configuration changes, test that the integration is configured correctly. To do this, provide the LDAP user credentials and click on the **Test** button.

LDAP Sync Configuration

Field	Description
Sync interval	This interval between UCP and the LDAP server helps users to synchronize in hours.
Enable sync of admin users	This option specifies that system admins should be synced directly with members of a group in the organization’s LDAP directory.

Revoke User Access

Just-in-Time User Provisioning setting:

When a user is removed from LDAP, the effect on the user's MKE account depends on the Just-in-Time User Provisioning setting:

- **Just-in-Time User Provisioning is false:** Users deleted from LDAP become inactive in MKE after the next LDAP synchronization runs
- **Just-in-Time User Provisioning is true:** Users deleted from LDAP can't authenticate, but their MKE accounts remain active

Data Synced from an Organization’s LDAP Directory

- MKE saves a minimum amount of user data required to operate
- It does not store any additional data from the directory server
- It enables syncing teams with a search query or group in an organization’s LDAP directory

Assisted Practice

Create MKE Client Bundles

Problem Statement: Your manager has asked you to create MKE client bundles that help run Docker commands on an MKE node.

Steps to Perform:

1. Sign in to MKE with your admin credentials and navigate to *My Profile*
2. Click on *New Client Bundle* dropdown and select *Generate Client Bundle* to download the certificate bundle
3. Unzip the *client-bundle.zip* file and start the client certificates
4. Use Docker CLI with client certificates

Configuration of Certificates

External Certificates with MKE

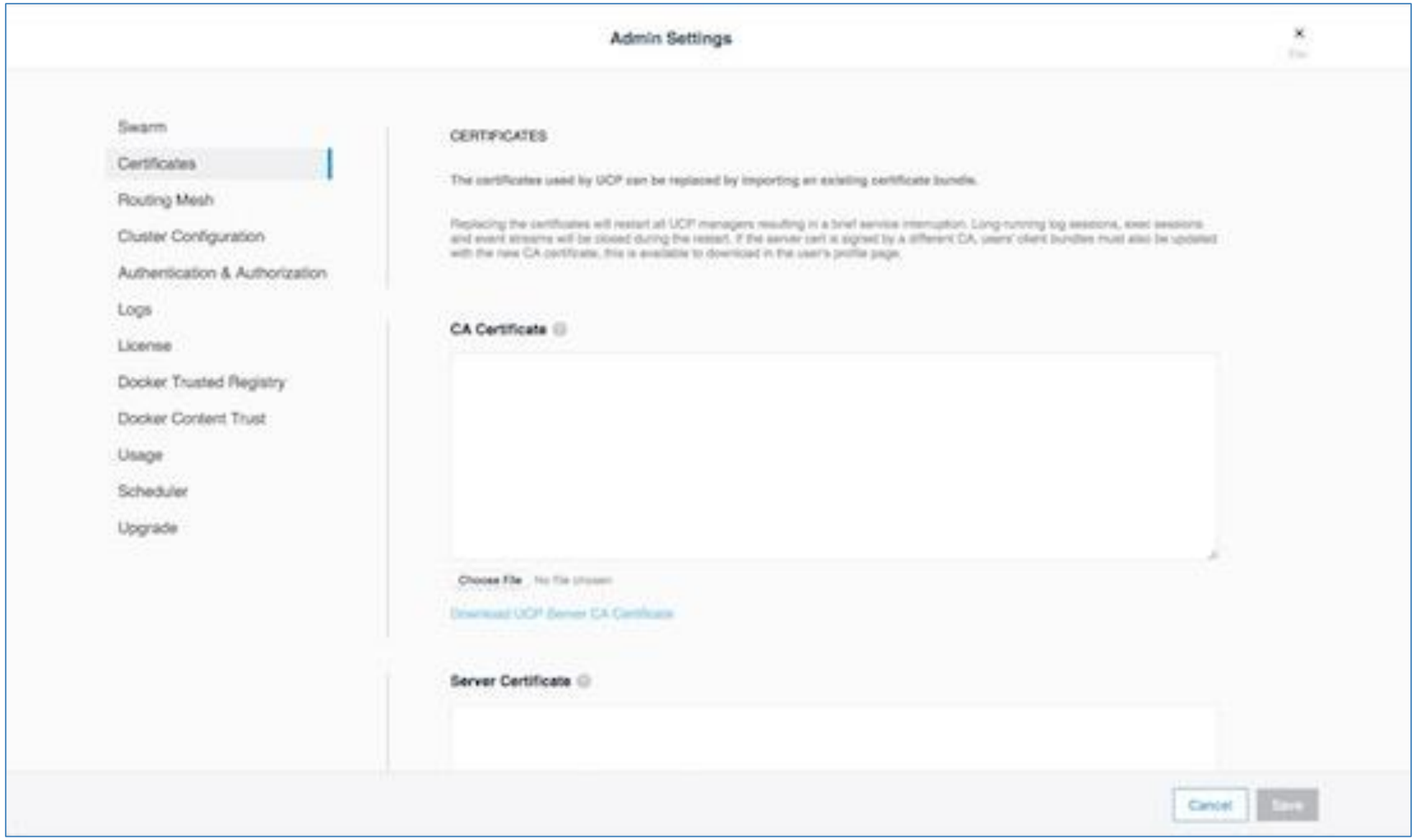
Configure MKE to use TLS Certificates:

- To ensure all communications between clients and MKE are encrypted, all MKE services are exposed using HTTPS
- By default, encryption is done using self-signed TLS certificates that are not trusted by client tools like web browsers
- To configure MKE to use your custom TLS certificates and keys:
  - Log in to the MKE web UI with admin credentials
  - Navigate to the **Admin Settings** page and click **Certificates**
  - Upload external certificates such as *Server certificate, CA certificate, Client CA,* and *Private key*
- Click **Save** to apply the changes

Note: If MSR is already deployed, then reconfigure it to trust the new MKE TLS certificates.

External Certificates with MKE

Configure MKE to use TLS certificates:



Source: https://docs.mirantis.com/containers/v3.1/dockeree-ref-arch/security/security-best-practices.html

External Certificates with MKE

Upload the following certificates and keys:

- A **ca.pem** file with the root CA public certificate
- A **cert.pem** file containing the domain TLS certificate and any intermediate public certificate
- A **key.pem** file with TLS private key. Make sure it is not encrypted with a password. Encrypted keys should have ENCRYPTED in the first line.

External Certificates with MSR

Configure MSR to use TLS certificates:

- To ensure all the communications between clients and MSR are encrypted, all MSR services are exposed using HTTPS by default
- If a **PEM-encoded TLS certificate** is not passed during the installation, MSR will generate a self-signed certificate
- Users can upload their own TLS certificates and keys using the MSR web UI or pass them as CLI options while installing or reconfiguring the MSR instance

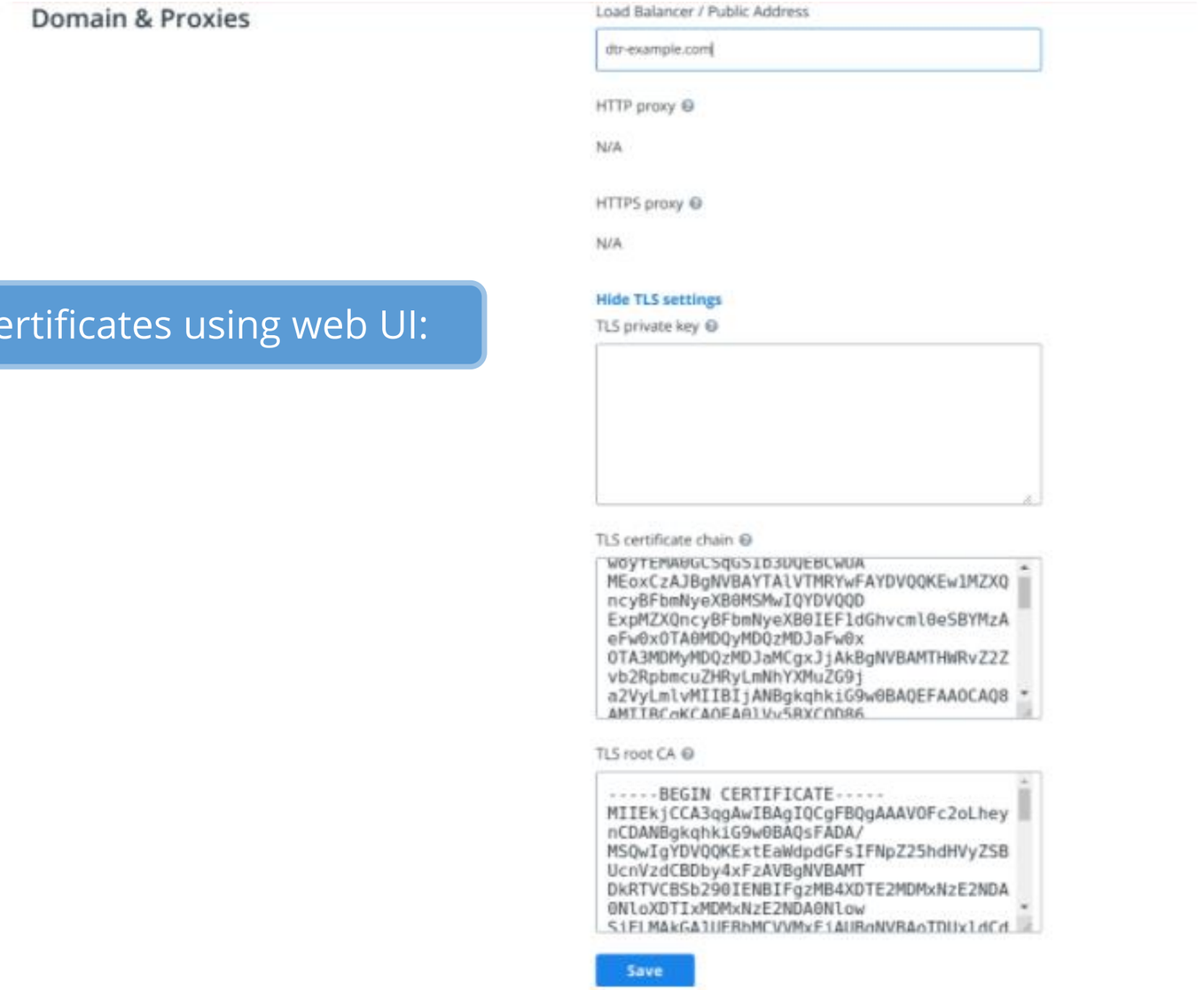
External Certificates with MSR

Replace server certificates using web UI:

- To configure MSR to use the external certificates and keys, go to MSR web UI
- Select **System** from the left navigation pane, and scroll down to **Domain & Proxies**
- Enter the MSR domain name and upload or copy and paste the certificate details:
  - **Load balancer/public address**: Domain name clients will use to access MSR
  - **TLS certificate chain**: Server certificate and any intermediate public certificates from the certificate authority (CA). This certificate needs to be validated for the MSR public address
  - **TLS private key**: Server private key
  - **TLS CA**: Root CA public certificate
- Click **Save** to apply the changes

External Certificates with MSR

Replace server certificates using web UI:



Configuration of Certificates

Understanding the Configuration

A custom certificate is configured by creating a directory under **/etc/docker/certs.d** using the same name as the registry's hostname, such as **localhost**. All ***.crt** files are added to this directory as CA roots.

The presence of one or more **<filename>.key/cert** pair(s) in Docker indicates that there are custom certificates required for access to the desired repository.

Configuration of Certificates

The following illustrates a configuration with custom certificates:

```
/etc/docker/certs.d/          <-- Certificate directory
    └── localhost:5000        <-- Hostname:port
        ├── client.cert       <-- Client certificate
        ├── client.key        <-- Client key
        └── ca.crt            <-- Certificate authority that signed the registry certificate
```

Configuration of Certificates

Create the client certificates

Use OpenSSL's **genrsa** and **req** commands to first generate an RSA key and then use the key to create the certificate

```
$ openssl genrsa -out client.key 4096
$ openssl req -new -x509 -text -key client.key -out client.cert
```

Note: These TLS commands only generate a working set of certificates on Linux. The version of OpenSSL in macOS is incompatible with the type of certificate Docker requires.

Configuration of Certificates

Troubleshooting tips

The Docker daemon interprets **.crt** files as CA certificates and **.cert** files as client certificates. The Docker daemon logs the following error message if a CA certificate is accidentally given the **.cert** extension instead of the correct **.crt** extension:

> Missing key KEY_NAME for client certificate CERT_NAME. CA certificates should use the extension **.crt**.

Configuration of Certificates

Example to show configuration of certificates

If the Docker registry is accessed without a port number, do not add the port to the directory name. The following shows the configuration for a registry on default port 443 which is accessed with docker login my-https.registry.example.com:

```
/etc/docker/certs.d/
    └── my-https.registry.example.com        <-- Hostname without port
        ├── client.cert
        ├── client.key
        └── ca.crt
```

Swarm Security and TLS

Swarm Security

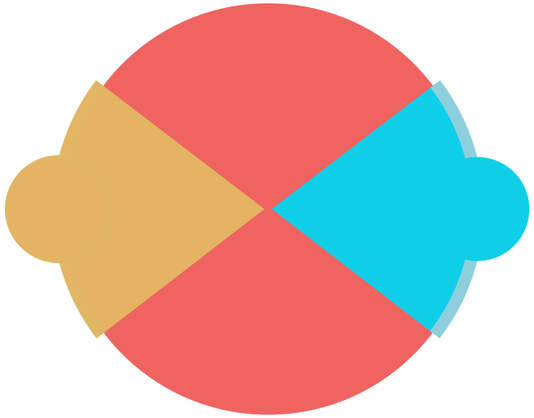
Overview of Swarm Security:

- The swarm mode Public Key Infrastructure (PKI) system built into Docker makes it simple to securely deploy a container orchestration system
- The nodes in a swarm use mutual Transport Layer Security (TLS) to authenticate, authorize, and encrypt the communications with other nodes in the swarm
- When a user creates a swarm by running **docker swarm init**, Docker designates itself as a manager node
- Users can specify their own externally-generated root CA, using the **--external-ca** flag of the **docker swarm init** command

Swarm Security

The manager node also generates two tokens to use when the user joins additional nodes to the swarm:

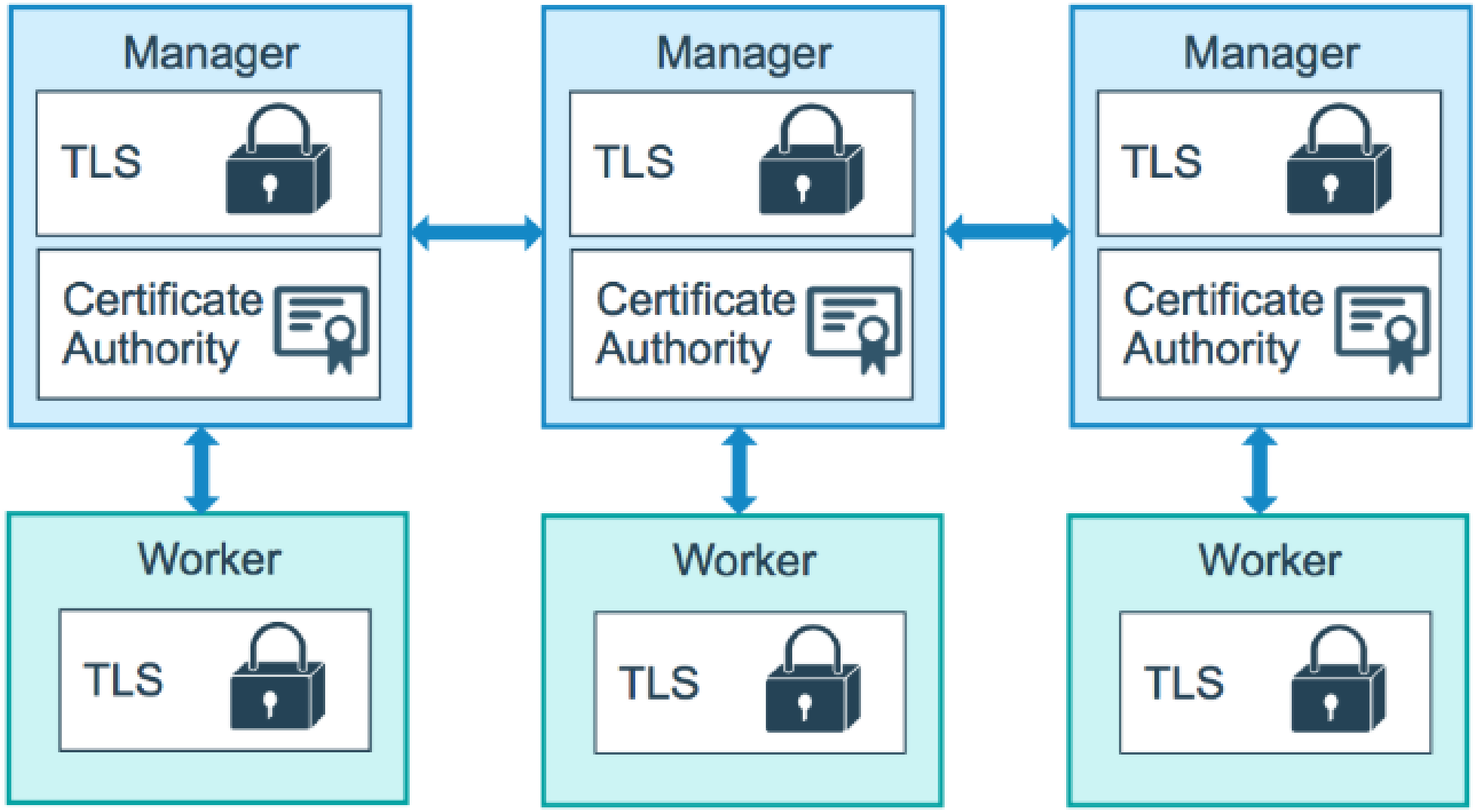
Worker Token



Manager Token

Swarm Security

The following diagram illustrates how manager nodes and worker nodes encrypt communications using a minimum of TLS 1.2.



Source: https://docs.docker.com/datacenter/dtr/2.3/guides/admin/configure/use-your-own-tls-certificates/

Swarm Security

Example to show information of a worker node certificate:

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number:
            3b:1c:06:91:73:fb:16:ff:69:c3:f7:a2:fe:96:c1:73:e2:80:97:3b
        Signature Algorithm: ecdsa-with-SHA256
        Issuer: CN=swarm-ca
        Validity
            Not Before: Aug 30 02:39:00 2016 GMT
            Not After : Nov 28 03:39:00 2016 GMT
        Subject: O=ec2adilxf4ngv7ev8fwsi61i7, OU=swarm-worker,
CN=dw02poa4vqvzxi5c10gm4pq2g
...snip...
```

Swarm Security

Rotating the CA Certificate:

- To generate a new CA certificate and password, run the **docker swarm ca—rotate**.
- To specify the root certificate and to use a root CA external to the swarm, the user can pass the **—ca-cert** and **—external-ca** flags if they prefer.
- Alternatively, to specify the exact certificate and key the user wants the swarm to use, they can pass the **—ca-cert** and **—ca-key** flags.

Swarm Security

Rotating the CA Certificate:

When the user issues the **docker swarm ca --rotate command**, the following things happen in sequence:

1. Docker generates a cross-signed certificate.

1. In Docker 17.06 and higher, Docker also tells all nodes to immediately renew their TLS certificates.

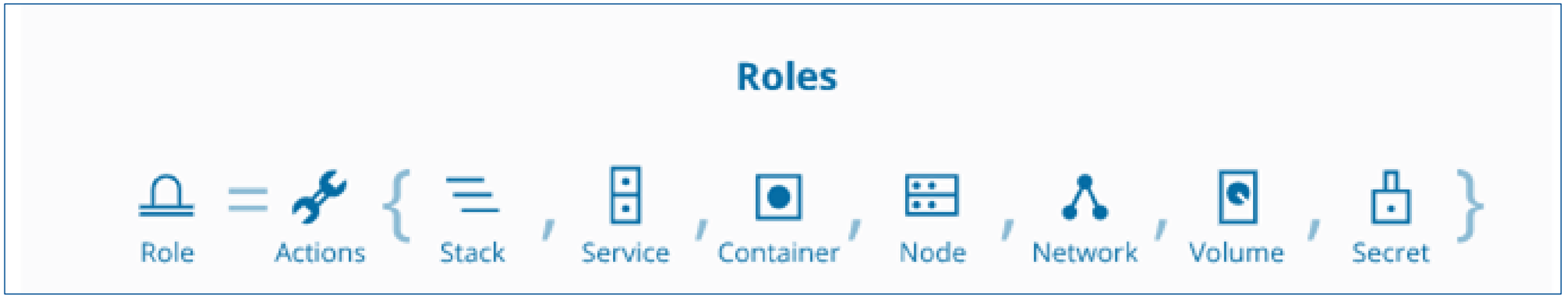
1. After every node in the swarm has a new TLS certificate signed by the new CA, Docker forgets about the old CA certificate and key material and tells all the nodes to trust only the new CA certificate.

Roles and Secrets

Roles

Introduction to Roles:

- MKE has two types of users: administrators and regular users
- Administrators can make changes to an MKE swarm cluster, while regular users have permissions that range from no access to full control over resources like volumes, networks, images, and containers
- Users are grouped into teams and organizations



Source: https://docs.docker.com/datacenter/ucp/2.2/guides/access-control/permission-levels/#roles

Secrets

Introduction to Secrets:

- Docker secrets are used to centrally manage the data and securely transmit it to only those containers that need access to it
- Secrets are encrypted during transit and at rest in a Docker swarm
- A given secret is only accessible to those services which have been granted explicit access to it, and only while those service tasks are running

Secrets

Sensitive data stored by secrets:

Users can use secrets to manage sensitive data which a container needs at runtime. Secrets have any of the following sensitive data:

- Usernames and passwords
- TLS certificates and keys
- SSH keys
- Other important data, such as the name of a database or internal server
- Generic strings or binary content (up to 500 kb in size)

How Docker Manages Secrets

Docker sends the secrets to the swarm manager over a mutual TLS connection when the user adds a secret to the swarm.

The secret is stored in the Raft log, which is encrypted.

The entire Raft log is replicated across the other managers, guaranteeing high availability for secrets.

Docker Secret Commands

Command	Description
docker secret create	Creates a secret from a file or STDIN as content
docker secret inspect	Displays detailed information on one or more secrets
docker secret ls	Lists secrets
docker secret rm	Removes one or more secrets

Key Takeaways

- Docker security prevents a compromised container from consuming a large amount of resources for disrupting service or performing malicious activities
- Mirantis Secure Registry (MSR) can scan images in the repositories using Docker Security Scanning
- A client bundle is a group of certificates downloadable directly from the Mirantis Kubernetes Engine (MKE)
- Docker secrets centrally manage the sensitive data and securely transmit it to only those containers that need access to it

Thank You