Introduction

The Docker Enterprise platform delivers a secure, managed application environment for developers to build, ship, and run enterprise applications and custom business processes. In the “build” part of this process, there are design and organizational decisions that need to be made in order to create an effective enterprise development pipeline.

What You Will Learn

In an enterprise, there can be hundreds or even thousands of applications developed by in-house and outsourced teams. Apps are deployed to multiple heterogeneous environments (development, test, UAT, staging, production, etc.), each of which can have very different requirements. Packaging an application in a container with its configuration and dependencies guarantees that the application will always work as designed in any environment. The purpose of this document is to provide you with typical development pipeline workflows as well as best practices for structuring the development process using Docker Enterprise.

In this document you will learn about the general workflow and organization of the development pipeline and how Docker Enterprise components integrate with existing build systems. It also covers the specific developer, CI/CD, and operations workflows and environments.

Prerequisites

Before continuing, become familiar with and understand:

- Docker Fundamental Concepts (https://docs.docker.com/engine/understanding-docker/)

Abbreviations

The following abbreviations are used in this document:

- UCP = Universal Control Plane
- DTR = Docker Trusted Registry
- EE = Docker Enterprise Edition
- DCT = Docker Content Trust
- CI = Continuous Integration
- CD = Continuous Delivery/Deployment
- CLI = Command Line Interface

General Organization

Several teams play an important role in an application lifecycle from feature discovery, development, testing, and to run the application in production. In general, operations teams are responsible for delivering and supporting the infrastructure up to the operating systems and middleware components. Development teams are responsible for building and maintaining the applications. There is also some type of continuous integration (CI) for automated build and testing as well as continuous delivery (CD) for deploying versions to different environments.
General Workflow

A typical CI/CD workflow is shown in the following diagram:

It starts on the left-hand side with development teams building applications. A CI/CD system then runs unit tests, packages the applications, and builds Docker images on the Docker Universal Control Plane (UCP). If all tests pass, the images can be signed using Docker Content Trust (https://success.docker.com/api/asset/\%2Frefarch%2Fdev-pipeline%2FDCT) and shipped to Docker Trusted
Registry (DTR). The images can then be run in other non-production environments for further testing. If the images pass these testing environments, they can be signed again and then deployed by the operations team to the production environment.

**UCP Clusters**

It is very common to separate production and non-production workloads for any business. UCP clusters shown above is a natural fit with existing infrastructure organization and responsibilities. A production environment with higher security requirements, restrained operator access, a high-performance infrastructure, high-availability configurations, and full disaster recovery with multiple data centers. A non-production environment has different requirements with the main goal being testing and qualifying applications for production. The interface between the non-production and production clusters is DTR.

The question of whether to have a separate UCP cluster per availability zone or have one "stretched cluster" mainly depends on the network latency and bandwidth between availability zones. There could also be existing infrastructure and disaster recovery considerations to take into account.

In an enterprise environment where there can be hundreds of teams building and running applications, a best practice is to separate the build from the run resources. By doing this, the image building process does not affect the performance or availability of the running containers/services.

There are two common methods of building images using Docker EE:

- **Developers build images on their own machines using Docker Desktop or Docker Desktop Enterprise (DDE) and then push them to DTR.** - This is suitable if there is no CI/CD system and no dedicated build cluster. Developers have the freedom to push different images to DTR.

- **A CI/CD process builds images on a build cluster and pushes them to DTR.** - This is suitable if an enterprise wants to control the quality of the images pushed to DTR. Developers commit Dockerfiles to version control. They can then be analyzed and controlled for adherence to corporate standards before the CI/CD system builds the images, tests them, and pushes them to DTR. In this case, CI/CD agents should be run directly on the dedicated build nodes.

  **Note:** In the CI/CD job, it is important to insure that images are built and pushed from the same Docker node so there is no ambiguity in the image that is pushed to DTR.

**DTR Clusters**

Having separate DTR clusters is very commonly used to maintain production and non-production environment segregation. A CI/CD system is used to run the unit tests, and tag the images in the non-production DTR. The images are later signed and promoted or mirrored to the Prod environment. This process gives additional control on the images stored and used in the production cluster such as Policy enforcement on image signing (https://docs.docker.com/ee/ucp/admin/configure/run-only-the-images-you-trust/).

Another option is a single DTR cluster to communicate with multiple UCP clusters can also be used to enforce enterprise processes such as Security scanning (https://docs.docker.com/docker-cloud/builds/image-scan/) in a centralized place. If pulling images from globally distributed locations takes too long then you can use the DTR Content Cache (https://docs.docker.com/ee/dtr/admin/configure/deploy-caches/) feature to create local caches.

  **Note:** Policy enforcement on image signing (https://docs.docker.com/ee/ucp/admin/configure/run-only-the-images-you-trust/) will not currently work if you have your DTR in a separate cluster from UCP.
The deployment best practices reference architecture ([https://success.docker.com/article/docker-ee-best-practices](https://success.docker.com/article/docker-ee-best-practices)) will guide you with the approach to deploy UCP and DTR clusters that works for your organization.

**Developer Workflow**

Developers and application teams usually maintain different repositories within the organization to develop, deploy, and test their applications. This section discusses the following diagram of a typical developer workflow using Docker EE as well as their interactions with the repositories:

A typical developer workflow follows these steps:

1. **Develop Locally** - On the developer's machine with Docker Desktop Enterprise or in a shared development environment, the developer locally builds images, run containers, and test their containers. There are several types of files and their respective repositories that are used to build Docker images.
   - **Version Control** - This is used mainly for text-based files such as Dockerfiles, `docker-compose.yml`, and configuration files. Small binaries can also be kept in the same version control. Examples of version control are git, svn, Team Foundation Server, Azure DevOps, and Clear Case.
   - **Repository Manager** - These hold larger binary files such as Maven/Java, npm, NuGet, and RubyGems. Examples include Nexus, Artifactory, and Archiva.
   - **Package Repository** - These hold packaged applications specific to an operating system such as CentOS, Ubuntu, and Windows Server. Examples include yum, apt-get, and PackageManagement.
   
   After building an image, developers can run the container using the environment variables and configuration files for their environments. They can also run several containers together described in a `docker-compose.yml` file and test the application.

2. **Push Images** - Once an image has been tested locally, it can be pushed to the Docker Trusted Registry. The developer must have an account on DTR and can push to a registry on their user account for testing on UCP. For example: `docker push dtr.example.com/kathy.seaweed/apache2:1.0`

3. **Deploy on UCP** - The developer might want to do a test deployment on an integration environment on UCP in the case where the development machine does not have the ability or access to all the resources to run the entire application. They might also want to test whether the application scales properly if it's deployed as a service. In this case the developer would use CLI-based access ([https://docs.docker.com/ee/ucp/user-access/cli/](https://docs.docker.com/ee/ucp/user-access/cli/)) to deploy the application on UCP ([https://docs.docker.com/ee/ucp/swarm/deploy-multi-service-app/](https://docs.docker.com/ee/ucp/swarm/deploy-multi-service-app/)).

   Use `$ docker context use <ucp context>` to point the Docker client to UCP. Then run the following command: `$ docker stack deploy --compose-file <compose.yml> <stack name>`
4. **Test the Application** - The developer can then test the deployed application on UCP from his machine to validate the configuration of the test environment.

5. **Commit to Version Control** - Once the application is tested on UCP, the developer can commit the files used to create the application, its images, and its configuration to version control. This commit triggers the CI/CD workflow.

### Developer Environment and Tools

**Docker Desktop Enterprise** provides local development, testing, and building of Docker applications on Mac and Windows. With work performed locally, developers can leverage a rapid feedback loop before pushing code or Docker images to shared servers / continuous integration infrastructure.

Docker Desktop Enterprise (DDE) takes Docker Desktop Community, formerly known as Docker for Windows and Docker for Mac, a step further with simplified enterprise application development and maintenance. With DDE, IT organizations can ensure developers are working with the same version of Docker Desktop and can easily distribute Docker Desktop to large teams using third-party endpoint management applications. With the Docker Desktop graphical user interface (GUI), developers do not have to work with lower-level Docker commands and can auto-generate Docker artifacts.

Installed with a single click or via command line, Docker Desktop Enterprise is integrated with the host OS framework, networking, and filesystem. DDE is also designed to integrate with existing development environments (IDEs) such as Visual Studio, and IntelliJ. With support for defined application templates, Docker Desktop Enterprise allows organizations to specify the look and feel of their applications.

### IDE

Docker Desktop Enterprise is not a native IDE for developing application code. However, most leading IDEs (VS Code, NetBeans, Eclipse, IntelliJ, Visual Studio) have support for Docker through plugins or add-ons. Our [labs](https://github.com/docker/labs/tree/master/developer-tools) contain tutorials on how to setup and use common developer tools and programming languages with Docker.

**Tip: Optimizing images sizes.** If an image size becomes too large, a quick way to identify where possible optimizations are is to use the `docker history <image>` command. It will tell you which lines in the Dockerfile added what size to the image. See [Best practices for writing Dockerfiles](https://docs.docker.com/develop/develop-images/dockerfile_best-practices/)

### Docker Client CLI Contexts

When working with Docker EE and the Docker command line, it is important to keep in mind the context that the command is running in.

- **Local Docker Engine** — This is the main context used for development of Dockerfiles and testing locally on the developer's machine.
- **Remote UCP CLI** — [CLI-based access](https://docs.docker.com/ee/ucp/user-access/cli/) is used for building and running applications on a UCP cluster.
- **UCP GUI** — The Docker EE web user interface provides an alternative to the CLI.
- **Remote UCP Node** — Sometimes it can be useful for debugging to directly connect to a node on the UCP cluster. In this case, SSH can be used, and the commands are executed on the Docker engine of the node.

A single Docker CLI can have multiple contexts. Each context contains all of the endpoint and security information required to manage a different cluster or node. The `docker context` command makes it easy to configure these contexts and switch between them.
As an example, a single Docker client on your company laptop might be configured with two contexts; dev-k8s and prod-swarm. dev-k8s contains the endpoint data and security credentials to configure and manage a Kubernetes cluster in a development environment. prod-swarm contains everything required to manage a Swarm cluster in a production environment. Once these contexts are configured, you can use the top-level docker context use <context-name> to easily switch between them. [Working With Contexts](https://docs.docker.com/engine/context/working-with-contexts/)

### CI/CD Workflow

A CI/CD platform uses different systems within the organization to automatically build, deploy, and test applications. This section discusses a typical CI/CD workflow using Docker EE and the interactions with those repositories as shown in the following illustration:

![CI/CD Workflow Diagram](https://via.placeholder.com/150)

A typical CI/CD workflow follows these steps:

1. **Build Application** — A change to the version control of the application triggers a build by the CI Agent. A build container is started and passed parameters specific to the application. The container can run on a separate Docker host or on UCP. The container obtains the source code from version control, runs the commands of the application’s build tool, and finally pushes the resulting artifact to a Repository Manager.

2. **Build Image** — The CI Agent pulls the Dockerfile and associated files to build the image from version control. The Dockerfile is setup so that the artifact built in the previous step is copied into the image. The resulting image is pushed to DTR. If [Docker Content Trust](https://docs.docker.com/engine/security/trust/content_trust/) has been enabled and [Notary](https://docs.docker.com/notary/getting_started/) has been installed (Notary ships within Docker Desktop Enterprise), then the image is signed with the CI/CD signature.

3. **Deploy Application** — The CI Agent can pull a run-time configuration from version control (e.g. docker-compose.yml + environment-specific configuration files) and use them to deploy the application on UCP [via the CLI-based access](https://docs.docker.com/ee/ucp/user-access/cli/) via the CLI-based access (https://docs.docker.com/ee/ucp/user-access/cli/).

4. **Test Application** — The CI Agent deploys a test container to test the application deployed in the previous step. If all of the tests pass, then the image can be signed with a QA signature by pulling and pushing the image to DTR. This push triggers the Operations workflow.
Tip: The CI Agent can also be Dockerized, however, since it runs Docker commands, it needs access to the host's Docker Engine. This can be done by mounting the host's Docker socket, for example:

docker run --rm -it --name ciagent \
-v /var/run/docker.sock:/var/run/docker.sock \
ciagent:1

Tip: Use Multi-Stage Builds (https://docs.docker.com/develop/develop-images/multistage-build/)

CI/CD Environment and Tools

The nodes of the CI/CD environment where Docker is used to build applications or images should have Docker Engine installed. The nodes can be labeled "build" to create a separate cluster.

There are many CI/CD software systems available (Jenkins, Visual Studio, TeamCity, etc). Most of the leading systems have support for Docker through plugins or add-ons. However, to ensure the most flexibility in creating CI/CD workflows, it is recommended that you use the native Docker CLI or rest API for building images or deploying containers/services.

Operations Workflow

The Operations workflow usually consists of two parts. It starts at the beginning of the entire development pipeline creating base images for development teams to use, and it ends with pulling and deploying the production ready images from the developer teams. The workflow for creating base images is the same as the developer workflow, so it is not shown here. However, the following diagram illustrates a typical Operations workflow for deploying images in production:
A typical Operations workflow follows these steps:

1. **Deploy Application** — The deployment to production can be triggered automatically via a change to version control for the application or it can be triggered by operations. It can also be executed manually or done by a CI/CD agent.
   A tag of the deployment configuration files specific to the production environment is pulled from version control. This includes a `docker-compose` file or scripts which deploy the services as well as configuration files. Secrets such as passwords or certificates that are specific to production environments should be added or updated. Starting with Docker 17.03 (and Docker Engine 1.13), Docker has native secrets management. The CD Agent can then deploy the production topology in UCP.

2. **Test Application** — The CD Agent deploys a test container to test the application deployed in the previous step. If all of the tests pass, then the application is ready to handle production load.

3. **Balance the Load** — Depending on the deployment pattern (Big Bang, Rolling, Canary, Blue Green, etc.), an external load balancer, DNS server, or router is reconfigured to send all or part of the requests to the newly deployed application. The older version of the application can remain deployed in case of the need to rollback. Once the new application is deemed stable, the older version can be removed.

### Enterprise Base Images

The Operations team will usually build and maintain “base images.” They typically contain the OS, middleware, and tooling to enforce enterprise policies. They might also contain any enterprise credentials used to access repositories or license servers. The enterprise base images are then pushed to DTR scanned, remediated, and then offered for consumption. The development teams can then inherit from the enterprise base images by using the keyword `FROM` in their Dockerfile referencing the base image in the enterprise DTR and then adding their application specific components, applications, and configuration to their own application images.
Tip: Squash function. Since the base images do not change that often and are widely used within an organization, minimizing their size is very important. You can use `docker build --squash -t <image>` to create only one layer and optimize the size of the image. You will lose the ability to modify, so this is recommended for base images and not necessarily for application images which change often.

Further Reading for Secure Production Pipelines

- Building a Docker Secure Supply Chain (https://success.docker.com/article/secure-supply-chain)

Summary

This document discussed the Docker development pipeline, integration with existing systems, and also covers the specific developer, CI/CD, and operations workflows and environments. Follow these best practices to create an effective enterprise development pipeline.