NVIDIA DOCA Developer Guide

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This guide details the recommended steps to set up an NVIDIA DOCA development environment.

Introduction

This guide is intended for software developers aiming to modify existing NVIDIA DOCA applications or develop their own DOCA-based software.

For steps to install DOCA on NVIDIA® BlueField® DPU, refer to the NVIDIA DOCA Installation Guide for Linux.

This guide focuses on the recommended flow for developing DOCA-based software, and will target the following environments:

- BlueField DPU is accessible and can be used during the development and testing process
    - Working within a development container
- BlueField DPU is inaccessible, and the development happens on the host or on a different server
    - Cross-compilation from the host
    - Working within a development container on top of QEMU running on the host

It is recommended to follow the former case, leveraging the DPU during the development and testing process.

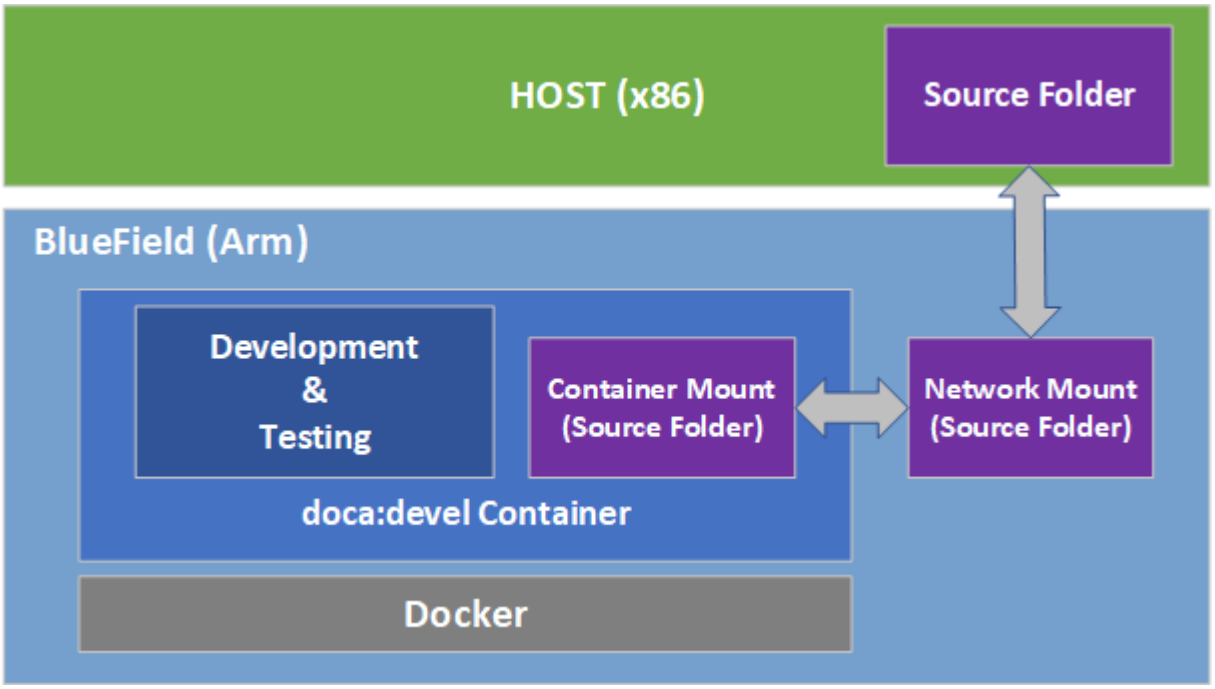
This guide recommends using DOCA's development container during the development process, whether it is on the DPU or on the host. Deploying development containers allows multiple developers to work simultaneously on the same device (host or DPU) in an isolated manner and even across multiple different DOCA SDK versions. This can allow multiple developers to work on the DPU itself, for example, without the need to have a dedicated DPU per developer.

Another benefit of this container-based approach is that the development container allows developers to create and test their DOCA-based software in a user-friendly environment that comes pre-shipped with a set of handy development tools. The development container is focused on improving the development experience and is designed for that purpose, whereas the BlueField software is meant to be an efficient runtime environment for DOCA products.

Developing Using BlueField DPU

Setup

DOCA's base image containers include a DOCA development container (`doca:devel`) which can be found on NGC. It is recommended to deploy this container on top of the DPU when preparing a development setup.



The recommended approach for working using DOCA's development container on top of the DPU, is by using docker, which is already included in the supplied BFB image.

1. Make sure the docker service is started. Run:

```
sudo systemctl daemon-reload
sudo systemctl start docker
```

2. Pull the container image:

    1. Visit the NGC page of the DOCA base image.

    2. Under the "Tags" menu, select the desired development tag.

3. The container tag for the docker `pull` command is copied to your clipboard once selected. Example docker `pull` command using the selected tag:

```
sudo docker pull nvcr.io/nvidia/doca/doca:1.5.1-devel
```

3. Once loaded locally, you may find the image's ID using the following command:

```
sudo docker images
```

Example output:

```
REPOSITORY                  TAG           IMAGE ID
CREATED         SIZE
nvcr.io/nvidia/doca/doca    1.5.1-devel   931bd576eb49   10
months ago   1.49GB
```

4. Run the docker image:

```
sudo docker run -v <source-code-folder>:/doca_devel -v
/dev/hugepages:/dev/hugepages --privileged --net=host -it
<image-name/ID>
```

For example, to map a source folder named `my_sources` into the same container tag from the example above, the command should look like this:

```
sudo docker run -v my_sources:/doca_devel -v
/dev/hugepages:/dev/hugepages --privileged --net=host -it
nvcr.io/nvidia/doca/doca:1.5.1-devel
```

After running the command, you get a shell inside the container where you can build your project using the regular build commands:

- From the container's perspective, the mounted folder will be named `/doca_devel`

> **Note**
>
> Make sure to map a folder with write privileges to `everyone`. Otherwise, the docker would not be able to write the output files to it.

- `--net=host` ensures the container has network access, including visibility to SFs and VFs as allocated on the DPU
- `-v /dev/hugepages:/dev/hugepages` ensures that allocated huge pages are accessible to the container

Development

It is recommended to do the development within the `doca:devel` container. That said, some developers prefer different integrated development environments (IDEs) or development tools, and sometimes prefer working using a graphical IDE until it is time to compile the code. As such, the recommendation is to mount a network share to the DPU (refer to NVIDIA DOCA DPU CLI for more information) and to the container.

> **Note**
>
> Having the same code folder accessible from the IDE and the container helps prevent edge cases where the compilation fails due to a typo in the code, but the typo is only fixed locally within the container and not propagated to the main source folder.

Testing

The container is marked as "privileged", hence it can directly access the HW capabilities of the BlueField DPU. This means that once the tested program compiles successfully, it can be directly tested from within the container without the need to copy it to the DPU and running it there.

Publishing

Once the program passes the testing phase, it should be prepared for deployment. While some proof-of-concept (POC) programs are just copied "as-is" in their binary form, most deployments will probably be in the form of a package (`.deb`/`.rpm`) or a container.

Construction of the binary package can be done as-is inside the current `doca:devel` container, or as part of a CI pipeline that will leverage the same development container as part of it.

For the construction of a container to ship the developed software, it is recommended to use a multi-staged build that ships the software on top of the runtime-oriented DOCA base images:

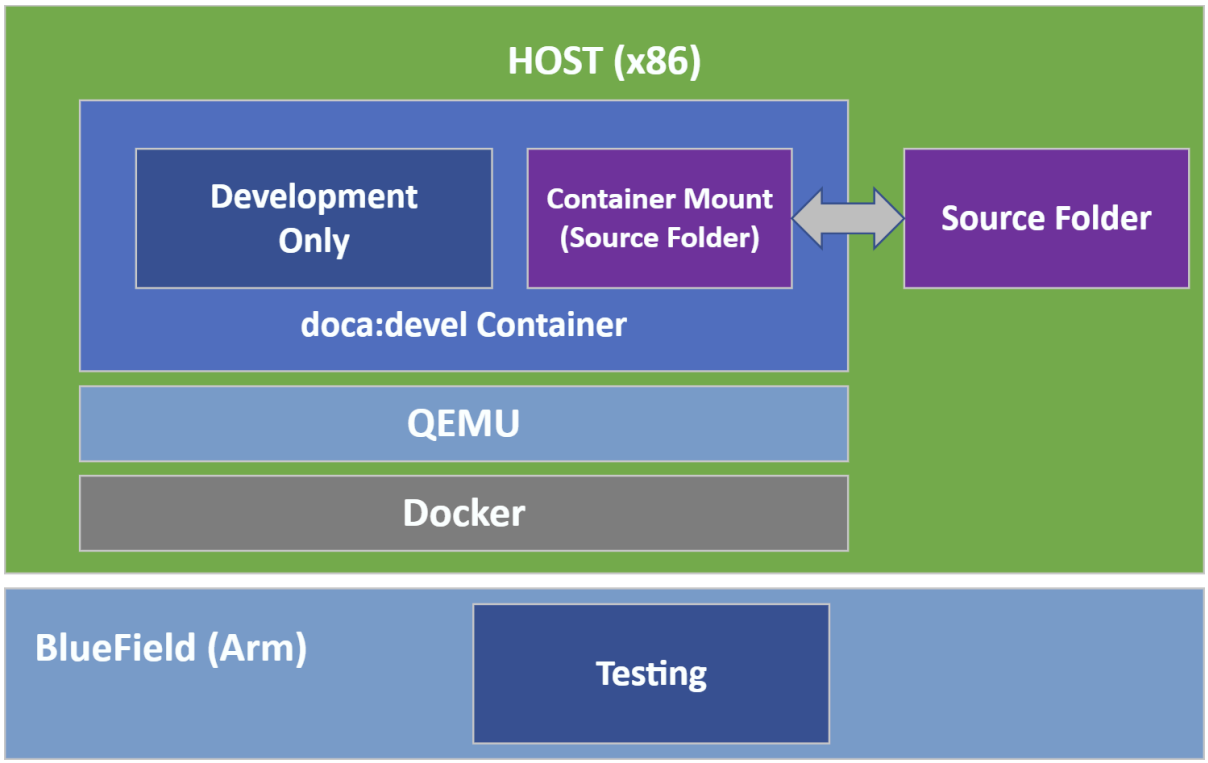
- `doca:base-rt` – slim DOCA runtime environment
- `doca:full-rt` – full DOCA runtime environment similar to the BlueField image

The runtime DOCA base images, alongside more details about their structure, can be found under the same NGC page that hosts the `doca:devel` image.

For a multi-staged build, it is recommended to compile the software inside the `doca:devel` container, and later copy it to one of the runtime container images. All relevant images must be pulled directly from NGC (using `docker pull`) to the container registry of the DPU.

Developing Without BlueField DPU

If the development process needs to be done without access to a BlueField DPU, the recommendation is to use a QEMU-based deployment of a container on top of a regular x86 server. The development container for the host will be the same `doca:devel` image we mentioned previously.



Setup

1. Make sure Docker is installed on your host. Run:

   ```
   docker version
   ```

   If it is not installed, visit the official Install Docker Engine webpage for installation instructions.

2. Install QEMU on the host.

   Note

This step is for x86 hosts only. If you are working on an aarch64 host, move to the next step.

Host OS	Command
Ubuntu	`sudo apt-get install qemu binfmt-support qemu-user-static` `sudo docker run --rm --privileged multiarch/qemu-user-static --reset -p yes`
CentOS/RHEL 7.x	`sudo yum install epel-release` `sudo yum install qemu-system-arm`
CentOS 8.0/8.2	`sudo yum install epel-release` `sudo yum install qemu-kvm`
Fedora	`sudo yum install qemu-system-aarch64`

3. If you are using CentOS or Fedora on the host, verify if `qemu-aarch64.conf` Run:

```
cat /etc/binfmt.d/qemu-aarch64.conf
```

If it is missing, run:

```
echo ":qemu-
aarch64:M::\x7fELF\x02\x01\x01\x00\x00\x00\x00\x00\x00\x00\x00\x00
aarch64-static:" > /etc/binfmt.d/qemu-aarch64.conf
```

4. If you are using CentOS or Fedora on the host, restart system binfmt. Run:

```
$ sudo systemctl restart systemd-binfmt
```

5. To load and execute the development container, refer to the "Setup" section discussing the same docker-based deployment on the DPU side.

Note

The `doca:devel` container supports multiple architectures. Therefore, Docker by default attempts to pull the one matching that of the current machine (i.e., `amd64` for the host and `arm64` for the DPU). Pulling the `arm64` container from the x86 host can be done by adding the flag `--platform=linux/arm64`:

```
sudo docker pull --platform=linux/arm64
nvcr.io/nvidia/doca/doca:1.5.1-devel
```

Development

Much like the development phase using a BlueField DPU, it is recommended to develop within the container running on top of QEMU.

Testing

While the compilation can be performed on top of the container, testing the compiled software must be done on top of a BlueField DPU. This is because the QEMU environment emulates an aarch64 architecture, but it does not emulate the hardware devices present on the BlueField DPU. Therefore, the tested program will not be able to access the devices needed for its successful execution, thus mandating that the testing is done on top of a physical DPU.

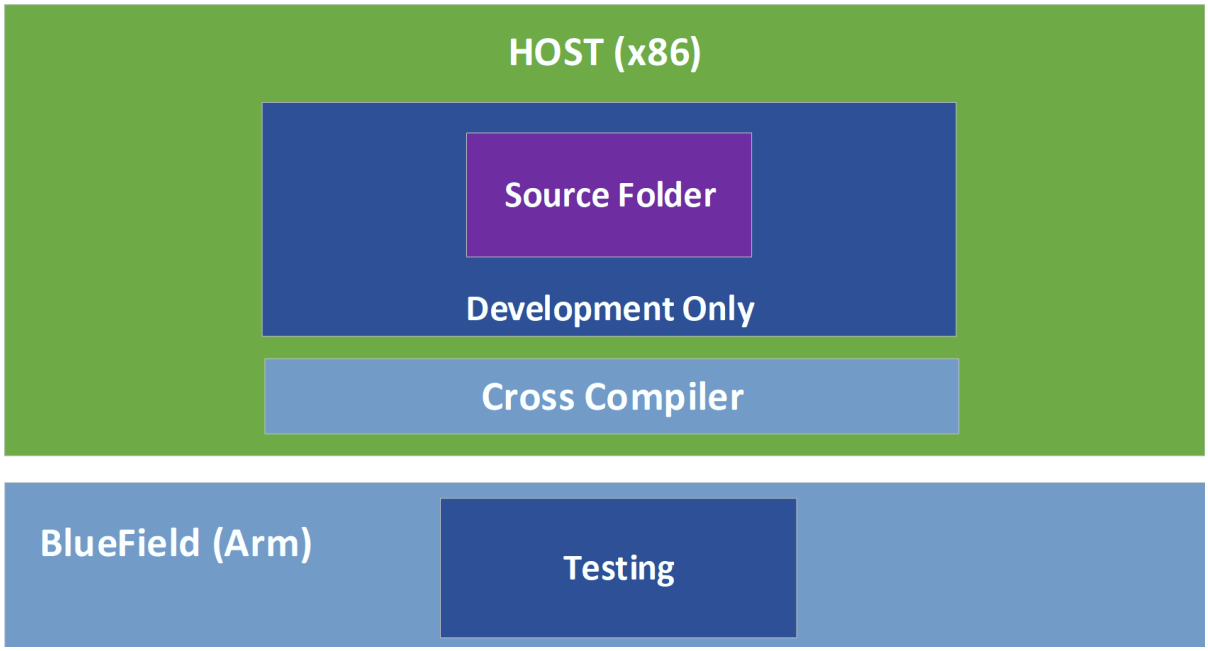
> **Note**
>
> Make sure that the DOCA version used for compilation is the same as the version installed on the DPU used for testing.

Publishing

The publishing process is identical to the publishing process when using a BlueField DPU.

Cross-compilation from Host

In a typical setup, developers prefer to work on a familiar host since compilation is often significantly faster there. Therefore, developers may work on their host while cross-compiling their project to the DPU's Arm architecture.



Setup

1. Install Docker and QEMU your host. See steps 1-4 under section Setup.

2. Download the `doca-cross` component as described in the NVIDIA DOCA Installation Guide for Linux and unpack it under the `/root` directory.

   Inside this directory one can find:

   - `arm64_armv8_linux_gcc` – cross file containing specific information about the cross compiler and the host machine
   - `DOCA_cross.sh` – script which handles all the required dependencies and pre-installations steps
   - A .txt file used by the script

3. To load the development container, refer to section "Docker Deployment" of the NVIDIA BlueField DPU Container Deployment Guide.

> **Note**

It is important to ensure that the same DOCA version is used in the development container and the DOCA metapackages installed on the host.

4. Start running the container using the container's tag while mapping the `doca-cross` directory to the container's `/doca_devel` directory:

```
sudo docker run -v /root/doca-cross/:/doca_devel --privileged
-it <imagename/ID>
```

   Now the shell will be redirected to be within the container.

5. Run the preparation script to copy all the Arm dependencies required for DOCA's cross compilation. The script will be in the mapped directory named `doca_devel`.

```
(container) /# cd doca_devel/
(container) /doca_devel# ./DOCA_cross.sh
```

6. Exit the container and run the same script from the host side:

```
(host) /root/doca-cross# ./DOCA_cross.sh
```

   The `/root/doca-cross` directory is now fully configured and prepared for cross-compilation against DOCA.

7. Update the environment variables to point at the Linaro cross-compiler:

```
export PATH=${PATH}:/opt/gcc-
linaro/<linaro_version_dir>/aarch64-linux-gnu/bin:/opt/gcc-
```

```
linaro/<linaro_version_dir>/bin
```

Everything is set up and the cross-compilation can now be used.

> **Note**
>
> Make sure to update the command according to the Linaro version installed by the script in the previous step. `<linaro_version_dir>` can be found under `/opt/gcc-linaro/`.

> **Note**
>
> Cross-compilation requires Meson version ⩾0.61.2 to be installed on the host. This is already provided as part of DOCA's installation.

DOCA and CUDA Setup

1. To cross-compile DOCA and CUDA applications, you must install CUDA Toolkit 12.1:
    1. The first toolkit installation is for x86 architecture. Select `x86_64`.
    2. The second toolkit installation is for Arm. Select `arm64-sbsa` and then cross.
    3. Select your host operating system, architecture, OS distribution, and version and select the installation type. It is recommended to use the deb (local) type.
2. Execute the following exports:

```
export CPATH=/usr/local/cuda/targets/sbsa-
linux/include:$CPATH
export LD_LIBRARY_PATH=/usr/local/cuda/targets/sbsa-
linux/lib:$LD_LIBRARY_PATH
export PATH=/usr/local/cuda/bin:/usr/local/cuda-11.6/bin:$PATH
```

3. Verify the `meson` version is at least 0.61.2 as provided with DOCA's installation.

Everything is set up and the cross-compilation can now be used.

Development

It is recommended to develop normally while remembering to compile using the cross-compilation configuration file `arm64_armv8_linux_gcc` which can be found under the `doca-cross` directory.

The following is an example procedure for cross-compiling DOCA applications from the host and to the Arm architecture:

1. Enable the meson cross-compilation option in `/opt/mellanox/doca/applications/meson_options.txt` by setting `enable_cross_compilation_to_dpu` to `true`.

2. Cross-compile the DOCA applications:

```
/opt/mellanox/doca/applications # meson cross-build --cross-
file /root/doca-cross/arm64_armv8_linux_gcc
/opt/mellanox/doca/applications # ninja -C cross-build
```

   The cross-compiled binaries are created under the `cross-build` directory.

3. Cross-compile the DOCA and CUDA application:

1. Set flag for GPU-enabled cross-compilation, `enable_gpu_support`, in `/opt/mellanox/doca/applications/meson_options.txt` to `true`.

2. Run the compilation command as follows:

```
/opt/mellanox/doca/applications # meson cross-build --
cross-file /root/doca-cross/arm64_armv8_linux_gcc -
Dcuda_ccbindir=aarch64-linux-gnu-g++
/opt/mellanox/doca/applications # ninja -C cross-build
```

   The cross-compiled binaries are created under the `cross-build` directory.

Note

Due to the system's use of the PKG_CONFIG_PATH environment variable, it is crucial that the cross file include the following:

```
[built-in options]
pkg_config_path = "
```

This definition, already provided as part of the supplied cross file, guarantees that meson does not accidently use the build system's environment variable during the cross build.

Testing

While the compilation can be performed on top of the host, testing the compiled software must be done on top of a BlueField-2 DPU. This is because the tested program is not able to access the devices needed for its successful execution, which mandates that the testing is performed on top of a physical DPU.

Note

Make sure that the DOCA version used for compilation is the same as the version installed on the DPU used for testing.

Publishing

The publishing process is identical to the publishing process when using a BlueField DPU.

Info

For questions, comments, and feedback, please contact us at DOCA-Feedback@exchange.nvidia.com.