DOCA YARA Inspection Application Guide

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This guide provides YARA inspection implementation on top of NVIDIA® BlueField® DPU.

Introduction

YARA inspection monitors all processes in the host system for specific YARA rules using the DOCA App Shield library.

This security capability helps identify malware detection patterns in host processes from an independent and trusted DPU. This is an innovative Intrusion Detection System (IDS) as it is designed to run independently on the DPU's Arm cores without hindering the host.

This DOCA App Shield based application provides the capability to read, analyze, and authenticate the host (bare metal/VM) memory directly from the DPU.

Using the library, this application scans host processes and looks for pre-defined YARA rules. After every scan iteration, the application indicates if any of the rules matched. Once there is a match, the application reports which rules were detected in which process. The reports are both printed to the console and exported to the DOCA Telemetry Service (DTS) using inter-process communication (IPC).

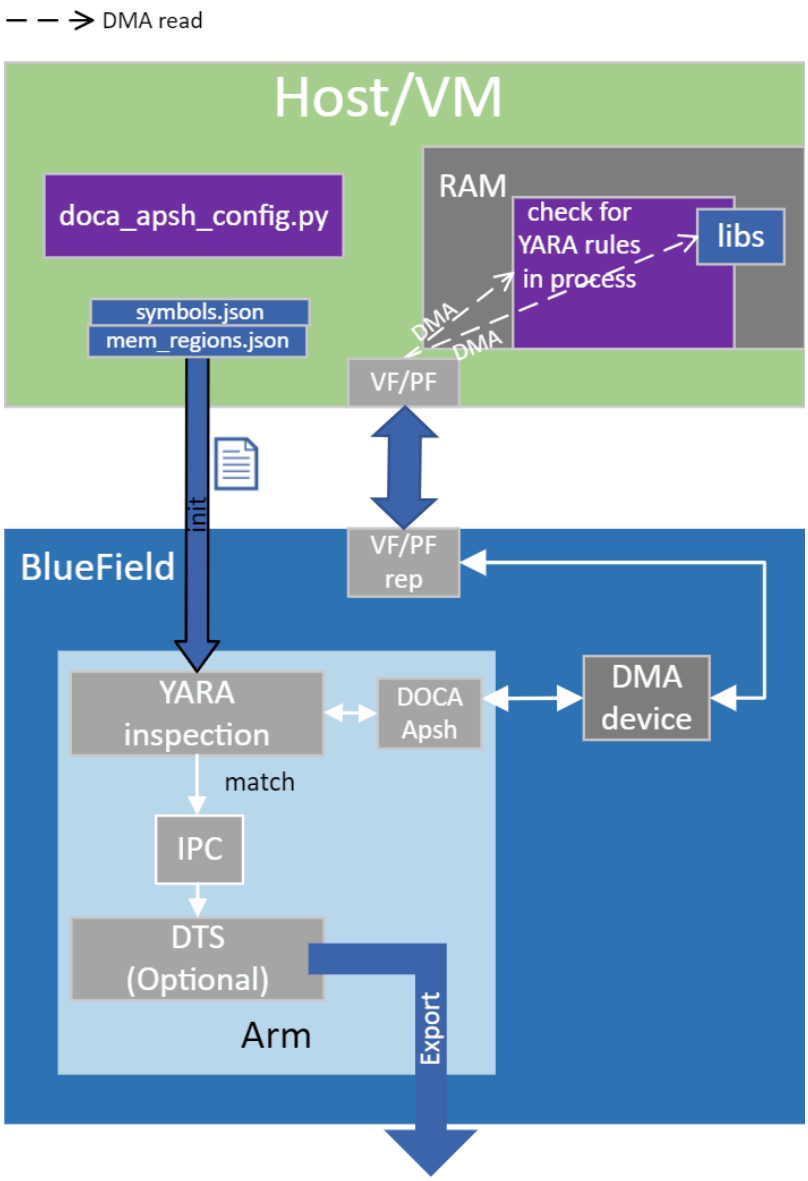
This guide describes how to build YARA inspection using the DOCA App Shield library which leverages DPU abilities such as hardware-based DMA, integrity, and more.

> **Note**
>
> As the DOCA App Shield library only supports the YARA API for Windows hosts, this application can only be used to inspect Windows hosts.

System Design

The host's involvement is limited to generating the required ZIP and JSON files to pass to the DPU. This is done before the app is triggered, when the host is still in a "safe" state.

Generating the needed files can be done by running DOCA App Shield's `doca_apsh_config.py` tool on the host. See DOCA App Shield for more info.

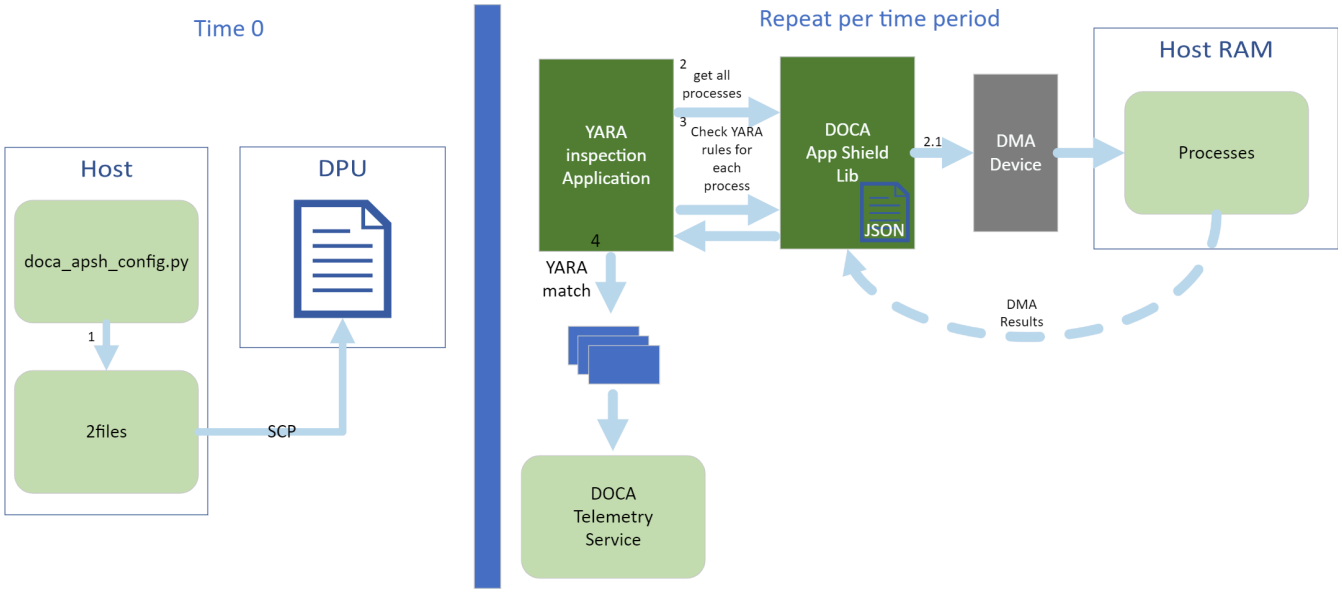


Application Architecture

The user creates the ZIP and JSON files using the DOCA tool `doca_apsh_config.py` and copies them to the DPU.

The application can report YARA rules detection to the:

- File
- Terminal
- DTS



1. The files are generated by running `doca_apsh_config.py` on the host against the process at time zero.

2. The following steps recur at regular time intervals:

    1. The YARA inspection app requests a list of all apps from the DOCA App Shield library.

    2. The app loops over all processes and checks for YARA rules match using the DOCA App Shield library.

    3. If YARA rules are found (1 or more), the YARA attestation app reports results with a timestamp and details about the process and rules to:

        - Local telemetry files – a folder and files representing the data a real DTS would have received

        > **Note**
        >
        > These files are used for the purpose of this example only as normally this data is not exported into user-readable files.

        - DOCA log

        - DTS IPC interface (even if no DTS is active)

3. The App Shield agent exits on first YARA rule detection.

DOCA Libraries

This application leverages the following DOCA libraries:

- DOCA App Shield
- 2024-10-09_07-10-18_DOCA Telemetry

Refer to their respective programming guide for more information.

Limitations

- The application is only available on Ubuntu 22.04 environments
- The application only supports the inspection of Windows hosts

Compiling the Application

> **Info**
>
> Please refer to the DOCA Installation Guide for Linux for details on how to install BlueField-related software.

The installation of DOCA's reference applications contains the sources of the applications, alongside the matching compilation instructions. This allows for compiling the applications "as-is" and provides the ability to modify the sources, then compile a new version of the application.

> **Tip**

For more information about the applications as well as development and compilation tips, refer to the DOCA Reference Applications page.

The sources of the application can be found under the application's directory: `/opt/mellanox/doca/applications/yara_inspection/`.

Compiling All Applications

All DOCA applications are defined under a single meson project. So, by default, the compilation includes all of them.

To build all the applications together, run:

```
cd /opt/mellanox/doca/applications/
meson /tmp/build
ninja -C /tmp/build
```

Info

`doca_yara_inspection` is created under `/tmp/build/yara_inspection/`.

Compiling Only the Current Application

To directly build only the YARA inspection application:

```
cd /opt/mellanox/doca/applications/
```

```
meson /tmp/build -Denable_all_applications=false -
Denable_yara_inspection=true
ninja -C /tmp/build
```

Info

`doca_yara_inspection` is created under `/tmp/build/yara_inspection/`.

Alternatively, one can set the desired flags in the `meson_options.txt` file instead of providing them in the compilation command line:

1. Edit the following flags in `/opt/mellanox/doca/applications/meson_options.txt`:
   - Set `enable_all_applications` to `false`
   - Set `enable_yara_inspection` to `true`
2. Run the following compilation commands :

```
cd /opt/mellanox/doca/applications/
meson /tmp/build
ninja -C /tmp/build
```

Info

`doca_yara_inspection` is created under `/tmp/build/yara_inspection/`.

Troubleshooting

Refer to the DOCA Troubleshooting for any issue encountered with the compilation of the application .

Running the Application

Prerequisites

1. Configure the BlueField's firmware

    1. On the BlueField system, configure the PF base address register and NVME emulation. Run:

    ```
    dpu> mlxconfig -d /dev/mst/mt41686_pciconf0 s
    PF_BAR2_SIZE=2 PF_BAR2_ENABLE=1 NVME_EMULATION_ENABLE=1
    ```

    2. Perform a BlueField system reboot for the `mlxconfig` settings to take effect.

    3. This configuration can be verified using the following command:

    ```
    dpu> mlxconfig -d /dev/mst/mt41686_pciconf0 q | grep -E
    "NVME|BAR"
    ```

2. Download target system (host/VM) symbols.

    - For Ubuntu:

    ```
    host> sudo tee /etc/apt/sources.list.d/ddebs.list << EOF
    deb http://ddebs.ubuntu.com/ $(lsb_release -cs) main restricted universe multiverse
    ```

```
deb http://ddebs.ubuntu.com/ $(lsb_release -cs)-updates main restricted universe multiverse
deb http://ddebs.ubuntu.com/ $(lsb_release -cs)-proposed main restricted universe multiverse
EOF
host> sudo apt install ubuntu-dbgsym-keyring
host> sudo apt-get update
host> sudo apt-get install linux-image-$(uname -r)-dbgsym
```

- For CentOS:

```
host> yum install --enablerepo=base-debuginfo kernel-devel-$(uname -r) kernel-debuginfo-$(uname -r) kernel-debuginfo-common-$(uname -m)-$(uname -r)
```

- No action is needed for Windows

3. Perform IOMMU passthrough. This stage is only needed on some of the cases where IOMMU is not enabled by default (e.g., when the host is using an AMD CPU).

> **Note**
>
> Skip this step if you are not sure whether you need it. Return to it only if DMA fails with a message in `dmesg` similar to the following:
>
> ```
> host> dmesg
> [ 3839.822897] mlx5_core 0000:81:00.0: AMD-Vi: Event logged [IO_PAGE_FAULT domain=0x0047 address=0x2a0aff8 flags=0x0000]
> ```

- Locate your OS's grub file (most likely `/boot/grub/grub.conf`, `/boot/grub2/grub.cfg`, or `/etc/default/grub`) and open it for editing. Run:

```
host> vim /etc/default/grub
```

- Search for the line defining `GRUB_CMDLINE_LINUX_DEFAULT` and add the argument `iommu=pt`. For example:

```
GRUB_CMDLINE_LINUX_DEFAULT="iommu=pt <intel/amd>_iommu=on"
```

- Run:

> **Note**
>
> Prior to performing a power cycle, make sure to do a graceful shutdown.

  - For Ubuntu:

```
host> sudo update-grub
host> ipmitool power cycle
```

  - For CentOS:

```
host> grub2-mkconfig -o /boot/grub2/grub.cfg
host> ipmitool power cycle
```

- For Windows targets: Turn off Hyper-V capability.

4. The DOCA App Shield library uses hugepages for DMA buffers. Therefore, the user must allocate 42 huge pages.

    1. Run:

    ```
    dpu> nr_huge=$(cat
    /sys/devices/system/node/node0/hugepages/hugepages-
    2048kB/nr_hugepages)
         nr_huge=$((42+$nr_huge))
         echo $nr_huge | sudo tee -a
    /sys/devices/system/node/node0/hugepages/hugepages-
    2048kB/nr_hugepages
    ```

    2. Create the ZIP and JSON files. Run:

    ```
    target-system> cd /opt/mellanox/doca/tools/
    target-system> python3 doca_apsh_config.py <pid-of-
    process-to-monitor> --os <windows/linux> --path <path to
    dwarf2json executable  or pdbparse-to-json.py>
    target-system> cp /opt/mellanox/doca/tools/*.* <shared-
    folder-with-baremetal>
    dpu> scp <shared-folder-with-baremetal>/* <path-to-app-
    shield-binary>
    ```

    If the target system does not have DOCA installed, the script can be copied from the BlueField.

    The required `dwaf2json` and `pdbparse-to-json.py` are not provided with DOCA.

    Note

If the kernel and process `.exe` have not changed, there no need to redo this step.

Application Execution

The YARA inspection application is provided in source form. Therefore, a compilation is required before the application can be executed.

1. Application usage instructions:

```
Usage: doca_yara_inspection [DOCA Flags] [Program Flags]

DOCA Flags:
  -h, --help                        Print a help synopsis
  -v, --version                     Print program version
information
  -l, --log-level                   Set the (numeric) log
level for the program <10=DISABLE, 20=CRITICAL, 30=ERROR,
40=WARNING, 50=INFO, 60=DEBUG, 70=TRACE>
  --sdk-log-level                   Set the SDK (numeric) log
level for the program <10=DISABLE, 20=CRITICAL, 30=ERROR,
40=WARNING, 50=INFO, 60=DEBUG, 70=TRACE>
  -j, --json <path>                 Parse all command flags
from an input json file

Program Flags:
  -m, --memr <path>                 System memory regions map
  -f, --vuid                        VUID of the System device
  -d, --dma                         DMA device name
  -o, --osym <path>                 System OS symbol map path
  -t, --time <seconds>              Scan time interval in
seconds
```

Info

This usage printout can be printed to the command line using the `-h` (or `--help`) options:

```
./doca_yara_inspection -h
```

Info

For additional information, refer to section "Command Line Flags".

2. CLI example for running the application on the BlueField:

```
./doca_yara_inspection -m mem_regions.json -o symbols.json -f
MT2125X03335MLNXS0D0F0VF1 -d mlx5_0 -t 3
```

Note

All used identifiers (`-f` and `-d` flags) should match the identifier of the desired devices.

Command Line Flags

Flag Type	Short Flag	Long Flag	Description
General flags	`h`	`help`	Prints a help synopsis
	`v`	`version`	Prints program version information
	`l`	`log-level`	Set the log level for the application: • DISABLE=10 • CRITICAL=20 • ERROR=30 • WARNING=40 • INFO=50 • DEBUG=60 • TRACE=70 (requires compilation with `TRACE` log level support)
	N/A	`sdk-log-level`	Sets the log level for the program: • DISABLE=10 • CRITICAL=20 • ERROR=30 • WARNING=40 • INFO=50 • DEBUG=60 • TRACE=70
	`j`	`json`	Parse all command flags from an input JSON file
Program flags	`m`	`memr`	Path to the pre-generated `mem_regions.json` file transferred from the host

	`f`	`pcif`	System PCIe function vendor unique identifier (VUID) of the VF/PF exposed to the target system. Used for DMA operations.
			To obtain this argument, run:
			`target-system> lspci -vv | grep "\[VU\] Vendor specific:"`
			Example output:
			`[VU] Vendor specific: MT2125X03335MLNXS0D0F0`

Flag Type	Short Flag	Long Flag	Description
			`[VU] Vendor specific: MT2125X03335MLNXS0D0F1` Two VUIDs are printed for each DPU connected to the target system. The first is of the DPU on `pf0` and the second is of the DPU on port `pf1`. **Note** Running this command on the DPU outputs VUIDs with an additional "EC" string in the middle. You must remove the "EC" to arrive at the correct VUID. The VUID of a VF allocated on PF0/1 is the VUID of the PF with an additional suffix, `VF<vf-number>`, where `vf-number` is the VF index +1. For example, for the output in the example above: • PF0 VUID = MT2125X03335MLNXS0D0F0 • PF1 VUID = MT2125X03335MLNXS0D0F1 • VUID of VF0 on PF0 = MT2125X03335MLNXS0D0F0VF1 VUIDs are persistent even on reset.
	`d`	`dma`	DMA device name to use
	`o`	`osym`	Path to the pre-generated `symbols.json` file transferred from the host
	`t`	`time`	Number of seconds to sleep between scans

Info

Refer to DOCA Arg Parser for more information regarding the supported flags and execution modes.

Troubleshooting

Refer to the DOCA Troubleshooting for any issue encountered with the installation or execution of the DOCA applications .

Application Code Flow

1. Parse application argument.
    1. Initialize arg parser resources and register DOCA general parameters.

        ```
        doca_argp_init();
        ```

    2. Register application parameters.

        ```
        register_apsh_params();
        ```

    3. Parse the arguments.

        ```
        doca_argp_start();
        ```

2. Initialize DOCA App Shield lib context.
    1. Create lib context.

```
doca_apsh_create();
```

2. Set DMA device for lib.

```
open_doca_device_with_ibdev_name();
doca_apsh_dma_dev_set();
```

3. Start the context

```
doca_apsh_start();
apsh_system_init();
```

3. Initialize DOCA App Shield lib system context handler.

1. Get the representor of the remote PCIe function exposed to the system.

```
open_doca_device_rep_with_vuid();
```

2. Create and start the system context handler.

```
doca_apsh_system_create();
doca_apsh_sys_os_symbol_map_set();
doca_apsh_sys_mem_region_set();
doca_apsh_sys_dev_set();
doca_apsh_sys_os_type_set();
doca_apsh_system_start();
```

4. Telemetry initialization.

```
telemetry_start();
```

1. Initialize a new telemetry schema.
2. Register YARA type event.
3. Set up output to file (in addition to default IPC).
4. Start the telemetry schema.
5. Initialize and start a new DTS source with the `gethostname()` name as source ID.

5. Loop until YARA rule is matched.
    1. Get all processes from the host.

    ```
    doca_apsh_processes_get();
    ```

    2. Check for YARA rule identification and send a DTS event if there is a match.

    ```
    doca_apsh_yara_get();
    if (yara_matches_size != 0) {
            /* event fill logic
            doca_telemetry_exporter_source_report();
    DOCA_LOG_INFO();
    sleep();
    ```

6. Telemetry destroy.

```
telemetry_destroy();
```

7. YARA inspection clean-up.

```
doca_apsh_system_destroy();
doca_apsh_destroy();
doca_dev_close();
doca_dev_rep_close();
```

8. Arg parser destroy.

```
doca_argp_destroy();
```

References

- `/opt/mellanox/doca/applications/yara_inspection/`