NVIDIA DOCA App Shield

Programming Guide

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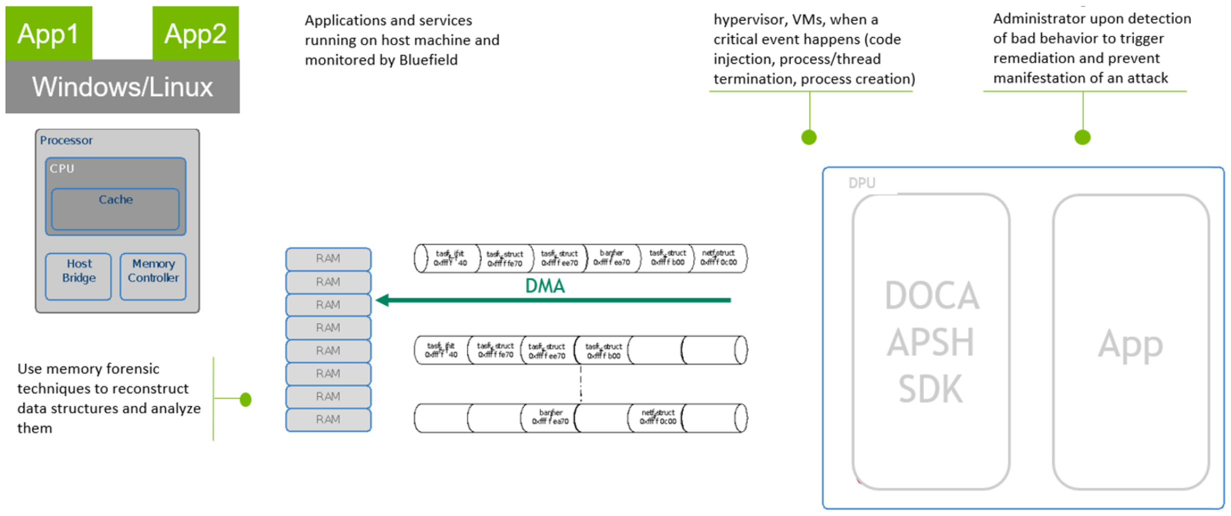
Chapter 1. Introduction

DOCA App Shield API offers a solution for strong intrusion detection capabilities using the DPU services to collect data from the host's memory. This solution provides intrusion detection and forensics investigation in a way that is:

- Robust against attacks on a host machine
- Able to detect a wide range of attacks (including zero-day attacks)
- Least disruptive to the execution of host application (where current detection solutions hinder the performance of host applications)

The App Shield detects attacks on critical services in a system. In many systems these services are responsible for assuring the integrity/privacy of the execution of other applications. For example, a scrubbing service is responsible for erasing the private data of users.

The following figure describes the relation between the DPU and the host memory where attacks may occur. The green squares are the assets that must resume operation unhindered. DOCA App Shield is responsible for acquiring information about processes to allow attack detection. To that end, DOCA App Shield exposes an API to the user allowing them to detect malicious activities (e.g., malicious processes, DLL files) by monitoring changes in critical memory parts directly from the Arm using DMA without involving the host OS or CPU.


App1
App2
Windows/Linux
Processor
CPU
Cache
Host Bridge
Memory Controller
Use memory forensic techniques to reconstruct data structures and analyze them
Applications and services running on host machine and monitored by Bluefield
RAM
task_struct
barsher
netf_struct
DMA
hypervisor, VMs, when a critical event happens (code injection, process/thread termination, process creation)
Administrator upon detection of bad behavior to trigger remediation and prevent manifestation of an attack
DPU
DOCA APSH SDK
App

Chapter 2. Prerequisites

To enable DOCA App Shield on the DPU, perform the following:

1. Create huge pages.
2. Enable NVMe emulation on the firmware.

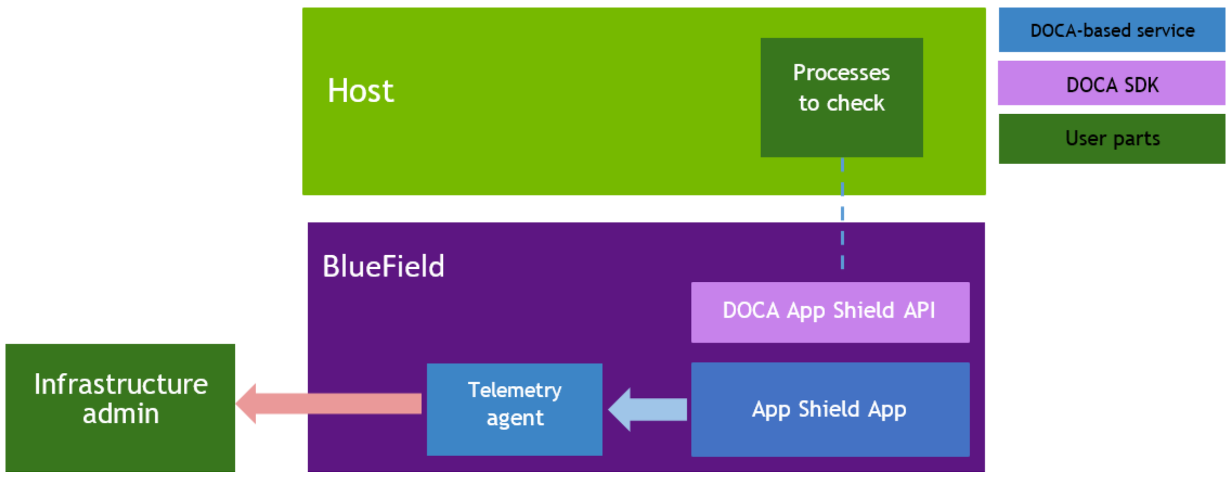
Run a config command on the host/VM. Refer to doca_apsh_config for information on creating config files specific to the host/VM.

Run the following command to configure the DOCA:

```
# On the bluefield system, configure PF base address register and NVME emulation
dpu> mlxconfig -d /dev/mst/mt41686_pciconf0 s PF_BAR2_SIZE=2 PF_BAR2_ENABLE=1
 NVME_EMULATION_ENABLE=1

#Do Cold boot (from host)
host> ipmitool power cycle

## repeat after every reboot
# Allocate huge-pages
dpu> rm -rf "/mnt/huge/*"
dpu> echo 42 > /sys/devices/system/node/node0/hugepages/hugepages-32768kB/
nr_hugepages
dpu> \
if [ ! -d "/mnt/huge" ] ; then
  mkdir "/mnt/huge"
fi
dpu> mount -t hugetlbfs -o pagesize=32MB none "/mnt/huge"

# Disable the mlnx-snap service
dpu> systemctl stop mlnx_snap
```

Chapter 3. Architecture

The following block diagram illustrates the App Shield application flow.



- App Shield App – user application implementing the specific use case
- Telemetry Agent – collect telemetry metrics
- Processes to check – the host process to track

Chapter 4. Dependencies

The library requires firmware version 24.32.1010 and higher.

Chapter 5. API

For the library API reference, refer to the DOCA APSH API documentation in the NVIDIA DOCA Libraries API Reference Manual.

Note: The pkg-config (`*.pc` file) for the App Shield library is named `doca-apsh`.

The following sections provide additional details about the library API.

5.1. doca_apsh_dma_dev_set

To attach a DMA device name to App Shield, calling this function is mandatory and must be done before calling `doca_apsh_start`.

```
doca_apsh_dma_dev_set(doca_apsh_ctx, doca_dev)
```

Where:

- `doca_apsh_ctx [in]` – App Shield opaque context struct
- `doca_dev [in]` – struct for DOCA Device with DMA capabilities

5.2. Capabilities Per System

For each initialized system, App Shield can retrieve the following information:

Function Name	Functions Information	Functions Signature	Return Type
Get modules	Returns an array with information about the system modules (drivers) loaded into the kernel of the OS	`doca_error_t doca_apsh_modules_get(struct doca_apsh_system *system, struct doca_apsh_module ***modules, int *modules_size);`	▶ Array of `struct doca_apsh_module` ▶ `int`: Size of the returned array ▶ `doca_error` status
Get processes	Returns an array with information about each processes running on the system	`doca_error_t doca_apsh_processes_get(struct doca_apsh_system *system, struct doca_apsh_procces ***processes, int *processes_size);`	▶ Array of `struct doca_apsh_procces` ▶ `int`: Size of the returned array

Function Name	Functions Information	Functions Signature	Return Type
			▶ `doca_error` status
Get library	For a specified process, this function returns an array with information about each library loaded into this process	`doca_error_t doca_apsh_libs_get(struct doca_apsh_process *process, struct doca_apsh_lib ***libs, int *libs_size);`	▶ Array of `struct doca_apsh_lib` ▶ `int`: Size of the returned array ▶ `doca_error` status
Get threads	For a specified process, this function returns an array with information about each thread running within this process	`doca_error_t doca_apsh_threads_get(struct doca_apsh_process *process, struct doca_apsh_thread ***threads, int *threads_size);`	▶ Array of `struct doca_apsh_thread` ▶ `int`: Size of the returned array ▶ `doca_error` status
Get virtual memory areas/virtual address description	For a specified process, this function returns an array with information about each virtual memory area within this process	`doca_error_t doca_apsh_vads_get(struct doca_apsh_process *process, struct doca_apsh_vad ***vads, int *vads_size);`	▶ Array of `struct doca_apsh_vma` ▶ `int`: Size of the returned array ▶ `doca_error` status
Get privileges	For a specified process, this function returns an array with information about each possible privilege for this process, as described here **Note:** Available for Windows only.	`doca_error_t doca_apsh_privileges_get(struct doca_apsh_process *process, struct doca_apsh_privilege ***privileges, int *privileges_size);`	▶ Array of `struct doca_apsh_privilege` ▶ `int`: Size of the returned array ▶ `doca_error` status
Process attestation	For a specified process, this function attests the memory pages of the process according to a precomputed golden hash file given as an input **Note:** Single-threaded processes are	`doca_error_t doca_apsh_attestation_get(struct doca_apsh_process *process, const char *exec_hash_map_path, struct doca_apsh_attestation ***attestation, int * attestation_size);`	▶ Array of `struct doca_apsh_attestation` ▶ `int`: Size of the returned array ▶ `doca_error` status

Function Name	Functions Information	Functions Signature	Return Type
	supported at beta level.		
Attestation refresh	Refreshes a single attestation handler of a process with a new snapshot	`doca_error_t doca_apsh_attst_refresh(struct doca_apsh_attestation ***attestation, int * attestation_size);`	▶ Array of `struct doca_apsh_attestation` ▶ `int`: Size of the returned array ▶ `doca_error` status

For each of the getter functions, a struct or an array of structs with the requested information is returned. To access this information, another getter function must be called specifying the exact information/attribute required from that struct.

```
const void *doca_apsh_proc_info_get(struct doca_apsh_proccess *process, enum
 doca_apsh_process_attr attr);
const void *doca_apsh_module_info_get(struct doca_apsh_module *module, enum
 doca_apsh_module_attr attr);
const void *doca_apsh_lib_info_get(struct doca_apsh_lib *lib, enum
 doca_apsh_lib_attr attr);
const void *doca_apsh_thread_info_get(struct doca_apsh_thread *thread, enum
 doca_apsh_lib_attr attr);
const void *doca_apsh_vad_info_get(struct doca_apsh_vad *vad, enum
 doca_apsh_vad_attr attr);
const void *doca_apsh_attst_info_get(struct doca_apsh_attestation *attestation, enum
 doca_apsh_attestation_attr attr);
```

These are macros that cast the returned values according to the types specified in `doca_apsh_attr.h`.

Usage example:

```
const uint pid = doca_apsh_proc_info_get(processes[i], DOCA_APSH_PROCESS_PID);
```

All the required attributes are defined in `/usr/include/doca_apsh_attr.h`.

Chapter 6. App Shield Initialization and Teardown

There are different structures in App Shield that must be used for a BlueField client to be able to introspect into a system running on the host side, whether it is a bare-metal machine or a virtual machine.

6.1. Init App Shield

The App Shield context structure is used to init the devices on the DPU required to start monitoring App Shield systems.

To use `doca_apsh_ctx`, call:

```
struct doca_apsh_ctx* doca_apsh_create(void);
```

For `doca_app_shield_ctx` to work, a RegEx device and an RDMA device must be set, using these two functions:

```
doca_error_t doca_apsh_dma_dev_set(struct doca_apsh_ctx *ctx, struct doca_dev *
 dma_dev);
doca_error_t doca_apsh_regex_dev_set(struct doca_apsh_ctx *ctx, struct doca_dev
 *regex_dev);
```

For example:

```
doca_error_t ret = doca_apsh_dma_dev_set(ctx, dma_dev);
```

After the above devices are set, the following function should be invoke:

```
doca_error_t doca_apsh_start(struct doca_apsh_ctx *ctx);
```

This establishes a connection to the devices.

When App Shield lib is no longer needed, a destruction must be called to deallocate any allocated memory:

```
void doca_apsh_destroy(struct doca_apsh_ctx *ctx);
```

6.2. Init System to Monitor

The system structure represents a system on the host that should be monitored. To instantiate an App Shield system, this function must be called:

```
struct doca_apsh_system *doca_apsh_system_create(struct doca_apsh_ctx *ctx);
```

A single `doca_apsh_ctx` instance may be associated with many App Shield systems.

The App Shield system has the following attributes:

- Layer – specifies the system type. Types: Bare metal, virtual machine, or a container (for future use).
- System DOCA Device – the remote device obtained from the DPU. The device should be connected to the host/VM and functions as a representor VF/PF. To query/obtain the DOCA device, refer to the NVIDIA DOCA Libraries API Reference Manual.
- System/symbol map – includes information about the OS that App Shield needs to introspect (e.g., Window 10 Build 18363/Linux Ubuntu 20.04) and the size and fields of the OS structures such as process struct, which helps App Shield with the memory forensic techniques it uses to access and analyze these structures in the host's memory. This can be obtained by running the `doca_apsh_config.py` tool on the host.
- Memory regions – contains the allowed physical memory regions that App Shield can access. This information is needed since there are memory regions reserved by different PCIe devices. Some of these regions map device registers which change the device's state each time the regions (certain physical addresses in these regions) are read. These changes may confuse the device firmware and may, therefore, cause the system to crash/freeze. This must be avoided. This can be obtained by running the `doca_apsh_config.py` tool on the host.

Each one of these attributes must be set by calling its suitable function:

```
doca_error_t doca_apsh_sys_system_layer_set(struct doca_apsh_system *system, enum
 doca_apsh_system_layer layer_type);
doca_error_t doca_apsh_sys_dev_set(struct doca_apsh_system *system, struct
 doca_dev_remote *dev);
doca_error_t doca_apsh_sys_os_symbol_map_set(struct doca_apsh_system
 *system, const char *system_os_symbol_map_path);
doca_error_t doca_apsh_sys_mem_region_set(struct doca_apsh_system
 *system, const char *system_mem_region_path);
```

For each system, after all the attributes are set, the following function must be called to start App Shield system monitoring:

```
doca_error_t doca_apsh_system_start(struct doca_apsh_system *system);
```

Other functions can be called to retrieve information from the system's memory after the App Shield system is started. These functions (also called capabilities) are expanded on in Capabilities Per System.

When the App Shield system is no longer needed, a destruction must be called to deallocate internal system memory:

```
void doca_apsh_system_destroy(struct doca_apsh_system *system);
```

6.3. doca_apsh_config

`doca_apsh_config` is used to get the config files necessary for running system analysis. Run the `doca_apsh_config` tool once system is up.

```
/opt/mellanox/doca/tools/doca_apsh_config.py <pid> --os <os> --path <dwarf2json-
path/pdbparse-to-json.py>
```

Get the `dwarf2json` executable which can be found in https://github.com/volatilityfoundation/dwarf2json. Note that the executable must be compiled using Go Programming Language. For instructions, refer to the `dwarf2json` library.

The tool creates the following files:

- Symbol Map – this file changes once the system kernel is updated or the kernel module is installed. The file does not change on system reboot.
- Memory Regions – this file changes when adding/removing hardware or drivers that affect the system's memory map (e.g., when adding register addresses). The file does not change once the system is rebooted.
- `hash.zip` – this file is required for attestation API but is unnecessary for all other APIs. The zip file contains the required documentation to attest to a single process. The file changes on lib/executable update.

Flags:

- `pid` – the process ID of the hashed process
- `os` – linux/windows
- `path` – path to the `dwarf2json` executable. Default `./dwarf2json`.

For example:

```
/opt/mellanox/doca/tools/doca_apsh_config.py 100 --os linux --path ./dwarf2json
```