NVIDIA DOCA App Shield Agent

Application Guide
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Chapter 1. Introduction

App Shield Agent monitors a process in the host system using the DOCA App Shield library (doca-apsh).

This security capability helps identify corruption of core processes in the system from an independent and trusted DPU. This is a major and innovate intrusion detection system (IDS) ability since it cannot be provided from inside the host.

The DOCA App Shield library gives the capability to read, analyze, and authenticate the host (bare metal/VM) memory directly from the DPU.

Using the library, this application hashes the un-writeable memory pages (also unloaded pages) of a specific process and its libraries. Then, at regularly occurring intervals the app authenticates the loaded pages.

The app reports pass/fail after every iteration until the first attestation failure. The reports are both printed to the console and exported to the DOCA telemetry service (DTS) using inter-process communication (IPC).

This document describes how to build secure process monitoring using the DOCA App Shield library, which leverages the DPU’s advantages such as hardware-based DMA, integrity, and more.
Chapter 2. System Design

The App Shield agent is designed to run independently on the DPU’s Arm without hindering the host.

The host’s involvement is limited to configuring monitoring of a new process when there is a need to generate the needed ZIP and JSON files to pass to the DPU. This is done at inception (“time 0”) which is 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 NVIDIA DOCA App Shield Programming Guide for more info.
Chapter 3. Application Architecture

The user creates three mandatory files using the DOCA tool `doca_apsh_config.py` and copies them to the DPU. The application can report attestation results 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.

   ![Diagram](image)

   **Note:** The actions 2-5 recur at regular time intervals.

2. The App Shield agent requests new attestation from DOCA App Shield library.
3. The DOCA App Shield library creates a new attestation:
   a. Scans and hashes process memory pages (that are currently in use).
   b. Compares the hash to the original hash.
   c. Creates attestation for each lib/exe involved in the process. Each of attestation includes the number of valid pages and the number of pages.
4. The App Shield agent searches each attestation for inconsistency between number of used pages and number of valid pages.

5. The App Shield agent reports results with a timestamp and scan count to:
   a). Local telemetry files – a folder and files representing the data a real DTS would have received. These files are used for the purposes of this example only as normally this data is not exported into user-readable files.
   b). DOCA log [without scan count].
   c). DTS IPC interface [even if no DTS is active].

6. The App Shield agent exits on first attestation failure.
Chapter 4. DOCA Libraries

This application leverages following DOCA libraries:

- DOCA App Shield library
- DOCA Telemetry library
Chapter 5. Configuration Flow

1. Parse application argument.
   ```c
   doca_argp_init();
   ```
   a) Initialize arg parser resources.
   b) Register DOCA general flags.
      ```c
      register_apsh_params();
      ```
   c) Register App Shield Agent application flags.
      ```c
      doca_argp_start();
      ```
   d) Parse app flags.

2. Initialize DOCA App Shield lib context.
   ```c
   doca_apsh_create();
   ```
   a) Create lib context.
      ```c
      doca_devinfo_list_create();
      doca_dev_open();
      doca_devinfo_list_destroy();
      doca_apsh_dma_dev_set();
      ```
   b) Set DMA device for lib.
      ```c
      doca_apsh_start();
      apsh_system_init();
      ```
   c) Start the context.

3. Initialize DOCA App Shield lib system context handler.
   ```c
   doca_devinfo_remote_list_create();
   doca_dev_remote_open();
   doca_devinfo_remote_list_destroy();
   ```
   a) Get the representor of the remote PCIe function exposed to the system.
      ```c
      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();
      ```
   b) Create and start the system context handler.

4. Find target process by pid.
   ```c
   doca_apsh_processes_get();
   ```

5. Telemetry initialization.
   ```c
   telemetry_start();
   ```
   a) Initialize a new telemetry schema.
   b) Register attestation type event.
c). Set up output to file (in addition to default IPC).

d). Start the telemetry schema.

e). Initialize and start a new DTS source with the `gethostname()` name as source ID.

6. Get initial attestation of the process.
   ```c
   doca_apsh_attestation_get();
   ```

7. Loop until attestation validation fail.
   ```c
   doca_apsh_attst_refresh();
   /* validation logic */
   doca_telemetry_source_report();
   DOCA_LOG_INFO();
   sleep();
   ```

8. DOCA App Shield Agent destroy.
   ```c
   doca_apsh_attestation_free();
   doca_apsh_processes_free();
   doca_apsh_system_destroy();
   doca_apsh_destroy();
   doca_dev_close();
   doca_dev_remote_close();
   ```

   ```c
   telemetry_destroy();
   ```

10. Arg parser destroy.
    ```c
    doca_argp_destroy();
    ```
Chapter 6. Dependencies

The minimum required firmware version is 24.32.1010.
The application is only supported in the Ubuntu 20.04 BlueField OS.
Chapter 7. Running Application

1. Refer to the following documents:
   - NVIDIA DOCA Installation Guide for details on how to install BlueField-related software.
   - NVIDIA DOCA Troubleshooting Guide for any issue you may encounter with the installation, compilation, or execution of DOCA applications.

2. The App Shield Agent binary is located under /opt/mellanox/doca/applications/app_shield_agent/bin/doca_app_shield_agent. To build the applications together, run:

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

3. To build only the App Shield Agent:
   a). Edit the following flags in /opt/mellanox/doca/applications/meson_option.txt:
      - Set `enable_all_applications` to `false`
      - Set `enable_app_shield_agent` to `true`
   b). Run the commands in step 2.

   **Note:** `doca_app_shield_agent` is created under `./build/app_shield_agent/src/`.

Application usage:

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

DOCA Flags:
- `-h, --help` Print a help synopsis
- `-v, --version` Print program version information
- `-l, --log-level` Set the log level for the app `<CRITICAL=0, DEBUG=4>`

Program Flags:
- `-p, --pid <arg>` Pid of the process to monitor
- `-e, --ehm <path>` Path to the process executable `hash.zip`
generated file
- `-m, --memr <path>` Path to the system memory regions map – `mem_regions.json` generated file.
- `-f, --pcif <arg>` System PCI (VF/PF) VUID to use for DMA connection
- `-d, --dma <arg>` DMA device name
- `-o, --osym <path>` Path to the system os symbol map – `symbols.json` generated file.
- `-s, --osty [windows|linux]` OS of the system where the process is running
4. The following steps need to be done only once.

- Configure the BlueField’s firmware.
  - 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
    ```
  - Perform a cold boot from the host. Run:
    ```
    host> ipmitool power cycle
    ```

- Note: These configurations can be checked using the following command:
  ```
  dpu> mlxconfig -d /dev/mst/mt41686_pciconf0 q | grep -E "NVME|BAR"
  ```

- 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
  - 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:

- **For Ubuntu:**
  ```bash
  host> sudo update-grub
  host> ipmitool power cycle
  ```

- **For CentOS:**
  ```bash
  host> grub2-mkconfig -o /boot/grub2/grub.cfg
  host> ipmitool power cycle
  ```

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

5. **Running the application on BlueField:**

   - **Pre-run setup:**
     
     a). The DOCA App Shield library uses hugepages for DMA buffers. Therefore, the user is required to provide allocate specific size huge pages. Run:
     ```bash
     dpu> rm -rf "/mnt/huge/*"
     dpu> sudo 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"
     ```

     b). Create the ZIP and JSON files. Run:
     ```bash
     Note: If the kernel and process .exe have not changed, there no need to redo this step.
     
     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 dwarf2json and pdbparse-to-json.py are not provided with DOCA. Follow the **NVIDIA DOCA App Shield Programming Guide** for more information.

   - **CLI example for running the app:**
     ```bash
     dpu> /opt/mellanox/doca/applications/app_shield_agent/bin/
     doca app shield agent -p 13577 -e hash.zip -m mem_regions.json -o symbols.json
     -f MT2125X03335MLNXS0D0F0VF1 -d mlx5_0 -t 3 -s linux
     ```
## Chapter 8. Arg Parser DOCA Flags

Refer to [NVIDIA DOCA Arg Parser User Guide](#) for more information.

<table>
<thead>
<tr>
<th>Flag Type</th>
<th>Short Flag</th>
<th>Long Flag/JSON Key</th>
<th>Description</th>
</tr>
</thead>
</table>
| **General flags**  | **l**      | **log-level**      | Set the log level for the application:  
  ‣ CRITICAL=0  
  ‣ ERROR=1  
  ‣ WARNING=2  
  ‣ INFO=3  
  ‣ DEBUG=4 |
| **v**              | **version**|                    | Print program version information |
| **h**              | **help**   |                    | Print a help synopsis |
| **Program flags**  | **p**      | **pid**            | PID of the process to be attested |
| **e**              | **ehm**    |                    | Path to the pre-generated `hash.zip` file transferred from the host |
| **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:"
```
<table>
<thead>
<tr>
<th>Flag Type</th>
<th>Short Flag</th>
<th>Long Flag/JSON Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Example output:</td>
<td><strong>Note:</strong> 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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[VU] Vendor specific: MT2125X03335MLNXS0D0F0</td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[VU] Vendor specific: MT2125X03335MLNXS0D0F1</td>
<td></td>
</tr>
</tbody>
</table>
|           |            | 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 |

NVIDIA DOCA App Shield Agent
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<th>Short Flag</th>
<th>Long Flag/JSON Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>o</td>
<td>osym</td>
<td>Path to the pre-generated symbols.json file transferred from the host</td>
<td></td>
</tr>
<tr>
<td>s</td>
<td>osty</td>
<td>OS type (windows or linux) of the system where the process is running</td>
<td></td>
</tr>
<tr>
<td>t</td>
<td>time</td>
<td>Number of seconds to sleep between scans</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 9. References

- /opt/mellanox/doca/applications/app_shield_agent/src/app_shield_agent.c
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