NVIDIA DOCA Firewall

Application Guide
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Chapter 1. Introduction

A firewall application is a network security application that leverages the DPU’s hardware capability to monitor incoming and outgoing network traffic and allow or block packets based on a set of preconfigured rules.

The firewall application is based on DOCA Flow gRPC, used for remote programming of the DPU’s hardware.

The firewall can operate in two modes:

- **Static mode** – the firewall application gets 5-tuple traffic from the user with a JSON file for packets to be dropped. The packets that do not match any of the 5-tuple are forwarded by a hairpin pipe.
- **Interactive mode** – the user can add rules from the command line in real time to execute different firewall rules.
Chapter 2. System Design

The firewall application is designed to run on the host and to use DOCA Flow gRPC client to send instructions to a server that runs on the BlueField DPU instance. The DPU intercepts ingress traffic from the wire and either drops it or forwards it to the egress port using a hairpin. The decision is made using traffic classification.
Chapter 3. Application Architecture

The firewall runs on top of DOCA Flow gRPC to classify packets.

3.1. Static Mode
1. The firewall application builds 4 pipes for each port: One control pipe, two drop pipes, and a hairpin pipe.

2. The drop pipes match only 5-tuple traffic with specific source and destination IPs and source and destination ports.
   - One of the drop pipes matches TCP traffic and the other matches UDP
   - The hairpin pipe matches every packet (no misses)
   - The control pipe serves as a root pipe and has two entries: The first entry forwards the TCP traffic to the TCP drop pipe, and the second entry forwards UDP traffic to the UDP drop pipe
   - The hairpin pipe serves as a forwarding miss component to the drop pipes. Therefore, every received packet is checked first against the drop pipes. If there is a match, then it is dropped, otherwise, it is forwarded to the hairpin pipe and is then matched.

3.2. Interactive Mode

Running in interactive mode initializes 2 ports, and the user then configures the pipes and entries.
- When adding a pipe or an entry, one must run commands to create the relevant structs beforehand
- Optional parameters must be specified by the user in the command line. Otherwise, NULL is used.
- After a pipe or an entry is created successfully, the relevant ID is printed for future use

Available commands:
- create pipe port_id=[port_id],<optional_parameters>
  Available optional parameters:
  - name=<pipe-name>
  - root_enable=[1|0]
  - monitor=[1|0]
  - match_mask=[1|0]
  - fwd=[1|0]
  - fwd_miss=[1|0]
  - type=[basic|control]
- add entry
  pipe_id=<pipe_id>,pipe_queue=<pipe_queue>,<optional_parameters>
  Available optional parameters:
  - monitor=[1|0]
‣ `fwd=[1|0]`

‣ add control_pipe entry
  priority=<priority>,pipe_id=<pipe_id>,pipe_queue=<pipe_queue>[,<optional_parameters>]

Available optional parameters:

‣ `match_mask=[1|0]`
‣ `fwd=[1|0]`

‣ destroy pipe port_id=[port_id],pipe_id=<pipe_id>
‣ rm entry pipe_queue=<pipe_queue>,entry_id=[entry_id]
‣ port pipes flush port_id=[port_id]
‣ port pipes dump port_id=[port_id],file=[file_name]
‣ query entry_id=[entry_id]
‣ create [struct] [field=value,…]

‣ **Struct options:** pipe_match, entry_match, match_mask, actions, monitor, fwd, fwd_miss

‣ **Match struct fields:**

<table>
<thead>
<tr>
<th>Fields</th>
<th>Field Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>flags</code></td>
<td></td>
</tr>
<tr>
<td><code>out_src_mac</code></td>
<td></td>
</tr>
<tr>
<td><code>out_dst_mac</code></td>
<td></td>
</tr>
<tr>
<td><code>out_eth_type</code></td>
<td></td>
</tr>
<tr>
<td><code>out_vlan_id</code></td>
<td></td>
</tr>
<tr>
<td><code>out_src_ip_type</code></td>
<td><code>ipv4,ipv6</code></td>
</tr>
<tr>
<td><code>out_src_ip_addr</code></td>
<td></td>
</tr>
<tr>
<td><code>out_dst_ip_type</code></td>
<td><code>ipv4,ipv6</code></td>
</tr>
<tr>
<td><code>out_dst_ip_addr</code></td>
<td></td>
</tr>
<tr>
<td><code>out_l4_type</code></td>
<td><code>tcp, udp, gre</code></td>
</tr>
<tr>
<td><code>out_tcp_flags</code></td>
<td><code>FIN, SYN, RST, PSH, ACK, URG, ECE, CWR</code></td>
</tr>
<tr>
<td><code>out_src_port</code></td>
<td></td>
</tr>
<tr>
<td><code>out_dst_port</code></td>
<td></td>
</tr>
<tr>
<td><code>tun_type</code></td>
<td></td>
</tr>
<tr>
<td><code>vxlan-tun_id</code></td>
<td></td>
</tr>
<tr>
<td><code>gre_key</code></td>
<td></td>
</tr>
<tr>
<td><code>gtp_teid</code></td>
<td></td>
</tr>
<tr>
<td><code>in_src_mac</code></td>
<td></td>
</tr>
<tr>
<td><code>in_dst_mac</code></td>
<td></td>
</tr>
<tr>
<td><code>in_eth_type</code></td>
<td></td>
</tr>
<tr>
<td><code>in_vlan_id</code></td>
<td></td>
</tr>
</tbody>
</table>
Fields | Field Options
--- | ---
in\_src\_ip\_type | ipv4, ipv6
in\_src\_ip\_addr
in\_dst\_ip\_type | ipv4, ipv6
in\_dst\_ip\_addr
in\_l4\_type | tcp, udp
in\_tcp\_flags | FIN, SYN, RST, PSH, ACK, URG, ECE, CWR
in\_src\_port
in\_dst\_port

Actions struct fields:

Fields | Field Options
--- | ---
decap | true, false
mod\_src\_mac
mod\_dst\_mac
mod\_src\_ip\_type | ipv4, ipv6
mod\_src\_ip\_addr
mod\_dst\_ip\_type | ipv4, ipv6
mod\_dst\_ip\_addr
mod\_src\_port
mod\_dst\_port
dec\_ttl | true, false
has\_encap | true, false
encap\_src\_mac
encap\_dst\_mac
encap\_src\_ip\_type | ipv4, ipv6
encap\_src\_ip\_addr
encap\_dst\_ip\_type | ipv4, ipv6
encap\_dst\_ip\_addr
encap\_tup\_type | vxlan, gtpu, gre
encap\_vxlan\_tun\_id
encap\_gre\_key
encap\_gtp\_teid

FWD struct fields:

Fields | Field Options
--- | ---
type | rss, port, pipe, drop
rss\_flags
rss\_queues
num\_of\_queues
<table>
<thead>
<tr>
<th>Fields</th>
<th>Field Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>rss_mark</td>
<td></td>
</tr>
<tr>
<td>port_id</td>
<td></td>
</tr>
<tr>
<td>next_pipe_id</td>
<td></td>
</tr>
</tbody>
</table>

- **Monitor struct fields:**
  - flags
  - id
  - cir
  - cbs
  - aging

The following is an example for creating a pipe and adding an entry:

```plaintext
create pipe_match
  out_l4_type=udp, out_src_ip_type=ipv4, out_src_ip_addr=0xffffffff, out_dst_ip_type=ipv4, out_dst_ip_addr=0xffffffff
create fwd type=drop
create fwd_miss type=pipe, next_pipe_id=1
create pipe port_id=0, name=drop, root_enable=1, fwd=1, fwd_miss=1
create pipe succeed with pipe id: 2
create entry_match
  out_src_ip_type=ipv4, out_src_ip_addr=10.1.20.208, out_dst_ip_type=ipv4, out_dst_ip_addr=10.1.3.216
add entry pipe_id=2, pipe_queue=0
add entry succeed with entry id: 0
```
Chapter 4. DOCA Libraries

This application leverages the DOCA Flow library.
Chapter 5. Configuration Flow

1. Parse application argument.
   a). Initialize the arg parser resources.
      `doca_argp_init();`
   b). Register application parameters.
      `register_firewall_params();`
   c). Parse application parameters.
      `doca_argp_start();`

2. Firewall initialization.
   `firewall_ports_init();`
   a). Create a new gRPC channel and initialize a stub.
   b). Initialize DOCA Flow and DOCA Flow ports.

3. Configure firewall rules.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Procedure</th>
</tr>
</thead>
</table>
| Static   | a). Initialize drop packets array from the input JSON file.
        |           |
        | b). Create hairpin pipe for both ports. This pipe includes one entry that matches every type of packet (no misses) which is then forwarded to the egress port through a hairpin.
        |           |
        | c). Creates TCP and UDP drop pipes that serve as root pipes for both ports. The built pipes have a 5-tuple match and entries from the processed JSON file that are dropped. In addition, the hairpin pipe serves as forwarding if the drop entries do not match. |
| Interactive | a). Initialize the firewall’s interactive command line.
         |           |
         | b). Free allocated resources.
         |           |
4. Firewall cleanup.
   `firewall_ports_destroy();`
   a). Destroy all DOCA Flow resources.
5. Arg parser destroy.
   `doca_argp_destroy();`
Chapter 6. Running the Application

1. Refer to the following documents:
   - NVIDIA DOCA Installation Guide for Linux 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.
   - NVIDIA DOCA Applications Overview for additional compilation instructions and development tips regarding the DOCA applications.

2. The firewall example binary is located under `/opt/mellanox/doca/applications/firewall/bin/doca_firewall`.

   **Note:** Before building the application, make sure that gRPC support is enabled. Set the `enable_grpc_support` flag in `/opt/mellanox/doca/applications/meson_options.txt` to true.

   To build all the applications together, run:
   ```
   cd /opt/mellanox/doca/applications/
   meson build
   ninja -C build
   ```

3. To build only the firewall application:
   a). Edit the following flags in `/opt/mellanox/doca/applications/meson_options.txt`:
      - Set `enable_all_applications` to false
      - Set `enable_firewall` to true
   b). Run the commands in step 2.

   **Note:** `doca_firewall` will be created under `.build/firewall/src/`.

Application usage:
Usage: `doca_firewall [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 program
  <CRITICAL=20, ERROR=30, WARNING=40, INFO=50, DEBUG=60>
- `--grpc-address ip_address[:port]` Set the IP address for the grpc server

**Program Flags:**
Running the Application

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- **m, --mode**  Set running mode *(static, interactive)*
- **r, --firewall-rules <path>**  Path to the JSON file with 5-tuple rules when running with *static* mode

**Note:** For additional information on the app use `-h`:

```
/opt/mellanox/doca/applications/firewall/bin/doca_firewall -h
```

4. Running the application on the host:

- For instructions on running the DOCA Flow gRPC server on the BlueField, refer to [NVIDIA DOCA gRPC Infrastructure User Guide](#).
- CLI example for running the app in interactive mode:

  ```
  /opt/mellanox/doca/applications/firewall/bin/doca_firewall --grpc-address 192.168.101.2 -l 50 -m interactive
  ```

- CLI example for running the app in static mode:

  ```
  /opt/mellanox/doca/applications/firewall/bin/doca_firewall --grpc-address 192.168.101.2 -l 50 -m static -d firewall_rules.json
  ```

5. To run `doca_firewall` using a JSON file:

   `doca_firewall --json [json_file]`

   For example:

   ```
   cd /opt/mellanox/doca/applications/firewall/bin
   ./doca_firewall --json firewall_params.json
   ```
## Chapter 7. 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>
<th>JSON Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Flags</td>
<td>l</td>
<td>log-level</td>
<td>Set the log level for the application:</td>
<td>&quot;log-level&quot;: 60</td>
</tr>
<tr>
<td></td>
<td>v</td>
<td>version</td>
<td>Print program version information</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>h</td>
<td>help</td>
<td>Print a help synopsis</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>mode</td>
<td>Set running mode {static or interactive}</td>
<td>&quot;mode&quot;: &quot;interactive&quot;</td>
</tr>
<tr>
<td>Program Flags</td>
<td>r</td>
<td>firewall-rules</td>
<td>Path to JSON rules file</td>
<td>&quot;firewall-rules&quot;: &quot;firewall_rules.json&quot;</td>
</tr>
</tbody>
</table>
Chapter 8. References

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