# 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.

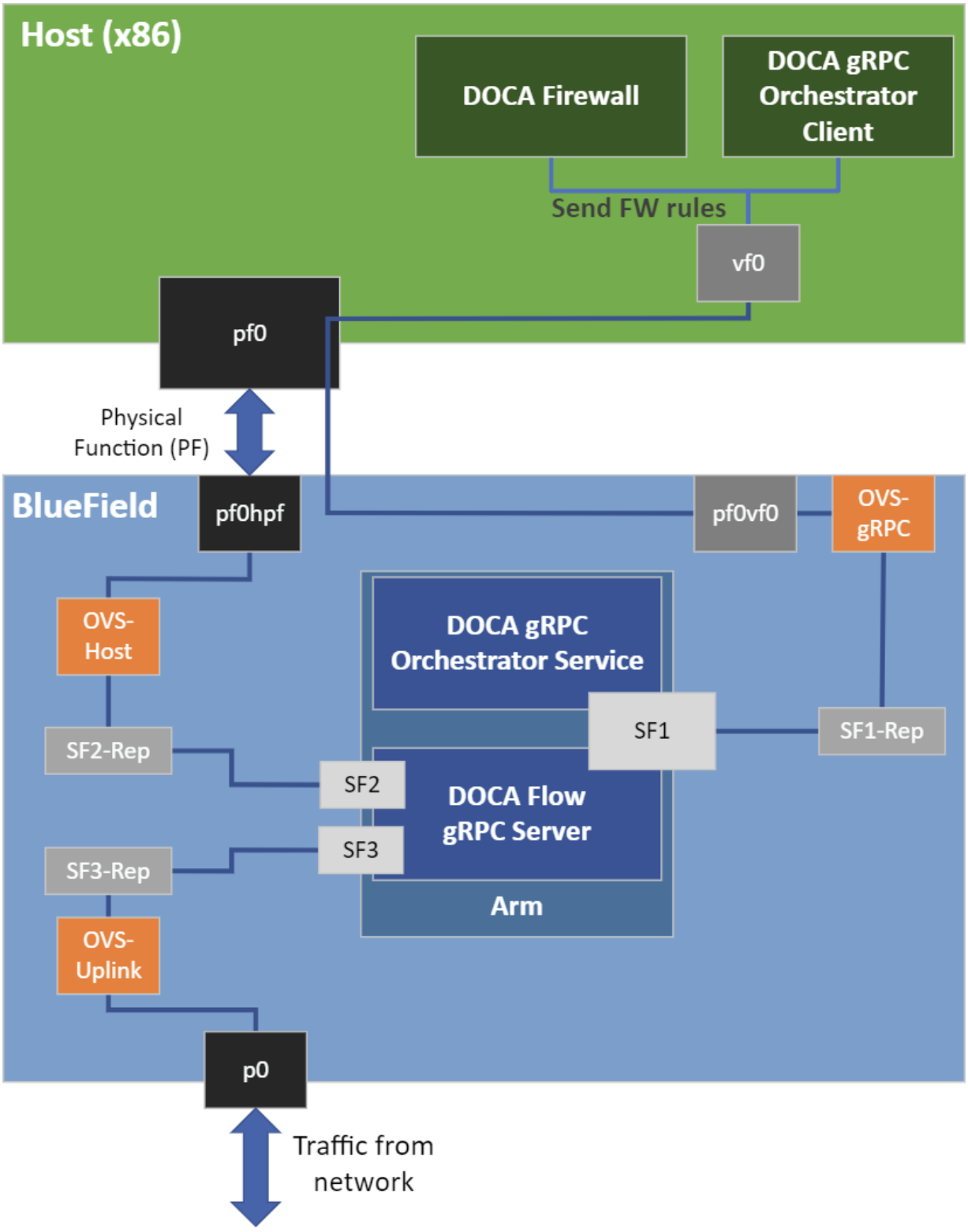
The firewall application is based on DOCA Flow gRPC, used for remote programming of the DPU's hardware.

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

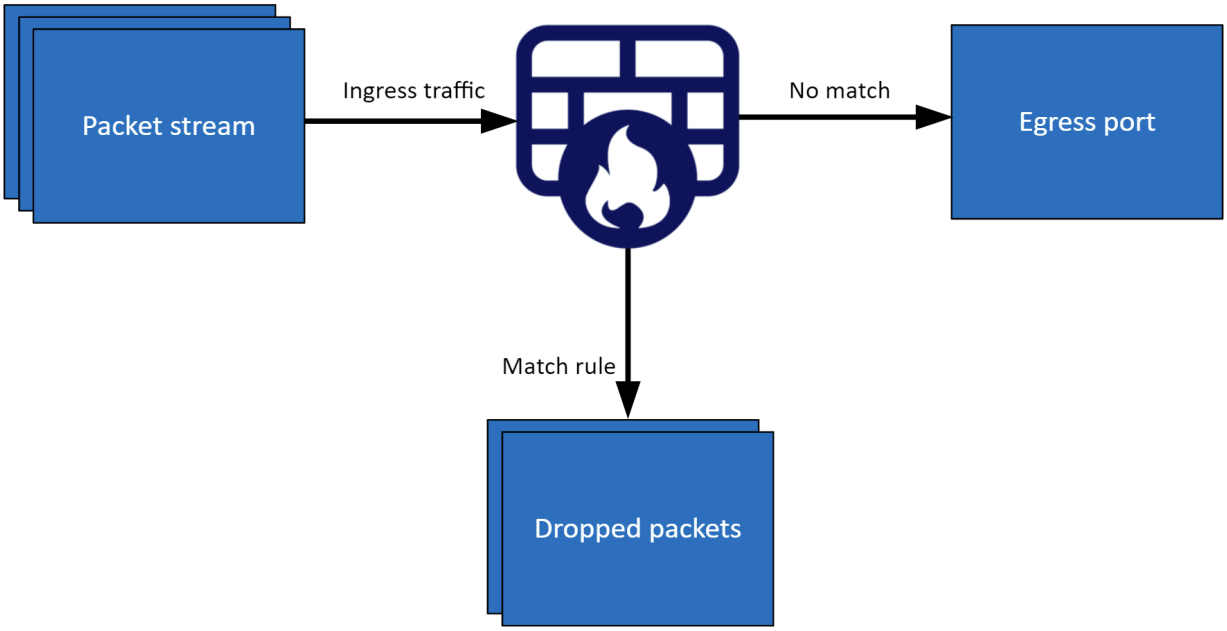
# Chapter 2. System Design

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.

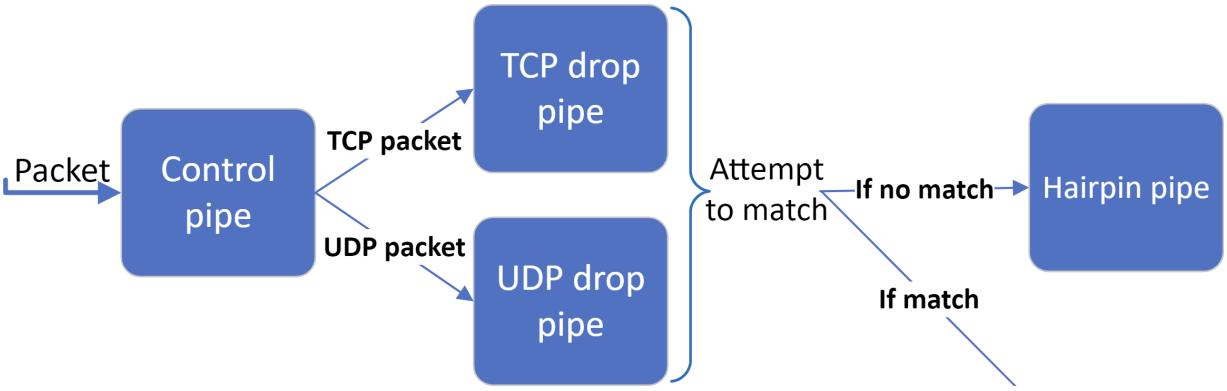

Host (x86)
DOCA Firewall
DOCA gRPC Orchestrator Client
Send FW rules
vf0
pf0
Physical Function (PF)
BlueField
pf0hpf
pf0vf0
OVS-gRPC
OVS-Host
DOCA gRPC Orchestrator Service
SF1
SF1-Rep
SF2-Rep
SF2
DOCA Flow gRPC Server
SF3
SF3-Rep
Arm
OVS-Uplink
p0
Traffic from network

# 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:

| Fields | Field Options |
|---|---|
| `flags` | |
| `out_src_mac` | |
| `out_dst_mac` | |
| `out_eth_type` | |
| `out_vlan_id` | |
| `out_src_ip_type` | `ipv4`, `ipv6` |
| `out_src_ip_addr` | |
| `out_dst_ip_type` | `ipv4`, `ipv6` |
| `out_dst_ip_addr` | |
| `out_l4_type` | `tcp`, `udp`, `gre` |
| `out_tcp_flags` | `FIN`, `SYN`, `RST`, `PSH`, `ACK`, `URG`, `ECE`, `CWR` |
| `out_src_port` | |
| `out_dst_port` | |
| `tun_type` | |
| `vxlan-tun_id` | |
| `gre_key` | |
| `gtp_teid` | |
| `in_src_mac` | |
| `in_dst_mac` | |
| `in_eth_type` | |
| `in_vlan_id` | |

| 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 | |

| Fields | Field Options |
|---|---|
| rss_mark | |
| port_id | |
| next_pipe_id | |

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

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

```
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_a
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.

| Mode | Procedure |
|---|---|
| Static | a). Initialize drop packets array from the input JSON file.<br>`init_drop_packets();`<br>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.<br>`firewall_pipes_init();`<br>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.<br>`interactive_cmdline();`<br>b). Free allocated resources.<br>`interactive_mode_cleanup();` |

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_option.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_option.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:
    -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.

| Flag Type | Short Flag | Long Flag/JSON Key | Description | JSON Content |
|---|---|---|---|---|
| General Flags | l | log-level | Set the log level for the application:<br>▶ CRITICAL=20<br>▶ ERROR=30<br>▶ WARNING=40<br>▶ INFO=50<br>▶ DEBUG=60 | `"log-level": 60` |
| | v | version | Print program version information | N/A |
| | h | help | Print a help synopsis | N/A |
| | - | grpc-address | Set the IP address for the gRPC server | `"grpc-address": "0.0.0.0"` |
| Program Flags | m | mode | Set running mode {`static` or `interactive`}<br>**Note:** This flag is mandatory. | `"mode": "interactive"` |
| | r | firewall-rules | Path to JSON rules file | `"firewall-rules": "firewall_rules.json"` |

# Chapter 8. References

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

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