NVIDIA DOCA DPI

Programming Guide

MLNX-15-060466 _v0.1 | April 2021

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Chapter 1. Introduction

Deep packet inspection (DPI) is a method of examining the full content of data packets as they traverse a monitored network checkpoint.

DPI provides a more robust mechanism for enforcing network packet filtering as it can be used to identify and block a range of complex threats hiding in network data streams more accurately. This includes:

- Malicious applications
- Malware data exfiltration attempts
- Content policy violations
- Application recognition
- Load balancing

1.1. Intended Audience

This document is intended for software developers writing DPI-based applications such as application recognition (AR), intrusion prevention system (IPS), and intrusion detection system (IDS).

The document assumes familiarity with the TCP/UDP stack and data packet development kit (DPDK).

1.2. Changes and New Features in 0.1

This section provides information regarding the features added and changes made in this software version.

- Added HTTP, DNS, SSL/TLS and FTP support
- Added cross packet regex scanning support

Chapter 2. Setup Configuration

DPI-based application can run either on the host machine, or on the BlueField DPU target. As the DPI leverages the Regular Expressions (RegEx) Engine, users must make sure it is enabled:

Please refer to the NVIDIA BlueField DPU Family Software Documentation and perform the following configurations:

1. The RegEx engine is enabled by default on the DPU. However on the host, run the following commands:

```
host$ sudo /etc/init.d/openibd stop
bluefield$ echo 1 > /sys/class/net/p0/smart_nic/pf/regex_en
bluefield$ cat /sys/kernel/mm/hugepages/hugepages-2048kB/nr_hugepages
400                                     // make sure to allocate 200 additional
 hugepages
bluefield$ echo 600 > /sys/kernel/mm/hugepages/hugepages-2048kB/nr_hugepages
bluefield$ systemctl start mlx-regex      // To verify the service is properly
 running, use "systemctl status mlx-regex"
host$ sudo /etc/init.d/openibd start
```

2. Make sure that the BlueField DPU runs in Ethernet mode, please refer to the DOCA Installation Guide to make sure that the device is running on the correct mode.
3. Move BlueField DPU to run in embedded mode (default).

> **Note:** Refer to DPU Modes of Operation > "Configuring ECPF Mode from Separated Host Mode" under DPU Runtime Guides in the SDK DOCA Developer Zone documentation.

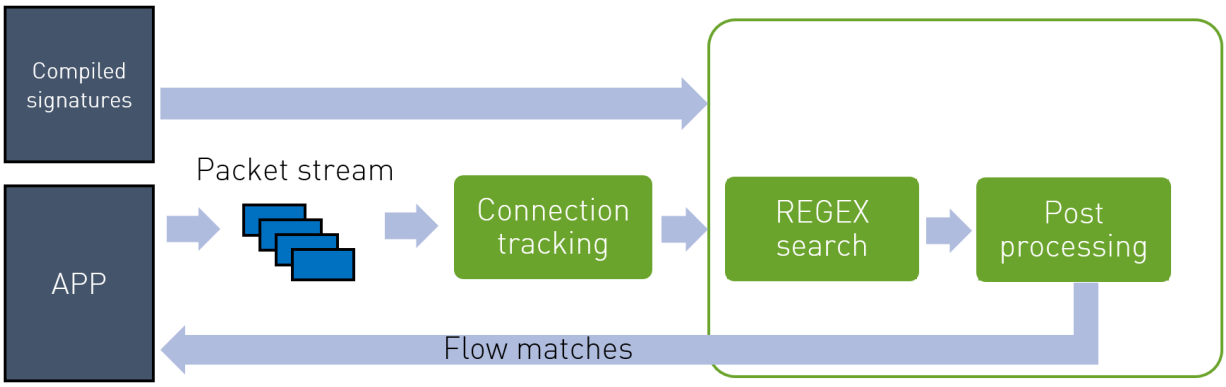
2.1. Known Issues

- The DOCA DPI library only supports inspection of the following protocols:
  - http 1.1/1.0
  - TLS/SSL ClientHello and certificate messages
  - DNS
  - FTP
- The DOCA DPI library does not support IP-based matching
- TCP/UDP stream-based signatures may detect applications on other protocols
- Non-TCP/UDP streams are not supported

- IP-based signatures are not supported

Chapter 3. DPI Architecture

The following diagram shows how packets are identified by the connection tracking protocol and then injected into the DPI library for processing.



3.1. Signature Database

The signature database is compiled into a CDO file by the DPI compiler. The CDO file includes:

- Post-processing table
- Compiled RegEx engine rules
- Other signature information

The application may load a new database while the DPI is processing packets.

For more information on DPI compiler, please refer to the DOCA DPI Compiler document.

3.2. DPI Queue

A DPI queue is designed to be used by a worker thread. The DPI queue holds the flow's state. Therefore, all packets from both directions of the flow must be submitted to the same DPI queue "in order". The connection tracking logic will handle out of order packets or retransmission.

3.3. Connection Tracking

For the DPI library to process cross-packet content, each packet must be injected along with a flow context and a direction. Packets from the same flow direction must be injected "in order". A flow direction is usually represented by a 5-tuple, but it can also be a 3-tuple for other protocols.

The connection tracking (CT) logic must handle out of order packets as well as fragmented packets. Once a connection has timed out or terminated, the application must notify the DPI library as well.

Chapter 4. DPI Initialization and Teardown

Before enqueueing packets for processing the DPI library must be initialized and loaded with signatures by the main thread:

```
struct doca_dpi_ctx *dpi_ctx  = doca_dpi_init(doca_dpi_config);
doca_dpi_load_signatures(dpi_ctx, cdo_filename);
```

The following configurations are available:

- nb_queues – number of DPI queues
- max_packets_per_queue – maximum number of packets concurrently processing per queue
- max_sig_match_len – maximum signature length guaranteed to be matched by the DPI library

  For example: A.*B and max_sig_match_len = 4 guarantees to match AxxB but does not guarantee to match AxxxB.

To close the DPI library, the user should call the following function:

```
doca_dpi_destroy(dpi_ctx)
```

Chapter 5. Packet Processing

5.1. Flow Life Cycle

- Once a new flow was detected by the connection tracking SW, the user should call `doca_dpi_flow_create()`
- Every incoming packet classified for this flow should be enqueued by `calling dpi_enqeue()`
- To poll for the results the application must call `doca_dpi_dequeue()`. The result will contain matching information (if matched).
- When the connection tracking SW detected that the flow was terminated or aged-out the application should notify the DPI library by calling `doca_dpi_flow_destroy()`

5.2. Enqueueing Packets for Processing

A call to `doca_dpi_enqueue()` may reject packets for processing for the following reasons:

- Packet is empty
- DPI queue is full (`doca_dpi_dequeue()` must be called first)

5.2.1. Packet Ownership

For every mbuf injected, the DPI engine creates an indirect mbuf. This allows the user to free the mbuf at any time after injection. The mbuf mechanism ensures the mbuf returns to the pool only after both the direct and the indirect mbufs are free.

If an external attach is used, users must follow the DPDK guidelines for `rte_pktmbuf_attach_extbuf()` to make sure the mbuf is freed when both the user and the DPI free the mbuf.

5.2.2. Flow Matching

A flow may match one or more signatures. The match result will be available to the application on `doca_dpi_dequeue()`. The DPI library will only report the matched signature with the highest priority.

The application may query for the application name using `doca_dpi_signature_get()`. To preserve performance, it is not recommended to call those functions while packets are being processed.

It is recommended that the application calls `doca_dpi_signatures_get()` after loading the database to acquire a copy of the signature names.

Chapter 6. Performance

6.1. Multithreading

The DPI library is designed to achieve optimal results in a multi-threaded environment. To achieve best performance, it is recommended that both the packet acquisition and the DPI processing will be done by the same thread.

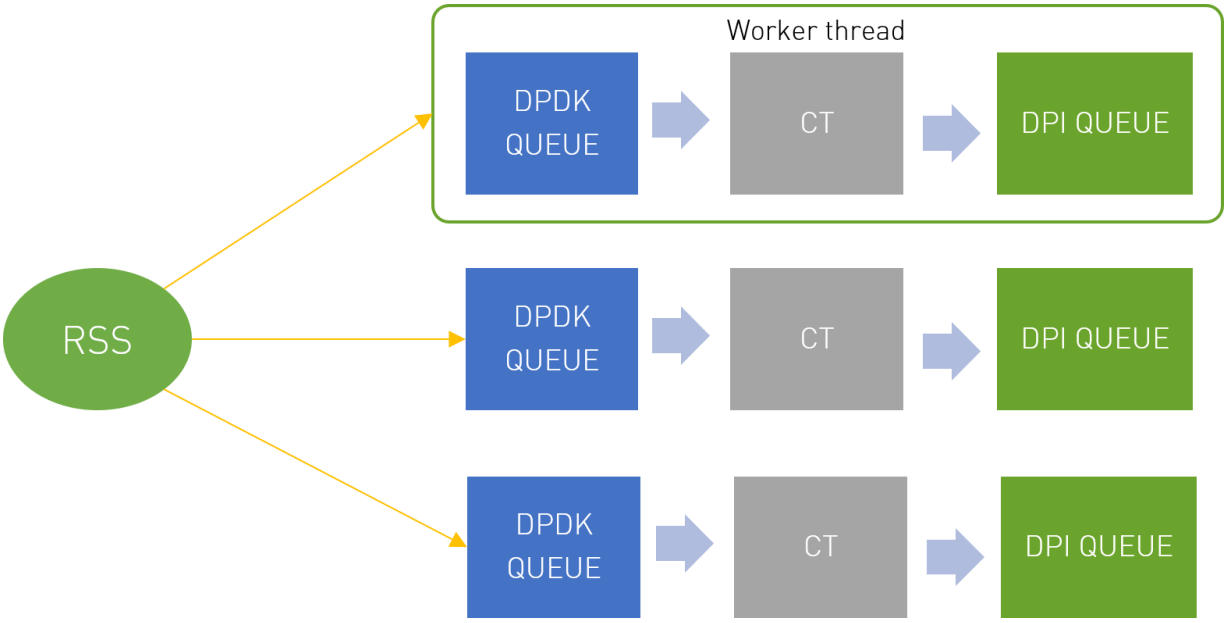
Because some of the DPI work is offloaded to the HW, it is highly recommended that the worker thread will work in a pipeline mode, meaning, it should never wait for a DPI job to be completed but rather go and fetch more packets to be processed. This way the SW can best utilize the CPU while the RegEx accelerator is processing the job.

The following pseudocode shows the recommended way to call the DPI library:

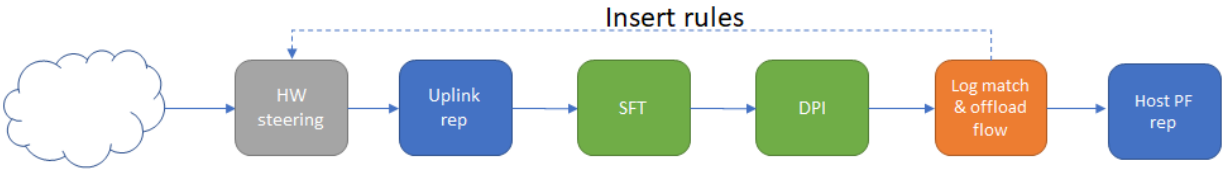
```
while(true) {
   mbufs = rx_burst()
   foreach mbuf in mbufs {
     flow_id = connection_tacking(qid, mbuf)
     if (new flow)
        doca_dpi_flow_create(qid, flow_id, parsing_info)
     status = doca_dpi_enqueue(flow_ctx, mbuf, offset)
     if (status ....)
   }
   while(doca_dpi_dequeue(qid, &result) == DOCA_DPI_DEQUEUE_READY)
     ... inspect result ...
   // At this point processing may not be completed for all packets, so the worker
   // should continue handling more incoming packets.
}
```

6.2. RSS and RTE_FLOW

Each flow's packets must be submitted exclusively to the same queue, for both directions. To achieve that users must either use symmetric RSS or manually (using `rte_flow`) direct both directions of the flow to the same DPDK queue.


Worker thread
DPDK QUEUE
CT
DPI QUEUE
RSS
DPDK QUEUE
CT
DPI QUEUE
DPDK QUEUE
CT
DPI QUEUE

Chapter 7. Packet Life Cycle Example



1. The packet is sent to the SFT for processing by calling `sft_process_packet()` to see if the hardware recognizes the flow.
2. If the packet is not marked with a zone ID by the HW, the SW must explicitly inform the SFT the zone of the packet with `sft_process_packet_with_zone()`.
3. If the packet is not marked with a flow ID by the HW or the SW, a new flow is created by calling `sft_activate()`.
4. If a new flow ID is assigned by the SFT, `doca_dpi_flow_create()` must be invoked before enqueuing the packet.
5. The packet is then processed by the DPI by calling `doca_dpi_enqueue()`.
6. If the packet is accepted by the DPI for processing, the result is dequeued by calling `doca_dpi_dequeue()`.
7. If a match is found, the result is printed and counted for statistics. The flow then is offloaded (sent directly to the host) because no further inspection is required.
8. To retrieve the match from the DPI engine, `doca_dpi_signature_get()` allows access to the sig_data struct which contains the signature ID and string. This action might affect DPI performance.
9. When the flow is terminated by the SFT, it should also be destroyed by invoking `doca_dpi_flow_destroy()` with the corresponding flow ID.
10. Additional statistics can be retrieved using `doca_dpi_stat_get()`.

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