Benchmarking Virtual Network Functions on competing hardware platforms - A green approach

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1 Introduction

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Following the expansion of network services and the diversification of users using these services is a trend of increasing energy consumption. Current estimates for total Information and Communication Technologies (ICT) contribution of Greenhouse Gas Emissions (GHG) is 1.4-2%, of which the larger consumer of energy are access networks (around 70% of total power consumption). Considering Control and User Plane Separation (CUPS), most power consumption comes from the user plane, where packet processing functionalities dimensioned to serve very high traffic rates under stringent requirements may increase energy consumption.

Thus in order to study the environmental impact of different access technologies with sufficient enough detail to drive larger scale adoption of energy efficient systems, there is a need to benchmark the different building blocks of access networks systems. These new "green" requirements however, must not conflict with the reliability and availability of existing and next generation networks, in terms of throughput and latency, for example.

Under this light, we propose a study to comparatively profile the performance of Network Functions (NFs) deployed at the termination of the access network. Typically deployed by a Broadband Network Gateway (BNG), this service is responsible for different services like the authentication of users, assigning of IP addresses, traffic shaping and so on. With Network Function Virtualization (NFV), this service is able to be deployed in different hardware configurations, which may present performance advantages comparatively to the alternatives.

Our goal is to characterise hardware accelerators primarily by their environmental impact. When different hardware accelerators perform the same

function, under the same configuration parameters (queue lengths, memory resources, CPU allocation, ...), the power consumption and energy efficiency can be evaluated and compared. This should help answer the following questions.

- *Under which conditions is a choice of hardware platform less environmentally impactful as others?*
- *Which metrics to analyse when analysing the energy consumption of NFV HWA (hardware accelerators)?*
- *How to measure GHG emissions generated by a component of the access networks?*

Research hypothesis The hardware platforms will show different energy consumption responses to different workloads.

2 Research methodology

Traditional network architectures, where dedicated devices are deployed to perform network functions like firewalling, NAT, ... are being converted to Network Function Virtualization (NFV) based architectures. This is justified by reductions in CAPEX and OPEX, since it opens up the possibility of using COTS hardware to deploy the same functions, and re utilising the same hardware in more flexible ways. However, this also creates a tradeoff where the performance of the NF may be reduced, due to the overhead of virtualisation [1]. Disaggregation of the VFs into subprograms that can be executed across different dataplanes and the independent offloading of the VF via different hardware resources may provide an insight to address these challenges [2].

This increases management and operation complexity!!

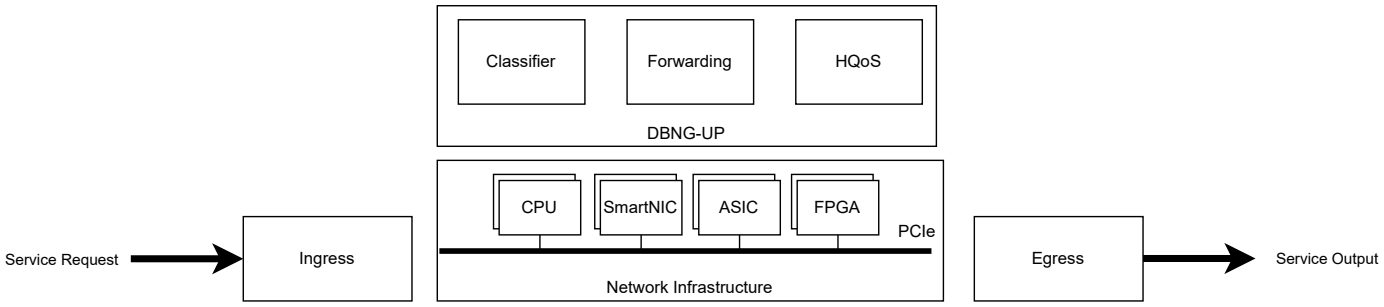

Figure 1: VF pipeline and representation of the available hardware resources for accelerating the pipeline

The notion of "splitting" the NF execution is based on the decomposition of a VNF pipeline into multiple sub-applications, managed either manually or by an agent responsible to allocate resources to each application such as [**?**]. This paradigm could allow for smarter resource allocations strategies by tailoring the sub-application to specific hardware resources or for the system to quickly and autonomously reacting to failures. Figure 1 shows a possible split of functionality, and the existing hardware resources to accelerate the BNG VF. Not represented in figure 1 is the possibility of other VFs sharing the same resource space.

In the BNG case, packet operations like encapsulation and decapsulation and header manipulation can be implemented in a programmable device like a Tofino, whereas this same device could not support the hierarchical traffic shaping methods required by todays operators. In table 1 we synthesise the considered forwarding device configurations and mixes thereof, the direction of traffic considered for the tests, and the deployed virtual functions.

Accelerator	**Traffic direction**	**VNFs**
Host (x86)	Upstream	Classifier + Forwarding
SmartNIC	Upstream	Classifier + Forwarding
Tofino	Upstream	Classifier + Forwarding
Tofino + FPGA	Downstream	Classifier + Forwarding + HQoS
SmartNIC + Host	Downstream	Classifier + Forwarding + HQoS
SmartNIC + SmartNIC [1]	Downstream	Classifier + Forwarding + HQoS

Table 1: Hardware accelerator combinations and the tested cases

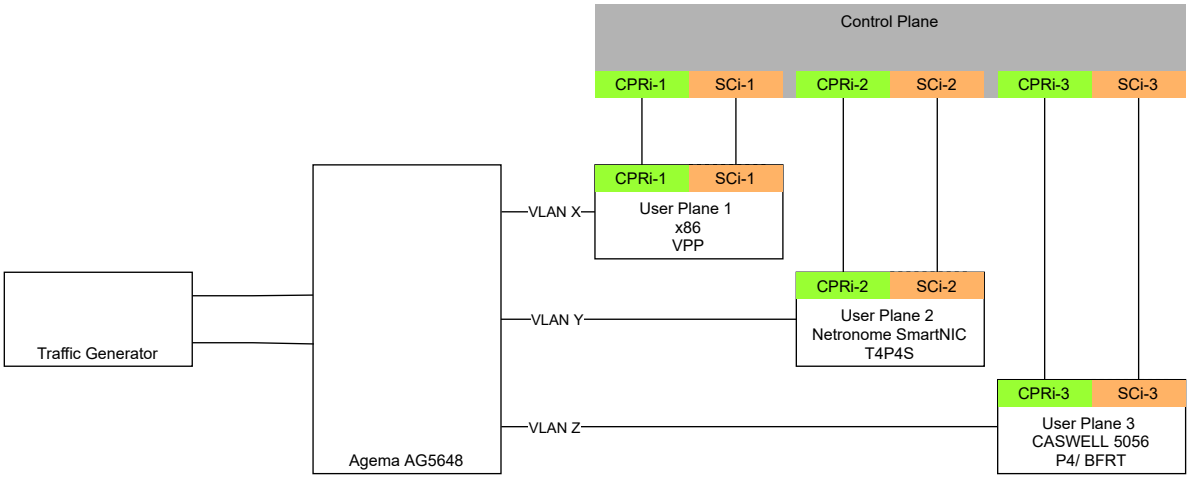

Figure 2: Planned testbed of the multiple dataplanes

Figure 2 shows the planned testbed for benchmarking the different plat-

forms. The goal of the effort is to study the energy consumption performance of different DBNG solutions based on the competing hardware platforms.

The hardware under study is in table 2. These platforms where chosen as they provide 3 different solutions to deploy the DBNG-UP.

- **General purpose CPU** This shall be a general purpose x86, and the UP will run on VPP. Also deploy a T4P4S based DPDK container.
- **Netronome SmartNIC** The Netronome 4000, and the UP will run on a DPDK application compiled from T4P4S.
- **CASWELL 5056** A combination between the Intel Tofino ASIC and Stratix FPGA. The P4 pipeline will run on the Tofino, and the FPGA run the traffic shaping application.

Accelerator	**Model**	**Target**
x86	Intel	DPDK
ASIC	Tofino	Intel SDE/ P4
FPGA	Stratix 10	Traffic shaping engine
SmartNIC	Netronome 4000	DPDK

Table 2: Hardware considered for building the testbed

Redesign this table in terms of Device Under Test/ Component Under Study

Comprehensive performance comparisons of HWAs are essential to drive the adoption of systems that correctly serve the needs of the services. However, due to the heterogeneous nature of the different HWA, it is a complex task to find performance metrics that accurately accounts for all available designs [**?**]. Typical metrics for benchmarking the BNG include throughput and latency [**?**] [**?**]. To ensure the measurements performed are meaningful, it is necessary to identify the Maximal Forwarding Rate (R^+) [**?**]. This rate is defined as the maximum packet forwarding rate achieved before packet losses, and similarly to [**?**], we study the throughput, latency and jitter achieved at low, average and high load compared to R^+. This metrics could allow us to compare the different optimal operating point for the systems under test.

Can we compare R^+ for different link BWs?

The following metrics were considered for the study.

- Latency and Jitter @ R^+ (µs)
- Energy consumed/ bit (W/bit)
- CO_2-e emitted / bit (kg/bit)

  Is this just derived from the energy consumed? Less energy consumed = less co2 emitted

- Simultaneous supported sessions [**?**]
- Traffic is shaped accurately [**?**]

Parameters and Factors

- **System Parameters**
  - –
- **Workload Parameters**
  - Traffic direction
  - Number of clients
  - Packet size
  - Packets per second

Further measurements will be taken based on the specific platform requirements. For example, we are interested in the energy consumption of the DPDK backend, and its scalability. How many VFs can there be deployed, and how does horizontal scaling of the DPDK processes affect the energy consumption. Possibly also investigate the performance differences between DPDK PMD drivers. Similarly for the SmartNIC, we are also interested in the horizontal scaling of the UP.

References

[1] G. P. Sharma, W. Tavernier, D. Colle, and M. Pickavet, "Vnf-aapc: Accelerator-aware vnf placement and chaining," *Computer Networks*, vol. 177, p. 107329, 2020.

[2] N. Sultana, J. Sonchack, H. Giesen, I. Pedisich, Z. Han, N. Shyamkumar, S. Burad, A. DeHon, and B. T. Loo, "Flightplan: Dataplane disaggregation and placement for p4 programs," in *18th USENIX Symposium on Networked Systems Design and Implementation (NSDI 21)*, pp. 571–592, USENIX Association, Apr. 2021.

References

[1] G. P. Sharma, W. Tavernier, D. Colle, and M. Pickavet, "Vnf-aapc: Accelerator-aware vnf placement and chaining," *Computer Networks*, vol. 177, p. 107329, 2020.

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