Performance Measurements of Virtualized Hierarchical Quality of Service

Rubens Figueiredo[1], Andreas Kassler[2], Holger Karl[3], Hagen Woesner[4]

[1] rubens.figueiredo@kau.se

[2] andreas.kassler@th-deg.de

[3] holger.karl@hpi.de

Broadband network access is typically managed by Broadband Network Gateways (BNGs), which implement complex services including authentication, authorization, and accounting (AAA), packet routing and forwarding, and Quality of Service (QoS) enforcement. QoS enforcement is especially complex to implement due to different subscriber tariffs, which require different traffic shaping, policing, and queue management policies to be supported in parallel at high fidelity. The recent network softwarization trend allows BNG functionality to be implemented as a Virtual Network Function (VNF). This enables flexible deployment strategies on commodity hardware, significantly reducing capital expenditure (CAPEX). However, the complex packet processing inside the BNG data plane makes it difficult to provide low and predictable latency at low loss at the scale required by access network subscribers. With the recent emergence of new, programmable, protocol-independent packet processing hardware targets (such as Field-Programmable Gate Arrays (FPGAs) or programmable ASICs), accelerating the BNG data plane on re-programmable hardware becomes feasible. But the vast range of deployment options makes it difficult to choose the programmable targets best suited for a particular key performance indicator.

The architecture and services of the BNG are described in several technical reports of the Broadband Forum. The functional split between control and user planes of the BNG was defined by the TR-459 [1], additionally describing the interfaces between these two componentsglossaries. The in-depth description of the different services is found in the TR-178 [2]. The design of BNG functionality as a VNF has been as well the target of academic studies. In Kundel et al. [3], the BNG was implemented in P4-enabled hardware targets and shows the achievable performance for the different targets. Since P4 is not designed to support packet queueing and scheduling, FPGAs are used to realize QoS functionality. Mejia and Rothenberg [4] proposes a P4-based BNG, using the MACSAD as the execution environment. The design of QoS functionality as a VNF, in particular packet scheduling, has been studied as well. Fejes et al. [5] proposes a system capable of describing hierarchical scheduling policies without needing to maintain a large set of queues. Xi et al. [6] proposes the offload of the Linux hierarchical token bucket (HTB) to Netronome SmartNIC. In this work, we measure and compare the performance of the same functionality based on different implementations, to characterize the tradeoffs between performance and flexibility.

To gain more insights into the different performance aspects of accelerating BNG packet processing functions, we perform a controlled benchmark study on the BNG use case on two targets. In particular, we first deploy a software version of BNG as a typical VNF on an x86 processor using the high-speed packet processing framework VPP. For the second BNG implementation, we disaggregate the data plane and implement typical BNG packet processing functions in P4 and deploy them on a programmable switching ASIC while traffic shaping is implemented on an FPGA.

For the benchmark, we create scenarios representing different residential network access patterns, focussing on VoIP and IPTV services, which are sensitive to delay and loss. Therefore, we focus our evaluation on the performance of the BNG data plane, particularly on the enforcement of Quality-of-Service policies. We analyze the following key performance indicators: i) the throughput shaping accuracy for different policies; ii) the packet-processing delay and delay variation; iii) the energy consumption of the BNG data plane.

References

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