EIT Digital – Industrial PhD position proposal

PhD thesis information

PhD Thesis – Title	Towards a comprehensive Quality of Service framework for next generation networks
PhD Thesis – Short summary	Network Quality of Service (QoS), fairness and resource sharing control are not completely solved problems. Available solutions lack scalability due to maintaining flow state, require re-tuning if the traffic changes, focus on a limited set of networking scenarios or require complex, centralized controllers and feedback loops. In this PhD thesis we aim at developing a comprehensive QoS framework enabling controlled resource sharing in a core-stateless manner and thus resulting in higher flexibility for defining operator policies and higher scalability enabling per user policies than existing approaches. This will eventually lead to more personalized Internet services provided for all of us.
Rationale/challenge – *describe the problem and why it is relevant*	QoS is one of the most studied area in networking with a vast array of valuable and practical knowledge. However, the issues of network QoS and resource management are still not fully solved problems. For example, QoS framework is considered a key issue in 5G standardization and one of the recent IRTF reports also lists a number of open challenges in the area of flexible resource sharing, QoS and congestion control. An ideal QoS solution would 1) allow a wide set of possible resource sharing policies. It should even enable different resource sharing policies for each user. This requires scheduling algorithms with higher scalability than the one of existing solutions. 2) be able to fulfil queueing delay requirements. The delay requirements of flows should be de-coupled from the throughput requirement or the importance of traffic. In today systems, traffic with lower delay requirements are prioritized, providing those flows better access to shared resources. 3) be lightweight to implement. Low computational and memory complexities and stateless solutions are required for practical usability. 4) support network virtualization. The solution shall support flexible resource sharing policies across multiple layers of virtual networks. There is no solution that can address all the above requirements.
Innovation – *describe what is the intended solution and the advance w.r.t. the state-of-the-art*	Existing QoS solutions are mostly based on weighted fair queuing (WFQ), priority scheduling or the combination of these (Hierarchical QoS) and require flow information at the resource nodes. In practice the number of queues to be maintained is linearly increasing with the number of flows or users to be distinguished (e.g. in a Broadband Network Gateway (BNG)), resulting in limited scalability and thus making per-user QoS hard or even impossible in practice. Core-stateless resource sharing solutions have emerged in the early 2000s, applying operator policies at the border of the network for marking the packets and using these marking to drop and schedule packets at resource nodes. By separating policy implementation from

	scheduling these approaches naturally scales well with the number of users; packet marking can be done in a distributed fashion while resource nodes are flow-unaware. The research topic is based on the Per Packet Value concept patented by Ericsson, targeting its exploitation and monetization. According to PPV concept, each packet is marked by a packet value representing the gain of the network operator that can be realized if the packet is successfully delivered. The goal is to maximize the operator's gain by dropping the least important packets in case of congestion. In this PhD, we will research and develop new techniques and protocols for the practical implementation and deployment questions of this concept, extend it with the support of other requirements like per-hop and end-to-end delay building a comprehensive QoS framework that has not existed so far.
Research focus/topics – *describe <u>how</u> you are going to solve the problem*	The research topic is based on the Per Packet Value (PPV) concept that assigns values to packets according to a throughput value function (TVF). The operators encode their policies into TVFs that are then applied by the marker nodes. The design of operator policies though TVFs will require analytical skills. The new protocols, techniques and extensions researched and developed for a PPV-based comprehensive QoS framework will first be validated through packet-level simulations. Then a prototype implementation using kernel bypassing solutions like DPDK and dataplane programming languages like P4 will be created to show the real-world applicability of the solution. We also plan to implement the features of the proposed framework in a cloud-native virtual router or other production-grade VNFs. A PPV-based Broadband Network Gateway has recently been demonstrated (industrial demo is submitted to SIGCOMM 2018) that can significantly improve the performance of the cloud-based BNG VNF, enabling to handle per user policies even for ten thousands of subscribers where existing systems face with technical limitations. Many potential areas related to 5G QoS, slicing and service chaining have been identified where core-stateless solutions can be exploited for reducing OPEX and CAPEX. The deployability analysis of these directions are part of research.
Deadlines/milestones (Gantt chart)	• State-of-the-art in the field of QoS and resource sharing including stateful and stateless approaches • Simulation-based study of existing solutions • Requirements of a comprehensive QoS framework and comparative analysis of existing solutions • Identification of potential use cases where PPV-like core stateless QoS may help in both solving technical challenges and reducing operational complexity and cost. • Analysis of deployability in the identified use cases and business value of the QoS. This latter to be evaluated in close cooperation with a few Ericsson customers.
	• Publish a concept paper at an international conference like Globecom or ICC. • Implementation of the selected parts of the QoS framework in simulation environment like NS-3 as well as in an experimental

	product (e.g. as a DPDK module that can be included in Ericsson's cloud native router) • Taking part in standardization and patenting work of the concept (MEF, IETF, etc.) flanking Ericsson in its endeavour.
	• Analysis of the concept in comprehensive simulations and emulations in testbeds. • Early product demos for potential Ericsson customers, showing the benefits of the proposed concept • Develop concepts on deployability and scalability taking into account industrial plans and constraints through strong interaction with Ericsson business and manufacturing teams. • Map potential customers and concrete selected use cases, how the product (e.g. cloud-native virtual router) could be merchandised.
	• Implementation and optimization of the algorithms • Patenting • Real world verification including performance tests and scalability tests under realistic traffic • Implementation in programmable dataplanes like P4 (experiments in Barefoot Tofino switches) • Finalize the Proof of Concept and product demos • The evaluation is done in cooperation with Ericsson and should cover all main aspects of deploying the solutions in real next-generation networks • Publish the findings in a journal paper.
	• Providing support for development units in the implementation of the QoS concept. • Summarize the results and complete the PhD thesis.
Expected outcome – *describe the expected results of the PhD*	• Contribution to keeping the leading role of Europe and Ericsson in 5G and NGN developments through new patents and standardization work (MEF, IETF, IRTF). (QoS is not yet solved in 5G.) • Novel solutions to leverage flexible and comprehensive QoS guarantees in NGNs. • Reducing OPEX (and CAPEX) of operators by the simple design and scalable approach. • Per user policies in a much more flexible way than nowadays. • More personalized services for end users: QoS-level customization and paying only for the service level that the user really requires. • Implementation integrated into Ericsson's cloud-native NF products. • Roadmap for real-world deployment. • High-quality publications.

Relevance for the Action Line (section to be filled out by the Action Line Leader)

Action Line	Digital Infrastructures
Alignment with Action Line – *statement from the Action Line Leader*	

indicating the relevance for the AL from his perspective	
Relevant IA – *List any relevant Innovation Activity (if applicable)*	

Partnership/financial information

Action Line Leader	Henrik Abramowicz
Industrial partner	Ericsson Hungary Ltd.
Industry advisor – *name and short bio*	Szilveszter Nádas received his MSc from the Budapest University of Technology and Economics in 2000, he is with Ericsson Research since then. His main research interest is Traffic Management. He worked with Network Dimensioning, Admission Control and Congestion Control. His current main interest is controlling resource sharing. On this field he is the author of more than 60 patents and several journal and conference papers.
Academic/research partner	Eötvös Loránd University (ELTE), Budapest, Hungary
Academic/research supervisor – *name and short bio*	Sándor Laki (male) received the MSc and PhD degrees in computer science from the Eötvös Loránd University, Budapest, Hungary, in 2007 and 2015, respectively. He is currently working as an assistant professor at the Department of Information Systems, Eötvös Loránd University. His research interests focus on active and passive network measurement techniques, traffic analytics, core-stateless resource sharing and QoS, programmable data planes and their application for new networking solutions. He is the author of more than 30 peer-reviewed papers and demo papers including publications at JSAC, INFOCOM and SIGCOMM.
HEI granting the title	Eötvös Loránd University (ELTE)
DTC location	Budapest
Geographical mobility plan	KTH Royal Institute of Technology
No. of PhD positions	1
PhD duration	4
Co-funding percentages: - Industry - Academia - EIT Digital	20% 30% 50%