Quantification of the Impact of 5G Network Slicing on Quality of Experience and Survivability

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I. Scope and Motivation

Beyond 5G (B5G) networks provide support for a diverse array of services with heterogeneous, and often very stringent requirements. This versatility places cellular network technologies at the cornerstone of the ongoing transformation towards a digitalized economy and society. Critical societal services (e.g., public safety and emergency networks) share the same underlying digital infrastructure as consumer services, despite extremely diverging requirements with respect to performance, security, and availability. This poses significant challenges towards the economically sustainable and reliable operation of B5G networks under both normal and adverse conditions, caused by malicious attacks or natural/technological hazards.

The thesis takes a dual perspective by focusing (i) on a user-centric network and service optimization by utilizing the Quality of Experience (QoE) for normal operation and (ii) including the user-centric approach in network survivability context, to ensure uninterrupted connectivity and design optimized recovery strategies in case of massive outages. For that, the thesis provides a comprehensive evaluation of the impact of 5G QoS differentiation mechanisms such as QoS Flows and network slicing on QoE, system utilization, and survivability.

II. Contributions of the Thesis

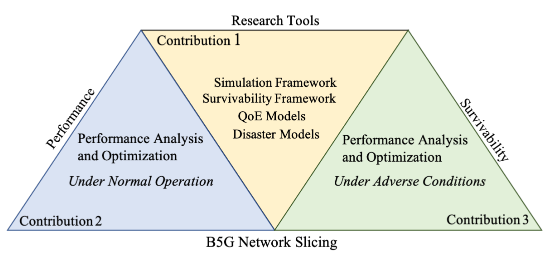

Fig. 1. Overview of the contributions.

This section provides an overview of the key contributions of the thesis:

Contribution 1 The first contribution is the methodology to evaluate the performance and survivability of network slicing. For this purpose, an implementation of Hierarchical Token Bucket (HTB) for OMNeT++/INET was developed and validated. HTB is a traffic shaping mechanism that leverages hierarchical tree structure to govern guaranteed and ceiling bitrate. The hierarchical structure of the classes allows for bandwidth sharing and high bandwidth conformance, making it a suitable approach for emulation of network slicing [3].

Contribution 2 The second contribution of this dissertation is the quantification of the impact of network slicing on QoE and system utilization, performed through comprehensive evaluations using the environment from Contribution 1. Evaluations consider both bandwidth-hungry and delay-sensitive applications, including video streaming, file download, Voice-over-IP (VoIP) and SSH. The results show that network slicing and QoS Flows can be used to provide good QoE, while at the same time admitting 16% more clients [1]. In addition, a set of often neglected slicing configuration parameters is evaluated, leading to the creation of guidelines for optimized configurations with higher average QoE and improved resource utilization. A notable outcome is that an adequate configuration of the queue size for VoIP and live video streaming slices can improve the average MOS for up to 1 and 2 points, respectively [2].

Contribution 3 Third contribution is a framework for quantification of the spatial and temporal evolution of general network performance under massive outages. Given that the availability and quality of communication services can play a crucial role for first responders in cases of natural disasters, having such a framework is beneficial for network operators. The framework allows for modeling dynamic and escalating disasters, including a variety of recovery actions (e.g., repair, relocate, and reroute). Lastly, this framework is applied to assess the survivability of different slicing configurations, including both critical and non-critical traffic. The results show that when specific optimized grouping of flows and prioritization schemes is applied, the time it takes to restore critical services with a set of remediation actions can be reduced by up to 10 times [4].

References

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[3] Marija Gajić, Marcin Bosk, Susanna Schwarzmann, Stanislav Lange, and Thomas Zinner. Demonstrating QoE-aware 5G Network Slicing Emulated with HTB in OMNeT++. In *IEEE INFOCOM 2022 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, pages 1–2, 2022.

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