TECHNISCHE UNIVERSITÄT DARMSTADT

Thesis (B.Sc. / M.Sc.)
Achieving QoE Fairness in Heterogeneous Content Distribution

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What is QoE fairness and how can it be achieved across multiple users and content types?

Quality of Experience (QoE) measures the perceived quality at the user end. It can be estimated with user studies and is often modelled in terms of Quality of Service (QoS) metrics. For example, the QoE of a video stream might drop if the bandwidth (QoS) is too low to handle the current resolution. Fairness can be defined in many different ways. It is often expressed in terms of guarantees, equality and equity.

Imagine multiple flows (e.g. video streams) that are forwarded through a network. The network has limited resources (e.g. available bandwidth, processing capabilities) that have to be distributed among the flows. The idea of guarantees is to ensure that each flow gets at least some proportion of the resources in order to provide at least a minimal level of functionality (user experience). Equality means that each flow gets the same share of resources, irrespective of the needs of the content type that is being transmitted (see TCP fairness [7]). With equity, the needs of the individual flows are taken into consideration when distributing the resources [4].

With this thesis, we want to study how to model and achieve fairness with different types of flows in the context of networking. It is also possible to consider flow transformations and different user requirements (e.g. different preferred video resolutions) instead. Each flow type should have its own stochastic utility function depending on the allocated resources. The aim is to achieve equal utility for all flows by learning the utility functions and then distributing the resources accordingly.

In this bachelor's or master's thesis, your tasks would be the following:

- Analyze related literature about fairness (in the context of network flows and QoE) [2]
- Create a formal model of the problem, e.g. as a variant of the stochastic multi-armed bandit problem [5], [1], [3] with multi-dimensional continuous controls for the resource allocation (can also be discrete)
- Select an appropriate approach to solve the problem (e.g. Reinforcement Learning [6])
- Implement a prototype
  - bachelor's thesis: proof of concept
  - master's thesis: extended proof of concept with realistic scenario
- Evaluation of the approach, e.g. in comparison with equality motivated by TCP fairness

There are no hard requirements for this topic. However, we recommend:

- Background in (statistical) Machine Learning and Reinforcement Learning
- Good programming skills in Python

For further information, please contact Anam Tahir.

References

[1] Peter Auer, Nicolo Cesa-Bianchi, and Paul Fischer. Finite-time analysis of the multiarmed bandit problem. *Machine learning*, 47(2):235–256, 2002.

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[3] Vishakha Patil, Ganesh Ghalme, Vineet Nair, and Yadati Narahari. Achieving fairness in the stochastic multi-armed bandit problem. In *AAAI*, pages 5379–5386, 2020.

[4] Michael Seufert, Nikolas Wehner, and Pedro Casas. A fair share for all: Tcp-inspired adaptation logic for qoe fairness among heterogeneous http adaptive video streaming clients. *IEEE Transactions on Network and Service Management*, 16(2):475–488, 2019.

[5] Aleksandrs Slivkins. Introduction to multi-armed bandits. *arXiv preprint arXiv:1904.07272*, 2019.

[6] Richard S Sutton and Andrew G Barto. *Reinforcement learning: An introduction*. MIT press, 2018.

[7] Huayan Amy Wang and Mischa Schwartz. Achieving bounded fairness for multicast and tcp traffic in the internet. In *Proceedings of the ACM SIGCOMM'98 conference on Applications, technologies, architectures, and protocols for computer communication*, pages 81–92, 1998.