Dating back sixty years to the seminal works by Shannon, information theory is a cornerstone of communications. Amongst others, it's significance stems from the decoupling of data compression and transmission as accomplished by the celebrated source and channel coding theorems. The success has, however, not been brought forward to communications networks. Yet, particular advances, such as in cross-layer optimization and network coding, show the tremendous potential that may be accessible by a network information theory.

A major challenge for establishing a network information theory is due to the properties of network data traffic that is highly variable (sporadic) and delay-sensitive. In contrast, information theory mostly neglects the dynamics of information and capacity and focuses on averages, respectively, asymptotic limits. Typically, these limits can be achieved with infinitesimally small probability of error assuming, however, arbitrarily long codewords (coding delays). Queueing theory, on the other hand, is employed to analyze network delays using (stochastic) models of a network's traffic arrivals and service. To date a tight link between these models and the information theoretic concepts of entropy and channel capacity is missing.

The goal of this project is to contribute elements of a network information theory that bridge the gap towards communications (queueing) networks. To this end, we use concepts from information theory to explore the dynamics of sources and channels. Our approach envisions envelope functions of information and capacity that have the capability to model the impact of the timescale, and that converge in the limit to the entropy and the channel capacity, respectively. The model will enable queueing theoretical investigations, permitting us to make significant contributions to the field of network information theory, and to provide substantial, new insights and applications from a holistic analysis of communications networks.

Non-equilibrium Information and Capacity Envelopes: Towards a Unified Information and Queueing Theory


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