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Machine Learning-assisted Link-Capacity Adjustment with Dynamic Margin Allocation for Optical Networks

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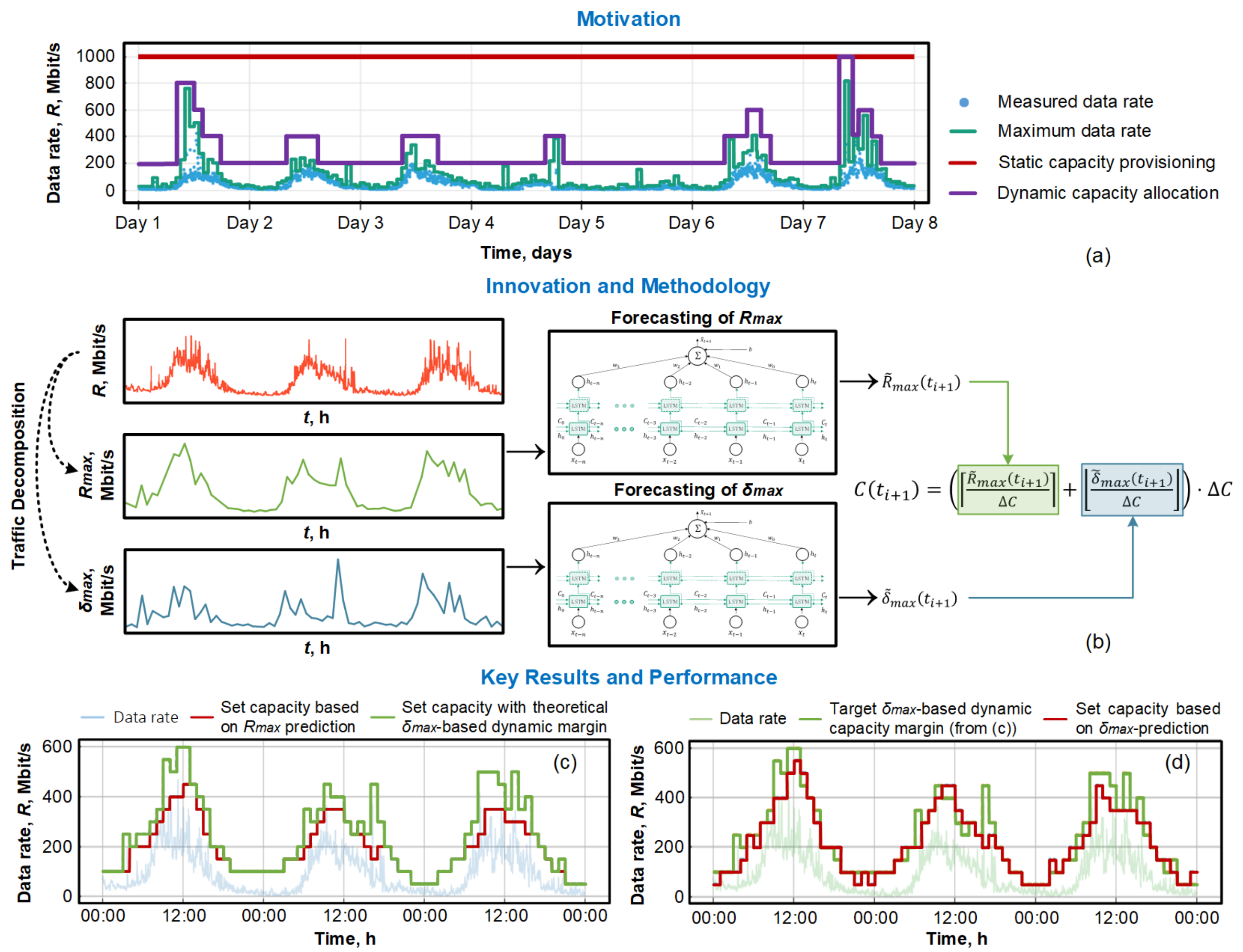
Why do networks need dynamic link-capacity adjustment and how can this be realized using traffic-forecasting techniques? How can traffic prediction be carried out with a high precision, such as to minimize the amount of capacity over-provisioning, while also mitigating the risk of under-provisioning?



The concept of link-capacity adjustment with dynamic margin allocation: (a) Traditional static vs. dynamic capacity provisioning schemes. (b) Feature engineering by applying traffic decomposition into hourly max traffic rate, Rmax, and max traffic variation, δ_{max}, with the subsequent parallel features' prediction (using 2 similar LSTM-NNs), followed by the computation of the next-hour link-capacity. (c) Calculated capacity based solely on R_{max} prediction (red), and with addition of an optimal δ_{max}-based capacity margin (green). (d) Experimental capacity computation based on the forecasted δ_{max} (red).

KEY FINDINGS

The dynamic link-capacity adjustment offers a high flexibility in network resource allocation, allowing for higher network operation efficiency. A promising way to accomplish the task of autonomous link-capacity allocation is by means of an efficient prediction of future traffic behavior related to its intensity and variation over time. The computation of future link-capacities to be allocated based solely on the forecasted traffic rate can lead to excessive bandwidth resource over-provisioning or even under-provisioning due to predictions' uncertainty, which primarily stems from the underlying traffic burstiness. To solve this limitation, we propose a novel link-capacity adjustment scheme using the so-called dynamic capacity margin allocation (DCMA), that relies on traffic forecasting using Long Short-Term Memory (LSTM) neural networks (NNs). The technique predicts in parallel the maximum traffic rate and maximum expected traffic variation within the next hour, and adds dynamic safety margins where "recommended" by the predictor, i.e., where the traffic burstiness is expected to be high, in order to mitigate the risk of capacity under-provisioning. We also show how this approach minimizes over-provisioning of real, fine-granular traffic flows, and quantify the resulting capacity gains.

M. Balanici, B. Shariati, P. Safari, G. Bergk, and J. K. Fischer, "Autonomous Capacity Adjustment with Dynamic Margin Allocation for Optical Enterprise Links," in Proc. of Optical Fiber Communication Conference, M1H.2, San Diego, CA, USA, March 2024.

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M. Balanici, G. Bergk, P. Safari, B. Shariati, J. K. Fischer, and R. Freund, "Demonstration of a Real-Time ML Pipeline for Traffic Forecasting in AI-Assisted F5G Optical Access Networks," in Proc. of European Conference on Optical Communication, Tu2.5, Basel, Switzerland, September 2022.