Autonomous Link-Capacity Adjustment using TeraFlowSDN Controller in a Disaggregated Optical Network Testbed

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Abstract *We demonstrate a closed-loop operation for the use-case of autonomous optical link-capacity adjustment in a partially-disaggregated testbed. Our proposal employs a state-of-the-art traffic forecaster for capacity provisioning and an instance of TeraFlowSDN Controller for (re)configuration of optical network elements, without interrupting the end-to-end service.*

In this work we demonstrate a Proof-of-Concept of an autonomous and dynamic link-capacity adjustment scheme in an open and partially disaggregated optical networking testbed following the Telecom Infra Project (TIP)-defined architecture, integrating the TeraFlowSDN (TFS) Controller for (re)configuration of an Optical Line System (OLS) using a dedicated OLS controller, and of third-party Optical Terminals (OTs) by means of an OpenConfig driver embedded inside the TFS. The closed-loop operation consists of a hardware photonic testbed, as well as a software control layer comprising our proprietary Network Observability Platform (NOBS) (Fig. 1).

The large photonic testbed located at Fraunhofer HHI premises in Berlin [1] comprises an optical metro-aggregation network consisting of an OLS represented by an Adtran MicroROADM ring containing three ROADMs (Fig. 1). At the peripheries of the metro testbed, two Adtran QuadFlex transponders are connected to their respective ROADM nodes through NETCONF-configurable and tunable dense wavelength-division multiplexing (DWDM) line interfaces, and also offer multiple 100G client ports. A Mellanox aggregation switch is connected to each of the two transponders on both sides of the optical testbed through 4x100G client interfaces. Moreover, a high-performance, programmable optical network tester (ONT)/traffic generator (TG) from VIAVI is connected through 8xSFP28 (8x25G) transceivers to the westside aggregation switch, generating a cumulative aggregated traffic consisting of multiple bursty and cyclic traffic flows with an aggregated data rate ranging between 0 to 200G. The generated traffic represents real-life traffic streams collected over a period of 12 weeks and scaled up to 25G (TG's port rate), and displays the so-called *daily tidal effect*, which essentially translates into low traffic intensity during the night and early morning hours, that grows steadily reaching its peak during

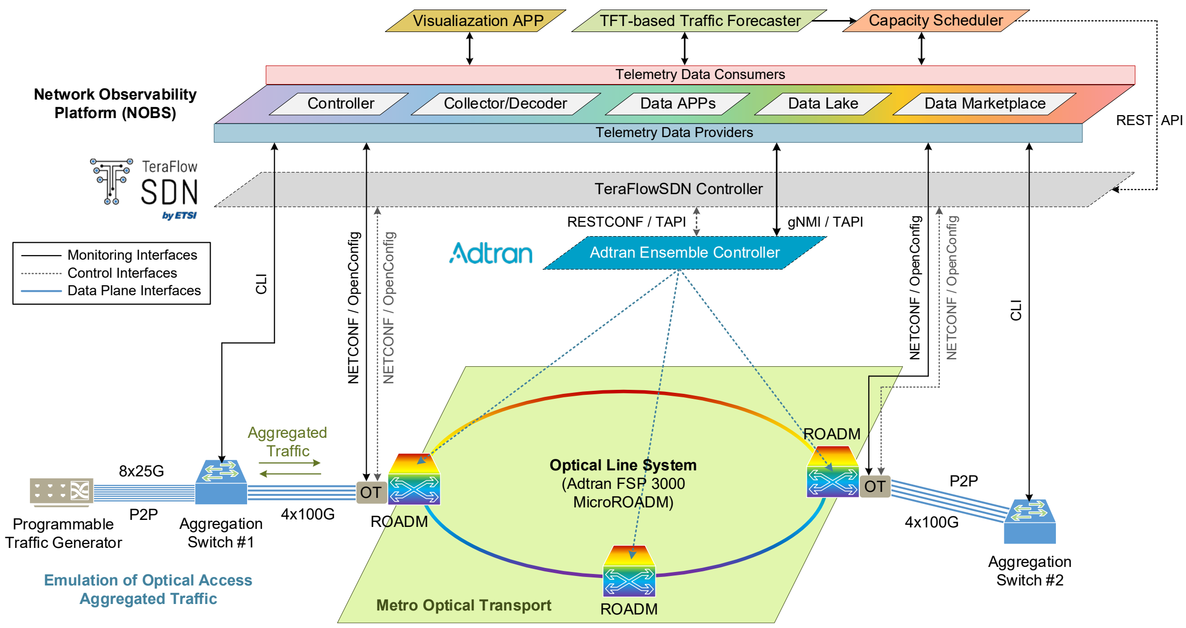

Fig. 1: The telemetry framework/NOBS platform and ML-pipeline, along with the control plane comprising TFS and ENC, coordinating with the data plane consisting of an optical metro-aggregation network testbed encompassing an OLS and OT.

This document is provided as supplementary material for the proof-of-concept demonstration presented at ETSI Software and Standards for Smart Networks and Services Conference & Hackfests 2024.

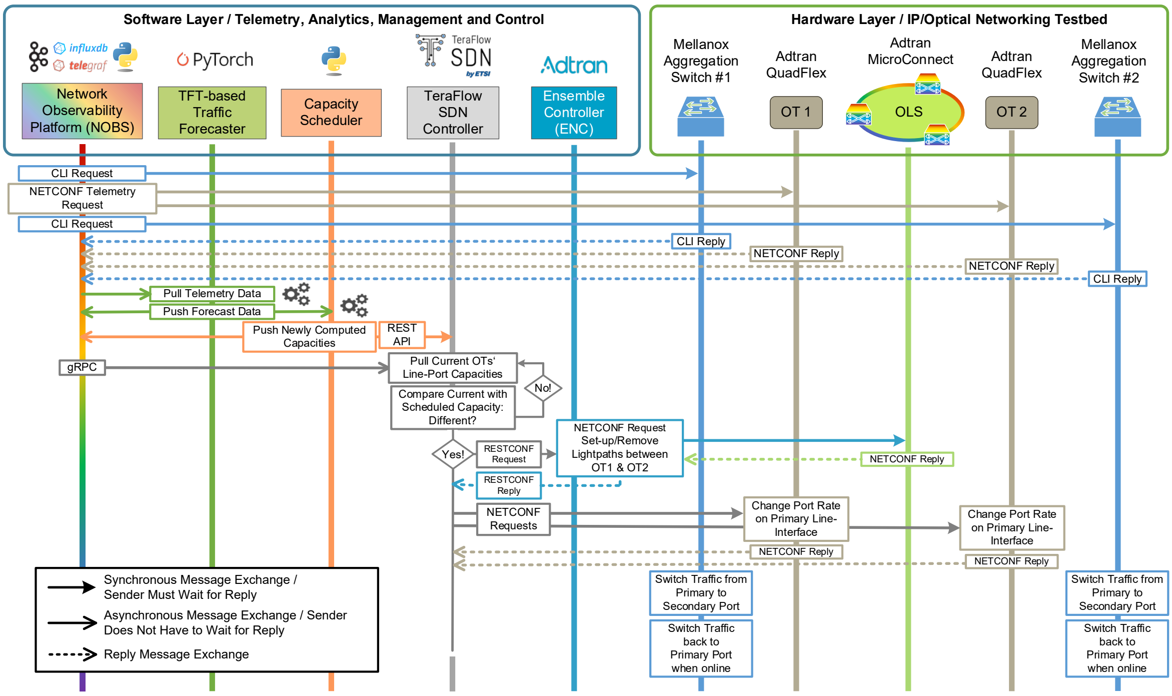

Fig. 2: Operation workflow of the autonomous link-capacity adjustment with TFS controlling the OLS and OTs/transponders' reconfiguration.

noon and afternoon, followed by a gradual decrease as the time progresses towards the evening and night hours. As such, while the lightpath and capacity of the OTs' primary line ports are being adaptively reconfigured according to the traffic load, a secondary optical line interface is kept idle in order to provide an internal rerouting path for the aggregated traffic. When the capacity adjustment is finally commissioned on the primary link, the cumulative traffic is rerouted back through the primary line port. It is worth noting that the ONT/TG and aggregation switches are essentially emulating the data layer and aggregated traffic originating from a variety of optical access networks.

When it comes to the control plane of the autonomous link-capacity adjustment, its operation and interaction with the photonic testbed is shown in the workflow diagram of Fig. 2. The control plane is represented by the software layer comprising our telemetry framework/NOBS solution developed and presented in [2,3], where telemetry data acquisition is carried out using protocols such as CLI-prompt and NETCONF (Fig. 1 and Fig. 2). Moreover, we deploy a novel ML-pipeline employing a Temporal Fusion Transformer (TFT) model for time-series prediction, in order to perform highly-accurate, multi-step ahead/multi-horizon traffic forecasting, based on which the future scheduled/required capacities are computed similarly to [4] in order to accommodate the expected/forecasted ingress traffic intensity. Heuristically, we choose a forecasting horizon of 5 traffic envelope (max/minute) samples ahead, because it provides enough time to reconfigure the OTs and OLS, and offers a decently accurate forecast of the future traffic behaviour, without prediction performance degradation. Finally, the control loop is closed by feeding the scheduled capacities into the TFS Controller, which controls the activation, deactivation and reconfiguration of the OTs' line rates according to the newly computed/scheduled capacities, using NETCONF/OpenConfig. The TFS orchestrates the optical lightpath reconfiguration by communicating with the OLS controller (Adtran Ensemble Controller (ENC)) using RESTCONF/TAPI v2.1 [5,6]. Worth noting is that the ENC controller has also access to the telemetry framework through gRPC/TAPI v2.5 to feed it with further telemetry statistics, upon request.

Lastly, in order to reconfigure traffic switching in a timely manner from the transponders' primary to their secondary line interfaces (serving as protection paths), while the primary line ports are being reconfigured, the aggregation switches employ protocols such as Link Aggregation Control Protocol (LACP), which group multiple physical ports together to form a single logical link. When the switch ports linked to the OT's primary line port shortly become unavailable due to reconfiguration downtime, the aggregated traffic is automatically distributed across the remaining active links (mapped to OT's secondary line port), thus guaranteeing no traffic loss [7].

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