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TAPI-based Telemetry Streaming in Multi-Domain Optical Transport Network

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Abstract: We demonstrate a TAPI-based telemetry streaming framework for automated service provisioning and monitoring in multi-domain optical networks. The demo showcases ML-based anomaly detection and network management across domains adhering to recommended YANG and protocol standards. © 2024 The Author(s)

1. Overview

With the significant increase in network traffic, optical transport networks play a vital role in supporting 5G and emerging services. Optical network vendors made commendable improvements in the transmission and monitoring capabilities over the optical terminal (OT) and optical line system (OLS) components. To prevent vendor lock-in for network management, network operators and vendors have collaborated to define generic open-source YANG data models to manage the network with unified communication. This comes with a tradeoff in complexity related to mapping and abstracting all device configurations and features to a generic data model. To address this, a partially disaggregated optical transport network is proposed with domain controllers taking care of the vendor domains underneath. Autonomous network decisions are required to maintain the SLA of the services with services provisioned across domains. Nevertheless, the complexities of monitoring and network automation persist, and standards are lacking for multi-domain networks.

Network automation in optical networks is one of the hot topics employing solutions with various machine learning (ML) algorithms. Monitoring and data analytics in a multi-domain setup are complex as they involve data retrieval from various sources. This encompasses difficulty as each vendor has their own way of telemetry YANG data model representation. Despite advancements, challenges persist in the realm of telemetry streaming and multi-domain network monitoring. This gives a problem statement with a new perspective on solutions focusing on generic TAPI data models for telemetry across optical domains. The work [1] proposed a fully disaggregated hierarchical SDN architecture and mainly focussed on ML-based estimation of bit error rate and signal-to-noise ratio. The approach in [2] proposed a partially disaggregated architecture with transceivers controlled by OpenConfig, and TAPI to manage OLS controllers. However, [1, 2] did not address the telemetry framework and network automation for the multi-domain network. The approach in [3] is an extension of [2] addressing the telemetry framework for optical transport networks with recommendations for suitable protocols and data analytics pipelines. Nonetheless, the work is mentioned as ongoing and network automation techniques are not discussed. Conversely, the approaches [4, 5] give a comprehensive overview of the telemetry pipeline architecture and evaluate protocols for transporting the telemetry data. The evaluation part focuses on intelligent data aggregation and data summarization techniques. However, the approaches fall short of discussing automation in the multi-domain network based on the summarized data.

2. Innovation

In this work, we present a partially disaggregated network with domain controllers managed by a multi-domain controller using ONF-TAPI for control and monitoring capabilities. The optical devices in the data plane are deployed as real entities in the Fraunhofer HHI testbed, Berlin [6] with each entity mounted to the respective domain controller. With data from multiple sources along the service path, data analytics is essential to summarise the data and derive insights from it. To emphasize this, ONF TAPI-based telemetry streaming is adopted to collect data from multiple domains with a unified data model. Additionally, an ML-based closed-loop automation use case is showcased to exhibit continuous monitoring and reconfiguration of the optical service across domains.

3. OFC Relevance

The demonstration addresses the gap in ONF-TAPI with telemetry streaming and highlights the adoption of a suitable protocol for data streaming. The experiment shows the end-to-end working sequence of closed-loop automation in a multi-domain network, leveraging the actions taking place in data, control, and management planes. Given the lack of proper standards for telemetry streaming in a multi-domain optical transport network, this demonstration provides the audience with insights into the comprehensive telemetry framework and related use-case scenarios. Also, this captures the attention of the service providers as the approach proposes vendor-neutral telemetry streaming in a multi-domain platform.

4. Demo content and implementation

We deployed an end-to-end network infrastructure as shown in Fig. 1 with components deployed in the data plane, control plane, and management plane. The OT and OLS components in the data plane are real network elements in the Fraunhofer HHI testbed, Berlin. We adopted a partially disaggregated architecture with two optical domains: *(a)* Domain-1: Adtran micro ROADMs with Quadflex terminals, and *(b)* Domain-2: Adtran CloudConnect ROADMS with Teraflex terminals controlled by individual domain controllers. Each vendor domain controller uses its native YANG model over the NETCONF protocol to configure the devices. During service creation, an optical channel is provisioned across different optical layer devices within the domain. The creation of network interfaces between higher and lower-order devices during channel provisioning is sequenced and managed by the respective domain controller.

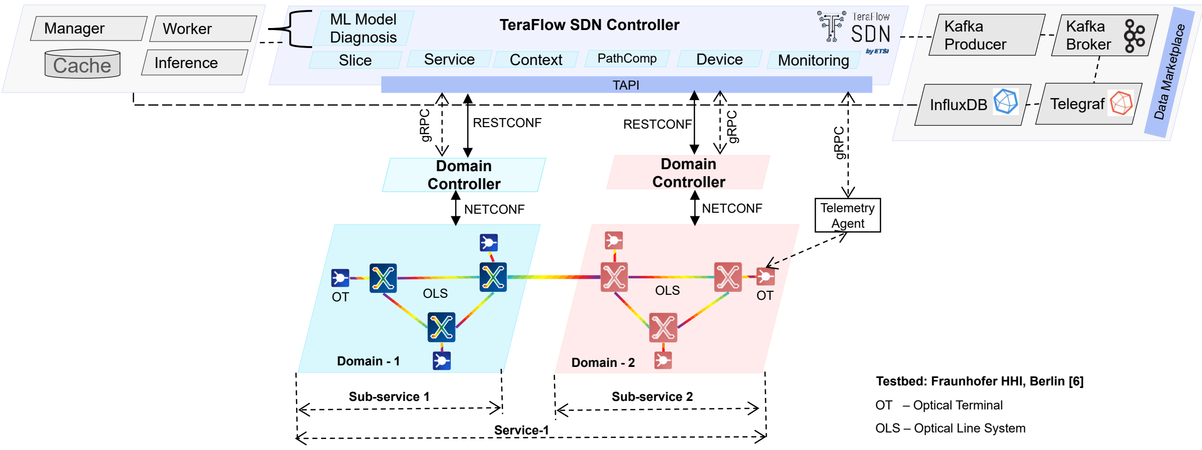


Fig. 1: Architecture: TAPI-based Telemetry Streaming in multi-domain OTN

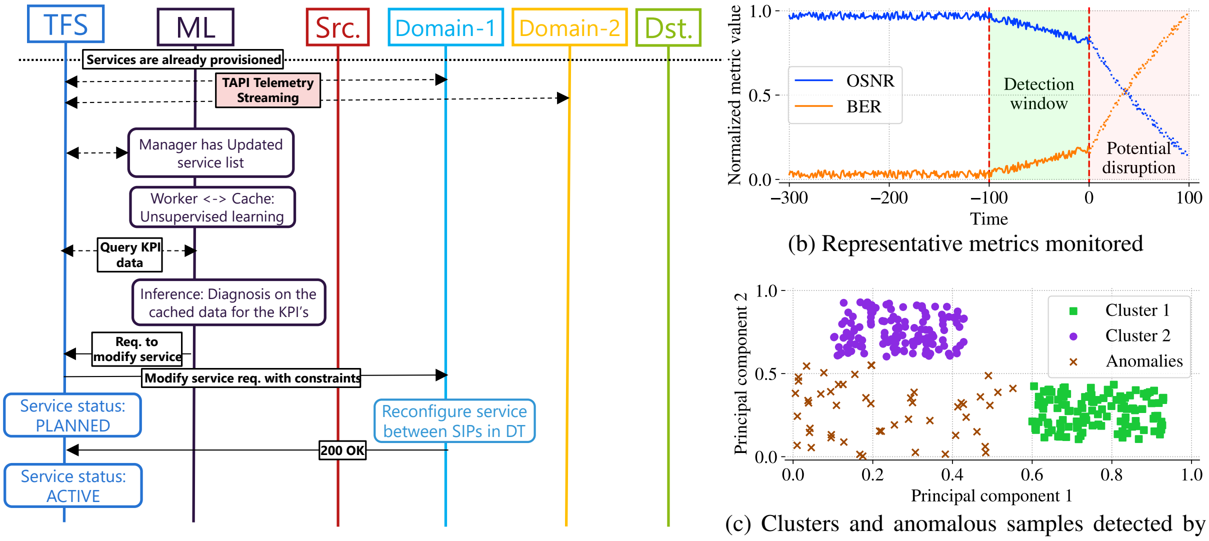
To facilitate the end-to-end service provisioning across multiple domains, the ETSI TeraFlowSDN (TFS) controller [7] is deployed in the management plane establishing communication with domain controllers through the ONF-TAPI YANG model. Each domain controller has its TAPI server which exposes functionalities including topology service, connectivity service, and streaming service. The TAPI driver in TFS is enhanced such that it manages multiple domain controllers via the RESTCONF protocol. The enhancements include: *(a)* Path computation considering different packet and optical layer devices, *(b)* API extensions to modify optical service in individual domains, and *(c)* TAPI client to capture service interface points from domain controllers. Currently, the OLS domain is referred to as a single entity in TFS, but it can capture all the interface points inside the domain. This requires manual input on link details which is configured after mounting the domain controller to TFS.

We demonstrate TAPI-based telemetry streaming where the key performance indicators (KPIs) of the service are retrieved across each domain using a unified data model. This addresses the gap of telemetry streaming in ONF-TAPI and provides a uniform way of retrieving telemetry data from multiple domains. Streaming of telemetry data brings up the evaluation of various protocols and data compression techniques for efficient data transfer. NETCONF, REST, and gRPC are common protocols used to retrieve performance data from the network. So, we observed key parameters including latency and payload size of the protocols gRPC and REST for telemetry streaming. We observed that gRPC is more effective for data streaming and data compression when compared to REST, and hence gRPC is adopted for telemetry streaming. The TAPI server of the domain controllers is modified such that telemetry data of services under the domain is streamed with a gRPC protocol. This data is continuously monitored by the TFS controller and sent to the analytics pipeline for aggregation and further processing.

5. Evaluation

With the deployed infrastructure, we initially set up a service through a multi-domain optical transport network. A service request is initiated between the client ports of optical terminals. At first, the service request is evaluated with the provided details like source, destination, and SLA requirements. Then, the path computation element (PCE) in TFS computes a path across domains with the help of link details provided while mounting the devices. With successful path computation, the service requests are calculated such that individual TAPI RESTCONF sub-service requests are generated to be provided to individual domain controllers. This can be seen in Fig. 1 where *"service-1"* is the main service between source and destination. In order to provision service across domains, *"sub-services 1 and 2"* are created with ingress and egress ports of the domain. The service interface point (SIP) details of these ports are conveyed through the RESTCONF sub-service request with the appropriate service type to be configured between them. The request also includes bandwidth, path-inclusion, path-exclusion, and frequency constraints of the optical channel.

This work addresses telemetry streaming in ONF-TAPI via gRPC. The telemetry framework requires continuous streaming of performance data from the network and gRPC protocol is used for telemetry streaming from the domain controller. The data is consumed by the TFS controller component and is aggregated by filtering only the KPI data using Kafka and Telegraf pipeline. The summarized data is stored in influxdb like in [4], which is a time-series database for further processing.



(a) Communication among components

(b) Representative metrics monitored

(c) Clusters and anomalous samples detected by the unsupervised learning algorithm

Fig. 2: Communication diagram and illustrative plots that will be shown in the demonstrator dashboard.

The significance of the telemetry framework in a multi-domain optical transport network is illustrated with the help of an ML application. An ML-based diagnosis module [8] is integrated into the TeraFlowSDN controller. The module uses the data collected through TAPI streaming telemetry to run an unsupervised learning algorithm for anomaly detection, and its workflow can be seen in Fig. 2a. In this demonstration, anomalies such as OT soft-failures will be imposed in the network [6]. Fig. 2b shows an illustrative of such potential failure. At time zero, the anomaly that started around 100 time units ago is detected. Without an anomaly detection algorithm, the situation would degrade in the future leading to potential disruption of the channel. Fig. 2c shows how the ML-based anomaly detection algorithm segregates the 300 monitoring samples at time zero, showing that two clusters are formed with a high density of samples.

Demo Presentation: A remote live demo is planned with an interactive dashboard showing live plots of KPIs of the service. Soft failure scenarios are triggered and ML-based diagnosis identifying the anomaly will be showcased. Such analysis will be illustrated through a custom dashboard developed for this demonstration. This is followed by the reconfiguration of the service with workflow as shown in Fig. 2a.

6. Conclusion

We demonstrate TAPI telemetry streaming with a closed-loop automation use case in a multi-domain optical network testbed. The experiment addresses the gap in ONF-TAPI on telemetry streaming from domain controllers and evaluates suitable protocols for continuous data exchange. The consumed telemetry data is aggregated with a data analytics pipeline and is stored for further processing. ML-based network automation use case is demonstrated, and its workflow in re-configuring the optical sub-service in the domain is showcased.

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