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# Enabling Per-Subcarrier Telemetry in DSCM-Based Transceivers within Disaggregated SDN Architectures


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***Abstract*—This work presents a disaggregated SDN-based architecture that enables per-subcarrier telemetry for DSCM transceivers. A containerized Pluggable Controller layer collects and normalizes vendor-specific metrics, exposing them through standardized interfaces. Experimental validation demonstrates enhanced observability compared to conventional carrier-level monitoring approaches.**



***Index Terms*—Software Defined Networks, Digital SubCarrier Multiplexing, Telemetry Plane**


## I. Introduction

The continuous increase in traffic demand, due to the growing use of digital services and applications, is leading to significant changes in optical transport networks and their operating requirements. As traffic volumes grow and become more dynamic, traditional control and management approaches reveal limited flexibility and scalability. In this context, Software Defined Networking (SDN) [1] has emerged as a key paradigm, enabling the separation between control and data planes and supporting centralized and programmable management of network resources. These capabilities allow operators to dynamically configure the network, improve resource utilization, and simplify operational processes. As a result, disaggregated network architectures are increasingly adopted, relying on open interfaces and standardized data models. This approach enables multivendor interoperability and greater flexibility in network deployment and operation. In such environments, network observability becomes increasingly important, as the optical infrastructure is not only a transport medium but also a source of operational information. The telemetry plane [2, 3] plays a key role by providing real-time visibility into physical-layer performance and enabling automation and optimization processes. Streaming telemetry mechanisms, combined with standardized data models such as OpenConfig and OpenROADM [4, 5, 6], enable scalable and interoperable data collection across multivendor architectures. In current optical systems based on single-carrier transceivers, telemetry is typically exposed at the level of the optical channel or physical port. Performance indicators such as optical signal-to-noise ratio (OSNR), Bit Error Rate (BER), and received power are generally aggregated and reported per carrier. While this level of granularity is sufficient for traditional point-to-point networks, it becomes limiting in more flexible optical systems. In this scenario, the evolution of coherent transceiver technologies further increases the need for more granular monitoring capabilities. A solution to address this requirement is Digital SubCarrier Multiplexing (DSCM) [7], which enables the subdivision of the optical spectrum into multiple digitally generated subcarriers that can be independently managed and assigned. This allows the creation of parallel transmission channels within the same optical carrier and supports flexible capacity allocation according to traffic requirements. Such capability is particularly relevant in point-to-multipoint (P2MP) [8] scenarios, where subcarriers can be selectively assigned to different leaf nodes, improving resource utilization and enabling dynamic service provisioning. To fully exploit the flexibility offered by DSCM-based P2MP systems, it is therefore essential to expose telemetry at the granularity of individual subcarriers. Per-subcarrier monitoring enables more accurate performance assessment, finer resource control, and enhanced fault localization. Moreover, when structured according to standardized data models, such telemetry can be integrated into disaggregated network environments, where the telemetry plane interfaces with SDN controllers, orchestration platforms, and Digital Twin (DT) [9] for real-time analysis and simulation. In this work, we investigate the architectural and modeling aspects required to support per-subcarrier telemetry in DSCM-based P2MP optical systems, and we discuss how such data can be structured to ensure scalability, interoperability, and effective integration within modern SDN-controlled and disaggregated networks.


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## II. Disaggregated architecture

The proposed solution is deployed within a disaggregated optical networking architecture, as illustrated in Figure 1. The architecture follows SDN principles and clearly separates orchestration, control, transport, telemetry, and analytical functions, enabling modularity, vendor independence, and functional scalability. At the highest layer, the orchestrator [10] is responsible for service-level coordination and end-to-end resource management across multiple network domains. It represents the global decision entity that translates service intents into network configurations, maintaining a unified view of the overall infrastructure. The orchestrator can interact with multiple SDN controllers, each responsible for a specific domain, as well as with the Pluggable Controller (PC) layer to enforce provisioning decisions. It also interfaces with the DT for advanced evaluation and optimization processes. The SDN Controller manages the optical transport infrastructure within a single domain, including the Reconfigurable Add Drop Multiplexers (ROADMs) deployed along the network. It provides centralized control of the photonic layer at domain level, handling spectrum allocation and device configuration across the optical nodes. In a multi-domain network, multiple SDN controllers may coexist, each operating independently on its own segment of the infrastructure. Through standardized interfaces between the SDN controller and the ROADMs, interoperability is ensured within disaggregated networks, enabling programmable and vendor-neutral control of the optical transport layer [11, 12]. The PC layer acts as an intermediate control entity specifically responsible for managing the transceivers, including DSCM transceivers. Differently from the SDN controllers, the PC operates as a centralized entity that can control transceivers across different domains. In particular, it can manage both endpoints of an optical connection, even when they belong to separate domains controlled by different SDN controllers. In the proposed architecture, this layer plays a crucial role in configuring device parameters, such as frequency, power, modulation format, and capacity, while also exposing per-subcarrier telemetry information. A dedicated telemetry plane is responsible for the collection and storage of operational data in real time. It receives telemetry streams from the PC layer and stores them within a time-series data management system, enabling both real-time monitoring and historical data analysis. This plane provides a consistent and centralized access point for physical-layer information, ensuring that telemetry can be consumed by higher-layer entities in a structured and interoperable way. The DT represents a virtualized replica of the physical network, leveraging telemetry data to perform simulations and performance estimation. By accessing real-time and historical data from the telemetry plane, the DT can evaluate network conditions and support what-if analyses. The interaction between the DT and the orchestrator enables feedback-driven operation, where insights derived from simulations can influence network configuration decisions across multiple domains. Overall, this disaggregated architecture decouples hardware, control, telemetry, and analytical functions while maintaining well-defined interfaces among all components. Such separation is fundamental to support multivendor environments, scalable telemetry collection, and advanced automation capabilities, particularly when per-subcarrier monitoring is required in DSCM P2MP systems.

## III. Setup and workflow

The experimental validation of the proposed per-subcarrier telemetry approach was conducted in a laboratory environment implementing the disaggregated architecture described in the previous section and illustrated in Fig. 1. The setup follows a partially disaggregated paradigm, where the control plane is distributed across multiple entities and network devices are provided by different vendors. The physical infrastructure consists of three ROADM nodes forming a multi-span optical transport network, with DSCM transceivers deployed at the network edges. The nodes are interconnected through multi-span optical links with different lengths: link AC extends over 520 km, link AB covers 160 km, and link BC covers 220 km. The optical transport layer is managed by an SDN controller, which is responsible for configuring the ROADMs and establishing end-to-end optical paths across the photonic domain. Although the proposed architecture supports multi-domain operation, the experimental setup is limited to a single-domain scenario, where a single SDN controller manages the entire transport network. At the edge of the optical domain, the DSCM transceivers are controlled through a PC layer, which has been fully implemented within this work. The PC is developed as a modular software solution written in Python and deployed as a containerized service to ensure portability and continuous operation. The container remains persistently active and acts as an intermediary between the physical devices and the upper-layer orchestration and analytical systems, enabling integration in heterogeneous environments while maintaining flexibility toward vendor-specific device interfaces. The PC exposes a northbound interface (NBI) based on REST APIs [13] toward the orchestrator, allowing higher-layer entities to configure transceiver parameters and retrieve structured telemetry data. On the southbound side, the controller communicates directly with the DSCM transceivers through Remote Procedure Calls (gRPC) [14], which are used both to configure device parameters and to collect telemetry data. This interaction enables full control of transmission settings, including frequency, power, modulation format, and capacity, while providing continuous access to performance metrics at subcarrier granularity. Since DSCM transceivers use vendor-specific commands and data formats, dedicated southbound interfaces are implemented for each device. This approach hides device-specific details and allows the upper layers of the architecture to operate independently from the underlying transceiver implementation, ensuring interoperability in multivendor environments [15, 16]. The collected telemetry data are forwarded to the telemetry plane, where they are stored in a time-series data management service. This enables continuous real-time monitoring while also supporting long-term data storage for extended analysis. Monitoring tools can

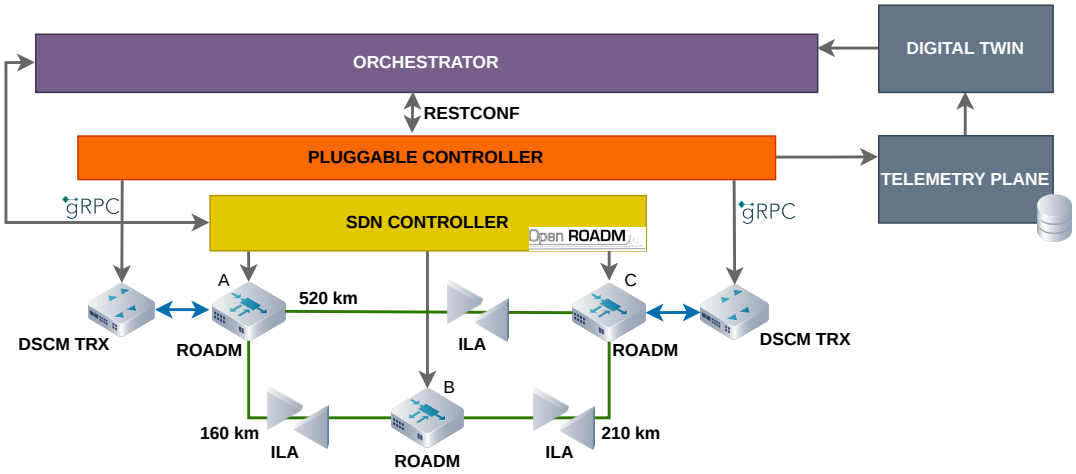



Fig. 1: The figure depicts the key components of the disaggregated network architecture and their logical interactions within the TuriNet testbed implementation.

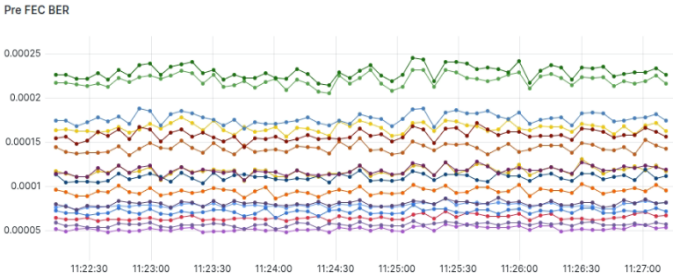
access the stored data for live visualization of carrier and subcarrier performance, while the same dataset can be used for offline post-processing, correlation analysis, and validation of physical-layer models. From an operational perspective, the workflow proceeds as follows. The orchestrator defines service-level requirements and instructs the SDN controller to establish the optical path across the ROADM network. In parallel, it interacts with the PC to configure the DSCM transceivers, including subcarrier allocation and transmission parameters. Once the optical service is active, the PC continuously collects per-subcarrier telemetry and streams it toward the telemetry plane. Since subcarriers can be independently managed in DSCM systems, each subcarrier can experience different transmission conditions and must therefore be monitored individually. For this reason, per-subcarrier telemetry is essential to accurately represent the state of the network. The stored data are then accessed by the DT, which performs simulations and performance estimations based on real network conditions. The availability of telemetry at subcarrier level enables the DT to operate with a higher level of detail, improving the accuracy of the analysis and supporting more effective decision-making. The results of these analyses are communicated back to the orchestrator, enabling informed reconfiguration of both the transport layer and the transceiver parameters [17]. This closed-loop interaction demonstrates how telemetry at subcarrier level can be integrated into a disaggregated SDN-controlled optical network, enabling real-time monitoring, advanced analytics, and dynamic optimization while preserving the separation between vendor-specific device control and standardized interfaces.

## IV. Results

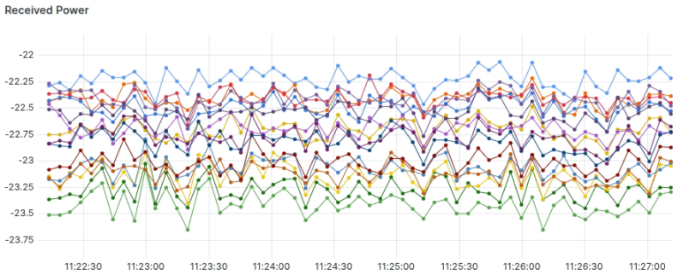
The proposed per-subcarrier telemetry approach has been validated in the TuriNet testbed by continuously collecting performance metrics from DSCM transceivers and visualizing them through a monitoring dashboard. The objective of this experimental evaluation is not only to observe physical-layer parameters, but also to demonstrate the correct operation, stability, and granularity of the telemetry pipeline within the disaggregated architecture. Figure 2(a) shows the time evolution of the BER measured independently for each subcarrier within the same optical channel. Each trace corresponds to a distinct subcarrier, confirming that the system can track performance metrics at subcarrier level. The observed trends demonstrate stable and continuous data acquisition and visualization. Figure 2(b) reports the received optical power for the same set of subcarriers. The results highlight the ability of the system to expose independent physical-layer measurements for each component of the carrier, while preserving the identity of individual subcarriers within the telemetry plane. The simultaneous monitoring of multiple parameters confirms the correct interaction among DSCM transceivers, the PC, the telemetry plane, and the visualization tools. Overall, the results validate the end-to-end workflow and demonstrate that vendor-specific information can be abstracted and exposed in a structured way within a disaggregated SDN-controlled environment. These results confirm that the proposed architecture enables stable and continuous per-subcarrier telemetry collection, improving observability compared to conventional carrier-level approaches and supporting advanced analysis and digital twin integration.

## V. Conclusions

This work demonstrated the feasibility of enabling per-subcarrier telemetry in DSCM-based P2MP optical networks within a disaggregated SDN-controlled architecture. The implemented solution successfully collects, normalizes, and exposes subcarrier-level performance metrics through a containerized PC layer, ensuring continuous operation and seamless integration with higher-layer systems. Experimental val-




(a) Pre-FEC BER measured over time for each individual subcarrier of the DSCM transceiver.




(b) Received optical power monitored over time at subcarrier granularity.

Fig. 2: Real-time monitoring of per-subcarrier telemetry collected in the experimental setup. (a) Pre-FEC BER and (b) received optical power for multiple subcarriers belonging to the same optical channel. The results confirm stable acquisition and independent observability at subcarrier level.

idation in the TuriNet testbed confirms the stability and effectiveness of the proposed approach. The results show that subcarrier-level monitoring significantly enhances network observability compared to conventional carrier-level telemetry, enabling finer fault localization and more accurate performance assessment. Such granularity becomes particularly relevant in P2MP scenarios, where individual subcarriers may experience different transmission conditions and service allocations. Equally important is the uniform organization of telemetry data according to standardized data models. A consistent data structure is essential to ensure interoperability in multivendor environments and to allow advanced post-processing algorithms to operate effectively. In particular, recovery mechanisms, optimization strategies, and digital twin simulations rely on structured and coherent datasets to accurately reflect the physical state of the network. By extending physical-layer observability to the subcarrier level, the proposed solution enables closer integration between optical performance monitoring and SDN-driven automation. This capability represents a significant step toward more intelligent and resilient disaggregated optical infrastructures.

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