# Demonstration of Self-Healing in IPoWDM Network with Dual Protection Using MBoSDM and NetDevOps Solutions in Support of 6G

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**Abstract:** We demonstrate autonomous self-healing in an IPoWDM network testbed comprising commercial equipment and MBoSDM prototype. We measured service provisioning time of under one minute and healing time of under 30 seconds in the considered usecase. © 2026 The Author(s)

## 1. Introduction

With the goal of supporting new emerging services for 6G such as ultra-low-latency and high-quality AR/VR video streaming, transport networks need to scale up their capacity in order to meet stringent requirements posed by such services. Multi-Band (MB) optical networks can increase the network capacity manifold by utilizing multiple bands within a fiber [1]. However, in order to meet the future capacity demand, the MB needs to be used jointly with Space Division Multiplexing (SDM), i.e., referred to as MBoSDM, such that the spatial dimension of the fiber (i.e. cores, modes) can also be efficiently utilized. This combination makes the network infrastructure a very complex entity that requires a sophisticated control plane solution. Furthermore, the provisioning of seamless and uninterrupted services to the end-users also requires integration of autonomous self-healing mechanisms into the network. This can be achieved by NetDevOps, i.e., the integration of development and operations in networking, that helps to automate configuration management and service deployment [2].

This work demonstrates an experimental validation of self-healing control framework (relying on passive monitoring) in MBoSDM optical network with IP over Wavelength Division Multiplexing (IPoWDM) technology using both commercial equipment and prototypes. The testbed is managed using a hierarchy of Software Defined Networking (SDN) controllers, network and service orchestration systems, as well as SDN agents designed specifically for our devices. High-reliability is achieved with dual protection self-healing mechanism that demonstrates the capabilities of both MBoSDM and NetDevOps solutions to keep the video streaming traffic flowing through the network even when two failures happen in the network simultaneously. The results showed that the end-to-end service provisioning in our testbed takes less than one minute, whereas the healing time was measured to be less than 30 seconds. The mentioned times include the latency that comes from the initialization of NetDevOps pipeline, which records device and service states, and maintains a history of each deployment [2].

## 2. Demo Architecture

Figure 1 shows the demo architecture for both data and control planes. The C-band domain (in the center of Fig. 1) contains three commercial Micro ROADMs connected in a ring, as well as Quadflex transponders from ADTRAN. The SDM-MB domain (on the left side of Fig. 1) contains the MBoSDM node prototype and two MB transceivers. The MBoSDM node is a passive 4×4 prototype that can switch both optical bands and spatial/fiber paths. The prototype uses a fixed multiband filter together with a fully configurable 12×12 optical fiber matrix switch. It includes eight multiband multiplexers and demultiplexers for band routing, and each input and output port has a monitoring point for measurement purposes [3]. The MBoSDM node and MB transceivers are controlled using NETCONF agents. A virtualized SDM-MB domain (on the right side of Fig. 1) also exists for fiber switching. Two Edgecore switches exist in the testbed which are equipped with 400G ZR+ pluggable transceivers. The Mellanox switches are used for traffic aggregation. Finally, two Linux boxes with Docker runtime are used where the Docker containers for video streaming services can be instantiated.

The testbed encompasses with a hierarchical SDN control plane. The service orchestrator is responsible for service instantiation, i.e., it instantiates Docker containers in the Linux boxes and asks the network orchestrator for providing

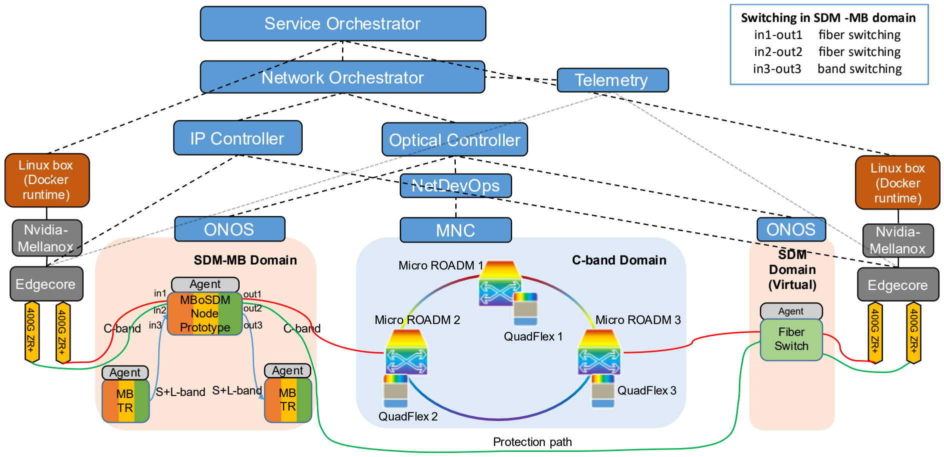

Fig. 1. Demo architecture showing multiple domains in the data plane, and the control plane hierarchy.

connectivity between them. The network orchestrator manages the connectivity resources in the network and interacts separately with controllers of both IP and optical domains. The IP controller manages the Edgecore switches and pluggable transceivers. The optical controller/orchestrator interacts with different domain controllers to provide an end-to-end optical service via an abstracted and standards based (TAPI) interface. Separate instances of the ONOS SDN controller [4] (extended for this demo to enable the control of fiber- and band-switching) manage each of the SDM-MB domains. The C-band domain is managed using ADTRAN Controller MNC which has a specialized interface for controlling the ADTRAN devices. The interaction of optical controller with MNC takes place via the NetDevOps tool which helps to perform continuous integration/continuous deployment (CI/CD) based monitoring and deployment. Finally, the telemetry system is used for monitoring different parameters from the network, which can trigger the network orchestrator to perform network reconfiguration when failures are detected in the network.

## 3. Experimental Validation

The experimental validation is done according to the sequence diagram in Fig. 2. The workflow begins when an admin sends an end-to-end service creation request to the service orchestrator. The service orchestrator asks for instantiation of Docker containers for video streaming in both Linux boxes and requests the network orchestrator to provide connectivity between them (Steps 1-2). The network orchestrator requests IP and optical controllers to provision the red path in Fig. 1 with direct connection between ROADM2 and ROADM3 in the C-band domain (Steps 3-4). The IP controller configures the Edgecore switches, whereas the optical controller configures three domains by interacting with both ONOS instances and NetDevOps/MNC (Steps 5-9). A failure (referred to as *Failure-1* in Fig. 2) is introduced in the C-band domain on the direct path between ROADM2 and ROADM3 which disrupts the traffic on

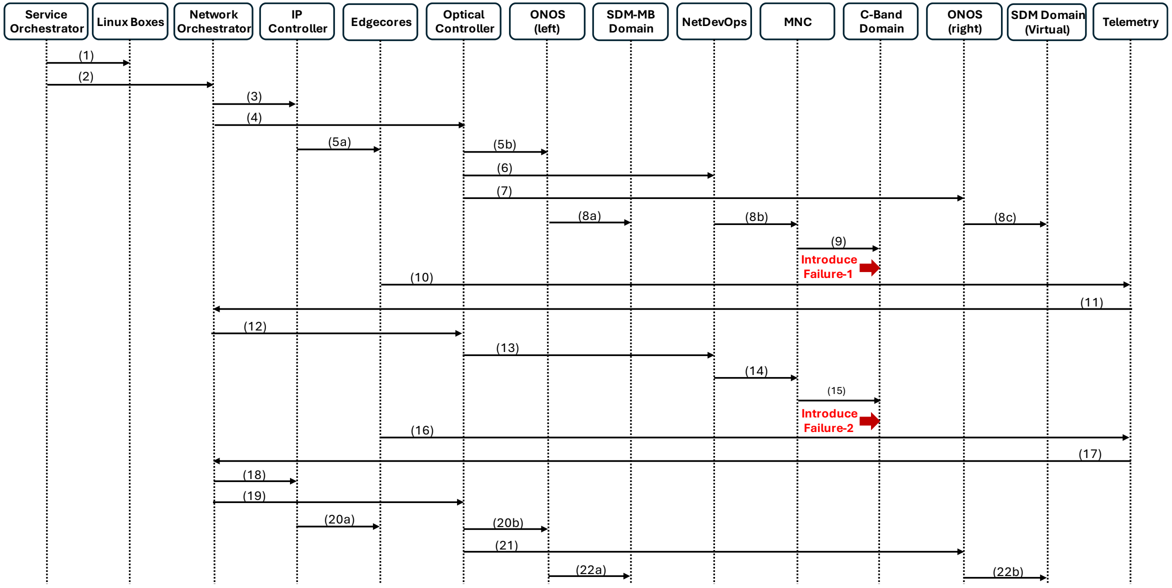

Fig. 2. Sequence Diagram. Each request is associated with a response; but the responses are not depicted here due to space constraints.

the red path. The telemetry system collects metrics (such as bit-error-rate, BER) from the Edgecore switches. When the BER exceeds a predefined threshold, the telemetry system sends a failure notification via REST API to the network orchestrator (Steps 10-11). The network orchestrator asks the optical controller to provide alternate path in C-band domain between ROADM2 and ROADM3 via ROADM1 using NetDevOps/MNC, which results in traffic flowing again on the red path (Steps 12-15). Another failure (referred to as *Failure-2* in Fig. 2) is introduced in the C-band domain on the alternate path between ROADM2 and ROADM3 (via ROADM1) which disrupts the traffic again on the red path. The telemetry system again detects the failure and informs the network orchestrator about it (Steps 16-17). Considering that there is no path available in the C-band domain after both of these failures, the network orchestrator (via IP and optical controllers) provisions the green protection path that bypasses the C-band domain, and switches the traffic to the green path (Steps 18-22). During the recovery phase (not shown in Fig. 2 due to space constraints), *Failure-2* in C-band domain gets fixed, and the network orchestrator switches the traffic back to the red path using alternate path between ROADM2 and ROADM3 via ROADM1 following the same procedure (Steps 3-9). Finally, *Failure-1* in C-band domain gets fixed, and the network orchestrator reverts the traffic on the red path to the direct connection between ROADM2 and ROADM3 (Steps 12-15).

Figure 3 shows some screenshots of the demo execution. Fig. 3(a) shows the service orchestrator that initiates multiple video streams for transmitting video traffic in the network. Fig. 3(b) shows the left ONOS instance where the MBoSDM node is controlled together with two transponders. Fig. 3(c) depicts the spectrum in MBoSDM node where one channel is active. Fig. 3(d) contains the underlying topology discovered by the optical controller. Fig. 3(e) shows the TeraFlowSDN based network orchestrator depicting the services being activated in the network. Finally, Fig. 3(f) depicts the NetDevOps pipeline where a service is created and rolled back to the original path once the failure is fixed.

We also collected some measurements from the ZR+ pluggables of Edgecore switches with our telemetry system. Over the red path in Fig. 1, the performance of the connection is RX-power -7.8dBm, BER 5.2E-3 and OSNR 25.7dB. After the reconfiguration with NetDevOps, the new performance of the connection is RX-power -7.4dBm, BER1.2E-2 and OSNR 24.7dB. In case of second failure, the green path is enabled by switching on the other ZR+ pluggable. In this case, the performance of the connection is RX-power -5.8dBm, BER 2.2E-3 and OSNR 26.7dB. Finally, we measured the end-to-end service provisioning time to be less than one minute, and healing time to be under 30 seconds.

## 4. Conclusion

This work demonstrates a self-healing and autonomous IPoWDM network that can meet the requirements of new emerging services for 6G by using MBoSDM and NetDevOps solutions. We depict the dual protection of our testbed where the control plane takes remedial actions when two simultaneous failures can occur in the network.

## Acknowledgements

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## References

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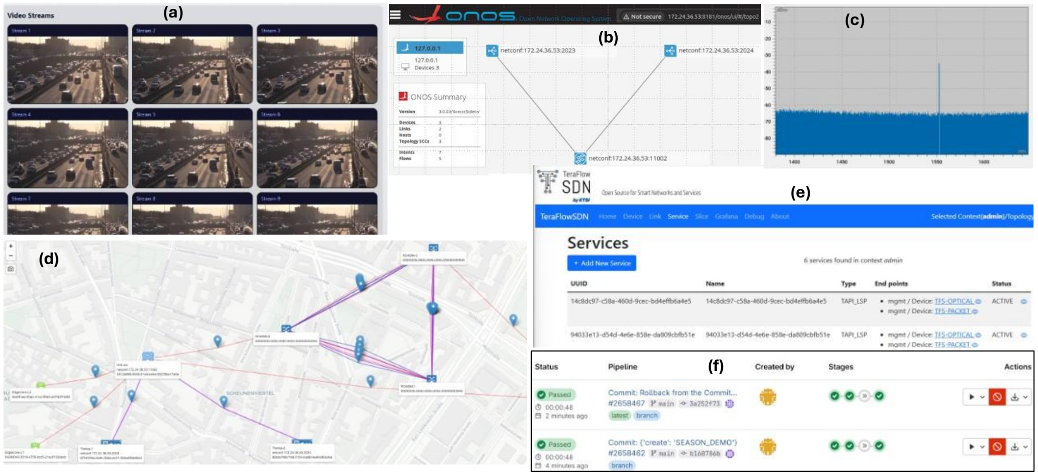

Services

+ Add New Service

6 services found in context *admin*

| UUID | Name | Type | End points | Status |
|---|---|---|---|---|
| 14c8dc97-c58a-460d-9cec-bd4effb6a4e5 | 14c8dc97-c58a-460d-9cec-bd4effb6a4e5 | TAPI_LSP | mgmt / Device: TFS-OPTICAL<br>mgmt / Device: TFS-PACKET | ACTIVE |
| 94033e13-d54d-4e6e-858e-da809cbfb51e | 94033e13-d54d-4e6e-858e-da809cbfb51e | TAPI_LSP | mgmt / Device: TFS-OPTICAL<br>mgmt / Device: TFS-PACKET | ACTIVE |

| Status | Pipeline | Created by | Stages | Actions |
|---|---|---|---|---|
| Passed<br>00:00:48<br>2 minutes ago | Commit: Rollback from the Commit...<br>#2658467 main 3a252f73<br>latest branch | | | |
| Passed<br>00:00:48<br>4 minutes ago | Commit: {'create': 'SEASON_DEMO'}<br>#2658462 main b168786b<br>branch | | | |

Fig. 3. Screenshots of demo execution. (a) service orchestrator, (b) ONOS controller, (c) spectrum analysis in MBoSDM node, (d) optical controller, (e) network orchestrator, (f) NetDevOps pipeline execution.