Enabling Router Bypass and Saving Cost using Point-to-Multipoint Transceivers for Traffic Aggregation

Antonio Napoli[(1)], Zdravko Stevkovski [(2)], José D. M. Jiménez[(3)], Edward J. E. Zuleta[(3)], Johan Bäck[(4)], João Pedro[(5)], Julia Rodriguez[(6)], Rafael Diaz[(6)], Jose Carrallo[(6)], Atul Mathur[(7)], Juan P. F.-P. Gimenez[(3)], Fady Masoud[(8)], Dave Welch[(7)]

[(1)] Infinera, UK; [(2)] Infinera, Germany; [(3)] Telefónica, Madrid, Spain; [(4)] Infinera, Sweden; [(5)] Infinera Unipessoal Lda, Portugal; [(6)] Infinera, Spain; [(7)] Infinera, USA; [(8)] Infinera, Canada;
anapoli@infinera.com; zstevkovski@infinera.com

Abstract: We propose combining point-to-multipoint coherent transceivers with a hybrid ROADM/filterless line system to enable a flatter IP-architecture for cost-effectively scaling metro-core/access networks. Considering various traffic and link engineering scenarios, we show CAPEX savings exceeding 40%.

1. Introduction

The telecommunications sector is experiencing a significant change with respect to where data are generated. Long-haul optical links connect large cities, countries and continents with high-capacity transponders [1], transporting traffic aggregated in metro and access networks. IP traffic is growing rapidly with the deployment of 5G and IoT, driven by an increase in the number of connected devices and the data they generate and consume [2]. The traffic pattern in this segment of the network is hub and spoke, and the traffic is transported over a network built with point-to-point (P2P) transceivers and successive electrial aggregation stages. Emerging point-to-multipoint (P2MP) transceiver solutions would be a more natural fit for this type of traffic [3,4].

In this work, we consider the deployment of P2MP coherent transceivers within a layer 0/3 (L_0–L_3) network of a general communications service provider (CSP), illustrated in Fig. 1. This topology includes five hierarchical layers (HL)s from access (HL_5) to core (HL_1) [4]. We aim at simplifying the connections between HL_5 (metro-access) and HL_3 (metro-core) by making use of P2MP transceivers.

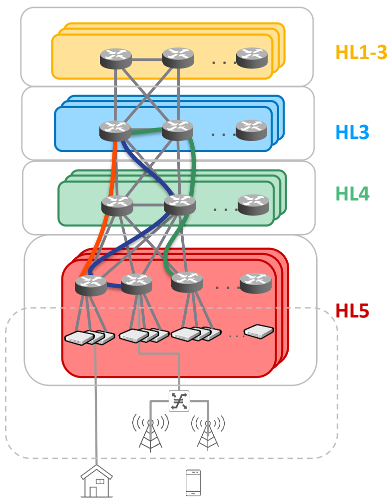

Fig. 1: Telefonica network topology architecture with the five hierarchic layers (HL).

The analysis comprises (i) assessing the optical transmission performance of the links to establish the maximum distances that could be covered; and (ii) comparing the techno-economics of our proposed solution – based on P2MP – against one based on P2P. Finally, we report that by enabling intermediate aggregation router bypass – in a reconfigurable optical add/drop multiplexer (ROADM) with 100G/400G P2MP transceivers, capital expenditure (CAPEX) savings of above 40% with respect to P2P solutions can be achieved.

2. Telefónica Network Architecture: benefits and considerations

This analysis follows two general design principles: (i) using a hybrid ROADM / filterless architecture; and (ii) leveraging a ROADM metro core to transport full 100G/400G coherent optical carriers from $HL_5 \rightarrow HL_3$ and vice versa. In this investigation, we propose to extend the use of coherent technology, employing P2MP coherent transceivers to bypass the intermediate layer at HL_4 when transmitting services directly from HL_3 to HL_5. While HL_4 routers cannot be necessarily be removed, they need fewer line ports, less switching capacity, and can be dedicated to local service termination and east-west traffic.

By using P2MP coherent transmission, the scalability of HL_5 nodes – which required to address, e.g., new 5G antennas or more high bandwidth end-users – is guaranteed, because it is possible to upgrade directly to 50G or 100G traffic capacities without adding or replacing optical transceivers [3]. At the HL_3 nodes, capacity can be added over time as aggregated traffic from subtending HL_5 nodes grows, providing a natural pay-as-you-grow cost curve. Another benefit of connecting directly HL_3 to HL_5 is the improvement in round trip delay associated with bypassing the HL_4 router. Reducing the number of active components would also positively impact the reliability, which could be quantified in a separate study.

Underpinning it all is a flexible yet cost-effective optical line system, where ROADMs in the metro core switch aggregate optical channels and access rings are implemented with a cost-effective filterless architecture.

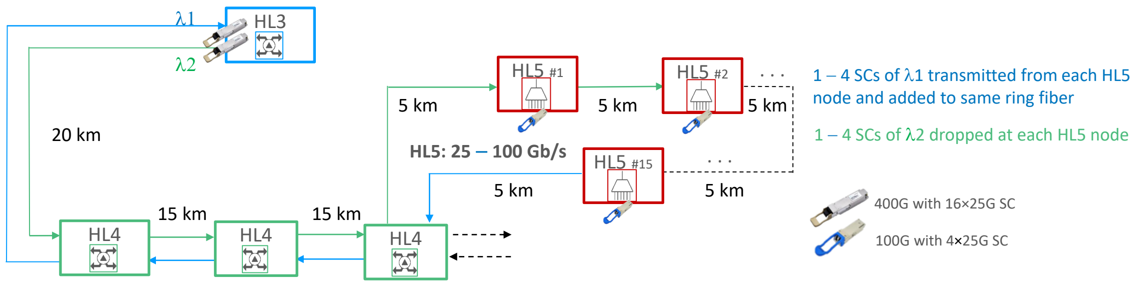

Fig. 2: Considered block diagram with the link engineering analysis.

3. Link Engineering for P2MP Transceiver Deployment

Fig. 2 shows the block diagram of a typical link – based on the network architecture depicted in Fig. 1. It describes the physical layer considered for evaluating the optical performance of our network when transmitting from HL_5 to HL_3 and vice versa.

We model the physical layer following Telefónica's requirements. We assume standard single mode fiber (SSMF), with an average fiber loss of 0.25 dB/km plus 0.5 dB/splice. The distance between each HL_5 nodes is 5 km. The HL_3 transceiver provides aggregate capacity of 400 Gb/s, and it transmits -12 dBm per 25G sub-carrier; while the HL_5 transceiver, operated at up to 100 Gb/s, transmits at -6 dBm per 25G sub-carrier (or -3 dBm per 25G sub-carrier if limited to 50 Gb/s max). Finally, the distance between each HL_4 router is 15 km, whereas the last HL_4 and HL_3 are 20 km apart.

To provide a comprehensive assessment of the transmission performance, the number of HL_4 and HL_5 nodes has been varied. HL_4 nodes are assumed to be commercial ROADMs with a 100 GHz window per P2MP channel. The amplifiers used in the HL_5 rings in the analysis are based on commercial amplifiers used in metro deployments [5]. The impact of realistic power error and ripple from each component is included in the analysis as it cascades through the link and adds to degradation of the optical signal-to-noise ratio (OSNR).

After extensive numerical simulations, where we varied the number of HL_5 from 1 to 15, and the number of HL_4 from 1 to 8, we concluded that – with operating OSNR margin of 1 dB – 14, 10, and 5 HL_5 nodes could be supported, when traversing 3, 4, and 5 HL_4 respectively. Translated to distance, this means HL_5 nodes can be located up to 115 km away from the HL_3, providing the operator the opportunity to realize significant traffic aggregation across a larger metro region.

4. Techno-Economic Analysis

In the P2P architecture, connecting $HL_3 \rightarrow HL_4$ is normally done via 100G coherent transceivers, while the connections $HL_4 \rightarrow HL_5$ could, in principle, be bridged by 25G gray optics. In the P2MP scenario, the 100G capable coherent transceivers would be deployed in the HL_5 nodes. Here, the distances $HL_3 \rightarrow HL_5$ can be >100 km, which according to the analysis reported in Sec. 3 is achieved with sufficient OSNR margin.

For the economic analysis, a comparison of the CAPEX of these two scenarios was performed. The capacity demand at HL_4–HL_5 is considered to grow from 25G up to 100G in 3 steps. The logical network topology from the HL_4 to HL_5 nodes is simple hub-and-spoke. In the P2P scenario, within the HL_4 router equipment, a typical statistical multiplexing of 1:5 (20%) is assumed, which contributes to reducing the traffic capacity on the section $HL_3 \rightarrow HL_4$. This is a variable parameter and can be adjusted according to a real case.

The main results of our techno-economic analysis are reported in Fig. 3. For the abstraction of the network displayed in Fig. 1, Fig. 3(a) and (b) contrast the P2P topology (where the complete aggregated traffic passes through the HL_4 router considering statistical multiplexing), with a P2MP architecture, where the HL_4 router is bypassed for the connections between $HL_5 \rightarrow HL_3$. For this analysis, we consider up to 16 HL_5 network elements. Fig. 3(c) reports the CAPEX for the two considered scenarios, showing the relative values and the percentage savings for the 3 traffic growth steps and for 3 different cases of HL_5 network elements (4, 8 and 16). The calculation indicates lower CAPEX for all considered models when P2MP capable transceivers were deployed, due to the lower number of transceivers required in the aggregation layer and lower occupation of the router ports. The savings are higher as the traffic load per HL_5 access node is growing.

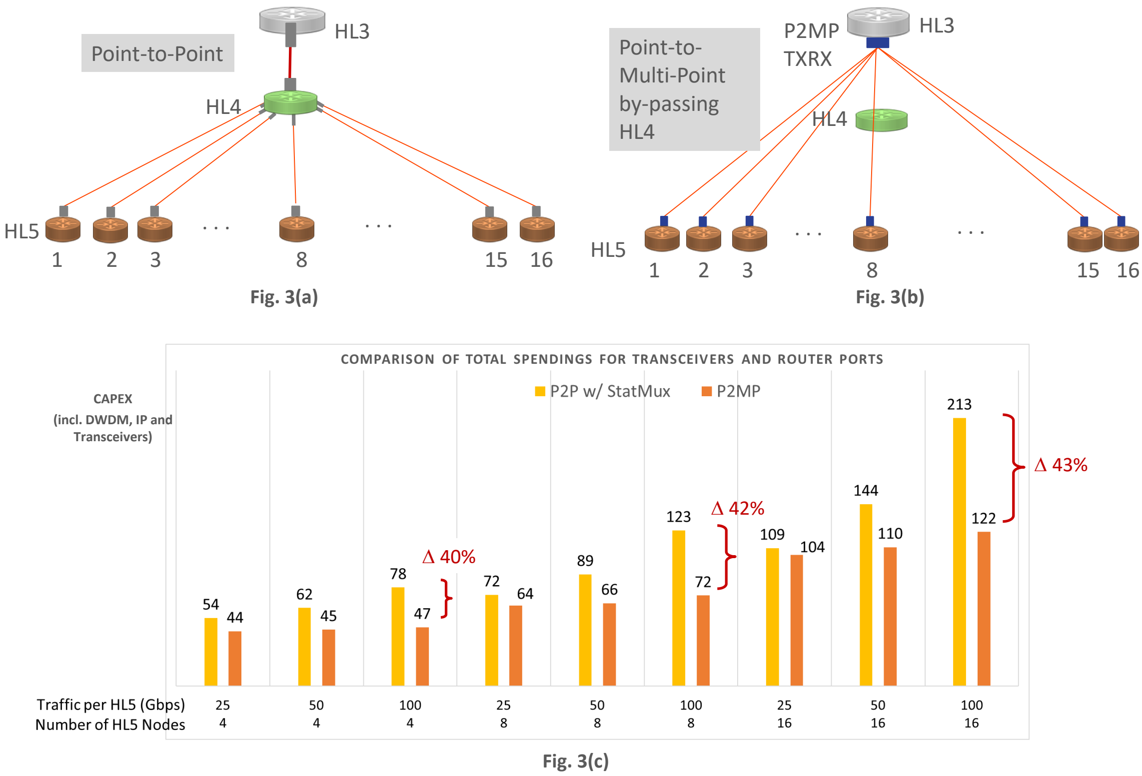

Fig. 3: Considered network abstraction for the techno-economic analysis (a) with P2P transceivers, and (b) with P2MP transceivers; c) Total transceiver CAPEX for P2P and StatMux in HL4 (yellow) and P2MP (orange).

5. Conclusion

We present a comprehensive analysis that shows the potential of point-to-multipoint coherent technology when applied to converged metro-core and -access networks. After assessing the optical performance, we carried out a techno-economic analysis which showed a CAPEX reduction above 40% when deploying point-to-multipoint transceivers with respect to point-to-point transceivers. Future investigations could include the operational advantages of the proposed architecture, quantifying savings from a reduction or elimination of site visits, automated and dynamic capacity allocation, remote troubleshooting and service turn-up.

References

1. H. Sun, M. Torbatian *et al.*, "800G DSP ASIC design using probabilistic shaping and digital sub-carrier multiplexing," J. lightwave technology **38**, 4744–4756 (2020).
2. "Cisco Annual Internet Report (2018-2023) White Paper," https://www.cisco.com.
3. D. Welch, A. Napoli *et al.*, "Point-to-multipoint optical networks using coherent digital subcarriers," J. Light. Technol. **39**, 5232–5247 (2021).
4. J. P. Fernández-Palacios, J. D. M. Jiménez, V. López, Ó. G. de Dios, and D. Larrabeiti, "Zero-touch elastic optical networks using sliceable bandwidth variable transponders," in *2020 22nd International Conference on Transparent Optical Networks (ICTON),* (IEEE, 2020), pp. 1–5.
5. J. Hernández, M. Quagliotti, L. Serra, L. Luque, R. López da Silva *et al.*, "Comprehensive model for technoeconomic studies of next-generation central offices for metro networks," J. Opt. Commun. Netw. **12**, 414–427 (2020).