# Live Network Demonstration of Point-to-Multipoint Coherent Transmission for 5G Mobile Transport over Existing Fiber Plant

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***Abstract*** *We report a live-network demonstration of coherent point-to-multipoint technology for mobile fronthaul applications with total transmission capacity up to 100 Gbps per radio unit and 400 Gbps per hub. We show significant network simplification enabled by coherent technology and Nyquist subcarriers.*

## Introduction

IP data traffic is increasing at a faster rate in metro and access than in the core network[1]. 5G deployment may further amplify this divergence by a factor 20[2]. Existing mobile transport uses optics (from the antenna to the data center (DC) for example), generally employing intensity-modulation direct detection (IM-DD)[3]. Passive optical networks (PON)s, with time-division multiplexing (TDM), dominate modern mobile transport front haul[4].

Coherent optical technology's footprint currently ranges from submarine applications to DC interconnect[5]. 400ZR is an important milestone in terms of cost, power consumption and footprint for coherent interfaces, and it has inspired further initiatives that leverage pluggable coherent interfaces in more demanding applications in terms of transmission[6]. However, bandwidth increments are in steps of 400G, even if the actual bandwidth demand might be lower, even below 100G.

Current optical network architectures are largely point-to-point (P2P). IP traffic, however, especially in access and metro, is predominantly hub and spoke. Here, it will be argued that a more efficient and cost-effective network architecture would natively support point-to-multipoint (P2MP) and replace electrical with optical aggregation.[7].

With the advent of 5G/6G, the cost-effective scaling of capacity in these network segments will be challenging with current technology and architectures. For example, mobile network operators (MNO)s are divesting their cell sites to real estate investment trusts (REIT)s, which rely on signing up multiple MNO tenants per site to increase profitability. These REITs might in turn plan to offer capacity services to their tenants, further driving up the traffic requirement per cell site. This scenario might benefit from replacing TDM with frequency domain multiplexing (FDM), since the latter allows faster scaling and heterogeneously adapting capacity. FDM techniques, realized with digital subcarrier multiplexing (DSCM)[8], can better exploit the tower resources in terms of network optimization and number of tenants.

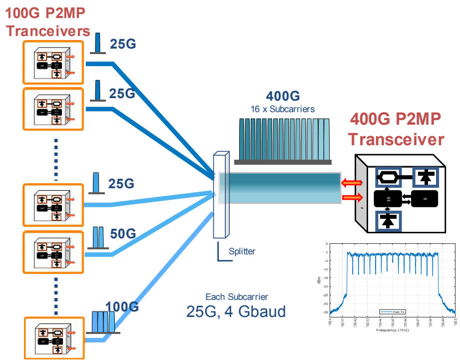


**Fig. 1:** Enabling high-capacity aggregation networks with digital subcarrier multiplexing and coherent technology.

In this contribution, we describe a field trial carried out by American Tower and Infinera, with P2MP coherent optical transmission in a carrier PON network environment for 5G fronthaul applications. We demonstrate how DSCM-based P2MP pluggables can be applied to existing networks, without the need to procure separate fibers for the DWDM link. In particular, the trial presented here demonstrates the seamless compatibility of coherent technology with existing GPON traffic over a single-fiber brownfield PON deployment in a metro regional area. This proof-of-concept shows the ability of operators to take advantage of the transformative value that coherent technology can deliver to existing network infrastructure.

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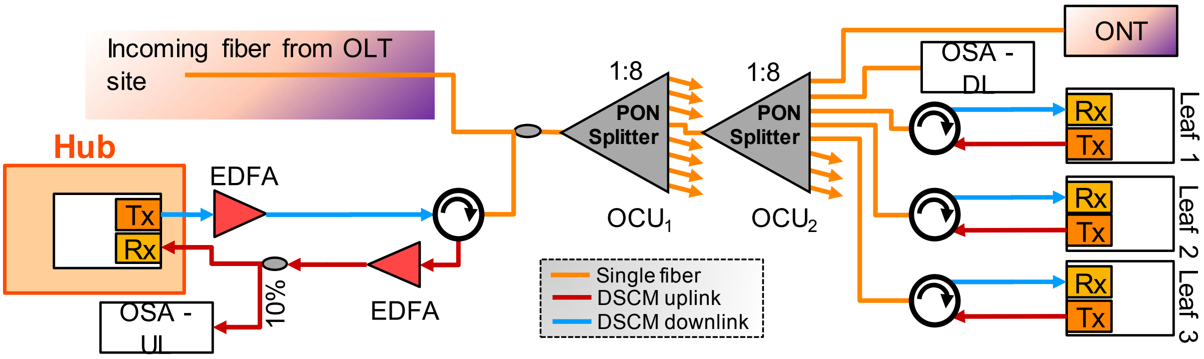


**Fig. 2:** Considered test-bed during the field trial.

## Technology background and network scenario

Figure 1 illustrates a P2MP optical system where the traffic is generated by numerous low-speed coherent transceivers, aggregated by an optical coupler into a DSCM channel with 16×25 Gbps SCs each at 4 GBaud and with 16-quadrature amplitude modulation (16QAM). This channel occupies 64 GHz (i.e., can be assigned a frequency slot equal or larger than 75 GHz in a DWDM link).

This approach has been proposed as a way to match the hub and spoke data traffic requirements and the transceivers' capabilities[7]. In the context of this work, the selected application scenario is important, as it paves the way for operators to leverage coherent and P2MP technology to cost-effectively launch new revenue-generating services and 5G, and in particular to enable the evolution of networks for new edge data center and 5G applications.

## Description of the field trial

Figure 2 illustrates the field trial carried out in Bogotá, Colombia. A 400G P2MP hub is connected to three leaf nodes – Leaf$_{1,2,3}$ – over a brownfield PON optical infrastructure. The hub broadcasts up to 16×25 Gbps SCs employing 16QAM, while Leaf$_{1,2,3}$ use up to 4×25 Gbps SCs each, also with 16QAM. Each SC transmits at 4 GBaud. After the hub, the 400G signal is fed to a booster Erbium-doped fiber amplifier (EDFA) that compensates for the link losses – fiber, optical coupler unit (OCU), PON splitter, circulators – before entering a circulator.

After the first circulator, a $1:2$ optical coupler unit (OCU$_1$) multiplexes PON traffic from an optical line termination (OLT) with the 400G channel from the hub. Between the coupler and the circulators, all channels propagate over single bidirectional fibers. The coupler is followed by two $1:8$ splitters (OCU$_2$ and OCU$_3$) which resemble a typical $1:64$ splitting ratio of a PON architecture. The two splitters account for ~20 dB of loss.

After the splitters, the co-propagated channels are received by an array of terminals: (i) by an optical network terminal (ONT) in the case of the OLT channel ; (ii) by an optical spectrum analyzer for the 400G signal (OSA); and (iii) by Leaf$_{1,2,3}$. These are equipped with circulators, which combine the transmitted and received channels from the leaf nodes onto the single bidirectional fiber. Between the second circulator and each leaf node, we have a pair of fiber patch cables. The leaf to hub path is identical.

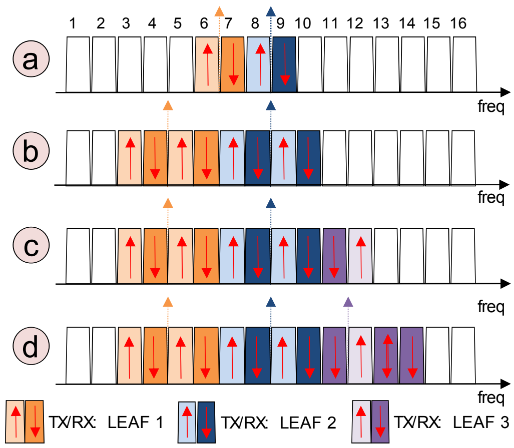


**Fig. 3:** Tx/Rx tested configurations.

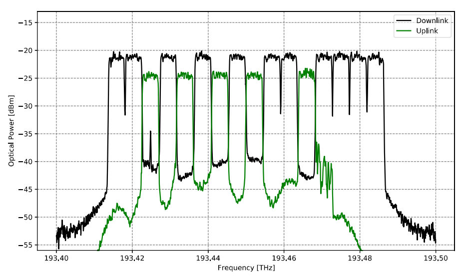


**Fig. 4:** Tx/Rx spectra for configuration ⓓ.

## Experiment and discussion

Figure 3 lists the SC configurations considered during the field trial. The same transceivers are employed in the up and down link, made possible by selecting some SCs in the up and others in the

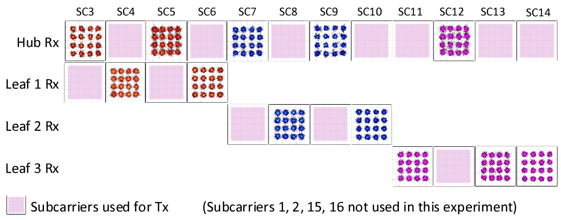


**Fig. 5:** Tx/Rx constellations for configuration ⓓ.

down direction. These selections were set by the software running on the hub and leaf nodes. The capacity to change their allocations in response to instantaneous traffic demand is a key aspect of our proposal[9] and a fundamental requirement of next generation optical networks.

The demonstration starts with configuration ⓐ of Fig. 3. Here, the hub assigns $SC_6$ in uplink and $SC_7$ in downlink to $Leaf_1$ and $SC_8$ in uplink and $SC_9$ in downlink to $Leaf_2$.

Next, more SCs are added to $Leaf_1$ and $Leaf_2$ This is configuration ⓑ, where $Leaf_1$ occupies positions $\{3, 4, 5, 6\}$ and $Leaf_2$ $\{7, 8, 9, 10\}$. In both cases, we increase the uplink and downlink throughput to/from each leaf by $+25$ Gbps.

The last two configurations, ⓒ–ⓓ, include traffic to/from $Leaf_3$ and demonstrate both symmetric and asymmetric traffic between the hub and this leaf. Particularly, in configuration ⓒ, we assign to $Leaf_3$ $SC_{11}$ and $SC_{12}$ for uplink and downlink transmission, respectively. In configuration ⓓ, we add more downlink SCs to $Leaf_3$, so that a final asymmetric throughput is obtained (25 Gbps uplink, 75 Gbps downlink).

Figures 4–5 show the measured spectra and constellations – in uplink/downlink – for configuration ⓓ. All constellations shown in Fig. 5 correspond to a pre-FEC bit error rate (BER) low enough to guarantee post-FEC error free transmission.

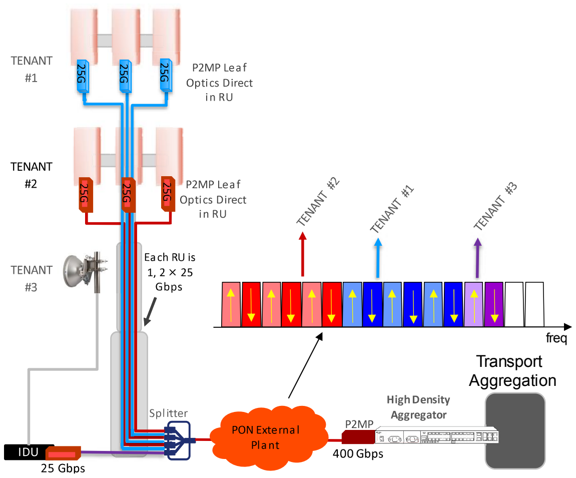


**Fig. 6:** Envisioning next generation mobile transport networks. RU: Radio unit; IDU: Indoor unit.

## Envisioning a future architecture for Mobile Transport Networks

Figure 6 describes an application of the P2MP technology presented in Fig. 2 to a typical mobile optical transport use case, where a mobile tower can host several tenants (three in this case - two at 75 Gbps each and one at 25 Gbps), with each one possibly requiring a different capacity. All tenants are equipped with devices transmitting and receiving up to 4 SC transmitting at 25 Gbps.

The approach tested in the field trial provides significant benefits in the scalability and simplification of the network architecture obtained by smart pluggables operating at e.g., 100 Gbps or 400 Gbps per node with 25 Gbps granularity. It can lead to important reductions in capital expenditure (CapEx) and operating expenditure (OpEx), while enhancing network scalability. The solution represents a paradigm shift in the way mobile transport networks can be built, promising a dramatic reduction in the total cost of ownership (TCO).

## Conclusions

The live demonstration of 400 Gbps point-to-multipoint transmission over a single-fiber PON infrastructure for 5G fronthaul applications reported demonstrates the feasibility of the proposed technology and the important savings and scalability improvements enabled by the simplified architecture.

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