



Introduction to Applications of XR Optics to Coherent Optical Communication Networks

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ABSTRACT:

Introduction to Operating Modes and Network Applications of XR optics.

The Open XR Optics Forum
www.openxropticsforum.org

Open XR Optics Forum

The Open XR Optics Forum is the multi-source agreement (MSA) working group for XR optics, the industry's first point-to-multipoint coherent pluggable transceiver technology. The Open XR Optics Forum's mission is to foster collaboration that will advance development of XR optics-enabled products and services, accelerate adoption of coherent point-to-multipoint network architectures, and drive standardization of networking interfaces to ensure ease of multi-vendor interoperability and an open, multi-source solution ecosystem.

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1 Introduction

XR pluggable coherent optics will enable a fundamental shift in the architecture and economics of optical networks, by creating an architecture built around digital subcarriers that is scalable and multi-generationally interoperable. This technology enables a significant reduction in the cost of deploying and operating optical networks. The applications span from high performance point-to-point connections to access aggregation at the edge of the network. XR optics are industry standard form factor pluggable transceivers, starting with CFP2 and QSFP-DD and evolving into QSFP-28 and OSFP/QSFP-DD for 800G that meet the MSA standards for electrical interfaces, power, thermals, and management (CMIS/CFP MSA MIS as examples). XR optics have basic modes of operation that can be managed just like any other 3rd party ZR+ optics.

With coherent optics, there are three vectors of development that are considered: minimizing space and power consumption, maximizing optical performance and features, and integration of system level features. XR optics balances these three competing objectives to expand the addressable application space beyond that offered by traditional pluggable coherent optics. Smart NRZ optics are pluggable optics in SFP+ form factor that are full L2 service aware and can be managed via the remote headend optic. In a similar fashion, XR optics evolve ZR+ capability by adding point to multipoint (P2MP) transmission capability and features focused on simplifying turn-up, management, and automation.

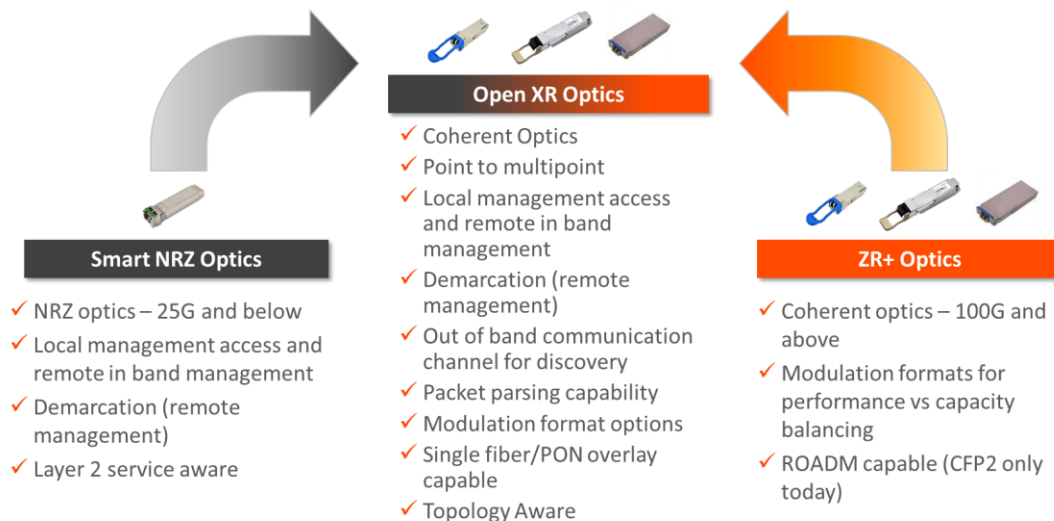


Figure 1: Open XR Optics

1.1 Operating modes

XR optics have 3 primary operating modes:

- Point to Point (P2P) 100G/200G/400G – In this mode of operation, XR optics transceivers are managed just like any other pluggable coherent optic. Added benefits beyond standard optical interfaces include remote management capabilities and support for operation over a single fiber (BiDi mode for operation over single fiber PON networks). The capacity of a 400G Open

XR module is defined using 16QAM modulation; lower order modulations can be used to increase reach at lower capacity. For example, a 400G module can operate at 300G or 200G using 8QAM or QSPK, respectively, to achieve greater reach.

- Breakout Cable 4 x 100G to 400G – In this mode of operation XR optics transceivers look like a 4:1 breakout transceiver (DR4/PAM4) to the host device, which is also DWDM tunable. The difference is that XR optics use a standard single mode fiber connected to a passive splitter (4:1 split) in place of an MPO breakout cable, enabling hundreds of kilometers in reach. Starting with CMIS 4.0 there is a standard mode of operation that enables provisioning of 400G DWDM optics with 4 x 100G lanes. XR optics support additional features, such as LLDP for port discovery. There is also an option to use the Open XR Controller software application to provide additional benefits like topology awareness, advanced alarming, troubleshooting tools, and L1 encryption.
- Flexible P2MP – In this mode of operation, XR optics transceivers can dynamically allocate bandwidth in 25G increments. This capability provides a scalable, flexible, and cost-effective solution by more closely aligning bandwidth allocation with the underlying needs, reducing the statistical multiplexing requirements (and cost), and enabling growth of capacity via simple remote provisioning. This deployment model uses the packet parsing capability in the optics themselves and is managed via the Open XR Controller software application.

Additional information on the Open XR Controller can be found in the Open XR Management Architecture document.

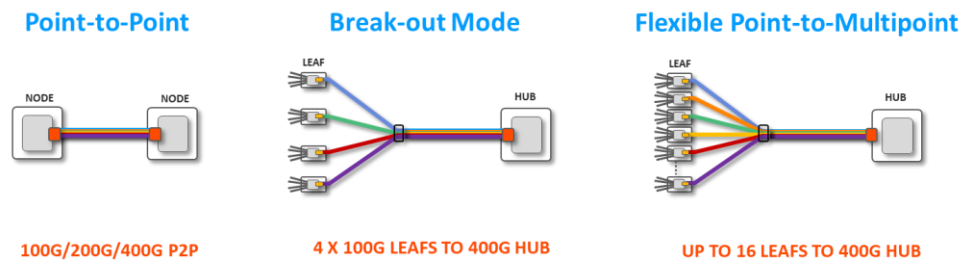


Figure 2: XR Optics Operating Modes

2 Point to Point Application

One differentiator for XR optics in the P2P mode of operation, relative to other pluggable options, will be the high performance in both CFP2 and QSFP-DD form factors; general reach is shown in Figure 2 below. The reach in an unamplified system is dictated by attenuation. In a single span amplified design the primary limit to reach is the Rx OSNR, which is a function of both the allowable launch power into the fiber and the noise figure of the amplifier(s) being used. Raman could be used to further increase reach, which would open additional applications, such as festoon cables. For the extended reach application over a line system, the performance is dictated by several items: fiber type, span losses, add/drop count, amplifier types and multiplexing structure. The maximum reach can be obtained with a dedicated line system between 2 points using hybrid EDFA/RAMAN amplifiers.

Initial XR optics will be in QSFP-DD or CFP2 module form factors, but the DSP can be placed into other module form factors, or directly into on-board optics/equipment instead of a pluggable module.

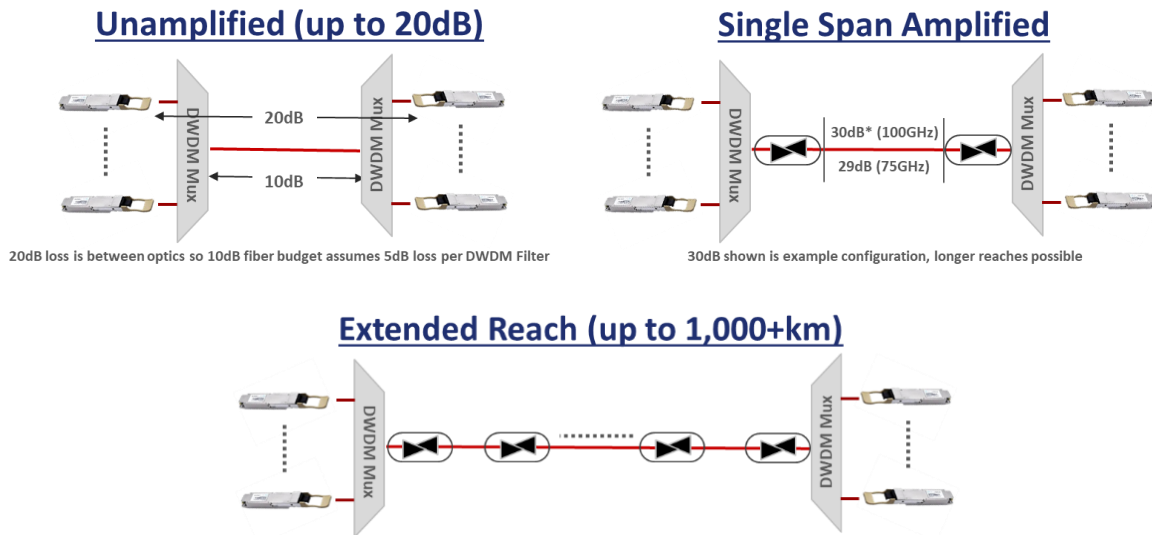


Figure 3: XR Optics Point to Point Reach Estimates

Beyond high performance, there are several other key advantages to using XR optics transceivers in P2P modes of operation:

- The subcarrier implementation enables single fiber BiDi applications, which can be used cost-effectively for a single fiber customer extension or PON overlay;
- The in-band and out-of-band management channels enable auto discovery, turn-up, and remote optical demarcation, where the XR optical transceiver installed in an end customer router is managed via the headend XR optical transceiver, removing the need for a NID device to demark the service at the customer premises;
- A built-in optical spectrum analyzer can be leveraged for fiber characterization or potentially as an OTDR function;
- Multigenerational XR optics provide operational flexibility to a network operator by enabling the ability to upgrade one end of a link from 400G to 800G independent of the other end of the link;
- The same module can be used in P2MP applications, simplifying the overall network architecture and maintenance.

3 Metro Broadcast Ring Application

XR optics introduce a paradigm-shifting opportunity to create optical P2MP networks that dramatically lower the cost and complexity of access, metro and even core networks. Most all-optical networks today are built using a series of bookended P2P optical links. However, the network traffic is typically between a set of lower capacity sites and a smaller number of higher capacity hubs, or P2MP. XR optics are built specifically to address this asymmetry.

Digital subcarriers enable optical aggregation of the traffic from multiple lower capacity XR optical transceivers into a single higher-speed XR optical transceiver. This reduces both the number of optical modules by 50% and the need for intermediate and expensive electrical multiplexing devices, such as leaf switches or aggregation routers. The technology enables a user to take advantage of the better cost-per-bit that higher speed optics offer, while simultaneously deploying less network capacity by leveraging the 25G granular capacity assignments.

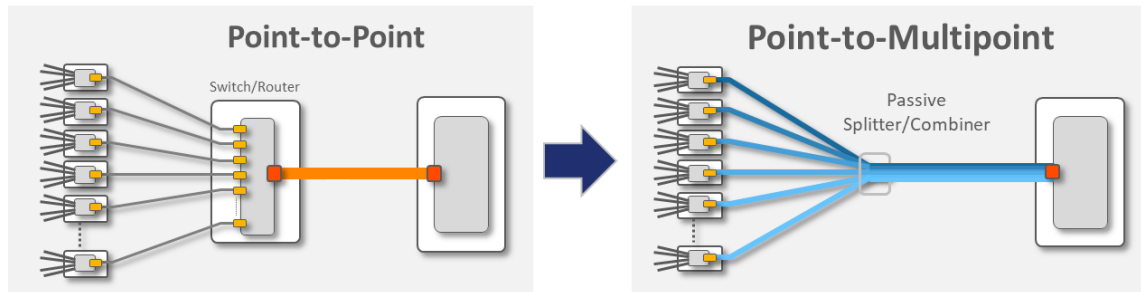


Figure 4: XR Optics Point to Multipoint Comparison

In a greenfield build scenario, a broadcast ring or horseshoe line system is an ideal architecture to take advantage of XR optics' P2MP capability. This enables the Hub site to broadcast out as much capacity as needed in aggregate for the entire ring, enables each Leaf site to consume as much capacity as it needs in 25G increments, and allows dynamic reallocation of bandwidth without any changes in the line system. The Hub site can easily scale with multiple 400G optics (and, in the future, 800G+ optics) seamlessly to take advantage of the lower price per bit. Similarly, the Leaf sites can be right sized, whether 25G or 400G+ is needed at a site, only deploying the capacity required. This architecture can also remove an electrical aggregation layer in the network, whether a muxponder, leaf switch, or aggregation router.

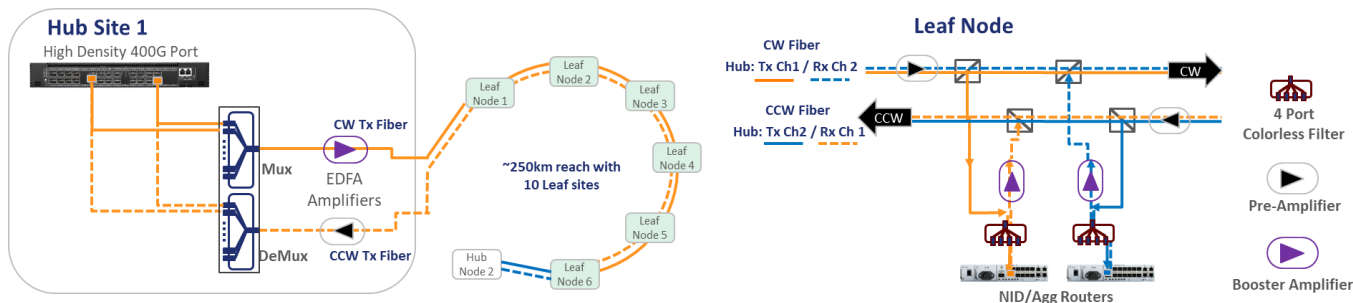


Figure 5: Metro Amplified Broadcast Ring

The line system is made up of EDFA amplifiers and passive splitters/y-cables. There are options to create reusable templates at every site, or to minimize line amplifiers and only deploy them as reach and performance dictates. The reach of the application varies by fiber plant and topology, but typical deployments should expect to be able to support 8-10 sites on a ring, at distances up to 250km. Once an XR optics architecture has been adopted, the future upgrade path also improves. Any Leaf site

could be upgraded from 100G to 400G to 800G optics at any point in time, without impacting any of the other sites across the ring. If the service provider wants to upgrade from 400G routers/ports to 800G to achieve a better cost per bit, that site can be upgraded without requiring any changes to the other sites, creating a disaggregated nodal upgrade model.

4 Metro ROADM Network Application

XR optics can work over an existing ROADM network in P2P applications, just as any other pluggable DCO. P2MP applications over a ROADM infrastructure are currently being evaluated. The application breadth is determined by the underlying operational requirements of the line system, with the largest dictating factor being the optical channel monitor function. One option is for XR optics to transmit over the ROADM infrastructure as a 400G P2P wave, and then at the far end hit a splitter as the signal exits the ROADM Mux/Demux card, creating an extended breakout cable function. In the opposite direction, all subcarriers would be combined to create a 400G signal back in the other direction.

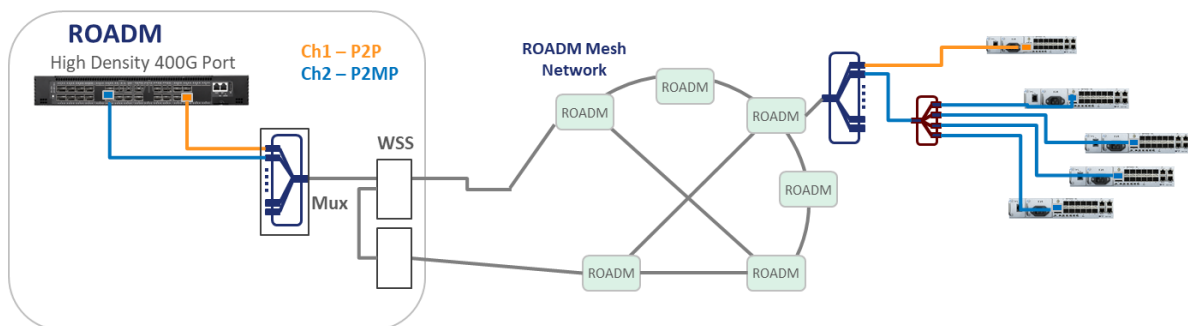


Figure 6: Metro ROADM Ring

5 Metro Access Application

The true technological differentiation of XR optics – its flexibility and enhanced feature sets – are demonstrated even more fully closer to the access edge of the network. Access networks are typically broadcast in nature and commonly deployed as single fiber architectures. Whether we consider campus ring topologies, passive tree architectures, PON overlay architectures, or Enterprise/wavelength extensions, the deployment guidelines are all similar. In the access space, service providers are faced with a tough question when they need to upgrade beyond 10G: should they upgrade to 25G or to 100G?

Upgrading from 10G to 25G presents several challenges. Today's architecture has an aggregation device that aggregates up to 24 SFP/SFP+ client ports into a 100G uplink, north bound to the spine layer. As client port bandwidths move above 10G, the 100G uplink will only support six 25G clients on average. This bandwidth increase, in turn, drives the requirement for additional aggregation devices for the same number of clients. The central office at the edge of the network may also be experiencing space and power limitations, unable to satisfy these increased demands. Further compounding the problem may be a need to add incremental services, such as edge compute, to access sites.

In access networks, the OPEX associated with planning, engineering, installing, and turning up devices is more than the CAPEX of the equipment itself. Assuming 30% YoY growth, upgrading to 25G only provides a lifecycle of a few years before another upgrade would be required. As a result, beyond the space and power concerns, upgrading from 10G to 25G does not meet the requirements of a 5-10 year technology lifecycle. XR optics eliminate a large consumer of space and power -the aggregation devices - and so help to solve the space and power limitations around bandwidth scaling and enabling new service types in the central offices.

When upgrading from 10G to 100G, only 15%-20% of the capacity is used initially, so additional stat muxing devices are needed at the central office for an efficient utilization of the uplink network connection. XR optics can operate at any bandwidth in 25G increments, so a user can install 100G optics but operate them efficiently without the need for a separate stat muxing device. In addition to eliminating the need for the aggregation device, a large part of the CAPEX savings comes from the fact that at the Hub site, a single 400G XR optic can service up to 16 x 100G XR optics.

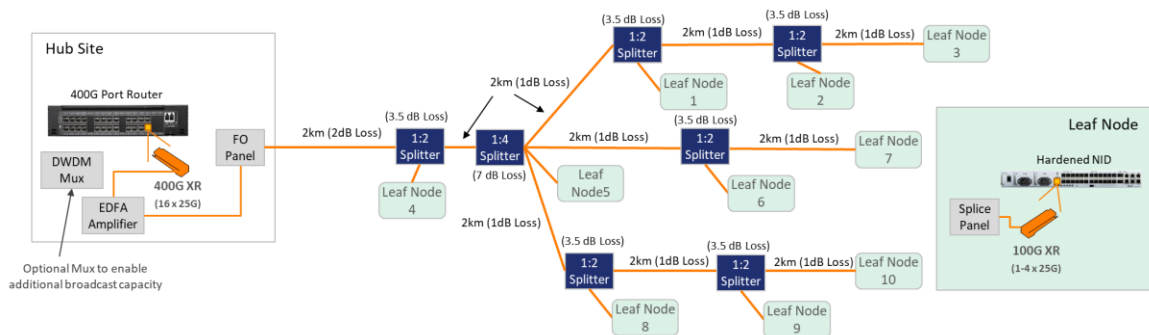


Figure 7: Access Broadcast Tree Application

For access applications, a broadcast architecture enables the user to allocate bandwidth dynamically to any site when needed, which has historically been one of the primary benefits of using a PON architecture. This broadcast network can take many different forms, but the end requirements for XR optics remain the same. Two of the most common architectures are the broadcast tree or ring, as shown in Figures 7 and 8, respectively. Figure 8 shows a working-and-protect configuration, with the orange color denoting transmission to the “working” router and the blue color denoting transmission to the “protect” router. Each Leaf node transmits both to the working and the protect router, in a standard 1+1 configuration. Both Figure 7 and Figure 8 represent a completely passive line system, with an option to add an amplifier at the Hub site for extended reach. This keeps the cost, space, and power profiles low for the Leaf nodes in the access network. Figure 9 shows a simplified version of the access tree, where there is a single splitter used, similar to a PON application.

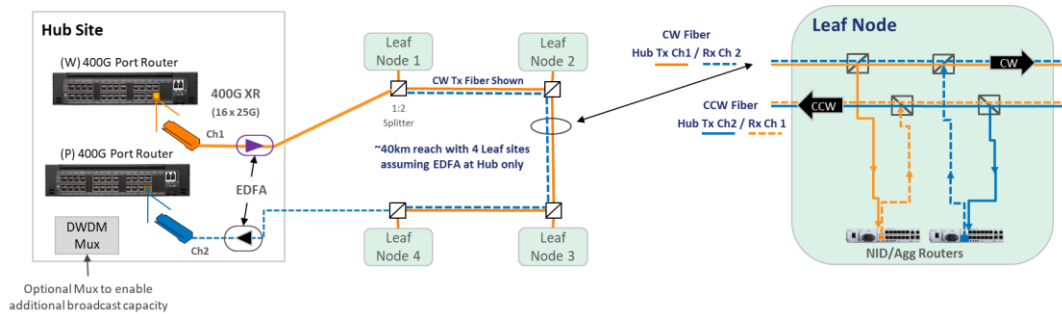


Figure 8: Access Broadcast Ring Application

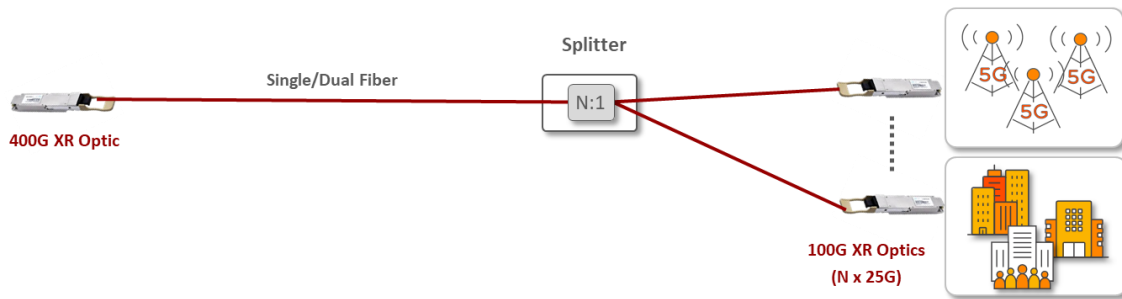


Figure 9: Access Fanout Application

Another access-centric solution is PON overlay. Their single fiber nature has typically limited PON capacities. DWDM capabilities for service rates above 25G are typically coherent, and a coherent module has a single optical subassembly for both Tx and Rx, giving rise to the need to transmit and receive on the same frequency. As a result, to date, large capacity single fiber working (SFW) solutions need a dual laser solution for the uplink and downlink capacity. With XR optics, users can allocate subcarriers for uplink and downlink individually, and thus efficiently enable coherent level capacity over an existing PON infrastructure. One option is to use a coexistence module (band mux) at the Hub side in the central office/local exchange building, to enable XR optics to use the same PON splitter/combiner in the access edge of the network, as shown in Figure 10. There is also an option to place a second coexistence module in the access side, to reduce the split ratio and extend the reach of the XR optics signal even further.

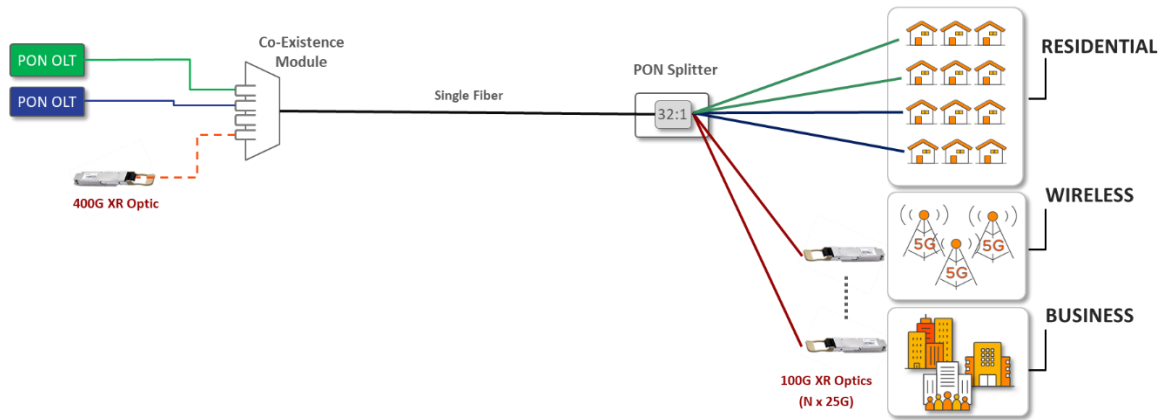


Figure 10: PON Overlay Application

6 Additional Applications

Additional applications are being considered. Some applications may rely on more complete host integration or the next generation of silicon. This document is a working document that will be updated as the applications grow and evolve over time.