

WDM-PON: A key component in next generation access

Summary

The last mile “access bottleneck” has been broken, but service providers can expect new challenges in bandwidth scalability thanks to the industry move toward higher definition video and Ultra High Definition Television (UHDTV) broadcast standards, and as more IP video, IPTV and personalized IP-based services are consumed.

This strong continued pressure in terms of rapidly growing bandwidth demand and limits to capital availability have led ILECs to leverage their installed base of TDM PON technologies and legacy copper network as long as possible. The need for extreme cost reduction that aggressive service pricing has placed on the access network has further compounded the problem. Meanwhile, municipalities, utilities, and building owners have found a business case supporting the roll out of point-to-point Active Ethernet solutions for FTTx.

Clearly the bandwidth scalability, QoS, and traffic patterns that will be required by video and broadcast standards will make copper access inadequate in the future. For the fiber based solutions currently being deployed, neither xDSL, TDM PON, nor active point-to-point Ethernet is the answer to the broadband requirements imposed by the next generation of bandwidth intensive, differentiated multimedia services and video traffic.

What operators will need to support new services and bandwidth and QoS requirements is a more scalable, centralized and future proof solution. For example, a passive optical access network that offers the disruptive economics carriers need while supporting symmetrical traffic patterns for business and the new QoS and latency requirements being driven by enterprise, mobile and residential subscribers.

WDM-PON leverages fiber and passive wavelengths to provide the most scalable, cost effective, and future proof solution available to address the capacity, security, and distance capabilities that service operators require while leveraging the benefits of a passive infrastructure. All these factors combine to make WDM-PON poised to become the disruptive next-generation access solution. It will enable high speed access for business, mobile backhaul, and eventually FTTH, while also enabling operators to build converged networks and consolidate the access network, eliminating Central Offices to reduce cost and significantly increase competitiveness.

There are several approaches to WDM-PON that vendors are developing today, with a number of proprietary approaches, and it will take considerable time for the standardization process to run its course. It will also take significant time for many of the WDM-PON solutions that have been proposed to date to gain the level of maturity needed to fully progress down the cost curve and become cost competitive across a wide variety of network applications.

But there is no need to wait for scalable, high capacity access bandwidth that supports symmetric as well as asymmetric traffic patterns and provides secure access at competitive cost. Transmode’s iWDM-PON solution gives operators these advantages for network applications such as enterprise access and mobile backhaul aggregation. In these cases the business case is already proven.

Transmode’s WDM-PON solution allows operators to enjoy the benefits of a scalable, low cost, passive and centralized optical architecture today, while extending optical transparency from the core to the access network. The solution provides an open, standards-based approach that also helps operators avoid stranding assets and embrace future standards, while retaining the flexibility to expand the solution to include more cell site backhaul and FTTH as WDM-PON technology progresses further down the cost curve.

The time for WDM-PON – assuming that the solution is open, flexible, standards based, and cost optimized – is now. Transmode’s iWDM-PON solution offers operators a no risk entry point today and a future roadmap tomorrow. iWDM-PON is a key enabling component in an operator’s next generation access strategy.



The need for WDM-PON

The last mile bandwidth bottleneck has been broken, but that does not mean that the challenge of overcoming access constraints has become a thing of the past. Service providers can expect a new bandwidth bottleneck in the relatively near future. This is due to the industry evolution toward higher definition video and UHDTV broadcast standards such as ITU BT 1201, ITU 1769 and SMPTE 2036 that are being introduced. Also, as more IP video, IPTV and personalized IP-based services are consumed the problem is compounded.

High bandwidth applications such as storage networking, video streaming, cloud-based software as a service (SaaS), collaborative computing, and online gaming and video sharing will also be contributing factors driving greater demand for ultra high bandwidth connections with low latency and differentiated QoS. Furthermore, in the case of the enterprise market, symmetrical traffic patterns will also be required.

Figures 1 - 3 show the kind of bandwidth that will be required by the enterprise, mobile network, and residential subscriber in the future as new video content and broadcast standards emerge and influence the bandwidth requirement of business customers and mobile users.

Business customers' requirements
Security requirements for networked resources and information must be reliably available but protected from unauthorized access.
High level QoS features must ensure end-to-end application performance on symmetric services.
Mission-critical distributed applications must be deployed and managed on a network-wide basis.
Support for the convergence of previously disparate data, voice, and video networks resulting in cost savings for the enterprise.
Easier deployment of productivity-enhancing applications, such as enterprise resource planning (ERP), e-learning, and streaming video.
Massive scalability and low latency for mission critical disaster recovery applications
Flexibility to support thousands of sites with Pay-as-you-go scalability as companies expand, merge, or consolidate.

Figure 1: Business customers' access requirements

Mobile users' requirements
Symmetric service at the base station
Support of LTE bandwidth requirements
Scalable fiber infrastructure, secured and not shared
Fault isolation to avoid the propagation of dropped calls and reduce churn
Synchronization distribution for efficient handoff between BTS/NodeB/eNodeB and remote sites, with support for multiple synchronization streams for wholesale scenarios
TDM support for backhaul of 2G/3G/4G traffic

Figure 2: Mobile backhaul network requirements

Speed	Application
Nx100 Mbps	Fast download of multiple Blue Ray DVDs, UHDTV, hyper HD gaming, telemedicine.
50-100 Mbps	Multi-streaming HDTV, VoD, HD telepresence.
35-50 Mbps	2 HD DVRs, HSIA, fast sharing for high resolution photo albums.
10-15 Mbps	SD IPTV
5-25 Mbps	HSIA

Figure 3: Residential User Requirements

Any new access network built today is a major investment that must offer long-term scalability, investment protection, a truly future proof solution, and disruptive economics. But each of the short term choices have weaknesses. Legacy xDSL networks have practical limitations on bandwidth, QoS, and in offering symmetrical capacity. Active point-to-point Ethernet solutions do not offer the required ease of scalability or cost advantages of a passive optical outside plant. GPON scales to 1 Gbps per user in theory, in practice the bandwidth offered is frequently no more than 100 Mbps Fast Ethernet. This is primarily due to the impact of factors like split ratio and distance. TDM PON and active point-to-point Ethernet solutions do not offer the disruptive economics of a truly centralized, passive architecture, allowing central office consolidation. In addition, Active Point-to-point Ethernet solutions do not offer easy scalability or the benefits of a truly centralized, passive architecture.

TDM PON does not offer the required degree of scalability, and to be truly cost effective, higher split ratios that sacrifice distance are required, and the kind of strong security required by mission critical applications can be a problem on any shared-access media. While it is true that TDM-PON standards continue to evolve in the short-term, it is also clear that this evolution is unlikely to provide the scalability or disruptive economics that will ultimately be required. WDM-PON is emerging as the preferred long-term solution.

The only way that service providers will be able to cost effectively scale to meet bandwidth requirements needed today and in the future will be to use fiber, passive plant, and the dedication of a wavelength per customer. The passive infrastructure will be required to achieve the OpEx cost efficiencies required, and to provide an easy means to achieve the high scalability, security, symmetrical bandwidth, and centralized architecture that will be needed. Low cost tunable lasers, colorless light sources and temperature hardened optical filters in passive outside plants are integral parts of this solution.

Introducing passive WDM into the access network also allows consolidation of access into a single, highly scalable architecture that backhauls traffic to centralized data centers or central offices, and switches at the lowest possible layer, providing low latency performance. By avoiding multiple layers of data aggregation, protocol conversions, and wavelength conversions, more efficient access network can be built that supports the long-term strategy to eliminate active sites and consolidate Central Offices, while scaling indefinitely to meet future demand.

WDM-PON solutions could also provide one access solution that can address business, mobile backhaul, data storage, and even FTTH requirements over time.

WDM Standardization Roadmap

Figure 4 shows the planned enhancements to standardization for the different PON solutions.

The FSAN/ITU-T agreement upon the final recommendation for XG-PON1 will be followed by NG-PON2. While XG-PON1 is an upgrade to existing TDM-PON standards, the NG-PON2 standard is a new approach for which WDM-PON is a strong, leading candidate.

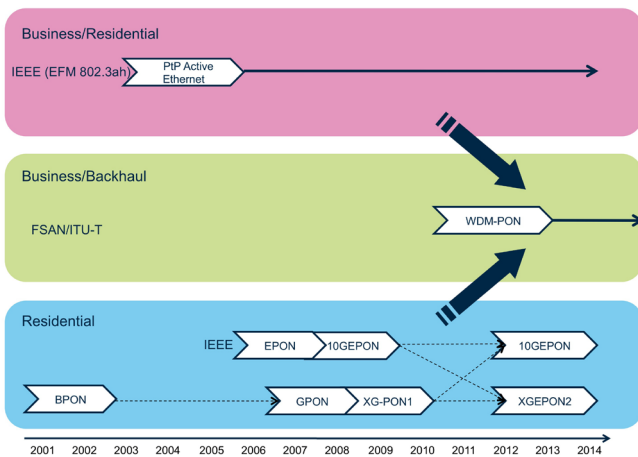


Figure 4: Roadmap for next-generation PON solutions standardization.

Advantages of WDM-PON

WDM-PON solutions provide the dedicated bandwidth of a point-to-point network with the fiber sharing inherent in PON networks. The architecture is somewhat similar to that of EPON and GPON, except an AWG (Array Waveguide Grating) filter separates the wavelengths for individual delivery to subscriber ONTs, being used instead of the splitter used in TDM-PON architectures.

A key advantage of WDM-PON is the use of a completely separate downstream wavelength for each of the subscribers. This separate wavelength provides more bandwidth to each subscriber, better security, and enhanced operational control since there is no potential interference between wavelengths in the downstream direction. Figure 5 shows a generic WDM-PON architecture.

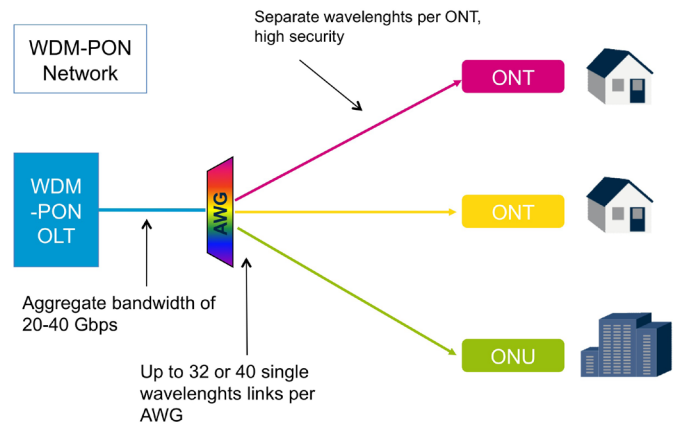


Figure 5: Generic WDM-PON architecture

Given its ability to help service providers survive current bandwidth demand as well as the next potential broadband access bottleneck, WDM-PON has become an important technology to consider, both in terms of its benefits and its market timing. As with any emerging technology, service providers need to consider the right strategy for initial deployment of WDM-PON. This includes how they can use WDM-PON for additional network applications in the future as the technology matures and costs come down and how they can potentially avoid stranding additional investments in BPON, GPON, and EPON technologies. These other technologies cannot be expected to scale to provide the bandwidth required at the cost per bit that will be needed in the future. The impact of WDM-PON technology on the opportunities to increase distance and split ratio, streamline the operations model, and enhance security are also important to understand.

Barriers to greater WDM-PON deployment

WDM-PON is a promising technology, but the cost of many of the early WDM-PON solutions proposed are simply too high during the early stages of this technology's development. It will take time for WDM-PON to mature and progress down the cost curve to the extent required for viable commercial pricing. Initially, WDM-PON will be more cost effective in access network builds for business services, storage networking, and some mobile backhaul aggregation or very large cell site needs. Additional cost reduction will enable WDM-PON to become commercially viable in addressing a larger portion of mobile backhaul requirements, and in addressing the price sensitive FTTH market.

An important factor that will reduce the cost of WDM-PON to meet the needs of FTTH as well as those of the enterprise will be the introduction of standard, colorless ONTs. The use of a single, standard ONT will result in higher production volumes that will translate into significant cost reduction for manufacturers. This degree of standardization will also reduce the complexity and cost of deployment, maintenance, and sparring, helping further decrease OpEx and TCO.

Another important factor in cost reduction is the work of international initiatives such as the GigaWam project, an effort sponsored by the European Community targeting cost reduction for WDM-PON. The intent of this initiative is to drive down costs for WDM-PON components such as tunable lasers, Fixed Laser arrays, Athermal AWG and Hybridization and integration of photonic components.

Types of WDM-PON Solutions

There are three types of colorless WDM-PON solutions under development:

- Reflective schemes: where the upstream optical carrier is remotely generated (typically at the C.O.) and sent to the ONT, where it seeds a modulating device (RSOA, REAM, IL-FPLD). A reflective scheme is shown in Figure 6.

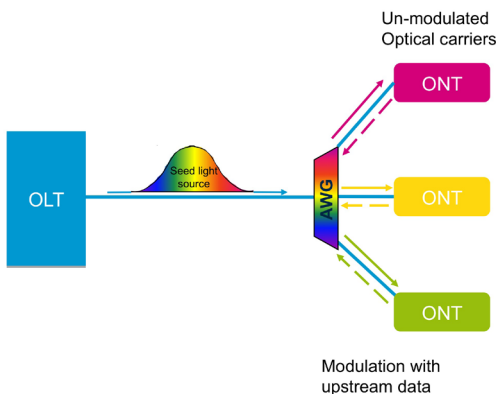


Figure 6: Reflective scheme

- Tunable lasers at the ONTs: where the upstream optical carrier is locally generated at the ONT. This is still a costly option, but ongoing research as well as the maturing of the technology in the industry will drive down costs over time. This type of solution is shown in Figure 7.
- Wavelength reuse is a solution where the downstream channel is re-modulated by the upstream signal and sent back to the CO, and this is shown in Figure 8.

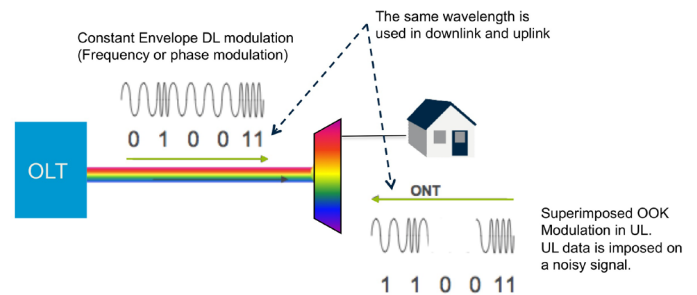


Figure 7: Tunable laser at the ONT

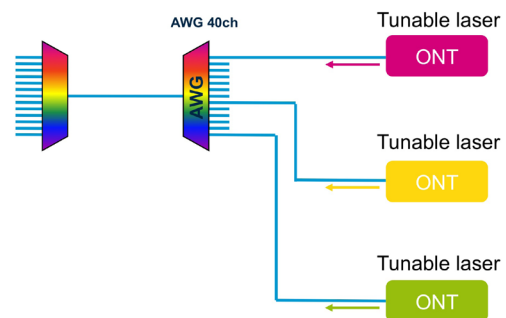


Figure 8: Wavelength reuse

What operators need to consider in WDM-PON

Operators need a WDM-PON solution that is open and standards-based, that protects the installed base of WDM, that simplifies operations, and that provides greater distance capabilities, end-to-end transparency, and ease of scalability.

Innovation that provides the certainty of improving the current business model today while leaving open flexible choices in the options available tomorrow is always desirable, particularly when it comes with flexibility and the ability to achieve a high level of consistency in operations to help drive a business case forward.

Conclusion

WDM-PON will play a key role in the future of access networks, providing unparalleled scalability as well as the cost advantages of a passive solution and the strategic benefits of more efficient converged access. While the business case for WDM-PON continues to evolve and will gradually embrace more applications in the network, operators need to evaluate the technology now and begin deploying it where the business case makes sense. But to do so, they need to have every assurance that they will be able to fully leverage this investment going forward, will have flexible options at their disposal, and run no risk of “stranding” assets in the process.

Optical transparency from the access network to the core, low cost, enhanced SFPs, the ability to mix and match passive with active interfaces where needed while leveraging the same DWDM platforms, the operational simplicity of leveraging the DWDM grid metro-wide, are just a few of the advantages of WDM-PON based solutions can provide. Transmode’s roadmap also includes leveraging colorless interfaces at the ONT to preserve the cost advantages of passive plant while ensuring performance and distance capabilities, and enabling FTTH solutions that make full use of the often limited single fiber asset available in the residential market.

Abbreviations list:

- AWG** – Arrayed Waveguide Grating
- BPON** – Broadband Passive Optical Network
- CWDM** – Coarse Wavelength Division Multiplexing
- DL** – Downlink
- DSL** – Digital Subscriber Line
- DWDM** – Dense Wavelength Division Multiplexing
- EPON** – Ethernet Passive Optical Network
- FE** – Fast Ethernet
- FTTx** – Fiber to the x
 - FTTB** – Fiber to the Building
 - FTTC** – Fiber to the Curb
 - FTTH** – Fiber to the Home
- GbE** – Gigabit Ethernet
- GPON** – Gigabit-capable Passive Optical Network
- IEEE** – Institute of Electrical and Electronic Engineers
- ILEC** – Incumbent Local Exchange Carrier
- LTE** – Long Term Evolution
- ODN** – Optical distribution network
- OLT** – Optical Line Termination
- ONU** – Optical Network Units
- ONT** – Optical Network Terminal
- PON** – Passive Optical Network
- SFP** – Small Form Pluggable
- UHDTV** – Ultra High Definition TV
- UL** – Uplink
- WDM** – Wavelength Division Multiplexing