WHITE PAPER / **OPTICAL FIBER OPPORTUNITIES**

EVALUATING PASSIVE OPTICAL NETWORKS FOR ELECTRIC UTILITIES

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Passive optical networks (PONs) are a flexible, scalable communication architecture. Utilities might be able to leverage existing assets and infrastructure to deliver enhanced, efficient and secure service through PONs that stand tall in comparisons with many wireless approaches.

The electric utility industry trends of voltage optimization, renewable energy integration, distributed generation and the development of a smarter grid aren't going away. As utilities work to address the ever-growing demands for data and device connectivity, a passive optical network (PON) has the potential to help optimize operations.

With an established network of valuable assets, infrastructure and secured rights-of-way, utilities are well-placed to benefit from PON technology. A PON represents an opportunity to optimize fiber-optic infrastructure to manage both legacy and new assets, especially distribution automation (DA) or voltage optimization (VO) devices. Leveraging a PON can increase efficiency in handling alternative energy sources, distributed generation, and the complications of variable renewable energy supply as the grid continues its transformation. Additionally, a PON could open new applications for the deploying utility.

WHAT IS A PASSIVE OPTICAL NETWORK?

PON architecture replaces structured cabling and uses optical splitters and point-to-multipoint (PMP) topology to deliver broadband access to multiple devices in a range of locations.

Optical networks are considered an especially effective solution for spanning the "last mile" to provide connectivity to a range of possible fiber-to-the-x (FTTx) end users. Both a PON and an active optical network (AON) are options to address this last mile of telecommunications; the difference is how broadband is delivered:

- **PON:** Beginning with an optical line terminal (OLT) at a central provider's office, a PON uses a single fiber-optic light source that runs through a passive optical splitter. The signal is multiplied and relayed to many other optical network terminals (ONT) and on to end devices. PON architecture uses encryption that allows each ONT to only access and deliver content addressed to the designated endpoint. The PON design is unique as the optical splitter uses prisms and is passive, requiring no electrical power to operate. The splitter can also act bidirectionally and receive data traffic using multiplexing. PON capabilities and capacities continue to evolve, achieving an increasing number of splits to accommodate larger numbers of FTTx applications.
- **AON:** The conventional design of an AON uses a dedicated fiber-optic line to manage signal data and direct signals for point-to-point communication. Unlike a PON design, an AON requires electric-powered routers, switches and equipment to be installed between the OLT and end device to enable dedicated fiber point-to-point broadband for end users.

BENEFITS AND CHALLENGES

As utilities continue to seek ways to improve efficiency, optimize cost and manage customer demand, exploring the potential advantages and challenges of a PON architecture is essential.

BENEFITS

- **Cost**: A PON can offer lower capital, installation and operating costs than many single-purpose networks. This is because it requires no additional equipment or ongoing power demand, and wear and tear on moving components, cables and cooling equipment is minimized. Likewise, the uniformity of equipment requirements reduces ongoing maintenance and equipment refresh costs associated with any one program or initiative.
- **Installation:** PONs can be easy to install, integrate and operate on an existing communication network. Any existing fiber or wireless systems could be incorporated into the PON architecture, making better use of the investment. Since additional powered equipment is not necessary, a high-voltage electrician is not required, and wiring cabinets and network changes are eliminated or minimized.
- **Security:** By design, PONs offer protection with optical fiber characteristics, immunity to electromagnetic interference, and less cabling, routers and switches. These features reduce network vulnerability. Similarly, a PON has limited network access controls and minimal human interaction.
- **Flexibility:** PONs offer advantages in non-core utility applications, including serving most internal broadband needs. Additionally, the deployment of dark fiber opens the door for the development

of alternative revenue streams. The many FTTx architecture options provide utilities the opportunity for a range of execution strategies and business opportunities.

FIBER TO THE X

Electric utilities have much of the infrastructure in place to install and leverage optical fiber in their existing networks. As a result, a range of configuration options, referred to as fiber-to-the x (FTTx), is possible, each utilizing optical fiber for "last mile" connectivity.

Configuration options continue to expand, but current FTTx configurations include:

- **FTTP (fiber to the premises): fiber optics that terminate at a defined place.**
- **FTTH (fiber to the home): optical fiber ends at a home or business boundary. One FTTH network structure is passive optical networks (PONs).**
- **FTTB (fiber to the business/building/basement): optical fiber that terminates at the boundary of the property.**
- **FTTA (fiber to the antenna): fiber optics send signals to a remote radio head to the top of a cell tower.**
- **FTTA is the backbone architecture for 5G technology.**
- **FTTN (fiber to the node/neighborhood): optical fiber stops at a streetside cabinet, which then uses existing copper or coaxial cables to deploy signals to the end user.**
- **FTTC (fiber to the curb/closet/cabinet): fiber-optic cabling is configured to end about 300 meters from an end user's premises.**

CHALLENGES

- **Infrastructure:** One of the biggest hurdles for utilities is routing and deploying the fiber-optic cables themselves. Overhead installations, whether optical ground wire (OPGW) or all-dielectric self-supporting (ADSS), can present challenges in the form of line outages, pole calculations and third-party attachment coordination. Underground installations also often run into environmental and regulatory hurdles. Utilities regularly overcome these issues, but such issues should be accounted for in any deployment plan and timeline.
- **Reach:** Many factors should be considered to maximize the range of a PON. Considerations include the number of splices and splitters, type of optical fiber used, and kind of light source.
- **Troubleshooting:** Test access should be planned during installation to avoid disruption for other PON system users when troubleshooting is needed.

APPLICATION TYPES

The deployment of optical fiber for better communication and management provides electric utilities with a wealth of application opportunities. Unlike many of the single-purpose networks deployed in the past, utilities can expect PON applications to evolve and expand over time. There are already several use cases worth considering for utilities:

- **Distribution automation:** PON optical fiber connects utility offices and substations within a distribution network to maintain reliability and security for critical operating infrastructure. Utilizing a PON can help simplify the complexity of using multiple networks for better automation, operational insight and grid resiliency.
- **Energy optimization:** By operating DA/VO devices to constantly adjust the voltage range and reduce the threshold of voltage delivery, utilities can control load concentration on the grid. The density of these devices can be achieved with PON architecture more easily than with many wireless solutions.

- **Renewables:** Renewable energy production continues to grow, resulting in numerous distributed generation installations and small microgrids that connect to the main electric grid. The PMP topology of a PON can aid in monitoring and transforming storage and transmission of the power generated by distributed installations into the larger electric grid.
- **Smart metering:** The FTTx nature of a PON scheme is ideal for smart metering applications because a single fiber can service multiple metering devices on the main trunk of the fiber-optic circuit. A PON scheme allows whole neighborhoods to be serviced by one optical fiber or fiber-optic pair, potentially reducing costs in comparison to many wireless architectures.
- **Reliability:** End-user demand for service will continue to grow. PONs can handle the bandwidth requirements for video surveillance of assets, substations, plants and equipment to keep systems operating. The specific purpose of a PON is to provide a connection to multiple devices through a single fiber. However, those devices do not necessarily need to be of the same type or have the same data requirements.
- **Operational integration:** As data crosses many boundaries, so do responsibilities and communication needs. Utilities can use PONs to break down internal and departmental communication barriers for improved operational integration and efficiency, allowing multiple services to ride the same fibers through the same network infrastructure.
- **Broadband access:** A PON is often the most economical method of providing connectivity to underserved communities. PONs can handle multiple end users without dedicated service to each device, and they require minimal equipment and investment to deploy. PONs are efficient in terms of allocating physical fiber resources. This often results in a surplus of unused fiber for uses other than the utility's primary service.

IS A PON RIGHT FOR YOUR UTILITY?

End users' demands call for a modern grid that must evolve to collect and manage more data from more sources, more reliably and securely. Fiber optics are one way to address these demands, and utilities are positioned to deploy fiber optics and provide optimized service using PON architecture.

While fiber optics is state-of-the-art technology, broad deployment depends on the traditional assets of utilities. Poles, lines, conduit, easements, handholes, rights-of-way and many other assets can prove essential to implement a PON strategy. Utility approaches for deployment could include an engineered plan for shoring up assets to structurally handle fiber installation, or they could extend to leveraging easements and rights-of-way to install PON systems underground.

Utilities need to evaluate their operations in the context of growing end-user demands to identify whether a PON

EVOLVING METHODOLOGIES

Passive optical network (PON) topology can be designed to leverage different technologies and approaches, depending on system specifications and standards. To meet project goals and attain emerging performance benefits, the right PON topology is key. While technology continues to evolve, there are some common approaches to consider:

- **APON (ATM passive optical network) emerged as the first PON standard for commercial applications and used asynchronous time-division multiplexing to encode data.**
- **BPON (broadband PON) improved APON architecture but presented bandwidth limitations that could not effectively handle video.**
- **EPON (Ethernet PON) uses Ethernet packets and is popular in many commercial applications.**
- **GPON (gigabit PON) delivers high bandwidth and fast service using three network layers to provide voice, and Ethernet for data and voice.**

strategy is appropriate. Utilities can start assessing the value of a PON strategy and organizational readiness by considering a few key questions:

- What are the expected demands on power networks over the next 5-15 years? (density, rural, large areas, internal, end user, security, resiliency, etc.)
- What is demanded of the in-the-field asset communications system?
- How can cross-department and internal communications be optimized?
- What are the gaps between demands and readiness?
- Does a fiber infrastructure exist? If so, how can it be utilized?
- What technology options (including PONs) are available to consider? What will be evaluated and by what criteria?

CONCLUSION

A passive optical network can deliver broadband network access to end users, enhance monitoring of utility assets and infrastructure, improve internal communications, and even offer an opportunity for expanded or shared services. In addition, the lack of active-powered devices lowers cost, simplifies installation and reduces ongoing maintenance. Electric utilities should consider PON technology in planning operational readiness to provide reliable, secure and efficient services.

BIOGRAPHIES

DERRICK BIGHAM, PE, is a fiber system engineer and network architect with Burns & McDonnell. He has nearly 10 years of experience in planning, designing and implementing both large and small utility communication infrastructure deployments. Derrick has led overhead and underground fiber installation projects, MPLS network deployments, PON architecture development and deployment efforts, and numerous utility communication system integrations.

JOSHUA SMITH is a fiber and telecom design lead with Burns & McDonnell. He has 15 years of experience in determining the scope, criteria and specifications of highly complex, large power fiber projects involving multiple networks, jurisdictions and disciplines. Joshua has designed, engineered and permitted a range of projects deploying fiber-optic connections, PON schemes, DA/VO distribution networks and more.

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25332-EPO-1021