Original Article

Active Ethernet in Residential Broadband Access Networks

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Abstract - The most popular technology used by a residential and small business broadband provider is Passive Optical Network (PON). In a PON architecture, the available bandwidth is shared among multiple subscribers via passive optical splitters. During peak usage times, heavy consumption by a few users can lead to network congestion, resulting in significantly slower speeds and performance degradation for all other users on the same shared segment. For a broadband Service Provider (BSP) it is a challenge when there are critical businesses to serve and they expect dedicated bandwidth downstream as well as upstream to carry heavy duty uploads for cloud native applications. The architecture of a network defines the performance a subscriber can expect when they opt for a high throughput service. Active Ethernet (AE) which is also sometimes known as point-to-point Active Fiber, is an access technology where each subscriber gets a dedicated fiber connection to the BSP's network.

Keywords - PON, fiber, active ethernet, P2P, Active Ethernet (AE), Passive Optical Network (PON), Broadband Access Networks, Residential Broadband, Small Business Connectivity , Dedicated Bandwidth.

1. Introduction

Fiber-to-the-premises (FTTP) access networks that use point-to-point optical Ethernet links for access are commonly known as Active Ethernet (AE) networks. Active Ethernet architecture offers immense operational and business advantages. By utilizing point-to-point fiber optic connections, BSPs can deliver dedicated, non-shared bandwidth directly to all of their subscribers. This architecture avoids the bandwidth splitting inherently seen in PON systems, ensuring consistent, symmetrical gigabit-plus speeds and guaranteeing superior Quality of Service (QoS) and lower latency, which are critical metrics for performance intensive applications like online gaming, real-time communication, and emerging cloud services. PONs use a single trunk fiber that extends from a central office to a passive optical splitter, which then fans out to multiple optical drop fibers connected to subscriber nodes. Other than the end terminating equipment, no component in the network requires electrical power, hence the term passive. Local carriers have long been interested in passive optical networks for the benefits they offer: minimal fiber infrastructure and no powering requirement in the outside plant [1]. BSPs are often seeing making a transition to AE architecture. The key drivers for such a shift are rooted in economic factors, network performance and long-term scalability requirements. As time progresses, subscribers crave for higher bandwidth as well as businesses with a continuous arc of rising expectations from their network, both of which drive the need to deploy AE for the BSP.

2. Primary Use Cases

2.1. Premium or Low-Density FTTH Deployment

In upscale housing developments or rural communities with relatively low user density, a BSP might run dedicated fibers to each home to deliver top-tier symmetric bandwidth. This is practical when the number of subscribers is small or when a high service quality differentiator is needed, outweighing the cost of extra fiber. In such cases, the network avoids the need for optical splitters and complex bandwidth sharing.

2.2. Municipal/Open-Access Networks

City-owned and governed fiber networks commonly use Active Ethernet to provide a neutral infrastructure where residents can choose among multiple retail service providers. A point-to-point Ethernet design simplifies wholesale access because each the link of individual subscribers can be handed off to multiple providers via VLANs at the central switch, rather than tying all users to a single BSP's PON architecture. Such a BSP-neutral approach can be facilitated by having AE deployment in a subscriber per port method.

2.3. Multi-Dwelling Units and Campus Environments

Broadband services in multi-dwelling units (MDU) or campus networks, often implement the Active Ethernet topology internally. Each unit or apartment can get a fiber to a basement or campus Ethernet switch. In such use cases the distances are shorter, and fiber aggregation is on-site, making the active approach quite manageable for the BSP. Additionally, such environments often demand features like Power over Ethernet (PoE), fine-grained VLAN segmentation, or high upstream capacity for services like security cameras and internal networks. Active Ethernet natively supports these needs as it extends the LAN capabilities over fiber.

3. Active Ethernet Network Elements

Active Ethernet networks are comprised of two primary network elements:

3.1. The OLT

The Optical Line Terminal (OLT) is a shelf equipped with two or more Ethernet line cards containing multiple ethernet ports. The OLT shelf serves as the Ethernet aggregation switch, terminating the optical fiber service drops to Optical Network Terminals (ONTs) that are installed at the subscriber premises providing uplink/transport trunks to the WAN. The OLT is typically environmentally hardened and so can be deployed at the central office or in a remote cabinet to extend the fiber reach.

3.2. The ONT

BSPs and telecom vendors offer a wide array of ONTs that operate in Active Ethernet mode. Each AE ONT is installed at the subscriber premises and terminates a point-to-point fiber. The Active Ethernet ONTs can support a variety of physical optical connections and speeds. For gigabit Ethernet speeds, the Active Ethernet ONT can support either the GigE 2-fiber Small Form-factor Pluggable (SFP) modules or GigE 1-fiber (Bi-directional) SFP modules [3]. The ONT converts optical signals to electrical for service delivery at the premises. Depending on the hardware some ONTs are designed to work in a PON topology, and some to work in AE. Some vendors build ONTs that are adaptable in both topologies and offer a hybrid solution in the same access network.
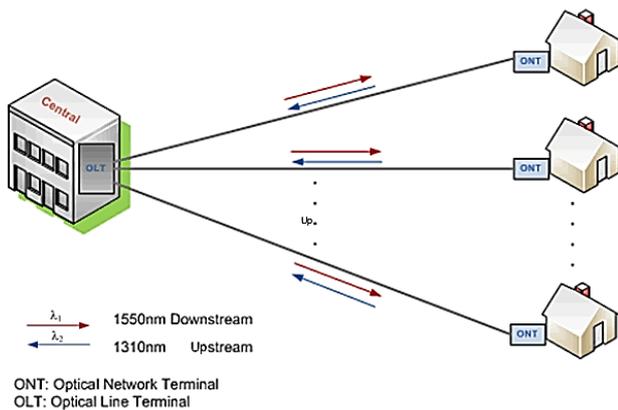

Figure 1. Point-to-point network architecture [2]

4. Deployment of AE

In a BSP's fiber optic access network the deployed OLTs can support two unique AE deployment models based on how the ONTs at the subscriber premises are managed:

4.1. External ONT management model

This is more of a traditional AE deployment model, also known as the pass through model, where the OLT serves purely as an aggregation switch for its Ethernet downlink ports that provide the point-to-point fiber drops to AE ONTs. The OLT forwards services-separated traffic between subscriber ONTs and the WAN, but the OLT does not participate in ONT services provisioning. Instead, a Central office (CO) or back-office array of servers in combination with an Equipment management system provide the required networking and management functions for the active ONTs, including all aspects of services provisioning. Hence the

"pass through" concept model for the OLT. The external management model would be deployed for any ONTs managed exclusively by an ACS via TR-069– the standard protocol for remote management of Customer Premises Equipment (CPE/ONTs). Excellent for provisioning, updates, and diagnostics [4]. To enable "pass-through" AE services, add the appropriate VLANs on the OLT 1GE/10GE downlink ports. From the perspective of OLT provisioning, all services are data services, including the service for ONT management.

The high-level process for configuring an OLT to support AE subscriber services using the external management model follows:

- Create a VLAN for ONT management.
- Create a VLAN for data services.
- Create additional VLANs for other services as needed (voice, video, secondary data, etc.).
- Configure the OLT uplink transport to add the AE management and service VLANs to it.
- Configure a downlink transport just for the OLT service ports and add the AE management and service VLANs to it.
- Configure each OLT ethernet port to support AE services by setting the port's role as a Network to Network Interface (NNI).

4.2. Internal ONT management model

This AXOS AE deployment model leverages a concept like PON by containing all ONT management and services configuration internally on the OLT within the Operating System (OS) using IP communications instead of the optical Network Unit (ONU) Management and Control Interface (OMCI). This approach eliminates the need to use external servers for managing Dynamic Host Configuration Protocol (DHCP) and File Transfer Protocol (FTP) services. The OLT shelf itself provides an internal DHCP server function to issue management IP addresses to the ONTs. It also hosts an FTP server function to push down configuration files and manage ONT operating firmware. The OLT could provide ONT service provisioning. For AE deployments using the internal ONT management model, the OLT serves as an aggregation switch for its ethernet service ports that provide the point-to-point fiber drops to AE ONTs. The OLT manages the ONT operating software as it hosts the required firmware images to push to the ONTs via FTP.

The high-level process for configuring an OLT to support AE subscriber services using the external management model follows:

- Create a VLAN on the OLT shelf for ONT management communications.
- Enable system level AR management mode in that VLAN.
- Configure the OLT ethernet downlink ports to support AE User Network Interface (UNI) services on a per port basis.
- Load the AE ONT firmware image file onto the OLT for distribution to the managed ONTs.

- Create the AE services VLANs on the system for HSI data, voice and video.
- Add all the services VLANs to the transport uplink of the OLT.
- Provision subscriber services on the AE ONTs.

4.3. Which AE deployment model to use?

With some OLTs supporting two different AE deployment mode options, there are several factors that my influence a BSPs decision about which model to use, best determined by addressing the following:

1. Does the OLT shelf contain both, a PON card, and an Active Ethernet card? In other words, is the OLT capable of supporting both industry standard topologies on a single shelf?
   - If the answer is yes, the BSP must use the external ONT management option. The internal management option may not be supported on most OLT with mixed card deployment.

2. Does the BSP already indulge in Active Ethernet deployments using the traditional external ONT management model?
   - The simple answer is yes, the BSP should continue to extend their current deployment model to new AE ONTs instead of opting for two different models.

3. Which types of ONTs will be used by the BSP in their new deployments?
   - If the ONTs being used are old school and support only traditional deployment, then external management would be the only option for the BSP.
   - If the ONTs being used support both type of deployments, then the management can be either internal or external.

4. In conclusion, unless a BSP is certain about the capabilities of all ONTs that will be deployed in their network, the easy decision is to stick with the external management which works with all ONT models.

5. External Management Server

The external management model is implemented with the use of a server in the BSP's network configured with AE services. For Active Ethernet in production use of RHEL or Rocky Linux is popular for their enterprise grade support. The server is secured with firewall rules and SELinux. Multiple ethernet interfaces are configured for management and subscriber traffic. Network setup can be automated using nmcli or Netplan for Ubuntu based systems.

Network management software which runs on Linux is designed to manage the OLT nodes. These systems support Active ethernet for high-performance fiber access. For Red Hat, Ubuntu and Linux networking setup:

Enable Ethernet Interface using newer command:
sudo ip link set eth0 up

Enable ethernet interfaces by assigning IP and turn up:
sudo ip addr add 192.168.1.100/24 dev eth0
sudo ip link set eth0 up [6]

Configure Active Ethernet setup:
nmcli connection add con-name active-ethernet ifname eth0
type ethernet ipv4.method auto
nmcli connection up active-ethernet [5]

6. Difference between AE and PON

Table 1. Comparison Of Active Ethernet And PON Topogies.

Feature	PON	Active Ethernet
Architecture	Point-to-multipoint with splitters	Point-to-point
Network Elements	Passive splitters, no active gear	Active switches, powered gear
Power Requirement	No power in distribution network	Requires power at intermediate points
Fiber Usage	Shared fiber among users	Dedicated fiber per user
Distance	Up to ~20 km	Up to ~10 km extendable
Cost	Lower CAPEX/OPEX	Higher due to active components
Bandwidth	Shared among users	Dedicated per user
Typical Use Case	Residential FTTH	Business, high-bandwidth links

7. Conclusion

Active Ethernet demonstrates clear advantages over PON in scenarios where a BSP needs to prioritize their performance, reliability, and service flexibility. Its point-to-point architecture ensures dedicated bandwidth for each subscriber, eliminating the shared capacity limitations inherent in PON systems. This approach not only provides consistent throughput but also simplifies network management, fault isolation, and scalability. Additionally, AE supports features such as VLAN segmentation, Quality of Service (QoS), and enhanced security protocols, making it particularly well-suited for enterprise environments and applications requiring stringent service-level agreements (SLAs).

While the initial deployment costs to the BSP coupled with power requirements of AE are higher as compared to PON, the investments can translate into superior network performance and operational control. As bandwidth demands continue to surge with the proliferation of cloud services, IoT

devices, and real-time applications, the need for a robust, future-proof access network solution becomes increasingly critical. AE, with its ability to deliver dedicated, high-capacity links and integrate with evolving technologies, is poised to play a pivotal role in next-generation network infrastructures. Its scalability and adaptability position it as a great business choice for BSPs aiming to meet the challenges of future digital demands.

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