

GPON vs. Traditional Switch Network Technology: A Comparative Analysis

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Abstract

The rapid evolution of networking technologies has introduced significant advances with the adoption of Gigabit Passive Optical Networks (GPON) and traditional Ethernet switch networks. GPON, a fiber-optic technology, provides high-speed, cost-effective solutions for large-scale deployments like residential broadband and smart cities. This paper presents a comparative analysis of GPON and traditional Ethernet switch networks, examining network architecture, performance, scalability, cost-effectiveness, and application suitability. Through mathematical modeling, this study examines trade-offs between the technologies in terms of throughput, delay, and network efficiency. While GPON excels in large-scale, cost-effective deployments with passive components, traditional Ethernet switches offer reliable, dedicated bandwidth for performance-sensitive applications. The findings provide insights for network administrators and decision-makers, helping them select appropriate technology based on specific use cases like residential broadband, enterprise networks, and data centers.

Keywords: GPON, Ethernet switches, fiber-optic networks, network architecture, bandwidth, scalability, cost analysis.

1. Introduction

The need for fast internet and reliable networks has risen substantially over twenty years. Data-intensive applications like video streaming, cloud computing, and IoT have exposed the limitations of copper networks. Fibre-optic technologies like Gigabit Passive Optical Networks (GPON) offer scalable, high-speed connectivity over distances. GPON uses passive optical components to provide high bandwidth while reducing costs, making it suitable for urban and rural broadband. GPON operates on a point-to-multipoint framework, where multiple users share a single optical fibre, which is effective for FTTH, smart cities, and 5G networks [1]. However, GPON has limitations in high-data environments, like data centres, where Ethernet switch networks provide better dedicated bandwidth and performance [2]. Ethernet, the most used networking technology, has evolved to meet the rising performance needs of modern applications. Conventional Ethernet switch networks use active components like switches and routers that manage data flow using MAC addresses [3]. These networks provide reliable performance, making them suitable for high throughput, low latency, and secure communication, such as in data centres, financial institutions, and high-performance computing environments [4]. However, conventional Ethernet switch networks require considerable power and maintenance and incur higher infrastructure costs when scaled to meet data demands [5]. Cloud computing and IoT devices require networks capable of handling high data traffic with scalability. Smart homes, enterprise backhaul, and residential broadband services, where cost-effectiveness is crucial, have utilised GPON. GPON's high bandwidth and low maintenance due to passive components make it appealing for budget-conscious deployments [6]. Ethernet switches remain prevalent in enterprise settings where uninterrupted connectivity is essential. Both technologies must advance to meet the requirements of future applications, including 5G, AI, and virtual reality [7]. Both technologies have pros and cons regarding cost, scalability, and performance. GPON networks share bandwidth among users, causing potential slowdowns during peak times [8]. Ethernet switches provide dedicated bandwidth, maintaining steady performance during heavy traffic, but cost more to operate. Software-Defined Networking (SDN) and Network Function Virtualization (NFV) are becoming popular in both technologies, offering ways to automate and manage networks [9]. This paper compares GPON and traditional Ethernet switch networks by examining network design, performance, costs, and scalability. We aim to help network designers, administrators, and decision-makers select appropriate network solutions for home internet, smart cities, and business networks. The paper provides insights into these networking technologies' strengths and weaknesses for current and future communication needs.

2. Overview of GPON Technology

GPON is a fibre-optic technology that delivers high-speed internet, voice, and video services over optical fibres. It uses point-to-multipoint architecture, connecting an Optical Line Terminal to multiple Optical Network Units through passive optical splitters. This design reduces active components while minimising power consumption and cost. GPON supports 2.5 Gbps downstream and 1.25 Gbps upstream speeds for bandwidth-intensive applications [10]. XGS-PON and NG-PON represent next-generation technology, offering 10 Gbps speeds with wavelength division multiplexing (WDM) [11]. GPON effectively delivers fibre-to-the-home services in urban and rural areas, providing cost-effective broadband access where traditional copper infrastructure is costly [12]. GPON serves enterprise networks and smart city applications requiring large-scale broadband deployment. Its passive nature makes it suitable for long-distance connectivity [13], while supporting 5G backhaul networks by providing high-capacity links for cells and base stations. Research on GPON's future focuses on improving scalability, reliability, and flexibility. Next-generation passive optical networks and WDM integration enable multiple wavelengths for data transmission, increasing capacity [8]. Research enhances GPON security protocols against cyber threats. As 5G and IoT grow, GPON's role in providing backhaul solutions becomes critical for modern networks [14].

GPON technology has evolved to meet demands for higher bandwidth, scalability, and network flexibility. A key advancement is XGS-PON and NG-PON2 [11]. These technologies offer symmetric speeds of 10 Gbps, improving upon GPON's 2.5 Gbps downstream and 1.25 Gbps upstream capabilities. XGS-PON is crucial for applications requiring symmetrical connectivity, such as cloud computing and industrial IoT [15].

WDM integration in NG-PON enables multiple data streams at different wavelengths over a single fibre, increasing bandwidth without additional fibre deployment. This enhancement improves network scalability for supporting increased data demands in next-generation networks, particularly 5G backhaul. GPON has become crucial for smart city infrastructures, enabling networks for smart grids, surveillance, and traffic management [16]. The integration of Software-Defined Networking (SDN) and Network Function Virtualisation (NFV) marks a key evolution. SDN and NFV enable dynamic resource allocation and automated management. SDN provides centralised control for real-time adjustments, while NFV virtualises network functions, improving scalability and cost-effectiveness. These technologies optimise GPON deployment while enhancing fault tolerance [17]. Research in GPON focuses on improving security, energy efficiency, and integration with 5G and IoT. GPON serves as a solution for 5G backhaul networks requiring high-capacity connectivity. Research enhances security protocols against unauthorised access. Combining multi-gigabit Ethernet with GPON enables faster interconnection between optical and copper networks. Ongoing research optimises GPON's performance to meet bandwidth demands [14].

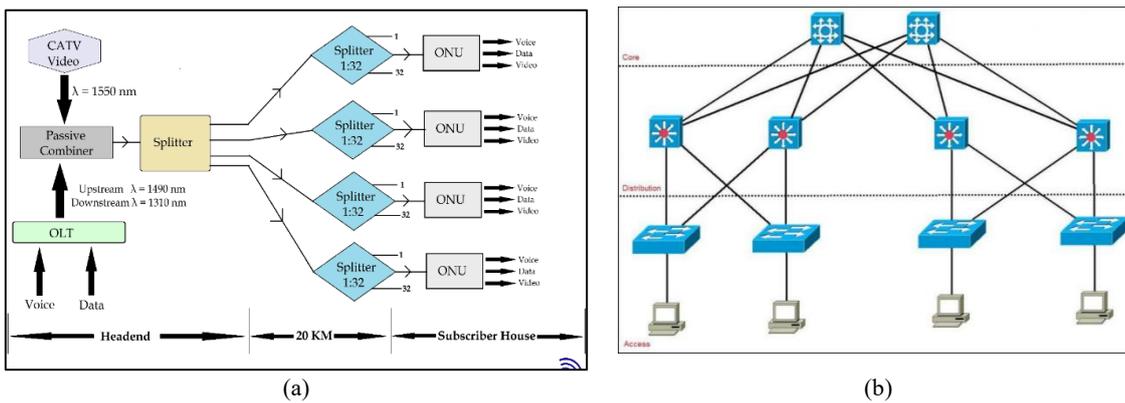


Figure 1: Illustrates the architecture of (a) a GPON network and (b) a traditional switch network. [18]

4. Comparative Analysis

When comparing GPON and Ethernet switch networks, key factors include performance and cost-effectiveness. GPON uses shared bandwidth, which can degrade as users increase. Ethernet networks provide dedicated bandwidth per port, ensuring consistent performance under high loads. This makes Ethernet ideal for low-latency applications like financial trading and data centres [12]. In high-throughput environments, Ethernet outperforms GPON due to non-shared bandwidth. GPON is highly cost-effective for residential broadband and smart city deployments due to lower operational expenses and minimal maintenance. Passive optical splitters reduce active components, lowering energy consumption and maintenance expenses [19]. GPON networks are scalable for large-scale urban and rural deployments, though initial fibre-optic installation costs exceed traditional copper Ethernet in areas lacking infrastructure. Ethernet switches, while suitable for small networks, become costly at scale, requiring more active components that increase both capex and opex [20]. GPON is useful when many users need internet over large areas. On fibre-to-home networks, GPON delivers fast Internet to homes using a point-to-multipoint setup. This method needs less infrastructure than traditional Ethernet networks, which use point-to-point connections [21]. GPON is beneficial for smart cities that need wide coverage. Ethernet is better for businesses because it offers more flexibility and low delay for important tasks, but it needs more complex infrastructure. Research in network automation, software-defined networking (SDN), and network function virtualisation (NFV) has improved both GPON and Ethernet networks. SDN allows centralised network control, making it easier to adjust traffic flow, which improves network performance and efficiency [22].

5. Performance

5.1. GPON vs Gigabit Ethernet (64 users)

Below is Figure 2 to describe the performance of both technologies in terms of the throughput and delay for GPON 2.5 Gbps and switch Gigabit Ethernet (1 Gbps).

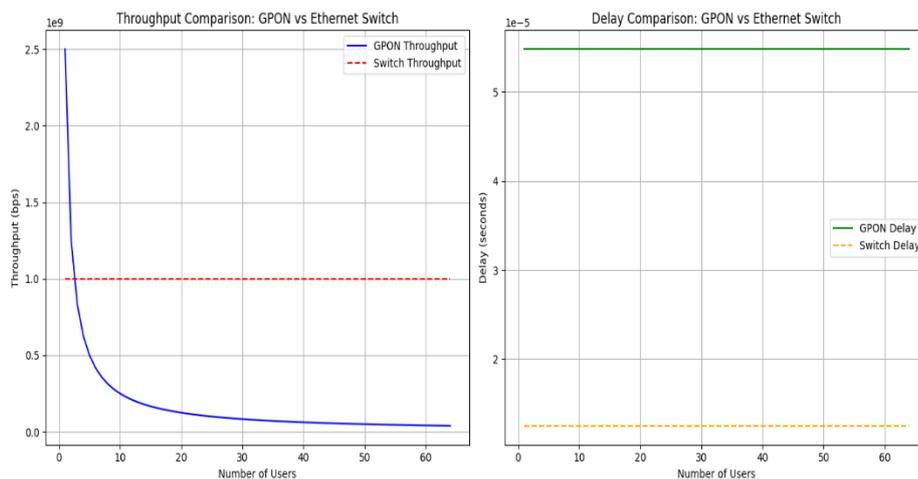


Figure 2. Throughput and delay versus number of users.

Figure 2 compares the GPON and Ethernet switch networks' throughput and delay as users increase. GPON uses shared bandwidth, decreasing it per user as network users grow. When 64 users are present, the GPON throughput decreases due to the distribution of 2.5 Gbps downstream bandwidth among them. Downstream bandwidth divided among users. Ethernet switch networks provide dedicated 1 Gbps throughput per port, ensuring stable performance regardless of users and improving it for enterprise networks. GPON and Ethernet show constant delays because of different factors. GPON's delay is caused by the propagation and transmission of fibre optics, which remains consistent even as the number of users increases; however, shared bandwidth can lead to queuing delays. The propagation and transmission of fibre optics remain consistent even as the number of users increases; however, optics propagation and transmission stay consistent with user increases, though shared bandwidth can create queuing delays. Ethernet switches maintain consistent delays through dedicated bandwidth and full-duplex capability. While both technologies meet delay requirements, Ethernet performs better for low-latency applications.

5.2. GPON, XG-PON, XGS-PON and Ethernet (1 Gbps and 10 Gbps) – Server Room Scenario

In this scenario, each user or port has a dedicated link that provides a specific link speed for all users. The following data represents the results for 62 users.

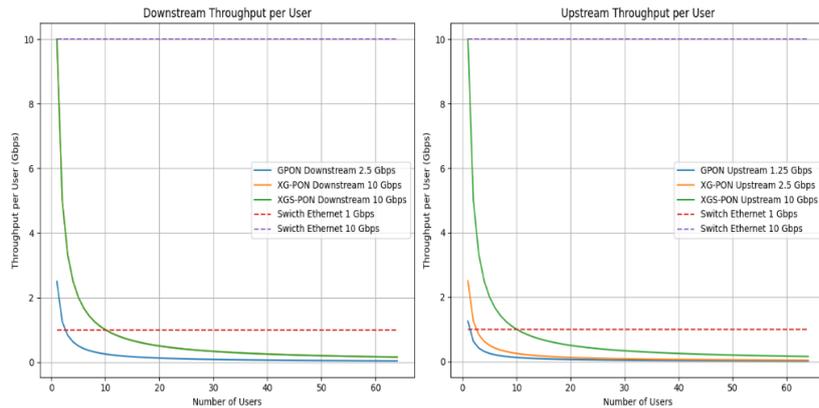


Figure 3. Throughput (Downstream and Upstream) for GPON and Ethernet.

Figure 3 illustrates that the throughput performance of GPON (Gigabit Passive Optical Network) decreases as the user count increases. GPON (Gigabit Passive Optical Network) throughput performance decreases with increasing user count. This pattern indicates that user load influences GPON performance, exposing its limited scalability at higher user densities. Switch Ethernet provides consistent performance per user across both 1 Gbps and 10 Gbps technologies, even as the number of users increases. A flat throughput curve indicates that switched Ethernet can efficiently handle a growing number of users without significantly reducing performance.

5.3. GPON, XG-PON, XGS-PON, and Ethernet (1 Gbps and 10 Gbps) – Server Room Scenario

In a scenario where access is to a single point, such as Internet access, the bandwidth is shared among users, as with GPON. Figure 4 below shows a comparison of user bandwidth.

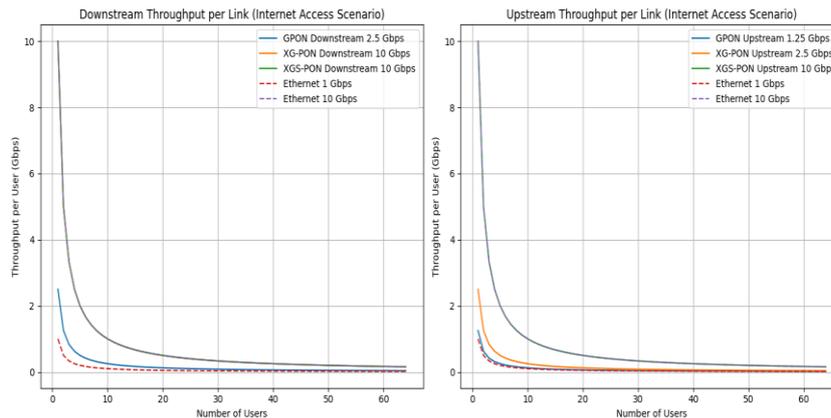


Figure 4. Throughput (Downstream and Upstream) for GPON and Ethernet per link for Internet Access Scenario.

Figure 4 compares the downstream throughput between GPON and Ethernet in Internet Access. With GPON, throughput decreases as more users share the 2.5 Gbps downstream bandwidth. This behaviour contrasts with Ethernet, where each user has dedicated bandwidth. In Ethernet (1 Gbps and 10 Gbps), throughput remains constant with no bandwidth sharing. Ethernet's ability to maintain high-speed access makes it more reliable for applications requiring consistent connections, like video streaming. GPON shows declining upstream performance as users increase, with its 1.25 Gbps bandwidth split among users. Ethernet provides dedicated bandwidth per user, with both 1G and 10G maintaining constant throughput.

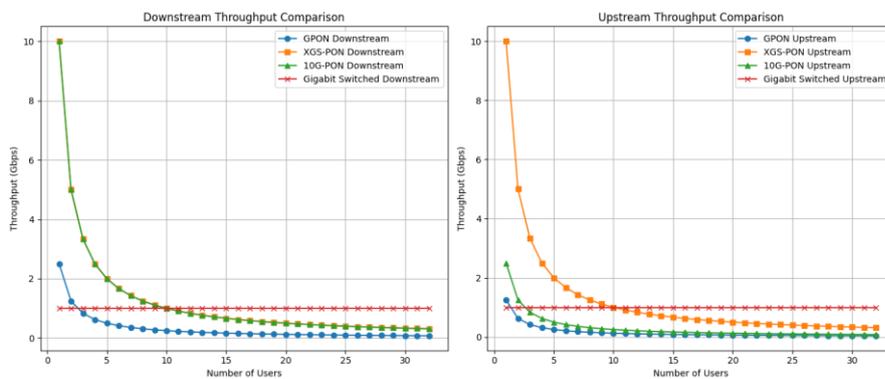


Figure 5. Comparison of GPON, XGS-PON, and 10G-PON employing a 32-channel splitter and Gigabit Switched Ethernet for a server room scenario.

Based on Figure 5, GPON shows throughput up to 2.5 Gbps, with performance varying by users' sharing bandwidth. XGS-PON shows higher throughput up to 10 Gbps, making it suitable for higher bandwidth needs. 10 G-PON demonstrates throughput up to 10 Gbps, showing better performance in certain scenarios. Gigabit Switched Downstream maintains 1 Gbps per connection as a dedicated link. For upstream comparison, GPON offers up to 1.25 Gbps shared throughput, which can cause congestion at peak times. XGS-PON and 10 G-PON provide up to 10 Gbps upstream throughput, suited for symmetric bandwidth applications like video conferencing. Gigabit Switched Upstream shows a consistent 1 Gbps per connection, providing dedicated bandwidth.

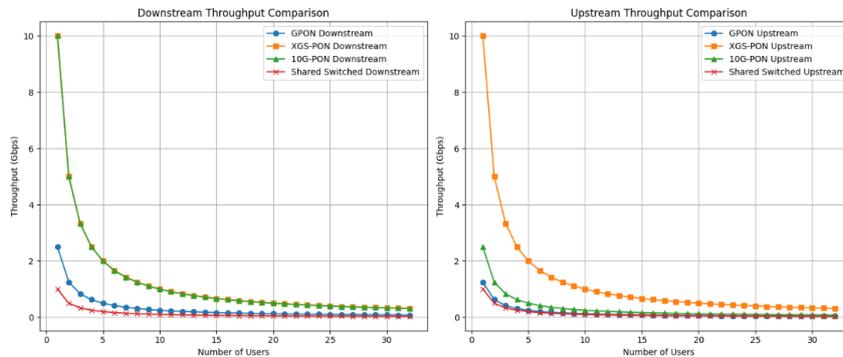


Figure 6. Comparison of GPON, XGS-PON, and 10G-PON employing a 32-channel splitter and Gigabit Switched Ethernet for accessing the Internet from a single point.

In Figure 6, Ethernet shares one Internet access point. Comparing GPON, XGS-PON, 10G-PON, and Shared Ethernet Switched networks reveal key performance differences. GPON (2.5 Gbps downstream, 1.25 Gbps upstream) is cost-effective but faces congestion with more users. XGS-PON and 10 G-PON, with 10 Gbps downstream and upstream, provide higher throughput for high-density environments. Shared switched networks deliver dedicated bandwidth but may face bottlenecks during peak usage. User count affects each technology's performance. GPON shows reduced throughput with increased users, while XGS-PON and 10G-PON maintain better performance.

6. Cost Comparison Between GPON and Ethernet Technology

The first costs of setting up GPON are high because it needs a lot of money for fibre-optic infrastructure, including expenses for things like optical line terminals (OLTs), optical network units (ONUs), and passive optical splitters [30]. Installing fibre-optic cables is more expensive than using traditional copper cables for Ethernet networks [31]. However, GPON's point-to-multipoint design helps lower the total amount of cabling needed. Ethernet networks rely on copper cables (such as Cat5e or Cat6) or fibre optics, based on required distance and bandwidth [23]. Initial setup costs for Ethernet infrastructure, including switches and cabling, are lower compared to GPON, particularly for smaller networks [24]. However, as networks grow, Ethernet needs additional active equipment like switches, increasing maintenance and operational expenses [23]. While Ethernet is more affordable initially, the need for more hardware to scale can drive up costs over time.

An operation and maintenance cost for GPON benefits from lower operational expenses due to passive components like splitters, which need no power or active management [25]. These passive elements reduce oversight needs and enable simpler maintenance. GPON's reduced reliance on active devices leads to lower energy consumption versus Ethernet networks [24]. The passive components are less prone to failure, reducing costly repairs and interventions [24]. Ethernet networks incur higher operational expenses due to active switches requiring continuous power and maintenance [26]. Network expansion necessitates the addition of more switches, leading to an increase in power consumption and operational expenses. The active equipment results in frequent troubleshooting and maintenance, adding to the operational burden. While Ethernet offers flexibility, its active components lead to higher energy demands and maintenance requirements as networks grow.

6.1. Summary of Cost Comparison

GPON is a more cost-effective solution for large-scale deployments and areas that require high bandwidth over long distances, thanks to its passive architecture, which helps lower both operational and maintenance expenses [17][25]. This makes GPON a more economical long-term investment. On the other hand, while Ethernet is initially more affordable for small-scale deployments, it becomes increasingly expensive as the network grows, primarily due to the need for active equipment and higher operational expenses [27].

Table 1: Use Case Comparison.

Use Case	GPON Suitability	Traditional Switch Suitability
Residential Broadband	High	Low
Enterprise Network	Medium	High
Data Centers	Low	High
Smart Cities	High	Medium

6.2. Advantages and Disadvantages

Table 2: Summarises the pros and cons of GPON and traditional switches.

Technology	Advantages	Disadvantages
GPON	High bandwidth, long reach, minimal maintenance, cost-effective for large-scale deployments	Shared bandwidth, higher initial cost, limited flexibility
Traditional Switches	Dedicated bandwidth, low latency, and flexibility for high-performance needs	Higher operational costs, limited distance, complex scalability

7. Conclusion

This paper compares the features and applications of GPON and traditional switch networks. GPON suits large, cost-effective deployments, like residential broadband and smart cities, whereas traditional switches are better for data centres and enterprise networks. The analysis shows GPON provides cost-effective shared bandwidth but has higher delays under heavy load, making it suitable for residential applications. Traditional Ethernet switches, with their dedicated bandwidth and low latency, suit high-performance environments, like data

centres. Network designers can use these insights to select appropriate technology based on bandwidth needs, distance, scalability, and budget.

8. Acknowledgements

This project was supported by an industry grant (Grant No. S/O 21702) from Clear Wisdom Sdn. Bhd. The author gratefully acknowledges the support and research facilities provided by Universiti Utara Malaysia (UUM) and the Faculty of Electronic Engineering Technology (FKTEN), Universiti Malaysia Perlis (UniMAP), which were instrumental in the successful completion of this project.

11. References

- [1] A. L. S. Aguiar, F. B. C. Sousa, and Y. V. L. De Melo, "Optical Distribution Network Design Using PSO," *IEEE Communications Letters*, vol. 27, no. 1, pp. 239–242, Jan. 2023, doi: 10.1109/LCOMM.2022.3218530.
- [2] X. Xue *et al.*, "ROTOS: A Reconfigurable and Cost-Effective Architecture for High-Performance Optical Data Center Networks," *Journal of Lightwave Technology*, vol. 38, no. 13, pp. 3485–3494, Jul. 2020, doi: 10.1109/JLT.2020.3002735.
- [3] B. Isyaku, K. B. A. Bakar, F. A. Ghaleb, and A. Al-Nahari, "Dynamic Routing and Failure Recovery Approaches for Efficient Resource Utilization in OpenFlow-SDN: A Survey," *IEEE Access*, vol. 10, pp. 121791–121815, 2022, doi: 10.1109/ACCESS.2022.3222849.
- [4] McKeownNick *et al.*, "OpenFlow," *ACM SIGCOMM Computer Communication Review*, vol. 38, no. 2, pp. 69–74, Mar. 2008, doi: 10.1145/1355734.1355746.
- [5] R. S. Tucker, "Scalability and energy consumption of optical and electronic packet switching," *Journal of Lightwave Technology*, vol. 29, no. 16, pp. 2410–2421, 2011, doi: 10.1109/JLT.2011.2161602.
- [6] S. Miladić-Tešić, G. Marković, D. Peraković, and I. Cvitić, "A review of optical networking technologies supporting 5G communication infrastructure," *Wireless Networks*, vol. 28, no. 1, pp. 459–467, Jan. 2021, doi: 10.1007/S11276-021-02582-6.
- [7] Y. L. Lee, D. Qin, L. C. Wang, and G. H. Sim, "6G Massive Radio Access Networks: Key Applications, Requirements and Challenges," *IEEE Open Journal of Vehicular Technology*, vol. 2, pp. 54–66, 2021, doi: 10.1109/OJVT.2020.3044569.
- [8] B. J. Hamza *et al.*, "Performance enhancement of SCM/WDM-ROF-XGPON system for bidirectional transmission with square root module," *IEEE Access*, vol. 9, pp. 49487–49503, 2021, doi: 10.1109/ACCESS.2021.3065285.
- [9] Y. Li and M. Chen, "Software-defined network function virtualization: A survey," *IEEE Access*, vol. 3, pp. 2542–2553, Dec. 2015, doi: 10.1109/ACCESS.2015.2499271.
- [10] V. Arya, M. Kumari, and A. K. Rana, "Historical development of passive optical network (PON): a review," *Journal of Optical Communications*, Sep. 2024, doi: 10.1515/JOC-2024-0177/MACHINEREADEABLECITATION/RIS.
- [11] N. Feng, M. Ma, Y. Zhang, X. Tan, Z. Li, and S. Li, "Key Technologies for a Beyond-100G Next-Generation Passive Optical Network," *Photonics 2023, Vol. 10, Page 1128*, vol. 10, no. 10, p. 1128, Oct. 2023, doi: 10.3390/PHOTONICS10101128.
- [12] S. I. Sadin *et al.*, "Design and Performance Evaluation of a Gigabit Passive Optical Network (GPON) Through Fiber-To-The-Home (FTTH) Technology," *International Conference on Recent Progresses in Science, Engineering and Technology, ICRPSET 2022*, 2022, doi: 10.1109/ICRPSET57982.2022.10188562.
- [13] H. S. Abbas and M. A. Gregory, "The next generation of passive optical networks: A review," *Journal of Network and Computer Applications*, vol. 67, pp. 53–74, May 2016, doi: 10.1016/J.JNCA.2016.02.015.
- [14] D. Breskovic, "Overview of Available Fiber Optic Backhaul Solutions for 5G/6G Networks," *2024 12th International Workshop on Fiber Optics in Access Networks, FOAN 2024*, pp. 22–26, 2024, doi: 10.1109/FOAN63517.2024.10765757.
- [15] A. Bin Sulaiman, S. Muhammad, Z. B. A. Man, M. Z. Bin Hamidun, M. F. Bin Amiruddin, and M. Bin Roslee, "50 GPON Network and Technical Exploration," *2024 IEEE Asia-Pacific Conference on Applied Electromagnetics, APACE 2024*, pp. 335–338, 2024, doi: 10.1109/APACE62360.2024.10877328.
- [16] F. J. Effenberger and D. Zhang, "WDM-PON for 5G Wireless Fronthaul," *IEEE Wirel Commun*, vol. 29, no. 2, pp. 94–99, Apr. 2022, doi: 10.1109/MWC.001.2100420.
- [17] V. Fulber-Garcia, M. C. Luizelli, C. R. P. dos Santos, E. J. Spinosa, and E. P. Duarte, "Customizable Mapping of Virtualized Network Services in Multi-datacenter Environments Based on Genetic Metaheuristics," *Journal of Network and Systems Management*, vol. 31, no. 4, pp. 1–31, Oct. 2023, doi: 10.1007/S10922-023-09760-1/FIGURES/18.
- [18] "Gigabit Passive Optical Network Or GPON Architecture Working." Accessed: May 05, 2025. [Online]. Available: https://headendinfo.com/gpon-gigabit-passive-optical-network/#google_vignette
- [19] A. Skoufis, G. Chatzithanasis, G. Dede, E. Filiopoulou, T. Kamalakis, and C. Michalakelis, "Technoeconomic assessment of an FTTH network investment in the Greek telecommunications market," *Telecommun Syst*, vol. 82, no. 2, pp. 211–227, Feb. 2023, doi: 10.1007/S11235-022-00971-6/FIGURES/7.
- [20] M. Asgarirad and M. N. Jahromi, "Taxonomy-based Comparison of FTTH Network Implementation Costs," *Majlesi Journal of Electrical Engineering*, vol. 14, no. 2, 2020, Accessed: May 07, 2025. [Online]. Available: <https://oicpress.com/mjee/article/view/4870/8166>
- [21] H. Alshaer, R. Shubair, and M. Alyafei, "A framework for resource dimensioning in GPON access networks," *International Journal of Network Management*, vol. 22, no. 3, pp. 199–215, May 2012, doi: 10.1002/NEM.801.
- [22] T. Thangappan, E. Manimaran, A. Arasu, R. Arulprakash, and J. S. Harish Ganapathi, "Review of Dynamic Bandwidth Allocation in GPON," *Proceedings of the 2020 IEEE International Conference on Communication and Signal Processing, ICCSP 2020*, pp. 884–888, Jul. 2020, doi: 10.1109/ICCSP48568.2020.9182151.
- [23] M. P. McGarry, M. Maier, and M. Reisslein, "Ethernet PONs: A survey of dynamic bandwidth allocation (DBA) algorithms," *IEEE Communications Magazine*, vol. 42, no. 8, 2004, doi: 10.1109/MCOM.2004.1321381.
- [24] D. Nessel, "PON roadmap [invited]," *Journal of Optical Communications and Networking*, vol. 9, no. 1, 2017, doi: 10.1364/JOCN.9.000A71.
- [25] ITU-T, "Gigabit-capable passive optical networks (GPON): General characteristics, Recommendation ITU-T G.984.1," *Networks*, 2008.
- [26] Gerd Keiser, "Ethernet in the First Mile," *Lightwave*, vol. 18, no. 7, pp. 139–153, Jun. 2001, doi: 10.1002/047176910X.CH8.
- [27] I. Sawad, R. Nilavalan, and H. Al-Raweshidy, "Backhaul in 5G systems for developing countries: A literature review," *IET Communications*, vol. 17, no. 6, pp. 659–669, Apr. 2023, doi: 10.1049/CMU2.12578;WEBSITE:WEBSITE:IETRESEARCH;WGROUP:STRING:PUBLICATION.