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# OPTIMIZING LOAD DISTRIBUTION FOR EFFICIENT CONTENT DELIVERY NETWORKS IN SUBURBAN AREAS

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***Abstract***

*Ensuring uninterrupted traffic flow is crucial for the efficient design and deployment of content delivery networks. The growing need for internet bandwidth in suburban areas has pushed service providers to upgrade their networks in order to meet the increasing demands. Nevertheless, it is essential to consider the importance of resource optimization in terms of reducing costs. An alternative plan must be devised by the service provider to effectively manage unpredictable fluctuations in demand. Enhancing the efficiency of computational resources enables network operators to adjust resource quantities in response to fluctuating traffic demands. Datacenters are interconnected using optical networking technologies. Our research focuses on developing a load distribution architecture that optimizes network utilization by minimizing redundancy. To optimize the utilization of these resources, it is crucial to strategically arrange the placement of SMF in OXCs. This will enable the establishment of a network of optical paths that effectively connect the data centers catering to users. Using SFPs of higher order will result in higher initial installation costs. However, the cost of upgrading the switches to meet the growing demand can be fairly substantial. Various devices can be used to establish network connectivity and facilitate the exchange of data. Afterwards, the proposed work is validated to assess its optimization and efficiency through the application of the Porter 5 force model. The results indicate that the proposed method of implementing higher order SFP is an effective approach for addressing the growing need for increased bandwidth.*

***Keywords:*** *Small Form Factor Pluggable (SFP), Optical Cross Connect (OXC), Five Force Model, Dense Wavelength Division Multiplexing (DWDM), Shortest Distance Algorithm.*

## I. INTRODUCTION

As digital communication becomes increasingly integral to daily life and economic activities, it is essential to invest in and innovate optical network technologies to ensure a sustainable and resilient future. The advent of 5G technology and the proliferation of IoT devices, present new challenges for network capacity and latency. Optical networks are well-suited to meet these challenges due to their high bandwidth and low latency characteristics. Among the various methods and platforms used in telecommunication, optical communication is a crucial and quickly developing subset. With its benefit and speed, bandwidth and security it guarantees reliable and fast information transfer over long distances. In 5G networks, the dense deployment of small cells requires a backhaul with high capacity and low latency, which optical fibers can provide. Similarly, the expected surge in data traffic from IoT

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devices can be efficiently managed by the scalable nature of optical networks, ensuring seamless connectivity and performance.

Optical networks leverage Dense Wavelength Division Multiplexing (DWDM) to maximize the use of available bandwidth. Here a single optical fiber can carry terabits of data per second, accommodating the exponential growth in data traffic driven by video streaming, cloud services, and other bandwidth-intensive applications. One of the major advantages of DWDM technique is their modularity, which allows for flexible and incremental upgrades. Unlike traditional networks that may require extensive infrastructure changes to scale up, optical networks can be enhanced by simply adding more wavelengths or upgrading terminal equipment. This means that network operators can increase capacity and performance with minimal disruption and cost. For instance, upgrading from a 10 Gbps to a 100 Gbps system can often be achieved by replacing endpoint equipment rather than the entire fiber infrastructure.

While the initial deployment of optical networks may involve higher costs compared to traditional copper-based networks, the long-term benefits are substantial. The scalability of optical networks means that as data demands grow, additional capacity can be added without significant physical expansion or new cabling. This reduces the overall cost of scaling up the network over time.

Numerous issues such as network scalability, wavelength allocation and administration, cost constraint and energy efficiency, are faced by optical communication. In order to increase security, efficiency and performance addressing these issues in optical communication and networks frequently calls for a combination of technology advancements regulatory cooperation and continuing research and development activities. The important component of customer satisfaction are availability and reliability. Sustaining network resilience is essential to establishing and preserving user and customer trust.

Utilizing Porter's Five Forces model to analyze optical network survivability offers a strategic viewpoint on how external competitive pressures and industry dynamics impact decisions about network architecture, investment in redundancy, and overall resilience. Network service providers may strengthen resilience and navigate the competitive landscape by understanding these forces. Michael Porter offers a comprehensive structural framework and analytical techniques that can assist the company in analyzing its industry and its evolution, comprehending its competitors and its own position, and translating this understanding into a competitive strategy that enables the company to compete more effectively and enhance its market position. A review of literature based on Michael Porter's Five Forces Model (Stonehouse and Snowdon, 2007; Porter, 1999; Ketels, 2006) reveals that research has been conducted on the transformation of government-owned telecommunication companies into competitive enterprises in the region, as well as on the establishment of new telecom service providers. Nevertheless, a thorough investigation of the regional market structure has not been conducted thus far. Hence, the objective of this study is to ascertain the immediate and enduring obstacles that would confront both established and new enterprises operating in the industry within the southern region of Karnataka.

## II. LITERATURE SURVEY

Xin Chen et,al [1] in “All-optical OXC transition strategy from WDM optical network to elastic optical network” explains contention-aware spectrum allocation (CASA) scheme with Transition aware OXC(TOXC). This method reduce the network capital expenditure transiting from WDM optical network to EON about 50%, with a minor traffic blocking performance degradation and about 10% accommodated traffic number detriment. Paper by M. Ruiz, L. Velasco, and J. Fernandez-Palacios, [2] surveys the notion of elastic optical networks (EONs), which allocate bandwidth in a flexible manner

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by adjusting the modulation format and spectrum consumption based on traffic demands. The text explores a range of strategies and algorithms employed in EONs to enhance the efficiency of bandwidth utilization. R.S. Kaler, Aanchal Sharma, Nivedita Nair and Kamaljit Singh Bhatia [3] discusses a range of strategies for managing bandwidth, such as wavelength division multiplexing (WDM), optical time division multiplexing (OTDM), and hybrid methods. The literature also explores strategies for optimizing bandwidth usage to achieve greater efficiency. P. Raju et al, [4] This study addresses routing and wavelength assignment (RWA) algorithms, which are essential for optimizing bandwidth efficiency in optical networks. The work compares alternative RWA algorithms and their efficacy in diverse network settings. Bharadwaj et al (2013) and R. Ramaswami & K.N. Sivarajan (2014) [5], [6] show how telecom businesses innovate to stay competitive. As corporations compete for market share, 5G technology has caused significant investments and strategic shifts. The convergence of telecom, internet, and media increases competition from non-traditional firms. Kim et al. (2010) [7] found that suppliers' bargaining power can be high when there are few expert suppliers. Key technologies like 5G equipment can be expensive and subject to supply chain disruptions if they have few suppliers. The report emphasizes strategic partnerships and vertical integration to reduce supplier influence. Kim and Oh (2004) and Li and Whalley (2002) [8] [9] have examined how telecom businesses must offer competitive pricing, high service quality, and new value-added services to retain customers. The rise of bundled services and OTT content providers empower buyers by offering more options and lower rates. Ghezzi et al. (2014) and Parker et al. (2016) [10], [11] propose that cloud-based services and SDN can remove those barriers and allow new companies to enter the market. These competitors use digital platforms to offer competitive services without infrastructure investments. Studies conducted by Kwon et al. (2009) and Wu (2013) suggest that the increasing availability of the internet and the widespread use of smartphones have led to a rise in alternative options for telecommunication services. This has created a need for telecom companies to expand their range of services and invest in new technologies in order to remain competitive.

## III. METHODOLOGY

When the demand increases, Optical Cross Connect (OXC) hardware must be changed if it has to upgrade from 10G to 25G or 40G. It involves cost investment which may be burden for service providers. A module of SFP (Small form factor pluggable) is a transceiver (also known as an SFP module) is just a hot-swappable, metal component that, when connected to another device using a cable, allows for the transmission of data. SFP ports are a crucial component of data transmission and high-speed telecommunications, particularly in expansive network environments. The major purpose of an SFP port is to enable a dependable, wired, high-speed connection over fiber optic cables between two devices over an extended distance. The SFP+ and QSFP+ are advanced modules and its specifications support transfer rates of up to 10 Gbps and 40 Gbps, respectively. These ports are compatible with a computer, network interface card, switch, server, or router. Large computer network applications typically require switches with two or more SFP ports. Figure 1 shows the internal blocks of SFP module and Figure 2 is the image of industrial module with two ports.

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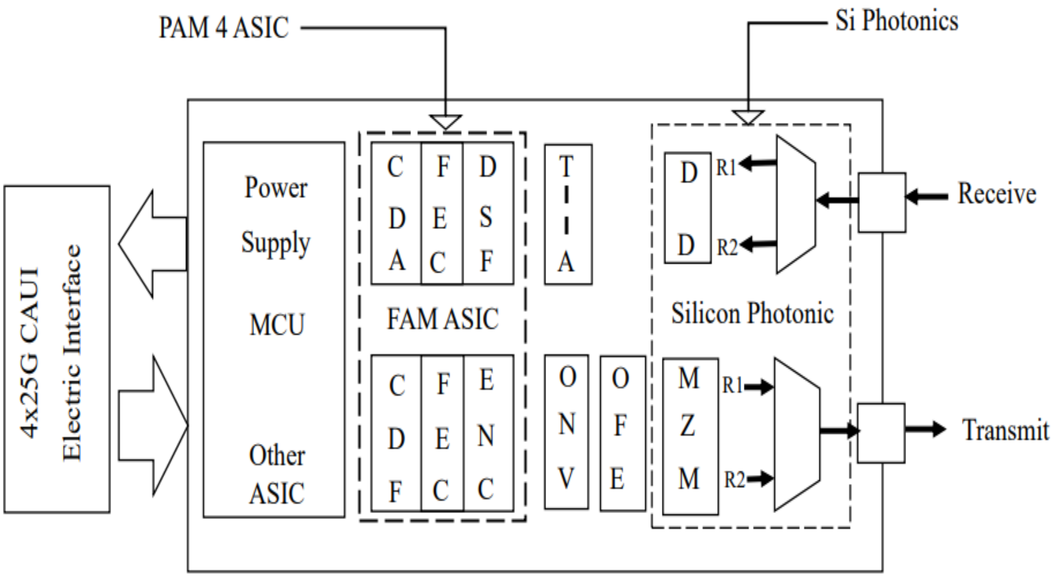


**Figure 1: Internal Block Diagram of SFP**

**Figure 2: SFP Module**

SFP ports along with the matching SFP modules are employed in many different applications to enable smooth, fast data transfers or long-distance communications connections. They are frequently used to join two one-gigabit network switches, expanding the capacity and enhancing the performance of a network. In practical scenario, the greatest distance that two devices can be linked via an SFP port will vary based on the data transfer rate of the SFP module, which in turn determines what kind of cable is required to make the connection.

We have considered a 5 node network which provides internet services in urban and surrounding rural areas (Figure 3). A 10G SFP modules were installed by service providers for uninterrupted services. As the demand for higher bandwidth increases, a node has to be upgraded to meet the Increasing demands by customers. For the up gradation of the existing network, Pluggable transceiver module is

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used with DWDM to utilize 10G port. These hardware ports can extend up to 80G with 40G for transmission and 40G for reception. This arrangement will also support the demand during node failure. This is an proposed alternate arrangement to minimize the cost and handle the demand effectively. Each node has OXC, whose port can be utilized for failure handling using pluggable transceiver module. This arrangement can extend up to 80G (40G for Tx & 40G for Rx). Shortest distance algorithm is used to calculate the physical path between nodes. During failure, calculation is performed for next available shortest path. Pre assigned routing path can handle the additional load. Rerouting is established without any time lag and data loss.

Specifications of the network under consideration used the wavelength in the range 1549.x –1550.x. Initial capacity of the fiber channel was 10G and intended Upgraded capacity is 10G + 10G. Multiplexing technology used is DWDM and Protocols used for data and control signal transmission is RSTP. Here the same capacity is proposed to be utilized during link failure and we have tested that upgraded 20G capacity can redirect the load towards destination without any time lag or data loss.

Parameters used in the routing algorithm to find the alternative path are:

- Smn = Set of spectrum slots on fiber link mn
- Eslot = Maximum number of spectrum slots per fiber link
- Dj = Traffic demand generated
- $X_{ij}$ = Route in a logical network from nodes i to j
- Vi = Number of spectrum slots allocated

For, $S_{mn}$ <= Eslot

**Min (σijmn $S_{mn}$ + max σ Dj. $X_{ij}$ + σ Vi)**

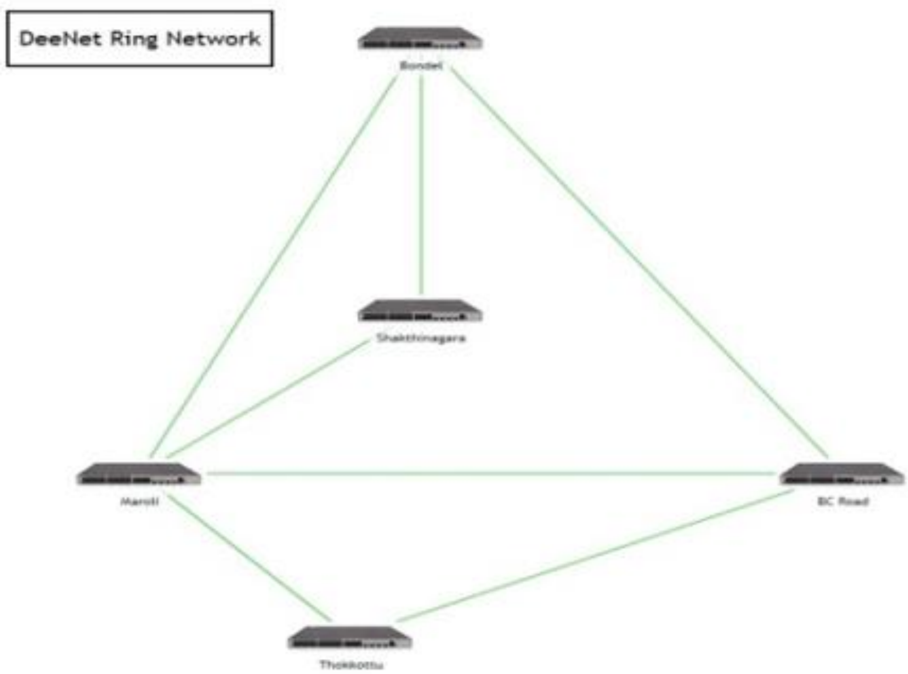


**Figure 3: Network under Consideration**

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**Figure 4: Bondel-Maroli data transfer under normal condition**

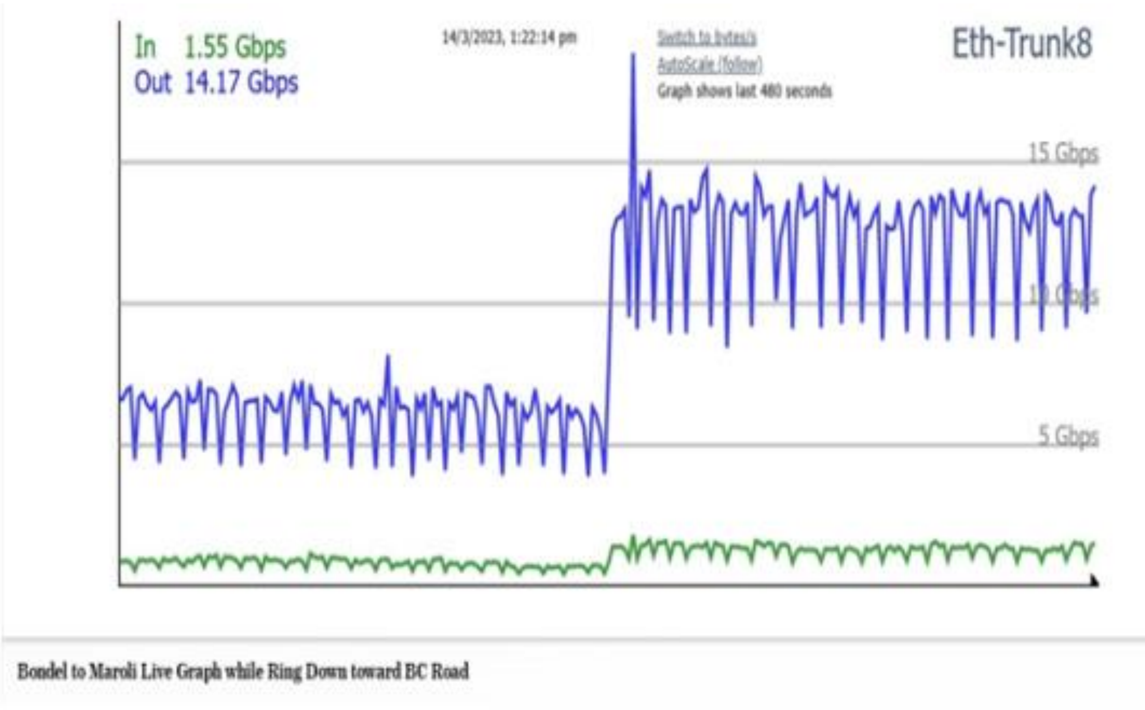


**Figure 5: Bondel to Maroli live graph while ring down**

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**Figure 6: Bondel to Maroli live while return to normal**

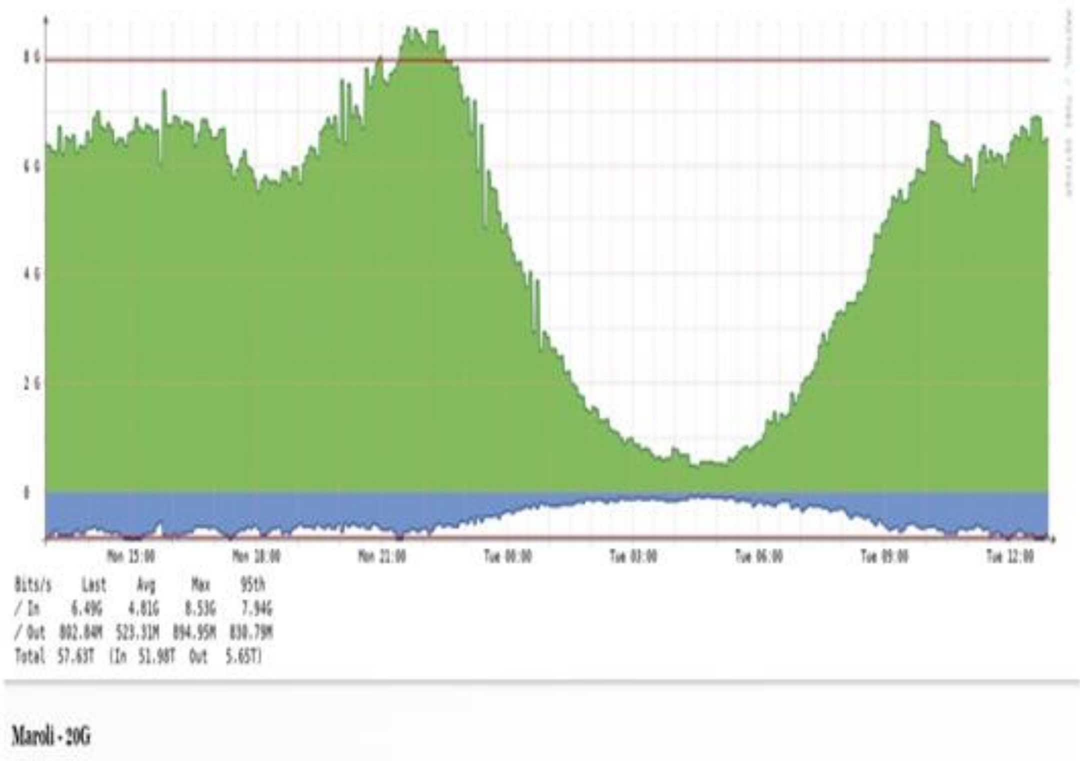


**Figure 7: Maroli 20G**

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**Figure 8: Main control room Bondel 40G**

## IV. RESULTS AND DISCUSSION

The experiment was carried out in association with a service provider and network under consideration was covering the area of 50Km (Figure 3). Data transfer rate under normal condition is 8.19Gbps. The graph shows data rate Vs time (Figure 4). Figure 5 shows the data shift to alternate route due to link failure. Due to the implementation of proposed method, the alternate link is able to handle the extra demand with data rate of 14.17Gbps. Data flow in reconstructed original path is shown in Figure 6. Figure 7 & 8 shows the data downloaded (green) and data uploaded (blue) in a substation and main control room respectively.

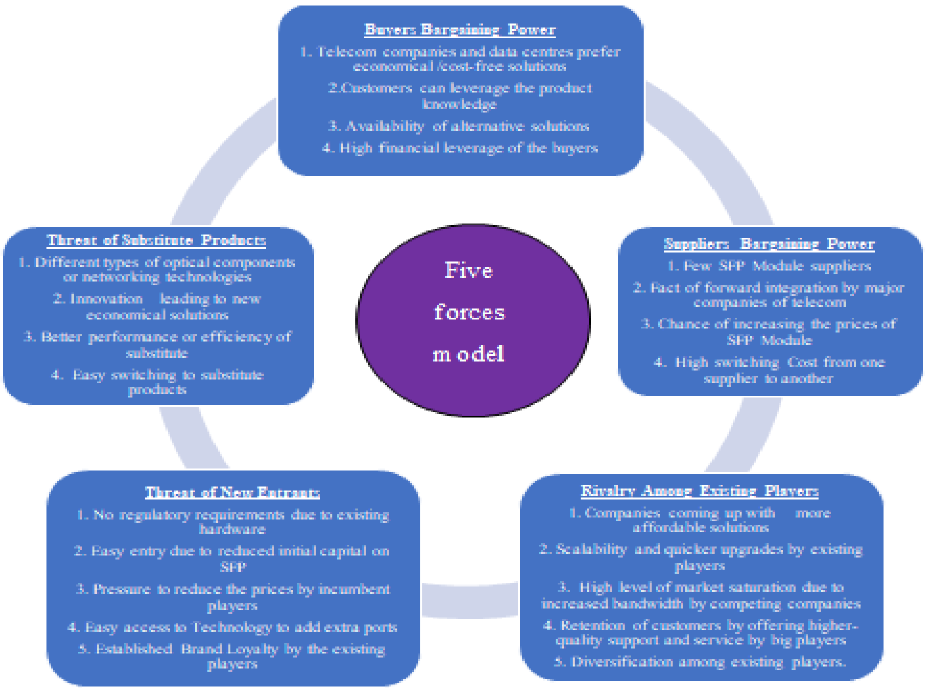


**Figure 9: Key points of 5 forces in Porter's model.**

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We have chosen 5 force model to analyze the optimization of utilization of adopted method.

Applying Michael Porter's Five Forces model [12] to the scenario where adding an extra port is more economical compared to changing the SFP influences the industry. Figure 9 shows the key points of 5 forces supporting the proposed work.

Here's an explanation for each of the five forces:

**Threat of New Entrants**: Within the realm of optical networks, Porter's Five Forces model emphasizes the potential risk posed by new participants as a result of many circumstances. The lack of regulatory standards for current hardware makes it easier to enter the market, while the decreased initial capital expenses for Small Form-factor Pluggable (SFP) modules also decrease financial obstacles. In addition, newcomers gain advantages from convenient access to technology that facilitates the incorporation of additional ports, hence facilitating rapid expansion. The increase in competition compels established firms to lower prices in order to maintain their market dominance. Nonetheless, the presence of strong brand loyalty among current customers poses a significant challenge for new entrants seeking to capture and retain their own customer base.

**Threat of New Products:** In Porter's Five Forces model, the threat of substitute products looks at how alternative solutions or technologies could replace industry products or services. In optical networking, this risk takes several forms. First, different optical components or networking technologies give users alternates to old solutions, which may reduce demand for established products. Second, optical technological developments offer new, economically viable options that could attract clients seeking improved functionality or cost-effectiveness. Better performance or efficiency from alternates challenges existing technologies by addressing changing customer needs adequately. As seamless optical network installations reduce adoption barriers, customers can easily switch to these substitutes, increasing their threat. The presence of alternative products in optical networking highlights the need for constant innovation and competitive pricing to reduce market loss.

**Rivalry among Existing Players:** Porter's Five Forces model analyzes industry competition, for optical networking, by studying rivalry among current players. Several factors feed this competition. First, companies compete by offering cheaper solutions, lowering costs and pressuring profit margins. Second, existing companies may quickly scale operations and upgrade technologies to stay competitive and gain market share. Due to the proliferation of high-bandwidth solutions from rival enterprises, market saturation increases competitive pressures by giving buyers more options. In a competitive environment, significant service providing companies use their resources to establish client loyalty and survive by providing excellent support and service. The optical networking industry's strong competition highlights the necessity for continual innovation, cost control, and customer-focused initiatives to stay ahead.

**Suppliers Bargaining Power:** SFP module suppliers have significant bargaining power in optical network survivability due to many considerations. First, the market has few SFP module vendors, reducing competition and increasing telecom companies' dependence on them. Forward integration by big telecom companies making their own SFP modules can worsen this power dynamic because they can use their production skills to negotiate better prices with external suppliers. Given the high switching costs of moving suppliers, suppliers raising SFP module prices is a major issue. This cost includes material expenses and potential downtime and compatibility concerns that could compromise network stability and survival. Thus, telecom businesses must actively handle supplier relationships to reduce these risks and strengthen their network services.

**Buyers Bargaining Power:** Telecom and data center buyers have significant bargaining power in optical network stability. These purchasers always seek cost-effective solutions to optimize operational

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expenses and network reliability. Their product expertise helps them evaluate and negotiate the best arrangements, typically resulting in better terms or cheaper supplier prices. Alternative options, such as optical transceivers or networking technologies, strengthen their bargaining position, permitting them to switch suppliers or products. Due to their considerable financial leverage, these purchasers can make large purchases or investments, which can be utilized to negotiate better contracts. Supplies must stay competitive and adaptable to satisfy these prominent buyers and ensure optical network survival and robustness due to their significant bargaining power.

## V. CONCLUSION

Applying the Five Forces Model to examine the survivability of optical networks provides an in-depth analysis of the competitive dynamics and strategic challenges in this sector. When assessing the power of suppliers, it becomes clear that a small number of influential suppliers and significant expenses associated with switching can have an influence on the stability of the network and the efficiency of costs. The buyer's ability to negotiate indicates how telecom corporations and data centers, using their financial might and alternative choices, can exert influence over market conditions in order to obtain more favorable terms.

In order to remain competitive in a challenging business environment, it is crucial to have strong and innovative network solutions, as the possibility of new competitors entering the market and the level of competition are significant factors to consider.

The presence of alternative products or services shows the necessity for continuous improvement and adaption to developing technologies. Collectively, these forces offer a comprehensive perspective on the elements that impact the ability of service providers to withstand and recover from disruptions.

This educates individuals with the knowledge required to make accurate decisions in order to improve the ability of the networks to withstand challenges, operate efficiently, and remain competitive in the ever-changing telecommunications industry.

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