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A proposed ring based model for optimum data transfer and its performance assessment

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Abstract
The demand for efficient solutions to transmit large volumes of data over Passive Optical Network networks has increased. This study examines two key challenges: network bottlenecks and capacity load issues. Based on these issues, a potential solution is proposed. The methodology involves a ring-based architecture consisting of N nodes, representing a complete Passive Optical Network system. These nodes serve as checkpoints for monitoring and identifying network faults. The distance between each node is uniform, and the system includes N checkpoints. The source and receiver nodes are dynamically selected. An optimized ring-based network model is introduced, offering reduced data loss and improved transmission speed. The proposed approach utilizes a ring topology with eight nodes and cores Passive Optical Network save points. To address the bottleneck issue, a tree-based network model is implemented, incorporating four hierarchical sub-networks. Performance comparisons based on packet delivery demonstrate that the proposed model achieves faster data transmission compared to existing systems.
Keywords: Ring Model, Data Transmission, Bottleneck, Capacity Load.

INTRODUCTION

With the rapid growth of the internet and wireless technologies, the demand for video-related services such as video conferencing, gaming, video-on-demand, internet streaming, and IPTV has significantly increased. In particular, the rising popularity of gaming has driven the development of advanced access methods capable of meeting higher bandwidth demands.

Traditional copper-based networks have nearly reached their maximum capacity and are insufficient for future requirements. Optical fiber has emerged as a promising alternative due to its superior performance. Passive Optical Networks are considered a cost-effective and efficient solution because they do not require active Passive Optical Network outside the central office, a feature not easily achievable with other technologies. Optical networking is now widely used for backbone and long-haul networks, while for local and metropolitan area networks, Passive Optical Network is becoming the preferred choice. Passive Optical Network, an optical fiber-based access network, is designed to provide virtually unlimited bandwidth to subscribers. It operates using a shared optical fiber that employs a passive optical splitter to distribute signals to individual users. Since Passive Optical Network lacks active elements in the access network beyond the central office, it is categorized as a "passive" system. This technology enables service providers to deliver a complete triple-play package, including voice, data, and video, with IPTV being a crucial Passive Optical Network of the data services. Passive Optical Networks are increasingly popular, particularly for the expansion of Fiber-to-the-Home (FTTH) infrastructures.

This study primarily focuses on evaluating packet delay and the capacity of sub-networks forming a Passive Optical Network through simulations and comparative analysis with standardized systems. A two-lane system based on ring topology is implemented to minimize packet loss compared to existing systems. Additionally, an aggregation-based bottleneck network is introduced, incorporating a secure system using the SHA algorithm. This approach enhances network security, reduces packet delay, and improves overall network capacity.

LITERATURE REVIEW

Passive Optical Network is a highly advanced access network known for its reliability, high data rates, and efficient signal transmission. Due to the increasing adoption of optical networks in metropolitan and wide-area networks, a bottleneck often arises between local area networks and network service providers. This challenge can be addressed by leveraging the bandwidth capacity of fiber optic network access. Several key parameters are essential for analyzing Passive Optical Network performance, including jitter, congestion control, delay, capacity, and throughput. Jitter refers to fluctuations in packet delay over time, often caused by electromagnetic interference and signal crosstalk. Congestion control deals with scenarios where excessive data traffic on a network link leads to degraded service quality. Delay represents the average time taken for a packet to travel from its source to the destination. Capacity denotes the maximum number of users a network can support, while throughput measures the average rate of successfully transmitted messages over a communication channel.

The primary objective of this paper is to assess key performance parameters of Passive Optical Network, specifically focusing on delay and capacity. Several previous studies have explored similar topics, providing valuable insights. For instance, Aurzada et al. (2011) conducted a probabilistic analysis of NG-Passive Optical Networks by evaluating the minimum capacity of sub-networks and analyzing packet delays. Similarly, Helonde et al. (2011) introduced the MRA algorithm to examine the impact of varying link capacities on packet delivery ratio and end-to-end delay. A study on mobile ad-hoc networks by Wang et al. (2011) explored node mobility models for delay analysis and multicast capacity, while Wang, Huang, Wang, Zhang, and Hu (2011) investigated the tradeoff between mobility and capacity. Lim et al. (2011) proposed a Quality of Service (QoS)-aware medium access control protocol for next-generation OFDMA-Passive Optical Networks, examining service-level differentiation and network throughput while introducing a new dynamic subcarrier allocation algorithm. Tanaka et al. (2011) developed a Dynamic Bandwidth Allocation (DBA) algorithm incorporating an adaptive status-reporting method and traffic monitoring for load balancing, improving data throughput and transmission delay. Another study analyzed existing DBA algorithms and their applications in long-reach Passive Optical Networks (LR-Passive Optical Networks). Skubic et al. (2009) compared Ethernet Passive Optical Network and Gigabit Passive Optical Network based on DBA characteristics, including jitter, delay, and bandwidth utilization. Their findings highlighted how different standards influence DBA performance, with minor differences observed between the two technologies. Additionally, Luo and Ansari (2005) examined a DBA scheme utilizing traffic prediction, assuming Gaussian-distributed prediction errors to estimate average delay. Overall, numerous studies have investigated Passive Optical Network capacity and delay performance under different protocols, each presenting varying results and insights.

PROPOSED METHODOLOGY

A ring-based architecture comprising *N* nodes is utilized to represent the complete Passive Optical Network system. These nodes, which are identical in structure, are evenly distributed in a circular formation. Each node serves as a checkpoint for monitoring network performance and detecting faults. The distance between nodes remains uniform, and the selection of source and receiver nodes is dynamic. In the absence of network faults, data transmission proceeds without interruption. However, if a fault occurs, the last recorded checkpoint identifies an alternative route to ensure continuous data transfer. The system allocates the total bandwidth into two sections: one for standard communication and the other as a recovery path. In the event of a failure, the recovery path is activated to maintain data transmission. This approach has demonstrated improved performance compared to previous systems. The study also addresses the bottleneck issue in Passive Optical Network architecture by implementing a hierarchical structure. Four interconnected sub-networks are arranged in a layered manner to manage data aggregation efficiently, enabling the transmission of larger data volumes. Additionally, a filtration mechanism is introduced to optimize network load distribution.

To analyze network delay and capacity challenges, two network topologies are evaluated: a ring topology and a tree topology. The latter incorporates the SHA algorithm to enhance network capacity. The simulation is conducted using MATLAB, with detailed findings outlined in the subsequent sections.

Ring based Network Model

To address challenges associated with high-speed Wireless Passive Optical Network networks, a ring-based network model is proposed. This model aims to optimize performance by enhancing speed and minimizing data loss. The proposed setup follows a ring topology comprising eight nodes, each serving as a save point for network monitoring. The network topology spans an area of 775m × 775m.Traffic generation is implemented using Constant Bit Rate (CBR) at a rate of 25 Mbps, with a packet size of 512 bytes. Communication can be initiated from any randomly selected node and directed to any destination node within the network. For instance, if data transmission begins at node 1, the destination is chosen at random. The simulation results indicate that the average packet transfer time is approximately 0.91 seconds.

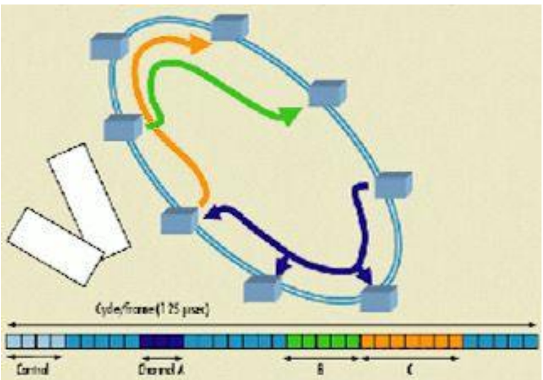

Figure 1: Ring Based Network Model

The analysis indicates that faults occurred at random locations within the network. Despite this, the system successfully identified an alternate route from the opposite side to reach the final destination node, ensuring packet delivery. In the presence of faults, the packet transmission time increased to approximately 5.02 seconds.

Tree Based Network Model

The bottleneck issue in Passive Optical Network architecture is addressed using a tree-based network model, incorporating four hierarchical sub-networks. This model captures the concept of data aggregation, enabling the transfer of large volumes of data across the network. A filtration approach is implemented to enhance data efficiency and manage network load, while the SHA algorithm is utilized for data authentication. The nodes are evenly spaced at a fixed distance of 41.56 meters, with a coverage range of approximately 15 meters. A comparative analysis of packet delivery performance highlights the advantages of the proposed model over the existing system. The previous system exhibited a higher fault occurrence rate and longer recovery times. For instance, in the existing model, packet delivery time increased from 10 seconds at five fault occurrences to 35 seconds at ten faults. In contrast, the proposed system maintained a recovery time of just 3 seconds for a single fault and only increased to 8 seconds even with ten faults, demonstrating significantly improved fault tolerance. Additionally, the proposed system outperformed the existing model in terms of packet transmission speed. The findings suggest that the new approach offers more efficient data transmission, better load management, and enhanced fault recovery, making it a more reliable solution for Passive Optical Network networks.

CONCLUSION

This study proposes a ring-based model for efficient large-scale data transfer across the network. The model is used to evaluate data transmission time between nodes and fault occurrence rates. The results indicate that the proposed system achieves higher efficiency. Furthermore, to address the bottleneck issue, a tree-based network model is introduced. Performance analysis demonstrates that this model outperforms the existing system, offering improved data transmission and fault recovery capabilities.

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