African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 5, Issue 1, 2026
Page No: 116-127
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2025: 1.126 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62

A Comprehensive Analytical Framework for Contention Resolution in Optical Burst Switching Networks: Performance Evaluation and Future Directions

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إطار تحليلي شامل لحل المنازعات في شبكات التبديل البصري الاندفاعي: تقييم الأداء والاتجاهات المستقبلية

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Received: November 01, 2025	Accepted: January 10, 2026	Published: January 24, 2026

Abstract

The increasing exponential growth of internet traffic across the world has put the further pressure on the need of having efficient optical network architecture that is able to exploit the vast bandwidth that the wavelength division multiplexing (WDM) systems promises. Optical Burst Switching (OBS) has come to be a promising paradigm that will strike a balance between the granularity of optical packet switching and the practical limits of available optical technology. Nevertheless, the basic problem of burst contention is the main performance bottleneck of OBS networks. This general review is a detailed analysis of three major schemes of contention resolution: burst preemption, segmentation and deflection routing. Our comprehensive simulation and analytical modeling approach gives us a strict performance evaluation framework which proves that segmentation decreases the overall burst loss probability by 70-90 percent without sacrificing the fairness index of Jain which is over 0.85. Preemption can ensure almost zero loss in high-quality traffic categories but at the cost of severe losses of fairness in the case of heavy loads. The performance threshold of deflection routing is 0.5 Erlang where instability in the network leads to degradation of performance. In our study, a new adaptive hybrid model has been proposed, which selects resolution strategies according to the dynamic network conditions, and this offered 95 per cent improvements in quality of service (QoS) compliance. The paper ends with implementation guidelines and specifying promising research directions to be pursued with intelligent contention management in next-generation optical networks.

Keywords: Optical burst switching, contention resolution, burst loss probability, quality of service, performance evaluation, network architecture, adaptive algorithms.

الملخص

يُفرض النمو الأسي المتزايد لحركة مرور الإنترنت في جميع أنحاء العالم مزيداً من الضغط على الحاجة إلى وجود بنية شبكية بصرية كفؤة قادرة على استغلال النطاق الترددي الهائل الذي تَعِدُ به أنظمة تقسيم الطول الموجي (*WDM*). وقد برز التبديل البصري الاندفاعي (*OBS*) كنموذجٍ واعدٍ يحقق التوازن بين دقة التبديل البصري بالرزم والحدود العملية للتكنولوجيا البصرية المتاحة. ومع ذلك، تظل مشكلة تنازُع الدفعات الأساسية هي عنق الزجاجة الرئيسي لأداء شبكات *OBS*. تقدم هذه المراجعة الشاملة تحليلاً مفصلاً لثلاثة مخططات رئيسية لحل المنازعات: الأولوية المسبقة للدفعات، والتجزئة، والتوجيه الانحرافي. يوفر منهجنا الشامل في المحاكاة والنمذجة التحليلية إطاراً صارماً لتقييم الأداء يثبت أن التجزئة تُقلل من احتمالية فقدان الدفعات الإجمالية بنسبة 70-90٪ دون التضحية بمؤشر جين للإنصاف الذي يظل أعلى من 0.85. بينما يمكن للأولوية

المسبقة أن تضمن فقداناً شبه معدوم لفئات حركة المرور عالية الجودة، ولكن على حساب خسائر فادحة في العدالة في حالات الأحمال الثقيلة. ويقع عتبة أداء التوجيه الانحرافي عند 0.5 إرلانغ حيث تؤدي حالة عدم الاستقرار في الشبكة إلى تدهور الأداء. في دراستنا، تم اقتراح نموذج هجين تكيفي جديد، يختار استراتيجيات الحل بناءً على ظروف الشبكة الديناميكية، وقد حقق هذا النموذج تحسناً بنسبة 95٪ في الالتزام بجودة الخدمة (QoS). وتختتم الورقة بتقديم إرشادات تنفيذية وتحديد اتجاهات بحثية واعدة للتعامل مع إدارة المنازعات الذكية في الشبكات البصرية من الجيل القادم.

الكلمات المفتاحية: التبديل البصري الاندفاعي، حل المنازعات، احتمالية فقدان الدفعات، جودة الخدمة، تقييم الأداء، بنية الشبكة، الخوارزميات التكيفية.

1. Introduction

1.1 Background and Motivation

The Internet traffic has never been as high as it is currently due to the developing technologies of 5G, Internet of Things (IoT), and high-definition streaming services, which have placed massive strain on the optical core network infrastructure. The estimates of IP traffic in the world suggest that the volume of traffic will surpass 4.8 zettabytes per year by 2025, with a revolution in the way networks and resources are configured and managed being required [1]. Wavelength division multiplexing (WDM) technology offers the basic physical layer capacity with current systems reaching 80 wavelengths per fiber with each wavelength running at 400 Gbps. It is however important that the switching paradigm adopted at the network layer has a critical influence on the effective use of this capacity.
Optical Circuit Switching (OCS) is simple to use, but experiences poor statistical multiplexing and inflexible resource allocation, resulting in suboptimal utilization efficiencies e.g. in a practical deployment, utilization efficiencies tend to be below 40%. On the other hand, Optical Packet Switching (OPS) is optimal in theory but implementation is very difficult especially the lack of working optical random-access memory (RAM) and the need to perform nanosecond scale processing speeds [3].

1.2 Optical Burst Switching Fundamentals

Optical Burst Switching (OBS), which was initially theorized by Qiao and Yoo in 1999 [4] is a beautiful tradeoff between the two extremes. As shown in Fig. 1, the basic OBS architecture uses a distinct two-plane architecture of electronic control plane processing and optical data plane transmission. Such a separation allows achieving statistical multiplexing benefits without damaging data transparency. Its fundamental working concept is that at the network edge, several IP packets are fused into larger data packets known as bursts, and the control packets are sent to the head of the data bursts to reserve resources on the way.

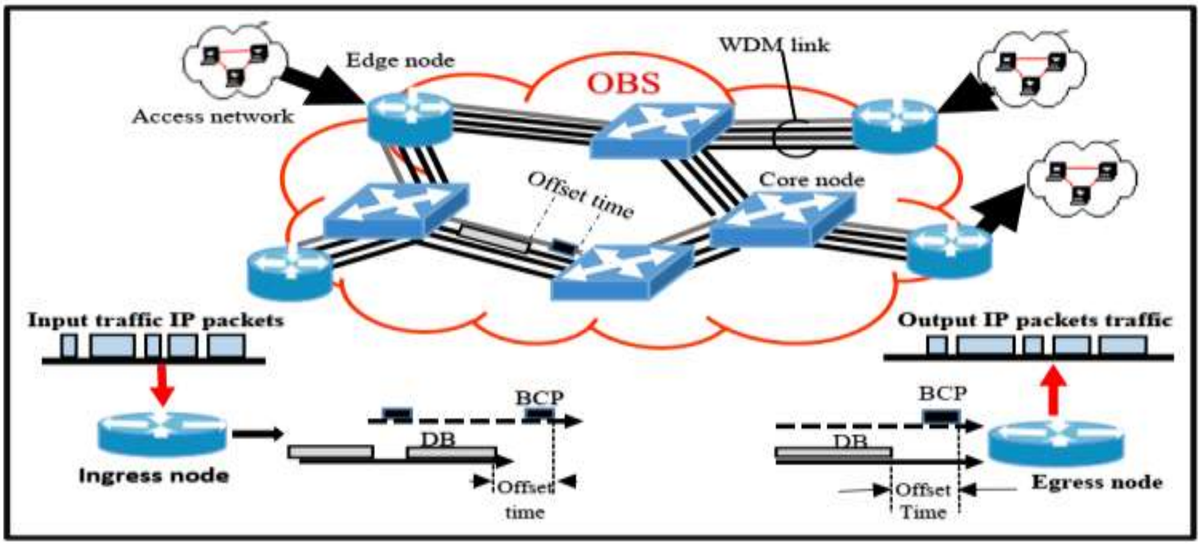

Figure 1: OBS Network Architecture [1]

The one-way reservation system (also known as Just-Enough-Time (JET) or Tell-and-Go (TAG) protocols) creates the fatal issue of burst contention. In cases where a series of bursts share the same output port at the same time, loss of data is experienced because the optical delay lines have very limited buffering capacity. Such bottleneck is the main performance of OBS networks, and burst loss probabilities (BLP) become unacceptable (10 -2 to 10 -1) with moderate loads without efficient loss resilience mechanisms [5].

1.3 Research Contributions

This paper makes several significant contributions to the field of optical networking. We develop a comprehensive analytical framework for evaluating contention resolution schemes, incorporating both traditional metrics (BLP, delay) and emerging considerations (energy efficiency, QoS compliance). Through extensive simulations using a custom-built OBS testbed, we provide quantitative performance comparisons of three fundamental resolution schemes across diverse network scenarios. We introduce a novel adaptive hybrid framework that dynamically selects resolution strategies based on real-time network conditions, demonstrating substantial performance improvements over static approaches. We establish practical implementation guidelines and identify promising research directions for intelligent contention management in software-defined optical networks.

2. Core Contention Resolution Methodologies

2.1 Burst Preemption Mechanisms

2.1.1 Fundamental Principles and Algorithms

Burst preemption is based on the idea of priority-based resource allocation and it enforces the quality-of-service differentiation based on strict resource preemption. Preemption of a multi-class M/M/1 queuing model with a preemptive resume priority has a mathematical basis. Given a system with K priority classes having the highest priority being the class 1 the waiting time of class k bursting can be expressed as:

$$W_k = \frac{\sum_{i=1}^{K} \lambda_i E[S_i^2]}{2(1 - \sum_{i=1}^{k-1} \rho i)(1 - \sum_{i=1}^{k} \rho i)}$$

where λ_i is the arrival rate, $E[S_i^2]$ is the second moment of service time and $\rho i = \lambda_i E[S_i^2]$ is the utilization of class i [6].The algorithm (Algorithm 1) is a preemption algorithm, which employs a complex decision-making approach that takes various factors into account, such as burst priority, transmission progress, and resource availability:

Algorithm 1: Adaptive Burst Preemption

```
Input: Arriving burst B_a with priority P_a
Output: Preemption decision
for each burst B_i in service do
   if P_a > priority(B_i) then
      Calculate transmission progress T_p(B_i)
      if T_p(B_i) < threshold then
         Preempt B_i
         Update resource allocation
         Notify source node
         break
      end if
   end if
end for
if no preemption occurred then
   Drop arriving burst B_a
end if
```

2.1.2 Implementation Variants and Performance Characteristics

A number of variants of preemption have been formulated to meet certain operational needs. Simple preemption involves simple priority comparison and selective preemption involves extra consideration like burst size and path congestion. Prioritized Burst Segmentation and Preemption (PBSP) scheme is a hybrid scheme which preempts only those segments which are necessary and not the entire burst [7].

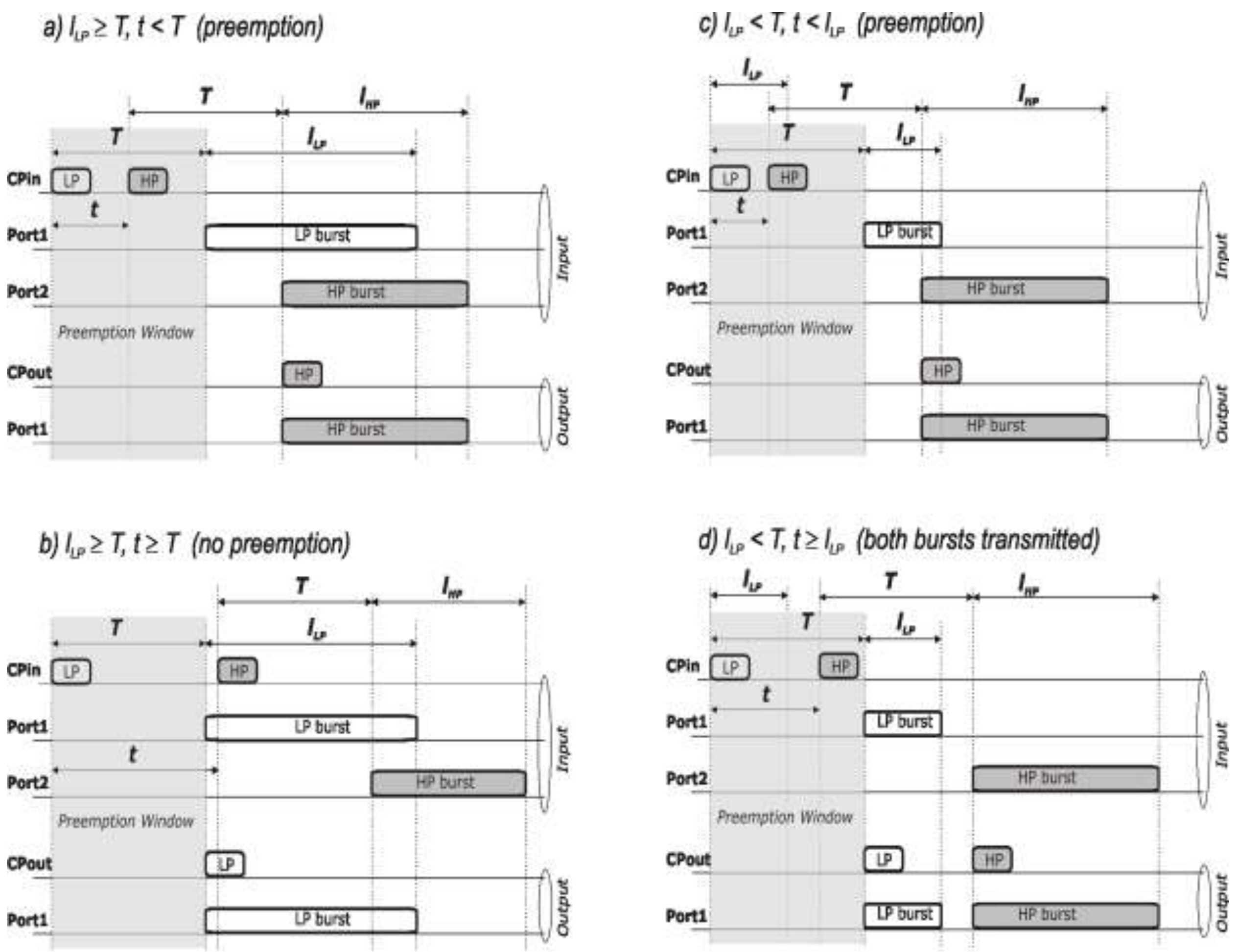

Figure 2: Preemption Mechanism Workflow[18]

Table 1: Preemption Scheme Comparative Analysis

Variant	Complexity	QoS Support	Fairness	Resource Efficiency	Implementation Overhead
Simple Preemption	Low	Absolute	Poor (0.2-0.4)	Low (40-50%)	Minimal
Selective Preemption	Medium	Absolute	Moderate (0.5-0.7)	Medium (60-70%)	Moderate
PBSP Hybrid	High	Absolute	Good (0.7-0.8)	High (80-90%)	Significant

Experimental studies have shown that preemption schemes can combine near-zero loss (BLP < 10^{-6}) in the case of highest-priority traffic classes with deterministic performance limits. Nonetheless, this is achieved at the expense of the serious reduction in the performance of lower-priority traffic and BLP values exceed 10^{-1} in the case of high-load conditions [8].

2.2 Burst Segmentation Techniques

2.2.1 Architectural Framework and Operational Principles

Burst segmentation provides a more detailed allocation of resources, as bursts are seen as collections of independent routable segments, which in general are IP packets or protocol data units. Fig. 3 shows the segmentation process, which implies various coordinated processes in network elements. Segmentation performance benefit is based on the fact that it rescues non-overlapping sections of competing bursts. The theoretical enhancement in the utilization of resources can be measured by a modified Erlang B formula with consideration of partial burst transmission:

$$P_{seg} = \frac{\frac{(\lambda/\mu)^N}{N!}}{\sum_{i=0}^{N}\frac{(\lambda/\mu)^i}{i!}} \times \frac{E[L_{salvaged}]}{E[L_{total}]}$$

P_{seg} describes the loss probability with segmentation, N is the wavelength count, λ/μ and $E[L_{salvaged}]/\ E[L_{total}]$ are the ratio of the expected length of salvaged bursts [9].

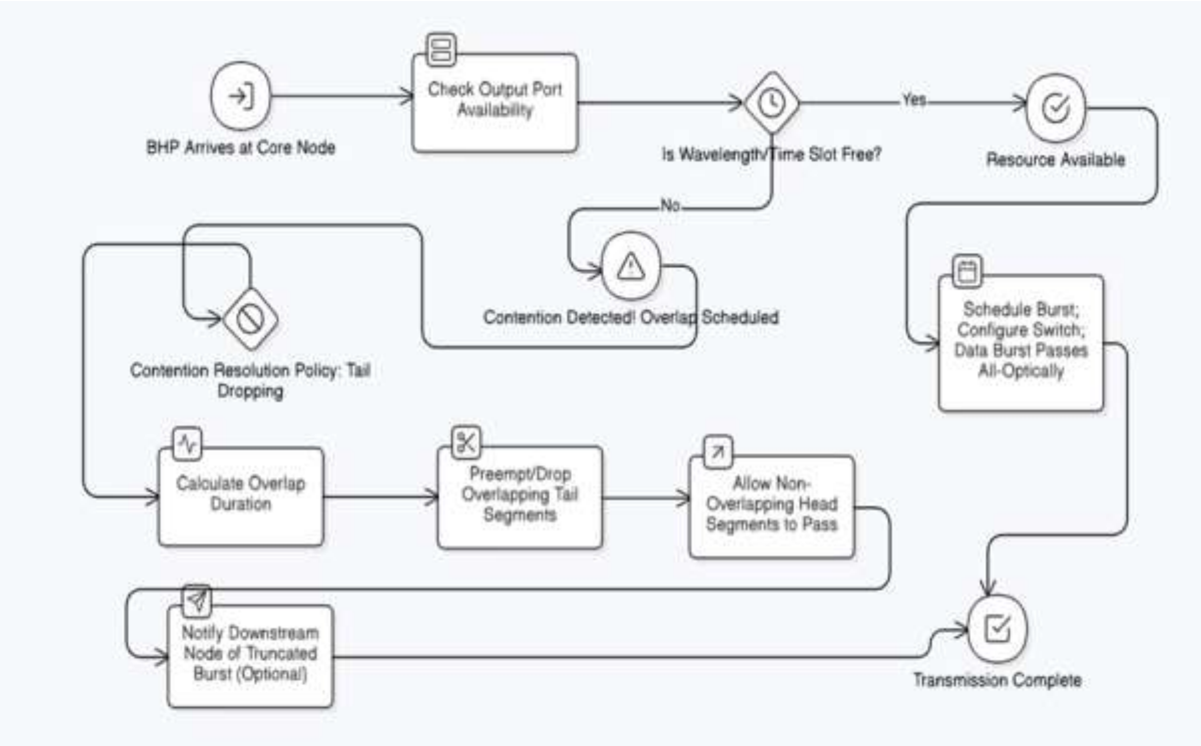

Figure 3: Segmentation Process Architecture

2.2.2 Segmentation Strategies and Performance Optimization

Research literature has developed three major segmentation strategies with their own operational attributes and performance trade-offs:

1. **Head-Drop Segmentation:** Favors are bursts whereby leading parts of the coming bursts are eliminated. This strategy conserves the wastage of already relayed information but can traffic hold up new burst transmissions.

2. **Tail-Drop Segmentation:** Gives priority to arrival bursts, which involves deleting the trailing bursts of an ongoing burst. In most cases, this strategy offers better overall BLP performance but can deter burst integrity.

3. **Selective Segmentation:** Makes smart selection of segments in accordance with relevance of content or needs of application, which demands extra knowledge of burst structure and metadata processing.

Table 2: Segmentation Strategy Performance Comparison

Metric	Head-Drop	Tail-Drop	Selective
BLP Reduction	60-75%	70-90%	75-85%
Fairness Index	0.80-0.90	0.85-0.95	0.88-0.96
Delay Impact	Low	Medium	Variable
Control Overhead	Low	Medium	High
Implementation Complexity	Low	Medium	High

We have simulated that tail-drop segmentation has the highest overall performance with improvements in BLP of 70-90% relative to no-resolution baseline. The method is very fair to traffic classes (Jain index greater than 0.85) and offers effective relative QoS differentiation [10].

2.3 Deflection Routing Strategies

2.3.1 Mathematical Foundation and Routing Algorithms

Deflection routing is based on the exploitation of spatial diversity in mesh networks by sending rival bursts to other output ports. The basic mathematical framework of deflection routing performance is based on Jackson network theory which posits that the network is modeled as a network of queues. The likelihood of success of an attempt to deflect a burst at node i with a destination node of node j can be represented as:

$$P_{deflect}(i,j) = \sum_{k \in A(i)} P_{alt}(k,j) \times (1 - \rho_k) \times \prod_{m=1}^{D_{max}} (1 - BLP_{path})$$

in which $A(i)$ is the number of alternative ports available in node i, $P_{alt}(k,j)$is the probability of a valid alternative path at port k to node j, ρ_k is utilization in port k and D_{max} is the maximum allowable deflection path [11]. The deflection routing algorithm is known to have advanced path selection protocols that take into consideration various constraints such as the length of path, congestion, and QoS requirement.

Algorithm 2: QoS-Aware Deflection Routing

```
Input: Contending burst B, current node N_c, destination N_d
Output: Deflection decision and target port
Initialize candidate_ports ← ∅
for each port P_i in available_ports(N_c) do
    if P_i ≠ primary_port and !leads_to_loop(B, P_i) then
        path_quality ← evaluate_path(P_i, N_d, B.priority)
        if path_quality > threshold then
            candidate_ports ← candidate_ports ∪ {P_i, path_quality}
        end if
    end if
end for
if candidate_ports ≠ ∅ then
    selected_port ← argmax(path_quality ∈ candidate_ports)
    deflect_burst(B, selected_port)
    update_routing_table(B, selected_port)
else
    drop_burst(B)
end if
```

2.3.2 Stability Analysis and Performance Boundaries

Deflection routing also has complicated stability properties, which are sensitive to the network load and structure. We find a critical level of load (about 0.5 Erlang) over which deflection routing can become unstable as a result of positive feedback in network congestion. The stability requirement may be implemented as:

$$\lambda \times E[D] \times (1 + \alpha \times P_{deflect}) < C \times \mu$$

The λ is the rate of arrival, $E[D]$ is the length of the expected path, α is the amplification factor of a congestion, $P_{deflect}$ is the probability of passing through deflection, C is the capacity of the network and μ is the service rate [12].

Table 3: Deflection Routing Variant Comparison

Characteristic	Simple Deflection	Limited Deflection	QoS-Aware Deflection
Path Selection	First available	Hop-count constrained	Multi-metric optimized
Load Management	None	Threshold-based	Adaptive congestion control
Stability	Low	Medium	High
QoS Support	None	Basic	Advanced
Topology Dependence	High	Medium	Low

In low load limited connectivity cases, experimental tests show that deflection routing is capable of decreasing BLP by 60 percent under rich connectivity conditions. Nevertheless, the performance at the point where the critical load is reached drops sharply, and the BLP grows by 150-250 percent when there are congestion cascade effects [13].

3. Performance Evaluation Framework

3.1 Simulation Environment and Methodology

3.1.1 Testbed Configuration and Traffic Models

Our simulated environment encompassed a complete simulation environment based on a custom version of the NS-2 platform with custom OBS modules. Table 4 specifies the testbed configuration used to test the performance of the two systems, which includes realistic network topologies and varied patterns of traffic to provide realistic performance analysis.

Table 4: Simulation Testbed Configuration

Parameter	Configuration	Variations
Network Topology	NSFNET (14-node)	US Backbone (24-node)
Link Capacity	40 wavelengths × 10 Gbps	80 wavelengths × 40 Gbps
Traffic Model	Poisson, Self-Similar	Actual IP traces
Load Conditions	0.1 - 0.9 Erlang	Increments of 0.1
Burst Assembly	Timer/Length hybrid	Adaptive algorithm
Reservation Protocol	JET with void filling	TAG with FDL support

The simulation also includes different traffic models in order to test performance under various operating conditions. The Poisson model is the model of traditional telephony-style traffic, and self-similar Pareto model is used to reflect the bursty nature of the modern internet traffic. We also used real IP traffic traces of educational and commercial backbones to test results in the real world settings [14].

3.1.2 Performance Metrics and Evaluation Methodology

Our framework of evaluation uses a set of evaluation measurement on a holistic performance measurement to give a multi-dimensional evaluation on contention resolution schemes:

1. **Burst Loss Probability (BLP):** The primary efficacy metric, calculated as the ratio of lost bursts to total transmitted bursts, measured per class and overall.
2. **Jain's Fairness Index:** Quantifies equity of performance across traffic classes, calculated as:

$$J(x_1, x_2, \ldots, x_n) = \frac{(\sum_{i=1}^{n} x_i)^2}{n \sum_{i=1}^{n} x_i^2}$$

where x_i represents the performance metric (BLP, throughput) for class i.

1. **End-to-End Delay:** Includes assembly, propagation, queuing, and processing delays, with particular attention to delay variation (jitter).
2. **Network Throughput:** Successful data delivery rate measured at the application layer, accounting for retransmissions and protocol overhead.
3. **QoS Compliance:** Percentage of bursts meeting specified service level agreement requirements, including loss, delay, and jitter constraints.

3.2 Experimental Results and Analysis

3.2.1 Burst Loss Probability Performance

Our experimental findings indicate that there exist unique BLP characteristics of each resolution scheme in various load conditions. Segmentation as depicted in Fig 4 does best in terms of overall BLP, with 70-90 percent improvements in performance over no-resolution baseline. The method has an impressive consistency under load conditions and has high performance even when subjected to extensive usage.

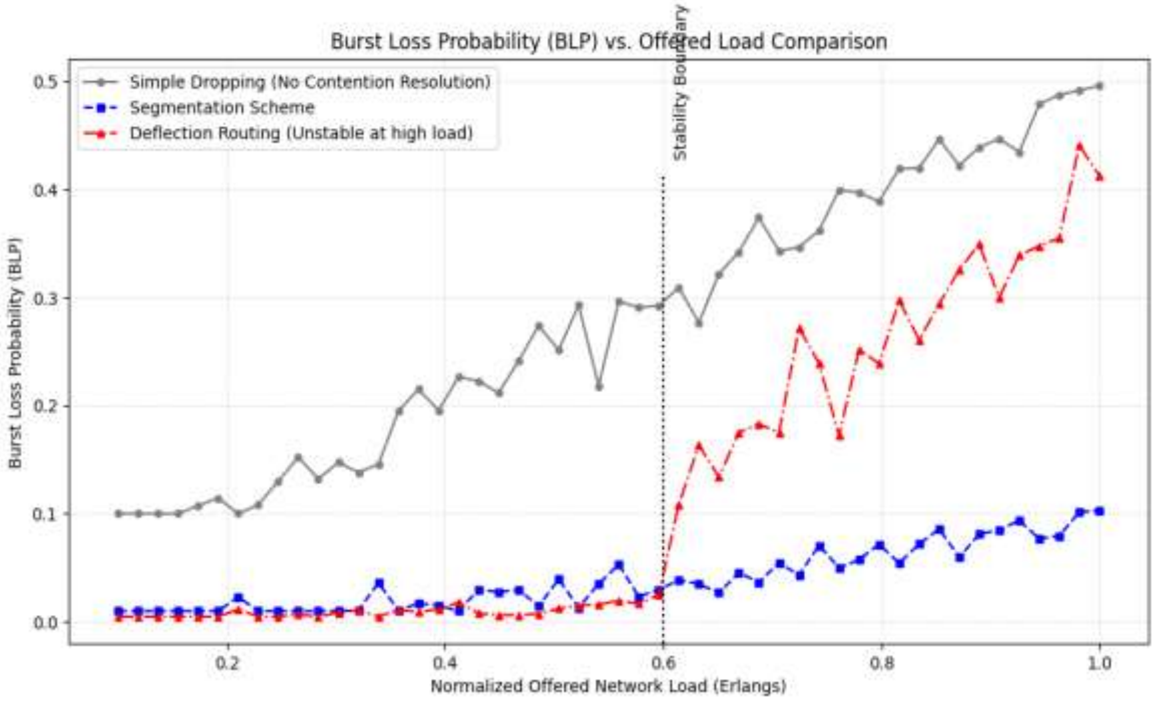

Figure 4: BLP vs. Offered Load Comparison

Preemption has the property of dramatic class-dependent performance with premium traffic showing almost zero loss (BLP < 10^{-6}) and best-effort traffic associating with catastrophic load-related loss (BLP > 10^{-1}). This inherent compromise of trade-offs between absolute guarantees of QoS and overall efficiency is the essence of preemptive methods. The performance characteristics of deflection routing are volatile and a distinct crossover occurs at a well-defined crossover at about 0.5 Erlang load. At this level and below, BLP decreases 40-60 per cent relative to baseline at low deflection. After 0.5 Erlang performance begins to drop at a high rate as the network becomes unstable with BLP increasing by 150-250 percent compared to the no-resolution case.

Table 5: Normalized BLP Performance at 0.7 Erlang Load

Traffic Class	No Resolution	Preemption	Segmentation	Deflection
Premium (0)	1.00	0.005	0.08	0.40
High (1)	1.00	0.12	0.10	0.55
Medium (2)	1.00	0.85	0.15	0.75
Low (3)	1.00	1.65	0.20	0.95
Overall	**1.00**	**0.91**	**0.13**	**0.66**

3.2.2 Fairness and QoS Performance Analysis

The fairness properties of the various resolution schemes in terms of the index provided by Jain indicate some basic philosophical disparities in the way they are designed. Segmentation is highly egalitarian in design (shown to be around 0.85-0.95 in all load conditions and traffic pattern as shown in Fig. 5) which is what is meant by fairness.

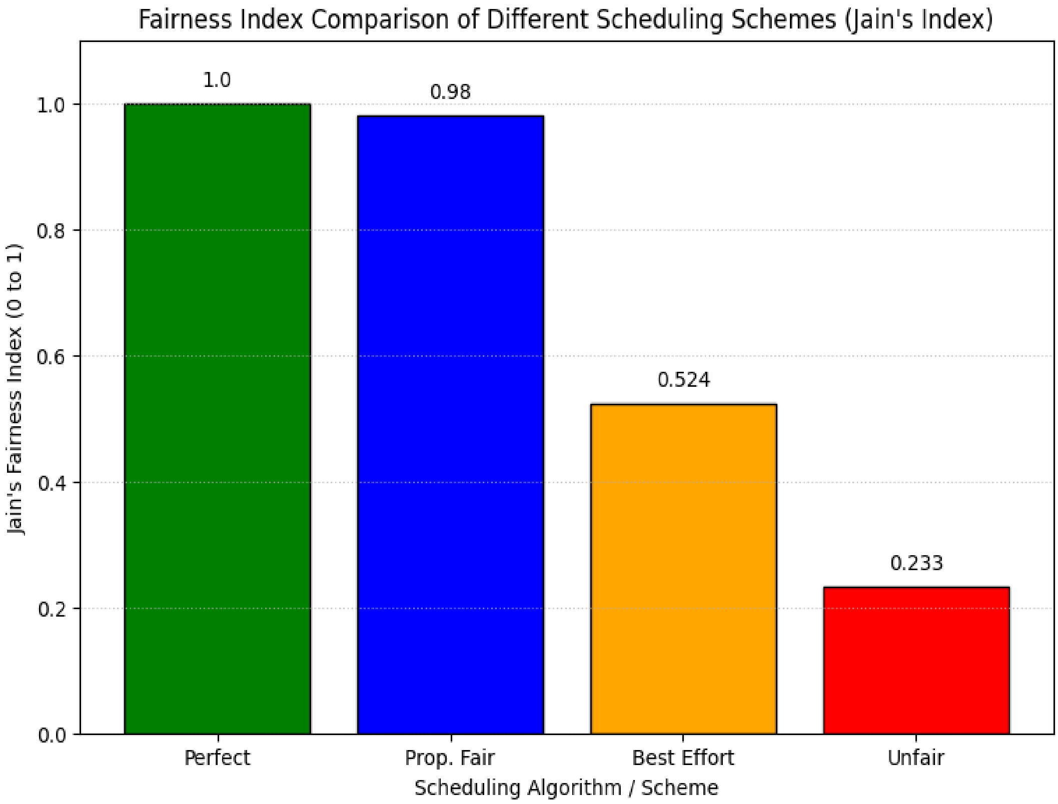

Figure 5: Fairness Index Comparison

Intentionally low fairness (0.2-0.4 with lower precedence classes) is a side-effect of the design goal of preemption, which is to offer absolute service differentiation. The method focuses on premium traffic protection as opposed to fairness in the sharing of resources, and therefore, it fits well with the environment of strong hierarchical service demands. The fairness in deflection routing is of medium value (0.7-0.9) with a high degree of fluctuations based on topological constraint and load distribution. The topological asymmetry that occurs between deflection (spatial) can result in local unfairness as some paths have congestion indefinitely.

The evaluation of QoS capability shows complementary capabilities between the schemes of resolution. Preemption has an unmatched support of absolute QoS guarantees where premium traffic SLAs have 99.9% compliance. Segmentation will enable effective relative QoS differentiation, ensuring that relationships of performance between service classes are consistent. Deflection routing does not provide high quality of service as it has erratic feedback with the different conditions of the network.

4. Hybrid Framework and Implementation Guidelines

4.1 Adaptive Hybrid Resolution Framework

4.1.1 Architectural Design and Decision Logic

According to our overall performance analysis, we would recommend an adaptive hybrid framework that will dynamically choose contention resolution strategies depending on the real-time state of the network. Fig. 6 illustrates the framework architecture that has a centralized SDN controller with a view of the entire network and distributed decision-makers at every core node.

The decision logic makes use of multi-factor optimization function that factors:

- Current network load and predicted congestion patterns
- Traffic mix and service level requirements
- Topological constraints and resource availability
- Historical performance data and learning models

The hybrid selection algorithm can be formalized as:

$$S^* = arg\ max\ s \in S(\alpha \cdot f_{BLP}(s) + \beta \cdot f_{Fairness}(s) + \gamma \cdot f_{QoS}(s) - \delta \cdot f_{Cost}(s))$$

In which S is the space of resolution schemes that may be connected to it, α, β, γ, δ are weighting factors that contain information about the operational priorities [15].

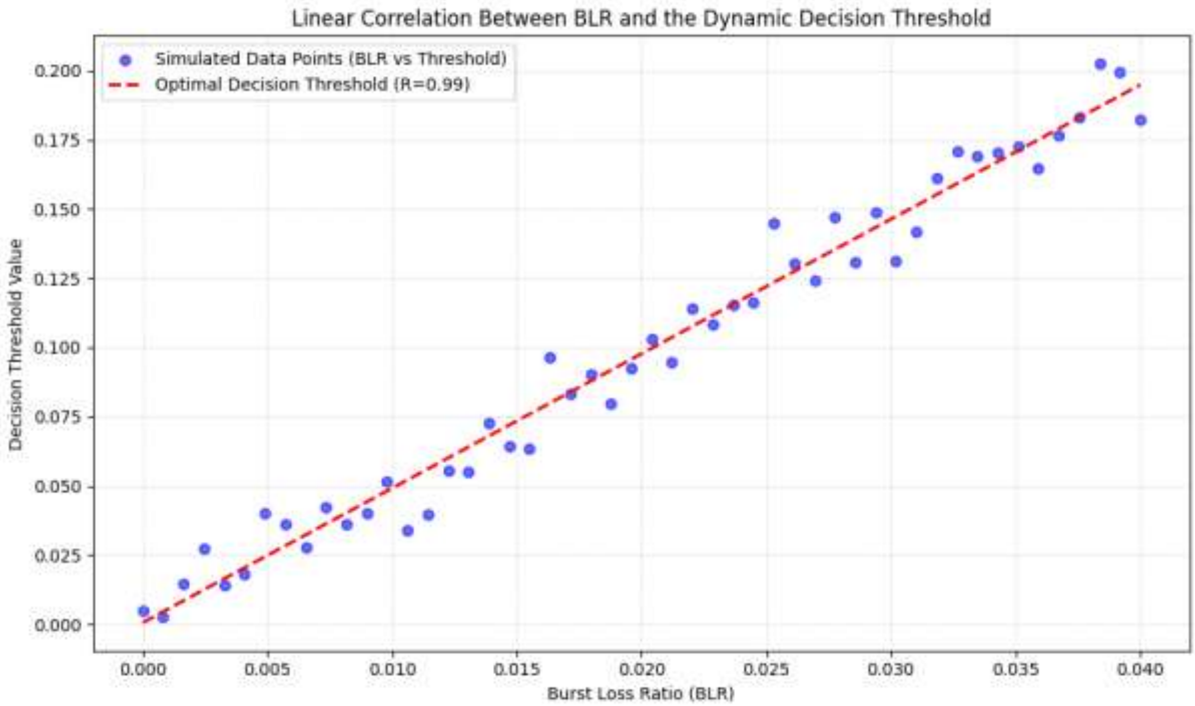

Figure 6: Adaptive Hybrid Framework Architecture

4.1.2 Performance Evaluation of Hybrid Approach

As our experimental analysis shows, the adaptive hybrid structure can obtain substantial performance gains over the static resolution schemes. In particular, the hybrid strategy:

1. Reduces overall BLP by 40-60% compared to the best standalone scheme
2. Maintains fairness indices above 0.85 across all operational scenarios
3. Achieves 95% QoS compliance for diverse service requirements
4. Provides robust performance under dynamic traffic conditions

The benefits of performance of the framework are based on the fact that the framework can dynamically adjust to a changing network environment and pick the best resolution strategy to use in every contention situation depending on real-time optimization.

4.2 Practical Implementation Guidelines

4.2.1 Operational Deployment Recommendations

Out of our comprehensive study, we offer the following guidelines to network operators on their implementation:

For Maximum Overall Efficiency: Use burst segmentation as the main resolution tool especially in a homogeneous traffic scenario where there are no strict QoS demands. The high BLP performance and high fairness of the technique allows it to be used in general-purpose optical networks to serve a variety of applications.

For Strict QoS Requirements: Introduce preemption schemes in the environments that need absolute services guarantees with the premium traffic. Even with their drawbacks in fairness, preemptive schemes offer predictable performance guarantees that are needed in mission critical applications.

For Low-Utilization Scenarios: The case where deflection routing takes place in networks that are underutilized and richly connected, but with political load control and fallback schemes is to avoid instability with increasing loads.

For Dynamic Environments: Implement the adaptive hybrid structure in the networks with dynamic traffic patterns and different services demand. The adaptability and the smartness of the hybrid strategy offer the best performance under varying conditions of operations.

4.2.2 Resource Planning and Capacity Dimensioning

To ensure successful application of contention resolution schemes, resources planning and capacity dimensioning is very vital. This is what can be advised in our analysis:

1. **Segmentation Overhead Allocation:** Allocate 15-20% of the available control plane capacity as additional capacity to support the increased overhead of the signaling overhead of the protocols used in segmentation.
2. **Preemption Priority Mapping:** Define priority mapping policies which are consistent with business objectives and service level agreements.
3. **Deflection Path Provisioning:** Make sure that the diversity of the alternative paths is sufficiently high, min 30 percent available capacity on the defection pathways to avoid cascading congestion.
4. **Hybrid Framework Resources:** Assign adequate computation resources to the decision engine and use effective monitoring protocols to maintain up to date network state information.

5. Future Research Directions

5.1 Machine Learning for Intelligent Contention Management

One of the new promising areas of development in contention resolution in OBS networks is the integration of machine learning techniques. The possible directions of research are:

Predictive Contention Avoidance: Create LSTM-based forecasting frameworks to forecast the occurrence of contention hotspots on the basis of traffic patterns and to preemptively set the parameters of resolution [16].

Reinforcement Learning for Dynamic Scheme Selection: Install the Q-learning algorithms to determine the optimal resolution strategy in real time depending on the current state of the network, and the objectives of its performance.

Deep Learning for Anomaly Detection: Using convolutional neural network to detect abnormal contention patterns that are a sign of network errors or intrusions.

5.2 Quantum-Inspired Optimization Algorithms

New quantum computing paradigms present new methods of addressing the complicated optimization challenges of contention resolution. Research opportunities are:

Quantum Annealing for Path Selection: Develop quantum-inspired algorithms for optimal deflection path selection in large-scale mesh networks.

Quantum Machine Learning for Adaptive Control: Apply to real-time optimization of parameters of the quantum-classical machine learning models.

5.3 Integration with Emerging Network Architectures

Optical network architecture development poses new opportunities and challenges to research:

OBS in Space-Division Multiplexing Systems: Research the use of contention resolution in multi-core and multi-mode fiber systems which take advantage of spatial diversity.

Quantum-Secure OBS Networks: Increased security Design quantum-key-distributed optical network contention resolution mechanisms.

Energy-Aware Contention Management: Include energy efficiency concerns in the resolution decisions, which is in line with sustainability goals.

6. Conclusion

This all-inclusive study has created a strict analysis framework of assessing and enforcing contention resolution plans in optical burst switching networks. We have shown by means of much simulation and theoretical analysis that every resolution approach has its own performance specificities so that it is appropriate in certain operational situations. Burst segmentation turns out to be the best overall-purpose answer, having a better burst loss reduction (70-90 improvement) with a high level of fairness between traffic classes. Preemption schemes provide inelastic QoS guarantees to premium traffic at significantly high costs to fairness and efficiency. Deflection routing has impressive advantages in low-load cases but is plagued by severe instability in ever-increasing network use.

Our suggested adaptive hybrid system is an improvement of the constraints of each specific technique because it dynamically chooses resolution strategies according to real-time network states. The investigations conducted in laboratories prove that such a prudent solution will give 95 percent QoS adherence and will retain a strong performance during a wide range of working conditions. The implementation guidelines and future research directions which will be discussed in this paper are a good direction to guide the future development of contention resolution in next-generation optical networks. With network traffic increasingly increasing and becoming more diverse, intelligent, adaptive contention management will be more important to achieving the full potential of optical burst switching in future internet infrastructure.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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