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Performance Evaluation of Static vs. Adaptive Burst Size Techniques in Next-Generation OBS Architectures

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Abstract
According to the majority of Internet users, the performance of real-time traffic applications is measured and evaluated in terms of quality, speed, and efficiency. Applications such as online games, remote surveillance cameras, and online surgeries always require a large amount of bandwidth and high transmission speed. Consequently, the Optical Burst Switching (OBS) network is the typical technology currently used as an infrastructure to support these highly demanding communications. However, Quality of Service (QoS) in network communication remains a challenge, particularly in reducing three key criteria: packet loss, packet delay, and packet jitter. In this research, a hybrid (threshold-based and timer-based) burst assembly technique is implemented at an edge node, and various traffic loads with different burst lengths are applied and analyzed. Based on this evaluation, burst assembly issues are identified and classified according to media QoS criteria. To address these challenges, the Adaptive Burst Size (ABS) assembly technique is proposed and developed as an enhancement to static burst size techniques. The ABS technique consists of two main components: the traffic classification section and the size adaptation section. In the traffic classification section, the DiffServ technique is applied, while the size adaptation section manages the ABS functionality. Through the design, integration, and

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implementation of the ABS technique, QoS issues in OBS networks are mitigated by reducing packet loss, packet delay, and packet jitter. Therefore, the ABS technique is considered a flexible, capable, and efficient burst assembly method.

Keywords: Optical Burst Switching (OBS), Burst Assembly, QoS, Static Burst Size (SBS), Adaptive Burst Size (ABS).

تقييم أداء تقنيات حجم الاندفاع الثابت مقابل التكيّفي في معماريات OBS في الجيل القادم

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المخلص

وفقًا لغالبية مستخدمي الإنترنت، يتم قياس وتقييم أداء تطبيقات حركة مرور المعلومات في الوقت الفعلي من حيث الجودة والسرعة والكفاءة. تتطلب هذه التطبيقات مثل الألعاب عبر الإنترنت وكاميرات المراقبة عن بعد والجراحات عبر الإنترنت وما إلى ذلك دائمًا قدرًا هائلاً من النطاق الترددي مع سرعة نقل عالية. وبالتالي، فإن شبكة (OBS) هي التقنية النموذجية المستخدمة حاليًا كبنية أساسية للتعامل مع معظم هذه الاتصالات عالية الطلب. ومع ذلك، أصبحت جودة الخدمة (QoS) لاتصالات الشبكة مشكلة خاصة في تقليل معدلات ثلاثة معايير رئيسية وهي فقدان الحزمة وتأخير الحزمة وتأخير اهتزاز الحزمة. في هذا البحث، تم تنفيذ تقنية التجميع المتدفقة الهجينة (القائمة على العتبة والمؤقتة) في عقدة حافة، و تم تطبيق وتحليل أحجام مختلفة من أحمال حركة المرور بأطوال نبضات مختلفة. من خلال تقييم هذه التحليلات، يتم الكشف عن مشكلات تجميع النبضات وتصنيفها بناءً على معايير جودة خدمة الوسائط. لذلك، تم اقتراح وتطوير تقنية تجميع حجم النبضة التكيفي للتغلب على مشكلات جودة الخدمة في تقنيات حجم النبضة الثابتة. يتم تطبيق تقنية ABS من خلال قسمين هما قسم تصنيف حركة المرور وقسم تكييف

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الحجم. في قسم تصنيف حركة المرور، يتم تنفيذ تقنية DiffServ. ويتم تطوير وظيفة ABS في قسم تكييف الحجم. من خلال تصميم ودمج وتنفيذ تقنية ABS، يتم حل مشكلات جودة الخدمة عبر شبكة OBS مع تقليل معدلات فقدان الحزمة وتأخير الحزمة وتأخير اهتزاز الحزمة. لهذا السبب، تعتبر تقنية ABS واحدة من تقنيات التجميع المتواصل المرنة والقادرة والفعالة.

الكلمات المفتاحية: التبديل البصري الاندفاعي (OBS)، تجميع الاندفاع (Burst Assembly)، جودة الخدمة (QoS)، حجم الاندفاع الثابت (SBS)، حجم الاندفاع التكيفي (ABS).

1. Introduction.

The rapid growth of digital services such as video-on-demand, online gaming, and virtual conferencing has significantly increased the demand for real-time internet applications. These applications require not only substantial bandwidth but also fast and reliable transmission of data packets across complex network infrastructures [1]. As a result, maintaining Quality of Service (QoS) has become a critical challenge in networking. Among these applications, video streaming has emerged as one of the most demanding. However, it suffers from issues such as frame delay, network jitter, and frame loss, all of which negatively affect the end-user experience [1][2]. These problems can lead to buffering, degraded visual quality, or even service interruptions. Because of these challenges, ensuring QoS in real-time services requires careful management of performance parameters throughout the entire transmission process [3].

Optical Burst Switching (OBS) networks have been proposed as a suitable infrastructure to address the needs of high-bandwidth and low-latency applications. OBS combines the efficiency of optical transmission with the flexibility of packet switching, making it a strong candidate for next-generation network architectures. Nevertheless, conventional burst assembly mechanisms still face limitations in meeting the stringent QoS requirements of real-time traffic, particularly with respect to packet loss, delay, and jitter.

Optical networks offer significant advantages in addressing many of the limitations associated with electronic networks. A key issue that

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optical networks can mitigate is the inability of electronic networks to handle high-capacity traffic loads [4][5]. The architecture of an Optical Burst Switching (OBS) network is composed of two primary components within the optical domain: the edge node and the core node. One of the critical functions of the OBS edge node is burst assembly, where incoming Internet Protocol (IP) packets are aggregated into optical bursts that are then scheduled for transmission across the network [6][7][8]. The burst assembly process is governed by two principal algorithms: threshold-based and timer-based. However, both algorithms face challenges, including increased delay and data loss, which negatively impact network performance. These issues are analyzed in detail below.

The threshold-based burst assembly algorithm operates by defining a fixed parameter, typically measured in bytes, to determine the size of each burst before it is forwarded from a queue [10][11]. When an incoming packet satisfies the aggregation size requirement, marking it as the last packet for the current burst, the burst transitions from the assembly queue to the forwarding queue and is scheduled for optical transmission. However, this method does not guarantee delay minimization. Under low input traffic, bursts may experience prolonged waiting times in the assembly queue until the predefined size is reached. Conversely, in high-traffic scenarios, the threshold is quickly met, leading to reduced delays [5][12][13]. While this fixed-burst-length approach can be efficient for general data traffic, it is unsuitable for applications requiring low latency, such as real-time traffic. In essence, the algorithm forces bursts to wait until either the fixed size is reached or the predetermined inter-departure time elapses, making it less adaptable to varying traffic demands.

The timer-based burst assembly algorithm, by contrast, relies on a single configurable, time-dependent parameter [14][15]. In this method, each queue is assigned a timer that corresponds to a designated time period, aligning with the inter-departure times of bursts associated with that queue. The timer starts when the system begins and resets upon the generation of each new burst [18]. Under low input load conditions, this method ensures a fixed minimum delay, thereby providing consistent performance. During high input load, however, the algorithm may produce bursts that are considerably larger in size [16][17]. Thus, the primary challenges

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associated with these techniques in OBS networks are packet loss and packet delay.

The issue of packet loss becomes particularly significant when minimal burst sizes are used for video traffic transmission [19][20][21]. Under high traffic demand, the frequency of frame losses tends to increase while frame delay decreases. As a result, although some video streams reach their destinations in satisfactory condition, others may experience significant degradation in quality. Consequently, for optimal video performance, it is essential to transmit a substantial number of frames while carefully managing burst aggregation time.

Regarding packet delay, studies of threshold-based burst assembly reveal that increasing the maximum burst size leads to higher overall delay, which may be necessary to ensure effective video transmission. Each video flow may experience varying degrees of end-to-end frame delay. Thus, larger burst sizes are correlated with improved video quality, as more transmitted frames generally enhance quality. However, generating larger bursts requires additional time to accumulate frames within a single burst. This accumulation time may exceed the predefined timeout, preventing timely forwarding of the burst.

3. Experimental Design.

3.1 Analysis & Identify the Traffic Load Parameters over OBS network.

The analysis stage plays a crucial role in the development of new techniques in the field of networking. In the context of this study, the analysis phase clarifies the characteristics of the Optical Burst Switching (OBS) network environment and identifies the challenges associated with burst creation and forwarding. To effectively conduct this analysis and ensure successful implementation, several critical requirements must be addressed in the OBS network environment.

These requirements include a comprehensive understanding of the network's operational characteristics, burst traffic behavior, and the protocols used to manage burst assembly and transmission. In addition, it is essential to evaluate performance metrics such as packet loss, delay, and overall throughput to ensure the network can accommodate various types of traffic, particularly multimedia

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applications. By addressing these factors, researchers can establish a robust framework for analyzing and optimizing OBS network performance [3][5][6]. This framework, in turn, facilitates the advancement of innovative techniques that enhance both efficiency and reliability.

The parameters applied in this study include:

- NSF network topology
- Bandwidth sizes: 50, 100, 150, …, 1000 Mbps
- Possible burst delay: 1 µs
- Burst timeout: 10 µs
- Burst size range: 10,000–16,000 bytes (increments of 1,000)
- Maximum queue length: 60,000 bytes
- Packet size range: 500–1500 bytes (increments of 50) [7][8][6]

All of these parameters were implemented using the NCTUns 6.0 simulator, and the results were obtained based on the configurations above.

The findings are presented as a pre-analysis of the current burst assembly methods (timer-based and threshold-based). The results are evaluated using three primary QoS metrics for real-time applications: frame loss, frame delay, and frame jitter.

3.1.1 Packet Loss Rate.

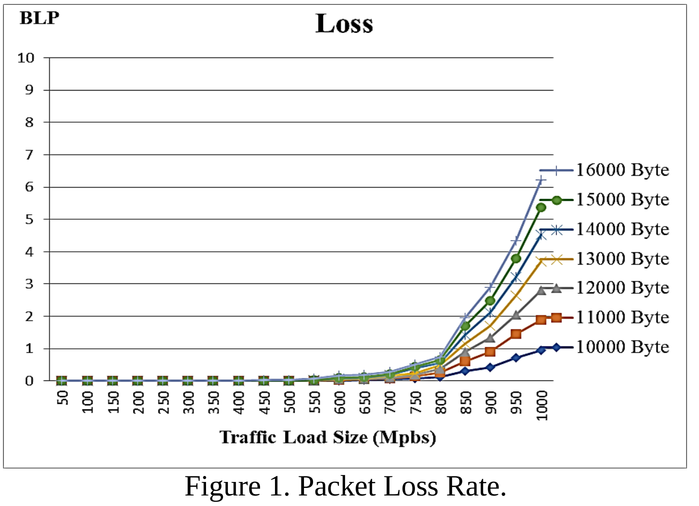

Figure 1. Packet Loss Rate.

Figure 1 illustrates the Burst Loss Probability (BLP) across varying traffic loads and burst sizes using a hybrid burst assembly approach (threshold/timer-based), where bursts aggregate until either the size threshold is reached or the timer expires. Under light traffic, loss rates remain consistently low across all burst configurations. However, as traffic intensity increases, smaller bursts generate higher transmission frequency and greater contention, while still maintaining relatively low packet loss. By contrast, larger bursts consume more bandwidth but result in significantly higher packet loss during collisions.

The relationship between packet size and loss rate is critical, as burst capacity directly depends on the ratio between packet size and the threshold. For example, a threshold of 15,000 bytes may contain 30 packets of 500 bytes each or 10 packets of 1500 bytes each. This ratio makes packet size a decisive factor in determining loss probability.

3.1.2 PACKET Delay Rate.

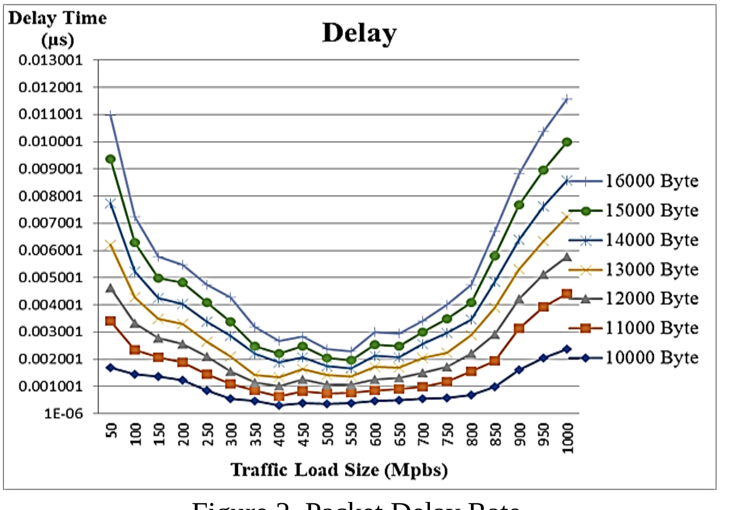

Figure 2. Packet Delay Rate.

Figure 2 illustrates the relationship between traffic delay time (μs) and varying traffic loads and burst sizes. Under light traffic, delays increase because the timer-based assembly mechanism forces packets to wait until the timeout expires. As traffic intensifies, delays grow progressively as packets queue while awaiting new burst assembly. The first-come-first-served switching mechanism further compounds these delays at congested ports.

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Packet size has a significant influence on delay rates. Large bursts under light traffic are more susceptible to timeout-related delays, while small bursts under heavy traffic create contention-induced congestion. Consequently, burst size emerges as a critical determinant of packet delay behavior across all traffic conditions.

3.1.3 Packet Jitter Rate.

Technically, jitter is the displacement or deviation of certain components of pulses in a high-frequency digital signal, as observed in real-time applications. Packet Delay Variation (PDV) is another term for jitter, defined as the difference in end-to-end latency between a subset of packets in a flow, with lost packets disregarded [8]. Therefore, the processing and delay time parameters of the OBS network should be used to determine the default delay time for a single packet:

$$\text{Packet Propagation Delay} = \underbrace{T_{\text{agg}}}_{\text{Aggregation Time}} + \underbrace{T_{\text{offset}}}_{\text{Offset Time}} + \underbrace{\sum_{i=1}^{N}\left(T_{\text{switch}}\right)}_{\text{Switching Time per Node}} + \underbrace{\theta}_{\text{Media Delay (E2E Path)}}$$

$$\text{Mean Jitter} = \frac{1}{n}\sum_{i=1}^{n}\left(T_{\text{Propagation},i} - T_{\text{Experimental},i}\right)$$

$$\text{Jitter \%} = \left(\frac{\text{Jitter Rate}}{T_{\text{Propagation Delay}}}\right) \times 100\%$$

Figure 3 displays the jitter findings graphically after we computed the jitter value from the experimental delay results:

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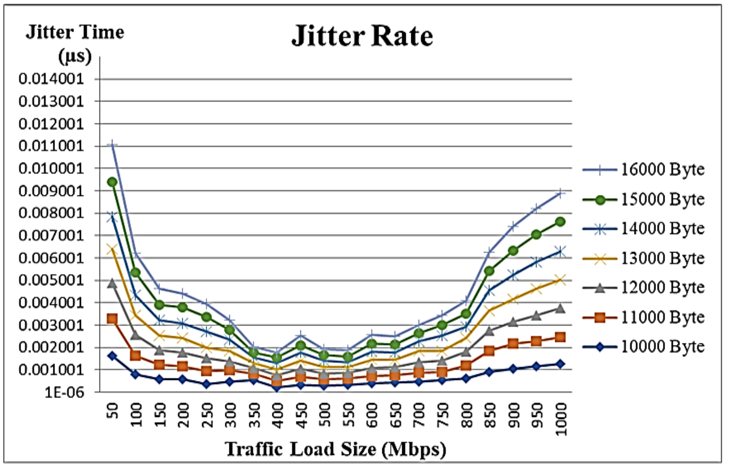

Figure 3. Packet Jitter Rate.

The traffic jitter time in microseconds across varying traffic loads and burst sizes illustrates the difference between Packet Propagation Delay Time and Experimental Packet Delay Time in Figure 3. Under light traffic conditions, the jitter rate increases because the first-come-first-served (FCFS) approach is used to queue packets in the buffer as they arrive. In this case, the assembler often waits for the last arriving packet before forming a new burst, which increases jitter. This is referred to as buffer packet delay queuing. Furthermore, when the burst timeout is reached, the burst is transferred from the burst assembly queue to the burst scheduling queue. This waiting process also increases jitter, a phenomenon described as buffer burst delay queuing.

Additionally, the first arriving packet must wait until the assembler completes aggregation before the burst can move to scheduling and forwarding through the channel to the next optical router. These increases jitter as well and are referred to as packet delay into the burst. When many bursts arrive at a switching port under high traffic load, the router initiates queue switching in a first-come-first-served order. Until the burst reaches the egress node for segmentation, all packets remain compressed within the burst. The delay in the burst switching procedure further contributes to increased jitter.

In summary, three main parameters—burst size, packet size, and traffic load—determine whether the three major performance criteria—loss, delay, and jitter—increase or decrease in the pre-

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analysis results. Under light traffic demand, the number of packets per burst grows as aggregation latency increases with burst size, reducing contention and burst loss rates. Conversely, under heavy traffic load, each increase in burst size results in more packets but shorter aggregation latency, which simultaneously increases burst loss and contention.

High-quality real-time application performance requires both an increase in transmitted frames and a reduction in jitter. Based on the analysis, a burst size of 10,000 bytes is identified as the near-optimal configuration, achieving the lowest rates of packet loss, packet delay, and packet jitter, while also considering the minimal number of packets carried at this size.

4. Design and Implement the Adaptive Size Burst Assembly Scheme.

The following aspects of the scheme's structural process are examined. Initially, traffic packets are received by the edge router, which classifies them into two categories: media packets and non-media packets. Non-media packets may need to wait for the completion of other traffic, after which the default burst size is applied. In the case of media packets, however, the edge router evaluates the traffic load. If the traffic load is high, the burst size is set to large; if the traffic load is medium, the burst size is set to normal; and if the traffic load is low, the burst size is set to small.
After classification and burst size determination, the edge router begins creating a new burst. During the burst assembly process, packets are aggregated from the queue, and the countdown timer starts once the first threshold is reached. Packet aggregation continues until either the timer exceeds the burst timeout or the burst reaches the required size. At that point, the edge router determines that the burst is ready for transmission. If the queue is not empty, the edge router generates a new burst and repeats the process. Conversely, if the traffic flow ends, the router remains idle until the next packet arrives. If traffic continues, the router immediately resumes burst creation, ensuring continuous processing of incoming data.

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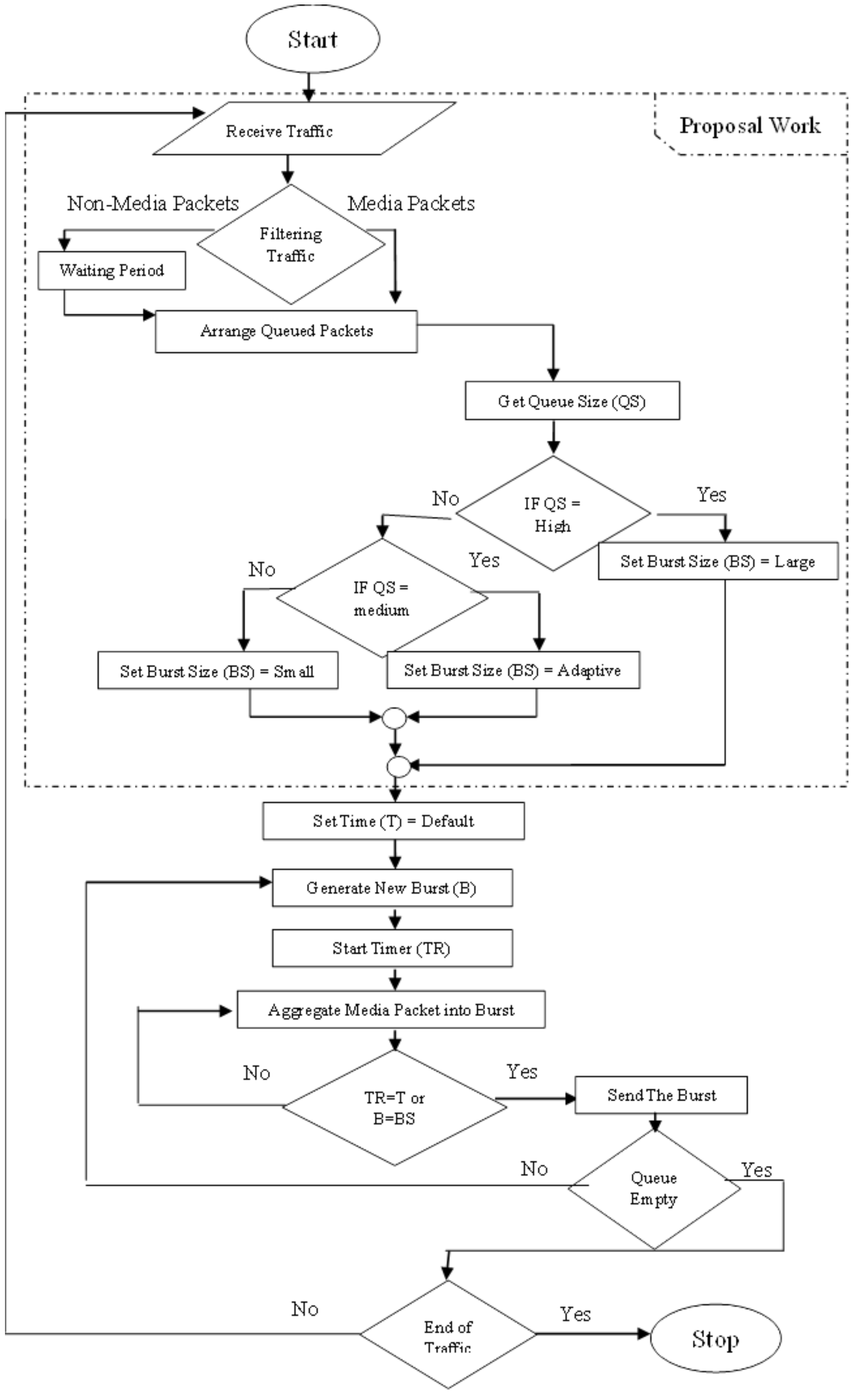

Figure 4. An Adaptive Size of Burst Assembly Scheme

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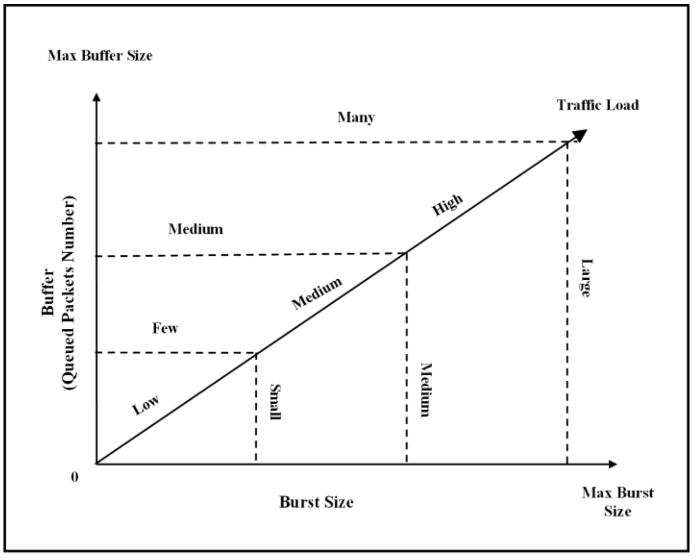

Figure 5. The Burst Size Adaptation Process

The adaptation process of burst size is a key component of the proposed technique, as illustrated in Figures 4 and 5. Classified packets are first arranged according to packet class before reaching the adaptation stage. Next, burst size is allocated for the incoming packet stream.

- Under high traffic load, the burst size is set to large.
- Under low traffic load, the burst size is set to small.
- Otherwise, the burst size is dynamically allocated according to the number of packets in the buffer.

When the buffer contains only a few queued packets, the burst size is kept small. As the number of queued packets increases, the burst size gradually increases as well, and vice versa. In this way, burst size is dynamically adjusted based on buffer capacity. Figure 6 presents the pseudo-code that describes the structure of the ABS technique:

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```
Begin
        While (Traffic Packets is Receiving) Do
                Set Received Packets into Buffer
                While (Buffer isn't Empty) Do
                        Filter Packets
                        Arrange Queue
                        Send Queued Packets
                End While
                While (Arranged Queued Packets aren't Stop) Do
                        IF Queue Size is High Then
                                Set Burst Size is Large
                        Else IF Queue Size is Medium Then
                                Set Burst Size is Adaptive
                        Else IF Queue Size is Low Then
                                Set Burst Size is small
                        End IF
                        Start Burst Assembly
                        Send Generated Burst
                End While
        End While
End
```

Figure 6. An Adaptive Size of Burst Assembly Scheme (Pseudo code).

Regarding traffic load classification, the DiffServ Expedited Forwarding (EF) mechanism is applied within the adaptive schema. The DiffServ domain provides a method for arranging packet streams according to class. As such, packets belonging to the media class are given higher priority than non-media packets. Moreover, the DiffServ domain guarantees QoS in terms of low loss, low latency, low jitter, and allocated bandwidth service. Figure 7 illustrates the traffic classification process.

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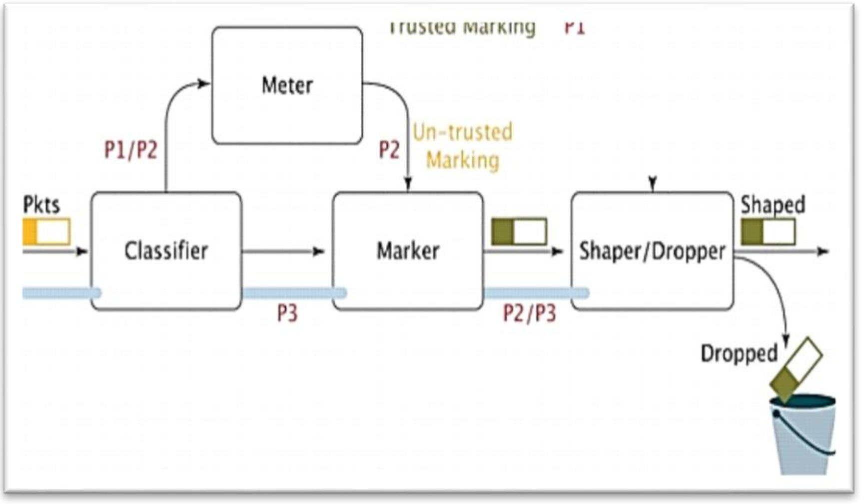

Figure 7. DiffServ Traffic Conditioner Block (Cisco, 2006).

Figure 7 shows the DiffServ Traffic Conditioner Block (DSTCB) technique, which is performed at the boundary of the DiffServ domain [22][23]. In traffic conditioning and classification, packets are queued and classified into predefined aggregations, then metered to determine compliance with traffic parameters. This determination is based on whether packets are in-profile or out-of-profile. Each packet is then marked appropriately by writing or rewriting the DiffServ Code Point (DSCP). Marked packets are either shaped into buffers or dropped in the event of congestion.
Through this process, traffic flows are classified, and packet streams are queued according to their respective classes to achieve the target flow rate. The results of implementing the Adaptive Burst Size (ABS) burst assembly technique are then examined, compared, and evaluated in terms of the three principal QoS metrics for real-time traffic: packet loss, packet delay, and packet jitter. These assessments are conducted following the integration of ABS with the simulator.

Figure 8 compares packet loss rates between static and adaptive burst sizes across varying traffic loads. The Adaptive Burst Size (ABS) technique demonstrates superior performance by maintaining zero packet loss under low-to-medium traffic conditions through dynamic threshold adjustment based on buffer occupancy.

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4.1 Packet Loss Rate.

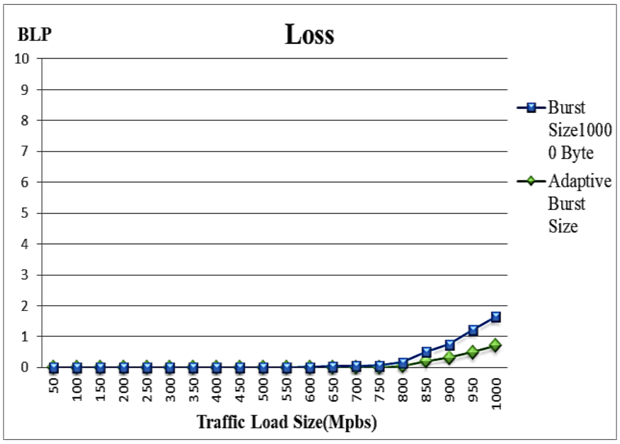

Figure 8. ABS Packet Loss Rate.

However, during heavy traffic, ABS increases burst sizes to accommodate queued packets, which leads to higher contention and, consequently, greater packet loss. While ABS effectively minimizes loss in moderate conditions by distributing bursts between small and medium sizes, its rapid aggregation under heavy loads results in larger bursts that exacerbate contention and increase loss rates. Overall, ABS significantly reduces packet loss compared to static sizing, with particularly strong improvements observed under low and medium traffic conditions.

4.2 Packet Delay Rate.

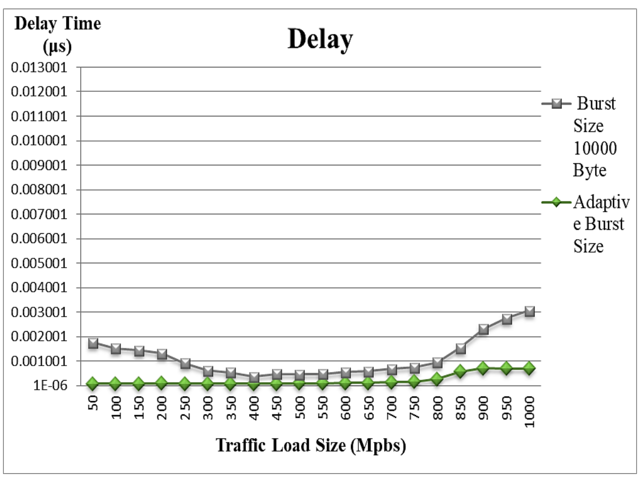

Figure 9. ABS Packet Delay Rate.

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Figure 9 compares delay times between static and adaptive burst sizes across varying traffic loads. The Adaptive Burst Size (ABS) technique maintains minimal delays (less than 0.00003 µs increase per load) under low-to-medium traffic conditions by dynamically adjusting burst sizes according to queue occupancy.
Under heavy traffic, ABS mitigates buffer congestion through three mechanisms:

1. Preventing burst postponement.
2. Creating new bursts from accumulated packets.
3. Optimizing transmission queue management through continuous size adaptation.

Although high traffic still introduces some transmission queue delays, the dynamic sizing of ABS, combined with edge-node traffic control via the DiffServ domain (DSD), significantly reduces both the absolute delay and its rate of increase compared to static burst sizing approaches.

4.3 Packet Jitter Rate.

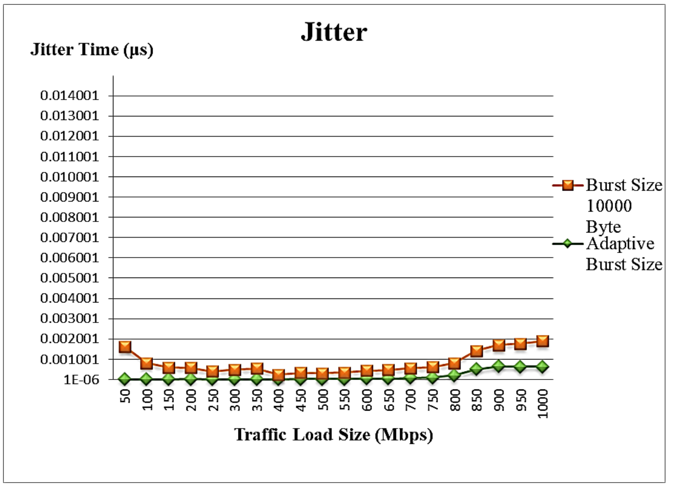

Figure 10. ABS Packet Jitter Rate.

Figure 10 illustrates the difference between experimental and packet propagation delay times by presenting traffic jitter values in microseconds across varying traffic loads, comparing static and adaptive burst sizes. The Adaptive Burst Size (ABS) technique decreases jitter delay rates under low and medium traffic conditions because queued packets are not delayed in the buffer, and scheduled bursts are smoothly routed through the channels. Under heavy traffic demand, the jitter delay rate increases slightly as packets arrive rapidly and are aggregated into bursts within the optical buffer. To accommodate the larger number of queued packets, ABS adaptively increases the burst size. In this scenario, the last arriving packet must wait in the queue until earlier packets have accumulated, while the first arriving packet is postponed until the adaptive threshold is reached. Despite these conditions, ABS still lowers the jitter delay rate compared to static burst sizing by dynamically adapting burst sizes to buffer conditions.

5. Results' Analysis and Evaluation

5.1 Packet Loss Rate Evaluation

Figure 8 presents the packet loss rate for both static and adaptive burst sizes, showing the relationship between burst loss probability (BLP) and varying traffic loads. In Static Burst Size (SBS), BLP rates increase according to the fixed threshold length as traffic load grows. By contrast, Adaptive Burst Size (ABS) lowers BLP rates through dynamic threshold adjustment. As a result, SBS frequently exhibits fluctuations in the number of lost packets, while ABS maintains either a steady rise or zero packet loss, depending on the traffic conditions. This behavior occurs because ABS determines burst size directly from the traffic load. Under light traffic, the burst size remains minimal. As traffic volume increases, the burst size grows adaptively, and under heavy traffic, the burst size becomes large. Thus, burst size plays a decisive role in determining whether packet loss rates increase or decrease. Overall, ABS is more efficient than SBS.

5.2 Packet Delay Rate Evaluation

Figure 9 shows packet delay rates for static and adaptive burst sizes across varying traffic loads. In SBS, packet delays increase in relation to fixed burst timeouts as traffic load rises. In contrast, ABS reduces delay rates by relying on dynamically adjusted burst timeouts. Consequently, SBS exhibits irregular increases or decreases in packet delay, whereas ABS consistently achieves either flat reductions or gradual increases. This is due to ABS adapting burst size to the traffic load: when traffic is light, the burst size remains minimal; as traffic volume rises, the burst size grows

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adaptively; and under heavy loads, the burst size becomes large. In such cases, queued packets do not need to wait unnecessarily for either buffer capacity or threshold completion, leading to reduced delay rates. In this respect, ABS outperforms SBS.

5.3 Packet Jitter Rate Evaluation

Figure 10 illustrates jitter delay rates for both static and adaptive burst sizes across a range of traffic loads. In SBS, jitter delay rates increase due to long packet latencies as traffic load grows. In contrast, ABS maintains lower jitter delay rates by relying on shorter packet latencies. As a result, SBS often exhibits unstable increases or decreases in jitter, whereas ABS demonstrates either steadily declining or moderately rising jitter rates. This again reflects ABS's adaptive mechanism: when traffic demand is low, burst sizes remain small; as traffic volume increases, burst sizes grow dynamically; and under heavy traffic, burst sizes become large. Consequently, the waiting time for aggregated packets at a threshold and the waiting time of ordered packets in a buffer are minimized, reducing end-to-end jitter. Therefore, ABS is more effective than SBS.

6. Conclusion

This research evaluated the performance of real-time applications using three primary criteria: packet loss rate, packet delay rate, and packet jitter rate. The experiments were conducted using the NCTUns 6.0 simulator to model the OBS network topology. The results demonstrate that the Adaptive Burst Size (ABS) technique significantly improves Quality of Service (QoS) in OBS networks. Specifically, ABS reduces packet delay rates, which in turn lowers jitter due to decreased end-to-end delay. In addition, ABS effectively decreases packet loss by dynamically adjusting burst sizes according to traffic conditions. Overall, the ABS methodology is shown to be an adaptable, robust, and efficient burst assembly approach for meeting QoS requirements in real-time traffic. Compared with static burst size techniques, the adaptive burst assembly method provides superior performance across all evaluated metrics.

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