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Comparative Performance Analysis of Traditional (SFQ, PCQ) and Modern (FQ-CoDel, CAKE) Queuing Algorithms on MikroTik RouterOS v7 for Broadband Network QoS Optimization

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ABSTRACT
Bufferbloat in broadband networks often leads to high latency, which degrades the Quality of Experience (QoE), particularly for time-sensitive activities. MikroTik RouterOS v7 introduces modern Active Queue Management (AQM) algorithms, such as FQ-CoDel and CAKE, which are claimed to outperform traditional algorithms like SFQ and PCQ. This study aims to analyze and compare the performance of these four queuing algorithms in a single-link gateway scenario on a 35 Mbps internet service. The research methodology employs a quantitative experimental approach by saturating the network with heavy traffic. Quality of Service (QoS) parameters—including throughput, delay, jitter, and packet loss—were measured based on TIPHON standards. The results indicate that modern algorithms offer superior overall QoS by simultaneously maintaining low latency and connection integrity, whereas traditional algorithms exhibit significant weaknesses in either latency stability (SFQ) or packet loss rates (PCQ). This study recommends the use of FQ-CoDel for resource efficiency and CAKE for maximum quality.

Keywords: *Bufferbloat, MikroTik RouterOS v7, FQ-CoDel, CAKE, Quality of Service*

ABSTRAK
Bufferbloat pada jaringan broadband sering menyebabkan latensi tinggi, yang menurunkan Kualitas Pengalaman (QoE), terutama untuk aktivitas yang sensitif terhadap waktu. MikroTik RouterOS v7 memperkenalkan algoritma Active Queue Management (AQM) modern, seperti FQ-CoDel dan CAKE, yang diklaim mengungguli algoritma tradisional seperti SFQ dan PCQ. Studi ini bertujuan untuk menganalisis dan membandingkan kinerja keempat algoritma antrian ini dalam skenario gateway single-link pada layanan internet 35 Mbps. Metodologi penelitian menggunakan pendekatan eksperimental kuantitatif dengan menjenuhkan jaringan dengan lalu lintas yang padat. Parameter Kualitas Layanan (QoS)—termasuk throughput, delay, jitter, dan packet loss—diukur berdasarkan standar TIPHON. Hasil menunjukkan bahwa algoritma modern menawarkan QoS keseluruhan yang superior dengan secara bersamaan mempertahankan latensi rendah dan integritas koneksi, sedangkan algoritma tradisional menunjukkan kelemahan signifikan dalam stabilitas latensi (SFQ) atau tingkat packet loss (PCQ). Studi ini merekomendasikan penggunaan FQ-CoDel untuk efisiensi sumber daya dan CAKE untuk kualitas maksimal.

Kata Kunci: Bufferbloat, MikroTik RouterOS v7, FQ-CoDel, CAKE, Quality of Service

Introduction

In today's digital era, internet connection stability has become a crucial necessity for modern society. The rapid growth of internet users and Internet of Things (IoT) devices demands the provision of consistent Quality of Service (QoS)[(1)]. However, broadband networks frequently encounter the bufferbloat phenomenon, where router buffers become oversaturated with data packets, leading to a significant surge in latency. This issue is particularly disruptive for delay-sensitive real-time applications, such as video conferencing, Voice over IP (VoIP), and online gaming[2]. To address this problem, Active Queue Management (AQM) on routers plays a vital role in regulating data packet flows[3].

Several previous studies have discussed the effectiveness of various queuing algorithms. Fathurrohim and Basuki investigated the use of the PCC Load Balancing method combined with CAKE in multi-ISP networks and found that CAKE was capable of distributing traffic fairly and maintaining throughput stability[4]. Meanwhile, Auriga et al. compared traditional algorithms such as SFQ, RED, FIFO, and PCQ in wireless networks, where SFQ demonstrated a more balanced performance in suppressing delay and jitter compared to FIFO, which tends to have low packet loss but high delay[5]. Another study by Jembre et al. highlighted the importance of consistent mobile broadband performance evaluation, given the variation in evaluation metrics used by national regulators across different countries[1].

The evolution of network operating systems, particularly MikroTik RouterOS v7, has introduced significant updates by natively incorporating modern algorithms such as FQ-CoDel (Fair Queue Controlled Delay) and CAKE (Common Applications Kept Enhanced). Rizkan et al. highlighted that CAKE is effective in mitigating bufferbloat by maintaining low latency under high traffic loads[6]. These findings are supported by Fadila and Cobantoro, who recommended FQ-CoDel as an optimal solution on RouterOS v7.15 for school environments[7]. However, Ray et al. warned that traditional internet speed measurement metrics often fail to capture network responsiveness under load (latency under load), necessitating a deeper characterization of AQM impacts[3]. Furthermore, Siahaan et al. emphasized the importance of bandwidth management using the PCQ method combined with web filtering to maximize internet connections in educational settings[8]. Rachman et al. also added that QoS analysis using Wireshark is crucial for identifying physical network issues in Fiber to the Home (FTTH) services[9]. Saleh and Shu proposed a new adaptive approach based on Derivative-based AQM (dAQM) that utilizes advanced traffic features for more precise congestion estimation, although its implementation remains in the experimental stage[2].

Despite extensive research, a research gap remains regarding a head-to-head comparison between traditional algorithms (SFQ, PCQ) and modern ones (FQ-CoDel, CAKE) in a single-link gateway scenario on medium-speed residential broadband services (35 Mbps). This study aims to fill this gap by analyzing the performance of these four queuing algorithms. The analysis is conducted comprehensively, covering not only standard TIPHON QoS parameters (throughput, delay, jitter, and packet loss) but also evaluating the efficiency of router CPU resource utilization as a determining factor for practical implementation.

Methods

This study employs a quantitative experimental method. The network topology is constructed using a broadband internet connection (ICONNET) with a 35 Mbps bandwidth, connected to a MikroTik RB450G router running the RouterOS v7 operating system. The testbed environment consists of three client devices—two Windows PCs and one Android smartphone—connected to the local subnet.

The experimental scenarios are divided into four stages based on the specific queue type enabled on the router's WAN interface to manage bandwidth sharing for the entire subnet. To ensure a baseline comparison of out-of-the-box performance, all algorithms (SFQ, PCQ, FQ-CoDel, and CAKE) are configured using their default initial parameters. Testing is conducted by running simultaneous traffic loads on all devices to saturate the network and simulate congestion conditions.

Data Collection Tools and Techniques Unlike traditional speed tests that only measure peak throughput, this study focuses on "responsiveness under load." Therefore, the primary data collection is performed using the Waveform Bufferbloat Test, a web-based tool specifically designed to measure latency variations during network saturation. Additionally, ICMP Echo requests (Ping) are executed continuously via the command line interface on Windows and the "PingTools" application on Android to validate packet loss rates.

Quality of Service (QoS) parameters are measured with reference to the ETSI TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks) TR 101 329 standards[10]. The measurement metrics are defined as follows:

1. Throughput: Measured as the aggregate effective data transfer rate recorded by the Waveform tool.
2. Delay (Latency): Measured as the "Active Latency" (Ping under load), representing the transit time when the network is fully utilized.
3. Jitter: Calculated based on the variance in latency recorded during the download and upload phases of the test.
4. Packet Loss: Calculated as the percentage of ICMP packets that failed to return during the saturation test period.

Simultaneously, the device workload (CPU Load) is monitored through MikroTik's internal logging features to evaluate the computational impact of each algorithm on the RB450G hardware. The obtained data is then classified based on the TIPHON quality index (Very Good, Good, Fair, Poor) to determine the most optimal algorithm.

Results

The experiments evaluated the performance of four queuing algorithms on a 35 Mbps broadband link. The baseline latency (Ping) to the test server without load was recorded at 26 ms. The network was then saturated to measure the impact of each algorithm on Throughput, Latency, Jitter, Packet Loss, and CPU Usage.

Table 1 presents the performance comparison. Notably, PCQ managed to maintain low latency comparable to modern algorithms, whereas SFQ suffered from severe bufferbloat.

Table 1. Comparison of Average Throughput and Latency (Ping)

Algorithm	Average Throughput (Mbps)	Average Ping (ms)	TIPHON Category
SFQ	33.2	215	Poor (Bufferbloat)
PCQ	34.8	35	Good
FQ-CoDel	34.1	31	Very Good
CAKE	34.5	29	Very Good

Figure 1 details jitter. Jitter represents the variation in latency. Lower jitter indicates a more stable connection.

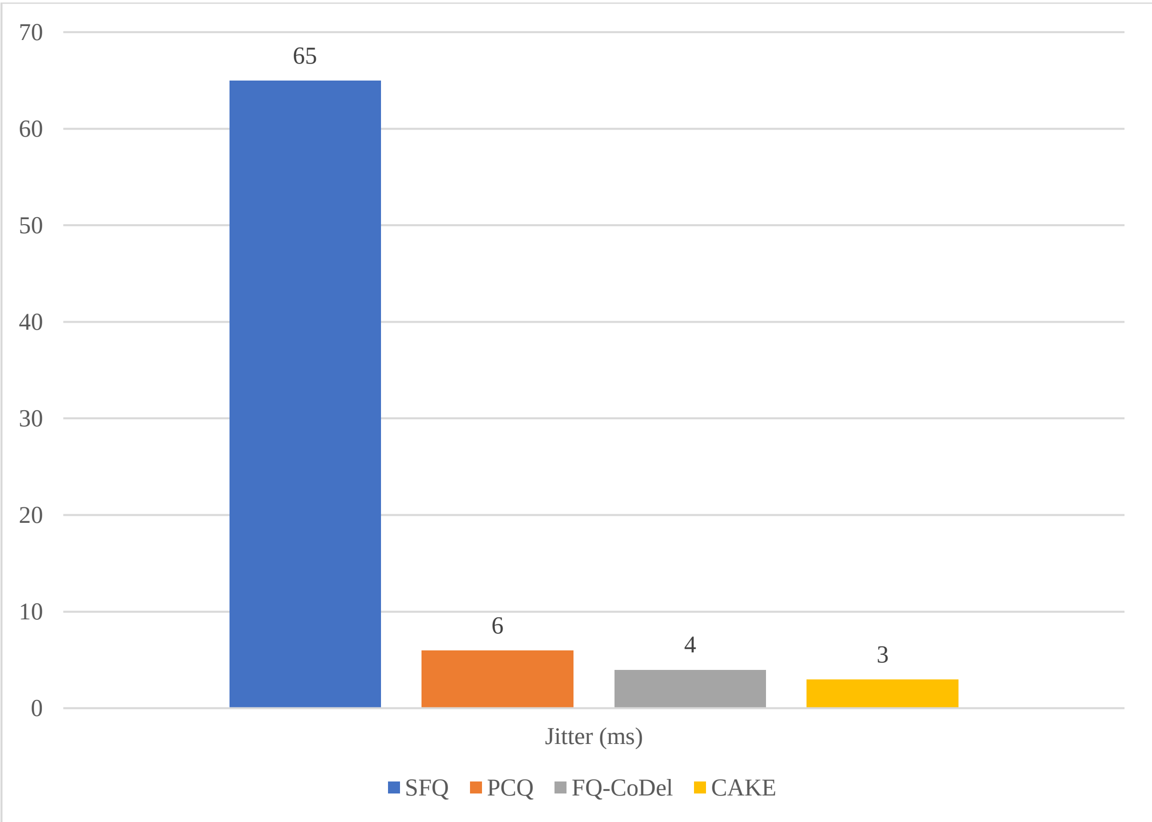

Figure 1. Comparison graph of jitter values across algorithms

Table 2 details the packet loss percentage. A significant distinction was observed between PCQ/SFQ and modern AQM algorithms. PCQ recorded a notable packet loss of 6%, while CAKE and FQ-CoDel maintained near-zero loss.

Table 2. Average Packet Loss

Algorithm	Average Packet Loss (%)	TIPHON Category
SFQ	8	Good
PCQ	6	Good
FQ-CoDel	0	Very Good
CAKE	0	Very Good

Table 3 highlights the trade-off between performance and hardware load on the RB450G device.

Table 3. CPU Load on RB450G Router (35 Mbps Load)

Algorithm	Average CPU Load (%)	Efficiency Status
SFQ	15	Highly Efficient
PCQ	25	Efficient
FQ-CoDel	45	Moderate
CAKE	70	Heavy

Discussion

The results highlight a specific behavior in the PCQ algorithm. While PCQ successfully maintained low latency (35 ms) similar to modern algorithms, it did so at the cost of high packet loss (6%). This occurs because PCQ enforces strict limits on sub-queue sizes for each stream. When the bandwidth is saturated, these sub-queues fill up quickly, and PCQ utilizes a "tail-drop" mechanism to discard excess packets immediately. While this strategy prevents latency from spiraling out of control (unlike SFQ, which buffered packets causing 215 ms delay), the high packet loss can degrade the quality of sensitive applications like video streaming (buffering) or gaming (teleporting issues).

In contrast, SFQ failed in both metrics, exhibiting high latency (215 ms) and high loss (8%), making it the least desirable option. CAKE and FQ-CoDel demonstrated superior Active Queue Management (AQM) by keeping latency low (~30 ms) and packet loss negligible (0%). They achieve this by intelligently dropping only specific packets to signal congestion to the sender (TCP ECN) without discarding valid data streams aggressively.

The results reveal a clear hierarchy in resource consumption. CAKE, despite offering the best QoS metrics (low ping, zero loss), imposed a 70% CPU load on the RB450G. This high usage is due to its sophisticated internal shaper and flow isolation features. PCQ proved to be an efficient alternative (25% CPU), but the high packet loss trade-off must be considered.

Conclusion

The experimental results conclusively demonstrate that modern Active Queue Management (AQM) algorithms significantly outperform traditional disciplines in mitigating bufferbloat. While the PCQ algorithm achieved the highest throughput (34.8 Mbps) and successfully maintained a low latency of 35 ms, it suffered from a high packet loss rate of 6%, which compromises the reliability of the connection. In contrast, the SFQ algorithm demonstrated the poorest performance, inducing severe latency spikes averaging 215 ms and a packet loss rate of 8%, rendering it unsuitable for latency-sensitive applications.

On the other hand, CAKE and FQ-CoDel successfully maintained network responsiveness by reducing latency to 29 ms and 31 ms, respectively, achieving the "Very Good" category according to ETSI TIPHON standards. Both algorithms also demonstrated superior connection stability with minimal jitter and near-zero packet loss. However, this performance enhancement incurs a computational cost; CAKE was found to be the most resource-intensive, consuming an average of 70% CPU on the RB450G hardware with 3 active clients.

Consequently, based on the trade-off between Quality of Service (QoS) improvements and hardware resource efficiency, FQ-CoDel is recommended as the most optimal solution for resource-constrained routers (such as single-core MIPSBE devices). It delivers QoS stability comparable to CAKE while maintaining a sustainable CPU load (45%). CAKE remains the superior choice for high-specification hardware where processing power is not a bottleneck, whereas PCQ and SFQ are no longer recommended for modern broadband networks requiring reliable real-time interaction capabilities. Future research should investigate the scalability of these algorithms on gigabit-speed connections and wireless transmission mediums to further validate their adaptability.

Recommendation For network administrators using resource-constrained hardware (like the RB450G) on a 35 Mbps link:

1. FQ-CoDel is the recommended solution. It offers the "sweet spot" of low latency, zero packet loss, and moderate CPU usage (45%).
2. CAKE provides the absolute best quality but is risky for old Routerboard like the RB450G if traffic exceeds 35 Mbps and more client due to high CPU load.
3. PCQ is acceptable only if CPU resources are critical and the application can tolerate 5-6% packet loss, but it is less ideal for reliable communication.
4. SFQ should be avoided due to severe bufferbloat performance.

Future research should investigate the scalability of these algorithms on gigabit-speed connections and wireless transmission mediums to further validate their adaptability.

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