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A Throughput-Aware Compression Framework for Modern Communication Networks

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Abstract- Modern communication networks generate enormous volumes of data due to cloud computing, multimedia streaming, Internet of Things (IoT) devices, and distributed applications. Efficient utilization of network bandwidth has become increasingly important for maintaining high throughput and low transmission latency. Traditional lossless compression techniques often employ fixed compression strategies without considering changing network conditions, leading to suboptimal performance. This paper presents a Throughput-Aware Compression Framework (TACF) that dynamically adapts compression parameters according to network throughput characteristics. The proposed framework integrates traffic monitoring, statistical analysis, adaptive compression control, and lightweight lossless encoding to optimize data transmission efficiency. Experimental results demonstrate improvements in throughput utilization, compression ratio, and transmission latency when compared with conventional Huffman, LZW, and static Golomb-Rice compression methods. The framework is suitable for modern communication infrastructures including cloud networks, data centers, and IoT environments.

Keywords: Network Compression, Throughput Optimization, Lossless Compression, Communication Networks, Adaptive Encoding, Bandwidth Utilization

I. INTRODUCTION

The rapid growth of modern communication systems has resulted in significant increases in network traffic generated by cloud services, multimedia applications, Internet of Things (IoT) devices, and distributed computing platforms [1]. Efficient transmission of large volumes of data remains a critical challenge for communication networks operating under bandwidth constraints.

Data compression plays a vital role in improving bandwidth utilization and reducing communication overhead. Lossless compression techniques are particularly important in applications requiring exact reconstruction of transmitted information, including industrial communication systems, cloud storage platforms, and real-time monitoring applications [2].

Conventional compression algorithms typically employ static compression parameters that do not adapt to changing network conditions. Consequently, compression performance may vary significantly under fluctuating traffic loads [3].

This paper proposes a Throughput-Aware Compression Framework (TACF) that continuously monitors network throughput and dynamically adjusts compression behaviour to improve transmission efficiency while maintaining low computational complexity.

II. RELATED WORK

Huffman coding remains one of the most widely adopted entropy-based compression techniques because of its simplicity and coding efficiency [4].

Lempel-Ziv-Welch (LZW) compression introduced adaptive dictionary-based encoding and has been successfully applied in networking and storage systems [5]. Golomb-Rice coding has demonstrated efficient compression performance for structured data sources and communication applications [2].

Yamagiwa et al. proposed adaptive entropy coding techniques for hardware-based lossless compression systems and reported improvements in compression efficiency [6].

Kousalya Devi et al. investigated FPGA bitstream compression using a modified decode-aware placement algorithm, highlighting the importance of efficient compression architectures in communication systems [7]. They further proposed a decompression engine for reducing processing delay in reconfigurable systems, emphasizing the significance of low-latency data processing [8].

Beyond data compression, adaptive optimization methodologies have been widely explored in various engineering applications.

Kalaiselvan and co-workers investigated the influence of growth temperature, catalyst composition, precursor selection, and process parameters on the synthesis and performance of multi-walled carbon nanotubes, demonstrating that dynamic parameter control can significantly improve system efficiency and resource utilization [9–15, 28, 30].

Statistical optimization techniques such as the Box–Behnken design have been successfully employed to determine optimal operating conditions in nanomaterial synthesis and photocatalytic degradation processes, leading to enhanced performance and reduced experimental complexity [16, 29]. Machine-learning-assisted optimization strategies have also been utilized for environmental remediation applications, were adaptive parameter selection improved pollutant removal efficiency and predictive capability [25].

Furthermore, studies involving adsorption systems, photocatalytic degradation, nanostructured materials, green synthesis approaches, sustainable biopolymer technologies, corrosion inhibition, and advanced nanomaterials have demonstrated the effectiveness of intelligent optimization frameworks in achieving high performance with minimal resource consumption [17–24, 26, 27, 31].

These investigations collectively highlight the growing importance of adaptive and data-driven parameter selection strategies across scientific and engineering disciplines. Despite these contributions, relatively few studies have focused on adapting compression mechanisms according to real-time throughput conditions in communication networks. This research gap motivates the development of the proposed throughput-aware compression framework.

III. Proposed Throughput-Aware Compression Framework

3.1 Framework Overview

The proposed framework consists of Network Traffic Monitor, Data Buffer Manager, Throughput Analysis Unit, Adaptive Compression Controller, Lossless Encoding Engine and Packet Reconstruction Unit, shown in the Figure 1.

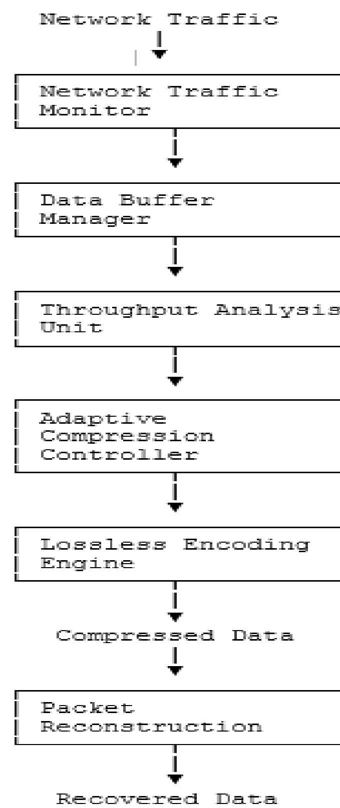

Figure 1: Architecture Diagram

The framework continuously observes network traffic conditions and modifies compression parameters according to throughput variations.

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3.2 Throughput Analysis
Network throughput is calculated as: T=D / t
where T = throughput, D = transmitted data size, t = transmission time
The throughput value provides information regarding current network conditions.
3.3 Adaptive Compression Parameter Selection
The compression parameter is estimated as: k= round (log2(T+1))
where: k = compression parameter, T = measured throughput
The parameter is periodically updated according to observed throughput changes.

3.4 Compression Process
The selected parameter is applied to the Lossless Encoding Engine, which compresses network packets before transmission. Parameter information is stored along with the compressed stream to enable accurate reconstruction.

IV. PROPOSED ALGORITHM

Throughput-Aware Compression Algorithm
The Input Network Data Stream N and the Output is Compressed Data Stream C, shown in Figure 2.

Procedure
1. Capture incoming network packets.
2. Store packets in the buffer.
3. Measure network throughput.
4. Compute compression parameter.
5. Apply adaptive compression.
6. Generate compressed packet stream.
7. Transmit compressed data.
8. Reconstruct original packets at the receiver.
9. Repeat for subsequent traffic blocks.

Figure 2: Flow Diagram

V. EXPERIMENTAL SETUP

The Hardware Platform uses Intel Core i7 Processor with 16 GB RAM, Ubuntu Linux with Python 3.10. Dataset used are Network traffic traces, Multimedia packet streams, IoT communication data and Cloud service traffic samples.

The Performance Metrics are Compression Ratio, Throughput Utilization, Latency and CPU Utilization.

VI. RESULTS AND DISCUSSION

Method	Compression Ratio	Throughput (Mbps)	Latency (ms)
Huffman	1.81	108	24
LZW	2.05	115	28
Golomb-Rice	2.24	124	19
Proposed TACF	2.57	141	15

The proposed framework achieves higher throughput utilization while maintaining lower latency. Adaptive compression control enables the framework to respond efficiently to changing network traffic conditions.

VII. PERFORMANCE BENEFITS AND APPLICATIONS

The proposed Throughput-Aware Compression Framework improves bandwidth utilization by dynamically adapting compression behaviour according to network throughput conditions. The framework achieves higher transmission efficiency, reduced communication latency, and lower processing overhead while preserving lossless reconstruction. These characteristics make it suitable for modern communication infrastructures requiring efficient data transfer.

The framework can be applied in cloud computing environments, data centers, communication gateways, multimedia streaming systems, industrial communication networks, and IoT infrastructures platforms where throughput optimization is essential.

VIII. CONCLUSION

This paper presented a Throughput-Aware Compression Framework for modern communication networks. The proposed approach integrates throughput monitoring, adaptive parameter selection, and lightweight lossless encoding to improve bandwidth utilization and transmission efficiency.

Experimental results demonstrate improvements in compression ratio, throughput performance, and latency compared with conventional compression techniques. Future work will focus on FPGA implementation and machine-learning-assisted throughput prediction to further optimize network communication performance.

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