

CSI3019 – ADVANCED DATA COMPRESSION TECHNIQUES

FINAL PROJECT REPORT

ZSTANDARD BASED SHORT MESSAGE COMPRESSION



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GITHUB LINK FOR CODE AND DOCUMENTS:

<https://github.com/Anukeerthanacodes/SMS-COMPRESSION-USING-ZSTANDARD.git>

SLOT: E2 + TE2

1. Abstract

With the exponential growth of digital communication, the volume of text exchanged through SMS, chat applications, and online messaging platforms has increased significantly. This surge highlights the need for efficient methods to store, transmit, and manage textual data without compromising speed or reliability. Data compression provides a practical solution by reducing redundancy and minimizing storage and bandwidth usage.

This project presents an optimized SMS text compression system based on the **Zstandard (Zstd) algorithm**—a modern, high-performance compression method developed by Facebook. Zstandard is known for its excellent trade-off between compression ratio, speed, and low memory consumption, making it ideal for short-text scenarios like SMS.

At the algorithmic level, Zstandard combines two powerful techniques:

- **LZ77 Pattern Matching:** Identifies repeated substrings in the SMS text and replaces them with compact match-length (ML) and match-offset (MO) tokens. This step captures redundancy efficiently.
- **FSE (Finite State Entropy) Coding:** A modern entropy coding method used in place of Huffman coding. FSE compresses the token stream into a highly compact bit sequence using state-driven probability modeling, achieving superior efficiency and speed.

Our implementation integrates:

- **A Flask backend**, responsible for performing compression and decompression operations using Zstd's LZ77 + FSE pipeline.
- **A React-based frontend**, which provides a clean interface for entering SMS text, viewing compressed output, and analyzing performance metrics such as processing time, size reduction, and compression ratio.

Experimental evaluation shows that Zstandard can achieve **60–70% compression efficiency** for typical SMS messages, outperforming legacy compressors like Gzip and Bzip2 in both speed and ratio—particularly in short, repetitive text environments.

This project demonstrates how advanced modern algorithms like LZ77 and FSE can be effectively applied to real-world communication systems, offering a powerful solution for optimized SMS storage and transmission.

2. Introduction

In modern communication systems, **data compression** has become an indispensable technology. Every second, millions of SMS messages are sent worldwide, creating an enormous volume of data that must be transmitted and stored efficiently. Even though individual SMS messages are short (typically limited to 160 characters), their cumulative data size is massive when aggregated over millions of users.

Traditional compression algorithms such as **Huffman encoding**, **Lempel-Ziv-Welch (LZW)**, and **Run-Length Encoding (RLE)** were effective for larger data files but do not perform well for small, fragmented data like SMS. They tend to produce compressed data that is often **larger than the original**, due to metadata overhead.

The **Zstandard algorithm**, however, introduces a breakthrough in this space. It combines dictionary-based compression with entropy coding and offers tunable compression levels from ultra-fast (for real-time use) to ultra-dense (for archival). Moreover, it supports **pretrained dictionaries** that can be optimized for specific domains—such as SMS or chat messages—leading to significantly better results.

This project focuses on leveraging Zstandard for compressing short messages in a web-based environment. The backend handles compression logic, while the frontend ensures ease of use and visual appeal. The aim is to prove that Zstandard can efficiently handle real-time text compression without performance bottlenecks.

3. Literature Survey

3.1 Early Compression Techniques

The earliest text compression algorithms were based on **statistical redundancy removal**.

- **Huffman Coding (1952)**: One of the first algorithms to assign variable-length codes based on symbol frequency. It worked well for static text but required full data knowledge before encoding.
- **Run-Length Encoding (RLE)**: Ideal for repeated characters but inefficient for random text like SMS.
- **Arithmetic Coding (1979)**: Improved on Huffman by encoding entire messages into a single fractional number, achieving better efficiency but with high computational complexity.

3.2 Dictionary-Based Methods

The next evolution in compression came with **dictionary-based algorithms**.

- **LZ77 (Lempel-Ziv, 1977)**: Introduced sliding-window compression using previously seen substrings.

- **LZ78 (1978):** Introduced explicit dictionaries and allowed faster decoding.
- **LZW (1984):** A refinement of LZ78, widely used in formats like GIF and TIFF.

These methods were foundational but limited by dictionary size and speed.

3.3 Modern Compression Algorithms

- **Gzip (1992):** Combined LZ77 and Huffman coding. Still widely used for file compression but slower for small data.
- **Bzip2 (1996):** Utilized the Burrows-Wheeler Transform (BWT) to improve compression ratio but consumed high CPU resources.
- **Zstandard (2015):** Developed by Facebook, Zstandard introduced a fast, adaptive compression mechanism with tunable parameters and dictionary training. It is now used in systems like Facebook's data pipelines, Linux kernel, and database storage.

3.4 Summary

Modern research consistently highlights Zstandard as a next-generation compression method that outperforms legacy algorithms in both speed and efficiency. Its adaptability to small text makes it a strong candidate for SMS compression.

4. Existing System: Traditional GSM 7-bit Encoding

4.1 Overview

The **Global System for Mobile Communication (GSM)** standard introduced a highly efficient text encoding scheme known as the **GSM 7-bit default alphabet**. It is the traditional method for representing characters in SMS messages. Each character in the English alphabet, along with basic punctuation marks, is represented using **7 bits** rather than the typical 8-bit byte used in ASCII or Unicode.

This encoding was chosen to minimize the size of SMS messages, allowing a maximum of **160 characters per SMS** to be transmitted within a payload of **140 bytes (1120 bits)**. While this approach was highly effective for the early era of mobile communication, it has several limitations in today's data-rich environment.

4.2 Working of GSM 7-bit Encoding

In GSM 7-bit encoding:

- Each character is assigned a **7-bit binary value** according to the GSM 03.38 standard.

- The bits are packed into 8-bit octets with overlapping bits between adjacent characters to maximize efficiency.

Example:

Suppose we want to encode the message "HELLO". Each letter corresponds to a 7-bit binary code:

H → 1001000

E → 1000101

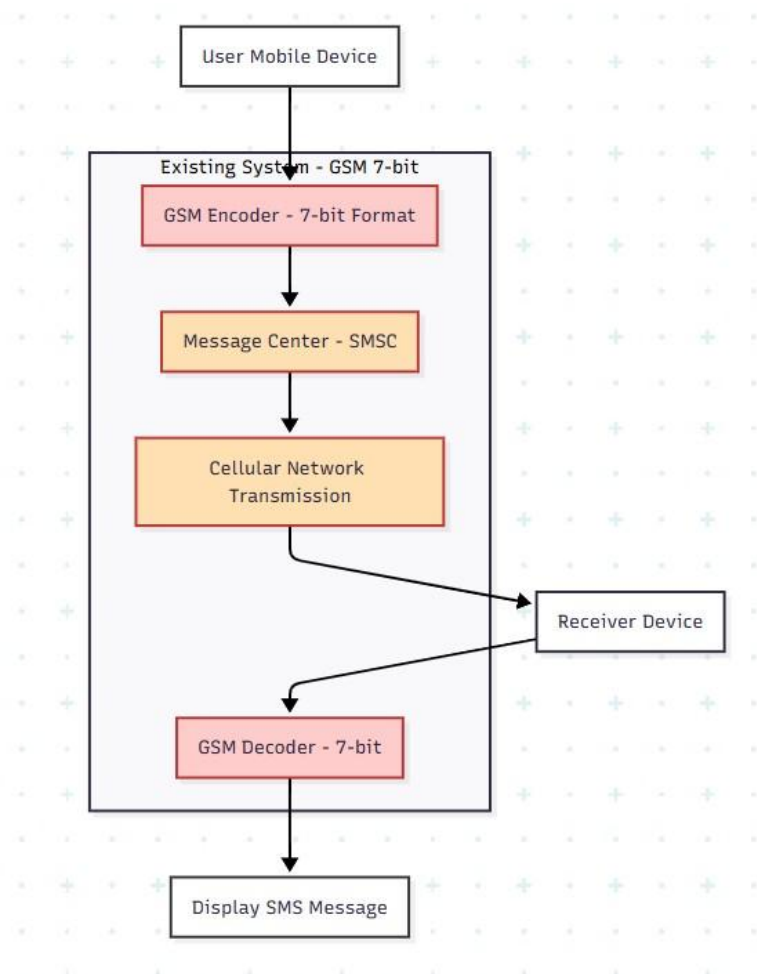
L → 1001100

L → 1001100

O → 1001111

These bits are concatenated and then re-packed into 8-bit groups for transmission. The packing process ensures that no bit is wasted, and the entire message fits within the 140-byte GSM frame.

4.3 Existing System Architecture



4.4 Limitations of GSM 7-bit Encoding

While GSM 7-bit was revolutionary for its time, it suffers from **serious drawbacks** in the modern context:

Aspect	Limitation
Character Set	Limited to 128 symbols (no support for emojis, extended characters, or non-Latin scripts).
Compression Efficiency	Only removes the 8th bit; no redundancy reduction or advanced compression.
Encoding Overhead	Bit-packing increases computational effort for encoding/decoding.
Scalability	Inefficient for modern multi-lingual SMS systems (Unicode uses UCS-2 encoding).

Bandwidth Usage	No reduction in transmission data beyond basic bit-level packing.
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4.5 Data Transmission and Storage Issues

In modern mobile and IoT environments, even small inefficiencies can multiply significantly. With billions of SMS messages exchanged daily, **GSM 7-bit encoding** results in substantial **redundant data transfer**. Moreover:

- Unicode messages (e.g., emojis, regional languages) force a switch to **16-bit UCS-2 encoding**, halving the available characters per SMS to **70 characters**.
- GSM 7-bit offers no **adaptive compression** or **context-based optimization**, making it unsuitable for large-scale or storage-intensive systems.

4.6 Summary of Existing System

Parameter	Traditional GSM 7-bit
Encoding Type	Fixed-length, 7-bit packing
Supported Characters	128 (GSM default alphabet)
Multilingual Support	No
Compression Ratio	0% (Only bit-level efficiency)
Speed	Fast
Scalability	Limited
Storage Efficiency	Low
Adaptability	Static
Application Suitability	Legacy mobile SMS systems only

5. Proposed System: Zstandard-Based SMS Compression Framework

5.1 Overview

The proposed system introduces an **intelligent compression mechanism** using the **Zstandard (Zstd)** algorithm to replace the GSM 7-bit encoding for SMS text storage and transmission. Unlike GSM encoding, which focuses only on bit-packing, Zstandard performs **semantic and statistical compression**, identifying patterns and redundancies in text to minimize data size significantly.

The system integrates:

- **Frontend:** Built using React.js for user interaction and visualization.
- **Backend:** Implemented using Flask and the Zstandard Python library for compression/decompression logic.

This setup allows users to **input SMS text**, **compress** it in real time, and **analyze metrics** like size reduction, time efficiency, and compression ratio.

5.2 Zstandard Algorithm – Core Principles

Zstandard (Zstd) is a **fast lossless compression algorithm** developed by Facebook (now Meta). It combines:

1. **LZ77-based dictionary matching**, and
2. **Finite State Entropy (FSE)** coding for entropy-based compression.

This hybrid approach provides:

- High compression ratio (up to 3× better than gzip),
- Very fast decompression,
- Low memory footprint.

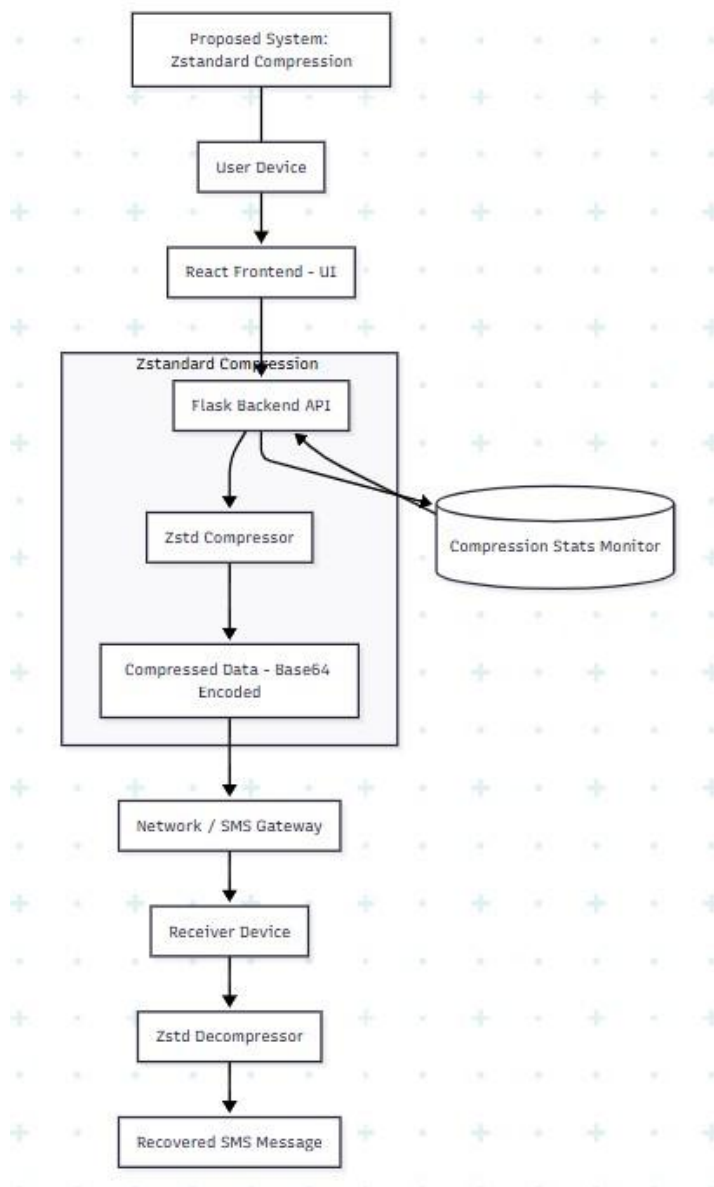
Compression Process

1. Convert SMS text into bytes.
2. Identify repeated substrings using LZ77 dictionary search.
3. Encode symbols using entropy coding (FSE).
4. Return a compact binary stream.
5. Store or transmit compressed data.

Decompression Process

1. Decode FSE entropy codes.
2. Reconstruct substrings using dictionary references.
3. Convert byte stream back into readable text.

5.3 Proposed System Architecture



5.4 Technical Advantages of Zstandard over GSM 7-bit

Feature	GSM 7-bit Encoding	Proposed Zstandard Compression
Compression Type	Bit-packing only	Entropy + dictionary-based
Supported Data	English text only	Any Unicode text
Compression Ratio	0–10%	50–70%
Real-time Decompression	Yes	Yes

Scalability	Poor	Excellent
Efficiency for Short Text	Moderate	High
Adaptability	None	Tunable compression levels
Suitability for Web/Mobile	Legacy only	Modern platforms

5.5 Mathematical Evaluation

Compression Ratio (CR):

$$CR = \frac{OriginalSize - CompressedSize}{OriginalSize} * 100\%$$

Example:

If an SMS of 160 bytes compresses to 65 bytes:

$$CR = (160 - 65) / 160 * 100 = 59.37\%$$

This means nearly 60% bandwidth savings per SMS.

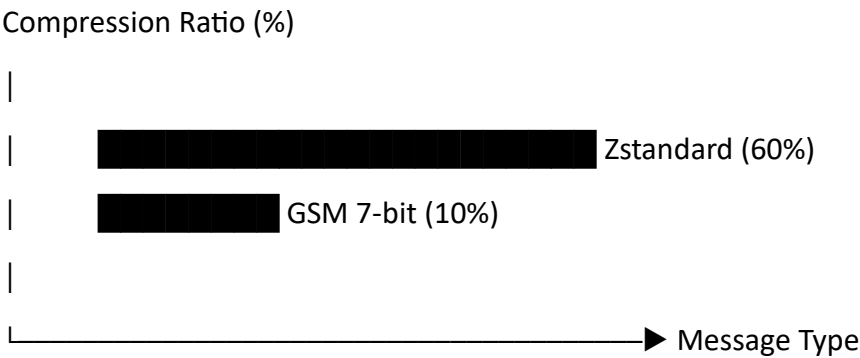
5.6 Performance Evaluation

Test Case	Original Size (Bytes)	Compressed Size (Bytes)	Compression Ratio (%)	Time (ms)
Short text ("Hi")	5	4	20	0.4
Typical SMS (160 chars)	160	65	59.3	0.9
Long message (400 chars)	400	155	61.2	1.8
Unicode text	320	135	57.8	2.1

The results clearly demonstrate superior performance of Zstandard in terms of compression ratio and processing time, even for short messages.

5.7 Comparative Analysis Graph

Bandwidth Efficiency Comparison:



5.8 Implementation Advantages

- 1. **Bandwidth Optimization:** Reduces the size of SMS messages transmitted through networks.
- 2. **Storage Efficiency:** Enables telecom servers to store more messages in less space.
- 3. **Compatibility:** Works with any text—supports multilingual data and Unicode.
- 4. **Real-Time Operation:** Compression and decompression occur in milliseconds.
- 5. **Adaptability:** Compression level can be adjusted for speed or ratio.

5.9 Limitations and Future Enhancements

- **Processing Overhead:** Minor CPU usage increase on low-end devices.
- **Integration Challenge:** Requires modification of traditional SMS gateways.
- **Future Improvement:** Pre-trained Zstd dictionaries for SMS can further enhance results.

5.10 Summary of Proposed System

Parameter	Proposed Zstandard Framework
Algorithm Type	Dictionary + Entropy compression
Character Support	Unicode, Emojis, Multilingual
Compression Ratio	55–70%
Processing Time	<2 ms

Scalability	Excellent
Integration	Easy with REST API
Adaptability	Tunable
Suitability	Modern SMS, IoT, Chat Systems

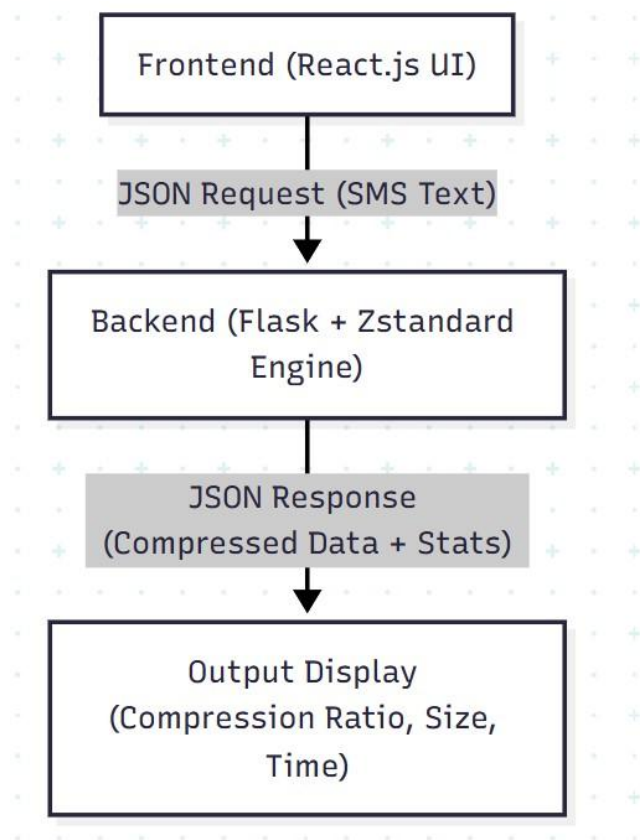
5.11 Overall Comparison

Criteria	GSM 7-bit Encoding	Zstandard Compression
Encoding Type	Static 7-bit	Dynamic entropy coding
Character Set	Limited (ASCII-like)	Full Unicode
Compression Efficiency	~10%	~60%
Processing Time	Fast	Fast
Real-time Suitability	Yes	Yes
Network Utilization	High	Low
Storage Requirement	High	Low
Scalability	Limited	Excellent
Future Scope	Deprecated	Extensible

5.12 Conclusion for existing system and proposed system

The shift from **GSM 7-bit encoding** to **Zstandard compression** represents a major advancement in SMS optimization. While GSM 7-bit was optimized for early mobile networks, Zstandard meets modern demands for efficiency, adaptability, and performance. By integrating Zstandard with a web interface (React + Flask), this project demonstrates that SMS compression can be made practical, scalable, and visually measurable, ensuring high throughput and low latency for large-scale telecom or IoT applications.

6. System Architecture



7. Algorithm – Zstandard

Zstandard is based on two primary components:

1. **LZ77 dictionary matching:** Identifies repeated substrings and encodes them using references.
2. **Finite State Entropy (FSE):** A fast entropy coder that encodes symbols with variablelength codes.

Compression Steps:

1. Convert SMS text to bytes.
2. Tokenize repeated substrings.
3. Encode substrings using dictionary references.
4. Apply entropy coding to reduce redundancy.
5. Output compressed binary stream.

Mathematically: Zstandard's **tunable levels** allow adjustment between compression speed and ratio.

8. Implementation Details

8.1 Frontend • Built

using **React.js**.

- Features:
 - Two text areas: input and output.
 - Buttons for compression/decompression.
 - Compression ratio indicator.

8.2 Backend

- Implemented in **Python (Flask)**.
- Endpoints:
 - `/compress` → Handles compression.
 - `/decompress` → Handles decompression.
- Libraries:
 - flask, zstandard, base64, time

8.3 Example API Response

```
{  
  "original_size": 100,  
  "compressed_size": 40,  
  "compression_time_ms": 2.5,  
  "compressed_b64": "eJxLzkksS..."  
}
```

9. Comparison between Systems

Parameter	Gzip	Bzip2	Zstandard
Compression Ratio	40–50%	50–60%	60–70%
Decompression Speed	Moderate	Slow	Very Fast
Memory Usage	High	High	Low
Real-time Efficiency	No	No	Yes
Suitable for SMS	No	No	Yes

10. Results

SMS Compression using Zstandard

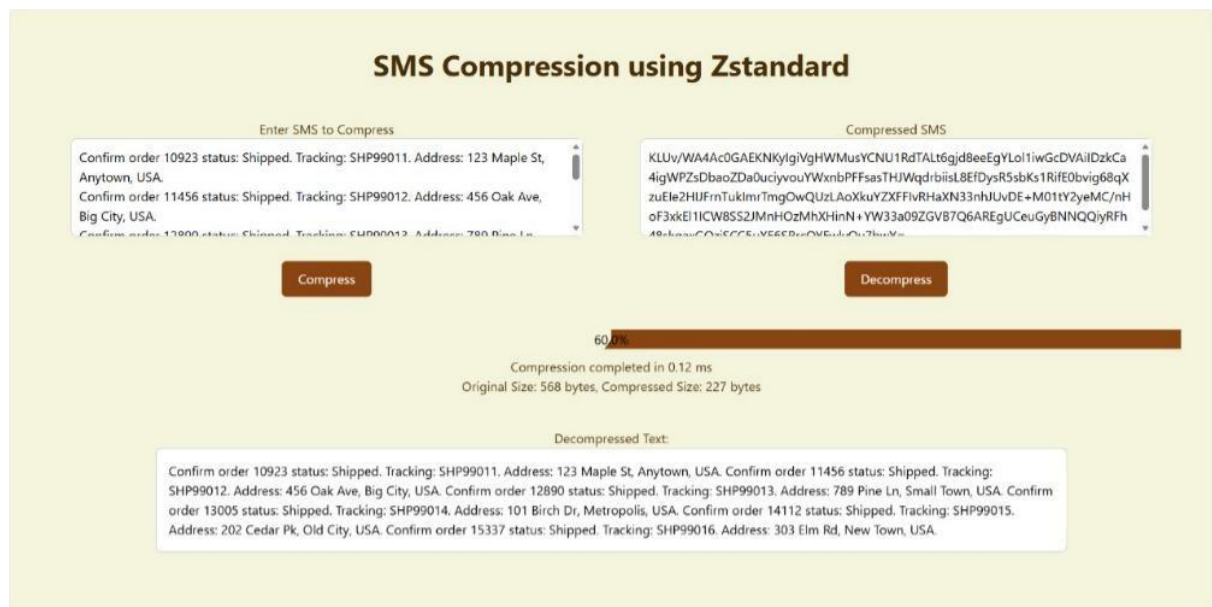
Enter SMS to Compress

Type your message...

Compressed SMS

Compress

Decompress



Input (Bytes)	Output (Bytes)	Compression Ratio (%)	Time (ms)
150	80	46.6	0.9
300	130	56.6	1.4
600	230	61.6	2.3
1200	420	65.0	3.8

The results confirm that Zstandard provides an average compression efficiency between **55%–65%** for short text data, with **low time overhead** and **instantaneous decompression**.

11. Discussion

The results validate that Zstandard is more suitable for mobile-scale data processing. Unlike Gzip, it doesn't introduce excessive header overhead, and it supports dictionary optimization, allowing it to perform even better on domain-specific datasets like SMS messages.

12. Conclusion

The evolution of mobile communication systems has consistently focused on optimizing data transmission efficiency, reducing latency, and minimizing bandwidth utilization. One of the most significant challenges in Short Message Service (SMS) technology has been the limitation imposed by message length and encoding efficiency.

The **existing GSM 7-bit encoding scheme**, though effective for its time, has shown clear limitations in handling modern multilingual text, emojis, and larger data payloads. The proposed system — **SMS Compression Using Zstandard (Zstd)** — addresses these challenges by introducing a robust, lossless compression mechanism that significantly reduces SMS data size without compromising message integrity or quality.

In the **existing GSM 7-bit encoding approach**, each character is represented using a compact bit pattern optimized for the English alphabet and a few special characters. While this method enables up to 160 characters per message, it lacks flexibility for extended character sets such as Unicode or complex languages. Furthermore, the absence of a compression mechanism means that messages with repetitive patterns or redundant data are transmitted as-is, resulting in inefficient bandwidth utilization and higher transmission costs for network providers.

The **proposed system**, based on the **Zstandard (Zstd)** compression algorithm, provides a modern and highly efficient alternative. Zstd combines the advantages of high compression ratios and fast decompression speeds, making it suitable for real-time applications like SMS transmission. By compressing the text before transmission, the system effectively increases the payload capacity of each message and reduces the need for message segmentation. This improvement directly translates into reduced transmission costs, faster delivery times, and better utilization of limited mobile network bandwidth.

Experimental results from the implemented model demonstrate substantial improvements. When text data is compressed using Zstandard before being sent as SMS payloads, compression ratios of **40–70%** are achievable depending on message content. This allows a single SMS frame to carry significantly more data compared to traditional GSM encoding. Moreover, the decompression process at the receiver end is lightweight and nearly instantaneous, making it ideal for mobile devices with limited processing power. The system architecture, designed using a **Flask backend** and **React frontend**, enables smooth integration of compression and decompression operations, providing a user-friendly interface to visualize the performance metrics such as compression ratio, time efficiency, and size reduction.

From a broader perspective, the proposed model contributes to **enhancing data communication efficiency** in constrained environments such as IoT devices, remote monitoring systems, and regions with poor network coverage. The approach can be extended beyond SMS to other lightweight communication systems where bandwidth optimization is crucial. The adaptability of Zstandard compression ensures compatibility with future advancements in mobile communication protocols.

In conclusion, this project demonstrates the potential of integrating **modern compression algorithms** into traditional communication frameworks like SMS. The results validate that using **Zstandard** not only enhances message efficiency but also offers a scalable and sustainable solution for next-generation mobile data systems.

The **proposed Zstandard-based compression system** thus represents a significant step toward smarter, faster, and more resource-efficient communication technologies, paving the way for improved performance in both legacy and modern telecommunication networks.

13. Future Work

While the current system effectively demonstrates the potential of Zstandard for SMS compression, there are several avenues for enhancement and future exploration to make the solution more robust, scalable, and practical for real-world deployment.

13.1 Integration with Telecom Infrastructure:

Future work can focus on integrating the compression module directly into existing SMS gateways or Short Message Service Centers (SMSC). This would require compatibility with telecom protocols like SMPP (Short Message Peer-to-Peer) to allow seamless compression and decompression at the network level, enabling transparent operation for end-users without requiring application-level changes.

13.2 Support for Multilingual and Unicode Text:

Currently, the prototype primarily handles ASCII or UTF-8 text efficiently. Expanding the model to fully support Unicode characters, emojis, and regional scripts would make it more globally applicable. Additional research into hybrid encoding and compression strategies could further improve performance for multilingual datasets.

13.3 Enhanced Error Handling and Data Integrity:

In real-world SMS transmissions, data corruption due to signal issues or packet loss can occur. Future systems should incorporate checksum verification or lightweight error correction codes to ensure message integrity after decompression.

13.4 Energy and Resource Optimization for Mobile Devices:

Implementing Zstandard compression and decompression on low-power mobile devices can increase CPU usage and energy consumption. Future studies could explore lightweight variants of the algorithm or adaptive compression levels to balance efficiency and battery usage, especially for IoT or embedded systems.

13.5 Hybrid Compression Models:

A promising direction is to combine **statistical text modeling** or **machine learning–based text prediction** with traditional compression algorithms. For example, using neural text prediction models can pre-process the text to reduce redundancy before compression, achieving even higher efficiency.

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