Journal of Information Systems Engineering and Management
2025, 10(35s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Enhancing Compression Efficiency in Weather WSNs: A Frequency-Based LZW Approach for Reduced Data Transmission

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ARTICLE INFO

Received: 18 Dec 2024

Revised: 10 Feb 2025

Accepted: 28 Feb 2025

ABSTRACT

One of the most critical constraints in weather wireless sensor networks (WSNs) is the amount of transmitted data. To address this, a method is proposed to focus on compressing weather data (temperature, humidity, visibility, pressure, wind bearing, and wind speed) using the LZW compression algorithm. Our approach involves analyzing the frequency of sensor data every second to optimize compression efficiency. The results demonstrate that the proposed method achieves a significantly higher compression ratio (CR) compared to the traditional LZW method. For instance, the highest CR observed with our method was 0.26981 for temperature data, whereas the traditional method yielded lower CR values across all weather conditions. Additionally, we evaluated the size reduction ratio (SR). The traditional method achieved an SR of 0.99201 for visibility data, while the proposed method achieved a lower SR of 0.75898, indicating more efficient data reduction.

Keywords: compression ratio, saving ratio, WSNs, weather data, LZW compression, frequency analysis.

INTRODUCTION

The utilization of Wireless Sensor Network (WSN) for collection data of weather is popular. [1] Since the weather data should be computed at least for every second for many regions which are unreachable by humans, the best way to do that is using WSN. The collected data of weather would be huge, so that it should be reduced by using one of the efficient data compression schemes. [2]

The data compressing is accomplished when the algorithm of compressing is implemented on the collected data. The compressing algorithm is classified into two types: lossy and lossless algorithm. The lossy compressing algorithm does a compressing for collected data, furthermore its implementing leads to loss some of the original data after decompressing the compressed data. However, lossless compressing algorithm keeps the original data without losing any bit of data. Most of the utilized compression methods in WSN are inefficient, because they are looking for frequencies of strings for compressing data. To improve the efficiency of the compressing algorithm in WSN, this paper proposes a scheme that changes the base of the lossless compression algorithm in WSN. The proposed scheme is based on the principle of compressing frequent readings (numbers) instead of frequent strings. The implementation of the proposed protocol reduces the size of the weather transmitted data efficiently over WSN. The proposed protocol is executed on the collected weather data then the LZW is implemented.

2. RELATED WORK

For reducing the size of transmitted data in WSN, many researchers proposed and tested various techniques to address the problem. The following techniques are proposed to reduce the size of the collected data in WSN before compressing by Lempel Zive Welch (LZW). In [3] the author introduced a method (Mixed Byte) to mix bytes of sequence of readings to make the works better than before. [3], while in [4], the authors introduced a method (Data Value Minimization) that computes and stores the difference between two successive readings. Some literature has proposed various techniques for improving the performance for WSNs. Most significant

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related studies are listed in the following statements. Aimed at optimization WSNs for superior energy efficiency and extended operational life spans. Authors in [5] introduced a scheme for evaluating energy efficiency of data compression in wireless sensor networks, one possible method that can lower the volume of data transferred between nodes and save energy, which is compressed data. The most energy-intensive aspect of wireless sensor networks is data communication. Authors in [6] proposed a data redundancy reduction WSN. The sensor nodes are randomly deployed where the sensor nodes are not situated far away from each other, the data aggregation and numerous data redundancy reduction algorithms are employed to solve this problem Partially Swarm. In[7] the authors focused on a vast number of tiny devices called sensor nodes that make up the networks. Numerous wireless communication techniques are used to link the routing protocols which are responsible for the channels of communication Energy efficiency, Routing Protocol with Energy Awareness (ERP). ERP is a query-based routing system made to route packets over a network while taking energy and distance into account. In [8] the author introduced an analysis of state-of-art data compression techniques in WSN. Initial, appropriate groups of conditions are determined for classifying predefining methods to define that experimental data compression in WSN because power utilization is a vital issue that affects the lifespan of WSN. For solving this problem namely energy-efficient medium access control or routing protocol. Amongst individuals presented models, the data compression model is utilized for reducing broadcasted data on wireless channels. In [9] the authors proposed a scheme that is based on data compression to improve the network lifetime and reduce energy consumption; the data volume must be reduced when sent from the sensor node to the sink node in the network. Compression algorithms are classified, including the lossless adaptive data compression algorithm) ALDC), which aims to analyze and discover strategies and is used to significantly reduce the amount of data before sending.

3. THEORETICAL BACKGROUND

3.1. Network Components of WSNs

The basic components of general WSNs are the sensor nodes. In WSNs, every sensor node has the ability of sensing, processing and communicating data to the crucial destination. The basic components of the sensor node are the communications unit, the processing unit, the sensor unit, and the memory unit to perform these operations. [10]

1-Sensing Unit: Sensors sense the environment and collect data before transmitting it and converting it into basic information (data) (current, voltage, etc.) for further processing.

2-Memory Unit: It is used to store data and program codes. To store program code, it uses electrically erasable and programmable memory (EEPRM) or read-only memory) ROM). To store data packets from neighboring nodes, it uses Random Access Memory (RAM) or read-only memory.

3-Power Unit: The main energy consumption at a node is because of transmission and computation where transmission is the most expensive activity at the sensor node in terms of Energy Consumption Mostly.

4-Processing Unit: This unit is responsible for the data get, Processes incoming and outgoing data and then executes it and modifying routing information considering the performance conditions of the sending.

5-Communication Unit: Typically each sensor node transmits data to another node directly or through multi-hop routing

3.2. Sensor network Applications

Thus, application fields of sensor networks are limitless. The following are a few examples: military applications control, communications, computing, surveillance, and targeting WSNs can also be used in monitoring friendly forces, environmental applications. Every path has a different set of environmental applications: the movement of birds, small animals and, monitoring environmental chemical/biological detection, Health applications: Doctors can by check the patients' present state using sensors which may detect heart rate or blood pressure. Commercial applications have many applications in this field. Tory control, identification of intruders, and vehicle tracking are using sensor networks to reach a so-called smart environment.

3.3 Type of WSN

The types of networks are depending on the environment so that they distribute it underwater, underground, on land and so on. Different types of WSNs include:

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Terrestrial WSNs: Terrestrial WSN consists in inexpensive node a large number of nodes placed on land in a given area, typically in an ad hoc manner in terrestrial WSNs. [11]

Underground WSN can be used to monitor soil so that parameters such as water content, mineral composition, salinity. [12] Underwater UWSNs can be applied to monitoring marine activities by monitoring the immediate surroundings of the marine organisms through acoustic device networks. The WSN is used to transfer data of marine organisms from one sensor to another. [13] Multimedia of WSN is important where Military wireless sensor network applications such as border surveillance and intrusion detection can have their accuracy and effectiveness enhanced by including human monitoring. [14]

3.4. WSN data compression

The process of converting an input data stream (original raw data) into an output data stream (bit stream).known as data compression with a reduce size. A stream can be a file, a buffer in memory, or individual bits transmitted on the communication channel, the process of reducing the size of data is known as data compression. Data compression is important in helping reduce the space required to store or transfer data ability. Compressed data must be decompressed because it requires additional processing, Enforces computational or other costs through decompression. Data compression is sometimes it is called source coding, where and the input symbols (pixels, bytes, ASCII codes, or bits) are used. Released through information source and have to be coded before being transfer to their destination. There are two types of compression, lossless compression and lossy compression. Lossy compression will reduce the size of files by eliminate some unnecessary There is data that is not recognized by humans after it is encrypted. This data is used to compress video and audio. Data compression is processed without losing any bit of data within the file to reduce the size without losing any data after decryption [15] The LZW data compression algorithm is a lossless dictionary-based technique that uses an index number is supplied for each symbol, character, and unique characters. First of all the input text file which we have to compress is read from the stored Lempel-Ziv string. Encoding produces Dictionary of strings encountered in the data stream .The dictionary was initially limited to all ACSII alphabetic characters, with the code being the de facto code whenever a new string appeared in the data stream, the strings adds to the dictionary and gives a symbol when the same word is encountered once more The longest matching entry in the dictionary over time the dictionary became used. Creates text strings. It is done by replacing the word by the symbol in the outgoing data stream. If a compound word is present corresponding to codes. It works in some LZW algorithms in both compressors and decompress or to ensure that the two dictionaries match, a dictionary with exactly the same rules will be created [16] the encoder and decoder code of LZW is illustrated in Algorithm 1. [17] [18]

```
Begin
Initialize table with single character strings
P ← first input character
While not end of input stream
C ← next input character
If P + C is in the string table
P ← P + C
Else
Output the code for P
Add P + C to the string table
P ← C
End While
Output code for P
End
```

(a) Coding

```
Begin
For I ← 0 to 255
Dictionary[i] ← Dictionary_ code (i)
End For
Pre ← read (data)
Output(Dictionary decode (Pre))
C ← empty
While true
input← (data)
If (input) is not in Dictionary
S ← Dictionary _decoding (pre)+C
Else S ← Dictionary _decoding (Input)
Output(S)
C ← first _character(S)
Dictionary [i++] ← Pre + C
Pre ← Input
End While
End
```

(b) Decoding

Algorithm1: LZW coding and decoding

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4. PROPOSED WORK

The proposed technique focuses on reducing the number of frequent input readings of sensor. When data is frequent, then it would be compressed with high compression rate. That means the data of the network would be reduced to increase network performance. Furthermore, first step is based on storing the reading input and its number of frequent. In the second step LZW compressing algorithm would be implemented after processing the data with proposed technique.

As illustrated in Figure 1, that shows how the proposed work deals with weather data readings for one hour. Each one minute one weather data reading is done. Initiate a counter for each new input reading and set to one, it is refereeing to the number of frequent of input data. Then the next input reading is compared to the previous one to check if the new input reading is equivalent to previous one. Whether they are equivalent then the counter would be increment. Otherwise, the current input data and the value of counter would be output, and the new input is considered as current input and the counter would be set to one. When the time (one hour) is finished, the process is going to output the current data input and the counter. The above demonstrated scheme is repeated until the end of life of the weather sensor node.

The proposed scheme is going to work on the six elements of the weather. They are temperature - humidity - visibility - pressure - wind bearing - wind speed. The weather data input is computed by sensor node for each hour and send to the sink node by using WSN network.

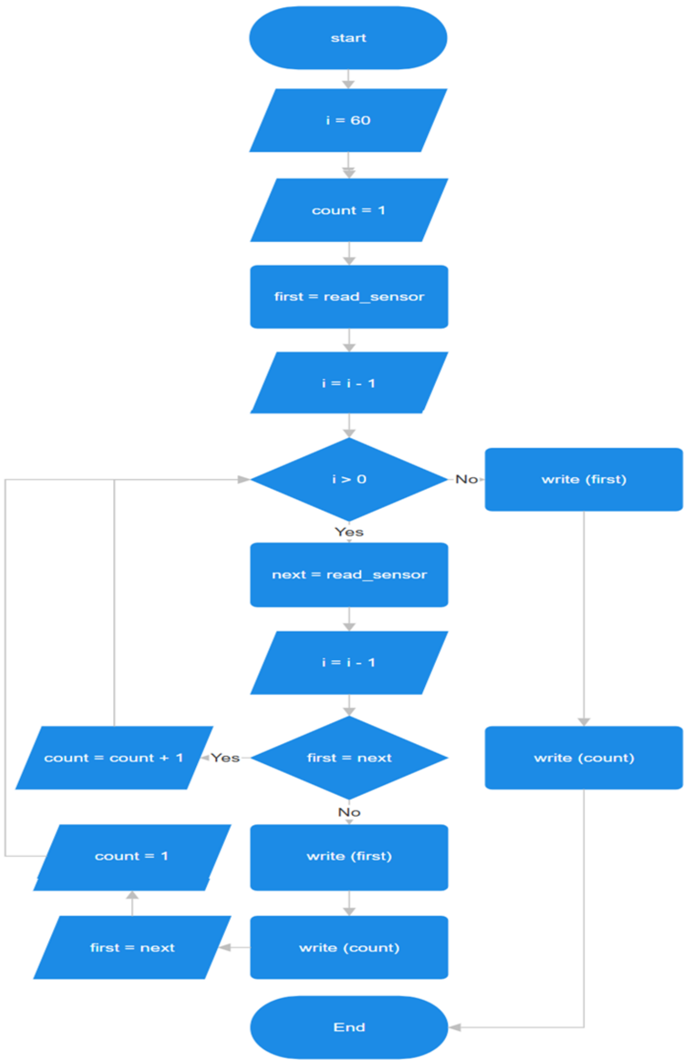

Figure 1: proposed work

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5. RESEARCH DESIGN

The designed as pre-test post-test experimental design. The collected data is quantitative, which is computed through implementing research tests. To test the impact of the proposed technique on the data compression ratio and its influences on the performance of WSN, two experiments are implemented. The first experiment (original state) includes two tests. The tests are measuring two metrics, which are compression ratio (CR), and saving percent of data (SR). The second experiment (proposed work) has the same tests as the first experiment.

The proposed work is tested by implementing two experiments. The data of the first and second experiment is collected by implementing the original and proposed technique, and the data is analyzed according to the compression metrics. The data set is weather data that is collected by sensors to measure (temperature, humidity, visibility, pressure, wind Speed, wind bearing). Each node has many sensors. The sensor reads input every one minute.

The first test computes a compression ratio metric by equation Eq.1. The Compression ratio is the size of the data after compression and before compression. The second test computes a saving ratio by equation Eq. 2.

Compression Ratio = $\frac{size\ after\ compression}{size\ before\ compression}$.... (Eq. 1)

Saving Rate = (1- CR *100%) .... (Eq. 2)

6. RESULT AND DISCUSSION

6.1. Data Size Evaluation

Table1 shows the size of the collected data, which represent temperature, humidity, wind, visibility, and pressure. The first column has a set of values that represent the size of the original data, while in the second column, which represents the data size after implementing the proposed technique.

Table 1: size of data before and after implementing the proposed technique

Sensors	original	proposed method
temperature	3460873	77505
humidity	2974133	61063
visibility	2427936	33275
pressure	4462751	94437
windSpeed	3057726	70525
windBearing	2391661	57411

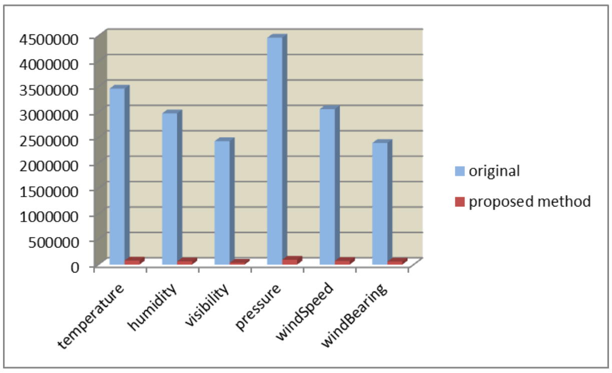

Figure1: data collection for original and proposed method of each sensor

The size of original temperature (3,460,873 bytes) is compared to its size after applying the proposed technique (77,505 bytes) to evaluate efficiency. A significant reduction in size is observed when using the proposed technique, streamlining data processing while retaining essential information and avoiding unnecessary complexity. For instance, the humidity column shows an original size of data is 2,974,133 bytes, whereas the proposed technique reduces it to 61,063 bytes. This trend persists across other weather elements: pressure, wind speed, and wind direction all exhibit substantially smaller size with the proposed technique.

The proposed technique is employed to minimize data size without compromising accuracy, resulting in enhanced measurement precision and data quality. By systematically reducing redundancy, the method ensures files remain both compact and functionally robust. The consistent improvement across all parameters—where

original sizes far exceed the proposed ones—validates the method's effectiveness. Thus, the proposed algorithm not only optimizes storage but also elevates data utility, demonstrating its superiority in balancing efficiency and accuracy. The core technology enables data size determination without compromising accuracy, improving the accuracy of data presence measurement. By systematically repeating iterations, this ensures

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that data remains functionally robust and easy to use. It emphasizes continuous improvement in all aspects, such as the original expansion process, which significantly increases the effectiveness of this method. Thus, the algorithm not only optimizes the storage process but also improves the data, demonstrating its superiority in balancing accuracy and precision.

Table 2 shows a comparison for various collected data sensors after compressing using LZW and LZW2. It used the LZW method once for the original, and a compressed size is obtained, meaning reducing the size of the original data. In the next step (LZW2), it uses LZW for the data yields of the proposed technique, and it obtains better results.

Table 2: size of data for each sensor after compression by LZW and LZW2

Sensors	lzw	lzw2
temperature	342553	20912
humidity	25857	9632
visibility	19422	8020
pressure	36278	20332
windSpeed	37922	18368
windBearing	30043	13726

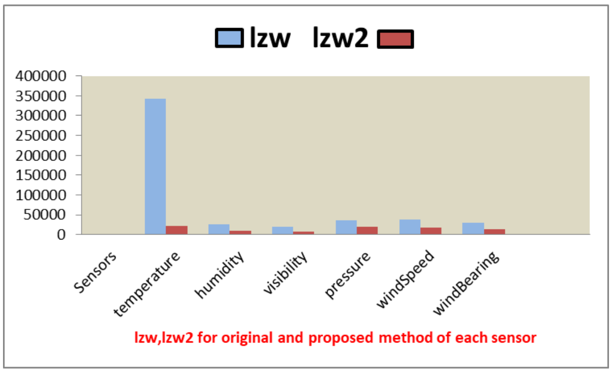

Figure 2: LZW, LZW2 for original and proposed method of each sensor

The analysis highlights a significant reduction in file sizes when comparing LZW column compression with LZW2 compression. For example, at temperature: the size of the LZW-compressed data (342,553 bytes) is significantly larger than the LZW2 result (20,912 bytes). At humidity, LZW produces a file size of 25,857 bytes, while LZW2 achieves a more efficient size of 8,020 bytes. Further optimization using double compression reduces the size of LZW2 to 9,632 bytes, outperforming LZW1 (19,422 bytes). At wind speed, LZW compression produces a file size of 37,922 bytes, while LZW2 reduces this size to 18,368 bytes. Dual-layer compression was applied to both the original data and the data processed using the proposed LZW2 method. The results consistently demonstrate the superiority of LZW2, as demonstrated in additional tests: for the original LZW-compressed data (36,278 bytes), LZW2 achieves a reduced size of 20,332 bytes.

The result confirms that LZW2 consistently produces smaller data sizes than LZW across all tested parameters. This improvement is attributed to algorithmic enhancements in LZW2, which streamline redundancy removal while preserving critical data integrity. The proposed method's efficiency underscores its potential for optimizing storage and processing workflows. Likewise, the wind bearing is, the size of the LZW (30043 bytes) is higher than the size using the proposed method (13726 bytes). In conclusion, we observe the weather conditions, including temperature, humidity, visibility, pressure, wind speed and direction, using the well-known compression method LZW, in relation to the size of the original files and the size of the files of the proposed method. For the purpose of reducing the size in order to obtain the best results, we note that the proposed method was also more accurate

6.2. Compression Ratio Evaluation

As shown in Table 3, rate of compression has significant differences between the LZW method (CR) and the proposed LZW2 method (CR2). For temperature sensor, the original method yields a CR of 0.09897, which is notably lower than CR2. In the humidity sensor, CR (0.00869) is substantially smaller than CR2 (0.15773), while for visibility sensor, CR2 (0.24102) outperforms CR (0.00799). Similarly, for pressure sensor, CR (0.00812) remains lower than CR2 (0.21529). The trend continues for wind speed sensor, where CR (0.01240) is less than CR2 (0.26044), and for wind bearing sensor, CR2 (0.23908) achieves a markedly higher ratio compared to CR (0.01256). These results collectively demonstrate that the proposed LZW2 method consistently delivers superior compression ratios across all tested parameters, confirming its effectiveness over the original LZW approach.

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Table 3: CR and CR2 for various sensors

Sensors	CR	CR2
temperature	0.09897	0.26981
humidity	0.00869	0.15773
visibility	0.00799	0.24102
pressure	0.00812	0.21529
windSpeed	0.0124	0.26044
windBearing	0.01256	0.23908

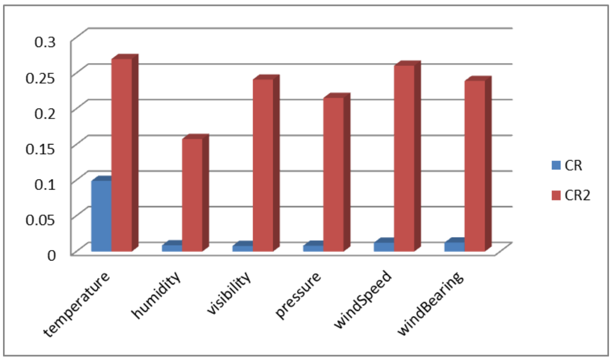

Figure 3: CR, CR2 for each sensor

6.3. Saving Rate Evaluation

As shown in Table 4, the rate of saving exhibits notable discrepancies between the original LZW method (SR) and the proposed LZW2 method (SR2). For instance, in the temperature sensor, the original method achieves a higher SR value (0.90103) compared to SR2 (0.73019), despite both rates being close to zero. A similar pattern emerges for humidity sensors, where SR (0.99131) surpasses SR2 (0.84227), and for visibility, where SR (0.99201) exceeds SR2 (0.75898). Similarly, for pressure sensors, SR (0.99188) remains higher than SR2 (0.78471). The trend continues for wind speed sensors, where SR (0.9876) is higher than SR2 (0.73956), and for wind bearing sensor, SR2 (0.76092) achieves a markedly lower value compared to SR (0.98744). These results indicate that the original LZW method is consistently less acceptable than the proposed LZW2 approach in terms of saving rates across all six parameters, even though the values themselves are minimal.

Table 4: SR and SR2 collection for various sensors

sensors	SR	SR2
temperature	0.90103	0.73019
humidity	0.99131	0.84227
visibility	0.99201	0.75898
pressure	0.99188	0.78471
windSpeed	0.9876	0.73956
windBearing	0.98744	0.76092

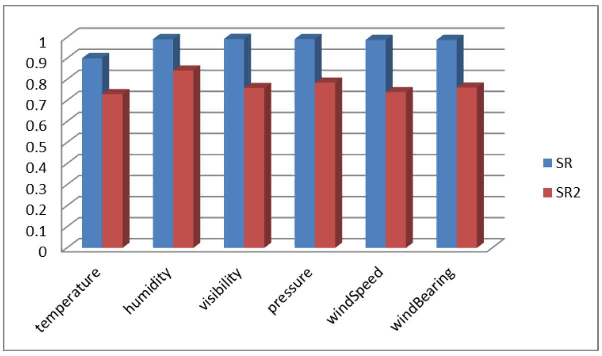

Figure 4: SR, SR2 for each sensor

In Table 1, the proposed method is utilized to find the number of repetitions of values for the weather data that is obtained from various sensors. The original data was very large data, and to reduce the size of this data, the repetitions for all values in order to save storage space is computed.

Thus, data is obtained of a reasonable size to be sent over WSN. The data is compressed by a well known lossless compression method LZW. The using of LZW with a proposed technique maintains the quality and accuracy of the data. It obvious that the proposed method is performing best for many metrics, which is the goal of it in order to obtain a high compression ratio, and increase productivity, and for the WSN

7. CONCLUSION

It is concluded from the diagrams that the proposed method is the best way to improve the compression ratio with the use of the well-known compression method LZW and to improve SR by reducing the data size. It is noticed that the CR of the proposed method with LZW is higher than the traditional method and the SR of the proposed method is lower than in the traditional method to provide a large storage space

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e-ISSN: 2468-4376
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