

Compression Method to Remove Unnecessary MSBs of IQ Data Frames in C-RAN

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Abstract. Smart phones are growing rapidly with the support of Over the Top (OTT) service and multimedia streaming service as well as existing Internet service. In the conventional Distributed-RAN (D-RAN) structure, a Base Band Unit (BBU) and a Remote Radio Head (RRH) are configured at one cell site. However, C-RAN, which is a new RAN structure, is composed of separated base stations in which BBU and RRH are separated. RRH is left in cell sites where radio signals are transmitted and received, and BBUs are collected and managed in different places. When the bandwidth of the LTE signal is 20 MHz and the 2×2 Multiple Input Multiple Output (MIMO) antenna is used, the CPRI requires 2.5 Gbps transmission. Since there is a limit to handle mobile traffic that is continuously increasing with the current transmission rate, several techniques for compressing IQ data before transmission have been proposed. In this paper, we apply the compression technique to remove unnecessary parts in the Most Significant Byte (MSB) of a basic frame after applying the existing Up/Down sampling and Non-linear Quantization. We measured the error vector magnitude (EVM) to measure the compression rate and the quality of the signal after compression to confirm the compression performance. Also, it was confirmed whether the experimental results satisfied the compression requirement of Open Radio Interface (ORI).

Keywords: CPRI · C-RAN · Compression · Up/down sampling · Non-linear quantization · ORI

1 Introduction

In the past, the mobile phone was simply a mobile phone with only a call function, but today's smart phone is born with various functions added to the mobile phone. Smart-phones with various functions such as TV, camera, Internet, etc., have steadily increased penetration, usage, and dependency. In addition, the smart phone supports OTT services such as YouTube, Mobile IPTV, and multimedia streaming services along with existing Internet services. For this reason, mobile traffic has rapidly increased, and a new RAN structure, C-RAN, has emerged in order to efficiently distribute mobile traffic [1].

In the conventional Distributed-RAN (D-RAN) structure, a Base Band Unit (BBU) and a Remote Radio Head (RRH) are configured at one cell site. However, C-RAN, which is a new RAN structure, is composed of separated base stations in which BBU and RRH are separated. RRH is left in cell sites where radio signals are transmitted and received, and BBUs are collected and managed in different places. Figure 1 shows the structure of D-RAN and C-RAN.

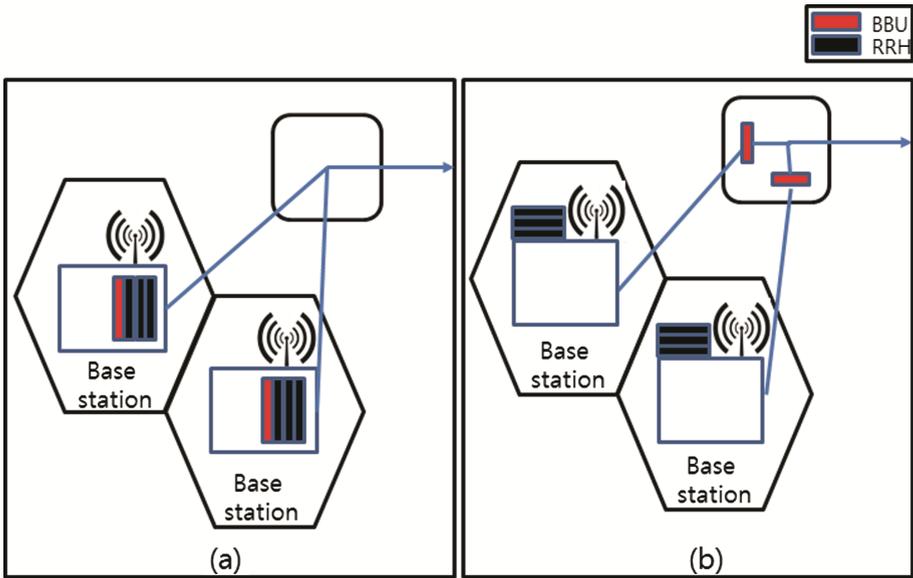


Fig. 1. (a) Structure of D-RAN (b) Structure of C-RAN

BBU and RRH exchange user data, CPRI control and management data, and synchronization information of CPRI frame through CPRI interface. User data is transmitted in the form of baseband digital IQ stream in IQ data block in CPRI basic frame. Control, management data and synchronization information are transmitted using CPRI subchannel which is control word in CPRI basic frame. Each basic frame that constitutes a subchannel consists of 1 byte of control word and 15 bytes of payload.

When the bandwidth of the LTE signal is 20 MHz and the 2×2 MIMO antenna is used, the CPRI requires a transmission rate of 2.45 Gbps [2]. There is a limit to the amount of traffic currently available to handle ever-increasing mobile traffic. One of the currently proposed methods is to increase the number of antennas, but this method is disadvantageous in that it is costly. Therefore, several techniques have been proposed to compress IQ data before transmission.

Currently, compression methods such as Up/Down sampling, Non-linear Quantization, and Block Scaling are available. In this paper, we apply the compression method to remove unnecessary parts in the MSB of the basic frame after applying the existing Up/Down sampling and non-linear quantization. We measured the error vector magnitude (EVM) to measure the compression rate and the quality of the signal after

compression to confirm the compression performance. Also, it was confirmed whether the experimental results satisfied the compression requirement of ORI.

2 Compression Method

2.1 Up/Down Sampling

In LTE environments, the sampling rate of ADC, DAC, and BBU processing exceeds the signal bandwidth [3]. For example, the sampling rate at 10 MHz LTE is 15.36 MHz and 1/3 of the spectrum does not convey LTE related information.

Therefore, when transmitting IQ data, up sampling the analog signal by K , and down sampling by L after low-pass filtering. On the receiver, perform up sampling by L and down sampling by K after low-pass filtering. Generally, because L is set larger than K , When compressing, it is called down sampling by decrementing by K/L , and it is called up sampling because it increases by L/K when reconstructing.

2.2 Non-linear Quantization

Unlike linear quantization, which divides the quantization level Q_q by a constant amount, non-linear quantization narrows the quantization level at a lower level and makes the quantization level wider at a higher level. [4] Applying quantization with an optimized distance between quantization levels reduces quantization noise and improves signal quality. Figure 2 shows linear quantization and Non-linear quantization.

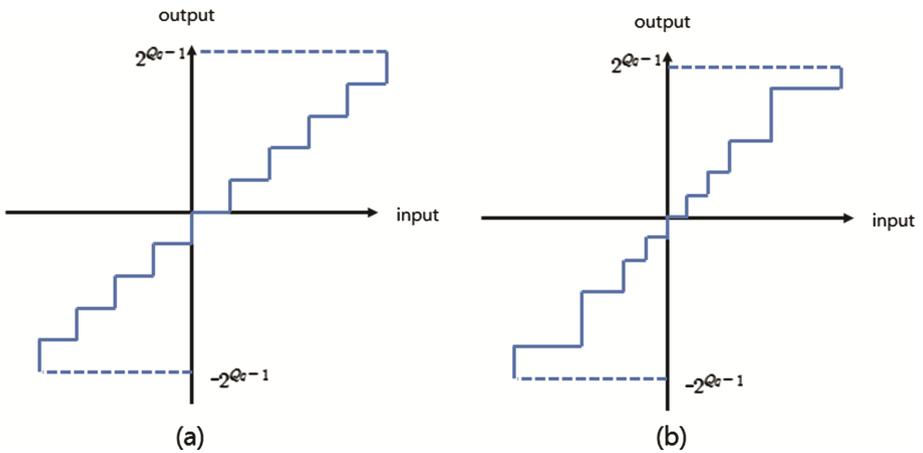


Fig. 2. (a) linear Quantization (b) Non-linear quantization

3 Proposed Compression Method

3.1 Remove the Unnecessary Part in MSB

When nonlinear quantization is performed, the analog value changes to a digital value consisting of only 0 and 1. Therefore, after nonlinear quantization, a frame with the same bits as the Q_q level is generated. If a small value is quantized, the value information can express the value by only the bits of the LSB part. Therefore, it can be concluded that the data of the MSB part is unnecessary when viewed from the receiver.

For example, assuming that the sender sends a value of 105, the 15 bits frame will consist of 00000001101001. However, the receiver does not need to receive all 15 bits value. Even if only 1101001 is received, It can know data is 105.

Therefore, before transmitting data from the transmitter, first determine whether the first bit of the MSB is 0 or 1, and then check how many times the same value as the first bit is repeated continuously. Then, the MSB part removes the repeated bits and transmits information on how many bits are removed and the remaining LSB data together.

On the receiver, first confirms whether the bit of the MSB part is 0 or 1, and confirms the number of bits removed. After that, by adding the same value as the first bit by the number of bits removed between the first bit and the LSB data, the data before compression is restored. Figure 3 shows the process of removing the MSB from the transmitting side and restoration from the receiving side.

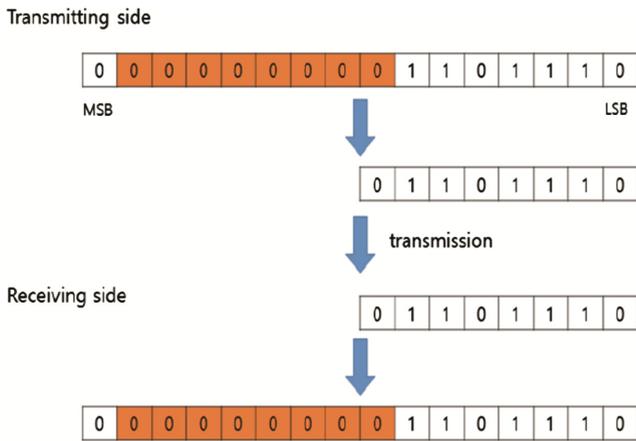


Fig. 3. The process of removing the MSB from the transmitting side and restoration from the receiving side

Most compression methods have EVM. For example, quantization generates EVM because it replaces existing values with quantization level values and substitutes them with approximate values when they are not the same value. But the compression method presented has the advantage of lossless compression without EVM. Therefore, when this compression method is applied to the conventional EVM compression method, the compression rate can be increased while maintaining the EVM.

Also, for existing linear or nonlinear quantization, the range of quantization is $[-2^{2q-1}, 2^{2q-1} - 1]$. However, when we apply the proposed method, we set $[1, 2^{2q-1}]$. When using the existing range, the first bit is necessary because the quantized value is negative or positive. Therefore, we have specified the range so that the quantized values are all positive. If all the quantized values are positive, the first bit is unconditionally zero. If the transmitter and receiver know the first bit is 0 in advance, the first bit can be removed as well when the unnecessary MSB is removed. By changing the range in this way, the compression rate can be further increased.

4 Experimental Process and Result

In this paper, to analyze the performance of the compression method that removes the unnecessary MSB part from the frame of IQ data, we simulate using MATLAB as follows.

According to the 3GPP standard, a 10 MHz channel frequency bandwidth was used and IQ data was generated with 15 bits according to the CPRI standard, and 16-QAM was used for modulation. The generated IQ data is passed through an inverse fast Fourier transform and a cyclic prefix is added. Next, after applying the down sampling and nonlinear quantization, we measure and remove the unwanted parts of the MSB.

On the receiver, the number of removed bits is checked, and the number of bits removed by the same value as the first bit is restored at the beginning of the LSB data, and then de-linear quantization and up sampling are applied. Figure 4 shows the process of compressing and restoring IQ data.

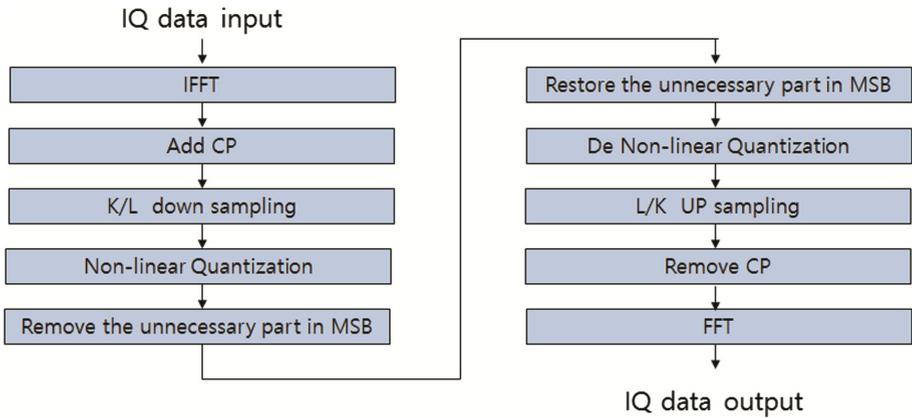


Fig. 4. The process of compressing and restoring IQ data

In the Up/Down sampling process, K is set to 2, L is set to 3, window size N_w is set to 64, low pass filter index I is set to $[-(N_w/2), (N_w/2) - 1]$ and the window function used for low pass filtering is the hamming window function [5]. The hamming window function is advantageous in that the processing time is short because of simplicity in comparison with other window functions. The Hamming window function $W(I)$ is as in

$$W(I) = 0.54 - 0.46 \cos \left(\frac{2\pi \left(I + \frac{N_W}{2} \right)}{N_W} \right) \tag{1}$$

In the Non-linear Quantization process, the Quantization level Q_q is set to 6, 8, 10, 12 and Quantization range is set to $[1, 2^{Q_q-1}]$. Figure 5 shows the values before and after quantizing the IQ data. The quantized values show that all values are positive.

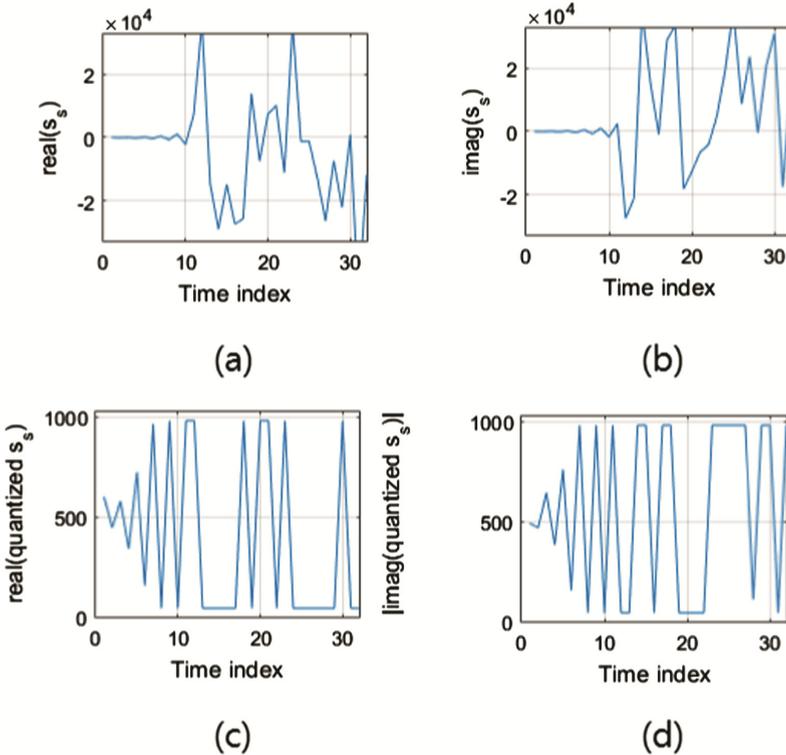


Fig. 5. (a) I data before quantization (b) Q data before quantization (c) I data after quantization (d) Q data after quantization

4.1 Experimental Process

With the advent of various compression technologies, ORI standardization organizations have introduced a standard that includes IQ data compression technology applicable to C-RAN. Requirements for compression set by ORI should be compressibility 50% or more, EVM 3% or less, latency 100 μ s or less [6]. If these three requirements are satisfied, it means that even if compression technology is applied, there is no

significant change from the previous data, and latency does not affect the operating system. EVM is as in

$$EVM = \sqrt{\frac{E[|\bar{x} - x|^2]}{E[|\bar{x}|^2]}} \times 100[\%] \tag{2}$$

Compression rate is measured by comparing the input signal before down sampling and the signal after removing MSB. When EVM is measured, it is compared with IQ data before passing IFFT and IQ data after FFT.

Table 1 the result of applying UP/Down sampling and non-linear quantization, which are conventional compression methods. it can be seen that as the nonlinear quantization level Q_q gradually increases from 6 to 12, the compression rate decreases from 77% to 50%, but the EVM also decreases from 0.98% to 0.70%. Latency was measured to be approximately 22.2 μ s.

Table 1. Compression rate, EVM and Latency result

Q_q level	Compression rate (%)		EVM (%)	Latency (μ s)
	I data	Q data		
6	77.2984	77.5928	0.9820	22.2472
8	67.3284	67.1239	0.9265	22.1058
10	58.3351	58.2959	0.8527	22.3819
12	49.9967	49.9896	0.7015	22.2824

Table 2 shows the compression ratio, EVM, and latency after adding the proposed compression method.

Table 2. Compression rate, EVM and Latency result

Q_q level	Compression rate (%)		EVM (%)	Latency (μ s)
	I data	Q data		
6	82.1139	82.1125	0.9820	29.2922
8	73.1244	73.0694	0.9265	29.1947
10	64.1148	64.0686	0.8527	29.2679
12	55.0015	55.0324	0.7015	29.2250

From the results, it can be seen that as the nonlinear quantization level Q_q gradually increases from 6 to 12, the compression rate decreases from 82% to 55%, but the EVM also decreases from 0.98% to 0.70%. In other words, the higher the compression ratio, the greater the error between the original signal and the original signal. Latency was measured to be approximately 29.2 μ s. Compared to the three ORI requirements, we can see that Q_q is satisfied in both 6, 8, 10, and 12.

Comparing the existing approach with the proposed approach, adding the MSB removal method increases the latency from 22.2 μ s to 29.2 μ s, but it can increase the compression rate by 5% for each Q_q level without generating additional EVMs.

5 Conclusion

There is a limit to the amount of traffic currently available to handle ever-increasing mobile traffic. Therefore, one of the ways to solve this problem is to transmit IQ data. Conventional compression methods include up/down sampling, nonlinear quantization, block scaling, etc.

In this paper, we propose a compression method that calculates and removes unnecessary MSBs in data frames after applying Up/Down sampling and Non-linear quantization.

As a result of experiments using MATLAB, we found that as the Q_q increases, the compression rate decreases, but the EVM decreases and it is restored close to the original signal. Latency was also measured almost constantly. Also, it was confirmed that these experimental results satisfied the compression conditions required by ORI.

Compared with the conventional compression schemes, the latency increased by 7 μ s, but the EVM was the same and the compression rate was improved by 5% for each Q_q level.

Acknowledgment. This work was supported by Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIP) (No. 2016-0-00106, Development of the RF-signal over IP Technology for the Smart Media Services based on Optical IP Network) and This research was supported by the MSIP (Ministry of Science, ICT and Future Planning), Korea, under the ITRC (Information Technology Research Center) support program (IITP-2017-2012-0-00628) supervised by the IITP (Institute for Information & Communications Technology Promotion).

References

1. de la Oliva, A., Hernández, J.A., Larrabeiti, D., Azcorra, A.: An overview of the CPRI specification and its application to C-RAN-based LTE scenarios. *IEEE Commun. Mag.* **54**(2), 152–159 (2016)
2. Tayq, Z., Quere, A., Anet Neto, L., Chanclou, P., Saliou, F., Grzybowski, K.: Performance demonstration of real time compressed CPRI transport. In: 42nd ECOC (2016)
3. Samardzija, D., Pastalan, J., MacDonald, M., Walker, S., Valenzuela, R.: Compressed transport of baseband signals in radio access networks. *IEEE Trans. Wireless Commun.* **11**(9), 3216–3225 (2012)
4. Guo, B., Cao, W., Tao, A., Samardzija, D.: LTE/LTE-A signal compression on the CPRI interface. *Bell Labs Tech. J.* **11**(2), 117–133 (2013)
5. Priya, K., Swethanjali, N., Arthi Bala Lakshmi, M.: Comparison of various filtering techniques USDE for removing high frequency noise in ECG signal. *IJSRTM* **3**, 211–215 (2015)
6. ORI Specification, V. 4. 1. 1 October 2014