Vector quantization based CPRI compression algorithm

Pratibha Chavan[1], Ajmal Shafi Shaikh[2]

[1]*Assistant Professor, Dept of E&TC, Trinity College of Engineering and Research, Pune, Maharashtra, India,*
[2]*PG Student, Dept of E&TC, Trinity College of Engineering and Research, Pune, MH, India.*

Abstract: With increasing demand of Internet and availability of handsets supporting high speed data rate. Technological evolution is to take place. 4G & 5G are the current technologies being used to cater the demand of high speed data download. These technologies are not only confined to high speed download or upload, but also they are different with their preceding technologies because of their ability to provide low latency. High Speed data, such as 10 Gbps in downlink & 1 Gbps in uplink and Low latency such as 1ms or less would make 5G as preferred and widely accepted technology in coming days. To provide high speed data and low latency a technique called cloud RAN (C-RAN) has been invented. In C-RAN base band processing unit and Radio units are kept away from each other. And these Hardware units are connected via a common public radio interface called (CPRI) instead of Coax or copper wire. In order to send the large amount of data, it needs to be compressed, which is the enhancement of CPRI. To compress the data, vector quantization-based algorithm is used for CPRI links, making use of Lloyd algorithm. For optimal performance methods, vector I/Q samples and enhanced initialization of the Lloyd algorithm for the Codebook training need to be investigated further.

Keywords:
Common public radio interface called (CPRI), Cloud RAN (C-RAN), Vector quantization(VQ),
Code book, Lloyd algorithm, LBG (Linday- Buzo-Gray), Kekre's Proportionate Error (KPE), Kekre's Median Codebook Generation (KMCG), Kekre's Fast Codebook Generation (KFCG).

Introduction: Mobile wireless data is expected to grow with a very fast pace and by the end of 2025 160 extra bytes per month are forecasted [1] [2]. Such a huge demand can only be catered by high speed network using 5G technology. By the year 2025, 45 percent of global data traffic is expected to be carried by 5G networks. Low latency, high speed & high downlink throughput will make 5G as preferred and widely accepted candidate. All these will be achieved by utilizing a massive number of antennas using beam forming in a direction, higher order modulation schemes, large bandwidths & wide range of frequencies from less than a 1 GHZ to up to 72 GHZ. With the introduction of Cloud RAN architectures, operators will be able to meet the future requirement of high speed data and low latency [3]. Cloud RAN (C-RAN) is an innovative new architecture that tries to meet the needs by centralizing the baseband processing unit, whereas Radio units can be kept near the antennas. Connection between Baseband Unit (BBU) & Radio unit (RU) is done via CPRI cable. The Common Public Radio Interface (CPRI™) is the successful industrial cooperation defining the publicly available specification for the key internal interface of radio base stations between the BBU & RU.CPRI data need to be compressed to provide the high speed large volume of data in a very less amount of time [4] [5]. This technique of compression of data over CPRI link is quiet cost effective compare to the physical connection of BBU & RU which needs more links to be deployed to address the increase in CPRI data rate. To cater the high data rate requirement compression of more than one CPRI link is needed. Deployment expenditures are greatly reduced with the deployment of CPRI link compression in conjunction with new links deployment. This Paper mainly focuses on CPRI link data compression which can be employed with certain changes in conventional distributed base station or new CRAN architecture. Technique commonly found in literatures for the compression of CPRI link is based on scalar quantization (SQ) [6-8]. In scalar quantization, each input symbol is treated separately in producing the output. For LTE/5G networks, time-domain OFDM I/Q Samples are carried over CPRI links. Removal of Cyclic Prefix & decimation to remove the inherent redundancy in oversampled LTE/5G signals have been proposed to achieve additional compression [6]. In a nonlinear scalar quantization, the quantizer is trained off-line using an iterative gradient algorithm. 3% compression gain is reported with approximately 2% EVM for 10MHZ downlink LTE data [7].

Compression gain of 3.3 times with approximately 2% EVM distortion using decimation, an enhanced block scaling and a uniform quantizer. Lloyd-Max scalar quantization with noise shaping was considered in [9].

Another approach is a vector quantization (VQ) compression, rather than scalar quantization due to the fact that I/Q samples of an OFDM symbol, IFFT (FFT) operation for downlink (uplink) are correlated over time. Such time correlations cannot be exploited by scalar quantization whereas vector quantization can does this by mapping ground samples into codewords, this approach helps to achieve better compression [10]. From complex I/Q samples, vectors need to be formed before quantization. Based on how the I/Q samples are placed within formed vectors, many vector methods are available for study. Lloyd algorithm is introduced to Vector quantization codebook training. To further enhance performance, study and papers proposed a modified algorithm with different style of initialization step, where multiple trials work in serial to generate efficient codebook. Multistage quantization vector (MSVQ) which is a low complexity vector is also considered in one of the papers. From the studies, analysis and simulation result shows with the proposed compression scheme a gain of 4 times compression in uplink and 4.5 times compression for downlink within 2 % EVM distortion can be achieved.

Section II of this paper is described as a CPRI Compression algorithm and in Section III contains the conclusion.

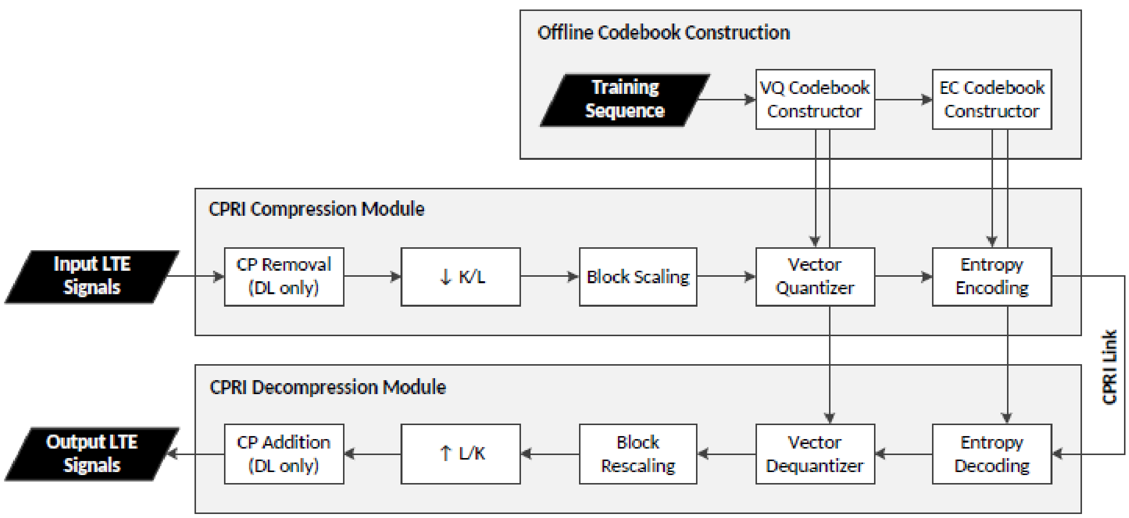

Fig1. Vector quantization based CPRI compression algorithm framework

A VECTOR QUANTIZATION BASED CPRICOMPRESSION ALGORITHM

i) System Framework: A system framework for vector quantization based CPRI compression and decompression for both downlink and uplink is shown in Fig. 2. CPRI Compression Module is located at Baseband unit (BBU) where input LTE/5G signals is fed as a downlink. It contains cyclic Prefix removal, decimation, block scaling, vector quantizer and Entropy encoding. CPRI decompression module is which performs the reverse operations. It deals with uplink and ADC output is the input to the CPRI compression module located in the RRU and CPRI decompression module located at the BBU which performs reverse operations. Cyclic Prefix Removal, Decimation, and Block Scaling are part of functional block and are standard entities for signal processing. Compression gains and function are mentioned below.

CP Removal block, enabled for downlink only, aims to eliminate the time domain redundancy from cyclic prefix. Compression gain from this block (i.e., CRCPR) can be expressed as

$$\text{CRCPR}=\frac{LSYM+LCP}{LSYM} \qquad (1)$$

Where *L*SYM and *L*CP denote IFFT output symbol length and cyclic prefix length, respectively. *Decimation* block aims to reduce the redundancy in the frequency domain. Compression gain from decimation can be expressed as

$$\text{CRDEC} = \frac{L}{\text{K}} \qquad (2)$$

Where L and K denote downsampling and upsampling times, respectively. Block Scaling block aims to lower the resolution of signal and maintain the dynamic range to be consistent with the quantization codebook. There is no compression gain from this block. In contrast, we need extra signaling over head of QBS bits for every NBS samples, where QBS is the target resolution and NBS is the number of samples forming a block.

ii) Vector Quantization: Vector quantization (VQ) is a classical quantization technique from signal processing that allows the modeling of probability density functions by the distribution of prototype vectors. It was originally used for data compression. It works by dividing a large set of points (vectors) into groups having approximately the same number of points closest to them. Each group is represented by its centroid point, as in k-means and some other clustering algorithms. Due to the powerful density matching ability of vector quantization algorithm is especially powerful for identifying the density of large and high-dimensional data. VQ is useful in a scenario where commonly occurring data have low error and rare high data error. VQ is used in lossy data compression, lossy data correction, pattern recognition, density estimation, Audio codec's, Video codec's and clustering algorithm.

Results:

Extension of Lloyd algorithm is referred to as LBG (Linday- Buzo-Gray) algorithm. LBG is a Vector quantization algorithm to drive a good codebook. comparison of LBG, KPE, KMCG and KFCG algorithms with respect to MSE for eleven color images of different category like portrait, collection of objects, Flower, Scenery, Monument of size 256x256 has been done. Below table shows total number of ED computations and total CPU units required with respect to total number of Comparisons of various mentioned algorithms.

Let M be the total number of training vectors, k be the vector dimension, N be the codebook size, 1 CPU unit is required for addition of 8 bit numbers 1 CPU unit for comparison. For multiplication/division of two 8 bits number 8 CPU units are required For multiplication of two 8 bits number 8 CPU units are required. To compute one squared Euclidean distance (ED) of k dimensional vector k multiplications and 2k-1 additions are required and hence 8k + 2k -1 CPU units are needed. To compute Centroid for M training vectors of k dimension, M-1 additions and k divisions are required and therefore M-1 + 8k CPU units are needed.

Below table shows Comparison of LBG, KPE, KFCG and KMCG algorithm with respect to total number of Comparisons, total number of ED computations and total CPU units required.

Let $P = \log_2 N$

Complexity Parameters	LBG	KPE	KFCG	KMCG
Total Comparisons	2MP	2MP	MP	$M \sum_{i=0}^{P-1} \log_2(M/2^i)$
Total No. of ED	2MP	2MP	0	0
Total No. of Centroids computed	$\sum_{i=0}^{P-1} 2^i$	$\sum_{i=0}^{P-1} 2^i$	$\sum_{i=0}^{P-1} 2^i$	0

Total CPU units	4MP(10k-1) + Pk(M-1)+ $\sum_{i=0}^{P-1} 2^i (8k)$	4MP(10k-1) + Pk(M-1)+ $\sum_{i=0}^{P-1} 2^i (8k)$	MP+ Pk(M-1)+ $\sum_{i=0}^{P-1} 2^i (8k)$	$M \sum_{i=0}^{P-1} \log_2 (M/2^i)$

Conclusion

A vector quantization based CPRI compression framework is deliberated in this paper. Based on results enhanced Lloyd algorithm is chosen for the learning of vector quantizer codebook. To achieve complexity reduction, multi-stage vector quantization is proposed to significantly reduce the vector codebook search latency. From various studies and research papers it's been observed that vector quantization based CPRI compression has shown superior compression gain by exploiting the time correlation among the I/Q samples. Link level simulation results in various research papers show that 4 times compression for uplink and 4.5 times compression for downlink can be achieved with approximate 2% EVM distortion.

REFERENCES

[1] A Vector Quantization Based Compression Algorithm for CPRI Link by Hongbo Si, Boon Loong Ng, Md. Saifur Rahman, and Jianzhong (Charlie) Zhang

[2] Fast codebook search algorithm for vector quantization using sorting technique, conference Paper January 2009.

[3] China Mobile Research Institute, "CRAN The Road Towards GreenRAN," White Paper, Oct. 2011.

[4] "Common public radio interface (CPRI); interface specification v5.0,"Sep. 2011.

[5] Radisys, "Evaluating Cloud RAN Implementation Scenarios," White Paper, Jun. 2014.

[6] D. Samardzija, J. Pastalan, M. MacDonald, S.Walker, and R. Valenzuela,"Compressed transport of baseband signals in radio access networks,"IEEE Transactions on Wireless Communications, vol. 11, no. 9, pp.3216–3225, Sep. 2012.

[7] Y. Ren, Y. Wang, G. Xu, and Q. Huang, "A compression method for LTE-A signals transported in radio access networks," in 2014 International Conference on Telecommunications (ICT 2014), May 2014,pp. 293–297.

[8] K. F. Nieman and B. L. Evans, "Time-domain compression of complexbasebandLTE signals for cloud radio access networks," in 2013 IEEEGlobal Conference on Signal and Information Processing (GlobalSIP2013), Dec. 2013, pp. 1198–1201.

[9] S. H. Park, O. Simeone, O. Sahin, and S. Shamai, "Robust andefficient distributed compression for cloud radio access networks," IEEETransactions on Vehicular Technology, vol. 62, no. 2, pp. 692–703, Feb.2013.

[10] A. Gersho and R. M. Gray, Vector quantization and signal compression.Springer Science & Business Media, 1992.