Performance Demonstration of Real Time Compressed CPRI Transport

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Abstract *A real time CPRI compression solution is experimentally investigated. Tests have been performed on a LTE fronthaul link measuring its impact on EVM and latency. The obtained results show a 73% compression compliant with 3GPP specifications.*

Introduction

With the massive increase of smart devices as well as multimedia and social networks services, the capacity demand of mobile networks is tremendously increasing. In order to deal with this, first studies on the future 5G network have begun where Virtualized Radio Access Network (V-RAN) was identified as a key enabling technology[1]. It proposes to centralise the Base Band Units (BBU) thanks to a new network segment called fronthaul. The latter connects the BBU to the Remote Radio Head (RRH) at the antenna sites and is based on Digitalized Radio over Fiber (D-RoF) according in most cases to the Common Public Radio Interface (CPRI)[2]. Some higher functions of the BBUs can then be virtualized and implemented in virtual machines on generic servers to allow a more flexible network.

The digitalization of the radio signal in the CPRI is based on a uniform quantization with a resolution of 15 bits which generates high bit rate signals in the fronthaul. For instance, a LTE downlink signal with 20 MHz bandwidth and 2x2 MIMO (Multiple Input Multiple Output) corresponding to a maximum bit-rate of approximately 150 Mb/s is transported at 2.45 Gb/s at the fronthaul (CPRI3). This value is likely to increase with the use of larger bandwidth signals and more antennas in the MIMO which will make the transport of CPRI quite challenging. Moreover, the total fronthaul traffic (number of CPRI links) is a function of the number of sectors and carriers considered at the antenna site which is still also increasing. Therefore, performing a compression or considering a new functional split[3] between the BBU and RRH will be necessary.

Furthermore, Corse Wavelength Division Multiplexing (CWDM) fronthaul is considered as one of the most reliable and cost effective solutions for CPRI transport: it provides up to 18 channels where every wavelength is associated to a CPRI link. One possible solution to upgrade CWDM is to divide each optical channel into 6 sub-channels offering up to 54 bidirectional optical channels[4].

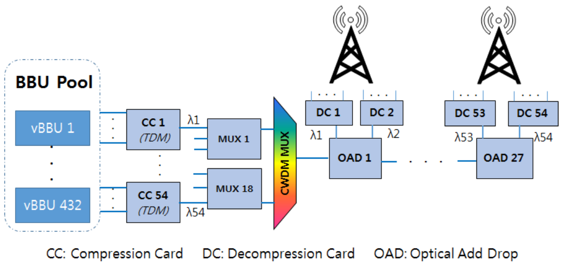

Fig. 1: Architecture under test

In order to further increase the number of transported CPRI links in the fronthaul, Time Division Multiplexing (TDM) could be used to aggregate several CPRI links in each wavelength. Tab 1 displays the number of CPRI links that could be transported with each solution. For instance, if we assume a CPRI compression rate of 50% and the use of bidirectional transceivers, up to 432 compressed CPRI signals could be time multiplexed (in groups of 8 links), then wavelength multiplexed to enable serving up to 27 antenna sites (16 CPRI links each) with a daisy chain topology using Optical Add Drops (OADs) as shown in Fig 1.

In this paper, we experimentally investigate a CPRI compression solution based on a Layer1 functional split[3] and yet adapted to currently deployed RAN equipment and also TDM aggregation of several CPRI signals into 10 Gbit/s frames. Performance measurements

Tab. 1: Number of transported CPRI links in different solutions

Solution	CWDM	Enhanced CWDM	Enhanced CWDM + TDM (compression)
Number of links	18	54	432

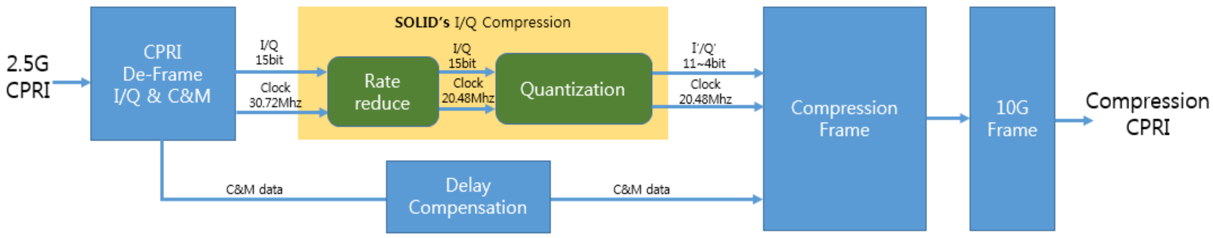

Fig. 2: CPRI compression algorithm

were carried out to evaluate the system in terms of mobile radio Error Vector Magnitude (EVM), fronthaul Round Trip Delay (RTD) and uplink/downlink latency imbalance.

CPRI compression algorithm

As shown in Fig. 2, after separating the Control and Management (C&M) data from the user data (I/Q), a compression algorithm is applied to the I/Q components. A delay compensation corresponding to the compression algorithm latency is performed in parallel on the C&M data. These two signals are then mapped into a CPRI frame with reduced bit rate. This process is performed on several CPRI links (up to 8xCPRI3 links) before encapsulation into a 10 Gb/s frame. At the reception, the reverse operation is applied to recover the signal at the initial bit rate.

The compression process consists mainly of three operations: a Layer 1 functional split equivalent operation[3], low-pass filtering of the LTE spectrum[5] and reduction of the quantification resolution. As matter of fact, after conversion to the analog form, low pass filter is used to remove up to 1/3 of unused LTE spectrum (border guard subcarriers) thus keeping 2/3 of the original bandwidth. For a 20 MHz downlink LTE signal, the clock frequency is reduced from 30.72 MHz (LTE sampling rate) to 20.48 MHz as represented in Fig. 2**.** The obtained signal is then digitalized using a uniform quantization after moving some of the BBU's L1 functions to the decompression card[3]. This method allows using less quantization bits while keeping compliancy with 3GPP recommendations.

Although, it is worth mentioning that this algorithm depends on the IQ mapping in the CPRI frame, ergo a software adaptation is needed from a RAN vendor to another.

Experimental setup

Fig. 3 shows the experimental setup carried out to evaluate the performance of the proposed CPRI compression technique. At the transmitter side, a signal generator creates a 20 MHz LTE signal. Standardized test models E-TM3.3, E-TM3.2 and E-TM3.1[6] are used to investigate the performance of QPSK, 16QAM and 64QAM mappings respectively. Then, an IQ box handles the LTE to CPRI conversion (sampling + quantization + coding); the bit rate is fixed to 2.45 Gb/s. These two components emulate the BBU.

The generated CPRI signal is fed to a compression card which allows the encapsulation of up to 8 CPRI 3 (2.45 Gb/s) links into a 10G frame using TDM.

At the receiver side, a decompression card de-multiplexes different CPRI links and restores them to their original bit rate. An IQ box is then used for CPRI to LTE conversion and a spectrum analyser with embedded demodulator handles the LTE performance assessment.

The optical transmission between the RAN test equipment and the compression/decompression cards is done with uncolored Small Form-factor Pluggable (SFP). Colored 10G Small Form-factor pluggable (XFP) are used at the output of the compression card and at the input of the decompression card which allows the use of CWDM to multiplex signals from other potential cards.

Finally, we compare the performances of the proposed solution to what could be obtained by simply reducing the number of quantization bits used in the standard digitalization of the baseband radio signals.

Experimental results

Two solutions are possible to perform real time CPRI compression: either compressing the CPRI signal internally in the RAN equipment

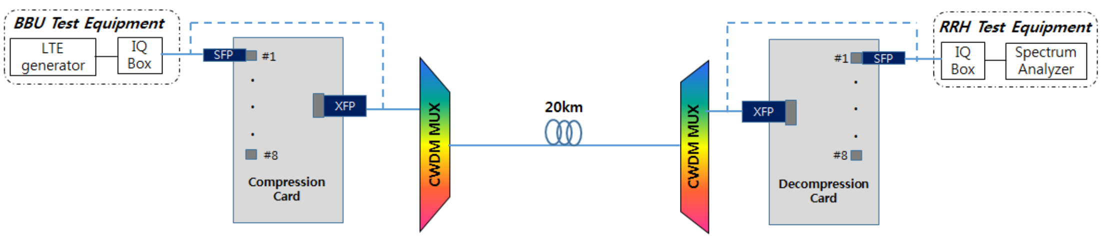

Fig. 3: Experimental setup

simply by reducing the number of bits used to quantize the radio signals (solution 1) or adding external compression equipment to the existing BBUs and RRHs (solution 2). We propose to compare both solutions in terms of EVM performance while varying the compression rate. The obtained results for different LTE modulations (QPSK, 16QAM and 64QAM) are depicted in Fig. 4. According to 3GPP, the maximum EVM shall not exceed 17.5% for QPSK modulation, 12.5% for 16QAM and 8% for 64QAM[6]. To take into account the EVM degradation caused by the amplification in the RRH, we take an extra 5% margin with respect to these values. This leads to an EVM threshold of 3% (-30.45dB) for 64QAM which is also compliant to Open Radio Interface (ORI) compression recommendation[7]. Figure 4 shows similar performances for all 3 LTE mappings, as expected. Also, a compression of up to 53% using solution 1 and 73% using solution 2 can be achieved while still respecting the 3% EVM threshold.

Therefore, CPRI compression permits having a 1.14 Gb/s bit rate per link with solution 1 and only 0.64 Gb/s with solution 2, thus 20% higher compression compared to solution 1. The fact that solution 2 has better performances can be explained by the low pass filtering and the integration of L1 functional split in the compression process.

As expected, the electronic processing needed in solution 2 generates some latency which was evaluated in terms of Round Trip Delay (RTD) and uplink/downlink latency imbalance. 10 measurements were carried out on the C&M CPRI channel using the appropriate CPRI test equipment. The maximal, average and minimal RTD values for different compression rates are presented in Fig. 5. We obtained practically the same RTD of approximately 8.5 µs for all tested compression rates. This value is largely below the ORI recommendation concerning the RTD (40 µs)[7]. Coordinated MultiPoint (CoMP) implementation for LTE-A tolerates a maximum RTD of 150 µs[8]. If we assume a C-band optical carrier

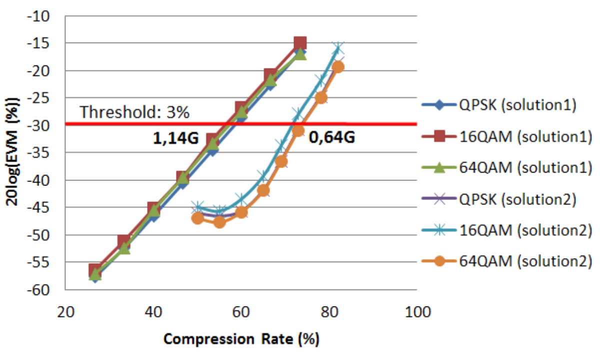

Fig. 4: EVM performance as a function of compression rate

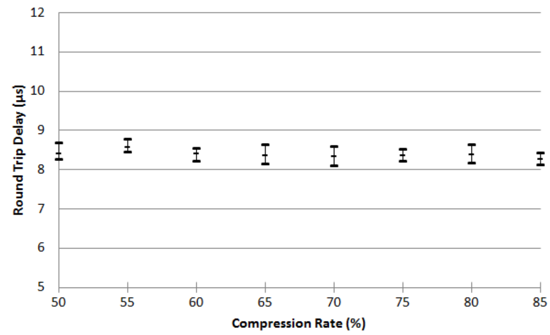

Fig. 5: Round trip delay as a function of compression rate

propagating through standard single mode fibre, this would correspond to approximately 15 km. Therefore, the latency introduced by solution 2 would reduce the maximum transmission distance by less than one kilometre (14.15 km).

The uplink/downlink latency imbalance is also an important parameter that must be evaluated since it could affect the User Equipment (UE) positioning accuracy. The maximum end-to-end latency imbalance is limited to ±163 ns by 3GPP[6]. Only ±16 ns is specified by RAN providers for the fronthaul segment. The latter value is respected by the compression system according to our measurements.

Conclusions

In this paper, we experimentally assessed the performance of a real time CPRI compression and TDM aggregation solution, based on a Layer 1 functional split yet usable in currently deployed RAN. Up to 73% compression was achieved on a CPRI signal at 2.45 Gb/s and compliance with 3GPP and ORI recommendations concerning EVM and latency was demonstrated.

Acknowledgements

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