Real-time Testbed for Validating Distributed Antenna Scenarios

Peethala, Sundar Daniel Victor; Kreul, Theo; Kaiser, Thomas

DOI: http://dx.doi.org/10.17185/duepublico/43879

URN: urn:nbn:de:hbz:464-20171219-074305-9

Link: http://duepublico.uni-duisburg-essen.de/servlets/DocumentServlet?id=43879

Source: Informationstechnische Gesellschaft im VDE (ITG) (Ed.): WSA 2016 - 20th International ITG Workshop on Smart Antennas, (ITG-Fb. 261), 2016, Berlin : VDE Verlag, 978-3-8007-4177-9, p. 267-270

WSA 2016 • March 9-11, 2016, Munich, Germany

Real-time Testbed for Validating Distributed Antenna Scenarios

Sundar Daniel V. Peethala, Theo Kreul, and Thomas Kaiser
Institut für Digitale Signalverarbeitung
Universität Duisburg-Essen
47057 Duisburg, Germany
Email: {sundar.peethala, theo.kreul and thomas.kaiser}@uni-due.de

***Abstract*—Distributed Antenna Systems (DAS) promise to deliver solutions for the future wireless challenges using multiple remote radio heads (RRHs) in a distributed architecture, thereby supporting high frequency re-use, increased coverage, decreasing interference and latency. DAS architecture consists of multiple RRHs connected to a centralized base station via an optical fiber network. This work explains different DAS deployment techniques on a real-time LTE system. It focuses on the implementation details of LTE PHY on a TI (Texas Instruments) DSP and corresponding processing blocks that need to be adapted to support the functionality of DAS. Different DAS use case scenarios of deployment, their advantages and key performance indicators, are analyzed. This work also includes the measurement results of deploying antenna selection scenario to investigate and validate DAS on a real-time LTE system.**

Keywords*—remote radio head (RRH), distributed antenna system (DAS), physical layer (PHY), long term evolution (LTE), digital signal processor (DSP)

I. Introduction

Distributed antenna systems (DAS) promise solutions for the future wireless challenges using multiple remote radio heads (RRHs) in a distributed architecture, thereby supporting high frequency re-use, increased coverage, decreasing interference and latency [1-2]. As supposed to a conventional collocated antenna system, a DAS system consists of RRHs that are geographically distributed. These distributed RRHs are connected to a central eNodeB by dedicated cables, usually optical fibers. DAS has potential advantages such as throughput improvement, call blocking rate reduction, coverage improvement and reduction in transmit power etc [3-4].

Fig.1 shows the usual cellular system, i.e. an eNodeB with collocated antennas and distributed antenna system, where the baseband signal processing is done in a centralized processing and distributed to different RRH locations usually using high speed optical fibers. Significant work on DAS has been done to understand the advantages and possible scenarios of DAS in comparison with collocated antenna systems [5-8]. In fact there was less work done [9], based on the existing LTE standard, to understand the real-time implementation adaptations for DAS

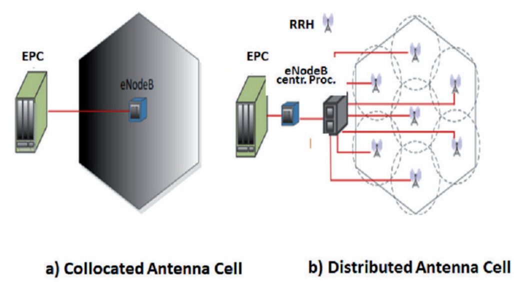

Fig. 1. Collocated vs Distributed Antenna Systems

techniques and scenarios. In this paper we mainly focus on the LTE physical (PHY) layer, and a detailed analysis of required adaptations of the LTE PHY processing blocks for accommodating DAS functionality is presented.

The rest of the paper is organized as follows: In Section II, LTE testbed and DAS adaptations are described. LTE testbed is a fully functional LTE system implemented on DSP and ARM boards that can communicate with commercial user equipments (UEs). Implementation details for DAS on LTE PHY is presented. Required adaptations of downlink shared channel (DLSCH) processing chain are proposed. Section III describes different use case scenarios for DAS. Section IV describes measurement setup and results of the measurements. Section V concludes the paper.

II. LTE testbed and DAS Adaptations

The LTE PHY layer is ported on a commercial Texas Instruments (TI) DSP which gives flexibility to modify the functionalities towards DAS. TI's TMS320C6670 DSP is a multicore fixed-point processor, for small cell eNodeB, with suitable hardware accelerators like fast fourier transform (FFT), bit co-Processor (BCP) and turbo decoder. Implementation of the processing blocks on a DSP gives a high level of flexibility to analyze, modify, append new features and measurements. Real-time tracing and debugging on code composer studio(CCS), a TI proprietary debugger, provides immense opportunities to fine tune and even select a correct set of precoding vectors in real-time.

Fig.2 represents a PHY level DAS architecture with centralized processing unit where the PHY level processing for all the

This work was conducted within the framework of the 5G-PPP COHERENT project, which is partially funded by the Commission of the European Union (Grant Agreement No.671639).

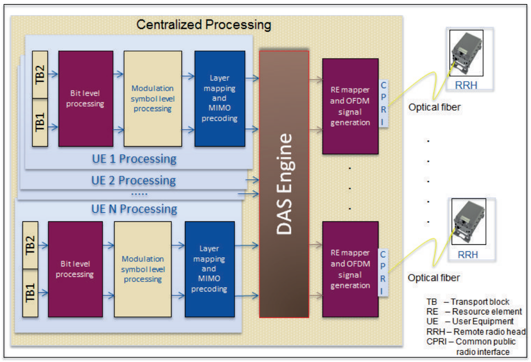

Fig. 2. Downlink shared channel transmitter processing chain adaptations for DAS

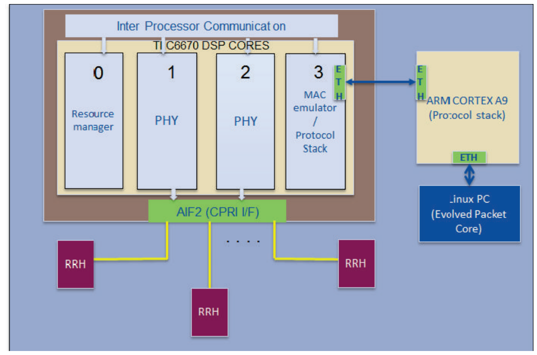

Fig. 3. Hardware Implementation blocks

UEs are done. In current cellular systems eNodeB constitutes both baseband processing and radio front-end. Recent advances in software defined radios (SDR) enable efficient and scalable implementation of radio access network (RAN) functionalities on programmable platforms. This makes it feasible to split the eNodeB into centralized processing and distributed RRH locations. A fronthaul link, an interface between RRH and centralized processing, is a new element that does not exist in a conventional eNodeB. The fronthaul connection is usually served by Common Public Radio Interface (CPRI) or Open Base Station Architecture Initiative (OBSAI) protocol.

In this section, without loss of generality, LTE downlink shared channel (DLSCH) processing at transmitter has been considered to realistically analyze the necessary adaptations required in DLSCH processing blocks to incorporate it in the DAS. This analysis can easily be extended for all downlink and uplink channels. For the LTE downlink shared channel processing chain a case with 2 transport blocks (TBs) per user equipment (UE) per subframe is assumed. After receiving TB data at the PHY, it starts per user and per TB related processing at bit level like cyclic redundancy check (CRC) generation and attachment, code block segmentation, turbo coding, rate matching and code block concatenation. The processed bits are forwarded to modulation symbol level processing that comprises of scrambling with a pseudo random sequence and modulation mapper. The generated modulation symbols for that user, i.e. the symbols from all the TBs pertaining to that UE are passed through layer mapping and MIMO precoding blocks. According to LTE specification, after the MIMO precoding the symbols are mapped into the allocated resource elements depending on the resource allocation type and number of resource blocks (RBs), and finally orthogonal frequency-division multiplexing (OFDM) signals are generated. But in the DAS, the outputs of the MIMO precoder for all the UEs allocated in that subframe could be further processed by DAS Engine block. It is obvious that one can also incorporate the MIMO precoding block into the DAS engine itself, but to make clear the adaptations w.r.t. the existing LTE standard the MIMO precoder and DAS precoder are shown separately.

As described in the Fig.3, the PHY layer processing blocks were ported onto the DSP. The DSP communicates with protocol stack, which is running on an ARM board, via Gigabit Ethernet. The antenna interface (AIF2), a hardware accelerator on the DSP receives the time-domain IQ samples from the DSP and converts them into CPRI frames that facilitate the transfer of baseband signal to the RRHs via optical cables. Protocol stack will communicate with evolved packet core (EPC), running on a linux PC. Although DSP is capable of processing for many users, without loss of generality, as a first step we have selected a use case with only 2 UEs per subframe with 2 RRHs. The current LTE testbed is fully functional to attach many commercial UEs and to communicate with them. Depending on the precoding techniques used within the DAS precoder, if no further processing on the UE is required a commercial UE can be used to communicate. In case further processing on the UE is required, Keysight's MXA LTE Signal analyzer is employed to analyze or capture IQ samples, which can be decoded offline using MATLAB.

III. Scenarios

TABLE I describes a set of possible use case scenarios where DAS can be deployed for optimizing the mentioned Key Performance Indicators (KPIs). In the case of LTE DLSCH, DAS Engine block is the main adaptation required at PHY layer. The processing in this block varies depending on the performance indicators that are targeted to be optimized. The first major change in the DAS is the architecture or the notion of cell itself. For a use case in DAS, each RRH can be configured as a single independent cell / cluster which is an equivalent case of small cell. Obviously the performance index in this scenario is high frequency reuse. Similarly, this table describes the possible configurations where DAS can be deployed for optimizing the desired KPI(s).

IV. Results

Fig.4 shows the LTE testbed and measurement equipment, i.e. Keysight's MXA. The microTCA chassis contains the TI DSP board and RRH board apart from the microTCA controller. The DSP and RRH are connected via CPRI using optical cable. Keysight's VSA software running on MXA signal analyzer is capable of real-time capturing and decoding of time domain LTE signals over the air. The VSA software can show very useful information like IQ constellation plots after channel equalization, spectrum, LTE channel decoding, error vector magnitude (EVM) for each LTE channel etc. for validating and analyzing the techniques. We have implemented and measured a simple DAS technique i.e. antenna selection [9]. In this approach the nearest user to the RRH would be

TABLE I. DAS SCENARIOS

Use cases	KPIs	Remarks
Small cell scenario	Frequency reuse	In a non DAS system, there will be a significant increase in handovers which has huge impact on latency of the system.This impact could be solved in the DAS by letting this decision at the PHY level because of the centralized processing
Co-operation	Coverage / Interference minimization	Current CoMP in LTE involves huge latency due to the cooperation of eNodeBs, this would be significantly reduced in a DAS due to centralized processing
Dynamic clustering	Latency, coverage, interference minimization	Cluster is similar to a Cell, it represents the set of UEs connected to a eNodeB, but it is dynamic not dependent on the geographic area which is usual in the case of a static cell. More processing power might be required
MU-MIMO	Improved per-user throughput in case of interference free users	In the case of interference free UEs, DAS can dynamically decide to allocate the same resources to the interference free UEs. The traditional resource allocation decision comes from the MAC scheduler that results in latency of the system. Some dynamic decisions can be leveraged to DAS on PHY layer
Antenna selection	Improved per-user throughput and reliability	DAS engine can dynamically assign the a RRH for each UE, that would give reliable throughput in addition to the advantage in using overlapping frequency and time resources for the UEs, thereby increasing the per-user throughput

served by that RRH. To validate this approach we have implemented LTE eNodeB with DAS functionality as described in the sections before. To support this approach overlapping RB allocation / scheduling for UEs was implemented, as in LTE UEs belonging to a cell are allocated different RBs. For the measurement LTE single stream (SISO) transmission for both the UEs has been configured. The RBs 0 to 7 (8 RBS) have been allocated for both the UEs. Different Radio network temporary identifier (RNTIs) for the UEs have been configured. As in the case of transmit antenna selection, two spatially separated transmit antennas are used and each transmit antenna sends the LTE signal for each UE. Different measurement trials have been done, in a closed room, by changing the distance between the two transmit antennas and observing the quality of decoded signals (EVM) on the LTE analyzer.

Fig.5 shows the results of first trial, to set a reference, where single transmit antenna is activated. In this case, one can see in the figure under "Ch1 Frame Summary" window, physical downlink shared channel (PDSCH) EVM (in percentage rms) to be 6.4558, which is a pretty good quality for QPSK signal at received power of -69.2 dBm. The distance between the UE and the nearest transmit antenna is 200 cm. In the second trial, the second transmit antenna is also activated but the distance between the two antennas is 300 cm. Fig.6 shows slight performance degradation of the first UE because of the interference from the second transmit antenna. The EVM is around 11.486%, still an acceptable quality of reception. In the last trial, the distance between the two antenna is 200 cm. Here one can clearly see the severe performance degradation in Fig.7, EVM is around 30.857%, which is not acceptable. One can clearly see the influence of the interference on the constellation points plot. From the trials, it is evident that transmit antenna selection is dependent on the separation distance between two antennas, therefore with enough separation between the antennas one can deploy the antenna selection technique in a DAS setup.

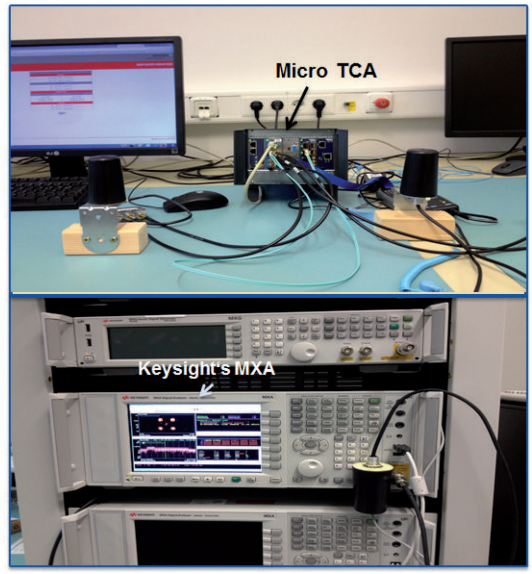

Fig. 4. LTE testbed and measurement setup

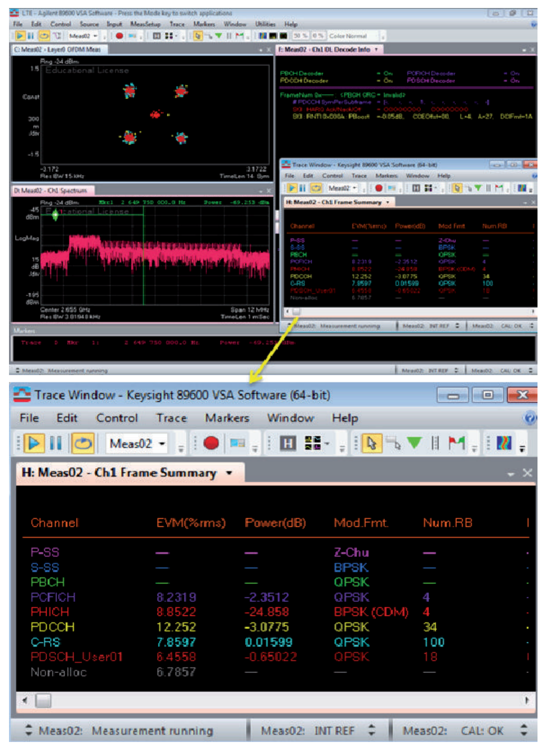

Fig. 5. Measurement results - single transmit antenna

V. CONCLUSION

In this paper we have described in detail the implementation of DAS on a real-time LTE system and proposed the required adaptations to LTE DLSCH processing blocks for DAS functionality, i.e the DAS Engine, to validate different DAS scenarios. We have highlighted the advantages and flexibility of software defined radio (SDR) based implementation of LTE and DAS i.e. for real-time selection of precoding techniques, tracing etc. Different use case scenarios in mobile communications, from the view of DAS deployment, are

ISBN 978-3-8007-4177-9

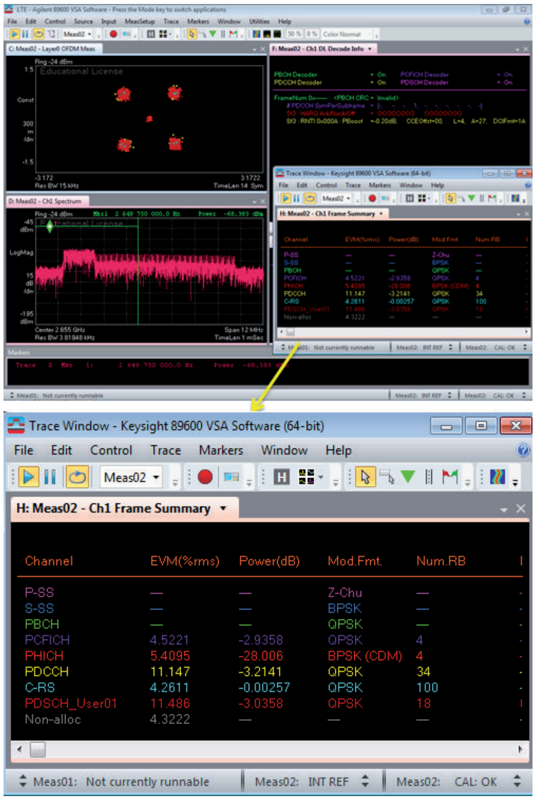

Fig. 6. Measurement results - two transmit antennas separated by 300 cm

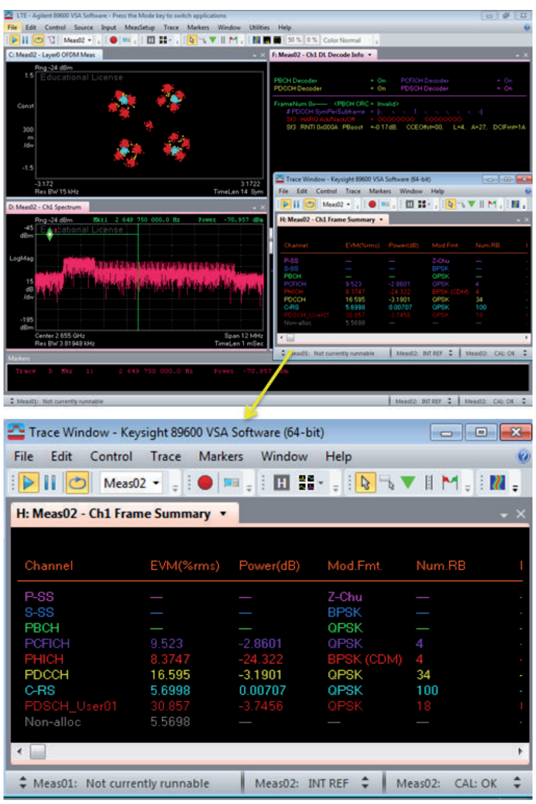

Fig. 7. Measurement results - two transmit antennas separated by 200 cm

analyzed and the KPIs and their advantages like latency improvement, throughput improvement, coverage improvement, quality of service (QOS) improvement, improved interference management etc. are highlighted. Finally, the DAS based LTE testbed is validated for antenna selection scenario using Keysight's MXA LTE analyzer. Error vector magnitude (EVM) is measured on the LTE analyzer for different trials by changing the separation distance between the transmit antennas. From the measurement results it is evident that with sufficient separation distance between the two RRHs, antenna selection technique can be deployed in a DAS setup, thereby improving the per-user throughput by scheduling overlapping RBs for the UEs. Thorough investigations w.r.t. the separation distance requirements, power requirements, channel variations etc. still remains to be made and other DAS scenarios need to be implemented.

References

[1] R. Heath, S. Peters, Y. Wang, and J. Zhang, "A current perspective on distributed antenna systems for the downlink of cellular systems," *IEEE Commun. Mag.*, vol.51, no.4, pp.161-167, April 2013.

[2] L. Dai, S. Zhou, and Y. Yao, "Capacity analysis in CDMA distributed antenna systems," *IEEE Trans. Wireless Commun.*, vol.4, no.6, pp.2613-2620, Nov. 2005.

[3] W. Choi, and J. G. Andrews, "Downlink performance and capacity of distributed antenna systems in a multicell environment," *IEEE Trans. Wireless Commun.*, vol.6, no.1, pp.69-73, Jan. 2007.

[4] R. Bosisio, and U. Spagnolini, "Interference Coordination Vs. Interference Randomization in Multicell 3GPP LTE System," *IEEE Wireless Communications and Networking Conference, 2008. WCNC 2008.*, vol., no., pp.824-829, March 31 2008-April 3 2008.

[5] Z. Liu, and L. Dai, "A Comparative Study of Downlink MIMO Cellular Networks With Co-Located and Distributed Base-Station Antennas," *IEEE Trans. Wireless Commun.*, vol.13, no.11, pp.6259-6274, Nov. 2014.

[6] K. T. Truong, and R. W. Heath, "The viability of distributed antennas for massive MIMO systems," *Asilomar Conference on Signals, Systems and Computers, 2013*, vol., no., pp.1318-1323, 3-6 Nov. 2013.

[7] H. Q. Ngo, A. Ashikhmin, H. Yang, E. G. Larsson, and T. L. Marzetta, "Cell-Free Massive MIMO: Uniformly great service for everyone," *IEEE 16th International Workshop on Signal Processing Advances in Wireless Communications (SPAWC), 2015*, vol., no., pp.201-205, June 28 2015-July 1 2015.

[8] A. A. M. Saleh, A. J. Rustako, and R. Roman, "Distributed Antennas for Indoor Radio Communications," *IEEE Trans. Commun.*", vol.35, no.12, pp.1245-1251, December 1987.

[9] Y. D. Beyene, R. Jantti, and K. Ruttik, "Cloud-RAN Architecture for Indoor DAS," *IEEE Access*, vol.2, no., pp.1205-1212, 2014.

