# Real-time Testbed for Validating Distributed Antenna Scenarios


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***Abstract*—Distributed Antenna System (DAS) seems to deliver promising 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 deployment techniques for DAS on a real-time LTE system. It focuses on the details of implementation of LTE PHY on a TI (Texas Instruments) DSP and the corresponding processing blocks that needs to be adapted to support the functionality of DAS. DAS use cases scenarios are investigated in detail focusing on the requirements and adaptations at LTE PHY and MAC layers. This work also includes the implementation of a set of DAS scenarios onto an LTE testbed to investigate and validate them in a real-time system.**



***Keywords*—remote radio head (RRH), user equipment (UE), long term evolution (LTE), digital signal processor (DSP)**


## I. INTRODUCTION

Distributed antenna system promises solutions for the future wireless challenges using multiple RRHs in a distributed architecture, thereby supporting high frequency re-use, increased coverage, decreasing interference and latency. Significant work [1], [2], [3], [4] to understand the advantages and possible scenarios of DAS in comparison with co-located antenna systems has been done. But, there was hardly any work done to understand how the DAS techniques reflect from the implementation aspects point of view and to investigate the major adaptations required to the PHY layer processing chains to accommodate these techniques.

In this work, LTE is taken as the starting point on which the detailed analysis of required adaptations for DAS is made. We have developed an LTE testbed that is a fully functional LTE system implemented on DSP and ARM boards that can communicate with commercial UEs. The LTE PHY layer is ported on a commercial TI DSP which gives flexibility to modify the functionalities towards DAS. TI's C6670 DSP is a multicore fixed-point processor for small cell eNodeB with suitable Hardware accelerators like FFT, BCP(Bit Co-Processor), 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 CCS, a TI proprietary debugger, that provides immense opportunities to fine tune and for e.g. even select a correct set of precoding vectors in real-time. The work includes description of the LTE testbed and detailed adaptations for DAS. It progresses to different use case scenarios for DAS, where analysis is made focussing on the implementation aspects. Finally, the results, observations and conclusions of the work will be presented.

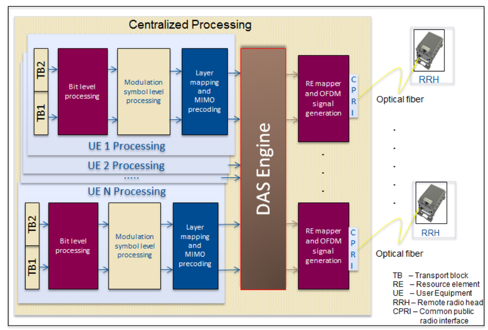


Fig. 1. Downlink shared channel transmitter processing chain adaptations for DAS

## II. LTE TESTBED AND ADAPTATIONS

Figure 1 represents a PHY level DAS architecture with centralized processing unit, where the PHY level processing for all the UEs are done, it replaces the ubiquitous base stations / cellular architecture, connected to many RRHs. Without loss of generality LTE downlink shared channel processing (DLSCH) for transmission has been taken as a use case to analyze realistically the necessary adaptations required for 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 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 CRC, 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

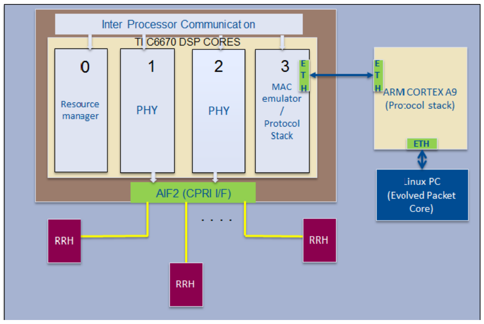


Fig. 2. Hardware Implementation blocks

resource allocation type and number of RBs and finally OFDM signal is 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 Figure 2, the PHY layer processing blocks were ported onto the DSP, it communicates with protocol stack, running on an ARM board via Gigabit Ethernet. The antenna interface component on the DSP receives the 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 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. Implementation of the processing blocks on a DSP gives us high level of flexibility to analyze, modify , append new features and trace measurements. Real-time tracing and debugging on CCS, a TI proprietary debugger provides immense opportunities to fine tune or even select the correct set of precoding vectors in real-time. The current LTE setup can communicate with commercial LTE UEs. Depending on the precoding techniques used within the DAS precoder, a commercial UE can be used to communicate if no further processing on the UE is required. In case of further processing on the UE is required, we employ a Keysight MXA LTE analyzer to 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 KPIs (Key Performance Indicators). 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 here is high frequency reuse. Similarly, this table describes the possible configurations where DAS can be deployed for optimizing the desired KPI(s). This work includes the implementation of a set of techniques onto the LTE testbed to investigate / validate the techniques in a real time scenario.

TABLE I. DAS Scenarios

| Use cases | KPIs | Impact | Remarks |
|---|---|---|---|
| Small cell scenario | Frequency reuse | Significant increase in handovers, which has huge impact on latency of the system | This 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 | More processing power might be required | 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 |
| 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 |

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