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A common operator for FFT and FEC decoding

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ABSTRACT

In the Software Radio context, the parametrization is becoming an important topic especially when it comes to multi-standard designs. This paper capitalizes on the common operator technique to present new common structures for the FFT and FEC decoding algorithms. A key benefit of exhibiting common operators is the regular architecture it brings when implemented in a Common Operator Bank (COB). This regularity makes the architecture open to future function mapping and adapted to accommodated silicon technology variability through dependable design.

1. Introduction

Over the past few years, a proliferation of communication standards has substantially increased the complexity of radio design. In typical designs, the communication standards are implemented separately using dedicated instantiations which are difficult to upgrade for the support of new features. In the present days, the concept of Software Radio (SWR), introduced by Mitola in [1], emerged from military research to become a cornerstone of modern communication system design. The SWR technique becomes the way to design flexible and reconfigurable architectures capable of supporting different transmission standards in a single platform. Although there is a common agreement on the SWR aim and benefit, the way of implementing SWR, also known as Software Defined Radio (SDR) varies, considering various tradeoffs requested by actual design (cost, flexibility, complexity, power consumption, speed, etc.), and current silicon technology.

A digital communication baseband chain, when supporting different standards, uses typical signal processing operations such as modulation, channel coding, equalization. These functions can be identified and then explored to take advantage from the similarities among common tasks in order to enhance power efficiency and area occupation [4]. In this context, parameterization technique has been introduced in [2,3]. It consists in identifying the common aspects among the targeted modes and standards in order to define a generic operation capable of handling the required tasks. This generic operation can switch from a configuration to another by a simple change of its parameters.

In this paper, we exploit a parameterization approach proposed in [4], called the common operator technique that can be considered to build a generic terminal capable of supporting a large range of communication standards. The main principle of the common operator technique was to identify common elements based on smaller structures that could be heavily reused across functions. This technique aims at designing a scalable transceiver based on medium granularity operators, larger than basic logic cells and smaller than Velcro Method or Common Function [4]. Similarly to flip flop or logic gate, a common operator is used regardless of the function executed by. From this point, the common operator technique claims to be less standard dependent than classical approach [5] where the entire specific building block required by a standard are implemented and executed when needed. It is expected that the reduction of the exploration space to telecommunication baseband functions will help exposing medium-grain common operators. The resulted implementation is expected to be more flexible and scalable to a wide range of standards. Such a regular structure is also well adapted to cope with silicon technology process variability. Indeed, as CMOS technology shrinks, the performance of the operator instances may vary across space (on the silicon wafer) and time [6]. Dealing with regular building blocks helps map the most demanding algorithms onto the best performing cells, enabling the design to be dependable or even self-healing. Many previous works focused on defining [7,12,14,15] implementing and managing [8] the Common Operators (CO). In this paper we investigate the commonalities of the FFT and FEC decoding operator. The core of the paper focuses on a new operator that exploits similarities between FFT butterflies and

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trellis decoding structures used in the Viterbi algorithm. These similarities are exploited to suggest a CO for the FFT and the Viterbi decoder. CO for FFT and FEC was already studied in [13,16] with a focus on Reed–Solomon (RS) decoder based on a FFT operator over GF(2^m). This work is recapped herein to highlight how it can be considered along with the FFT/Viterbi CO to build a more general library framework for FFT/FEC functions.

Then, the paper is organized as follows. Section 2 presents the common operator technique. In Section 3 we briefly recap the work of [13,16]. Then, in Section 4 we focus on the new FFT/Viterbi CO, exposing the similarities and their exploitation to build a new CO. The Section 5 proposes a set of two common structures for FFT and FEC decoding algorithms; finally the results and the performances of these common operators are discussed in Section 6.

2. The common operator technique

The conventional approach to implement a multi-standard radio device is to instantiate multiple transceiver chains each dedicated to an individual mode or standard (Fig. 1). With this approach most of the hardware needs to be redesigned whenever an additional standard is to be considered. This conventional approach called "Velcro" does not exploit any common aspects between the different standards [4]. In order to capitalize on the commonalities among the various signal processing operations for different standards, we need to identify firstly these commonalities and secondly find the optimal way to implement a generic hardware with reconfigurable modules. This idea led to the definition of the Common Function approach (CF) [2] which consists in function sharing between different standards. For each standard all the components dedicated to the same "Functionality" were merged into the same Common Function. The Common part includes the components required by at least two functions (ore function modes) and each dedicated part is related to the standard specific components of each individual function. The resource sharing brought by the CF approach allows the non-duplication of redundant components and a possible complexity reduction.

The Common Operator (CO) approach follows the principles that of Common Function and consists in identifying lower granularity common elements based on structural aspects. The intrinsic design of the CO is performed independently of standards. Thus, a CO is defined to perform signal processing operations regardless of the function executed. This approach aims at designing a scalable transceiver based on medium granularity operators, larger than basic logic cells and smaller than functions. In contrast with the CF, a CO is not specific to a single function set; it permits a more flexible design and scalable to a wide range of standards.

Fig. 2 presents a graphical breakdown of a multi-standard terminal proposed in [14]. From top to bottom, the granularity of the considered components is decreased down to basic LUT or MAC. The CO consists in identifying medium granularity building blocks in such a graph to eventually address the top level functionality. The more similar the function to implement will be, the easier the identification of such blocks and the larger their granularity. For this reason, the restriction of the functional space to PHY building blocks is expected to help a lot in finding medium granularity, highly reusable operators. With a similar aim, this is one step further to identifying the Multiply ACcumulate (MAC) as a basic building block for signal processing functions.

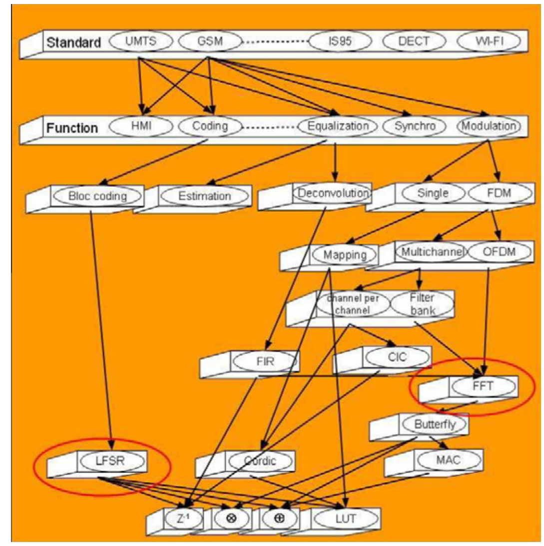

Fig. 2. An example of a breakown of several standards.

It was shown beneficial to implement the common operators in a bank to form a regular architecture previously referred to as Common Operator Bank (COB) [8], where the COs can be mapped and used by the considered standards (Fig. 3).

In the present work we define common operators for FFT and FEC decoding algorithms. These algorithms are completely different in nature, if we compare their processed data and their functionality. However, when explored in the parametrization context, functional and structural similarities can be identified. In the following sections we highlight similarities between FFT and FEC decoding algorithms (Convolutional and Block channel decoding) to define a FFT/FEC CO toolbox. One can represent this way of doing by a graph sketched in Fig. 4. The interpretation of Fig. 4 is the following: performing some steps of block channel decoding (Reed Solomon) and complex FFT can be done with DMFFT operator [13]. Similarly, the proposed work intends to perform complex FFT and convolutional channel decoding thanks to a common operator termed as FFT/Viterbi.

The idea is to propose implementations of common operators that permits the use of the computational operations required for the FFT butterfly to perform Viterbi and Reed Solomon (RS) decoding.

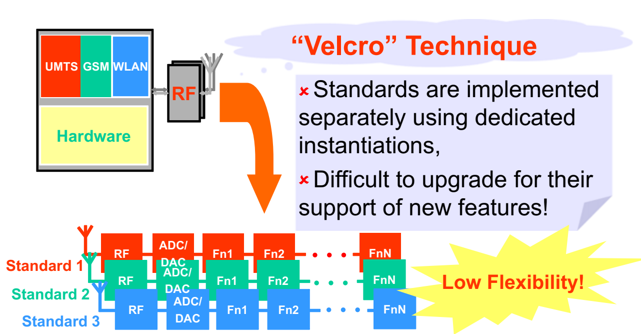

Fig. 1. Velcro technique.

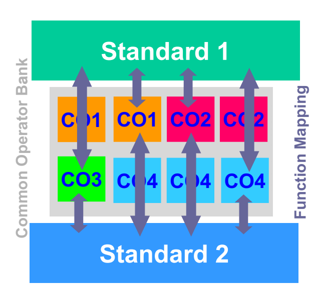

Fig. 3. Common operator bank for multistandard design.