An energy efficient weakly programmable MIMO detector architecture

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Multiple-antenna or MIMO systems have the potential to increase the data rate of wireless communication systems and, thus, they have been adopted by recent communication standards like, e.g. WiMax, WiFi, or LTE. The best communications performance is achieved for an iterative processing between MIMO detector and channel decoder. As for channel codes, the encoding on the transmitter side is simple but the detection of the MIMO signals at the receiver can be very complex.

There exist a wide range of sub-optimal algorithms which allow trade-offs of communications performance versus implementation complexity and energy consumption. Linear detection methods, e.g. successive interference cancellation, have the lowest complexity but also the lowest communications performance. Optimal soft-input soft-output sphere detection is the most demanding detection algorithm but it offers the best communications performance and the ability for iterative detection and decoding. The resulting signal-to-noise ratios (SNR) for a specifically targeted error rate range over more than 10dB for the different detection algorithms.

In current standards, like LTE, the quality of service (QoS) is dynamically adjusted at runtime, e.g. higher data throughput rates are specified for higher SNR. This is due to the fact that for higher SNR, the required communications performance can be achieved by lower complexity algorithms, which enables higher throughput. Energy consumption is one of the most critical implementation metrics for mobile receivers. Thus, complexity adaptive processing is key for enabling energy efficient architectures [1]. Therefore, flexible energy efficient MIMO detection architectures are mandatory to fulfill the requirements of modern standards like LTE.

However, in the literature, mainly two types of architectures are presented: highly optimized architectures which perform exactly one algorithm, e.g. [2] or [3], or processor architectures based on very small-grained operations, e.g. complex number operations in [4].

Almost all detection algorithms can be mapped to a search in a tree structure. We will show that all these algorithms can be constructed by only five coarse-grained algorithmic kernels: an enumeration unit which decides which child node is visited next, a computation unit for the interference reduction, a computation unit for the Euclidean distance, administration of nodes, and administration of computed metrics. We present an architecture based on these kernels which is able to perform most of the existing algorithms. The complexity of these algorithms covers all classes from linear up to almost exponential complexity, e.g. linear successive interference cancellation, fixed effort detection, or sphere detection. As all algorithms are performed with the same algorithmic kernels, the overhead for flexibility is negligible.

In contrast to the existing approaches, this is the first weakly programmable MIMO detector architecture which offers just the necessary flexibility. In this way, the detection algorithm can be chosen and parameterized during runtime according to the current channel conditions and QoS requirements leading to a highly energy efficient implementation. The architecture has been implemented and synthesized on a 65nm technology, resulting in an area of 0.26 mm^2, a power consumption of 15mW and throughputs between 35Mbit/s up to 720 Mbit/s.

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