SMART ANTENNA APIS: FROM CONCEPT TO PRACTICE

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ABSTRACT

The Smart Antenna Working Group of the SDR Forum is developing an application programming interface (API) supporting inter-operability and compatibility of various kinds of smart antenna systems operating in a SDR (Software Defined Radio) network following an open-architecture model. The Smart Antenna API consists of three components: (1) an SAControl Component, which is used for controlling the smart antenna system, (2) an SAAlgorithmDevice Component, which is used for executing various algorithms such as beamforming, DOA (Direction-of-Arrival) estimation, STC (Space Time Coding), channel estimation, spatial multiplexing, etc, and (3) an SASynchronnization Component, which is used for calibration. This paper introduces the Smart Antenna API, illustrating its use as a standard model and standard service in advanced wireless networks, and defining a roadmap for the API for additional standardization.

1. INTRODUCTION

A Smart Antenna is an array of antennas that are used in conjunction with a signal processing subsystem within a wireless base station, wireless gateway, or mobile terminal device to significantly improve wireless system performance [1]. These improvements are well known, and include increased communications capacity, enlarged cell coverage, and improved operations during handover. Smart Antenna Systems generally come in one of four basic types:

- Beamforming Systems – these types of systems allow the antenna to adaptively adjust its beam pattern to receive and transmit from specific directions. Beamforming can be used to extend the communications range in a specific direction, or to allow more users to access a network through techniques such as spatial division multiple access (SDMA) that group users within different designated beams.
- Diversity Combining Systems – These systems mitigate the multipath fading effects inherent in many wireless networks by combining the signals from multiple spatially diverse antennas together to improve signal quality.
- Space-time Equalization Systems – These types of systems use temporal processing on the signals received from multiple spatially diverse antennas to correct frequency distortion in the received signal path.
- Multiple-Input Multiple Output (MIMO) Systems – In MIMO system, data is transmitted from one or more transmit antennas to one or more to receiver antennas [2]. If the antennas are sufficiently far apart, the signals traveling between the transmit and receive antennas will fluctuate or fade in an independent manner. As such, by encoding the transmit signals using either spatial multiplexing or a space-time diversity code, processing in the receiver can be used to extract the transmitted data. MIMO systems offer a significant increase in performance over more traditional single input single output communication links, which has led the IEEE 802 committee to design MIMO technology into the 802.16 standard [3].

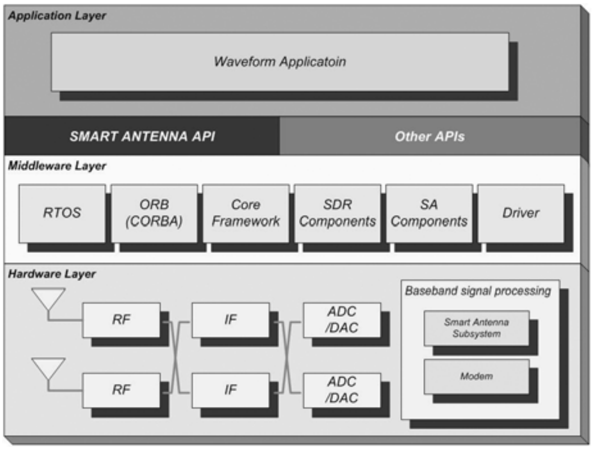

Figure 1: Layered View of an SDR-based Smart Antenna Open Architecture

The high-level architecture for a typical wireless base station incorporating smart antenna technology is illustrated in Figure 1 [4]. This architecture consists of an array of M transmit antennas and N receive antennas, each with an associated RF/IF processing chain. The smart antenna processing generally takes place in the baseband signal processing subsystem, consisting of one or more channel cards implemented using programmable technologies that include application specific standard processors (ASSPs), field programmable gate arrays (FPGAs), digital signal processors (DSPs) and general purpose processors (GPPs), The interfaces between the various hardware components and subsystems are facilitated through APIs that access device drivers specific to the hardware.

2. RATIONALE FOR A SMART ANTENNA API

The advantages inherent in smart antenna technologies are compelling more and more communications systems engineers to incorporate these technologies into their advanced wireless systems. These systems are also increasingly utilizing software defined radio (SDR) technologies to reduce operations and maintenance costs (OPEX), speed time to market, improve network interoperability, and allow new features and capabilities to be added to the radio system while in service and without the need for a hardware upgrade.

Members of the SDR Forum foresaw these trends, and in 2004 formed the Smart Antenna Working Group (SA WG) under the Forum's Technical Committee. The charter of this working group is to specify a standardized API for smart antenna systems operating in an SDR network, providing inter-operability and compatibility among systems produced by different vendors with different functions. The workgroup specifically focused on allowing various kinds of beamforming systems, diversity systems, MIMO (Multi Input Multi Output) systems, etc., to all be managed together in an open architecture SDR network.

3. CONCEPT OF THE SMART ANTENNA API

In order for the SDR system to exploit the merits of a smart antenna, the SA WG determined that it was necessary to define an open-architecture that allowed all of the different kinds of smart antenna technologies to be properly reconfigured by software download. The basic principle of the open-architecture smart antenna system suggested by SA WG is to partition the entire smart antenna system according to function, with each partition referred to as a "component." After partitioning the system into components, the SA WG then defined a separate API for controlling each component, which as a whole defines the "SA API Specification."

It was important that the SA API be approached in such a way that any non-smart antenna system can easily be converted to a smart antenna architecture. More specifically, the SA WG defined a requirement on the SA API that it should be possible to convert any communication system

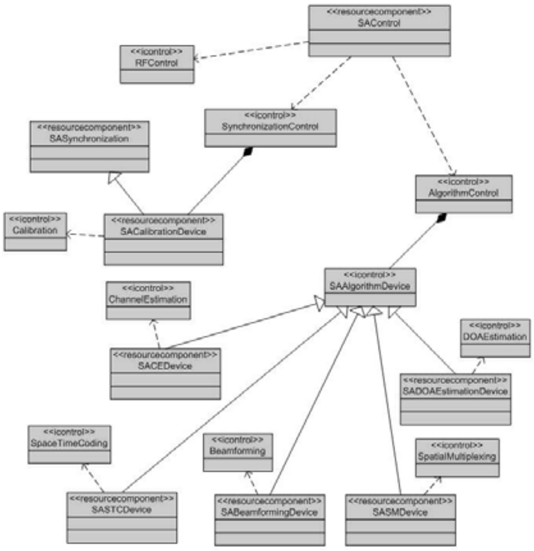

Figure 2: PIM of the SDR Forum Smart Antenna API

into a smart antenna system by simply plugging-in the smart antenna software modules implemented in accordance with the SA API. In other words, the SA API defines the components and API's needed for non-smart antenna system to be extended with smart antenna technology. Consequently, the SA API should facilitate a new Commercial Off The Shelf (COTS) market for smart antenna modules by driving economies of scale in manufacturing and thus significantly reducing the investment cost for smart antenna systems. In addition, service providers should be able to upgrade their non-smart antenna system to include smart antenna technology by integrating the smart antenna module into their network.

4. PLATFORM INDEPENDENT MODEL OF SMART ANTENNA API

In defining the SA API, the SA WG decided to follow the Model Driven Architecture (MDA) approach. The main objective of MDA is to enable the portability and/or reusability of architectural models across different platforms [5]. In order to achieve this objective, a model should first be defined independently of a specific technology or implementation platform, with the resulting model referred to as a Platform Independent Model (PIM). Once the PIM is complete, the various functionalities defined by the model can then be mapped to a specific platform. This model is referred to as the Platform Specific Model (PSM).

Figure 2 illustrates the PIM of the SA API that has been developed by the SDR Forum Smart Antenna Working Group. This PIM consists of three groups of facilities:

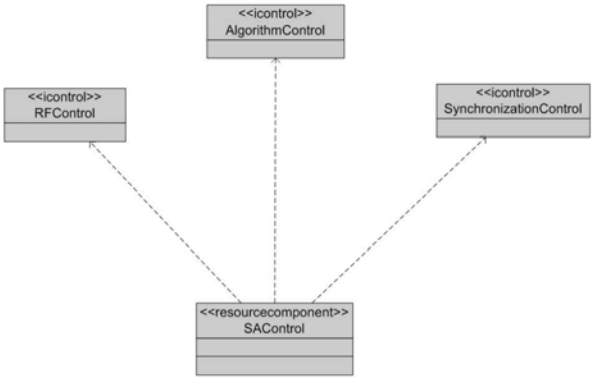

Figure 3: SA API Control Facilities

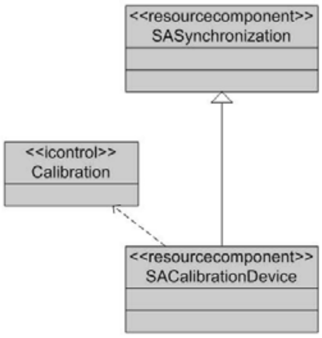

Figure 4: SA API Synchronization Facilities

SAControl facilities, SASynchronization facilities, and SAAlgorithm facilities.

The SAControl facilities, shown in Figure 3, include the base SAControl component along with control interfaces for the RF/IF component and the other two groups of facilities. The SAControl inherits from the Synchronization Control interface, the Algorithm Control interface, and the RF Control interface allowing this component to control the RF/IF component, SASynchronization facilities, and the SAAlgorithm facilities as appropriate. The RFControl Interface is designed to control multiple RF/IF components, since a smart antenna system inherently requires multiple RF chains.

The Synchronization Facilities of the SA API, illustrated in Figure 4, are for calibration. The SASynchronization component is realized by inheriting interfaces from Calibration and Latency as shown.

The algorithm facilities are used to execute all the algorithms for beamforming, DOA (Direction Of Arrival), channel estimation, spatial multiplexing, and STC (Space Time Coding). Figure 5 illustrates Algorithm Facilities. SAAlgorithmDevice is a core component of Smart Antenna System and parent component of all Algorithm components.

Figure 5: SA API Algorithm Facilities

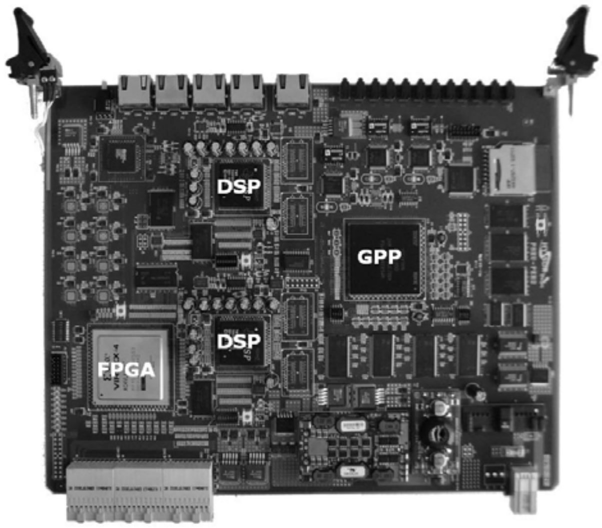

Figure 6: Photograph of implemented Baseband Signal Processing part of SDR smart antenna system.

Since all Algorithm components, i.e. SASTCDevice, SABeamformingDevice, SACEDevice, SASMDevice, and SADOAEstimationDevice Component, are generalized from the same parent component, i.e. SAAlgorithmDevice, a unified control interface can be provided.

5. PRACTICAL IMPLEMENTATION OF SA API

The Smart Antenna Working group has chosen the Common Object Request Broker Architecture (CORBA) and extensible Markup Language (XML) as a target platform for the initial PSM of the SA API.

Figure 6 is a photograph of implemented Baseband Signal Processing part of SDR smart antenna system. A hardware platform for the Baseband Signal Processing consists of a FPGA, two DSPs, and a GPP as shown in Figure 6. The SAControl component, which performs mainly logical operations, is loaded into a GPP, while the SAAlgorithm and SASynchronization, components, which require high-speed digital signal processing, are loaded into an FPGA or DSP as appropriate. Since CORBA for DSPs and FPGAs is not yet commonly used, adaptors are needed for SAAlgorithm and SASynchronization to bridge between the FPGA or DSP device interface and CORBA.

7. CONCLUSION

In this paper, the SA API for an SDR system is introduced. The proposed SA API provides flexibility, portability, interoperability, and compatibility for the smart antenna systems to operate in SDR network. It is noteworthy that the SA API can not only create COTS market but also lower down development costs of the smart antenna systems. In addition, non-smart antenna systems can easily be converted to smart antenna systems with the proposed SA API.

ACKNOWLEDGEMENT

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