Standardizing smart antenna API for SDR networks

In addition to defining the smart antenna application-programming interface (API), this article will also describe the smart antenna API in detail and explore its benefits. Plus, it will introduce the smart antenna working group and the process they are following in developing this API, as well discuss steps toward standardization.

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The Smart Antenna Working Group of the SDR Forum is developing an application-programming interface (API) supporting interoperability and compatibility of various kinds of smart antenna systems operating in a software-defined radio (SDR) network following an open-architecture model. The smart antenna API consists of three components:

1. SAControl component is used for controlling the smart antenna system.
2. SAAlgorithmDevice component is used for executing various algorithms such as beamforming, direction-of-arrival (DOA) estimation, space-time coding (STC), channel estimation and spatial multiplexing.
3. SASynchronization component is used for calibration. This article 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.

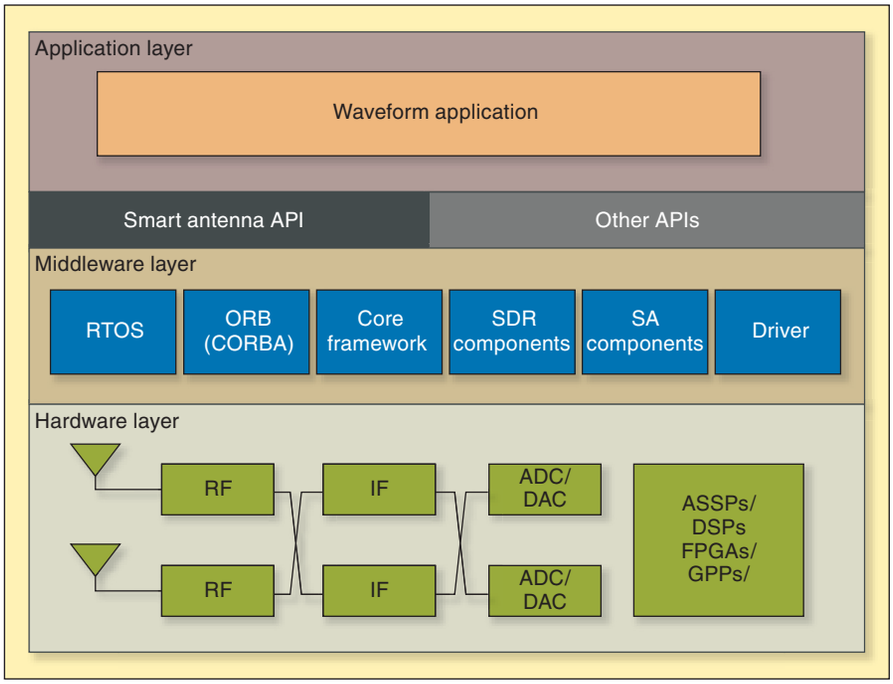

Figure 1. Example of an SDR-based smart antenna open architecture.

Background

A smart antenna (SA) 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 the MIMO system, data is transmitted from one or more transmit antennas to one or more 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].

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

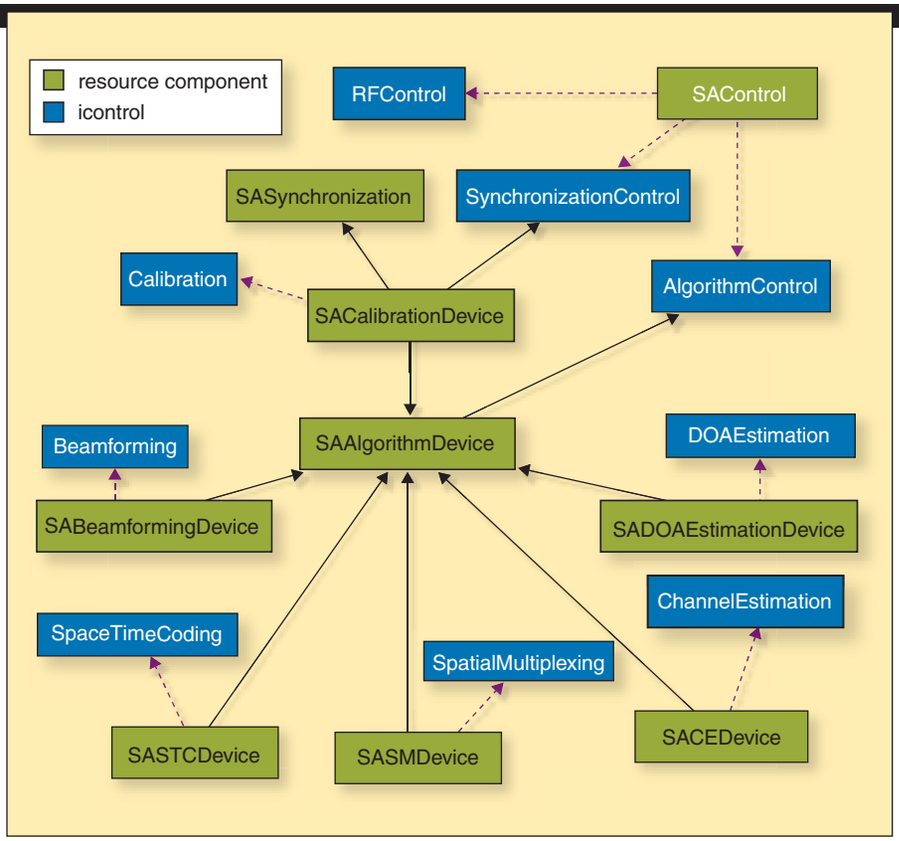

Figure 2. PIM of the SDR Forum SA API.

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.

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 using 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 (SAWG) 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 interoperability and compatibility among systems produced by different vendors with different functions. The working group specifically focused on allowing various kinds of beamforming systems, diversity systems and MIMO systems to all be managed together in an open architecture SDR network.

The process of creating the SA API

In order for the SDR system to exploit the merits of a smart antenna, the SAWG 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 SAWG 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 SAWG 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 an SA architecture. More specifically, the SAWG defined a requirement on the SA API that it should be possible to convert any communication system 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 systems 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.

Platform-independent model

In defining the SA API, the SAWG 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

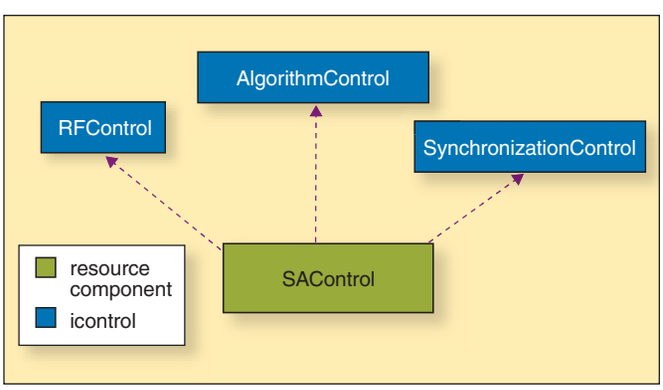

Figure 3. SA API control facilities.

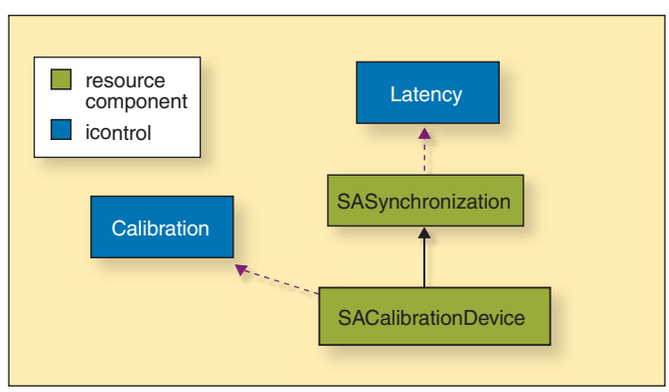

Figure 4. Synchronization facilities.

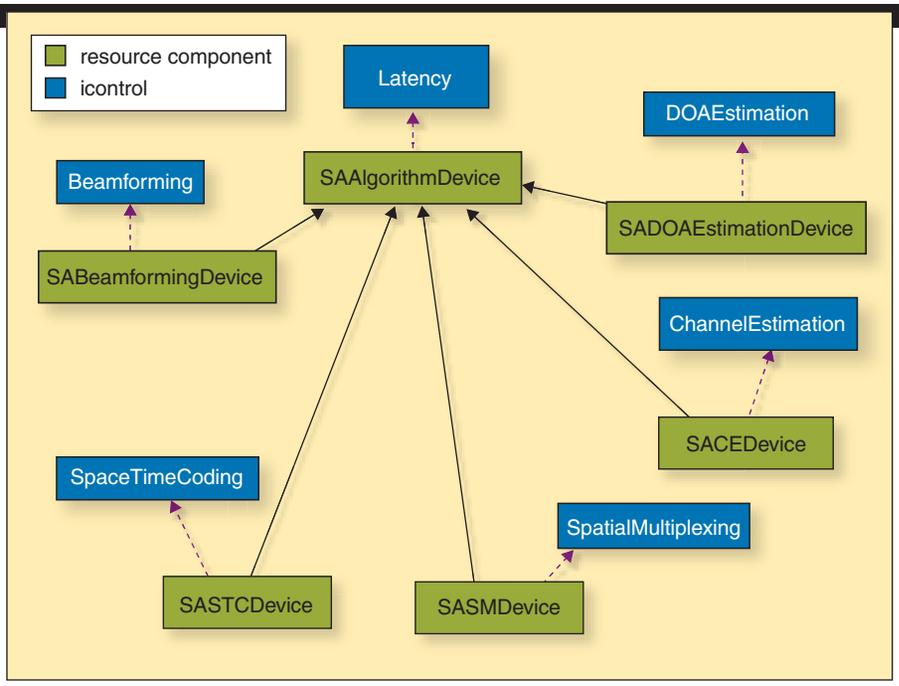

Figure 5. Algorithm facilities.

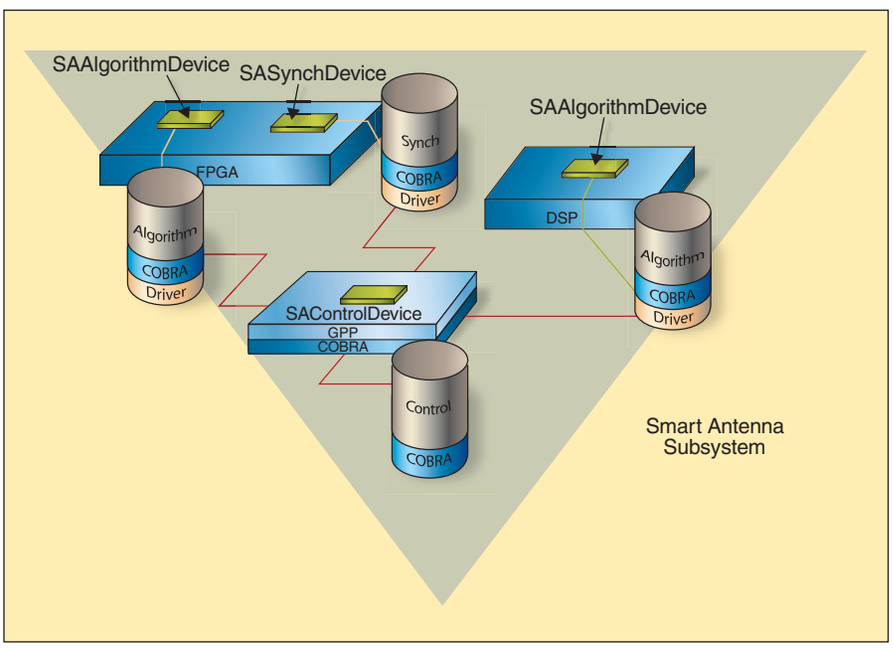

Figure 6. Deployment diagram of SA API.

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's SAWG group. This PIM consists of three groups of 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, channel estimation, spatial multiplexing, and STC. Figure 5 illustrates algorithm facilities. SAAlgorithmDevice is a core component of SASystem and parent component of all algorithm components. Because all algorithm components, such as SABeamformingDevice, SASTCDevice, SACEDevice, SASMDevice, and SADOAEstimationDevice, are generalized from the same parent component, i.e., SAAlgorithmDevice, a unified control interface can be provided.

Platform specification model of SA API

The SAWG 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 illustrates a deployment diagram of SA API, showing how each component is deployed to a hardware device. 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.

Next steps

The SA API is largely complete, and the Smart Antenna Work Group plans to promote this document to the SDR Forum for balloting later this year. Once this ballot is complete, the SA API will be an approved SDR Forum specification available for use by the larger community. In addition, the SDR Forum intends to submit the approved SA API to the Object Management Group (OMG) for standardization through its process in response to a request for proposal issue by the OMG's Software-Based Communications Domain Task Force (SBC-DTF)[6] The SDR Forum, in support of its members, has been closely collaborating with the SBC-DTF so that the results of this work can provide a standard architecture of a smart antenna base station system operating in SDR to the broader community.

Conclusion

In this article, 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 the SDR network. It is noteworthy that the SA API not only creates COTS market but also lowers development costs of the SA systems. In addition, non-smart antenna systems can easily be converted to smart antenna systems with the proposed SA API. RFD

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