A Technical Review of SCA Based Software Defined Radios: Vision, Reality and Current Status

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Abstract

The SCA 2.2.2 architecture has achieved widespread adoption in the military communications market. Hundreds of thousands of SCA enabled software defined radios (SDRs) have been deployed to date, and world-wide dozens of programs are working to field more of these types of radios. The reasons for this success are the benefits enabled through adoption of the SCA: proven cost and delivery time advantages, lower logistical overhead through enhanced inter-component interoperability, simplified insertion of new communications capabilities in deployed radios, enhanced coalition interoperability through portability of waveforms and reduced development risk. As a result of this success, new countries and new organizations have begun to explore the use of the SCA, driving a second generation of SDR market adoption.

Successful deployment of SCA 2.2.2 based SDRs has identified improvements to be made to advance the technology further. The Wireless Innovation Forum is working in close collaboration with the U.S. Department of Defense Joint Tactical Networking Center (JTNC) to evolve the SCA. The resulting SCA 4.1 specification represents the future of defense SDR technology.

Keywords

Software Communications Architecture, SCA, Software Defined Radio, SDR

1 INTRODUCTION

Recent market studies have shown that SDR technology has become ubiquitous in modern tactical communications systems, with the total market for SDR based tactical radio production estimated at $5 billion (USD) in 2015 [1]. The reasons stated for the extensive use of SDR in the tactical radio market are twofold. First, the defense market generally does not command sufficient volume to justify the fabrication of ASIC based radio technologies prevalent in the commercial wireless sector. As such, the use of off the shelf programmable processing technologies inherent in SDR is the norm, making the deployment of software defined radios widespread. Second, equipment manufacturers and their customers gain significant advantages by utilizing SDR technology in an environment where migration to a new communication standard is challenging, including:

"... using the same platform for different radio applications (waveforms and user services), featuring upgradeable and flexible solutions, supporting the rapid deployment of mission-ready systems".

- Fabio Casalino, Selex ES [2]

A key technology in the deployment of many defense related SDRs is the Software Communications Architecture (SCA). The SCA is an implementation-independent, architectural framework that specifies a standardized infrastructure for a software defined radio. Initially, developed and published by the U.S. Department of Defense (DoD), the SCA is maintained by the Joint Tactical Networking Center (JTNC) in collaboration with various industry partners and organizations, such as the Wireless Innovation Forum [3]. The specification has significantly influenced the evolution of the software defined radio domain and its concepts have been used within multiple industries, products and countries worldwide [4].

In this paper, an overview of SDR in the tactical radio market is provided. The SCA is then introduced, highlighting the adoption of the SCA in the world-wide defense communications market. The rationale for improvements in the SCA based on experiences with these deployed systems is then presented, the evolutionary enhancements in SCA 4.1 are introduced, and next steps are discussed.

2 WHAT IS SOFTWARE DEFINED RADIO

The IEEE Standards Association defines software defined radio as "radio in which some or all of the physical layer functions are software defined" [5]. A radio, in this definition, is any kind of device that wirelessly transmits or receives signals in the radio frequency (RF) part of the electromagnetic spectrum to facilitate the transfer of information. Traditional hardware based radio devices limit cross-functionality and can only be modified through physical intervention. This results in higher production costs and minimal flexibility in supporting multiple and evolving waveform standards. By contrast, software defined radio technology provides an efficient and comparatively inexpensive solution to this problem, allowing multi-mode, multi-band and/or multi-functional wireless devices that can be enhanced using software upgrades.

SDR defines a collection of hardware and software technologies where some or all of the radio's operating functions (also referred to as physical layer processing) are implemented through modifiable software or firmware operating on programmable processing technologies [6]. These devices include field programmable gate arrays (FPGA), digital signal processors (DSP), general purpose processors (GPP), programmable System on Chip (SoC) or other application specific programmable processors. The use of these technologies allows new wireless features and capabilities to be added to existing radio systems often without requiring new hardware.

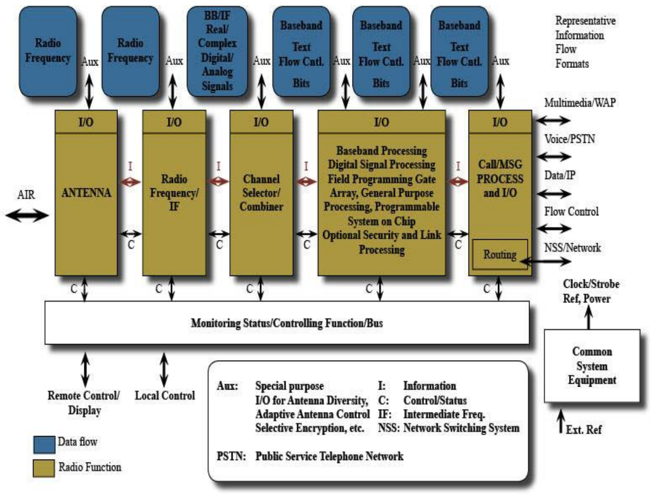

Fig. 1. Wireless Innovation Forum Generalized Functional Architecture [7]

3 The Software Communications Architecture: A Key Technology Defense SDR Communications

Advances in digital processor technology, increases in analog-to-digital sampling rates and other technological developments have enabled the continuing growth of complex signal processing in the digital domain. This increase in digital processing has appreciably altered the architecture and design of radio systems. Recent generations of SDRs have evolved to become highly software intensive, complex systems facilitating further advancement of communications capabilities. SDRs have enabled more cost effective radio platform life cycles by providing for the update and addition of system functions and features, without requiring hardware modifications.

Prior to the establishment of the SCA as an open standard, these SDRs were developed using proprietary software architectures that tightly coupled hardware platforms and waveform applications in a manner that was unique to each manufacturer. The SCA has built upon the capabilities of these preceding generations of SDRs, moving today's radios significantly forward by leveraging large-scale commercial software industry investments in technology, and by promoting open standardization. The SCA specification and associated technologies facilitate broad software reuse and application portability across SDR platforms, while enabling achievement of the key industry-wide objectives [8][9][10]:

- Enhanced interoperability between SDRs and across entire communications system, especially critical for mission essential communications.
- Reduction of the time and cost required to develop and deploy SDRs and associated systems, including the incremental roll-out of new SDR and communication system features and functions.

The SCA provides a set of rules and constraints which define the interactions between software applications (i.e., waveforms) and radio hardware platforms, leveraging an Object Oriented (OO) software paradigm and employing Component Based Development (CBD) technologies. CBD technologies are sometimes referred to the "industrial revolution" of software, fostering the advent of interchangeable software parts, built to predefined specifications [11]. With CBD technologies, software components can be thought of as software integrated circuits with a set of defined functionality, performance and input/output. Components can be assembled together to create entire applications, such as waveform applications for an SDR.

The SCA specification also defines a core set of open system interfaces and profiles that provide for the configuration, assembly, deployment and management of components, which ultimately comprise the software applications (e.g. waveform). The components of these software applications can be distributed across various SDR hardware processing elements in a manner determined by the platform developers that support the overall SDR requirements, hardware platform capabilities and design, in conjunction with the SDR software design and configuration.

3.1 Global Adoption of SCA in Defense Communications

There are over two dozen "programs of record" involved in the acquisition and deployment of SCA based SDRs. A sample of these programs are shown in Table 1. Other countries evaluating the adoption of SCA based SDR technology include Brazil, Singapore, Turkey, the United Arab Emirates and Israel.

Table 1

SCA BASED SDR PROGRAMS

Country	Program
ESSOR Nations (Finland, France, Italy, Poland, Spain, and Sweden)	European Secure Software Defined Radio (ESSOR) program
France	COmmunications Numeriques TACtiques et de Theatre (CONTACT) Program
Germany	Streitkräftegemeinsame Verbundfähige Funkgeräte-Ausstattung (SVFuA) Program
India	Army SDR Program Naval SDR Program IAF (Indian Air Force) SDR Program
Italy	Forza NEC/Future Soldier : Land SDR radios National SDR Program (SDR-N) : Land SDR radios SDR Naval Program
Japan	Ground and Maritime SCA SDR
Korea	Tactical Multi-band and Multi-role Radio (TMMR) Program
Poland	Guarana SDR National Programme
Sweden	Tactical Data Radio System (TDRS) Program Tactical Ground Radio System (TGRS) program
United Kingdom	Land Environment Tactical Communications and Information Systems (LE TacCIS) program
United States	Digital Modular Radio (DMR) Rifleman Radio, Airborne SANR (Small Airborne Networking Radio) SALT (Small Airborne Link16 Terminal) Mid-Tier Networking Vehicular Radio (MNVR) SRW Appliqué Family of Advanced Beyond LOS Terminals (FAB-T) ARC-210 ARC-231 MIDS-J Program Navy Multiband Terminals (NMT) Next Generation Handheld Radio (NGHH)

3.2 SCA Based SDR Deployments

More than 400,000 radios have been delivered and deployed through these programs to date, using SCA 2.2.2 as a baseline technology. A subset of these radios is shown in Table 2.

TABLE 2
SCA BASED SDR DEPLOYMENTS

Manufacturer	Equipment	Number
General Dynamics and Thales	AN/PRC-154A Rifleman Radio	25,000 [12]
General Dynamics and Rockwell Collins	AN/PRC-155	3,700 (ordered) [13]
Harris Corporation	AN/PRC-117G	22,000 [14]
Harris Corporation	AN/PRC-152	160,000 [15]
Rafael Advanced Defense Systems	BNET Software Defined Radio	Deployment numbers not publically released
Raytheon	RT-1987 / ARC231, MAINGATE, NMT, and FAB-T	Deployment numbers not publically released
Rockwell Collins	ARC-210 TacNet WDL TacNet TTR CRIIS DTL	To date, over 30,000 units deployed, the latest generation of which (ARC-210 RT-1939) is SCA enabled [16]

	TruNet Network Communications Solution	
Rockwell Collins/Thales	FlexNet Family	Deployment numbers not publically released
Rohde & Schwarz	R&S® SDTR Vehicular Tactical Radio	Deployment numbers not publically released
Selex ES	Swave™ Family (HH, VM-3, MB-1, VB-1, VQ-1)	Deployment numbers not publically released
Thales	AN/PRC-148 JTRS Enhanced MBITR	200,000 [17]
Thales	Fastnet and Nextwave Families	Deployment numbers not publically released
Ultra Electronics	TCS AN and GRC-245	Deployment numbers not publically released
ViaSat/ Data Link Solutions (DLS)	MIDS-JTRS	Deployment numbers not publically released

3.3 SCA Waveform Applications

Communication waveforms are one example of the types of applications that are used in SDRs. Waveforms are mixed and matched on these platforms based on mission need. For example, the Harris PRC-117G currently supports SINCGARS, Havequick II, VHF/UHF AM and FM, MIL-STD-188-181B SATCOM, ANW2 [18]. The Soldier Radio Waveform (SRW) was recently added as a new waveform application [19]. Other SCA based waveforms deployed on the radios identified in Table 2 or in development in support of these communications systems include the following:

- Easy II
- EPLRS
- ESSOR High Data rate Waveform (HDRWF)
- FlexNet
- Harris High Performance Waveform (HPW)
- HF (various types)
- Integrated Waveform (IW)
- Joint Combat Waveform (JCW)
- Joint Networking Waveform (JNW)
- JTRS Bowman
- Link-16
- MIL-STD-188-220 (ENS TDC ENS SoftINC)
- Mobile User Objective System (MUOS)
- NATO Narrow Band Waveform(NBWF)
- PR4G-Fastnet
- Quicklook
- R&S HDR Waveforms
- SATURN
- SEM-Family
- Soldier Broadband Waveform (SBW)
- Talon
- Tactical Targeting Network Technology (TTNT) Waveform
- TDRS Waveform
- VHF/UHF Line of Sight (VULOS)
- Wideband Networking Waveform (WNW)

The value of the SCA in allowing radio manufacturers to support these many and varied waveforms cannot be understated:

"SCA Standards are key success factors for reducing cost in porting common waveforms onto platforms from different suppliers and bringing benefits to radio manufacturers in advancing their product portfolio such as reduced time to market, reduced development costs, and the availability of ported waveforms, therefore providing more options to customers"

\- *David Renaudeau, Thales [2]*

"The SCA specifications are an important corner stone to SDR standardization and - in combination with an open architecture and near target development platforms - a prerequisite to enable timely and cost efficient porting and integration of waveforms, especially multinational and secure waveforms for combined operations."

- *Rüdiger Leschhorn, Rohde & Schwarz [2]*

As a result of the application portability provided by the SCA, many of these waveforms cited exist on platforms provided by different vendors, greatly easing the interoperability issues that have plagued radio communications in the past. The widespread implementation of the Soldier Radio Waveform (SRW) across multiple vendor radios as illustrated below is an example of how the SCA enables interoperability (see Figure 2).

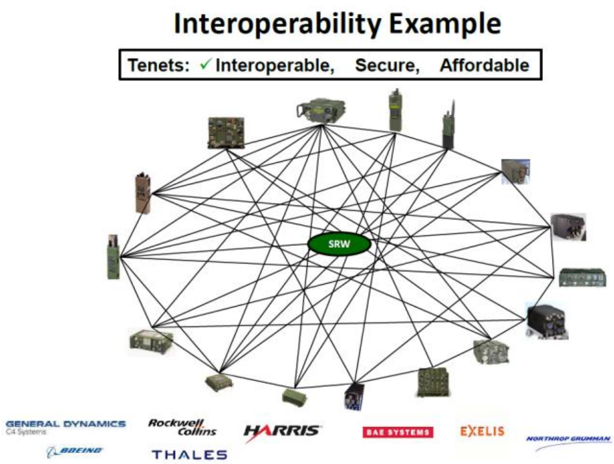

Fig. 2: Through the SCA, simplified porting of a common waveform application across multiple radio platforms simplifies interoperability [20]

4 EVOLVING BEYOND SCA 2.2.2

As with any technology, usage in real world environments highlighted improvements in the SCA specification that were necessary to allow further market penetration. Chief among these were improving the ability of the architecture to scale to address the size, weight, power and cost requirements of certain radios, enabling faster boot times, improving support for devices such as Digital Signal Processors (DSPs) and Field Programmable Gate Arrays (FPGAs) that are utilized in most radio architectures and enhancing the ability to migrate legacy waveforms to an SCA model. The need for these improvements led programs such as the European Secure Software Defined Radio (ESSOR) program to define their own SCA based SDR software architectures[21][22].

To support these capabilities, a new evolution of the baseline specification was needed, so in 2009, the Joint Program Executive Office for the Joint Tactical Radio System (JPEO JTRS) initiated the SCA Next project. The Wireless Innovation Forum brought the voice of the international community to the collaboration process, providing contributions from member organizations worldwide and from programs such as ESSOR [23][24][25]. The result of these and other efforts was SCA 4.0, which provided improved scalability and better support lightweight and ultra-lightweight environments for development on resource constrained processors such as DSP's and FPGAs [26]. An intermediate version 4.0.1 was later released with editorial changes, etc.

In 2012, management of the SCA for the US DoD was transferred to the Joint Tactical Networking Center (JTNC). In November 2013 the evolution of the SCA continued through a workshop hosted by the Wireless Innovation Forum's Coordinating Committee on International SCA Standards (CCSCA) and with participation from the JTNC to further improve the SCA specification[27]. Key areas for additional improvement defined at this workshop included better backwards compatibility with SCA 2.2.2 and additional updates to the Application Environment Profiles (AEPs) and Interface Definition Language (IDL) profiles. A work plan was established, with the Wireless Innovation Forum taking the lead in developing technical solutions in multiple areas.

4.1 The WInnForum's Technical Contributions to SCA 4.1 Specification

Well over 2000 hours were volunteered by the Wireless Innovation Forum's member representatives in developing these solutions. Their efforts resulted in multiple recommendations that were incorporated into the SCA 4.1 Specification, including the following [28]:

- **Application Backwards Compatibility.** This recommendation provides comments on the modifications to SCA 4.0 necessary to support application backwards compatibility with SCA 2.2.2.
- **Naming Conventions.** This recommendation proposes changes to the SCA 4.0.1 specification to use a naming convention for the interfaces and components. The goal is to improve readability of the specification.
- **Process Collocation and Core Affinity Deployment.** This recommendation proposes changes the Draft SCA 4.1

specification to provide the capability to support dynamic threading, when intended, for Executable Device Component OS process address space and also for a separate OS process address space. The proposal also intends to allow application threads to be mixed with platform component threads in the same OS process address space. Finally, this proposal adds support for multicore devices deployment via core affinity requirements in a SAD and DCD supported by an executable device component that manages a multi-core processor

- **Push Registration Allocation Properties.** This recommendation proposes changes to the SCA 4.0.1 specification to support late device registration with the DomainManager. This change will allow the Core Framework to better accommodate Device components with multiple implementations and to manage plug and play devices.
- **Scalable Components.** This recommendation proposes changes to the SCA 4.0.1 specification to improve component scalability by allowing component developers to choose whether or not to implement some of the standard sub-component interfaces. The scalability will also be used to support the different profiles of the specification (see Figure 3).
- **Scalable Manager Components.** This recommendation proposes changes to the SCA 4.0.1 specification to add support for scalability of the manager components. This will allow developers to choose whether or not to implement all of the manager interfaces. The manager scalability will also be used to support the different profiles of the specification.

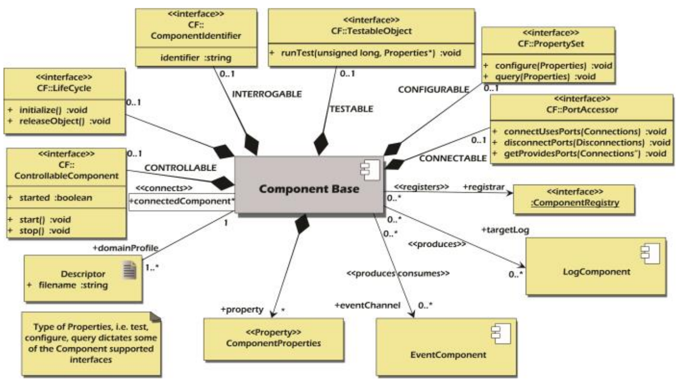

Fig. 3. Proposed Component Base UML model

The volunteer efforts also produced two new Wireless Innovation Forum SDR Standards were incorporated into the SCA 4.1 Specification [29]:

- **WInnF Lw & ULw AEPs.** This SDR Standard defines POSIX AEPs for interaction between SDR Applications and the Operating Environment (OE) in resource constrained architectures (see Figure 4). Two Base AEPs functions groups, the Lightweight (Lw) and the Ultra-Lightweight (ULw), are defined. The documents contains normative content for Base AEPs functions groups plus support sections giving SCA-like contents overview tables and detailed rationale for the design choices. It also provides two function groups that can extend the Base AEPs function as required by the porting assumptions. This SDR standard harmonizes and improves prior work from JTNC and ESSOR into a single converged solution.

- **WInnF PIM IDL Profiles.** This SDR standard defines Platform Independent Model (PIM) IDL Profiles for the definition of application specific interfaces among SDR components. Two PIM IDL Profiles are defined: the "Full" and the "Ultra-Lightweight" Profiles. The document contains normative content for the defined profiles, a support section with content overview tables and extension perspectives, and a rationale section which explains the design choices. This SDR standard also harmonizes and improves prior work from JTNC and ESSOR into a single converged solution.

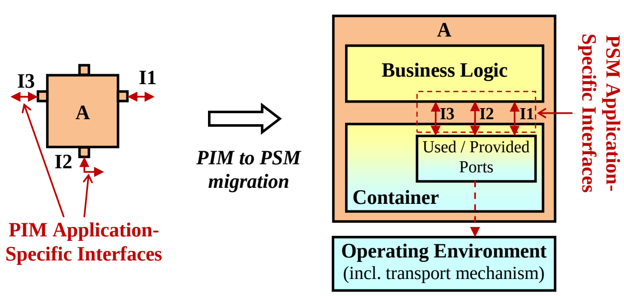

Fig. 4. Positioning the PIM IDL Profile usage

4.2 *SCA 4.1 Finalization and Perspectives*

The SCA 4.1 draft specification was released by the JTNC in January of 2015, and the comment period closed in March of that same year. Issues in the specification identified in the collected comments were adjudicated by the Wireless Innovation Forum, with final recommendations delivered to the JTNC in June of 2015 [30]. The final specification incorporating these changes was released by JTNC in August of 2015, and was endorsed by the members of the Wireless Innovation Forum in December of 2015 *"as a preferred software architecture for software defined radios"* [31]. Early implementation results show that the SCA 4.1 addresses most of the issues identified in SCA 2.2.2, and early adoption is being considered in multiple products and programs [32][33]. SCA 2.2.2 was in use for almost 10 years, and it is anticipated that SCA 4.1 will remain a stable, core reference specification for a similar period of time. Near term enhancements to the SCA-based set of standards will likely lie, therefore, in the development and harmonization of application programming interfaces (APIs) complementing the core specification. APIs in development or under consideration include:

- Dynamic spectrum access
- Enhanced timing
- International security services
- Power management
- Transceiver (WINNF Transceiver Next project)

A number of artifacts have also been discussed supporting the migration to this new specification, including an SCA 4.1 users guide, a SCA 2.2.2 to SCA 4.1 porting guide and defining industry agreed metrics for measuring waveform portability.

5 Conclusions

SDR is a dominant technology in defense communications, bringing multiple benefits to radio manufacturers and their customers world-wide. The SCA is a proven framework supporting these SDRs with over 400,000 SCA enabled radios currently in deployment. This success has also made the SCA attractive for applications beyond the military radio market, with the SCA 4.1 specification specifically referencing use in commercial communications terminals, electronic warfare applications, and test and measurement instruments. With its component-based design approach, the SCA has considerably changed the way radios are developed, enabling a higher degree of deployment flexibility and leading to cost reduction when supporting multiple missions. From an original US DoD vision of a standard military radio development software architecture, the SCA, with version 4.1, has moved forward as an international specification, with government and industry collaborating to leverage the technologies the SCA combines to advance radio communications as a defense capability.

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