

## WAVEFORM PORTABILITY FOR SOFTWARE DEFINED RADIOS

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### ABSTRACT

A primary goal in the development of the Software Communication Architecture (SCA) for Software Defined Radios (SDRs) is waveform portability. This paper examines the recently published SCA V2.2 document and its supplements [1] [2] [3] [4] [5] to determine whether all of the requirements currently specified are necessary and sufficient to assure waveform portability. Collaboration diagrams of Joint Tactical Radio (JTR) set interfaces and waveform application interfaces were used to examine the interfaces specified in SCA V2.2 to determine their existence and use during different state transitions of the JTR set and waveform applications. The analysis identifies those requirements that are not necessary for waveform portability and makes recommendations for the handling of these requirements.

The paper additionally identifies interfaces that need to be added to the existing SCA documents to assure waveform portability and recommends an approach for the addition of these items.

### 1. INTRODUCTION

The SCA V2.2 documents contain requirements for many interfaces and behaviors within a JTR set. Earlier

investigations looked at the SCA documents and determined that implementation of requirements from different sections of the SCA document apply to different JTRS development groups.

Table 1 is a table taken from the Joint Tactical Radio System (JTRS) Home Page [6]. It shows which development groups are responsible for implementing interface requirements from different sections of the SCA. Table 1 does not, however, attempt to define all of the groups that need to understand and use the interfaces that are implemented. The requirements that are especially of interest are those that define interfaces between the waveform application and the JTR set. These requirements are critical to allow a waveform to be easily ported to different JTR sets. They are external interfaces of a JTR set and of the waveform application and if they can be identified then the remaining requirements can be classified as internal interface requirements for the JTR set or for the waveform application. These internal interface requirements are not necessary for waveform portability and do not belong in the SCA documents as requirements. Implementing and testing these internal requirements does not enhance waveform portability.

An analysis of the SCA 2.2 documents was conducted [7] to go beyond the conclusions shown in Table 1 to determine the set of interfaces that both the Waveform

**Table 1 Developer Responsibilities for SCA Implementation**

	Operating Environment																	Applications (Rules & Requirements)	Logical Devices	General Software Rules	API Supplement	Security Supplement												
	Core Framework																																	
	Base Application Interfaces						Framework Control Interfaces				Framework Services Interfaces																							
	Port	LifeCycle	TestbedObject	PropertySet	ResourceFactory	Resource	Domain Management		Device	DeviceManager	File Services			Timer	Logger	StringConsumer	File Manager						Domain Profile											
Application Factory							Application	File			FileSystem	File Manager																						
Application (Waveform) Developers	X	X	X	X	X	X			X						X		X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Hardware Device Developers	X	X	X	X	X			X	X								X			X	X	X	X	X										
Core Application Services Developers							X	X	X	X	X	X	X	X			X																	
System Developers	X	X													X																			X

developer and the JTR set developer must either implement or use to assure waveform portability.

## 2. DESCRIPTION OF ANALYSIS

The SCA documents contain over one thousand requirements. This section describes how these requirements were evaluated to determine a set of requirements that are essential to assure waveform portability. These are requirements for the interface between the JTR set and the waveform application.

Figure 1 is taken from Section 3.1.1 of SCA V2.2. As shown in the figure, the Operating Environment (OE) contains the CORBA ORB, the Operating System (OS) and the Core Framework (CF). The figure additionally shows the relationship of the OE to applications' Resources and to non-CORBA components or Device Drivers. Since multiple applications exist within a JTR set it is not clear from the figure exactly what interfaces are required for waveform portability.

To more clearly define the internal and external interfaces the items shown in Figure 1 were rearranged in Figure 2 and shown within the confines of a JTR set. In figure 2 a JTR set is all hardware and software necessary to install, instantiate and allow proper operation of a waveform application.

Figure 2 clearly shows the external interfaces to the

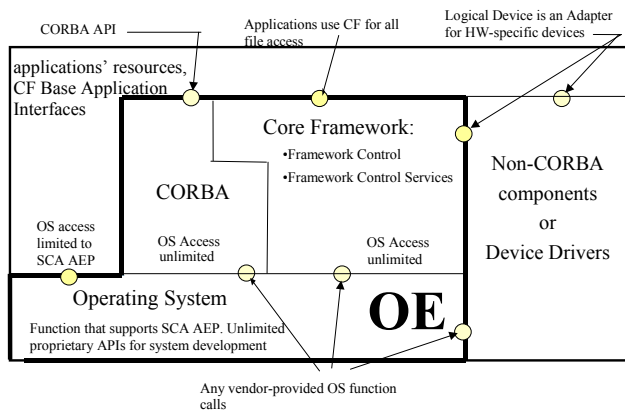
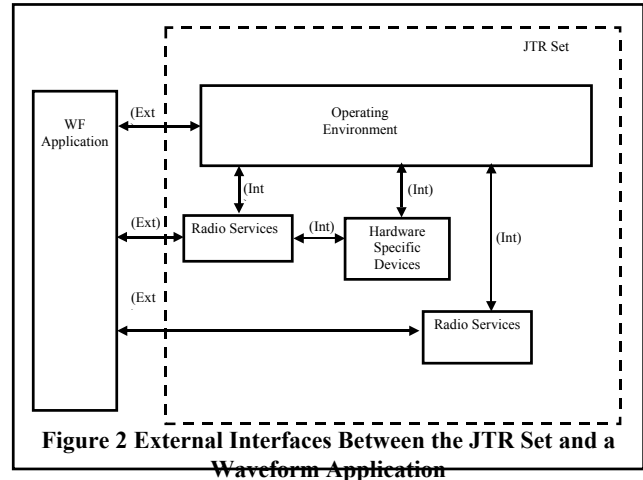


Figure 1 Relationships of Key SCA Elements

waveform application. As shown these external interfaces are not only between the waveform application and the OE but also between the waveform application and other applications known as Radio Services (RSvcs). In addition, Figure 2 shows internal interfaces between the OE and RSvcs and Hardware Specific devices.

The SCA V2.2 does not specifically address Radio Services, however, the Application Program Interface (API) supplement of the SCA V2.2 does define general building blocks that can be further developed to build these well-



defined interfaces between waveform applications and RSvcs.

RSvcs are services provided by the JTR set that implement a well-defined interface facilitating waveform configuration and control of hardware specific devices and access to other JTR set services. Examples of other RSvcs are:

- applications for HCI interface: These applications allow a human operator to access data and to update parameters within the JTR set.
- applications that support modem or audio functions that are called and used by a waveform
- Other RSvcs as determined by the JTR set implementation.

To support maximum waveform portability common RSvcs that interface to waveform applications should be identified and their interfaces defined and agreed to within the JTRS community. These interfaces can then be used in JTR sets within each cluster or even across clusters to simplify porting of the waveform application to multiple JTR sets.

Hardware Specific Devices, as shown in Figure 2, are hardware-defined devices that are persistent and exist independent of a waveform. They are implemented, tested and delivered with the JTR set. Devices exist before waveforms are instantiated and after they are torn down. New devices are added only as a result of a development program to enhance or add capability to the JTR set. There are different devices that support a JTR set. The RF, I/O and the Security Devices, for example, are hardware specific and have a well-defined interface for configuration, control and data flow. Radio Services, as shown in Figure 2, allow a waveform application to interface to these hardware specific devices using a well-defined API. When the waveform is instantiated the devices are configured and connections are made to them through the RSvcs. General Purpose Processors (GPPs), Digital Signal Processors (DSPs), Field Programmable Gate arrays and Application

Specific Integrated Circuits (ASICs) are examples of lower level devices provided with the JTR set. Some of these lower level devices are programmed prior to waveform instantiation and are independent of the waveform. Others are available to be programmed at the time of waveform instantiation according to the domain profile. The JTR set has the capability to utilize these devices as required to instantiate a waveform.

For the purpose of this study, adding hardware specific devices to support a waveform was not considered. If a waveform is dependent upon a piece of hardware that a JTR set does not have then this hardware is added by the set developer and tested in a separate development effort. The waveform is then ported to the JTR set after the device is implemented.

The objective of the analysis was to examine the requirements in SCA V2.2 to determine which were requirements for one of the external interfaces identified in figure 2. These external requirements are necessary to assure waveform portability. Requirements that are not necessary for waveform portability were then examined to determine whether or not they could be removed from the SCA document.

## 2.1 Assumptions

The following assumptions apply to the study:

- Devices are persistent. As stated in Section 2.1 hardware specific devices and their Radio Services exist independent of waveform applications but are used by waveform applications. Examples of these devices are:
  - I/O Device
  - Security Device
- Radio Services exist independent of waveform applications but are used by waveform applications. These services are provided by the set developer with the JTR set. They implement a well-defined interface that the waveform can use to interface to the hardware specific devices.
- Middleware Services (within the OE) exist independent of waveform applications. The Log Service (optional), CORBA Naming Service and the CORBA Event service are the services defined in the SCA at this time. These are services offered by the JTR set. They are installed and tested by the set developer and delivered with the set and used by both the JTR set and by the waveform application.
- Domain Management (within the OE) is implemented by the JTR set and exists independent of waveform applications. The SCA V2.2 states in Section 3.1.3.2, “The implementation of the Application, ApplicationFactory and DomainManager interfaces are coupled together and must be delivered together as a

complete domain management implementation and service.” The SCA V2.2 further defines the requirements for the Application, ApplicationFactory and the DomainManager interfaces and for the behaviors of the objects that implement these interfaces. Domain Management is used to instantiate waveform applications according to the Domain Profile however, many of these requirements are for registering Device Managers, Devices and Services. These behaviors are needed prior to waveform instantiation and therefore, Domain Management exists independent of waveform applications.

## 2.2 JTR Set and Waveform Lifecycle Scenarios

The SCA documents do not describe when the interfaces and object behavior are required during the different states of the JTR Set and waveform lifecycle. For instance some of the interfaces are required at power up, some at waveform instantiation and others are not needed until the waveform is operating or until it is torn down. All of these states were investigated and realizations were developed for

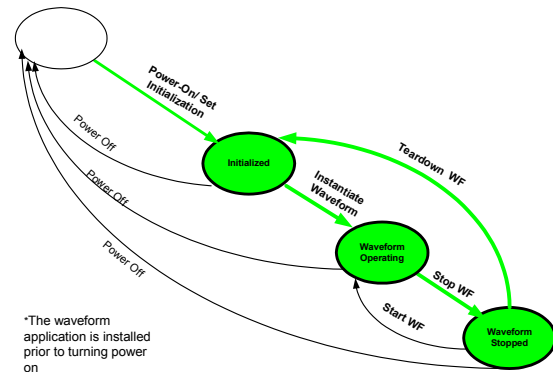


Figure 3 States and State Transitions That Were Analyzed

each. Figure 3 shows the states of the JTR set with an installed waveform. The study effort concentrates on the following states and state transitions as shown by the thick gray (green if viewed on the PC) lines in Figure 3:

**State Transition : Power-On/Set Initialization** as the JTR set transitions from the Power off State to Initialized State

**State Transition : Instantiate Waveform** as the JTR set transitions from the Initialized State to the Waveform Operating State

**State: Waveform Operating**

**State Transition: Stop WF** as the JTR set transitions from the Waveform Operating State to the Waveform Stopped State

**State Transition: Teardown WF** as the JTR set transitions from the Waveform Stopped State to the Initialized State

### 2.3 Requirements Analysis

Sequence diagrams and collaboration diagrams were created to realize each state or state transition, however, space does not permit these diagrams to be displayed in this paper. Figure 4 is a summary diagram that shows the external and internal interfaces between instantiated objects for the State Transition: Instantiate Waveform. This diagram is the end result of identifying each interface necessary to instantiate a waveform. This summary diagram shows what interfaces are external and are important for waveform portability versus what interfaces are internal only and are not important for waveform portability. As shown in the diagram, all interfaces between objects that cross the boundary line that encloses the waveform application are external interfaces. All interfaces that do not cross the boundary line that encloses the waveform application are internal interfaces either to the JTR set or the waveform application.

Figure 4 shows all of the interfaces used during waveform instantiation and the data and control paths that are established. As shown in the figure, the Device, ExecutableDevice, LoadableDevice & AggregateDevice interfaces to Logical Devices from Domain Management (Application object) are internal to the JTR set. Because

As shown in the figure, there are external interfaces from waveform application objects to the Devices through the Device's RSvc. These interfaces are located in the lower right of Figure 4 and are labeled "Data/Control". These interfaces are well-defined APIs and are external interfaces required for waveform portability.

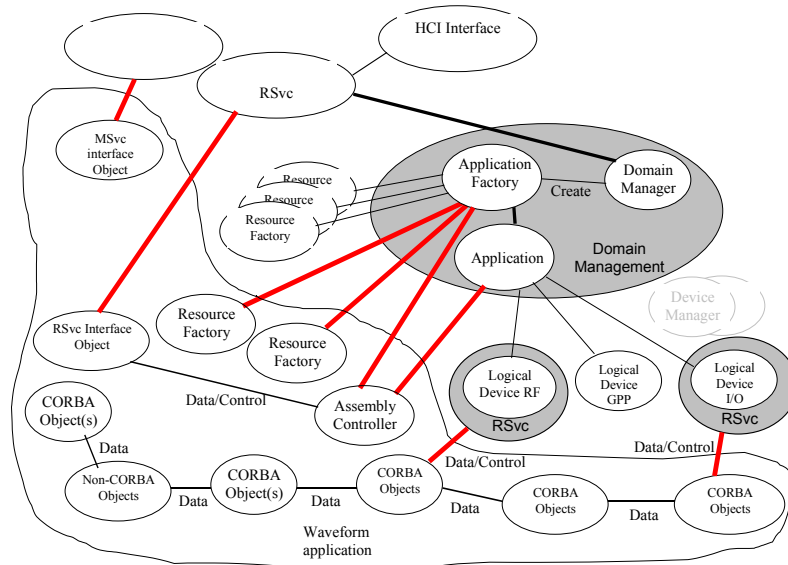
The interface between the waveform RSvc Interface object and the System Control RSvc and between the waveform MSvc (Middleware Service) Interface object and the Msvc application respectively are external. These interfaces are well-defined APIs and are external interfaces required for waveform portability.

Other interfaces shown between objects within the JTR set's Domain Management and the Waveform Application's Assembly Controller object and the Waveform Application's Resource Factories are Base Application Interfaces that are external interfaces required for waveform instantiation.

Interfaces between the objects within the Domain Management are internal to the JTR set. Since Domain Management is implemented in the JTR set the Domain Manager, Application Factory and Application interfaces were always internal to the JTR set for all states and state transitions.

### 3. WAVEFORM PORTABILITY REQUIREMENTS

As a result of the analysis the following are the major areas of the SCA V2.2 specifying requirements in order of



**Figure 4 Diagram Illustrating Internal vs. External Interfaces for Waveform Instantiation**

devices and device Radio Services are provided with the set these interfaces are always internal for all states and state transitions.

criticality that are necessary for waveform portability:  
 ➤ **Operating System:** Waveform applications directly use Operating System functions and services provided

by the JTR set thus the requirements associated with them are external requirements affecting waveform portability.

- **Middleware and Services:** The JTR set provides and waveform applications use CORBA middleware functions and services thus the requirements associated with them are external requirements affecting waveform portability.
- **Base Application Interfaces:** All of the requirements for these interfaces apply to waveform instantiation and tear down. They define interfaces between the JTR set objects and waveform objects and these interfaces are necessary for waveform portability.
- **API supplement:** The requirements contained within the API supplement are used to define the interfaces between waveform objects and Radios Services within the JTR set. These interfaces allow waveform objects to interact with JTR Set specific Devices, e.g. INFOSEC, RF, I/O, etc. within the JTR set during waveform execution. The requirements specified in the SCA API Supplement V1.1 are external requirements that affect waveform portability.
- **FileSystem, File, and Log interfaces:** Waveform applications may use files and the log services during operation thus the requirements that apply to these interfaces are necessary for waveform portability.
- **Domain Profile:** The Domain Profile provides the waveform definition during waveform installation onto the set. It is a set of files that contains the information that the JTR set Domain Management uses to instantiate a waveform. The requirements of Domain Profile are external requirements affecting waveform portability.

### 5. REQUIREMENTS NOT AFFECTING WAVEFORM PORTABILITY

The following are the major areas of the SCA V2.2 specifying requirements that are not necessary for waveform portability:

- **Framework Control Interfaces:** The Framework Control Interfaces are concerned with internal JTR set operations such as initializing and registering the persistent devices within the JTR set. Those interfaces and operations are independent of the waveform application, they are clearly internal and are not necessary for waveform portability.
- **Framework Services Interfaces:** The File Manager interfaces are used by the JTR set Domain Management and the Device Managers within the JTR set. The requirements for this interface are not necessary for waveform portability.
- **Security:** The security requirements specified in the SCA V2.2 and SCA Security Supplement V1.1 are

primarily functional requirements internal to the JTR Set and duplicative of NSA requirements. The majority of the security requirements are not necessary for waveform portability.

### 6. CONCLUSIONS AND RECOMMENDATIONS

The analysis used the JTR Set and waveform lifecycles to examine the SCA V2.2 specified interfaces to determine their existence and use during different states of the JTR set and waveform lifecycles. The analysis determined that less than half of the total requirements in SCA V2.2 are necessary for waveform portability as shown in Figure 5. A detailed summary is presented in Table 2 showing the number of requirements and whether or not they are necessary for waveform portability within each section of the SCA document.

As a result of this analysis it is recommended that the

SCA V2.2 Document Sections	Requirements	Not Necessary for WF Portability	Necessary for WF Portability	Total
Base Application Interfaces	Port	0	5	5
	LifeCycle	0	5	5
	TestableObject	0	9	9
	PortSupplier	0	2	2
	PropertySet	0	8	8
	ResourceFactory	0	12	12
	Resource	0	6	6
Framework Control Interface	General	0	1	1
	Application	22	9	31
	Application Factory	46	1	47
	Domain Manager	143	1	144
	Device	42	0	42
	Loadable Device	12	0	12
	Executable Device	18	0	18
	Aggregate Device	7	0	7
	Device Manager	39	0	39
Framework Services Interface	File	0	1	1
	FileSystem	0	20	20
	File Manager	0	39	39
	Timer	16	0	16
	Timer	0	0	0
Domain Profile	Domain Profile	0	10	10
OS	OS	0	2	2
OS	OS	0	185	185
CORBA	CORBA	0	1	1
CORBA	CORBA	0	1	1
Log Service	Log Service	0	37	37
Radio Service	Radio Service	0	10	10
General Application Requirements	General Application Requirements	0	10	10
Application Interfaces	Application Interfaces	0	3	3
Device Profile	Device Profile	11	0	11
HW Critical Interfaces	HW Critical Interfaces	0	2	2
HW Critical Interfaces	HW Critical Interfaces	0	3	3
API Supplement	API Supplement	65	0	65
Security	Security	278	16	294
<b>Total</b>		<b>634</b>	<b>465</b>	<b>1099</b>

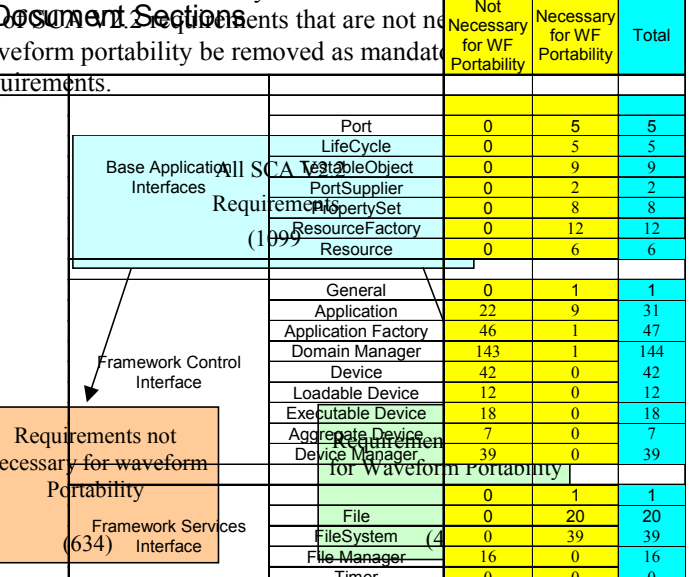


Figure 5 Summary of SCA V2.2 Requirements Analysis

The analysis also showed that real-time data and control paths are required from the waveform implementation-specific hardware devices within the JTR set. These control paths are well-defined APIs within Radio Services provided by the JTR set. Examples of Radio Services are Security, I/O (audio, serial, Ethernet), and File Manager. The implementation of Radio Services are JTR set specific, however, the waveform application interface Service must be defined as a standard to support waveform portability. Radio Services should be defined and agreed to by the JTRS community. Each Radio Service must be specified in the SCA so that Radio Services' interfaces across clusters are consistent.

SCA V2.2 Document Sections	Requirements	Not Necessary for WF Portability	Necessary for WF Portability	Total
Device Profile	Device Profile	0	1	1
HW Critical Interfaces	HW Critical Interfaces	0	3	3
API Supplement	API Supplement	65	0	65
Security	Security	278	16	294
<b>Total</b>		<b>634</b>	<b>465</b>	<b>1099</b>

## 6. REFERENCES

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