ABOVE 2 GHZ COMMON COMMUNICATION SYSTEM ARCHITECTURE

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ABSTRACT

This paper presents a generic Communication System Architecture for a multi-band SATCOM radio that is capable of operating at high data rates and that allows enhancement to support a dynamic network routing capability. Using domain knowledge of the Milstar, AEHF, and SHF SATCOM systems, a functional decomposition is suggested that provides maximum reuse of SCA components for the development of radios with widely varying platform requirements, from stationary ground radios to ship and airborne mounted platforms. A method to assess what requirements each component must satisfy is discussed. Component categories are defined that allow components to be grouped according to their overall purpose and function within the radio. This leads to the establishment of a set of common SCA components that support all radio platforms. A discussion ensues identifying the functions provided by each component along with the key requirements satisfied by each.

1. RADIO REQUIREMENTS

One of the first steps in developing a radio is to understand the requirements that must be satisfied. When attempting to create a common set of components that could be used in a variety of different radios with varying requirements, this task becomes even more difficult. Figure 1 illustrates an example of varying requirements that may need to be satisfied by a waveform in three different radios. As shown in the figure, a radio rarely needs all functionality provided by a given waveform.

There are multiple ways to deal with the variability the different sets of requirements impose on establishing a set of common components that could support all three radio configurations. First, the entire superset of requirements could be imposed on the components, but that would mean including functions not universally needed resulting in greater expense and inefficiencies. A second approach

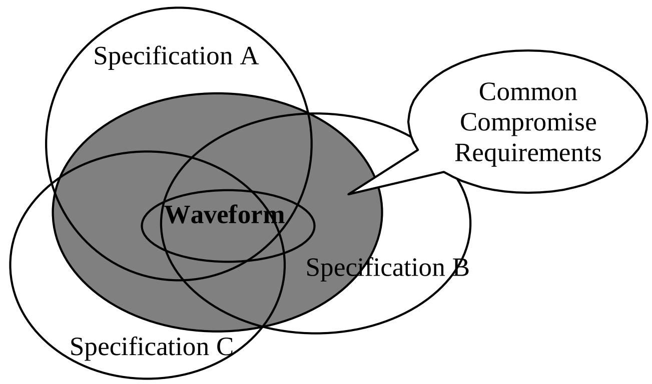

Figure 1. Three Different Sets of Radio Requirements

would be to expand upon the common set of requirements to encompass more, but not all, of the requirements needed by each of the different radios (as indicated by the darker shaded region in Figure 1). This method entails some guesswork to establish the proper set of requirements to include with possible consequences later on when requirements change. A third approach is the componentization of the requirements that also supports nonfunctional requirements such as modularity, flexibility, scalability, etc. This third approach has the added benefit of providing support for multiple, simultaneous waveforms as well as providing a mechanism to easily meet specific mission requirements.

2. DECOMPOSITION METHODOLOGY

The requirements established for the radio components are the input for the next step in the process – a functional decomposition of the requirements into radio components. Figure 2 illustrates this process. The requirements are analyzed and decomposed into a set of functions that the radio needs to perform. These functions are then allocated to components that will reside in the radio. A component may be realized by either hardware or software implementation, or a combination of the two. Due to the higher processing needs in above 2 GHz radios, more components may be

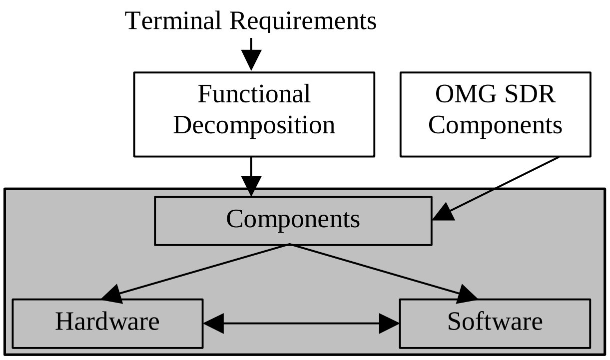

Figure 2. Component Partitioning

implemented in hardware as compared to less than 2 GHz radios. In time, however, the hardware components are expected to migrate toward software solutions.

Figure 2 also shows that consideration will be given to components available from other sources as this process evolves. In general, the decomposition rules are as follows:

- Assign requirements to functions
- Assign functions to components
- Identify dependence of components on categories of requirements (as defined below)
- Reduce dependencies to a single category
  - – Develop components with capabilities that reduce dependencies
  - – Push multiple dependency functions to lowest decomposition level to separate dependencies
- Decompose to primitive component capabilities
  - – Uses building block APIs
  - – Enables portability of components
  - – Enables flexibility to meet specific radio requirements

3. RADIO COMPONENTS

The components within a radio will be grouped based on the category of requirements they satisfy. The categories are: Platform, Waveform, Control, and Network. These categories are an extension of the categories we developed during our system engineering process. That process identified the Platform, Waveform, and Network categories. The software architecture development process has added the Control category. Each of the software categories is described in more detail in the sections that follow. For the purposes of this paper, the architectural framework of a radio refers to the general components and their nominal arrangement. The number and implementation details of the components in specific radio configurations may differ.

The remainder of this paper describes a representative SCA software architectural framework for an above 2 GHz SATCOM radio that may be implemented for any platform and any waveform(s), network(s), or control system(s). The architectural elements consist of the radio components

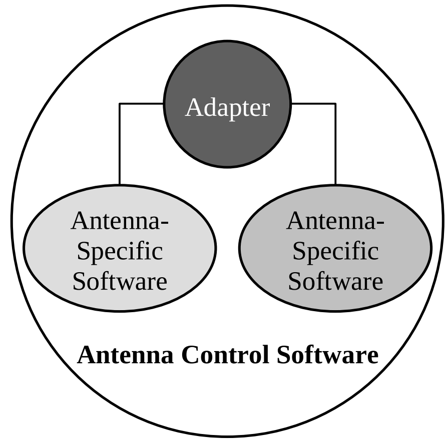

Figure 3. Example Antenna Component Design

outlined below. A specific radio implementation is developed by assembling a specific set of radio components into a specific configuration. When configuring a radio, it is necessary to consider how it will be used such that the appropriate hardware support can be provided.

3.1. General Component Design

In general, components abstract the uniqueness of individual hardware components, waveforms, networks, or control systems. For example, a physical radio might contain two different antenna types. A single software component would represent these two hardware entities and encapsulate their unique attributes. This encapsulation is accomplished by using a subcomponent design pattern which consists of an adapter and the antenna specific software component(s) as shown in Figure 3.

4. PLATFORM COMPONENTS

The platform components contain all of the hardware, interfaces, and low level software (e.g., device drivers, etc.) required to support the radio applications. All of these components are SCA Devices or Services. The platform components provide a framework to which waveform, network, or control components are connected. A specific platform is procured with its mission in mind. In this way the platform is sized for the number of planned waveforms, networks, and types of control. This platform will then include the components required to support its intended use.

4.1. Antenna Control Software (ACS)

4.1.1. ACS Overview

The ACS services requests to control the antenna(s) in specific modes of operation (e.g., point, spiral, track, etc.). One aspect of this function is to isolate the antenna(s) from the rest of the software so that it is sufficient to only request an operating mode and pointing position and ACS determines how to control the antenna(s) in the requested mode. ACS combines satellite specific pointing information with current navigation inputs to generate antenna pointing angles, determines when antenna handover is needed based on blockage tables, and performs antenna spatial tracking using input Receive Signal Level (RSL) values.

4.1.2. ACS Requirements
Key system level performance requirements allocated to the ACS include the following services:

- Performs antenna control for one or many antennas on a single platform
- Performs antenna control for all antenna types (e.g., single band, multi-band, etc.)
- Performs antenna control for all platforms (e.g., ship, shore, sub, vehicle, airplane, etc.)
- Performs antenna control in all modes (e.g., point, spiral, track, test, slew, etc.)
- Performs simultaneous control of multiple antennas for a single waveform
- Determines antenna blockage conditions and initiates antenna handovers
- Uses processed navigation data to maintain antenna pointing under platform motion
- Monitors antenna health (i.e., status and self test)
- Monitors radome hatch interlocks

4.2. Amplifier Software (AMS)

4.2.1. AMS Overview
The AMS determines the type of amplifier(s) in use, performs the initialization associated with the amplifier(s), implements warm-up if necessary to support 'instant-on' operation in support of antenna handovers or start of uplink acquisition. Thereafter, AMS services requests to enable/ disable the amplifiers and to set the power level as indicated by the requests. A single instance of AMS controls amplifiers for a single band in a system that supports simultaneous multi-band operation.

4.2.2. AMS Requirements
Key system level performance requirements allocated to the AMS include the following services:

- Provides amplifier control for all amplifier types (e.g., SSA, TWT, etc.)
- Provides simultaneous control of multiple amplifiers
- Provides amplifier mode control (e.g., off, initialization, warm-up, stand-by, on, test, etc.)
- Provides transmit power level control and leveling
- Monitors amplifier health (i.e., status and self test)

4.3. Built-In Test Software (BTS)

4.3.1. BTS Overview
The BTS coordinates the online collection and analysis of fault status information. BTS provides a fault isolation capability in the radio for the startup, online, and offline modes of operation. BTS is responsible for responding to critical faults where safety or security may be compromised. The BTS fault isolation tables are loaded to reflect the current hardware along with a menu of potential outputs to be reported to the operator.

4.3.2. BTS Requirements
Key system level performance requirements allocated to the BTS include the following services:

- Performs system status collection
- Performs system status analysis
- Performs fault isolation
- Monitors system inputs
- Initiates alarms and operator messages

4.4. Clock Administration Software (CAS)

4.4.1. CAS Overview
The CAS recovers, sets, maintains, adjusts, and provides Time of Day (TOD). The CAS handles both UTC and Milstar TOD formats.

4.4.2. CAS Requirements
Key system level performance requirements allocated to the CAS include the following services:

- Sets and maintains system time
- Recovers system time after power outage
- Supports time setting from external sources (e.g., cesium, GPS, rubidium, operator, etc.)
- Monitors time source health (i.e., status and self test, if available)

4.5. Communications Plan Executor Software (CPS)

4.5.1. CPS Overview
The CPS sequences through a series of data sets executing them one at a time to provide an auto-processing function. CPS executes the selected communications plan, which includes logon modes, port configurations and channel configurations.

4.5.2. CPS Requirements

Key system level performance requirements allocated to the CPS include the following services:

- Accepts Communication Plans, including adaptation data
- Manages the data sets that make up a Communications Plan
- Executes Communications Plan sequences
- Initiates satellite Antenna Controller functions
- Initiates satellite Communications Controller functions
- Supports ad hoc Communication Plan modifications

4.6. Fabric Switch Software (FSS)

4.6.1. FSS Overview

The FSS establishes a physical/logical connection between the radio Control, Network, and Waveform components and the radio platform. This becomes the backbone used for all radio component connections.

4.6.2. FSS Requirements

Key system level performance requirements allocated to the FSS include the following services:

- Initializes the switch fabric
- Configures the switch fabric to support routing
- Monitors the traffic and health of the switch fabric
- Detects bandwidth problems

4.7. Mode Sequencer Software (MSS)

4.7.1. MSS Overview

The MSS is used in systems that provide simultaneous support for multiple waveforms. The MSS coordinates the operation of all embedded software in all modes of operation including startup/initialization, offline BIT, downlink acquisition and tracking, uplink acquisition and tracking, and satellite logon/logoff. MSS supports both manual and automatic sequencing operations.

4.7.2. MSS Requirements

Key system level performance requirements allocated to the MSS include the following services:

- Performs system configuration/initialization
- Downloads radio application software
- Maintains system mode
- Coordinates mode transitions
- Supports manual and automatic sequencing
- Conducts orderly power down
- Allocates antenna and amplifier resources

4.8. Navigation Control Software (NCS)

4.8.1. NCS Overview

The NCS interfaces with available navigation hardware devices. NCS determines the type of navigation devices available, interfaces with them to obtain the inputs, and provides them to other functions as needed. NCS performs required calculations to compensate for any navigation input latencies.

4.8.2. NCS Requirements

Key system level performance requirements allocated to the NCS include the following services:

- Interfaces with various navigation hardware (e.g., analog, digital, Inertial Navigation System, etc.)
- Supports manual navigation inputs
- Performs latency compensation calculations
- Provides processed navigation data for the radio (e.g., transpolar coordinates, attitude, speed/velocity, position, periscope bearing, etc.)
- Monitors navigation data inputs
- Monitors navigation source health (i.e., status and self test)

4.9. Power Supply Control Software (PPS)

4.9.1. PSS Overview

The PSS provides services for monitoring and turning on/off the power for system hardware. Power sequencing is done by a control or management function.

4.9.2. PSS Requirements

Key system level performance requirements allocated to the PSS include the following services:

- Provides individual power control
- Controls hardware initialization
- Monitors Power Distribution Unit status
- Controls main power (off only)

4.10. Pointing and Ranging Software (PRS)

4.10.1. PRS Overview

The PRS calculates satellite visibility and pointing information from a single ephemeris format. If a system were to accept multiple ephemeris formats, it would have an instance of PRS for each format. Satellite range and range rate are also calculated. PRS also determines and reports when ephemeris is out-of-date.

4.10.2. PRS Requirements

Key system level performance requirements allocated to the PRS include the following services:

- Determines satellite visibility
- Determines satellite pointing
- Determines satellite range and range rate
- Determines best agile beam number
- Determines leap seconds
- Accepts ephemeris data
- Maintains multiple ephemeris data storage
- Supports ephemeris data output
- Initiates ephemeris data updates
- Performs satellite antenna coverage calculations

5. WAVEFORM COMPONENTS

Waveform components perform the data and radio frequency manipulations required to move user data to and from a signal in space. The Waveform components may be SCA Waveforms, Devices, or Services. The platform components provide a plug and play interface for various waveform components. The specific waveform components in use determine what type the radio is. For example, a radio using an X-band SATCOM waveform would be considered an X-band SATCOM radio. If the waveform is changed to a Milstar waveform, the radio would become a Milstar radio.

5.1. Modem Software (MDS)

5.1.1. MDS Overview

The MDS is a set of components that provide modem functions, applicable to many different waveforms. MDS configures and controls the modem to implement the desired uplink and downlink channel baseband data manipulations including coding, interleaving, and modulation. MDS loads and initializes all modem downloadable components (e.g., FPGAs, DSPs, etc.) MDS monitors decoder metrics to determine when valid downlink data is being received on a channel and handles the processing associated with the modem channels. MDS coordinates the generation of TRANSEC key streams and uses the key streams to apply time/frequency functions to the user data, access control messages, etc. MDS controls the generation of clocks and performs DL time/frequency tracking. MDS supports antenna tracking by providing RSLs to the ACS. MDS also performs the specialized security functions. MDS maintains the set of keys used for all radio operations. It controls the operation of the crypto device to load keys, generate desired key streams, and distribute the resulting key streams. It purges obsolete keys and provides the capability to encrypt/ decrypt access control messages.

5.1.2. MDS Requirements

Key system level performance requirements allocated to the MDS include the following services:

- Controls modem hardware
- Performs modulation/demodulation
- Performs encoding/decoding
- Performs interleaving/deinterleaving
- Performs acquisition and tracking (i.e., frequency and time) functions
- Provides signal measurements for antenna tracking
- Performs channel maintenance
- Performs signal processing
- Supports antenna handover time changes
- Provides access control message queuing/filtering
- Provides access control message CRC generation/ detection
- Supports access control message encryption/decryption
- Supports access control message cover/decover
- Supports TRANSEC generation and key functions
- Conducts modem self test
- Supports tracking telemetry and control

5.2. Resource Administration Software (RAS)

5.2.1. RAS Overview

The RAS coordinates operations between the Waveform components including management and allocation of the radio's uplink resources and port usage. RAS processes each notification from MDS as to when an uplink access control message is output and routes it to the appropriate Waveform for processing.

5.2.2. RAS Requirements

Key system level performance requirements allocated to the RAS include the following services:

- Coordinates waveform components
- Manages radio downlink/uplink resources
- Directs access control message encapsulation
- Keeps track of pending access control messages
- Coordinates simultaneous waveform operations
- Interfaces with MDS for channel set-up and control
- Performs protocol scheduling
- Performs front end processing for waveform functionality
- Conducts satellite loopback testing
- Initiates rekey requests

5.3. Waveform Access Control Software (WAS)

5.3.1. WAS Overview

The WAS provides the sequencing control to implement the access control protocols with a processing satellite.

5.3.2. WAS Requirements

Key system level performance requirements allocated to the WAS include the following services:

- Parses received access control messages
- Generates access control messages for transmit
- Implements access control protocols

6. CONTROL COMPONENTS

The control components provide user control and monitoring of the system. The platform components provide a plug and play interface for various control component implementations. The control components are either SCA Services or Devices.

6.1. Operator Control Software (OCS)

6.1.1. OCS Overview

The OCS interfaces to the various operator interfaces. OCS determines the active operator device and enables it for radio control. OCS is responsible for collecting messages and reporting to the Operating Environment for data logging. OCS supports a MIB for relay of external commands/status. OCS also supports the handling and routing of data sets from other systems (e.g., MPE).

6.1.2. OCS Requirements

Key system level performance requirements allocated to the OCS include the following services:

- Monitors/selects active Operator Interface Unit
- Supports Operator Interface Unit devices (e.g., keypad inputs, display, file I/O, alarm, etc.)
- Provides user and maintainer displays
- Supports remote Operator Interface Units
- Provides an SNMP client
- Enforces operator screen execute restrictions
- Supports the data recording interface
- Maintains history files
- Supports engineering screens

7. NETWORK COMPONENTS

Network components provide the user data interface for the radio and between radio components. The platform components provide a plug and play interface for various Network components. The Network components are either SCA Services or Devices. The capabilities of network components may vary from providing a single serial interface to an Ethernet router. This provides the radio a dynamic routing capability.

7.1. Baseband Control Software (BCS)

7.1.1. BCS Overview

BCS initializes and configures the baseband ports based on database tables during radio startup. BCS initializes and initiates associated processing as requested during channel setups and/or testing. BCS supports circuit switched and/or packet switched data processing for baseband data by accumulating (e.g., elastic stores), packetizing, flow control, and routing data between ports and the modem. Radios that include both a Red and Black side would have two instances of this component.

7.1.2. BCS Requirements

Key system level performance requirements allocated to the BCS include the following services:

- Configures baseband ports
- Controls user network interface
- Supports elastic stores
- Performs user data packetizing
- Performs baseband signal monitor and control
- Supports required signaling for external devices (e.g., TDMA Interface Processor, etc.)
- Supports baseband loopback
- Supports COMSEC stream generation
- Supports COMSEC key functions
- Supports encryption/decryption of user data
- Monitors baseband health (i.e., status and self test)

8. CONCLUSION

The SCA software components presented in this paper represent a set that can fulfill the requirements associated with an above 2 GHz multi-band SATCOM radio. Until these components are actually used in a wide variety of different radios and platforms with varying requirements, it remains to be seen if they will live up to their promise. As this software is reused in more and more radios, it will evolve into the envisioned final product.