SOFTWARE COMMUNICATION ARCHITECTURE (SCA) FOR ABOVE 2 GHZ SATCOM

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ABSTRACT

Rockwell Collins has demonstrated an above 2 Gigahertz (GHz) beyond line of sight Satellite Communication (SATCOM) radio that implements the Software Communication Architecture (SCA) for a Military Satellite Communication (MILSATCOM) Waveform. The demonstration system was used to verify the capability to implement Military Strategic, Tactical And Relay (MILSTAR) waveforms using the SCA. The project included the use Commercial Off The Shelf (COTS) Portable Operating System Interface (POSIX) compliant operating system and open source Common Object Request Broker Architecture (CORBA) Object Request Broker (ORB) to enhance the porting of a complex waveform. The system was used as a proof of concept demonstration for the MILSTAR waveform Low Data Rate (LDR), as well as a test platform for high data rate analysis. This paper discusses the design and integration, porting issues and lessons learned from the project. Presentation material will include future goals and ongoing activity related to high speed data communications using 1 Gigabit (Gb) Ethernet for high speed satellite communications that exceed those of traditional High Frequency (HF) / Ultra High Frequency (UHF) / Very High Frequency (VHF) waveforms.

1. INTRODUCTION

Maximizing technology portability and reuse, which results in minimized development costs, is the driving force behind the Joint Tactical Radio System (JTRS) and SCA compliancy mandate. This paper describes methods used to achieve significant technology reuse and portability between JTRS/SCA-compliant developments and identifying potential roadblocks to future growth expected with the higher data rates associated with the Extremely High Frequency (EHF) waveforms.

2. SOFTWARE COMMUNICATION ARCHITECTURE (SCA)

The SCA defines standard interfaces that allow waveform applications to run on multiple hardware sets. The SCA defines a Core Framework (providing a standard operating environment) that must be implemented for all SCA capable hardware environments. The Core Operating Environment (COE) consists of a POSIX compliant Operating System (OS) and CORBA ORB. Interoperability among radio sets is enhanced because the same base waveform software can be ported to all radio sets. Not all Joint Tactical Radio (JTR) hardware is the same, but the environment in which the software is executed must support the SCA. SCA compliance alone is not enough to allow for easy portability. JTR requirements must be taken in to account to allow for hardware (HW) and platform portability. SCA systems that do not comply with the JTR requirements are more likely to incur software portability issues.

3. COMPLIANCY OVERVIEW

On June 17, 2003 the Assistant Secretary of Defense (ASD) for Command, Control, Communications, and Intelligence (C3I) signed a Radio Frequency (RF) Equipment Acquisition Policy directing that all radio systems and associated waveforms operating at or above 2 Megahertz (MHz) "are required to be developed in compliance with JTRS/SCA." [1]

3.1 JTRS Compliancy Standards

Specific JTRS compliancy guidelines are defined within the JTRS Operations Requirement Document (ORD)[2]. This document, however, does not address waveforms above 2GHz. JTRS compliance for above 2GHz waveforms may be provided in a future replacement to the ORD.

Rockwell Collins evaluation of the SCA and the JTRS ORD has derived the following key suggested requirements for increasing the portability of above 2GHz solutions. These Rockwell Collins suggestions for above 2GHz may be more restrictive than what is ultimately mandated.

[1] Assistant Secretary of Defense for Command, Control, Communications, and Intelligence Memorandum, Subject: Radio Acquisition Policy, dated June 17, 2003.
[2] JTRS ORD V3.2, dated 9 April 2003

Strict adherence to the SCA:

- CORBA
- Core Framework
- POSIX Compliant Operating System
- APIs (Security, Radio Management, HAL-C, etc.)

Strict adherence to JTRS Cluster I HW standards:

- Ethernet backplane
- Simple modular approach, i.e. Network Information Security (INFOSEC) Unit (NIU) + Transceiver + Power Amplifier (PA) + antenna
- National Security Agency (NSA) Certified Programmable Crypto
- Multiple Independent Crypto Channels to support Multi-Level Security
- Interfaces for various platforms (e.g. MIL-STD 1553, RS-232, RS-422, RS-423, RS-485, Ethernet, etc.)
- Modem Hardware Abstraction Layer (MHAL)

Define strict 2GHz Interfaces

- Antenna Control
- Standard IF

3.2 SCA Compliancy Standards

The SCA specification establishes an implementation-independent framework for the development of JTRS software configurable radios. The SCA and the JTR ORD work in harmony to produce a specification to which hardware and software are developed to provide an environment for Software Defined Radios (SDR).

Specific SCA compliancy guidelines for software and waveforms below 2GHz are defined in the Software Communications Architecture document release 2.2.1[3]. SCA release 3.0 provides compliancy guidelines for extension to waveforms such as antenna control and a Hardware Abstraction Layer for hardware Connectivity (HAL-C).

The SCA Hardware (HW) Framework tells the designer what minimum design specifications must be met by hardware devices. These specifications assure software written to the SCA guidance will run on SCA compliant hardware. However, the HW Framework in itself is not enough to force portability for software.

The JTRS program recognized this short coming and developed the Modem Hardware Abstraction Layer. The MHAL provides an abstraction layer between the modem hardware and modem software. It creates well defined software interfaces for communication between the modem specific hardware components.

The MHAL, as well as other interface specifications, were developed on JTRS. Since the JTRS is composed of loadable waveforms, radio sets, and network management software, the portability of all these components is dependant on well defined interfaces.

4. OVERVIEW OF MILSTAR LDR DEMO

This section provides an overview of past (and ongoing) JTRS/SCA-related proof-of-concept programs undertaken by Rockwell Collins. The success of these programs, as well as lessons learned during their execution, provides a significant basis for the analysis. JTR/SCA compliance levies significant performance requirements on the target hardware environment as related to raw processing bandwidth and data throughput. The following sections also analyze the ability to design to accommodate these performance requirements.

4.1 Rockwell Collins MILSTAR LDR Demo

This Rockwell Collins Internal Research and Development (IR&D) program was a proof-of-concept demonstration to evaluate the feasibility of a complex Above 2GHz waveform (MILSTAR LDR) implementation within a JTRS and SCA environment.

Results of this effort are very pertinent to SCA feasibility discussion, as it directly addresses the implementation of a Above 2GHz waveform as required for future JTRS programs.

This effort required the following significant accomplishments:

- Procurement and use of a JTRS Vehicle Adapter
- Development of a prototype JTR-style Wideband Receiver/Exciter Modem Module (WB REMM) to implement the MILSTAR LDR waveform
- Development of a prototype JTR-style NIU to provide the SCA Operating Environment and required cryptography for MILSTAR LDR
- Port of existing SCA version 2.2 Rockwell Collins JTRS Core Framework (RCCF) software into the demonstration environment [Note: The software ported for this program originated from software being developed during the Step 2a, 2b programs. The CJCF was developed in C++ and was updated from SCA 2.0 to SCA 2.2 when reused. Included in this development was the port of commercial open source CORBA Object Request Broker ORB technology. The CORBA ORB used in the quick demo is OmniORB. Rockwell Collins NIU environment consisted of the CJCF, VxWorks – POSIX operating system and the CORBA ORB open source OmniORB technology.
- Port of the MISTAR LDR waveform into the SCA environment

[3] Software Communications Architecture Specification, JTRS-5000SCA V2.2.1 April 30, 2004

4.2 Rockwell Collins MILSTAR LDR Highlights

MILSTAR LDR Quick Demonstration Highlights:

- Portability of JTR-style Network INFOSEC Unit (NIU) and Wideband Receiver Exciter Modem Module (WB REMM) prototype hardware into the actual JTRS Vehicle Adapter Environment
- Portability and functionality of the Rockwell Collins SCA 2.2 Core Framework
- Migration of MILSTAR LDR software to SCA 2.2
- Portability of MILSTAR LDR waveform onto new hardware target
- Successful development of all eXtensible Markup Language (XML) and required devices
- Adequate processing bandwidth and throughput to support the waveform, in a environment, using CORBA and an open source CORBA ORB
- Execution of the MILSTAR LDR waveform on the JTRS hardware target
- Interoperability proven with a Point-to-Point (PTP) voice call to a legacy SATCOM terminal

This effort successfully culminated with operation of the MILSTAR LDR waveform on a JTRS-style hardware target within the SCA operating environment, and a subsequent interoperability demonstration with a legacy Single Channel Anti Jam Man Portable (SCAMP) MILSTAR terminal. A PTP call was setup through a MILSTAR Satellite Simulator (SATSIM) between the two terminals.

4.3 Lessons Learned

The open source OmniORB CORBA ORB performance was sufficient for the purposes of the research. Surprisingly, the ORB was not a major factor in waveform performance. The major timing concerns ended up being processor loading and task priorities. When managing the tight timing constraints of MILSATCOM waveforms the task priorities had to be managed carefully in order to achieve the optimal configuration. Proper working knowledge of CORBA ORB technology, threading models, and data types is also key to providing high speed low latency designs. Having access to the ORB source code is also helpful for careful timing analysis.

The success of the demo was the ability to leverage existing designs for hardware and software, apply lessons learned from previous and ongoing developments and also apply them to the project. Reuse of the Collins JTRS Core Framework (CJCF) from the JTRS 2A and 2B program helped with the quick integration of the Core Framework. The CJCF was ported from one OS and Commercial ORB to a different OS and open source ORB. The OS port was very easy; however the ORB port was more difficult. Various vendor specific ORB macros and data types crept in to the CJCF. The code had to be scrubbed to remove all vendor specific ORB references. However, without this previous code development to start from, the integration and development would have taken much longer. The ability to consult with JTRS SCA experts and Waveform developers provided useful knowledge that reduced integration time.

The ability to reuse the SCA-architected MILSTAR LDR code significantly reduced program integration time. For the IR&D project, the MILSTAR LDR C++ code base was ported from a non-SCA implementation. However, the code base was originally developed to be in the spirit of SCA 2.0. The code was virtually SCA compliant; it just lacked a CORBA transport. This allowed the porting of the code to a full SCA environment to be much easier.

Having all the software, hardware and systems engineers with extensive MILSATCOM and SCAMP terminal knowledge in house certainly helps, too.

5. BACKPLANE ANALYSIS

The predominant physical transport for networking today is 100Base-TX Ethernet. This is usually transmitted over a category 5 twisted pair cable. The data rates of future wideband waveforms exceed the 100 megabits per second transfer rate offered by 100Base-TX Ethernet. Thus, an alternative physical transport will be necessary.

The JTRS Rotary Wing Vehicle Adapter being built by Rockwell Collins contains a 1000Base-T Ethernet connection from each connector to the NIU. 1000Base-T Ethernet allows for a data transfer rate of a gigabit per second. The data transfer at the Ethernet Physical layer is not equivalent to the data transfer at an application layer since each network layer adds overhead to the transfer.

5.1 Analysis

Rockwell Collins set up a very controlled test to determine max streaming data rates in a JTRS SCA Radio environment between two physically separated processors. The tests were conducted with both 100Base-TX and 1000Base-T physical Ethernet transports. The test consisted of timing the round trip of a client request for a bounded CORBA sequence of various sizes and data types. The server would simply return the requested CORBA sequence. It was determined that the size of the data sequence significantly affected the achievable data rate. This is reasonable when there is a fixed overhead associated with a CORBA data packet. The test environment includes the use of the MILSTAR LDR hardware and software environments using 533 MHz Power PC 440GX, operating system using VxWorks 5.5 and CORBA ORB using omniORB 4.0.3.

The test data was mapped to a best fit linear graph and algebraic functions for estimation were obtained. The functions obtained are reasonably accurate for data sequence sizes less than 65,000 bytes.

$$\text{100Base-TX}: \; y = (\frac{.205\mu S}{B} \cdot x) + 650\mu S$$

$$\text{1000Base-T}: \; y = (\frac{.103\mu S}{B} \cdot x) + 350\mu S$$

uS = microsecond
B = Byte
y = total time in microseconds (*uS*).
x = data transfer in bytes (*B*)

5.2 Analysis Conclusions

Using the obtained functions for estimation, we can determine the effects of modifying data packet sizes for both 100Base-TX and 1000Base-T physical transports.

For example, the transfer of a 32,000 byte CORBA sequence on 100Base-TX would take 7210 microseconds, resulting in a data rate of 35.50 Mbps. However, transferring a packet of 8000 bytes on 100Base-TX takes 2290 microseconds, or 27.94 Mbps. This is over a 20% reduction in throughput. Although, nearly 28 Mbps is sufficient to operate at LDR, MDR and XDR data rates, including the actual communication data as well as any INFOSEC/TRANSEC information necessary for communications.

The transfer of a 32,000 byte CORBA sequence on 1000Base-TX would take 3646 microseconds, or 70.21 Mbps. If the sequence size is reduced to 8000 bytes on 1000Base-TX, the result transfer is 54.5 Mbps. Again, the result is a significant reduction in throughput.

Since the physical transport increased by a factor of 10, but the throughput only doubled, it is reasonable to conclude that the limiting factor is not the physical layer on the 1000Base-T tests. The computer boards used for the tests can only create data packets at a certain speed. It is concluded that the throughput limit is a result of the processor speed not a physical channel limit.

In a case where large data rates are required, the SCA allows for modification of the transport mechanism from the standard CORBA GIOP/TCP/IP stack. These tests proved that the current generation of hardware will allow for these high data rates by switching the networking communication stack.

In additional investigations in to the throughput limitations, tests were conducted to determine the maximum throughput for the same system using a different communication stacks. Tests were conducted using the SCA preferred CORBA General Inter-Orb Protocol (GIOP). GIOP is a protocol which allows the standard communication between CORBA ORBs. It is not itself a complete transport, it must operate with an additional lower level protocol, such as the Transmission Control Protocol / Internet Protocol (TCP/IP). Tests were also conducted using just a TCP/IP communication transfer, without CORBA. And finally, tests were conducted using the User Datagram Protocol (UDP). All tests were conducted on the 1000Base-T physical layer.

The remarkable results were the throughput rates achievable with a UDP/IP transfer mechanism. The test system computer processors were sufficient to sustain a phenomenal rate of over 400 Mbps of end data throughput.

Final conclusions are that Ethernet bus speed improvements from 100 Mbps to 1000 Mbps will be needed to perform higher data rates and current HW limitations allows for future growth over 400 Mbps.

REFERENCES

[1] Memorandum for service acquisition executives Under Secretary of Defense (Comptroller) Assistant Secretary of Defense (SO/LIC), Inspector General of the Department of Defense, Directors of the Defense Agencies, Director, Joint Staff

[2] JOINT TACTICAL RADIO SYSTEM (JTRS), OPERATIONAL REQUIREMENTS DOCUMENT (ORD), REVISION # 3.2, 11 March 2003

[3] Subject: Radio Frequency (RF) Equipment Policy, Date June 17, 2003

[4] SUBJECT:" Radio Frequency (RF) Equipment Acquisition Policy Reference ASD(C3I) Memorandum, SUBJECT: Radio Acquisition Policy, dated August 28, 1998

[5] Software Communications Architecture Specification JTRS-5000 SCA V3.0 August 27, 2004

[6] Specialized Hardware Supplement to the Software Communication Architecture (SCA) Specification JTRS-5000 SP V3.0 27 August 2004

[6] Application Program Interface Supplement to the Software Communications Architecture Specification JTRS-5000API V3.0 August 27, 2004

