A Reference Architecture for Payload Reusable Software (RAPRS)

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Goals & Approach

♦ Goals
• Design a software architecture that can be reused across a broad range of payloads
  → Eliminate custom, single-use-only designs
  → Provide synergy by sharing software, developers, and tools

♦ Approach
• Apply modern software architecture design styles
  → Support distributed processing architectures
• Identify current technologies and standards for implementing in highly-embedded systems
  → Systems that have a fraction (<1%) of the processing resources of desktop computers
Motivation

♦ SNL is developing a standard data processing architecture called Joint Architecture Standard (JAS) and a new software architecture is needed to support it

♦ This would lower cost and risk to all programs by providing a mature platform to build payload software on

♦ Internal Research & Development funding was available

♦ We have a unique opportunity in which some of our payloads needed to be redesigned
Features of JAS

♦ JAS is a modular, node-based architecture that uses
  • High-speed serial data interfaces
  • Industry standard protocols
  • Hardware and software building blocks

♦ Nodes
  • Several processing nodes
  • Mass SDRAM & non-volatile memory nodes
  • Have 2 common HW components
    → System monitor & communications (SMAC) port
    → Point-of-load (POL) power converters
  • Number and type are determined by system requirements

♦ JAS supports
  • Rad-hard ASIC processors
  • FPGA-based soft-core signal processors
  • HDL for custom logic designs

♦ JAS offers COTS-based development and test environment for rapid system demonstration.
Software Requirements

♦ Required

• Design a modular, scalable, and reusable platform
• Support payloads with **significant** onboard processing needs
  → Command and Data Handling (C&DH)
    – Support tens of thousands of command and telemetry parameters
  → Complex instrument control
  → Sensor data processing from kbits/s to Mbits/s
• Support payloads in a variety of orbits from LEO to GEO
  → Real-time and intermittent ground system interaction
• Support new and legacy ground systems

♦ Desired

• Dynamically update software without system interruption
  → Support new missions through software reconfiguration
Minimum Hardware Configuration

♦ CPU – Hard or soft-core processors
  • 32-bit processor with hardware floating point unit, 75+ MHz
    → LEON3 SPARC, PPC-603, PPC-750

♦ RAM – Depends on application requirements
  • 16MBytes to 64MBytes

♦ NVRAM – Store hardware and software applications
  • 1Mbyte to 64Mbytes

♦ PROM – Boot loader and applications
  • 128Kbytes to 256Kbytes

♦ Network – Depends on mission requirements
  • Nominally >10Mbps for C&DH
Platform Abstraction Services (PAS) provide a standardized and abstracted communication interface to all payload hardware.

Payload Common Services (PCS) provide many of the functions necessary for controlling a payload and communicating with the ground system.

Payload Specific Services (PSS) are the functions that are unique for each payload.

A layered architecture allows RAPRS to be reusable on different hardware.
Event-Driven Service Oriented Architecture

♦ Combines modular services of SOA with an event-driven architecture to create a “reactive system”

♦ ED-SOA decouples software services and simplifies the interfaces between them
  • Services send and receive “events” through a publish/subscribe interface
  • Events are routed based on “topics” to subscribing services

♦ An Embedded Service Bus (ESB) allows services to be seamlessly distributed across JAS nodes

Even-Driven SOA provides the modular and scalable framework for RAPRS
A Software Service

♦ Services are defined based on architecture analysis

♦ Implemented in terms of a standard framework
  • Service Function
  • Service Interface

♦ The framework is implemented with:
  • An Active Object (AO) Framework provides the event-driven execution framework
  • Data Distribution Service (DDS) provides the ESB
Platform Abstraction Services

- Provide standard interfaces to upper-layer services for accessing payload hardware
- Access payload hardware regardless of location or communication interface
  - Hides the details from upper-layer services
- Based on CCSDS-SOIS
  - Services APIs are implemented as events
- Subnetwork Layer Services can be implemented in hardware (VHDL) or software
Payload Common Services

- Translate between F/G protocol and payload events
- Execute commands
- Collect and report SOH data
- Manage and distribute time
- Upload and store HW/SW apps.
- Collect and report messages
- Read/Write to a data recorder
- Deploy HW/SW apps.
- Monitor payload HW/SW state
- Distribute configuration data
- Templates for Application and Device Drivers

Programs can pick and choose the services they need
Embedded Scripting Languages

- An embedded scripting language allows services to be customized at runtime making them more reusable

- How it works
  - Develop the service with basic functions and hooks to run scripts
  - Implement program-specific functions in the scripting language
  - At run-time a reference to the appropriate scripts is passed into the service

- Examples
  - Commanding Service runs scripts to perform “complex” commands
  - Gateway Service executes scripts to translate between events and the F/G communication protocol

- Advantages
  - Services are more reusable
  - Scripts can change without having to recompile the software

- Disadvantages
  - Performance
  - Capability is limited by the features of the scripting language

- Lua can extend programs written C, C++, Ada, Java and others
Payload Configuration and Interface

- The payload is defined in terms of XML data files
  - CCSDS-XTCE is used as the schema
- An XML Data Binding compiler converts XML elements to software objects
  - Creates the classes as well as parsing and serialization code
  - Code Synthesis XSD/e XML Schema to C++ Compiler
- Flight software uses the software objects to manage the configuration and state of the payload
- Ground software uses the software objects to send commands and process telemetry data
Current R&D efforts have focused on proving the JAS hardware
Software activities focused on developing infrastructure and demonstrating the architecture
  • Demonstrated the layered architecture and abstraction
  • Demonstrated the event-driven framework using Rhapsody OXF
  • Implemented many of the Platform Abstraction Services
    → Spacewire network configuration and monitoring
    → RMAP and CCSDS packet protocols
    → Time distribution
    → Remote file system access
    → Loading bit-files applications in FPGAs
  • Testing with RTEMS and Linux running on the LEON3
  • Porting Opencvsplice DDS to RTEMS to demonstrate an ESB
  • Gathering resource and performance data
Future Plans

♦ New programs are planning to use JAS/RAPRS and we are working on architectural concepts for them

♦ Continue to mature the framework and develop a library of new services over the next 1-2 years
  • Finish implementing the Payload Abstraction Services
  • Detailed design of the Payload Common Services

♦ As programs adopt this architecture, the library will grow so others can take advantage of existing services
References

♦ Opensplice DDS
  • http://www.prismtech.com/opensplice

♦ IBM Rational Rhapsody OXF
  • http://www.ibm.com/software/awdtools/rhapsody/

♦ Quantum Platform
  • http://www.state-machine.com/qp/

♦ XML Data Binding
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♦ CodeSynthesis XSD/e
  • http://www.codesynthesis.com/products/xsde/

♦ XTCE
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  • http://public.ccsds.org/publications/archive/660x0b1.pdf

♦ Lua
  • http://www.lua.org/about.html