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Welcome to the Mercury / Nova SCA Tutorial Overview

Software Defined Radio Technical Conference
November 17, 2003

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Mercury / Nova Alliance

- Mercury Computer Systems is a leading supplier of scalable high performance systems for embedded real-time signal processing applications. This technology enables rapid development and re-configuration of high performance SDR systems using COTS components
- Nova Systems Solutions is a division of Nova Engineering Inc. specializing in applied research in SDR Markets
- Facilitators
  - Rick Woodring – Nova Systems Solutions
  - Murat Bicer – Mercury Computer Systems
  - Ron Gallerie – Mercury Computer Systems

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Agenda

- What is SCA?
- What does it mean?
- SCA Technical Content
- Examples & Demonstrations
- What is the future direction of SCA?

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What is SCA?

- Stands for *Software Communications Architecture*
- It is an open, non-proprietary specification i.e. it is a set of rules that constrain the design of Software Defined Radios
- It is one of the elements of the software defined radio that will increase interoperability of radios i.e. the ability of radios to talk to each other
- It is required by the JTRS, and then validated by the JTEL, for firms that want to be involved in large contracts for the government

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SCA Viewpoints

Waveform Developers

- Focus on the knowledge and skills required by the SCA
- Related Skills
  - UML/Object Orientation
  - CORBA
  - XML
- Observe waveforms in the SCA environment

Hardware Engineers

- How to interface hardware with the emerging software requirements in the radio business

Managers

- What direction to provide and where resources and infrastructure need to be allocated

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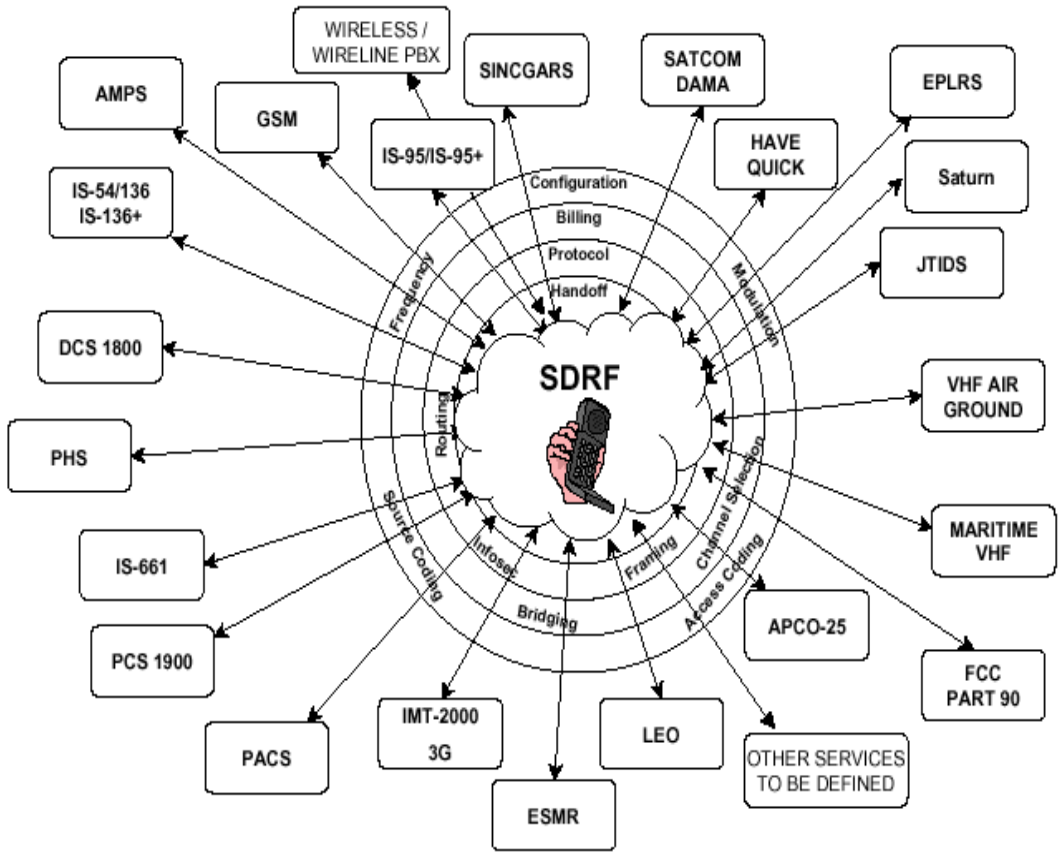
Why SDR?
Multi-Billion Dollar Market for …

An SDR base station can communicate with any kind of terminal (i.e. Cellular, Telephone, PDA) by downloading new software



An SDR terminal can be used for any wireless communication by downloading new software

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SDR Goals

- Interoperability of different SDR systems
- Portability of applications software between different SDR implementations
- Upgradeability in terms of easy technology insertion
- Reduced development time of new waveforms through the ability to reuse design modules
- Reduced system acquisition, operation and supportability costs
- ANSWER: Standardization =SCA

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SCA Overview Summary

- SCA is a large set of standard interfaces
- SCA Core-framework provides interoperability and portability
- Plug and play development
- Makes waveform application development easier
- Cuts recurring development time by increasing portability
- Required for JTRS programs
- Easy assembly of applications through XML

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SCA in Pictures

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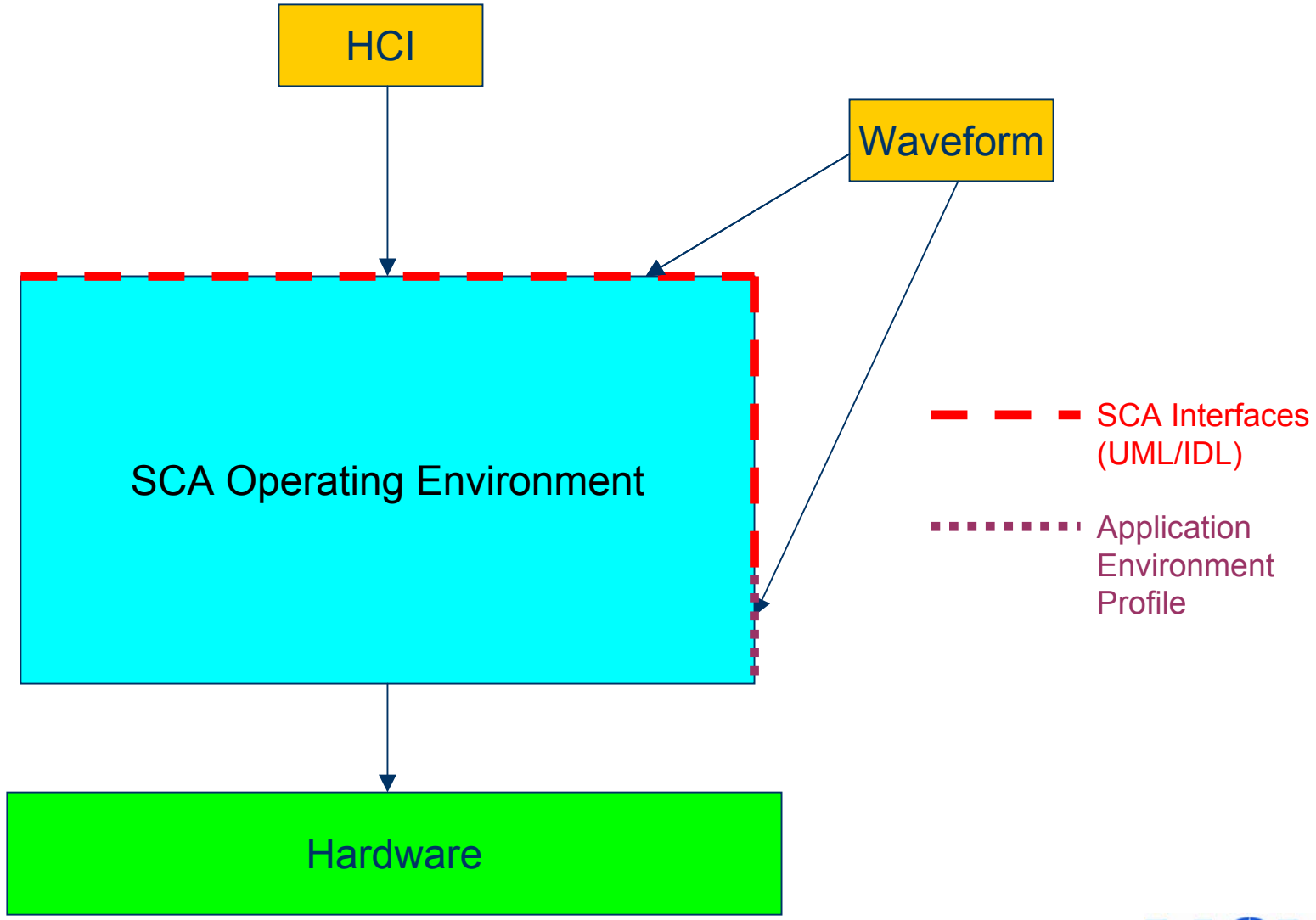
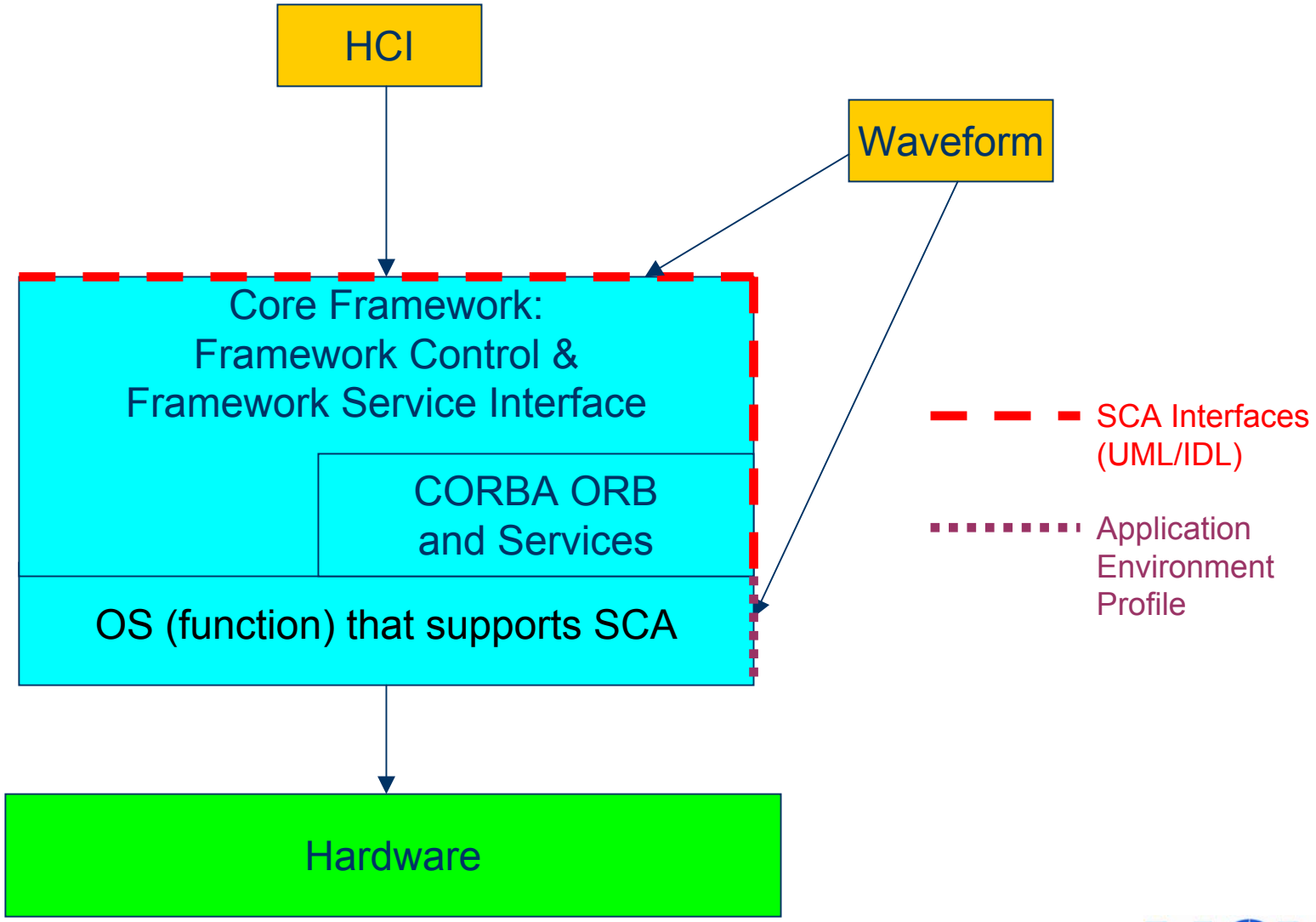
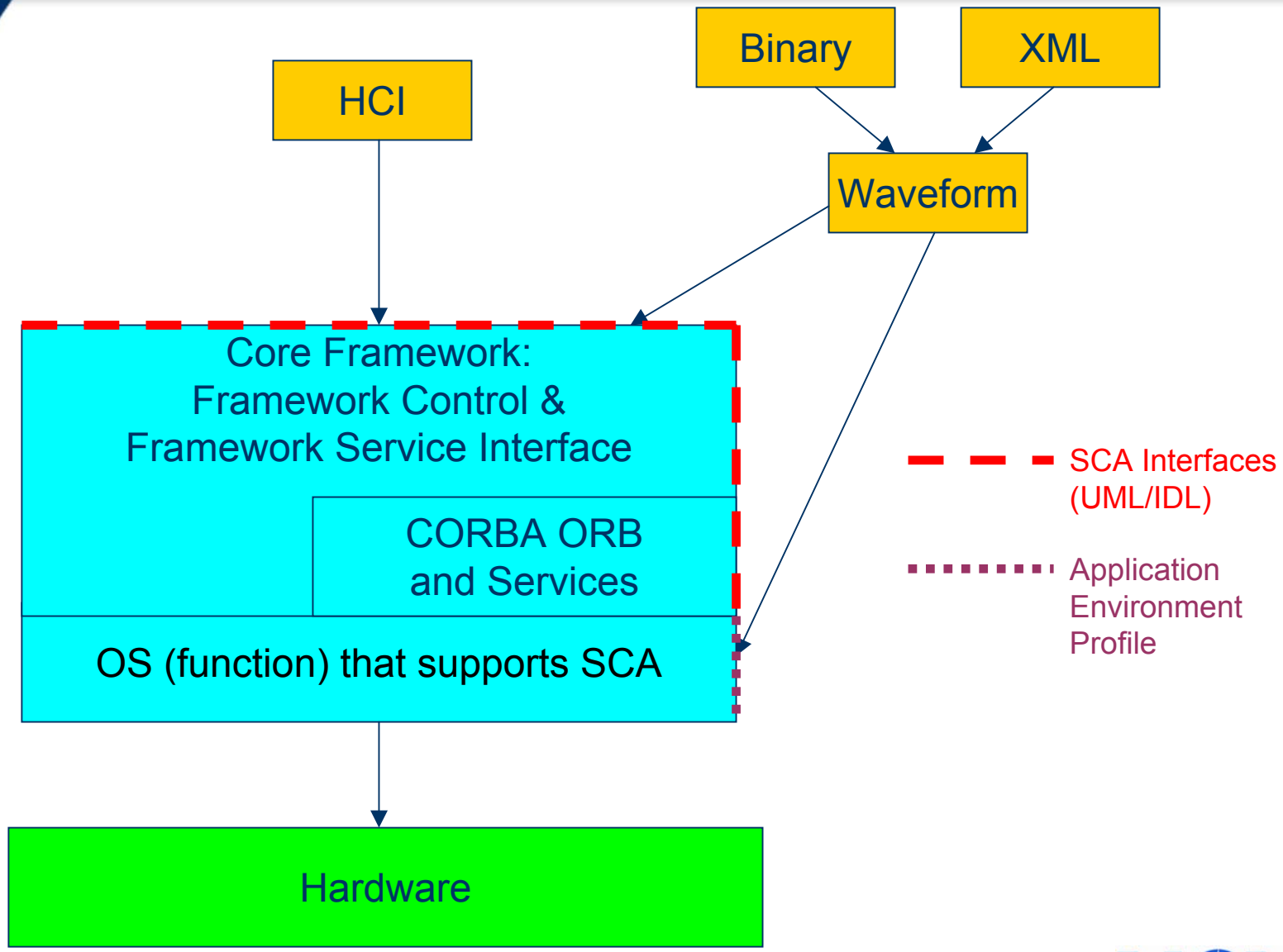
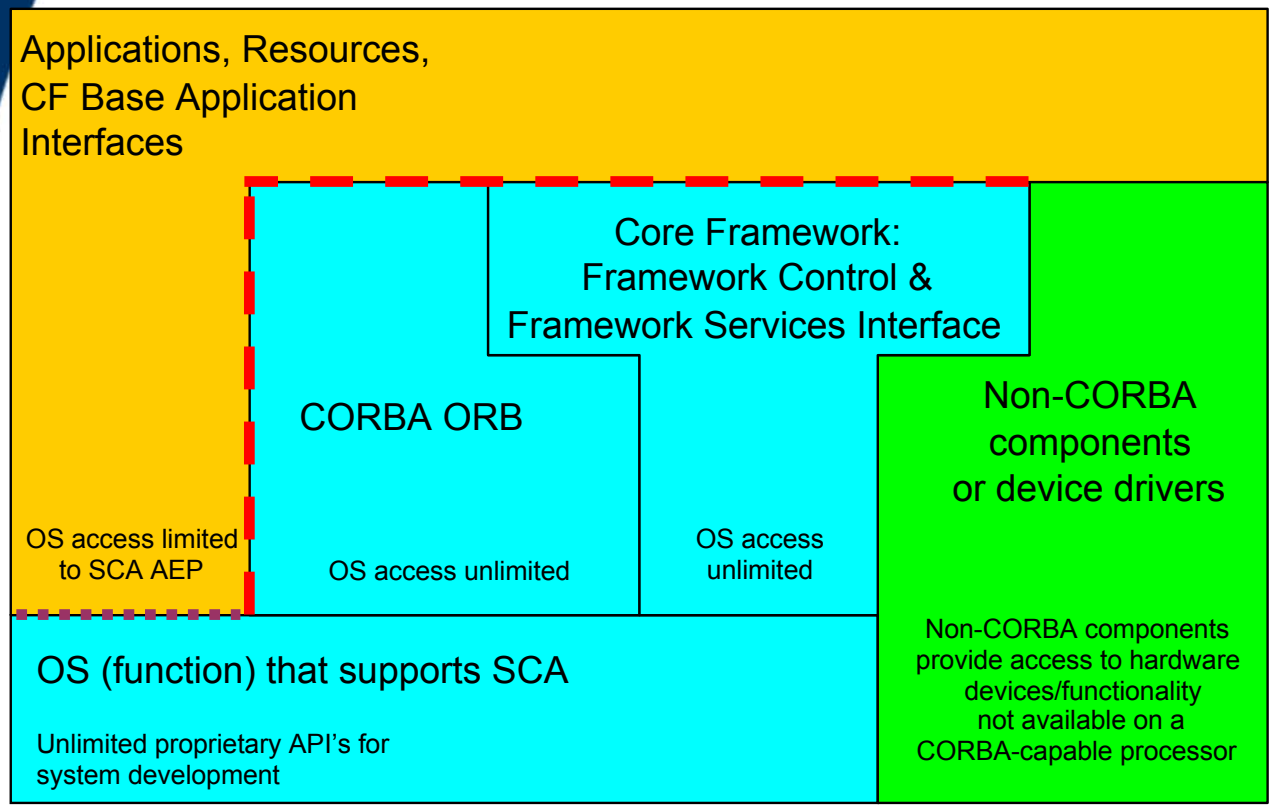






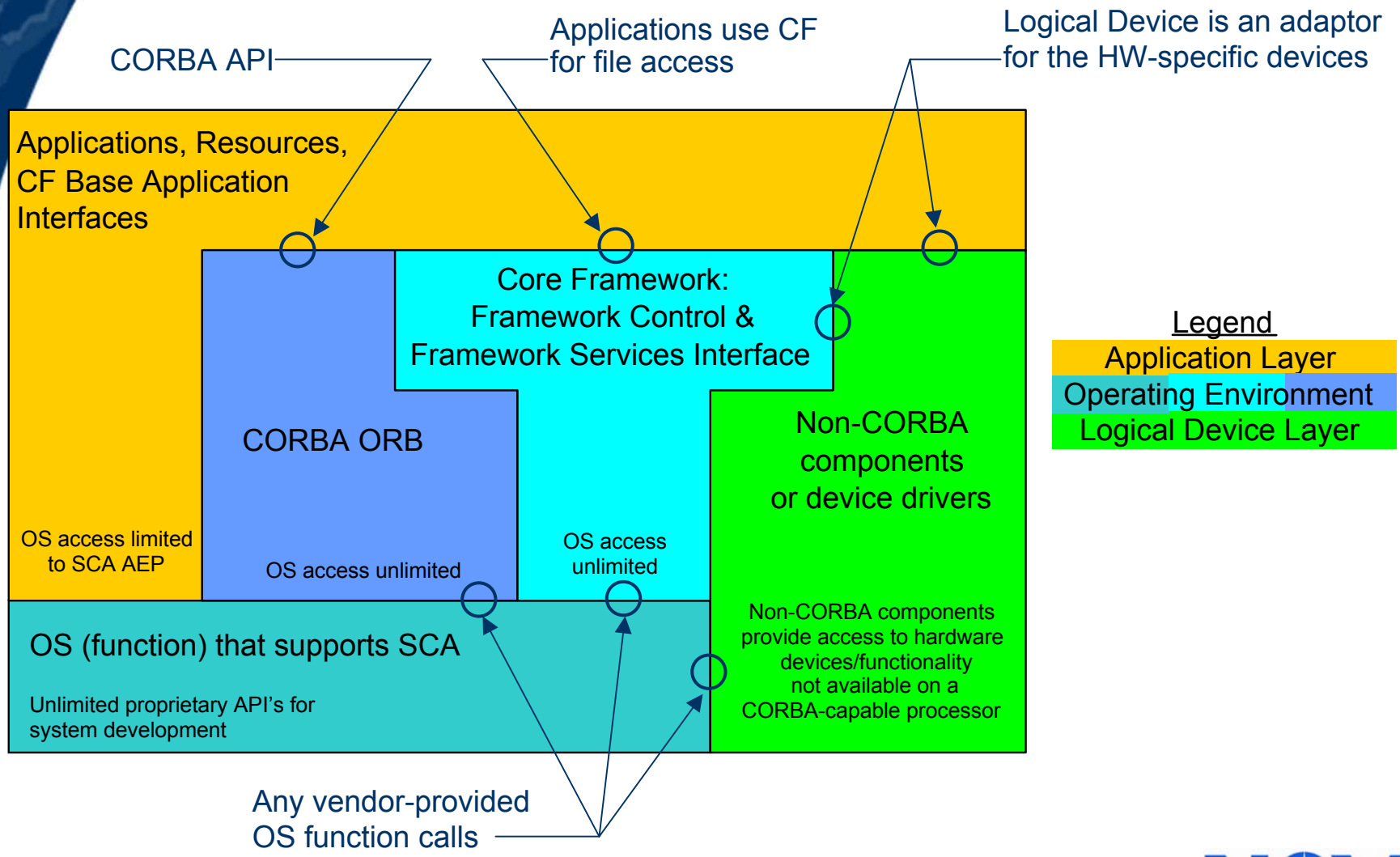


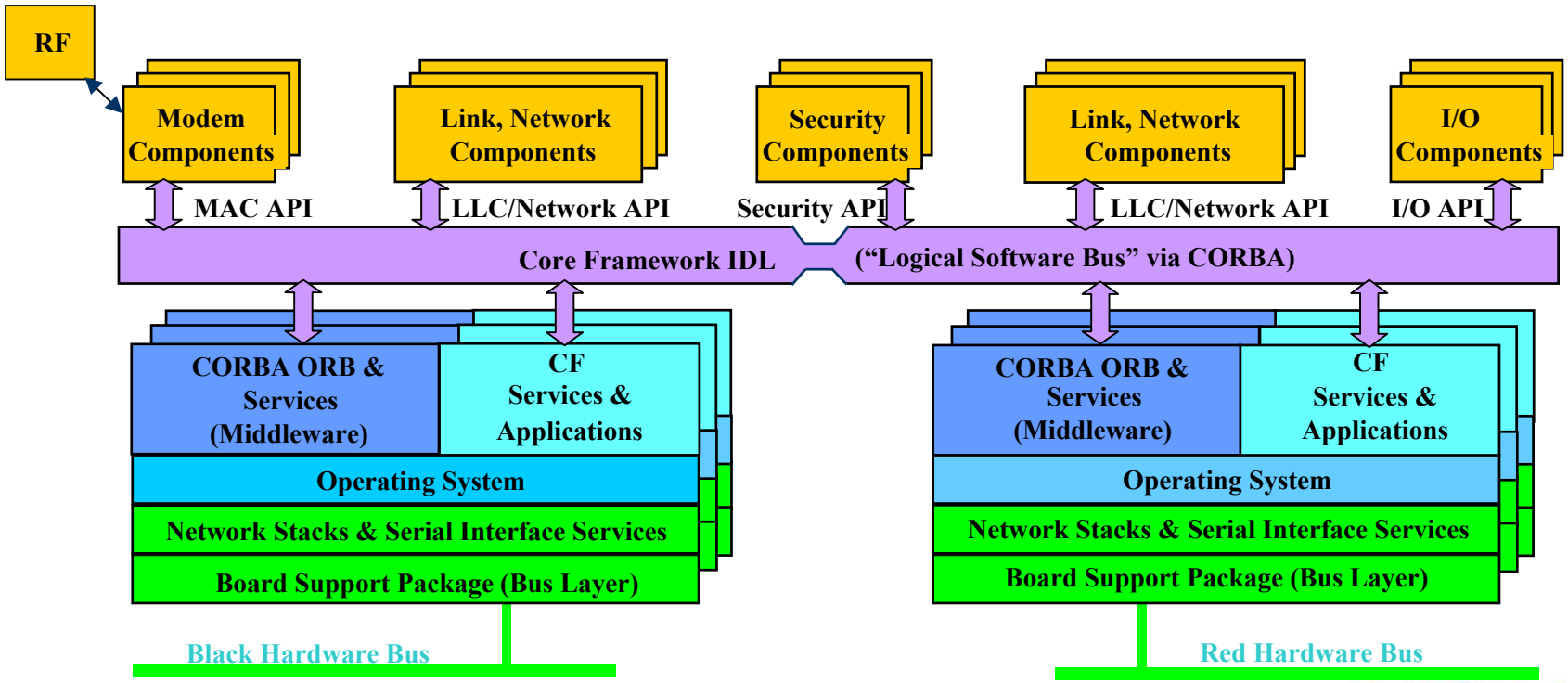
Legend

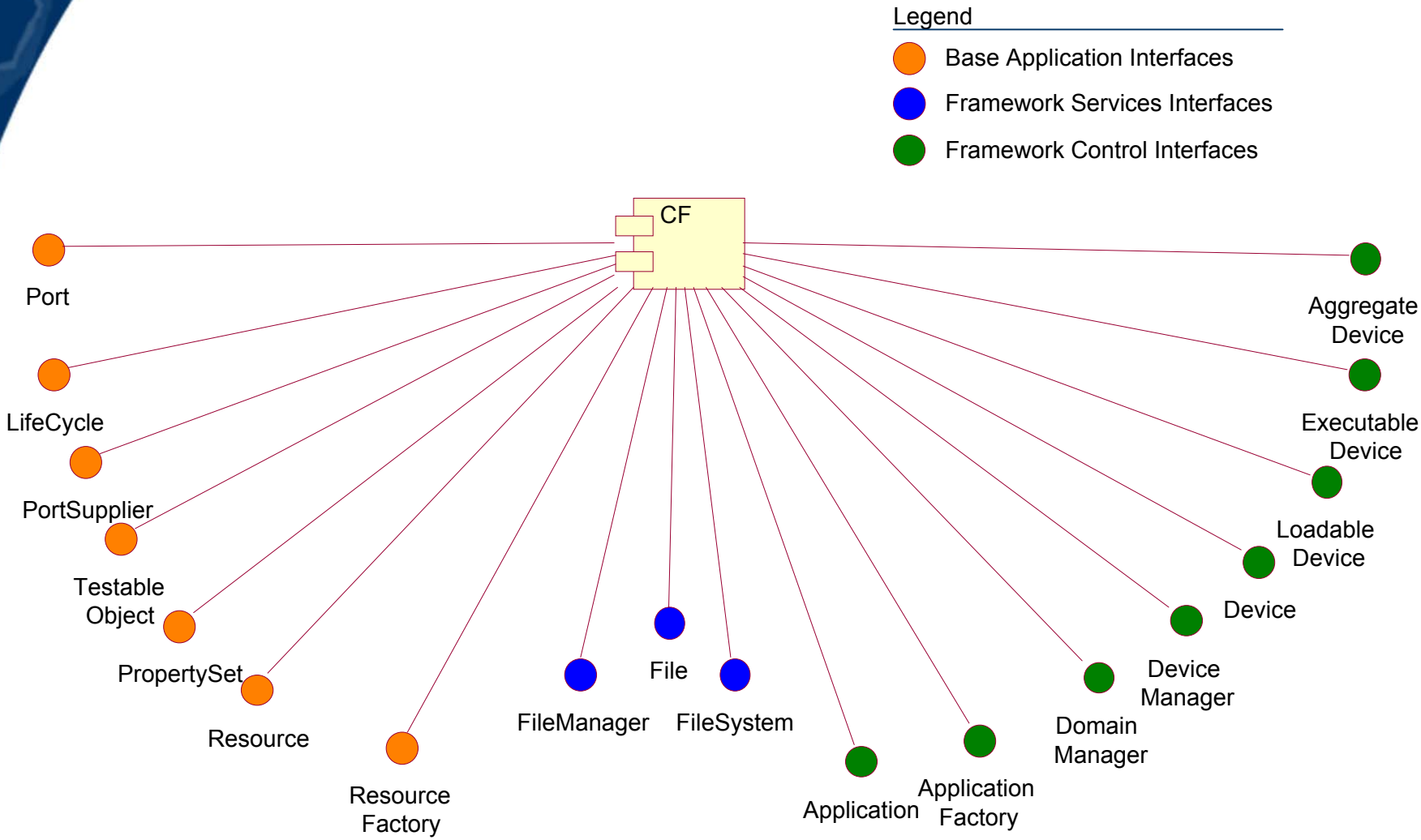
Application Layer

Operating Environment

Logical Device Layer







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Introduction to the SCA

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SDR Goals

- Interoperability of different SDR systems
- Portability of application software between SDR implementations
- Ease of technology insertion (upgrades)
- Reduced development time of additional waveforms through design module reuse
- Reduced system acquisition, operation and supportability costs

Where to Begin: Standardization of Architecture

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Software Architecture

- Foundation of a digital system
- Provides level of abstraction from implementation
- Describes system as collection of elements, connections, and topology
- Defines interfaces between elements
- Allows elements to communicate
  - Multiple vendors

Solution: Software Communications Architecture

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Strengths of SCA

- Component Abstraction
  - Isolate applications from hardware changes
  - Localize effect of infrastructure changes
  - Allow addition/upgrade of hardware
- Components are designed for portability
  - Maximize use of commercial protocols
  - Faster time-to-market
  - Reduced development costs
- Use of CORBA distributed environment
  - Provide distributed processing environment
  - Additional nodes can be added to system

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Weaknesses of SCA

- Still evolving
  - Version 2.2 adopted 17 November 2001
  - Ambiguous or conflicting requirements
  - Validation process still under development
- Few reference examples
- No certified compliant products*
  - Commercial product compliance not validated
- Adaptors can be abused as compliance loophole

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SCA Elements

*Section 2 of SCA Standard

- Operating Environment
- Application Layer
- Logical Device Layer
- General Software Rules

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Operating Environment Layer

- Operating environment layer entities
  - Operating System (OS) Layer
  - CORBA Middleware & Services
  - Core-Framework (CF)
- Common environment for applications
- Impose design constraints on waveforms

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Operating System

- Real-time embedded OS
- Support for multi-threaded processes
- Implement services specified in SCA Application Environment Profile (AEP)
  - Minimum subset of POSIX OS that must be implemented
  - Additional services can be implemented by OS
- All files access must occur through the CF::FileSystem (not the OS)

- Good to know:
  - CF::Applications are limited to AEP mandatory services
  - CF::Applications in operating environments may use all OS services

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CORBA Middleware

- Cross-platform framework
  - Standardize client/server interactions
- Separate applications and underlying OS/hardware
  - Abstraction of actual hardware
  - Provides deployment location transparency
- Used as message passing system in a distributed environment
  - Bit packing & hand-shaking

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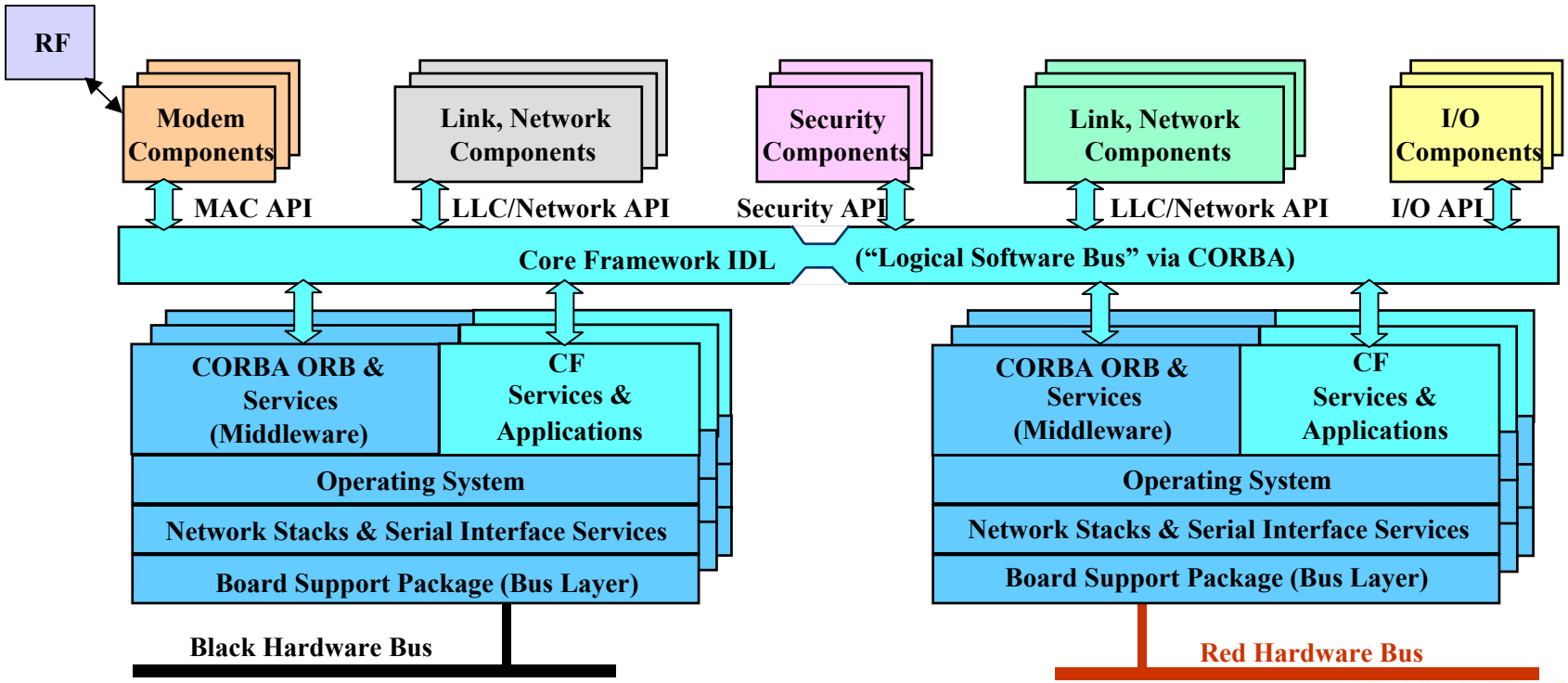
CORBA Middleware



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Core-Framework

- Core set of application-layer interfaces and services
  - Abstraction of underlying hardware and software
- Manages system components
  - Applications and factories
  - Resources and devices
- Provides for installation and execution of applications
- Separated into 4 functional categories:
  - Base application interfaces
  - Framework control interfaces
  - Framework services interface
  - Domain profile

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Application Space

- Application space entities
  - Application
  - Adaptor
- Waveforms are applications that perform user communication functions
- Waveforms are segmented into *levels**
  - Modem level digital signal processing
  - Link level protocol processing
  - Network level protocol processing
  - Inter-network routing
  - Security

* Application levels are based upon the Open Systems Interconnection (OSI) model for networking systems

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Applications

- Consist of one or more SCA components
  - XML used to describe component inter-connections
  - Inherit CF::Resource interface for control and configuration
  - Interface can be extended to increase functionality
- Uses SCA device as a software proxy for actual hardware devices
- Internal design not dictated by SCA

- Good to know:
  - Direct access to the OS is limited
  - Only AEP mandatory services may be used

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Adapters

- Based on Adaptor design pattern
- Provide CORBA wrapper for hardware or non-CORBA components
  - Translate CORBA requests to interface local operations of the element
- Transparent to CORBA-capable resources
- Intended to support for legacy components
- Not meant as loophole for poor design

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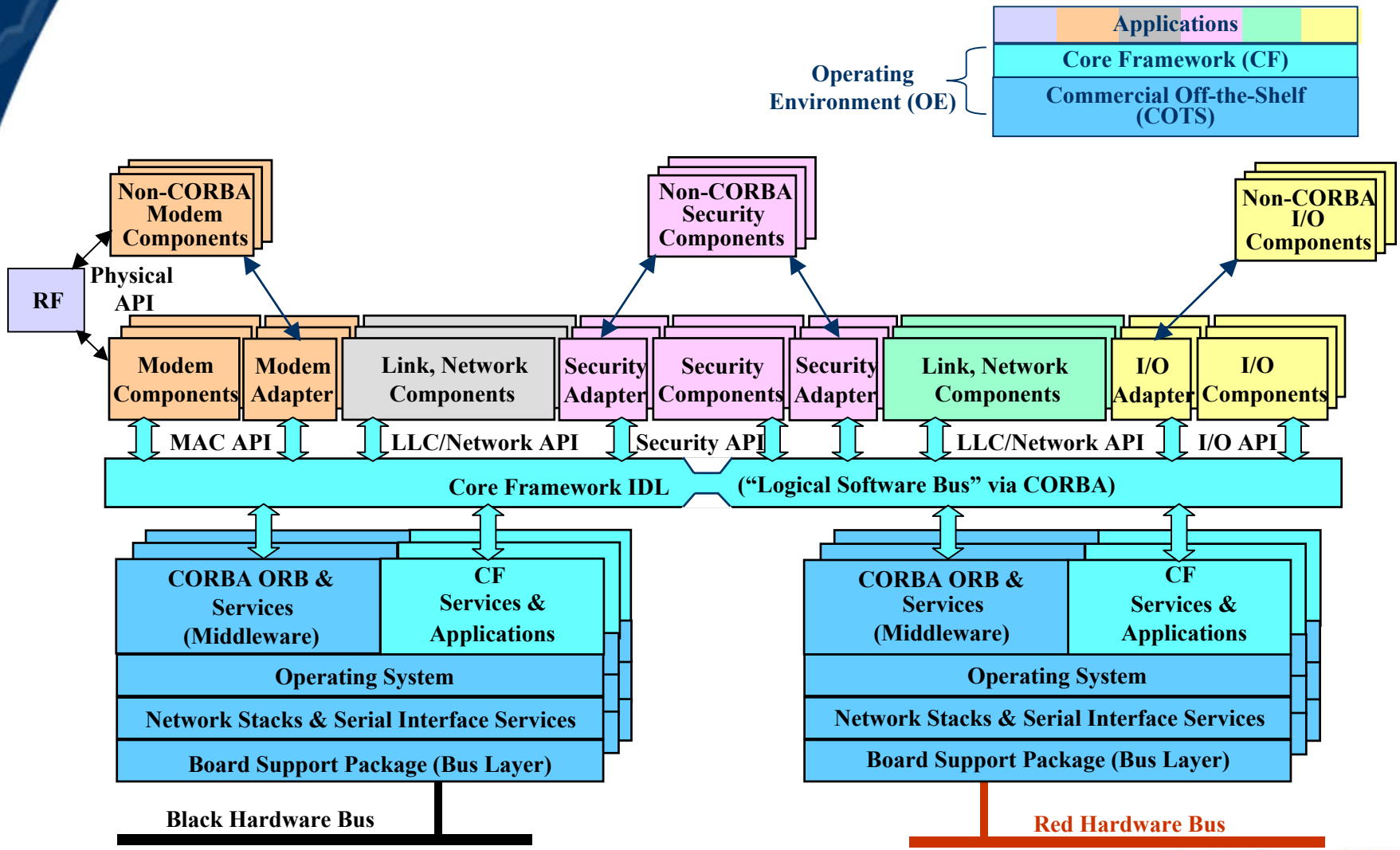
How Adaptors Connect Pieces



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Logical Device Layer

- Logical device space entities
  - Bus Layer (Board Support Package)
  - Network & Serial Interfaces
- Provide support for commercial communication protocols
  - System bus
  - Serial communication
  - Networking

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Bus Layer (Board Support Package)

- Capable of operating on commercial bus architectures
  - Ex: VME PCI, CompactPCI, Firewire (IEEE-1394), Ethernet
- Supports reliable transport mechanisms
  - May include error checking and/or correction
- Red and black (crypto) subsystems may use different bus architecture

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Network & Serial Interface Service

- Relies on commercial components to support multiple, unique interface
- Physical Serial and Network Interfaces
  - RS-232, RS-422, RS-423, RS-485, Ethernet, 802.x
- Low-level protocols
  - PPP, SLIP, LAPx
- Waveform networking may exist at OS layer
  - Commercial IP stack routing between waveforms

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General Software Rules

- New software development
  - Develop in high order language
  - Develop independent of platform/environment
    - Minimum portability issues
  - Assembly language acceptable when needed to meet performance requirements
- Legacy software porting
  - Not required to rewrite in high order language
  - Use adaptor to have SCA interface

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Key Points

- SCA provides a set of software interfaces that must be implemented by:
  - Operating system supplier
  - Radio hardware vendor
  - Core-framework provider
  - Waveform developer
- Core-framework assists in waveform development
  - Connect components
  - Load/run applications
- Increases code portability and reusability
  - Cut recurring development time
  - Cut recurring development costs

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Enabling Technologies

UML/OOP, CORBA, XML

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What is UML

- UML = “Unified Modeling Language” (Graphical)
- Does not specify design methodology
  - Successor to many Object Oriented (OO) Design & Analysis methods
- CASE tools
  - Code generation
  - Reverse engineering
  - Code merging
- Standardized by the OMG

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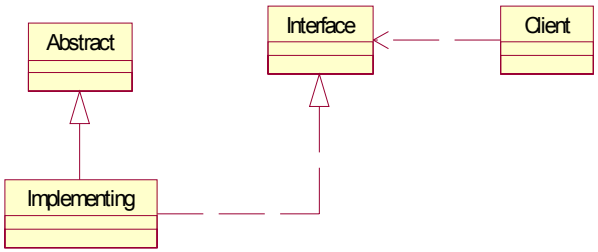
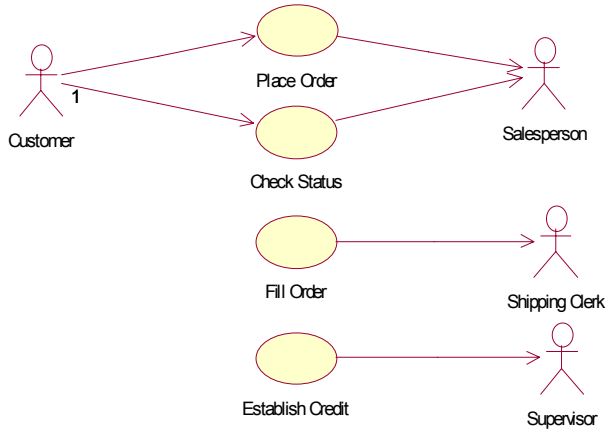
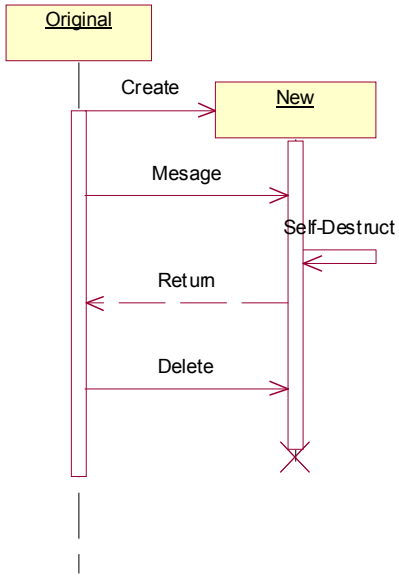
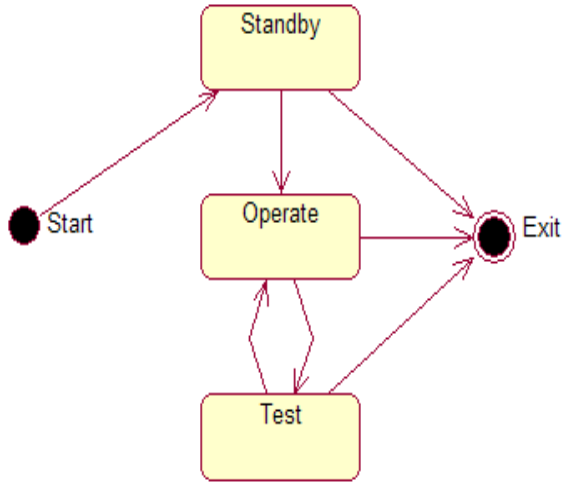
What does it look like?









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What is UML used for?

- Provides a common language for functional specifications
  - Natural language is not precise enough
  - Code is too detailed
- Highlight important details
  - Provide overall view of a system
- Logical decomposition of large projects
  - Focus on details without losing overall goals
  - Separate implementation task into parts
  - Build individually testable components

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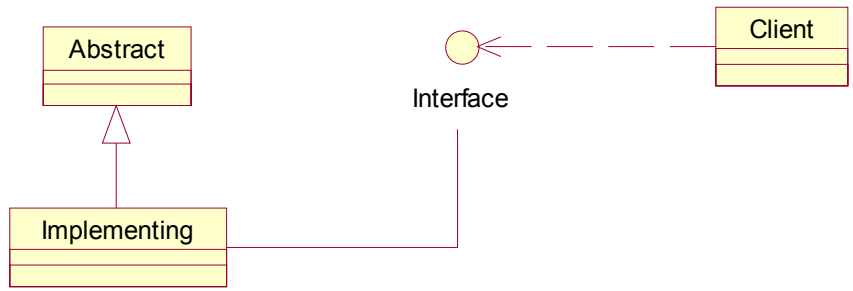
Class Diagram

- Used by SCA Spec
- Provides overview of system
- Defines software interfaces
  - Attributes
  - Operation signatures
- Shows relationships between objects



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Key UML Points

- Technical communication language
  - Read documents written by developers
  - Read technical articles published in journals
- Shows opportunities for compont reuse
- Benefits of modeling before coding
- Write documentation for future maintenance of designed product

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What is CORBA

- "CORBA" = Common Object Request Broker Architecture
- Open architecture, cross-platform middleware
  - Hides the actual communication mechanisms under an Object Request Broker (ORB) software bus
- Assists in development of "distributed applications"
  - Multiple processors
  - Over a network
  - Hide object communication issues
  - Provide common services
- Allows interaction only through defined interfaces
- Specification written/maintained by OMG

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What is a CORBA object

- "Virtual" entity capable of being located by an ORB and accepting requests from clients
- Must be implemented in a programming language
- An implementation of an interface

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What is CORBA used for?

- Develop distributed applications
- Develop platform-independent applications
- Hide low-level complexity with minimum performance cost
  - Threads, Events, Messages
- Automate common networking tasks
- Many ORB's are available commercially

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Interface Definition

- Textual representation of UML class diagram
- Specified in Interface Definition Language (IDL)
- Defines contract between client and server
  - Defines attributes, types
  - Defines operations, parameters

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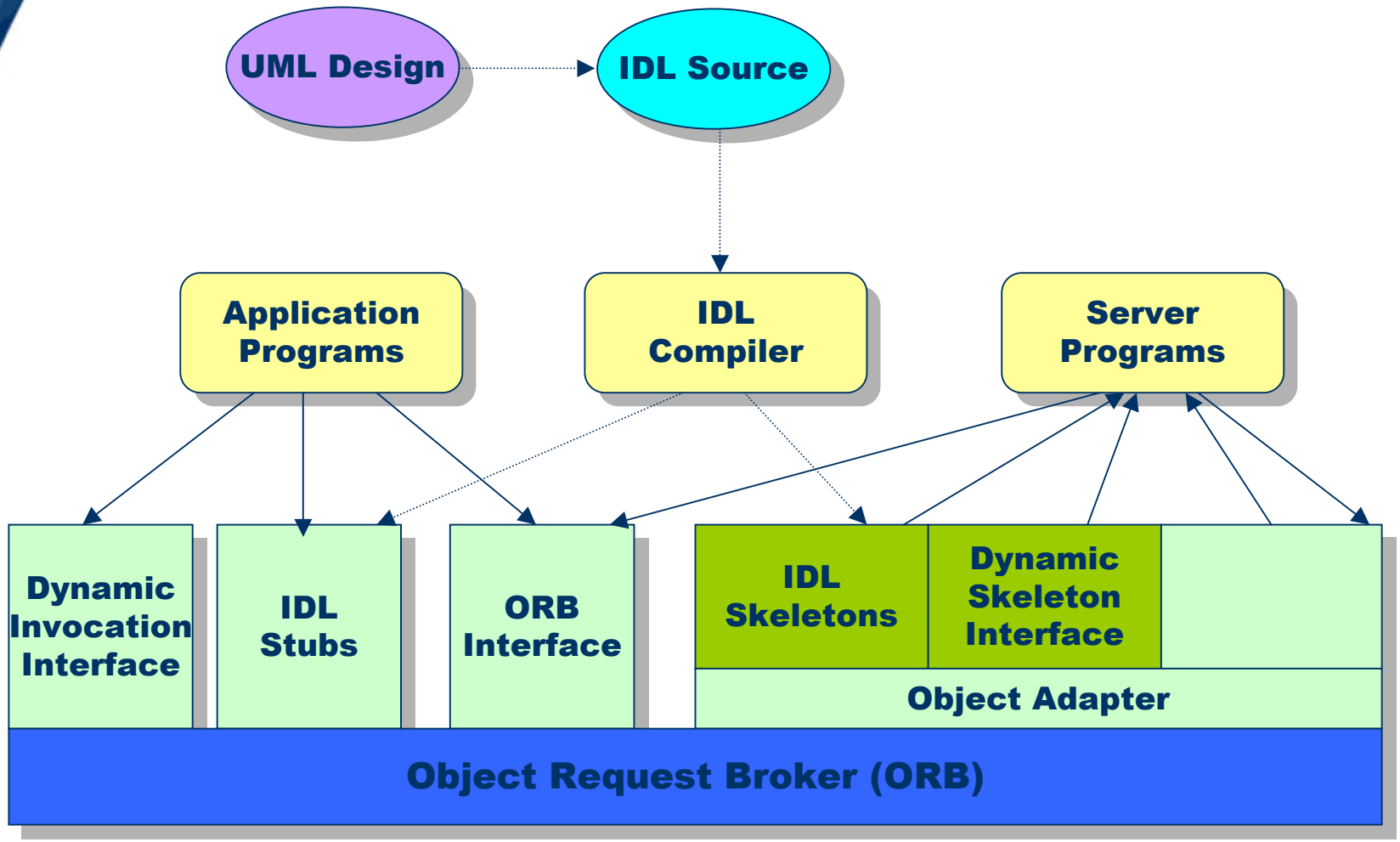
Development Process (Graphical)



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Application Development Process

- UML may be used to generate IDL
- IDL is compiled for each implementation language to generate stubs and skeletons
- All server implementations include server skeletons
  - Skeletons define known types, operations, and direction of data flow
- All client implementations include client stubs
  - Stubs define known types, operations, and direction of data flow
- Servant implementation of operations is written in an "implementation" file
  - Unpopulated class may be provided by IDL compiler
  - Realizes the abstract interface

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Key CORBA Points

- CORBA middleware is required by SCA
- Reduced development cost
  - Support additional platforms with one version of code
  - Orb handles object communication details
  - Integration of new and legacy components
- Increased functionality
  - Work in heterogeneous network
    - Distributed object deployment
    - Networking is transparent to client/server

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What is XML

- "XML" = eXtensible Markup Language
- Markup language (much like HTML)
- Encapsulates data in identification tags
- Categorizes data which assists in sorting, processing, and searching
- Uses a Document Type Definition (DTD) or an XML Schema to constrain data architecture

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How does SCA use XML

- Defines domain profile for the system
  - Collection of XML
  - Describes identity, capabilities, properties, inter-dependancies, and location of components
  - Structure is described in 8 DTD files
- XML (based on DTD's) describes every component of the system
  - Hardware Components
  - Software Components
  - Applications
  - Domain Manager

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Example XML

- **Not Tagged:**

  Nova Systems Solutions
  Richard Woodring, Software Engineer
  5 Circle Freeway Dr.
  Cincinnati, OH 45014

- **Tagged:**

```
<Company>
   <CompanyName>Nova Systems Solutions</CompanyName>
   <Employee>
            <Name Role="Software Engineer">Richard Woodring </Name>
            <Address>
                     <Street>5 Circle Freeway Dr.</Street>
                     <City>Cincinnati</City>
                     <State>OH</State>
                     <ZipCode>45014</ZipCode>
            </Address>
   </Employee>
</Company>
```


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XML Documents

- XML has two types of documents
  - Document Type Definition (DTD)
  - XML data
- Role of DTD
  - Defines data structures used to hold data
  - Specify rules for architecture of structures
- Role of XML
  - Store data as specified in DTD
- XML Editing tools available

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Key XML Points

- XML must conform to DTD specification
  - DTD file describes structure of XML document
  - XML file stores data
- All SCA components are described in XML
- XML editing can be greatly simplified by the right tool

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SCA CF Interface Overview

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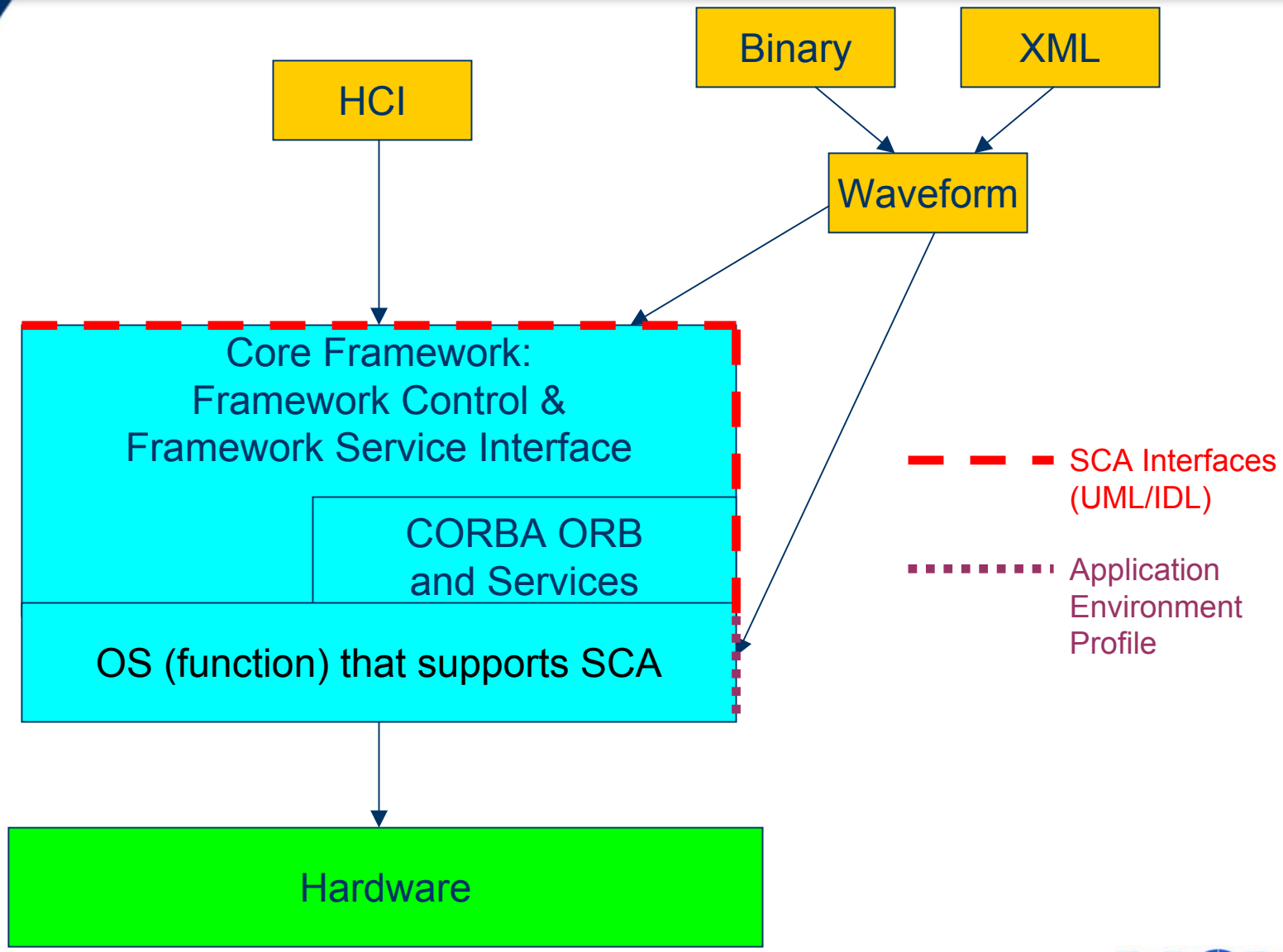
Where are we now?



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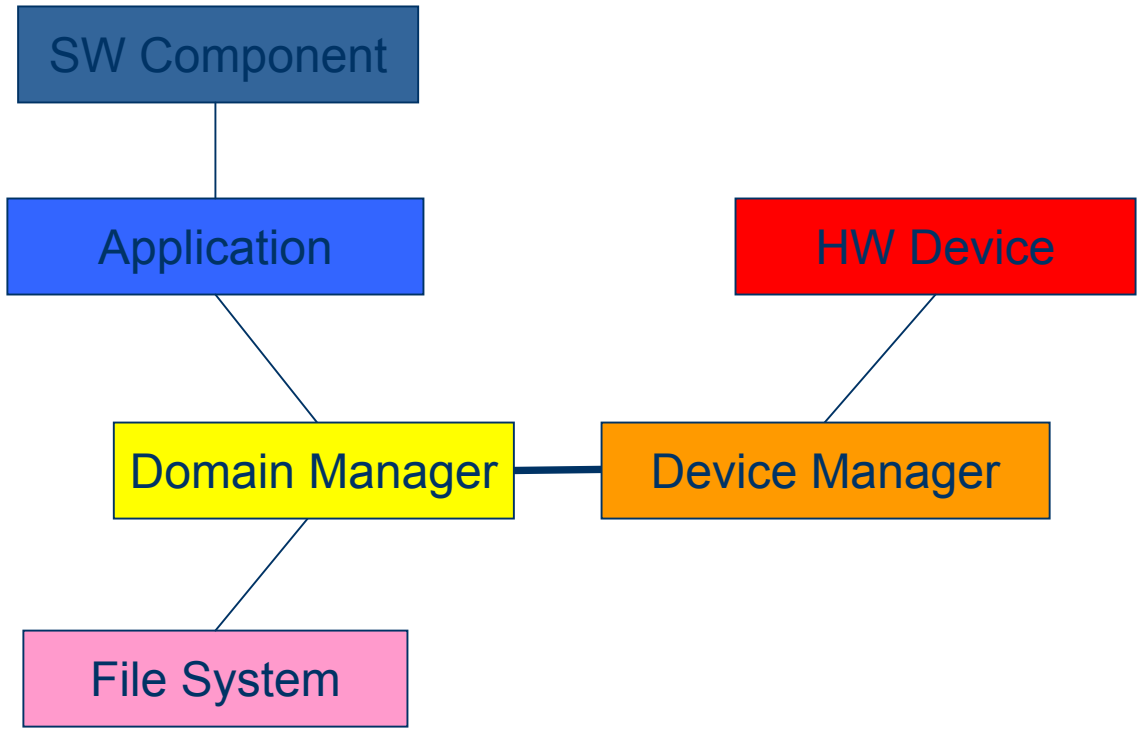
Core Framework Interfaces (Simplified)



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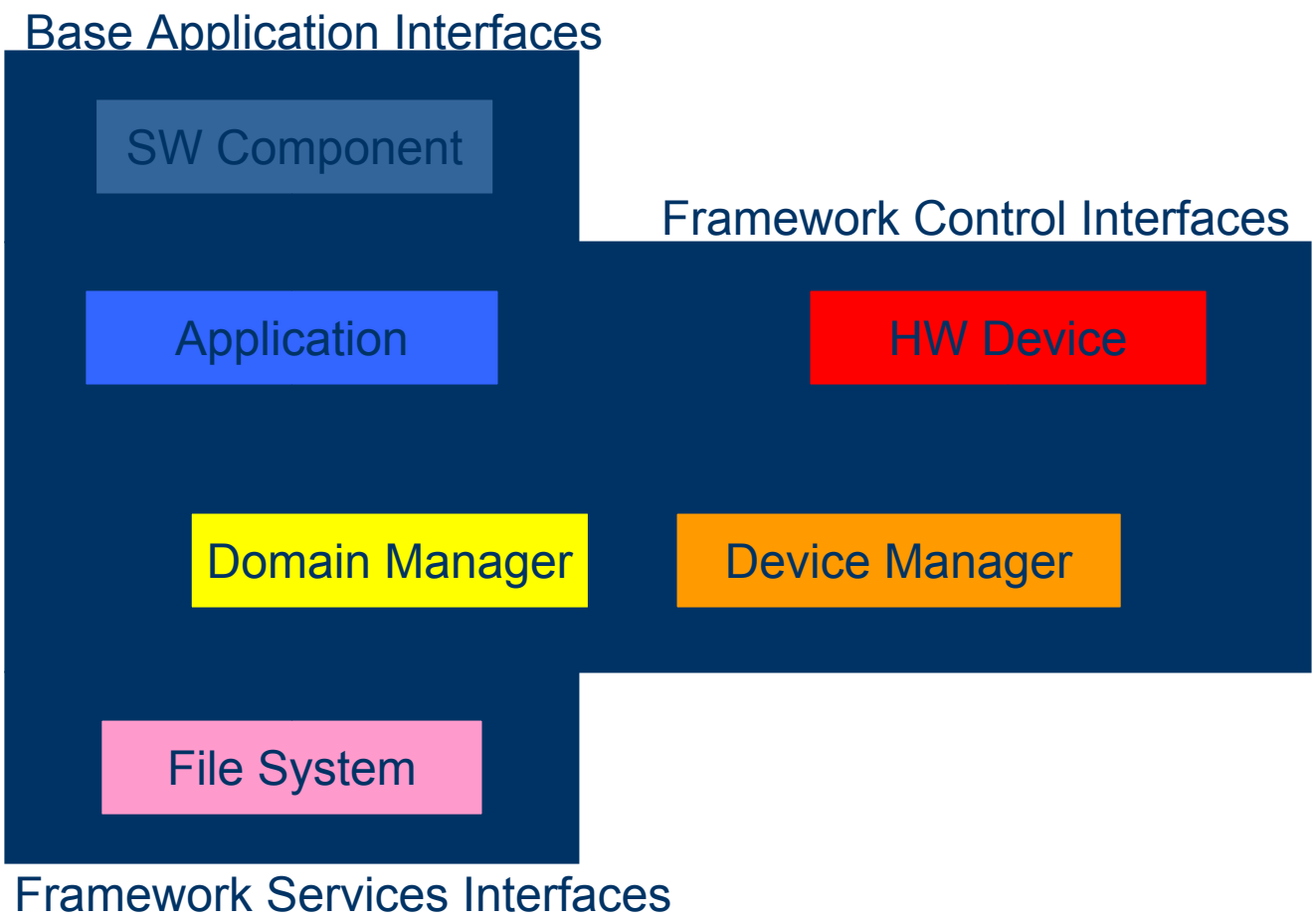
Core Framework Interface Categories



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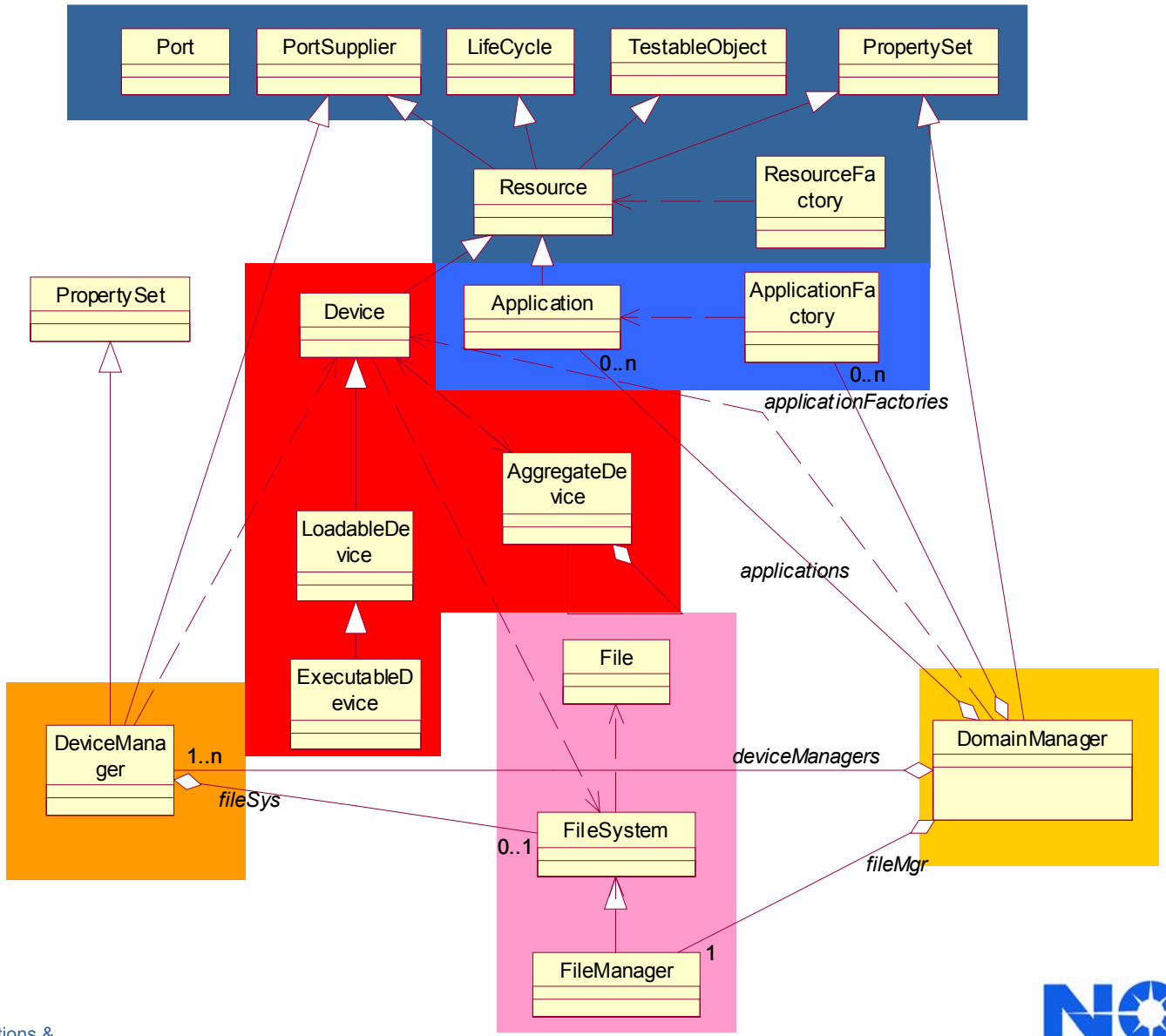
Core Framework Interfaces (Detailed)



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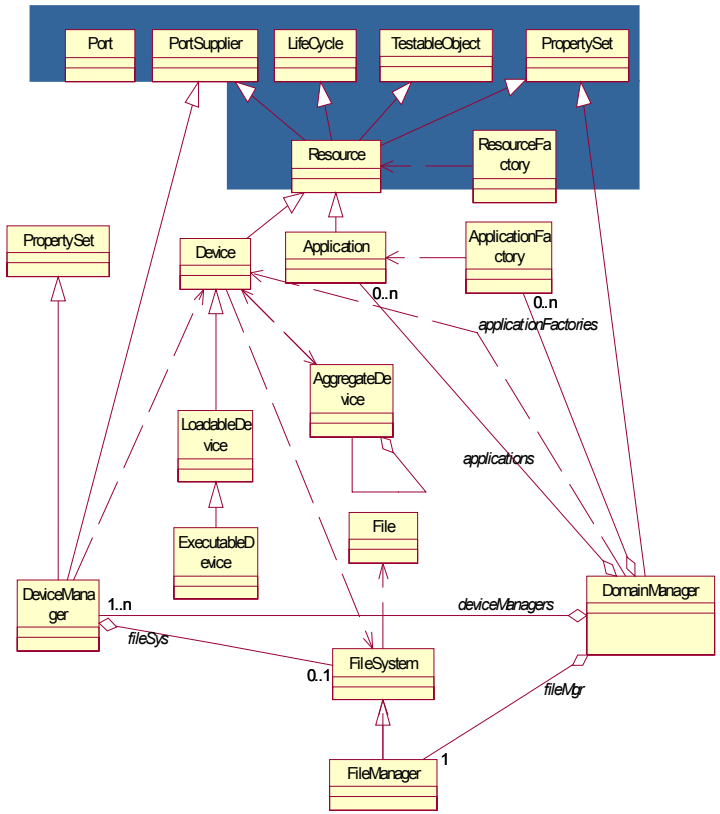
Base Application Interfaces

- Port
- Port Supplier
- Life Cycle
- Testable Object
- Property Set
- Resource
- Resource Factory



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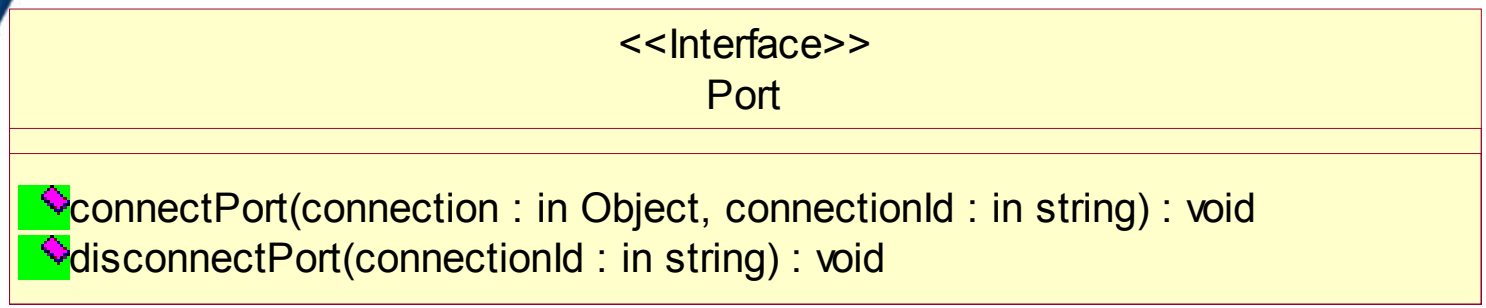
Port Interface



- Used to connect waveform components
- Provides channel for transferring data or control information
- Methods of using ports include:
  - Push/pull
  - Synchronous/asynchronous
  - Mono/bi-directional
  - Flow control

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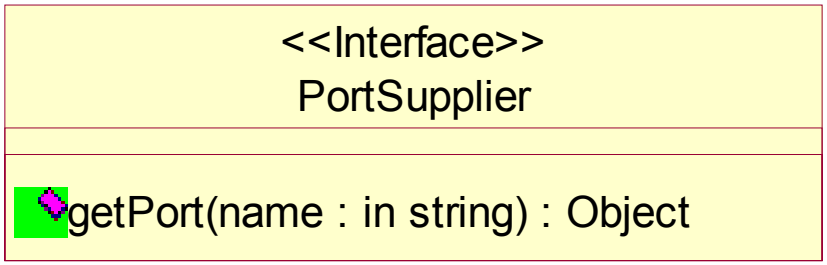
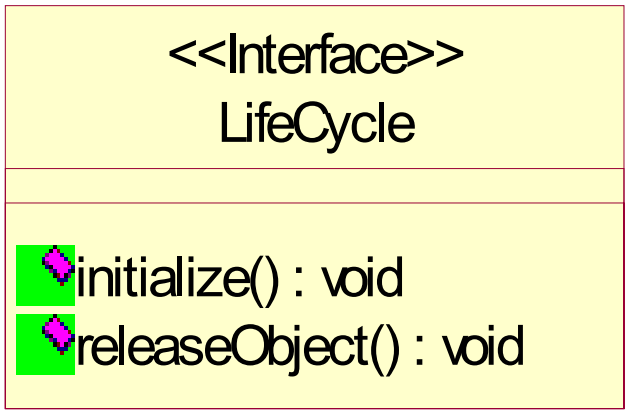
Port Supplier Interface



- Provides an operation to get a reference to a components port
- Used by CF during application instantiation

Life Cycle Interface



- Used to set objects to known state and tear down instantiated objects
- Same interface used for a resource, device, or application
- Initialize is always called by the CF
- Release Object is called from client.
  - Opposite of ApplicationFactory::Create()

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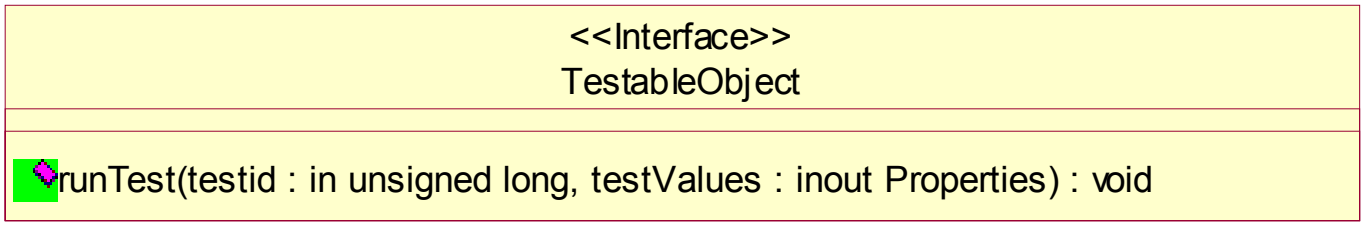
Testable Object Interface



- Allows components to be “Black Box” tested
- Can be used to test single component, resource, or full application
- Operation used to test component implementation
- Results of tests are *returned* in test the testValues parameter

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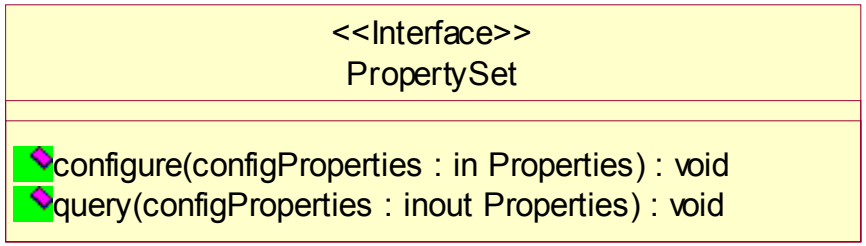
Property Set Interface



- Defines operations to access component properties
- Properties (and default values) are specified in XML files for component
- Query operation *returns* value in Properties parameter

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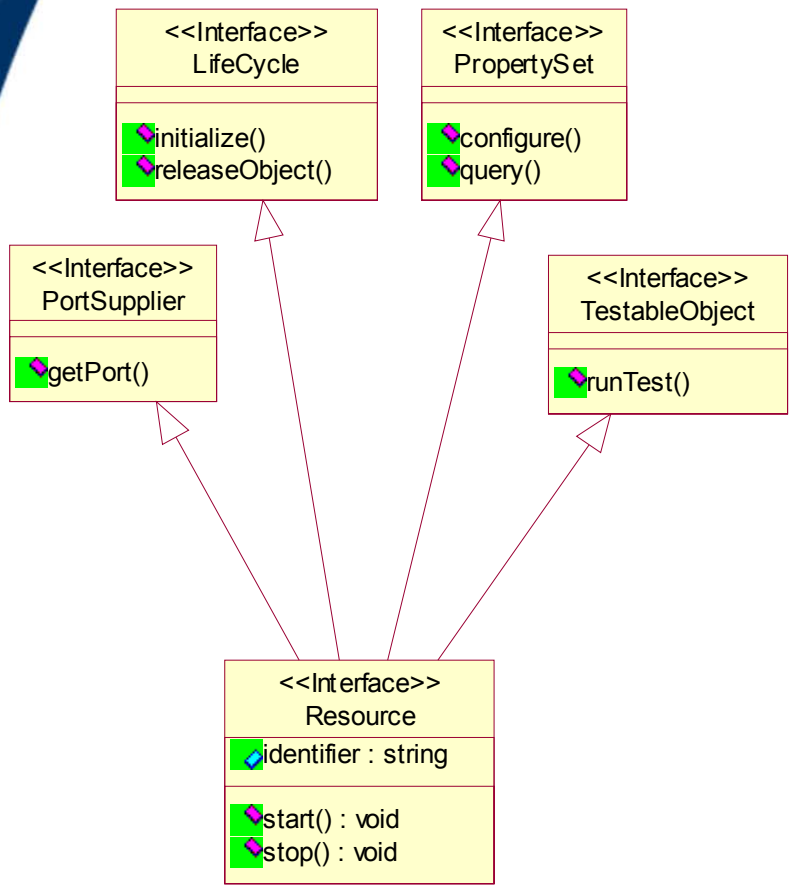
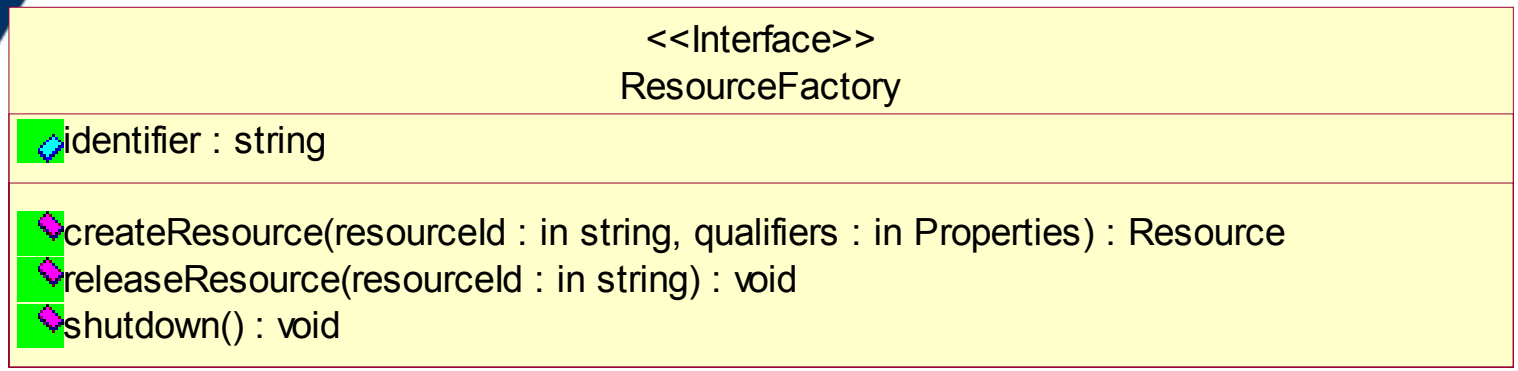
Resource Interface



- Common API for control and configuration
- Implemented by all system components
- An application may have multiple interfaces that inherit CF::Resource

Resource Factory Interface



- Used to create and tear down individual resources
- Provides client-server isolation among CF::Resources
- Provides standard method of obtaining a CF::Resource without knowing its identity

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Base Application Interfaces Review

- Application components implement the CF::Resource interface
- Application components are connected with ports
- Component properties are described in properties descriptor XML
- ReleaseObject operation tears down an application
- CF::TestableObject provides interface for “Black Box” testing

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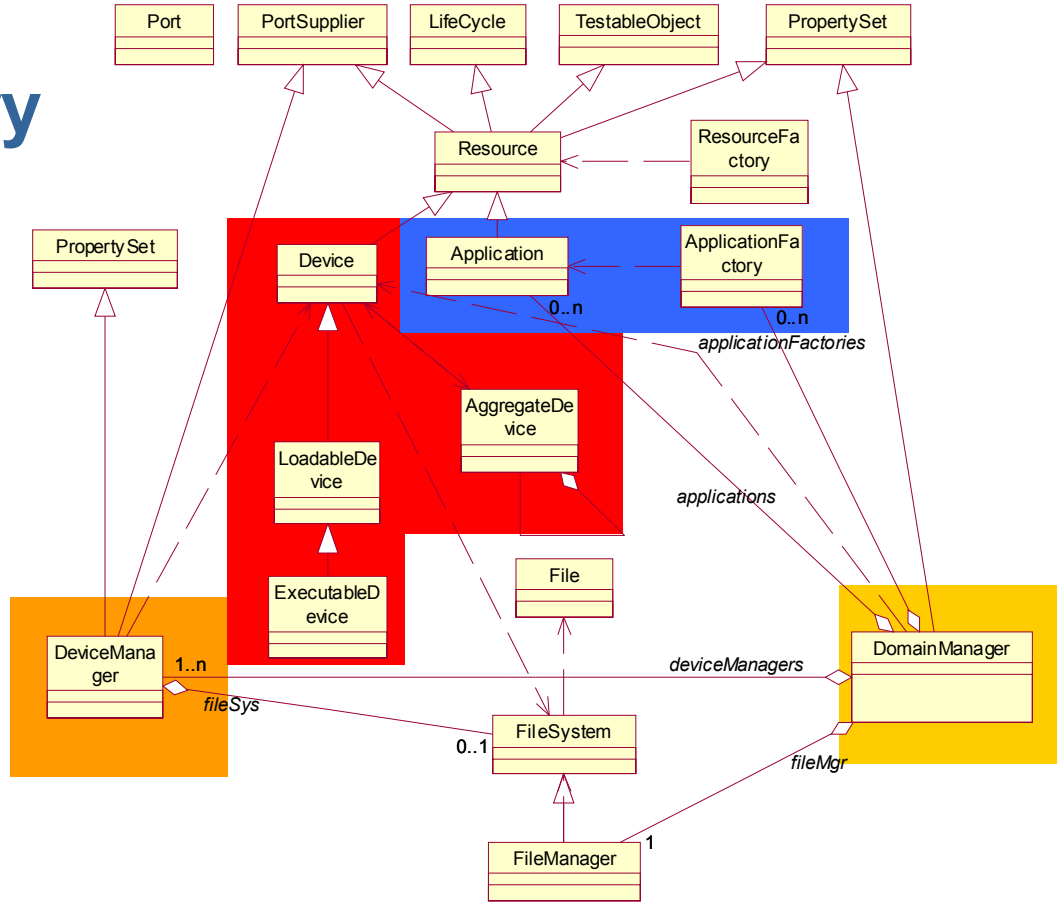
Framework Control Interfaces

- Application
- ApplicationFactory
- Device
- LoadableDevice
- ExecutableDevice
- AggregateDevice
- DeviceManager
- DomainManager



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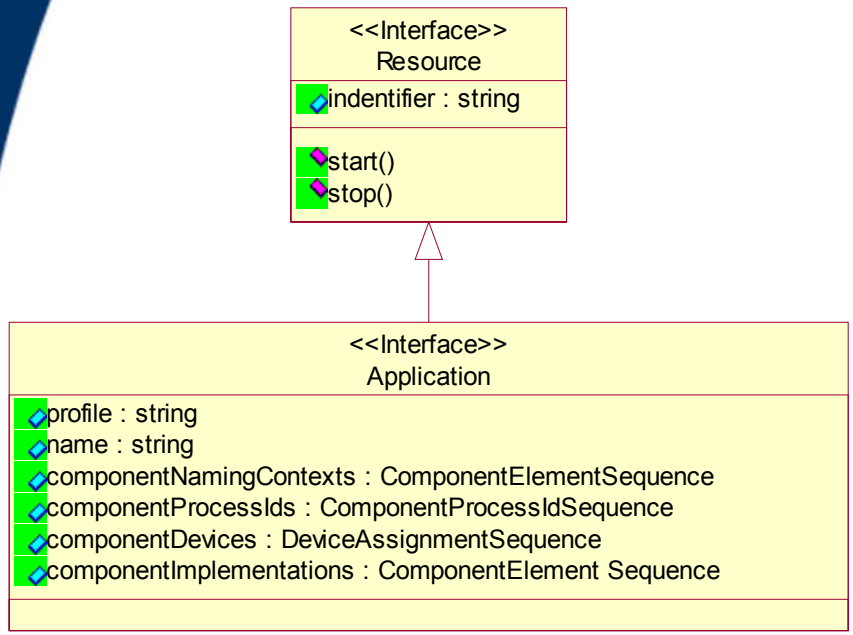
Application Interface



- Proxy for application's assembly controller and software resources
- Single reference to the waveform application
- Common interface supports generic user interfaces
- Implemented by the CF
- Application name is assigned by client (per instance)
- All other attributes are obtained from XML files and assigned by the CF

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Application Factory Description

- **Builds application by:**
  - Requesting allocation of resources
  - Instantiating and configuring components
  - Connecting component ports

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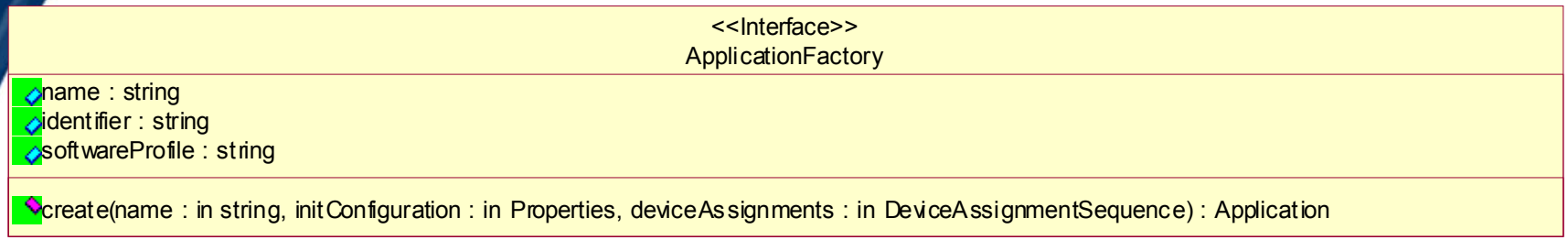
Application Factory Interface



- Based on the factory design pattern
- When a waveform application is installed, a new application factory is created
- Creates an instance of an installed application by:
  - Requesting allocation of resources
  - Instantiating and configuring components
  - Connecting component ports
- Implemented by the CF
- Used by the client to create an instance of an application

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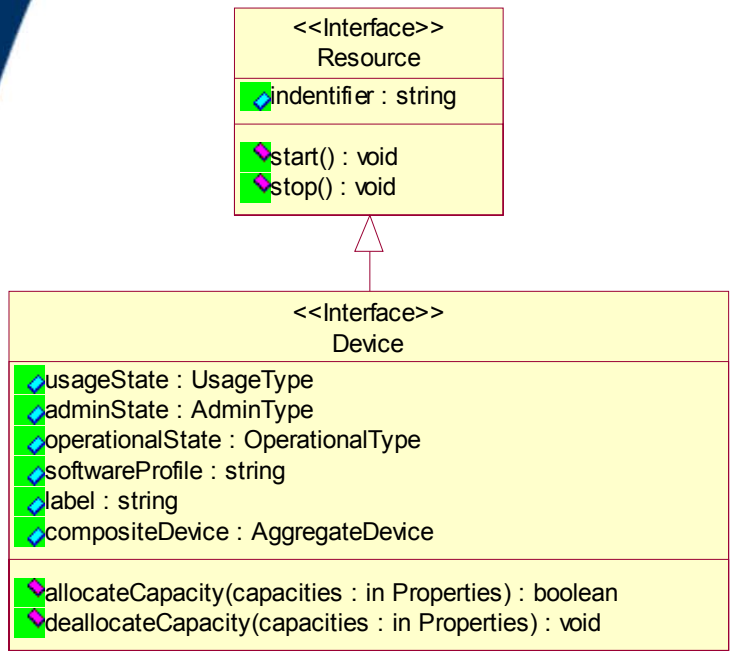
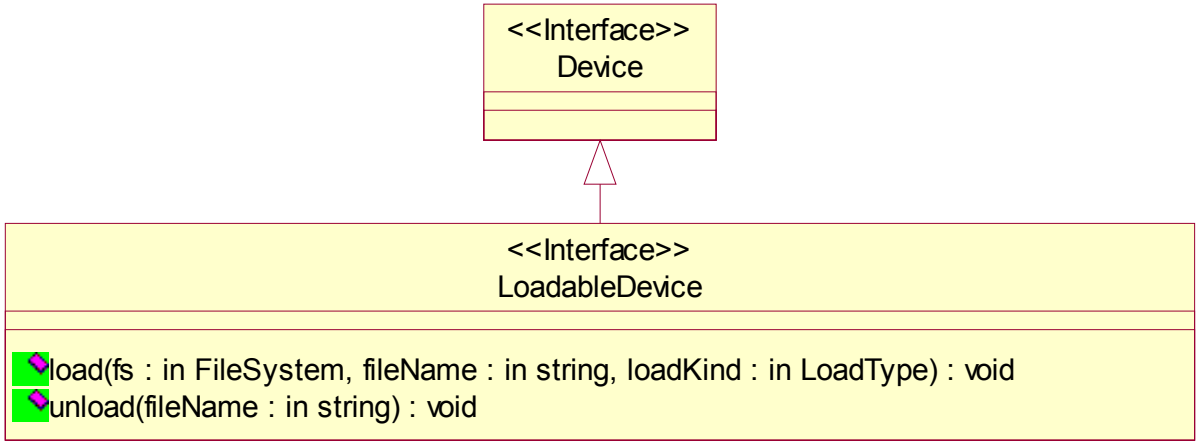
Device Interface



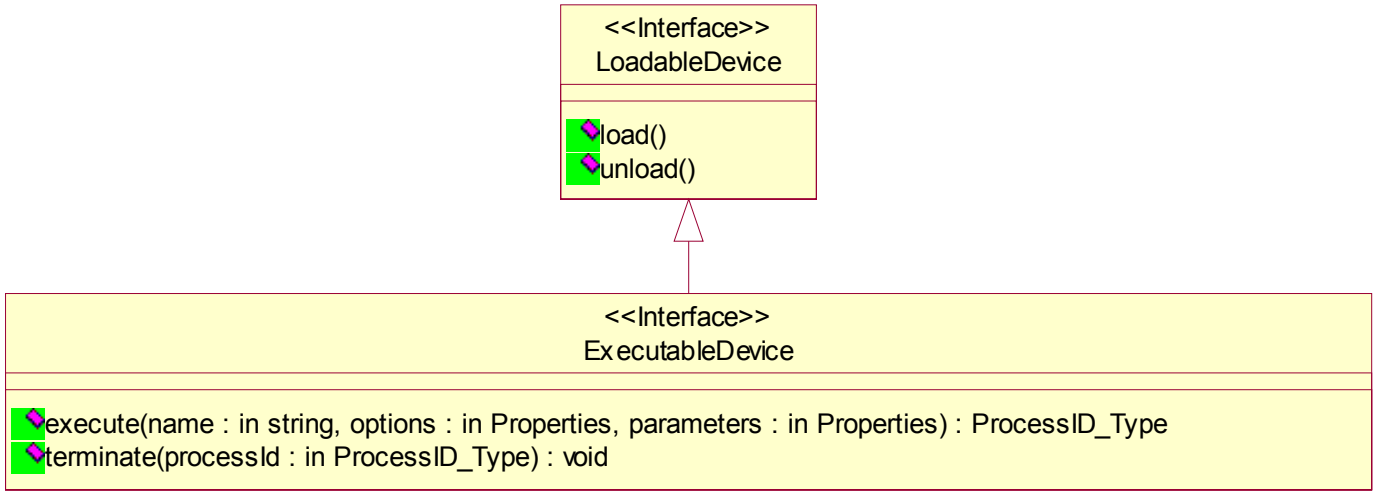
- Logical abstraction for a hardware
- Extends CF::Resource Interface
  - Capacity allocation operations (e.g. memory, performance, etc.)
  - Adds state management
    - Administrative (Unlocked, Shutting Down, Locked)
    - Usage (Idle, Active, Busy)
- Operations are used by the CF

Loadable Device Interface



- Add software loading/unloading capability to the Device interface
  - Loadable software includes:
    - Kernel Module
    - Driver
    - Shared Library
    - Executable
- Example of Loadable Device
  - FPGA

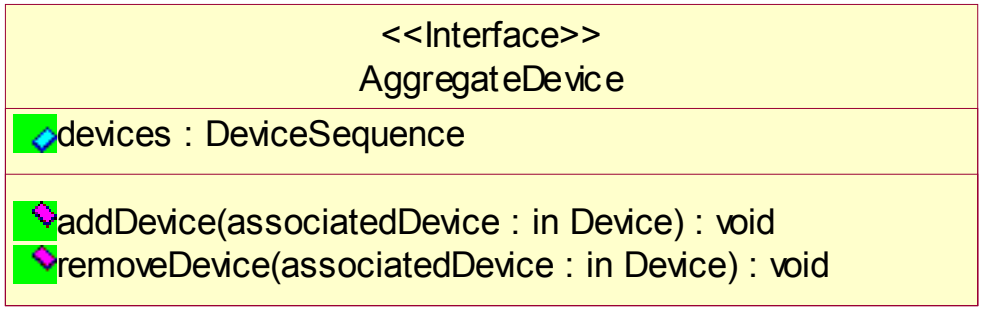
Executable Device Interface



- Adds software execution capability to the Loadable Device interface
- Usually used for devices running a multi-thread OS

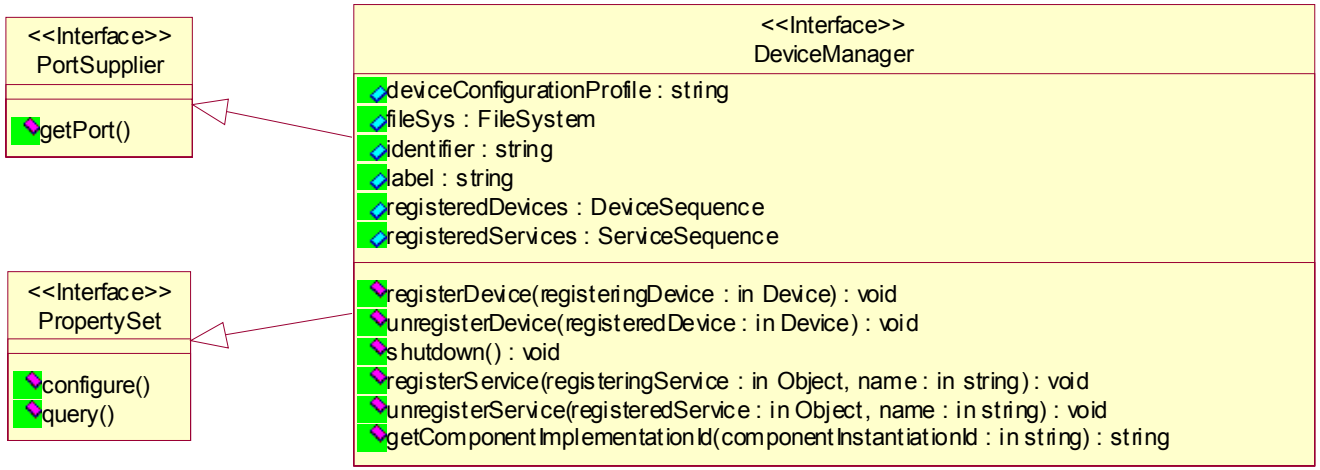
- Examples of Executable Devices
  - General Purpose Processor
  - DSP

Aggregate Device Interface



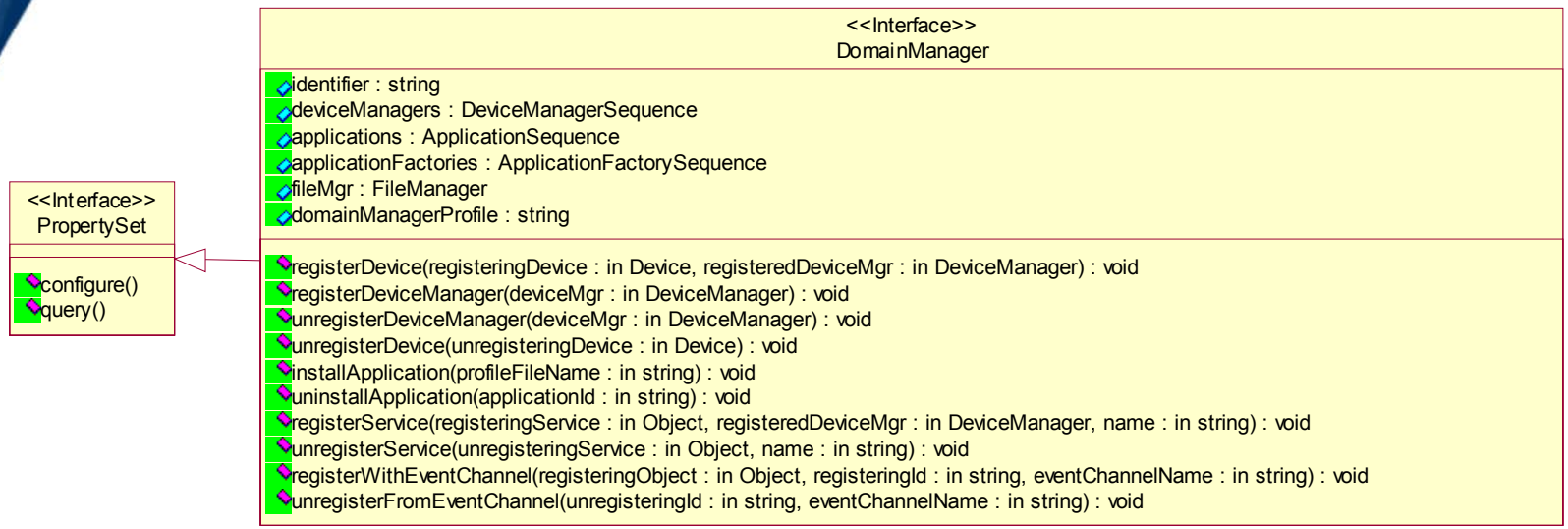
- Allows multiple devices to be associated
  - Tightly – One device contains the other
  - Loosely – Devices can exist independently
- Aggregate relations described in Device Configuration Descriptor (DCD) XML

Device Manager Interface



- Manages registration of devices and services installed in the system
- Maintains lists of registered devices
- Registered Devices sequence
  - Provides a list of devices registered in the domain
- Operations are mostly used by the CF

Domain Manager Interface



- Main control and configuration of the system
- Has knowledge of all system components
  - Any system component can be found through the domain manager
- Provides interfaces to the CF used by clients

- Implemented by the CF provider

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Domain Manager Interface Highlights

Attributes

- **Device Managers sequence**
  - Provides a list of devices managers installed in the domain
- **Applications sequence**
  - Used by clients to obtain list of previously instantiated applications
- **Application Factory sequence**
  - Used by the client to obtain list of previously installed application factories
- **File Manager reference**
  - Used by components (and optionally clients) to access file systems managed by the CF

Operations

- **Install/Uninstall Application Operations**
  - Used by the clients to install and uninstall an application (factory)

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Framework Control Interfaces Review

- Domain manager is used to install or uninstall waveform applications
- Application factories are used to instantiate and installed application
- CF::Application is standard interface for communicating with any application
- Operations most often used by waveform developers:
  - Domain Manager
    - Install/Uninstall CF::Applications
    - Find installed and instantiated CF::Applications
- All framework control operations are implemented by the CF provider

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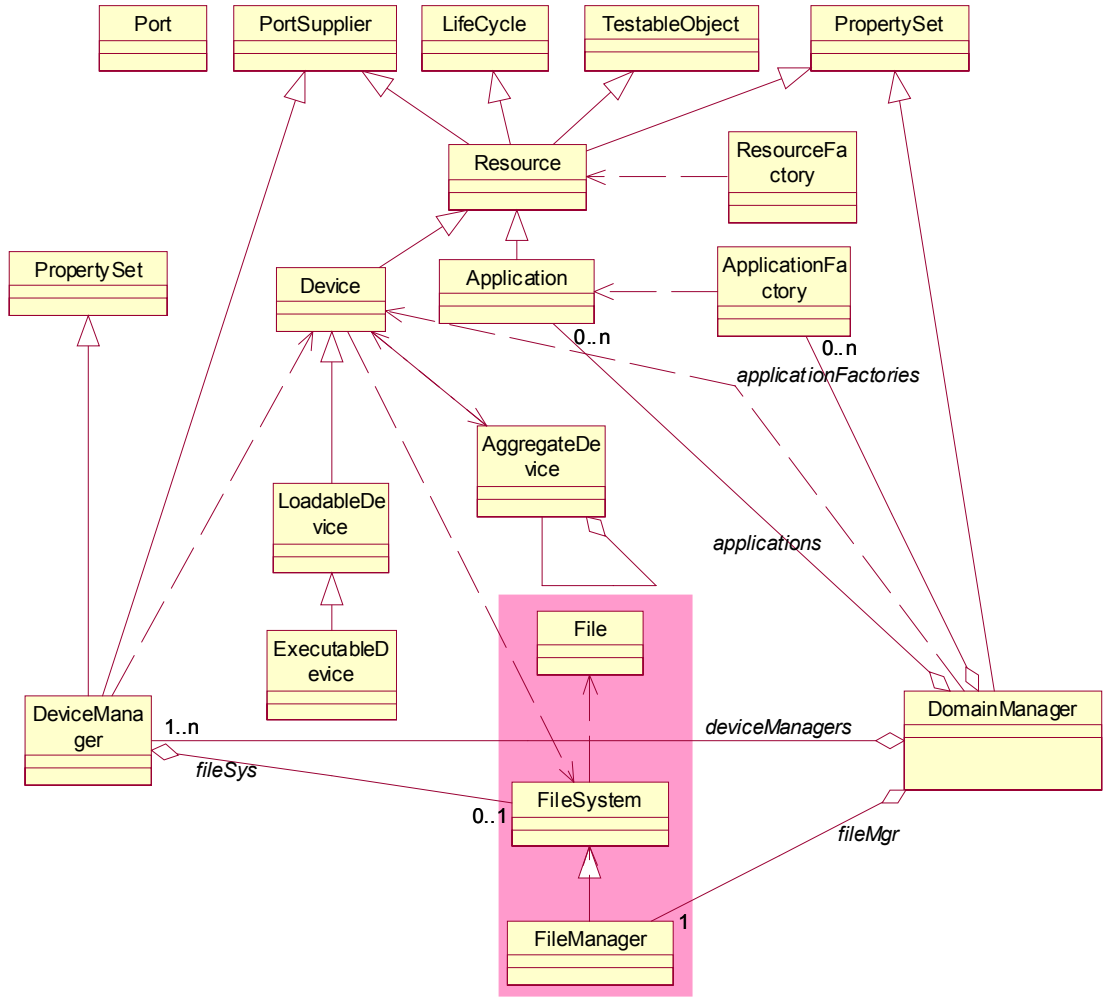
Framework Services Interfaces

- File
- File System
- File Manager
- Timer



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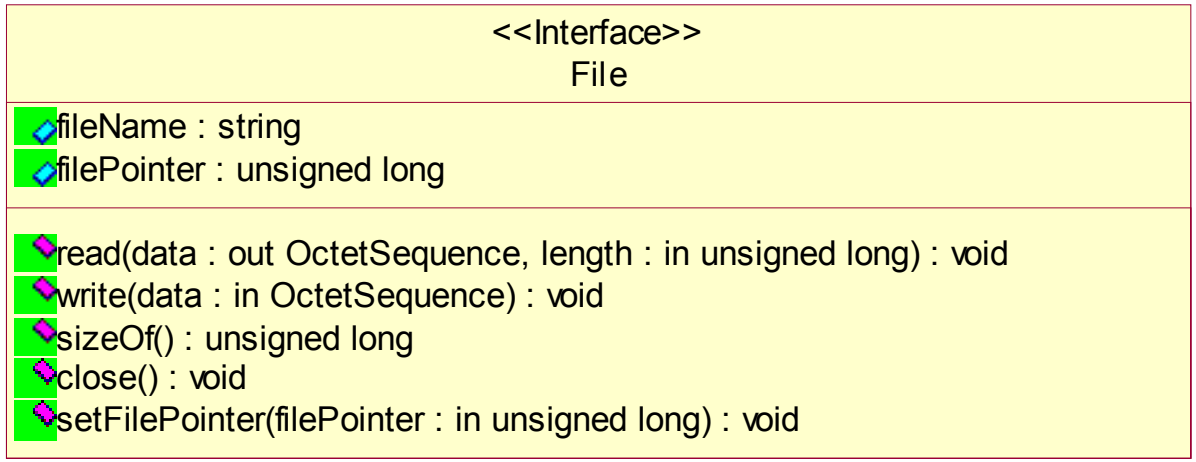
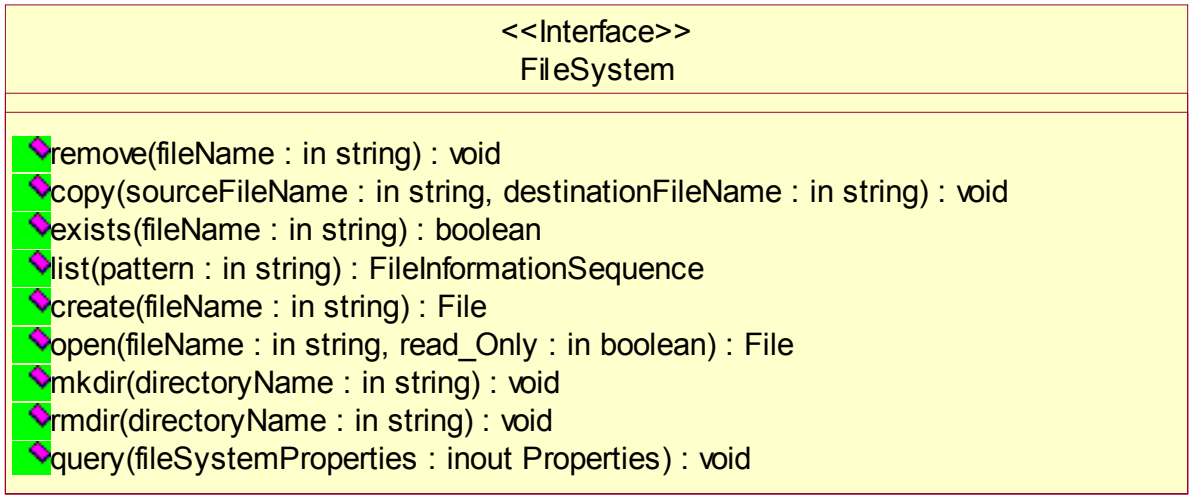
File Interface



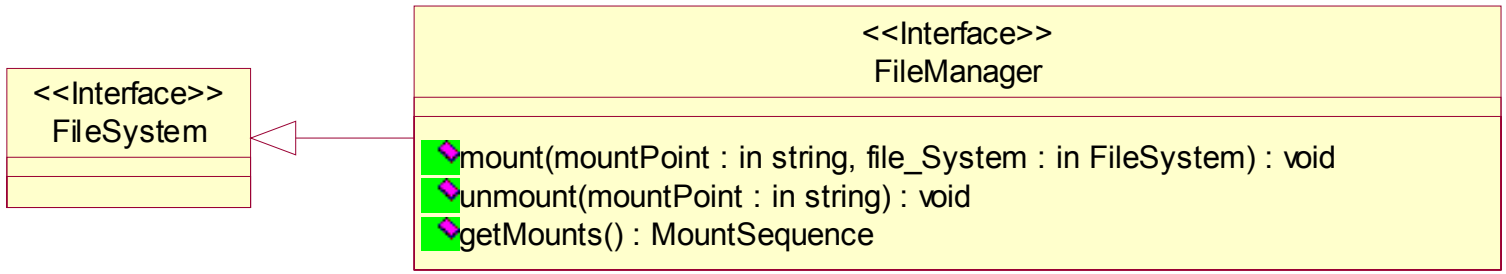
- Read/Write files in the CF::FileSystem
- Abstracts location of files
  - Red-side or Black-side
  - Local or Remote
- Modeled after the POSIX/C file interface
  - Modeled as a sequence of octets
  - Contains pointer to next read or write octet

File System Interface



- Provides distributed (network) file system
- Enables remote access to a physical file system
- Abstracts host file system to SCA interface
- Ensures a CORBA based file access technique
  - Enforces same security bypass/access rules as all CORBA objects

File Manager Interface



- Provide access to multiple (possibly distributed) CF::Filesystems
- Inherits from CF::FileSystem and can be used as if it were one CF::FileSystem
  - Capable of performing CF::FileSystem operations across CF::FileSystem boundries
- One CF::FileManager contains all registered CF:FileSystems
  - All files can be managed from one object

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CF::FileManager Example

- Given: CF::FileSystem residing on PC1 is mounted in CF::FileManager as FS1
- Request:

  Open(/FS1/training/sca.ppt)
- Result

  FileManager calls FS1→open(/training/sca.ppt)

NOTE: The CF::FileManager also provides a copy operation that can spans multiple CF::FileSystems by delegating operations to the appropriate CF::FileSystem.

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Framework Services Interfaces Review

- File operations are modeled after POSIX standard
- All file access operations must us CF::File interface (not OS calls)
- A domain can have multiple file systems, but only one file manager
- All files in a system can be accessed through CF::FileManager interface

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SCA Domain Profile

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How does SCA use XML

- Defines domain profile for the system
  - Collection of XML
  - Describes identity, capabilities, properties, inter-dependancies, and location of components
  - Structure is described in 8 DTD files
- XML (based on DTD's) describes every component of the system
  - Hardware Components
  - Software Components
  - Applications
  - Domain Manager

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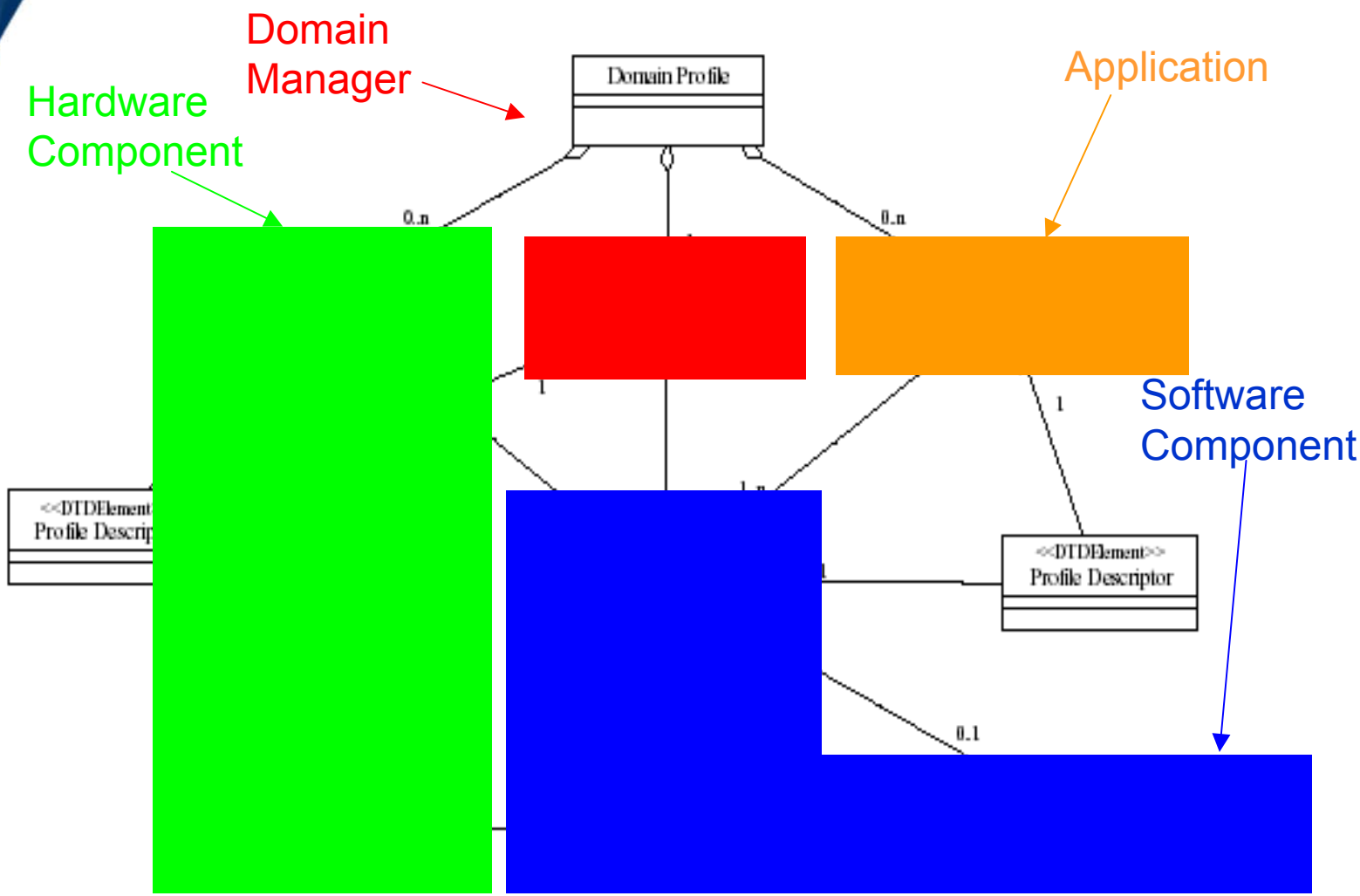
How does XML relate to SCA



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Domain Manager XML Files

- **Domain Profile**
  - Collection of XML files that describe hardware and software components
  - Conform to SCA DTD's in Appendix D
- **DomainManager Configuration Descriptor (DMD)**
  - Configuration information for domain manager
  - List of services to be started by domain manager

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Application XML Files

- Software Assembly Descriptor (SAD)
  - Contains information about the components and connections that make up an application.
  - Designates AssemblyController component
  - Used by ApplicationFactory when creating an application.

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Software Component XML Files

- **Software Package Descriptor (SPD)**
  - identifies a software component's implementation(s).
  - Contains general information about a software package
    - Name
    - Author
    - property file
    - implementation code information
    - hardware and/or software dependencies
- **Software Component Descriptor (SCD)**
  - Contains information about a specific SCA software component
    - Resource
    - ResourceFactory
    - Device
  - Contains information about
    - interfaces that a component provides and/or uses
    - Has a reference to Device Package Descriptor file.

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Assembly Controller

- Main controller for an application
- Instantiation of CF::Resource for an application
  - Implements waveform custom logic
- Application operations delegated to assembly controller
  - CF::Application is implemented by CF vendor
  - Assembly controller is implemented by waveform developer

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Device Configuration XML Files

- **Device Package Descriptor (DPD)**
  - A DPD identifies a class of a device
  - Has Properties that define specific properties for a class of device
    - Capacity, serial number, etc.
- **Device Configuration Descriptor (DCD)**
  - A DCD contains information about the children Devices for a Device
    - how to find the DomainManager
    - Configuration information (Log, FileSystems,etc.) for a Device.

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General XML Files

- **Properties Descriptor.**
  - A Property File contains information about the properties applicable to a software package or a device package.
  - Contains information about the properties of a component
    - Configuration
    - Test
    - Execute
    - Allocation types.
  - Used by software components and devices
- **Profile Descriptor**
  - A Profile Descriptor contains an absolute file name for either an SPD, SAD, DMD or DCD

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Key Domain Profile Points

- All SCA components, waveforms & devices are described in XML
- Domain Profile has 4 logical groups
  - Domain Manager (DMD)
  - Hardware Component (DCD, DPD, PRF)
  - Software Component (SCD, SPD, PRF)
  - Application (SAD)

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Additional SCA Topics

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Topics

- CORBA Services
- SCA API Supplement
- SCA Security Supplement
- Devices
- Other

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CORBA Service

- Naming Service
  - Required by the domain manager
  - Allow clients to find object based on name
  - Similar to telephone “white pages” or internet DNS
  - Allow clients to use meaningful names
- Event
  - Generic notification functionality
  - Usage specified by SCA
- Others

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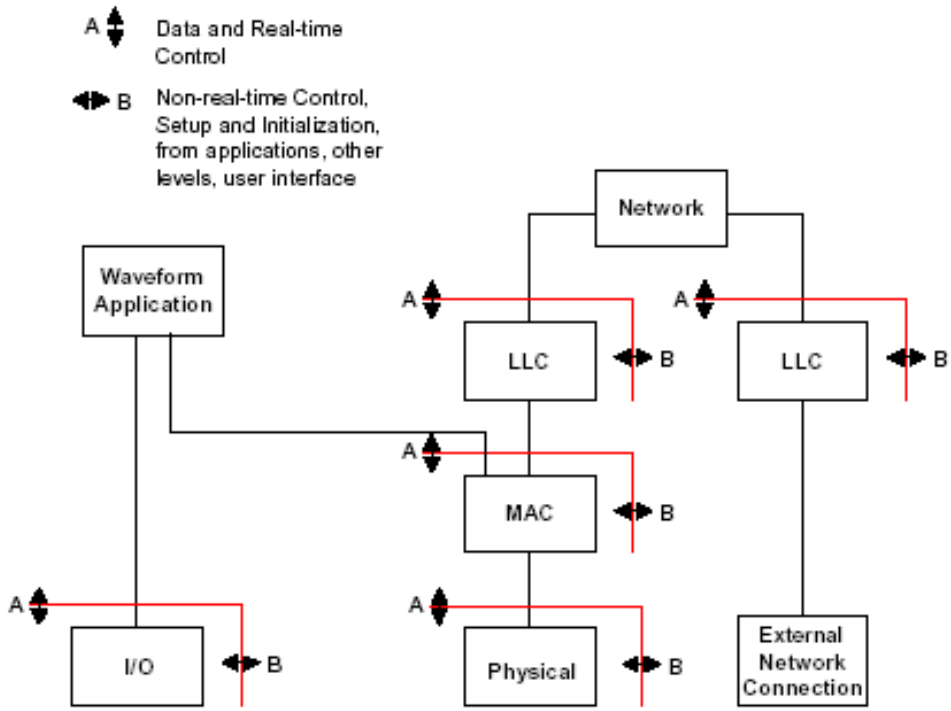
Building Block Service Definitions

- Generic Packet
- Physical Real Time
- Physical Non-Real Time
- Media Access Control
- Logical Link Control
- I/O
- Network



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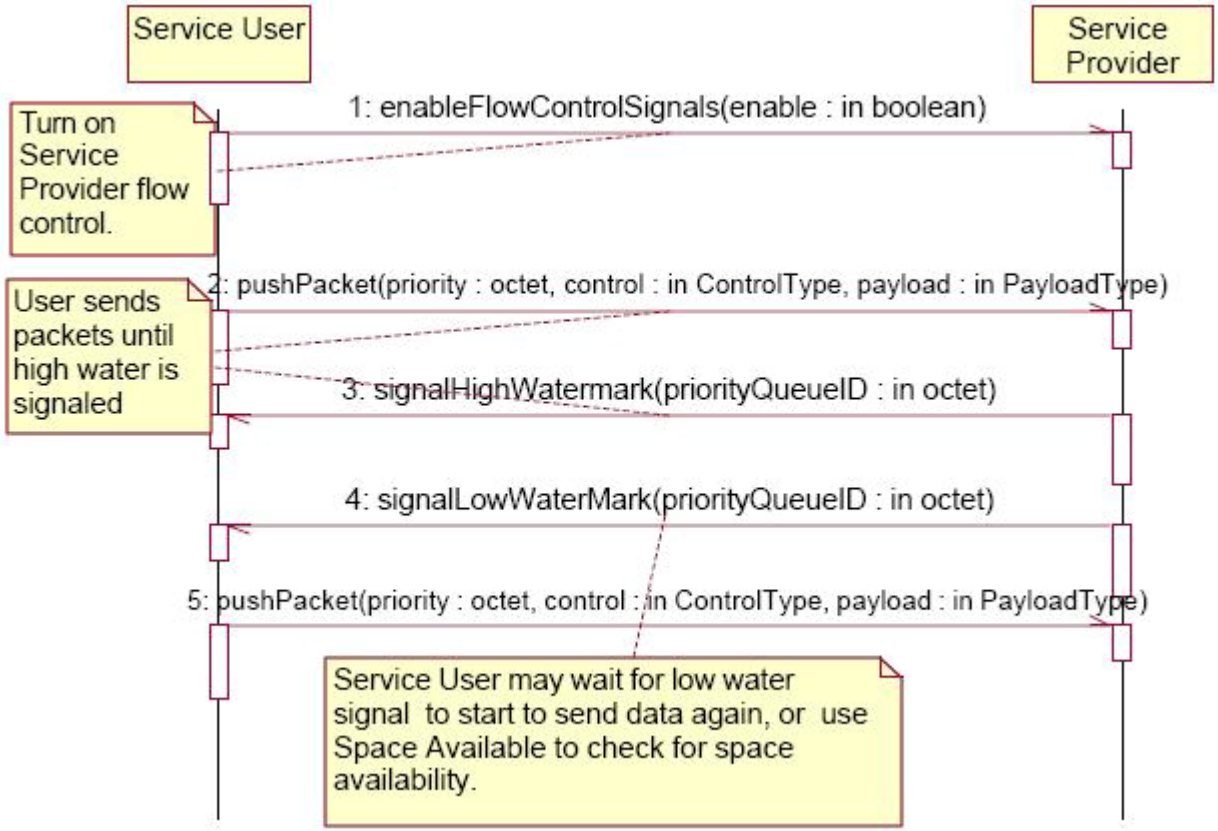
Example API Sequence Diagram



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Security Overview

- Historical background of communications systems and security
- Explains JTRS security architecture
- Lists security requirements for JTRS
- Defines security API

- Not required to implement a waveform

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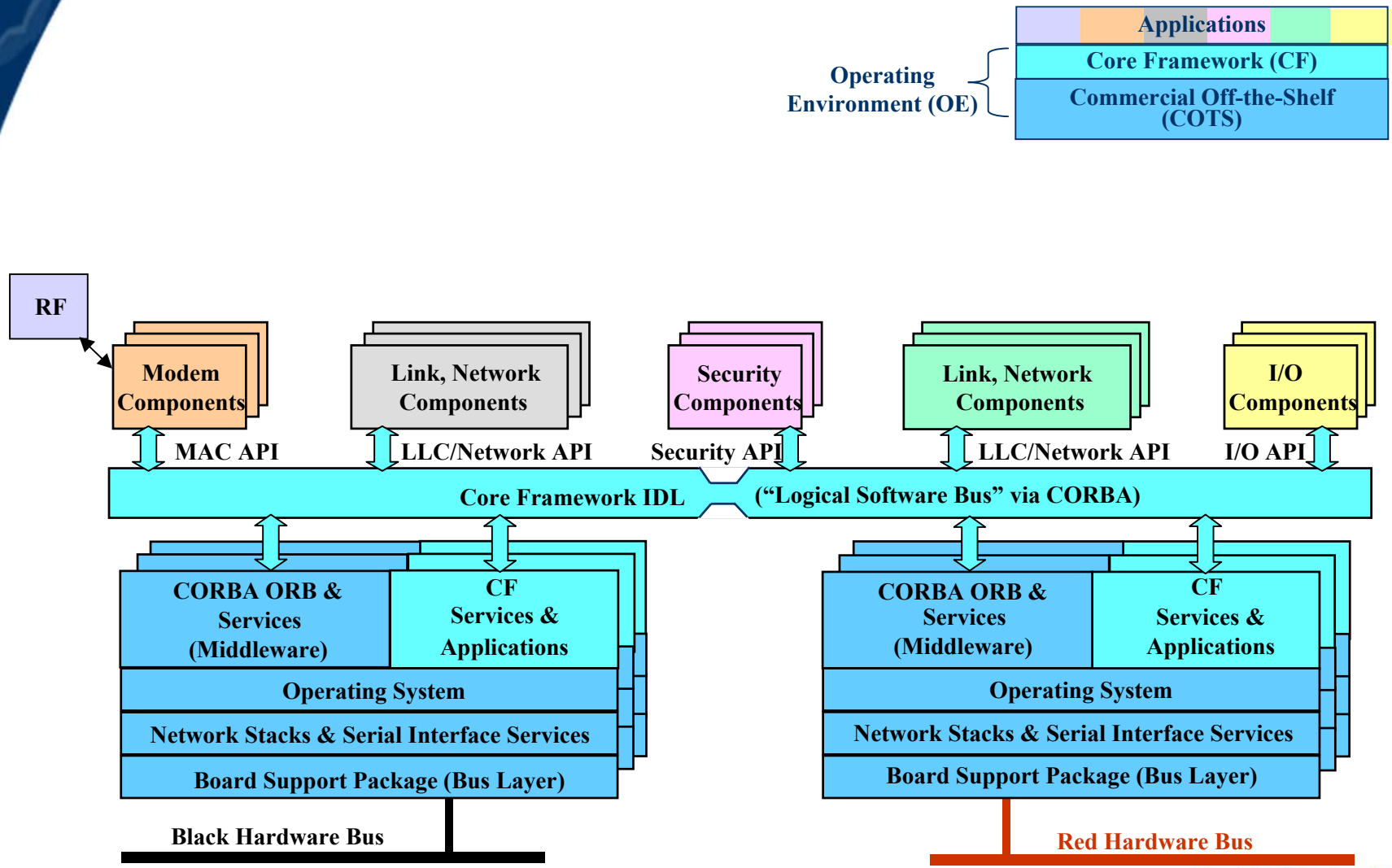
Location of Security API



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Other Misc.

- Device Manager
- Device packages, registration, etc.
- Component deployment

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Next Generation SCA

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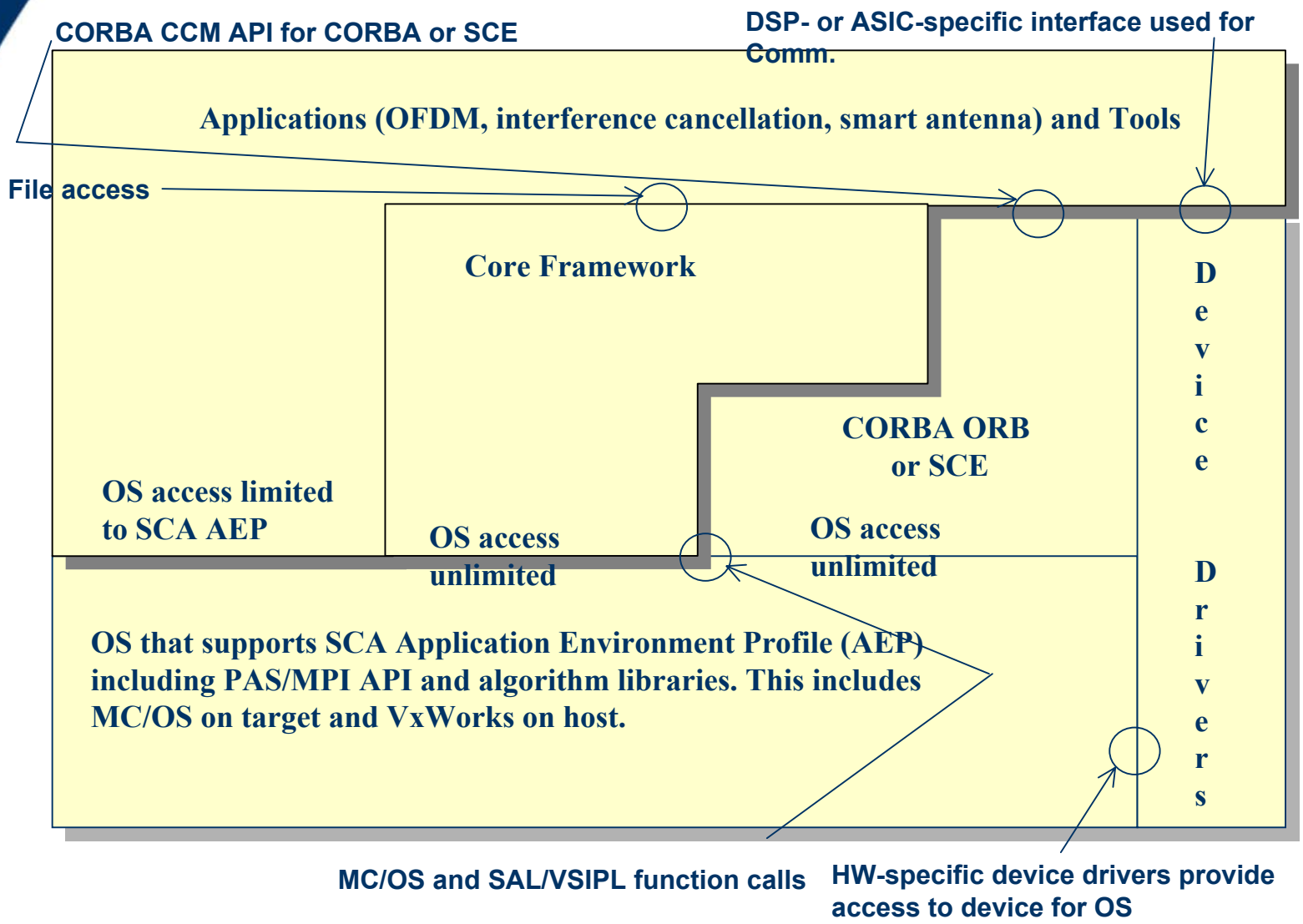
Software Architecture



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SCA Issues

- Portability vs. Performance
- Adapters for ASICs and FPGAs
- "Out-of-synch" with OMG standards
- Scalable Embedded Multiprocessing - Components with data-parallel implementations
- Loose definition of Ports

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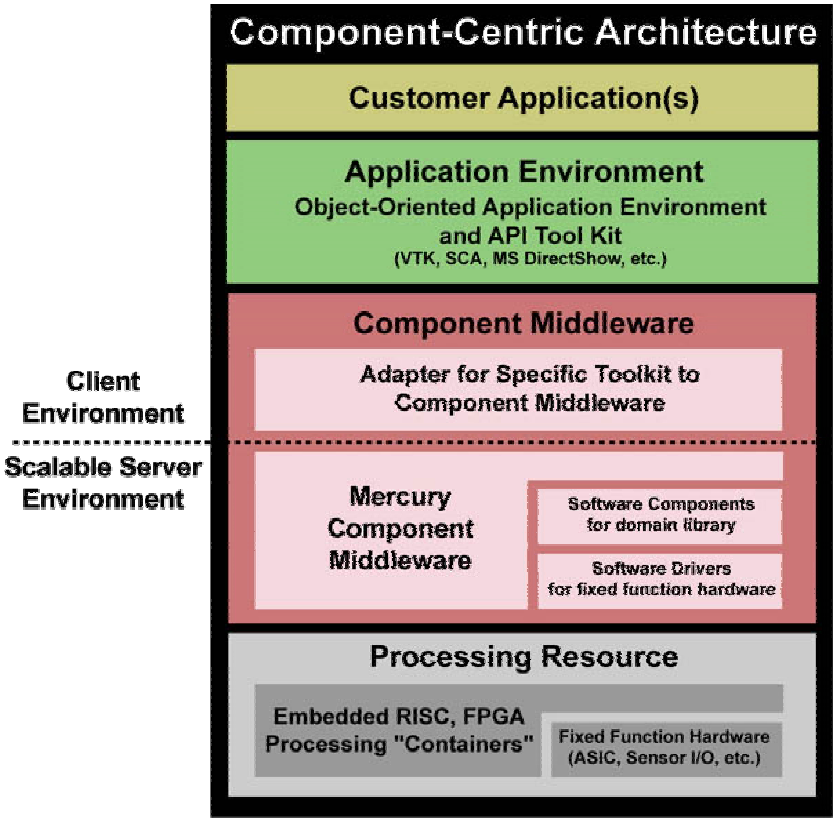
Scaleable Heterogeneous Components

SCA implementation that operates with

- Conventional middleware
- Unique CORBA compliant middleware (SCE) that supports seamless FPGA, DSP and SW component interoperability and low-level machine standards



- High performance, scalable middleware
- Heterogeneous hardware
  - G4s, Pentiums
- FPGA components
- Dynamically scale application-performance based on available resources
- Component authoring tool
- Data-reorg, data-flow

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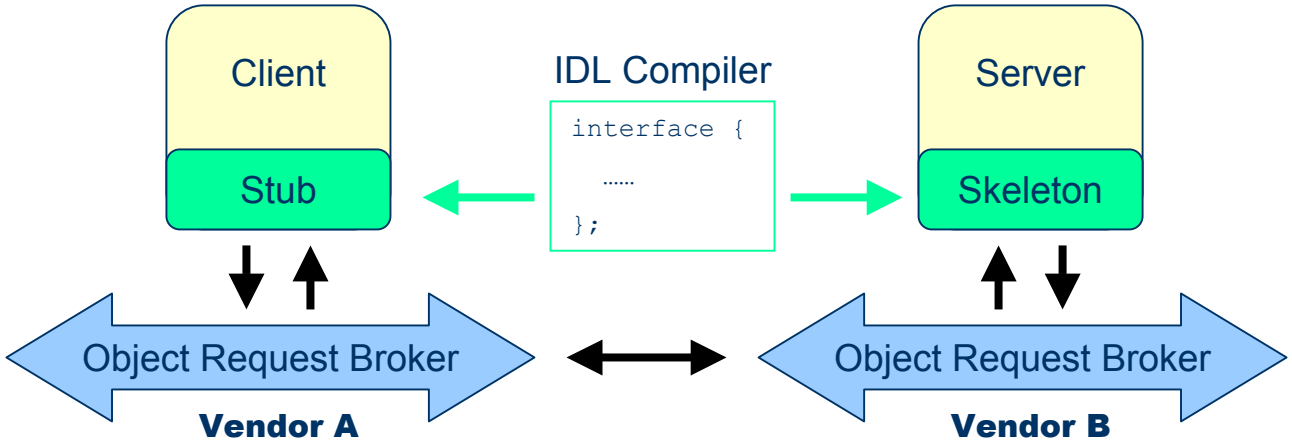
CORBA



- Vendor independent architecture and infrastructure ("middleware")
- Interoperability across networks, vendors and programming languages

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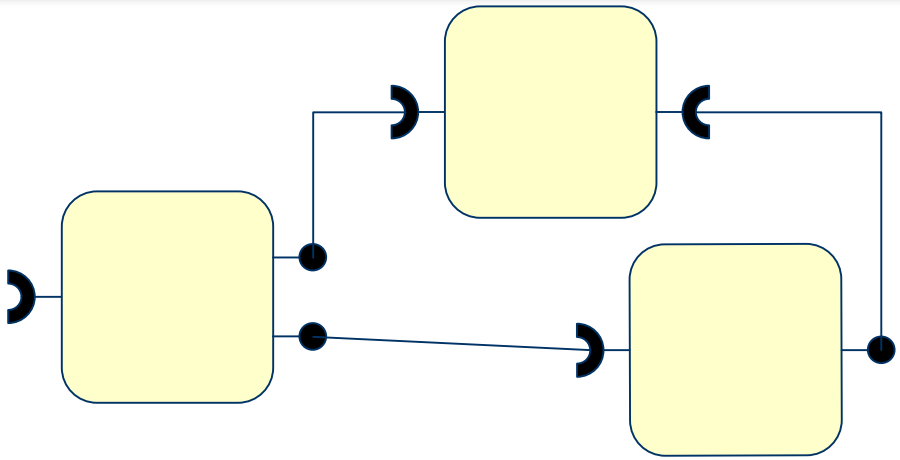
CORBA Component Model



- Components have ports
  - Offered ports: “facets”
  - Required ports: “receptacles”
- Can be interconnected into an Assembly
  - “Assembly based development”
- Better reuse of components

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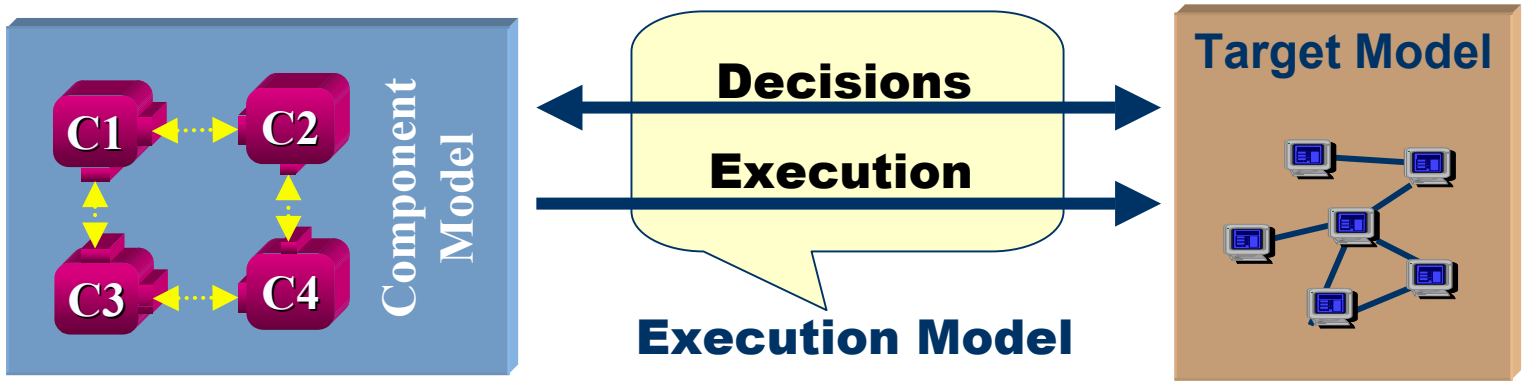
Deployment and Configuration



- Automatic deployment and configuration of component-based applications into distributed heterogeneous environments
  - One-file distributions and installation
  - Hardware resources modeling and matching
  - Encompass SMP/DSP/FPGA target devices

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Mercury Efforts at the OMG

- Deployment and Configuration submission
  - Adopted in June 2003
- Software Radio submission
  - Standard architecture for software radios
- Profile existing services for embedded systems
  - Lightweight CCM
  - Lightweight Logging
  - Lightweight Services (Naming, Events)

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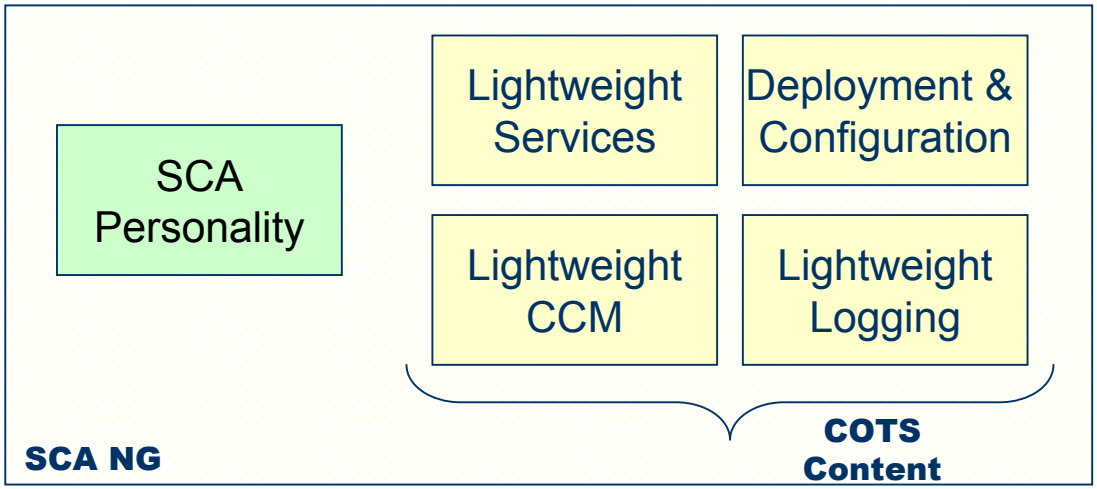
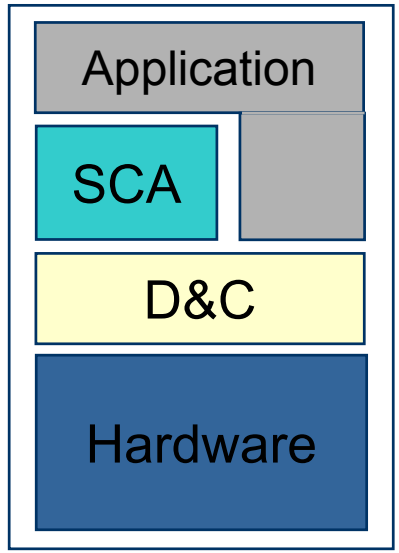
Next Generation SCA





- **Leverage existing and emerging specifications**
  - **Increase COTS content in SCA specification**
  - **Inherit advanced features (e.g. Component Model, heterogeneous deployment)**
  - **SCA itself becomes more lightweight**
- **Mercury is a member of SCA TAG**

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Component Model for FPGA

- Improved time to market
- Ease of implementation
- Pre-qualified IP
- Algorithm portability
- Lightweight infrastructure
- Skill set reduction

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FPGA Infrastructure

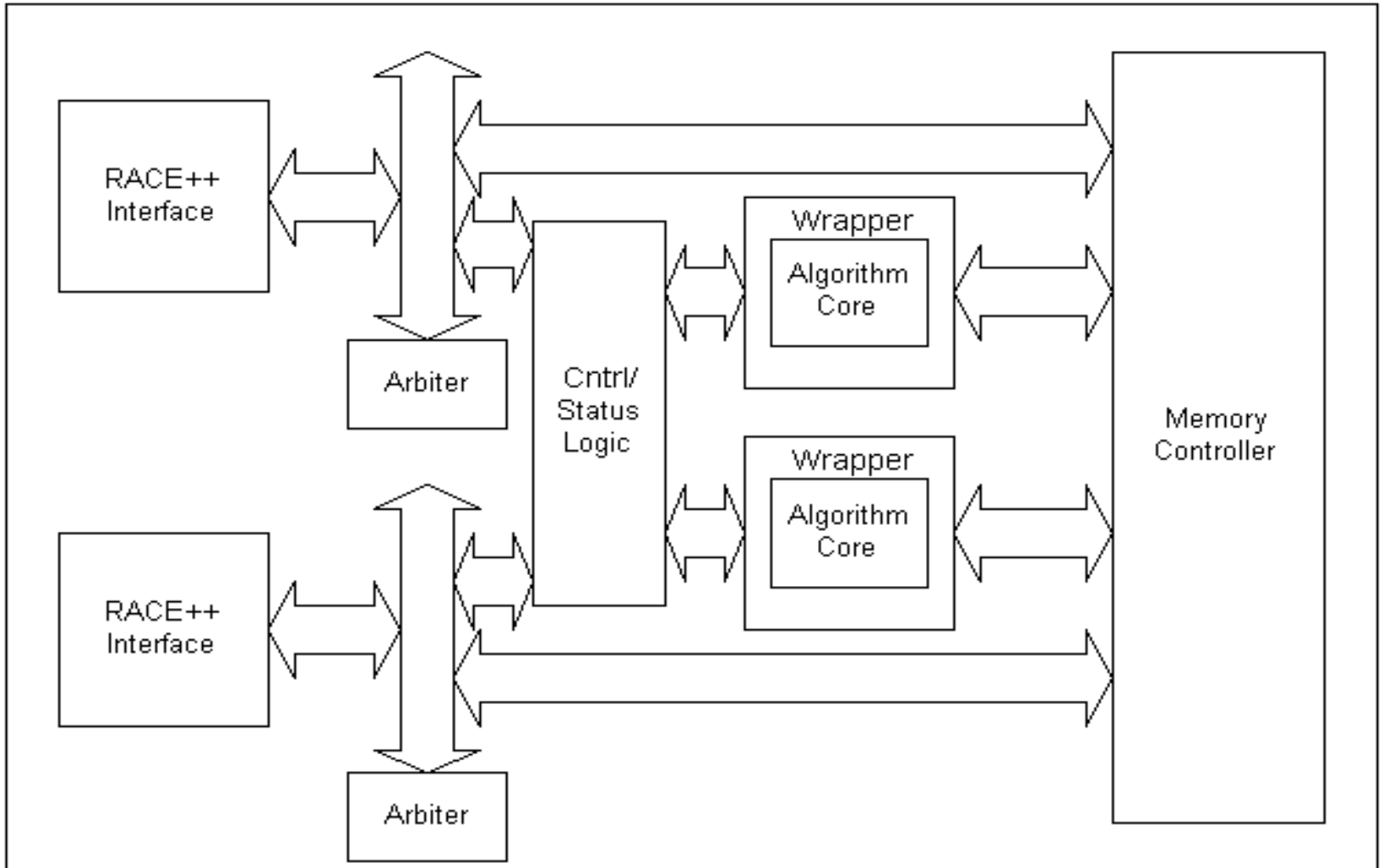

Figure 1. Memory Based Infrastructure.

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Interoperability

- Consistent data transfer protocol
- No bridging between SW and FPGA
- Simple protocol with efficient implementation
- Complex data transfer pattern support
- Interconnect independent

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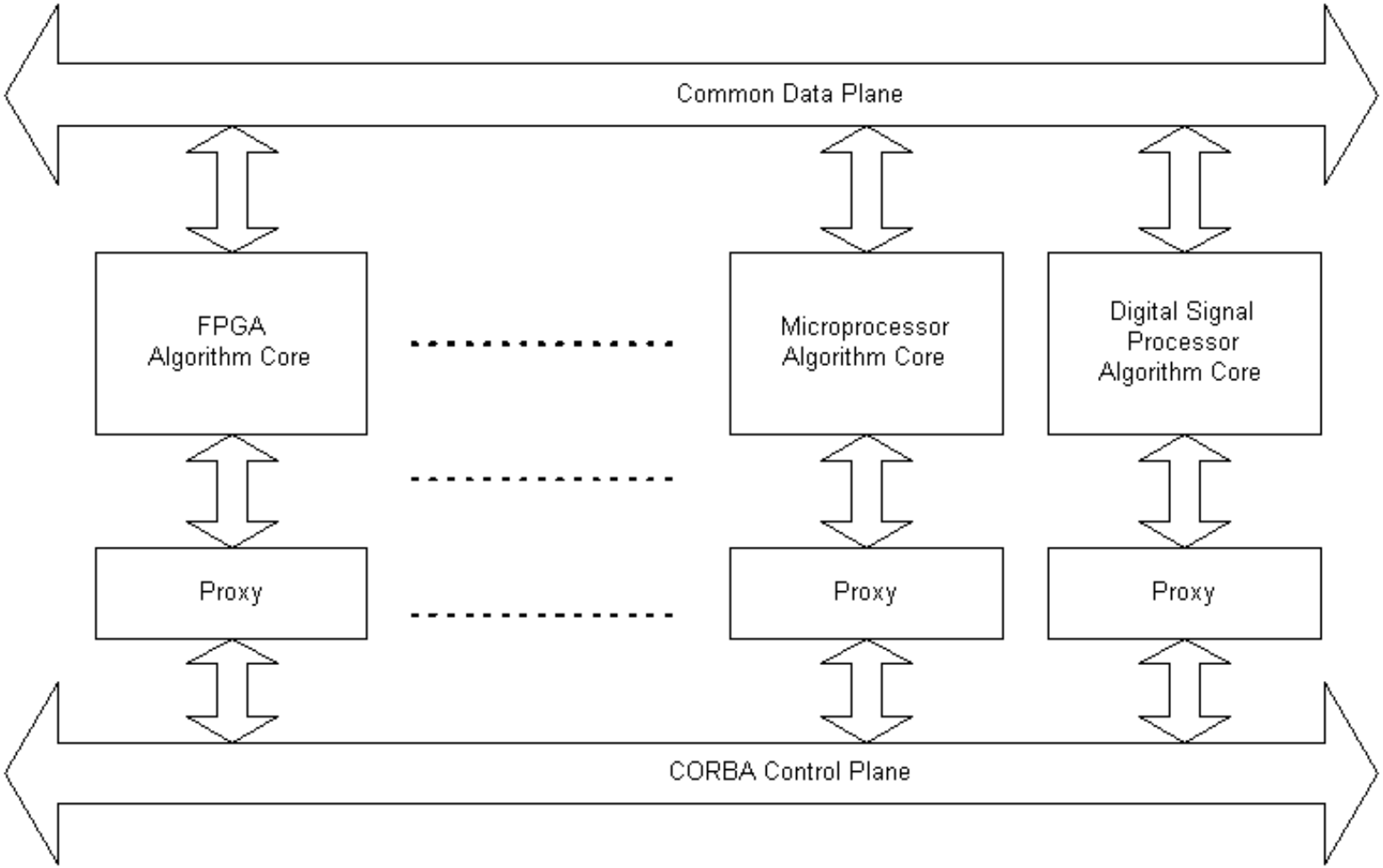
Integrated System



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Summary

- SCA supports waveform interoperability
- Next Generation SCA will support
  - A suite of OMG standards
  - Interchangeability of SW and HW components
  - Lighter weight CORBA-related specifications
  - Low level embedded standards and parallel objects
  - More transparent waveform development

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