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Communication, Navigation, Identification and Reconnaissance

Experience Report on Developing a Software Communications Architecture (SCA) Core Framework

OMG SBC Workshop

Arlington, Va.

September, 2004

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SCA Overview

SCA Definitions and FAQs

- What exactly is a Core Framework?
  - Per the SCA…A set of defined interfaces in three categories:
  - Base Application, Framework Control, Framework Services

- Industry groups these according to deliverable products
  - CF developers provide implementations for Application deployment and configuration
  - CF developers may also provide tools to help end users of their product
    - To help Application developers write SCA compliant Waveforms
    - To help Radio System developers build SCA compliant radios
  - Application Developers provide implementations needed to support their waveform specifications
  - Radio System Developers provide implementations needed to supply SCA compliant radios to Application developers and to the end-users

- Different developers use different CF interfaces to accomplish their goals

SCA Definitions and FAQs

- What does it mean to have "A CF running on a radio"?
  - The radio has SCA-compliant implementations supporting deployment and configuration
  - Radio processing elements have SCA-compliant DeviceManagers
    - Allowing instantiation of SCA-compliant Devices
  - Radio HW elements are abstracted using SCA-compliant Devices
  - One processing elements runs an SCA-compliant DomainManager
    - Allowing the installation of Applications
    - Supporting the creation of SCA-compliant ApplicationFactory(ies)

- The SCA refers to the above as an Operating Environment
  - Also encompasses the Operating System, associated device drivers, and CORBA ORB

The Parts of SCA Software Development

- **Core Framework Developers**
  - **Implement DomainManager, DeviceManager(s), ApplicationFactory, and Application**
    - **To a large degree, the finite set of functions the SCA specifies must be coupled**
      - **e.g. DomainManager and ApplicationFactory implementations are coupled together beyond their SCA interfaces**
    - **The end products are capable of parsing Domain Profiles and instantiating Applications via Devices**
  - **CF developers may also specialize in implementation of Loadable and Executable Devices**
    - **These platform-dependent entities differ from other Devices in that they only load and execute component software on particular platforms**
      - **e.g. - SCA compliant Loadable and Executable Devices can be developed for Linux, LynxOS, Integrity, VxWorks etc.**

The Parts of SCA Software Development

- Radio System Developers
  - Develop the remaining Devices that abstract physical hardware.
    - e.g – Device abstractions for Modems, Antenna, I/O, etc.

- Application Developers
  - May develop entire Applications
  - Or may specialize in the development of particular components
    - For use by other Application Developers

- Service Developers
  - Develop entire radio appliqués that serve general radio needs
    - E.g. – Fault Management, Spectrum Management, etc.
  - Note however, Services are still quite loosely defined in the SCA

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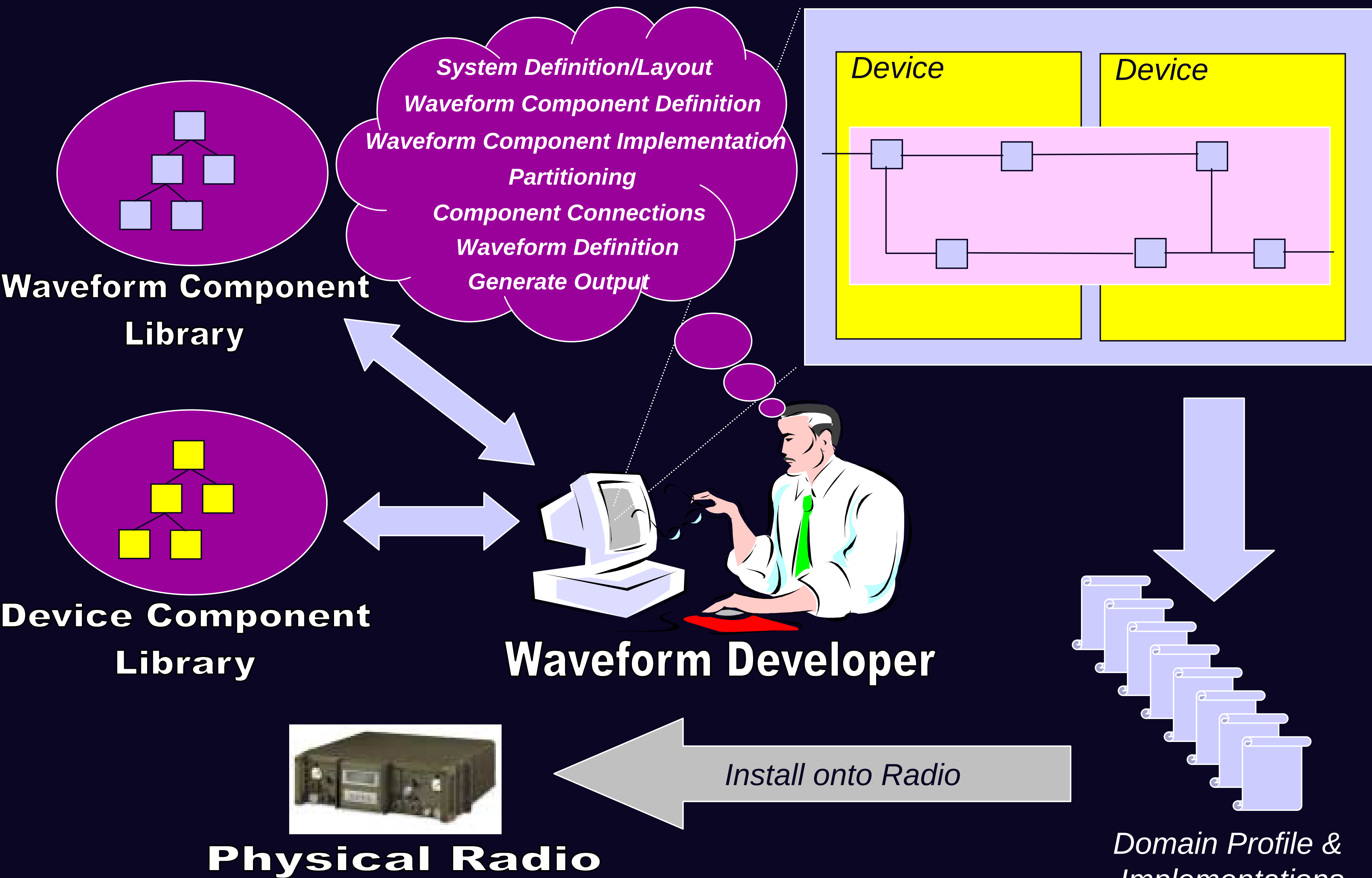
Waveform Development



Application Deployment

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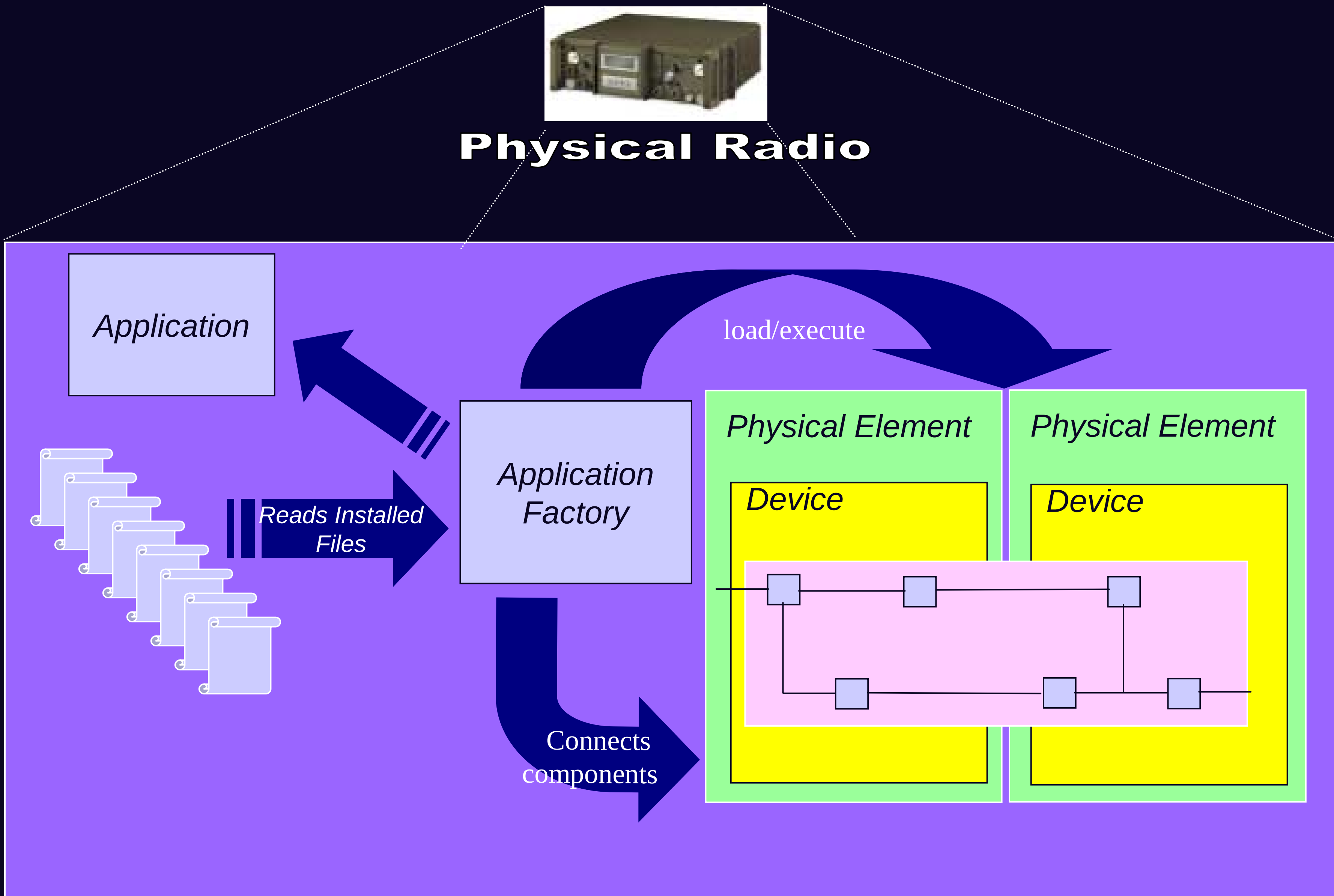

Legacy Radios Contrasted to SDRs

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Typical Legacy Radio	SDR
1 channel / waveform	Multiple simultaneous channels and waveforms
No application abstraction	Software architectures (e.g. JTRS SCA, OMG SWRADIO)
CRYPTO – Single waveform, non-programmable encryption	Programmable multiple waveform encryption
Mature CPUs/custom radio OS	Immature CPUs/POSIX OS
1 or 2 CPUs – few interfaces	Many distributed CPUs – tens of interfaces
Service designed custom networks	Self-Forming Networks
Voice and limited data services	Voice and data, routing, radio services (message translation, spectrum management, etc.)

Benefits and Impacts of Mandating a Framework

Software/Middleware Benefits and Impacts

- **Key enablers for portability & re-use are software-based waveforms and middleware**
- **This portability comes at a cost**
  - **Additional software layers**
  - **Remote procedure calls and associated transport overhead**
- **Software/middleware costs**
  - **Increased I/O overhead, due to middleware layering**
  - **Reduced determinism (higher jitter, latency) due to packetization**
- **Operating system costs**
  - **More layers to access physical hardware**
  - **Address space separation overhead**
    - **Hardware independence comes at cost**
    - **Layers between application software, operating system, board support package and device drivers**

Addressing Software/Middleware Impacts

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- Moore's Law continues to hold
  - Processing power is increasing
  - Interconnect speed is increasing
  - Interconnect latency is decreasing
  - Power consumption is decreasing
  - Size is decreasing
- These benefits advance at compounded rates
- Middleware vendor advances
  - Standardization allows ORB vendors to increase performance and lower footprint without impact to application software
    - Real-time deterministic ORBs implementations available
    - High-speed, low-latency pluggable protocols
    - Collocation optimizations
    - Zero-copy techniques
- Preemptive real-time operating systems
  - Low-latency context switching
  - Efficient compilers

Software Architecture Benefits and Impacts

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- Software frameworks are key enablers to provide
  - Deployment and configuration mechanisms
  - Component-based software development techniques
  - Radio platform standardization
  - Scalability across radio platforms
- They properly segregate the responsibility of the waveform, radio platform and radio service developers
- Software frameworks themselves typically have little performance impact
  - Once done deploying a waveform the framework is not involved in waveform processing
  - In other words… "It steps out of the way"
  - Does not involve itself in the data-flow paths of a waveform
  - Re-involves itself on request to tear down waveform

Software Architecture Benefits and Impacts

- Framework speed optimizations
  - Focused on the speed of waveform deployment and teardown
  - Cannot optimize speed at which waveform moves data
    - This is a function of the middleware and O/S used
- Framework footprint optimizations
  - Focused on reducing the “run time” footprint
  - Examples
    - Memory used per component deployed, per connection, etc.
    - Middleware and O/S play a role here as well
    - O/S’s supporting dynamic libraries lower total memory cost

High-Speed interconnects and I/O Benefits and Impacts

- **The evolution of higher-speed I/O interfaces and higher-performance processors mitigates much of the additional software layering and middleware overhead**
- **Efficient transports that increase throughput and lower latency can be written for these interfaces**
- **Middleware can be layered on these efficient transports to lower middleware impact even more**
- **Advancement in these areas are mostly revolutionary vs. evolutionary**
  - **Requiring users to abandon entire implementations each time a new quantum leap is made**

Technology areas being addressed by industry for application in SDRs

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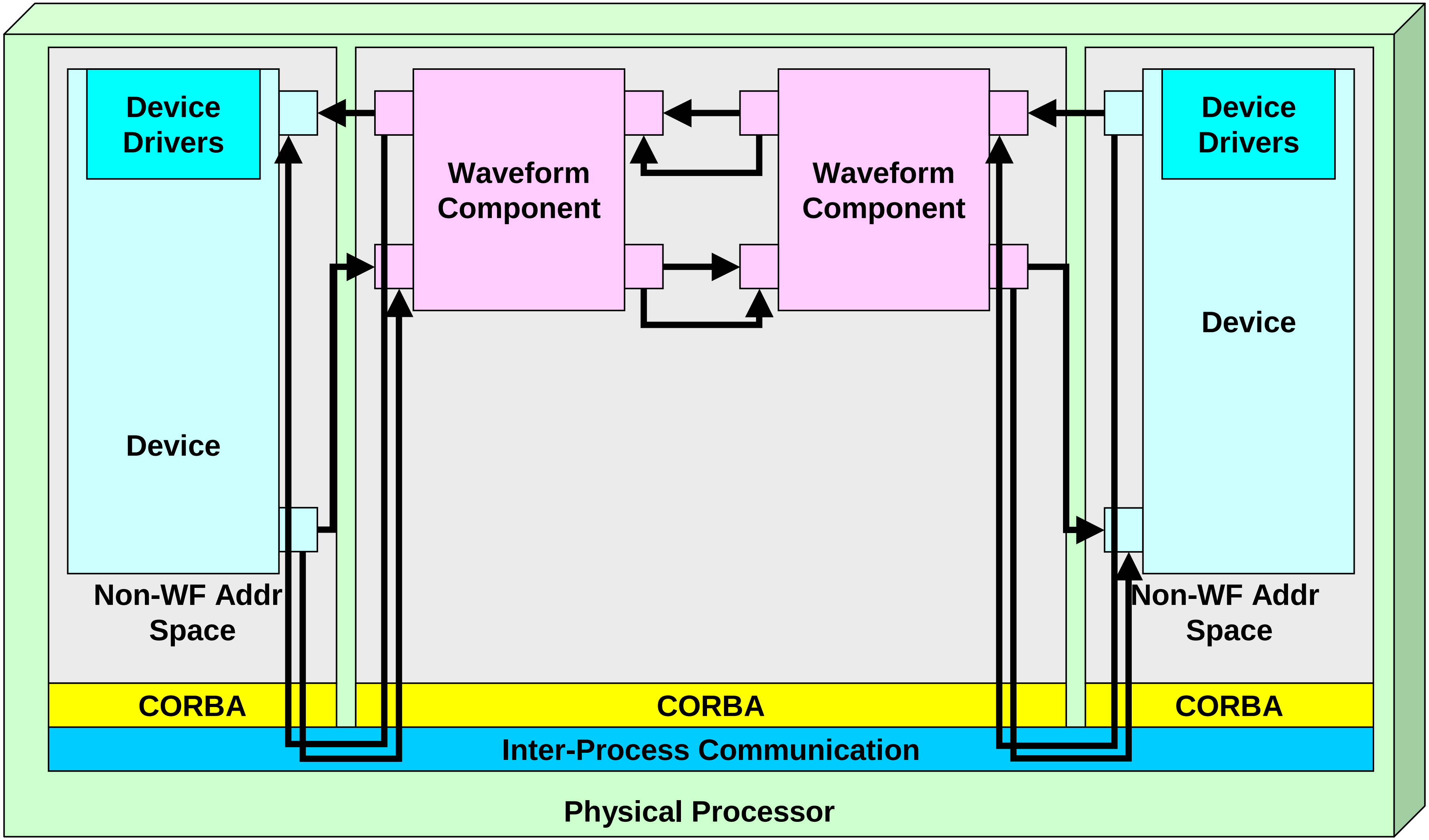
- Software/middleware ✓
  - Metrics successfully collected, all near-term requirements satisfied
    - http://www.atl.external.lmco.com/projects/QoS/orb/index.html
- Software frameworks ✓
  - JTRS/SCA already being applied to systems
    - JTRS Steps 2a, 2b, 2c, Cluster 1, AJCN, WIN-T, FAB-T
- High-performance, low-power computing resources ✓
- High-speed I/O and interconnects ✓
  - Gigabit Ethernet now directly integrated into many CPUs, bridge chips, and FPGAs
  - High-speed switching fabrics on vendor roadmaps, gaining acceptance, e.g., RapidIO, PCI-Express

Techniques required to meet performance constraints

- Use high performance middleware designed for real-time environments
  - Use middleware constructs that eliminate “deep copies” between waveform components wherever possible
- Use efficient and high performance coding language and compilers
  - Apply optimization techniques
  - Use profiling tools to find additional inefficiencies
  - Disabling native exceptions can provide significant performance increases
- Proper partitioning of software components is key
  - Partition components with high throughput/low latency requirements in the same address space.
  - Use middleware collocation optimizations
    - e.g. Turns CORBA calls into C++ call - Overhead virtually disappears

Collocation Optimizations a must!



Advantages and Successes from Using Middleware

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- Lessons learned in building and fielding JTRS radios
  - Of all the elements of the software system middleware capable components were the least problematic to build and integrate
    - RTOS, device drivers, middleware, software frameworks, and application components
  - Apart from developing the waveform software, a large percentage of effort is in debugging drivers, BSPs, hardware, and RTOS
- Middleware like CORBA is standardized, therefore easy to use
- Location transparency and architecture portability allows
  - Software development and testing on non-target platforms, which eases integration onto target
  - For the reuse, repartitioning and redeployment of software onto other radio platforms

SCA Myths

SDR/SCA Myths

- "Moore's Law won't help"
  - Faster, lower-power processors and interconnects make SDRs a reality in wider bands and smaller footprints
- Wideband can't be done
  - It is already being done in SCA-based systems
- Processing overhead and power consumption unacceptable
  - High-performance, low-power, and low-cost processors with power-saving capabilities available today
  - Look no further than your own PDA or Blackberry

SDR/SCA Myths

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- Doesn’t scale to handheld devices
  - BAE Systems has demonstrated full SCA-compliant framework and waveform running in iPAQ PDA
- Portability and reprogramability ends at the MODEM boundary
  - DSP middleware available today and mature
- Requires extensive experience with CORBA, XML, C++, SCA, etc. and takes a long time to come up to speed
  - Pattern-oriented software development, OMG MDA, and model-integrated computing techniques can readily address this

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Patterns and Principles of framework/component design applicable to the SCA

Patterns and Principles of framework/component design applicable to the SCA CF

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- Extension Interface/Objects Pattern
- Component Configurator Pattern
- Proxy
- Wrapper Façade, Facade
- Template Method
- Strategy

- Details of how these patterns are applied to the CF can be found in Monday's *Effective Component and Application Development using the Software Communication Architecture* Tutorial

Extension Objects Pattern – Benefits Summary

- Maintain the CF::Resource and CF::Device abstractions while simultaneously providing for unanticipated "interface" extensions
- Keeps clients of waveforms decoupled from various interfaces that they don't use
- Allows for easy addition of new services inside components with a minimal impact to client code
- Prevents bloated interfaces

Component Configurator – Benefits Summary

- Waveform applications can load and unload their component implementations at run-time without having to modify or statically relink the entire application.
- Waveform applications can be easily redeployed and redistributed depending on changes in operation environment (e.g. load balancing, tighter security concerns)
- Deployment of waveforms no longer coupled to the deployment of the Core Framework on any other part of the Operating Evironment.
- CF::Application provides a centralized repository and administrative mechanism for waveform management
- SAD file provides fast and easy mechanism to change the "schematic" of the waveform without recompiling or relinking.

Proxy and Wrapper Façade Pattern – Benefits Summary

- **Complex waveforms hidden behind single abstraction**
- **Well known interface established between Core Framework and the Waveform (CF::Application and Assembly Controller bridge the two)**
- **Hide distribution mechanics (e.g. Components**
- **Seamlessly allow the addition of new connection semantics (e.g. fan-out and controller number of connections)**
- **Simplify access to OS APIs (e.g. APIs for Threading)**

Template Pattern – Benefits Summary

- **Allows clean separation of much of the SCA required component mechanics from the business logic of the particular waveforms**
- **Provides higher level frameworks for many of the SCA facilities.**

Strategy Pattern – Benefits Summary

- XML Parsing
  - Encapsulate XML parsing algorithms and technologies and make them pluggable
    - e.g. DOM, SAX, proprietary method
  - Decouple the Core Framework from the particular XML technology being used.
- Capacity Allocation
  - Encapsulate capacity model algorithms from the Devices that implement them.
  - Allows component developers to leverage "capacity frameworks" in higher level classes while at the same time "tweaking" their behavior with component-specific behavior

Questions?