SPECTRUM SIGNAL PROCESSING

Support for Specialized Hardware Devices within the SCA CoreFramework

SBC Workshop
15 September 2004

flexComm
building blocks for
software reconfigurable platforms

Agenda

- Context.
- Modem architecture models.
- Waveform – modem portability.
- Dedicated modem resource model.
- Extending the CoreFramework into the modem.
- Dealing with non-CORBA enabled devices.
- Need for a hardware abstraction layer.
- Pooled modem resource model.
- Shared modem resource model.
- Supporting advanced waveforms.
- Summary.

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Context

- **Techniques developed during the building of an SCA2.2 platform on top of a high-performance SDR modem engine.**
- **Goals of this activity:**
  - Build an SDR platform that encourages and supports the design of portable waveforms.
  - Minimize effort of porting existing waveforms to the platform.
  - Produce re-usable modem platform components (by designing for a wide range of modem architectures).
- **Lessons learned – limitations of SCA2.2 leading to change proposals for future specifications.**

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Modem Architectures: Device Selection

Goal: Maximize Waveform Portability.

- **General Purpose Processors (GPPs) are used wherever possible.**
  - Maximize reconfigureability of application.
  - Maximize portability of software components.
- **Digital Signal Processors (DSPs) are used where size and power constraints limit the use of GPPs.**
  - Floating-point preferred to fixed.
- **FPGAs are used wherever DSPs do not meet performance requirements .**
- **ASICs are used as little as possible.**
  - i.e. Never J

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Modem Architectures: Interconnection

- **The topology in which the selected processing devices are interconnected determines redundancy and reconfigurability properties of the modem platform.**
- **SCA makes possible several different architectures, but they generally break into 3 models:**
    - Dedicated Modem Resources.
    - Pooled Modem Resources.
    - Shared Modem Resources.
- **In addition, a number of advanced waveform applications (i.e. beyond 2 GHz) require non-traditional architectures for waveform support.**
    - Array Processing.
    - Shared Resource Applications.

We will consider each of these in detail as we proceed.

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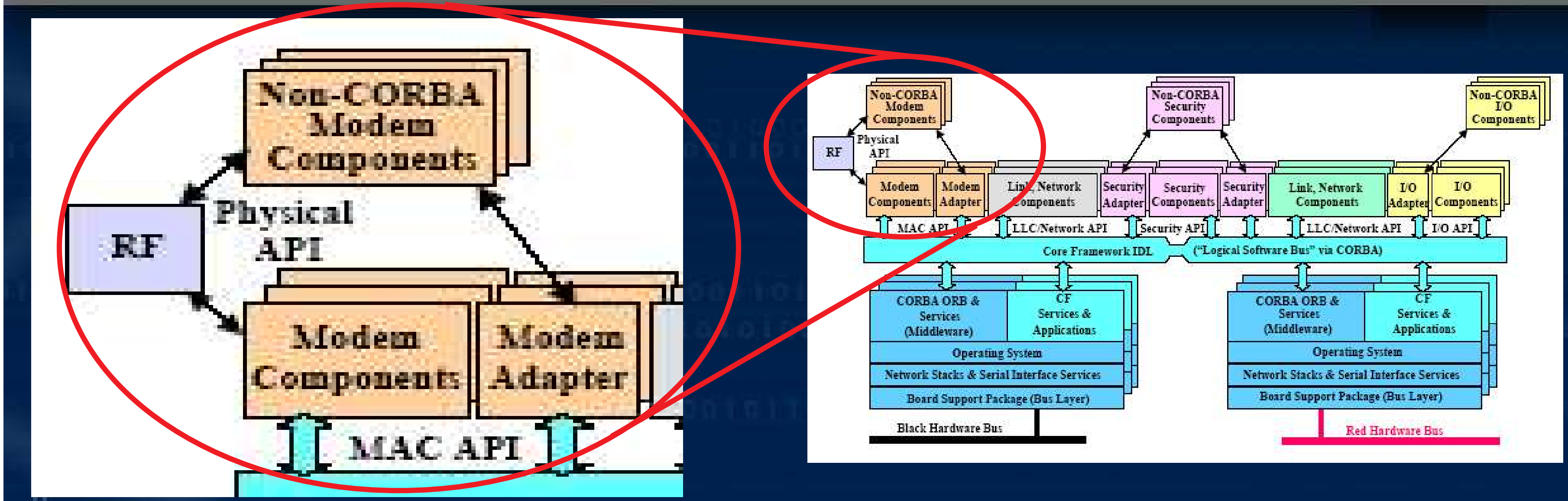
Waveform – Modem Portability: SCA view of the Modem


Non-CORBA Modem Components
RF
Physical API
Modem Components
Modem Adapter
MAC API
Non-CORBA Security Components
Non-CORBA I/O Components
Link, Network Components
Security Adapter
Security Components
Security Adapter
Link, Network Components
I/O Adapter
I/O Components
LLC/Network API
Security API
LLC/Network API
I/O API
Core Framework IDL
("Logical Software Bus" via CORBA)
CORBA ORB & Services (Middleware)
CF Services & Applications
Operating System
Network Stacks & Serial Interface Services
Board Support Package (Bus Layer)
Black Hardware Bus
CORBA ORB & Services (Middleware)
CF Services & Applications
Operating System
Network Stacks & Serial Interface Services
Board Support Package (Bus Layer)
Red Hardware Bus

- SCA treats the modem as just one of many entities within a waveform.
- Much of the literature tends to regard the modem as a single component within a radio.

Waveform – Modem Portability

- **But, SCA does not constrain modem architecture:**
  - Designers are free to use any combination of GPPs, DSPs, FPGAs and interconnects that meets system requirements and constraints.
  - Different architectures are likely to be fundamentally incompatible.
- **One way of dealing with this is to abstract away the architecture of the modem (i.e. define a ModemDevice) .**
- **But with this approach, waveform portability is limited to the modem boundary.**
  - The waveform ModemDevice that must run on the ModemDevice will have to be re-written for each modem architecture.
  - Yes, the rest of the waveform will be portable but only to whatever interface ModemDevice exports.

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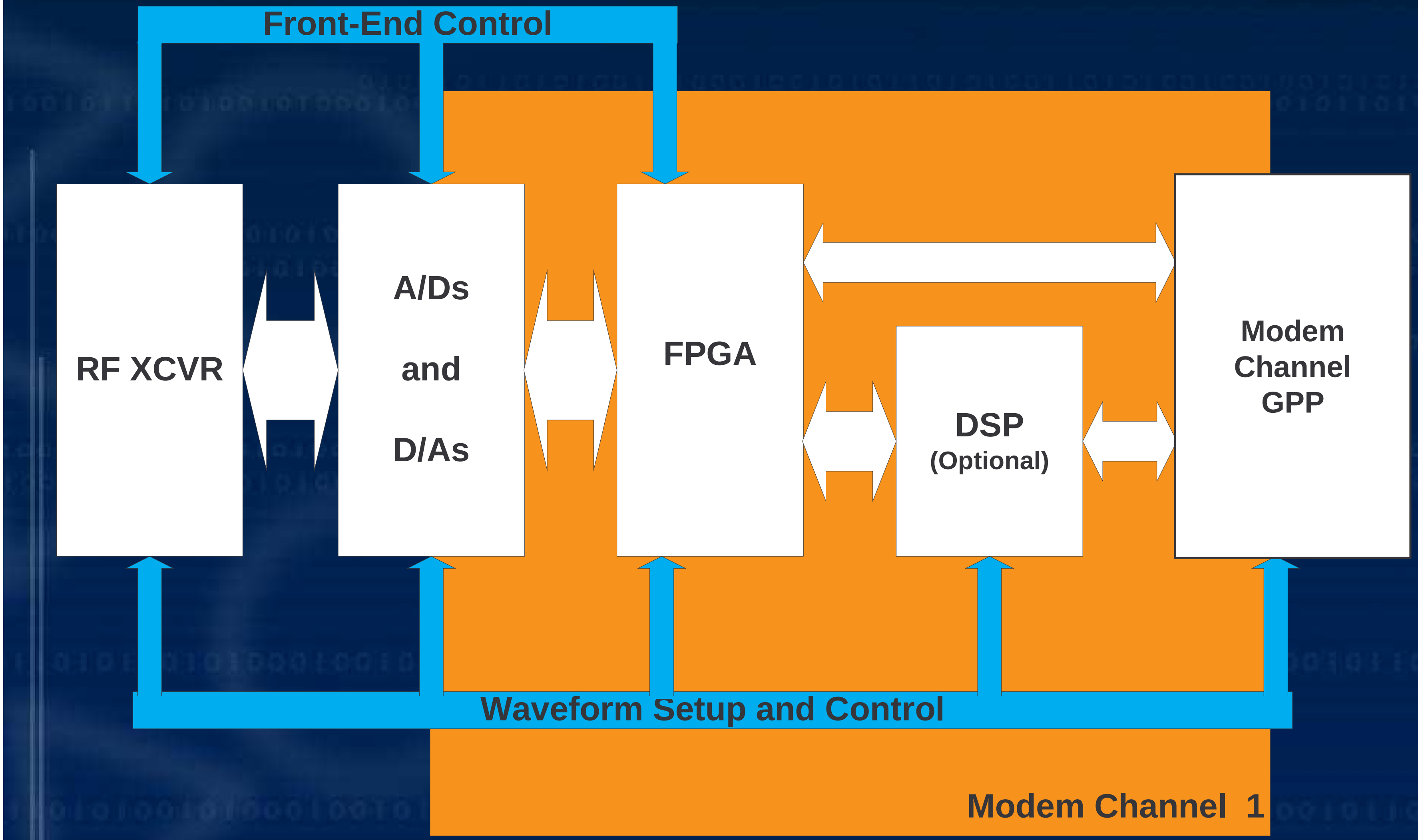
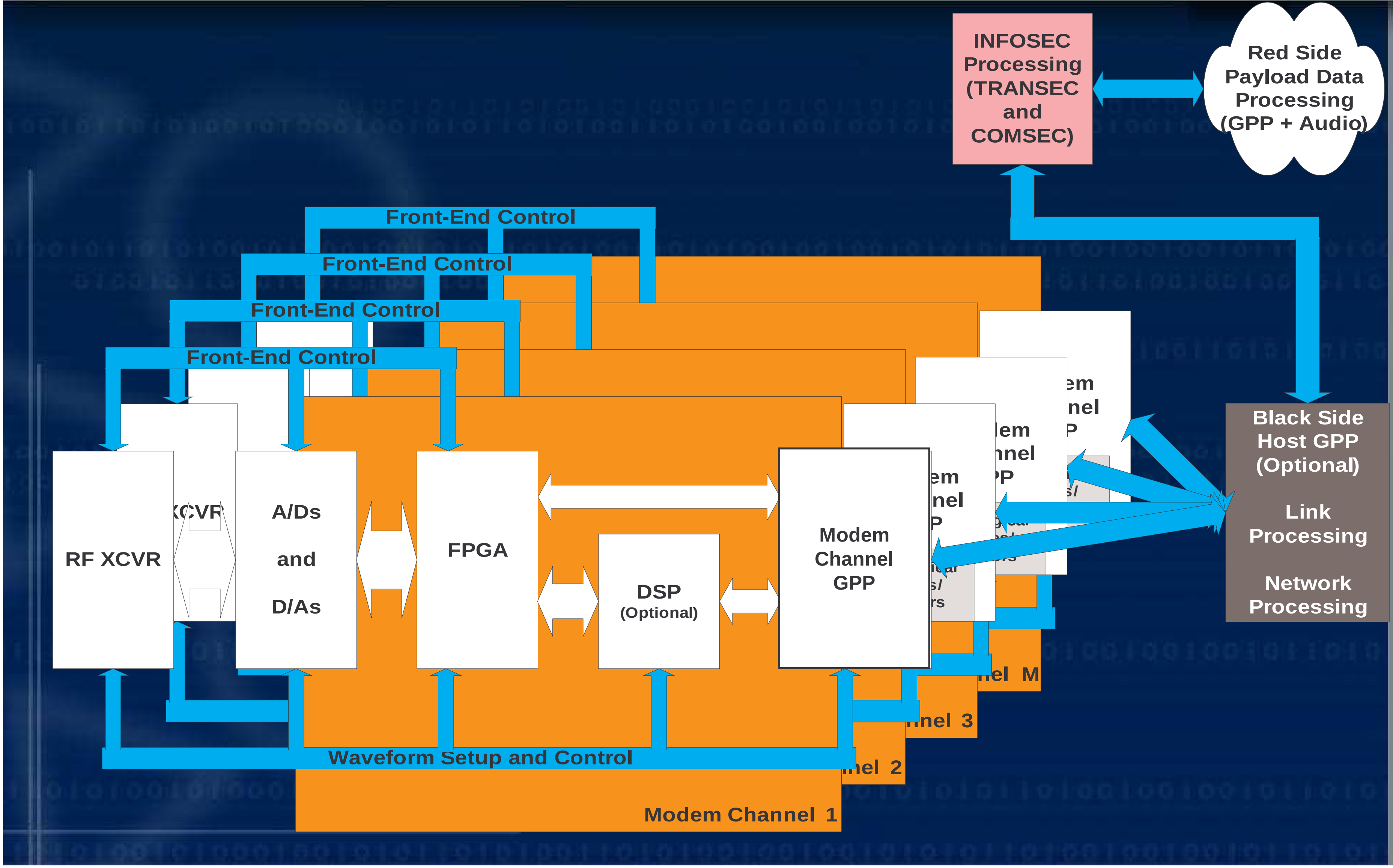
Dedicate Resource Model Example: A single channel modem



Scalability Achieved in a Dedicated Resource Model by Adding Additional "Modem Channels"



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Extending the CF Inside the Modem

- We are better off exposing all the processing elements inside the modem to the CF as Logical Devices.
- Allows for a common application interface for functions such as set-up, tear-down, connection and control of waveform resources inside the modem at a component level.
- Promotes the ability to drop standard COTS building blocks directly onto devices within the modem, which provides portability and re-use benefits.

Components Required in the Example Dedicated Resource Model

GPP Logical device

DSP Logical Device

FPGA Logical Device

Device Manager

Per Modem Channel

Limits of Portability

- While the modem building blocks are in theory re-usable, they still have to be hooked together in a way which is ultimately architecture specific.

<u>Contention:</u>

There is no such thing as a completely portable (useful, real-world) SCA (2.2) Waveform Application.

- However porting effort can be minimized.

Minimizing the Porting Effort

- **In the best case we will avoid the need to write/modify anything that needs compilation.**
- **In order to achieve this we need to do two things:**
  - Define a standard method for interfacing CORBA waveform components to waveform components running on non-CORBA enabled devices. (Typically control flows).
  - Define a standard way of interconnecting components running on non-CORBA enabled devices (Data flows).

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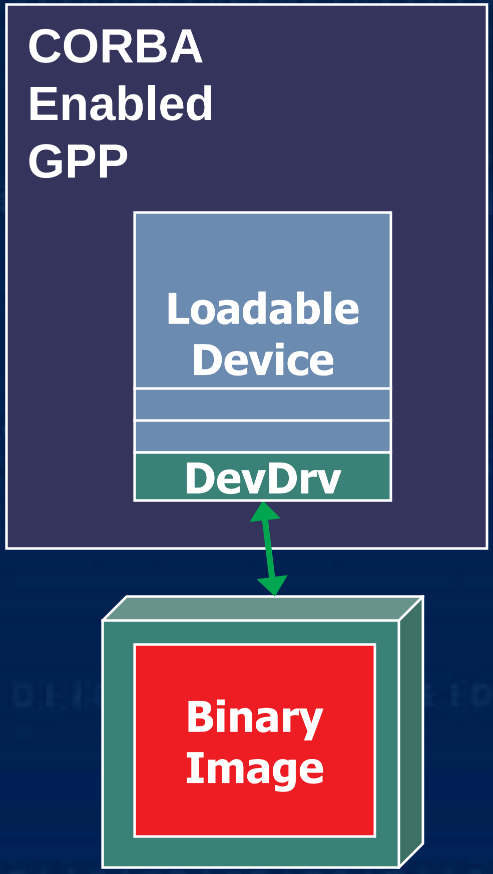
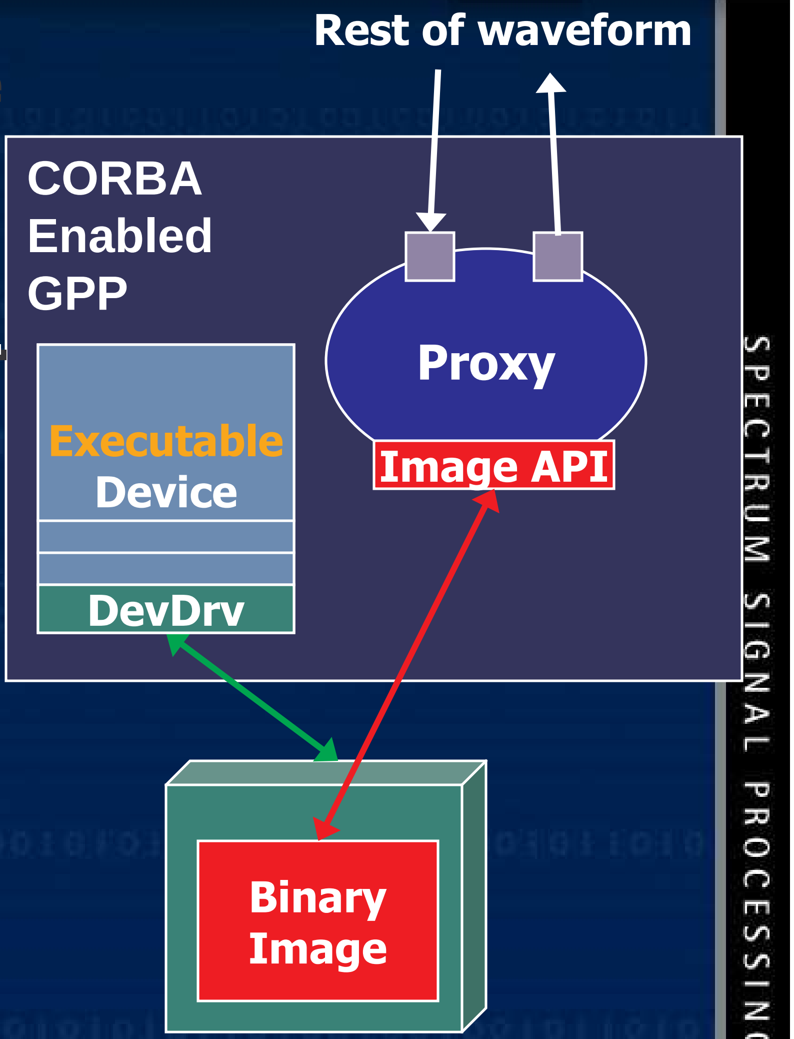
Non-CORBA Enabled Devices (NCEDs)

- FPGAs and DSPs (for now).
- Need to provide a CF::LoadableDevice running on a CORBA enabled GPP which has access to the physical device.
- This enables a waveform application to drop a Binary Image (FPGA Core or DSP Code) onto the device.
- However, having done so, how is this Image configured and controlled by the waveform application, and how is data flow to and from it set up?



Binary Image Proxies

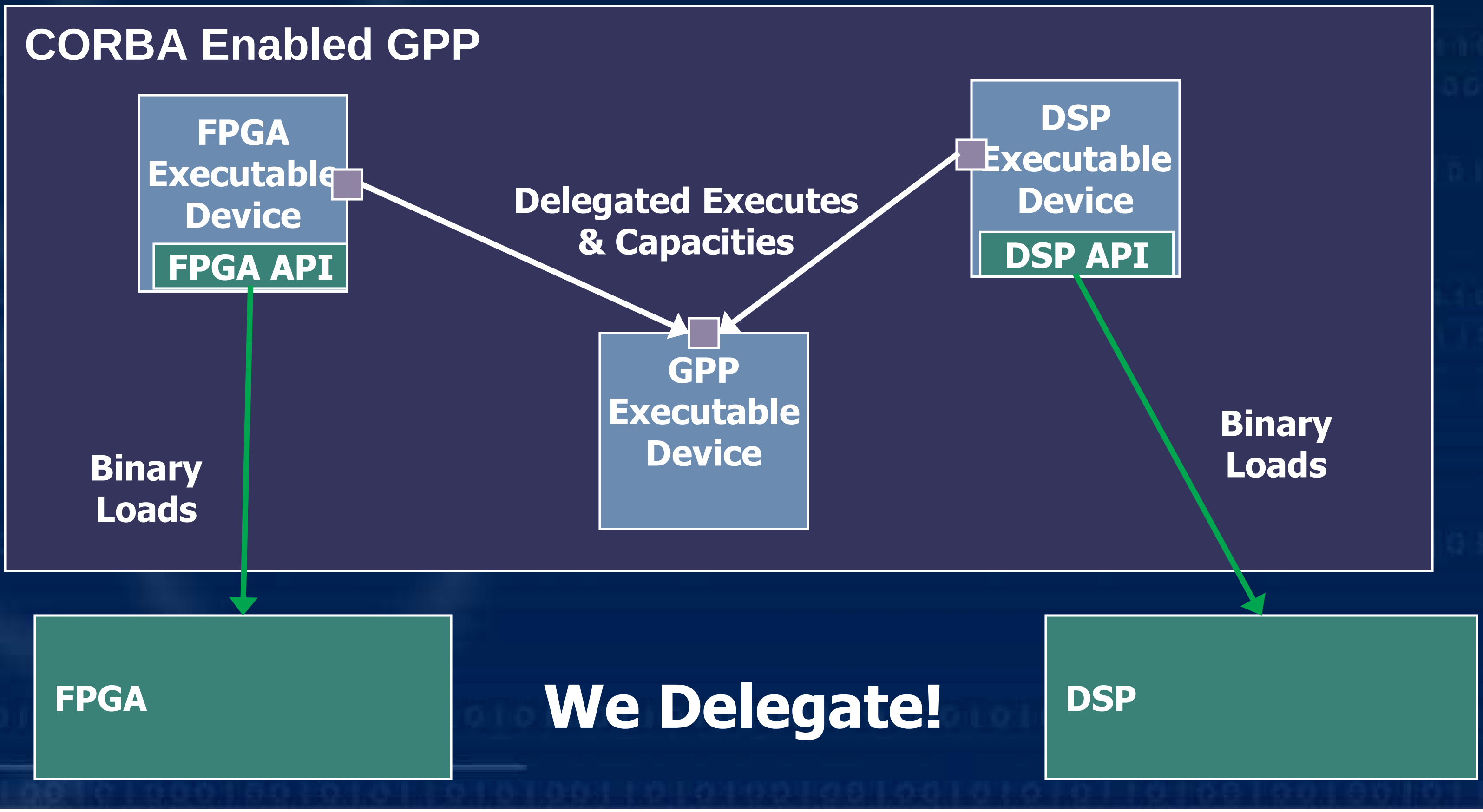
- **We need to provide a CORBA interface via which we can setup and control the Binary Image.**
- **Create a proxy, with a suitable (component specific) provides port interface, to manage the Binary Image.**
- **But, to control the Image, the proxy needs hardware level access the FPGA. How can we ensure this?**
- **Extend the LD to be an ExecutableDevice.**
  - Specify a collocation requirement between proxy and Image.
  - Binary loads go to the physical device.
  - Executable loads go to the collocated GPP.



ExecutableDevice Delegation

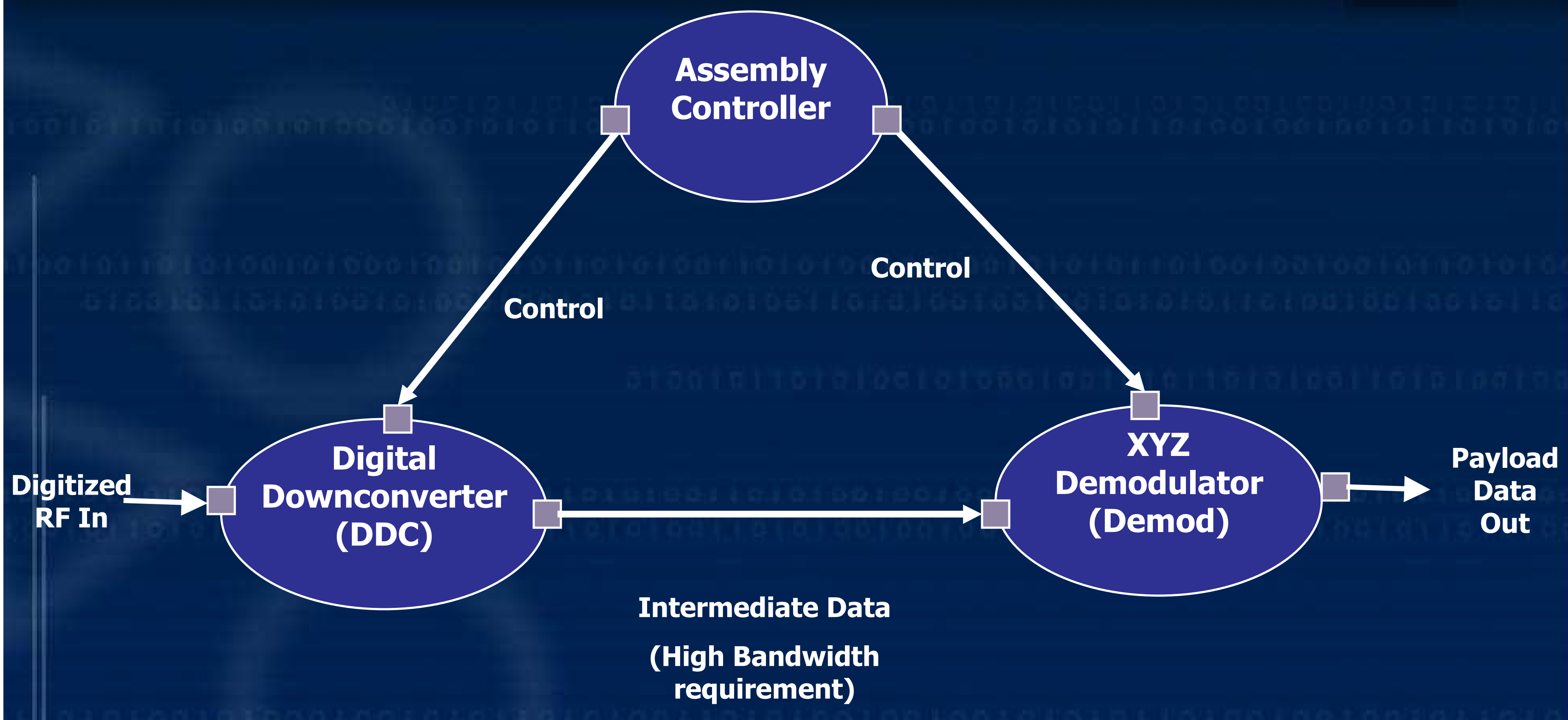
We may have several such "virtual" ExecutableDevices but only one physical GPP.

How do we manage its capacities?

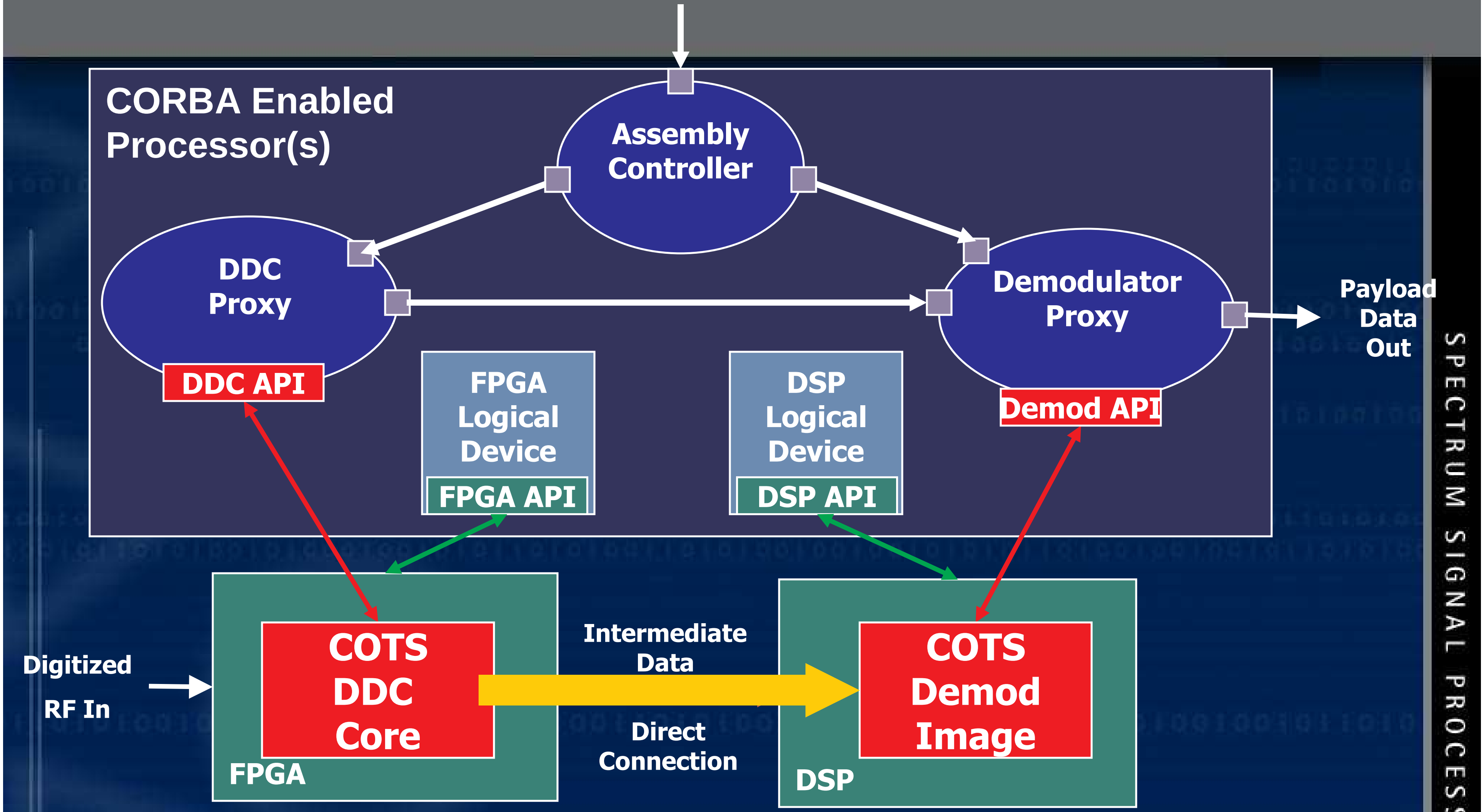


We Delegate!

Sample Waveform Instantiation on the example Dedicated Resource Architecture



Capacity Allocation and Component Deployment



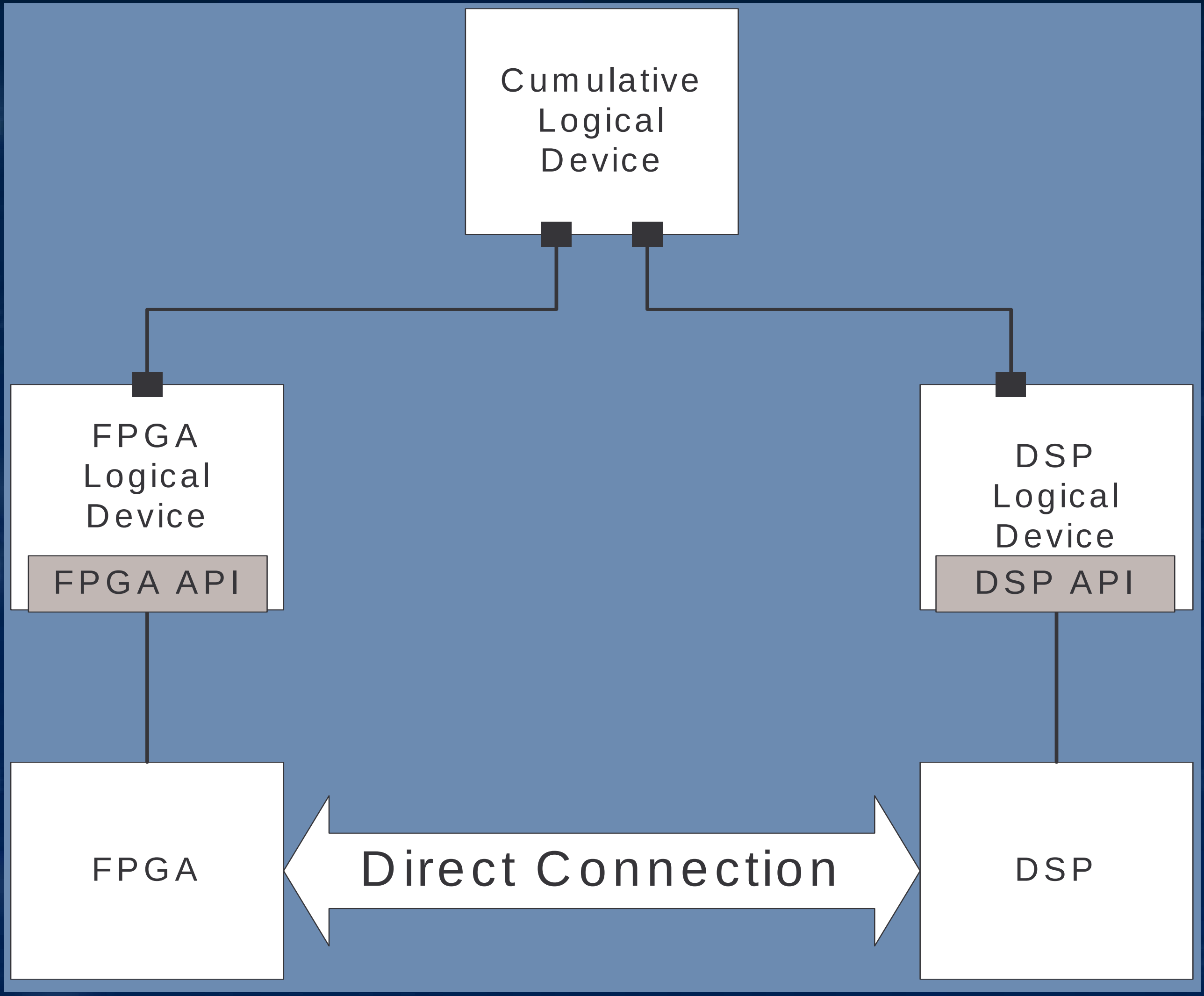
Question: How do you guarantee that the AppFactory selects an FPGA and DSP that have the correct type of direct connection?

The Problem with Allocating Capacity to Support Direct Connections in a Dedicated Resource Architecture

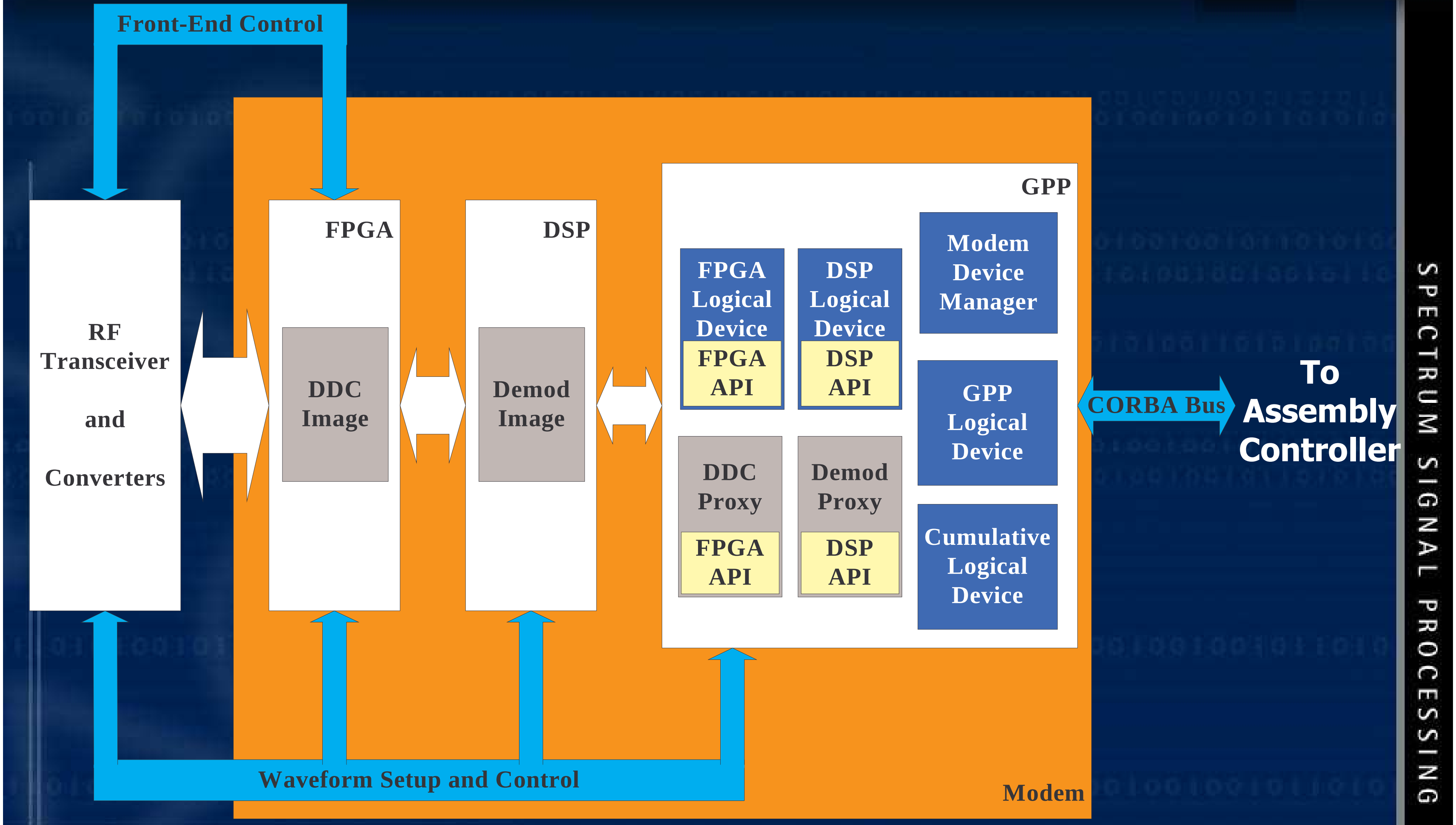
How do you guarantee that the AppFactory selects two devices with the correct type of direct connection?

- Force the selection of specific processing devices using deviceAssignments on ApplicationFactory::Create().
  - Try all valid assignments (higher level management layer required) .
  - Offline (during porting) pre-determination and testing of valid assignments.
- Require that both devices have the same value for a particular property.
  - For example Slot_ID.
  - Not supported in SCA 2.2!
- Provide a Logical Device that associates each of the valid FPGA and DSP pairs into a new Logical Device.

"Cumulative" Logical Device



Deployed Waveform Components Using the "Cumulative" Logical Device



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The Need for Hardware Abstraction

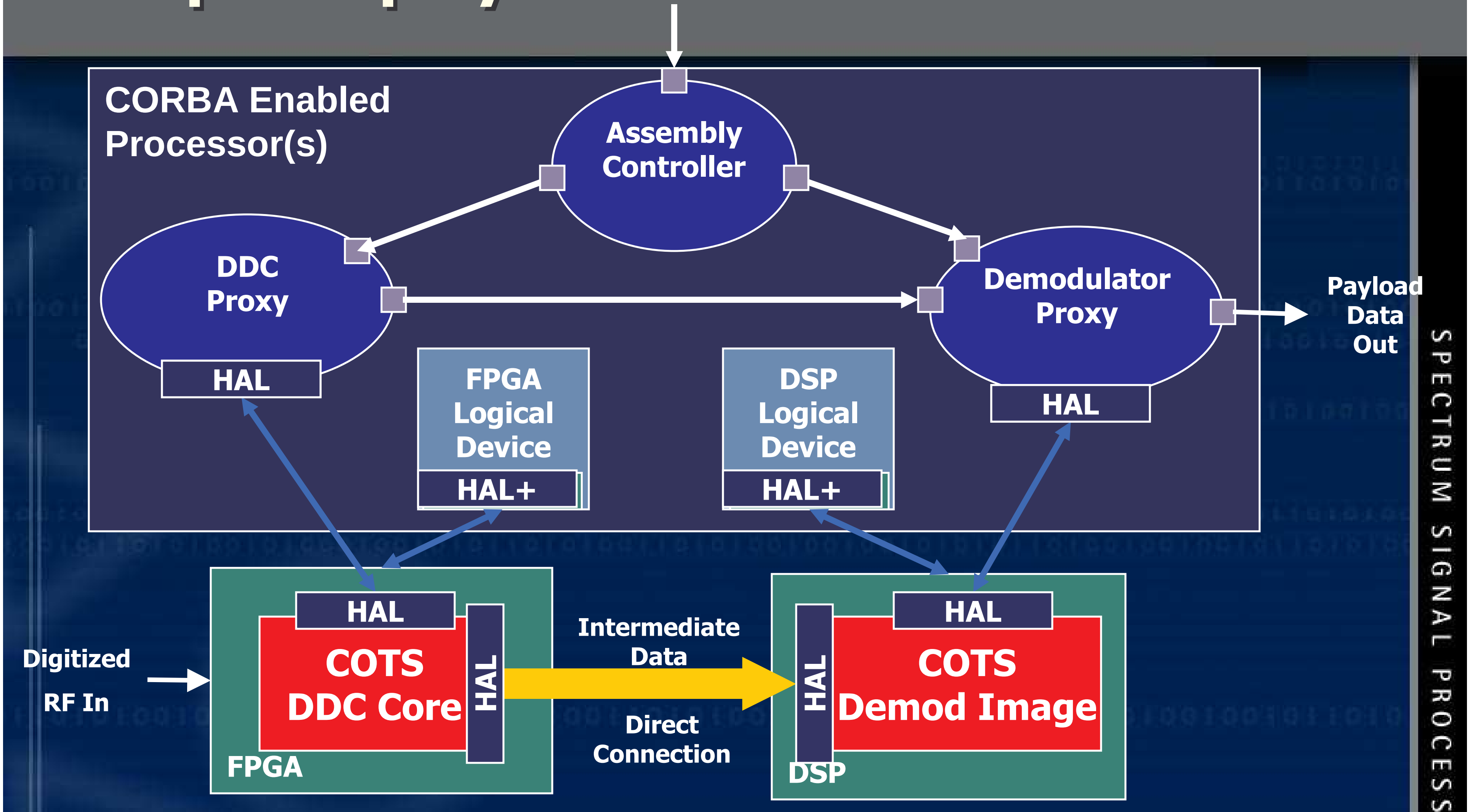
Have we achieved portability of the waveform components for NCEDs?

No:

- **The mechanism via which a proxy communicates with its Binary Images is platform specific.**
- **The interface between a Binary Image and a physical communication link is platform specific.**

We need to abstract and standardize these interactions.

Use of Hardware Abstraction Layer (HAL) in Sample Deployment



Hardware Abstraction Layer (HAL) Requirements

- **Define a model for NCE data communications.**
- **HAL for GPPs and DSPs:**
  - Define a standard API.
  - Abstracts hardware register/memory access.
  - Abstracts loading and unloading of NCEDs.
- **HAL for FPGAs:**
  - Define standard set of signals for interfacing to communication transport mediums.
  - Define standard registers for managing FPGA Images.

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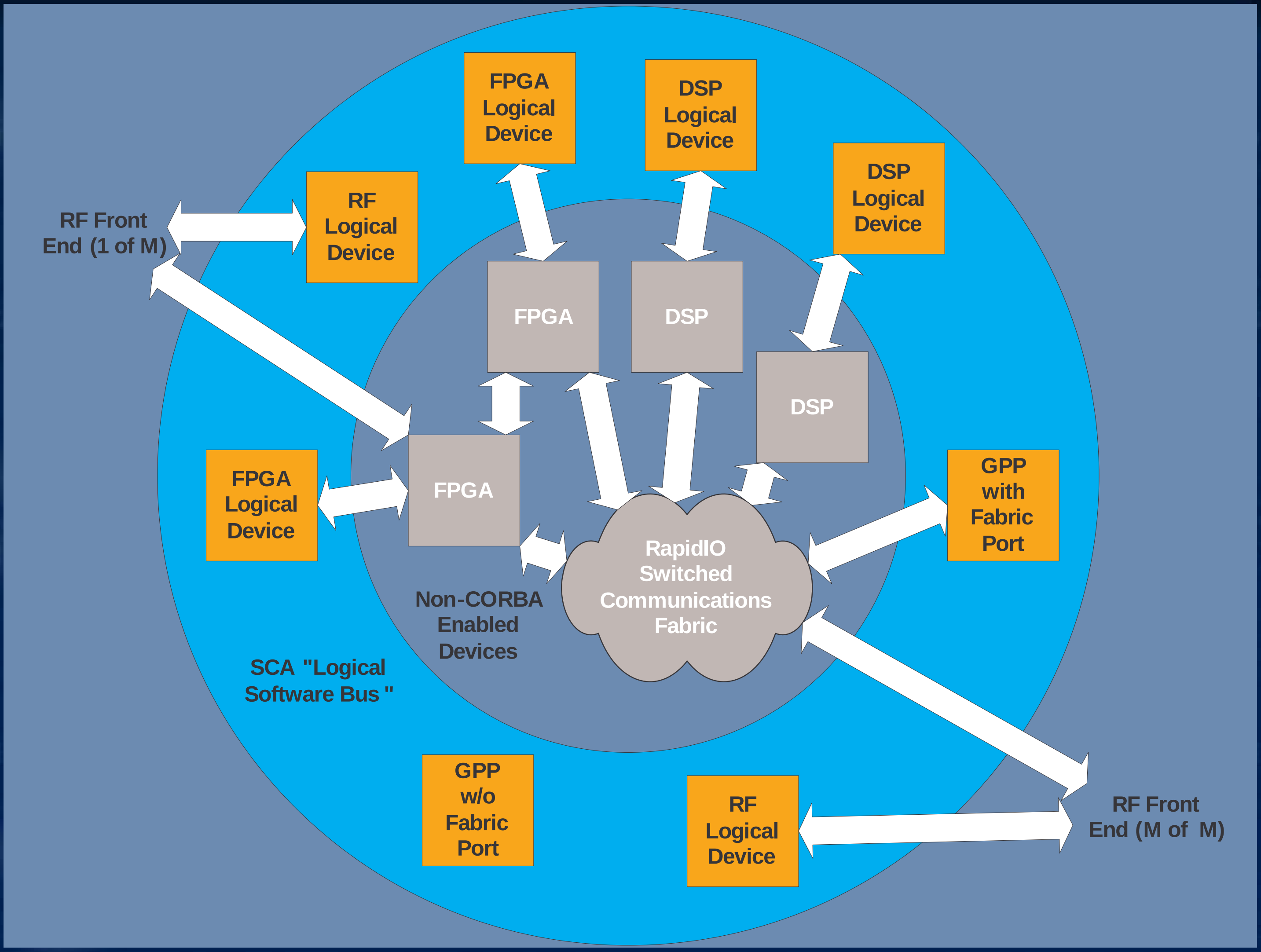
Pooled Resource Modem Architecture



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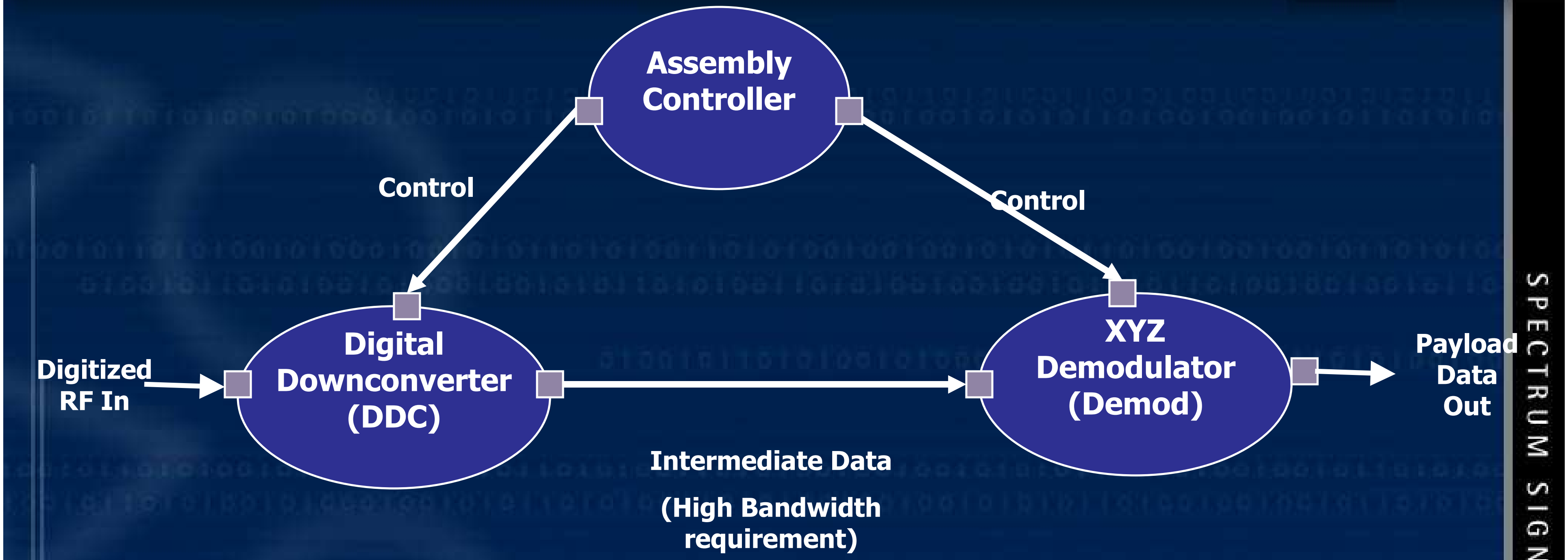
Sample Waveform Instantiation on a Pooled Resource Architecture



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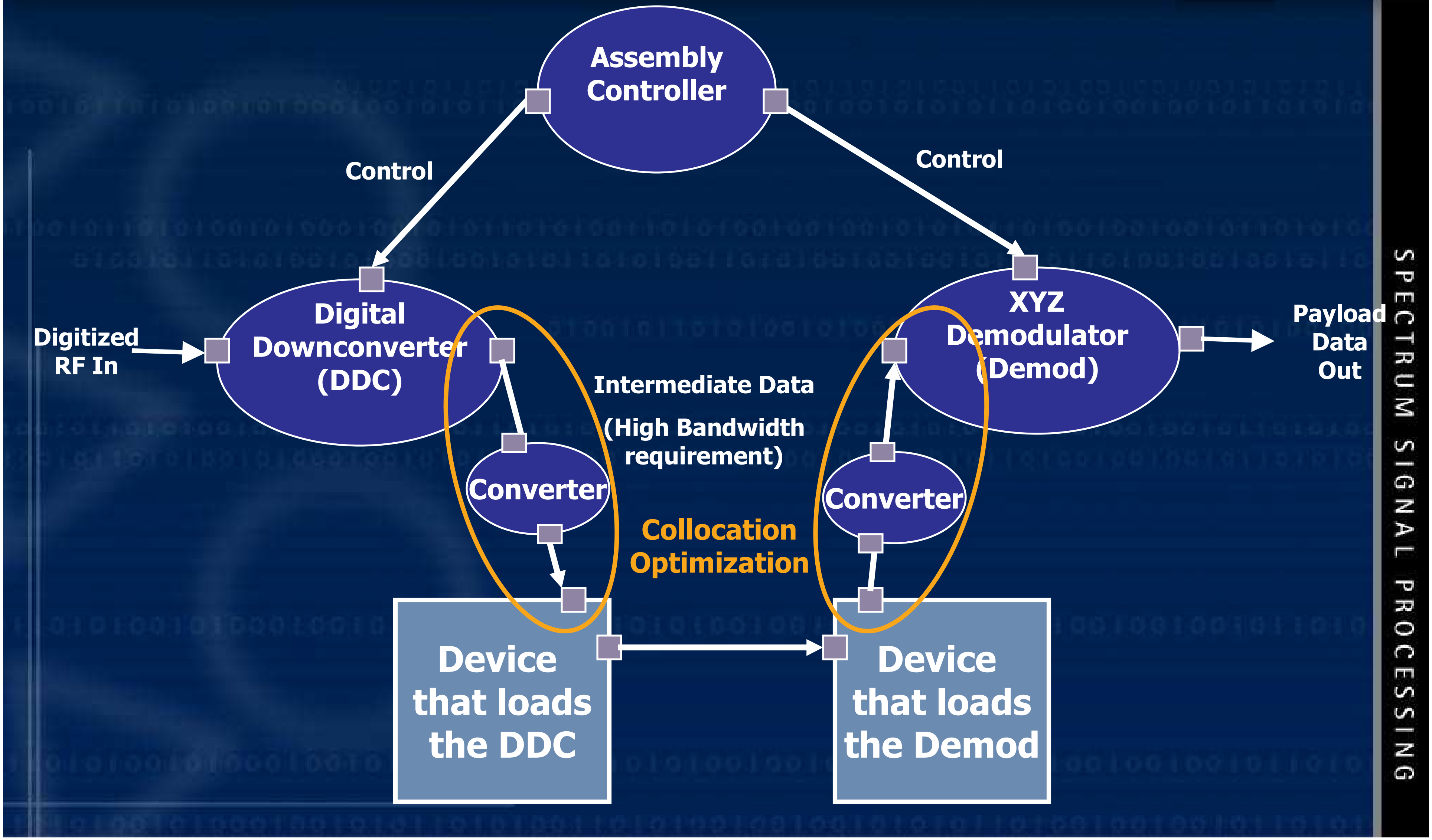

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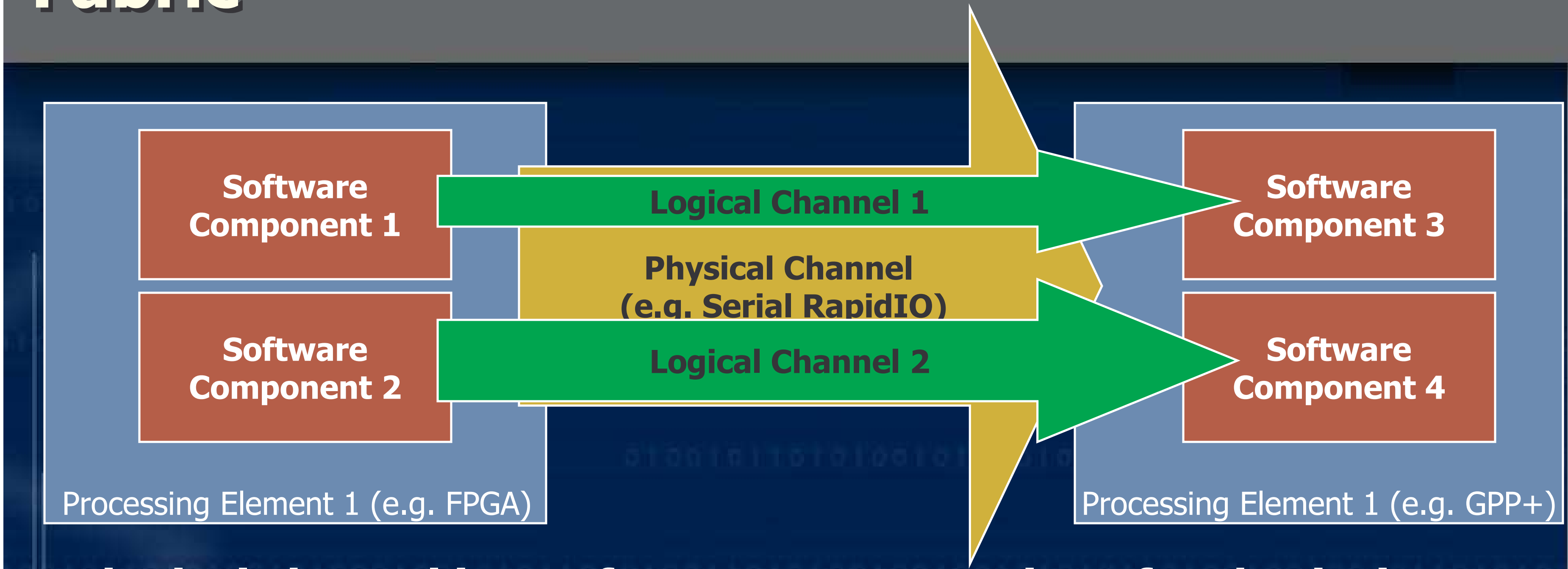
Logical Channel Support Through Switched Fabric

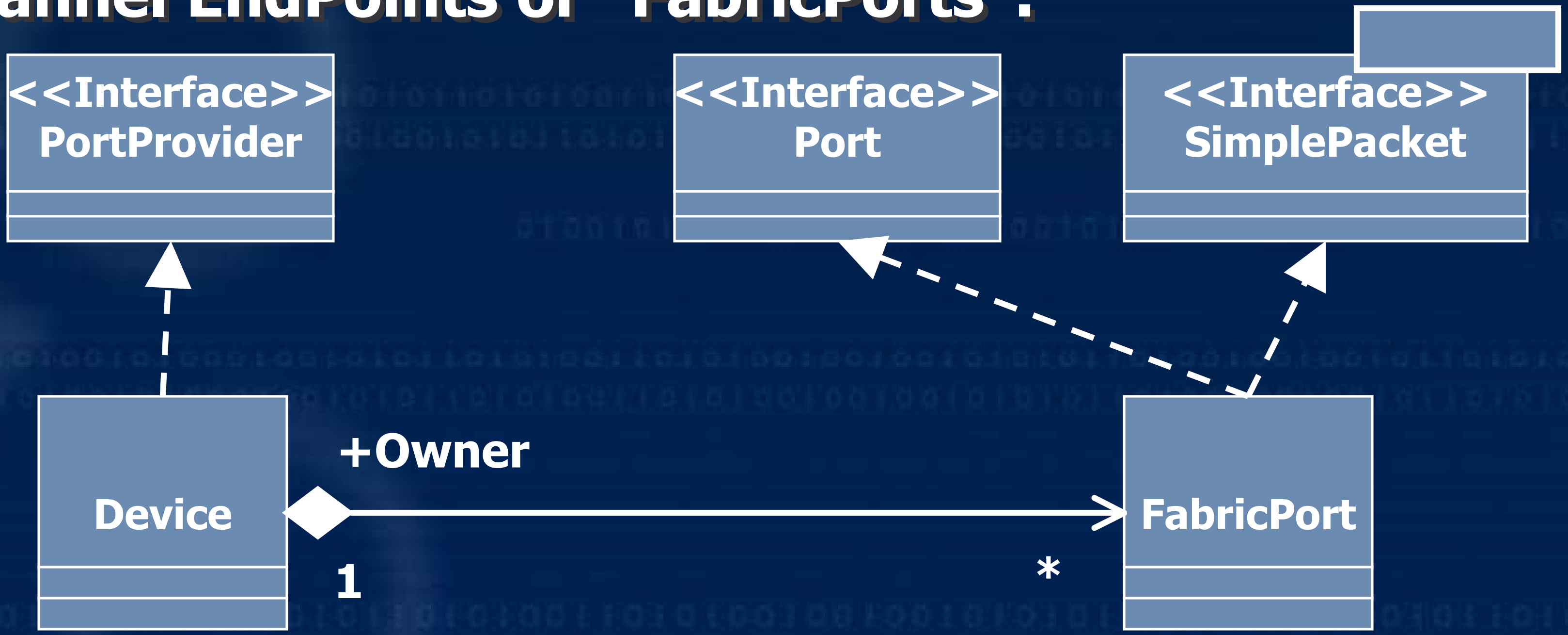


A logical channel is a software representation of a physical channel

- Multiple logical channels occupy a single physical channel.
- Composite data rate of the supported logical channels must be sufficient to support.
  - The latency and determinism requirements of the application.
  - Any overhead required for the channels.

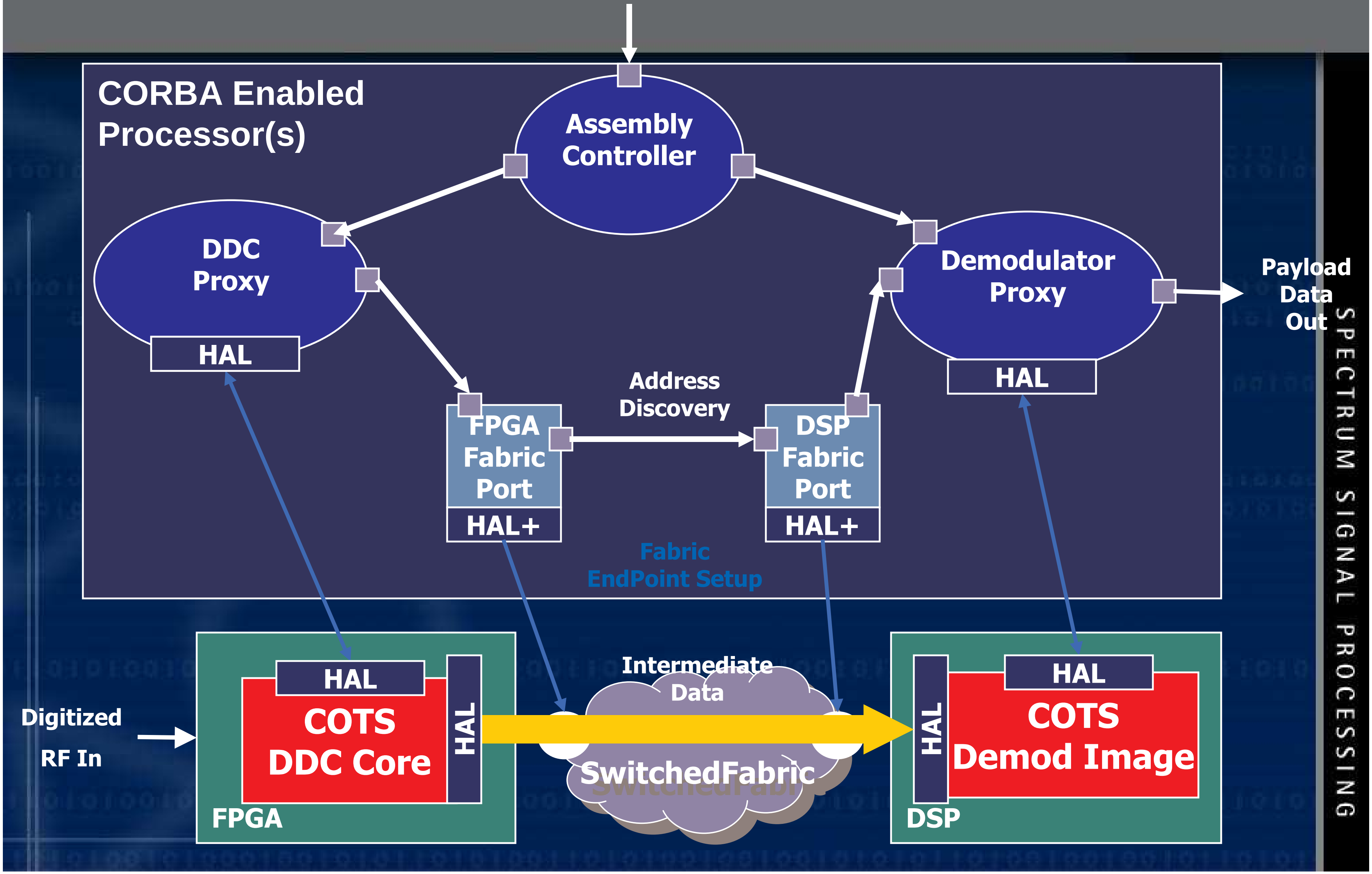
Device Support for Logical Channels

- Each Device that has access to the Switched Fabric needs to support multiple Logical Channel EndPoints or "FabricPorts".



- Device delegates each Switched Fabric connection to a free FabricPort.

Sample Waveform Deployment in Shared Resource Model



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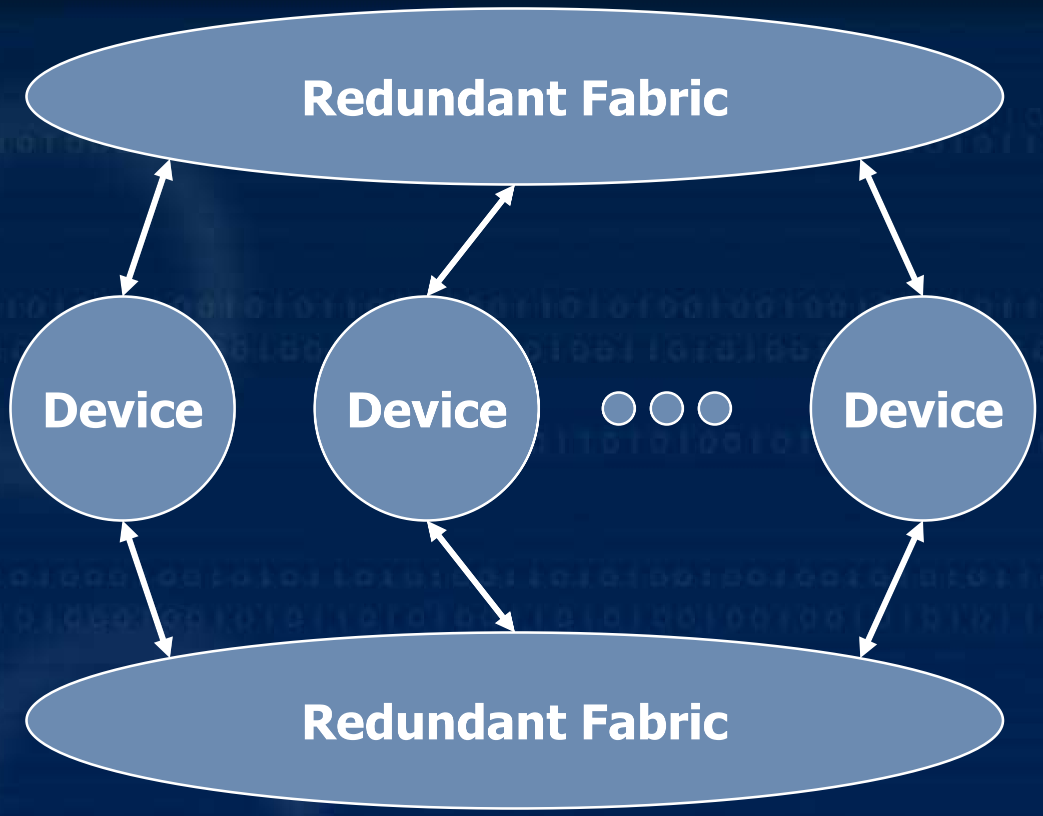
Other Design Considerations: Redundancy



Support for redundant fabric may be required to eliminate fabric as single point of failure.

- May require FabricPort is mirrored on both fabrics.

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Shared Resource Model

- **We may wish to optimize hardware resource utilization by sharing processing devices between waveform applications.**
- **Operating Environment supporting resource partitioning:**
  - GPP:
    - Use a secure O/S (e.g. DO-178B Certified).
  - FPGA:
    - Requires 3 key technologies:
      - Partial Reconfiguration.
      - Re-locatable bitstreams.
      - Support for channelized I/O.
    - These technologies are often device dependent.
    - Tools are maturing.

Other Considerations for the Shared Resource Model: Redundancy

- **With application resources from multiple waveforms operating on a single processor, if that processor goes down, it takes all of the supported waveforms with it.**
- **May require a redundant copy of each waveform operating on the platform.**
  - Typical paradigm employed in commercial telco for 5 nines performance.
  - Domain profile must be tailored to accommodate.

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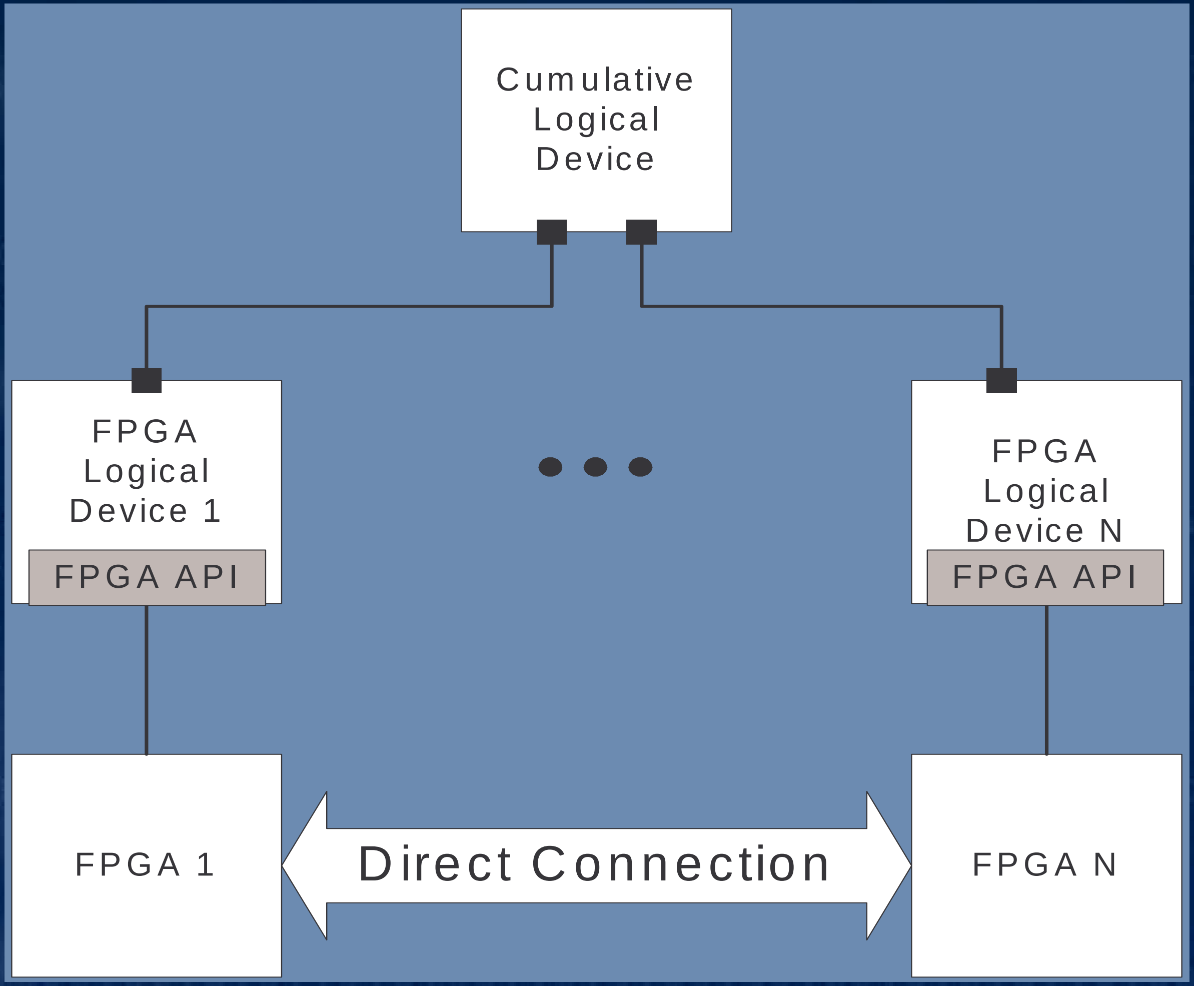
Supporting Advanced Waveforms

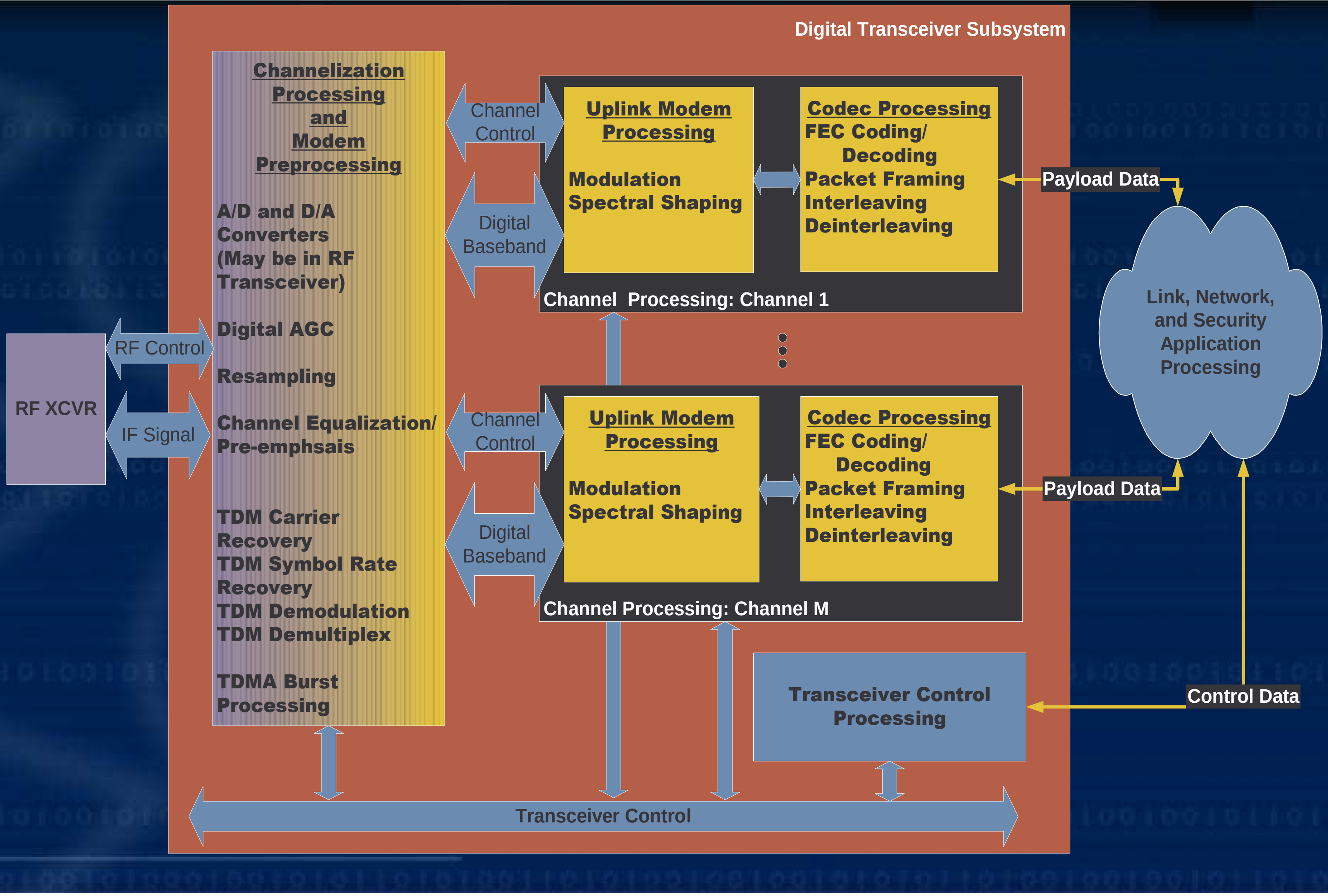
Applications such Advanced SATCOM may require special techniques such as:

- **Array Processing.**
  - Required when the processing requirements of an application resource exceed the capacity of a single processing device.
- **Shared Application Resource.**
  - Required when a front end application resource is shared across multiple back end waveform applications.
  - Especially troublesome when backend resources must be dynamically loaded.

Cumulative Logical Device Supporting Array Processing



Shared Application Resource



Digital Transceiver Subsystem

Channelization Processing and Modem Preprocessing

A/D and D/A Converters (May be in RF Transceiver)

Digital AGC

Resampling

Channel Equalization/ Pre-emphsais

TDM Carrier Recovery
TDM Symbol Rate Recovery
TDM Demodulation
TDM Demultiplex

TDMA Burst Processing

RF XCVR

RF Control

IF Signal

Channel Control

Digital Baseband

Uplink Modem Processing

Modulation
Spectral Shaping

Codec Processing
FEC Coding/ Decoding
Packet Framing
Interleaving
Deinterleaving

Channel Processing: Channel 1

Channel Control

Digital Baseband

Uplink Modem Processing

Modulation
Spectral Shaping

Codec Processing
FEC Coding/ Decoding
Packet Framing
Interleaving
Deinterleaving

Channel Processing: Channel M

Payload Data

Payload Data

Link, Network, and Security Application Processing

Transceiver Control Processing

Control Data

Transceiver Control

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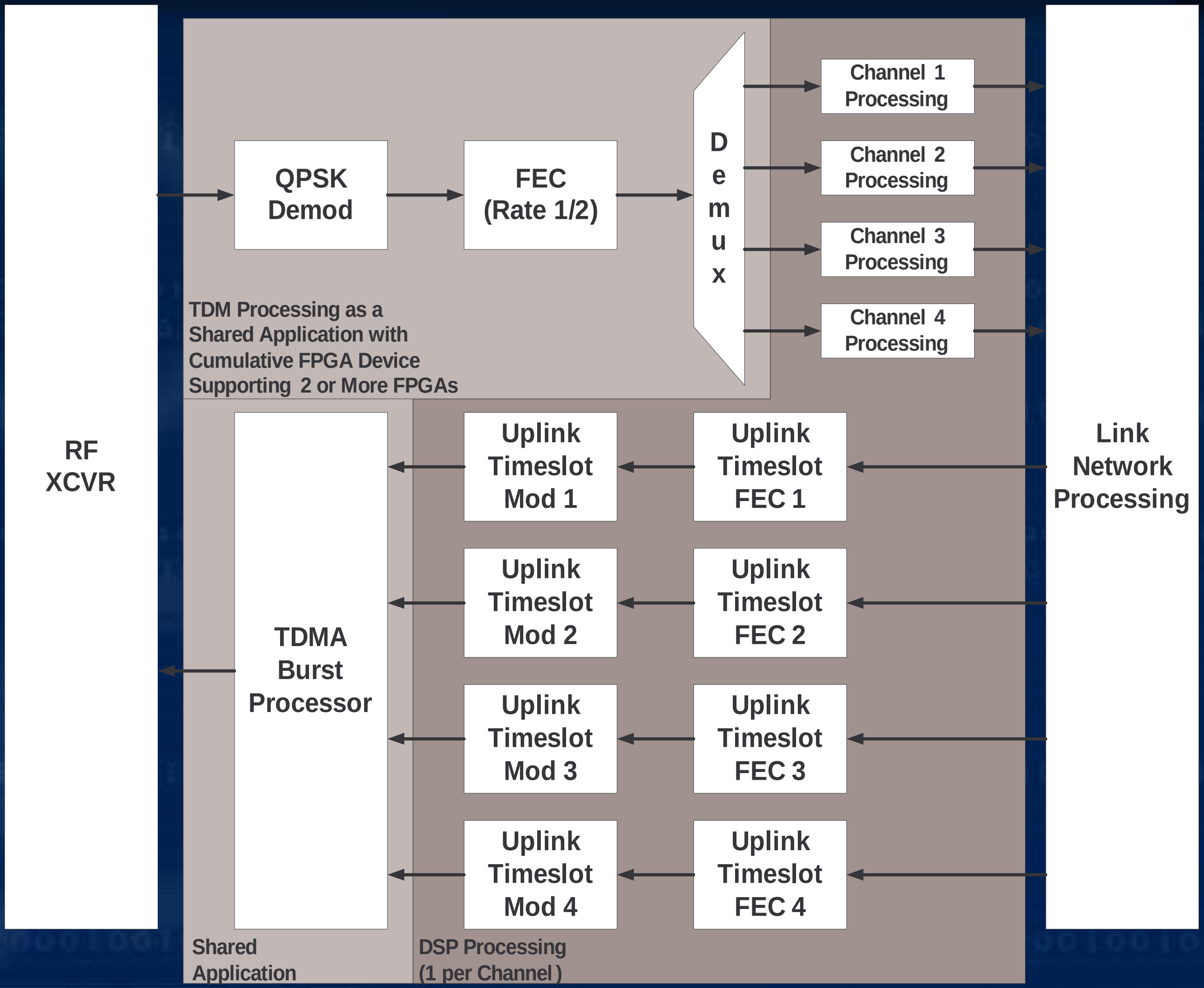
Supporting a Shared Application Resource with the SCA

- **A shared application resource, such as a channelizer, is instantiated as a separate application.**
  - This application encapsulates all common front end functions.
- **This resource registers with the naming service.**
  - It provides "channels" to which external application components may attach.
  - Each channel acts as a front end resource for a backend waveform application.
- **Waveform channels that need this shared resource attach to it upon instantiation.**
  - The shared resource application manages channel availability.
  - The shared application resource will only allow itself to be torn down if no waveform application is using it.
- **Behaves a bit like a dynamically created "device".**

Example: 4 Port Satellite Terminal



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- **With careful design, the SCA Core Framework can support a wide variety of modem platform architectures.**
  - Dedicated Resources.
  - Pooled Resources.
  - Shared Resources.
  - Combinations of the above.
- ***Such support can be provided in a way that minimizes waveform porting effort while leveraging high-performance features of the platform.***
- **Support for advanced waveforms may require both array processing and shared resource processing, both of which can be accommodated by the SCA.**