Stepping into UPF 2.1 world: Easy solution to complex Power Aware Verification

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Agenda

- Introduction
- Power Aware Verification
- Unified Power Format
- Evolution of UPF
- Why UPF 2.1
- Verification Challenges
- General Migration Tips
- Conclusion

Introduction

Electronic Devices have become

- Complex
- Energy Aware

Require sophisticated Power Management

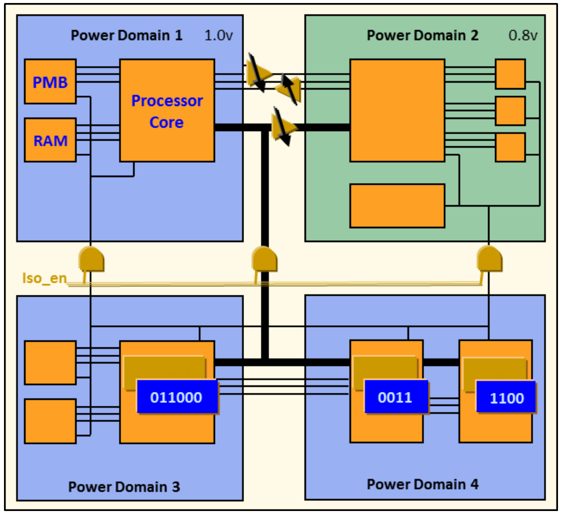
- Power Gating
- Multi Voltage
- Biasing
- DVFS

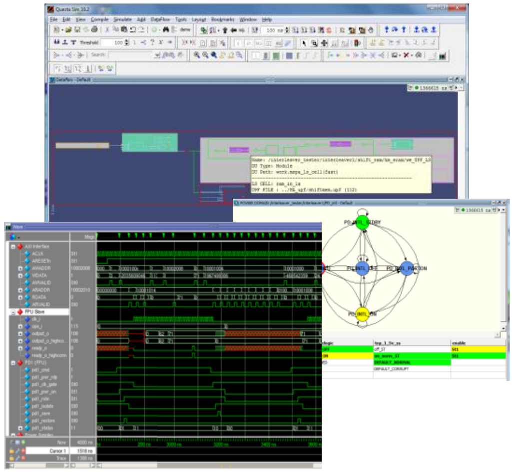
Advanced Power Aware Verification

- To ensure functional correctness









Verifying Power Management is even more **Complex**!!

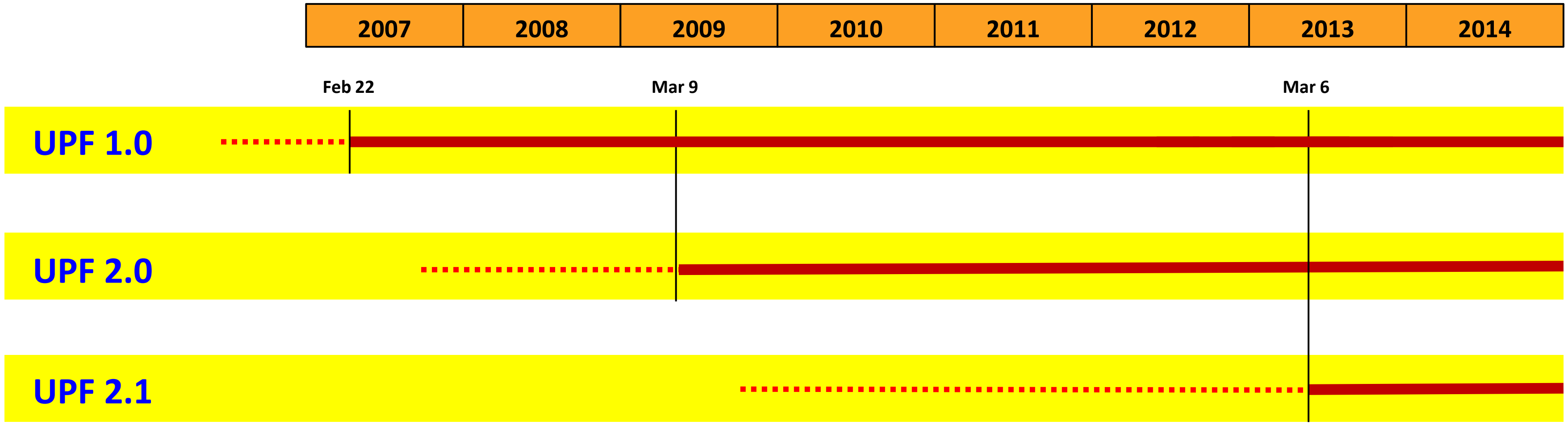
- Many strategies used in conjunction
  - Power gating, multi voltage, etc.
- Power management structures interact
  - Affect design functionality
- More scenarios to verify
  - Power Modes, Complex protocols
- Various stages of the design flow
  - RTL, Gate Level, Place & Route
- Complete knowledge about power management
  - Power Architecture, Power Cell behavior
- HDLs are not equipped to provide such information
  - Power Intent Specification formats

Unified Power Format (UPF)

- IEEE Standard for expressing Power Intent
  - To define power management
  - To minimize power consumption
  - Especially static leakage
  - Enables early verification of power intent
- An Evolving Standard
  - Accellera UPF in 2007 (1.0)
  - IEEE 1801-2009 UPF (2.0)
  - IEEE 1801-2013 UPF (2.1)
- Based upon Tcl
  - Tcl syntax and semantics
  - Can be mixed with non-UPF Tcl
- And HDLs
  - SystemVerilog, Verilog, VHDL
- For Verification
  - Simulation or Emulation
  - Static/Formal Verification
- And for Implementation
  - Synthesis, DFT, P&R, etc.

Evolution of UPF

- UPF 1.0 was defined by Accellera
  - Focused on adding power intent to HDL
  - Relatively simple concepts and commands
- UPF 2.0 approved in March 2009
  - Backward compatible with UPF 1.0
  - Supports IP development, refinement



- UPF 2.0, 2.1 were defined by IEEE
  - Building on UPF 1.0 concepts
  - Adding new abstractions, flow support
- UPF 2.1 approved in March 2013
  - Clarifies and enhances UPF 2.0 features
  - Adds a few new capabilities

Why UPF 2.1

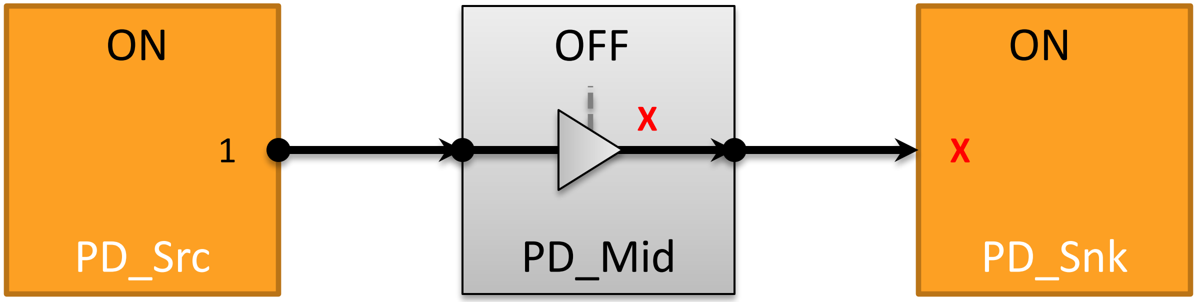
UPF 2.0 has some limitations

- **Inability to capture complex scenarios**
  - Missing information
  - Gap in Power Aware Verification
- **Unclear and inconsistent concepts**
  - Different interpretations
  - Non-portable

UPF 2.1 to the rescue!

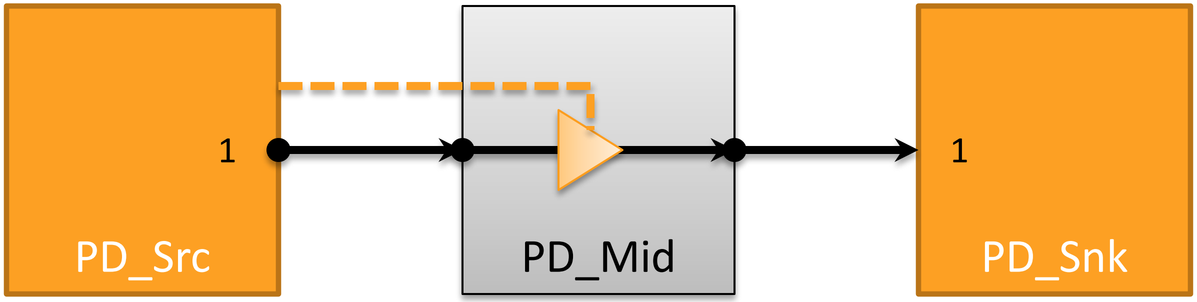
- New features to address limitations of UPF 2.0
- Provides more clear and consistent semantics
  - Promotes interoperability

Verification Challenge: Repeater Insertion



- Repeaters are inserted at long boundary crossings
- May use incorrect supplies
  - Result in a functional bug
- Need to guide tools to use proper supplies
  - Same information can be used by verification tools
- UPF 2.0 provides some capability
  - Incomplete and lacked proper semantics
- Use proprietary commands to achieve the desired behavior

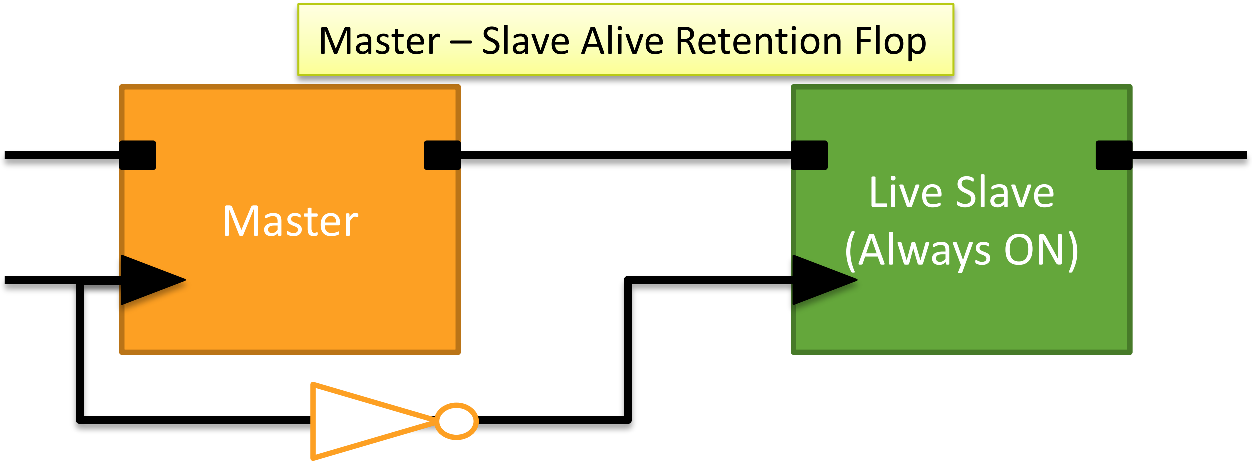
UPF 2.1 Solution: Repeater Insertion



- UPF 2.1 provides a new strategy command
  - set_repeater
- Similar to other strategy commands
  - Well defined semantics
- More flexible
- Enables verification at RTL stage

```
create_power_domain PD_Src \
  -supply {primary aon_ss}
create_power_domain PD_Mid \
  -supply {primary sw_ss}
create_power_domain PD_Snk \
  -supply {primary aon_ss}
set_repeater rep_sw \
  -domain PD_Mid \
  -repeater_supply_set \
   PD_Src.primary \
  -source PD_Src.primary \
  -sink PD_Snk.primary
```

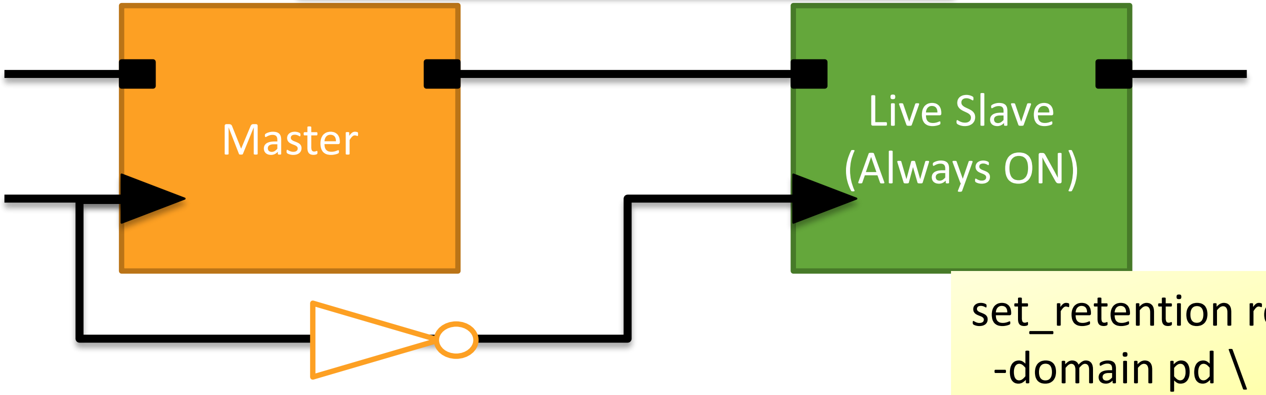
Verification Challenge : Retention Cells



- Master/Slave-alive retention flops
  - Value is retained in always on master/slave latch
  - Occupies lesser area than balloon style retention
  - No additional controls
- UPF 2.0 didn’t model them
  - Verification was dependent on proprietary implementation

UPF 2.1 Solution: Retention Cells

Master – Slave Alive Retention Flop




```
set_retention ret_ms \
  -domain pd \
  -retention_condition { ret }
```

- UPF 2.1 extended retention to master/slave alive cells
  - Well defined semantics to enable early verification
- Use set_retention without –save/restore_signal

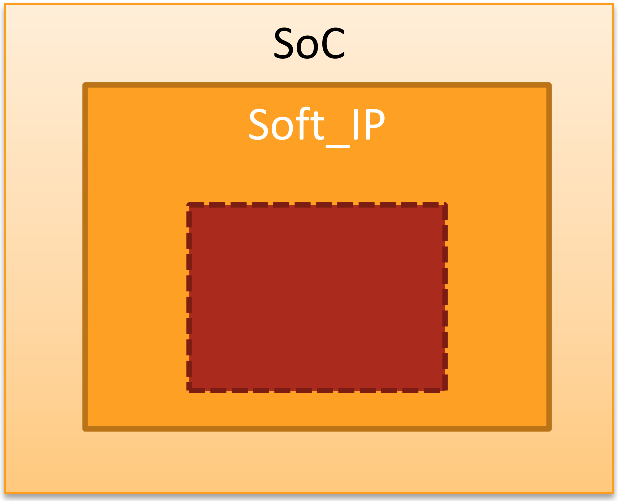
Verification Challenge: Soft IP Constraints

```
create_power_domain pd_softIP \
  -include_scope

load_upf soft_ip.upf \
  -scope softIPinst
#.... Integrate the softIP ...
```

Valid UPF Usage

```
create_power_domain pd_other \
  -elements { softIPinst/child }
```

Potentially Dangerous



- IP providers define constraints related to power management
  - Powering of regions within IP
  - Clamping constraints
  - Retention constraints
  - Power States
- IP integrator has to ensure that constraints are not violated
- UPF 2.0 can model the constraints, but has a limitation

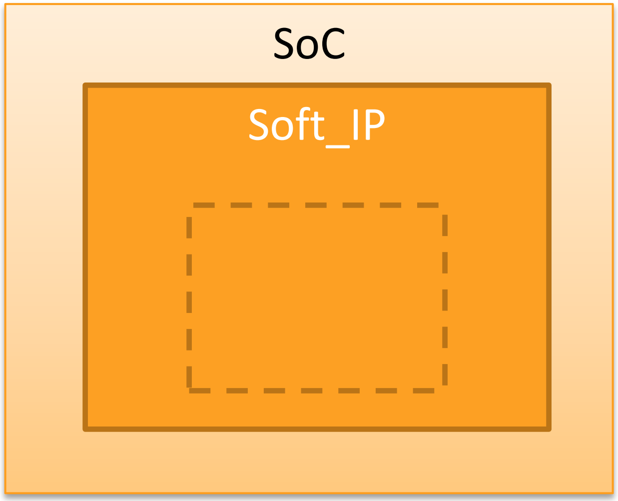
UPF 2.1 Solution: Soft IP Constraints

```
create_power_domain pd_softIP \
  -include_scope -atomic \

load_upf soft_ip.upf \
  -scope softIPinst
#.... Integrate the softIP ...
```

~~create_power_domain pd_other \~~
~~-elements { softIPinst/child }~~

In-valid for atomic PD

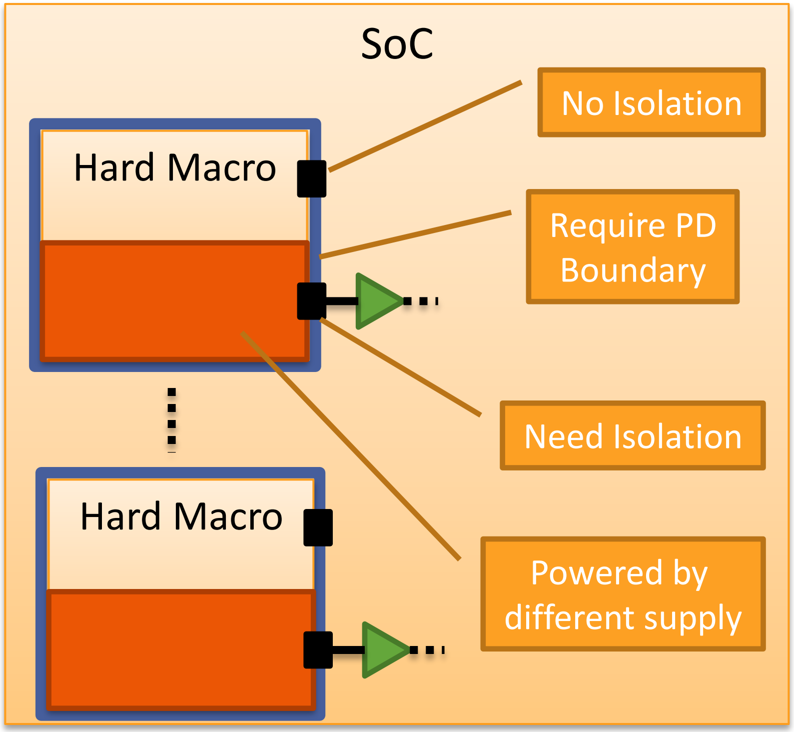
Causes Error



- Defines Atomic Power Domains
  - create_power_domain –atomic
- Cannot remove elements from Atomic power domain
- Verification tools can flag error if atomic property is lost during integration

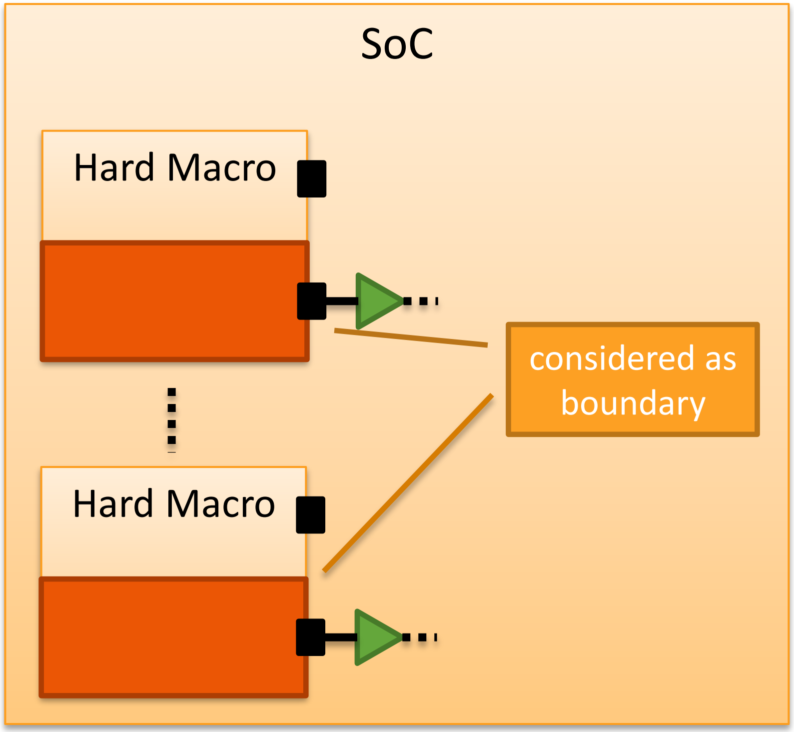
Verification Challenge: Hard Macro Boundary

- Isolation/level shifters need to be placed at the boundary of Hard Macros
- UPF 2.0 requires explicit domain boundary
- Need to be careful of redundant isolation
- Large number of such instances increases the verification complexity



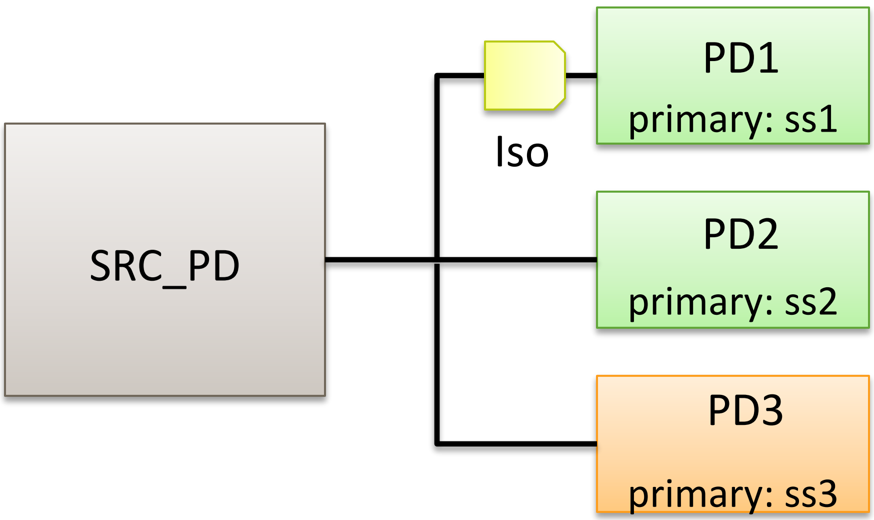
UPF 2.1 Solution: Hard Macro Boundary

- Automatically considers hard macro boundary pin powered by different supply as a boundary
- Avoids creation of explicit power domains



Verification Challenge: Supply Equivalence

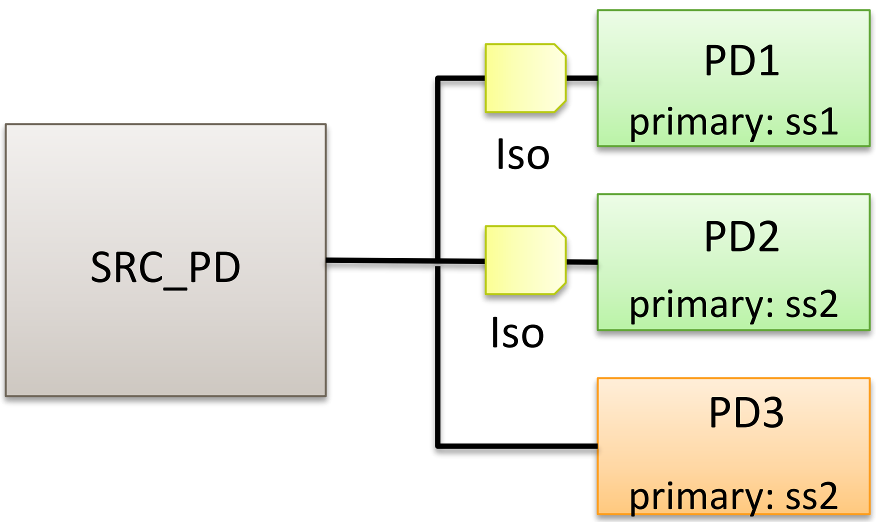
- Iso/LS cells depend on source/sink supplies
- Strategy commands use supply sets as source/sink filters
  - requires supply matching
- UPF 2.0 does not define semantics for supply matching
  - Inconsistent interpretation between tools




```
# ss1 and ss2 are equivalent
create_supply_set ss1   -function { power vdd1 }   -function { ground vss }
create_supply_set ss2   -function { power vdd1 }   -function { ground vss }
create_supply_set ss3   -function { power vdd2 }   -function { ground vss }

create_power_domain pd1   -supply {primary ss1}
create_power_domain pd2   -supply {primary ss2}
create_power_domain pd3   -supply {primary ss3}

set_isolation iso \
  -sink ss1 \
  # ... Other options ...
```

UPF 2.1 Solution: Supply Equivalence

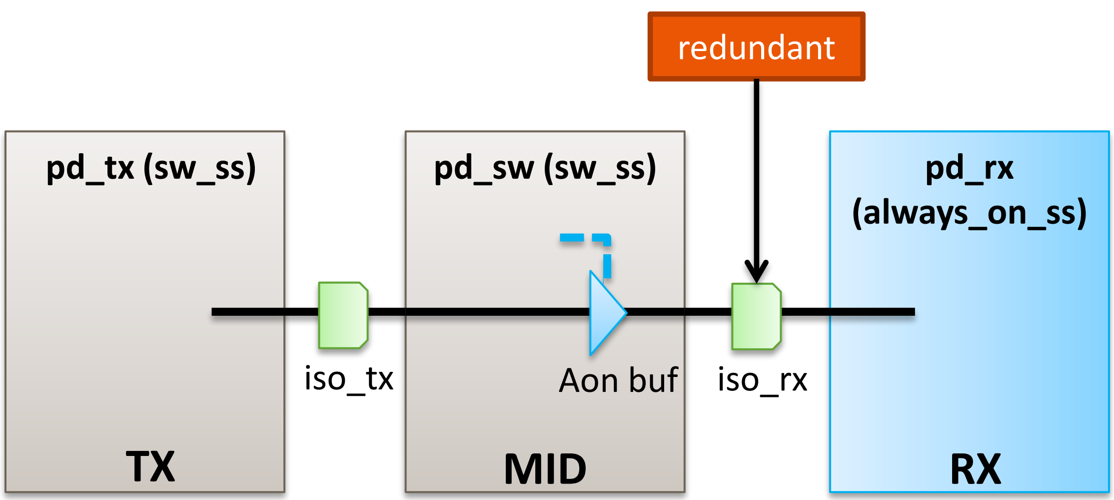
- UPF 2.1 defines rules for matching of supplies
  - Concept of “Supply Equivalence” defined
- New command “set_equivalent”
  - Explicitly state the supply equivalence incase it is not evident in design
- Default to match equivalent supplies
  - When matching to be done only for identical supplies, use option “-use_equivalence” to be FALSE




```
create_supply_set ss1
create_supply_set ss2
create_supply_set ss3

set_equivalent   -sets { ss1 ss2 }

create_power_domain pd1   -supply {primary ss1}
create_power_domain pd2   -supply {primary ss2}
create_power_domain pd3   -supply {primary ss3}

set_isolation iso \
  -sink ss1 \
  # ... Other options ...
```

Verification Challenge: Strategy interactions

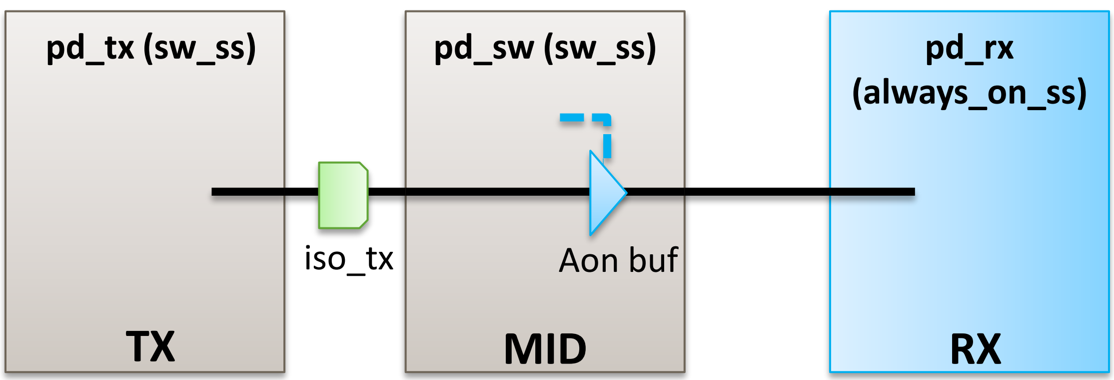
- A complex system may have hundreds of strategies
  - Many strategies may interact
- Relative placement of power management cells
  - How insertion of one strategy cells affects placement subsequent cells
- UPF 2.0 was unclear about strategy interactions
- Problem of interoperability
  - Different tools have interpreted this in different ways




```
create_power_domain pd_tx –elements {tx} \
   –supply {primary sw_ss}
create_power_domain pd_sw –elements {mid} \
   –supply {primary sw_ss}
create_power_domain pd_rx –elements {rx} \
   –supply {primary always_on_ss}
set_isolation iso_tx –domain pd_tx \
   –sink pd_rx.primary \
   –applies_to outputs
set_isolation iso_rx –domain pd_rx \
   –source pd_tx.primary \
   –applies_to inputs
set_port_attributes –domain pd_sw \
   –applies_to outputs \
   –repeater_supply always_on_ss
```

UPF 2.1 Solution: Strategy interactions

- UPF 2.1 defines clear semantics for strategy interaction
- UPF 2.1 defines order of strategy implementation
  - Retention > Repeater > Isolation > Level Shifter
  - A strategy may affect the -source/sink filters of a subsequent applied strategy
- Consistent behavior across tools




```
create_power_domain pd_tx  –elements {TX} \
    –supply {primary sw_ss}
create_power_domain pd_sw  –elements {MID} \
   –supply {primary sw_ss}
create_power_domain pd_rx  –elements {RX} \
   –supply {primary always_on_ss}
set_isolation iso_tx –domain pd_tx \
   –sink pd_rx.primary \
   –applies_to outputs
set_isolation iso_rx –domain pd_rx \
   –source pd_tx.primary \
   –applies_to inputs
set_repeater –domain pd_sw \
   –source pd_tx.primary –sink pd_rx.primary \
   –repeater_supply always_on_ss
```

And many more UPF 2.1 features…

- **Some more additions/extensions**
  - Power cell modeling
  - Hard Macro modeling
  - Supply constraints
- **Some deprecations/restrictions**
  - Supply set functions
  - Supply nets for strategies
- **More clarifications**
  - Supply sets

Refer to full paper for Exhaustive List

General Migration Tips

- Need to **translate** proprietary commands to new UPF 2.1 commands
- Be aware of **deprecations** and avoid using them in new UPF code
  - Refer to UPF 2.1 lrm for details
- Careful about the **syntax changes** and migrate towards new syntax
  - Refer to Table 2 in the Appendix section of the paper
- Understand the **semantics differences** and update UPF code to honor the updated semantics
  - Refer to the Verification challenges and Table 1 in the Appendix
- Be aware of **restrictions** added in the standard and avoid using styles that violate the restrictions
- Use **proper methodology** for achieving verification success and interoperability

Conclusion

- Power Aware Verification has become **complex**
  - Lots of **challenges** to verify power management
- **Limitations** in UPF 2.0 and 1.0 has started to limit power aware verification
- UPF 2.1 has taken **leaps** to ease the verification burden
  - **New additions** to fill the gap
  - **Clarification** of many concepts
  - Some **deprecations/restrictions** to simply concepts
- **A more powerful and finely tuned standard**

THANK YOU

Questions ??