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Design Space Exploration and Profiling of Multi-Context Coarse-Grained Reconfigurable Systems

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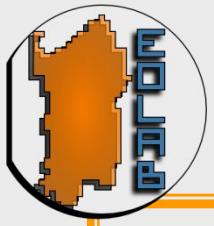

Outline

- Introduction
  - Background
  - Research Evolution
  - MDC Approach
  - Problem Definition
- The MDC DSE and profiler
  - Combinations Generator
  - Low-level Feedback Analysis
- Experimental Results
  - Design Under Test
  - Pareto Analysis
- Final Remarks

Background

- Systems and applications on the market are becoming every day more complex and power hungry.

ICT TRENDS	EXAMPLES
• Ubiquitous access	• Domestic robot
• Personalized services	• Telepresence
• Delocalized computing and storage	• The car of the future
• Massive data processing systems	• Aerospace and avionics
• High-quality virtual reality	• Human ++
• Intelligent sensing	• Computational science
• High-performance real-time embedded computing	• Realistic games
	• Smart camera networks

SOURCE: http://www.hipeac.net/roadmap

- Flexibility, Portability, wearability, implantability, battery life limits, real-time along with computational correctness needs to be taken into account.

Background

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INTEGRATION, SPECIALIZATION and HIGH PERFORMANCE REQUIREMENTS

in such

COMPLEX COMPUTATIONAL HUNGRY ENVIRONMENTS

has threatened the

TRADITIONAL DESIGN FLOW.

SOURCE: http://www.hipeac.net/roadmap

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Research Evolution

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- Multi-Dataflow Composer (MDC) tool: concrete definition of the hardware template and of the D-MoC based mapping strategy. [DASIP 2011, JRTIP]

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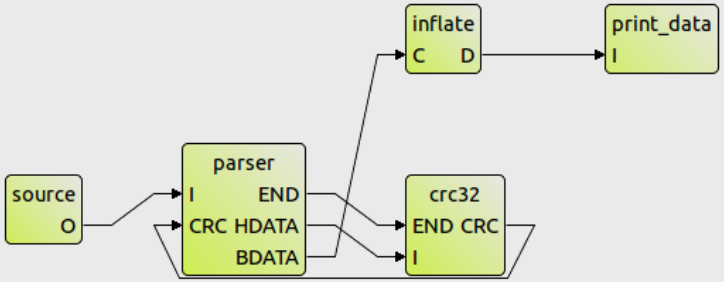
- Integration of the full high-level to hw composition and generation framework. [ISCAS 2012]

MDC Approach: basics

Modular Dataflow Formalism



[SOURCE: http://orcc.sourceforge.net/]

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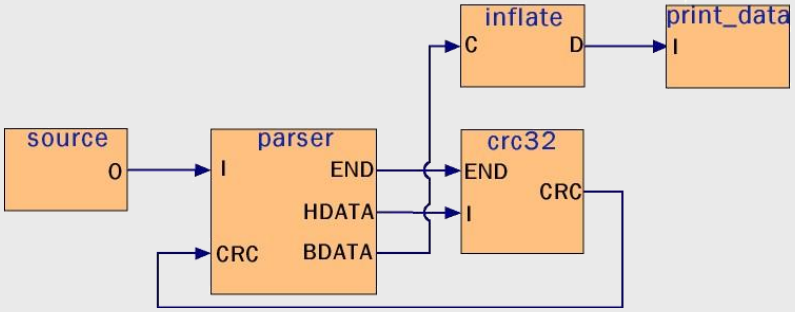
HW Platform



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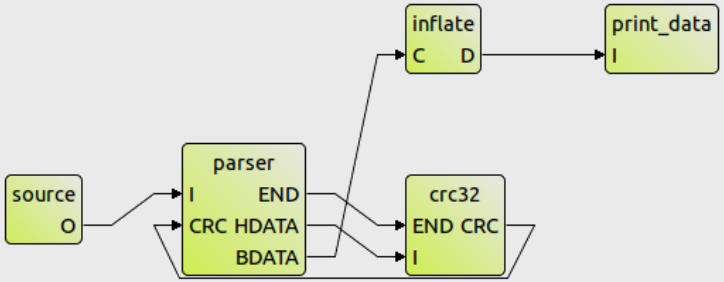

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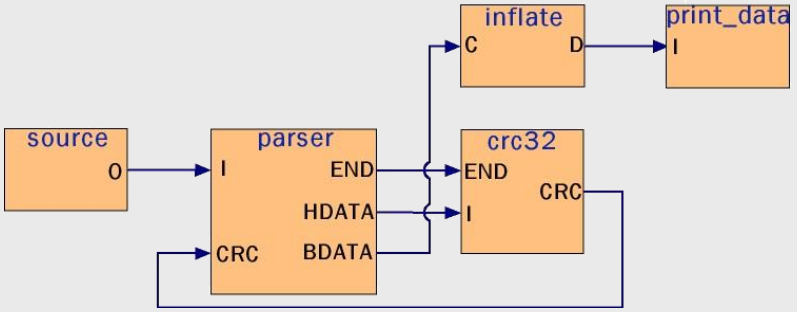

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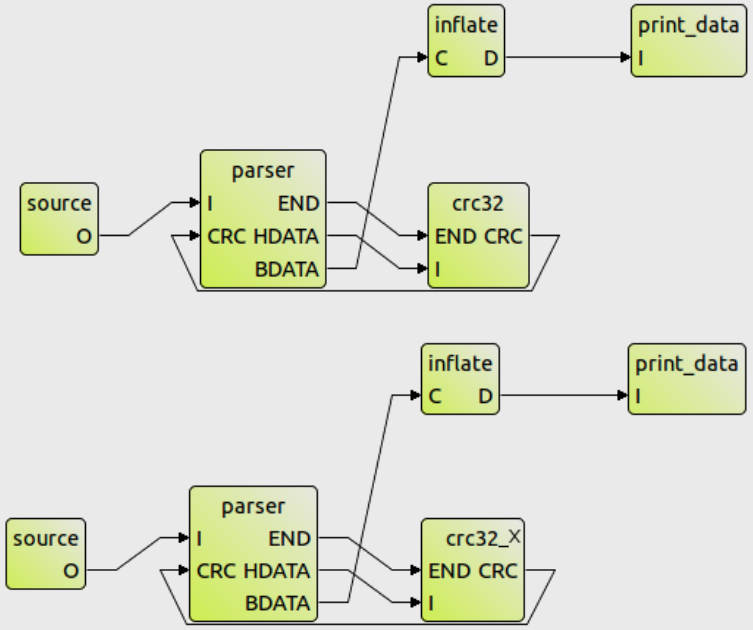

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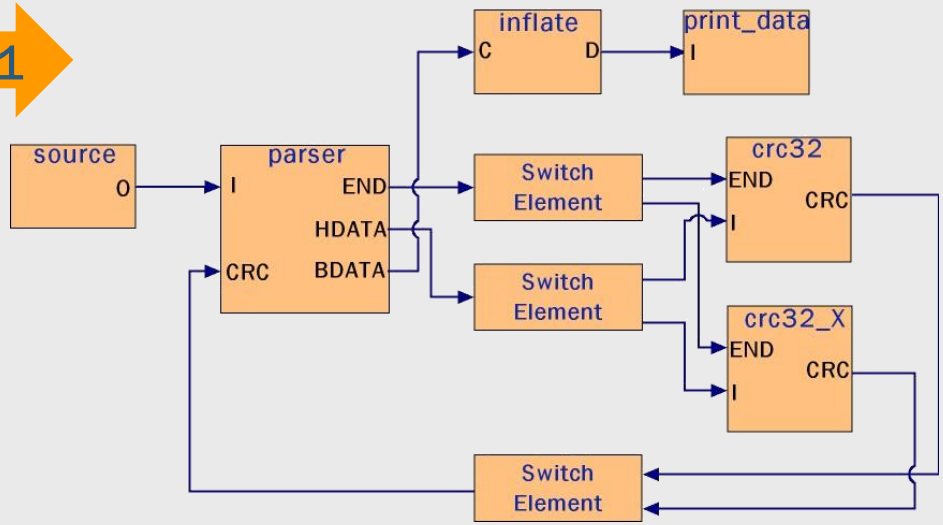
Coarse Grained Reconfigurable HW Platform



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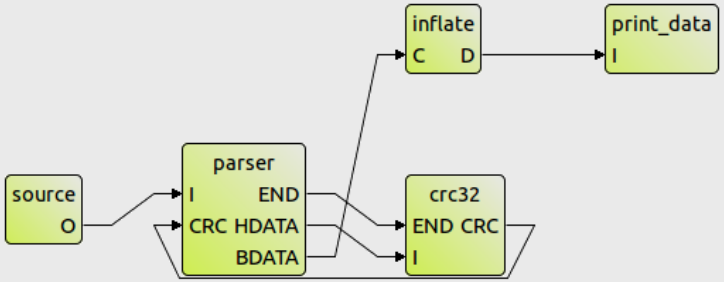

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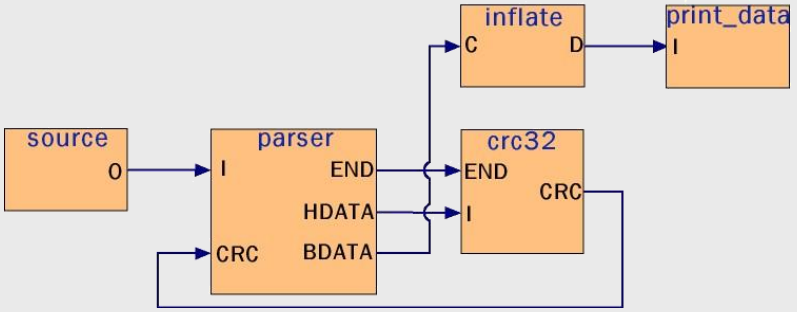

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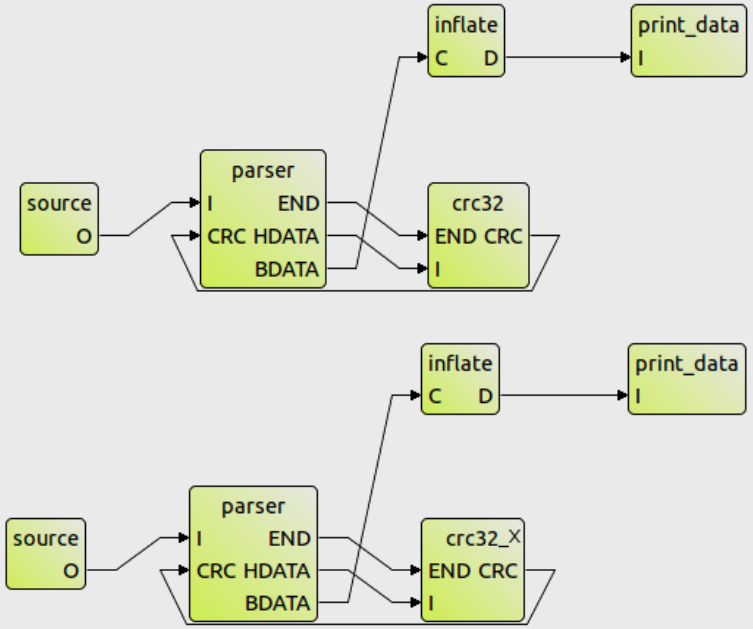

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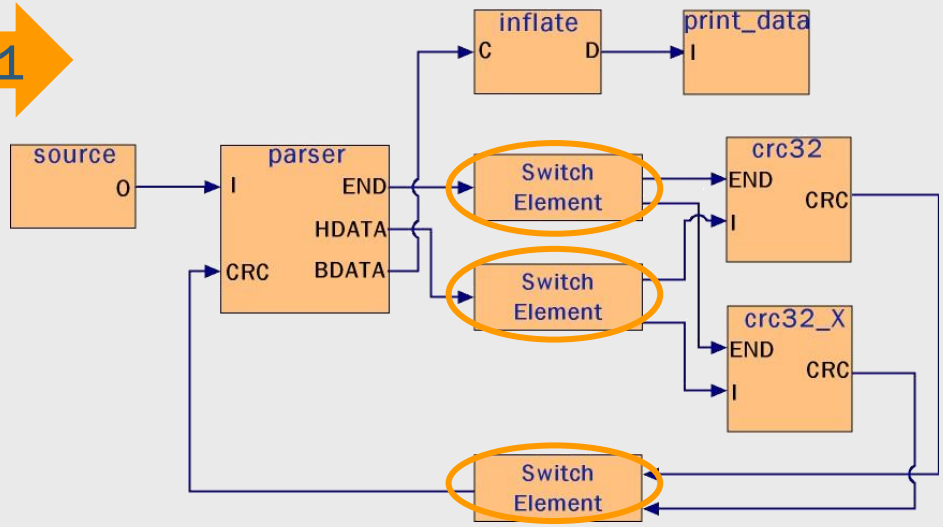
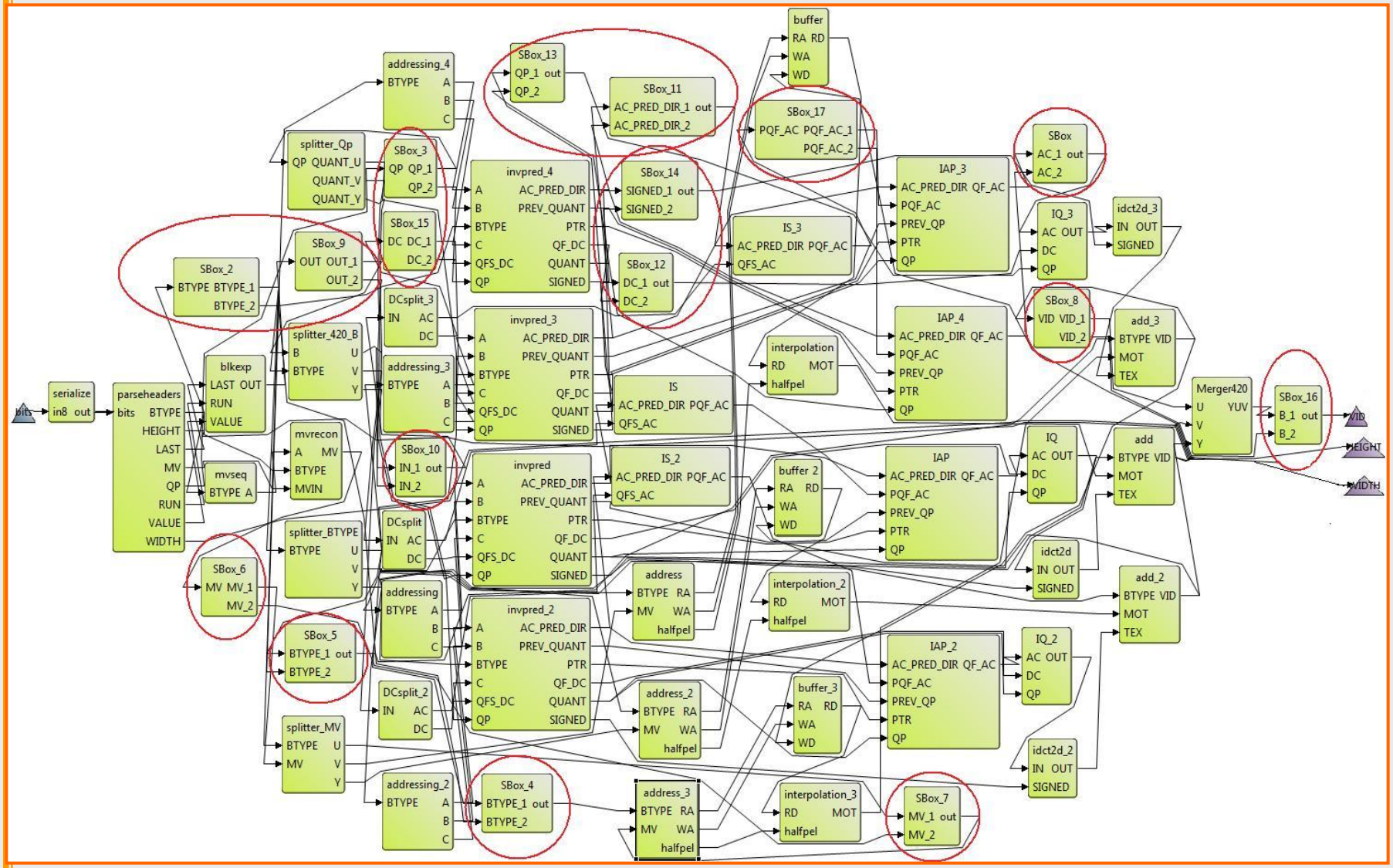


MDC Approach: complexity



[F. Palumbo et.al. , *"RVC: A multi-decoder CAL composer tool"*, in *Proc. DASIP 2010*]

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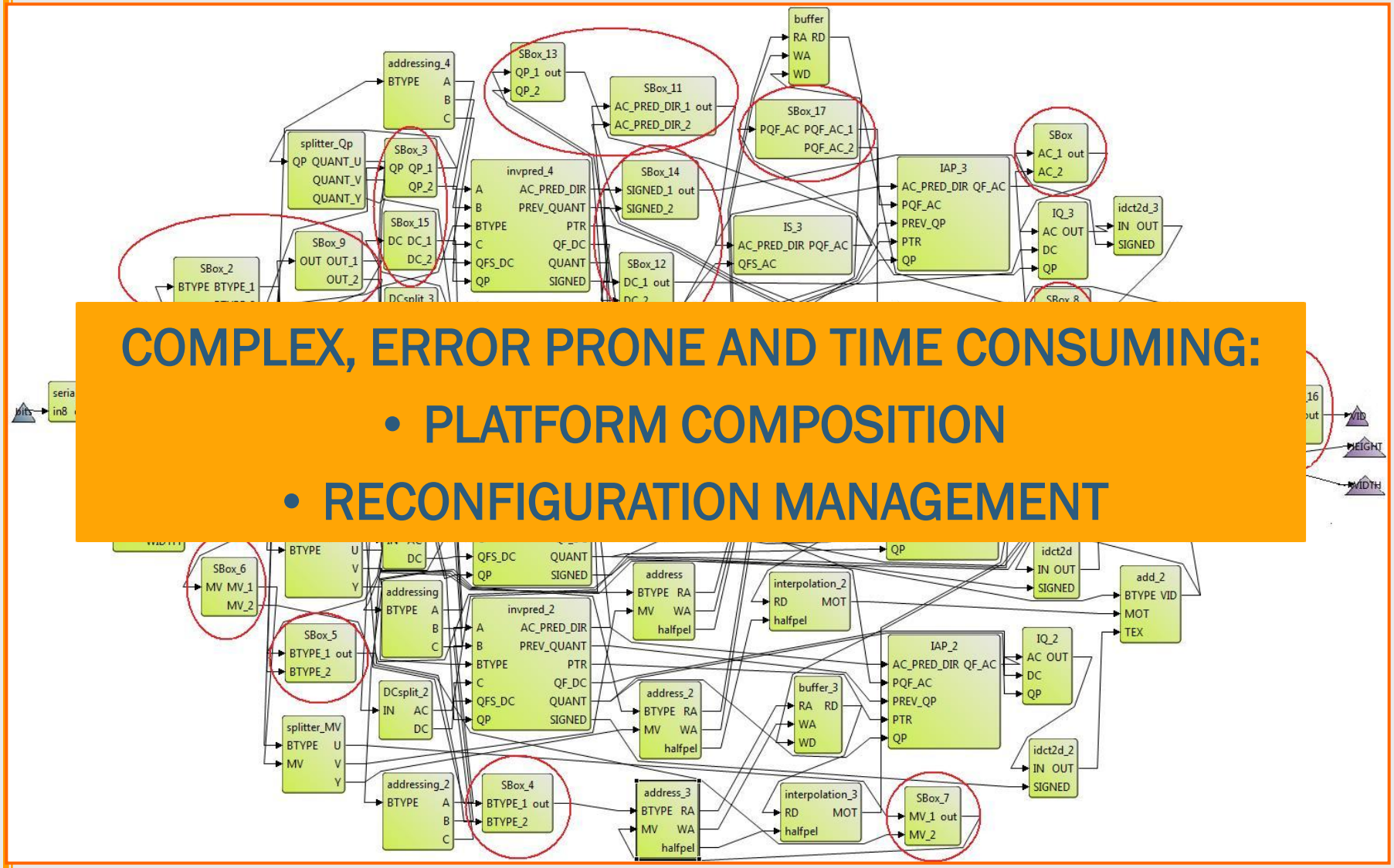


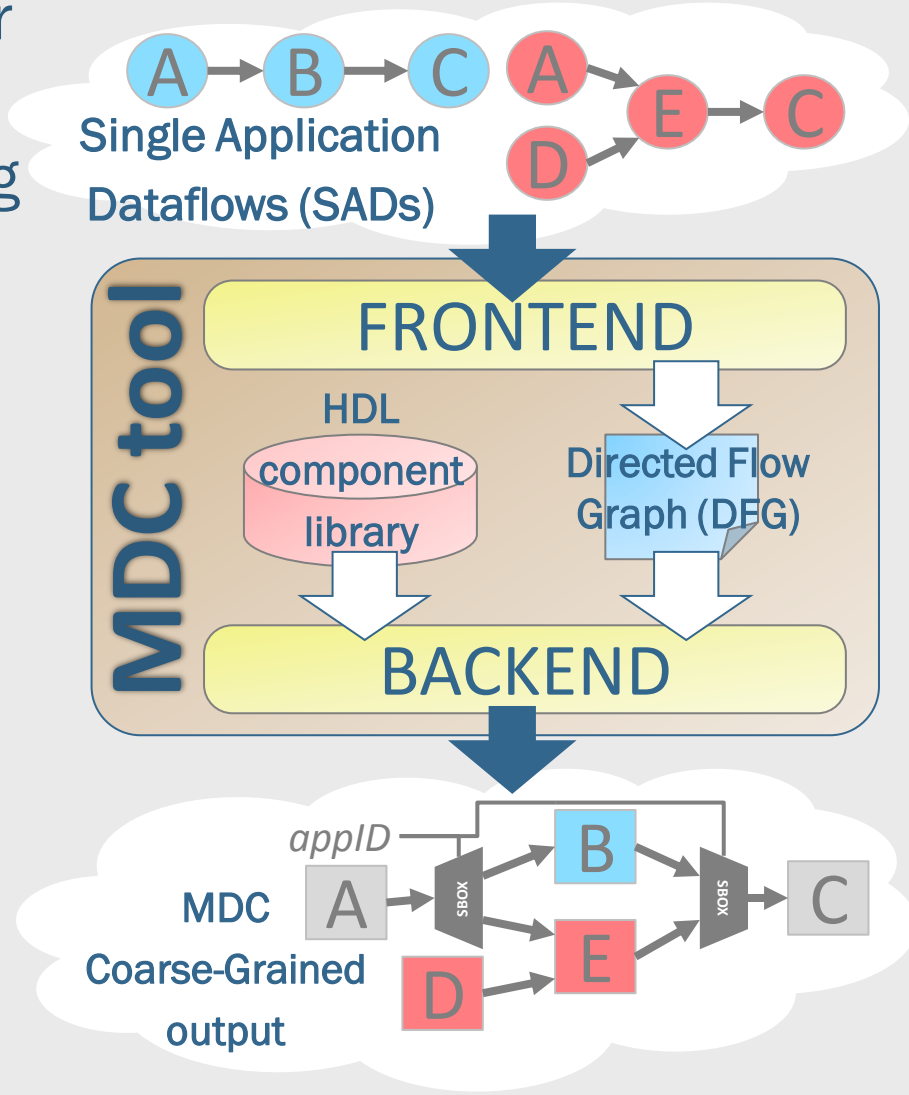
COMPLEX, ERROR PRONE AND TIME CONSUMING:

- PLATFORM COMPOSITION
- RECONFIGURATION MANAGEMENT

[F. Palumbo et.al. , *"RVC: A multi-decoder CAL composer tool"*, in *Proc. DASIP 2010*]

MDC Approach: the tool

- The Multi-Dataflow Composer (MDC) tool **IS** an automatic platform generator combining different dataflow networks (SADs) on a coarse-grained reconfigurable template.
- The MDC **IS** responsible of providing runtime programmability of the hw substrate to switch among given the SADs.
- The MDC **IS NOT** capable of High Level Synthesis from SAD to hw.



MDC Approach: the tool

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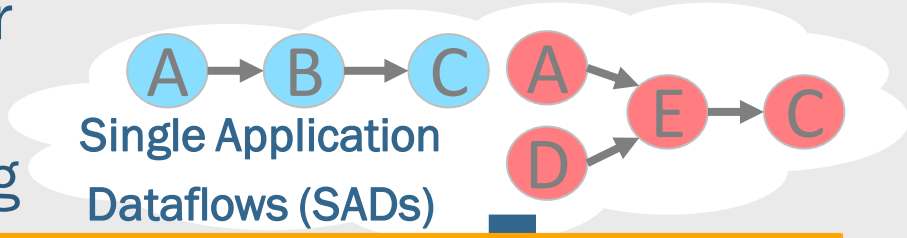


benefits of the MDC approach have been already demonstrated

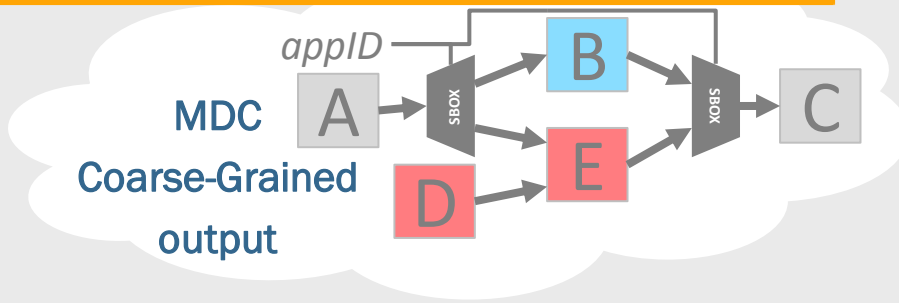
[F. Palumbo et.al. ,*"The multi-dataflow composer tool: generation of on-the-fly reconfigurable platforms"*, in Jrnl of Real Time Image Processing]

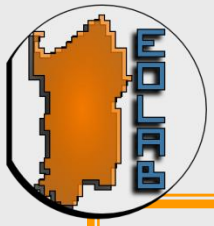
BUT

an early stage trade-off analysis may be extremely useful

given the SADs.

- The MDC **IS NOT** capable of High Level Synthesis from SAD to hw.





Problem Statement

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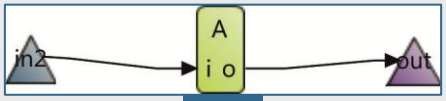
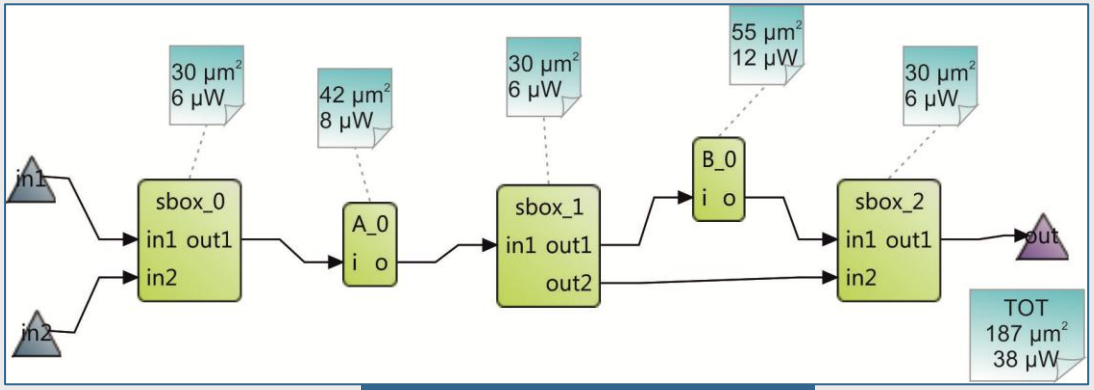
- Merging all the SADs is **not always** the best choice

α

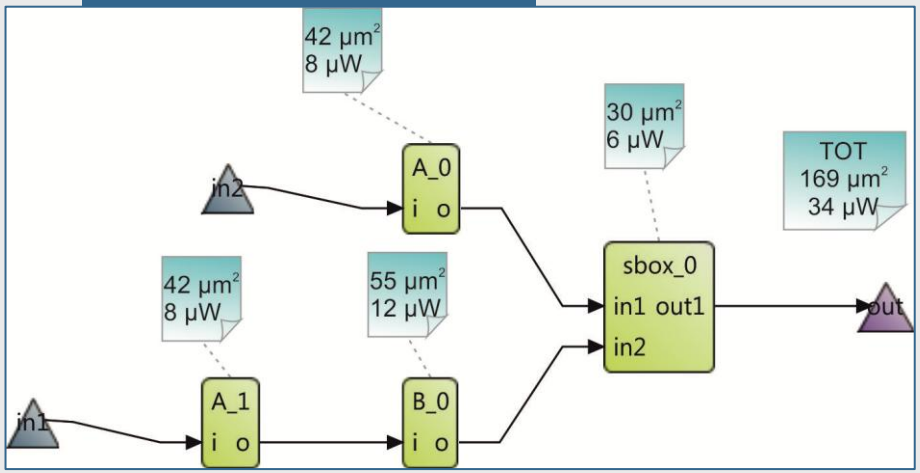


β



merged α and β

not merged α and β



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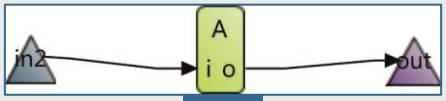
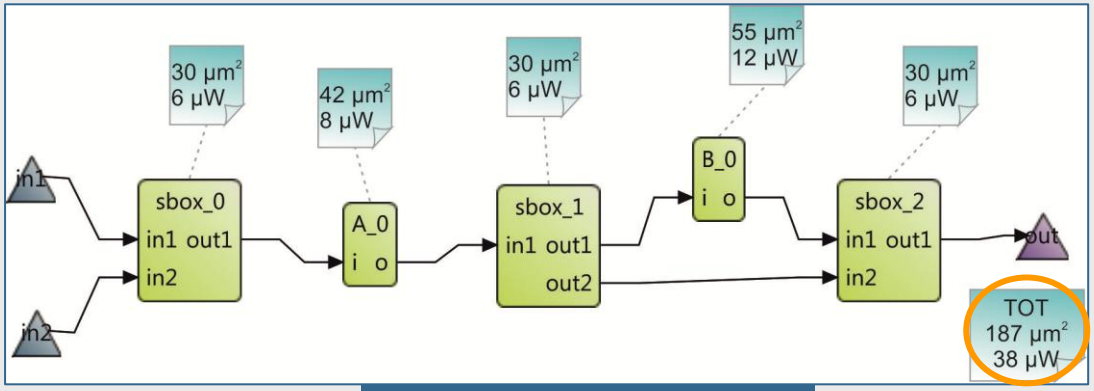


β



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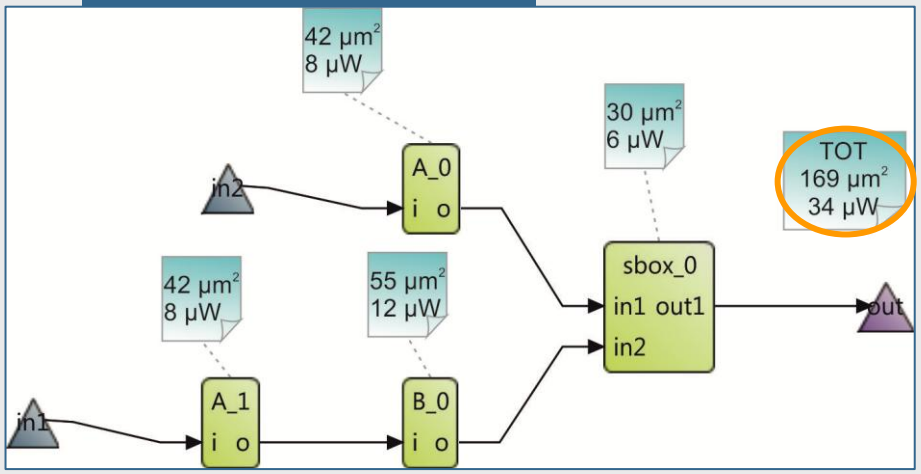

Problem Statement

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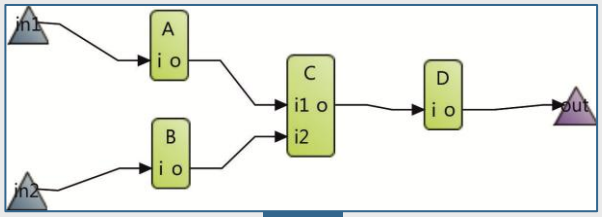
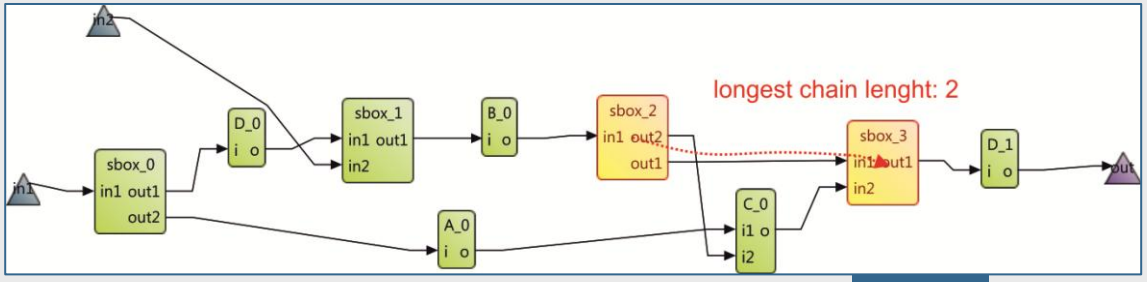
- Different outputs with **different orders** of the SADs



γ

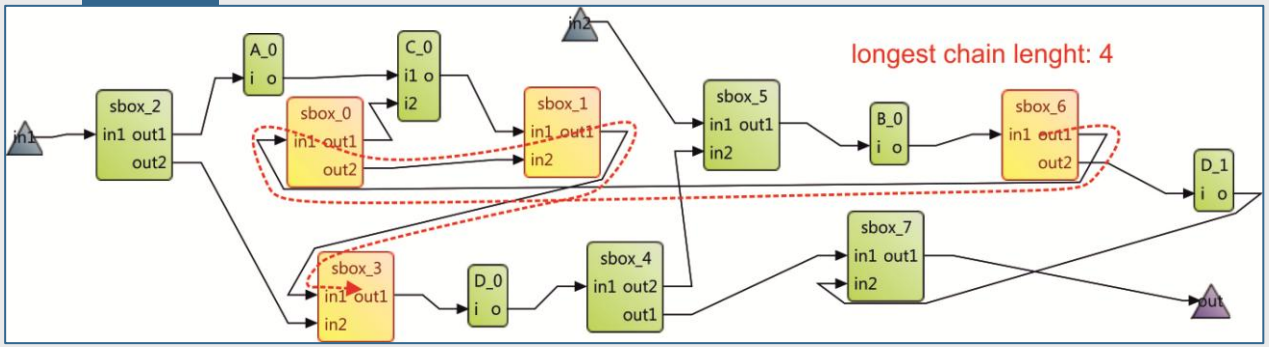
δ

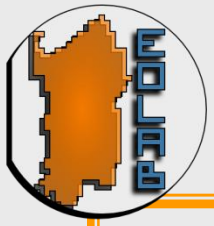
ε



εγδ

γδε





The MDC DSE and profiler

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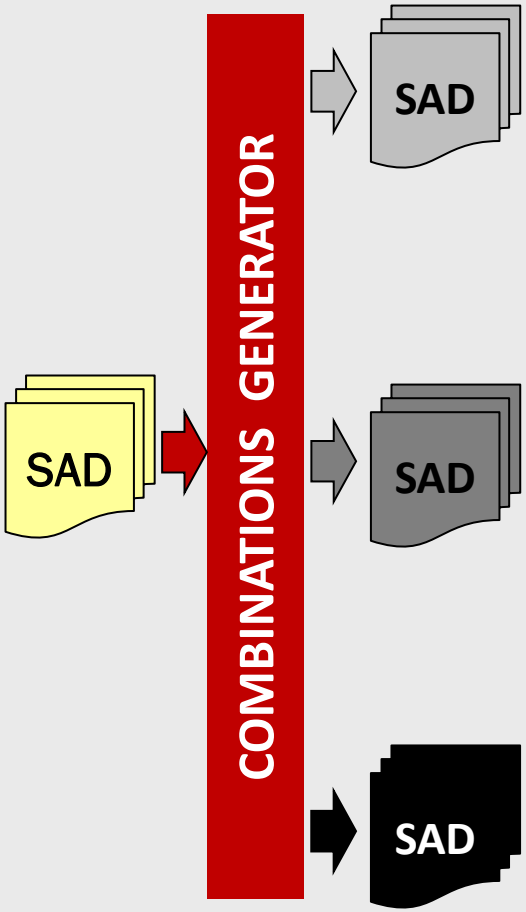

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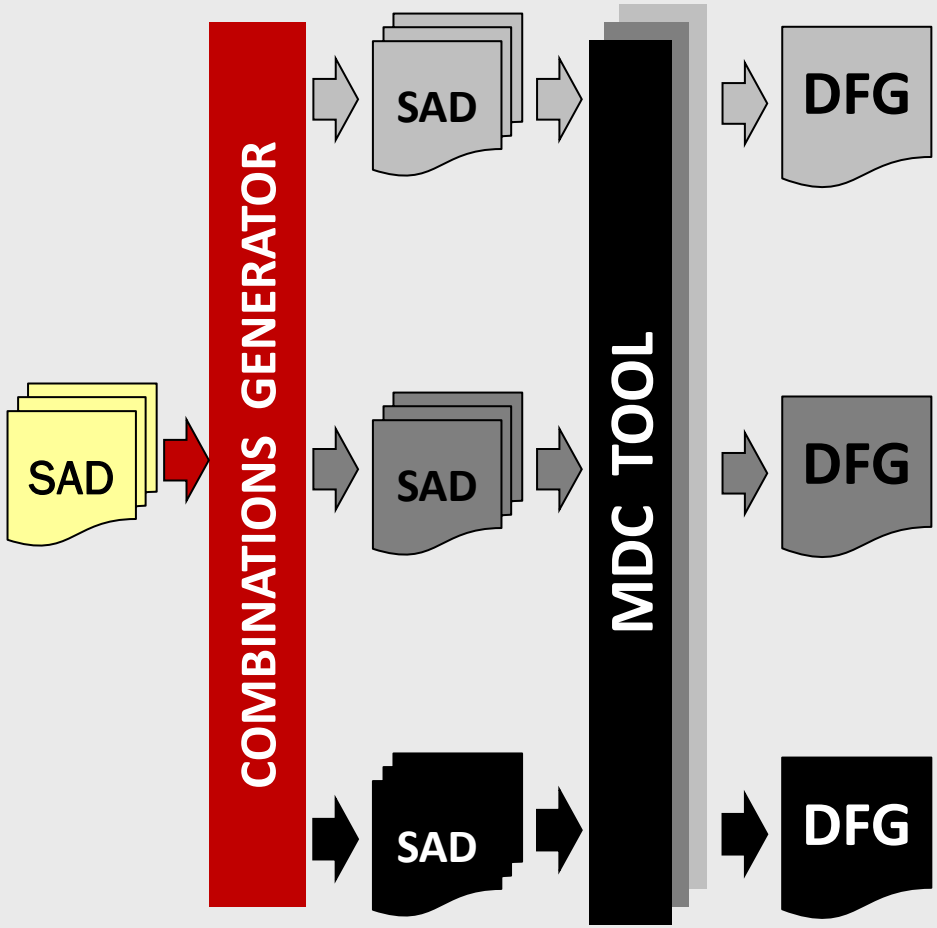

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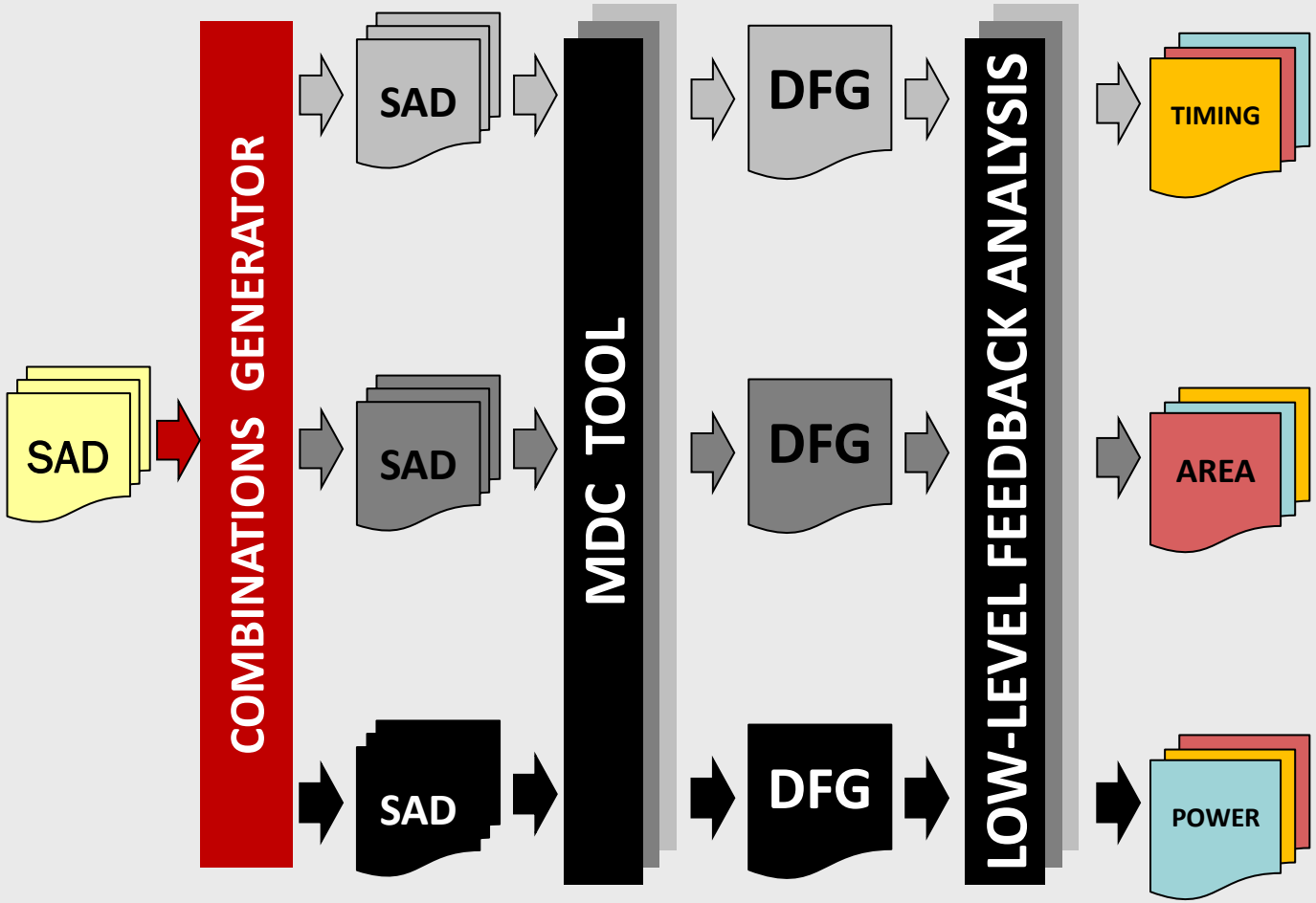

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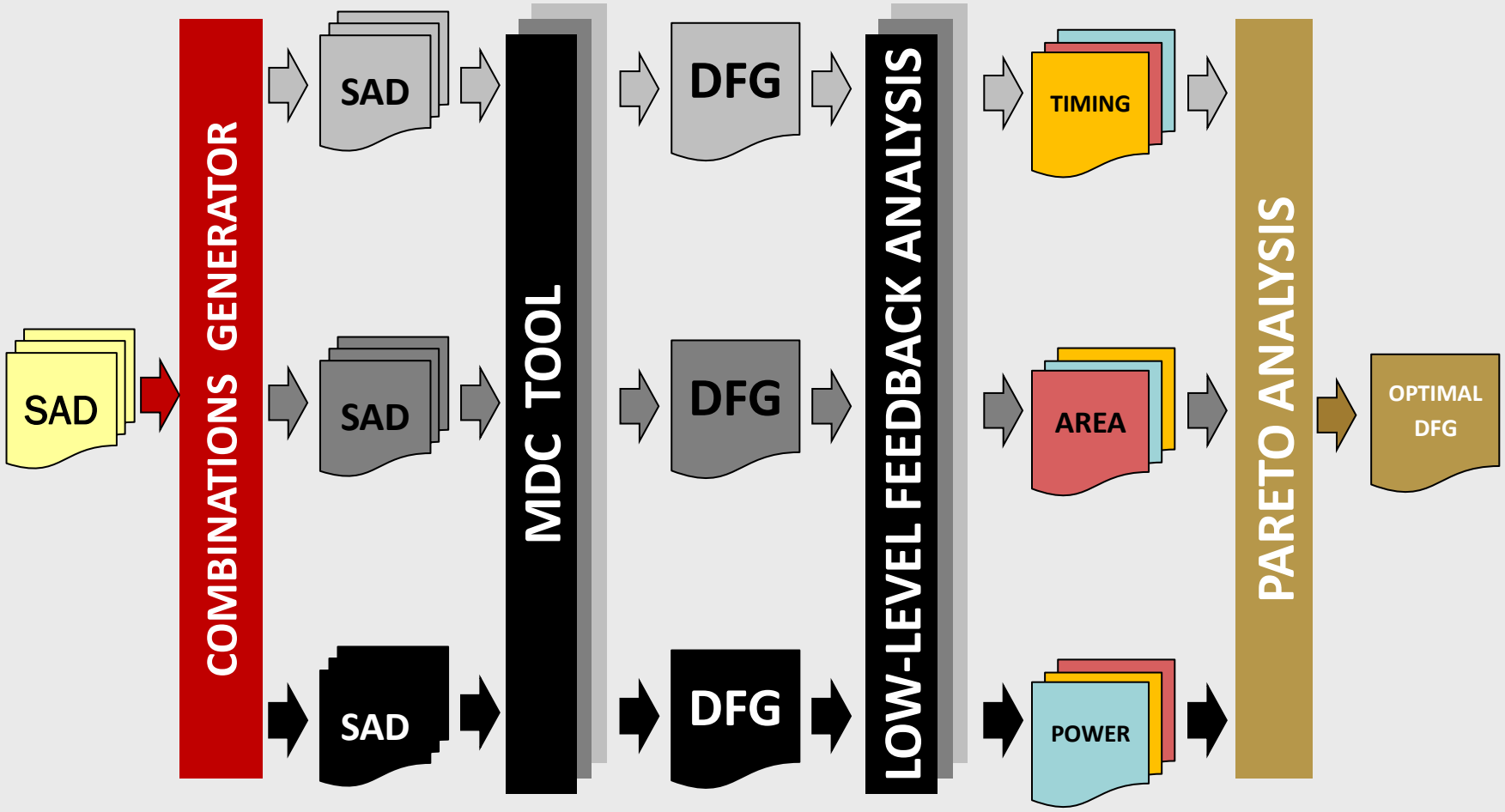

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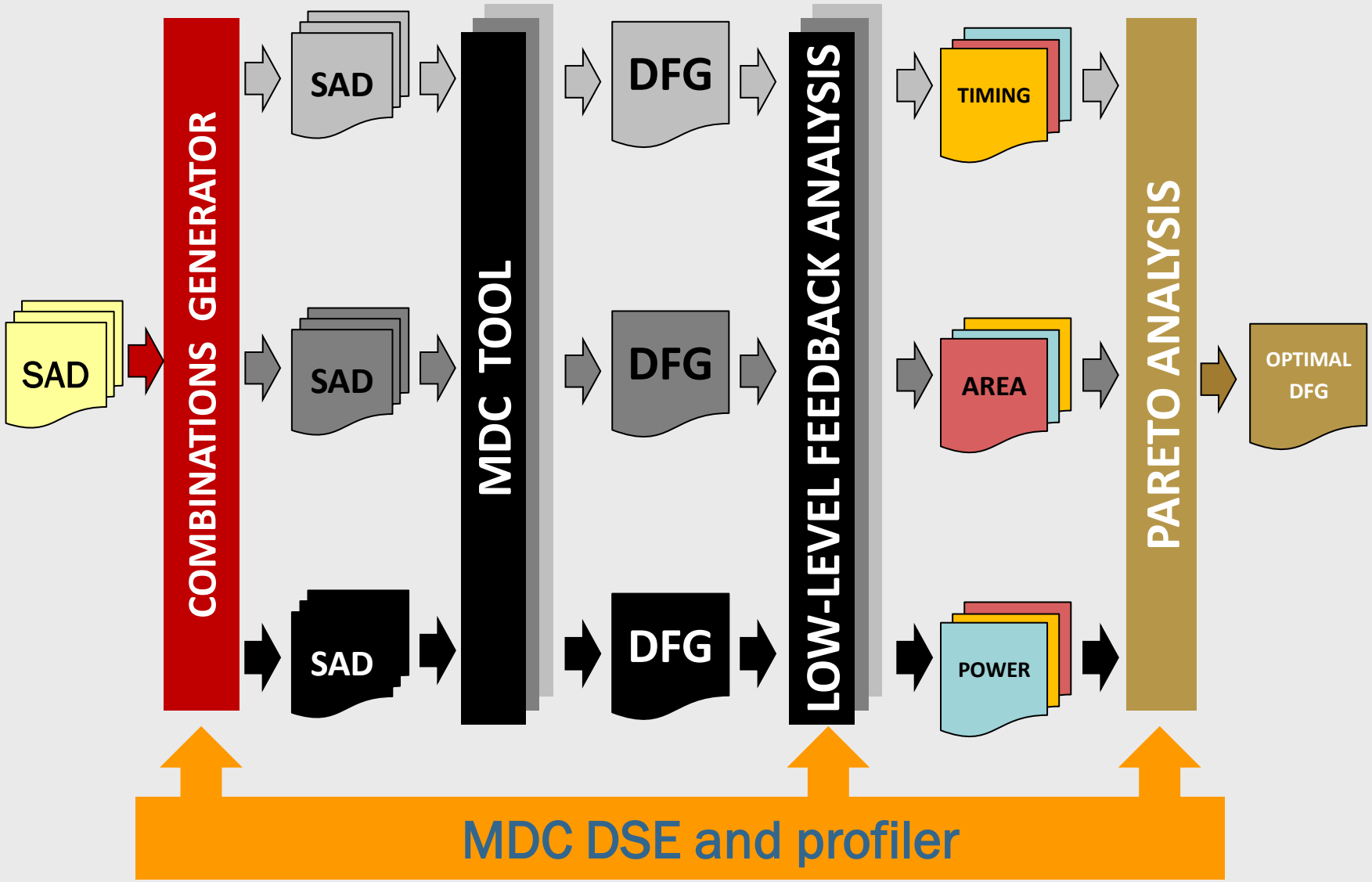
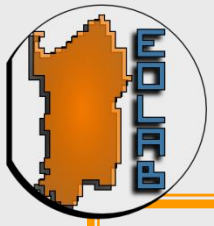


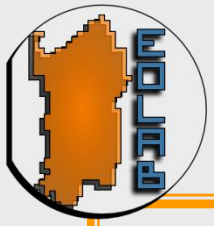


Combinations Generator (1)

Number and type of combinations:

- ***D_notMer:*** not merged composition of the *N* input SADs in placed in parallel;
- ***D_Mer:*** as much resources as possible are shared merging together all the *N* input SADs;
- ***D_partMer:*** it is not maximized resource sharing; any DFG is composed of *i* not merged SADs in parallel with one of the permutations f the other *N-i.*

$$D = D\_notMer + D\_Mer + D\_partMer = 1 + N! + \sum_{K=2}^{N-1} \prod_{j=k}^{N} j$$



Combinations Generator (2)

$N = 4$ $SADs = \{D_1, D_2, D_3, D_4\}$

$D = D\_notMer + D\_Mer + D\_partMer = 61$

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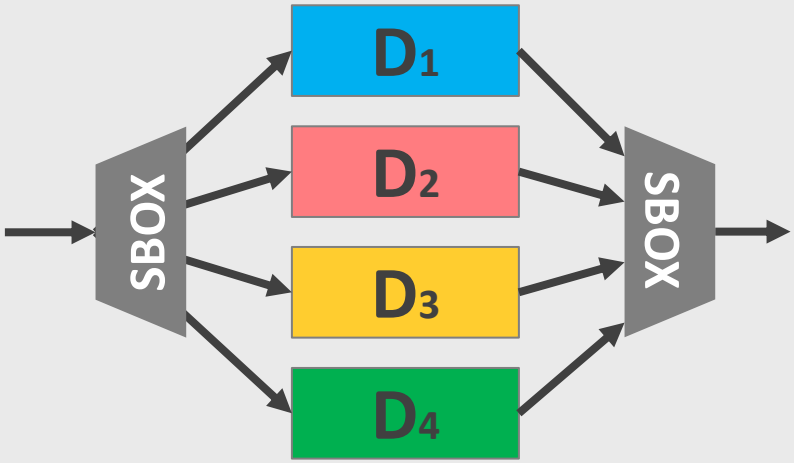

$D\_notMer = 1$

Combinations Generator (2)

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$D = D\_notMer + D\_Mer + D\_partMer = 61$

$D_{1234} = D_1+D_2+D_3+D_4$

$D_{1243} = D_1+D_2+D_4+D_3$

⋮

$D_{4321} = D_4+D_3+D_2+D_1$

$D\_Mer = N! = 1 \cdot 2 \cdot 3 \cdot 4 = 24$

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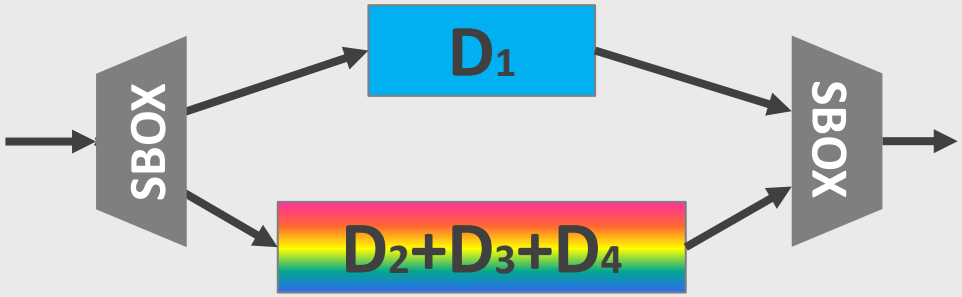
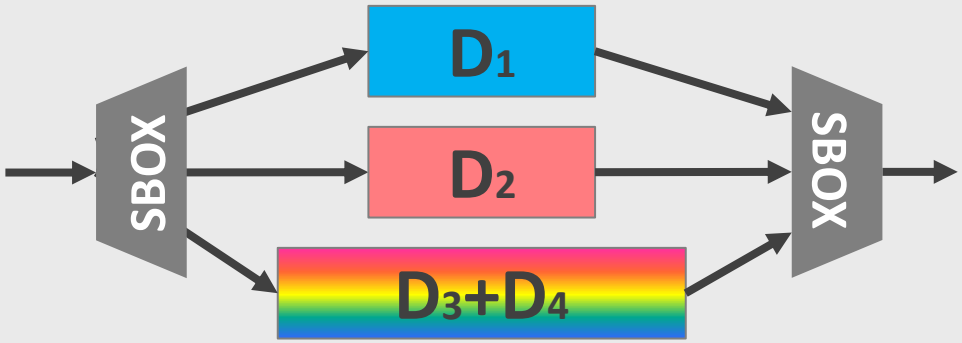


$$D\_partMer = \sum_{K=2}^{3} \prod_{j=k}^{4} j = 2 \cdot 3 \cdot 4 + 3 \cdot 4 = 36$$



Low-level Feedback Analysis: area and power

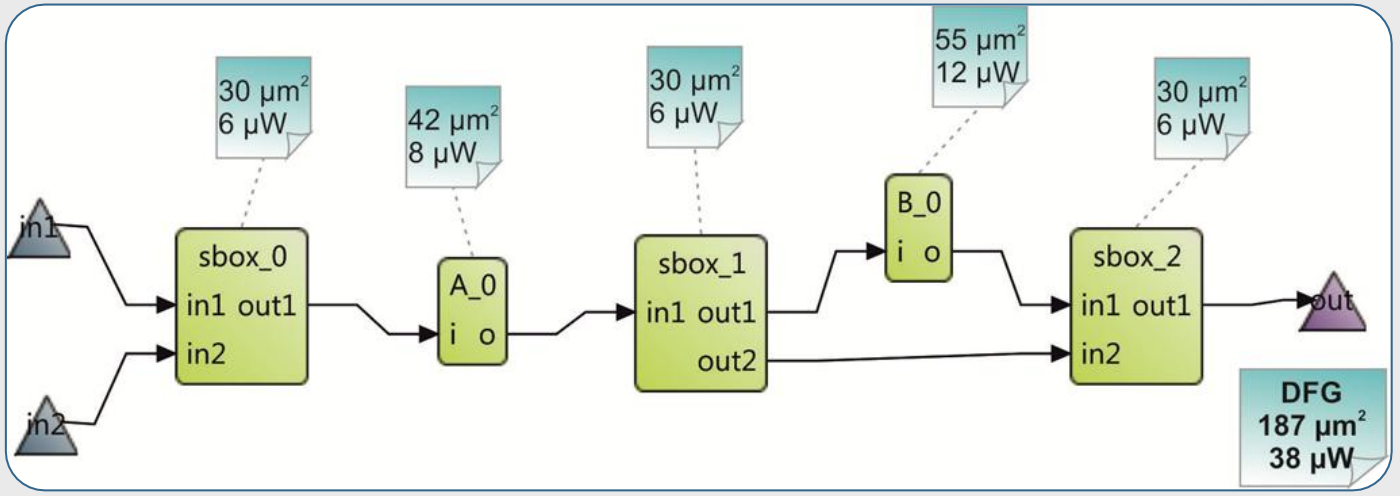
$DFG = \langle V,E \rangle$

V = set of vertices $v_i \in V$

E = set of edges $e_i \in E$

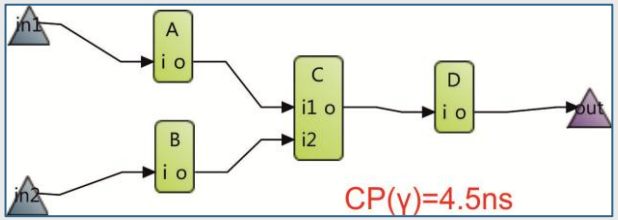
$a_i = Area(v_i) \rightarrow Area(DFG) = \sum a_i$

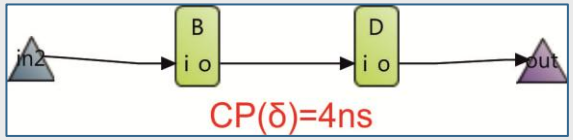
$p_i = Power(v_i) \rightarrow Power(DFG) = \sum p_i$

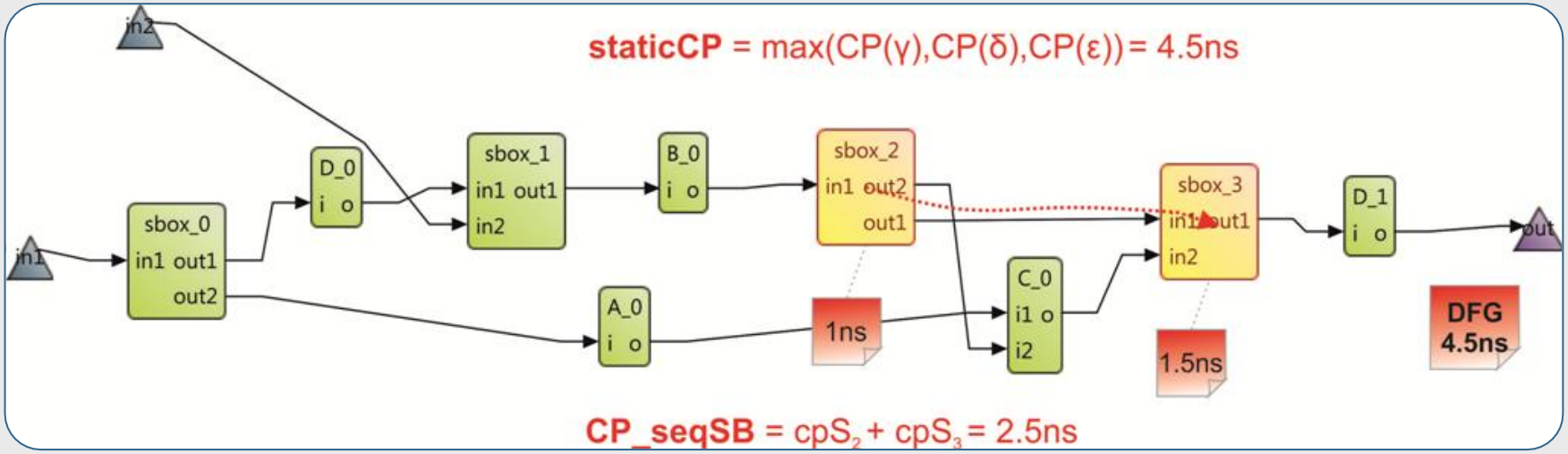


Low-level Feedback Analysis: frequency

- cpN_j=CP of the j-th SAD
  → **staticCP**=max(cpN_j)
- cpS_i=CP of the i-th Sbox
  → **CP_seqSB**=Σ cpS_i







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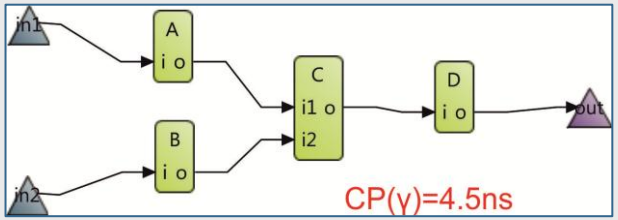

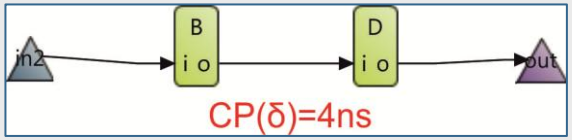

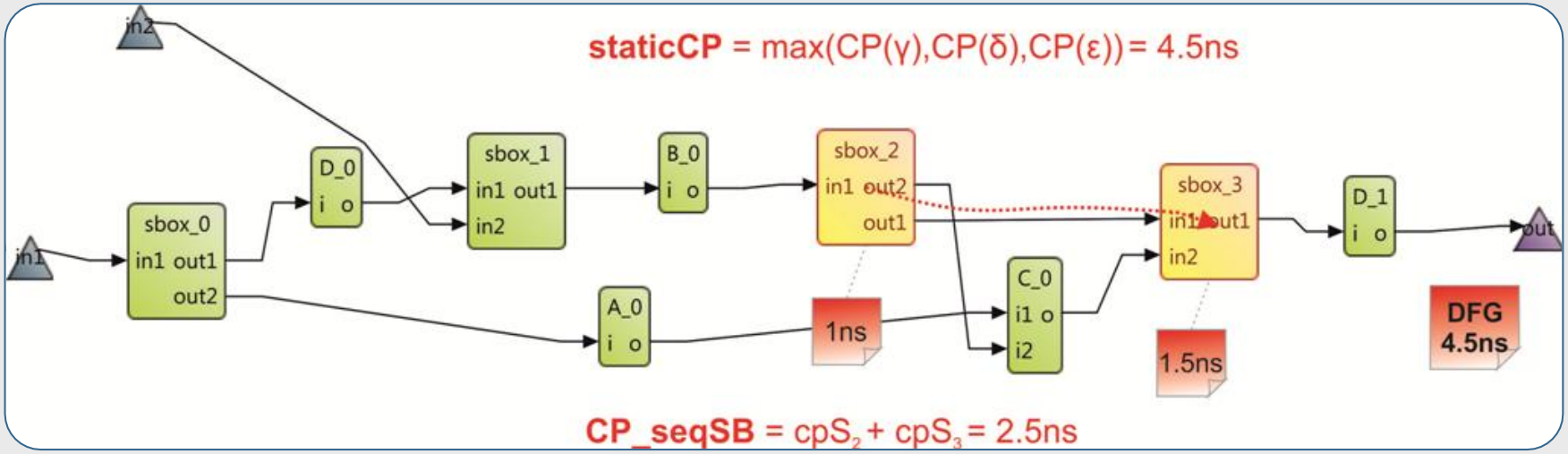

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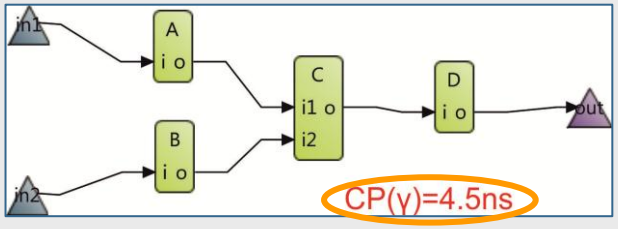
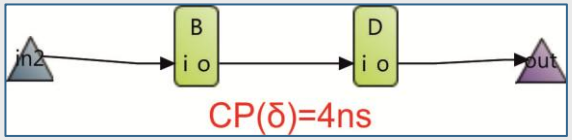
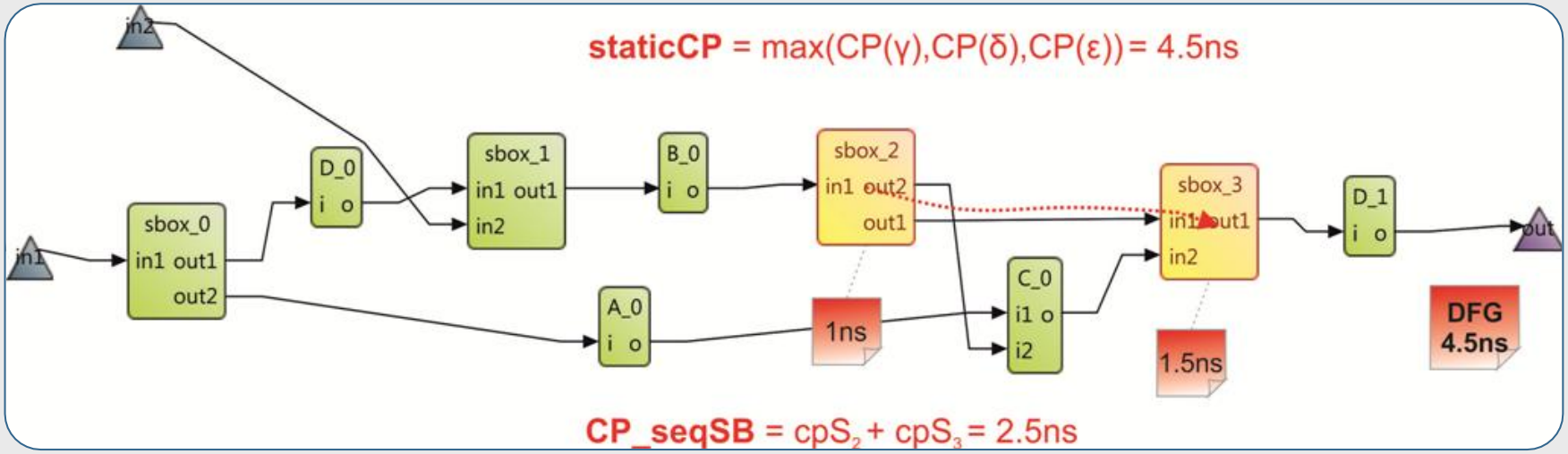
  → **CP_seqSB**=Σ cpS_i

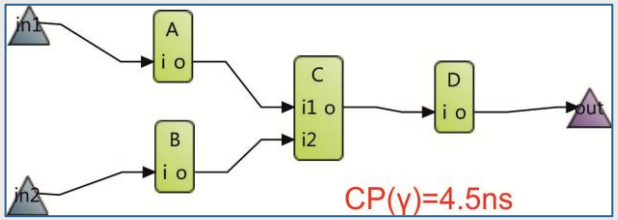


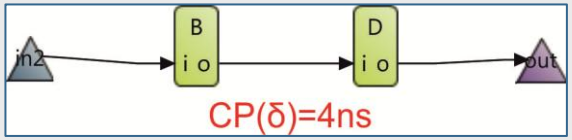


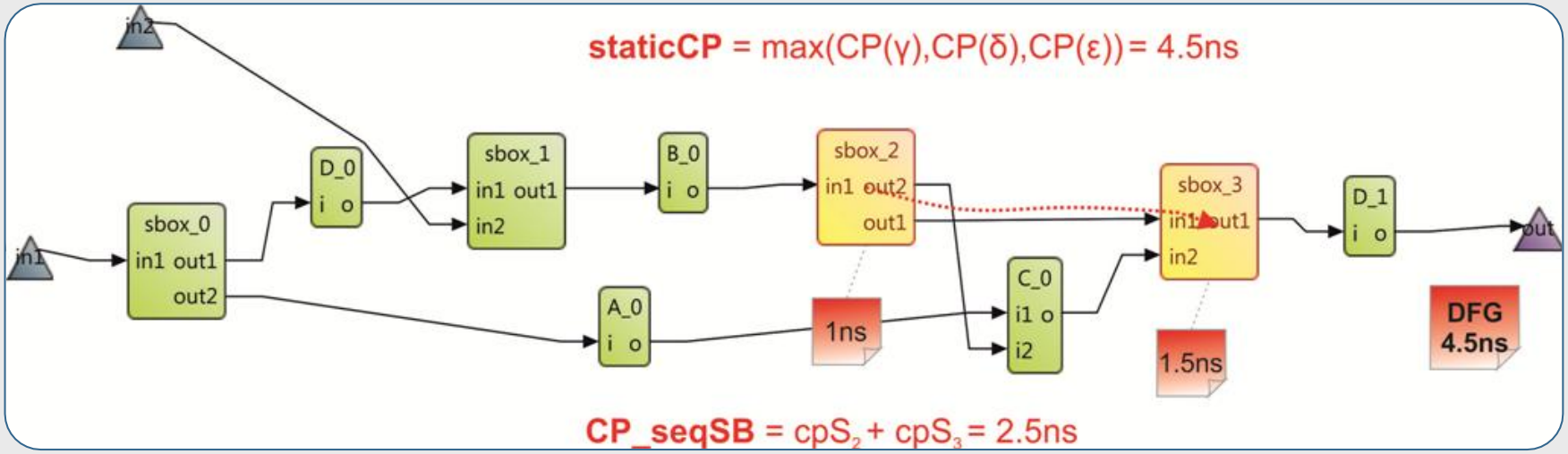


Low-level Feedback Analysis: frequency

- cpN_j=CP of the j-th SAD
  → **staticCP**=max(cpN_j)
- cpS_i=CP of the i-th Sbox
  → **CP_seqSB**=Σ cpS_i



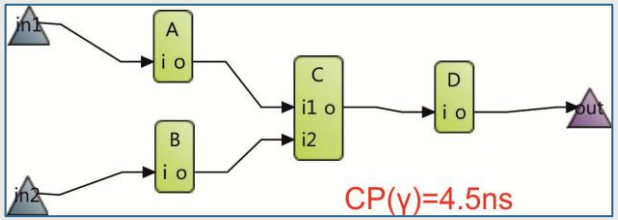


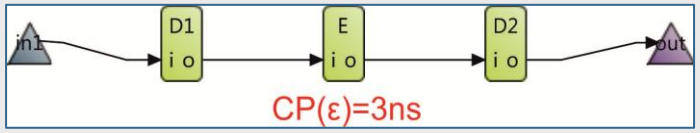


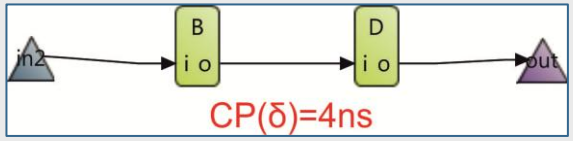
Low-level Feedback Analysis: frequency

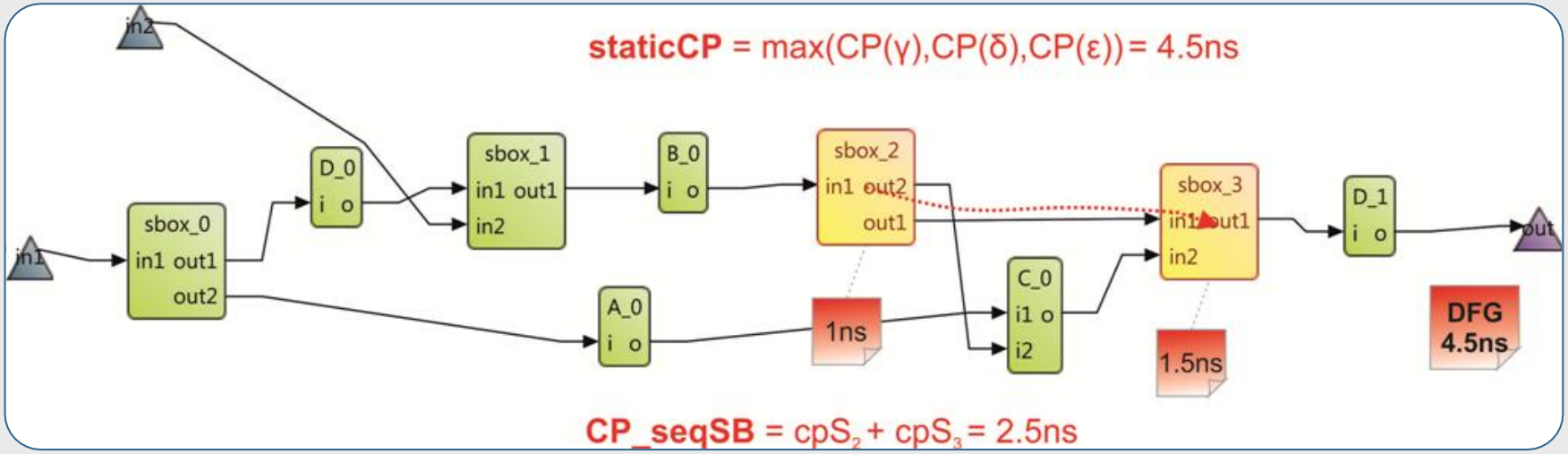
- cpN_j=CP of the j-th SAD → **staticCP**=max(cpN_j)
- cpS_i=CP of the i-th Sbox → **CP_seqSB**=Σ cpS_i

CP(DFG) =max(Cpstatic,CP_seqSB)





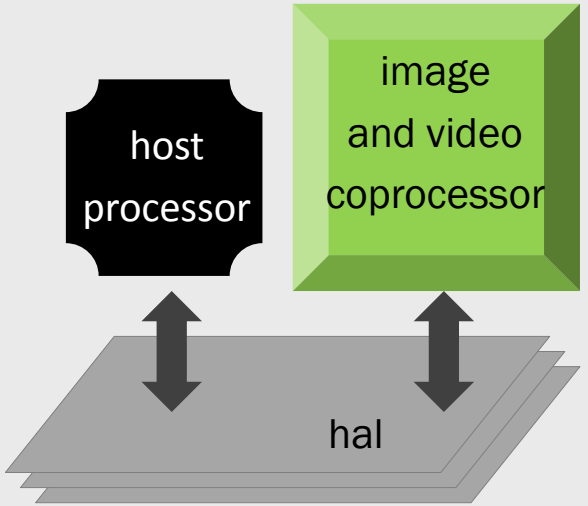




Design Under Test

Table: composition of the different analyzed use cases.

SADs	UC1	UC2	UC3
Qsort	X	-	X
Min_Max	X	X	X
Corr	X	-	X
Abs	X	X	X
Rgb2Ycc	X	-	X
Ycc2Rgb	X	-	X
Sbwlabel	-	X	X
Median	-	X	X
Cubic	-	X	X
Cubic_Conv	-	X	X
Check_GeneralBilevel	-	X	X



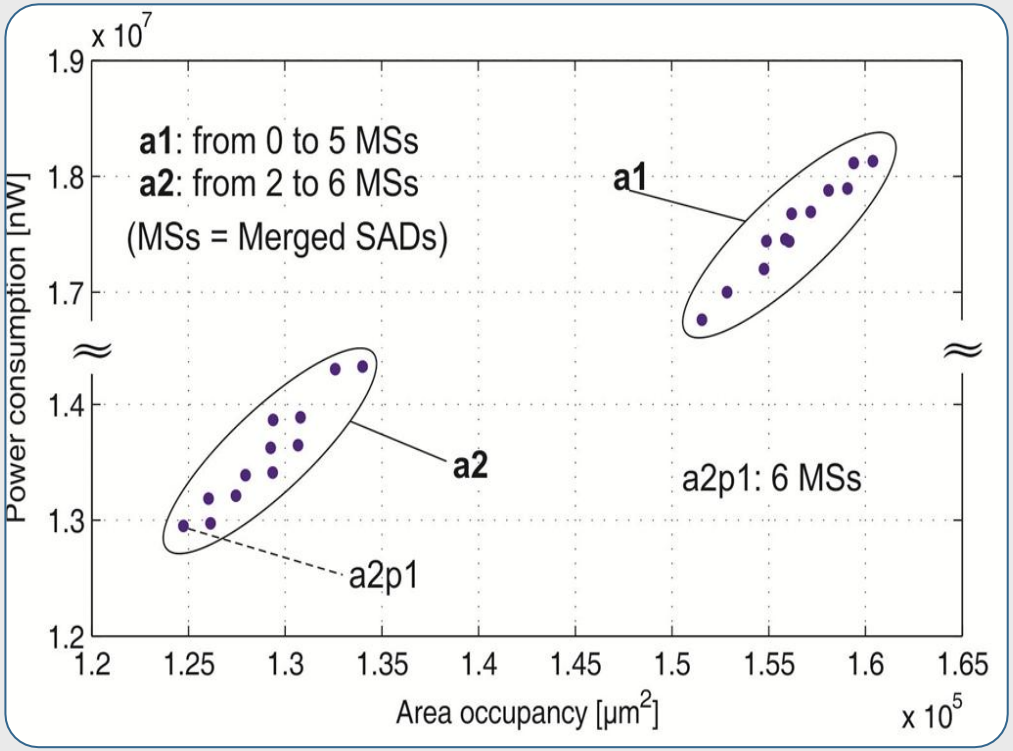
[F. Palumbo et.al. ,*"The multi-dataflow composer tool: generation of on-the-fly reconfigurable platforms"*, in Jrnl of Real Time Image Processing]

UC1: Antialiasing

UC2: Zoom

UC3: Antialiasing & Zoom

UC1 - Pareto Analysis



UC1: Antialiasing

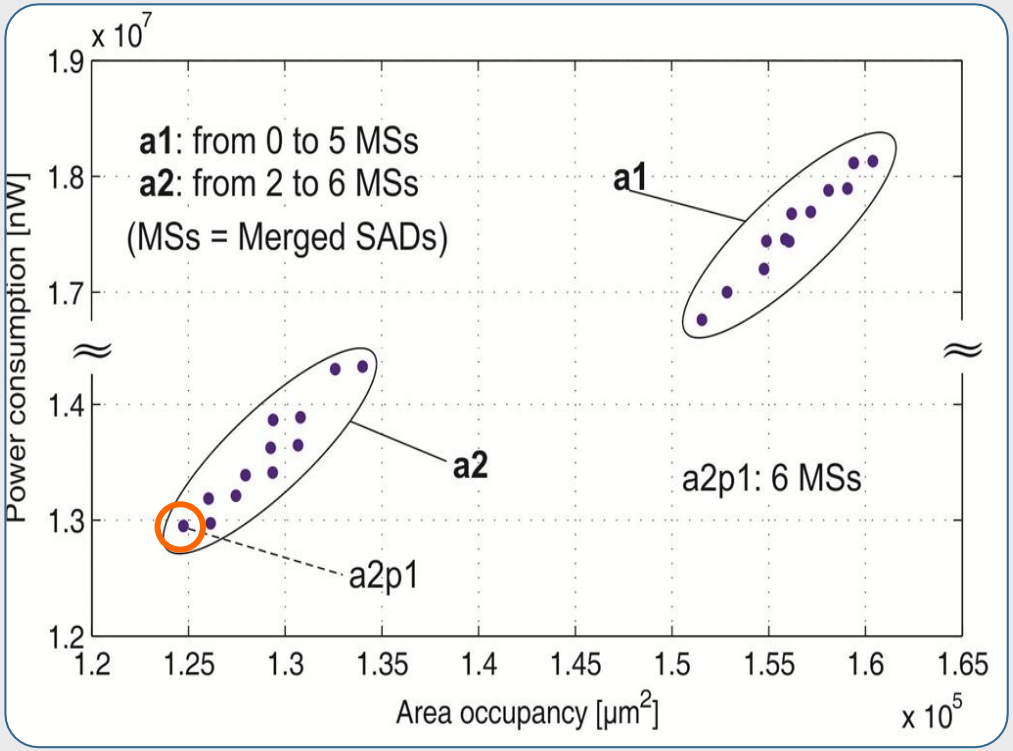
Involved SADs:

6

Design Space size:

1951 points

UC1 - Pareto Analysis



UC1: Antialiasing

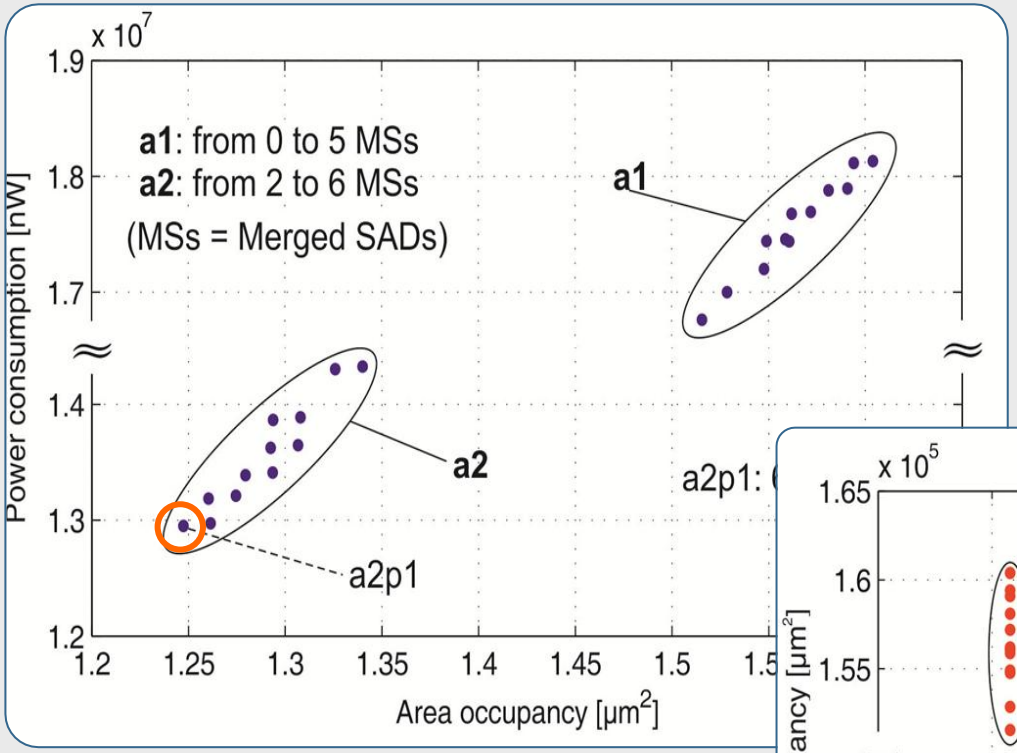
Involved SADs:

6

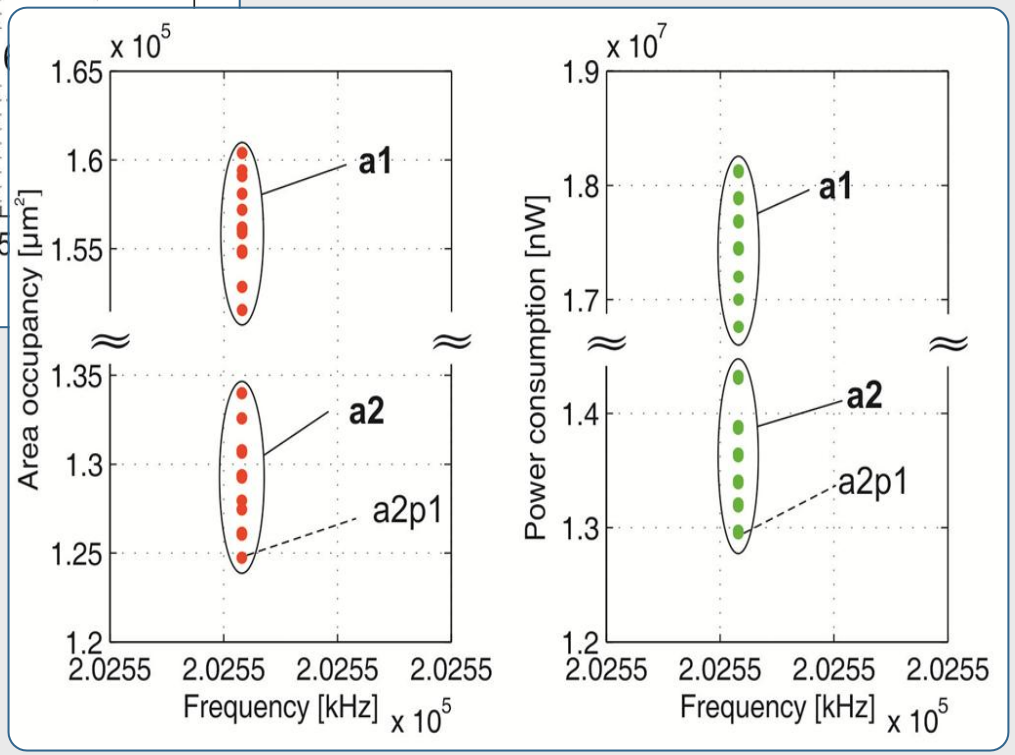
Design Space size:

1951 points

UC1 - Pareto Analysis



UC1: Antialiasing



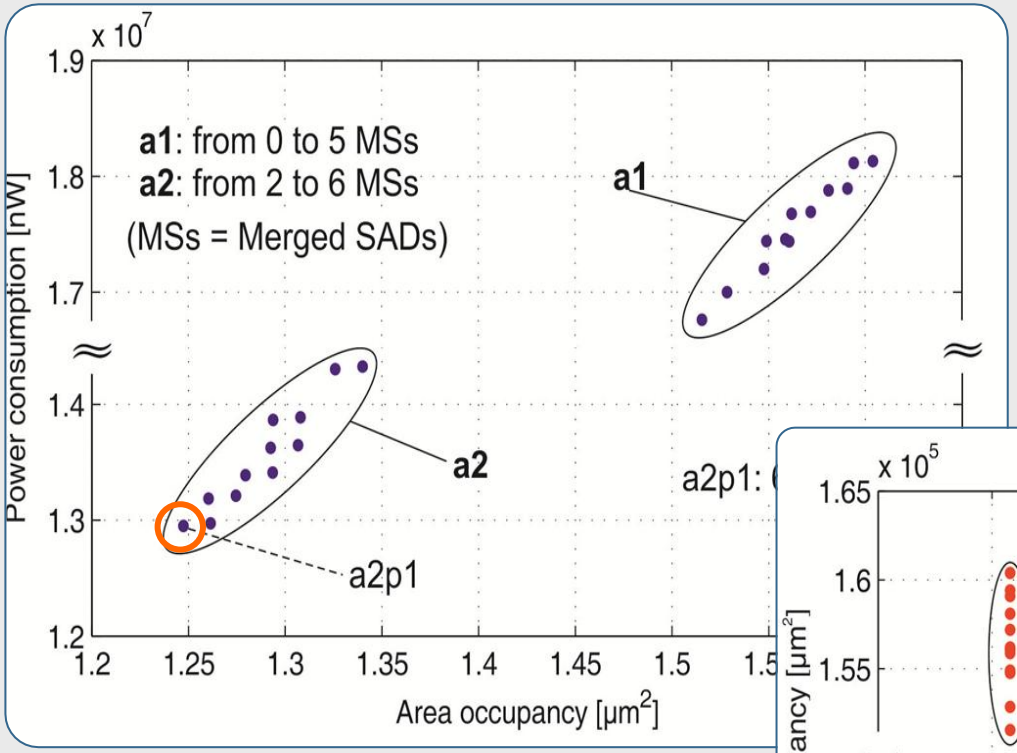
Involved SADs:

6

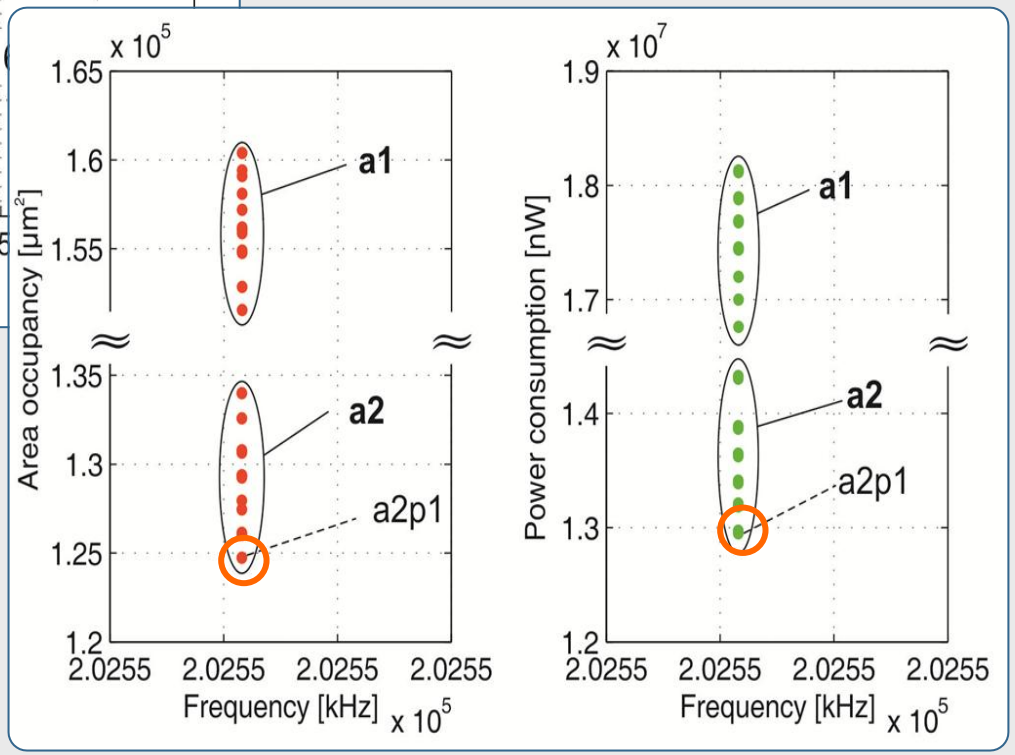
Design Space size:

1951 points

UC1 - Pareto Analysis



UC1: Antialiasing



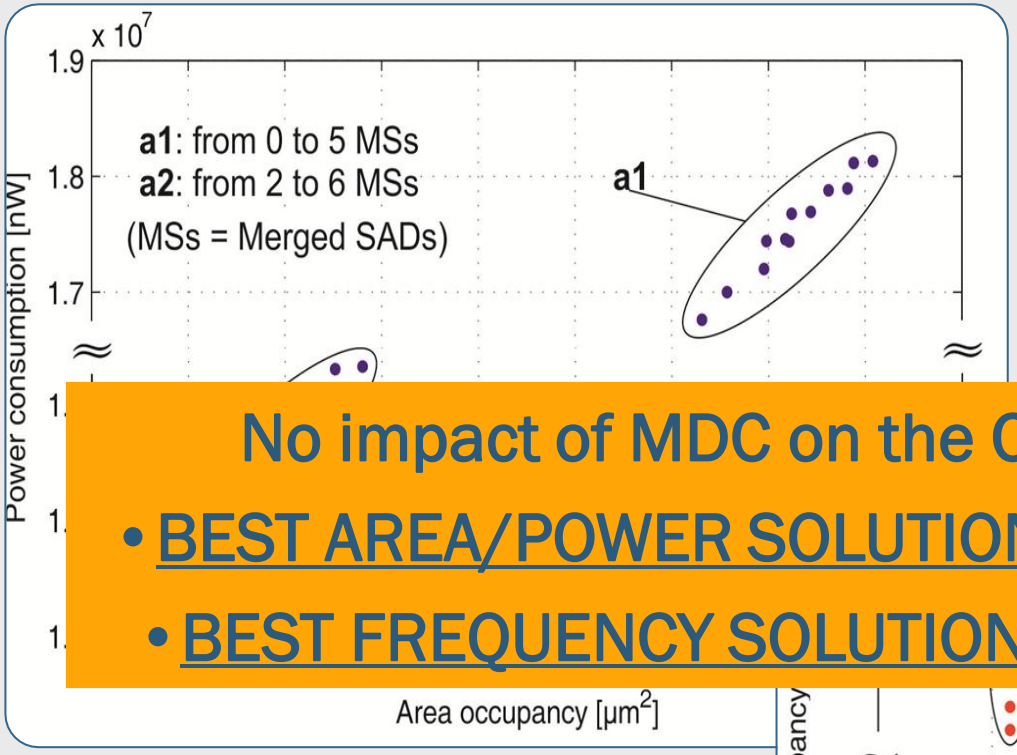
Involved SADs:

6

Design Space size:

1951 points

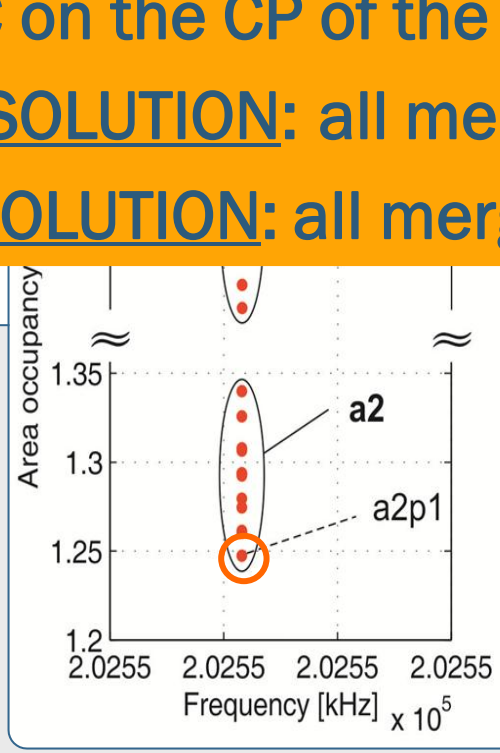
UC1 - Pareto Analysis

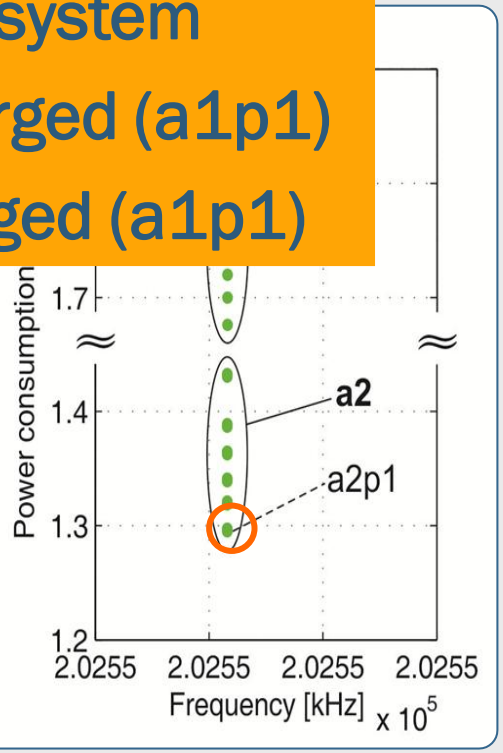


UC1: Antialiasing

No impact of MDC on the CP of the system

- **BEST AREA/POWER SOLUTION: all merged (a1p1)**
- **BEST FREQUENCY SOLUTION: all merged (a1p1)**





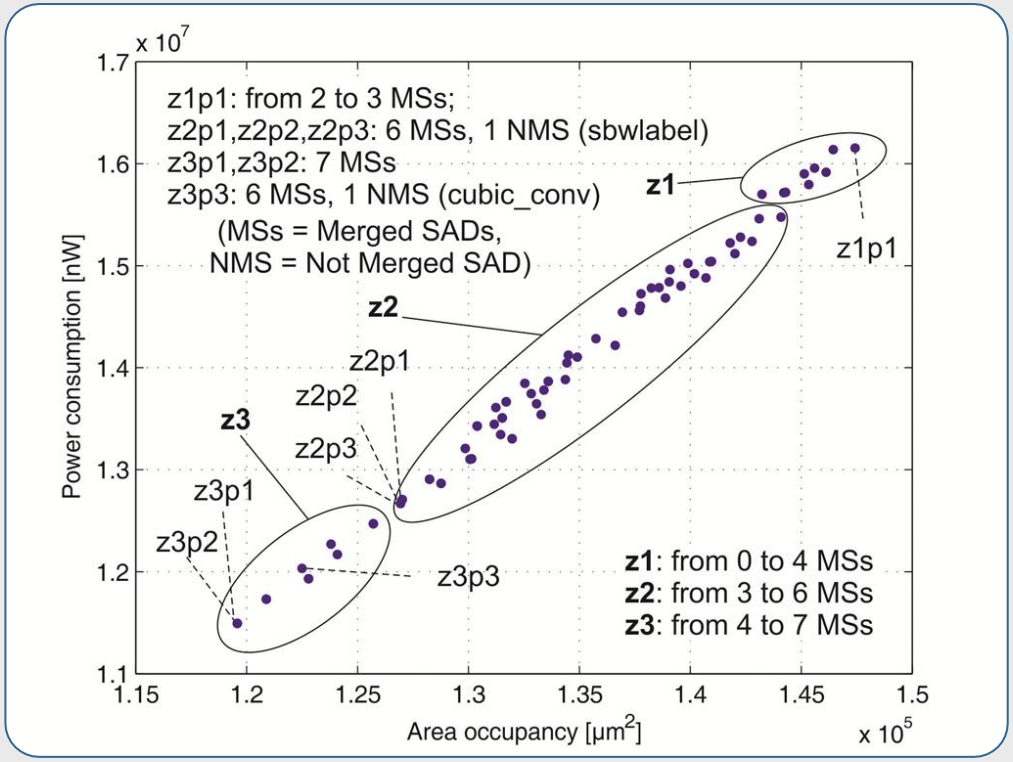
Involved SADs:

6

Design Space size:

1951 points

UC2 - Pareto analysis



UC2: Zoom

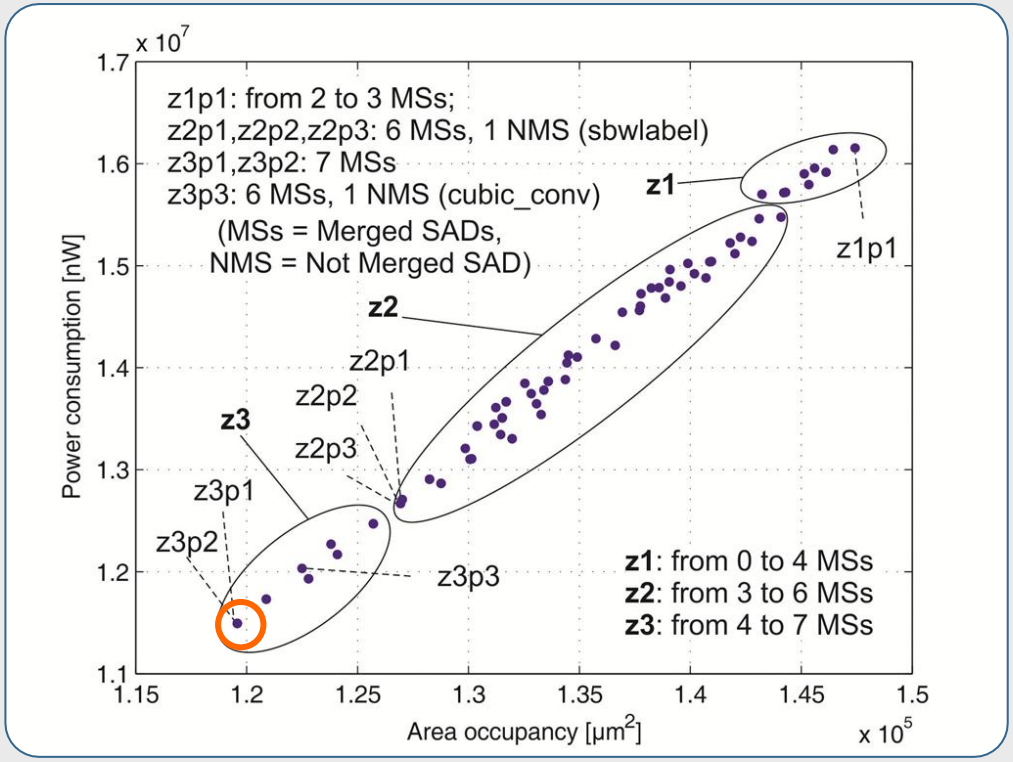
Involved SADs:

7

Design Space size:

13693 points

UC2 - Pareto analysis



UC2: Zoom

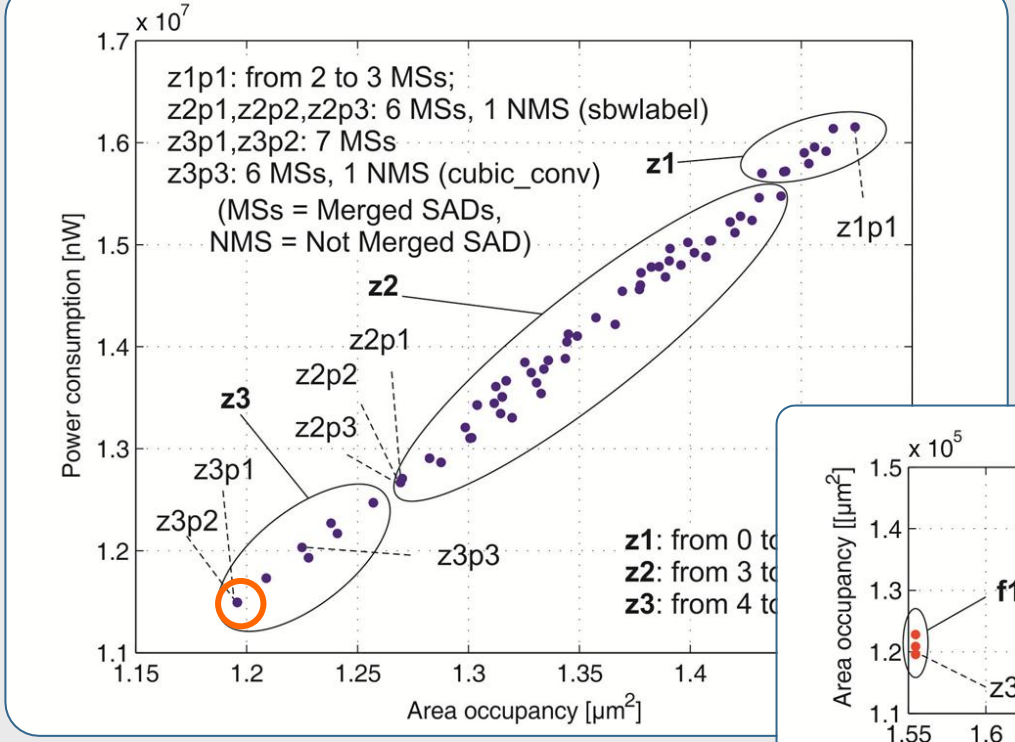
Involved SADs:

7

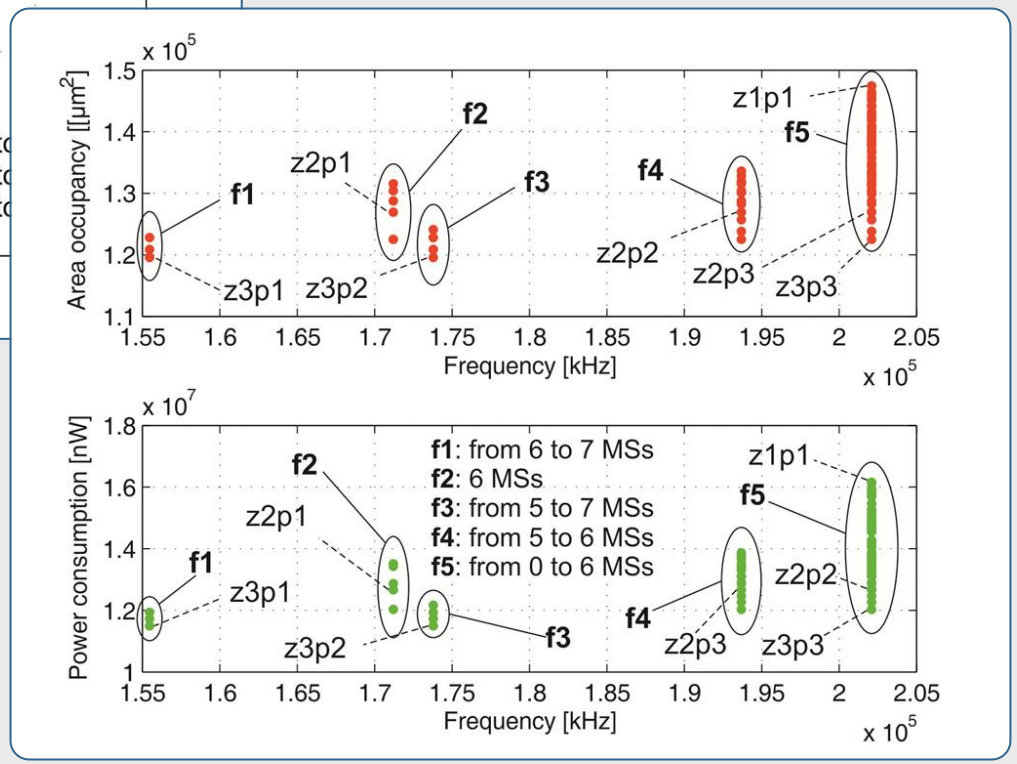
Design Space size:

13693 points

UC2 - Pareto analysis



UC2: Zoom



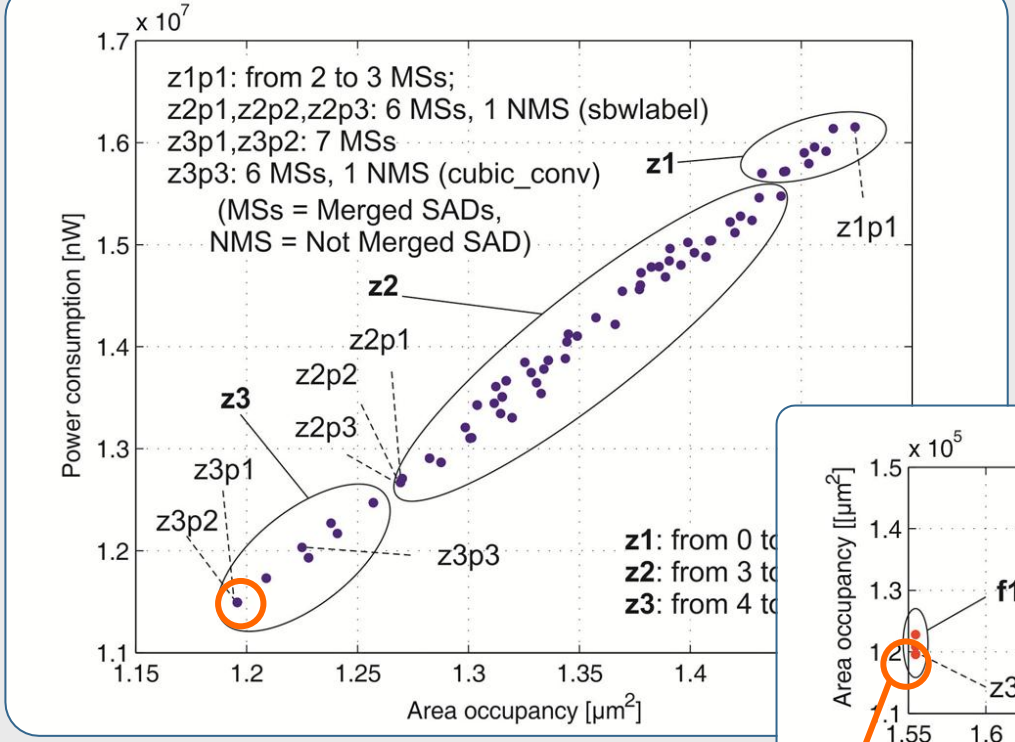
Involved SADs:

7

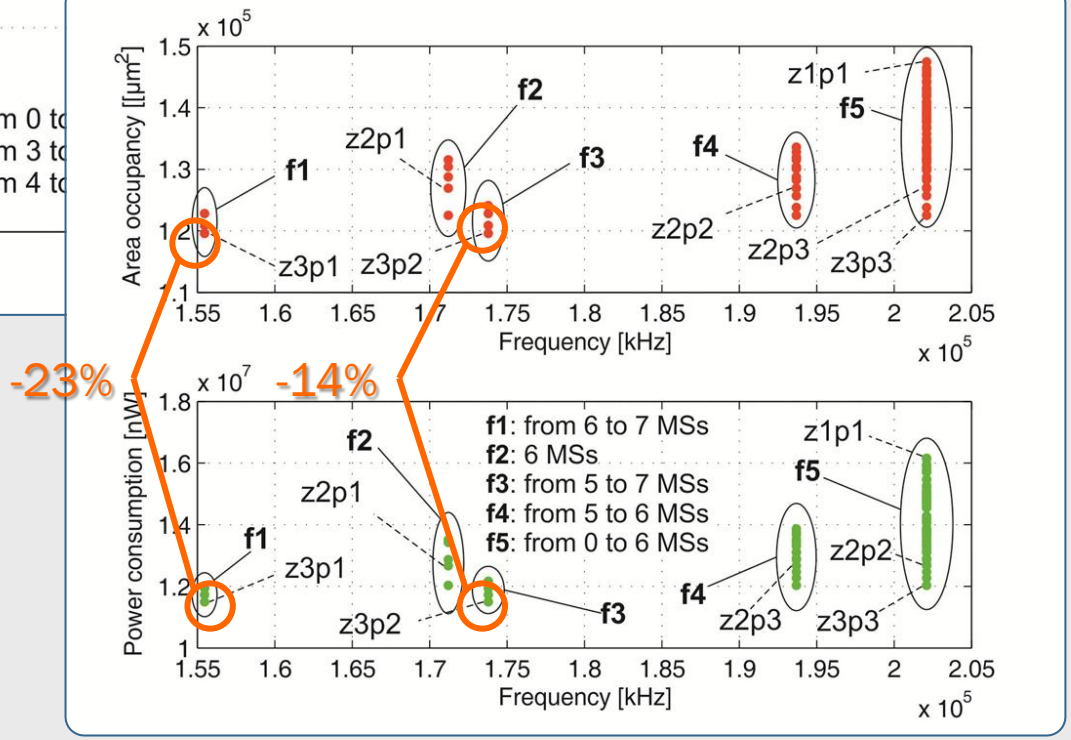
Design Space size:

13693 points

UC2 - Pareto analysis



UC2: Zoom



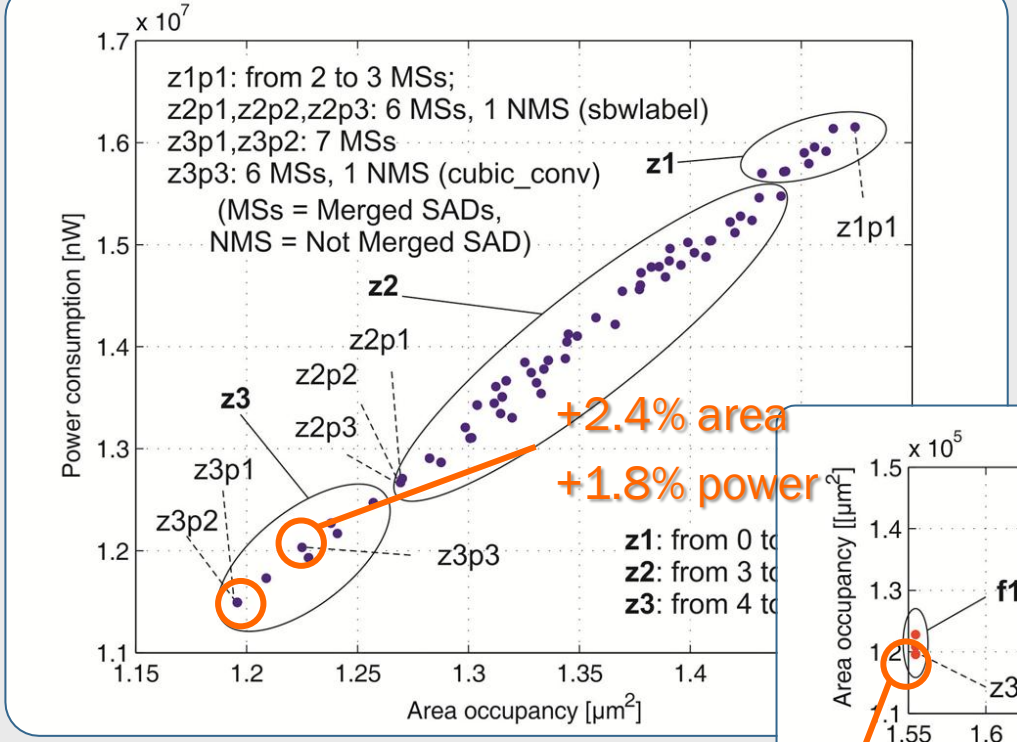
Involved SADs:

7

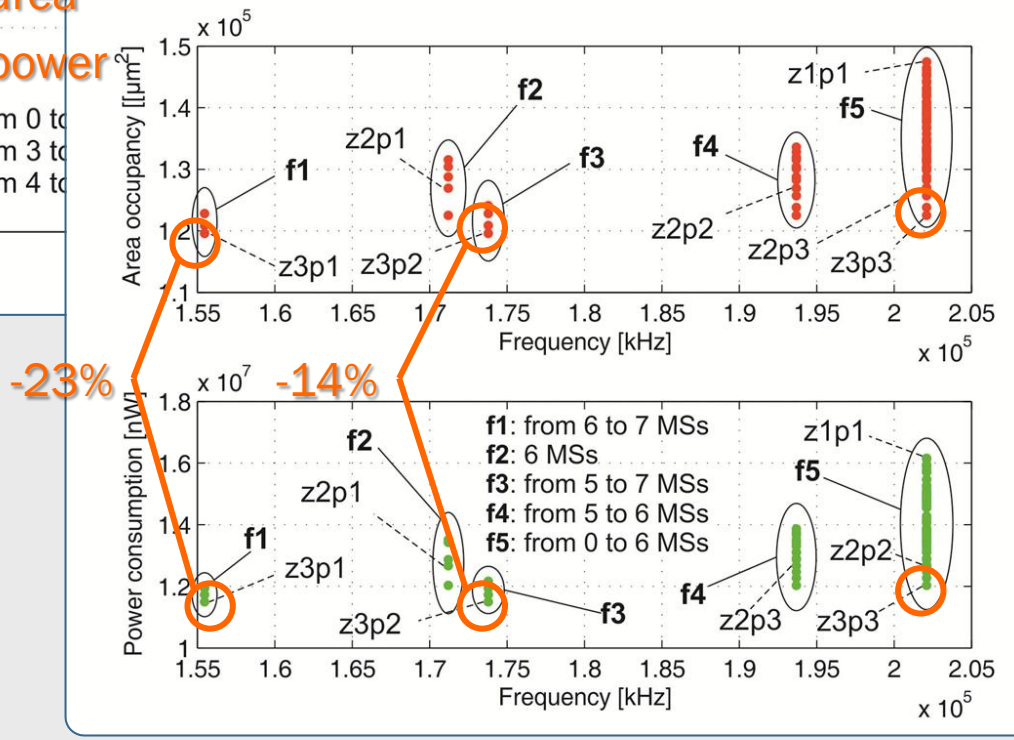
Design Space size:

13693 points

UC2 - Pareto analysis



UC2: Zoom



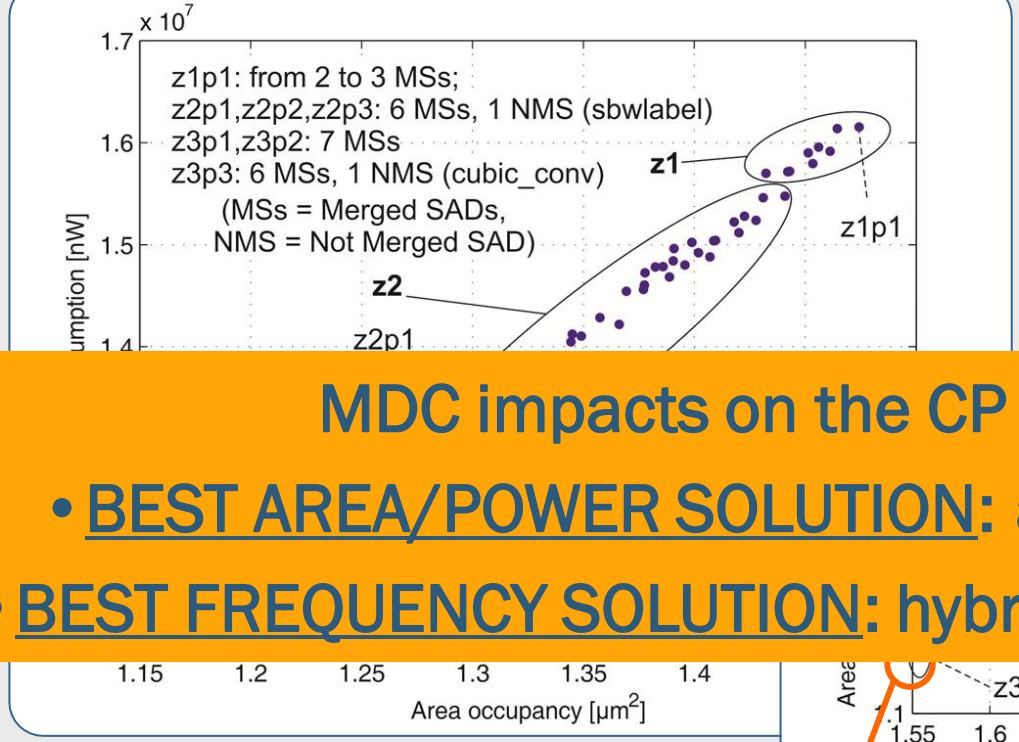
Involved SADs:

7

Design Space size:

13693 points

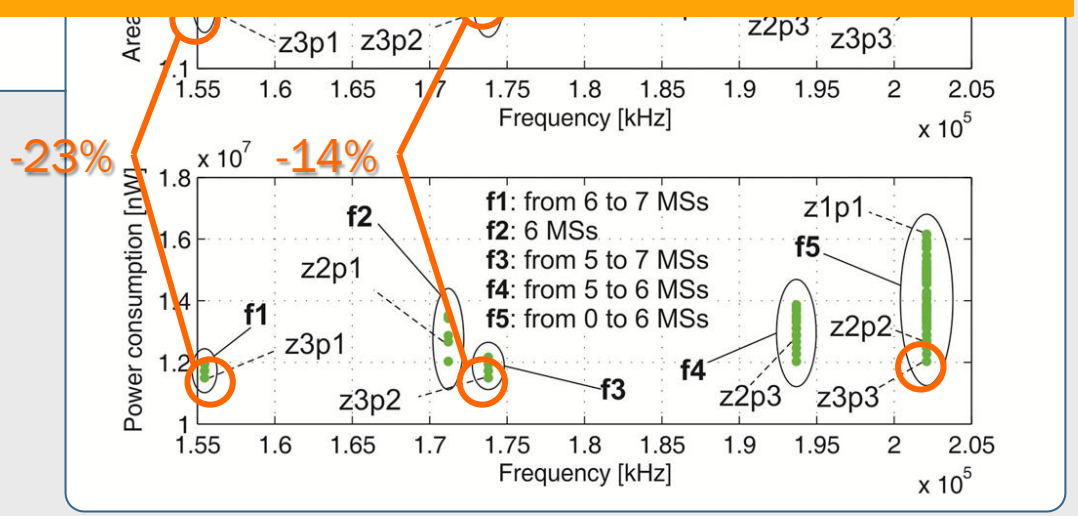
UC2 - Pareto analysis



UC2: Zoom

MDC impacts on the CP of the system

- **BEST AREA/POWER SOLUTION**: all merged (z3p1,z3p2)
- **BEST FREQUENCY SOLUTION**: hybrid, 6 merged SADs (z3p3)



Involved SADs:

7

Design Space size:

13693 points

UC3 - Pareto analysis

Table: percentage of the SAD overlapping actors with respect to an all merged solution.

SADs	UC1	UC2	UC3
Qsort	2,94%	-	1,89%
Min_Max	2,94%	3,12%	1,89%
Corr	11,76%	-	9,43%
Abs	2,94%	3,12%	1,89%
Rgb2Ycc	20,59%	-	15,09%
Ycc2Rgb	26,47%	-	18,87%
Sbwlabel	-	15,62%	11,32%
Median	-	18,75%	13,21%
Cubic	-	18,75%	11,32%
Cubic_Conv	-	9,38%	5,66%
Check_GeneralBilevel	-	18,75%	11,32%

UC3: Antialiasing & Zoom

Involved SADs:
11

Design Space size:
108505101 points

UC3 - Pareto analysis

Table: percentage of the SAD overlapping actors with respect to an all merged solution.

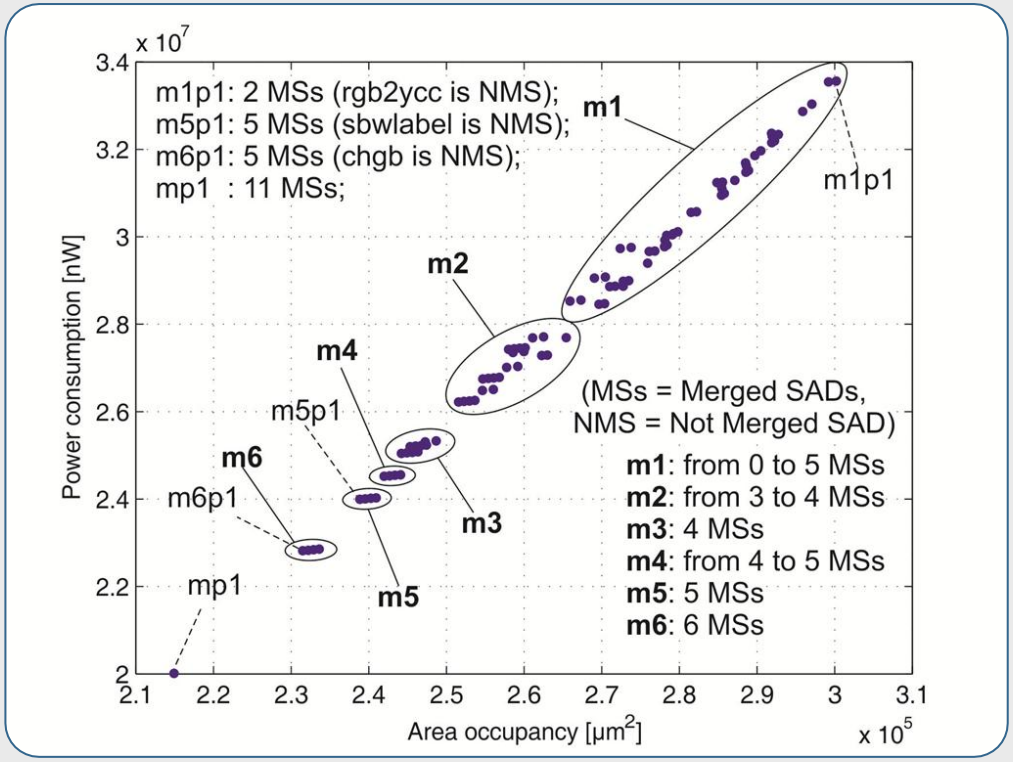
SADs	UC1	UC2	UC3	
Qsort	2,94%	-	1,89%	
Min_Max	2,94%	3,12%	1,89%	
Corr	11,76%	-	9,43%	
Abs	2,94%	3,12%	1,89%	
Rgb2Ycc	20,59%	-	15,09%	←
Ycc2Rgb	26,47%	-	18,87%	←
Sbwlabel	-	15,62%	11,32%	←
Median	-	18,75%	13,21%	←
Cubic	-	18,75%	11,32%	←
Cubic_Conv	-	9,38%	5,66%	
Check_GeneralBilevel	-	18,75%	11,32%	←

UC3: Antialiasing & Zoom

Involved SADs:
11

Design Space size:
108505101 points

UC3 - Pareto analysis



UC3: Antialiasing & Zoom

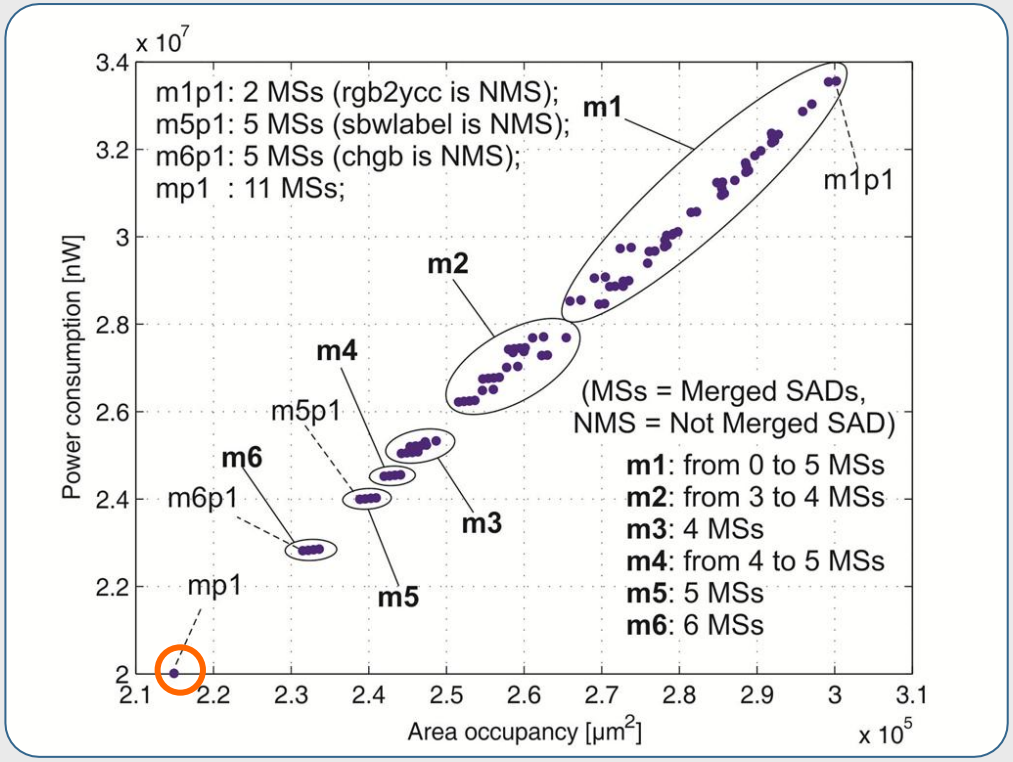
Involved SADs:

6 of 11

Design Subpace size:

1951 points

UC3 - Pareto analysis



UC3: Antialiasing & Zoom

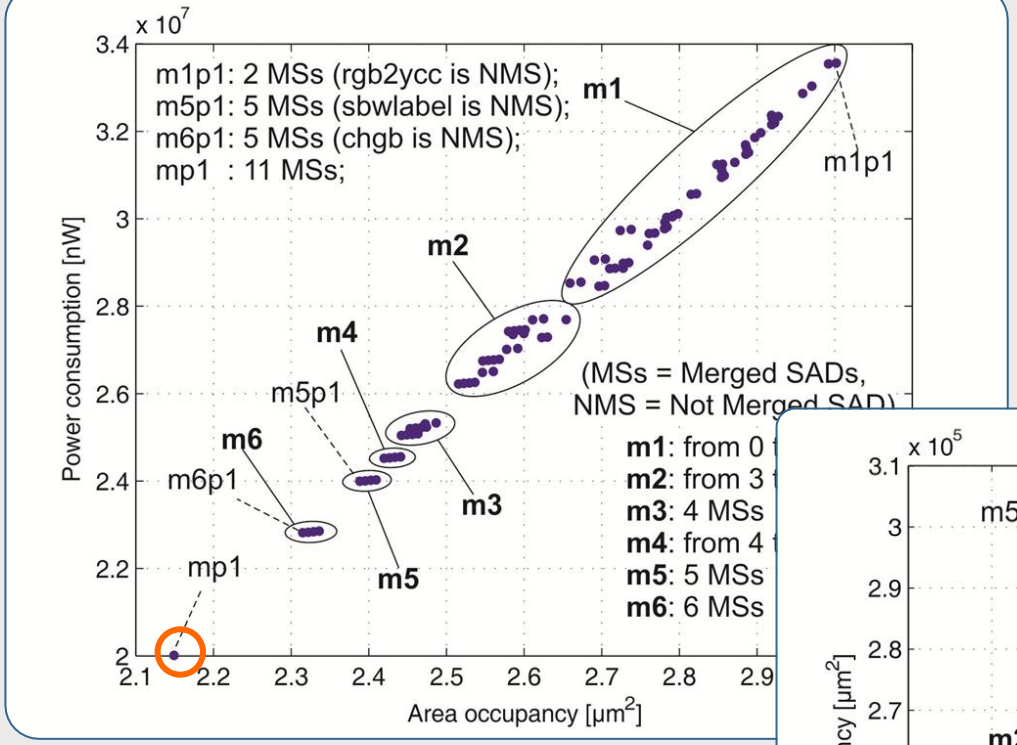
Involved SADs:

6 of 11

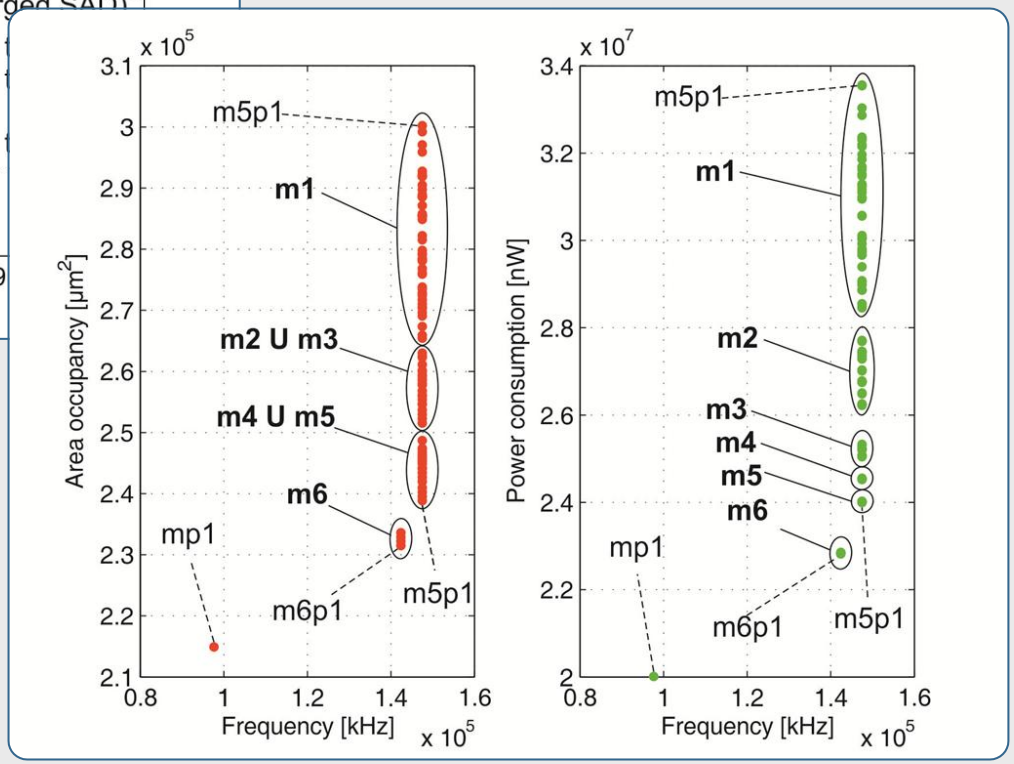
Design Subpace size:

1951 points

UC3 - Pareto analysis



UC3: Antialiasing & Zoom



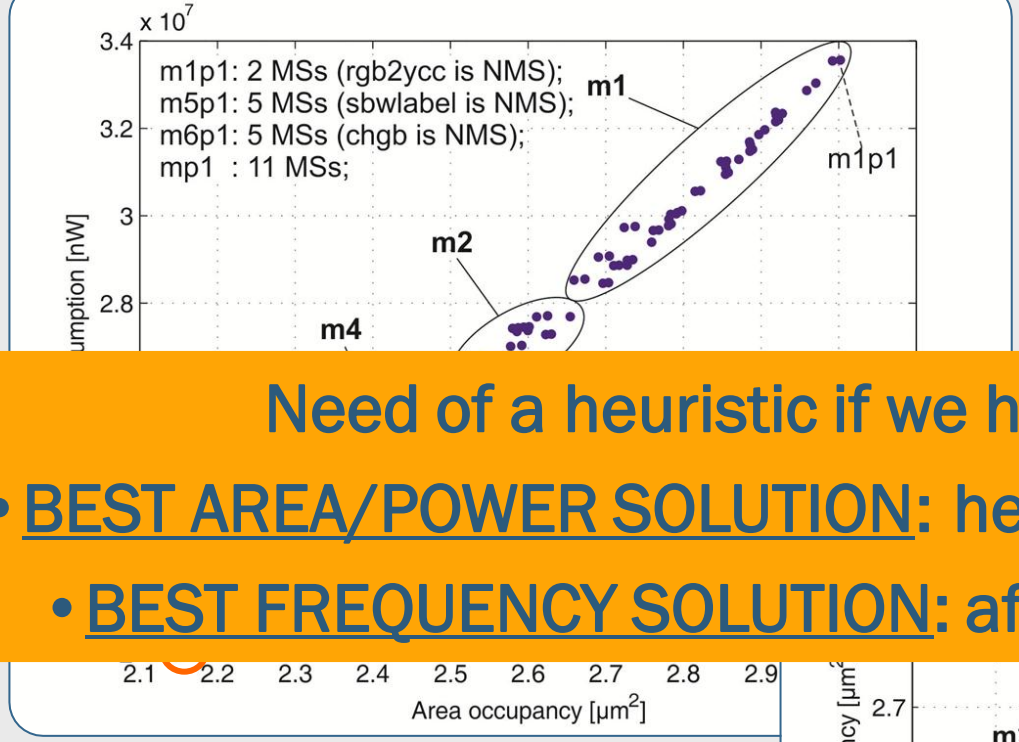
Involved SADs:

6 of 11

Design Subpace size:

1951 points

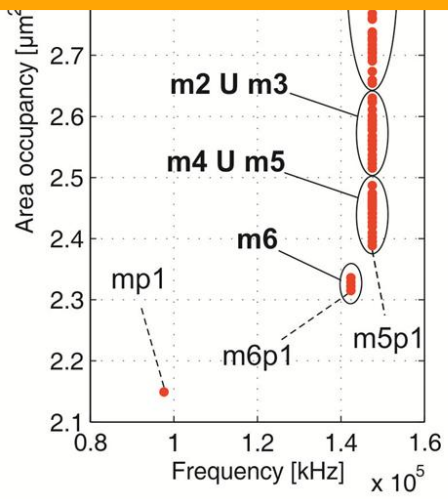
UC3 - Pareto analysis

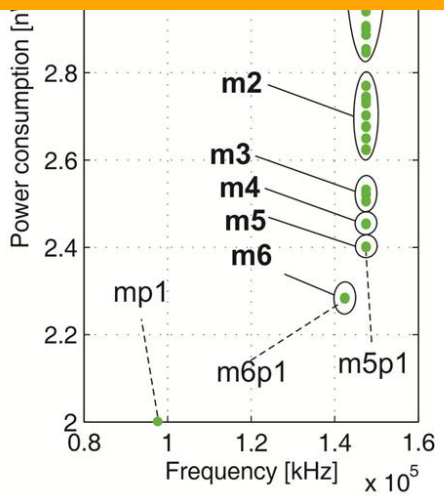


UC3: Antialiasing & Zoom

Need of a heuristic if we have many SADs

- **BEST AREA/POWER SOLUTION**: heuristic only on all merged
- **BEST FREQUENCY SOLUTION**: affine proposed heuristic





Involved SADs:

6 of 11

Design Subpace size:

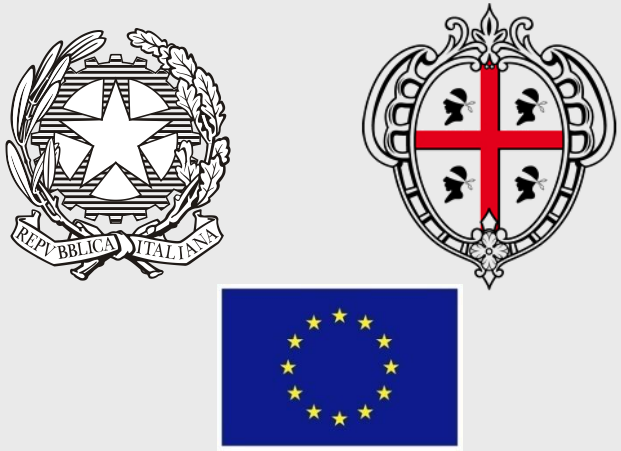
1951 points

Final Remarks

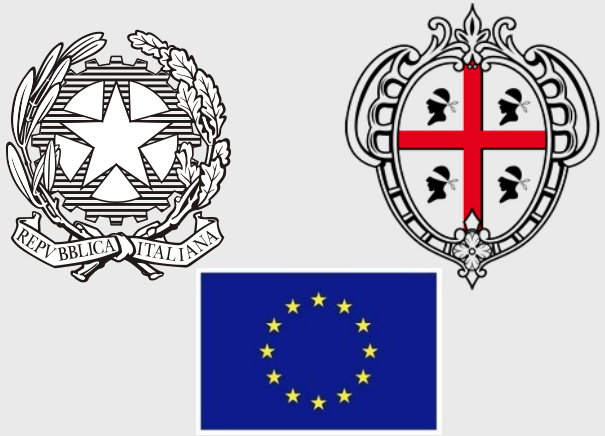
- A DSE and a profiling methodology specifically conceived to guide designers targeting multi-context architectures has been presented:
  - The DSE and profiling are performed at a high level of abstraction, but back annotated low-level information are considered.
- Synthesis trials confirmed the applicability of the proposed methodology with an estimation error lower (on average) than the 7%.
  - Accuracy can be improved adopting more accurate parameterized models to compute the metrics of interest.
- Future developments will regard
  - Accuracy improvement
  - Introduction of automated clever heuristics, based on high-level information, to limit the dimension of the design space.

Acknowledgements

The research leading to these results has received funding from:



the Region of Sardinia L.R.7/2007 under grant agreement CRP-18324 [RPCT Project]



the Region of Sardinia, Young Researchers Grant, POR Sardegna FSE 2007-2013, L.R.7/2007 “Promotion of the scientific research and technological innovation in Sardinia” under grant agreement CRP-18324 RPCT Project

8th International Symposium on Image and Signal Processing and Analysis - 2013
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IEEE Signal Processing Society

September 4th-6th, 2013,
Trieste, Italy

EURASIP

DSE and Profiling of Multi-Context Coarse-Grained Reconfigurable Systems

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