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UNIVERSITAT POLITÈCNICA DE CATALUNYA

ALOE Framework and Tools

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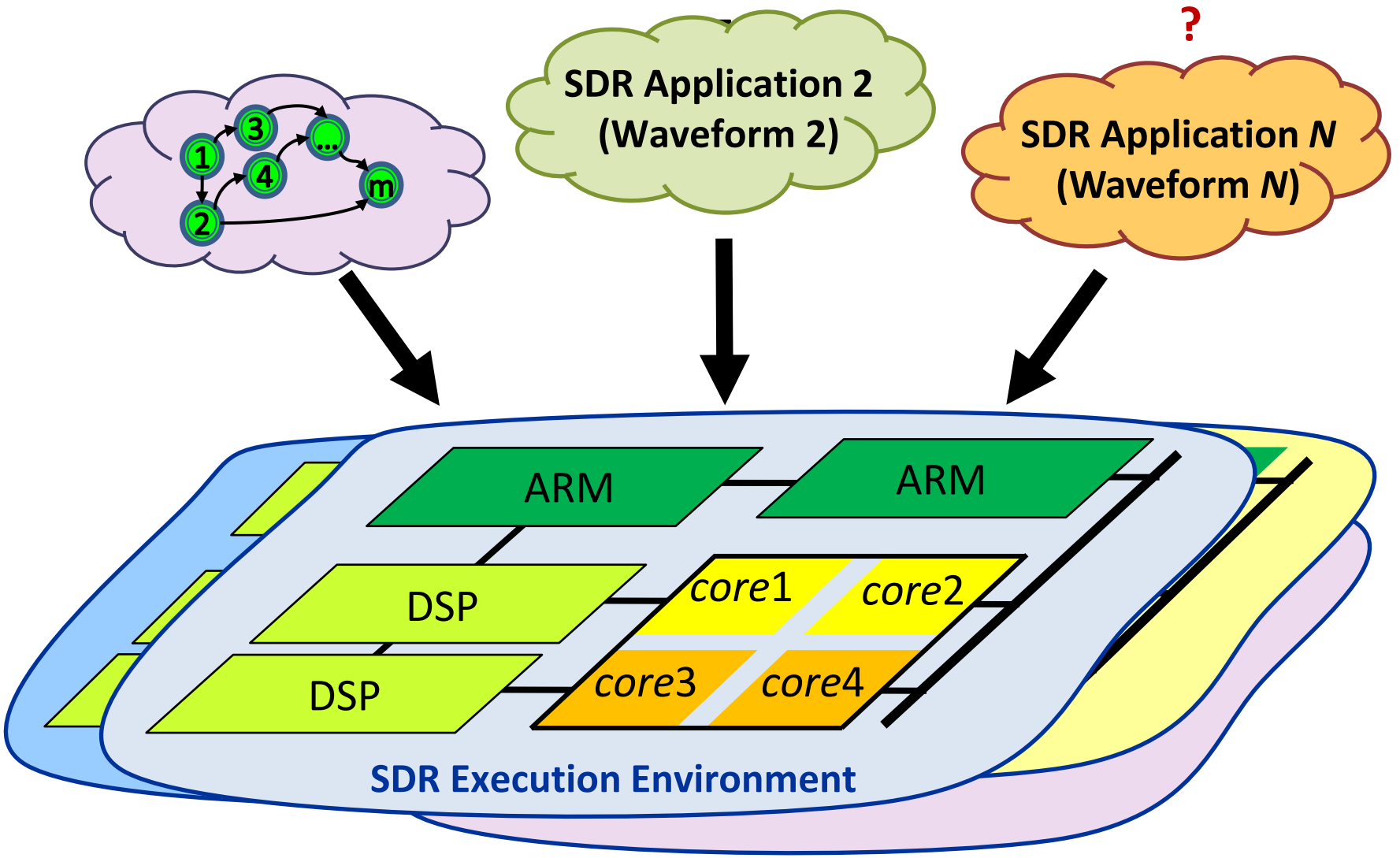

1
2
3
4
...
m
SDR Application 2
(Waveform 2)
?
SDR Application N
(Waveform N)
ARM
ARM
DSP
DSP
core1
core2
core3
core4
SDR Execution Environment

Flexible
Low Overhead

Pipelined Execution
+
Online Mapping

Simplified Scheduling

Flexible Multiprocessing

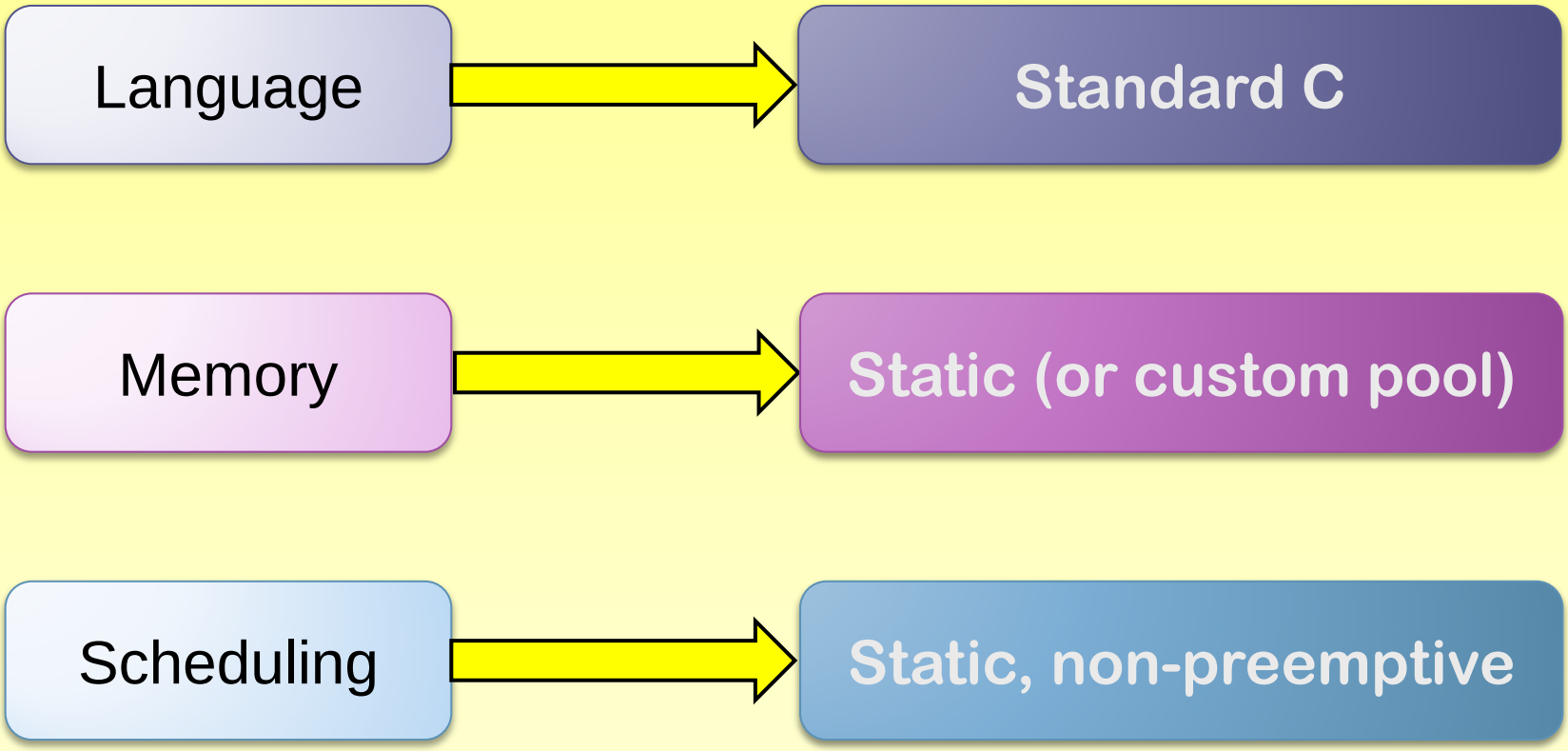
ALOE

Outline

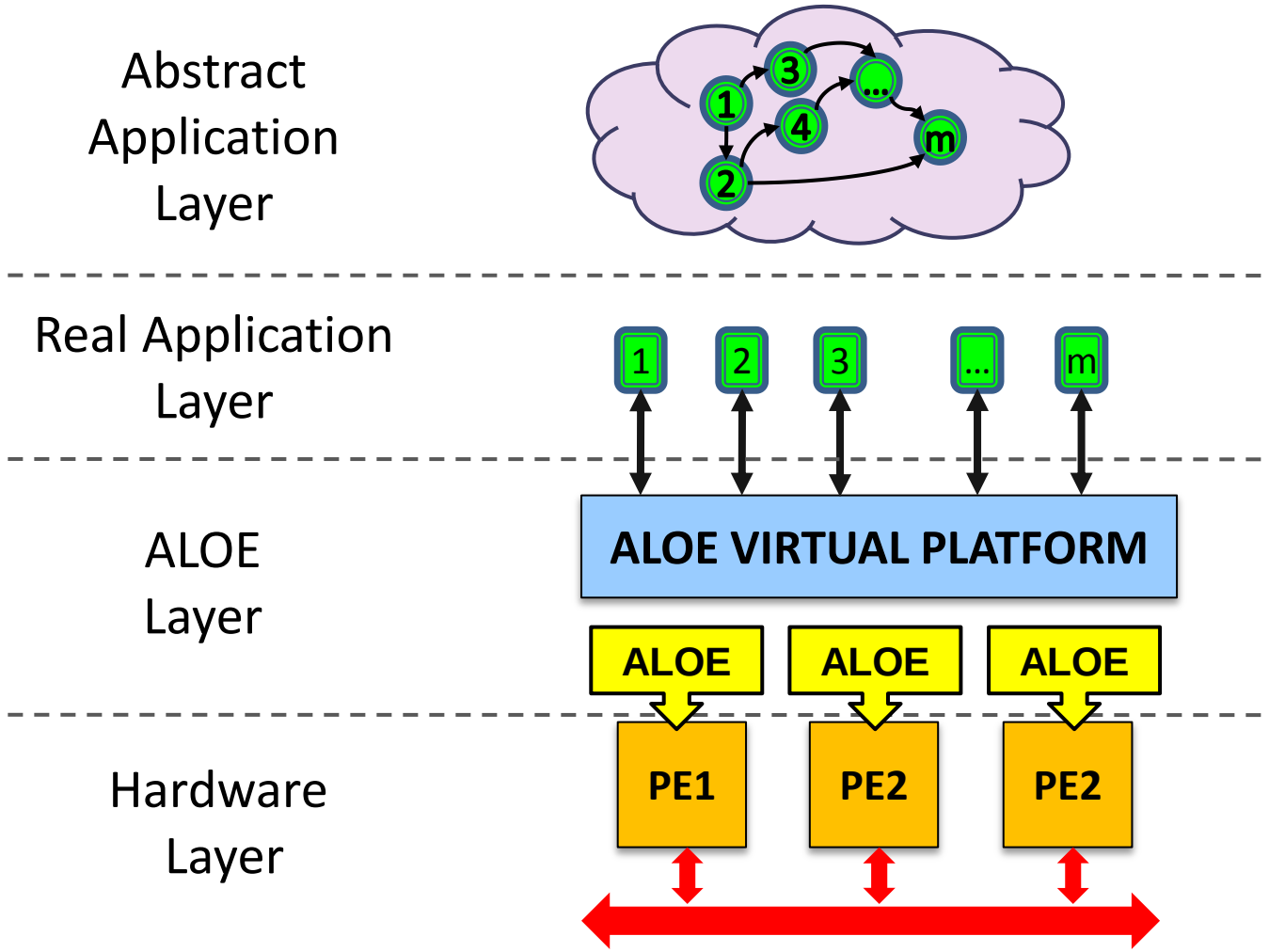
1. ALOE Framework
2. Computing Resource Management
3. ALOE Tools
4. Waveform Development
5. Summary

1.1 Lightweight Framework

- How to design a low-overhead framework?

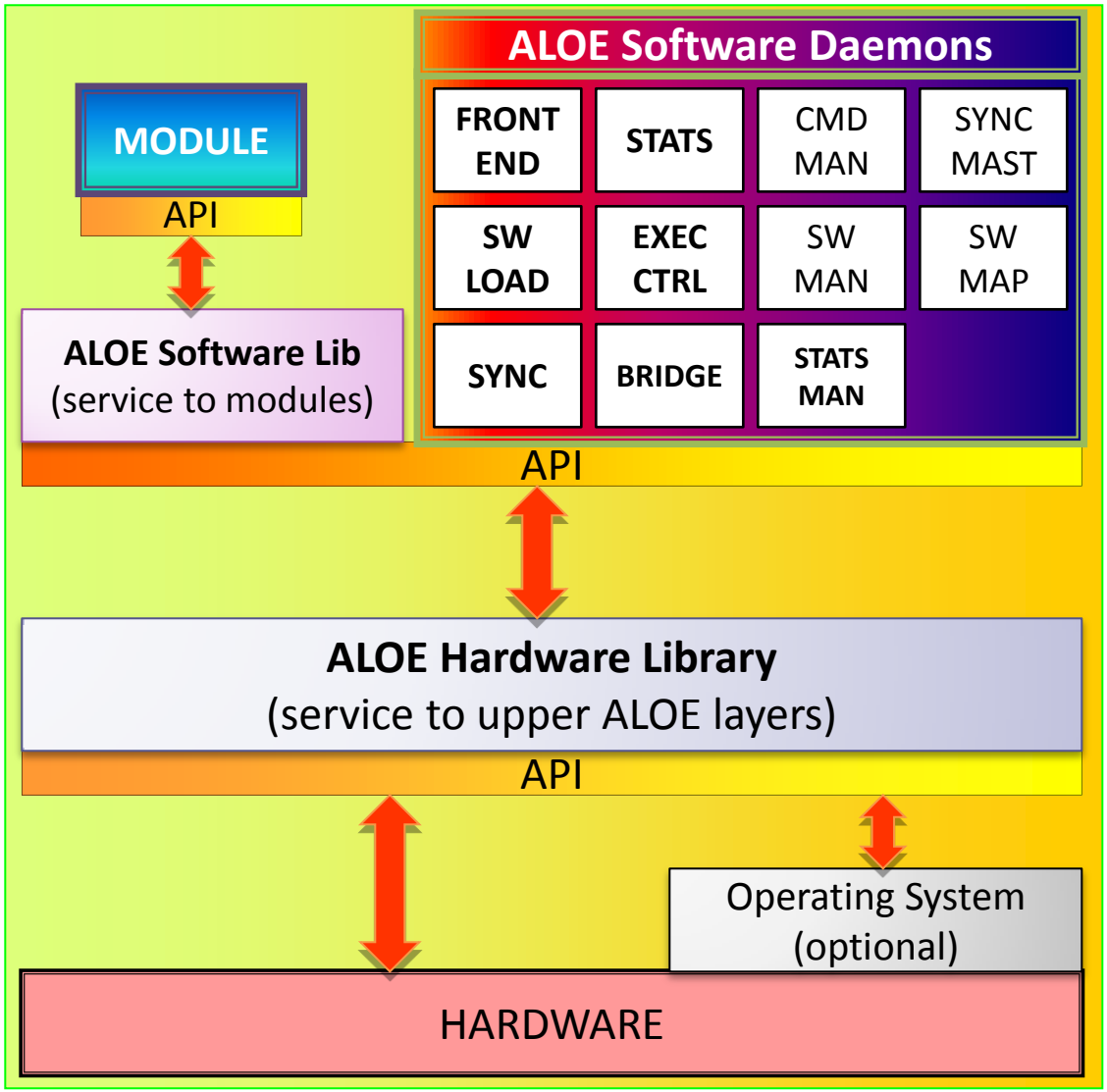


1.2 ALOE Layers



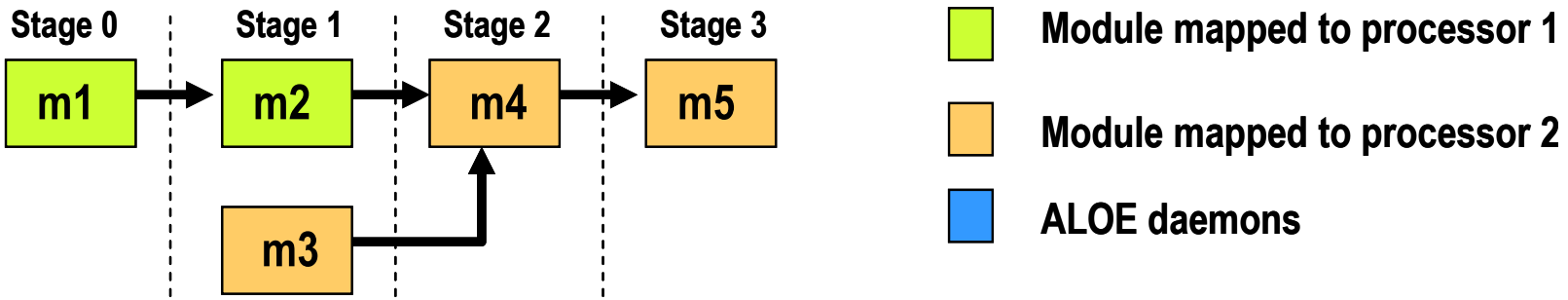
PE: Processing Element

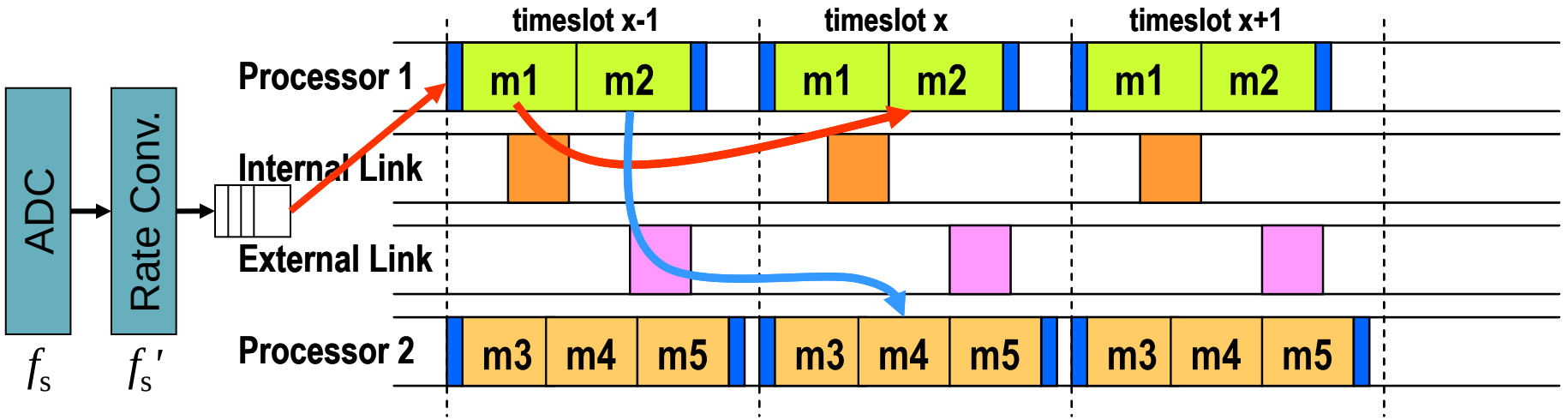
1.3 ALOE Architecture



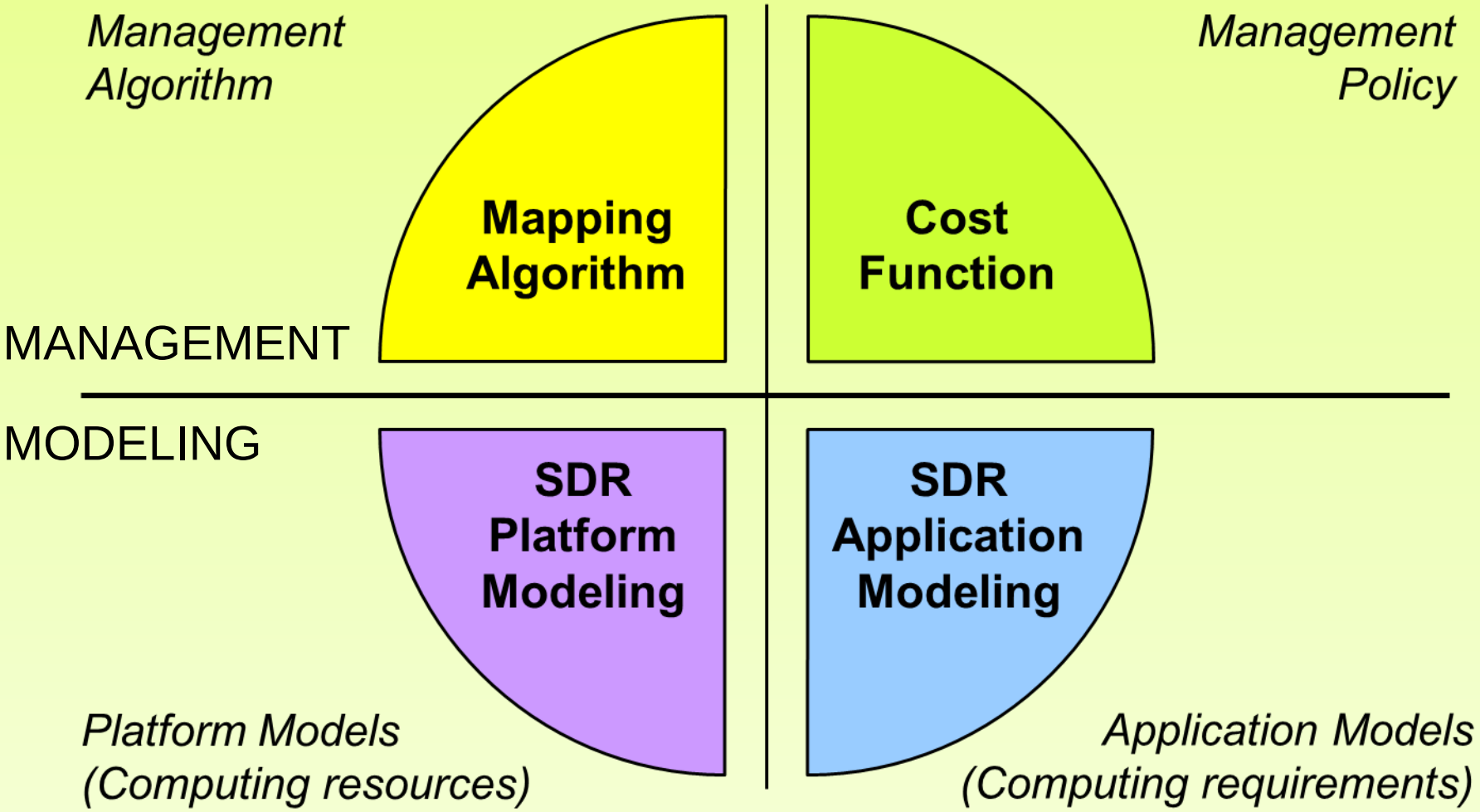
1.4 ALOE Time Management

- **Time slots** synchronized to ADC/DAC
- Relaxed **synchronization**
- Cooperative, static **scheduling**
- Deterministic **latency**





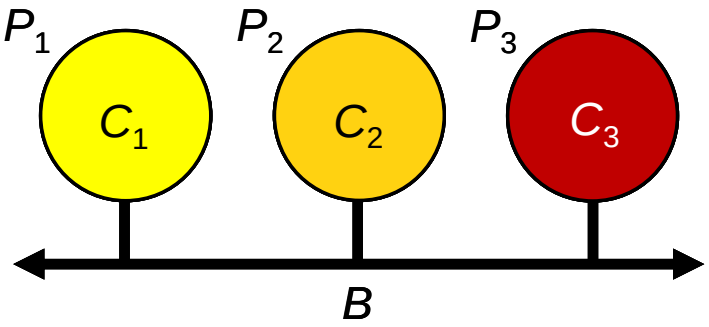
2. Computing Resource Management



2.1 SDR Platform Modeling

- Processing resources and requirements
- Inter-processor bandwidth resources and requirements

Example: SDR Platform Model



$$\boldsymbol{C} = (C_1, C_2, C_3)\ \text{MOPTS}$$

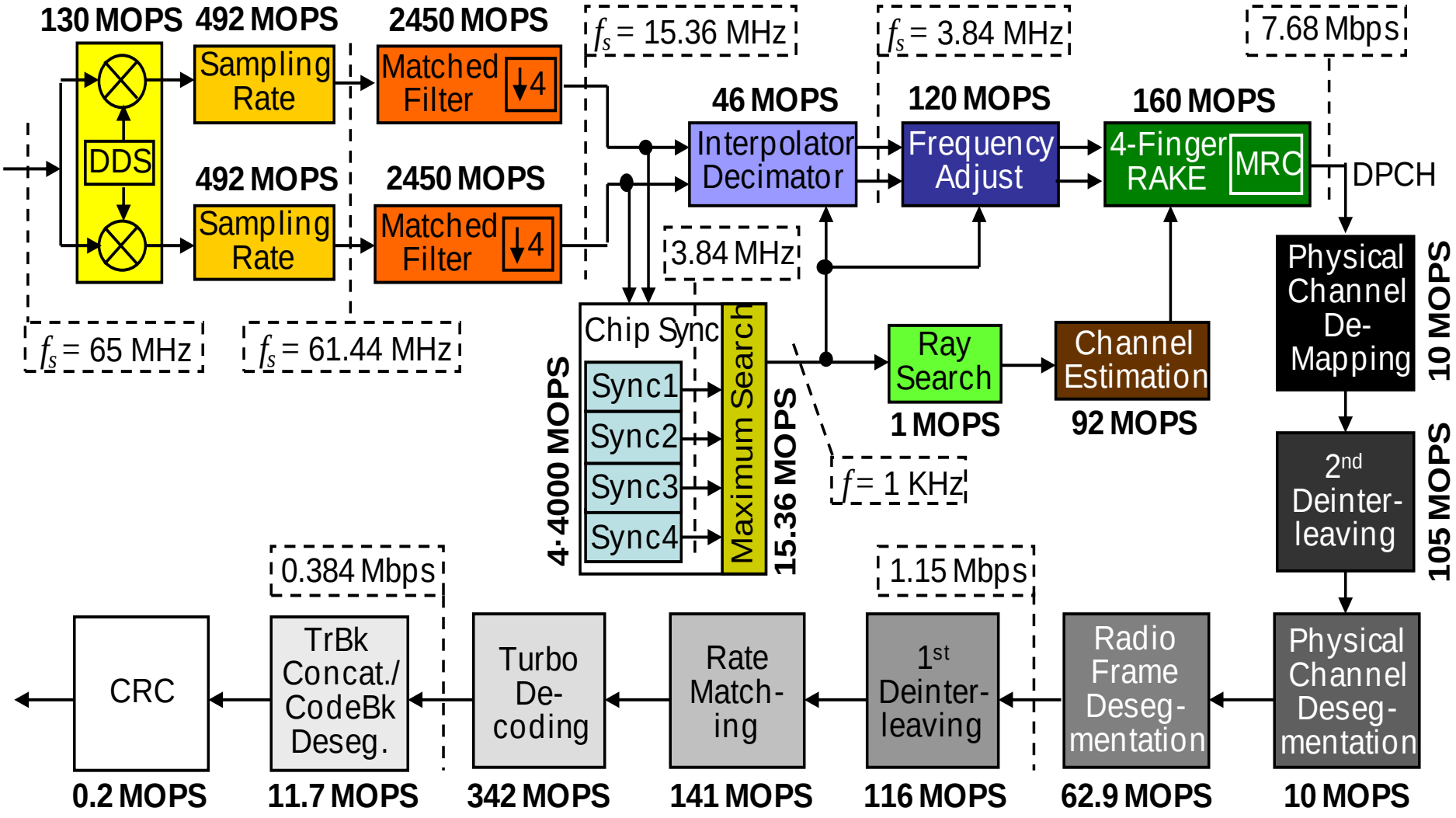
$$\boldsymbol{B} = \begin{pmatrix} \infty & B & B \\ B & \infty & B \\ B & B & \infty \end{pmatrix}\ \text{MBPTS}$$

MOPTS	Million operations per time slot
MBPTS	Mega-bits per time slot

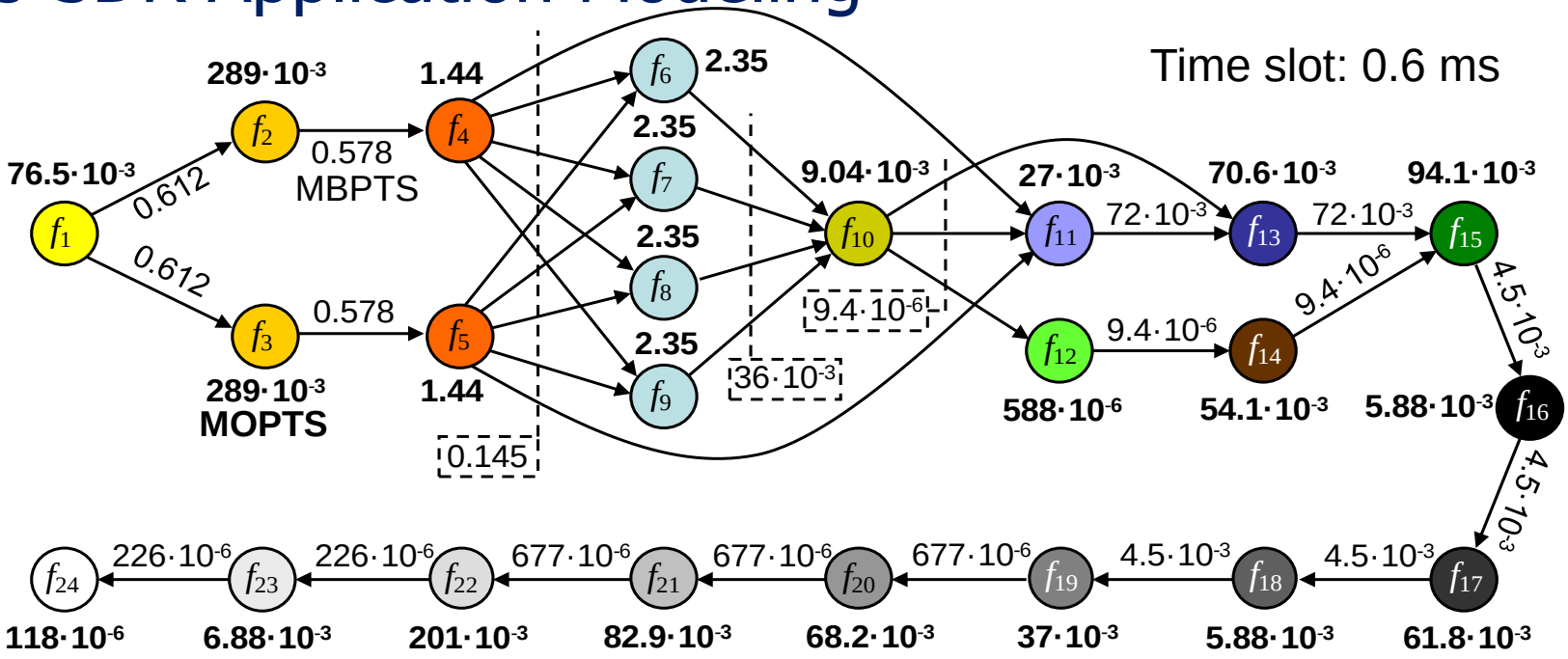
processor-internal bandwidths

- Abstraction layers provide computing resources & requirements in above units
- Availability of software modules for each processor type

2.2 Waveform: UMTS Downlink Receiver



2.3 SDR Application Modeling



(a)

Function model: $\boldsymbol{c}$ = (0.076, 0.289, 0.289, 1.44, 1.44, 2.35, 2.35, …) MOPTS c_T = 13.675 MOPTS

Dataflow model:

$$\boldsymbol{b} = \begin{pmatrix} 0 & 0.612 & 0.612 & 0 & 0 & 0 & \cdots \\ 0 & 0 & 0 & 0.578 & 0 & 0 & \cdots \\ 0 & 0 & 0 & 0 & 0.578 & 0 & \cdots \\ 0 & 0 & 0 & 0 & 0 & 0.145 & \cdots \\ 0 & 0 & 0 & 0 & 0 & 0.145 & \cdots \\ 0 & 0 & 0 & 0 & 0 & 0 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix} \text{ MBPTS} \qquad con = 0.12$$

Stage model: $\boldsymbol{s}$ = (1, 2, 2, 3, 3, 4, 4, 4, 4, 5, 6, 6, 7, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17)

2.4 The t_w-mapping & Cost Function

- Dynamic programming
- Parameter *w* controls algorithm complexity
- Cost function independent
  - control different resources
  - define different optimization goals

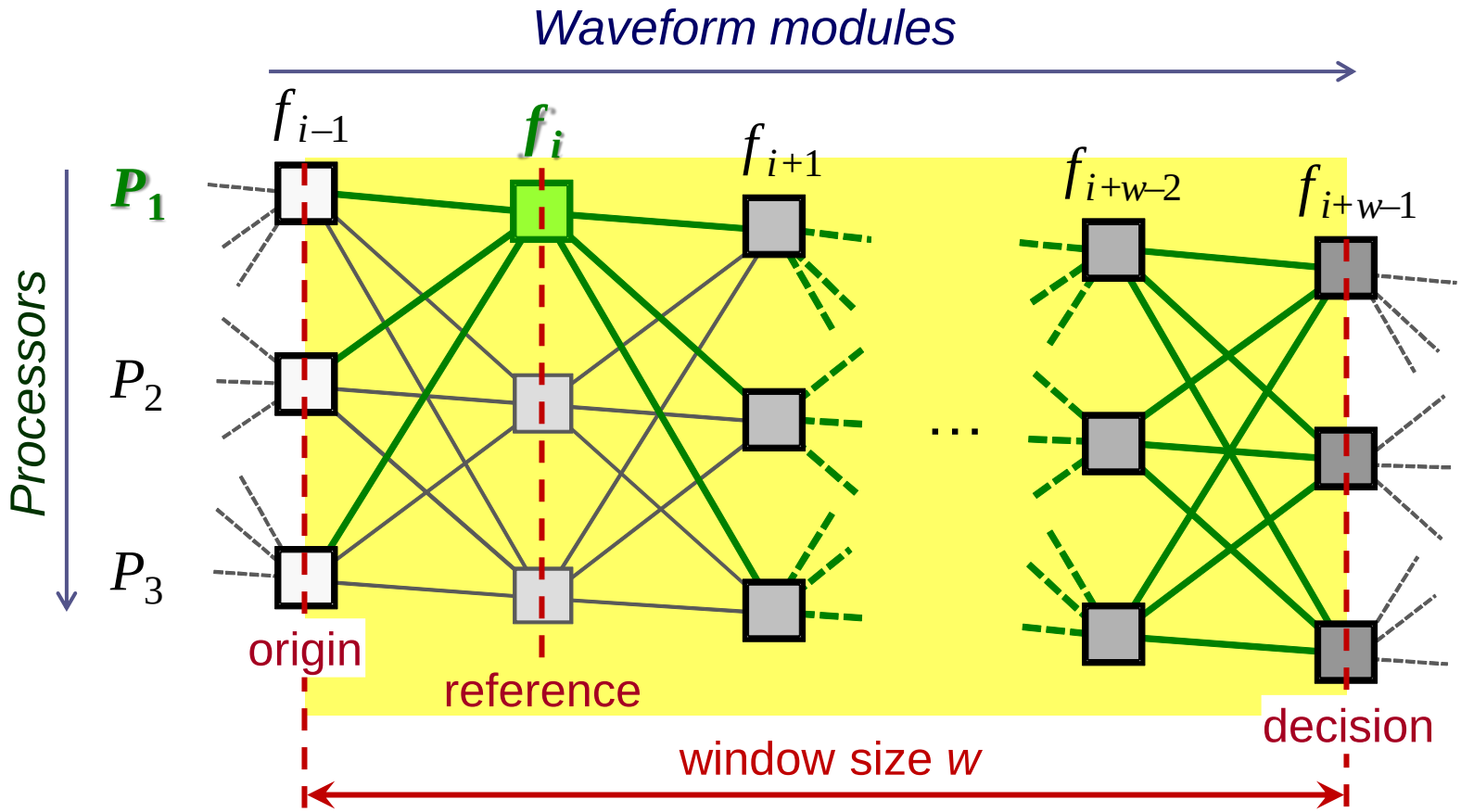
Two-term cost function:

$$\text{Cost} = \frac{\text{processing requirement}}{\text{available processing power}} + \frac{\text{bandwidth requirement}}{\text{available bandwidth}}$$

balance processing load *minimize data flows*

V. Marojevic, “Computing Resource Management in Software-Defined and Cognitive Radios,” doctoral dissertation, Dept. Signal Theory and Communications, UPC, 2009.

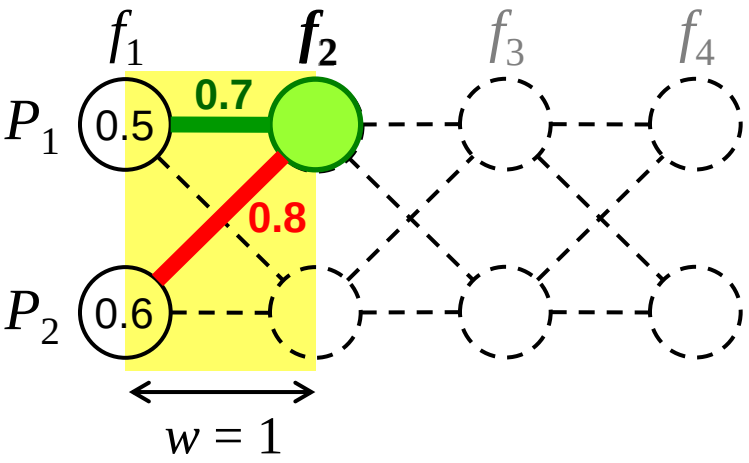
2.4 The t_w-mapping & Cost Function



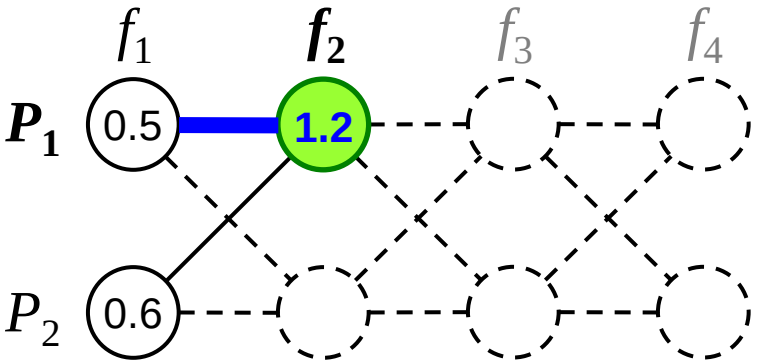
$\{P_1, f_i\}$ represents the mapping of waveform component f_i to processor P_1

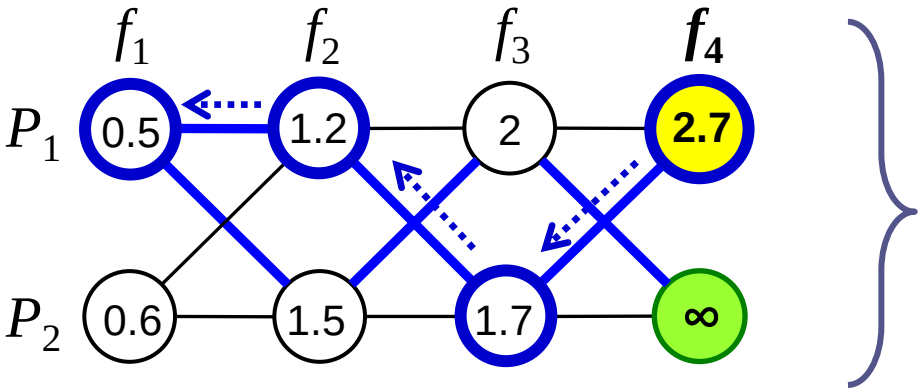
2.4 The t_w-mapping & Cost Function

Path costs



Decision





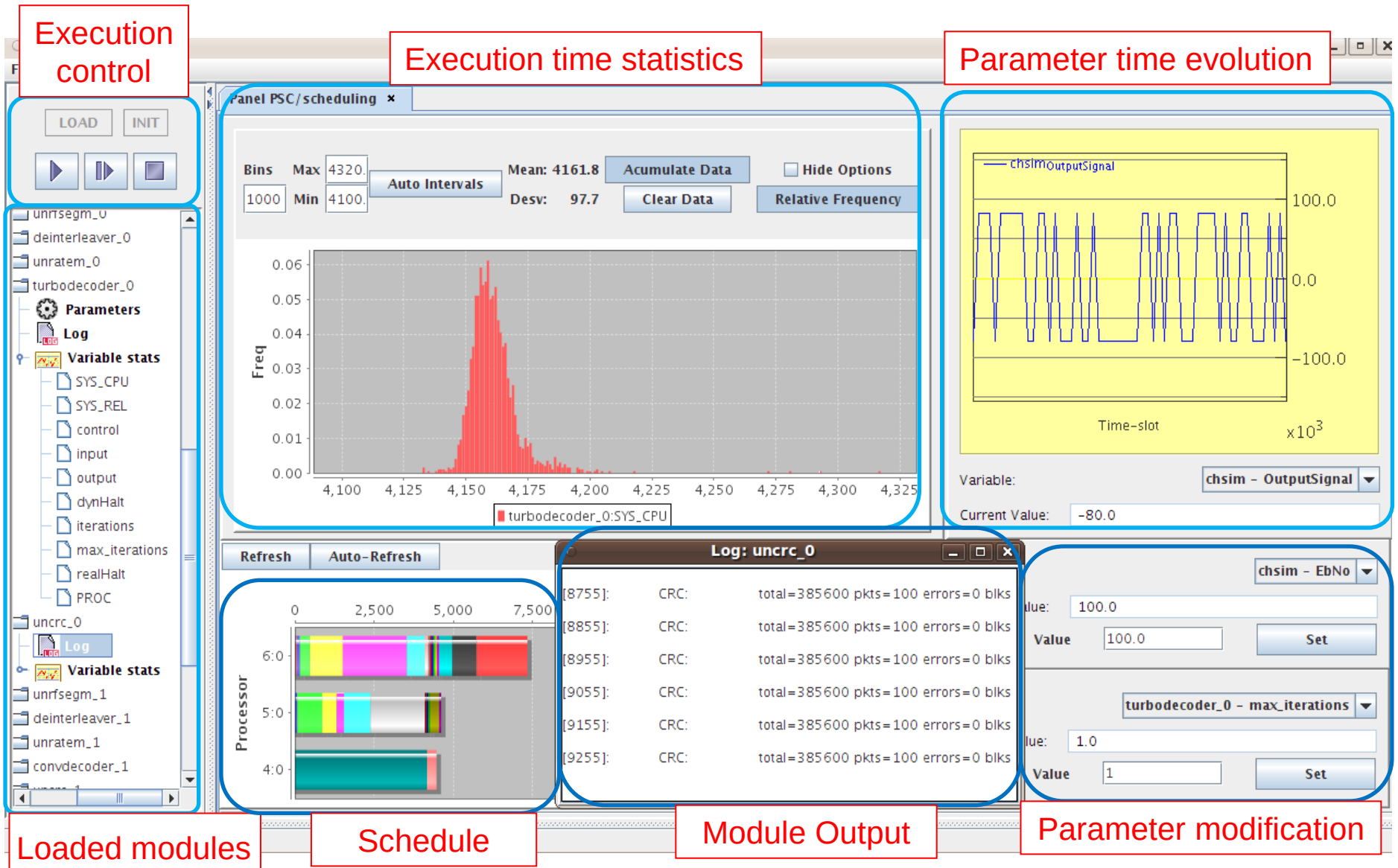
$f_1, f_2, f_4 \rightarrow P_1$

$f_3 \rightarrow P_2$

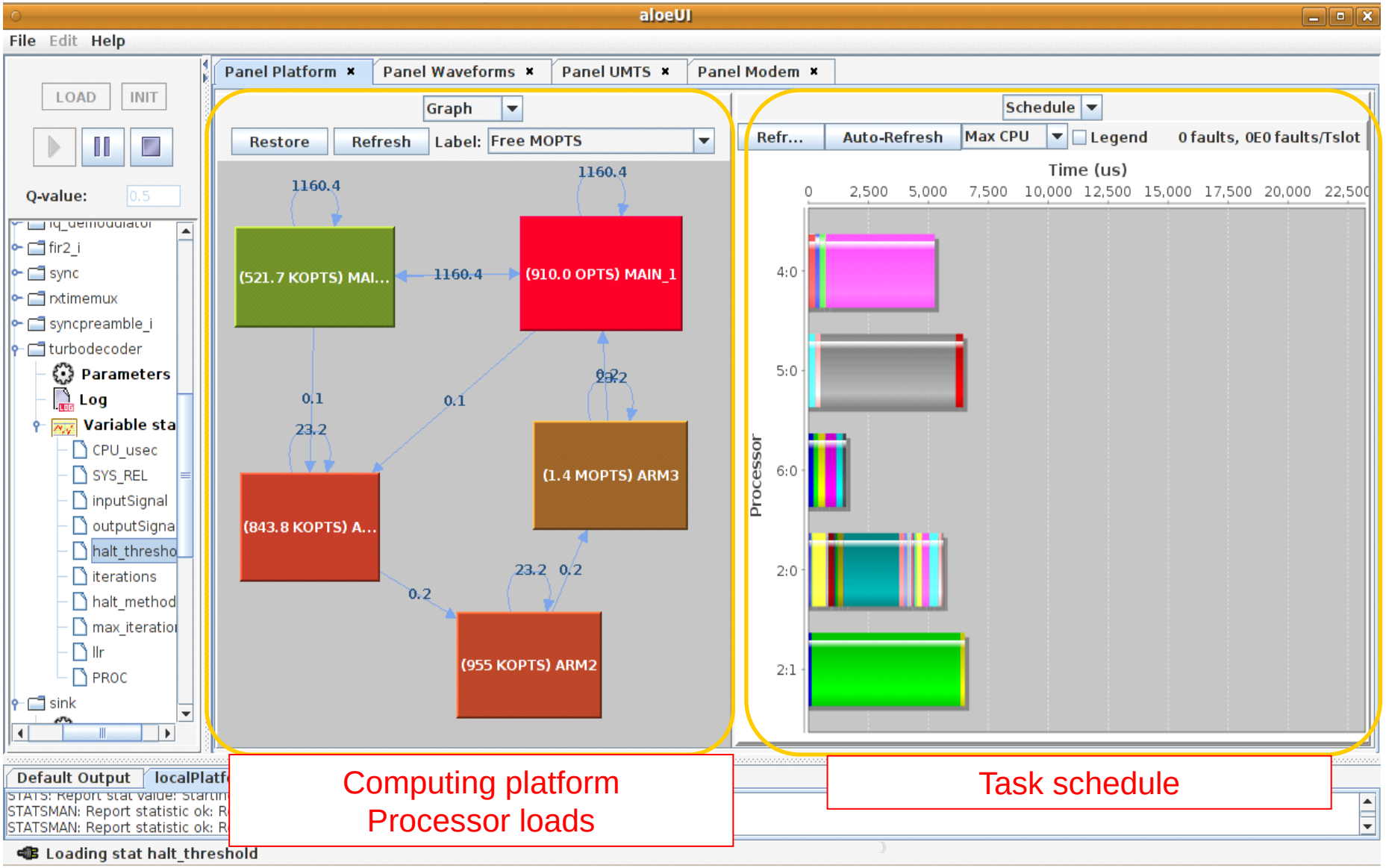
3. ALOE Tools

- Development and Debugging Tools
  - ALOE lab sessions
  - Source code templates
  - Automatic code generation tools (Simulink Target)
  - Graphical user interface

3.1 Graphical User Interface (I)



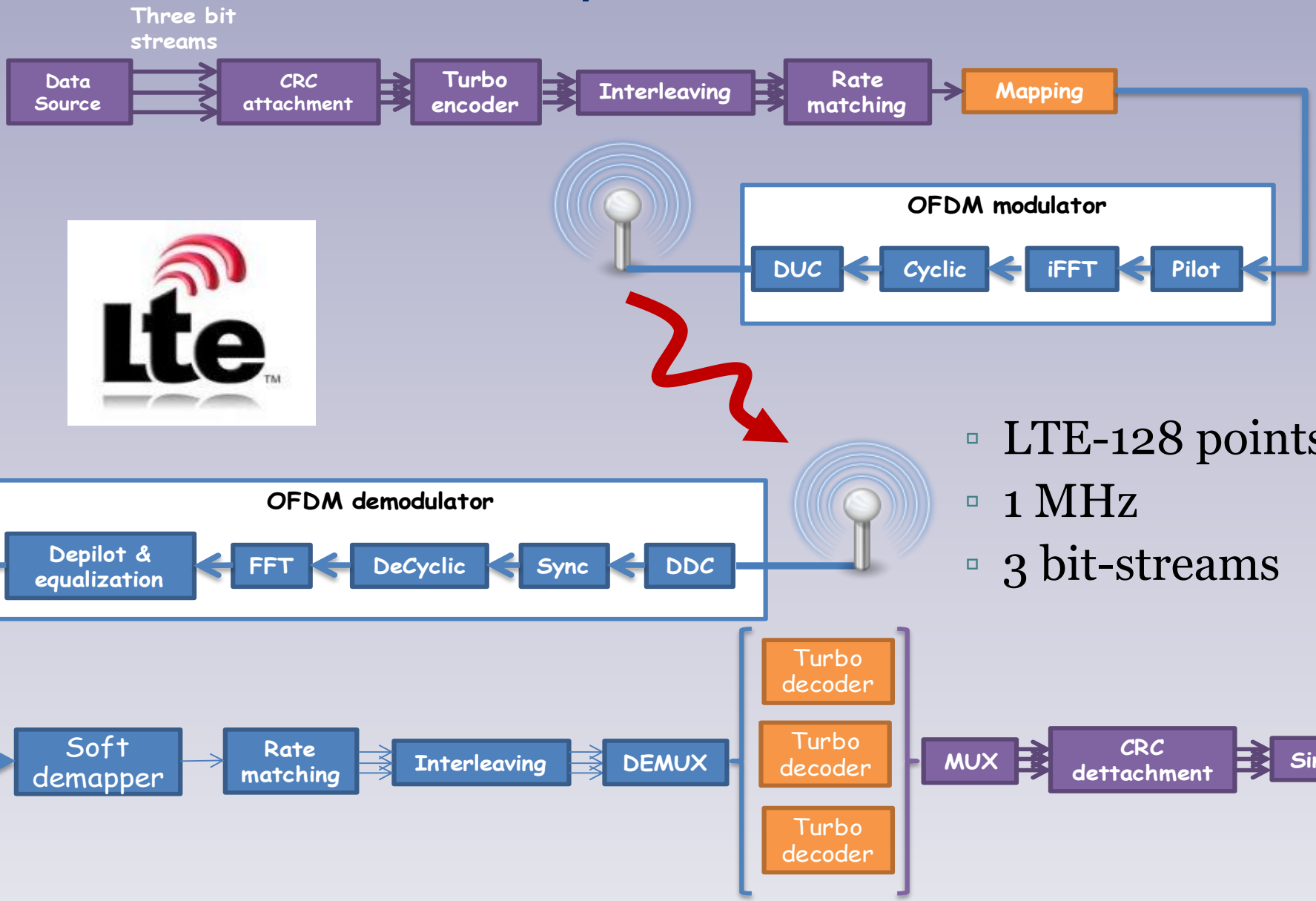
3.1 Graphical User Interface (II)



Computing platform
Processor loads

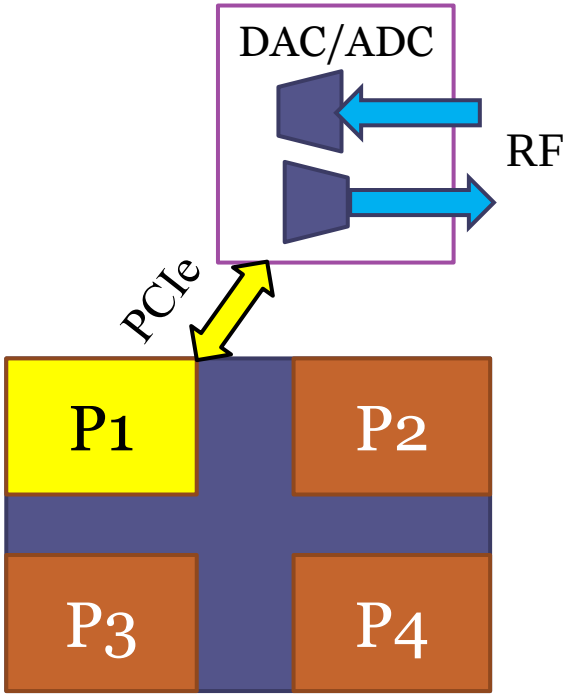
Task schedule

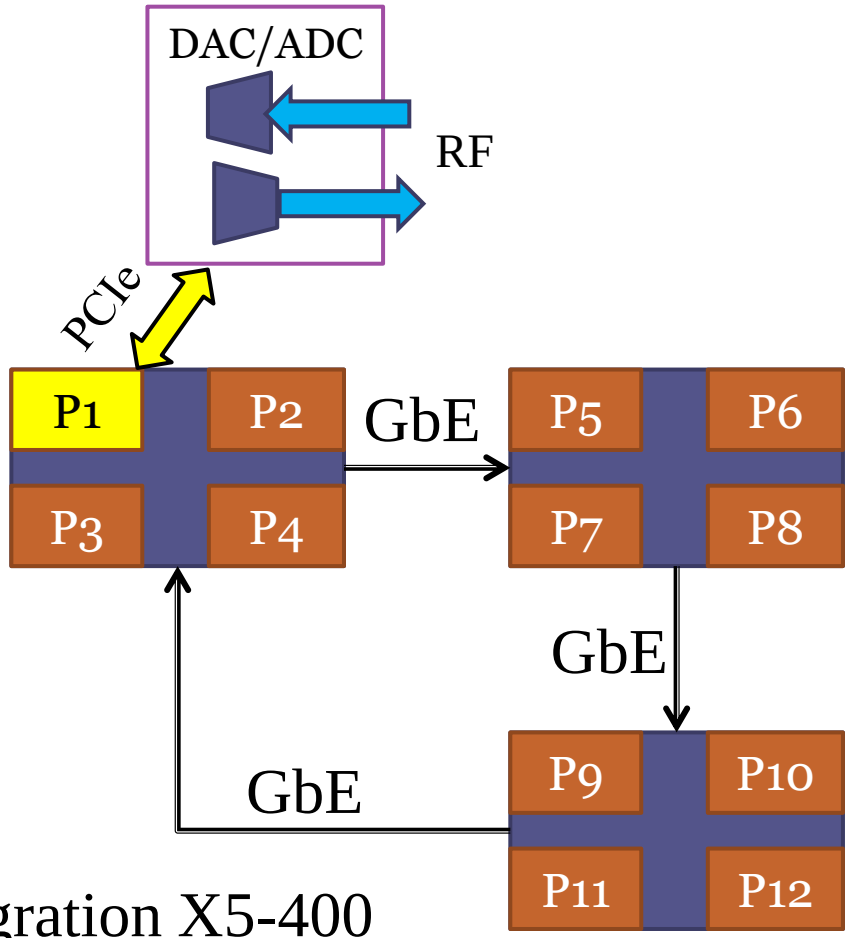
4. Waveform Development



- LTE-128 points.
- 1 MHz
- 3 bit-streams

4.1 Processing Platforms

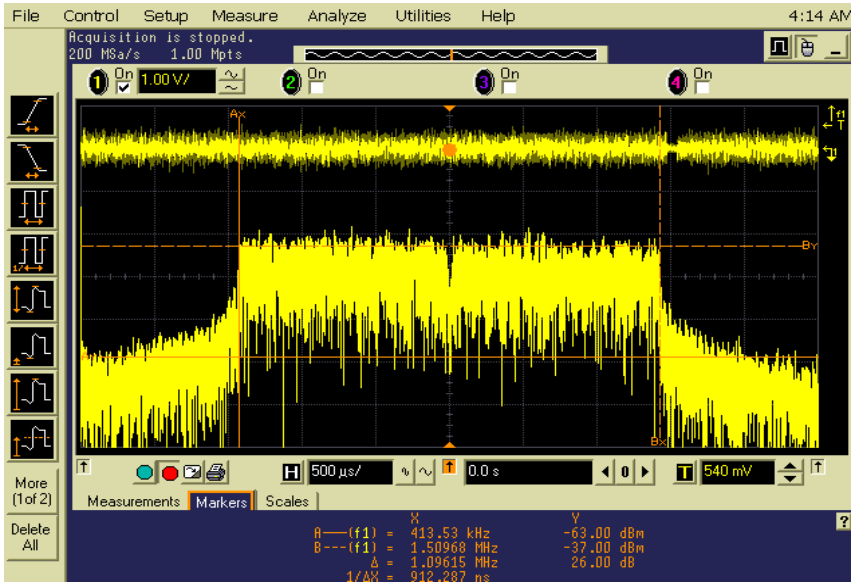




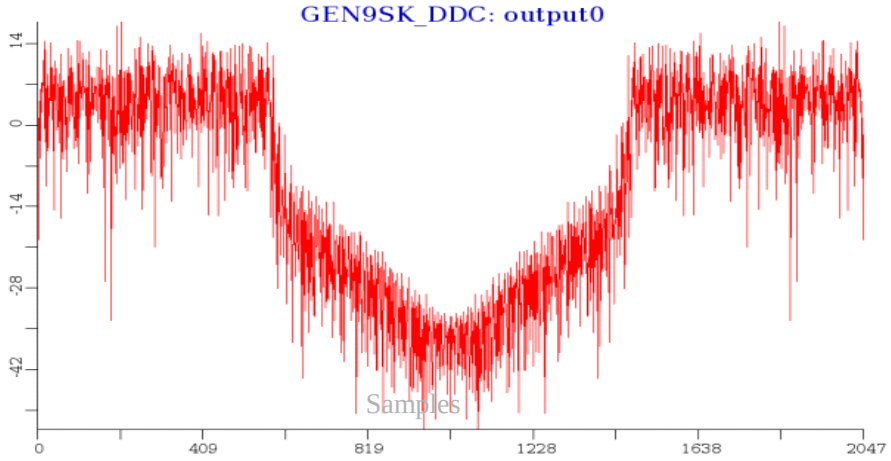
i7 Quad-Core, 2,6 GHz
ADC/DAC board: Innovative Integration X5-400
Sampling Rate: 61,44 MHz
Time-slot: 2 ms. E2E-latency: 40 ms.

4.2 Signal Captures

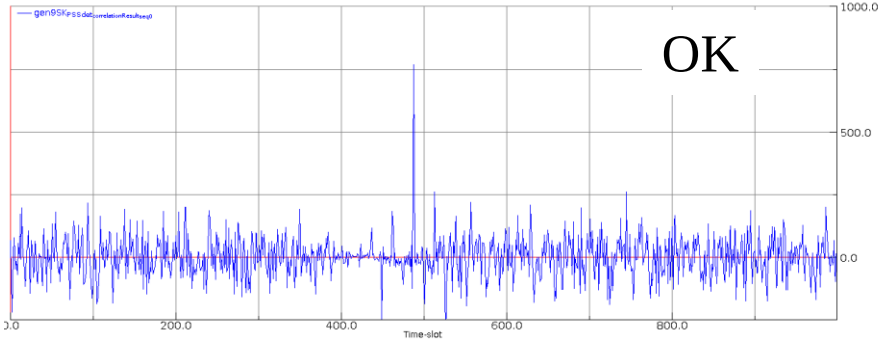
DA output (time and frequency domain)

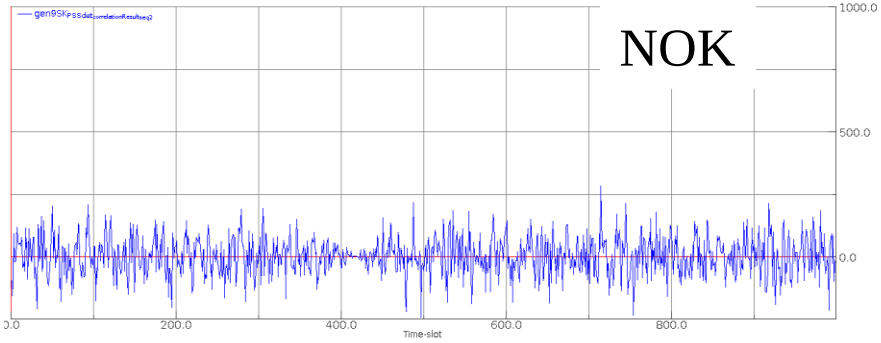


DDC output



Sync module output:
Correlation with Zhou sequence





5. Summary

ALOE Project

- Open source framework for SDR
- Non-commercial research version
- Tested:
  - GPPs under Linux (x86 and ARM7)
  - DSPs under RTOS-BIOS (TMS C64xx)
  - UMTS bit-level, LTE (1 MHz)
- Documentation and downloads at http://flexnets.upc.edu/