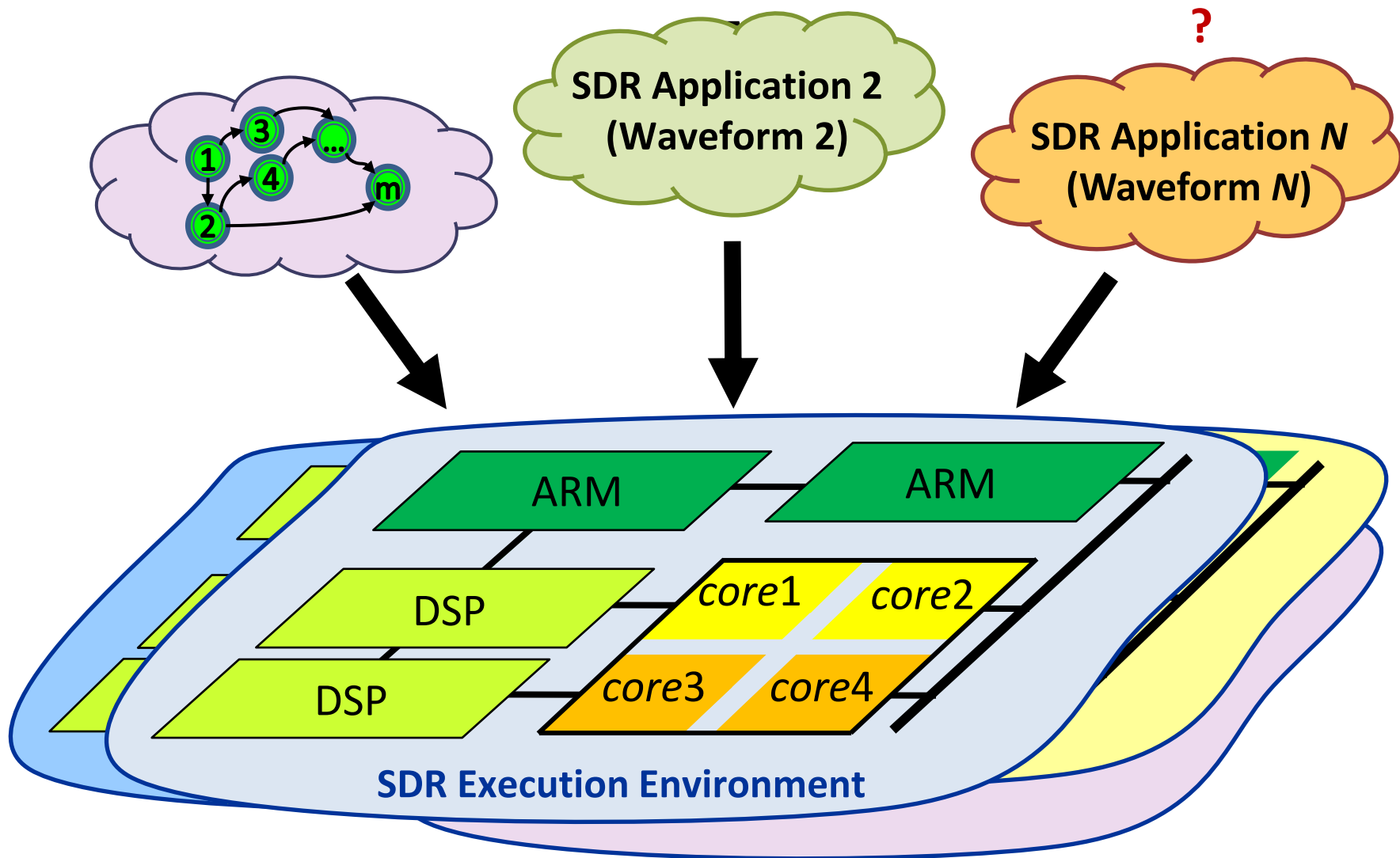


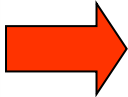


# ALOE Framework and Tools

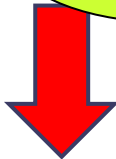
Vuk Marojevic  
Ismael Gomez  
Antoni Gelonch



**Flexible  
Low Overhead**



**Pipelined Execution  
+  
Online Mapping**



**Simplified  
Scheduling**

**Flexible  
Multiprocessing**



**ALOE**

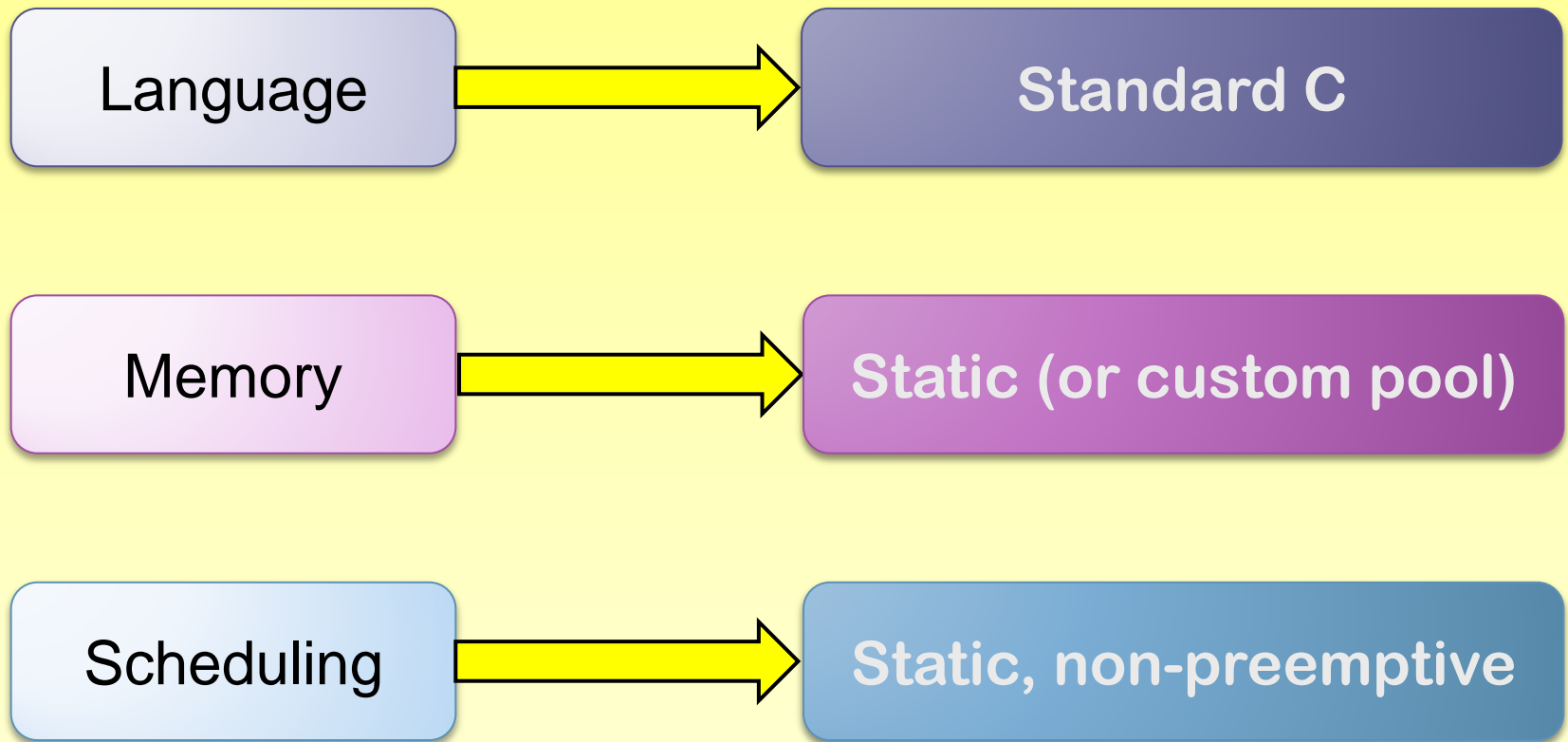


# Outline

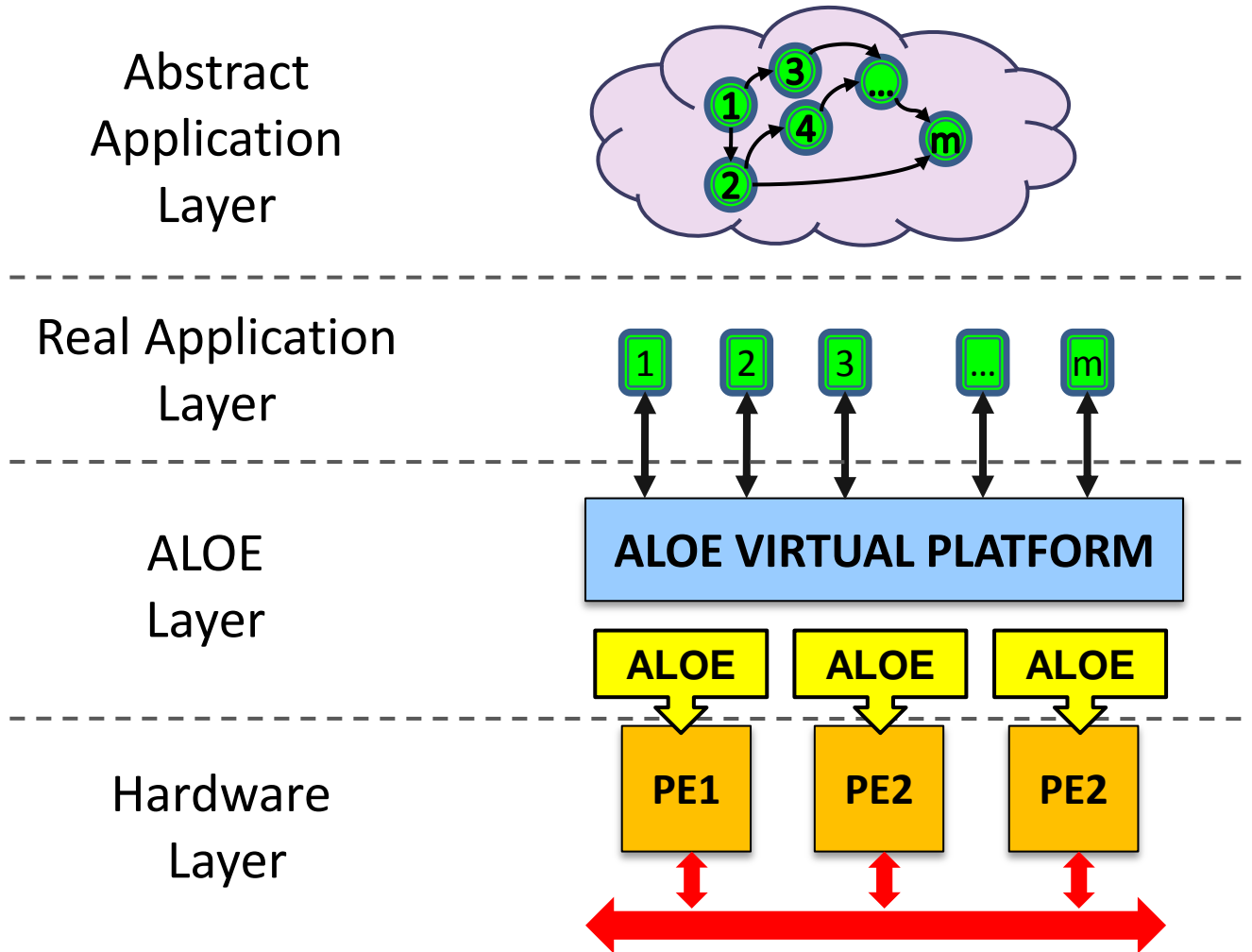
1. ALOE Framework
2. Computing Resource Management
3. ALOE Tools
4. Waveform Development
5. Summary

# 1.1 Lightweight Framework

- How to design a low-overhead framework?

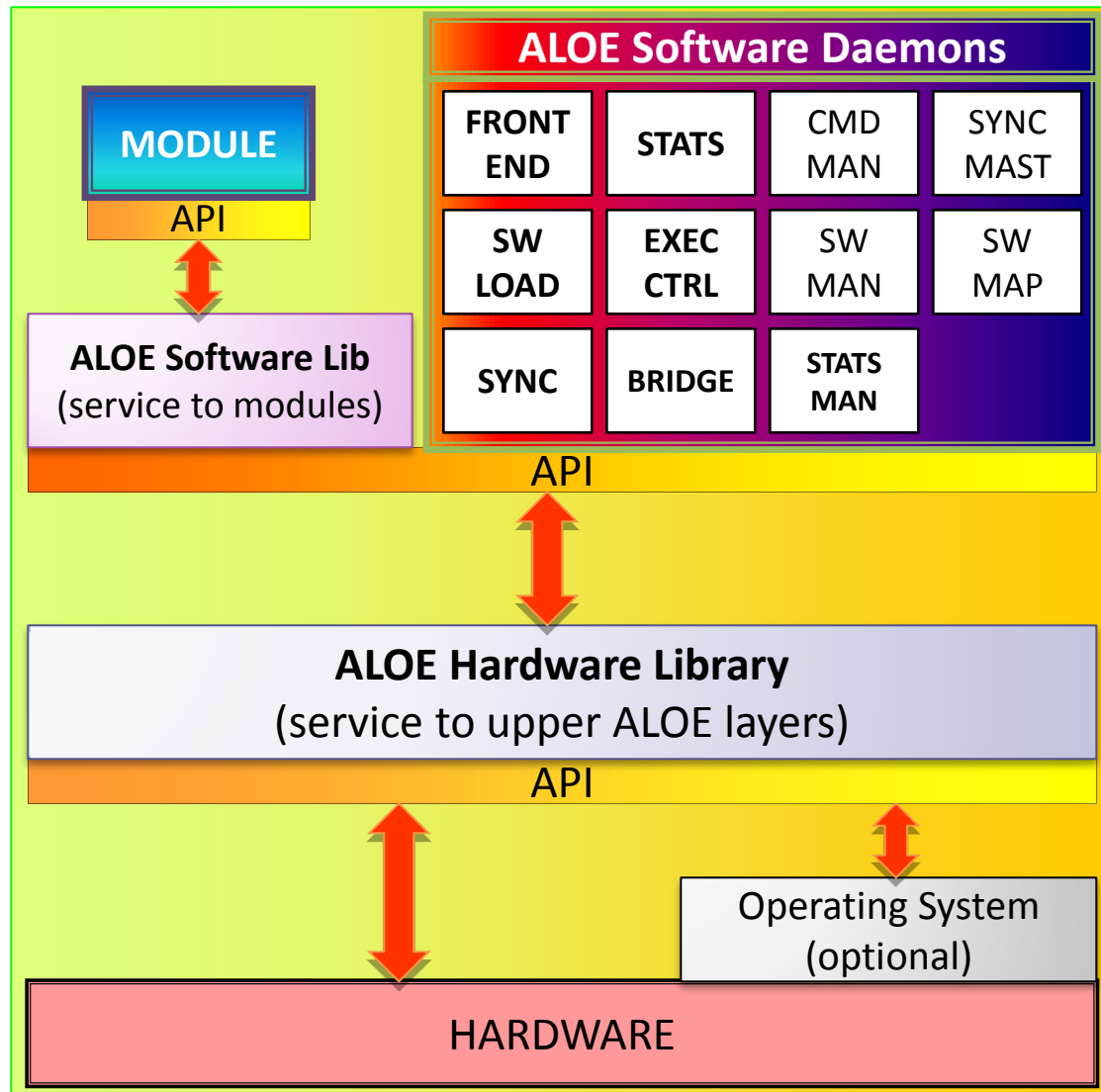


## 1.2 ALOE Layers



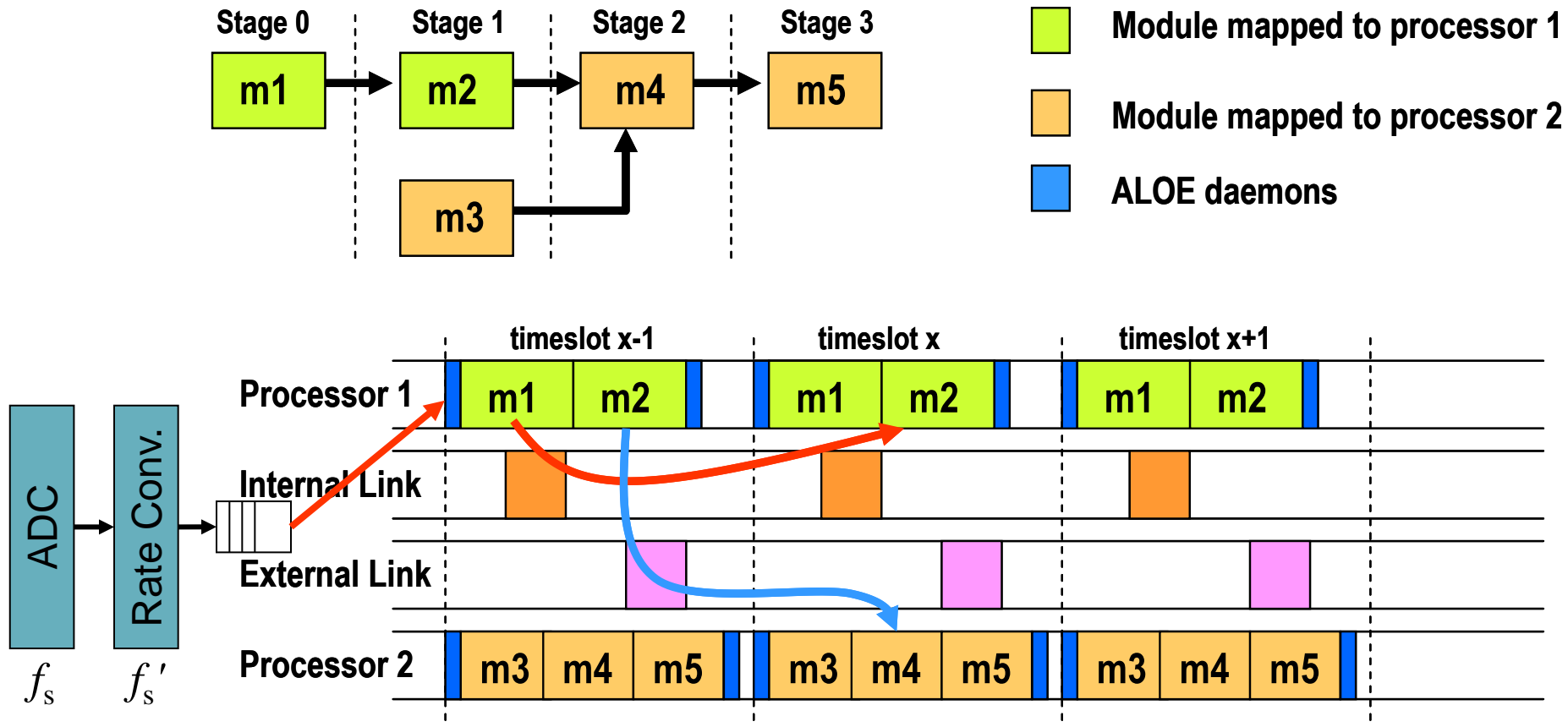
PE: Processing Element

# 1.3 ALOE Architecture



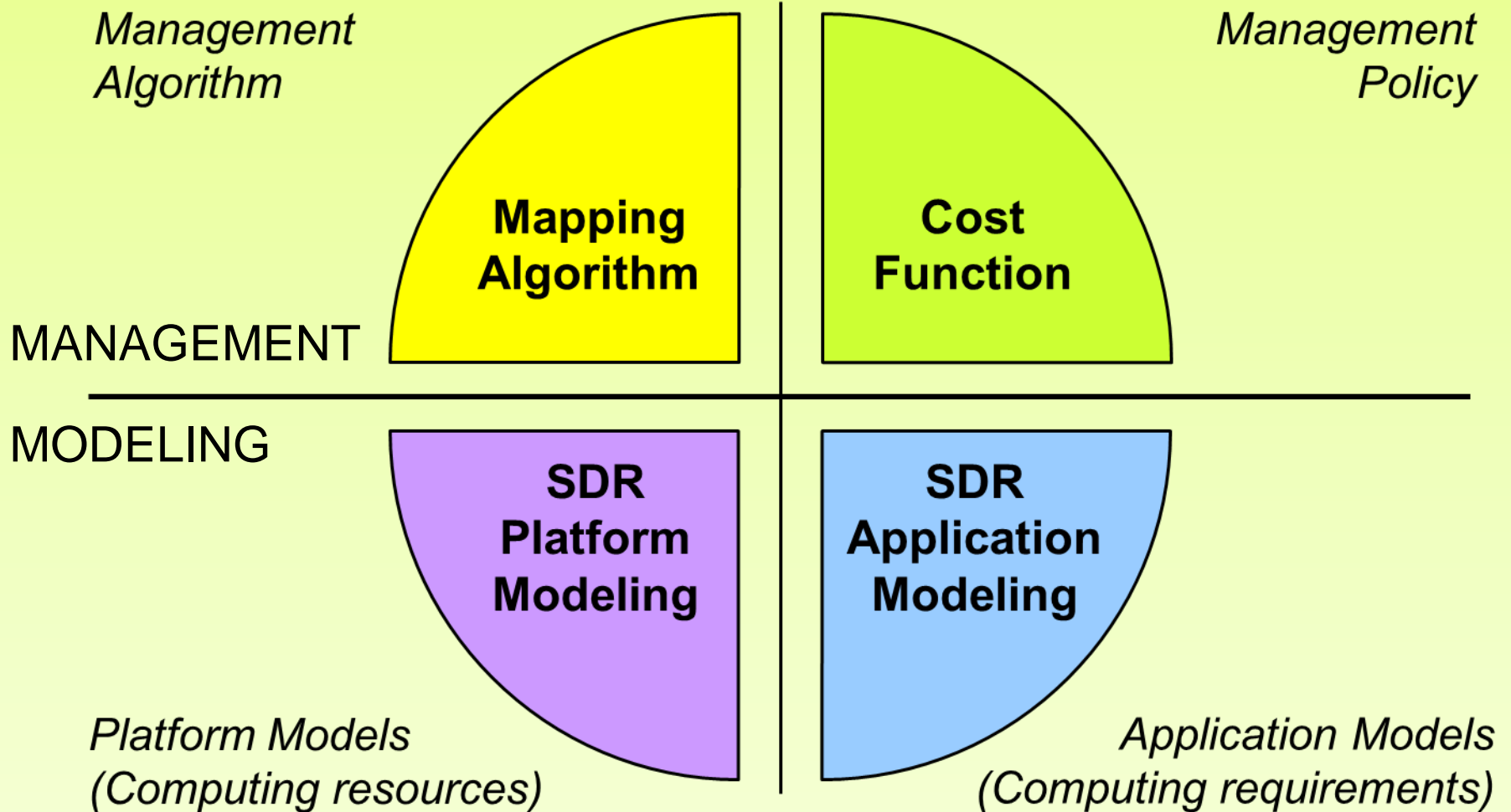
# 1.4 ALOE Time Management

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





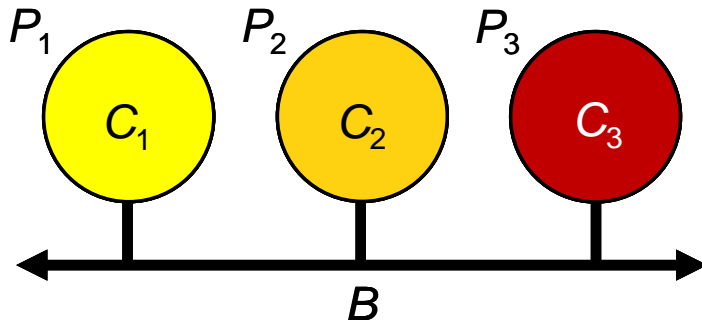
## 2. Computing Resource Management



## 2.1 SDR Platform Modeling

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

### Example: SDR Platform Model



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

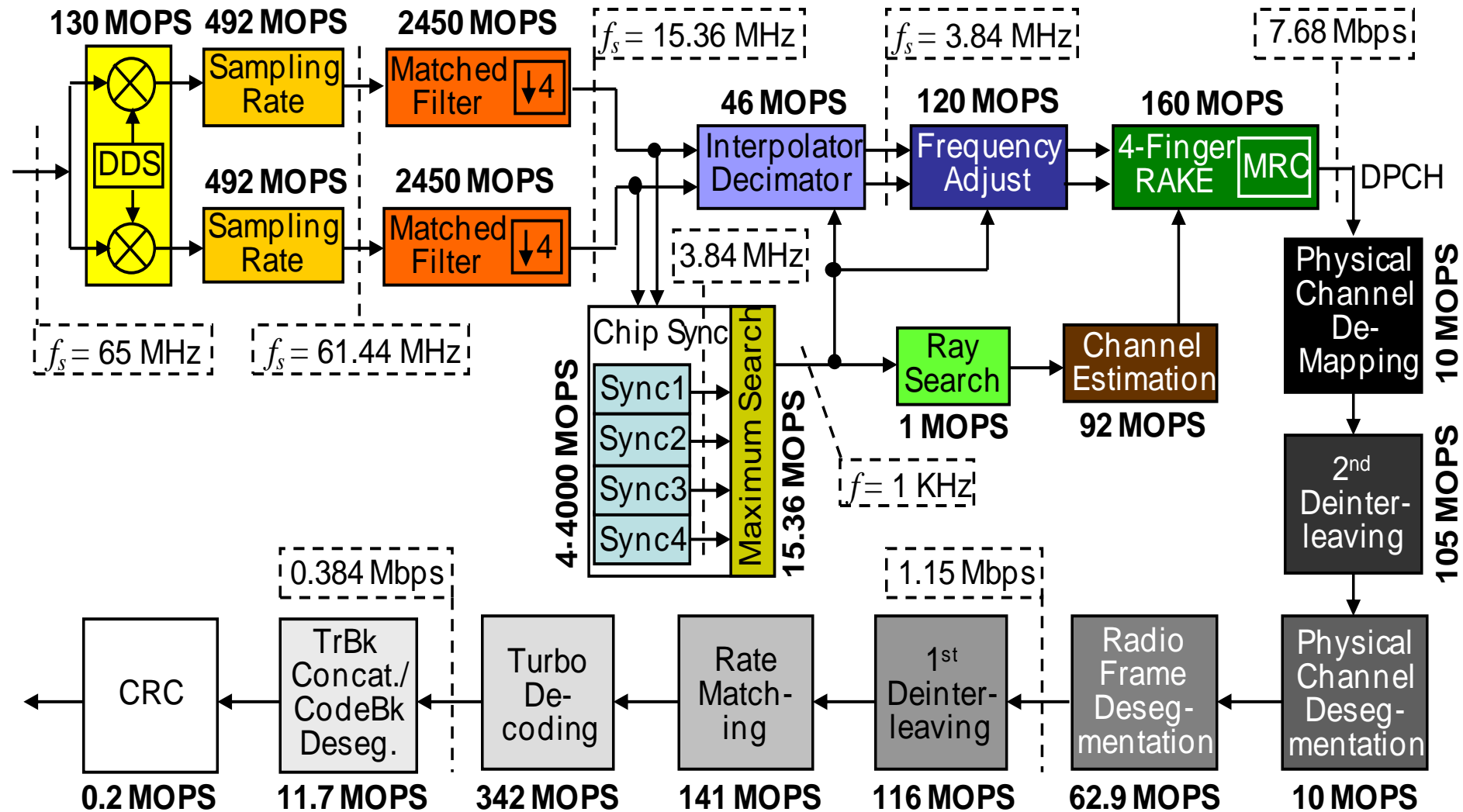
$$C = (C_1, C_2, C_3) \text{ MOPTS}$$

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

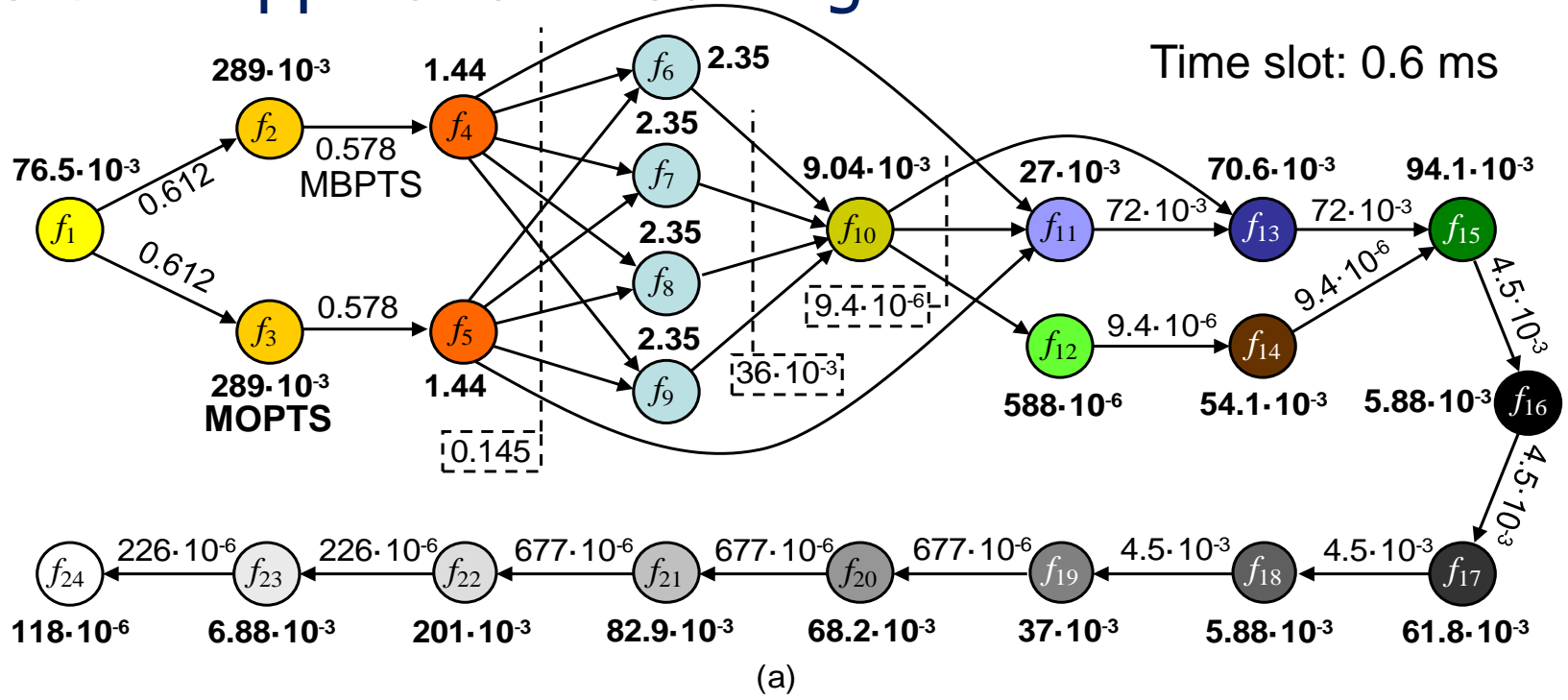
processor-internal bandwidths

- 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



Function model:  $c = (0.076, 0.289, 0.289, 1.44, 1.44, 2.35, 2.35, \dots)$  MOPTS  $c_T = 13.675$  MOPTS

Dataflow model:  $b = \begin{pmatrix} 0 & 0.612 & 0.612 & 0 & 0 & 0 & \dots \\ 0 & 0 & 0 & 0.578 & 0 & 0 & \dots \\ 0 & 0 & 0 & 0 & 0.578 & 0 & \dots \\ 0 & 0 & 0 & 0 & 0 & 0.145 & \dots \\ 0 & 0 & 0 & 0 & 0 & 0.145 & \dots \\ 0 & 0 & 0 & 0 & 0 & 0 & \dots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix}$  MBPTS  $con = 0.12$

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

## 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:

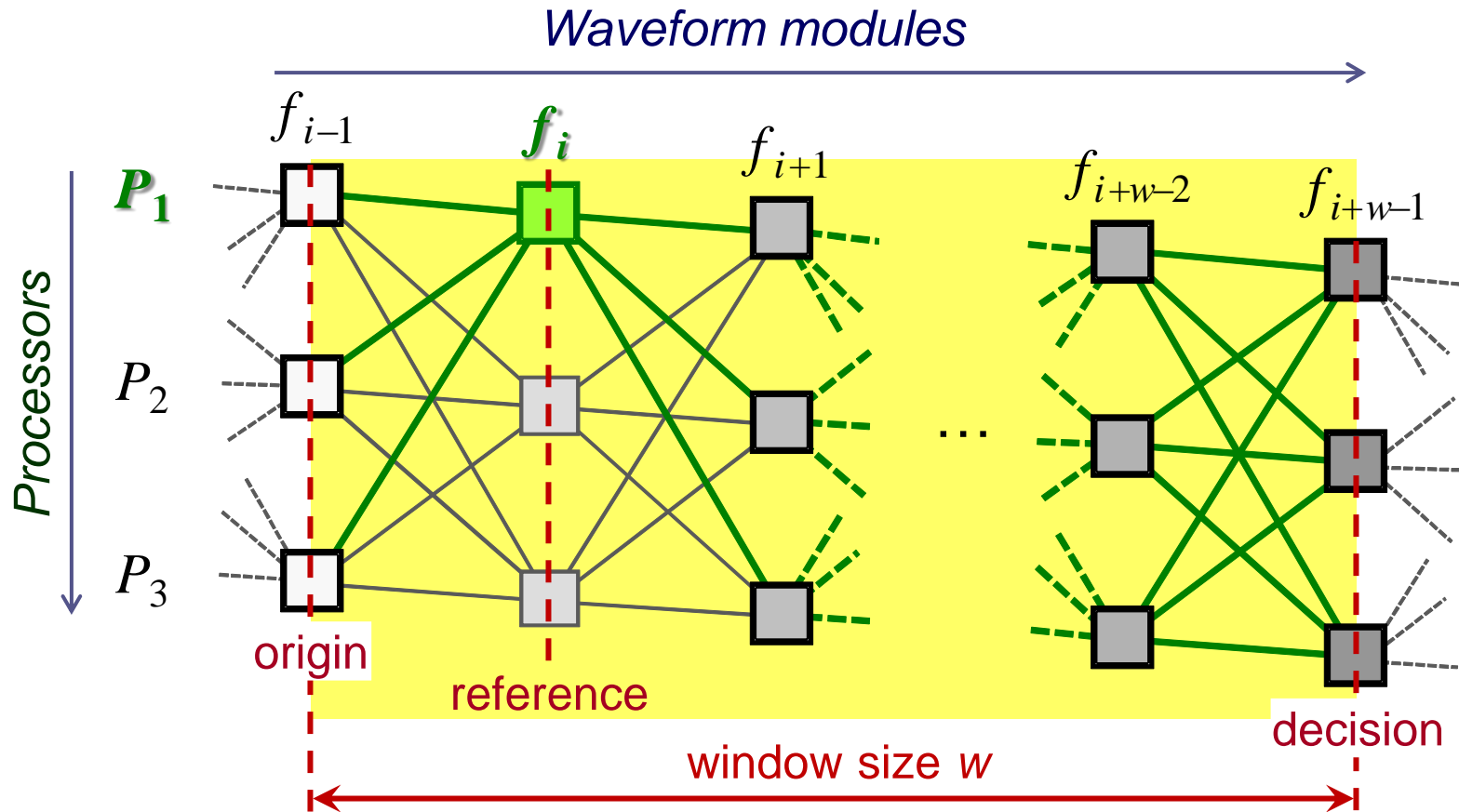
$$\text{Cost} = \frac{\text{processing requirement}}{\text{available processing power}} + \frac{\text{bandwidth requirement}}{\text{available bandwidth}}$$

*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.

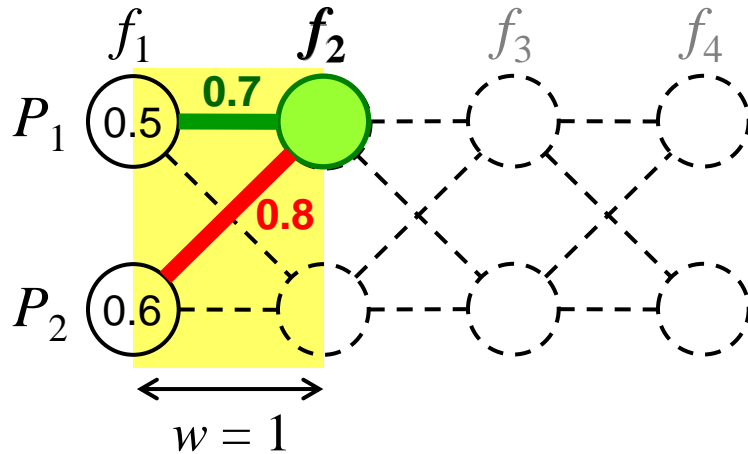
## 2.4 The $t_w$ -mapping & Cost Function



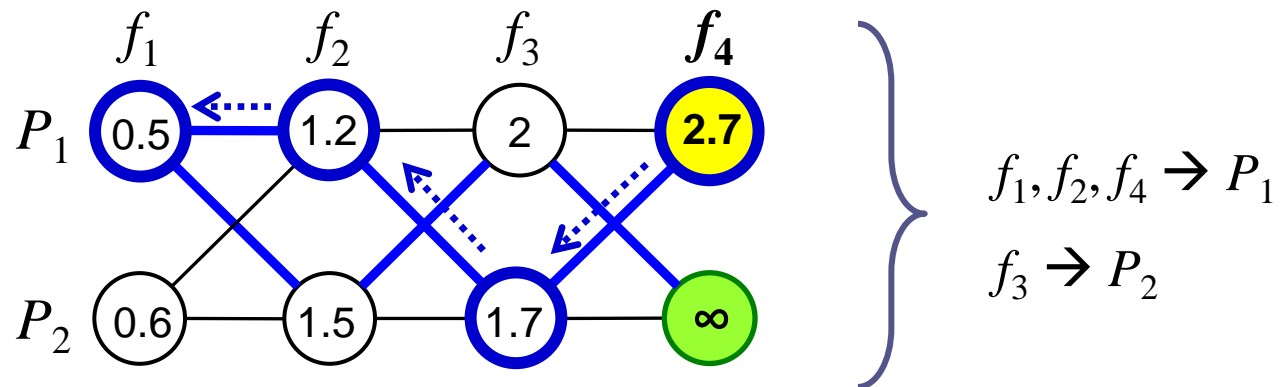
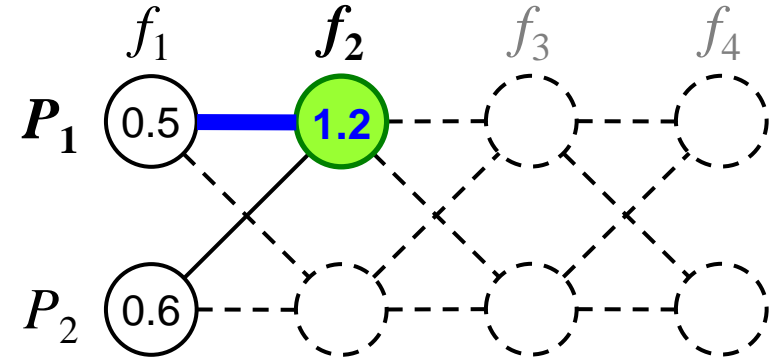
$\{P_1, f_i\}$  represents the mapping of waveform component  $f_i$  to processor  $P_1$

## 2.4 The $t_w$ -mapping & Cost Function

Path costs



Decision



## 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)

Execution control

Execution time statistics

Parameter time evolution

The screenshot displays a simulation GUI with several key components:

- Execution Control:** A top-left panel with 'LOAD' and 'INIT' buttons, and playback controls (play, stop, refresh).
- Loaded Modules:** A tree view on the left showing a hierarchy of modules including 'unrsegm\_u', 'deinterleaver\_0', 'unratem\_0', 'turbodecoder\_0', 'Parameters', 'Log', 'Variable stats', 'SYS\_CPU', 'SYS\_REL', 'control', 'input', 'output', 'dynHalt', 'iterations', 'max\_iterations', 'realHalt', 'PROC', 'uncrc\_0', 'unrsegm\_1', 'deinterleaver\_1', 'unratem\_1', and 'convdecoder\_1'.
- Execution Time Statistics:** A central histogram titled 'Panel PSC/scheduling' showing the frequency distribution of execution time. Statistics include: Bins: 1000, Max: 4320, Min: 4100, Mean: 4161.8, Desv: 97.7. It includes buttons for 'Auto Intervals', 'Acumulate Data', 'Clear Data', and 'Relative Frequency'.
- Parameter Time Evolution:** A plot on the right showing the signal 'chsimOutputSignal' over 'Time-slot x 10^3'. Below the plot, it shows 'Variable: chsim - OutputSignal' and 'Current Value: -80.0'.
- Schedule:** A Gantt chart at the bottom left showing processor usage for processors 4:0, 5:0, and 6:0 over time (0 to 7,500).
- Module Output:** A log window titled 'Log: unrc\_0' showing CRC results for various processors (e.g., [8755]: CRC: total=385600 pkts=100 errors=0 blks).
- Parameter Modification:** A control panel at the bottom right for 'chsim - EbNo' (Value: 100.0) and 'turbodecoder\_0 - max\_iterations' (Value: 1), each with a 'Set' button.

Loaded modules

Schedule

Module Output

Parameter modification

# 3.1 Graphical User Interface (II)

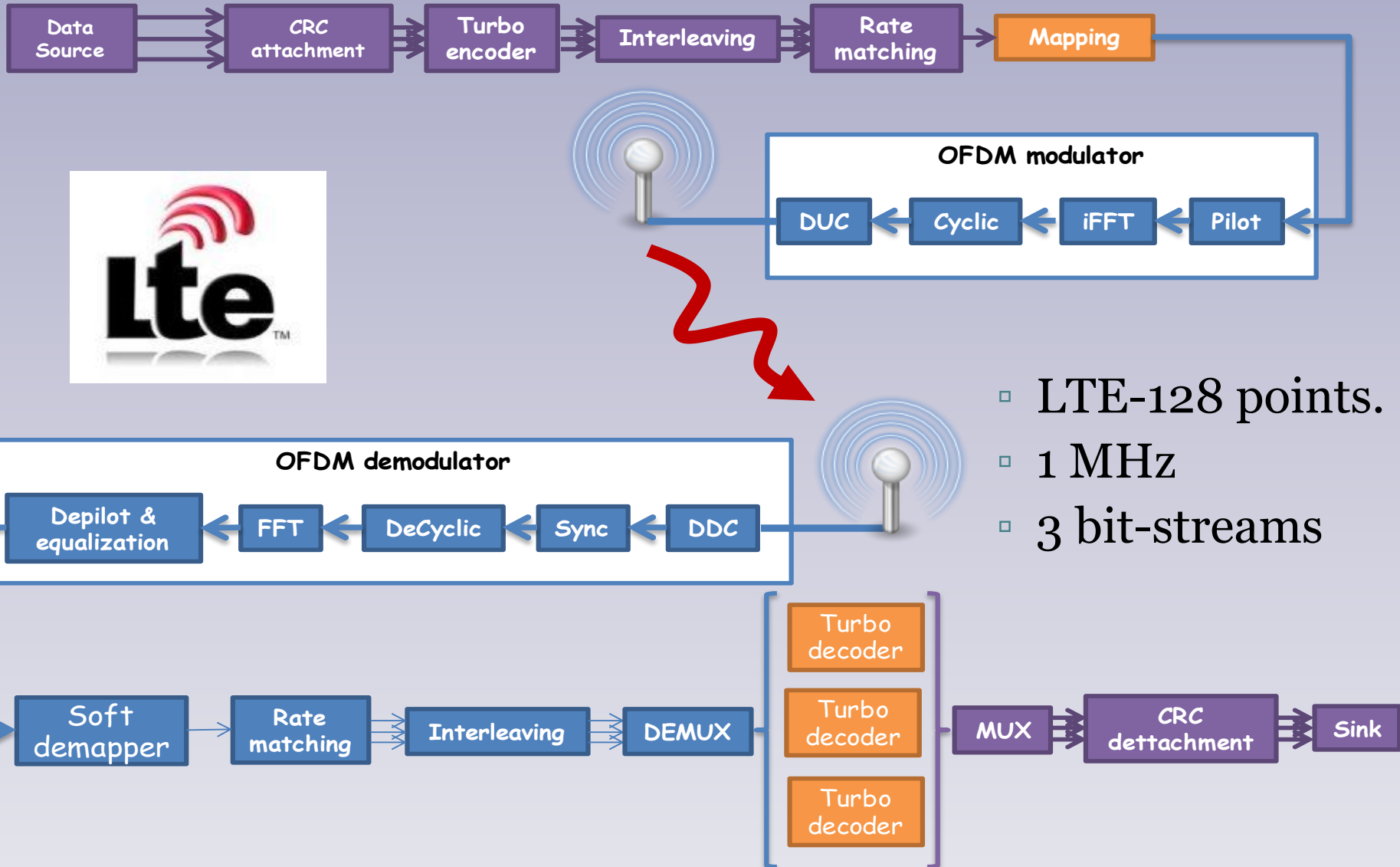
The screenshot displays the aloeUI software interface. On the left is a sidebar with a file tree and a 'Parameters' section. The main area is divided into two panels. The left panel, titled 'Graph', shows a network diagram of a computing platform with five nodes: (521.7 KOPTS) MAI..., (910.0 OPTS) MAIN\_1, (843.8 KOPTS) A..., (1.4 MOPTS) ARM3, and (955 KOPTS) ARM2. Nodes are connected by bidirectional arrows with numerical values. The right panel, titled 'Task schedule', shows a Gantt chart with 'Time (us)' on the x-axis (0 to 22,500) and 'Processor' on the y-axis (4:0, 5:0, 6:0, 2:0, 2:1). The bottom of the window features a 'Default Output' window with system statistics and a status bar.

**Computing platform Processor loads**

**Task schedule**

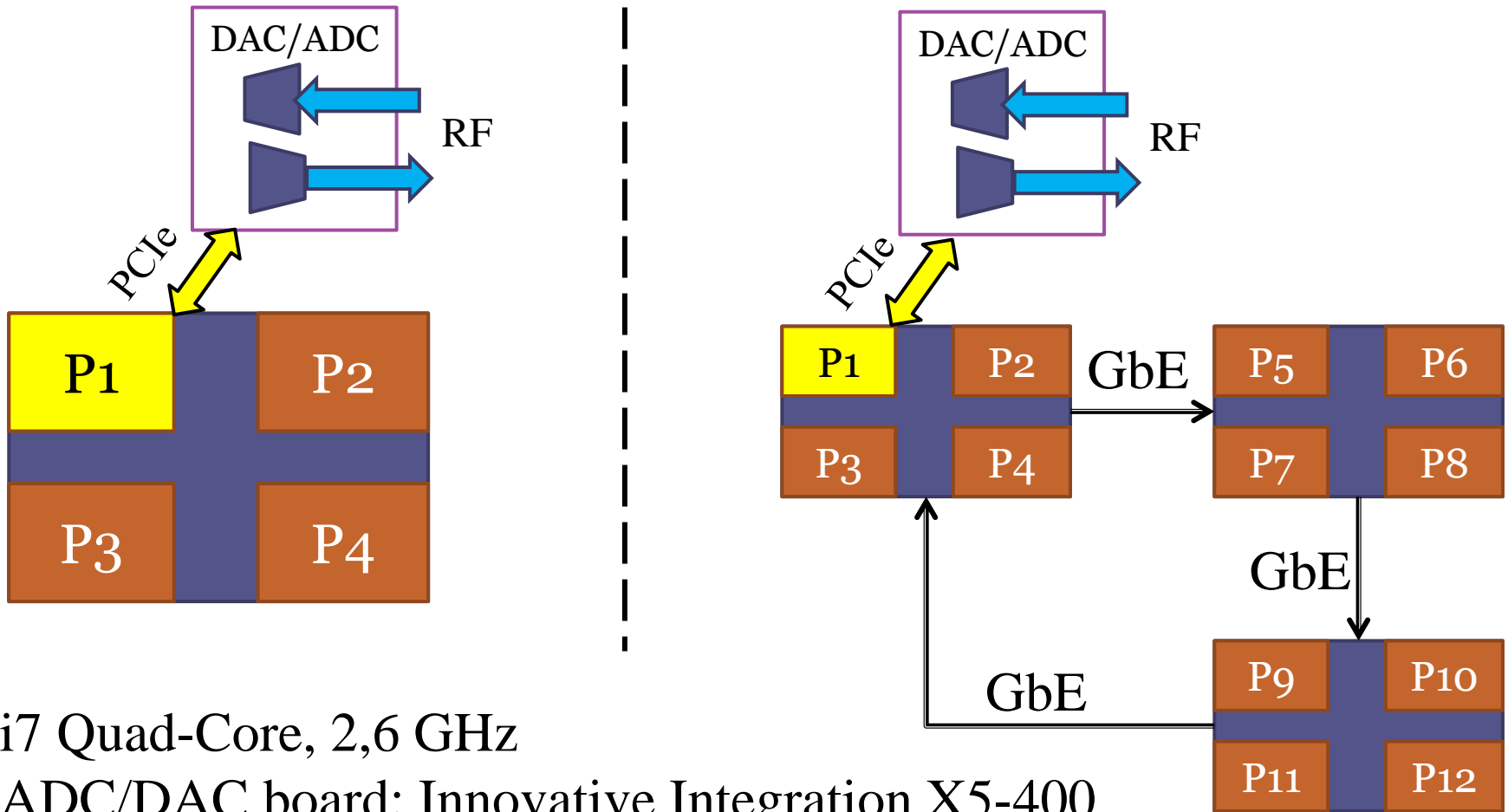
# 4. Waveform Development

Three bit streams



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

# 4.1 Processing Platforms



i7 Quad-Core, 2,6 GHz

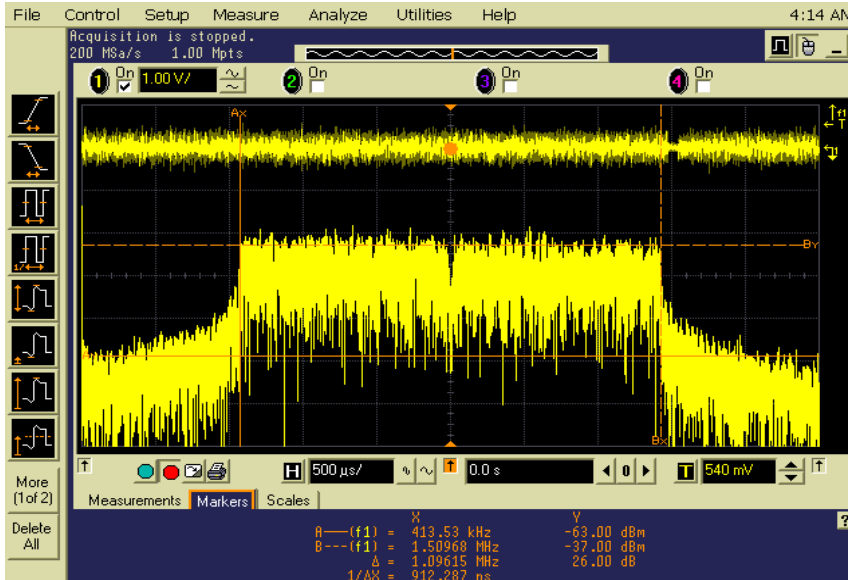
ADC/DAC board: Innovative Integration X5-400

Sampling Rate: 61,44 MHz

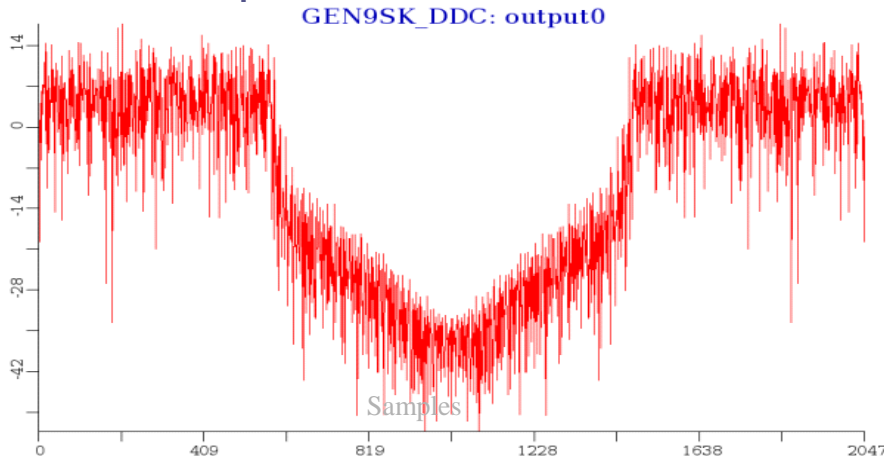
Time-slot: 2 ms. E2E-latency: 40 ms.

# 4.2 Signal Captures

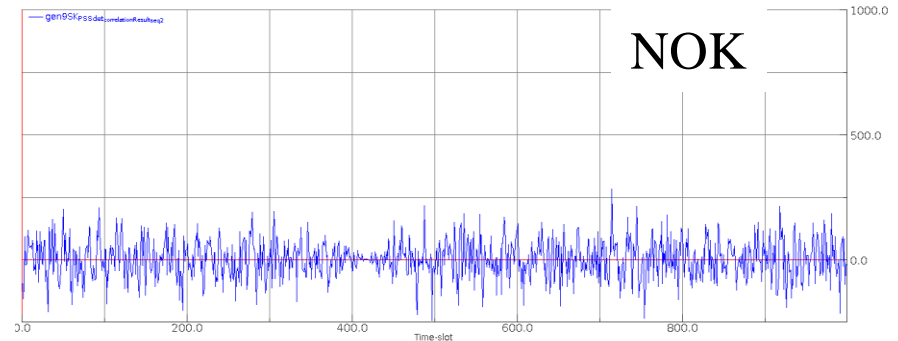
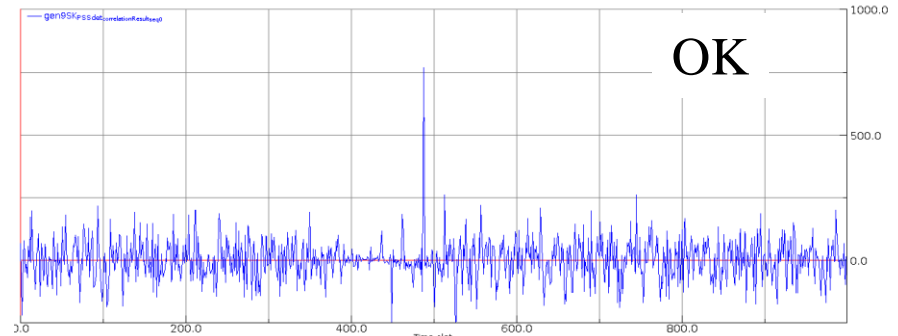
DA output (time and frequency domain)



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/>