



SDR Tools and Projects for Electrical Engineering Education

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Contents

- Introduction
- SDR Framework ALOE
- SDR Educational Tools
- Student Projects
- Lessons Learned



Context

- Software-defined radio (SDR) unifies radio engineering to computer science issues
- SDR adds additional difficulties to common wireless communications practices
- Software design and portability are important in SDR research and development



University Education

- Universities provide theoretical background
- Teach practical engineering tools beyond simulation environments
- Prepare students for their profession or grad school
- School of Telecommunications and Aerospace Engineering (EETAC)
 - Project based learning (PBL)
 - Technical and scientific courses in Telecommunication and Aerospace Science and Technology (BSc, MSc, PhD)



Our Contribution

- Flexible wireless communications systems and networks (FlexNets) project
- Abstraction layer and operating environment (ALOE) + a set of research and educational tools
- Framework and tools continuously evolving for and with our students
- Available for free download from:

<http://flexnets.upc.edu/trac/>

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Welcome to FlexNets - ALOE Middleware

FlexNets (Flexible Wireless Communications Systems and Networks) is an open-source research initiative that explores new means for leveraging the flexibility in radio communications. It provides a platform for collaborative research efforts on software-defined radio (SDR), cognitive radio, and similar concepts that promote flexibility in wireless communications.

The mission of **FlexNets** is easing the design, development, and deployment of flexible radio communications systems and networks. **FlexNets** provides software tools for sharing hardware and software resources. It facilitates introducing real-time computing resource management approaches and testing them in different SDR scenarios.


FlexNets is divided into several projects:

- **ALOE: Abstraction Layer and Operating Environment** (former PHAL-OE - Platform and Hardware Abstraction Layer Operating Environment) is a lightweight middleware that eases the deployment and portability of waveforms on multiprocessing platforms.
=> Go to [QuickStartGuide](#) to download and install ALOE latest version
- **FlexWaves: Flexible Radio Waves** is a software repository containing waveform modules. UMTS and WiMAX are currently available.
- **FlexCRM: Flexible Computing Resource Management** develops a flexible computing resource management framework for managing the distributed and limited computing resources of multiprocessing platforms and the real-time computing requirements of waveforms.
- **aloeUI: Graphical User Interface for ALOE** provides a user-friendly control interface for loading and executing waveforms, displaying real-time signal evolution, capturing execution time statistics, etc.
- **ALOEedu: ALOE Education** offers educational material on flexible wireless communications, including self-explanatory laboratory sessions.

Contact

We are continuously updating **FlexNets**. If interested, please send an email to flexnets.pmt@upc.edu and we will inform you about new contents available for download.

- [People](#)
- [Related publications](#)



SDR Framework ALOE

(Abstraction Layer and Operating Environment)



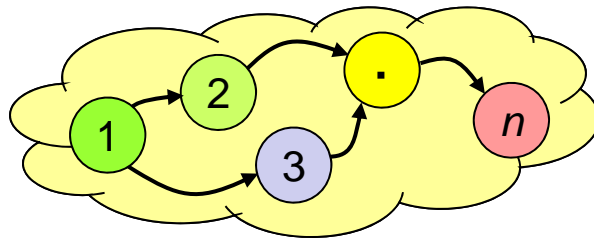
Features

- real-time execution
- waveform execution control
- synchronized distributed computing
- packet-oriented data flows
- cognitive computing resource management
- external configuration and management

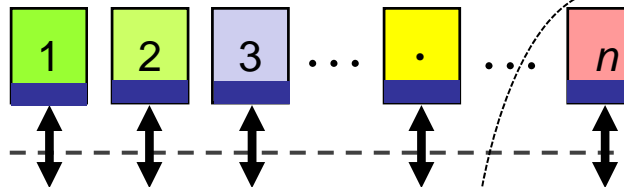
I. Gomez, V. Marojevic, A. Gelonch, "ALOE: an open-source SDR execution environment with cognitive computing resource management capabilities," *IEEE Commun. Mag.*, vol. 49, iss. 9, pp. 76-83, Sept. 2011.⁸

Architecture

Abstract Application Layer



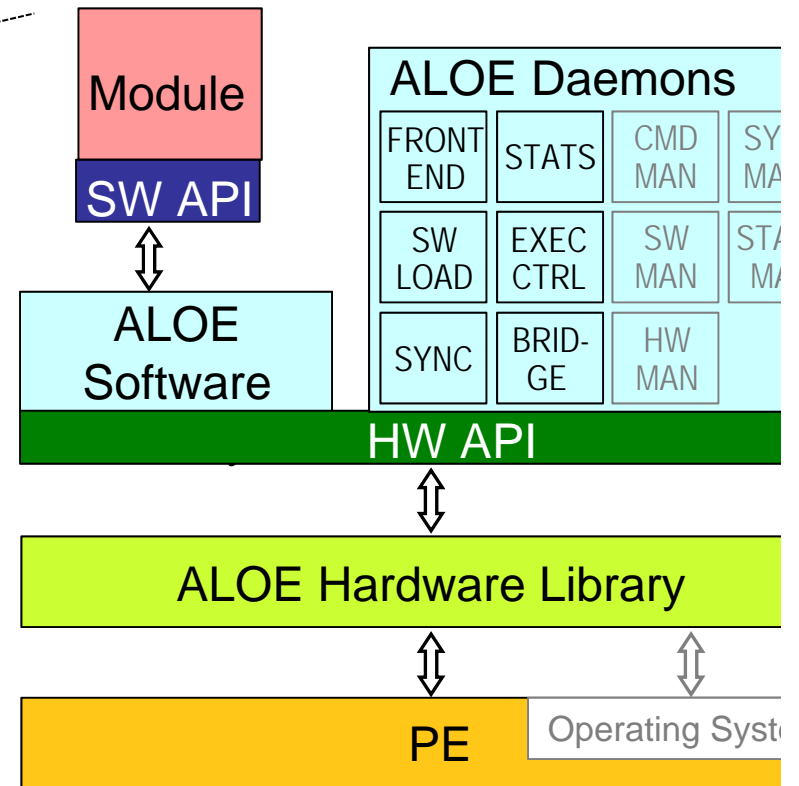
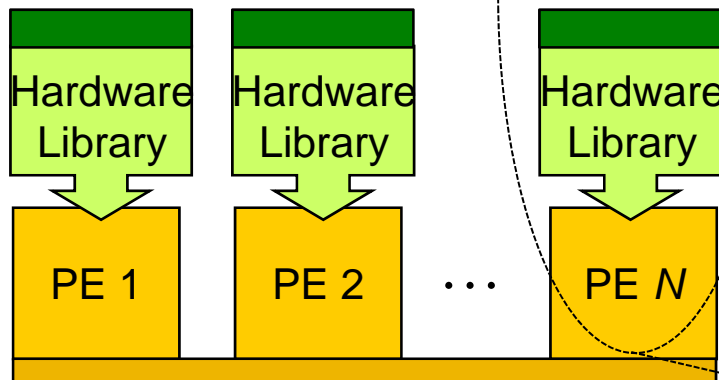
Real Application Layer



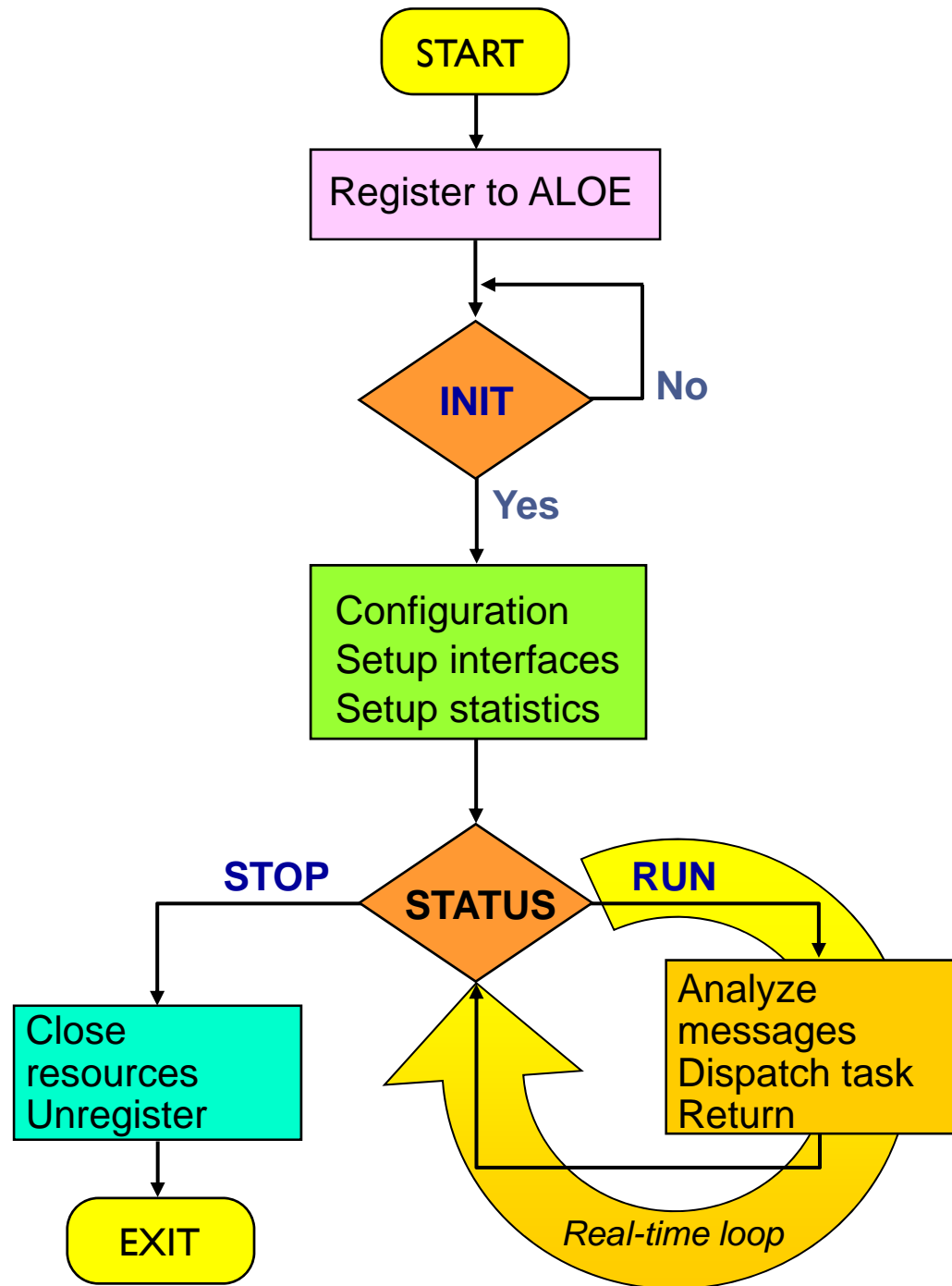
Platform Layer



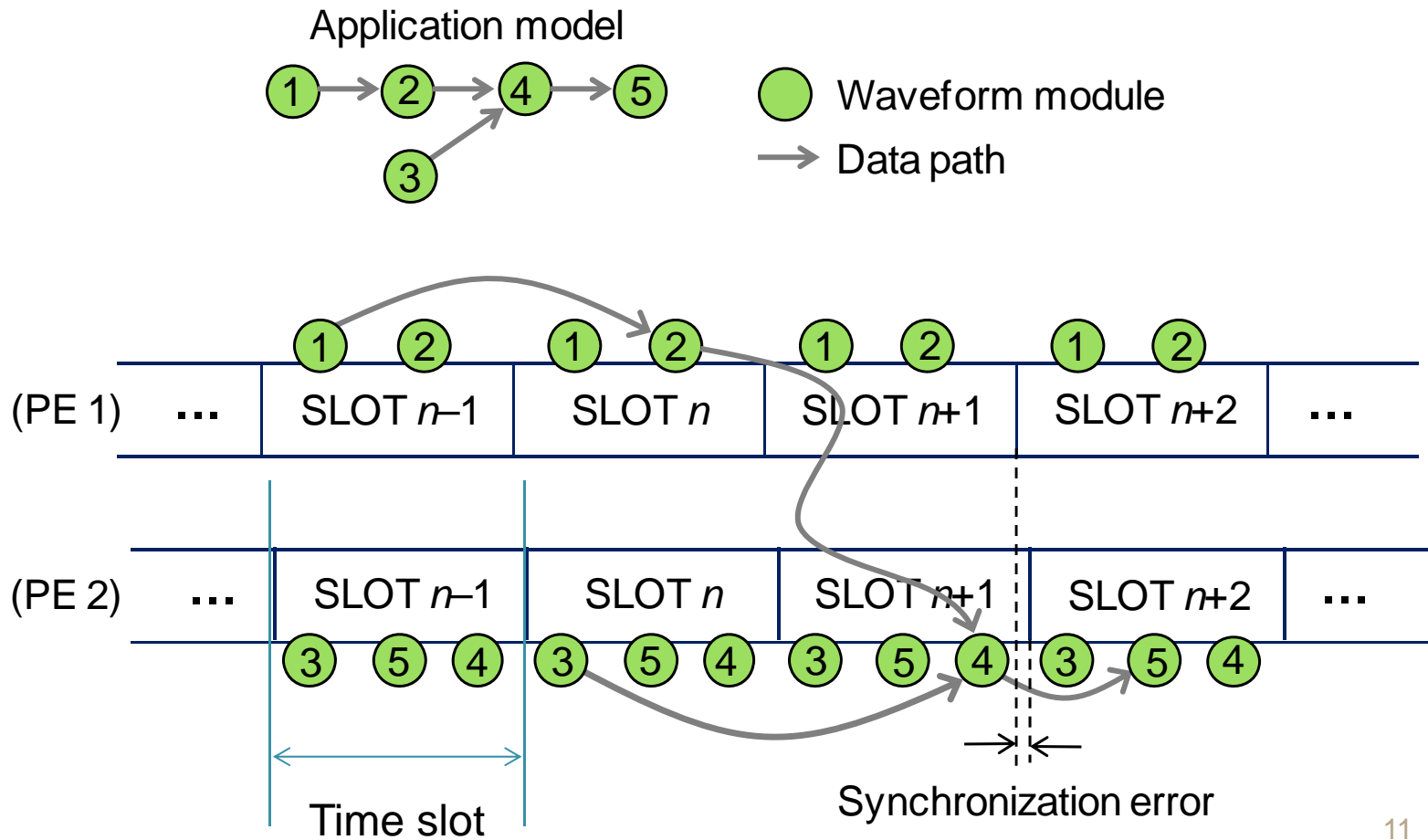
Hardware Layer



Module Execution Flowchart



Waveform Execution





SDR Educational Tools

ALOE Sessions

Session	Objective
1 Introduction to ALOE	Introduction + Installation Guide
2 Creating a Waveform	Create and run a waveform
3 Creating Components	Create and debug waveform components
4 ALOE User Interfaces	GUI for loading, initializing and running waveforms and monitoring parameters
5 Multiprocessing	Configure multiprocessor platform
6 Creating Waveform Components w Simulink	Use Simulink for creating waveform components
7 Computing Resource Management Framework	Introduction and use of framework
8 Computing Resource Management Tools	Presentation and use of tools



ALOE Skeleton

- ALOE framework specific execution pattern
- Controls real-time execution process, obtains status of modules and interrupt them if necessary
- Waveform components need to following certain design rules
- ALOE skeleton:
 - template for implementing digital signal processing algorithms in C (and C++ soon)
 - Defines general input/output interfaces, provides data conversion facilities, organizes the code into different sections (execution phases)



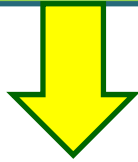
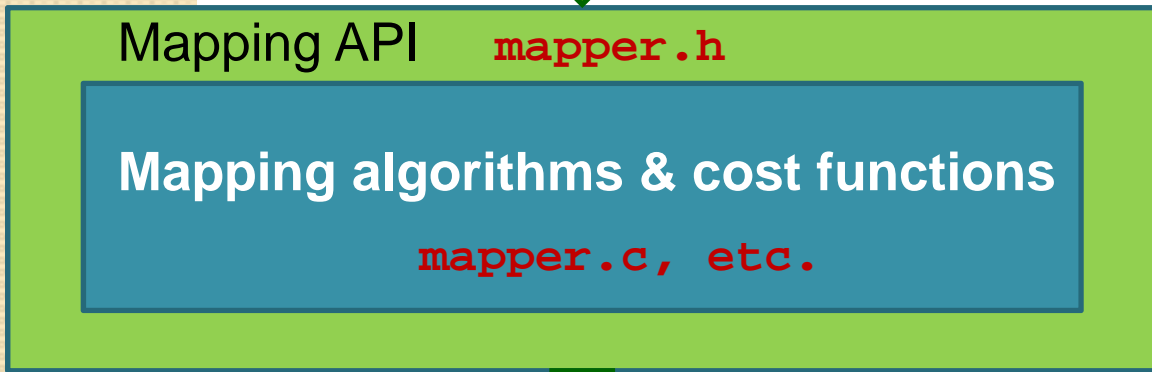
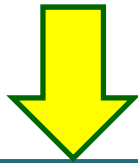
Computing Resource Management

- Context: real-time distributed computing
- Framework and tools for implementing and analyzing computing and resource management algorithms
- Computing resource models and resource allocation algorithms
- API and simulation environment
- Tools
- Source codes available at <http://flexnets.upc.edu/trac/>



C functions
`api_test.c`

Application & platform models,
mapping parameters

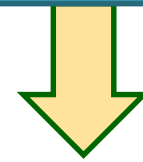
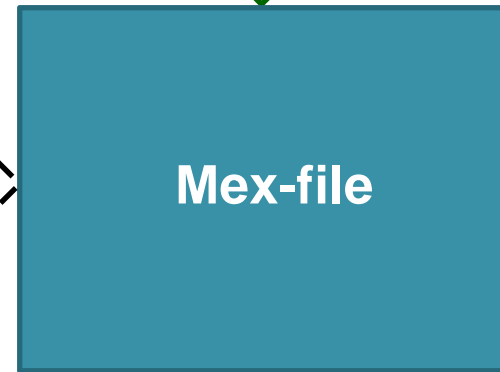
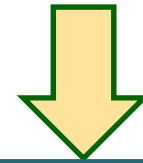


Mapping result, cost, others

C functions
`api_test.c,`
`etc.`

Matlab scripts

Application & platform models
mapping parameters



Mapping result, cost, others

Matlab scripts





Student Projects



Context

- *Wireless Communications* subject (4th year EE)
- Theoretical and **practical part**
- Students in groups of 5-6 develop semester-long wireless communications project
- SDR projects since 2007
 - Provide overview of wireless communications transmitters and receivers
 - Real-time digital signal processing implications and solutions



SDR Computing Resource Management

- Six students developed three sub-projects:
 - Mapping algorithms
 - Waveform modeling
 - Scheduling simulator

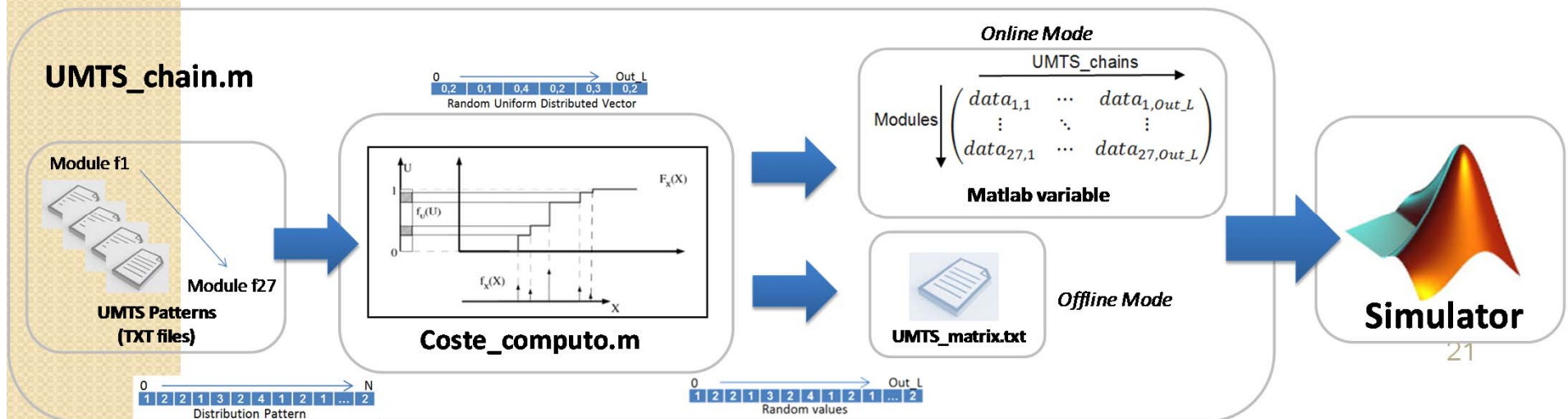


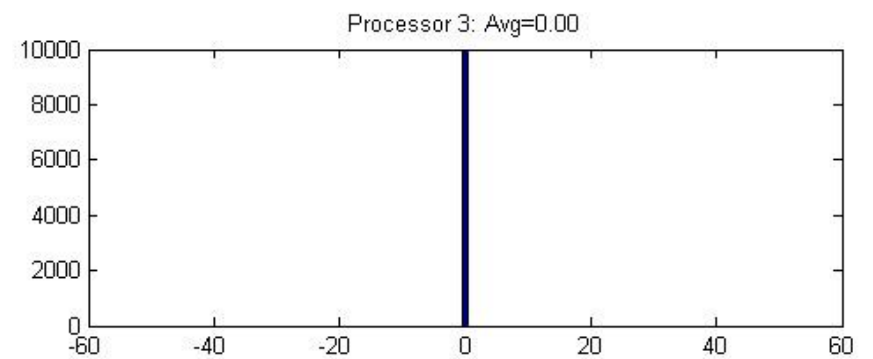
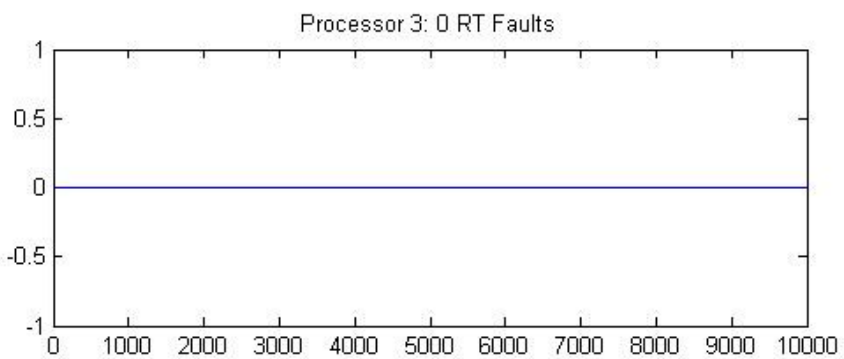
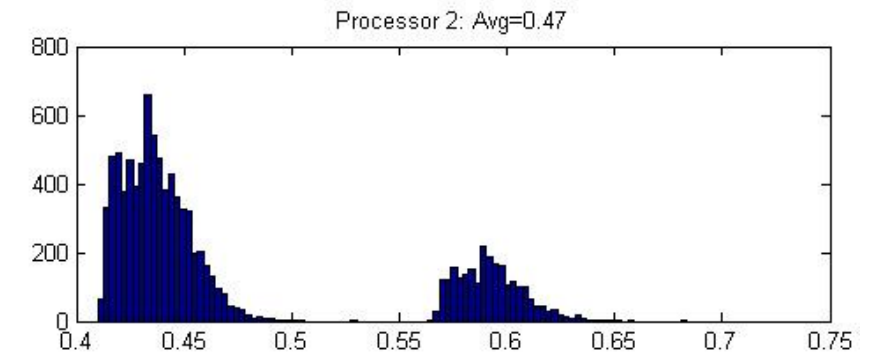
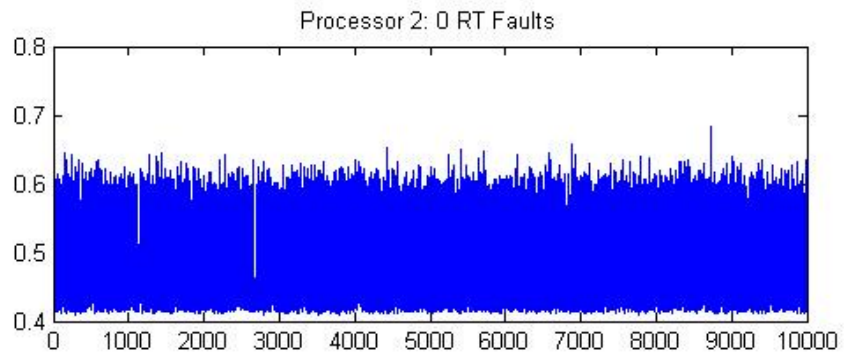
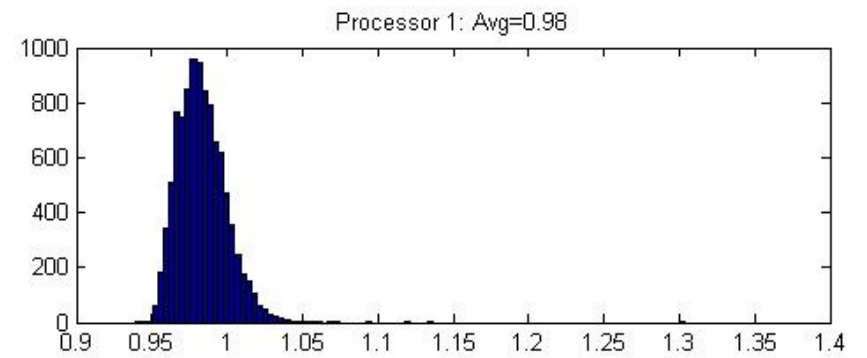
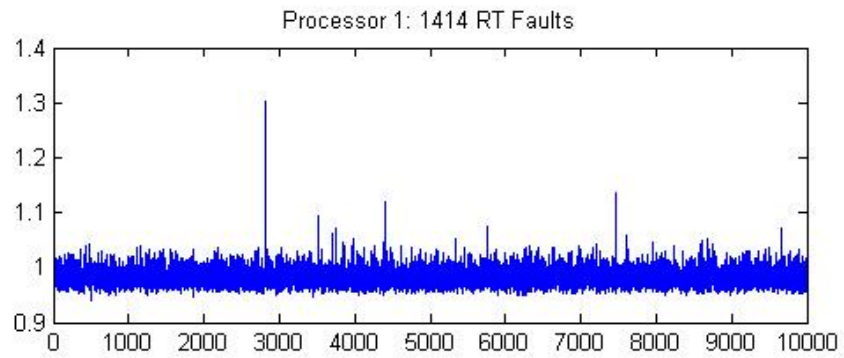
SDR Computing Resource Management

- Students learned:
 - real-time processing implications,
 - processing requirements and capacities
 - MAC as a suitable signal processing metric,
 - Pipelined execution (continuous data flow)
 - Modeling metrics MOPTS and MBPTS, derived from million operations per second (MOPS) and mega-bits per second (Mbps),

SDR Computing Resource Management

- Execution time measurements of signal processing modules of UMTS bit-rate transceiver running on ALOE
- Generate random data (execution times) based on real measurements
- Simulate real-time variations of execution time







Lessons Learned

- Different feedback
- Tools generally appreciated by our students
- Visual tools (GUIs) most popular
- Develop more user-friendly tools, requiring fewer initial skills
- Still, motivation work necessary



Conclusions

- ALOE framework and tools allow a quick start into new student projects
 - Insights into modern wireless system engineering problems
 - SDR concepts and research issues
 - Discuss and develop solutions in short time
- Current SDR project: SDR cloud computing resource management analysis and solutions