Quantitative Evaluation in Embedded System Design

Validation of Multiprocessor Multithreaded Architecture

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Agenda

- Introduction
- The MULTIVAL project
  - Validation of distributed and asynchronous systems
  - The CADP toolbox
- Performance evaluation
  - From LOTOS to Markov chains
  - Methodology
  - Example : a simplified xSTream queue
- Conclusion

Introduction

- Asynchronous computing becomes widely used:
  - Increased computing performances
  - Increased flexibility and scalability
  - Energy consumption optimization

- Asynchronous computing is found at many levels:
  - Grids, clusters
  - Multiprocessor architectures
  - Multicore processors
  - Asynchronous logic

Introduction

Challenges in distributed system design:

- Break with the synchronous design approach

- High functional complexity

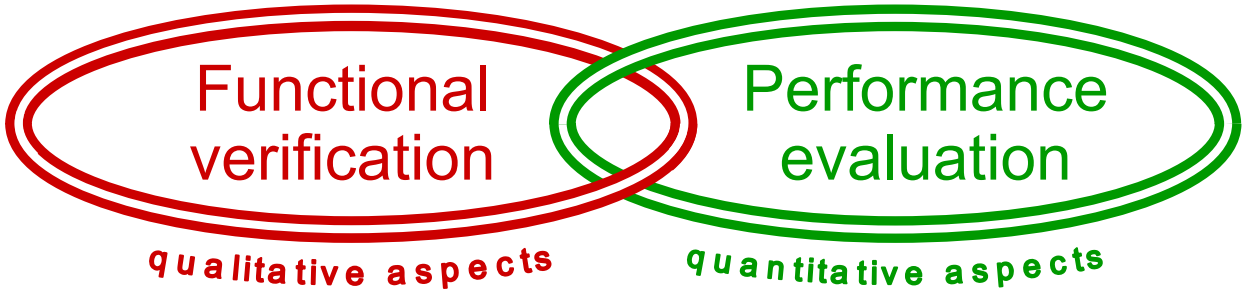
  → functional verification more difficult

  → no industrial methodology

- High degree of concurrency

  → communication latencies may appear

  → but time constraints have to be respected



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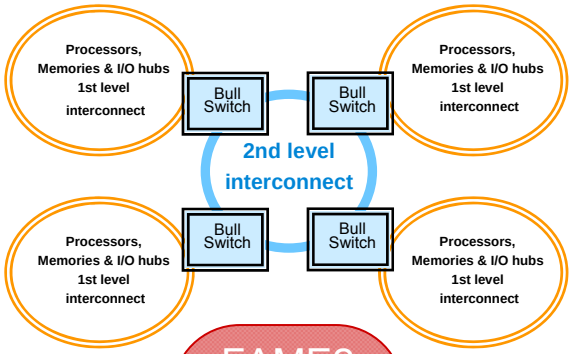
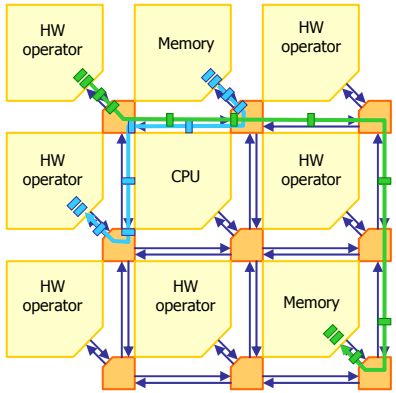
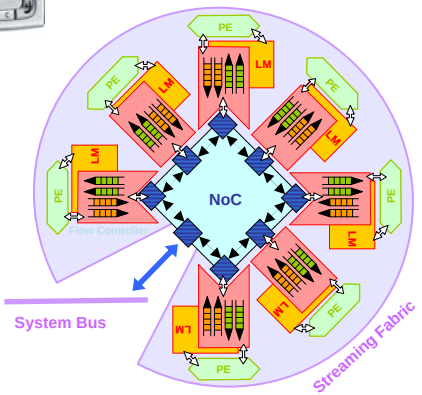
MINALOGIC / MULTIVAL

http://www.inrialpes.fr/vasy/multival/



Functional verification & performance evaluation of asynchronous hardware using formal methods



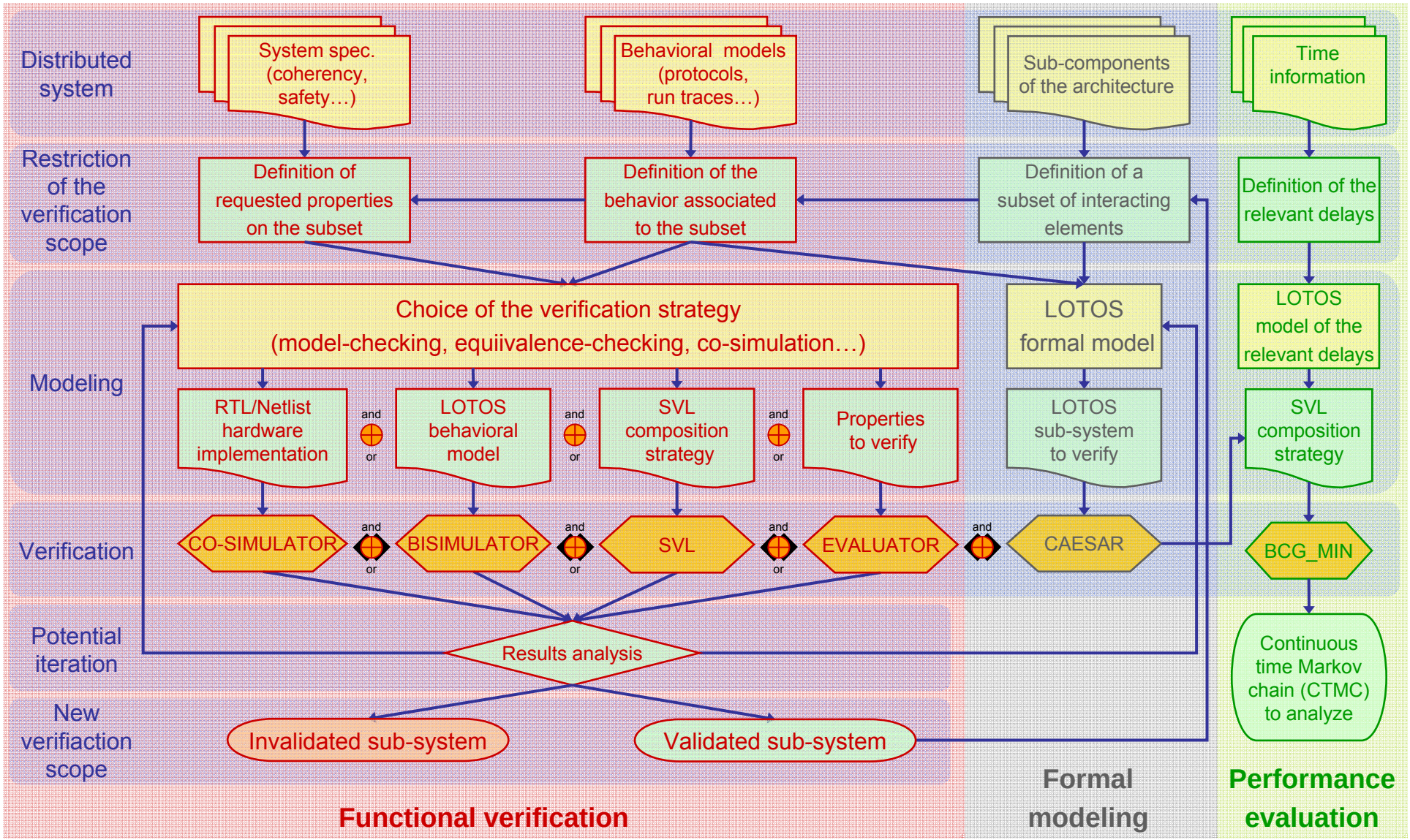


CADP toolbox

http://www.inrialpes.fr/vasy/cadp/

- Formal modeling of asynchronous systems
  - Formal models of the architecture behaviors
  - High-level languages translated into LOTOS (ISO 8807)
- CADP tools helping hardware conception :
  - Compilers, translators and model generators
  - Functional verification :
    - Model checking, equivalence checking
    - Co-simulation (RTL – LOTOS)
  - Performance evaluation :
    - Functional models enriched with time information. Performance evaluation based on IMC theory.

CADP methodology



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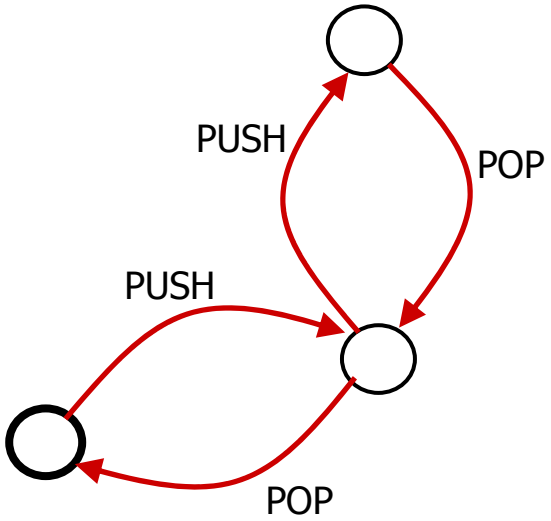
From LOTOS to Markov chains
- Interactive Markov Chain (IMC) formalism [Hermanns] -

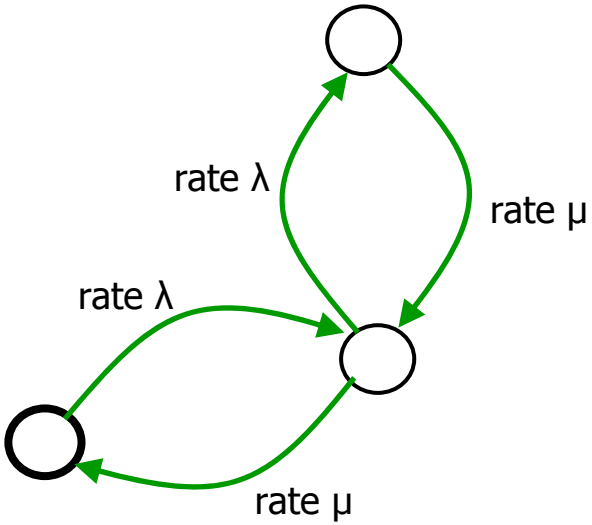
The behavior of a physical system can often be represented by :

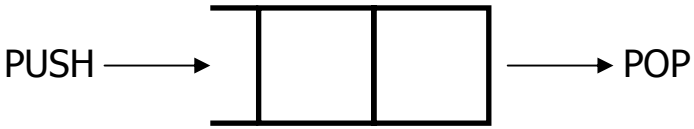
- All the states the system may occupy
- How the system moves from one state to another — action based / time based

Functional behavior:
Labeled Transition System (LTS)



Timed behavior:
Continuous Time Markov Chain (CTMC)





From LOTOS to Markov chains
- Interactive Markov Chain (IMC) formalism [Hermanns] -

The behavior of a physical system can often be represented by :

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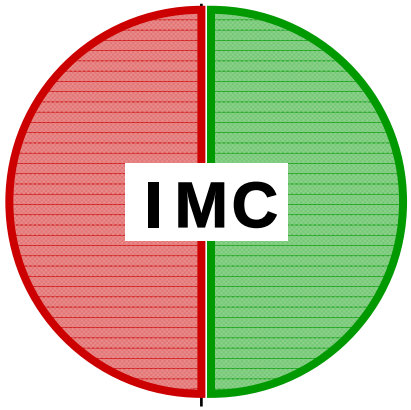
Functional behavior:
Labeled Transition System (LTS)

- Composition
- Concurrency
- Synchronization

↓ ↓ ↓

Description of large systems & formal verification



Timed behavior:
Continuous Time Markov Chain (CTMC)

- Performance measures
- No composition
- No synchronization

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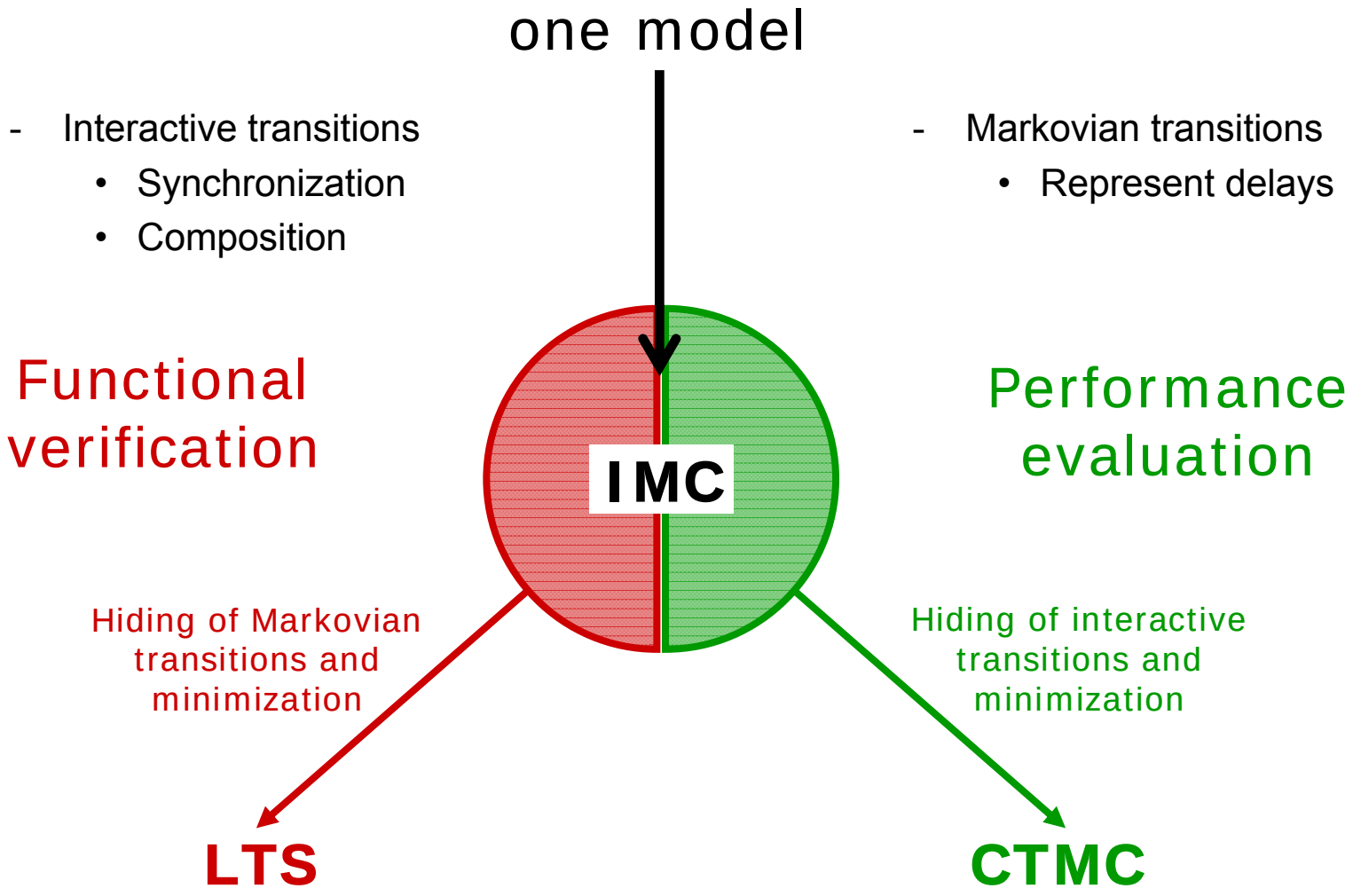
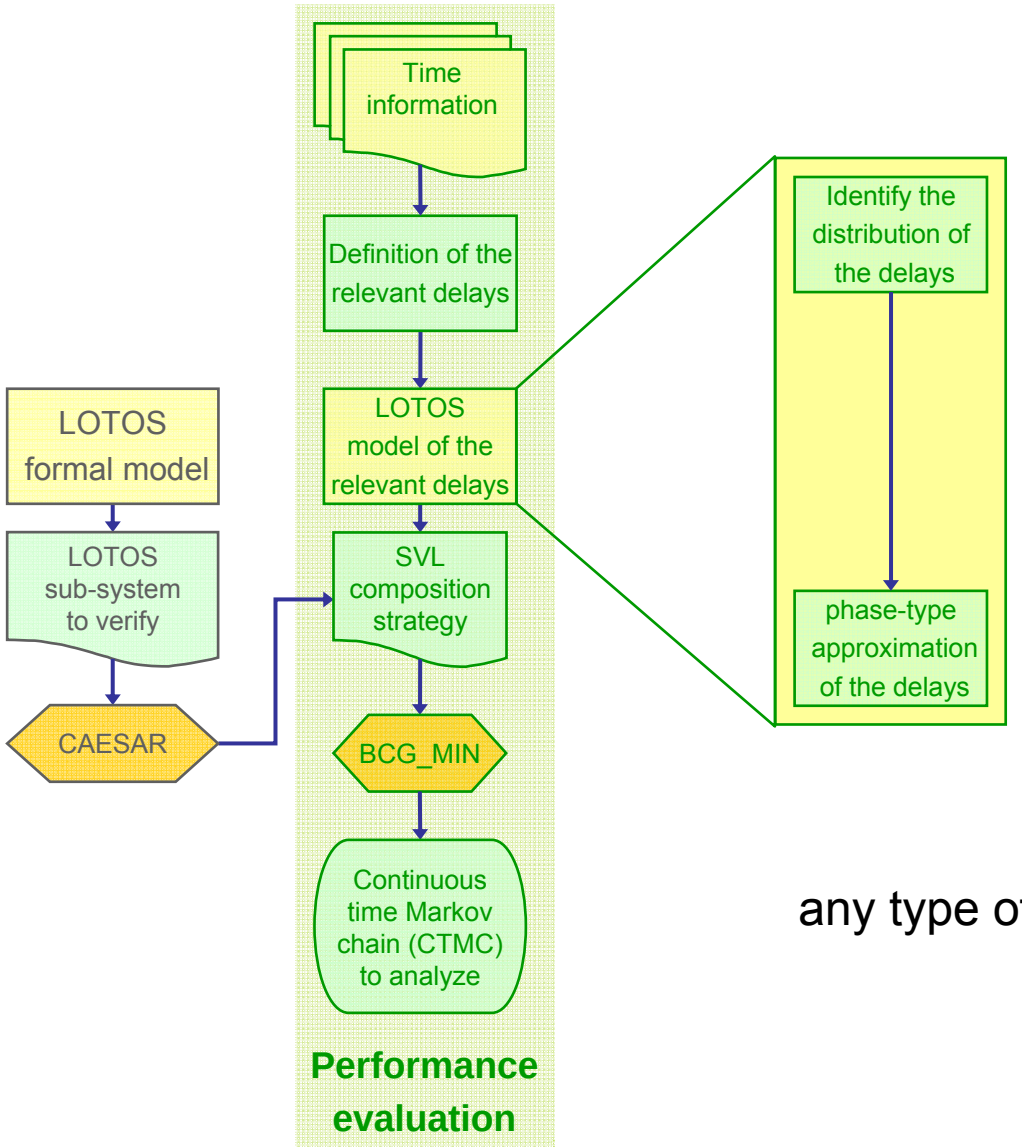
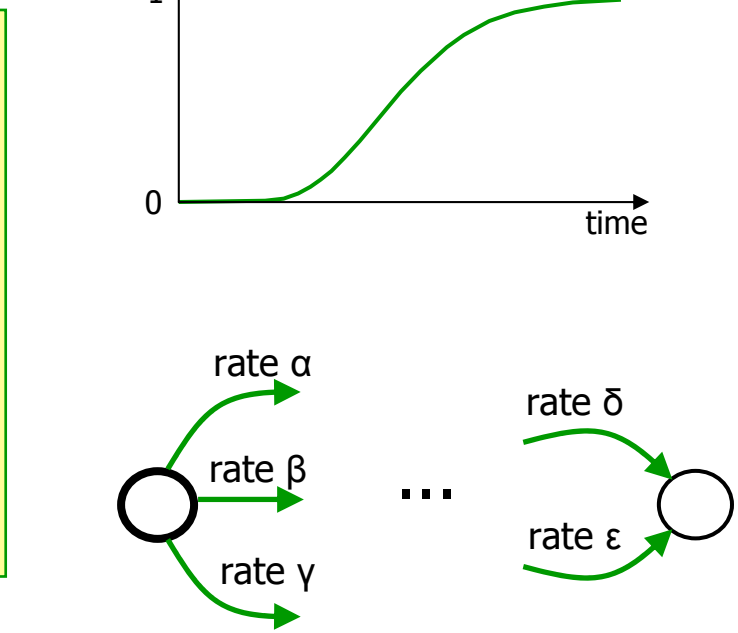
Performance evaluation of complex systems reserved to specialists

From LOTOS to Markov chains
- Interactive Markov Chain (IMC) formalism [Hermanns] -



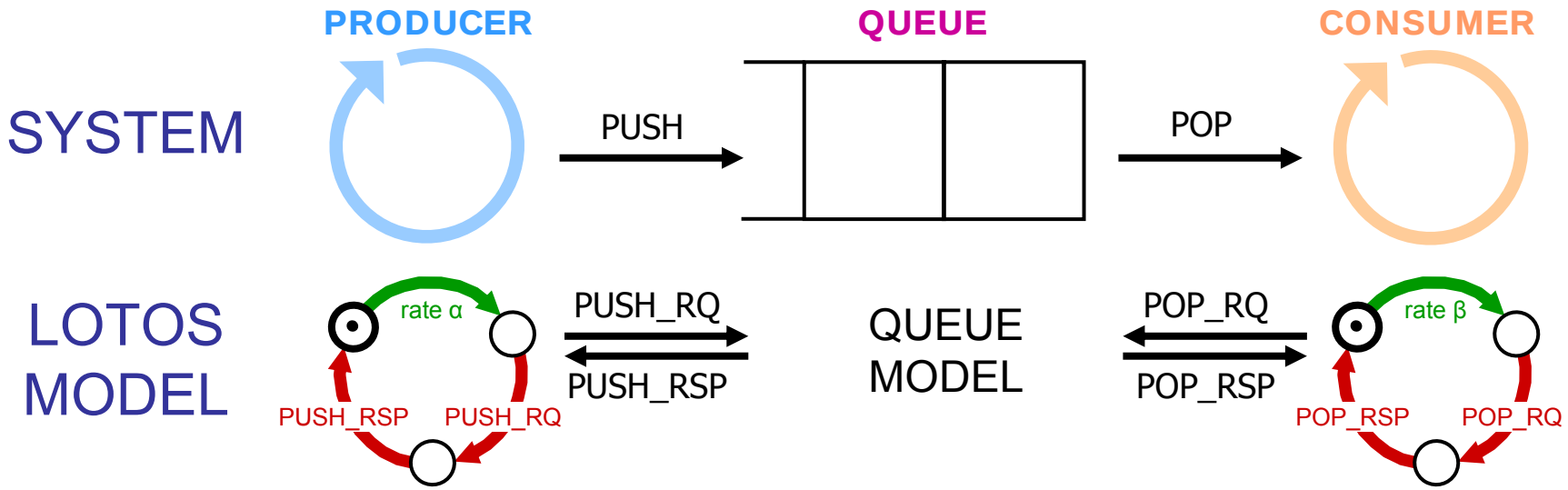
From LOTOS to Markov chains

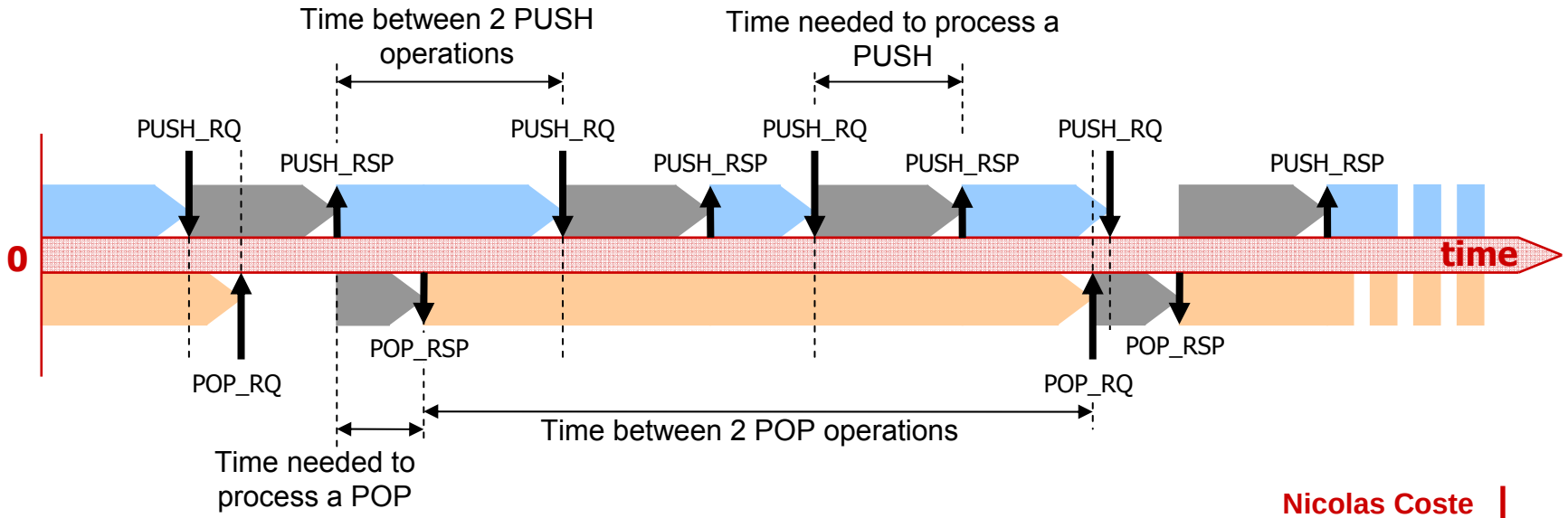




any type of general distribution can be fitted
by a
phase-type distribution

Example: a simplified xSTream queue





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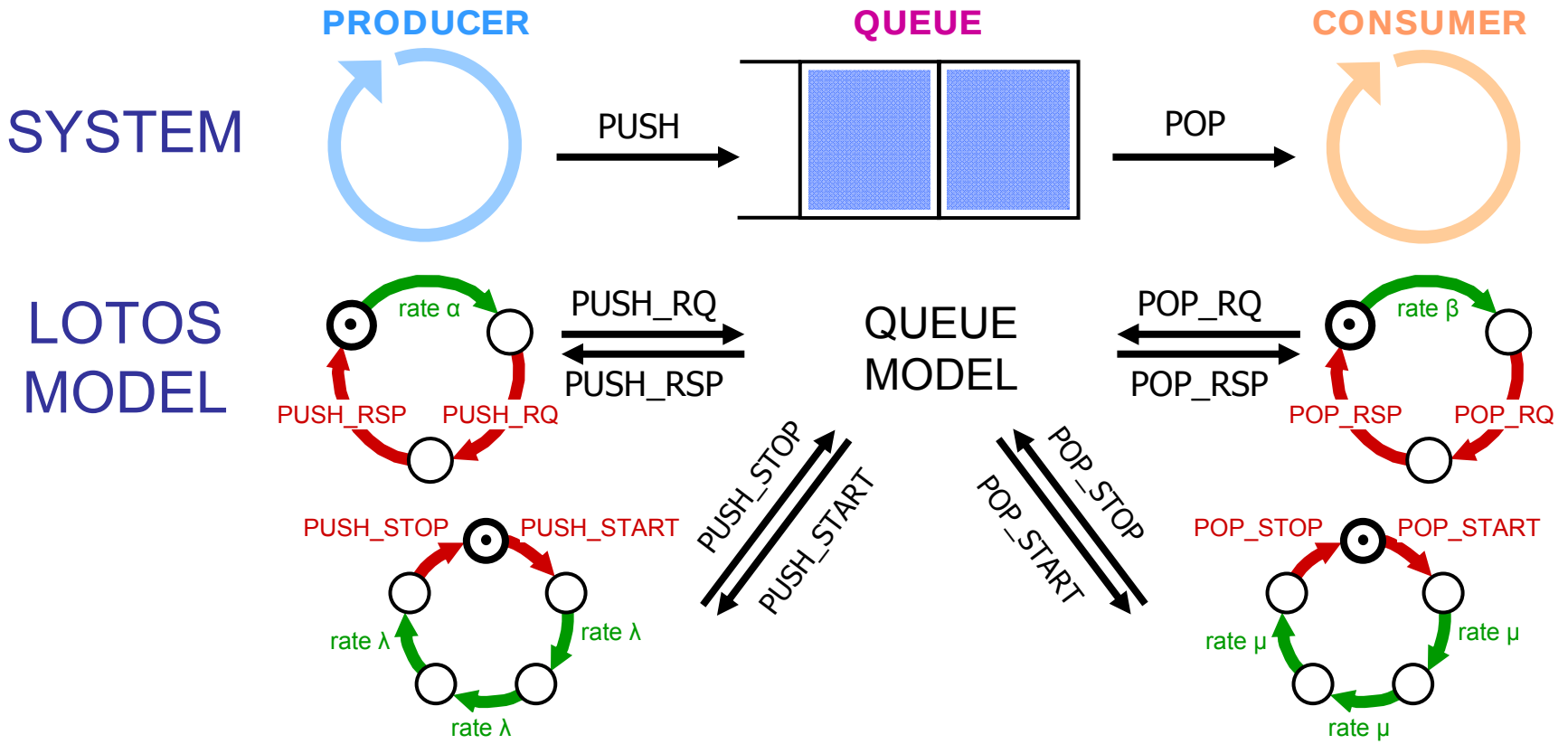
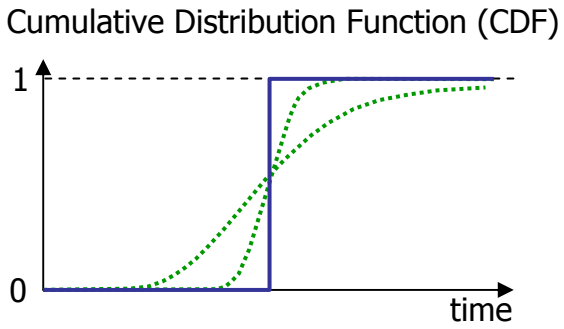


Time needed to process a PUSH and Time needed to process a POP



Erlang distribution

Conclusion

Several early results…

- Functional verification
  - Two functional issues highlighted in xSTream
  - Formal verification of the FAUST NoC router
  - Theoretical results on isochronous forks in asynchronous circuits
- Performance evaluation
  - Prediction of latencies of an MPI benchmark on the FAME2 architecture for different topologies, different software implementations of the MPI primitives and different cache coherency protocols.
  - Possibility to predict latencies, throughputs and queue occupancy in the xSTream architecture.

Conclusion

… but nothing can be taken for granted.

- Functional verification

  - 2 different approaches (top-down and bottom-up)
  - But we are never sheltered from state explosion → expertise is needed !

- Performance evaluation

  Trade-off between good phase-type approximation and state explosion
  No knowledge of the accuracy gain due to a better phase-type approximation