Modèles de performance et émulation pour le dimensionnement autonome d'applications distribuées à base de composants

Introducing queuing network-based performance awareness in autonomic systems

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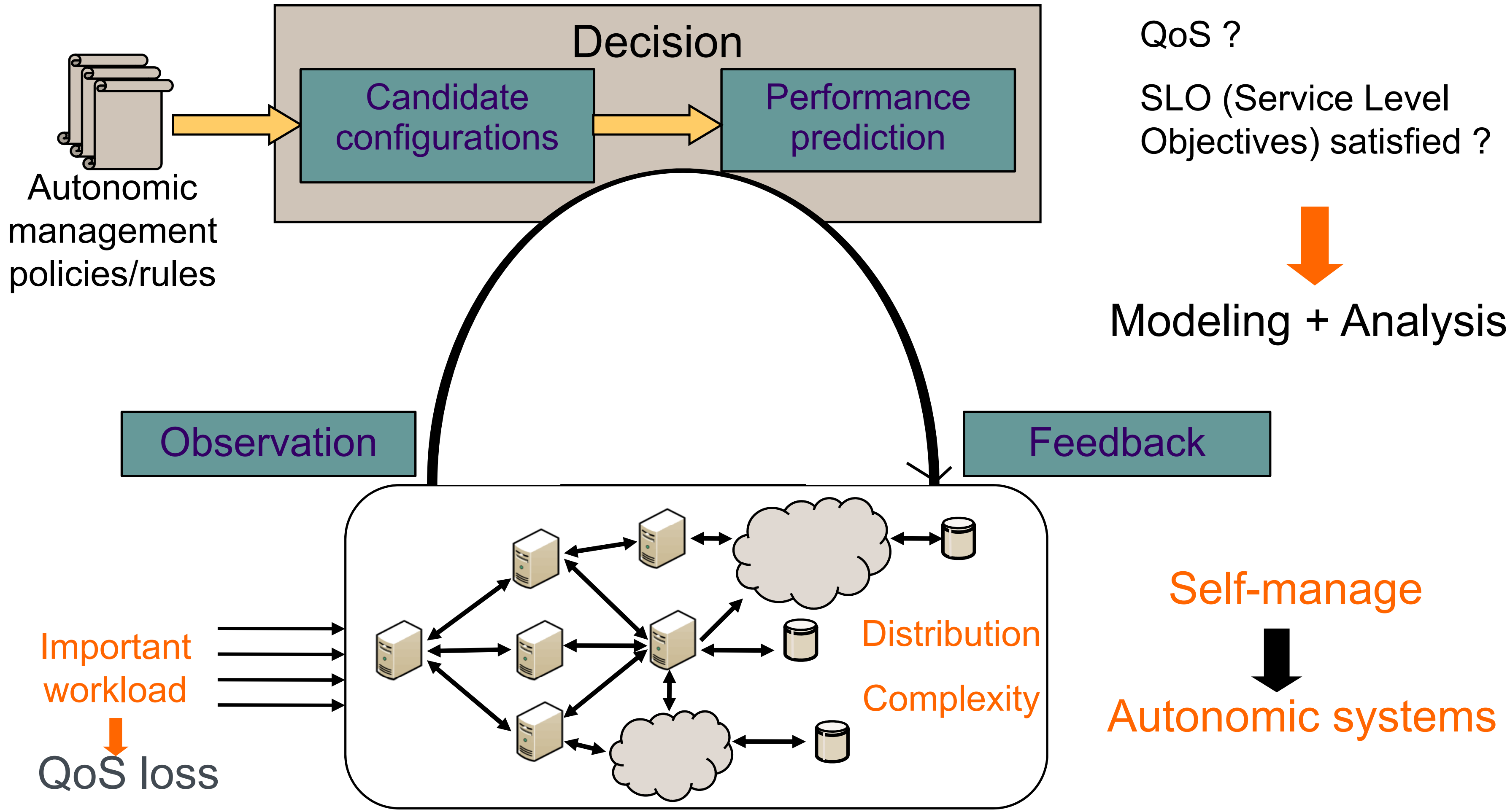
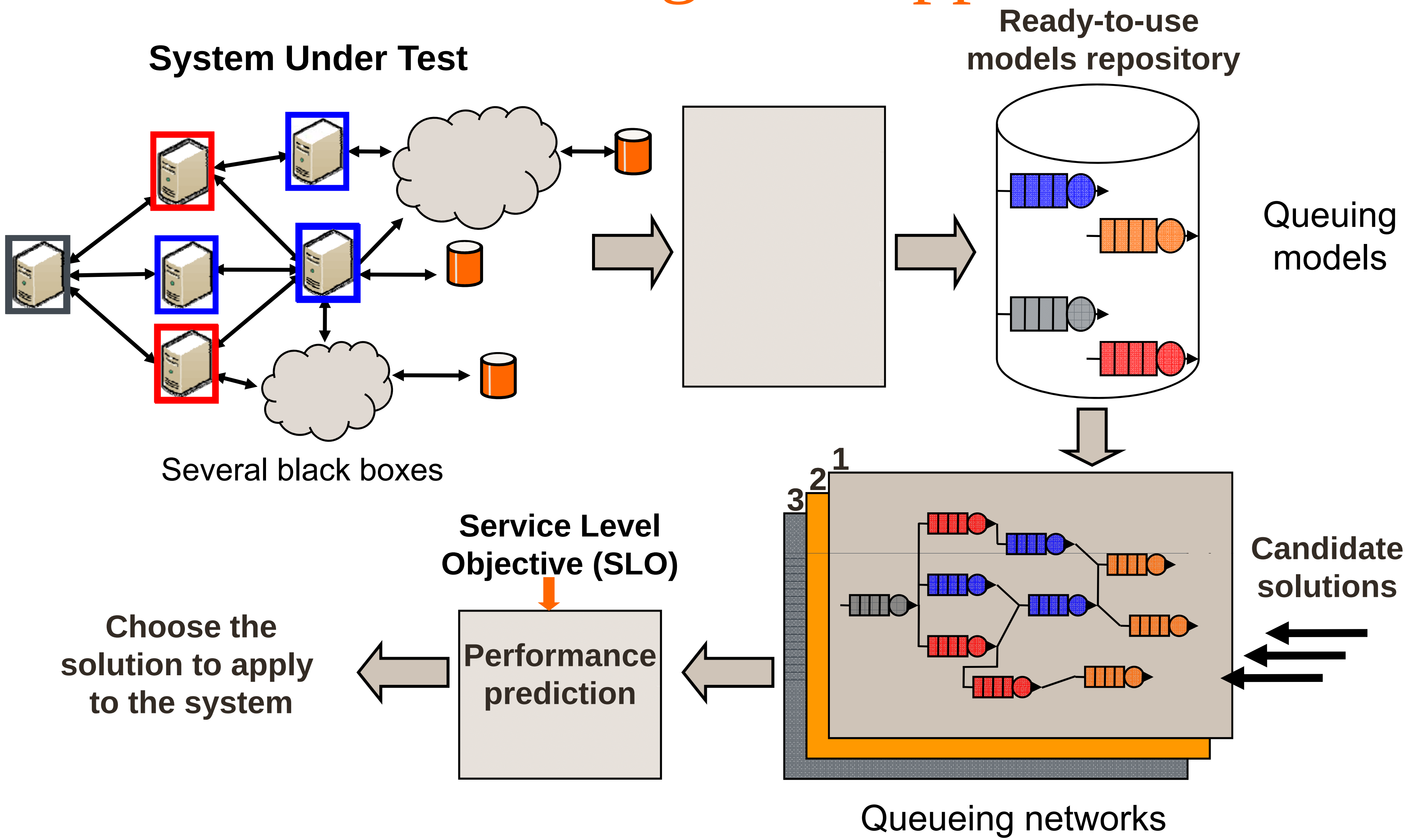
Outline

1. Towards autonomic management
2. Modeling black boxes
3. Automatic black box model identification
4. Experimental results
5. Conclusion & future work

Towards Autonomic management



Overview of our global approach



Automatic black box model identification

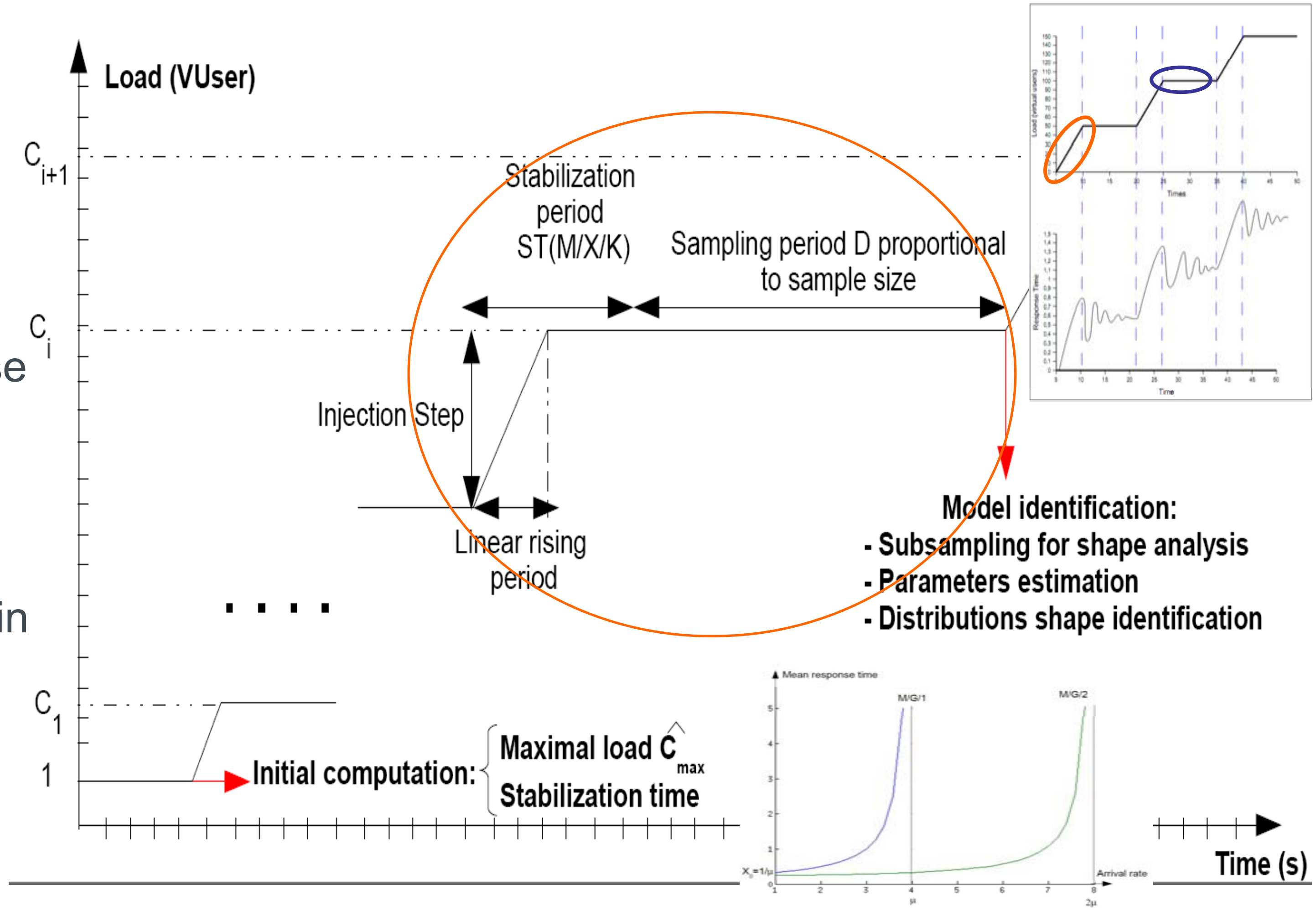
Goal: Capture the complete behavior of a black box and limit points

Principle

1. Several automatic load injection steps.

2. Start with a low injected load, increase load until black box saturation.

3. Collect measures in each step (response times, resources utilization), deduce a queueing model



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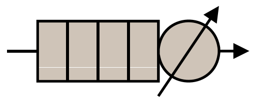
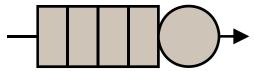
Modeling :

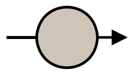
- Load-dependent black boxes : Queuing and service times depend on the load.



- Load-independent black boxes : The service time does not depend on the load.



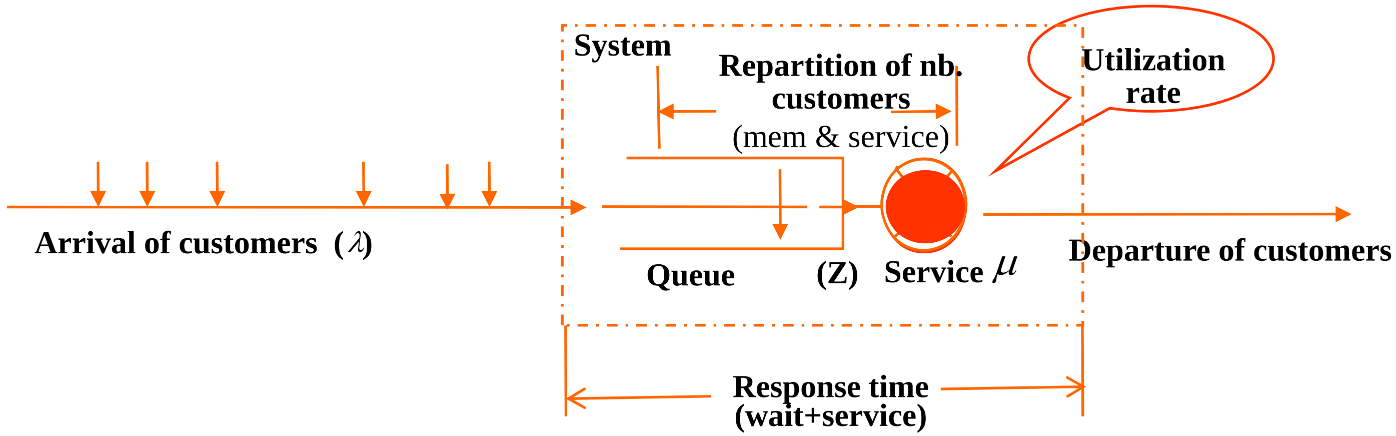
- Constant delay black boxes : Service time does not depend on the load and there is no queuing



We define the type of each black box according to the test results

Queuing models

Queue with 1 server



λ = **arrival rate of customers** : mean *number of arrivals per time unit*

μ = **service** rate : mean *number of served customers per time unit*

Z = scheduling **policy** : *FIFO, PS, RR, random, …*

Queue model : **T / X / m / K / Z**

Interarrival time distribution

Service time distribution

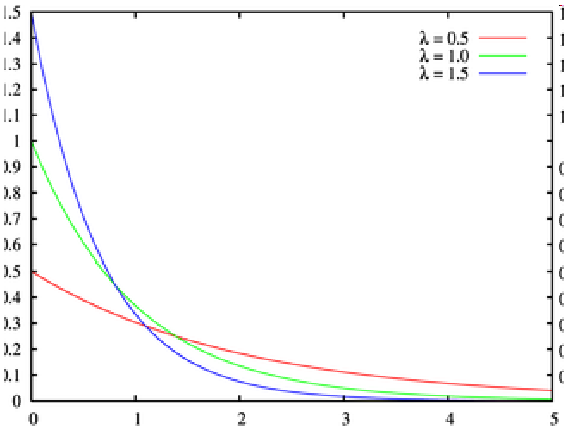
Queue Capacity

Number of servers

Queueing models

- <u>M/M/K model</u> : Inter-arrivals *Exponential(λ)*, Service *Exponential(μ)*, Infinite Capacity, K servers, *FIFO* → Analyzable by MVA algorithm

Exponential distribution (λ)



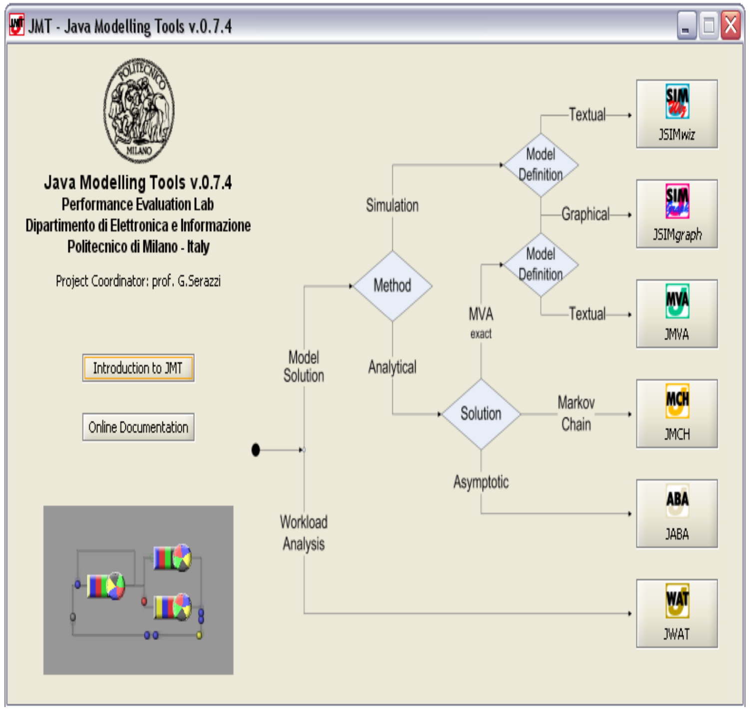
$$\text{Prob}\{T \le t\} = 1 - e^{-\mu t}, \quad t \ge 0$$

- <u>M/G/K model</u> : Inter-arrivals *Exponential(λ)*, *General* service, Infinite capacity, K servers, *FIFO* → Analyzable by R. Marie Algorithm

- <u>G/G/K model</u> : *General* Inter-arrivals, *General* service, Infinite capacity, K servers, *FIFO* →Simulable

Java Modelling Tool (JMT)

- Suite of tools developed by Politecnico di Milano, 2006 -2009



- Six Java applications:

1. JSIMGraph, JSIMWiz: QN models designer/simulator (graphical/ Wizard interface)

2. JMVA: Mean Value Analysis of BCMP compliant QN models

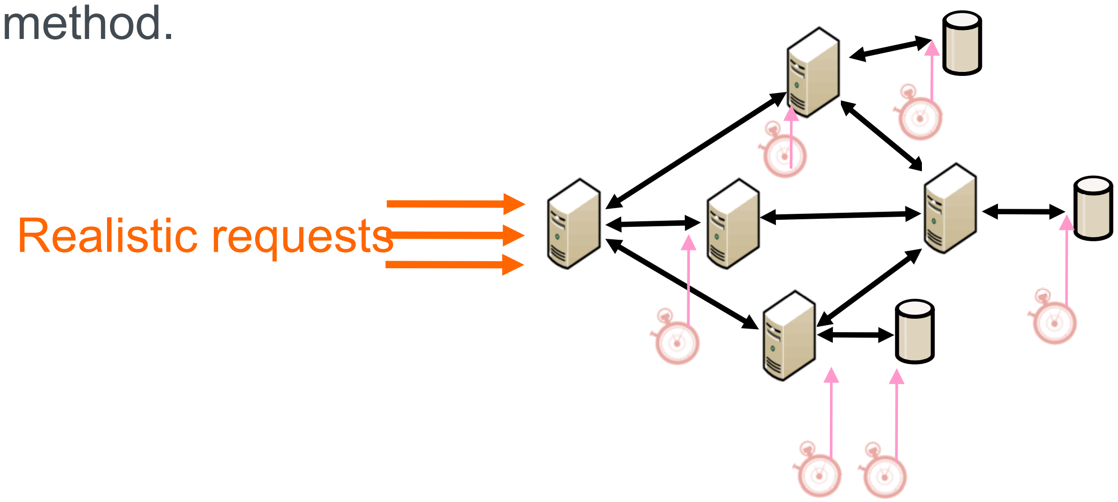
3. JABA: asymptotic analysis of QN models for identification of the bottlenecks

4. JWAT: Workload Analysis from log/ used data

5. JMCH : Markov chain (M/M/1, M/M/1/K models) simulator

Inter-arrival times distribution

- Collect arrival times of submitted requests
- Deduce the inter-arrival sample,
- Identify the shape of the inter-arrival sample →
  - use statistical tests against several distribution families: exponential, heavy-tail, etc (Kolmogorov-Smirnov test).
  - Keep distributions whose p-value > 0.1
  - Estimate distribution parameters with the Maximum likelihood estimator method.



Service time distribution

- Inject load requests with exponential inter-arrivals.
- Collect response times (R_k), inter-arrival times (t_k) and utilization of all resources (U).
- Inferring service times $(X_k)_{1 \leq k \leq n}$

$$\begin{cases} R_k = [R_{k-1} - t_k]^+ + X_k & \text{1 server} \\ R_k = [R_j - t_{j,k}]^+ + X_k & \text{Several servers} \end{cases}$$

- Identify the shape of the service time sample with Kolmogorov-Smirnov tests.

- Validation : Compare empirical measures with theoretical ones
  - mean response time,
  - mean waiting time bound

Number of servers (K)

- $Cmax = Cmax_0$, $K=1$
- Iterate until saturation
  - When reaching the maximal load Cmax, check the utilization of all black box resources.

    If , for all resource, $U < 1$

    $K=K+1;$

    $Cmax = Cmax_0 * K$

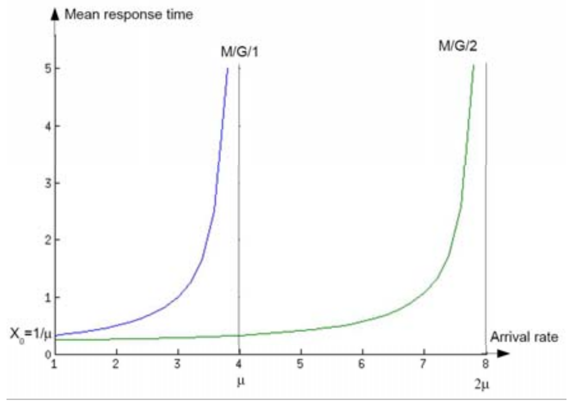
  - If, for a resource, $U \approx 1$

  Stop injection experiment,

  K = last identified value

Achieving self-regulated injection

1. Injection policy



- Initial maximal load Cmax = 1/ $\overline{R}$

  (R: response time measures sample)

- Injection step, Rising period
- Sampling period: Number of measures *n* >= $\left(\frac{100 z \sigma_n}{r\bar{m}}\right)^2$

2. Estimation of the stabilization time

Stabilization time = convergence time of the queue Markov chain

(Restriction to Engset models)

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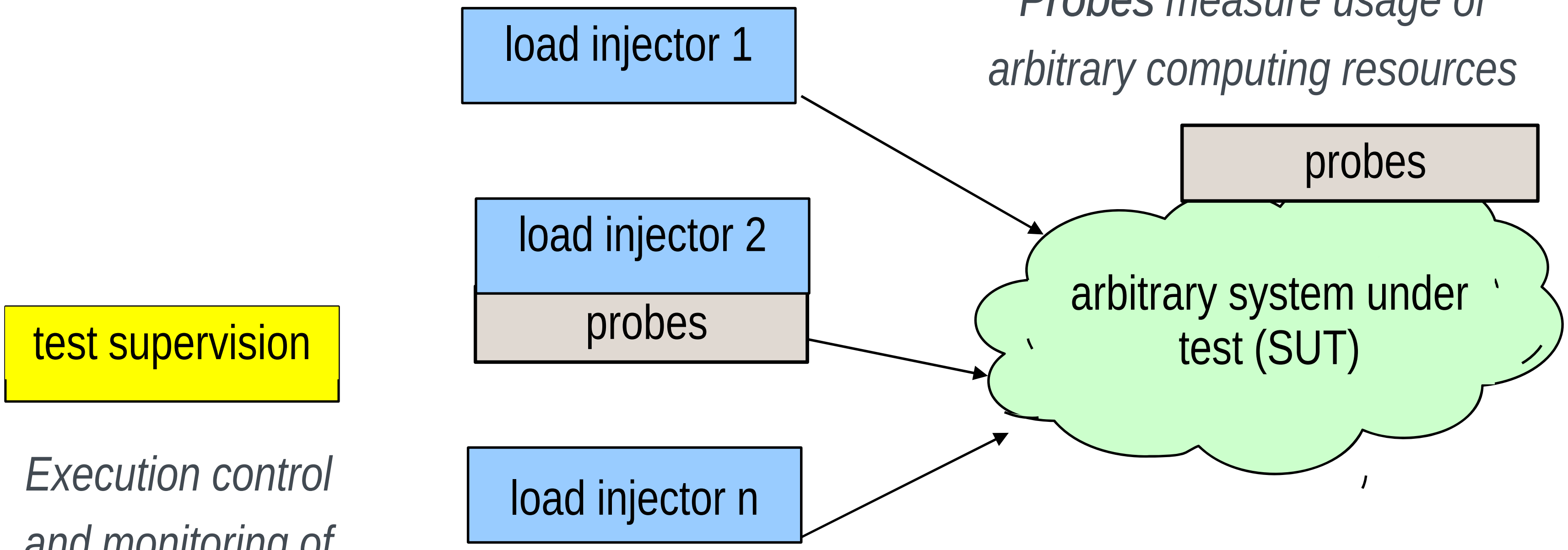
CLIF Load Injection Framework



Probes measure usage of arbitrary computing resources

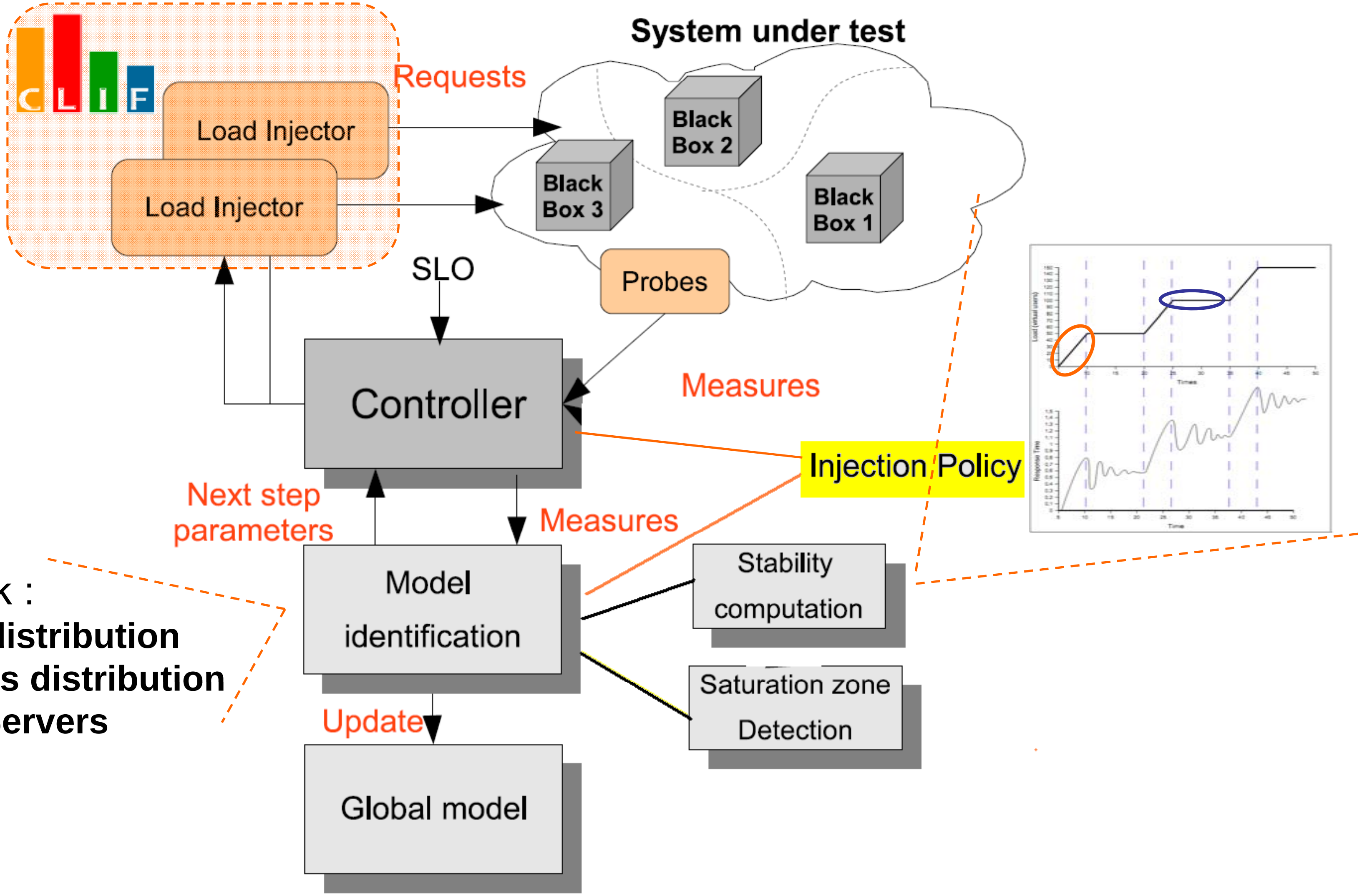
Execution control and monitoring of load injectors and resource probes.

Load injectors :

- *send requests, wait for replies, measure response times*
- *according to a given scenario*
- *for example, emulating the load of a number of real users (through so-called virtual users)*

Architecture of FAMI

(Framework for Automatic Modelling Identification)



Model T/X/k :
- **Interarrival distribution**
- **Service times distribution**
- **Number of Servers**

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Experimental results

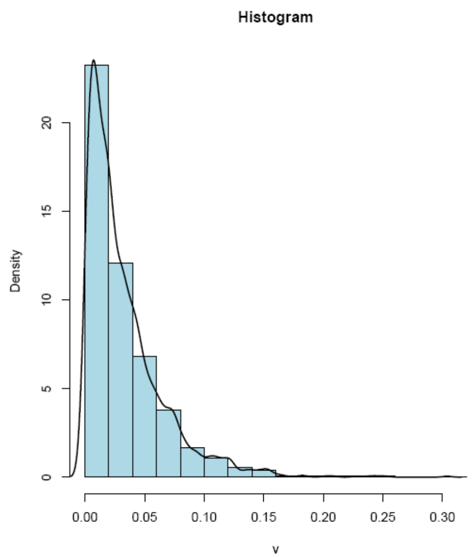
- Test-bed: Rubis Web-based application, workstation with 2 PIII 1.4Ghz, 1GO RAM.
- Injector Machine: workstation with quadri-processor Xeon 2Ghz, 2GO RAM.

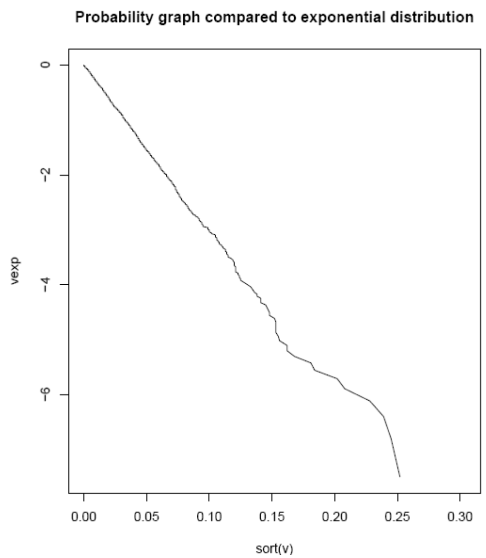
- 1st injection step
  - Average service time: $X_0 = 0.021$ s
  - Theoretical stabilization time = 0.043s
  - $Cmax_0 = 45.30$ Virtual users (requests)/s

- After 27 minutes of the experiment (12 steps), we reached
  - Number of virtual users = 120 vusers
  - Saturated resource : CPU → CPU load = 96%

Experimental results

Inter-arrival times distribution





CV^2=1.015 with a 95% confidence interval

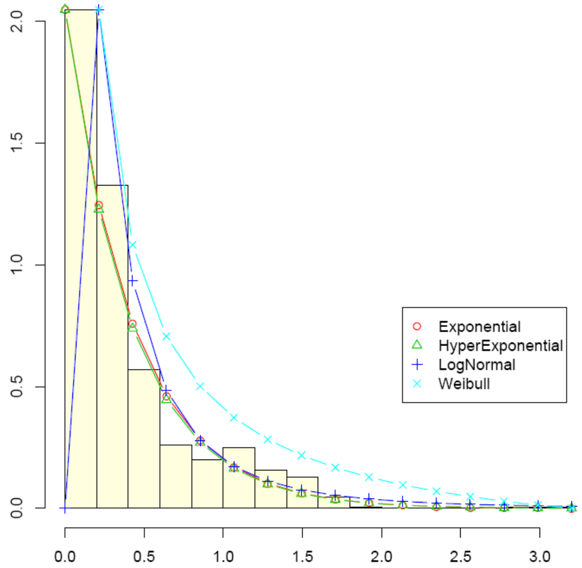
cv^2 → a possible fitness to an exponential distribution

λ =30.34 req/s

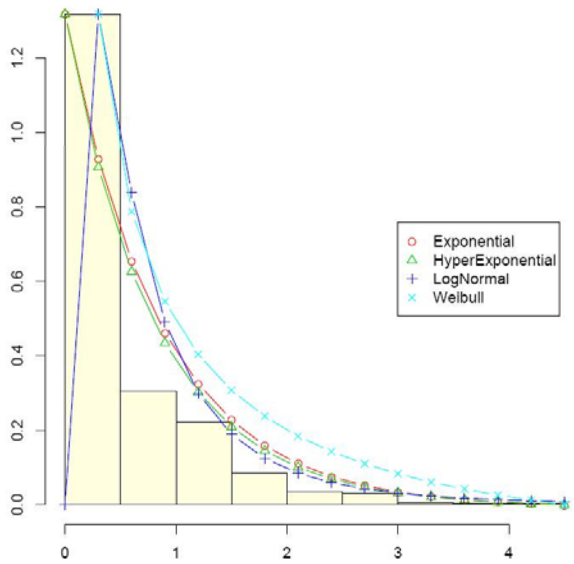
Kolmogorov-Smirnov test : p-value=0.59

Experimental results

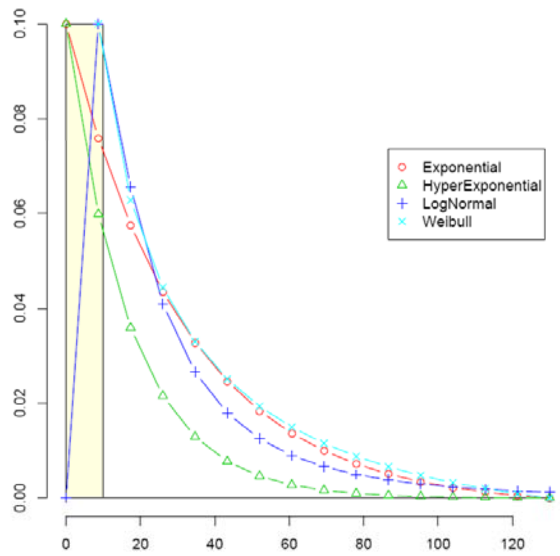
Service times distribution



80 Vusers



100 Vusers



120 Vusers

Identified distributions: Exponential (M), Lognormal (LN), Hyperexponential (Hr), Gamma (Γ), Weibull (Weib)

Experimental results

Identified Queue models

Load	Identified Model(s)	Parameters	Mean	CV^2
10	-	-	0.02	0.03
20	**M/LN/1**, $M/\Gamma/1$	$\lambda = 20,\ \mu = -3.80,\ \sigma = 0.20$	0.02	0.04
30	**M/LN/1**, $M/\Gamma/1$	$\lambda = 30,\ \mu = -3.71,\ \sigma = 0.30$	0.03	0.11
40	**M/LN/1**	$\lambda = 40,\ \mu = -3.52,\ \sigma = 0.51$	0.04	0.90
50	**M/LN/2**, $M/\Gamma/2$	$\lambda = 50,\ \mu = -3.44,\ \sigma = 0.51$	0.04	0.74
60	**M/LN/2**	$\lambda = 60,\ \mu = -3.00,\ \sigma = 0.89$	0.08	2.18
70	**M/M/2**, M/Hr(2)/2, M/LN/2, M/Weib/2	$\lambda = 70,\ \mu = 5.26$	0.19	1.96
80	**M/M/2**, M/Hr(2)/2, M/LN/2, M/Weib/2	$\lambda = 80,\ \mu = 2.48$	0.40	1.03
90	**M/M/2**, M/Hr(2)/2, M/LN/2, M/Weib/2	$\lambda = 90,\ \mu = 1.75$	0.57	1.46
100	**M/M/3**, M/Hr(2)/3, M/LN/3, M/Weib/3	$\lambda = 100,\ \mu = 1.73$	0.58	1.07
110	**M/M/3**, M/Hr(2)/3, M/LN/3, M/Weib/3	$\lambda = 110,\ \mu = 0.96$	1.04	23.90
120	M/M/3, **M/Hr(2)/3**, M/LN/3, M/Weib/3	$\lambda = 120,\ \mu_1 = 0.1321,\ \mu_1 = 2.5624$	9.72	0.74

Light load : M/LN/K model

Heavy load : M/M/K model

Conclusion

- Automatic performance modelling process of black boxes, based on a self regulated load injection testing and a theoretical approach.

- Benefit: performance prediction of an assembly of black boxes, useful when applying autonomic features.

- Development of a framework, FAMI, based on CLIF, which delivers a set of queue models for a range of workload.

- Difficulties:
  - Isolating a black box.
  - Configuration options necessary to test a black box (maximum connections, concurrent threads, ...).

Future work

- Improve the computation time of the stabilization time.
- Integrate, in the FAMI framework, a performance analysis/simulation tool.
- Instantiate the obtained FAMI framework to achieve self-sizing feature.

Thank you for your attention