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Formal Techniques for Simulations of Distributed Web System Models

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Approaches

(Alba, A., Czachorski, T., Kounev, S., Li, Z., Requeno, J., Bennaceur, W., Vu, D., Xiong, X., Zatwarnicki, K., Zhou, J.)

We can not always add more and more new devices to improve performance, because the initial and maintenance cost will become too high. Power consumption depends on the load and on the number of running nodes in the cluster-based distributed Web system.

The question:

What is the performance of the system?

The main aim of the work was to develop models of cluster-based distributed Web system.

The related works can be divided into publications based on analysis of QN and PN models.

Computer system (experiments) and performance model (simulations)

Workload
⇓

Configuration parameters
⇓

Computer system
⇓
Measured performance parameters

Workload model
⇓

Configuration parameters
⇓

Performance model
⇓
Calculated performance parameters (response time)

Rak, T.: Response Time Analysis of Distributed Web Systems Using QPNs. Mathematical Problems in Engineering (2015) 1–10

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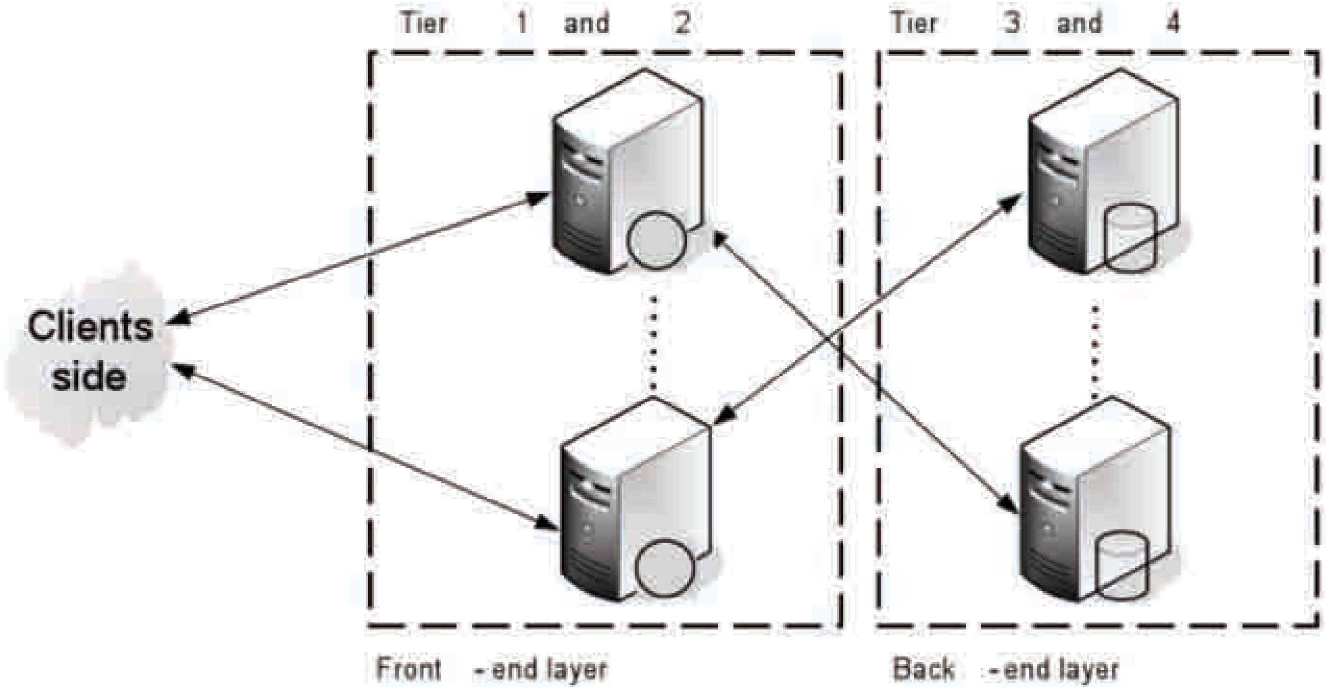
Model of the system



Two-layers architecture.

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My approach joins LT and PE

- Educated Guess
- Load Testing (LT)
- Performance Engineering (PE) models (provide some recommendations to realize the required performance level):
  - Performance model (used to predict performance of the system under study)
  - Availability model
  - Reliability model
  - Cost model

Rak, T., Werewka, J.: Performance analysis of interactive internet systems for a class of systems with dynamically changing offers. Lecture Notes in Computer Science, vol. 7054, Springer (2012) 109–123

Queueing Nets and Petri Nets

QNs – quantitative analysis

Queueing Nets have queues, scheduling disciplines and are suitable for modeling competition of equipment.

PNs – qualitative analysis

Petri Nets have tokens representing the tasks and are suitable for modeling software.

QNs

- Arrival process[1] e.g. Poisson, Erlang, Hyper-exponential, General
- Service process is the time which each request spends at the station e.g. Logarithmic, Chi-square, Hyper-exponential, Exponential[2]; Service times are Independent and Identically Distributed
- Scheduling strategies (queueing disciplines) e.g.: First In First Out (FIFO), Last In First Out, Last In First Out with Preempt and Resume, Round Robin with a fixed quantum, Small Quantum $\Rightarrow$ Processor Sharing (PS), Infinite Server (IS) = fixed delay[3]
- Number of servers[4]
- Number of buffers (waiting room size[5])

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[1] We analyzed closed queueing networks.

[2] We analyzed queueing systems with the exponential clients' service process.

[3] We used IS for clients station, PS for FE servers and FIFO for BE server.

[4] This model considers a single server queue.

[5] Size of the queue is infinite.

PNs

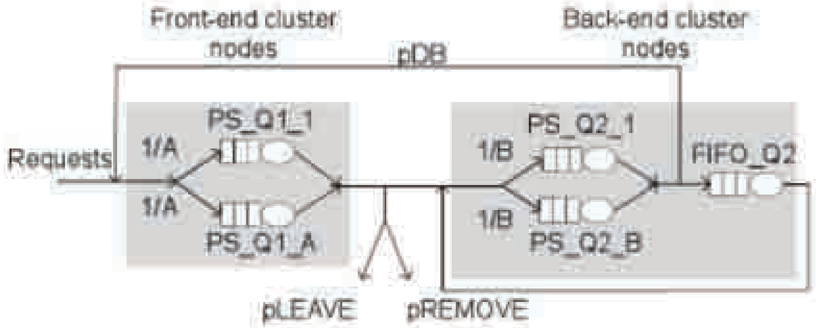
- Set of places
- Set of transitions
- Token color function[6]
- Incidence function (routing probability[7]) assigns natural numbers to arcs (weights of arcs)
- Initial marking[8] (number of tokens)

[6] It specifies the types of tokens that can reside in the place and allow transitions to fire in different modes.

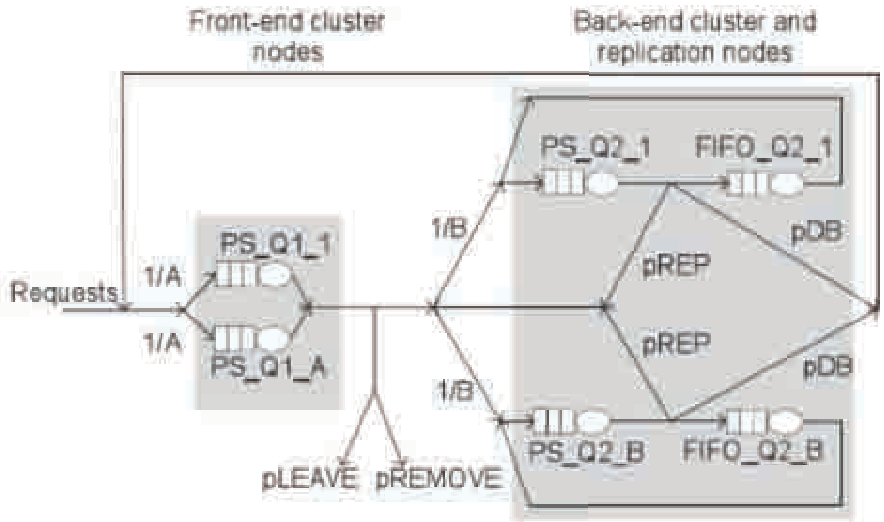
[7] Routing of clients contains all system resources in both layers.

[8] It specifies how many tokens are contained in each place.

Models in CSIM



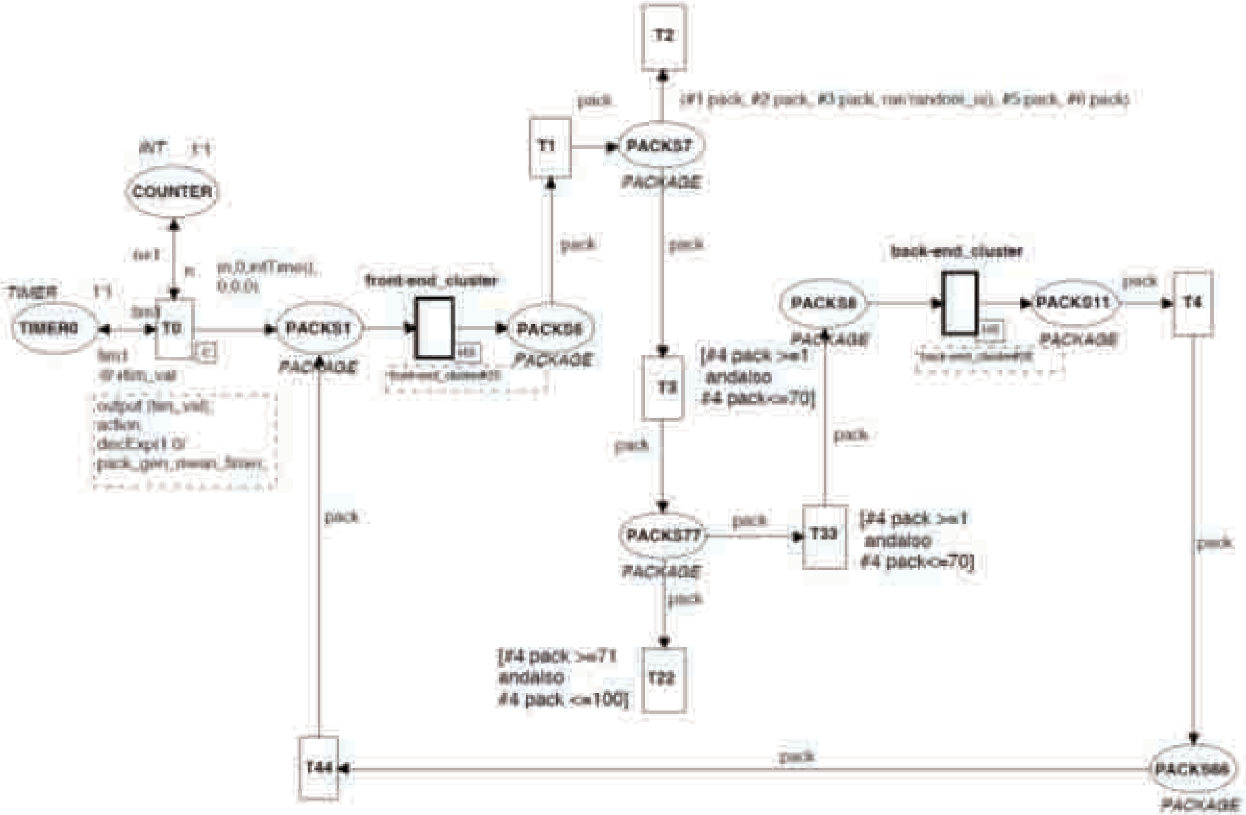
a)

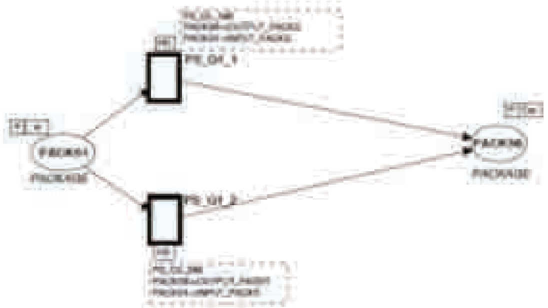


b)

Queuing model with clusters in both layers: a) model III, b) model IV.

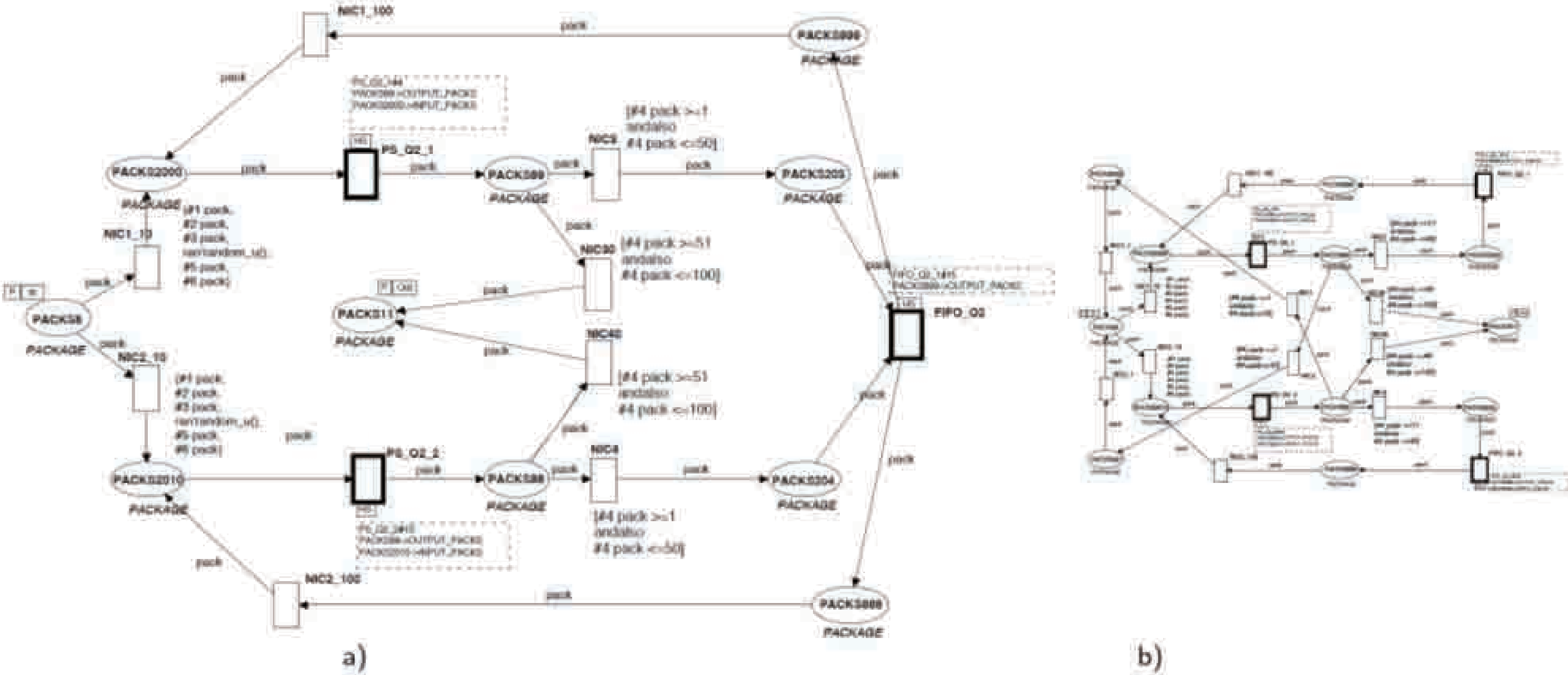
Models in TCPNs (1)





Net models III and IV based on TCPN: a) main page, b) sub-page (front-end).

Models in TCPNs (2)



Net models based on TCPN: a) sub-page with the back-end layer - model III (example), b) sub-page with the back-end layer - model IV (example).

The configuration

- $A = 4$ and $B = 2$,
- $\lambda = 100, 300, 500[1/s]$,
- the same service values for all queues $\mu = 100[1/s]$,
- $TQ = 0.0001[s]$,
- queues - $M/M/1/PS/\infty$ and $M/M/1/FIFO/\infty$,
- flow probabilities - $pLEAVE = 30\%$, $pREMOVE = 30\%$ and $pDB = 55\%$,
- simulation time in all cases $100000[s]$.
- $m = 1$.

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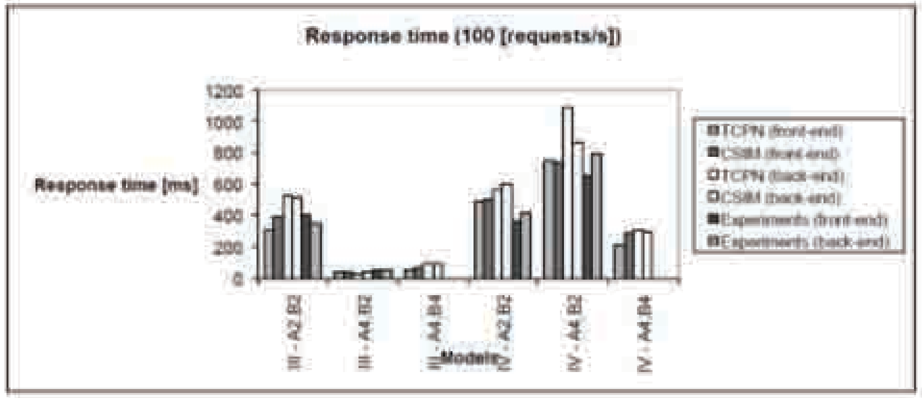
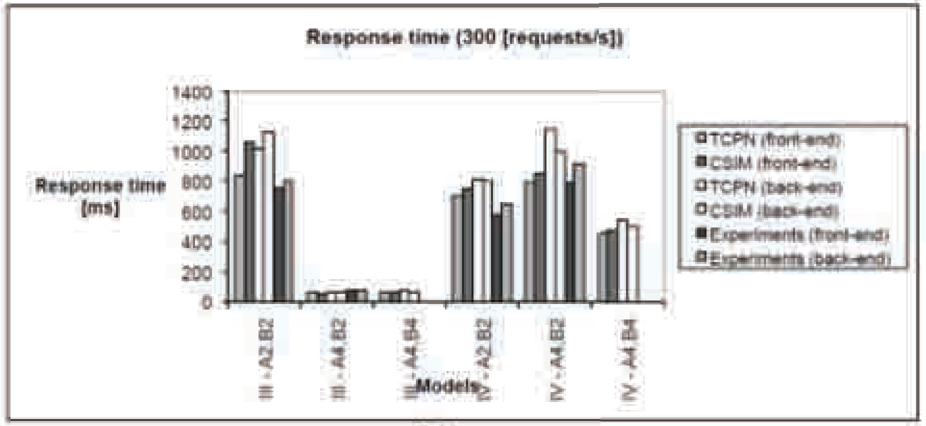
Response time

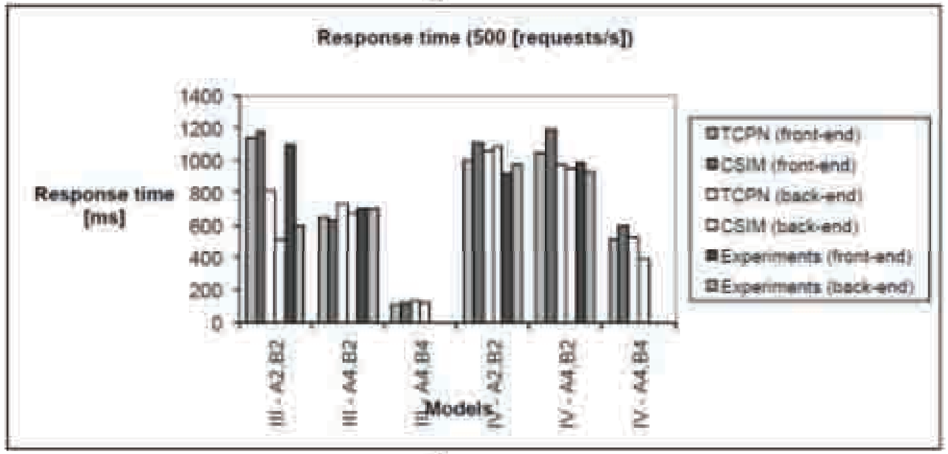
Comparing the results of TCPN simulation models and experiments resulted in errors (III and IV): 13.9% and 14.9%.
Comparing the results of CSIM simulation models and experiments resulted in errors (III and IV): 14.3% and 16.6%.



a)



b)



c)

Comparison of response times simulations and experiments results for an average response time [ms]: a) 100[requests/s], b) 300[requests/s] and c) 500[requests/s] as well as

Conclusions

Convergence of simulation results with the real system results confirms correctness

- We can use this analysis to apply the modification of the system without interfering into the system construction or into software (main achievement)
- It is possible to analyze the compromise between perceived average response time and energy consumption by nodes in the system (practical value)
- The average error between simulation results for all cases is about 15%
- TCPN and CSIM simulation results confirm the convergence of models and the possibility to use them in practice

Daniel A. Menascé

"Verify and validate the models (...) a certain acceptable mergin of error (...) resource utilizations within 10%, system throughput within 10%, and response time within 20% are consideren acceptable."

Formal Techniques for Simulations of Distributed Web System Models

Thank you for your attention!

> Suppose one of you wants to build a tower. Won't you first sit down and estimate the cost to see if you have enough money to complete it? – The Bible, Luke 14:28