Cluster-based Web System Models for Different Classes of Clients in QPN

Tomasz RAK

Department of Computer and Control Engineering
Rzeszow University of Technology

Two client classes.

RZESZOW UNIVERSITY OF TECHNOLOGY

Table of contents

Table of contents

Approaches
(Chen, X., Kounev, S., Koziolek, H., Meier, P., Rathfelder, C., Spinner, S., 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 ⇓	Workload model ⇓	Configuration parameters ⇓

Computer system	Performance model
⇓	⇓
Measured performance parameters	Calculated performance parameters

Performance metrics e.g.: throughput, response time.

Table of contents

Multi-Layered Laboratory Environment

Server/Parameters	Experiment
"Clients"	10.10.10.1
GlassFish AS nodes	10.10.10.4-5
Oracle DBS node	10.10.10.2
AS threads pool	30 per node
DBS connections pool	40
Number of RPS	15-60
Number of clients	500
Experiment time [s]	300

Application has all important functionalities for online stock trading system.

Rak, T.: Performance Modeling Using Queueing Petri Nets. In Gaj, P., Kwiecień, A., Sawicki, M., eds.: Computer Networks, Cham, Springer International Publishing (2017) 321–335

Transaction emulates a specific kind of client session.

Table of contents

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

Daniel A. Menascé

"PE analyzes the expected performance characteristics of a system during the different phases of its life cycle."

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.

QPNs add queueing and time aspects to the net

Queueing Petri Nets have the advantages of QNs (e.g., evaluation of the system performance, the network efficiency) and PNs (e.g., logical assessment of the system correctness). QPNs integrate hardware and software aspects of the system behaviour into the same model.

QNs

- Arrival process[1] e.g. Poisson, Erlang, Hyper-exponential, General
- Service process is 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])

[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 single server queue.

[5] Size of the queue is infinite.

PNs

- Set of places
- Set of transitions
- Token color function[6]
- Incidence function (routing[7] probability[8]) assigns natural numbers to arcs (weights of arcs)
- Initial marking[9] (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 class N_1 contains all system resources in both layers. Routing of clients class N_2 contains only resources in FE layer.**

[8] Probability $RO_k(i, i')$ on routing path for one client class is always equal 1, only for resources in FE layer $RO_k(FE, FE\_CPU_n) = 1/3$ because there are three resources $n = 3$ in the FE cluster.

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

Mathematical QPN model

$$QPN = (PL, TR, CO, IN, MA, QU, WE) \quad (1)$$

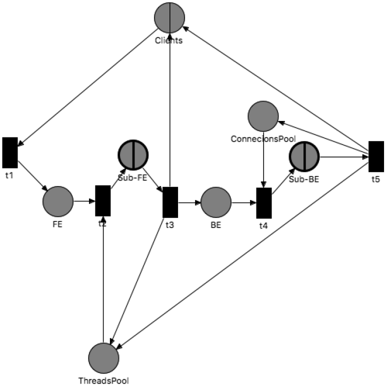
where:

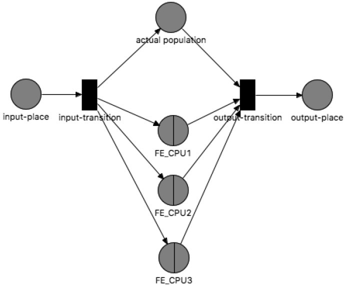
- $PL = \{FE, BE, ThreadsPool, ConnectionsPool\}$,
- $TR = \{t_1, t_2, t_3, t_4, t_5\}$,
- $CO(p_i)$ for $c = \{N_1, N_2, tp, cp\}$, where:
  - N_1 and N_2 - client-classes,
  - tp - threads,
  - cp - connections,
- $IN(p, t)$,
- $MA(p) = \{Clients(250, 250), ThreadsPool(30, 60, 90), ConnectionsPool(40)\}$,
- $QU =$

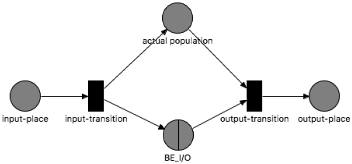
  $(QU_1, QU_2, (-/M/\infty/IS_{Clients}, null, -/M/1/PS_{Sub-FE}, null, -/M/1/FIFO_{Sub-BE}, null, null))$,

  where:
  - $QU_1 = \{Clients, FE\_CPU_n, BE\_I/O\}$, where $n = \{1, 2, 3\}$,
  - $QU_2 = \varnothing$,
- $WE = (WE_1, WE_2)$, where:
  - $WE_1 = \varnothing$,
  - $WE_2 = TR$,
  - $\forall c \in CO(t_j) : w_j(c) := 1$ (all transition firings are equally likely).

Model of the system







QPN net is used to predict the system response time.

Types of queues and tokens

Queues			
Name	Scheduling Strategy	Number Of Servers	Description
QU_Clients	IS	1	Client queue
QU_FE1	PS	1	FE1 queue
QU_FE2	PS	1	FE2 queue
QU_FE3	PS	1	FE3 queue
QU_BE	FCFS	1	BE queue

Colors		
Name	Real Color	Description
N1		FE-BE Requests Class
N2		FE Requests Class
tp		Threads
cp		Connections

- Clients node (*CLIENTS* queueing place) is modeled by queueing place with Infinite Server scheduling strategy (-/M/1/IS/∞ queueing system)
- Nodes of FE layer (*FE_CPU* queueing places) are modeled by queueing places with Processor Sharing scheduling strategy (-/M/1/PS/∞ queueing systems)
- Node of BE layer (*BE_I/O* queueing place) is modeled by queueing place with First In First Out scheduling strategy (-/M/1/FIFO/∞ queueing system)

- Client-classes ($N_1 = (C_j)_1$, $N_2 = (C_{j'})_2$)
- Application server threads *tp*
- Database server connections *cp*

Input parameters of simulations (client and system)

Parameter	One class (N_1)	Two classes (N_1 and N_2)
Clients queueing place	500	250+250[a]
$X_{Clients}$ [RPS]	15; 30; 45; 60	7.5 and 7.5; 15 and 15; 22.5 and 22.5; 30 and 30
ThreadsPool place	30; 60; 90[b]	30; 60; 90
ConnectionsPool place	40[c]	40
Simulation time [s]	300	300

[a] Each request emulates a specific type of client session with multiple round-trips over the system. Transactions are selected by the driver based on the mix (*Browse* 50%, *Purchase* 25% and *Manage* 25%). *Browse* requests are placed in FE layer and *Purchase*/*Manage* requests are placed in FE and BE layer, that why we use 50%/50% division for client-classes (N_1 and N_2).

[b] Threads for FE nodes respectively – Initial marking per node (1, 2, 3).

[c] Connections for BE node – Initial marking per node (1).

Think time (client) and service demand (system) for two client-classes

$(X_{Clients})_k[RPS]$ [a]	$(X_{Clients})_k[RPMS]$ [b]	$TT_k[ms]$
7.5; 7.5	0.0075; 0.0075	133.33; 133.33
15; 15	0.015; 0.015	66.67; 66.67
22.5; 22.5	0.0225; 0.0225	44.44; 44.44
30; 30	0.03; 0.03	33.33; 33.33

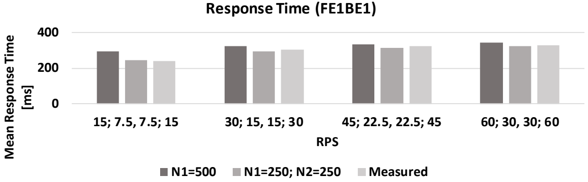
(a) RPS – Requests Per Second.
(b) RPMS – Requests Per MilliSecond.

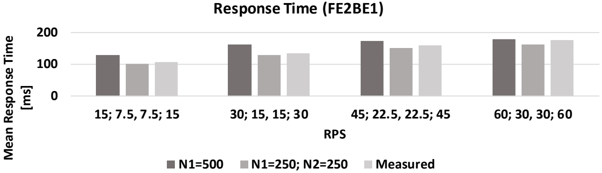
Resource i	$(X_i)_1[RPS]$	$(X_i)_2[RPS]$	$(X_i)_1[RPMS]$	$(X_i)_2[RPMS]$	$(SD_i)_k[ms]$
FE_CPU_n	1,400	1,400	1.4	1.4	0.714
BE_I/O	7,500	7,500	7.5	7.5	0.133

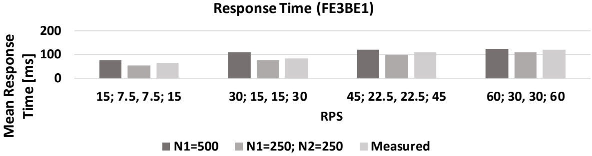
Table of contents

Response time

One class and two classes - one, two and three nodes in FE layer (500 clients, different RPS workload)







Response time error

One class and two classes - one, two and three nodes in FE layer (500 clients, different RPS workload)

Client think time [ms]	Model with one client class [ms]	Model with two client-classes [ms]	Measured [ms]	Error for one client class [%]	Error for two client-classes [%] [a]
133.33 and 133.33	291.14	224.58	241.00	20.63	6.94
66.67 and 66.67	323.46	291.87	303.00	6.55	3.85
44.44 and 44.44	334.45	312.62	321.00	4.16	2.64
33.33 and 33.33	340.31	324.71	330.00	2.98	1.74
133.33 and 133.33	128.58	102.11	106.66	20.55	4.27
66.67 and 66.67	162.36	128.44	135.01	20.26	4.87
44.44 and 44.44	173.49	150.63	159.42	8.83	5.51
33.33 and 33.33	178.48	162.33	175.43	1.74	7.47
133.33 and 133.33	76.46	56.23	65.12	17.41	13.65
66.67 and 66.67	110.32	76.78	85.28	29.36	9.96
44.44 and 44.44	121.23	99.38	110.83	9.38	10.34
33.33 and 33.33	126.59	109.76	120.94	4.68	9.25

[a] For the service response times, the relative prediction error was smaller than 20%

Conclusions

Convergence of simulation results with the real system results confirms correctness

- We can use this analysis to apply the systems modification without interfering into the system construction or into software (main achievement)
- It is possible to analyze the compromise between a perceived average response time and energy consumption by nodes in the system (practical value)
- The modeling approach presented in this paper differs from my previous works where it was based on QNs and Time Coloured PNs
- The modeling approach presented in this paper differs from my last work based on QPNs because the types of tokens (requests classes) were not used earlier

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."

Cluster-based Web System Models for Different Classes of Clients in QPN (CN'19)

Thank you for your attention!

Answer for comment of reviewer:

- The QPN model was simulated using the method of non-overlapping batch means method to estimate steady state mean token residence times. The average predicted response times are within 95[%] confidence interval of the measured average response times. The data reported by SimQPN (QPME) are very stable.

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