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CONTENTS

Analysis of n-Tier Electronic Commerce Architecture Using Different Queuing Models

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Abstract

Electronic Commerce is fetching more endemic as more populace come to recognize its expediency and its ability to proffer a speedy response to requests of the end user. Almost all of the conventional Electronic Commerce architecture is based upon the client-server structure that divulges a certain level of inadequacy on the issues reminiscent of performance and scalability. In this paper, we are particularly concerned about issues of performance to see how well Electronic Commerce architecture works using n-tier phases and evaluated the same using queuing theory. This paper presents a performance analysis of the Electronic Commerce architecture and its mathematical inference for analyzing the performance using three different queuing models, namely, M/G/1, G/M/1 and G/G/1. The paper evaluates the performance of the n-Tier Electronic Commerce architecture on the basis of memory estimation and response time of the end user requests under the high bursty traffic. We are expecting that the estimations should be helpful in the perceptive of the spectrum of impending for the implementation of the architecture in the real-time scenario. Finally, a comparative upshot of performance estimations, and strongly deem that the result is going to be very useful in understanding about blueprint and implementation of n-Tier Electronic Commerce architecture aiming at the very large-scale amalgamation.

Keywords: n-Tier Electronic Commerce (EC) architecture, Queuing theory, M/M/1, M/G/1, G/M/1, G/G/1

1. Introduction

Electronic Commerce, wherein, there is the transaction of tangible stuff and information - is an astoundingly contentious subject. Steven Levy [1] asserts in his article that electronic money and commerce are going to be the factual "killer application" of the Internet. According to [2], in September 2010, 28.8% world population is using Internet, which comprises of 1,971 million users worldwide. Though the computation to locate the number of Internet users seems uncomplicated, but to find the statistics of Electronic Commerce dimensions is difficult, due to the below stated grounds:

1. Different types of Electronic models exist.
2. Goods and services choices, distinctiveness, and prices offered in these types of Electronic Commerce models.
3. Difficulty to trail international transactions (if any); and business costs and productivity for these models.

In this paper, we focused on the commonly adopted architecture used in industries, and have simulated the results using queuing theory. The paper focuses exclusively on the working module based on three aspects of queuing theory, namely, G/M/1, M/G/1 and G/G/1, to find the response time for n-Tier Electronic Commerce architecture, under soaring traffic. It was stalwartly encouraged to use queuing theory rather than "second speculation", because there is less leeway to wallow, as the result the output is calculated through the software developed and implemented in the real-time scenario. We ponder on n-Tier EC Architecture, as this is where the performance is most intricate with multi-tiered software architectural topologies from client tier to web tier, to mid-tier application-server tier, and to the database tier. Each tier in n-Tier EC architecture desires to perform optimally in order to accomplish the paramount overall performance for the complete application.

The rest of this paper is structured as follows. First, we instigate the different types of Electronic Commerce architecture and the relevance of n-Tier architecture over other models. Section 2 elaborates the proposed n-Tier EC architecture. In Section 3, we have specified the rudiments of queuing theory by describing the mathematical assumptions for queuing models in order to intimate the response time for G/M/1, M/G/1 and G/G/1 Queuing models. Section 4 mentions the study for formulating the response time using probabilistic analysis. Section 5 delivers the output of the research conducted for different queue models. Section 6 gives the conclusion.

2. Proposed n-Tier Electronic Commerce Architecture

The early EC architecture was based on 2-tier structure, which consists of two parts are specified in Figure 1.

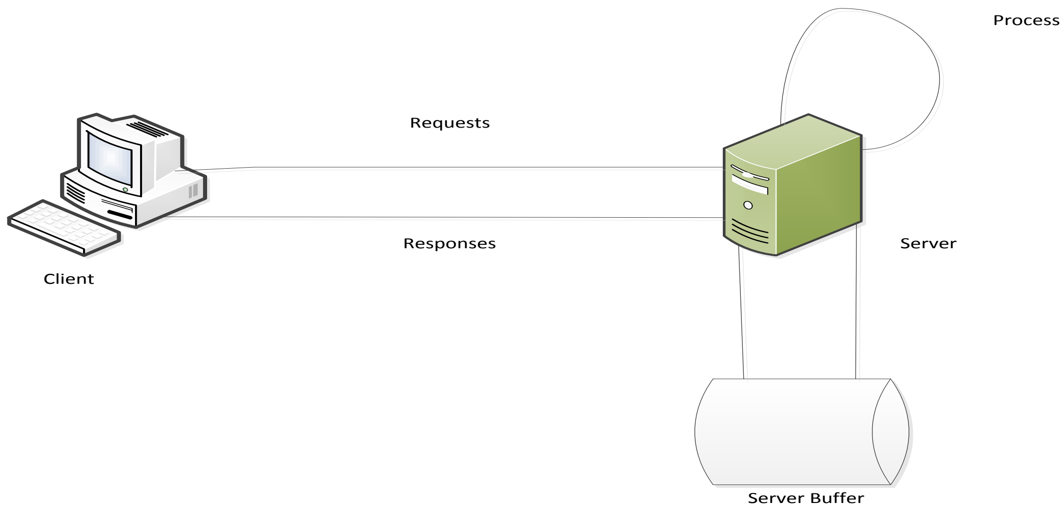

Figure 1: 2-Tier EC architecture

The model mentioned in Figure 1, was well recognized and adopted in business, being more competent by distributing processing among client and server. In the said model, the Client sends request to the server, which gets processed and response is send back to the Client. The quandary arises, when the number of clients' increases, the request has to indefinitely wait in the Server Buffer. To remove this problem, n-Tier EC architecture was proposed as indicated in Figure 2 [3]. It must be noted that in n-Tier EC architecture, the number of Application Server can be more than 2 (up to n, depends on the complexity of the system).

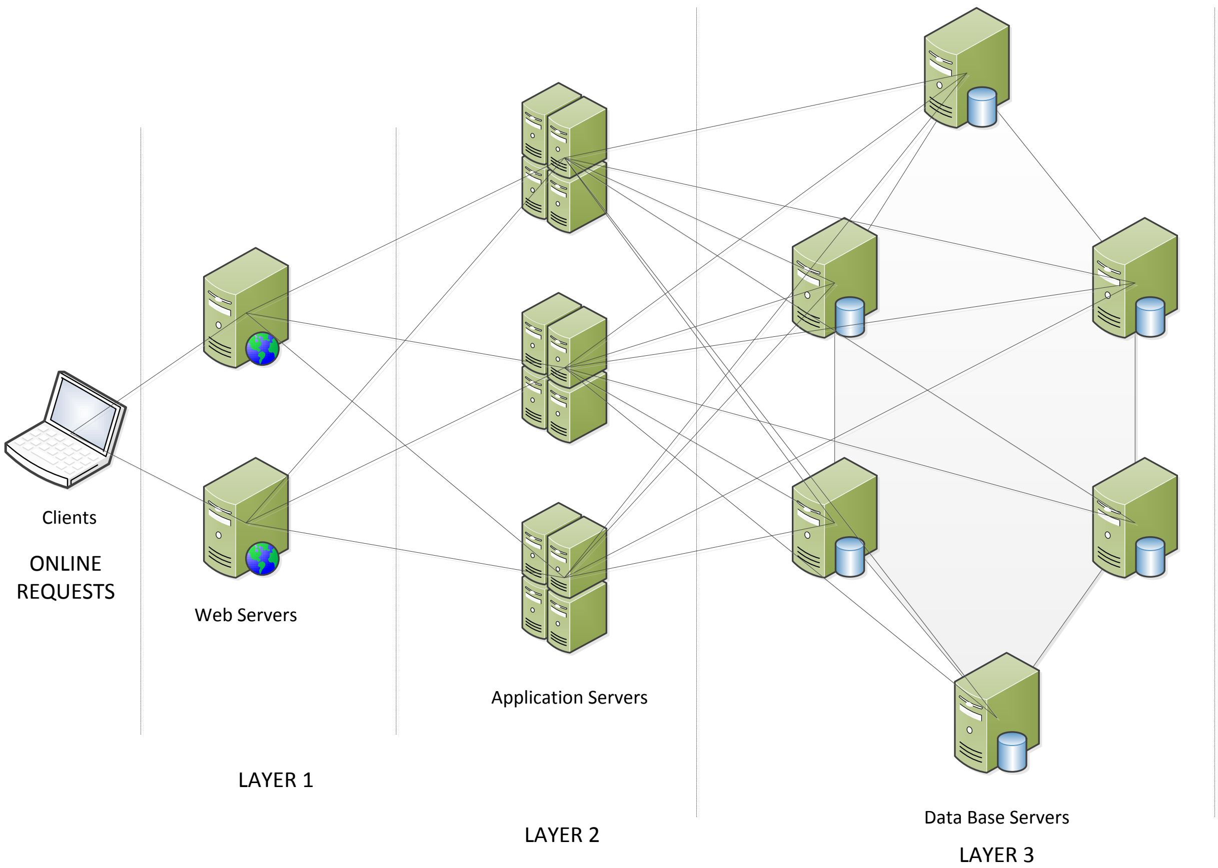

Figure 2: n-Tier Electronic Commerce architecture

For simplicity, a hypothesis that entire development is abridged to a single arrival process and the response is engendered consequently at apiece tier of the EC architecture. In this architecture, Buffer provides podium for each request to reside in it. In the study, all the request and response generated are random; the assessment of throughput is a foremost challenge as [4]:

1) *No data ought to be overflowed / freezed out.*
2) *Ergodic situation needs to be maintained at every Layer.*

These two problems are of foremost substance of the planned study. If we scrutinize Figure 2, the EC architecture bear a resemblance to Queuing theory, it is therefore premeditated to lug out the study by employing Queuing Theory.

3) Mathematical Assumptions for n-Tier EC architecture

It is assumed that the number of requests that disembark at the web server are $R_1, R_2, \ldots\ldots, R_n$. These requests are random in nature and is being denoted by λ . Based on these assumptions, the total number of requests can be mathematically embodied as:

$$\lambda = \frac{R_1 + R_2 + \ldots\ldots + R_n}{T} \qquad (1)$$

These requests are processed at each of the mentioned servers (web server, application server and database server) of the n-Tier EC architecture and is being denoted by μ .

$$\mu = \frac{Rp_1 + Rp_2 + \ldots\ldots + Rp_n}{T} \qquad (2)$$

Based on equations (1) and (2), there are three possible conditions, on which the n-

Tier EC architecture can be based [5].

Condition 1: When $\lambda > \mu$, this case is often referred as *Transient State*. If $\lambda > \mu$, then, there will be overflow of data at the buffer of each server. This makes the system unstable. Hence, under no circumstances λ should be greater than μ.

Condition 2: When $\lambda = \mu$, this case is called as *Null State*. This is a very typical case and randomly occurs. This state is typical used for academic studies only, and, practically, this neither occurs nor is desirable.

Condition 3: When $\lambda < \mu$, this case is termed as *Ergodic State.* If this situation is maintained then there will be finite Response Time of data, which will be needed to be stored at stated server.

4 Analytical study of queue models for estimation of response time

The finite response time is calculated with random arrival of data at the web server in the n-Tier proposed EC architecture. In the present study, when a very huge amount of data is arriving at the Web Server, and very huge random departure occurs, problem becomes very complicated to be solved analytically. This problem gets further complicated when the data arrives to the Web Server from different channels at different rates. Had it been arriving from a single channel and departing through another single channel, the queuing model would have been proximated to $M/M/1$, where first M describes the arrival process to be Markovian. Markovian arrival process is nothing but Poisson arrival where inter-arrival distribution is negative exponential. The second M, describes the departure process with processing unit 1. In case of multi-arrival channels, this assumption does not fit in. The most effective distribution can be considered for the process of arrival or departure to be a general distribution. On such cases, the queue model becomes $G/M/1$ and $M/G/1$. However, if arrival or departures both are considered multi-channel, which is the present day working of Internet, the appropriate model becomes $G/G/1$. Hence, the most suitable study should be to compute the Queuing parameters of all the four models and then choose the worst case providing safest and stable working. It is worth to repeat that $M/M/1$ queue model have been analytically studied for the estimation of average response time. However, in case of general distribution, it is very complicated to compute the queuing parameters mathematically. Therefore various queue models, namely, $G/M/1$, $M/G/1$ and $G/G/1$ are taken into consideration for the arrival and departure time by simulating the model on computer and compute the average response time.

4.1 Response time formulation

For estimation of probability of "n" data in the Server(s) Buffer, certain assumptions are to be made. This can be given as follows [6]:

1) Δt is a very small time, in which only one process can occur, i.e., either arrival or departure of data.
2) The Ergodic state is maintained throughout the study.
3) The state of arrival is λ and state of departure is μ.

Probability of one arrival = $\lambda\Delta t$

and, probability of one departure = $\mu\Delta t$

Then, Probability of no arrival = $1-\lambda\Delta t$

and, Probability of no departure = $1-\mu\Delta t$

Now, consider that there are "n" data present at any time "t". This, will be represented by $P_n(t)$. If the time is increased from "t" to "$t+\Delta t$" and at the end of this time, let the data present is "n". Then, this state can be arrived at from the states as given below:

$$P_n(t+\Delta t)=\begin{cases} P_n(t).(1-\lambda\Delta t).(1-\mu\Delta t) \\ P_{n+1}(t).\mu\Delta t \\ P_{n-1}(t).\lambda\Delta t \end{cases} \quad (3)$$

or,

$$P_n(t+\Delta t)=P_n(t).(1-\lambda\Delta t)(1-\mu\Delta t)+P_{n-1}(t).\lambda\Delta t+P_{n+1}(t).\mu\Delta t \quad (4)$$

or,

$$\frac{P_0(t+\Delta t)-P_0(t)}{\Delta t}=-\lambda P_n(t)-\mu P_n(t)+\lambda P_{n-1}(t)+\mu P_{n+1}(t) \quad (5)$$

But,

$$\frac{Lim}{\Delta t\to 0}\left\{\frac{P_n(t+\Delta t)-P_n(t)}{\Delta t)}\right\}=\frac{d}{dt}\ P_n(t)=0 \quad \textit{for stable condition}$$

Thus, the R.H.S. of eq. (5) becomes

$$P_{n-1}(t).\lambda-(\lambda+\mu).P_n(t)+P_{n+1}(t).\mu=0 \quad (6)$$

To solve, eq. (6), we need to consider the initial condition, i.e., there is 0 (nil) presence of data at time (t+Δt) in Queue. This can be obtained from the states as given under:

$$P_0(t+\Delta t)=P_0(t).(1-\lambda.\Delta t) \quad =P_1(t).\mu\Delta t$$
$$=P_0(t)(1-\lambda\Delta t)+P_1(t)\mu\Delta t$$

$$\left(\frac{(P_n(t+\Delta t)-P_n(t)}{\Delta t}\right)=-P_0(t)\lambda+P_1(t).\mu \quad (7)$$

Thus, L.H.S. of eq. (7) becomes

$$\frac{Lim}{\Delta t\to 0}\left\{\frac{(P_n(t+\Delta t)-P_n(t)}{\Delta t}\right\}$$

$$\frac{d}{dt}\ P_0(t)\ =0,\ \textit{at stable state} \quad (8)$$

Hence, eq. (8) becomes

$$P_1(t)=\ {}^{\lambda}\!/_{\mu}\ .P_0(t) \quad (9)$$

From eq. (6) and eq. (9), following can be easily derived as:

$$P_0(t)=\ {}^{\lambda}\!/_{\mu}{}^{0}\ .P_0(t)$$
$$P_1(t)=\ {}^{\lambda}\!/_{\mu}{}^{1}\ .P_0(t)$$
$$P_2(t)=\ {}^{\lambda}\!/_{\mu}{}^{2}\ .P_0(t)$$
$$P_3(t)=\ {}^{\lambda}\!/_{\mu}{}^{3}\ .P_0(t) \quad (10)$$
$$\vdots$$
$$P_n(t)=\ {}^{\lambda}\!/_{\mu}{}^{n}\ .P_0(t)$$

Summation of all the equations in eq. (10) is given as under:

$$\sum_{i=0}^{n}P_i(t)=\ (\lambda/\mu)^0+(\lambda/\mu)^1+(\lambda/\mu)^2..........+(\lambda/\mu)^n\ \ P_0(t) \quad (11)$$

Based on limiting condition, when $n\to\infty$, and ${}^{\lambda}\!/_{\mu}<1$, L.H.S. becomes 1 and R.H.S. becomes $\left[{}^{1}\!\Big/_{1-{}^{\lambda}\!/_{\mu}}\right]P_0(t)$

Thus eq. (10) becomes

$$1=\left[\frac{1}{1-{}^{\lambda}\!/_{\mu}}\right]P_0(t) \quad (12)$$

If eq. (11) is substituted in eq. (10), then [7]

$$P_n(t) = \left(\lambda/\mu\right)^n \left(1-\lambda/\mu\right) \quad \textbf{\textit{(13)}}$$

Hence, the probability for the presence of "n" data can be computed at any time "t" provided rate of arrival and rate of departure at the Gateway Server is known.

4.2 Estimation of Response Time

In the previous section, the probability density function for the existence of "n" data has been derived as:

$$P_n(t) = \left(\lambda/\mu\right)^n \left(1-\lambda/\mu\right) \quad \textbf{\textit{(14)}}$$

For variable "n" the average value can be written as:

$$Q(n) = \sum_{n\to\infty}^{N} nP_n(t) \quad = \sum_{n\to\infty}^{N} \left(\lambda/\mu\right)^n \left(1-\lambda/\mu\right)$$

$$= \left(1-\lambda/\mu\right) \sum_{n\to\infty}^{N} \left(\lambda/\mu\right)^n$$

$$= \left(1-\lambda/\mu\right) \left\{\lambda/\mu + 2\left(\lambda/\mu\right)^2 + 3\left(\lambda/\mu\right)^3 + \ldots\ldots\ldots\right\}$$

$$= \left(1-\lambda/\mu\right) \left(\lambda/\mu\right) \left\{1 + 2\left(\lambda/\mu\right) + 3\left(\lambda/\mu\right)^2 + \ldots\ldots\ldots\right\}$$

$$= \left(1-\lambda/\mu\right) \left(\lambda/\mu\right) \frac{d}{d\left[\lambda/\mu\right]} \left\{\left(\lambda/\mu\right) + \left(\lambda/\mu\right)^2 + \left(\lambda/\mu\right)^3 + \ldots\ldots\right\}$$

$$= \left(1-\lambda/\mu\right) \left(\lambda/\mu\right) \frac{d}{d\left[\lambda/\mu\right]} \left\{ \frac{\lambda/\mu}{1-\lambda/\mu} \right\}$$

$$= \left(1-\lambda/\mu\right) \left(\lambda/\mu\right) \left(\frac{\left(1-\lambda/\mu + \lambda/\mu\right)}{\left(1-\lambda/\mu\right)^2} \right)$$

$$= \frac{\lambda/\mu}{1-\lambda/\mu} \quad \textbf{\textit{(15)}}$$

[8][9][10]

The eq. (15) measures the average value of response time for the proposed n-Tier Electronic Commerce architecture. .

5 Experiment using Queuing Models

Three different Kendal Queue models are used for study [11],[12]:

1. $M/G/1$ (Arrival Markovian, Departure General)
2. $G/M/1$ (Arrival General, Departure Markovian)
3. $G/G/1$ (Arrival General, Departure General)

Queue Analysis for all the above three models is necessary to calculate the response time. It must be noted that analytical calculation for M/G/1, G/M/1 or G/G/1 is very complicated. It is therefore proposed to carry out comprehensive study simulation of each model on the computer. It will be General distribution arrival or General distribution departure needs to be studied here, so that, two sets of Strings of size 50000 Bytes be stored in the System. They can be called, $Ar,\ Ar(i),\quad for\ i \in 0\ to\ 50000$ and $Dr,\ Dr(i),\quad for\ i \in 0\ to\ 50000$. These two Strings are used to compute response time for n-Tier EC architecture.

5.1 Computational Results

In cases of simulation study, best results are obtained when entire program are seen at one stretch of time. As random generation is used to be pseudo, hence, manipulation should be carried out for the generation of random number. The results obtained after running the programs are consolidated in the following table.

S.No.	λ	μ	Response time M/M/1	Response time M/G/1	Response time for G/M/1	Response time for G/G/1
1	5000	5001	5000	5102	5098	5538
2	7500	7501	7500	7653	7647	8400
3	10000	10001	10000	10204	10194	11190
4	12500	12501	12500	12755	12740	14126
5	15000	15001	15000	15306	15283	17695

Table 1: ***Response Time Computations***

6 Conclusion

The program developed using Java 7.0 are executed on the computer and the average value of response time for arrival rates in range of 5000-15000 are determined for $M/G/1, G/M/1$ and $G/G/1$ models. It was observed in the experiment that M/G/1 queue model was best suited for lesser number of requests, however, for larger number of requests arriving at the web server, G/M/1 model was the most suitable method. The study will be further conducted for more number of requests arriving at the system.

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