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A New Mathematical Method to Estimate Resources for E-commerce Application

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***Abstract*--Considering convergence of vast and different technologies in new generation networks, the required quality of service is the key success factor. The site implementation according to special benchmarking (TPC-W), to achieve the acceptable service performance may be offered in a cost effective manner, is very complicated.**

In this paper a mathematical method will be introduced to help providers to make informed decisions with respect of right level of resources (number and server capacity, number and power of CPUs, and amount of permanent and temporary memory). The numerical results show that the new formulation confirms the results e-commerce site emulation in an acceptable level.

Keyword- e-commerce, QoS, resource, TPC-W, emulation, mathematical method

I. INTRODUCTION

E-commerce, comprising commercial interactions of goods and services between different parties electronically, is becoming a pervasive way of conducting business.

In order to foster an interest in customers to use the provided services, the desired service quality should be provided because customer dissatisfaction, turn them to other trading competitors [3].

In general a set of core Quality of Service (QoS) properties which are common for various web service applications is defined (Figure1). These set of QoS properties are predefined in detail with all necessary attributes and relationships. Other QoS properties can be defined and added to the ontology according to the requirements of particular applications and domains.

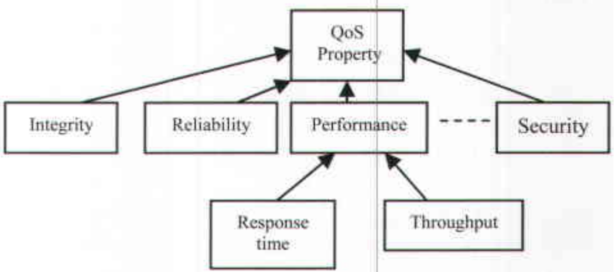

Figure 1: The class hierarchy of QoS properties

Figure1 represents the class hierarchy of some QoS properties. The center of this hierarchy is the class QoS Property. Integrity, Reliability, Performance, and Security are some direct subclasses of the class QoS Property. These classes represent main QoS criteria. Some of them may include several subclasses representing QoS sub-criteria. For example, in e-commerce, quality of service is measured according to the performance of the service. The most important parameters which determine the e-commerce services performance are response time and throughput, which are the parameters will be discussed in this paper. Response time is the interval between the time of sending the first byte of the request and the time of receiving the last byte of the response. Throughput is the average rate of requests which are processed successfully in the time unit.

In e-commerce for supplying services with agreed quality, offering an optimum level of infrastructure resources such as servers, CPUs, interconnections and memories, is a vital factor. Resource provisioning may be guided based on an intuitive or a heuristic expectation of performance. Provisioning based on heuristics and intuition, may lead to more resources than are actually necessary. Clearly providing more resources than needed guarantees interactions quality, but as the expense is an important factor in network designing, especially in trading networks, estimating optimum level of resources is very important. So a quantitative performance estimate may guide the provider in making informed decisions about the right level of resources, so that acceptable service performance may be provided in a cost-effective manner.

Although e-commerce sessions include large amount of requests which are performed according to different sequences, agility and flexibility are major issues to be observed in their infrastructure.

According to wide domain of e-commerce uses in the shape of trade relations, such as business-to-customer, business-to-business, and even business-to-government and also because of complicated specifications of these uses, exact prediction of performance and estimation of necessary resources are not possible and are a challenging topics which requires a systematic performance estimation methodology based on the representation of e-commerce workload.Performance analysis of e-commerce applications may be performed in the view of either service provider or the customer. Parameters such as throughput and resource usage are more important from a provider's perspective, while session length and its availability are important in user's view.

As the virtualization technologies facilitate agile resources provisioning and increase flexibility in network design in order to provide better service qualities and reduce resource estimation risks, emulation of e-commerce applications in smaller dimensions, based on special benchmarking and measuring necessary parameters such as throughput, server capacity, CPU utilization and needed memory, can help to predict a suitable level of resources. One of the most complete and widely used evaluating benchmarks of e-commerce interactions, is TPC-W, which specifies necessary indexes for simulation and performance evaluating parameters .As implementing the TPC-W benchmark, either a distributed application for multi tier architectures or a set of distinct components installed on a single machine, is a complex task and involves managing a wide spectrum of software and communication technologies, it may not be commodious for some small or medium providers to simulate their sites before implementation .So a numerical method which confirms the results of e-commerce site emulations can be used by designers to equip their servers with required level of resources.

In section 2, TPC-W as a benchmark for e-commerce systems is introduced. In sections 3 and 4 the mathematical method for nomination of hardware resources in e-commerce servers is specified and after implementing the obtained formulas in MATLAB platform, three important factors on the server capacity - the number of used CPUs, saturation point and response time- are compared with our simulations and real e-commerce site emulation. Finally, the paper is concluded in section 5.

II. E-COMMERCE BENCHMARK

As mentioned before, emulation of an e-commerce before setting up, and based on a suitable benchmark, can help estimate optimum level of resources. The most current benchmark for e-commerce interactions is TPC-W [8],[9],[11]. TPC is an assembly for creation of standard methods in order to quantitative evaluation of trade interactions performing. In this benchmark, interactions are defined as trading transactions of goods, services or money. TPC-W was defined by this assembly in 2000, for evaluation of performing interactions in e-commerce, through internet. In TPC-W, necessary indexes of an e-commerce and performing evaluation parameters are specified. Main specifications of TPC-W consist of Online and multiple browsing sessions, Creation of dynamic pages with database availability and promotion possibility, Use of secure socket layer (SSL), multiple charts in Database with different measures, attributes and relations and database interaction coordination [10].

A. TPC-W architecture

The structure of TPC-W, like other e-commerce benchmarks, is based on client server model. (Figure 2)

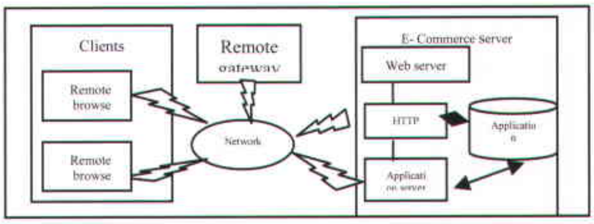

Figure 2. TPC-W architecture [8]

According to Figure 2, clients act functions as remote browser emulators and produce the customers' load in the network.

Payment gateway emulator simulates the entity to authenticate the payments reliability. Web server receives users' requests and leads them towards the application server for necessary processing. Then if required, interactions are guided towards the database server.

The system which consists of HTTP server, web server and application server, relates with users through the network [8].

TPC-W uses a concept of emulated browsers group, for imposing load to the system. A browser is realized as a process or threat that emulates user's relation with system, by sending and receiving HTML content and using HTTP and TCP/IP, through network contacts.

Requests are distinguished by thinking time definition as bellow: $Z=T_2-T_1$

T_1: The time of receiving the last byte of a request by the user
T_2: the time before sending the first byte of the next request by the user

In TPC-W another time named response time is defined as below: WIRT(R) $=T_2-T_1$

T_1: Time of sending the first byte of the request by the user
T_2: Time of receiving the last byte of that request by the user

Response time is an important factor in evaluating the electronic sites and whatever the time is shorter, site's function is better.

The relation of thinking and response time define as formula (1):

$$R = \frac{M}{WIPS} - \overline{Z} \qquad (1)$$

In which $\overline{Z}$ is the average of thinking time, M is the number of emulated browser (EB) and WIPS is Throughput [10].

B. TPC-W Interactions

Interactions in e-commerce are performed according to the users' selections. There are 14 types of interactions or requests In which, the interactions are classified to search or order group [3].

With respect to the portion of buy to search, Three patterns are defined by TPC-W: Web interaction per second (WIPS), Web interaction per second-browsing (WIPSb) and Web interaction per second-ordering (WIPSo).WIPS is the primary group where WIPSb and WIPSo are the secondary ones. Each TPC-W request consists of navigation pattern in which next selected request is specified after current selection. Possibility of transition from request i to request j, can be calculated [3].

III. SERVER PROVISIONING

The key factor in e-commerce success is providing optimum level of resources. In this way, using a quantitative methodology, based on TPC-W and according to requested applications, May be useful but implementing the TPC-W benchmark is a complex and expensive task and it may not be cost effective for some small or medium providers to simulate their sites before implementation. So using a mathematical method which confirms the results of e-commerce site emulations can help designers to predict the required level of resources.

Mostly, architecture of an e-commerce application consists of 3 levels: web server, application server and database server.

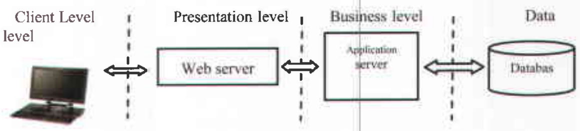

Figure 3. Resources in each level [3]

According to figure 3, considerable resources in each level, are the servers. Number of these resources depends on throughput and type of interactions. So the first step in required resources estimation is correct evaluation of the number of servers in each level. It is performed by throughput specification of each level in this architecture.

A. *Performance analysis*

As explained, considerable resources of each level are the servers. So the first step in resources providing, is prediction the number of required servers. Functional performance analysis, which uses quantitative methods, gives designers the most exact estimation of number of required servers. Performance analysis of e-commerce applications is performable in two views: 1) end user view 2) service provider view. Matrixes like session length and its availability are important in user's view, because they have a direct effect on the user's experience. On the other side, throughput and CPU utilization are very important for service providers. In this paper, resources providing is based on the trade interaction workload and according to server throughput.

Each request throughput is calculated by formula (2) [3][19]:

$$S_j = \sum_{i=0}^{m} \frac{1}{z+R} \pi_{j,i} . N . O_i \qquad (2)$$

That N is the sum of m groups of users and O_i is their distribution, z is thinking time, R is response time and $\pi_{j,i}$ indicates the possibility of each request in steady state.

According to formula (2), throughput of each server is specified by formula (3):

$$S = \sum_{j=1}^{n} S_j \qquad (3)$$

General throughput of each server is specified in formula (4).

$$N_k = \frac{S_k}{C_k} \qquad (4)$$

According to the type of the server, k may be a for application server w for web server and d for database server. C_k is the server capacity.

As it can be seen in formula (4), throughput and server capacity are the factors which determine the number of servers. Each server throughput is the amount of interactions which are referred in the time unit. Although the exact throughput value prediction is impossible, we suppose that a network designer or provider can predict it experimentally so the only factor which is indicator of required servers' number is server capacity.

Each server capacity is defined as the number of interactions which can be processed successfully in the time unit. There are some important parameters which influence server capacity. These parameters can be divided in three main groups; the first one contains the parameters relate each other via formulas directly, such as S=B/C, in which S is the average time of interactions processing, B is the server busy time and C is the number of processed requests. Second group involves parameters relate each other indirectly. It means although there isn't any direct formula between them but the effect of these parameters on each other is undeniable, for example growing up the value of C results in processor usage increasing (while there is no direct formula between them). Finally third group consists of the independent parameters which are chosen by the designer, such as the number of processors and the amount of used memory. These three groups of parameters collected as a table and the relation between them are investigated in our previous paper [19].

According to formula C_P=C/B (C_P is server capacity) if the interactions be processed in shorter time, the capacity of the server will grow up. So increasing the number of processed interactions in time unit (C), or deceasing the required time for request processing (B) is the purpose in server capacity designing. [19]

The most important elements which specify the capacity of the server are the number of used CPUs and amount of the resources such as memory. As mentioned before emulation of e-commerce applications in smaller dimensions is very complicated and expensive so a mathematical method which confirms the results of site emulations can be suitable alternative for hardware resources estimating.

B. *Server Capacity*

In e-commerce system, like other computer systems, obey the queuing networks laws, this kind of networks can be used as a modeling method in these systems.

Generally in queuing networks a set of single or multiple servicing centers and customers are defined. The most important parameters which are investigated for performance evaluating, are incoming requests rate, response time and service time.

The base of the queuing systems is birth-death process in which the birth means entrance and death means exit of one customer(or request).in this system, N indicates the number of users(customers or requests) and t means the time.

There are some points which should be considered in this process:

- If N(t)=n, the remaining time for the next entrance has Poisson distribution with λ_n, n=0,1,2,......
- If N(t)=n, the remaining time for the next exit, has exponential distribution with μ_n, μ=1,2,......

In each time only one entrance or exit happens. The system is analyzed in steady state

State diagram for e-commerce based on the birth-death process is shown in figure4. Generally if the system is in state n, one entrance changes the state to n+1 and one exit changes it to n-1[20]

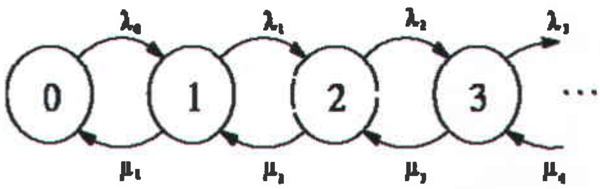

Figure 4. Birth-death process diagram for e-commerce

Generally in birth-death process as the entrance and exit are happened after each other, there is an important principle:

Entrance rate=Exit rate

So by using this fact these formulas (5),(6) and (7) can be obtained for this process:

$$P_{n+1} = \frac{\lambda_n \lambda_{n-1} \cdots\cdots \lambda_0}{\mu_{n+1} \mu_n \cdots\cdots \mu_1} P_0 \qquad (5)$$

$$R_n = \frac{\lambda_{n-1} \lambda_n \cdots\cdots \lambda_0}{\mu_n \mu_{n-1} \cdots\cdots \mu_1} \qquad (6)$$

$$P_n = R_n * P_0 \qquad (7)$$

Which P_{n+1} is the probability of state n+1, P_0 is the probability of state 0 and is stated as formula (8):

$$P_0 = \frac{1}{1+\sum_{n=1}^{\infty} R_n} = \frac{1}{\sum_{n=0}^{\infty} R_n}$$
(8)

It is notable that as the time intervals between entrances and offering services are considered exponential, these processes have Poisson distribution. Although In the case in which data sending continues even after receiving requested services, Poisson distribution may not be accurate. But for other kinds of distributions (such as Erlang) the obtained formulas will be very complicated. in the other hand as the users usually are human beings ,the Poisson distribution can be acceptable.

So the e-commerce system can be shown by M/M/C/K/K symbol, in which first and second M indicate exponential distribution for entrance and exit intervals, C is the number of used processors, first K is the system capacity which shows the amount of resources are assigned to the system .and second K equals to the system capacity and indicates the total number of customers.

According to the figure 4 R_n and P_n can be calculated as formulas (9) and (10):

$$R_n = \begin{cases} \frac{k!}{(k-n)!\,n!}\left(\frac{\lambda}{\mu}\right)^n & n \le c \\ \frac{k!}{(k-n)!\,c!\,c^{n-c}}\left(\frac{\lambda}{\mu}\right)^n & c \le n \le k \\ 0 & n > k \end{cases} \quad (9)$$

$$P_0 = \frac{1}{\sum_{n=0}^{\infty} R_n} = \frac{1}{\sum_{n=0}^{c-1}\frac{k!}{(k-n)!\,n!}\left(\frac{\lambda}{\mu}\right)^n + \sum_{n=c}^{k}\frac{k!}{(k-n)!\,c!\,c^{n-c}}\left(\frac{\lambda}{\mu}\right)^n} \quad (10)$$

So the number of customers waiting in queue (L_q), the number of customers in the system (L), system response time (R) and waiting time in queue (R_q) are obtained as following formulas:

$$L_q = \sum_{n=c}^{K}(n-c)P_n \quad (11)$$

$$L = \sum_{n=0}^{c-1} nP_n + L_q + c\left[1 - \sum_{n=0}^{c-1} P_n\right] \quad (12)$$

$$R = \frac{L}{\lambda_\alpha} \quad (13)$$

$$R_q = \frac{L_q}{\lambda_\alpha} \quad (14)$$

$$\text{where } \lambda_\alpha = \sum_{n=0}^{k-1}\lambda P_n = \lambda(1 - P_k) \quad (15)$$

IV. NUMERICAL RESULTS EVALUATION

In this section obtained formulas in the previous section are implemented in MATLAB platform and according to some important parameters the behavior of the system is recognized. By precision in the obtained results one finds out that the behavior of introduced numerical method is compatible with our simulation and e-commerce site emulation results. Provided that e-commerce site emulation based on special benchmark proves to be a complex task without economic rationalization, this mathematical schema can be employed by providers to optimum resource estimation.

Although in the server sites, both hardware and software components have critical effects; in this paper only the effects of hardware elements on server capacity were surveyed.

A. *Server Capacity & CPUs*

To clarify the influence of the number of used processors on the server capacity, the graph of web interaction per second vs. the number of used processors, according to formula (1), was extracted (figure 5-a).As the server capacity is dependent on different parameters such as response time (R), so according to formulas (11) to (13) and (15), for reaching that graph required parameters such asL_q, L and R were calculated at first.

In the other hand our simulation output of one e-commerce system by the specifications in table I (a,b) is shown in figure 5-b and another e-commerce emulated site by the specifications in table II, is shown in figure 5-c [8]. However, it seems that using more CPUs, leads in more responded interactions and so efficiency improving. But, whether always increasing the number of used CPUs can help promotion of completed interactions and server capacity?

According to our formulas implementation in figure 5-a, and our site simulation in figure 5-b, it is clear that the effect of the number of used CPUs on the completed interactions in time unit and system capacity, has hard dependence on applied memory. In the situation of maximum resource starvation (k=10 in figure 5-a and RAM=1GB in figure 5-b), the server has approximately no scalability. With more resources (k=40 in figure 5-a and RAM=2GB in figure 5-b), adding a second processor increases WIPS (efficiency) slightly, but more CPUs don't have remarkable effect on efficiency. With k=50, adding second CPU increases WIPS noticeably, but using more processors only allows a small increment. In the condition of no resource restriction (k=70 in figure 5-a and RAM=4GB in figure 5-b), adding processors generates useful WIPS and so efficiency increment.

Also In the site emulation as figure 5-c shows, while minimum amount of memory (128Mb) is used, system's scaling is zero, it means that nevertheless more expenses and use of more CPUs, no increasing in performed interactions in time unit and server capacity is observed. Use of higher memory (256 Mb) and increasing the CPUs into 2, amount of supplemented interactions in time unit will be promoted; but increasing more CPUs will not help capacity promotion and system efficiency. Using of two CPUs with 512 Mb memories, creates remarkable growth in successful interactions, and if using the third CPU promote the result less, then CPU addition will be inconclusive. But, if there is no limitation in used memory, addition of CPUs, increase server scaling and its capacity remarkably.

TABLE I-a: SIMULATED E-COMMERCE SITE SYSTEM SPECIFICATION

Factor	Description	Levels
HTTP server	Apache 1.3.14	-
Common gateway interface	PHP v4.0.4 using permanent connections	-
Database	Oracle 8i v8.1.7 with dedicated servers	-
Operating system	Linux Red Hat v6.2,kernel 2.2.18	-
Motherboard	Intel SC450NX 4 CPU	-
CPU	Pentium III Xeon 550 MHz 512 Kbytes	1,2,3,4
RAM	EDO ECC 133 MHz	128.... .1,536
Disk drive	SCSI Seagate Cheetah 18 Gbytes	
Network	Ethernet 100 Mbps	

TABLE I –b: SIMULATED E-COMMERCE SITE SOFTWARE SPECIFICATION

Software type	Purpose of use
Visual Studio 2008	Web site designing
SQL Server 2008	Data base designing
WAPT	Load generator to the server
ESX	Virtual environment implementation

TABLE II. ONE E-COMMERCE SITE SPECIFICATION [8]

Factor	Description	Levels
HTTP server	Apache 1.3.14	-
Common gateway interface	PHP v4.0.4 using permanent connections	-
Database	Oracle 8i v8.1.7 with dedicated servers	-
Operating system	Linux Red Hat v6.2,kernel 2.2.18	-
Motherboard	Intel SC450NX 4 CPU	-
CPU	Pentium III Xeon 550 MHz 512 Kbytes	1,2,3,4
RAM	EDO ECC 133 MHz	128....1,536
Disk drive	SCSI Seagate Cheetah 18 Gbytes	
Network	Ethernet 100 Mbps	

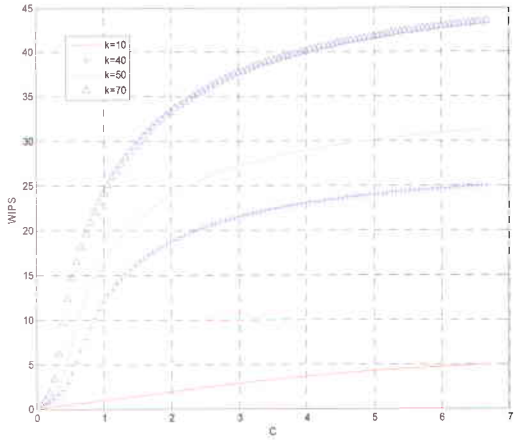

Figure 5-a. Web interactions per second vs. the number of used processors in the formulas implementation

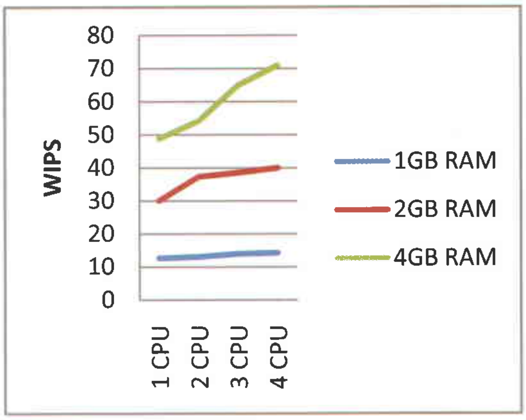

Figure 5-b Web interactions per second vs. the number of used processors in the simulation

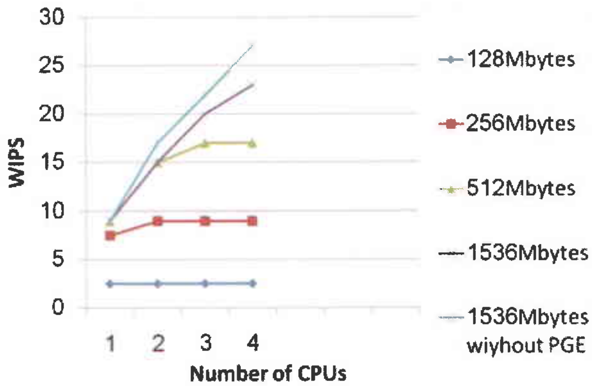

Figure 5-c: Relation between WIPS, CPU and RAM in one site emulation [8]

B. *Saturation Point*

In this part, by calculating some parameters such as L_q, L R_q and R (implementing formulas (11) to (15)), the influence of load factors on the WIPS metric is shown in figure 6-a and the result of the emulated site is given in figure 6-b.

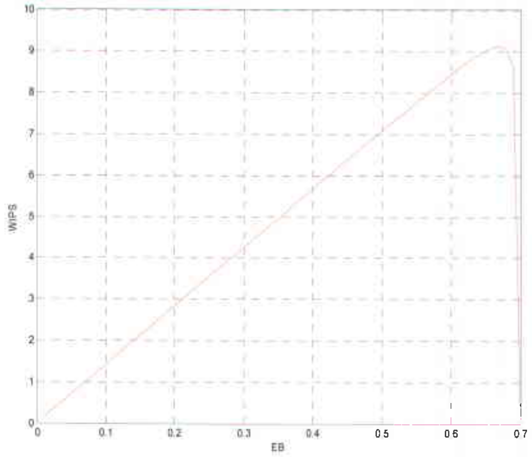

Figure 6-a. Relation between WIPS and incoming requests

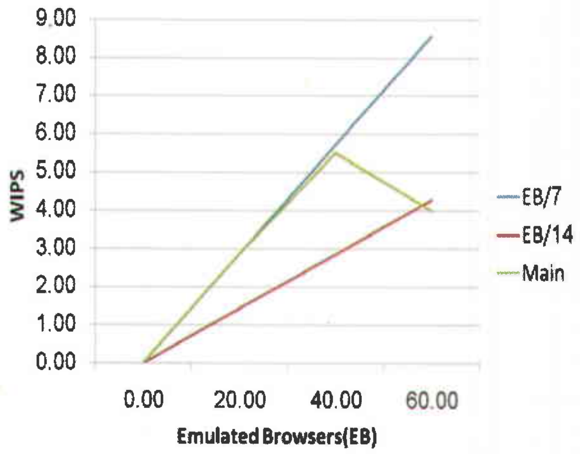

Figure 6-b. Relation between WIPS and the number of emulated browsers of e-commerce site emulation [8]

Also the obtained graphs of the waiting time in queue vs. entrance rate and the number of waiting customers in queue vs. efficiency are shown in figures (7) and (8) respectively.

One of the most important factors in e-commerce sites designing is system saturation point specification. Saturation point is maximum users, which system can process and complete their interactions successfully. obviously in both figures 6-a and 6-b,by considering software and hardware factors stable, adding the users' number, more than a limitation, will cause increasing the waiting time in queue (Figure7) and finally leads to extra CPU utilization. In this situation supplemented interactions in time (WIPS) will be dropped.

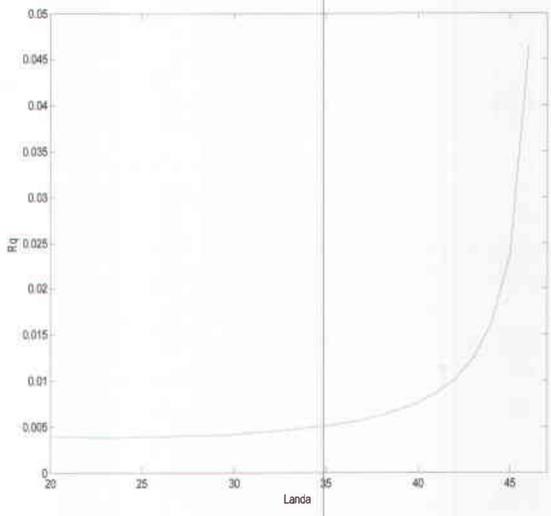

Figure7: Waiting time in queue vs. entrance rate in formulas implementation

This point also can be realized in our formulas implementation, (Figure 8) which shows the number of waiting customers in queue vs. the efficiency.

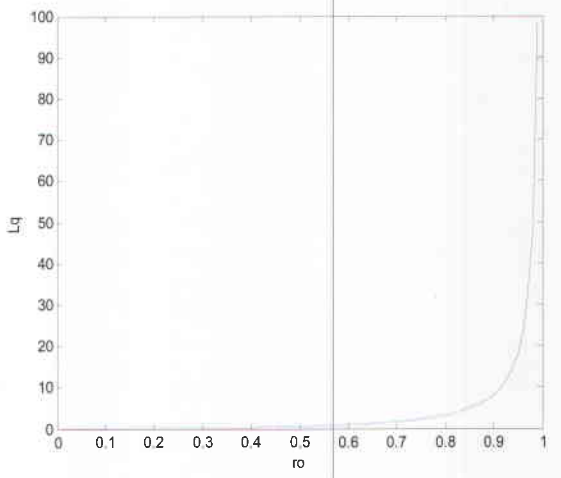

Figure 8: The number of waiting customers in queue vs. efficiency in formulas implementation

As it is seen, the number of waiting customers in queue increases suddenly between the values 0.9 and 1 of efficiency by very sharp slope which is the result of over usage of processors and reaching the system to the saturation point.

In TPC-W benchmark, adding or deleting one user shows minimum changes in throughput. Theoretically, if interactions supposed very fast (R=0), minimum increase in amount of interactions in time unit (according to formula (1)), equals to reversed average of customer's think time, that is 1/7 or 0.1428 seconds for adding a user to the system. Also , as TPC-W rules do not allow the system throughput be less than 50% of possible maximum addition ,so It is necessary that the number of interactions in time unit be between EB/7 and EB/14 in all times.

C. *R esponse Time*

One of the most important parameters in an e-commerce site success is the response time. If the customer doesn't receives his response in the agreed time, may cancel the transaction and may even turn to the competitor's sites. At the minimum, this will result in a financial loss for the provider. It may also tarnish the provider's reputation and may discourage the customer from ever using the site again.

As the final part of this section, the effect of the number of emulated browsers on response time is cleared by calculating parameters such as L_q , L, R_q and finally R (implementing formulas (11) to (13) and (15)), as figure 9-a. The simulation and the emulated site results are shown in figures 9-b and 9-c respectively. [7].

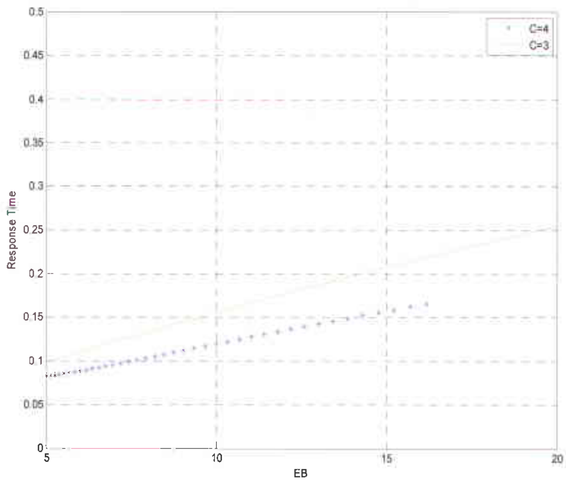

Figure9-a. Response time vs. emulated browsers in formulas implementation

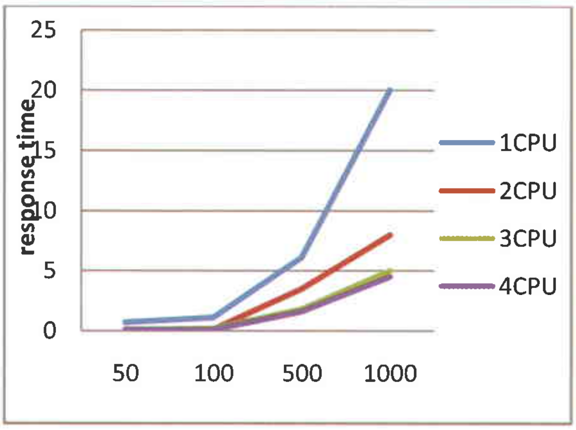

Figure 9-b. Response time vs. emulated browsers in simulation

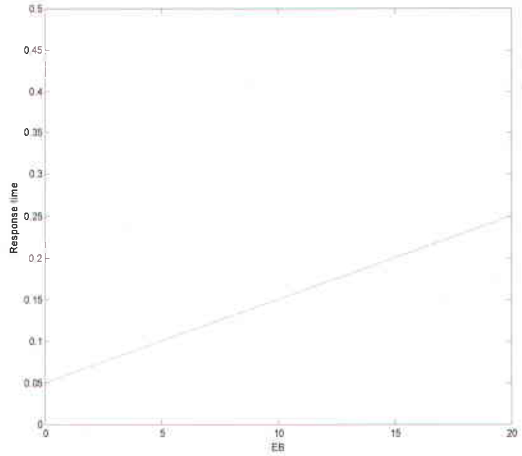

Figure 9-c Relation between emulated browsers and response time in e-commerce site emulation [7]

The influence of the number of users on response time is the factor which should be considered by site designers. By increasing the active users, more interactions will be directed to servers. In the condition of stable hardware, more interactions cause more CPU utilizations. In this situation the number of waiting interactions in queue and finally the response time of the system will grow up. This fact can be seen in both figures 9-a, 9b and 9-c.

The next important point in Figure 9-a and 9-b is the influence of the number of used processors on response time. By increasing the number of CPUs, the power of the server in analyzing the incoming requests will be improved and so the interactions will be answered more rapidly.

At least 90% of the interactions must have response time less than time limitation that is specified in TPC-W [15].In measurement time period, examined system must be in steady state and thinking time average must be at least 7 seconds and average of new entered customers to system must be between 19-21 percent in this period .the purpose of these limitations is avoiding sudden increasing in interactions.

V. CONCLUSION

In this paper after investigating the effective parameters on server capacity and introducing the relation between them, a new mathematical method has been introduced to estimate the required level of resources based on the most important system performing parameters, like throughput and response time. This method can be used to guide resource provisioning of an e-commerce site. By considering the numerical results in MATLAB platform, our simulation results and the real e-commerce site emulation, it is clearly showed there is a proper confirmation of the new method with the real implementation.

As the future field of research by considering incorporating performance metrics which are directly related to end user's shopping experience, such as

session length and session availability, we aim to extend the resource provisioning methodology. In the other hand the proposed numeric model can be presented for other types of mathematical distributions such as Erlang.
Also by emerging software components such as processors specification, the behavior of the system and the required resources will be predicted and analyzed more accurately.

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