An Evaluation of Client-Side Dependencies of Search Engines by Load Testing

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***Abstract*— Nowadays, web based large-scale systems, such as search engines, are widely used. The popularity of search engines created a new environment in which the applications need to be highly scalable due to the data tsunami generated by a huge load of requests. In this context, the main problem is to validate how far the web applications especially search engines can deal with the load generated by the clients. Load testing, in general, refers to the practice of accessing the system behavior under load. In this paper, we study on search engine performances' dependencies related to network bandwidth and Internet browsers in aspect of load testing. We observed that search engines' speed is dependent on Internet browsers and network bandwidth.**

Keywords-search engine; load testing; Internet browser; network bandwidth.

I. INTRODUCTION

Web-based applications are widely used nowadays because of their advantages, such as cross-platform without distribution and installation of software on thousands of clients, easy to be used and managed, etc. Therefore, web-based applications need to scale to thousands of concurrent users. To assure the quality of these systems, load testing is a required testing procedure in addition to conventional functional testing procedures, such as unit and integration testing [1].

Load testing, in general, refers to the practice of accessing the system behavior under load [1]. The load testing aims to identify and isolate system bottlenecks, tune application components, predict system scalability, and make judgments on system architecture or design, while performance models are used in analyzing the performance and scalability characteristics of the system under study [2].

In the literature, there are various load testing studies for web-based applications, using different technologies. One of these studies is conducted by A. Habul and E. Kurtovic. Their study presents a methodology for load testing an Ajax application [3]. Another study is about performance comparison between different web-based application architectures which are .NET and Java EE [4]. One of them is for peer-to-peer applications [5].

In this paper, we aim to present basic load testing approach for web applications with high intensity of use. Search engine applications are at the top of these applications.

From a user perspective, the client-side performance is more important than server performance. So, the client-side performance is considered for load testing in this study. Seeking client-side performance, response time, error rate, CPU usage and memory consumption are taken into consideration. These metrics are interpreted for two criterion, including bandwidth and browser for search engines by HP LoadRunner, which is a performance and load testing tool.

The paper starts by giving information on load testing and load testing metrics, then introduces testing environment. In fourth section, load testing results are given. Finally, the results obtained in this research are discussed.

II. LOAD TESTING

A. Load Testing

The analyze of the performance of the web-based system can be achieved using load testing and/or performance modeling approaches. Load testing is carried out to determine a system's behavior under both normal and expected peak load conditions. It helps to identify the maximum operating capacity of an application such as any bottlenecks and determine which element is causing degradation.

B. Load Testing Metrics

1) Response Time: Response time is a time defined by interval between client request and response from server. Response time is the key software performance metric for server-client applications.

2) Error Rate: Error Rate is the mathematical calculation that produces a ratio of unanswered requests to all requests. The percentage reflects how many responses are HTTP status codes indicating an error on the server, as well as any request that never gets a response. Error Rate is a significant metric because it measures "performance failure" in the application. It tells how many failed requests

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are occurring at a particular point in time of your load test [7].

3) Client-side Resource Utilization (CPU Usage and Memory Consumption)

CPU usage is the amount of CPU time used by the Web Service while processing the requests and memory consumption is the amount of memory used by the Web Service while processing the requests.

III. TEST ENVIRONMENT

To measure dependencies of the search engine according to the intended use, a simple scenario was chosen. Scenario steps are provided below:

- Open browser
- Enter search engine address
- Type "wikipedia" query string
- Click search button
- Click "http://www.wikipedia.org/" address

The scenario contains three transactions that are opening search engine, searching and redirection to Wikipedia. It has been run for 1000 concurrent users for all cases. Concurrent users mean that all of users send their requests to the server at the same time.

This scenario was run for three search engines that are Google, Yandex and Bing according to two criteria, which are network bandwidth and Internet browsers. These Internet browsers are Google Chrome, Internet Explorer, Mozilla Firefox versions of which are supported HP LoadRunner. For the other case, two different network bandwidth values were selected: 1.5 Mbps (Asymmetric Digital Subscriber Line-ADSL) and 10 Mbps. Windows Performance Monitor application is used to measure CPU and RAM usage ratios.

Testing environment consists of a PC hardware that runs LoadRunner 11.5 testing tool. The technical characteristics of this PC are:

- Intel i5 CPU @3.2 GHz
- 4 GB RAM
- 64-bit operating system
- Windows 7 Professional

IV. EXPERIMENTAL RESULTS

In this study, in order to compare dependencies of search engines, load test scenario was run on two different cases. These are Internet browser and network bandwidth.

A. Internet Browser

The reason for choosing the browser is to understand whether speed of search engines depends on Internet browser or not.

Load test results of selected search engines are given in Table I, Table II and Table III for different browsers.

LoadRunner computed average response times of each transaction and we computed average response time that are given in Tables I-III as linear average of three transactions for each Internet browser.

TABLE I. BING PERFORMANCE COMPARISON

Bing	Search Engines		
	Google Chrome	IE	Mozilla Firefox
CPU	15%	13%	11%
RAM	38%	36%	40%
Average Response Time (s)	2,547	1,946	2,359
Error Rate	0,122	0,002	0,007

a. At 10 Mbps network bandwidth

TABLE II. YANDEX PERFORMANCE COMPARISON

Yandex	Search Engines		
	Google Chrome	IE	Mozilla Firefox
CPU	23%	15%	12%
RAM	38%	33%	33%
Average Response Time (s)	2,102	2,101	1,979
Error Rate	0,0003	0	0,0003

a. At 10 Mbps network bandwidth

TABLE III. GOOGLE PERFORMANCE COMPARISON

Google	Search Engines		
	Google Chrome	IE	Mozilla Firefox
CPU	22%	22%	20%
RAM	39%	39%	40%
Average Response Time (s)	3,368	3,417	3,143
Error Rate	0	0	0

a. At 10 Mbps network bandwidth

In Table I, load test results for Bing are shown. According to Table I:

- In terms of the use of PC resources, it is observed that Bing used CPU at least on Mozilla Firefox.
- In terms of the use of average response time, it is been observed that Bing was the fastest search engine running on IE.
- It is observed that errors in Bing are arised respectively due to the server and timeout period (LoadRunner timeout period: 120 s.).

In Table II, load test results for Yandex are shown. According to Table II:

- In terms of the use of PC resources, it is observed that Yandex used the least CPU on Mozilla Firefox.

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- In terms of the use of average response time, it is observed that Yandex was the fastest search engine running on Mozilla Firefox.

In Table III, load test results of Google are shown. According to Table III:

- In terms of the use of average response time, it is observed that Google was the fastest search engine running on Mozilla Firefox.

As a result, with regard to above statements, it can be considered that search engines' performance depend on Internet browser.

B. Network Bandwitdh

Network bandwidth used by the Internet user determines the speed of download and upload and is a parameter considered in the load test.

At first, widely used by the Internet users for network bandwidth ADSL (1.5 Mbps) is selected. Secondly, for putting forward dependence of search engines to network bandwidth, 10 Mbps, nearly ten times ADSL is selected.

The comparisons of 10 Mbps and ADSL for search engines are shown in the following tables.

We computed average response time that are given in Tables IV-VI as linear average of three transactions' average response times by LoadRunner for each Internet browser.

TABLE IV. BING PERFORMANCE COMPARISON

Bing	Internet Browsers					
	Chrome		IE		Firefox	
	ADSL	10 Mbps	ADSL	10 Mbps	ADSL	10 Mbps
CPU	14%	15%	14%	13%	14%	11%
RAM	39%	38%	36%	36%	39%	40%
Average Response Time (s)	3,117	2,547	2,921	1,946	3,04	2,359

TABLE V. YANDEX PERFORMANCE COMPARISON

Yandex	Internet Browsers					
	Chrome		IE		Firefox	
	ADSL	10 Mbps	ADSL	10 Mbps	ADSL	10 Mbps
CPU	25%	23%	28%	15%	26%	12%
RAM	38%	38%	44%	33%	36%	33%
Average Response Time (s)	2,405	2,102	2,416	2,101	2,35	1,979

TABLE VI. GOOGLE PERFORMANCE COMPARISON

Google	Internet Browsers					
	Chrome		IE		Firefox	
	ADSL	10 Mbps	ADSL	10 Mbps	ADSL	10 Mbps
CPU	22%	22%	21%	22%	22%	20%
RAM	40%	39%	30%	29%	40%	40%
Average Response Time (s)	3,7	3,368	3,466	3,417	3,731	3,143

In Table IV, it is observed that the decrease in network bandwidth only caused an increase in response time. In other words, we could say that Bing is slowed down when bandwidth is reduced.

In Table V, it is shown that when network bandwidth is reduced, CPU utilization of Yandex increased in IE and Firefox browsers. Also, it is observed that an increase in network bandwidth caused lower RAM usage by Yandex in IE and lower response times in all browsers.

In Table VI, it is observed that the decrease in network bandwidth only caused an increase in response times.

As a result, in terms of PC resource usage and speed, Yandex depends on network bandwidth. In terms of speed, Google and Bing browsers can be considered to be depended on network bandwidth.

C. Comparing Search Engines in Point of Transactions

The scenario contains three transactions that are opening search engine, searching and redirection to Wikipedia. The comparison of the transactions is given in Table VII.

We computed average response time that are given in Table VII as linear average of three Internet browsers' average response times by LoadRunner for each transactions.

The curves of variation of transactions' response time due to elapsed time for Google, Yandex and Bing are given in Fig. 1, Fig. 2, and Fig. 3, respectively.

TABLE VII. TRANSACTION PERFORMANCE COMPARISON

Average Response Time (s)	Transactions		
	Opening Search Engine	Searching	Redirecting
Bing	4,058	0,682	2,11
Yandex	2,995	1,467	1,720
Google	1,036	0,794	8,412

a. At 10 Mbps network bandwidth

According to opening search engine transaction, Google can be considered the fastest search engine. For searching transaction, it is observed that Bing and Google are faster than Yandex. By redirecting transaction, Google is said to be the slowest search engine. The reason for Google's slow redirecting is when user clicks the link, Google firstly send user their own servers to get information for their ranking algorithms and then provide the connection to selected link.

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V. CONCLUSION AND FUTURE WORK

In this paper, we aimed at presenting search engine performances' dependencies on network bandwidth and Internet browsers. We evaluated client-side performance of search engines for load testing.

As a result of load testing, it is observed that search engines' performance depend on Internet browser and Google is the least dependent on Internet browsers.

As network bandwidth increases, the utilization of PC resources by search engines decreases and speed of search engines increases as expected. However, usage of PC resources by Yandex increases. In this instance, Yandex is the most dependent on network bandwidth.

In future study, in addition to client-side load testing, it is planned to evaluate the behavior of the server during load testing.

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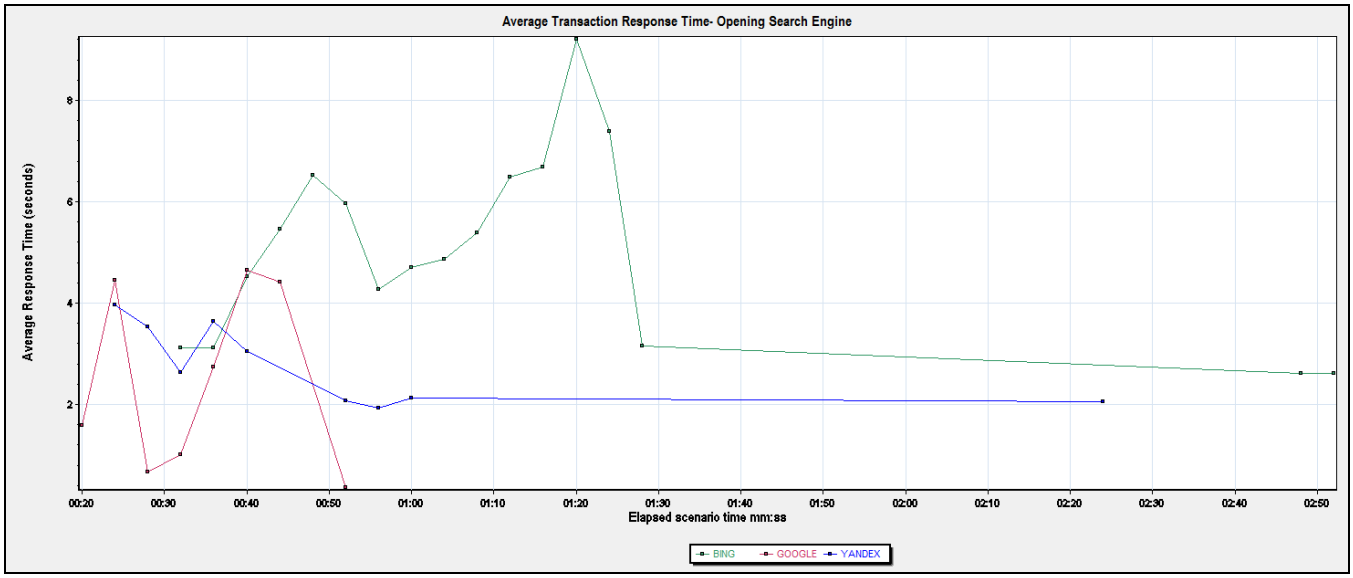

Figure 1. Opening search engine transaction response time.

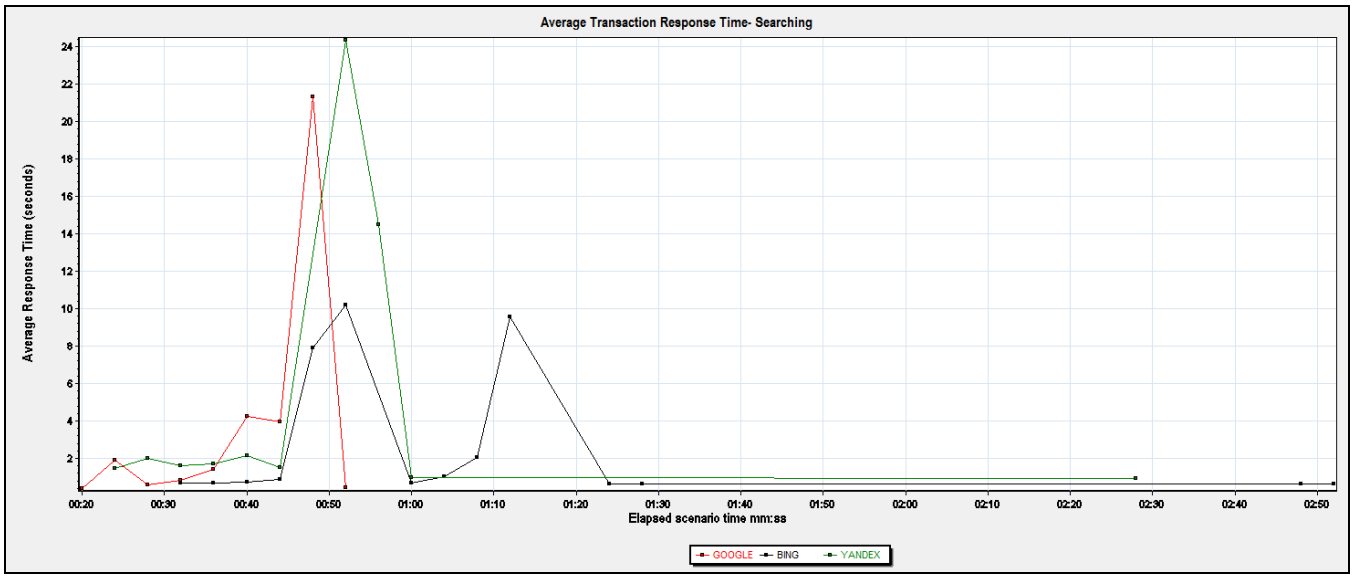

Figure 2. Searching transaction response time.

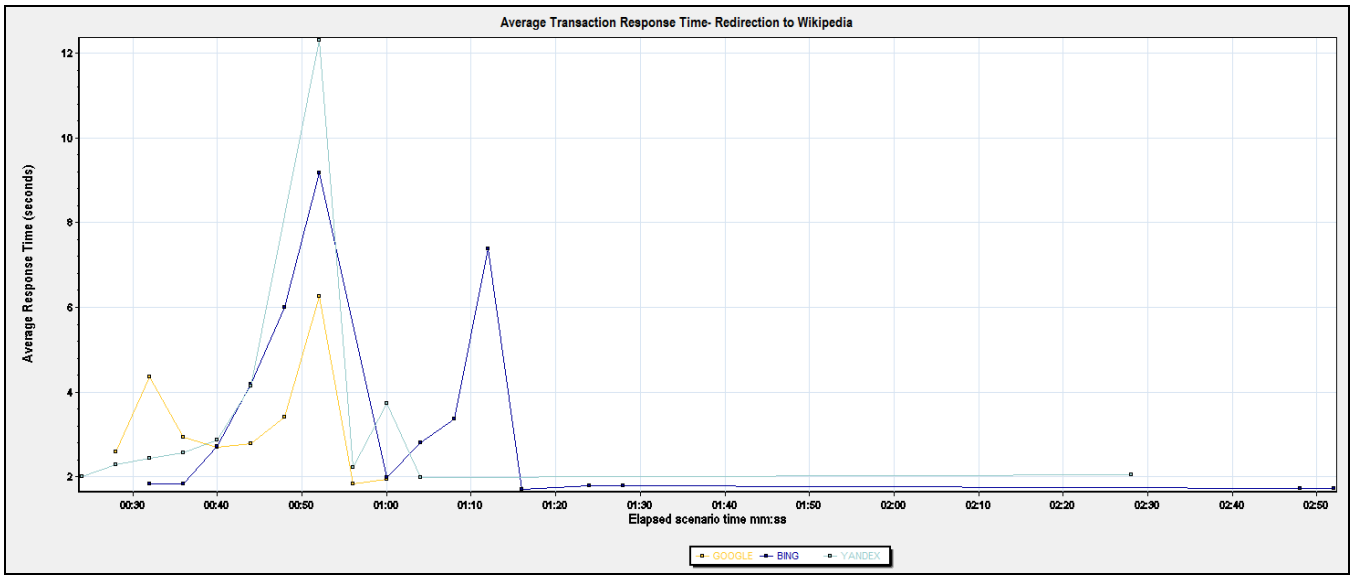

Figure 3. Redirection to Wikipedia transaction response time.

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