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Full Length Research Paper

An experimental performance evaluation of different remote servers to analyze the effect of divergent load and congestion

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In terms of provisioning of guaranteed QoS to the end-user, the performance of remote servers is a critical issue for internet service providers to remain competitive in the market. The end-user would like to have a quick and instant response from the webmail server to enjoy the service. Load and congestion are the greatest hurdles in web based linkage and conversation. The efficiency of web page retrieval is degraded due to the peak use of internet and also because of its highly complex architecture. This paper provides an experimental effort to analyze the effect of load and congestion on web services and measures the performance characteristics like Response time, Latency, jitter, Round Trip Time, hits lost ratio, Page error rates, sending and receiving speed, availability and reliability for accessing different popular and vastly used remote servers (Yahoo Server, Gmail Server, Hotmail Server) to conclude, how load and congestion cause the increment in latency of services? Is there any significant relationship between congestion and hop counts? We contributed new and novel results for further discussions.

Key words: QoS, congestion avoidance, load, latency, response time, congestion, hop count's relationship.

INTRODUCTION

The rapid evolution of dramatic internet growth has motivated the people to interact with each other through electronic means. In current epoch of technology, electronic linkage through internet communication is the need of every organization and an individual as well. Almost, all over the world, everyone likes to use those web services which provide best performance capabilities without having load and congestion. Although the future visit of web user entirely depends on the previous experience regarding response and the Quality of Service (QoS) of any utilized remote utility. Hence, the performance and efficiency greatly matters for both end users and the services providers. The quick access of any remote service depends upon a number of factors such as available network bandwidth, latency, jitter, response time, hits ratio, availability and reliability. All these performance characteristics are badly affected by the congestion and load. When load increases, the communication delay is also increased. Moreover, the large increment in load leads to an unwanted situation referred to as congestion. Therefore, the Quality of Service (QoS) is highly interlinked with the congested situation. Hence, it is evident that the effect of these two factors that is, congestion and load cannot be neglected while measuring the performance of network related applications.

The two most well know services for measuring the performance of internet service are (1) Active Probing and (2) Web Page Instrumentation as discussed by Cherkasova et al. (2002). In active probing, any fixed point machine in internet is used to measure the end to end performance characteristics while, Web Page Instrumentation relies on codes (java script) to measure the downloadable time of individual objects from the target website according to Cherkasova et al. (2002) and Fielding et al. (1999). This paper focuses on active probing to measure the performance characteristics of vastly used web servers like yahoo, Gmail and Hotmail. The main objective of the current work is to conclude

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relationship among heterogeneous congestion, RTT, hop counts and load conditions. To acquire experimental results, according to Credle et al. (2005) the literature supported tool named as web application testing tool (WAPT 6.0) is used. WAPT is a cost effective and efficient tool, which is commonly used for load, stress and performance benchmarking of network and internet applications. The rest of the paper is organized as follow. Literature review provides an overview of related work. In materials and methods, we presented the methodology, experimental results, discussion and comprehensive analysis for future debate related to load and congestion.

LITERATURE REVIEW

In congested situation router starts dropping the packets due to the increment of time session and as a result the both user and services have to bear bandwidth loss, network blocking and re-transmission. Rangwala et al. (2008) said when congestion occurs in a point it also suffers the neighbors into congestion. Congestion occurrence varies in wired and wireless networks. In wireless network congestion locations can be identified through average number of retransmissions (Fu et al., 2003), channel utilization (Xu et al., 2003) and mean time to recover loss (Paek and Govindan, 2007) but in wired network it is not easy to predict exact congested location due to a large number of congested neighbors (Xu et al., 2003). We made an effort to find out how congestion can be detected through Round Trip Time and hop counts. Is there any significance relation with RTT, hop counts and congestion? Congestion free communication is ultimate desire of every user. It is reality that, congestion always degrades the efficiency of online services and produces several other hurdles (delay, network jam, packet loss, re-transmission etc.) for end to end communication.

In May 17 2002, Ludmila Cherkasova and fellows have reported a novel approach to measure the end to end service performance of web applications. According to them a web page is composed of many objects and the complex architecture of internet makes it difficult to measure the performance characteristics of web applications. They introduced a passive system which traces network packets from server side to determine the retrieval of web pages. Furthermore, this study has reported that the measurement of response time is the critical metric for both end users and service providers to find out the Quality of Service (QoS) because, users mostly open those web sources which respond quickly as agreed by Cherkasova et al. (2002).

Microsoft Research Center designed measurement related approach based on admission control heuristics. They have reported that round trip time (RTT) is the main and basic network measurement metric for judging the real performance of host and server (Gunawarden and Massoulie, 2006). Seshan et al. (1997) reported that users often make decisions on the basis of response from hosts. Furthermore, they have presented a system named as Shared Passive Network Performance Discovery (SPAND) to measure network performance characteristics such as bandwidth, latency, packet loss and probability. Furthermore, they implemented the Cisco's Distributed Director with Director Response Protocol (DRP) to measure the characteristics of Wide Area Network (WAN). For this purpose the DRP Server uses metrics like hop by hope bandwidth, latency, peak available bandwidth, bottleneck bandwidth and routing metrics.

Probing technique is a well known heuristic for measuring the network performance by estimating the Round Trip Time (RTT), latency and highest bandwidth (Seshan et al., 1997). Probes have many other resemblance names such as NetDyn probes (Bolot, 1993), Packet Fair (Keshav, 1995) and bprobs (Carter and Crovella, 1996). But in study (Seshan et al., 1997) passive measurements are used rather than active measurements. The common characteristics of service level agreements (SLAs) monitoring are delay, jitter, packet loss rate and network availability (Shaikh and Greenberg, 2005; Sommers et al., 2007). In terms of providing better Quality of Service (QoS), Internet performance measurements have been calculated through web browsing by considering the delay jitter as a metric as discussed in study (Janc et al., 2009). Reliable communication is primarily concerned with the World Wide Web (WWW), File Transport Protocol (FTP) and Email communication (Andrei Gurtov). In 2005 Davenhall A. C. and Leese M. J. reported most well known metrics to measure the performance of network services (Paek and Govindan, 2007). These metrics include latency (the time between dispatch of a packet and receipt of an acknowledgement), jitter (wide range of time-scales or delay variations in the rate of packet while travelling across the network), Capacity or Bandwidth (the capability of link in terms of throughput), Availability (the situation when network is unavailable) and Reliability (the sum of availability and the frequency of packet losses or corrupted plus overall performance of the utilized service).

It is claimed by Wang et al. (2006), still there is no criteria to investigate router's burden immediately by the host. Efficiency is not only matters in wired network but it also concerns with wireless networks. Minimization of routing load and optimal utilization of resources are key factors for every type of networks (Kara et al., 2010). Reduction of end to end latency can actively plays a sufficient role in handling of congestion in worldwide linkage. For this purpose the authors of study (Jasem et al., 2010) have modified the Additive increase and Multiple decrease (AIMD) congestion control method with utilization of drop tails technique for active queue management to calculate end point latency. They claimed that, the new AIMD algorithm is outperformed for calculating

the end to end congestion delay because it is able to decrease the queue length. Furthermore, the same study reported the reasons of delay as follows:

1. Congestion due to high traffic.
2. Hardware based delay due to slow processing speed.
3. Buffer overflowing and queuing delay.
4. Propagation delay.

Avoidance of delays and congestion greatly concerns with optimal performance in communication networks. Many performance metric tools are available for networks and web application testing like WAPT 6.0, Microsoft Web Stress Tool, Web Bench, Load Runner (Credle et al. 2005) and Manage Engine Application Manager 9 by Zoho Corporation but we selected the WAPT 6.0 which provides consistence and cost effective approach. WAPT is evaluated extensively by the authors of study (Vali, 2005) and they claimed satisfactory opinion about WAPT performance. Many research studies (Gupta and Sharma, 2010; Horák et al., 2009; Rajputet et al., 2010) used WAPT tool for getting similar results related to networks and internet applications. Hence, WAPT is a good decision for measuring performance metrics of network related communication.

Consequently, this paper measures all the reported measurement metrics to date with additional metrics for example; hits lost probability, error rates, response time, sending and receiving speed and most importantly, the effect of congestion and load on the performance as these factors cannot be ignored while benchmarking the network and internet application. The relation between load, congestion, hop counts and Round Trip Time (RTT) is analyzed with support of graphical representation. The presented study also discusses the current status of Yahoo, Gmail and Hotmail Servers against hacking attempts from security point of view.

MATERIALS AND METHODS

Within each ongoing second, many users get connected/ disconnected on web servers; hence it is too difficult to determine the actual number of users utilizing different kind of applications at some specific time. In this paper, the main concern is to find out how load caused latency and congestion through the performance based bottleneck characteristics of vastly used servers like Yahoo Server, Gmail Server and Hotmail Server? Our keen motive is to find out, is there any kind of relationship among congestion load and hop counts? For this purpose, we used remote network benchmarking utility named as Web Application Testing Tool (WAPT 6.0) that has significant literature support. We measured a variety of performance characteristics (Jitter, Response Time, Page error rates, hits lost ratio, sending and receiving speed, Availability and Reliability) through WAPT for several days of February and March 2010 in different time spans (early morning, noon, evening and nights) for a sample set of many virtual users. This experimental evaluation has been performed for all three peak loaded servers (Gmail, Yahoo and Hotmail) on the same machine (CPU = 2.4 GHz. Ram = 2 GB, OS = WinXP, Firewall Disabled) with same link speed in King Saud University, Riyadh KSA. Each time, a set of results have been taken for three desired servers as summarized in Tables 1, 2 and 3. Similarly, Route structure investigation commands were also being used in the same way on different times to analyze the Round Trip Time, TTL and number of hop counts as well as to judge the situation of congestion and load as summarized in Tables 4 and 5. The presented results are completely new and different as compared to the prior work for a novel contribution in the area of performance evaluation of networks through load, congestion, response time and several other factors as mentioned earlier.

From Tables 4 and 5 shows that the average response time of Yahoo server is 0.50 sec, Gmail is 1.25 s and Hotmail server is 2.39 s, therefore, Yahoo server is best in terms of average response time.

The results of Tables 4 and 5 shows, in case of congestion, path is changed, which may result more no. of hop counts penalty that caused much increase in latency/RTT. Similarly, in case of high load, RTT is increased, which may leads to congestion and as a result overall performance is degraded. So in case of high load and congestion, no. of hop counts are necessarily increased and most probably, when the difference of hop greater than 2 and RTT is greater than OR equal to {Normal(RTT) + (Normal RTT / 2) } in between the normal and loaded condition, it means there is necessarily congestion. RTT has a direct relation with congestion (Bass, 1997). Also, the higher number of hop counts means; there is congestion (Armitage et al., 2006). The graphical relationship (Less C.) of RTT and congestion has been shown in Figure 1.

The graphical results show that large increment in RTT means high load or “load plus congestion” but in case of large increment in hop counts with some increment in RTT means there is necessarily congestion. With consistent hop counts if RTT increases up to maximum extent then most probably it indicates high load which may leads to congestion. The error rates of different servers have been reported in Table 6.

The Graphical representation of Table 7 has been shown in Figure 3, which provides a clear estimation about the decision.

EXPERIMENTAL PERFORMANCE ANALYSIS OF YAHOO, GMAIL AND HOTMAIL SERVERS

Results of Tables 1 to 3 shows that the average response time of Yahoo server is 0.50 s, Gmail is 1.25 s and Hotmail server is 2.39 s, therefore, Yahoo server is best in terms of average response time.

The results of Tables 4 and 5 show that in case of congestion, path is changed, which may result more number of hop counts penalty that caused much increase in latency/RTT. Similarly, in case of high load, RTT is increased, which may leads to congestion and as a result overall performance is degraded. So, in case of high load and congestion, number of hop counts is necessarily increased and most probably, when the difference of hop Counts is greater than 2 and RTT is greater than or equal to {Normal(RTT) + (Normal RTT / 2)} in between the normal and loaded condition, it means there is necessarily congestion. RTT has a direct relation with congestion (Bass, 1997). Also, the higher number of hop counts means; there is congestion (Armitage et al., 2006). The graphical relationship (Less, 2009) of RTT and congestion has been shown in Figure 1. Now we analyze the effect of load and congestion on RTT and Hop count as shown graphically in Figure 2. The graphical results show that large increment in RTT

Table 1. Experimental performance analysis of yahoo server. Test executed on: IJAZ / Administrator, Test allocated Time: 00:01:20 (HH:MM:SS).

Experimental test starting and finishing time with date (MM/DD/YYYY)	Total KBytes send	Total KBytes received	Receiving speed (kb/s)	Sending speed (kb/s)	Response time (Sec)			Hits Per Sec.	Page per Sec.	Hits Lost = (Hits/Sec – Page/Sec)
					Min.	Avg.	Max.			
Start: 2/22/2010 3:25:10 PM Finish: 2/22/2010 3:26:30 PM	1224	6663	666	122	0.37	0.39	0.57	48.8	0.75	48.8 – 0.75 = 48.05
Start: 2/22/2010 8:42:13 PM Finish: 2/22/2010 8:43:33 PM	830	4965	496	83	0.37	0.4	0.56	33	01	33 – 01 = 32
Start:2/22/2010 12:11:06 PM Finish:2/22/2010 12:12:26 PM	815	4442	444	81.5	0.37	0.4	0.52	32.5	0.5	32.05 – 0.5 = 32
Start: 2/22/2010 11:15:44 AM Finish: 2/22/2010 11:17:04 AM	1123	6095	610	112	0.37	0.38	0.41	44.8	0.7	44.8 - .07 = 44.1
Start: 2/22/2010 11:56:14 PM Finish: 2/22/2010 11:57:34PM	20	109	10.9	2.0	0.37	0.37	0.37	0.8	0.01	0.8 – 0.01 = 0.79
Start: 2/23/2010 10:33:48 AM Finish: 2/23/2010 10:35:08 AM	1224	6699	670	122	0.37	0.4	0.88	48.8	0.75	48.8 – 0.75 = 48.05
Start: 2/23/2010 11:54:31 PM Finish: 2/23/2010 11:55:51 PM	1183	6453	32.3	118	0.37	0.39	0.55	47.2	0.74	47.2 – 0.74 = 46.46
Start: 2/23/2010 12:10:57 PM Finish: 2/23/2010 12:12:17 PM	802	4353	435	80.2	0.37	0.4	0.55	32	0.5	32 - 0.5 = 31.5
Start:23/02/2010 5:28:11 PM Finish:23/02/2010 5:29:31 PM	1183	6436	644	118	0.34	0.4	0.48	47.2	0.74	47.2 – 0.74 = 46.46
Start:2/24/2010 10:39:02 AM Finish:2/24/2010 10:40:22 AM	1184	6408	641	118	0.37	0.39	0.54	47.2	0.74	47.2 – 0.74 = 46.46
Start:2/25/2010 12:54:14 AM Finish:2/25/2010 12:55:34 AM	802	4345	434	80.2	0.37	0.39	0.46	32	0.5	32 – 0.5 = 31.5
Start:2/25/2010 4:27:58 PM Finish:2/25/2010 4:29:18 PM	1203	6562	656	120	0.37	0.4	0.77	48	0.75	48 – 0.75 = 47.25
Start:2/26/2010 1:02:14 AM Finish:2/26/2010 1:03:34 AM	400	2176	218	40	0.66	1.32	2.05	16	0.25	16 – 0.25 = 15.75
Start:2/26/2010 2:28:03 PM Finish:2/26/2010 2:29:23 PM	400	2177	218	40	0.87	0.87	0.87	16	0.25	16 – 0.25 = 15.75

Table 1. Contd.

Start:2/27/2010 1:20:26 AM Finish:2/27/2010 1:21:46 AM	407	2771	277	40.7	0.45	0.9	1.88	16.3	0.25	16.3 – 0.25 = 16.05
Start: 2/28/2010 12:04:42 AM Finish: 2/28/2010 12:06:02 AM	400	2172	217	40	0.41	0.43	0.43	16	0.25	16 – 0.25 = 15.75
Start:2/28/2010 8:32:29 PM Finish:2/28/2010 8:33:49 PM	400	2176	218	40	0.53	0.54	0.55	16	0.25	16 – 0.25 = 15.75
Start: 3/1/2010 12:44:19 PM Finish: 3/1/2010 12:45:39 PM	26	147	14.7	2.62	1.2	1.25	1.3	1.05	0.03	1.05 – 0.03 = 1.02
Start:3/1/2010 3:44:41 PM Finish:3/1/2010 3:46:01 PM	514	22808	2281	51.4	0.38	0.42	1.49	20.1	20.1	20.1 – 20.1 = 0.00
Start: 3/2/2010 10:12:33 AM Finish: 3/2/2010 10:13:53 AM	380	2107	211	38	0.38	0.48	1.48	15.2	0.24	15.2 – 0.24 = 14.96
Start: 03/02/2010 7:29:24 PM Finish: 03/02/2010 7:30:44 PM	400	2172	217	40	0.39	0.39	0.39	16	0.25	16 – 0.25 = 15.75
Start:3/3/2010 10:36:43 AM Finish:3/3/2010 10:38:03 AM	474	20676	2068	47.4	0.37	0.42	1.4	18.5	18.5	18.5 – 18.5 = 0.00
Start:3/3/2010 11:50:59 AM Finish:3/3/2010 11:52:19 AM	400	2175	218	40	0.39	0.39	0.39	16	0.25	16 – 0.25 = 15.75
Start:03/03/2010 11:15:59 PM Finish:03/03/2010 11:17:19 PM	400	2177	218	40	0.38	0.41	0.46	16	0.25	16 – 0.25 = 15.75
Start:03/04/2010 11:02:24 PM Finish:03/04/2010 11:03:44 PM	400	2176	218	40	0.4	0.4	0.4	16	0.25	16 – 0.25 = 15.75
Start:03/05/2010 12:03:09 AM Finish: 03/05/2010 12:04:29 AM	400	2216	222	40	0.39	0.43	0.78	16	0.25	16 – 0.25 = 15.75
Start:03/05/2010 8:43:54 PM Finish:03/05/2010 8:45:14 PM	360	1958	196	36	0.38	0.38	0.38	14.4	0.23	14.4 - 0.23 = 14.17
Start:03/05/2010 11:45:02 PM Finish: 03/05/2010 11:46:22 PM	380	20.63	206	38	0.38	0.41	0.59	15.2	0.24	15.2 – 0.24 = 14.96
Average			462.74	63.25	0.44	0.50	0.77			23.48 (Avg. hits lost)

Table 2. Experimental performance analysis of gmail server. Test executed on: IJAZ / Administrator, Test allocated Time: 00:01:20 (HH:MM:SS).

Experimental test starting and finishing time with date (MM/DD/YYYY)	Total Kbytes send	Total Kbytes received	Receiving speed (kbit/s)	Sending speed (kbit/s)	Response time (S)			Hits per S.	Page per S.	Hits lost = (hits/S to page/S)
					Min	Avg.	Max			
Start:2/22/2010 11:11:15 AM Finish:2/22/2010 11:12:35 AM	2338	16639	1664	234	0.2	0.22	0.35	60.2	8.6	60.2 to 8.6 = 51.6
Start:2/22/2010 3:21:45 PM Finish:2/22/2010 3:23:05 PM	2256	16058	1606	226	0.2	0.23	0.31	58.1	8.30	58.1 to 8.3 = 49.8
Start:2/22/2010 8:37:37 PM Finish:2/22/2010 8:38:57 PM	1923	13688	1369	192	0.24	0.27	0.34	49.5	7.08	49.5 to 7.08 = 41.92
Start:2/23/2010 10:30:17 AM Finish:2/23/2010 10:31:37 AM	2437	17339	1734	247	0.2	0.26	3.28	62.7	8.96	62.7 to 8.96 = 53.74
Start:2/23/2010 5:21:05 PM Finish:2/23/2010 5:22:25 PM	2376	16909	1691	238	0.2	0.23	0.66	61.2	8.74	61.2 to 8.74 = 52.46
Start:2/24/2010 10:46:53 AM Finish:2/24/2010 10:48:13 AM	2430	17293	1729	243	0.2	0.23	0.71	62.5	8.94	62.5 to 8.94 = 53.56
Start:2/25/2010 1:01:40 AM Finish:2/25/2010 1:03:00 AM	1558	11166	1117	156	0.31	0.34	0.4	40.2	5.74	40.2 to 5.74 = 34.46
Start:2/25/2010 4:22:09 PM Finish:2/25/2010 4:23:29 PM	2420	17316	1732	242	0.2	0.23	0.67	62.3	8.9	62.3 to 8.9 = 53.4
Start:2/26/2010 12:57:19 AM Finish:2/26/2010 12:58:39 AM	741	5326	533	74.1	0.51	0.73	2.59	19.2	2.74	19.2 to 2.74 = 16.46
Start:2/26/2010 2:32:24 PM Finish:2/26/2010 2:33:44 PM	776	5569	557	77.6	0.51	0.59	0.97	20	2.86	20 to 2.86 = 17.4
Start:2/27/2010 1:16:24 AM Finish:2/27/2010 1:17:44 AM	942	6758	676	94.2	0.51	0.54	0.77	24.3	3.48	24.3 to 3.48 = 20.82
Start:2/27/2010 4:09:59 PM Finish:2/27/2010 4:11:19 PM	803	K5755	576	80.3	0.59	0.68	0.9	20.7	2.96	20.7 to 2.96 = 17.74

Table 2. Contd.

Start:2/27/2010 8:48:30 PM Finish:2/27/2010 8:49:50 PM	1123	8036	804	112	0.39	0.45	0.86	29	4.41	29 to 4.14 = 24.86
Start:2/28/2010 12:13:56 AM Finish:2/28/2010 12:15:16 AM	3436	10274	1027	144	0.33	0.36	0.64	37	5.29	37 to 5.29 = 31.71
Start:2/28/2010 12:07:11 PM Finish:2/28/2010 12:08:31 PM	308	3021	302	30.8	1.09	1.23	2.06	6.47	6.47	6.47 to 6.47 = 0.00
Start:2/28/2010 8:26:03 PM Finish:2/28/2010 8:27:23 PM	939	6725	673	93.9	0.46	0.54	0.69	24.2	3.46	24.2 to 3.46 = 20.74
Start:3/01/2010 12:27:34 AM Finish:3/01/2010 12:28:54 AM	676	4857	487	67.7	0.65	0.714	0.88	17.5	2.5	17.5 to 2.5 = 15
Start:3/01/2010 10:18:22 PM Finish:3/01/2010 10:19:42 PM	2073	14811	1481	207	0.22	0.24	0.32	53.4	7.63	53.4 to 7. 63 = 45.77
Start:3/1/2010 12:53:10 PM Finish:3/1/2010 12:54:30 PM	394	2841	284	39.4	1.05	1.15	1.3	10.2	1.46	10.2 to1.46 = 8.74
Start:3/2/2010 10:21:43 AM Finish:3/2/2010 10:23:03 AM	2267	16213	1621	227	0.22	0.24	0.35	58.4	8.34	58.4 to 8.34 = 50.06
Start:03/02/2010 7:18:58 PM Finish:03/02/2010 7:20:18 PM	2158	15439	1544	216	0.22	024	0.41	55.6	7.94	55.6 to 7.94 = 47.66
Start:3/3/2010 10:40:46 AM Finish:3/3/2010 10:42:06 AM	2174	15575	1557k	217	0.22	0.25	0.82	56	8	56 to 8 = 48
Start:3/3/2010 3:48:44 PM Finish:3/3/2010 3:50:04 PM	2226	15948	1595	223	0.22	0.24	0.55	57.3	8.19	57.3 to 8.19 = 49.11
Start:3/03/2010 11:24:12 PM Finish3/03/2010 11:25:32 PM	2239	16043	1604	224	0.22	0.24	0.32	57.7	8.24	57.7 to 8.24 = 49.46
Start:3/04/2010 11:07:55 PM Finish:3/04/2010 11:09:15 PM	2192	15703	1570	219	0.22	0.24	0.36	56.4	8.0	56.4 to 8.06 = 48.34

Table 2. Contd.

Start:3/05/2010 12:15:20 AM Finish:3/05/2010 12:16:40 AM	2222	15925	1592	222	0.22	0.24	0.38	57.2	8.18	57.2 to 8.18 = 49.02
Start:3/05/2010 8:35:49 PM Finish:3/05/2010 8:37:09 PM	2192	15703	1570	219	0.22	0.24	0.5	56.4	8.0	56.4 to 8.06 = 48.34
Start:3/05/2010 11:53:07 PM Finish: 3/05/2010 11:54:27 PM	2212	15852	1585	221	0.22	0.24	0.34	57	8.14	57 to 8.14 = 48.86
Average			1224.28	170.96	0.36	1.25	0.81			37.46

Table 3. Experimental performance analysis of hotmail server. Test executed on: IJAZ / Administrator, Test allocated Time: 00:01:20 (HH:MM:SS).

Experimental test starting and finishing time with date (MM/DD/YYYY)	Total Kbytes send	Total Kbytes received	Receiving speed (kbit/s)	Sending speed (kbit/s)	Response time (S)			Hits Per S.	Page per S.	Hits lost = (hits/Sec to page/S)
					Min.	Avg.	Max.			
Start:2/22/2010 10:57:54 AM Finish:2/22/2010 10:59:14 AM	1273	16565	1656	127	0.92	1.9	3.06	32.7	4.67	32.7 to 4.67 = 28.03
Start:2/22/2010 3:18:01 PM Finish:2/22/2010 3:19:21 PM	1058	13767	1377	106	0.96	1.69	3.16	27.2	3.89	27.2 to 3.98 = 23.31
Start:2/22/2010 11:59:40 PM Finish:2/22/2010 12:01:00 AM	1406	18589	1859	141	0.93	1.58	2.96	36.1	5.16	36.1 to 5.16 = 30.94
Start:2/23/2010 10:22:37 AM Finish:2/23/2010 10:23:57 AM	1355	17027	1703	135	0.93	1.8	2.76	34.8	4.97	34.8 to 4.97 = 29.83
Start:2/23/2010 5:32:32 PM Finish:2/23/2010 5:33:52 PM	1310	18552	1855	131	0.92	1.73	2.66	33.7	4.83	33.7 to 4.83 = 28.87
Start:2/23/2010 11:50:37 PM Finish:2/23/2010 11:51:57 PM	1297	17619	1762	130	0.94	1.62	2.66	33.3	4.76	33.3 to 4.76 = 28.54
Start:2/24/2010 10:43:02 AM Finish:2/24/2010 10:44:22 AM	1058	13460	1346	106	0.95	1.86	5.19	27.2	3.89	27.2 to 3.89 = 23.31

Table 3. Contd.

Start:2/25/2010 12:58:02 AM Finish:2/25/2010 12:59:22 AM	1317	17315	1732	132	0.94	1.7	2.61	33.9	4.84	33.9 to 4.84 = 29.06
Start:2/25/2010 4:32:39 PM Finish:2/25/2010 4:33:59 PM	1253	17321	1732	125	0.96	1.85	3.17	32.2	4.6	32.2 to 4.6 = 27.6
Start:2/26/2010 12:53:43 AM Finish:2/26/2010 12:55:03 AM	563	7149	715	56.3	0.96	6.84	30.5	14.5	2.08	14.5 to 2.08 = 12.42
Start:2/26/2010 2:35:53 PM Finish:2/26/2010 2:37:13 PM	604	7844	784	60.4	1.01	6.53	13.5	15.6	2.23	15.6 to 2.23 = 13.37
Start: 2/27/2010 1:12:32 AM Finish:2/27/2010 1:13:52 AM	1256	17866	1786	126	0.92	1.72	2.6	32.3	4.61	32.3 to 4.61 = 27.69
Start:2/27/2010 4:13:42 PM Finish:2/27/2010 4:15:02 PM	634	7996	800	63.4	1.56	2.87	5.34	16.4	2.36	16.4 to 2.36 = 14.04
Start: 2/27/2010 8:53:02 PM Finish:2/27/2010 8:54:22 PM	1092	15235	1523	109	1.0	1.71	3.17	28.1	4.01	28.1 to 4.01 = 24.09
Start:2/28/2010 2:50:35 PM Finish:2/28/2010 2:51:55 PM	375	5067	507	37.5	2.2	3.86	4.93	9.71	1.39	9.71 to1.39 = 8.32
Start:2/28/2010 12:08:54 AM Finish:2/28/2010 12:10:14 AM	1160	16042	1604	116	0.99	1.72	3.19	29.8	4.26	29.8 to 4.26 = 25.54
Start:03/01/2010 12:24:11 AM Finish:03/01/2010 12:25:31 AM	840	9831	983	84	1.37	2.48	3.81	21.6	3.09	21.6 to 3.09 = 18.51
Start:3/1/2010 3:15:13 PM Finish:3/1/2010 3:16:33 PM	287	3071	307	28.7	2.6	4.88	7.1	7.44	1.06	7.44 to1.06 = 6.38
Start:03/01/2010 10:24:12 PM Finish:03/01/2010 10:25:32 PM	997	12183	1218	97.7	0.96	1.8	2.81	25.6	3.66	25.6 to3.66 = 21.94
Start:3/2/2010 10:17:28 AM Finish:3/2/2010 10:18:48 AM	990	11986	1199	99	0.94	2.25	4.76	25.5	3.64	25.5 to 3.64 = 21.86

Table 3. Contd.

Start:3/02/2010 7:23:45 PM Finish:3/02/2010 7:25:05 PM	780	9635	963	78	1.0	1.83	2.87	20.1	2.88	20.1 to 2.88 = 17.22
Start:3/3/2010 11:42:29 AM Finish:3/3/2010 11:43:49 AM	904	10825	108	90.4	1.04	2.04	1.96	23.3	3.33	23.3 to 3.33 = 19.97
Start:3/3/2010 3:45:02 PM Finish:3/3/2010 3:46:22 PM	788	9891	989	78.8	0.99	1.89	3.27	20.3	2.91	20.3 to 2.91 = 17.39
Start:03/03/2010 11:31:41 PM Finish:03/03/2010 11:33:01 PM	1189	14620	1462	119	0.94	1.69	2.69	30.6	4.41	30.6 to 4.41 = 26.19
Start:03/04/2010 11:13:14 PM Finish:03/04/2010 11:14:34 PM	1154	14998	1500	115	0.97	1.82	2.89	29.7	4.24	29.7 to 4.24 = 25.46
Start:03/05/2010 12:07:13 AM Finish:03/05/2010 12:08:33 AM	1055	12720	1272	105	0.97	1.86	2.8	27.1	3.88	27.1 to 3.88 = 23.22
Start:03/05/2010 11:48:50 PM Finish:03/05/2010 11:50:10 PM	1300	17235	1723	130	0.94	1.72	2.86	33.4	4.78	33.4 to 4.78 = 28.62
Start:03/05/2010 8:39:49 PM Finish:03/05/2010 8:41:09 PM	1058	14015	1401	106	0.98	1.82	2.69	27.2	3.89	27.2 to 3.89 = 23.31
Average			1315.75	101.18	1.09	2.39	4.71			22.32

means high load or “load plus congestion” but in case of large increment in hop counts with some increment in RTT means there is necessarily congestion. With consistent hop counts if RTT increases up to maximum extent then most probably it indicates high load which may leads to congestion. The error rates of different servers were reported in Table 6.

DISCUSSION AND ANALYSIS

In internet communication, the high load leads to congestion. It has been observed that under heavy load, the turn around time is increased and in case of congestion, the number of hop counts and RTT both are increased, which consequently cause high latency. In case of load without congestion, the number of hop counts may or may not be increased but the increment in the number of hop counts is definitely small as compare to congested situation. Table 7 shows that the Yahoo server seems to be best because of minimum response time (0.50 s) and with 100% availability than Hotmail and Gmail servers. In terms of round trip time, there is a slight difference between Yahoo and Gmail servers, which is only 3 min but in case of Response Time, the difference is quite high (0.75 s). On the other hand, the reliability of all three selected servers is almost same. Overall, the Hotmail server has greatest average response time as compared to Yahoo server with average hits lost ratio difference (1.16) which is negligible as its effect is medium and the difference between average response time of yahoo and Hotmail server is (1.89 S) which clearly indicates that Yahoo server is best in case of performance characteristics to negate load and congestion because, vigorous response time survives the online resources from load and congestion.

Conclusion

Most likely, the user evaluates the performance of remote services according to response time, latency, reliability and availability, delay and jitter that are affected under loaded and congested

Table 4. Experimental results of yahoo server.

Web mails	S/No.	TTL	Round trip time (RTT)(m/s)			No. of hop counts	Effect of congestion and load
			Min.	Avg.	Max.		
Yahoo server	1	49	176	177	178	13	No extra Load and Congestion found
	2	49	175	176	177	13	No extra Load and Congestion found
	3	49	177	177	177	13	No extra Load and Congestion found
	4	49	176	176	179	13	No extra Load and Congestion found
	5	49	206	207	208	15	Congestion found on node 12 in between nodes te-8-3.bas-a2.re4.yahoo.com [216.39.49.65] and ae1-151.msr2.re1.yahoo.com [216.115.108.23] as Request Time out
	6	49	204	207	212	15	Congestion found on node 12 in between nodes t2c1-p5-0-0.us-ash.eu.bt.net [166.49.164.65] and ae1-p151.msr2.re1.yahoo.com [216.115.108.23] as Request Time out
	7	49	205	206	208	15	Congestion found on node 12 in between nodes t2c1-p5-0-0.us-ash.eu.bt.net [166.49.164.65] and ae1-p141.msr1.re1.yahoo.com [216.115.108.19] as Request Time out
	8	49	176	177	178	13	No extra Load and Congestion found
	9	49	173	175	176	13	No extra Load and Congestion found
	10	49	172	174	178	13	No extra Load and Congestion found
	11	49	173	174	177	13	No extra Load and Congestion found
	12	49	210	217	222	13	Some Load found as RTT increased
	13	49	447	459	469	13	High Load found as RTT increased (no congestion)
Average			205	208	211		

Table 5. Experimental results of gmail server.

Web mails	S/No.	TTL	Round trip time (RTT) (ms)			Number of hop counts	Effect of congestion and load
			Min.	Avg.	Max.		
Gmail server	1	50	104	104	105	15	No extra Load and Congestion found
	2	50	104	105	108	15	No extra Load and Congestion found
	3	50	106	108	113	15	No extra Load and Congestion found
	4	50	106	106	107	15	No extra Load and Congestion found
	5	50	123	124	126	16	Some load found and no Request time is out
	6	50	123	125	128	16	Some load found and no Request time is out
	7	50	123	125	129	16	Some load found and no Request time is out
	8	50	107	107	110	15	No extra Load and Congestion found
	9	47	207	209	211	26	Small load found on nodes (8,9,23 & 24) and leads to congestion as Congestion found on nodes (19,20,21 and 22) in between nodes [209.85.249.32] and (209.85.250.141)
	10	45	253	256	263	27	Small load found on nodes 8, 22, 23 [209.58.60.2], [209.85.250.141] and [209.85.254.112] respectively with IPs. Congestion Found on nodes (19, 20, 21, 22) in between nodes [209.85.249.32] and (209.85.250.141).

Table 5. Contd.

	11	45	255	258	263	27	Small load found on node (9 and 14) [209.58.26.41] and [4.69.132.61], respectively. Congestion found on nodes (19,20,21,22,23 & 24) in between nodes (209.85.249.32) and [209.85.248.44]
	12	45	628	632	638	20	High Load found as RTT increased (leads to congestion)
	13	45	396	410	423	18	Medium Load found on each node (leads to congestion)
Avg.			203	205	209		

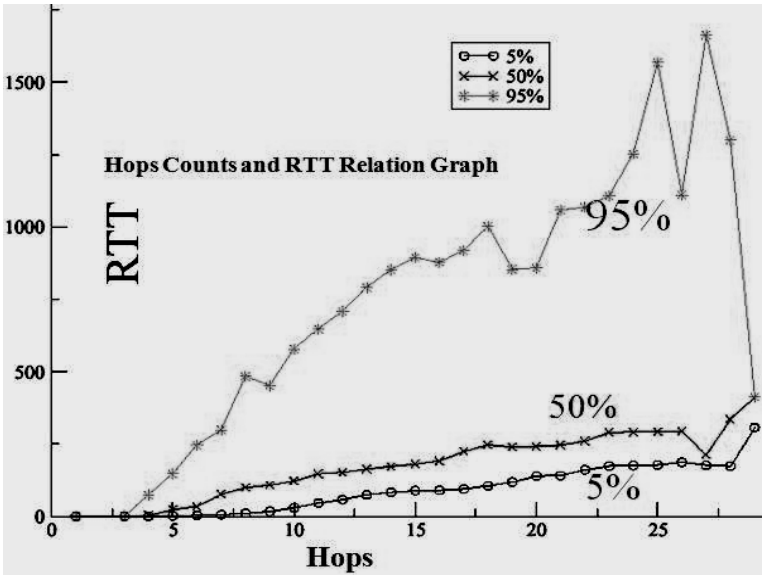

Figure 1. Hop counts and RTT relationship.

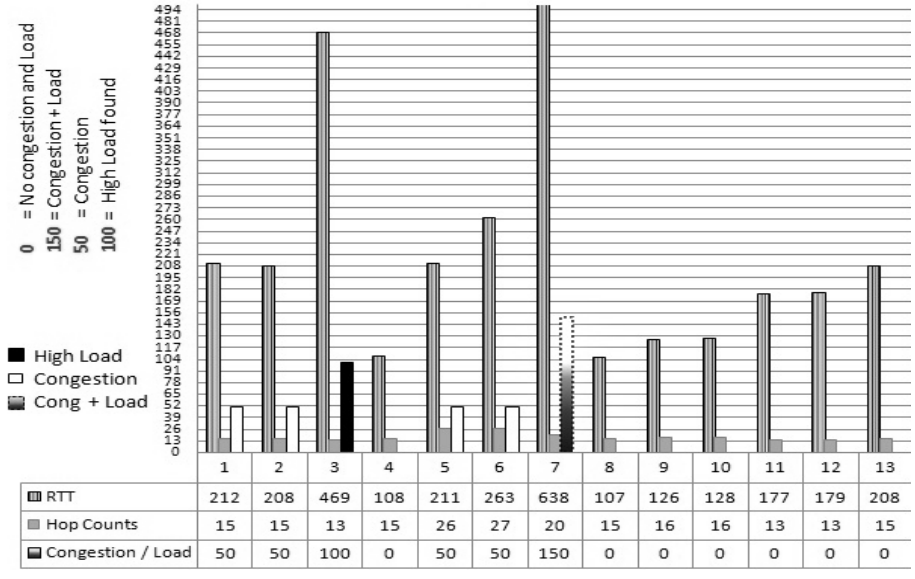

Figure 2. RTT and hop count's effect on load and congestion.

Table 6. Page error rates.

Remote servers	S/No.	Session performed	Session with errors	Hits with errors	Page with errors	Overall errors percentage
Yahoo server	1	27	7	7	7	0.54
	2	20	0	1	0	0.08
	3	23	3	3	3	0.23
	4	29	9	9	9	0.69
	5	17	0	7	0	0.64
	6	20	0	2	0	0.16
						Average = 0.39%
Gmail server	1	611	1	1	1	0.02
	2	640	0	1	0	0.02
	3	646	0	1	0	0.02
	4	656	0	2	0	0.04
	5	446	5	19	5	0.61
						Average = 0.14%
Hotmail server	1	230	0	3	0	0.19
	2	233	0	9	0	0.55
	3	249	2	7	2	0.4
	4	293	0	1	0	0.05
	5	312	1	1	1	0.05
						Average = 0.25%

Table 7. Performance evolution.

Performance characteristics	Yahoo server	Gmail server	Hotmail server	Effect of characteristics on end user preference and real performance
Avg. response time (RT)	0.50 S.	1.25 S.	2.39 S.	High
Avg. round trip time / Latency	208 ms	205 ms	---	High
Avg. sending speed	63.25 kb/s	170.96 kb/s	101.18 kb/s	Not considered (vary in case link speed and hardware)
Avg. receiving speed	462.74 kb/s	1224.28 kb/s	1315.75 kb/s	Not considered (vary in case link speed and hardware)
Avg. hits lost	23.48	37.46	22.32	Medium
Avg. error rate (%)	0.39%	0.14%	0.25%	Least (Mostly No affect on end user performance)
Availability	100%	100%	100%	High
Reliability	Same	Same	Same	High
Security against hacking attempts	Low	Low	Medium	High

situations. Congested situation causes substantial amendment in path with large penalty of hop counts. The increment in hop counts gives birth to measureable latency which results enormous effect on other performance metrics with quantifiable increment in Round Trip Time (RTT). Consequently, overall efficiency of remote services is degraded. Our observation against experimental results (Tables 4 and 5) clearly invokes that, if the difference of hop greater than 2 and RTT is greater than OR equal to {Normal(RTT) + (Normal RTT / 2)

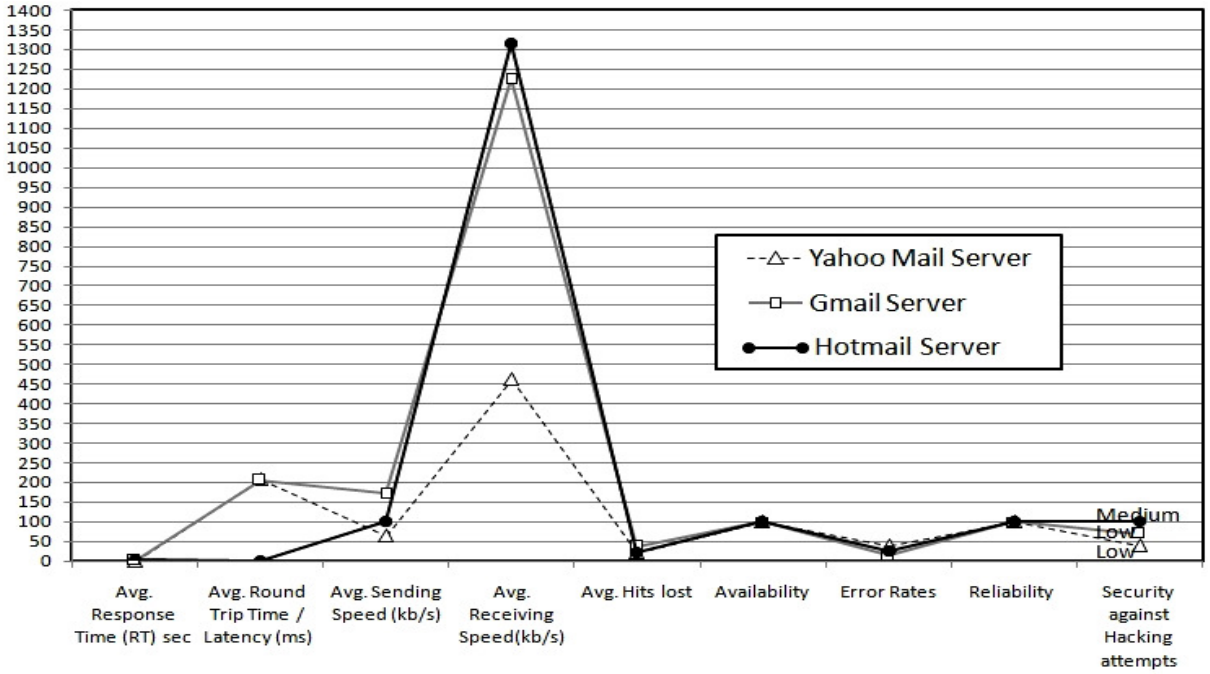

Figure 3. Performance metrics evaluation graph.

} in between the normal and loaded condition, it means there is granted congestion otherwise the situation is said to be highly overloaded. High load may leads congestion but not necessarily congestion until the above mentioned conditions are not satisfied. It means RTT has a relation with congestion and load but hop counts have direct relationship with congestion.

Future directions

The future of global electronic linkage wishes to perceive quickly responding services with minimized degree of load and congestion in prospective communication. The live monitoring of loaded situation can survive the network to enter in congested situation by understanding the actual relationship among load, congestion, RTT, and hop counts as we have been concluded in this paper. But the situation when a router at some point in communication route is out of order then path will necessarily be changed. In this situation, if the degree of hop counts is greater than 2 then according to our discovered relationship this situation is said to be congested but actually this situation may be congested or may not be congested? In future, there is need to realize the effect of dead router(s) over congestion? How we can point out; the longest path and service latency is happened either due to congestion or dead router(s)? Is the dead router will just cause latency and hop counts increment or it associates some probability of high load and congestion? These questions warmly welcome the researchers to chase these challenges. We confidently advised the researchers to utilize our derived relationship while developing the congestion avoidance algorithms.

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