A critical Performance Analysis of Thin Client Platforms

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Abstract—The nature of operation of Thin Client computing makes their performance to be affected by both the quality of the network and the terminals. For the past few years, there are few analyses on the performance of Thin Clients that can produce reliable, valid, and up-to-date results collected in a well designed and evaluated experiment based research. This paper analyses the performance of Thin Clients through experiment based research. The approach is to use benchmark application which is designed specifically for measurement of desktop computers by inserting delays in the visual elements of such benchmark application. In this technique, packet’s behavior is measured on the network as the application is executed from the server to a Thin Client. The analysis through measurements of the performance shows that the improvement of computer processing power has a lot of performance metrics and comparing the trend with the results collected nearly seven years ago by previous researchers. Moreover, the bandwidth is found to be the main bottleneck for the performance of Thin Clients while the CPU is of less concern.

Keywords—Thin Client computing, web-based applications, multimedia applications, benchmark application, and performance.

I. INTRODUCTION (HEADING 1)

Recently, Thin Client computing has gained a significant popularity in many organizations. The reasons behind relies on the its architecture where each applications are executed in server and accessed by Thin Clients which are diskless dumb terminals [3,6]. The interests on the performance behavior attracts attention to several group of people especially researchers in Network Computing, vendors and IT personnel for better understanding and decisions support. For the past few years, there are few analyses on the performance metrics of Thin Client Protocols despite of a considerable improvement of performance of computer terminals and network quality. This paper analyses the performance behavior of Thin Clients through conducting a benchmark experiment and combine observing the discrepancies as compared to the previous research done by Nieh (2000) and Yang (2001). Both measured protocols were found to have the same trend of performance metrics under different network bandwidths. This allows us to pick one of them to represent the rest of Thin Clients for batter analyzing them since we are interested with the discrepancies in terms of trends under different bandwidths instead of real values.

The rest of this paper is organized as follows: section II discusses the performance metrics of Thin Clients. Section III discusses the experiment design where the previous test-bed is reduced to reflect the needs of this research as RDP is a chosen protocol to investigate, section IV analyses the results collected by this research while section V is a conclusion for the paper.

II. THIN CLIENT PERFORMANCE METRICS

A. latency

In a network, latency, a synonym for delay, is an expression of how much time it takes for a packet of data to travel from one designated point to another [14,10]. In some usage, latency is calculated by sending a packet that is returned to the sender; and the round-trip time is considered as the latency. Daniel et al. (2003) points out that, the main drawback of latency happens in the case when one of the data flows has greater latency than the other. The data flow with lower latency will increase its windows size at much higher rate, and thus bandwidth consumption, and would therefore penalize the greater latency data flow. In addition, as the total available network bandwidth is consumed, both TCP connections continue to fight for the bandwidth, continually pushing the network in and out of congestion. Therefore, the latency should be as small as possible for a network to have good performance.

For web page applications, per-page latency of less than one second has been shown to be desirable to ensure that the flow of a user’s browsing experience is not
interrupted [14]. The performance measurement in Thin Client computing should, thus, include total latency of execution of web pages and per page latency. The total latency of Thin Client is time duration of start to the end of client-server operation based on the operations involved.

B. Amount of Data Transferred

The amount of transferred data from server to client in server-based computing can determine a performance of such Thin Client. Normally, the more the data transferred to a network from client to server, the high the performance a Thin Client have. This metric can also be influenced by some performance optimisation techniques For example; caching web pages in Thin Clients might reduce the amount of transmitted data as it allows local accessing of pages instead of requesting them to travel from server [11].

In Thin Client computing, the correct measurement of amount of data transferred is through a network [7]. The measurement requires special network monitoring tools that capture the packets on a switch or hub, which passes the traffic from server to client.

C. Multimedia Display Quality

Multimedia includes a combination of text, audio, still pictures, animation, video, and interactivity contents. The quality of display of multimedia contents determines the performance of Thin Client under measurement. But, the amount of data transferred during execution of video playback. For example, is not enough to quantify the video quality of such platform. According to Nieh J et al. (2001), the best approach to measure the video quality is to use the following formula in equation (i).

\[
V_Q = \frac{\text{Data Transferred}(24 \text{ fps}) / \text{Playback Time}(24 \text{ fps})}{\text{Ideal FPS}(24 \text{ fps})} \\
\frac{\text{Data Transferred}(1 \text{ fps}) / \text{Playback Time}(1 \text{ fps})}{\text{Ideal FPS}(1 \text{ fps})}
\]

Where:

- Data transferred (24 fps) is the amount of data transferred in normal condition (in ideal used is 24fps) as a video playback is executed. Data transferred (1 fps) is the amount of data transmitted as a slowest possible rate of video execution, which is believed to be the most possible amount of data. Playback time (1 fps) and playback time (1 fps) are the time duration for execution of a video at normal speed and the duration for slowest rate respectively. The ideal fps values are the integer values that correspond to 1 and 24 respectively.

The video quality metric involved in the above formula takes into account only the amount of discarded data. However, it does not take into consideration tendency of some of video data to be more important to the overall multimedia display quality of a particular video sequence than others. For example if the video frames are looking the same as the previous or next one in a frame sequence does not affect the user perceived video quality when compared to the case where the updates that are not similar to each of the case in the neighboring frames are discarded.

D. Bandwidth Utilization

The portion of bandwidth utilised by the application can have an impact on the performance of Thin Client computing. Lian et al (2001) defines effective bandwidth of a network as the maximum amount of meaningful data that can be transferred per unit time, exclusive of factors such as headers, padding and stuffing. Some of factors that affects the availability and utilisation of the network bandwidth are the sampling rates at which the various devices send information over the network, the number of elements that require synchronous operation, the data or message size of the information and the medium access control sub layer protocol that controls the transmission of information [12].

E. CPU Utilization on Client and Server

CPU plays a very huge part in Thin Client computing. Both server and client should have enough power to process the execution of activities. The system under performance measurement should have reasonable processing speed to support the executing application. Normally, if the processing power of client and server are not utilised to higher percentage, then it indicates that the performance is not caused by less power of the systems. This conclusion is drawn through taking into account that the large the free portion of utilised CPU the less the processing dependency on that particular computing machine [13]. This research includes the CPU utilisation metric as part of performance analysis. The measurement of the percentage utilisation of CPU is simple to measure as it just involves taking a reading from a respective computer.

III. EXPERIMENTAL DESIGN

The design of a test-bed follows the slow-motion benchmarking technique [4,7,8]. In slow-motion benchmarking, the network packet traces are used to monitor the latency and data transferred between the client and the server. In this case, the benchmark application is altered by introducing delays between the separate visual components of that benchmark, such as web pages or video frame so that the display update for each component is fully completed on the client before the server begins to process the next one. The test bed seen in Figure 1 is a modified version of the original test-bed which measured the performance of Thin Clients nearly 7 years ago. It is specifically suitable for measuring the performance of RDP protocol. Thin Client is connected to a hub where it receives packets from the terminal server through establishing RDP connection to it. The Packet monitor is connected to the same hub to
timestamp and record the network packets that are broadcasted on a network hub connected to it.

Figure 1: A designed version of Test-bed for this experiment (Adopted from [7])

A benchmark server run windows 2003 server operating system and hosts web and multimedia applications. In this experiment, ZiffDavis i-Bench benchmark suite version 5.0 [9] was used. The packet monitor machine runs WildPackets’ Omnipeek 5.0 [5] and its function is to trap and record all network traffic traversing from Server to Client. The Packet emulator runs Bandwidth Controller Standard [1] whose function is to regulate the bandwidth of the packets passing through it by changing the effective bandwidth to a required range of experiment such as 128kbps, 768kbps, 1.5Mbps, 10Mbps, and 100Mbps. A Terminal server is a Windows Server 2003 having RDP version 6.0 while a Thin Client is a normal PC running windows XP professional. The connection is established through RDP connection between a Terminal Server and a Thin Client.

For the optimum performance, one could expect a switch to be used instead of a hub simply because hub has its shortcomings such as packet broadcasting. The reason we used hub is the need to compare the trends of these results with the previous set since the previous experiments also used hub in the same place. On the other hand, switch that will fit this purpose are so expensive. They are expensive because of their complexity since they must be capable of supporting port mirroring functionality [2]. However, a hub is also capable because we are much interested with the trends of the performance metrics and not real values.

Table 1 illustrated the two sets of hardware and software used to collect the two sets of results which will be combined to assist in analyzing the performance. The values with red caption corresponds to a new set of hardware and software and with black caption are for the previous experiment which was done by Nieh et al. (2000) and Yang et al. (2002).

<table>
<thead>
<tr>
<th>Table 1: A summary of hardware and software specifications used in new and previous experiment</th>
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<tr>
<td>Hardware Specifications</td>
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<tr>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>128kbps</td>
</tr>
<tr>
<td>768kbps</td>
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<tr>
<td>1.5Mbps</td>
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<td>10Mbps</td>
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<td>100Mbps</td>
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IV. RESULTS AND DISCUSSIONS

The analysis shows that the total latency during the execution of web pages is much higher in low bandwidths than in higher bandwidth. This trend can be seen in both sets of results that at 128kbps, the value of total latency is very high compared to the values in the rest of and widths. Also, when comparing the two trends in Fig. 2, the performance behaviour of Thin Clients in terms of Total latency did not change to a significant extent despite of the improvement of computer performance based specifications such as RAM and storage.

Figure 2: Total latency of web benchmark with default configurations (Adopted from [7])

Fig. 3 shows a trend of the amount of transferred data for the new and previous experiments in various bandwidths. The analysis shows that the amount of data transferred is nearly the same for each of the bandwidths as both lies between 5.1MB and 5.4MB for new results and 4.96MB to 4.98MB for the previous results. The variation on the values in the figure may be caused by network instability during execution of web pages. Although, by comparison the two trends, the bandwidth of the medium seems to have an impact on the amount of data transferred in the new experiment than in the previous one although it is not uniform. This can be contributed by one of the processing...
upgrades in the computers that make them eager to send more and more data to a network.

Another investigation is due to the random nature of the graphs. The new graph indicated roughly the increase in data transfer versus bandwidth. The previous indicates the roughly constant values. This shows that in new experiment, the amount of transferred data plays part on the performance of Thin Clients since it varies with frequency in contrast to the previous case where this metric seems to be not the right metric to describe the performance of a Thin Client.

Figure 3: The amount of data transferred by video benchmark at 24fps and at slow-motion in 100mbps for new and previous experiment combined (Adopted from [7])

The video quality was measured by the use of equation (i) and Figure 4 illustrates the findings as seen that the quality of display in RDP is very excellent at 100mbps as it reaches 97% followed by the rest of bandwidths. The trend of previous experiment shows that the data collected in the previous research by Nieh et al. (2001) has a video display quality with a maximum of 57%. This shows that, recent computers discard an average of only 3% of data when executing video applications while the previous computers discarded an average of 43% of data.

This discrepancy of the performance of video display can be contributed by the following reasons. Firstly, there is a big possibility that the Video Graphics Array (VGA) device have improved in quality in recent computers where the processing of pixels is of much higher efficiency than in the older machines. Also, there is a possibility that the improvement of processor efficiency results to the processing of much higher instructions per second there by transmitting more data from server to client in which deliberately the video quality improved as a function of the amount of data transferred.

Another improvement can be on the NICs. Most of the new computers used were able to transport Gigabytes of data per second; therefore there is a possibility that at the large amount of data is transferred at the high speed NICs but small of them being transferred in the low speed NICs. However, this has a small chance due to the fact that in transmission processes, the medium that transmits low speed data is always taken as reference of the overall transmission medium as it always transmit to its maximum capacity while discarding the excess of any of the data.

Figure 4: Video quality with default settings in current and previous research combined (Adopted from [7])

The analysis of bandwidth utilization shows two main findings. Firstly, at higher bandwidth, the bandwidth becomes less utilized than in low bandwidth, as seen in Figure 5 where the at 100mbps the usage is around 23% while at 128kbps the usage is around 90%. This trend was almost also the case in previous research done by Yang et al. (2001) as seen in the trend in Figure 4 where the bandwidth utilization is much higher in low bandwidths than in high bandwidth.

Another observation from this experiment is that, recent computing environments tend to utilize the most of the available bandwidth during execution of applications. It can be seen in Figure 4 that at the same bandwidth value, the percentage utilization of the bandwidth is much higher in recent experiment compared to the previous research. This suggests that there is an improvement in the amount of data which is sent to the medium. Moreover, this suggests that the increase in processing power tends to improve the processing speed in applications and hence an improved amount of data travelling on the network per second that leads to high percentages of bandwidth utilization.

Figure 5: Bandwidth utilization when downloading web pages in current and previous research combined (Adopted from [7])

The analysis shows that the server side is more loaded than client side. The previous research shows the same trend as seen in Figure 6 although there are some additional investigations due to the advancement in computing power where the analysis shows that the CPU utilization in both client and server has become much less, indicating that the portion of processing power used to execute the web applications is much less in new systems. This also suggests that, as processing power contributes a very small extent to
the performance of web applications as it does not seem to be much utilized.

Figure 6: CPU utilization in Client and Server for current and previous research combined (Adopted from [7])

V. CONCLUSION

This paper presents some performance details of Thin Client computing by concentrating on their behavior in various bandwidth levels. It analyses the main performance metrics in Thin Client computing through measuring them in a designed experiment and executing the desired version of applications and measuring the network behavior. The discussion relies on the findings of the experiment and the previous findings in the past Thin Client performance experiments. This paper is limited to the performance behavior in default configurations on both Thin Client and server. Future research will concentrate on the analysis of performance behavior with performance-based Thin Client configurations such as caching, merging and compression being enabled in various bandwidth levels on the same approach. In the future, a further performance research will be conducted involving the newly enhanced Zero Client PCs.

REFERENCES


