

PC vs. thin client performance in typical office application scenarios

Executive summary

Intel Corporation (Intel) commissioned Principled Technologies (PT) to compare the performance of PCs and two types of thin clients on test networks with varying numbers of active clients, each running the same typical office application tasks. We measured the response time users would experience on each system while performing common office functions with leading office applications. We tested the following representative client platforms:

- **PC:** Dell OptiPlex 210L PCs, basic managed PC desktops running Windows XP Professional
- **Sun thin client:** Sun Microsystems Sun Ray 2 thin client running Sun Ray proprietary software
- **Wyse thin client:** Wyse Winterm 5150SE, Linux-based thin clients running Wyse Linux V6

We set up test networks that supported five of each type of client and were otherwise as identical as possible given the demands of the thin clients. Each network used a standard file server, an HP ProLiant DL360 3.4 MHz server with an Intel Xeon processor and Microsoft Windows Server 2003 Enterprise Edition. Where necessary, this server also ran the software to support the thin clients. The Sun Ray 2 test network additionally required a Sun Fire V240 server, which translates the proprietary Sun thin client protocol into RDP for the Windows Server. We installed Microsoft Office 2003 and Adobe Acrobat 7.0 Standard on each platform, locally on the PC and on the shared server for the thin clients. To make the comparison as apples-to-apples as reasonably possible, in all but one case, in which storing a file locally on the PCs seemed more like what real users would do, we stored the test data files on the file server.

We focused on operations that would typically make users wait, because those operations by their nature tend to be the ones on which users would most appreciate performance improvements. We tested the following four scenarios, two with a single active task and two with multiple tasks running at the same time:

- Single task scenarios
 - Calculating subtotals in Microsoft Office Excel 2003
 - Compressing a PDF from within Adobe Acrobat 7.0 Standard
- Multitasking scenarios
 - Changing the view in a Microsoft Office PowerPoint 2003 presentation while compressing a folder in Windows Explorer
 - Opening large XML files in Microsoft Office Word 2003 and Microsoft Office Excel 2003

We tested each scenario first on a single client with exclusive access to the file server and then repeated the scenario with 2, 3, 4, and 5 clients running concurrently. We collected the response time on each of the participating clients. Our results graphs and tables show the effect the load of additional clients had on response time. Figure 1 illustrates the results for a simple single-task scenario, calculating Excel subtotals.

As you can see, the performance of the PCs stayed the same as we added more simultaneously active users. By being able to do the computation work locally, the PCs did not have to rely on the file server for more than supplying the data.

KEY FINDINGS

- On 4 different scenarios involving up to 5 systems simultaneously running the same common office tasks, PCs consistently and dramatically outperformed both Sun Ray 2 and Wyse Winterm 5150SE thin clients in the multi-client tests.
- PC performance stayed consistent on most tests as we added simultaneously active clients, while the performance of both types of thin clients plunged as we increased the number of active clients.
- With 5 simultaneously active users, PCs delivered basically the same response time on each system, while different thin client users often experienced dramatically different response times.

The thin clients, by contrast, delivered dramatically worse response time as more clients worked at the same time, with performance dipping to below 20 percent of what it was with a single active client. This performance dip occurred because all the active thin clients had to rely on the single shared server to not only supply the data files but also do the computation work.

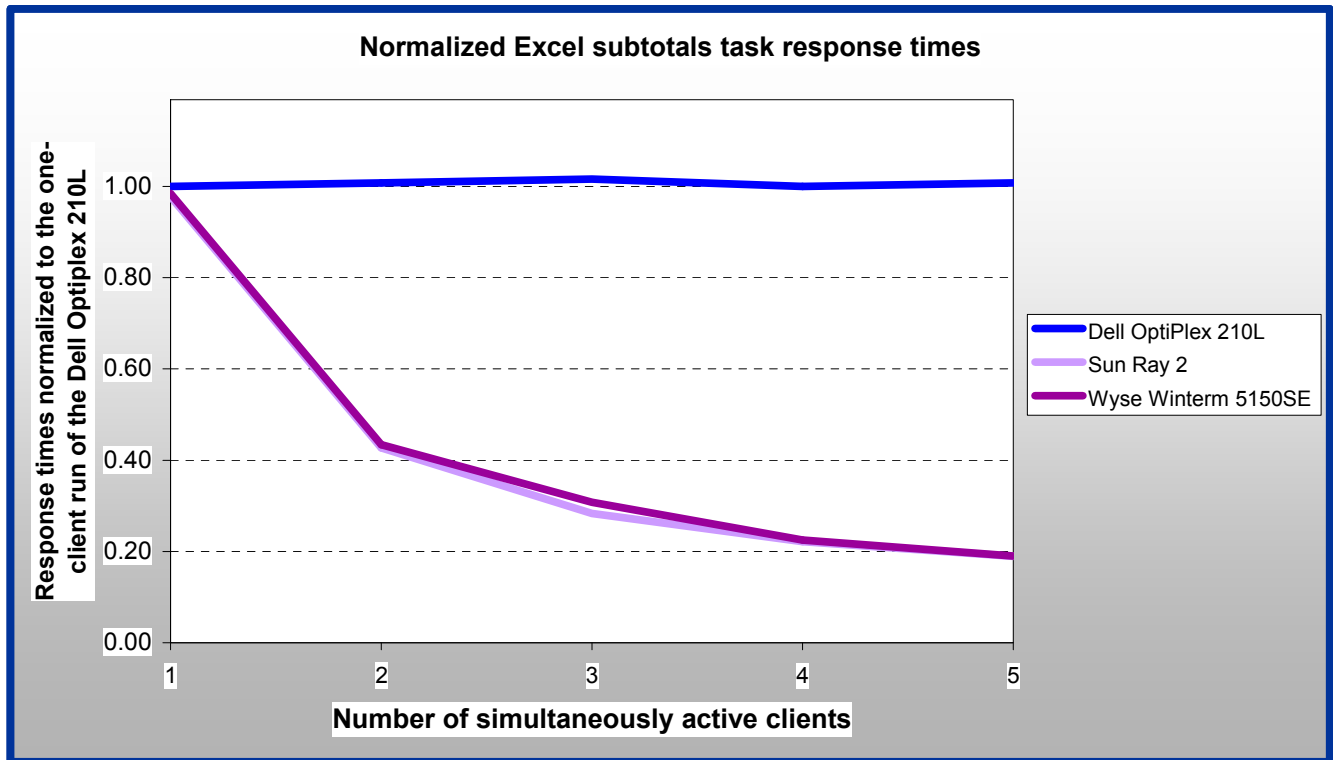


Figure 1: Results for the Excel subtotals task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

As Figure 1 also shows, the different types of clients delivered similar response time with only a single client running the test. In this case, each thin client had the server acting as essentially a dedicated PC for that client, so it is no surprise that the PCs and the thin clients performed about the same. The moment we added a second active client, however, thin client performance plunged, because those two clients then had to share the server.

In our tests, all the clients performed the same task at the same time, though each had its own copies of all data files. Though typically people are not doing exactly the same thing at exactly the same time, most networks with a similarly capable server would be supporting a lot more than a mere 5 simultaneous users. Further, during normal work hours a great many of those users would be working on different tasks at the same time. Our test cases are thus probably less demanding on the server than real user networks.

In the following sections we discuss our test application scenarios (Application scenarios), examine the results of our tests (Test results and analysis), and provide detailed information about how we actually performed the tests (Test methodology). In the appendices, we present the configurations of the test systems, explain how to manually execute the application functions in our scenarios, and discuss some issues in the development of the test scripts.

Application scenarios

To gauge performance on typical office applications, we developed a set of 4 test scenarios. We focused primarily on processor-intensive operations that often force users to wait, because users are likely to appreciate performance improvements on such operations. Each scenario contains 1 to 3 timed common business functions. We created 2 scenarios that include a single task and 2 that include multiple tasks running at the same time.

Single task scenario: Calculating subtotals in Microsoft Excel

In our first scenario, Carson, the head of sales for a specialty retailer, is reviewing a sales report in Excel and wants to get totals for each of her associates. Her spreadsheet is a 1.79MB Excel file on the file server. The worksheet has 11,511 rows of sales data in 11 columns. She selects Data/Subtotals from the Excel menu. The Subtotals dialog displays, and she fills in information on the subtotal she needs. She presses Enter and waits for the recalculation to complete.

We timed this task from the point she presses Enter until the Excel status bar displays Ready at the end of the calculation.

Single task scenario: Compressing a PDF from within Adobe Acrobat

In our second scenario, Parker, the assistant to a marketing director, has a 4.01MB PDF of a white paper that he wants to put on the company's Web site. He plans to save download time for customers by reducing the files size. He has the file open in Adobe Acrobat 7.0 Standard and selects File/Reduce File Size. When the Reduce File Size dialog displays, Parker changes the Make Compatible with: selection to Acrobat 7.0 or later and presses OK. In the Save As dialog, he enters compressed.pdf as the file name and presses Save. Acrobat compresses the file and then displays a Conversion Warning saying that the PDF contained image masks that were not down-sampled. Parker presses OK, and Acrobat displays his compressed PDF.

We timed this task from the point he presses OK in the Reduce File Size dialog until the Conversion Warning appears at the end of the compression.

Multitasking scenario: Changing the view in a Microsoft PowerPoint presentation while compressing a folder in Windows Explorer

In the third scenario, Maya, a project manager, has a 265MB folder in her My Documents folder that she wants to compress and copy to an FTP site for a customer. (We stored this folder locally on the PCs, because a typical PC user would likely work on such a large amount of data locally. We necessarily stored the folder on the file server for the thin clients.) She locates the folder in Windows Explorer, right-clicks it, and selects Send to/Compressed (zipped) Folder from the drop-down menu that displays. She continues working while Windows Explorer compresses the file. Her next task is to edit a PowerPoint deck for an upcoming customer presentation. The PowerPoint file is on the file server. While the compression is still running, she opens the 30.4MB, 36-slide PowerPoint deck and selects View\Slide Sorter so she can find the slide she wants. She then must wait for the slides to display. She will later copy the 195MB compressed (zipped) folder to the FTP site.

We timed 3 tasks:

- the Windows Explorer task, from the time Maya starts the compression until the Compressing dialog disappears
- the PowerPoint open task, from the time she clicks the desktop shortcut to open the file until PowerPoint displays all the slide snapshot on the left
- the PowerPoint change view task, from the time she selects View\Slide Sorter until PowerPoint displays all the slide images.

Multitasking scenario: Opening large XML files in Microsoft Word and Microsoft Excel

In this scenario, Akhil, a financial analyst, wants to update an 11MB Word XML file with data from a 29.9MB Excel spreadsheet that is also in XML format. He opens Windows Explorer and locates the file server folder that holds the files. He selects both files, presses Enter, and waits for the files to display.

We timed 2 tasks:

- the Excel open, from when he presses Enter until Excel opens the file and displays Ready in its status bar
- the Word open, from when he presses Enter until Word opens the document and updates the page count in its status bar

For more details on how we executed and measured these scenarios, our specific test functions, and the files the scenarios use, see Appendix B.

Test results and analysis

In this section we examine the results of the tests run with the application scripts we created. We ran each scenario 5 times on each of the 3 test platforms for each client count (1 active client, 2 active clients, and so on up to 5 active clients).

For each of those results sets, we present a single time: the mean response time, in seconds, of all the participating clients in one of the five runs of the scenario. We call that run the representative run.

We used a different process to select the representative run for single-task and multitasking scenarios. For single task scenarios, we calculated the mean response time for all the clients participating in each test run of a script. That process yielded one result for each of the five runs. We consider the representative run to be the one with the median of those results.

For multitasking scenarios, we had to consider the results of all the tasks we timed. Because the foreground task is the one on which, by definition, users are waiting, we used the foreground task to select a representative run. So, as we did with the single-task scripts, we calculated the mean response time on the foreground task for all the clients participating in each test run of a multitasking script. That process yielded one foreground result for each of the five runs. We consider the representative run to be the one with the median of those results. We then calculated the mean response time of each other task for all the clients on that run, and we report those results.

In the following sub-sections we explore these results in more detail. Because our goals were to compare how well the thin clients fared against the PCs and to show how well each type of client performed as we added more simultaneously active clients, we normalized all comparisons to the performance of the tests with a single active PC. The result for a run with one active PC is thus always 1.00, because that run is the comparison basis. Results higher than 1.00 indicate how much faster a given client type ran with a particular client count and script than a single active PC with the same script. Results lower than 1.00 indicate how much slower a given client type ran with a particular client count and script than a single active PC with the same script. Because of the normalization, higher result numbers are better. For example, a result of 0.80 for 2 active clients of type X would mean those clients completed the script 20 percent slower than a single PC running the same script.

We present the results for each task in each scenario in both tabular and graphical form. Each results table shows the results of each type of client with 1, 2, 3, 4, and 5 simultaneously active clients. Each graph shows how each type of client's response time changed as we moved from 1 active client to 5 active clients.

As all the results show, with just 5 clients simultaneously running the same script, the PC clients always dramatically outperformed the thin clients.

For more details on each scenario, see the Application scenarios section and Appendix B.

Single task scenario: Calculating subtotals in Microsoft Excel

Figure 2 shows the response times for each of the client platforms running this Excel subtotals task. Though all clients of all types were getting the test file from the file server, the PCs were able to perform the computation locally, while the thin clients had to rely on sharing the server's processor to do the same work. The server was able to handle the file requests from the PCs without slowing under load, but having to perform the computations for the thin clients caused the server to slow as we added more clients.

The result, as you can see, is that PC performance held steady as we added clients, while with 5 active clients the performance of both types of thin clients fell to about 20 percent that of the PCs. Consequently, PC users would

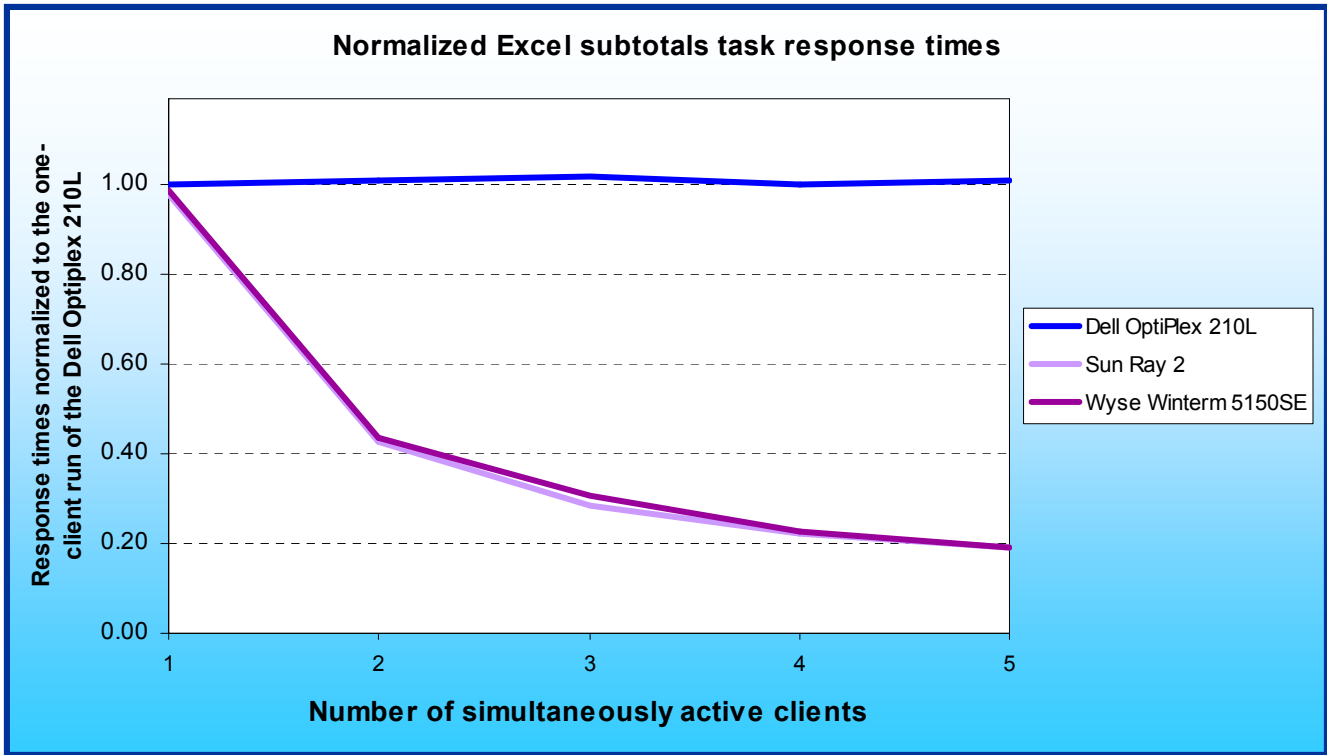


Figure 2: Results for the Excel subtotals task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

have experienced the same response time as we added users, while thin client users would have experienced dramatically worse response time with only 5 of them running the test.

Figure 3 details the response times for each of the three client platforms running this task. The performance results in the left section of the table show the mean response time, in seconds, of all the participating clients in each run of the test. Lower performance results are better. The center column shows the number of simultaneously active clients in the test whose results that row provides. The comparative ratings in the right section of the table show the response time normalized to the result with 1 active PC client. Higher comparative ratings are better.

| PERFORMANCE RESULTS (in seconds) | | | Number of simultaneously active clients | COMPARATIVE RATING | | |
|----------------------------------|-----------------------|---------------------|---|--------------------|-----------------------|---------------------|
| PC solution | Thin-client solutions | | | PC solution | Thin-client solutions | |
| Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE | | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| 12.9 | 13.2 | 13.1 | 1 | 1.00 | 0.98 | 0.98 |
| 12.8 | 30.2 | 29.7 | 2 | 1.01 | 0.43 | 0.43 |
| 12.7 | 45.5 | 41.9 | 3 | 1.02 | 0.28 | 0.31 |
| 12.9 | 58.3 | 57.3 | 4 | 1.00 | 0.22 | 0.23 |
| 12.8 | 68.1 | 67.9 | 5 | 1.01 | 0.19 | 0.19 |

Figure 3: Results for the Excel subtotals task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

As Figure 3 also shows, the percentage differences in performance between PCs and thin clients translate into time differences users most definitely notice. With a single client active, all the clients completed the task in roughly 13 seconds. With 5 clients doing the same test, PC performance stayed basically the same, while thin client performance went to about 68 seconds--an increase of 55 seconds, or nearly a minute, in response time.

Single task scenario: Compressing a PDF from within Adobe Acrobat

Figure 4 and 5 show the performance for each of the three types of clients on this Acrobat PDF compression task.

PC response time again held basically steady as we added clients, with the response time for 5 simultaneously active clients at worst 4 percent lower than the response time with a single client. Both thin clients, by contrast, dropped greatly as we added clients, going to 68 percent (Sun Ray 2; 67 percent for Wyse Winterm 5150SE) as fast with only 2 clients active and dropping to 30 percent (Sun Ray 2; 29 percent for Wyse Winterm 5150SE) as fast with 5 simultaneously active clients.

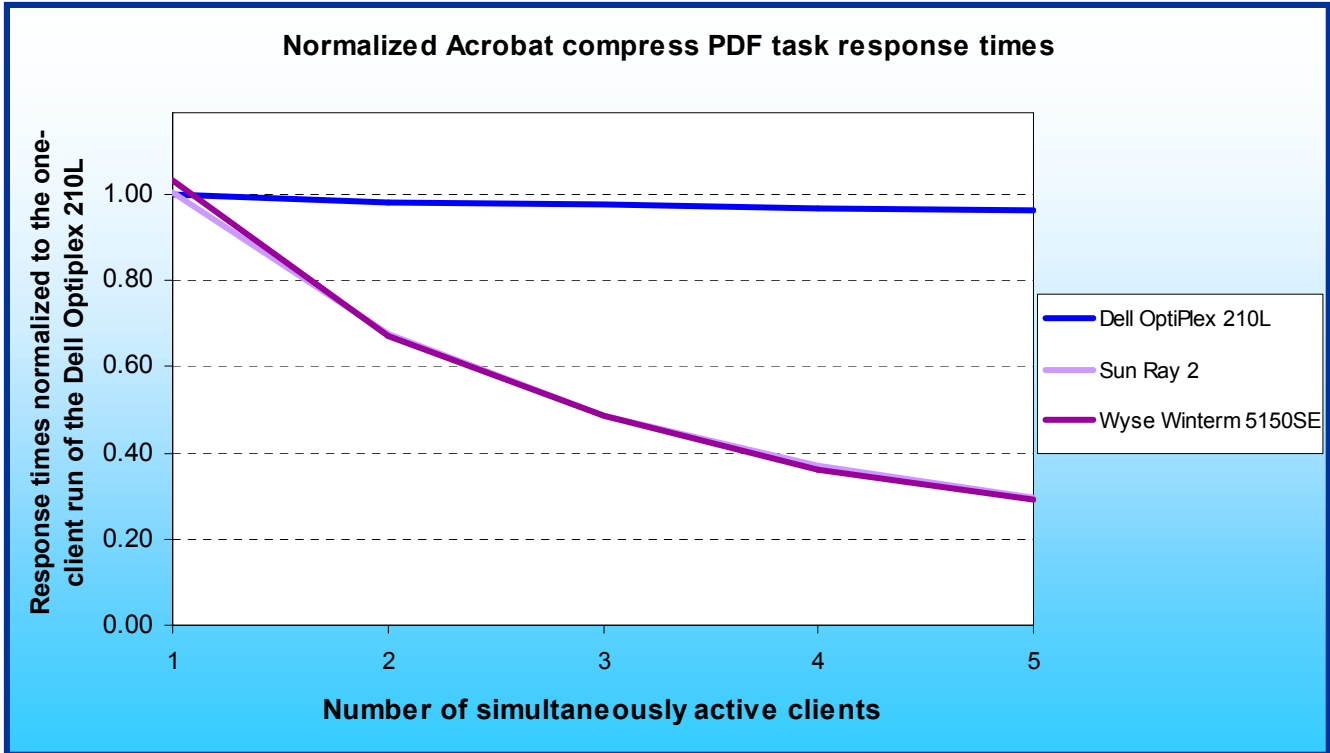


Figure 4: Results for the Acrobat compress PDF task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

As the one-client results in Figure 5 show, the thin clients were actually a tiny bit, 1 to 3 percent, faster with only one client active. The reason for this slight performance edge is that in the one-client test each thin client basically has the full power of the server available to it.

| PERFORMANCE RESULTS (in seconds) | | | Number of simultaneously active clients | COMPARATIVE RATING | | |
|----------------------------------|-----------------------|---------------------|---|--------------------|-----------------------|---------------------|
| PC solution | Thin-client solutions | | | PC solution | Thin-client solutions | |
| Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE | | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| 16.1 | 16.0 | 15.6 | 1 | 1.00 | 1.01 | 1.03 |
| 16.4 | 23.8 | 24.0 | 2 | 0.98 | 0.68 | 0.67 |
| 16.5 | 33.0 | 33.1 | 3 | 0.98 | 0.49 | 0.49 |
| 16.6 | 43.7 | 44.3 | 4 | 0.97 | 0.37 | 0.36 |
| 16.7 | 54.0 | 55.1 | 5 | 0.96 | 0.30 | 0.29 |

Figure 5: Results for the Acrobat compress PDF task for all three client platforms. All results are normalized to the 1-client PC result. Higher comparative ratings are better.

In this scenario, the PCs again used the server purely to hold the files; both the initial and the compressed files were on the server. The PCs performed the compression locally. The thin clients, by contrast, had to rely on the

server not only to hold the files but also to compress them, so as the number of clients sharing the server increased, the response time also increased.

The response-time differences for the thin clients were ones users would definitely notice, with response time going from about 16 seconds in the one-client case to 54 to 55 seconds in the five-client case--an increase of 39 seconds.

Multitasking scenario: Changing the view in a Microsoft PowerPoint presentation while compressing a folder in Windows Explorer

In this scenario, the users are running multiple tasks at the same time: a folder compression via Microsoft Explorer in the background, and opening and then changing the view of a PowerPoint presentation in the foreground. We present the results of our tests of each of those tasks in this section.

Windows Explorer task results

Figures 6 and 7 show the performance of each of the types of clients on the background Windows Explorer file compression task.

As Figure 6 shows, response time for the PCs held basically constant as we added test clients, while the thin

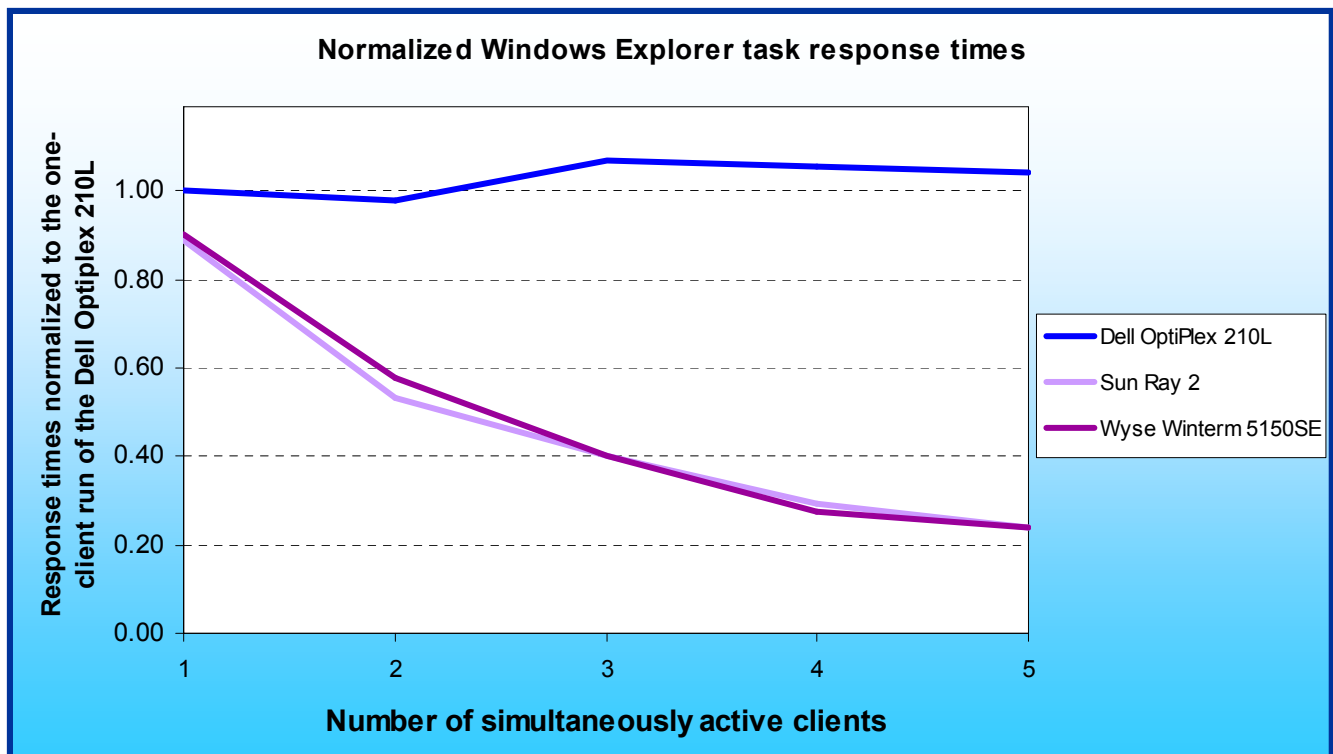


Figure 6: Results for the Windows Explorer task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

client performance both started lower than that of the PCs with 1 client active and then dropped dramatically as we went to 5 active clients. The slight increase in PC performance is probably because as the server became busier supplying the PowerPoint file for the file open, the PCs had to wait briefly and so had more processor cycles available for the file compression.

As Figure 7 details, the single PC actually finished the task 4.2 seconds faster than the Sun Ray 2 thin client and 3.6 seconds faster than the Wyse Winterm 5150SE thin client. As we added clients running the test, however, this performance lead widened dramatically, because PC performance stayed basically the same as thin client performance plunged.

| PERFORMANCE RESULTS (in seconds) | | | Number of simultaneously active clients | COMPARATIVE RATING | | |
|----------------------------------|-----------------------|---------------------|---|--------------------|-----------------------|---------------------|
| PC solution | Thin-client solutions | | | PC solution | Thin-client solutions | |
| Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE | | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| 33.8 | 38.0 | 37.4 | 1 | 1.00 | 0.89 | 0.90 |
| 34.5 | 63.7 | 58.5 | 2 | 0.98 | 0.53 | 0.58 |
| 31.6 | 84.4 | 84.2 | 3 | 1.07 | 0.40 | 0.40 |
| 32.1 | 116.1 | 122.3 | 4 | 1.05 | 0.29 | 0.28 |
| 32.5 | 141.4 | 142.7 | 5 | 1.04 | 0.24 | 0.24 |

Figure 7: Results for the Windows Explorer task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

With 5 clients running the test simultaneously, the PCs finished the task 108.9 seconds faster than the Sun Ray 2 thin clients and 110.2 seconds faster than the Wyse Winterm 5150SE thin clients--differences of nearly two minutes.

Microsoft PowerPoint file open task results

The two foreground tasks in this test suffered on all platforms as the server had to supply all the clients with the data they needed. Figures 8 and 9 illustrate this effect on the performance of all the types of clients on the Microsoft PowerPoint file open task.

As you can see in Figure 8, as we added clients the performance of all three types of clients dipped. With 5 active PCs, PC performance dropped to 55 percent of that of a single PC; a single PC completed the task in 9.9

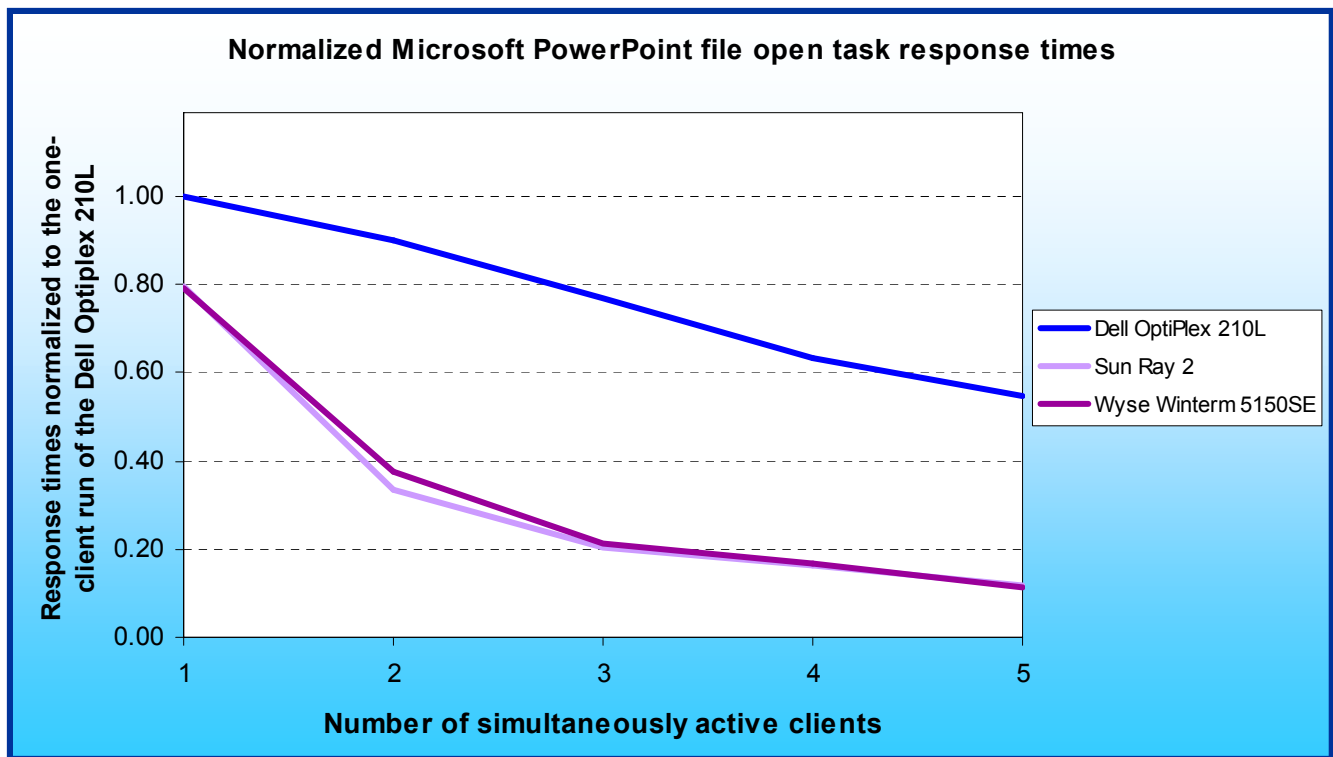


Figure 8: Results for the Microsoft PowerPoint file open task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

seconds, while with 5 PCs the response time was 18.1 seconds. The PCs still dramatically out-performed both types of thin clients, however: as Figure 9 shows, thin client response time dropped to 11 percent (Wyse Winterm 5150SE) or 12 percent (Sun Ray 2) of the response time of the single-PC case. Both types of thin clients

completed the task in less than 13 seconds with only 1 client active, but with 5 clients active the task took over 80 seconds--over 70 seconds slower.

| PERFORMANCE RESULTS (in seconds) | | | Number of simultaneously active clients | COMPARATIVE RATING | | |
|----------------------------------|-----------------------|---------------------|---|--------------------|-----------------------|---------------------|
| PC solution | Thin-client solutions | | | PC solution | Thin-client solutions | |
| Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE | | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| 9.9 | 12.4 | 12.5 | 1 | 1.00 | 0.80 | 0.79 |
| 11.0 | 29.6 | 26.3 | 2 | 0.90 | 0.33 | 0.38 |
| 12.9 | 48.4 | 46.4 | 3 | 0.77 | 0.20 | 0.21 |
| 15.6 | 61.2 | 58.4 | 4 | 0.63 | 0.16 | 0.17 |
| 18.1 | 82.9 | 87.7 | 5 | 0.55 | 0.12 | 0.11 |

Figure 9: Results for the Microsoft PowerPoint file open task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

Microsoft PowerPoint change view task results

As Figures 10 and 11 show, PC performance on the second foreground task, the Microsoft PowerPoint change view task, once again held steady as we added clients even though the background Windows Explorer task was still running. Both types of thin clients actually beat the PC in the single-client test case, but their performance dropped in half when we added a second simultaneously active client. With five active clients the Sun Ray 2 thin clients turned in noticeably better times than the Wyse Winterm 5150SE systems, but both were far below the

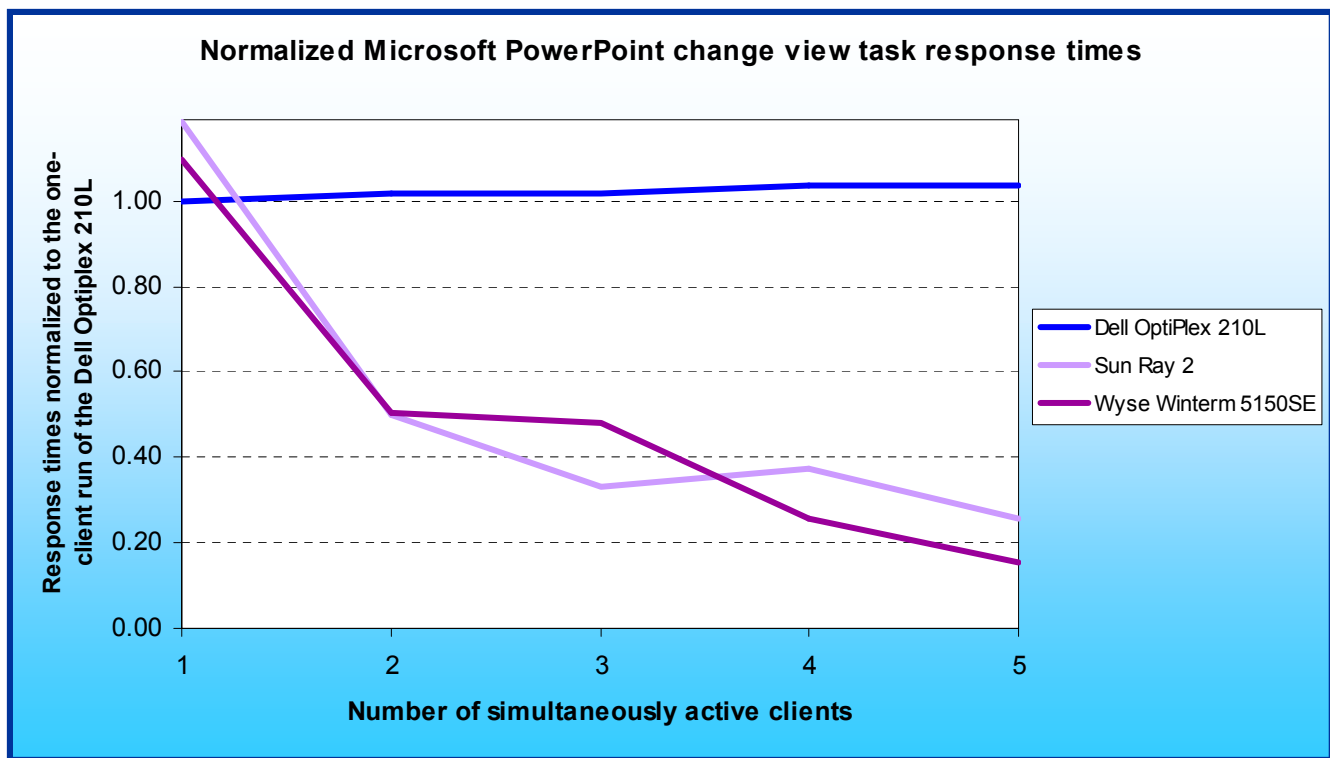


Figure 10: Results for the Microsoft PowerPoint change view task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

PCs in performance.

The actual time penalties were again ones that users would notice. As Figure 11 shows, the average response time of the Sun Ray 2 thin clients went from 4.8 seconds with 1 active client to 22.4 seconds with 5 active clients, while the response time of the Wyse Winterm 5150SE thin clients dropped from 5.2 seconds with 1 client to 37.3 seconds with 5 clients.

| PERFORMANCE RESULTS (in seconds) | | | Number of simultaneously active clients | COMPARATIVE RATING | | |
|----------------------------------|-----------------------|---------------------|---|--------------------|-----------------------|---------------------|
| PC solution | Thin-client solutions | | | PC solution | Thin-client solutions | |
| Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE | | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| 5.7 | 4.8 | 5.2 | 1 | 1.00 | 1.19 | 1.10 |
| 5.6 | 11.4 | 11.3 | 2 | 1.02 | 0.50 | 0.50 |
| 5.6 | 17.2 | 11.9 | 3 | 1.02 | 0.33 | 0.48 |
| 5.5 | 15.2 | 22.4 | 4 | 1.04 | 0.38 | 0.25 |
| 5.5 | 22.4 | 37.3 | 5 | 1.04 | 0.25 | 0.15 |

Figure 11: Results for the Microsoft PowerPoint change view task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

In this multitasking scenario, even with the data files residing on the server the PCs were able to use their local computing power to respond dramatically more quickly than the thin clients on the foreground tasks and to complete the background task more than 4 times faster than the thin clients--a performance win on all fronts for users.

Multitasking scenario: Opening large XML files in Microsoft Word and Microsoft Excel

Our last test scenario includes two tasks that both read large data files from the server and are processor-intensive: opening XML files in Microsoft Word and Microsoft Excel at the same time. The test begins both file opens at the same time, so the two tasks begin running simultaneously.

Microsoft Excel XML file open task results

Figures 12 and 13 show the response times for each of the client platforms running the Windows Explorer task in this scenario.

As the graph shows, performance for all the platforms dipped as we added clients and the server had to do more work to service the additional systems. The PCs, however, stayed significantly ahead of the thin clients as we added clients, with the 5 PCs running at 64 percent the speed of the single-PC case; by contrast, the thin clients

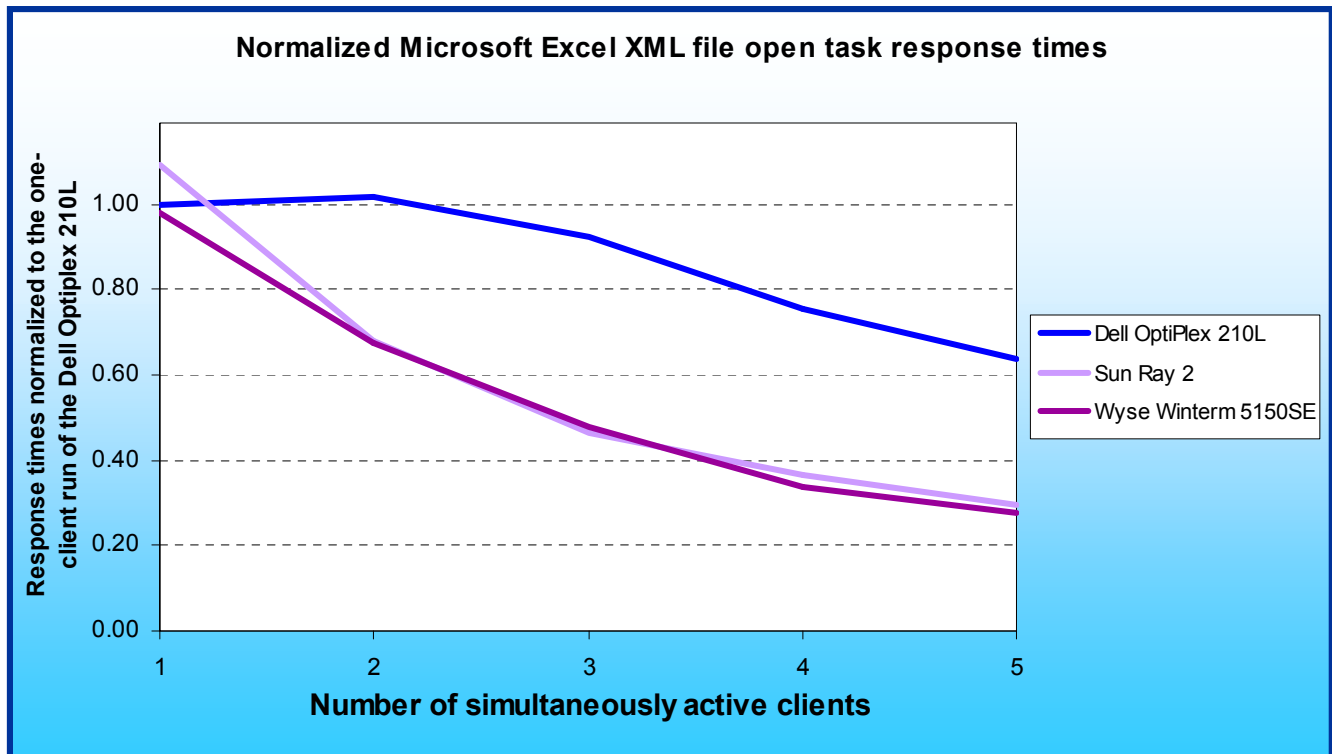


Figure 12: Results for the Microsoft Excel file open task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

ended at less than 30 percent of the performance of the single-PC case.

As both this graph and the detailed results in Figure 13 show, the single Sun Ray 2 thin client was actually 9 percent faster the single PC--but the Sun Ray 2 effectively had the file server dedicated to it (and the requisite Sun Fire V240 server also supporting it).

| PERFORMANCE RESULTS (in seconds) | | | Number of simultaneously active clients | COMPARATIVE RATING | | |
|----------------------------------|-----------------------|---------------------|---|--------------------|-----------------------|---------------------|
| PC solution | Thin-client solutions | | | PC solution | Thin-client solutions | |
| Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE | | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| 14.0 | 12.8 | 14.3 | 1 | 1.00 | 1.09 | 0.98 |
| 13.8 | 20.6 | 20.7 | 2 | 1.01 | 0.68 | 0.68 |
| 15.2 | 30.1 | 29.4 | 3 | 0.92 | 0.47 | 0.48 |
| 18.6 | 38.5 | 41.3 | 4 | 0.75 | 0.36 | 0.34 |
| 22.0 | 47.8 | 50.3 | 5 | 0.64 | 0.29 | 0.28 |

Figure 13: Results for the Microsoft Excel XML file open task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

The time differences among the client types grew from small (just over a second) in the one-client case to quite large with 5 active clients, where the PCs finished in 22 seconds, while the Sun Ray 2 thin clients took 47.8 seconds to do the same work, and the Wyse Winterm 5150SE thin clients needed 50.3 seconds.

Microsoft Word XML file open task results

Running at the same time as the Excel XML file open, the Microsoft Word XML file open task also involved opening a substantial file on the server and processing the XML to yield the Word file. Figures 14 and 15 show the results for this task. As you can see, the results were quite similar to those on the Excel XML file open task, though this time the single PC outperformed both single thin clients. The reason for this difference is probably the load the server was facing. While each PC ran the XML processing locally, the thin clients were relying on the

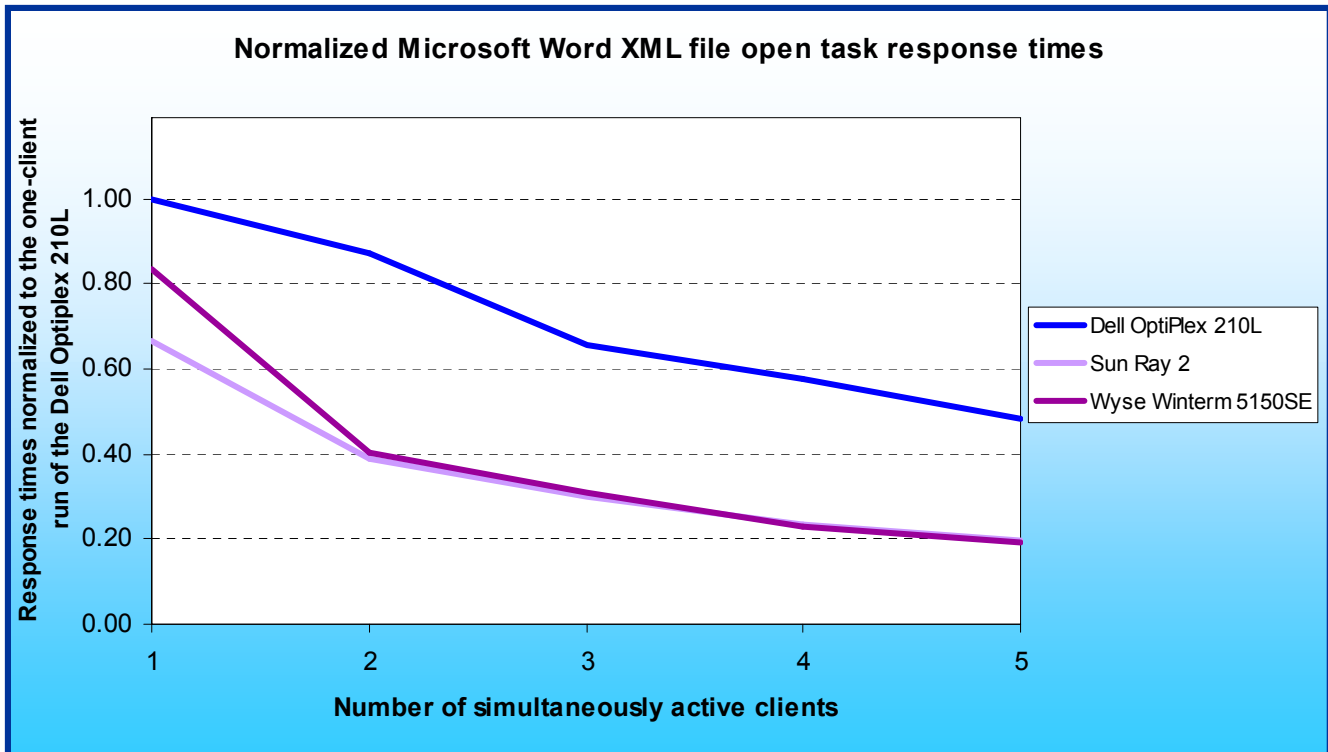


Figure 14: Results for the Microsoft Word XML file open task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

server to do that work--and the server also had to supply the data files and handle the Word XML processing for them at the same time.

As Figure 15 shows, with 5 active clients the PCs, which, like the thin clients, had to rely on the server to supply the files, ran at 48 percent the speed of the single-PC case. The thin clients, by contrast, ran at only 20 percent (Sun Ray 2) and 19 percent (Wyse Winterm 5150SE) of the speed of the single PC.

| PERFORMANCE RESULTS (in seconds) | | | Number of simultaneously active clients | COMPARATIVE RATING | | |
|----------------------------------|-----------------------|---------------------|---|--------------------|-----------------------|---------------------|
| PC solution | Thin-client solutions | | | PC solution | Thin-client solutions | |
| Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE | | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| 10.2 | 15.3 | 12.2 | 1 | 1.00 | 0.67 | 0.84 |
| 11.7 | 26.1 | 25.2 | 2 | 0.87 | 0.39 | 0.40 |
| 15.5 | 34.0 | 33.1 | 3 | 0.66 | 0.30 | 0.31 |
| 17.7 | 43.4 | 44.7 | 4 | 0.58 | 0.24 | 0.23 |
| 21.1 | 51.3 | 53.6 | 5 | 0.48 | 0.20 | 0.19 |

Figure 15: Results for the Microsoft Word XML file open task for all three client platforms. All results are normalized to the one-client PC result. Higher comparative ratings are better.

In the five-client case, these percentage differences translated into time savings of more than 30 seconds for the PCs as compared to the thin clients.

As we noted earlier, to provide an apples-to-apples comparison, we forced all the clients to store the data they needed on the server. The PCs, of course, could have stored the data locally. Had we allowed the PCs to do so, their performance edge in the multi-client tests would almost certainly have been much larger.

Uneven service

In all of our results discussions to this point, we have focused on average response time. In multi-user networks, all systems of the same type should generally receive the same type of response time when performing the same operations on the same files. In our tests, that was certainly the case with the PCs. Consider, for example, the Microsoft PowerPoint change view task. Figure 16 shows the range of response times for the five-client tests of this task on each of the client types. The PCs, as we would hope and expect, showed remarkably little variance, with the difference between the best response time a system received (5.3 seconds) and the worst (5.8 seconds) only half a second.

| Range of response times for the five-client results on the Microsoft PowerPoint change view task | | | |
|--|--------------------|-----------|---------------------|
| | Dell OptiPlex 210L | Sun Ray 2 | Wyse Winterm 5150SE |
| Minimum response time (seconds) | 5.3 | 14.1 | 16.8 |
| Maximum response time (seconds) | 5.8 | 30.8 | 27.9 |
| Range of response times (seconds) | 0.5 | 16.7 | 11.1 |

Figure 16: Range of response times for the runs of the five-client test for the PowerPoint change view task for all three client platforms. Lower numbers are better.

As the same table shows, on some tasks the thin clients, by contrast, delivered very different response times to each user, a phenomenon we refer to as "uneven service." In the five-client test of this PowerPoint operation, one Sun Ray 2 thin client finished the test in 14.1 seconds, while another took 30.8 seconds--a difference of 16.7 seconds. The Wyse Winterm 5150SE thin clients ranged in completion times from 16.8 seconds to 27.9 seconds, a difference of 11.1 seconds. This level of uneven service would result in different users having very different computing experiences, something IT managers generally want to avoid.

Test methodology

We evaluated the performance of each of the application scenarios (see “Application scenarios”) both by hand and with automated test scripts, which we developed with IBM’s Visual Test 6.5. Appendix B details the steps we followed when we hand-timed the scenarios. In this paper, we concentrate our discussions on the results of the automated scripts, because those results are generally more repeatable than hand timings, especially in tests involving multiple clients running simultaneously.

We created a test network for each of the client types: Dell OptiPlex 210L PCs, Sun Ray 2 thin clients, and Wyse Winterm 5150SE thin clients. Each test network included a file server, five client systems, and, for the Sun Ray 2 thin clients, the special Sun server they require. We used a pair of identical file servers to allow us to have two networks under test at a time. Appendix A provides detailed configuration information on all of the different systems we used in our test. We used a 100-Mbps network infrastructure whenever possible, because that infrastructure is common in enterprises today.

For the Sun Ray 2 thin client test network, we set up user accounts and Windows Terminal Server on the file server. For the Wyse Winterm 5150SE thin client test network, we set up the file server so it would have accounts for all five Wyse Winterm 5150SE thin clients and run the Citrix Access Essentials software they required to be able to execute the office applications in our test scripts. In all of these test networks, we assigned each system a static IP address, with one exception: the Sun Fire V240 server automatically assigned IP addresses to the Sun Ray 2 thin clients. The PCs required no special setup.

We installed the Microsoft Office 2003 and Adobe Acrobat 7.0 Standard applications so that they would be available to all the clients. The test scripts run tasks in these applications. Because the thin clients do not have disks, all their applications and data files reside on the file server. We installed the PC applications on each PC, but to make the performance comparison as fair as possible, we stored the data files on the server except in one case in which storing a file locally made more sense in the usage model.

We ran four test scripts on each test network with five client configurations:

- 1 client running the script
- 2 clients simultaneously running the script
- 3 clients simultaneously running the script
- 4 clients simultaneously running the script
- 5 clients simultaneously running the script

This approach allowed us to gauge the response-time effects on end users of adding clients to each test network.

For each test script on each test network, we first performed the following script setup steps:

- reboot (in the appropriate order; more on that in the discussions below) the systems in the test network
- create a desktop shortcut for the test script
- create a desktop shortcut for the setup script that prepares the data files for testing
- create a desktop shortcut for the script that cleans up data files between runs of the script
- run the setup script

After we finished this setup process for each script, we ran that script on that network five times in each of the above five client configurations. If any test or script failed, we discarded that test’s results and ran the test again. We rebooted the test network systems between each run of each test script.

We refer in this paper only to the median results of each set of five runs on each test network configuration. The scripts produce times (in milliseconds), with lower times to complete a given function indicating better performance. We round those times to tenths of seconds in this report.

In the following sections we discuss how to set up each test network and how to execute the tests on that network.

Test network setup

Some setup steps were the same for all the test networks, while others were specific to each network.

We performed the initial setup of the shared file server the same way on all the test networks. The first subsection below outlines that process. The thin clients do not have disks, so the file server held both their applications and the test data. For the PC test network, the file server held only the test data; we installed the applications locally, as typical users would.

The subsequent subsections discuss each test network and the steps we took to set it up. Each of those discussions includes three sections:

- Instructions for setting an additional server: The Sun Ray 2 thin clients required a special Sun server.
- Test network-specific setup instructions for the file server. On each thin client test network, the file server also ran the software necessary to support the thin clients. We outline the steps necessary to set up that software in this section.
- Instructions for setting up the clients.

Setting up the file server for all three test networks

We followed this process to initially prepare the file server.

1. Install an OEM copy of Microsoft Windows 2003 Server Enterprise Edition, Service Pack 1.
2. Create two partitions: one for the server, and one for the test applications and files the clients use.
3. Apply the following updates from the Microsoft Windows Update site:
 - Windows Server 2003 Security Update for Windows Server 2003 (KB908531)
 - Windows Server 2003 Windows Malicious Software Removal Tool - April 2006 (KB890830)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB911562)
 - Windows Server 2003 Cumulative Security Update for Internet Explorer for Windows Server 2003 (KB912812)
 - Windows Server 2003 Cumulative Security Update for Outlook Express for Windows Server 2003 (KB911567)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB913446)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB911927)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB908519)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB912919)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB904706)
 - Windows Server 2003 Update for Windows Server 2003 (KB910437)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB896424)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB900725)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB901017)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB899589)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB902400)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB905414)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB899591)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB890046)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB899587)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB896358)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB896422)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB896428)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB893756)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB899588)
 - Windows Server 2003 Security Update for Windows Server 2003 (KB901214)
 - Windows Server 2003 Update for Windows Server 2003 (KB898715)

4. Install Microsoft Office 2003.
5. Apply all Microsoft Office 2003 updates (as of May 31, 2006) from the Microsoft Office Update Web site.
6. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose Security Center.
 - c. Click Change the way Security Center Alerts me on the left.
 - d. Uncheck Firewall, Automatic Updates, and Virus Protection.
7. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose Automatic Updates.
 - c. Select Turn off Automatic Updates.
8. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose System.
 - c. Choose the System Restore tab.
 - d. Select Turn off System Restore on all drives.
9. Set up the script folders for each test system (PC or thin client):
 - a. Create a folder named User Files.
 - b. Within that folder, create five folders, named User1 through User5. These folders will hold the individual script directories.
10. Copy the four script folders into each of these directories. You will end up with five copies of the scripts, one for each user. These folders contain all of the files the scripts need to execute. Each of the four script folder's names identifies the test script. Each of those folders contains a folder named SC1. Each SC1 folders contains the same three subfolders:
 - a. Content: all the test files the script uses
 - b. Results: initially empty but will contain the results file the script creates
 - c. Scripts: the script's source and executable files.
11. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk.
12. Using Symantec's Ghost utility, make an image of the hard disk. (This image lets us return to a clean and consistent starting point whenever necessary.)

Setting up the PC test network

Figure 17 illustrates the test network for the PC clients. Connect the systems as this diagram shows.

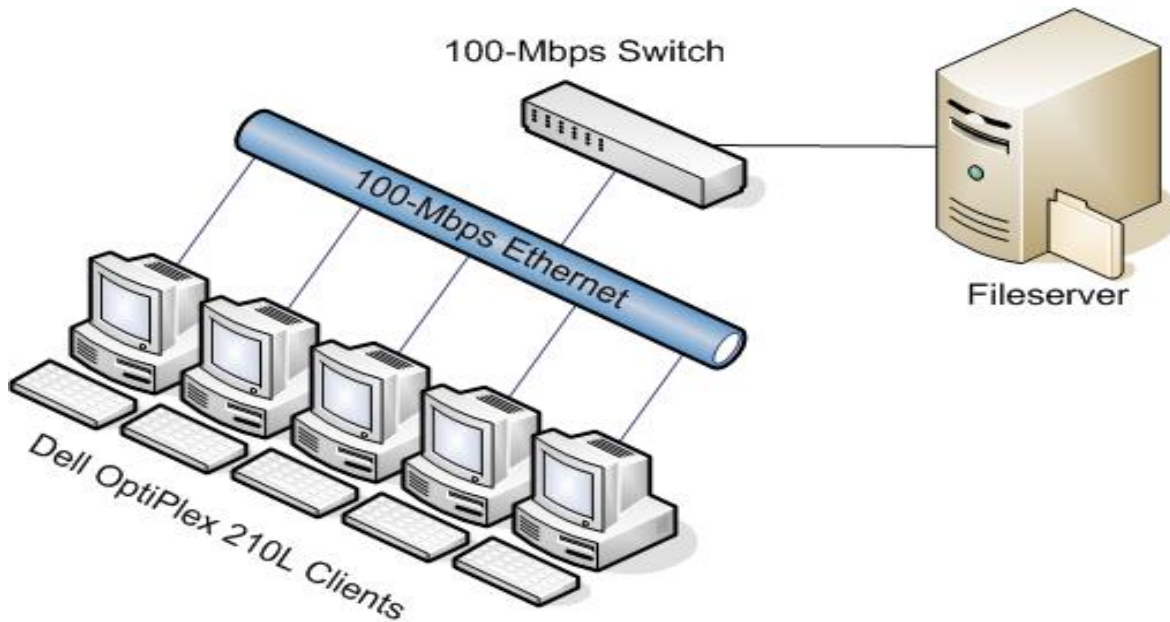


Figure 17: The PC test network. The blue lines represent 100-Mbps network connections.

Setting up any additional servers in the PC test network

The PC test network does not require any servers beyond the file server.

Additional file server set up for the PC test network

The PC test network does not require any specific file server setup beyond the steps we outlined above.

Setting up the PC clients

Repeat these steps on each of the five PC clients.

1. Start with the OEM image of the systems.
2. Apply all XP critical updates (as of May 31, 2006) from the Microsoft Windows Update Web site, including Windows XP SP2. Do not install any of the optional updates.
3. Install Microsoft Office 2003.
4. Apply all Office 2003 updates (as of May 31, 2006) from the Microsoft Office Update Web site.
5. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose Security Center.
 - c. Click Change the way Security Center Alerts me on the left.
 - d. Uncheck Firewall, Automatic Updates, and Virus Protection.
6. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose Automatic Updates.
 - c. Select Turn off Automatic Updates.
7. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
 - a. Open the system Control Panel.
 - b. Choose System.
 - c. Choose the System Restore tab.
 - d. Select Turn off System Restore on all drives.
8. Change the PC's IP address to 192.168.1.5[X], where X is the client number of the PC. (We numbered the PCs 1 through 5.)
 - a. Click Start → Control Panel → Select Network Connections.
 - b. Select Local Area Connection.

- c. In the Local Area Connection Status dialog, select Properties.
 - d. In the Local Area Connection Properties dialog, select Properties.
 - e. Select the Use the following IP address radio button.
 - f. Enter the IP Address.
 - g. Select OK on the top two open dialog boxes.
 - h. Select Close to close the third dialog box.
9. Map the network drive Q: to \\[servername]\fileserver\user files\user[X], where X is as above.
 - a. Right-click My Computer.
 - b. Select Map Network Drive.
 - c. Select Q: from the Drive drop-down menu.
 - d. Type \\[servername]\fileserver\user files\user[X], where X is as above, as the Folder name.
 - e. Click Finish.
 10. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
 11. Configure the Visual Test Runtime application so that it will work with all the test scripts:
 - a. Copy the following five Visual Test dll files into \WINDOWS\SYSTEM32:
 - IEHelper.dll
 - Vtaa.dll
 - VTest60.dll
 - Vtres.dll
 - WebDrive.dll
 - b. Open a command prompt.
 - c. Type cd \WINDOWS\SYSTEM32, and press Enter.
 - d. For each of the following three dlls, type regsvr32 [dll filename], and press Enter. (This command registers a dll with the system.)
 - IEHelper.dll
 - Vtaa.dll
 - WebDrive.dll
 12. Install Adobe Acrobat 7.0 Standard.
 13. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk of each PC.
 14. Using Symantec's Ghost utility, make an image of each PC's hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)

Setting up the Sun Ray 2 thin client test network

Figure 18 shows the test network for the Sun Ray 2 thin clients. Those clients require the Sun Fire V240 server. They also require the file server to run the Windows Terminal Server software. We used a 1-Gbps connection between the Sun Fire V240 server and the file server to minimize any performance effect that connection might have. Connect the systems as this diagram shows.

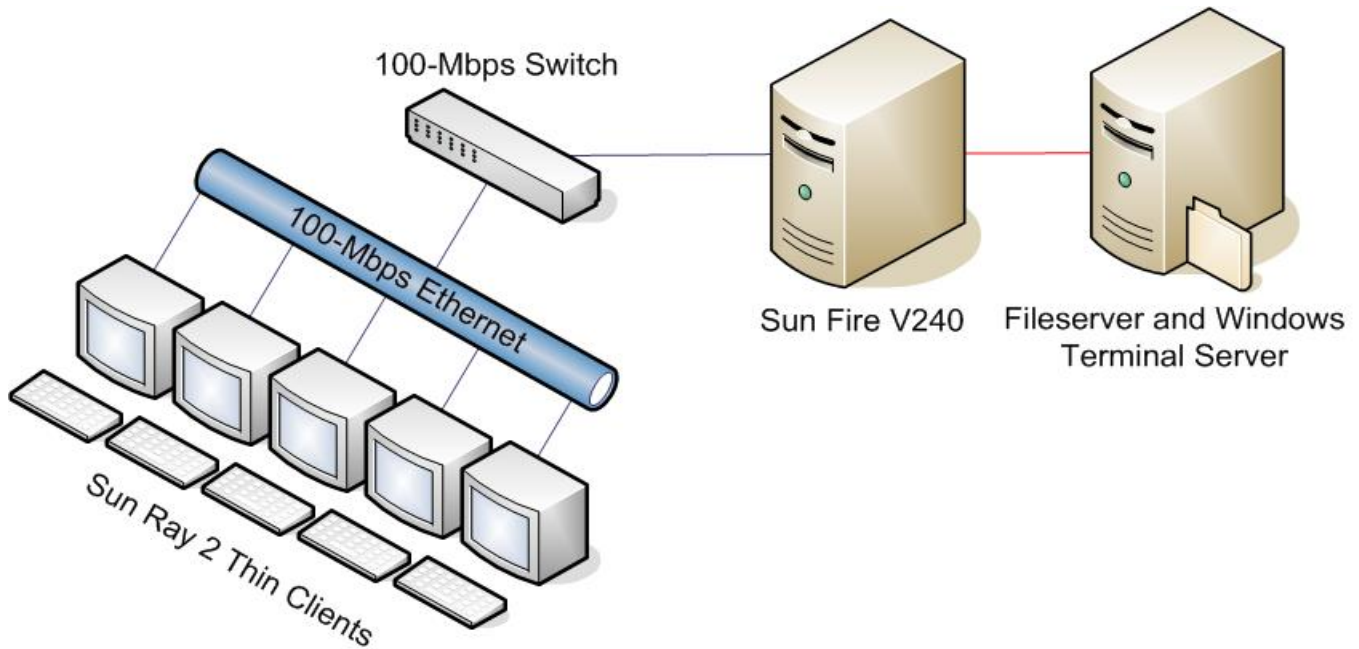


Figure 18: The Sun Ray 2 thin client test network. The blue lines represent 100-Mbps network connections. The red line represents a 1-Gbps network connection.

Setting up any additional servers in the Sun Ray 2 thin client test network

We followed this process to set up the Sun Fire V240 server:

1. Following the instructions for the V240 on Sun's Web site (<http://www.sun.com/products-n-solutions/hardware/docs/html/819-4209-10/>), set up a server with two NICs: one for the connection with the Sun Ray 2 thin clients, and one for the connection with the file server.
2. Install the following products that the V240 needs to support the Sun Ray 2 thin clients:
 - Sun Ray Server Software 3.1
 - Sun Ray Connector for Windows OS 1.0
 - Sun Desktop Manager 1.0
3. Using the default settings, configure the thin client NIC to have an exclusive network for the Sun Ray 2 thin clients.
4. When the installation software asks whether it should configure the Sun Fire server to have controlled access mode, select Yes. This configuration lets the Sun Fire server directly control how the Sun Ray 2 thin clients boot.
5. Create a user account, ruser, with the password, "password", to allow telnetting into the server.

Additional file server set up for the Sun Ray 2 thin client test network

We set up the file server so it would have accounts for all five Sun Ray 2 thin clients, run the Windows Terminal Server software they required to be able to execute the office applications in our test scripts, and contain the Adobe Acrobat and Visual Test software the scripts required.

1. Create five users (RUSER1 through RUSER5). Give each remote desktop privileges and the password "password".
2. Change the IP address of the Sun Fire V240 server to 10.41.1.80.
3. Configure the Visual Test Runtime application so that it will work with all the test scripts:
 - a. Copy the following five Visual Test dll files into /WINDOWS/SYSTEM32:
 - IEHelper.dll
 - Vtaa.dll
 - VTest60.dll
 - Vtres.dll
 - WebDrive.dll

- b. Open a command prompt.
- c. Type `cd \WINDOWS\SYSTEM32`, and press Enter.
- d. For each of the following three dlls, type `regsvr32 [dll filename]`, and press Enter. (This command registers a dll with the system.)
 - IEHelper.dll
 - Vtaa.dll
 - WebDrive.dll
4. Make sure Windows Terminal Services is active on the server and supporting the thin clients.
5. Install Adobe Acrobat 7.0 Standard.
4. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk.
5. Using Symantec's Ghost utility, make an image of the hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)

Setting up the Sun Ray 2 thin clients

Repeat these steps on each of the five Sun Ray 2 thin clients.

1. Boot the file server.
2. Boot the Sun Fire v240.
3. Log in as `ruser[X]` on the Sun Ray 2, where X is the number of this client (1 to 5).
4. Configure it to run terminal services immediately upon boot.
5. Configure it to have a display resolution of 1024x768 and 24-bit color depth.
6. Map the network drive Q: to `\\[servername]\fileserver\user files\user[X]`, where X is as above.
 - a. Right-click My Computer.
 - b. Select Map Network Drive.
 - c. Select Q: from the Drive drop-down menu.
 - d. Type `\\[servername]\fileserver\user files\user[X]`, where X is as above, as the Folder name.
 - e. Click Finish.
7. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
8. Log out of the thin client.
9. Log on to the file server as administrator.
10. Open a command prompt.
11. Type `telnet 10.41.1.180`, and press Enter. You can access the Sun Fire V240 only via telnet, because it does not have a monitor, keyboard, or mouse.
12. When the system prompts you for a username, log in as `ruser` with password "password".
13. Wait for the login process to complete.
14. Type `su` to log on as the administrator with password "password".
15. Type `sync;sync;init 6`, and press Enter.
16. On the file server, click Start → Shut Down.
17. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
18. Type an explanatory comment in the comment box.
19. Press enter.
20. You may see a warning dialog that says shutting down will close remote connections and that asks if you want to end them. Click Yes, and the file server will restart.

Setting up the Wyse Winterm 5150SE thin client test network

Figure 19 illustrates the test network for the Wyse Winterm 5150SE thin clients. Those clients require the file server to run the Citrix Essentials software. Connect the systems as this diagram shows.

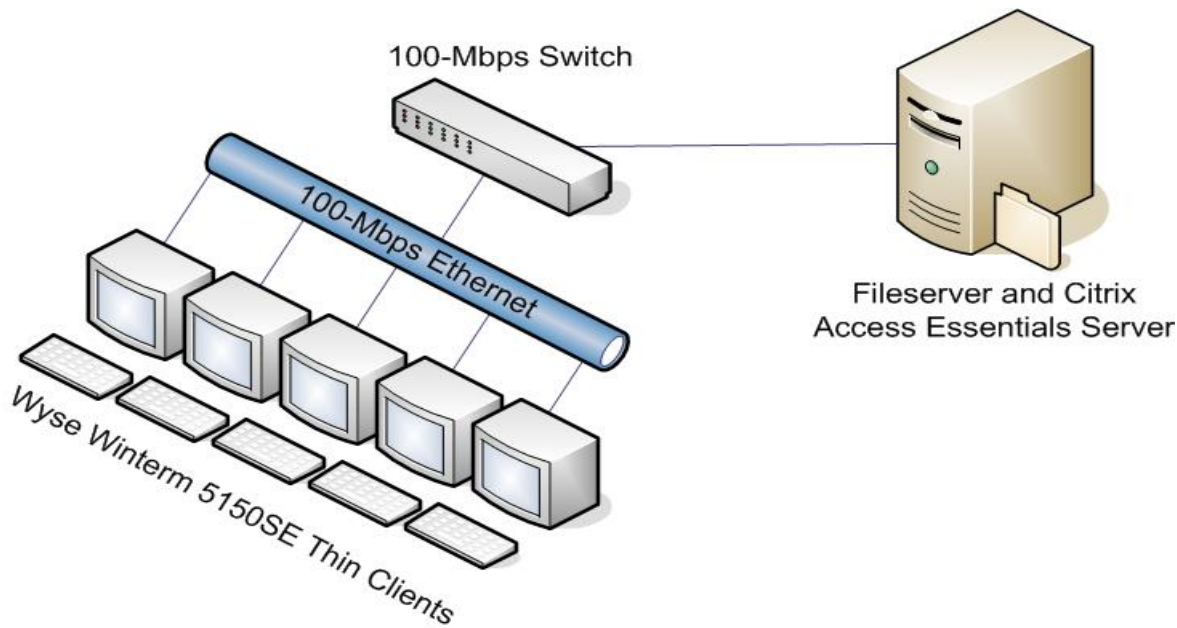


Figure 19: The Wyse Winterm 5150SE thin client test network. The blue lines represent 100-Mbps network connections.

Setting up any additional servers in the Wyse Winterm 5150SE thin client test network

The Wyse Winterm 5150SE test network does not require any servers beyond the file server.

Additional file server set up for the Wyse Winterm 5150SE thin client test network

We set up the file server so it would have accounts for all five Wyse Winterm 5150SE thin clients, run the Citrix Access Essentials software they required to be able to execute the office applications in our test scripts, and contain the Adobe Acrobat and Visual Test software the scripts required.

1. Create five users (RUSER1 through RUSER5). Give each remote desktop privileges and the password "password".
2. Install Citrix Access Essentials using all defaults.
3. Set up RUSER1 through RUSER5 so each account has Citrix user permissions.
4. Change the Citrix connection settings to permit the Wyse Winterm 5150SE thin clients to run unpublished applications.
 - a. Open the Citrix Connection Configuration tool.
 - b. Double-click the ica-tcp connection to open its properties.
 - c. Click the Advanced button in the lower left.
 - d. In the Initial Program group box, uncheck the Only launch Published Applications checkbox if it is checked.
5. Configure the Visual Test Runtime application so that it will work with all the test scripts:
 - a. Copy the following five Visual Test dll files into /WINDOWS/SYSTEM32:
 - IEHelper.dll
 - Vtaa.dll
 - VTest60.dll
 - Vtres.dll
 - WebDrive.dll
 - b. Open a command prompt.
 - c. Type `cd \WINDOWS\SYSTEM32`, and press Enter.
 - d. For each of the following three dlls, type `regsvr32 [dll filename]`, and press Enter. (This command registers a dll with the system.)
 - IEHelper.dll
 - Vtaa.dll
 - WebDrive.dll

6. Install Adobe Acrobat 7.0 Standard.
7. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk.
8. Using Symantec's Ghost utility, make an image of the hard disk. (This image lets us return to a clean and consistent starting point whenever necessary.)

Setting up the Wyse Winterm 5150SE thin clients

Repeat these steps on each of the five Wyse Winterm 5150SE clients.

1. Boot the file server.
2. Boot the Wyse Winterm 5150SE thin client.
3. Change the IP address of the thin client to 192.168.1.5[X], where X is the number of the client.
 - a. Click Start → Control Panel → Select Network Connections.
 - b. Select Local Area Connection.
 - c. In the Local Area Connection Status dialog, select Properties.
 - d. In the Local Area Connection Properties dialog, select Properties.
 - e. Select the Use the following IP address radio button.
 - f. Enter the IP Address.
 - g. Select OK on the top two open dialog boxes.
 - h. Select Close to close the third dialog box.
4. Configure each Wyse Winterm 5150SE to have a display resolution of 1024x768 and 24-bit color depth.
5. Create a remote desktop connection with the file server.
 - a. Click Start → Connection Manager.
 - b. In the Connection manager window, click the Add button.
 - c. In the first window, select ICA, and click Next.
 - d. Under the Network tab, enter the following:
 - I. In the Description box: TCSEVER
 - II. In the Browser Server box: 192.168.1.250
 - III. In the Server box: 192.168.1.250.
 - e. Under the Window tab, set the Window Colors to 16 Million and the Window Size to Full screen.
 - f. Under the Login tab, enter the following:
 - I. In the User Name box: RUSER[X], where X is as above
 - II. For the password: password
 - III. For the domain: TCSEVER
 - IV. Click the Connect automatically after login check box
6. Map the network drive Q: to \\[servername]fileserver\user files\user[X], where X is as above.
 - a. Right-click My Computer.
 - b. Select Map Network Drive.
 - c. Select Q: from the Drive drop-down menu.
 - d. Type \\[servername]fileserver\user files\user[X], where X is as above, as the Folder name.
 - e. Click Finish.
7. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
8. Log on to the file server as administrator.
9. Click Start → Shut Down.
10. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
11. Type an explanatory comment in the comment box.
12. Press enter.
13. You may see a warning window that says shutting down will close remote connections and that asks if you want to end them. Click Yes, and the file server will restart.

Running the tests

Setting up the servers and clients is much more complicated than the testing process. When you have correctly set up the clients, they will automatically connect to the server(s). Executing the tests on a particular type of client involves three relatively straightforward phases:

1. Getting the systems ready to go. In this phase, you make sure all the systems in the test network are on, appropriately connected (e.g., clients are connected to the file server), and ready for testing.
2. Setting up the test script you want to run. Each script has a setup script that you must run once on each client before testing on that client with that script. The setup script makes sure the data files are ready, the application windows are where the test script expects to find them, and so on.
3. Running the test scripts and recording results. You must reboot the test network systems before each run of each test script and start the test script at the same time on all the clients under test.

Phase 1 varies for each test network. We detail it below in the sections on the test networks. In all of these discussions, we assume you have already completed the setup process we outlined earlier. We also assume any client systems you do not want to include in a test will not be on.

Phase 2 is the same regardless of the type of client you are testing. Once you have readied all the systems to go and are working on a client, follow this process to prepare the client to run a test script:

1. Double-click the desktop shortcut Shortcut to UserX at [servername], where X is the number of the client and servername is the name you gave the file server.
2. You will see four folders, one for each script. Open the folder that contains the script you are testing.
3. Inside that folder is a folder named SC1. Double-click that folder.
4. You will see three folders: Content, Results, and Scripts. The Scripts folder contains the individual script files. Double-click the Scripts folder.
5. In the Scripts folder, find the files SC1-Setup.pc6 and SC1main.pc6. Create desktop shortcuts to each of them.
6. Some scripts require an additional preparation or cleanup program. If so, the Script folder will contain a third file named SC1-Prep.pc6 or SC1cleanup.pc6, respectively. If either file exists, create a desktop shortcut to it.
7. Run SC1-Setup.

Phase 3 is largely the same regardless of the type of client. Once you have finished the above script setup phase, do the following for each test you want to run:

1. Reboot all the servers and the clients you will be using in the test. This process varies by client type; we outline it for each client test network below.
2. Wait 10 seconds after the Windows hourglass has disappeared on all the clients to ensure a consistent starting state.
3. On each client you want to test, if there is a shortcut to SC1-Prep or SC1cleanup, do the following:
 - a. Double-click that shortcut.
 - b. Wait until you see a confirmation window that prep has completed, or, in the case of SC1cleanup, wait 30 seconds.
4. Start the script at the same time on all the clients you are testing by clicking the Shortcut to SC1main and pressing Enter on each client.
5. When the test completes, record the results of each client.

As we discussed at the beginning of the Test methodology section, we ran each script five times on each test configuration of each network (e.g., five times with one active PC, five times with two active PCs, and so on.)

In the following three subsections, we detail the first phase for each of the three types of test networks. As

Testing the PC clients

This section provides the test execution preparation steps specific to the PC test network.

1. Power on the file server.
2. When the server is fully active, power on all the PCs you are testing.

Getting the PC test network systems ready to go

Follow these steps to ready the file server and PCs for testing:

1. Power on the file server.
2. When the server is fully active, power on the PCs you are testing.

Reboot the PC test network systems

Follow these steps to reboot the file server and PCs for testing:

1. Log on to the file server as administrator.
2. Click Start → Shut Down.
3. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
4. Type an explanatory comment in the comment box.
5. Press Enter.
6. You may see a warning window that says shutting down will close remote connections and that asks if you want to end them. Click Yes, and the file server will restart.
7. When the server is fully active, power on the PCs you are testing.

Testing the Sun Ray 2 thin clients

This section provides the test execution preparation steps specific to the Sun Ray 2 test network.

Getting the Sun Ray 2 test network systems ready to go

Follow these steps to ready the file server, the Sun Fire V240 server, and the Sun Ray 2 thin clients for testing:

3. Power on the Sun Fire V240 server.
4. Power on the file server.
5. When both servers are fully active, power on the Sun Ray 2 thin clients you are testing.
6. When each Sun Ray 2 prompts you to log on, log on as ruser[X], where X is the number of the client.

Rebooting the Sun Ray 2 test network systems

Follow these steps to ready the file server, the Sun Fire V240 server, and the Sun Ray 2 thin clients for testing:

1. Log on to the file server as administrator.
2. Open a command prompt.
3. Type telnet 10.41.1.180, and press Enter.
4. When the system prompts you for the username, log in as ruser with password "password".
5. Wait for the login process to complete.
6. Type su to log on as the administrator with password "password".
7. Type sync;sync;init 6, and press Enter.
8. Click Start → Shut Down.
9. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
10. Type an explanatory comment in the comment box.
11. Press Enter.
12. You may see a warning window that says shutting down will close remote connections and that asks if you want to end them. Click Yes, and the file server will restart.
13. When both servers are fully active, power on the Sun Ray 2 thin clients you are testing.
14. When each Sun Ray 2 prompts you to log on, log on as ruser[X], where X is the number of the client.

Testing the Wyse Winterm 5150SE thin clients

This section provides the test execution preparation steps specific to the Wyse Winterm 5150SE test network.

Getting the Wyse Winterm 5150SE test network systems ready to go

Follow these steps to ready the file server and Wyse Winterm 5150SE thin clients for testing:

1. Power on the file server.
2. Wait two minutes after the server finishes booting. (This step avoids potential thin-client connection issues.)
3. Power on all the Wyse Winterm 5150SE thin clients you are testing.

Rebooting the Wyse Winterm 5150SE test network systems

Follow these steps to ready the file server and Wyse Winterm 5150SE thin clients for testing:

1. Log on to the file server as administrator.
2. Click Start → Shut Down.
3. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
4. Type an explanatory comment in the comment box.
5. Press Enter.
6. You may see a warning window that says shutting down will close remote connections and that asks if you want to end them. Click Yes, and the file server will restart.
7. Wait two minutes after the server finishes booting. (This step avoids potential thin-client connection issues.)
8. When the server is fully active, power on the Wyse Winterm 5150SE thin clients you are testing.

Appendix A: Test system configuration information

This appendix provides detailed configuration information about the each of the several types of systems we used in this test

| Test PCs | Dell OptiPlex 210L |
|---|--------------------------|
| System configuration information | |
| General | |
| Processor and OS kernel: (physical, core, logical) / (UP, MP) | 1P1C2L / MP |
| Number of physical processors | 1 |
| Single/Dual-Core processors | Single |
| System Power Management Policy | Home/Office Desk |
| CPU | |
| System type | Desktop |
| Vendor | Intel |
| Name | Intel Pentium 4 650 |
| Stepping | 3 |
| Socket type | LGA775 |
| Core frequency (GHz) | 3.4 |
| Front-side bus frequency (MHz) | 800 |
| L1 Cache | 16 KB + 12 Kμops |
| L2 Cache | 2 MB |
| Platform | |
| Vendor | Dell |
| Motherboard model number | 0HC918 |
| Motherboard chipset | Intel i915G Chipset |
| Motherboard revision number | B1 |
| Motherboard serial number | 5PT4V91 |
| BIOS name and version | Dell A01 |
| BIOS settings | Default |
| Memory module(s) | |
| Vendor and model number | Samsung M378T3354CZ3-CD5 |
| Type | PC4300 DDR-2 |
| Speed (MHz) | 533 |
| Speed in the system currently running @ (MHz) | 266 |
| Timing/Latency (tCL-tRCD-tRP-tRASmin) | 4-4-4-11 |
| Size | 512 MB |
| Number of sticks | 2 |
| Chip organization | Double-sided |
| Channel | Dual |
| Hard disk | |
| Vendor and model number | Samsung HD080HJ/P |
| Number of disks in system | 1 |
| Size | 80 GB |
| Buffer Size | 8 MB |
| RPM | 7200 |
| Type | SATA |
| Controller | Intel 82801FB (ICH6) |
| Driver | Intel 7.0.0.1011 |
| Operating system | |

| | |
|--------------------------------|-----------------------------------|
| Name | Microsoft Windows XP Professional |
| Build number | 2600 |
| Service pack | SP2 |
| File system | NTFS |
| Kernel | ACPI Multiprocessor PC |
| Language | English |
| Microsoft DirectX version | 9.0c |
| Graphics | |
| Vendor and model number | Intel 915G |
| Type | Integrated |
| Chipset | Intel 82915G Express Chipset |
| BIOS version | 3414 |
| Memory size | 128 MB Shared |
| Resolution | 1024 x 768 |
| Driver | Intel 6.14.10.4299 |
| Network card/subsystem | |
| Vendor and model number | Intel PRO/100 VE |
| Type | Integrated |
| Driver | Intel 8.0.15.0 |
| Other Network Card Information | Intel PRO/100 VE |
| Optical drive 1 | |
| Vendor and model number | LG GWA4164B |
| Type | DVD-RW |
| Dual/Single layer | Dual |
| USB ports | |
| # of ports | 6 |
| Type of ports (USB1.1, USB2.0) | USB 2.0 |

Figure 20: Detailed system configuration information for the test PCs (Dell OptiPlex 210L systems).

| Thin clients | Sun Ray 2 | Wyse Winterm 5150SE |
|---|---------------|--------------------------|
| General | | |
| Processor and OS kernel: (physical, core, logical) / (UP, MP) | Unknown | 1P1C1L / UP |
| Number of physical processors | 1 | 1 |
| CPU | | |
| System type | Thin Client | Thin Client |
| Vendor | Raltron | AMD |
| Name | CO66 | Geode GX |
| Core frequency (MHz) | 48 | Unknown |
| Front-side bus frequency (MHz) | Unknown | PCI 66MHz bus |
| Memory module(s) | | |
| Size | Unknown | 64 MB Flash / 128 MB DDR |
| Operating system | | |
| Name | None | Wyse Linux V6 |
| Graphics | | |
| Vendor and model number | VGA | VGA- type (DB-15) |
| Type | Integrated | Integrated |
| Resolution | 1024 x 768 | 1024 x768 |
| Network card/subsystem | | |
| Vendor and model number | 10/100 Base-T | 10/100 Base-T |

| | | |
|------------------|------------------------|------------------------|
| Type | Integrated | Integrated |
| USB ports | | |
| Number | 2 | 4 |
| Type | USB 1.1 | USB 2.0 |
| Monitor | | |
| Type | ViewSonic Optiquest Q7 | ViewSonic Optiquest Q7 |
| Screen size | 17" | 17" |
| Refresh rate | 75 Hz | 75 Hz |

Figure 21: Detailed system configuration information for the Sun Ray 2 and Wyse Winterm 5150SE thin clients we tested.

| | |
|---|---|
| File server both the PCs and thin clients used | HP ProLiant DL360 1U Rack Server |
| System configuration information | |
| General | |
| Processor and OS kernel: (physical, core, logical) / (UP, MP) | 1P1C2L / MP |
| Number of physical processors | 1 |
| Single/Dual-Core processors | Single |
| System Power Management Policy | AC/Always On |
| CPU | |
| Vendor | Intel |
| Name | Intel Xeon |
| Stepping | A |
| Socket type | mPGA-604 |
| Core frequency (GHz) | 3.4 |
| Front-side bus frequency (MHz) | 800 |
| L1 Cache | 16 KB + 12 Kμops |
| L2 Cache | 2 MB |
| Platform | |
| Vendor and model number | HP |
| Motherboard model number | 382146-405 |
| Motherboard chipset | Intel E7520 Chipset |
| Motherboard revision number | A05 |
| Motherboard serial number | USE617N2DF |
| BIOS name and version | HP P54 |
| BIOS settings | Default |
| Memory module(s) | |
| Vendor and model number | Infineon HYS72T128000HR-5-A |
| Type | PC2-3200 DDR-2 |
| Speed (MHz) | 400 |
| Speed in the system currently running @ (MHz) | 200 |
| Timing/Latency (tCL-tRCD-iRP-tRASmin) | 3-3-3-11 |
| Size | 2048 MB |
| Number of RAM modules | 2 |
| Chip organization | Double-sided |
| Channel | Single |
| Hard disk | |
| Vendor and model number | Maxtor 6L160M0 |
| Number of disks in system | 2 |
| Size | 160GB |
| Buffer Size | 8 MB |
| RPM | 7200 |

| | |
|----------------------------------|---|
| Type | SATA |
| Controller | Intel 6300ESB (ICH-S) |
| Controller driver | Microsoft 5.2.3790.1830 |
| Operating system | |
| Name | Microsoft Windows 2003 Server, x32 Enterprise Edition |
| Build number | 3790 |
| Service Pack | SP1 |
| File system | NTFS |
| Kernel | ACPI Multiprocessor PC |
| Language | English |
| Microsoft DirectX version | 9.0c |
| Graphics | |
| Vendor and model number | ATI Rage XL |
| BIOS version | GR-xlcpq-5.882-4.333 |
| Type | Integrated |
| Memory size | 8 MB shared |
| Resolution | 1024 x 768 |
| Driver | ATI 5.10.2600.6014 |
| Network card/subsystem | |
| Vendor and model number | HP NC7782 Dual-port Gigabit Server Adapter |
| Type | Integrated |
| Driver | HP 8.39.1.0 |
| Optical drive | |
| Vendor and model number | HLDS GCR-8240N |
| Type | CD-ROM |
| USB ports | |
| # of ports | 2 |
| Type of ports (USB 1.1, USB 2.0) | USB 2.0 |

Figure 22: Detailed system configuration information for the server both the PCs and the thin clients used.

| Server the Sun Ray 2 thin clients required | Sun Fire V240 |
|---|--------------------|
| System configuration information | |
| General | |
| Processor and OS kernel: (physical, core, logical) / (UP, MP) | 2P3C3L |
| Number of physical processors | 2 |
| Single/Dual-Core processors | Single |
| System Power Management Policy | N/A |
| CPU | |
| Vendor | Sun Microsystems |
| Name | UltraSPARC IIIi |
| Socket type | mPGA-959 |
| Core frequency (GHz) | 1.5 |
| L1 Cache | 32 KB + 64 KB |
| L2 Cache | 1 MB |
| Platform | |
| Vendor and model number | Sun Microsystems |
| Motherboard model number | PWA-EENXs |
| Motherboard serial number | 0328MIC-0616H01Y8R |
| Memory module(s) | |

| | |
|---|-----------------------|
| Vendor and model number | Micron MT18VDDT6472G |
| Type | PC2100 |
| Speed (MHz) | 266 |
| Speed in the system currently running @ (MHz) | 266 |
| Timing/Latency (tCL-tRCD-iRP-tRASmin) | CL2 |
| Size | 2048 MB |
| Number of RAM modules | 4 |
| Chip organization | Double-sided |
| Channel | Dual |
| Hard disk | |
| Vendor and model number | Fujitsu MAW3073NC |
| Number of disks in system | 2 |
| Size | 72 GB |
| Buffer Size | 8 MB |
| RPM | 10000 |
| Type | SCSI |
| Controller | LSA0725 / LSI53C1010R |
| Operating system | |
| Name | Solaris 10 |
| Build number | 3/05 |
| Service Pack | N/A |
| File system | UFS |
| Language | English |
| Network card/subsystem | |
| Type | Integrated |
| Optical drive | |
| Vendor and model number | TEAC DV-28E-N93 |
| Type | DVD-ROM |
| USB ports | |
| # of ports | 2 |
| Type of ports (USB 1.1, USB 2.0) | USB 1.1 |

Figure 23: Detailed system configuration information for the server the Sun Ray 2 thin clients required.

Appendix B: Instructions for running the application scenarios

This appendix summarizes the script for each application scenario and explains how we manually tested and timed each of those scenarios. Though the vast majority of our discussions in this report focus on the results of the automated tests, we verified that manually performing the same functions yielded results similar to those of the automated scripts.

As the instructions below reflect, to get the most consistent possible timings and to make our hand-timed actions more like the ones the automated scripts perform, we sometimes chose to follow procedures for launching applications that were different from those typical users would follow. (See Appendix C for additional information on scripting issues.) When we made such choices, we also independently verified that the typical user procedures would still show similar results.

Consequently, we are confident that the benefits PCs delivered in these scenarios are benefits that users can expect to realize in real work situations and are not artifacts of the measurement or scripting technology.

We ran all application scenarios five times on each of the systems under test, and we reported the median of those runs.

The following subsections, which assume you have already completed all of the setup work in the Test methodology section, describe how to run each of the individual scenarios.

Single task scenario: Calculating subtotals in Microsoft Excel

The application involved

- Microsoft Office Excel 2003

The data file involved

- Sales2002a1.xls, a 1.79MB Excel worksheet (located on the file server)

The script

The script for the scenario performs the following tasks:

- Open Sales2002a1.xls. (We did not time that task, because we focused on a single function.)
- Start the Excel timer, and perform the subtotal function.
- Stop the Excel timer when Excel finishes calculating the subtotals.
- Close Excel. (We did not time that task, because we focused on a single function.)

The manual process

To execute the test, follow these instructions. You will need a stopwatch.

1. Reboot the system.
2. Open Sales2002a1.xls.
3. Select Data/Subtotals...
4. Fill in the Subtotal dialog as follows:
 - At each change in: Size.
 - Use function: Average.
 - Add subtotal to: Quantity.
 - Uncheck Replace current subtotals.
5. Start stopwatch, and press OK.
6. Stop stopwatch when the Inserting Subtotals progress bar goes away and the status bar says Ready.
7. Close Excel, choosing No when Excel asks whether you want to save.

Single task scenario: Compressing a PDF from within Adobe Acrobat

The application involved

- Adobe Acrobat 7.0 Standard

The data file involved

- Computing.pdf, a 4.01MB PDF file (on the file server)

The script

The script for the scenario performs the following tasks:

- Open Computing.pdf. (We did not time that task, because we focused on a single function.)
- Start the Acrobat timer, and tell Acrobat to compress the PDF.
- Stop the Acrobat timer when the Conversion Warning dialog displays.
- Close the Conversion Warning window.
- Close Acrobat.
- Delete Compress.pdf, the file the script just created. (We did not time these three final tasks, because we focused on a single function.)

The manual process

To execute the test, follow these instructions. You will need one stopwatch.

1. Reboot the system.
2. Open Computing.pdf.
3. Select File/Reduce File Size.
4. In Reduce File Size dialog, select Acrobat 7.0 or later.
5. Press OK.
6. In the Save As dialog, give the new file the name, Compress.
7. Start the Acrobat stopwatch, and press Save.
8. Stop the Acrobat stopwatch when a Conversion Warning dialog displays.
9. Press Enter to close the Conversion Warning dialog.
10. Exit Acrobat.
11. Delete Compress.pdf.
12. Empty the recycle bin.

Multitasking scenario: Changing the view in a Microsoft PowerPoint presentation while compressing a folder in Windows Explorer

The applications involved

- Microsoft Windows Explorer for Windows XP Professional (Service Pack 2)
- Microsoft Office PowerPoint 2003

The data files involved

- FourFiles, a 265MB folder that the scenario uses to create a 168MB compressed (zipped) folder (on the file server for the thin clients; local for the rich clients)
- Content.ppt, a 30.4MB Microsoft PowerPoint presentation (on the file server)

The script

The script for the scenario performs the following tasks:

- Open Windows Explorer. (We did not time this task, because it occurs outside the multitasking section of the script.)
- Navigate to FourFiles.
- Start the timer for Explorer Compress, and start compressing FourFiles.
- Start the PowerPoint Open timer, and double-click the Content.ppt desktop shortcut.
- Stop the PowerPoint Open timer when the bottom slide in the slide viewer loads.
- Start the PowerPoint Change View timer, and select View/Slide Sorter.

- Stop the PowerPoint Change View timer when the last slide loads in the Slide Sorter view.
- Stop the Explorer Compress timer when Explorer finishes compressing the file.
- Close all open applications. (We did not time these tasks, because they occur outside the multitasking section of the script.)

The manual process

First, prepare each system by following these steps once:

1. Open Windows Explorer.
2. Ensure that it allows enough space on the right to allow double-clicking a desktop shortcut there.
3. Create a desktop shortcut to Content.ppt. Place it on the right side of the desktop, to the right of the Explorer window.

To execute the test, follow these instructions. You will need three stopwatches to time three different tasks.

1. Reboot the system.
2. Open Windows Explorer.
3. Navigate to the folder that contains FourFiles.
4. Start the first stopwatch, and click Send to/Compressed (zipped) folder.
5. Start the second stopwatch, and double-click the Content.ppt desktop shortcut.
6. Stop the second stopwatch when the slide viewer finishes displaying the slides that fit in the PowerPoint window.
7. Start the third stopwatch, and select View\Slide Sorter from the PowerPoint menu.
8. Stop the third stopwatch when the slider sorter finishes displaying the slides that fit in the PowerPoint window.
9. Stop the first stopwatch when Explorer finishes creating the compressed FourFiles.zip.
10. Close all open applications, choosing No if any application asks whether to save changes.
11. Delete FourFiles.zip.
12. Empty the recycle bin.

Multitasking scenario: Opening large XML files in Microsoft Word and Microsoft Excel

The applications involved

- Microsoft Office Excel 2003
- Microsoft Office Word 2003
- Microsoft Windows Explorer for Windows XP Professional (Service Pack 2)

The data files involved

- SalesSummary.xml, an 11MB XML document (on the file server)
- Excel2minlarge.xml, a 28.9MB XML document (on the file server)

The script

The script for the scenario performs the following tasks:

- Open Windows Explorer. (We did not time this task, because it occurs outside the multitasking section of the script.)
- Navigate to the directory that contains SalesSummary.xml and Excel2minlarge.xml.
- Open SalesSummary.xml and Excel2minlarge.xml, and starts one timer for the Word document open and one timer for the Excel document open.
- Stop the Excel timer when the Excel document finishes loading and Ready appears in the lower left of the document.
- Stop the Word timer when the Word document finishes loading and the page count on the bottom of the page equals the actual page count of the document.
- Close all open applications. (We did not time these tasks, because they occur outside the multitasking section of the script.)

The manual process

First, prepare each system by following these steps once:

1. Open SalesSummary.xml and Excel2minlarge.xml.
2. Arrange their windows so that both are visible and you can see at least the lower left of the Excel status bar and enough of the Word status bar to be able to see the document page count.

To execute the test, follow these instructions. You will need two stopwatches.

1. Open Windows Explorer.
2. Navigate to the directory that contains SalesSummary.xml and Excel2minlarge.xml.
3. Select both SalesSummary.xml and Excel2minlarge.xml.
4. Start both stopwatches, and hit Enter to open both SalesSummary.xml and Excel2minlarge.xml.
5. Stop the first stopwatch when Excel finishes loading Excel2minlarge.xml and the Ready statement appears in the lower left of the document.
6. Stop the second stopwatch when Word finishes loading SalesSummary.xml and the page count on the bottom of the page shows 1/42.
7. Close all the applications.

Appendix C – Issues in script development

To the best of our knowledge, despite its age IBM's Visual Test 6.5 remains the tool most widely used today for constructing application-based benchmarks and performance tests for PCs running various versions of Microsoft Windows. We have used this product (and previous versions of it) for many years to build performance tests. The tool does, however, have some stated limitations that unavoidably affect the way one develops performance tests with it.

First, the product's own documentation notes that its primary goal is to be a tool for automating application testing, not for benchmark development. Consequently, the granularity of some of its functions and the way some of its functions behave are not ideal for benchmark development.

IBM also does not officially support Visual Test 6.5 for the Windows XP operating system. Because Windows XP is the leading and most current desktop version of Windows today, we nonetheless felt it was essential to use that operating system in our tests.

The presence of any scripting tool has the potential to affect the performance of a system. The tool unavoidably must, for example, occupy some memory and consume some processing power. Consequently, developing a performance-measurement script with such a tool involves maintaining a delicate balance between using the tool to automate typical real user behavior and minimizing the effects of the tool on system performance. To make sure the results of our scripts were accurate, we also hand-timed each of the functions we scripted.

To minimize these limitations and problems, we sometimes had to use scripting techniques that would achieve the same results as typical user behavior but not exactly mirror that behavior. Such techniques include inserting delays to mimic user think time and launching applications by clicking the OK button of a pre-filled Run command line. The hand timing instructions we provide in Appendix B reflect those techniques, so following those instructions will yield results similar to those the scripts produce. Whenever we had to use one of these alternative techniques, we manually verified that doing so did not materially alter the way the system behaved and that real users performing the same actions in more typical ways would see the type of performance benefits we describe.

The timings the scripts produce also inevitably contain some variability. This variability is a result of the combination of the tool's limitations and the generally asynchronous nature of the many processes Windows XP and other modern operating systems have running at any given time.

Finally, though one of the goals of this effort was to produce reliable scripts, we were not trying to build bulletproof benchmarks for wide distribution and use. We developed the scripts to mimic user behavior on our specific test systems; on different systems the scripts might show different levels of performance benefits or even fail to work. So, although the scripts are as reliable, self-contained, and free of system dependencies as we could reasonably make them within the project's timeframe, they do sometimes fail or encounter problems. Should a problem occur, rebooting the system and running the script again will generally yield a good result.



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