Project Server 2013 Performance Lab

# Summary

Project Server 2013 is a complex product with a “scale-out” model for both the Web Front-End (“WFE”) tier and the Project Application Service (“APP”) tier. There is no single “ideal” topology for a Project Server deployment—hardware needs will vary based on dataset and workload. This performance lab created by the Microsoft Project Server engineering team explores the behavior of a “large” synthetic dataset in response to several common workloads. You can use this information to provide a rough baseline for Project Server 2013 performance in this defined lab environment. It is important to note that your actual performance may differ due to numerous variables in your own environment.

**Note**: For more information about running your own Project Server 2013 performance tests, see the Microsoft TechNet article set, [Run a Project Server 2013 Performance Test Lab](http://technet.microsoft.com/en-us/library/ee956502(v=office.15).aspx) (http://technet.microsoft.com/en-us/library/ee956502(v=office.15).aspx).

# Environment Configuration

For the purposes of this exercise, virtual machines were used for everything except for the database tier. The capabilities of the test SQL Server were deliberately reduced to provide guidance more in line with that offered by the rest of SharePoint. It is very likely that mainstream “production” hardware will be faster than the hardware used for this performance lab exercise because the focus was on building a consistent topology with repeatable behaviors.

## Hardware

For this exercise, two different types of machine were used:

* Dell PE2950s (late Intel Core2-based), which acted as VM hosts and a Visual Studio Team System (VSTS) test machine.
* A more recent HP ProLiant machine with an attached storage array acted as a SQL Server database server.

|  |  |  |  |
| --- | --- | --- | --- |
| **Machine Type** | **Host Machine/VSTS Test Machine** | **Hyper-V Guest** | **SQL Server** |
| **Model** | Dell PE 2950 | (On Dell PE 2950) | HP ProLiant (unknown submodel) |
| **CPU** | Xeon L5420 | - | Xeon L5630 |
| **Speed (GHz)** | 2.5 | - | 2.13 |
| **Processors** | 2 | - | 2 |
| **Cores Per Processor** | 4 | - | 4 |
| **Threads Per Core** | 1 | - | 2 |
| **Total Cores** | 8 | 4 | 8 |
| **Total Threads** | 8 | 4 | 16 |
| **Memory (GB)** | 32 | 12 | 48 |
| **OS Storage** | 558 GB (3x 300GB RAID-5) | 128 GB (Fixed-size VHD) | 558 GB (3x 300 GB RAID-5) |
| **Other Storage** |  |  | SQL Data: 3 TB (12x 300 GB RAID-5)  SQL Log: 1.07 TB (8x 300 GB RAID-1+0) |

## Software

* Test machine
  + Windows Server 2008 R2 x64
  + Visual Studio Ultimate 2010
  + Visual Studio Test Agent and Controller
  + Running directly on physical machine
* WFE/APP machines
  + Windows Server 2008 R2 x64
  + SharePoint/Project Server 2013
  + Virtual machines—up to one WFE and one APP per physical machine
* Database tier
  + Windows Server 2008 R2 x64
  + SQL Server 2012, using attached disk array for storage
  + SQL limited to eight threads, 16GB of memory using configuration parameters

## Data

For this capacity planning exercise, a “Large” synthetic data set was used, which has the following basic characteristics:

* 10,000 users
  + 8,000 Team Members
  + 1,000 Project Managers
  + 800 Resource Managers
  + 200 Administrators
* 5,000 projects
  + Nominal size ~175 tasks
  + Two assignments per non-summary task
  + Typical “team” size: 10 users per project
  + Approximately 18 task custom field values per task (including computed and manually-entered data)

# Test Methodology

For this exercise, a set of VSTS web tests for different common areas of PWA functionality was created, and then load tests were constructed based on these tests. The load tests are summarized below:

|  |  |
| --- | --- |
| Test Name | Basic Steps |
| Home Page | As a team member, navigate to the PWA home page (/default.aspx) |
| Resource Center | As a resource manager, navigate to Resource Center (/resources.aspx) and wait for the grid to load |
| Project Center | As a project manager, navigate to Project Center (/projects.aspx) and wait for the grid to load |
| Project Information | 1. As a project manager, navigate to Project Center (/projects.aspx) and wait for the grid to load 2. Select a project, and navigate to the Project Information PDP (without “checking-out” the project) |
| Project Schedule  (Read-Only) | 1. As a project manager, navigate to Project Center (/projects.aspx) and wait for the grid to load 2. Select a project, and navigate to the Project Schedule PDP (without “checking-out” the project) |
| Project Schedule  (Read-Write) | 1. As a project manager, navigate to Project Center (/projects.aspx) and wait for the grid to load 2. Select a project, and navigate to the Project Schedule PDP, “checking-out” the project 3. Once the Project Schedule view loads, edit the duration of a task in the project 4. Click the Save button, then wait for the “Save Completed” notification 5. Click the Close button and check-in the project |
| My Tasks  (Navigate Only) | As a team member, navigate to the My Tasks (/tasks.aspx) page and wait for the grid to load |
| My Tasks  (Save, Submit) | 1. As a team member, navigate to the My Tasks (/tasks.aspx) page and wait for the grid to load 2. Edit the percent complete on a task 3. Save all changes 4. Submit all changes |
| My Timesheet  (Navigate Only) | As a team member, navigate to the Timesheet for the current period (/timesheet.aspx) and wait for the grid to load |
| My Timesheet  (Save) | 1. As a team member, navigate to the Timesheet for the current period (/timesheet.aspx) and wait for the grid to load 2. Edit the hours on a single task 3. Save |
| Task Approvals  (Navigate Only) | As a project manager, navigate to the Approvals page (/approvals.aspx) and wait for the grid to load |
| Task Approvals  (Approve) | 1. As a project manager, navigate to the Approvals page (/approvals.aspx) and wait for the grid to load 2. Select one item from the grid, and click the “Approve” button |

## Load Tests

Five load tests were defined, based on different mixtures of the web tests described in the preceding section:

|  |  |  |
| --- | --- | --- |
| Load Test Name | Web Test | Percentage of Mix |
| General Read-Only | Home Page Navigate | 30 |
| My Tasks Navigate Only | 15 |
| Project Center | 10 |
| Project Information | 5 |
| Project Schedule Read-Only | 10 |
| Resource Center | 5 |
| Task Approvals Navigate | 10 |
| Timesheet Navigate | 15 |
| General Read-Write | Home Page Navigate | 24 |
| My Tasks Navigate | 12 |
| Project Center | 8 |
| Project Information | 4 |
| Project Schedule Read-Only | 8 |
| Resource Center | 4 |
| Task Approvals Navigate | 8 |
| Timesheet Navigate | 12 |
| My Tasks Read-Write | 8 |
| Timesheet Save | 8 |
| Task Approvals-Approve Updates | 4 |
| My Tasks | My Tasks Save/Submit | 100 |
| Timesheets | Timesheet Save | 100 |
| Project Schedule | Project Schedule Read-Write | 100 |

## Basic Approach

Each load test was run with a “step load”, generally starting around 10 users, with a 10-user step once every 10 minutes (except for Schedule Web Part, in which smaller user counts were used). As user load increased, throughput generally increased until it hit a “plateau”, then eventually fell again (often accompanied by increasing error rates). Thus, the smallest user load that appeared to be on the plateau was selected. The Visual Studio graph view was then zoomed to include *only* that step, and the performance counter values collected were then analyzed.

In between tests, the Project Server Queue was waited on to drain, and typical “idle” CPU and resource usage patterns were allowed to resume. After running the entire battery of tests against a given configuration, the configuration was then altered and all of the WFE and APP machines were restarted.

# Results

The following tables display results of running each of the five load tests. Each of the load tests were run using three different topologies:

* One Web Front End server and one Application server
* Two Web Front End servers and two Application servers
* Four Web Front End servers and four Application servers

## Read-Only Mix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WFEs** | | | 1 | 2 | 4 |
| **APPs** | | | 1 | 2 | 4 |
| **SQL Config** | | | 8 CPUs, 16 GB | 8 CPUs, 16 GB | 8 CPUs, 16 GB |
| **Category** | | **Performance Counter/Metric** | **Average** | | |
| **VSTS Metrics** | | User Load | 20 | 20 | 20 |
| Requests Per second (RPS) | 26 | 45.3 | 52.2 |
| Latency (ms) | 750 | 430 | 370 |
| **WFE** | Processor | % Processor Time | 95.7 | 75.3 | 36.8 |
| Network Interface | Bytes Received /Sec | 4063664 | 3987356 | 2319754 |
| Bytes Sent / Sec | 4329635 | 1611202 | 876426 |
| Bytes Total / Sec | 8393299 | 5598558 | 3196181 |
| .NET Memory | % Time in GC | 2.15 | 2.69 | 1.06 |
| Physical Disk | Avg. Disk Queue Length | 0.011 | 0.0096 | 0.0064 |
| Avg. Disk Read Queue Length | 0.00019 | 0.00035 | 0.00033 |
| Avg. Disk Write Queue Length | 0.011 | 0.0092 | 0.0061 |
| Disk Reads/sec | 0.0051 | 0.06 | 0.058 |
| Disk Writes/sec | 19.8 | 20.2 | 14.6 |
| Memory | Available Mbytes | 8156 | 8812 | 8684 |
| Page Faults/sec | 3298 | 1341 | 858 |
| Pages/sec | 36.3 | 29.1 | 22.5 |
| Process | Working Set | 3901003008 | 3238073088 | 3282233600 |
| Thread Count | 919 | 824 | 867 |
| **APP** | Processor | % Processor Time | 79.5 | 48.3 | 26.3 |
| Network Interface | Bytes Received /Sec | 2632440 | 2164364 | 1250796 |
| Bytes Sent / Sec | 2332451 | 1789685 | 1050938 |
| Bytes Total / Sec | 4964892 | 3954049 | 2301734 |
| .NET Memory | % Time in GC | 2.73 | 2.34 | 3.77 |
| Physical Disk | Avg. Disk Queue Length | 0.0053 | 0.0056 | 0.0044 |
| Avg. Disk Read Queue Length | 0.00008 | 0.0002 | 0.00026 |
| Avg. Disk Write Queue Length | 0.0052 | 0.0054 | 0.0041 |
| Disk Reads/sec | 0.01 | 0.0033 | 0.053 |
| Disk Writes/sec | 10.2 | 10.8 | 9.15 |
| Memory | Available Mbytes | 8418 | 8581 | 8929 |
| Page Faults/sec | 3788 | 1201 | 775 |
| Pages/sec | 29.9 | 22.6 | 16.4 |
| Process | Working Set | 3946870784 | 3873371648 | 3503090688 |
| Thread Count | 1085 | 1026 | 1114 |
| **SQL** | Processor | % Processor Time | 15.8 | 28.3 | 30.6 |
| (Corrected to #CPUs) | 31.6 | 56.6 | 61.2 |
| Network Interface | Bytes Received /Sec | 873330 | 1383432 | 1377308 |
| Bytes Sent / Sec | 4141387 | 8038028 | 9237779 |
| Bytes Total / Sec | 5014717 | 9421460 | 10615090 |
| Physical Disk | Avg. Disk Queue Length | 0.27 | 0.63 | 0.072 |
| Avg. Disk Read Queue Length | 0.24 | 0.6 | 0.055 |
| Avg. Disk Write Queue Length | 0.03 | 0.021 | 0.017 |
| Disk Reads/sec | 70 | 191 | 19.8 |
| Disk Writes/sec | 190 | 155 | 135 |
| Memory | Available Mbytes | 29282 | 29270 | 29006 |
| Page Faults/sec | 89.7 | 723 | 1095 |
| Pages/sec | 0.089 | 0.12 | 0.0083 |
| Process | Working Set | 18140024832 | 18146037760 | 18412230656 |
| Thread Count | 828 | 841 | 890 |
| SQL-Specific | SQL Locks: Average Wait Time [ms] | 91 | 176 | 63.9 |
| SQL Locks: Lock Wait Time [ms] | 1573 | 280 | 214 |
| SQL Locks: Deadlocks/s | 0.027 | 0 | 0 |
| SQL Latches: Average Wait Time [ms] | 0.66 | 1.63 | 1.89 |
| SQL Statistics: SQL Re-Compilations/s | 26.9 | 6.95 | 4.1 |

## Read-Write Mix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WFEs** | | | 1 | 2 | 4 |
| **APPs** | | | 1 | 2 | 4 |
| **SQL Config** | | | 8 CPUs, 16 GB | 8 CPUs, 16 GB | 8 CPUs, 16 GB |
| **Category** | | **Performance Counter/Metric** | **Average** | | |
| **VSTS Metrics** | | User Load | 30 | 30 | 30 |
| Requests Per second (RPS) | 23.2 | 45.4 | 13.4 |
| Tests Per Second | 8.56 | 16.8 | 5.18 |
| Latency (ms) | 1200 | 640 | 2140 |
| **WFE** | Processor | % Processor Time | 66.1 | 69.6 | 9.23 |
| Network Interface | Bytes Received /Sec | 4626554 | 4505253 | 691174 |
| Bytes Sent / Sec | 1231916 | 1277282 | 203527 |
| Bytes Total / Sec | 5858470 | 5782535 | 894701 |
| .NET Memory | % Time in GC | 1.18 | 2.57 | 0.55 |
| Physical Disk | Avg. Disk Queue Length | 0.011 | 0.011 | 0.0059 |
| Avg. Disk Read Queue Length | 0.0011 | 0.00039 | 0.0015 |
| Avg. Disk Write Queue Length | 0.0099 | 0.01 | 0.0044 |
| Disk Reads/sec | 0.44 | 0.14 | 0.31 |
| Disk Writes/sec | 19.2 | 19.1 | 7.86 |
| Memory | Available Mbytes | 7944 | 8534 | 9373 |
| Page Faults/sec | 1512 | 1980 | 653 |
| Pages/sec | 41.5 | 37.4 | 14.4 |
| Process | Working Set | 4118957568 | 3526286080 | 2684924160 |
| Thread Count | 924 | 881 | 846 |
| **APP** | Processor | % Processor Time | 94.7 | 94.2 | 82.2 |
| Network Interface | Bytes Received /Sec | 1637490 | 2001299 | 538426 |
| Bytes Sent / Sec | 1508089 | 1604961 | 320830 |
| Bytes Total / Sec | 3145579 | 3606260 | 859256 |
| .NET Memory | % Time in GC | 5.85 | 4.99 | 4.97 |
| Physical Disk | Avg. Disk Queue Length | 0.0094 | 0.0089 | 0.026 |
| Avg. Disk Read Queue Length | 0.00093 | 0.00054 | 0.019 |
| Avg. Disk Write Queue Length | 0.0085 | 0.0084 | 0.0079 |
| Disk Reads/sec | 0.48 | 0.28 | 5.32 |
| Disk Writes/sec | 16.5 | 15 | 12.3 |
| Memory | Available Mbytes | 6910 | 7159 | 8962 |
| Page Faults/sec | 1863 | 1412 | 1179 |
| Pages/sec | 56 | 47.7 | 54.7 |
| Process | Working Set | 5995823616 | 5569628672 | 3505365760 |
| Thread Count | 1601 | 1356 | 1113 |
| **SQL** | Processor | % Processor Time | 14.7 | 27.6 | 20.7 |
| (Corrected to #CPUs) | 29.4 | 55.2 | 41.4 |
| Network Interface | Bytes Received /Sec | 612731 | 1222628 | 861968 |
| Bytes Sent / Sec | 4579411 | 9248158 | 3885005 |
| Bytes Total / Sec | 5192142 | 10470790 | 4746973 |
| Physical Disk | Avg. Disk Queue Length | 0.76 | 1.96 | 0.62 |
| Avg. Disk Read Queue Length | 0.51 | 1.02 | 0.36 |
| Avg. Disk Write Queue Length | 0.25 | 0.94 | 0.26 |
| Disk Reads/sec | 133 | 215 | 84.7 |
| Disk Writes/sec | 150 | 246 | 216 |
| Memory | Available Mbytes | 29295 | 29032 | 28860 |
| Page Faults/sec | 1079 | 1025 | 684 |
| Pages/sec | 0.0019 | 0.002 | 0.0017 |
| Process | Working Set | 18134951936 | 18387417088 | 18557847552 |
| Thread Count | 821 | 867 | 930 |
| SQL-Specific | SQL Locks: Average Wait Time [ms] | 76.4 | 72.1 | 347 |
| SQL Locks: Lock Wait Time [ms] | 10.3 | 124 | 6758 |
| SQL Locks: Deadlocks/s | 0.0019 | 0.002 | 0.0052 |
| SQL Latches: Average Wait Time [ms] | 1.12 | 2.73 | 8.78 |
| SQL Statistics: SQL Re-Compilations/s | 1.12 | 2.15 | 10.7 |

## My Tasks

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WFEs** | | | 1 | 2 | 4 |
| **APPs** | | | 1 | 2 | 4 |
| **SQL Config** | | | 8 CPUs, 16 GB | 8 CPUs, 16 GB | 8 CPUs, 16 GB |
| **Category** | | **Performance Counter/Metric** | **Average** | | |
| **VSTS Metrics** | | User Load | 20 | 20 | 20 |
| Requests Per second (RPS) | 43.4 | 88.5 | 96.5 |
| Latency (ms) | 460 | 450 | 210 |
| **WFE** | Processor | % Processor Time | 93.6 | 94 | 49.9 |
| Network Interface | Bytes Received /Sec | 10285000 | 10599970 | 8242607 |
| Bytes Sent / Sec | 5711342 | 5928287 | 955324 |
| Bytes Total / Sec | 15996340 | 16528260 | 9197931 |
| .NET Memory | % Time in GC | 2.42 | 2.09 | 1.35 |
| Physical Disk | Avg. Disk Queue Length | 0.0084 | 0.011 | 0.0064 |
| Avg. Disk Read Queue Length | 0.000051 | 0.00022 | 0.00069 |
| Avg. Disk Write Queue Length | 0.0083 | 0.011 | 0.0057 |
| Disk Reads/sec | 0.0085 | 0.046 | 0.25 |
| Disk Writes/sec | 14.5 | 17.6 | 12.1 |
| Memory | Available Mbytes | 7846 | 8235 | 8494 |
| Page Faults/sec | 6958 | 3939 | 3681 |
| Pages/sec | 30.6 | 35.5 | 20.5 |
| Process | Working Set | 4226279936 | 3875187456 | 3578682368 |
| Thread Count | 912 | 892 | 855 |
| **APP** | Processor | % Processor Time | 79.9 | 81.4 | 42.1 |
| Network Interface | Bytes Received /Sec | 2933528 | 3384315 | 1898064 |
| Bytes Sent / Sec | 4345488 | 4440225 | 2519359 |
| Bytes Total / Sec | 7279015 | 7824539 | 4417423 |
| .NET Memory | % Time in GC | 3.6 | 2.7 | 4.86 |
| Physical Disk | Avg. Disk Queue Length | 0.0036 | 0.0052 | 0.004 |
| Avg. Disk Read Queue Length | 0.000093 | 0.00014 | 0.0004 |
| Avg. Disk Write Queue Length | 0.0035 | 0.0051 | 0.0036 |
| Disk Reads/sec | 0.0017 | 0.032 | 0.056 |
| Disk Writes/sec | 6.6 | 8.52 | 7.67 |
| Memory | Available Mbytes | 8517 | 8940 | 9046 |
| Page Faults/sec | 3838 | 3022 | 1787 |
| Pages/sec | 16.3 | 17.8 | 11.2 |
| Process | Working Set | 3838775296 | 3436531456 | 3311634176 |
| Thread Count | 1046 | 1006 | 1045 |
| **SQL** | Processor | % Processor Time | 8.42 | 18.4 | 23 |
| (Corrected to #CPUs) | 16.84 | 36.8 | 46 |
| Network Interface | Bytes Received /Sec | 520929 | 1082702 | 1558834 |
| Bytes Sent / Sec | 8487251 | 14175730 | 24405360 |
| Bytes Total / Sec | 9008180 | 15258430 | 25964200 |
| Physical Disk | Avg. Disk Queue Length | 11.4 | 9.86 | 18.4 |
| Avg. Disk Read Queue Length | 0.39 | 0.023 | 0.91 |
| Avg. Disk Write Queue Length | 11 | 9.83 | 17.5 |
| Disk Reads/sec | 52 | 15.4 | 94.6 |
| Disk Writes/sec | 247 | 287 | 425 |
| Memory | Available Mbytes | 29297 | 29177 | 28995 |
| Page Faults/sec | 69.6 | 1296 | 425 |
| Pages/sec | 0 | 0.21 | 981 |
| Process | Working Set | 18127892480 | 18202353664 | 18422937600 |
| Thread Count | 797 | 862 | 836 |
| SQL-Specific | SQL Locks: Average Wait Time [ms] | 35 | 52.5 | 82.7 |
| SQL Locks: Lock Wait Time [ms] | 0.24 | 1.7 | 9.19 |
| SQL Locks: Deadlocks/s | 0 | 0 | 0 |
| SQL Latches: Average Wait Time [ms] | 3.04 | 1.54 | 3.42 |
| SQL Statistics: SQL Re-Compilations/s | 0.0017 | 0.0019 | 0 |

## Timesheets

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WFEs** | | | 1 | 2 | 4 |
| **APPs** | | | 1 | 2 | 4 |
| **SQL Config** | | | 8 CPUs, 16 GB | 8 CPUs, 16 GB | 8 CPUs, 16 GB |
| **Category** | | **Performance Counter/Metric** | **Average** | | |
| **VSTS Metrics** | | User Load | 20 | 20 | 20 |
| Requests Per second (RPS) | 49.5 | 82.9 | 80.6 |
| Latency (ms) | 400 | 240 | 250 |
| **WFE** | Processor | % Processor Time | 94.9 | 73.5 | 29.7 |
| Network Interface | Bytes Received /Sec | 3105622 | 3923321 | 1873863 |
| Bytes Sent / Sec | 2701754 | 1928475 | 905202 |
| Bytes Total / Sec | 5807376 | 5851796 | 2779066 |
| .NET Memory | % Time in GC | 2.17 | 1.61 | 0.69 |
| Physical Disk | Avg. Disk Queue Length | 0.0094 | 0.0099 | 0.0058 |
| Avg. Disk Read Queue Length | 0.0003 | 0.00017 | 0.00025 |
| Avg. Disk Write Queue Length | 0.0091 | 0.0097 | 0.0056 |
| Disk Reads/sec | 0.053 | 0.025 | 0.062 |
| Disk Writes/sec | 346938 | 18.6 | 12.1 |
| Memory | Available Mbytes | 7735 | 8852 | 8261 |
| Page Faults/sec | 3967 | 684 | 359 |
| Pages/sec | 32.7 | 38.2 | 18.7 |
| Process | Working Set | 4341928448 | 3209713920 | 3824219136 |
| Thread Count | 910 | 877 | 860 |
| **APP** | Processor | % Processor Time | 90.7 | 56.3 | 23.6 |
| Network Interface | Bytes Received /Sec | 3079385 | 3199650 | 1504748 |
| Bytes Sent / Sec | 1177299 | 802007 | 379830 |
| Bytes Total / Sec | 4256684 | 4001657 | 1884577 |
| .NET Memory | % Time in GC | 2.87 | 2.17 | 4.22 |
| Physical Disk | Avg. Disk Queue Length | 0.0059 | 0.0056 | 0.0044 |
| Avg. Disk Read Queue Length | 0.00034 | 0.000067 | 0.00013 |
| Avg. Disk Write Queue Length | 0.0055 | 0.0055 | 0.0043 |
| Disk Reads/sec | 0.056 | 0.0085 | 0.025 |
| Disk Writes/sec | 10.8 | 10.9 | 9.23 |
| Memory | Available Mbytes | 8442 | 8581 | 8964 |
| Page Faults/sec | 6109 | 490 | 285 |
| Pages/sec | 32.3 | 27.7 | 14.3 |
| Process | Working Set | 3909341696 | 3790592768 | 3399687424 |
| Thread Count | 1085 | 1027 | 1084 |
| **SQL** | Processor | % Processor Time | 17.2 | 25.6 | 29.5 |
| (Corrected to #CPUs) | 34.4 | 51.2 | 59 |
| Network Interface | Bytes Received /Sec | 1345140 | 2147449 | 1960111 |
| Bytes Sent / Sec | 4499184 | 11394140 | 11045650 |
| Bytes Total / Sec | 5844323 | 13541590 | 13005760 |
| Physical Disk | Avg. Disk Queue Length | 0.92 | 0.97 | 0.71 |
| Avg. Disk Read Queue Length | 0.0044 | 0.24 | 0.071 |
| Avg. Disk Write Queue Length | 0.88 | 0.73 | 0.64 |
| Disk Reads/sec | 7.39 | 53.1 | 9.47 |
| Disk Writes/sec | 261 | 300 | 272 |
| Memory | Available Mbytes | 29290 | 29134 | 28963 |
| Page Faults/sec | 70.1 | 775 | 1007 |
| Pages/sec | 0 | 0 | 0 |
| Process | Working Set | 18133454848 | 18286241792 | 18454003712 |
| Thread Count | 819 | 873 | 928 |
| SQL-Specific | SQL Locks: Average Wait Time [ms] | 1656 | 16188 | 40189 |
| SQL Locks: Lock Wait Time [ms] | 11460 | 30152 | 61389 |
| SQL Locks: Deadlocks/s | 0 | 0 | 0 |
| SQL Latches: Average Wait Time [ms] | 0.86 | 1.58 | 3.02 |
| SQL Statistics: SQL Re-Compilations/s | 34.7 | 10.4 | 7.73 |

## Project Schedule

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **WFEs** | | | 1 | 2 | 4 |
| **APPs** | | | 1 | 2 | 4 |
| **SQL Config** | | | 8 CPUs, 16 GB | 8 CPUs, 16 GB | 8 CPUs, 16 GB |
| **Category** | | **Performance Counter/Metric** | **Average** | | |
| **VSTS Metrics** | | User Load | 10 | 20 | 24 |
| Requests Per second (RPS) | 6.37 | 12.3 | 16.8 |
| Tests Per Second | 2.25 | 0.47 | 0.72 |
| Latency (ms) | 1070 | 1020 | 940 |
| **WFE** | Processor | % Processor Time | 12 | 11 | 9.6 |
| Network Interface | Bytes Received /Sec | 1509556 | 1331775 | 1214992 |
| Bytes Sent / Sec | 293222 | 264394 | 231015 |
| Bytes Total / Sec | 1802778 | 1596169 | 1446007 |
| .NET Memory | % Time in GC | 0.44 | 0.7 | 0.74 |
| Physical Disk | Avg. Disk Queue Length | 0.0035 | 0.004 | 0.0034 |
| Avg. Disk Read Queue Length | 0.000017 | 0.00033 | 0.000039 |
| Avg. Disk Write Queue Length | 0.0035 | 0.0037 | 0.0033 |
| Disk Reads/sec | 0.0018 | 0.11 | 0.0067 |
| Disk Writes/sec | 8 | 8.22 | 6.82 |
| Memory | Available Mbytes | 9098 | 9046 | 9212 |
| Page Faults/sec | 903 | 832 | 820 |
| Pages/sec | 14.4 | 13.4 | 9.94 |
| Process | Working Set | 2926594304 | 2997687296 | 2763213824 |
| Thread Count | 853 | 859 | 860 |
| **APP** | Processor | % Processor Time | 89.3 | 81 | 53.8 |
| Network Interface | Bytes Received /Sec | 1335610 | 1705056 | 1119083 |
| Bytes Sent / Sec | 1338621 | 1244646 | 894354 |
| Bytes Total / Sec | 2674231 | 2949702 | 2013437 |
| .NET Memory | % Time in GC | 8.52 | 8.44 | 5.95 |
| Physical Disk | Avg. Disk Queue Length | 0.034 | 0.032 | 0.019 |
| Avg. Disk Read Queue Length | 0.00027 | 0.001 | 0.00021 |
| Avg. Disk Write Queue Length | 0.034 | 0.031 | 0.019 |
| Disk Reads/sec | 0.52 | 1.03 | 0.56 |
| Disk Writes/sec | 63.2 | 58.3 | 39.3 |
| Memory | Available Mbytes | 8085 | 7615 | 8425 |
| Page Faults/sec | 6862 | 5852 | 3986 |
| Pages/sec | 249 | 268 | 184 |
| Process | Working Set | 4330732032 | 4839394304 | 3931627264 |
| Thread Count | 1185 | 1160 | 1132 |
| **SQL** | Processor | % Processor Time | 9.89 | 24.9 | 27.3 |
| (Corrected to #CPUs) | 19.78 | 49.8 | 54.6 |
| Network Interface | Bytes Received /Sec | 1413021 | 2555691 | 3841693 |
| Bytes Sent / Sec | 2644530 | 552011 | 8206095 |
| Bytes Total / Sec | 4057551 | 8076302 | 12047790 |
| Physical Disk | Avg. Disk Queue Length | 0.061 | 0.68 | 2.99 |
| Avg. Disk Read Queue Length | 0.035 | 0.12 | 0.054 |
| Avg. Disk Write Queue Length | 0.025 | 0.56 | 2.93 |
| Disk Reads/sec | 11.2 | 15 | 13.7 |
| Disk Writes/sec | 97.7 | 178 | 249 |
| Memory | Available Mbytes | 29327 | 29050 | 28921 |
| Page Faults/sec | 1581 | 2305 | 2541 |
| Pages/sec | 0 | 0.014 | 0 |
| Process | Working Set | 18101880832 | 18372917248 | 18498338816 |
| Thread Count | 818 | 842 | 861 |
| SQL-Specific | SQL Locks: Average Wait Time [ms] | 163 | 104 | 154 |
| SQL Locks: Lock Wait Time [ms] | 59 | 565 | 491 |
| SQL Locks: Deadlocks/s | 0 | 0 | 0 |
| SQL Latches: Average Wait Time [ms] | 0.91 | 2.6 | 8.09 |
| SQL Statistics: SQL Re-Compilations/s | 3.24 | 6.62 | 8.11 |

# Analysis of test results

Generally speaking, it appears that “typical” Project Server interactions produce approximately equal CPU load on the WFE and APP tiers. However, there are some exceptions: the Project Schedule page and Approvals both appear to be much heavier on the APP tier than on the WFE tier. This is due largely to the Project Calculation Service, which runs exclusively on the APP tier. In environments that must support large amounts of interactive schedule editing, scale-out almost exclusively depends on the number of APP machines available, as well as available disk bandwidth on the SQL Server. In most other environments, it seems that a 1:1 WFE-to-APP ratio is fairly reasonable.

Virtually all of the test mixes scaled well to a two WFE/two APP configuration, but did not gain much throughput when we added more machines beyond that. Based on the activity in the farm, it seems likely that the performance of the SQL Server database became a bottleneck at this point, and that allocating additional resources to the Database tier would further improve performance. In the read-write scenarios, a fairly high amount of disk traffic on our SQL Server, increasing lock times, and so on was observed. An appropriately-configured SQL Server, with a fast storage system, is **strongly** recommended; otherwise, sustained write traffic will become a bottleneck.

Although it was not experimented with in-depth, it’s important to remember that many of the “read-write” test scenarios included a substantial “asynchronous” component, in the form of jobs later processed by the Project Server Queue service. We strongly recommend that administrators watch the behavior of this service, both in terms of CPU utilization on the APP tier, and IO traffic on the Database tier, because there may actually be cases (as seen in our overall read-write mix) where adding more APP servers to the farm actually *reduces* total throughput, because of increased resource utilization and contention in Queue jobs.