

**RD Gateway Capacity Planning in Windows Server 2008 R2**

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Abstract

The Remote Desktop Gateway (RD Gateway) role service enables authorized remote users to connect to Remote Desktop Protocol (RDP) accessible resources on internal corporate networks, from any Internet-connected device that can run the Remote Desktop Connection (RDC) client. This whitepaper contains scalability results, testing methodologies, analysis, and guidelines for RD Gateway. It describes the most relevant factors that influence the capacity of a given deployment, methodologies to evaluate capacity for specific deployments, and a set of experimental results for different combinations of usage scenarios and hardware configurations.



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# Section 1: Test Environment and Lab Setup

### Hardware

The following servers were tested for Remote Desktop Services capacity planning data:

**RD Gateway server:**

* HP xw9400 workstation
* Dual Proc-Dual Core AMD Opteron 2400MHz
* 4 GB RAM
* Windows Server 2008 R2 Enterprise Operating System
* NVIDIA nForce Networking Controller with 100 MBs intranet network

**Remote Desktop client:**

* HP dc5750 SFF
* Dual core 2500 MHz AMD Athlon
* 4 GB RAM
* Windows 7 Professional Client Operating System

**Remote Desktop Session Host:**

* HP dc5750 SFF
* Dual core 2500 MHz AMD Athlon
* 4 GB RAM
* Windows Server 2008 R2 Enterprise Operating System

### Lab Setup

All the tests use this lab setup, environment unless specified otherwise.

Setup consists of eight Remote Desktop Connection clients, one RD Gateway server and one Remote Desktop Session Host (RD Session Host) server. All the eights clients are part of one workgroup while the RD Gateway server and the RD Session Host server are part of another workgroup. The RD Gateway server has two network cards; one connected to the clients network and another to the RD Session Host server.



Figure - Test setup configuration

### Test Tools

The RD Gateway scalability tests were run using two tools; TSGSClient.exe, a low level client to simulate Remote Desktop Connections and TSGSServer.exe, a low level server to simulate an RD Session Host. These tools allow simulated loads on a server to be easily placed and managed. These tools do not impact testing because there is no change to the flow on the gateway for connections. This was done to simplify the hardware requirements required if full client connections were created.

* **TSGSServer.exe** runs on the RD Session Host server and listens on the specified port (Port 1234 in testing). The application waits for incoming connections. Once connection is established TSGSServer.exe reads all incoming packets and sends back the number of packets specified on the command line.
* **TSGSClient.exe** runs on the Remote Desktop client computer and establishes a connection to TSGSServer.exe through RD Gateway using the same published RD Gateway APIs as Remote Desktop Connection. On the client side, a new instance of TSGClient.exe is launched for each connection. After the connection is established, TSGClient.exe sends and receives packets based on the different test scenarios.

# Section 2: Testing Methodology

### Defining response time

Response time is the key metric used to calculate the performance of RD Gateway. Response time is the time taken for a data packet to travel from the Remote Desktop Client through the RD Gateway server to the RD Session Host server and back to Remote Desktop Client. In our tests, a timer is started on the Remote Desktop Client, TSGSClient.exe in this case, before the “send” call for the data packet, thus ensuring that the time taken for constructing the data packet is not included. The timer is stopped as soon as the packet sent by the server, TSGSServer.exe, is received. For the purposes of testing, only one data packet is sent at a time.

The threshold for acceptable response time for Remote Desktop Services, without RD Gateway, has been established as 200ms through user surveys. As RD Gateway adds overhead, it was determined that the additional overhead should be no more than 20% of the RD Session Host server response time. This means that the RD Gateway server should not add more than 40 ms of delay.

These tests are run on a private network: hence network delays, RTT time here can be assumed as 0 ms, are practically zero. The processing times on the client and the server are negligible. Hence the response time measured in our tests is equal to the time taken for RD Gateway processing and should be less than 40 ms (as defined above).

### Defining Knowledge worker Scenarios

Knowledge worker scenarios are user scenarios developed on the basis of **SQM** (Software Quality Metrics) data. These metrics were used to average a typical knowledge workers usage in Remote Desktop Services which includes MS Office application usage.

We ran the knowledge worker scenario V1 in a Remote Desktop Services environment and studied the data flow pattern. Based on the pattern, we determined that the average data flow is 90 bytes every 100ms per connection. This knowledge worker scenario includes office applications like Word, Excel and Outlook and also Internet Explorer. We have used these numbers for the scalability tests.

The knowledge worker scenario v2.2 which includes PowerPoint along with the other Office Applications has a data rate of 125 bytes per second from the client to the server and 8345 bytes from the server to the client at an average of 5 packets every second.

### Scenarios

* Knowledge worker:
	+ Knowledge Worker v1: WinWord, Excel, Outlook , Internet explorer
	+ Knowledge Worker v2: WinWord, Excel, Outlook, PowerPoint, Internet explorer
* Number of Processors Variation Test
* Amount of Physical Memory (RAM) Variation Test
* Frequency Variation Test
* Packet Size Variation Test
* ‘Central Vs. Local’ Network Policy Server (NPS)
* RD Gateway Server Farm Test
* RD Gateway Server running inside a virtual machine Test

# Section 3: Test Results and Analysis

### Scenarios

The scenarios used for testing are automated and meant to simulate real user behavior. Although the scripts used in these scenarios simulate tasks that a normal user could perform, the users simulated in these tests are tireless—they never reduce their intensity level. The simulated clients type at a normal rate, pause as if looking at dialog boxes, and scroll through mail messages as if to read them, but they do not get up from their desks to get a cup of coffee, they never stop working as if interrupted by a phone call, and they do not break for lunch. The tests assume a rather robotic quality, with users using the same functions and data sets during a thirty-minute period of activity. This approach yields accurate but conservative results.

#### Knowledge Worker Scenario v1:

For this scenario, 90 bytes of data are sent from the client every 100 milliseconds and the server responds by sending 90 bytes back. Connections are opened at 10 second intervals from each client in a round robin manner.

Test results demonstrate that the response time crosses the threshold of 40 ms when the total number of connections reaches ~1230. Performance logs show, at ~1230 connections, the CPU usage in the RD Gateway is nearing 100% (99.XX%) while memory usage, committed bytes, was less than 30%, demonstrating the CPU is becoming the bottleneck while other resources were available.

|  |  |  |
| --- | --- | --- |
| **RD Gateway hardware configuration** | **Usage pattern per connection** | **Number of connections** |
| HP xw9400 workstationDual Proc-Dual Core AMD Opteron 2400MHz4 GB RAM | Client to Server: 90 bytes per packetServer to Client: 90 bytes per packetOne Packet every 100ms | 1230 |

Table - RD Gateway usage pattern at threshold for Knowledge Worker Scenario V1

Another interesting observation is the relationship of the response time to the number of connections. Reading Table 2 – Response time per number of connections, you will see that the response time grows almost linearly with the increase in number of connections. At the threshold the response time suddenly raises significantly. The behavior is consistent with CPU numbers, when 1230 connections are reached the CPU has reached 100% utilization, so the RD Gateway is not getting the CPU cycles it requires to process the connections leading to a higher response time.

|  |  |
| --- | --- |
| **Number of connections** | **Response time** |
| 1 | 0 |
| 100 | 0 |
| 250 | 0 |
| 500 | 0 |
| 750 | 3 |
| 1000 | 12 |
| 1230 | 66 |

Table - Response time per number of connections

####  Knowledge worker scenario v2.2:

The knowledge worker v2.2 scenario consists of a series of interactions with Microsoft Office 2007 applications (Word, Excel, Outlook, and PowerPoint) and Internet Explorer. The set of actions and their frequency in Office segments of the scenario are based on statistics collected from the Software Quality Management data submitted by Office users and should represent a good approximation of an “average” Office user.

Test results demonstrate that the response time crosses the threshold of 40 ms when the total number of connections reaches ~1173. Performance logs show, at ~1173 connections, the CPU usage in the RD Gateway server is nearing 100% (99.XX%) while memory usage, committed bytes, was less than 30%, demonstrating the CPU is becoming the bottleneck while other resources were available.

|  |  |  |
| --- | --- | --- |
| **RD Gateway hardware configuration** | **Usage pattern per connection** | **Number of connections** |
| HP xw9400 workstationDual Proc-Dual Core AMD Opteron 2400MHz4 GB RAM | Client to Server: 25 bytes per packetServer to Client: 1669 bytes per packetOne Packet every 200ms | 1173 |

Table - RD Gateway usage pattern at threshold for Knowledge Worker Scenario V2.2

### Number of Processors Variation Test

The results of the knowledge worker tests indicate that the CPU is causing the bottleneck. In the next set of tests, we varied the number of CPU’s available on the RD Gateway server using Operating System setting, bcdedit.exe. The system configuration, test environment and the data usage pattern was the same as the knowledge worker scenario tests, except for the number of CPUs.

The number of processor variation test is run on a HP xw9400, with 4 Logical processors. The tests are run varying the number of processors from 1 to 4. Test results demonstrate that increasing the number of processors also increases the number of connections that can be established, before the threshold of 40 ms is reached.

|  |  |
| --- | --- |
| **Number of logical processors**  | **Connections at 40 ms response time**  |
| **1 Logical Processor** in HP xw9400 workstation Dual Proc-Dual Core AMD Opteron 2400MHz | ~368 |
| **2 Logical Processor** in HP xw9400 workstation Dual Proc-Dual Core AMD Opteron 2400MHz | ~656  |
| **4 Logical Processor** in HP xw9400 workstation Dual Proc-Dual Core AMD Opteron 2400MHz | ~1230  |

Table - Connection response time per number of logical processors

### Physical memory (RAM) Variation Test

The results of the knowledge worker tests indicate memory was not a bottleneck. To better understand the effect of memory, memory was modified on the test machine using bcdedit.exe. In these tests, the 4 GB on the machine was limited to 1 GB and 2 GB, with 4 logical processors. These tests were run to discover how efficient the RD Gateway server is at using different amounts of physical memory.

Test results indicate that the number of connections does not decrease significantly when the physical memory is decreased from 4GB to 1GB. Tests demonstrate that RAM has minimum impact on RD Gateway server scalability numbers, as available CPU approaches 100% utilization while memory is still available. RD Gateway server can operate efficiently on a server computer with memory as low as 1 GB. Increase scalability by increasing the number of CPUs.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Physical memory (A)** | **40ms cutoff connections (B)**  | **Available memory at cutoff point (C)** | **Average memory used per connection****(A– C) / B** |  |
| 1GB  | ~1132  | 0.32 GB | ~0.61 MB |  |
| 2GB  | ~1157 | 1.29 GB | ~0.62 MB |  |
| 4GB  | ~1230  | 3.16 GB | ~0.69 MB |  |

Table - Average memory used per connection per physical memory

Available memory is the amount of physical memory (RAM) available to processes
running on the server. This memory gets reduced when new processes are created or existing processes allocate more memory.

### Data Rate Variation Test

As noted earlier, the results of the knowledge worker tests indicate the processor is the bottleneck resource. If the CPU load is increased on the RD Gateway server, the threshold, response time < 40 ms, is expected to be reached at a lower connection number. One factor that can impact the CPU load on the RD Gateway server is the number of data packets the RD Gateway server has to process per second. In production deployments it is likely that various applications will have variable data flow pattern. The data flow pattern is directly related to the frequency of data packets sent and the size of data packets. There is limit to the size of the data which can be sent as single packet, and if the data is too big it is sent as a series of smaller packets.

In this test, the frequency at which the data is sent is kept constant at 100 milliseconds but the number of bytes sent is varied. The hardware configuration is kept at the highest level, including 4 logical processors and 4 GB of RAM. The results of the data rate variation tests indicate the RD Gateway server performance decreases with an increase in packet size, but the relation is not directly proportional. The RD Gateway server channel sends larger data units as a series of smaller packets, causing an increased number of packets processed at the RD Gateway server leading to higher CPU utilization. Higher CPU utilization causes the threshold to be reached at a fewer number of connections. Hence transmission of large continuous data streams e.g. large data file transfers, over an RD Gateway connection will negatively impact the number of concurrent sessions supported by the RD Gateway.

|  |  |
| --- | --- |
| **Data packet size** | **Number of connections**  |
| 10 bytes  | ~1300 connections |
| 90 bytes  | ~1230 connections  |
| 200 bytes  | ~1199 connections |
| 500 bytes  | ~975 connections  |
| 1000 bytes  | ~887 connections  |
| 2000 bytes | ~258 connections  |

Table - Data packet size for number of connections

Figure - Numer of connections versus packet size

### Frequency Variation Tests

For the frequency variation test, the packet size was kept consistent at 90 bytes (same as knowledge worker scenarios) and the interval between successive packets is varied. For these different intervals the RD Gateway server will have to process different amount of packets per second.

The results of the tests indicate that as the duration between packets is increased, the RD Gateway server is able to manage more connections. The table for the frequency variation test illustrates, the CPU utilization is very low for the high interval values, for an interval as low as 10 milliseconds the threshold was reached at approximately 494 connections. The results of these tests confirm that the more packets/sec processed at the RD Gateway server the fewer connections the server can manage. Hence bandwidth intensive sessions will negatively impact the number of concurrent sessions supported by the RD Gateway server.

|  |  |  |  |
| --- | --- | --- | --- |
| **Data frequency**  | **CPU %** | **Connections** | **Response time** |
| 10ms  | 100%  | ~494 | Crossing 40 ms |
| 100ms  | 100% | 1230 | Crossing 40 ms |
| 500ms  | 23% | 1230 | 4 ms |
| 1000ms  | 14% | 1230 | 0 – 1 ms |

Table - Data frequency thresholds

### ‘Central vs. Local’ Network Policy Server Test

Remote Desktop connection authorization policies (RD CAPs) allow you to specify who can connect to a RD Gateway server. You can specify a local RD CAP store (RD CAPs that are stored on the RD Gateway server) or a central RD CAP store [RD CAPs that are stored on a central Network Policy Server (NPS), formerly known as a Remote Authentication Dial-In User Service (RADIUS) server].

The lab setup for this test is slightly different than the previous tests. Instead of having the Remote Desktop connection authorization policies (RD CAPs) and Remote Desktop resource authorization policies (RD RAP) present on the server where the RD Gateway role is installed, these authorization policies are stored on a different server. When a new connection is made, the RD Gateway server locates this other server to retrieve the authorization policies. For more information on RD CAPs and RD RAPs, see [Understanding Authorization Policies for Remote Desktop Gateway](http://technet.microsoft.com/en-us/library/cc731435.aspx) (http://technet.microsoft.com/en-us/library/cc731435.aspx)

The results of the tests are compared with a local server that is running NPS, or authorization policies being accessed locally, which is covered in the knowledge worker basic test. When using a central server that is running NPS, CPU utilization hits 100% and response time crosses 40 ms at ~1230 connections which is the same results as using a local server that is running NPS. As tests are conducted in a private domain, in isolated LAN environment, we are assuming no network delay in contacting the central server that is running NPS.

|  |  |
| --- | --- |
| **Type of deployment** | **Number of connections when response time crosses 40 milliseconds** |
| Central server running NPS | ~1230 connections |
| Local server running NPS | ~1230 connections  |

Table – Central versus local server running NPS

In a production environment external factors like delays in network, can possibly affect the response time when using a central server running NPS. However the management advantage of a central server running NPS compensates for the performance difference. This is especially true when Administrators are managing large number of RD Gateway servers.

### Remote Desktop Gateway Server Farm Test

On a corporate network where thousands of computers may access Remote Desktop Services, a single RD Gateway server may not be adequate. In these scenarios, an RD Gateway server farm can be created allowing multiple RD Gateway servers to be available to route the data.

For more information on RD Gateway server farms see [Create a Remote Desktop Gateway Server Farm](http://technet.microsoft.com/en-us/library/cc732370.aspx) (http://technet.microsoft.com/en-us/library/cc732370.aspx)

The tests were performed using two and three RD Gateway servers in the RD Gateway server farm. In the lab setup for the test, the Remote Desktop Clients are routed to the RD Gateway servers using a DNS server which rotates the next available server in a round robin manner.

A DNS server is configured to route the requests in a Round Robin fashion to the two RD Gateway servers which are in turn configured as a part of a RD Gateway server farm.

|  |  |
| --- | --- |
| **Machines in farm** | **Number of connections when response time crosses 40 milliseconds** |
| 1 | ~1230 |
| 2 | ~1970 |
| 3 | ~2700 |

Table - Number of connections for machines in farm

* When only one gateway machine is used with DNS routing, threshold, response time crosses 40 ms, is reached at ~1230 connections.
* With two machines in a farm, the response time crosses 40 ms at around ~1970 connections.
* With three machines in a farm, the response time crosses 40 ms at around ~2700 connections.
* The results of the tests indicate for every new RD Gateway server added to a RD Gateway server farm, the number of connections supported by the server farm increase by (.6 \* number of connection by single RD Gateway server)
* **Number of connections** ~= [1 + .6\*(n-1)] \* number of connections supported by single TS Gateway server

### RD Gateway Running inside a Virtual machine test

In this test, the RD Gateway role is installed on a virtual machine. The virtual machine has two network adapters which are bound to the virtual machine host machine’s adapters. 2 GB of memory and 4 processors are allocated to the virtual machine.

|  |  |
| --- | --- |
| **Data rate** | **Number of connections when response time crosses 40 milliseconds** |
| Knowledge Worker Scenario V190 bytes every 100 ms | ~582 connections |
| Knowledge Worker Scenario V225 bytes / 1669 bytes every 200 ms | ~579 connections  |

Table - Scenario data rates for number of connections

# Section 4: Summary

* The test results indicate that the actual number of users that a specific server configuration can support varies depending on the processor type, and the user scenario (typing speed, applications used, and frequency). In addition to the performance results outline by the tests, UI rendering for an applications can also impact the number of connections.
1. **CPU and number of Connections:**

|  |  |
| --- | --- |
| **Number of logical processors**  | **Number of connections**  |
| **1 Logical Processor** in HP xw9400 workstation Dual Proc-Dual Core AMD Opteron 2400MHz | ~368 |
| **2 Logical Processor** in HP xw9400 workstation Dual Proc-Dual Core AMD Opteron 2400MHz  | ~656 |
| **4 Logical Processor** in HP xw9400 workstation Dual Proc-Dual Core AMD Opteron 2400MHz  | ~1230  |

Table - Processors and number of connections

1. **Data frequency vs number of users**

|  |  |
| --- | --- |
| **Data frequency**  | **CPU % /Connections/Response time**  |
| 10ms  | 100% at ~527 connections crossing 40 ms  |
| 100ms  | 100% at 1230 connections  |
| 500ms  | 20% at 1230 connections, response time around 4 ms |
| 1000ms  | 14% at 1230 connections, response time 0ms to 1 ms |

Table - Data frequency versus number of users

1. **Data packet size vs number of users**

|  |  |
| --- | --- |
| **Packet size** | **Number of connections**  |
| 10 bytes  | ~1300 |
| 90 bytes  | ~1230 connections  |
| 200 bytes  | ~1199 connections |
| 500 bytes  | ~975 connections  |
| 1000 bytes  | ~887 connections  |

Table - Data packet size versus number of users

### Related Links

For more information, please refer to the following links:

Remote Desktop Services Gateway
http://technet.microsoft.com/en-us/library/dd560672(WS.10).aspx

RD Gateway Step-by-Step Guide
 http://technet.microsoft.com/en-us/library/dd983941(WS.10).aspx

What's New in Remote Desktop Services for Windows Server 2008 R2
http://technet.microsoft.com/en-us/library/dd560658(WS.10).aspx

Configuring the Remote Desktop Gateway Server

http://technet.microsoft.com/en-us/library/cc754191.aspxGateway Settings

* Self-signed certificate is used.
* Local server running NPS for all tests except for a test with RD CAPs that are stored on a central Network Policy Server.
* Low level client and server uses port 1234 for communication; all ports are allowed in the RD RAP for the RD Gateway.
* All users allowed access in the RD CAP.
* RD RAP policy set to allow access to Any network resource
* Password authentication is used.

### Knowledge Worker Script

Typing Speed = 35 WPM

Definition: a worker who gathers, adds value to, and communicates information in a decision support process. Cost of downtime is variable but highly visible. Projects and ad-hoc needs towards flexible tasks drive these resources. These workers make their own decisions on what to work on and how to accomplish the task. The usual tasks they perform are marketing, project management, sales, desktop publishing, decision support, data mining, financial analysis, executive and supervisory management, design, and authoring.

## Knowledge Worker v1

* Connect User “smcxxx”
* Start (Microsoft Excel) - Load massive Excel spreadsheet and print it
* Start (Outlook) - Send a new mail message
( email2 )
Start (Command Prompt) - Use the file system, dir /s
Start (Internet Explorer) and browse 10 intranet websites

Start (Word) - Type a page of text

(Document2 )
Switch To (Excel)

* Switch To Process, (Outlook) - read message and respond
( Reply2 )
* Now, Toggle between apps in a loop
* loop(1000)
* Switch To Process, (Excel)
* Switch To Process, (Outlook) - Mail Message
( email2 )
Start (Command Prompt) - Use the file system, dir /s
Switch To Process, (Internet Explorer), and browse 10 intranet websites
* Switch To Process, (Word) - Type a page of text
( Document2 )
* Switch To Process, (Excel), create a spreadsheet and graph
* Switch To Process, (Outlook) - read message and respond
( reply2 )
* Minimize Outlook
* End of loop
* Logoff

## Knowledge Worker v2.2

Typing Speed = 35 words per minute

Definition: the Knowledge Worker scenario includes creating and saving Word documents, printing Excel spreadsheets, communicating by e-mail in Outlook, adding slides to PowerPoint presentations, running slide shows, and browsing Web pages in Internet Explorer. The following workflow details the scenario.

* Connect User “smcxxx”
* **Start (Outlook) -** Send new e-mail messages
* Send a new appointment invitation
* Send a new e-mail message
* Minimize Outlook
* **Start (Word) -** Start and exit Word
* **Start (Microsoft Excel)** - Start and exit Excel
* loop(forever)
* **Start (Word) -** Type a page of text and print
* Open a Word document
* Type a page of text
* Modify and format text
* Check spelling
* Print
* Save
* Exit Word
* **Start (Microsoft Excel)** - Load Excel spreadsheet, modify, and print it
* Load Excel spreadsheet
* Modify data and format
* Print
* Save
* Exit Excel
* **Start (PowerPoint) -** Load presentation and run slide show
* Load a PowerPoint presentation
* Navigate
* Add a new slide
* Format text
* Run slide show
* Save file
* Exit PowerPoint
* **Switch To Process, (Outlook) -** send e-mail,read message, and respond
* Send e-mail to other users
* Read e-mail and respond
* Minimize Outlook
* **Start (Internet Explorer) -** Load presentation and run slide show
* Loop (2)

URL http://tsexchange/tsperf/WindowsServer.htm
URL http://tsexchange/tsperf/Office.htm
URL http://tsexchange/tsperf/MSNMoney.htm

* End of loop
* Exit Internet Explorer
* End of loop

Test Script Flow Chart

