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# Juniper Networks® Steel-Belted Radius® Carrier

## Performance, Planning, and Tuning Guide

Release

8.4.0



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*Juniper Networks® Steel-Belted Radius® Carrier Performance, Planning, and Tuning Guide*

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September 2017—Revision 1

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# Table of Contents

|                  |   |              |
|------------------|---|--------------|
|                  | <b>About This Guide</b> .....   | <b>xxxix</b> |
|                  | Objective .....   | xxxix        |
|                  | Audience .....  | xxxix        |
|                  | Documentation Conventions .....   | xxxix        |
|                  | Related Documentation .....   | xli          |
|                  | Obtaining Documentation .....   | xlvi         |
|                  | Documentation Feedback .....  | xlvi         |
|                  | Requesting Technical Support .....  | xlvii        |
| <b>Part 1</b>    | <b>Performance, Planning, and Tuning</b>  |              |
| <b>Chapter 1</b> | <b>Overview of Performance, Planning, and Tuning of Steel-Belted Radius Carrier</b> ..... | <b>3</b>     |
|                  | Steel-Belted Radius Carrier Overview .....  | 3            |
|                  | Document Organization .....   | 4            |
|                  | Performance Theory .....  | 4            |
|                  | Performance Theory: Threads .....   | 5            |
|                  | Thread Models .....   | 6            |
|                  | Thread Priority .....   | 6            |
|                  | Locking Threads to a Processor .....  | 7            |
|                  | Performance Theory on Contention .....  | 7            |
|                  | Managing Contention .....   | 9            |
|                  | CPU Utilization .....   | 10           |
|                  | Case 1: More CPU versus More GHz per CPU .....  | 11           |
|                  | Case 2: Virtual CPU versus Physical Cores .....   | 11           |
|                  | Performance Theory on Memory Data Structures .....  | 12           |
| <b>Chapter 2</b> | <b>Understanding Performance Metrics</b> .....  | <b>15</b>    |
|                  | Metrics and Definitions .....   | 15           |
|                  | Components of a Sample Use Case .....   | 17           |
|                  | Average Peak Rates .....  | 20           |
|                  | Spike Rates at Peak .....   | 21           |
|                  | Utilities to Measure the Performance of an Existing System .....                          | 21           |
|                  | prstat .....  | 22           |
|                  | sar .....   | 24           |
|                  | iostat .....  | 25           |
|                  | vmstat .....  | 26           |
|                  | prtdiag and sosreport .....   | 26           |
|                  | psrinfo .....   | 27           |
|                  | psradm .....  | 28           |
|                  | cpuinfo on Linux .....  | 28           |

|                  |  |           |
|------------------|--|-----------|
|                  | Taskset on Linux . . . . .   | 29        |
|                  | Disabling a CPU on Linux . . . . .                                   | 30        |
|                  | System Statistics . . . . .  | 30        |
| <b>Chapter 3</b> | <b>Performance Planning . . . . .</b>                                | <b>35</b> |
|                  | Understanding SBRC Call Models . . . . .                             | 35        |
|                  | Understanding the Memory Utilization Levels . . . . .                | 37        |
|                  | Memory Utilization on Standalone . . . . .                           | 37        |
|                  | Memory Utilization on SSR Cluster . . . . .                          | 38        |
|                  | Understanding the CPU Requirements . . . . .                         | 40        |
|                  | Standalone or Front-End Applications . . . . .                       | 44        |
|                  | Back Ends . . . . .  | 44        |
|                  | Retries . . . . .  | 44        |
|                  | Load Balancing on RADIUS Front-End Applications and Downstream Proxy |           |
|                  | Devices . . . . .  | 45        |
|                  | Stateful and RADIUS-Aware . . . . .                                  | 46        |
|                  | Network Configuration for SSR . . . . .                              | 46        |
|                  | Why Latency Kills Performance: D-D and S-D . . . . .                 | 47        |
|                  | Subscriber Scaling . . . . .   | 47        |
|                  | Why Are Interims Hard, and When Can They Be Thrown Away? . . . . .   | 47        |
|                  | Handling Downstream Latency and Traffic Spikes . . . . .             | 48        |
|                  | Thread Control . . . . .   | 48        |
|                  | Flood Control . . . . .  | 49        |
|                  | Settings . . . . .   | 49        |
| <b>Chapter 4</b> | <b>Understanding the SBRC Network Architecture . . . . .</b>         | <b>51</b> |
|                  | SBRC Architecture Overview . . . . .                                 | 52        |
|                  | Understanding “Geodiversity” Between the SSR D Nodes . . . . .       | 54        |
|                  | NDB Cluster Timeout Dependencies . . . . .                           | 55        |
|                  | High Throughput Configurations . . . . .                             | 57        |
|                  | Risks to Uptime within the Architecture . . . . .                    | 57        |
| <b>Chapter 5</b> | <b>Debugging Performance and Functionality Problems . . . . .</b>    | <b>59</b> |
|                  | Determining the Effective Performance and Peak Capacity . . . . .    | 59        |
|                  | Calculating Performance Scaling on an Existing System . . . . .      | 60        |
|                  | Debugging Performance Issues . . . . .                               | 62        |
|                  | CPU Bound . . . . .  | 63        |
|                  | I/O Bound . . . . .  | 65        |
|                  | Contended Systems . . . . .  | 67        |
|                  | Notes on Debugging Performance Issues . . . . .                      | 68        |
| <b>Chapter 6</b> | <b>Special Topics in Performance . . . . .</b>                       | <b>69</b> |
|                  | Multifactor Authentication over EAP . . . . .                        | 69        |
|                  | EAP-TLS, TTLS, and WiMAX . . . . .                                   | 70        |
|                  | Reauthentication Cache . . . . .                                     | 70        |
|                  | Cipher Suites and Key Sizing . . . . .                               | 70        |
|                  | Cipher Suite Scaling . . . . .                                       | 71        |
|                  | Reducing the Number of Round Trips . . . . .                         | 72        |
|                  | Certificate Management . . . . .                                     | 72        |
|                  | Multiple TLS/TTLS-Only Front-End Applications . . . . .              | 72        |



|                  |   |           |
|------------------|---|-----------|
|                  | EAP-SIM/AKA and authGateway . . . . .   | 72        |
|                  | External Authentication and Accounting . . . . .                                      | 73        |
|                  | JavaScript . . . . .  | 74        |
|                  | Proxy Radius . . . . .  | 75        |
|                  | Smart Static Accounting . . . . .   | 75        |
|                  | Spooled Accounting . . . . .  | 76        |
|                  | IP Pools through the SSR . . . . .  | 76        |
|                  | Accounting-Off or Accounting-On with AutoStop Enabled . . . . .                       | 77        |
| <b>Chapter 7</b> | <b>SBRC System-of-Systems Performance Reference . . . . .</b>                         | <b>79</b> |
|                  | Hardware Used . . . . .   | 79        |
|                  | CPU Utilization . . . . .   | 80        |
|                  | Test Results Summary . . . . .  | 80        |
|                  | Pap Authentication, Accounting Start, Accounting Stop . . . . .                       | 81        |
|                  | Pap Authentication, Accounting Start, Accounting Stop—Sessions<br>Preloaded . . . . . | 81        |
|                  | Accounting Only—Sessions Preloaded, One Start and One Stop, Four D<br>Nodes . . . . . | 81        |
|                  | Accounting Only—Sessions Preloaded, One Start and One Stop, Two D<br>Nodes . . . . .  | 82        |
|                  | Standalone: Auth/start/stop CPS . . . . .   | 82        |
|                  | Standalone: Accounting for 200 Threads . . . . .                                      | 82        |
|                  | Standalone: Authentication Only . . . . .   | 83        |
|                  | LDAP Authentication Only . . . . .  | 83        |
|                  | Oracle 11g . . . . .  | 84        |
|                  | LCI Queries against the SSR through SBRC . . . . .                                    | 84        |
|                  | IP Address Allocation . . . . .   | 84        |
|                  | IP Address Allocation with Eight Threads, Two D Nodes . . . . .                       | 85        |
|                  | IP Address Allocation with Eight Threads, Four D Nodes . . . . .                      | 85        |
|                  | TTLS . . . . .  | 86        |
|                  | TTLS Plus Storing Resumption Context . . . . .  | 87        |
|                  | WiMAX . . . . .   | 87        |
|                  | 4D node system: M5000 . . . . .   | 87        |
|                  | Standalone: M9000 . . . . .   | 88        |
|                  | Standalone: T3 . . . . .  | 88        |
|                  | SSR and Standalone Performance: E4870 and X5687 CPUs . . . . .                        | 89        |



# List of Figures

|                  |  |           |
|------------------|--|-----------|
| <b>Part 1</b>    | <b>Performance, Planning, and Tuning</b>                 |           |
| <b>Chapter 2</b> | <b>Understanding Performance Metrics</b>                 | <b>15</b> |
|                  | Figure 1: Viewing Authentication Statistics              | 30        |
|                  | Figure 2: Viewing Authentication Statistics              | 31        |
|                  | Figure 3: Viewing Accounting Statistics                  | 32        |
|                  | Figure 4: Viewing Accounting Statistics                  | 33        |
| <b>Chapter 4</b> | <b>Understanding the SBRC Network Architecture</b>       | <b>51</b> |
|                  | Figure 5: SSR Redundancy Architecture                    | 53        |
|                  | Figure 6: High Throughput Configurations                 | 57        |
| <b>Chapter 5</b> | <b>Debugging Performance and Functionality Problems</b>  | <b>59</b> |
|                  | Figure 7: CPU-Bound Utilization                          | 64        |
|                  | Figure 8: I/O-Bound Utilization                          | 66        |
|                  | Figure 9: Contended Systems Utilization                  | 67        |
| <b>Chapter 6</b> | <b>Special Topics in Performance</b>                     | <b>69</b> |
|                  | Figure 10: Statistics of Authentication Rates on Solaris | 73        |



# List of Tables

|                  |   |              |
|------------------|---|--------------|
|                  | <b>About This Guide</b> . . . . .   | <b>xxxix</b> |
|                  | Table 1: Notice Icons . . . . .   | xl           |
|                  | Table 2: Text and Syntax Conventions . . . . .  | xl           |
|                  | Table 3: Steel-Belted Radius Carrier Documentation . . . . .                                  | xli          |
|                  | Table 4: RFCs Related to Steel-Belted Radius Carrier . . . . .                                | xlii         |
|                  | Table 5: 3GPP Technical Specifications . . . . .  | xlvi         |
| <b>Part 1</b>    | <b>Performance, Planning, and Tuning</b>  |              |
| <b>Chapter 1</b> | <b>Overview of Performance, Planning, and Tuning of Steel-Belted Radius Carrier</b> . . . . . | <b>3</b>     |
|                  | Table 6: Document Organization . . . . .  | 4            |
| <b>Chapter 2</b> | <b>Understanding Performance Metrics</b> . . . . .  | <b>15</b>    |
|                  | Table 7: Key Performance Metrics . . . . .  | 15           |
|                  | Table 8: Sample Use Case Tasks . . . . .  | 18           |
|                  | Table 9: prstat Output Description . . . . .  | 22           |
| <b>Chapter 3</b> | <b>Performance Planning</b> . . . . .   | <b>35</b>    |
|                  | Table 10: Memory Utilization on Standalone . . . . .  | 37           |
|                  | Table 11: Memory Utilization on SSR Cluster . . . . .   | 38           |
|                  | Table 12: SPARC Processor Models . . . . .  | 41           |
|                  | Table 13: SPARC Processors . . . . .  | 42           |
|                  | Table 14: Intel Processor Examples . . . . .  | 43           |
| <b>Chapter 5</b> | <b>Debugging Performance and Functionality Problems</b> . . . . .                             | <b>59</b>    |
|                  | Table 15: Worksheet for Calculating Performance Scaling . . . . .                             | 61           |
| <b>Chapter 6</b> | <b>Special Topics in Performance</b> . . . . .  | <b>69</b>    |
|                  | Table 16: Cipher Suite . . . . .  | 71           |
| <b>Chapter 7</b> | <b>SBRC System-of-Systems Performance Reference</b> . . . . .                                 | <b>79</b>    |
|                  | Table 17: CPU Utilization . . . . .   | 80           |
|                  | Table 18: Pap Authentication, Accounting Start, Accounting Stop . . . . .                     | 81           |
|                  | Table 19: Pap Authentication, Accounting Start, Accounting Stop—Sessions Preloaded . . . . .  | 81           |
|                  | Table 20: Accounting Only—Sessions Preloaded, One Start and One Stop, Four D Nodes . . . . .  | 82           |
|                  | Table 21: Accounting Only—Sessions Preloaded, One Start and One Stop, Two D Nodes . . . . .   | 82           |
|                  | Table 22: Standalone: Auth/start/stop CPS . . . . .   | 82           |
|                  | Table 23: Standalone: Accounting for 200 Threads . . . . .                                    | 83           |
|                  | Table 24: Standalone: Authentication Only . . . . .   | 83           |

|  |    |
|--|----|
| Table 25: Authentication Only .....  | 83 |
| Table 26: Oracle 11g .....   | 84 |
| Table 27: LCI Queries against the SSR through SBRC .....                             | 84 |
| Table 28: IP Address Allocation with Two D Nodes .....                               | 84 |
| Table 29: IP Address Allocation with Two D Nodes and Eight Execute<br>Threads .....  | 85 |
| Table 30: IP Address Allocation with Four D Nodes and Eight Execute<br>Threads ..... | 85 |
| Table 31: TTLS with Five RADIUS Auth/Challenge Pairs per Accept .....                | 86 |
| Table 32: TTLS Plus Storing Resumption Context .....                                 | 87 |
| Table 33: WiMAX .....  | 87 |
| Table 34: SSR Performance .....  | 89 |
| Table 35: Standalone Performance .....   | 89 |

# About This Guide

This preface provides the following guidelines for using the *Steel-Belted Radius Carrier Performance, Planning, and Tuning Guide*:

- [Objective on page xxxix](#)
- [Audience on page xxxix](#)
- [Documentation Conventions on page xxxix](#)
- [Related Documentation on page xli](#)
- [Obtaining Documentation on page xlvi](#)
- [Documentation Feedback on page xlvi](#)
- [Requesting Technical Support on page xlvii](#)

## Objective

---

This guide describes how to plan and tune the performance of Steel-Belted Radius Carrier running on the Solaris and Red Hat Enterprise Linux operating systems.

It provides tips, use cases, and tools you need to:

- Improve SBRC performance through planning, analysis, and configuration
- Increase SBRC throughput and reliability
- Analyze specific use cases, in the lab or in the production environment, to identify areas of potential performance enhancement and to limit the impact of resource constraints and failure scenarios

## Audience

---

This guide is intended for users who are network or system architects and managers planning a new, or upgrading an existing, SBR Carrier Installation. It also provides guidance to system engineers to better troubleshoot performance issues.

## Documentation Conventions

---

[Table 1 on page xl](#) defines notice icons used in this guide.

Table 1: Notice Icons

| Icon            | Meaning            | Description   |
|-----------------|--------------------|---|
| <b>NOTE:</b>    | Informational note | Indicates important features or instructions.                               |
| <b>CAUTION:</b> | Caution            | Indicates a situation that might result in loss of data or hardware damage. |
| <b>WARNING:</b> | Warning            | Alerts you to the risk of personal injury.                                  |

Table 2 on page xl describes the text conventions used throughout this manual.

Table 2: Text and Syntax Conventions

| Convention                        | Description   | Examples   |
|-----------------------------------|---|--|
| <b>Text Conventions</b>           |   |  |
| <b>Bold text like this</b>        | Represents commands and keywords in text.   | <ul style="list-style-type: none"> <li>Issue the <b>clock source</b> command.</li> <li>Specify the keyword <b>exp-msg</b>.</li> </ul>  |
| <b>Bold text like this</b>        | Represents text that the user must type.  | <b>host1(config)#traffic class low-loss1</b>   |
| <b>Fixed-width text like this</b> | Represents information as displayed on your terminal's screen.  | <pre>host1#show ip ospf 2  Routing Process OSPF 2 with Router ID 5.5.0.250  Router is an Area Border Router (ABR)</pre>  |
| <i>Italic text like this</i>      | <ul style="list-style-type: none"> <li>Emphasizes words.</li> <li>Identifies variables.</li> <li>Identifies chapter, appendix, and book names.</li> </ul> | <ul style="list-style-type: none"> <li>There are two levels of access, <i>user</i> and <i>privileged</i>.</li> <li><i>clusterId</i>, <i>ipAddress</i>.</li> <li><i>Appendix A, System Specifications</i>.</li> </ul> |
| Plus sign (+) linking key names   | Indicates that you must press two or more keys simultaneously.  | Press Ctrl+b.  |
| <b>Syntax Conventions</b>         |   |  |
| Plain text like this              | Represents keywords.  | terminal length  |
| <i>Italic text like this</i>      | Represents variables.   | <i>mask</i> , <i>accessListName</i>  |
| < > (angle brackets)              | Enclose a list of possible selections.  | <add   replace>  |
| (pipe symbol)                     | Represents a choice to select one keyword or variable in a list of choices that is separated by the pipe symbol.  | <pre>diagnostic   line</pre> <p>In this example, you must specify <i>add</i> or <i>replace</i> but cannot specify both:</p> <pre>&lt;add   replace&gt;</pre>   |



Table 2: Text and Syntax Conventions (*continued*)

| Convention                   | Description  | Examples   |
|------------------------------|--|--|
| [ ] (brackets)               | Represent optional keywords or variables.                                    | [ internal   external ], or<br><add   replace> = Attribute [,Attribute], where the second attribute is identified as optional by the brackets.<br><br>When they are used in a configuration files brackets identify a section of the file.<br>In scripts or in operating system commands, brackets indicate the default response or entry. |
| [ ]* (brackets and asterisk) | Represent optional keywords or variables that can be entered more than once. | [ level1   level2   l1 ]*  |
| { } (braces)                 | Represent required keywords or variables.                                    | { permit   deny } { in   out }<br>{ clusterId   ipAddress }  |

## Related Documentation

[Table 3 on page xli](#) lists and describes the Steel-Belted Radius Carrier documentation set.

Table 3: Steel-Belted Radius Carrier Documentation

| Document  | Description  |
|---|--|
| <i>Steel-Belted Radius Carrier Installation Guide</i>                                   | Describes how to install the Steel-Belted Radius Carrier software on the server.   |
| <i>Steel-Belted Radius Carrier Administration and Configuration Guide</i>               | Describes how to configure and operate the Steel-Belted Radius Carrier and its separately licensed modules.  |
| <i>Steel-Belted Radius Carrier Reference Guide</i>                                      | Describes the settings and valid values of the Steel-Belted Radius Carrier configuration files.  |
| <i>Steel-Belted Radius Carrier Release Notes</i>  | Contains the latest information about features, changes, known problems, and resolved problems.  |
| <i>Steel-Belted Radius Carrier Performance, Planning, and Tuning Guide (This guide)</i> | Provides tips, use cases, and tools you need to: <ul style="list-style-type: none"> <li>• Improve SBRC performance through planning, analysis, and configuration</li> <li>• Increase SBRC throughput and reliability</li> <li>• Analyze specific use cases, in the lab or in the production environment, to identify areas of potential performance enhancement and to limit the impact of resource constraints and failure scenarios</li> </ul> |



**NOTE:** If the information in the Release Notes differs from the information in any guide, follow the Release Notes.

## Requests for Comments (RFCs)

The Internet Engineering Task Force (IETF) maintains an online repository of Request for Comments (RFCs) online at <http://www.ietf.org/rfc.html>.

Table 4 on page xlii lists the RFCs that apply to Steel-Belted Radius Carrier.

**Table 4: RFCs Related to Steel-Belted Radius Carrier**

| RFC Number | Title   |
|------------|---|
| RFC 1035   | <i>Domain Names - Implementation and Specification</i> . P. Mockapetris. November 1987.   |
| RFC 1155   | <i>Structure and Identification of Management Information for TCP/IP-based Internets</i> . M. Rose, K. McCloghrie, May 1990.      |
| RFC 1213   | <i>Management Information Base for Network Management of TCP/IP-based internets: MIB-II</i> . K. McCloghrie, M. Rose, March 1991. |
| RFC 2006   | <i>The Definitions of Managed Objects for IP Mobility Support using SMIv2</i> . D. Cong and others. October 1996.                 |
| RFC 2104   | <i>HMAC: Keyed-Hashing for Message Authentication</i> . H. Krawczyk, M. Bellare, R. Canetti. February 1997.                       |
| RFC 2246   | <i>The TLS Protocol</i> . T. Dierks, C. Allen. January 1999.  |
| RFC 2271   | <i>An Architecture for Describing SNMP Management Frameworks</i> . D. Harrington, R. Presuhn, B. Wijnen, January 1998.            |
| RFC 2284   | <i>PPP Extensible Authentication Protocol (EAP)</i> . L. Blunk, J. Vollbrecht, March 1998.  |
| RFC 2433   | <i>Microsoft PPP CHAP Extensions</i> . G. Zorn, S. Cobb, October 1998.  |
| RFC 2548   | <i>Microsoft Vendor-specific RADIUS Attributes</i> . G. Zorn. March 1999.   |
| RFC 2607   | <i>Proxy Chaining and Policy Implementation in Roaming</i> . B. Aboba, J. Vollbrecht, June 1999.                                  |
| RFC 2618   | <i>RADIUS Authentication Client MIB</i> . B. Aboba, G. Zorn. June 1999.   |
| RFC 2619   | <i>RADIUS Authentication Server MIB</i> . G. Zorn, B. Aboba. June 1999.   |
| RFC 2620   | <i>RADIUS Accounting Client MIB</i> . B. Aboba, G. Zorn. June 1999.   |
| RFC 2621   | <i>RADIUS Accounting Server MIB</i> . G. Zorn, B. Aboba. June 1999.   |
| RFC 2622   | <i>PPP EAP TLS Authentication Protocol</i> . B. Aboba, D. Simon, October 1999.  |

Table 4: RFCs Related to Steel-Belted Radius Carrier (*continued*)

| RFC Number | Title  |
|------------|--|
| RFC 2719   | <i>Framework Architecture for Signaling Transport</i> . L. Ong et al., October 1999  |
| RFC 2809   | <i>Implementation of L2TP Compulsory Tunneling via RADIUS</i> . B. Aboba, G. Zorn. April 2000.   |
| RFC 2865   | <i>Remote Authentication Dial In User Service (RADIUS)</i> . C. Rigney, S. Willens, A. Rubens, W. Simpson. June 2000.  |
| RFC 2866   | <i>RADIUS Accounting</i> . C. Rigney. June 2000.   |
| RFC 2867   | <i>RADIUS Accounting Modifications for Tunnel Protocol Support</i> . G. Zorn, B. Aboba, D. Mitton. June 2000.  |
| RFC 2868   | <i>RADIUS Attributes for Tunnel Protocol Support</i> . G. Zorn, D. Leifer, A. Rubens, J. Shriver, M. Holdrege, I. Goyret. June 2000.                         |
| RFC 2869   | <i>RADIUS Extensions</i> . C. Rigney, W. Willats, P. Calhoun. June 2000.   |
| RFC 2882   | <i>Network Access Servers Requirements: Extended RADIUS Practices</i> . D. Mitton. July 2000.  |
| RFC 2960   | <i>Stream Control Transmission Protocol</i> . R. Stewart and others. October 2000.   |
| RFC 3046   | <i>DHCP Relay Agent Information Option</i> . M. Patrick. January 2001.   |
| RFC 3118   | <i>Authentication for DHCP Messages</i> . R.Droms and others. June 2001.   |
| RFC 3162   | <i>RADIUS and IPv6</i> . B. Aboba, G. Zorn, D. Mitton. August 2001.  |
| RFC 3344   | <i>IP Mobility Support for IPv4</i> . C. Perkins. August 2002.   |
| RFC 3539   | <i>Authentication, Authorization, and Accounting (AAA) Transport Profile</i> . B. Aboba, J. Wood. June 2003.   |
| RFC 3575   | <i>IANA Considerations for RADIUS (Remote Authentication Dial-In User Service)</i> . B. Aboba, July 2003.  |
| RFC 3576   | <i>RFC3576 - Dynamic Authorization Extensions to Remote to Remote Authentication Dial In User Service</i> . Network Working Group, 2003                      |
| RFC 3579   | <i>RADIUS (Remote Authentication Dial In User Service) Support For Extensible Authentication Protocol (EAP)</i> . B. Aboba, P. Calhoun, September 2003.      |
| RFC 3580   | <i>IEEE 802.1X Remote Authentication Dial In User Service (RADIUS) Usage Guidelines</i> . P. Congdon, B. Aboba, A. Smith, G. Zorn, J. Roese, September 2003. |
| RFC 3588   | <i>Diameter Base Protocol</i> . P. Calhoun, J. Loughney, E. Guttman, G. Zorn, J. Arkko. September 2003.  |

Table 4: RFCs Related to Steel-Belted Radius Carrier (*continued*)

| RFC Number | Title  |
|------------|--|
| RFC 3748   | <i>Extensible Authentication Protocol</i> . B. Aboba, L. Blunk, J. Vollbrecht, J. Carlson, H. Levkowitz. June 2004.  |
| RFC 3957   | <i>Authentication, Authorization, and Accounting (AAA) Registration Keys for Mobile IPv4</i> . C. Perkins and P. Calhoun. March 2005.  |
| RFC 4005   | <i>Diameter Network Access Server Application</i> . P. Calhoun, G. Zorn, D. Spence, D. Mitton. August 2005.  |
| RFC 4017   | <i>Extensible Authentication Protocol (EAP) Method Requirements for Wireless LANs</i> . D. Stanley and others. March 2005.   |
| RFC 4072   | <i>Diameter Extensible Authentication Protocol (EAP) Application</i> . P. Eronen, G. Zorn, T. Hiller. August 2005.   |
| RFC 4186   | <i>Extensible Authentication Protocol Method for Global System for Mobile Communications (GSM) Subscriber Identity Modules (EAP-SIM)</i> . H. Haverinen, J. Salowey. January 2006. |
| RFC 4187   | <i>Extensible Authentication Protocol Method for Global System for 3rd Generation Authentication and Key Agreement (EAP-AKA)</i> . J. Arkko, H. Haverinen. January 2006.           |
| RFC 4282   | <i>The Network Access Identifier</i> . B. Aboba and others. December 2005.   |
| RFC 4284   | <i>Identity Selection Hints for the Extensible Authentication Protocol (EAP)</i> . F. Adrangi, V. Lortz, F. Bari, P. Eronen. January 2006.   |
| RFC 4306   | <i>Internet Key Exchange (IKEv2) Protocol</i> . C. Kaufman. December 2005.   |
| RFC 4372   | <i>Chargeable User Identity</i> . F. Adrangi and others. January 2006.   |
| RFC 4510   | <i>Lightweight Directory Access Protocol (LDAP) Technical Specification Road Map</i> . K. Zeilenga, June 2006.   |
| RFC 4666   | <i>Signaling System 7 (SS7) Message Transfer Part 3 (MTP3) - User Adaptation Layer (M3UA)</i> . K. Morneault, J. Pastor-Balbas. September 2006.                                    |
| RFC 4668   | <i>RADIUS Authentication Client MIB for IPv6</i> . D. Nelson. August 2006.   |
| RFC 4669   | <i>RADIUS Authentication Server MIB for IPv6</i> . D. Nelson. August 2006.   |
| RFC 4670   | <i>RADIUS Accounting Client MIB for IPv6</i> . D. Nelson. August 2006.   |
| RFC 4671   | <i>RADIUS Accounting Server MIB for IPv6</i> . D. Nelson. August 2006.   |
| RFC 5281   | <i>Extensible Authentication Protocol Tunneled Transport Layer Security Authenticated Protocol Version 0 (EAP-TTLSv0)</i> . P. Funk, S. Blake-Wilson. August 2008.                 |

Table 4: RFCs Related to Steel-Belted Radius Carrier (*continued*)

| RFC Number | Title   |
|------------|---|
| RFC 5448   | <i>Improved Extensible Authentication Protocol Method for 3rd Generation Authentication and Key Agreement (EAP-AKA)</i> . J. Arkko, V. Lehtovirta, P. Eronen. May 2009. |
| RFC 5997   | <i>Use of Status-Server Packets in the Remote Authentication Dial In User Service (RADIUS) Protocol</i> A. DeKok. August 2010.  |
| RFC 6733   | <i>Diameter Base Protocol</i> . V. Fajardo, J. Arkko, J. Loughney, G. Zorn. October 2012.   |
| RFC 6911   | <i>RADIUS Attributes for IPv6 Access Networks</i> W. Dec, B. Sarikaya, G. Zorn, D. Miles, B. Lourdelet. April 2013.   |

### 3GPP and 3GPP2 Technical Specifications

The Third-Generation Partnership Project (3GPP) and 3GPP2 maintains an online repository of Technical Specifications and Technical Reports at <http://www.3gpp.org> and <http://www.3gpp2.org>, respectively.

Table 5 on page xlv lists the 3GPP Technical Specifications that apply to Steel-Belted Radius Carrier.

Table 5: 3GPP Technical Specifications

| 3GPP TS Number                   | Title   | Applicable Sections   |
|----------------------------------|---|---|
| 3GPP TS 22.234<br>Version 12.0.0 | <i>Requirements on 3GPP system to Wireless Local Area Network (WLAN) interworking</i>     | <ul style="list-style-type: none"> <li>Section 5.1.7: Interworking between PLMN and WLANs</li> </ul>  |
| 3GPP TS 23.003<br>Version 12.6.0 | <i>Numbering, addressing, and identification</i>  | <ul style="list-style-type: none"> <li>Section 2.2: Composition of IMSI</li> </ul>  |
| 3GPP TS 23.008<br>Version 12.6.0 | <i>Organization of subscriber data</i>  | <ul style="list-style-type: none"> <li>Section 3B: Definition of subscriber data I-WLAN domain</li> </ul>   |
| 3GPP TS 23.234<br>Version 12.0.0 | <i>3GPP system to Wireless Local Area Network (WLAN) interworking; System description</i> | <ul style="list-style-type: none"> <li>Section 6.1: Reference Model</li> <li>Section 6.2: Network Elements</li> </ul>   |
| 3GPP TS 23.402<br>Version 12.8.0 | <i>Architecture enhancements for non-3GPP accesses</i>                                    | <ul style="list-style-type: none"> <li>Section 4.1: Concepts</li> <li>Section 4.3: Network Elements</li> </ul>  |
| 3GPP TS 24.302<br>Version 14.4.0 | <i>Access to the 3GPP Evolved Packet Core (EPC) via non-3GPP access networks; Stage 3</i> | <ul style="list-style-type: none"> <li>Section 6: UE – EPC Network protocols</li> <li>Section 8: PDUs and parameters specific to the present document</li> </ul>  |
| 3GPP TS 29.002<br>Version 12.7.0 | <i>Mobile Application Part (MAP) specification</i>  | <ul style="list-style-type: none"> <li>Section 6: Requirements concerning the use of SCCP and TC</li> <li>Section 7.1: Terminology and definitions</li> <li>Section 7.2: Modelling principles</li> <li>Section 7.3: Common MAP service</li> </ul> |

Table 5: 3GPP Technical Specifications (*continued*)

| 3GPP TS Number                   | Title  | Applicable Sections  |
|----------------------------------|--|--|
| 3GPP TS 29.273<br>Version 12.7.0 | <i>Evolved Packet System (EPS); 3GPP EPS AAA interfaces</i>                            | <ul style="list-style-type: none"> <li>• Section 4: SWa Description</li> <li>• Section 5: STa Description</li> <li>• Section 6: SWd Description</li> <li>• Section 7: SWm Description</li> <li>• Section 8: SWx Description</li> <li>• Section 9: S6b and H2 Description</li> <li>• Section 10: Result-Code and Experimental-Result Values</li> </ul>                                    |
| 3GPP TS 33.402<br>Version 14.2.0 | <i>3GPP System Architecture Evolution (SAE); Security aspects of non-3GPP accesses</i> | <ul style="list-style-type: none"> <li>• Section 6: Authentication and key agreement procedures</li> <li>• Section 7: Establishment of security contexts in the target access system</li> <li>• Section 8: Establishment of security between UE and ePDG</li> <li>• Section 9: Security for IP based mobility signalling</li> <li>• Section 14: Temporary identity management</li> </ul> |

**WiMAX Technical Specifications**

The WiMAX Forum Networking Group (NWG) maintains a repository of technical documents and specifications online at <http://www.wimaxforum.org>. You can also view the WiMAX IEEE standards, 802.16e-2005 for mobile WiMAX and 802.16-2004 for fixed WiMAX, online at <http://www.ieee.org>.

**Third-Party Products**

For information about configuring your Ultricom software and hardware, or your access servers and firewalls, consult the manufacturer's documentation.

## Obtaining Documentation

To obtain the most current version of all Juniper Networks technical documentation, see the products documentation page on the Juniper Networks website at <http://www.juniper.net/>.

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- Document name
- Document part number

- Page number
- Software release version

## Requesting Technical Support

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Technical product support is available through the Juniper Networks Technical Assistance Center (JTAC). If you are a customer with an active J-Care or JNASC support contract, or are covered under warranty, and need post-sales technical support, you can access our tools and resources online or open a case with JTAC.

- **JTAC Policies**—For a complete understanding of our JTAC procedures and policies, review the *JTAC User Guide* located at <http://www.juniper.net/us/en/local/pdf/resource-guides/7100059-en.pdf>
- **Product Warranties**—For product warranty information, visit <http://www.juniper.net/support/warranty/>
- **JTAC Hours of Operation**—The JTAC centers have resources available 24 hours a day, 7 days a week, 365 days a year.

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- Find CSC offerings: <http://www.juniper.net/customers/support/>
- Search for known bugs: <http://www2.juniper.net/kb/>
- Find product documentation: <http://www.juniper.net/techpubs/>
- Find solutions and answer questions using our Knowledge Base: <http://kb.juniper.net/>
- Download the latest versions of software and review release notes: <http://www.juniper.net/customers/csc/software/>
- Search technical bulletins for relevant hardware and software notifications: <https://www.juniper.net/alerts/>
- Join and participate in the Juniper Networks Community Forum: <http://www.juniper.net/company/communities/>
- Open a case online in the CSC Case Manager: <http://www.juniper.net/cm/>

To verify service entitlement by product serial number, use our Serial Number Entitlement (SNE) Tool located at <https://tools.juniper.net/SerialNumberEntitlementSearch/>

**Opening a Case with JTAC**

You can open a case with JTAC on the Web or by telephone.

- Use the Case Manager tool in the CSC at <http://www.juniper.net/cm/>
- Call 1-888-314-JTAC (1-888-314-5822 – toll free in the USA, Canada, and Mexico)

For international or direct-dial options in countries without toll-free numbers, visit <http://www.juniper.net/support/requesting-support.html>

When you contact technical support, be ready to provide:

- Your Steel-Belted Radius Carrier release number (for example, Steel-Belted Radius Carrier Release 7.x).
- Information about the server configuration and operating system, including any OS patches that have been applied.
- For licensed products under a current maintenance agreement, your license or support contract number.
- A detailed description of the problem.
- Any documentation that may help in resolving the problem, such as error messages, memory dumps, compiler listings, and error logs.



## PART 1

# Performance, Planning, and Tuning

- [Overview of Performance, Planning, and Tuning of Steel-Belted Radius Carrier on page 3](#)
- [Understanding Performance Metrics on page 15](#)
- [Performance Planning on page 35](#)
- [Understanding the SBRC Network Architecture on page 51](#)
- [Debugging Performance and Functionality Problems on page 59](#)
- [Special Topics in Performance on page 69](#)
- [SBRC System-of-Systems Performance Reference on page 79](#)



## CHAPTER 1

# Overview of Performance, Planning, and Tuning of Steel-Belted Radius Carrier

This chapter provides an overview of Steel-Belted Radius Carrier, general performance concepts, and key use cases on CPU utilization. The following topics are included in this chapter:

- [Steel-Belted Radius Carrier Overview on page 3](#)
- [Document Organization on page 4](#)
- [Performance Theory on page 4](#)

## Steel-Belted Radius Carrier Overview

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Steel-Belted Radius Carrier (SBRC) is an authentication, authorization, and accounting (AAA) solution that provides data services for wireline, wireless, and converged carriers. SBRC interfaces with a wide variety of network access equipment, and authenticates remote and wireless LAN (WLAN) users against numerous back-end databases, allowing you to consolidate the administration of all your remote and WLAN users.

SBR Carrier has been qualified and is supported on Oracle Solaris 10, 11.0, 11.1, and 11.3 (SPARC) and Red Hat Enterprise Linux 6.1, 6.5, 6.6, 6.7, 7.0, and 7.2 on Intel (Xeon) platforms.

SBR standalone is supported on both 32-bit and 64-bit versions of the Linux operating systems. SBR cluster is supported only on 64-bit version of the Linux operating system.

The following are the basic operations of SBRC:

- Receives RADIUS requests (UDP packets) from multiple network access devices, or Radius clients.
- Routes RADIUS packets using the proxy functionality.
- Performs a wide array of internal processing.
- Authenticates users against its own or an extended array of supported back-end databases.

- Accounts to files or one or more back-end databases.
- Maintains the current session state either in memory in a standalone configuration, or in the Session State Register (powered by Oracle MySQL NDB) in a clustered configuration.

The performance of SBRC is a function of the hardware resources on which the software executes and the wide array of internal processing required to handle the work. Each additional level of processing done has an impact on the overall resources of a system. As the complexity of processing increases, the effective performance on a given amount of CPU and I/O decreases.

## Document Organization

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The *Juniper Networks Steel-Belted Radius Carrier Performance, Planning, and Tuning Guide* is organized as shown in [Table 6 on page 4](#).

**Table 6: Document Organization**

| Chapter  | Description   |
|--|---|
| Chapter 1, "Overview of Performance, Planning, and Tuning of Steel-Belted Radius Carrier" (This chapter) | Provides an overview for understanding SBRC general performance theory concepts.  |
| Chapter 2, "Understanding Performance Metrics"   | Provides information about key utilities that you can use to analyze the performance characteristics of an existing or planned system.  |
| Chapter 3, "Performance Planning"  | Provides information that helps you understand the effects of various call models on SBRC memory utilization levels, CPU requirements, load balancing on SBRC front-end applications, and downstream proxy devices. |
| Chapter 4, "Understanding the SBRC Network Architecture"   | Describes the highly reliable network architecture of SBRC. Explains existing error-handling techniques in SBRC that can improve the performance and reliability of the network.                                    |
| Chapter 5, "Debugging Performance and Functionality Problems"  | Provides information you can use to determine the scalability of an existing SBRC system and debug the system performance issues.   |
| Chapter 6, "Special Topics in Performance"   | Provides additional details about the performance of certain subsystems that affect SBRC.   |
| Chapter 7, "SBRC System-of-Systems Performance Reference"  | Provides performance results tested on a given system-of-systems to estimate the SBRC load.   |

## Performance Theory

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The performance of a transaction processing system such as SBRC, and each component of a system, can be characterized by various metrics. Using these metrics, performance can be classified under the following areas of analysis:

- **Throughput**—Calculated based on the rate of system input and output. Often referred to as bandwidth, throughput is measured in work items per second.
- **Utilization**—Calculated based on the impact of a given throughput on the internal components of a system, which can be in terms of CPU utilization, I/O utilization, or memory utilization. These metrics are used for scalability analysis to determine which components of the system are the most impacted for a given workload.
- **Latency**—Measured as the difference in time between input and the corresponding output.

Throughput and latency are often linked to the amount of memory utilization (or in some cases, thread utilization) required to act as a buffer to store the state of the transaction waiting to be processed. For example, consider the following use case. A processor is idle for either 1 or 10 seconds before returning a result (such as when the user has entered an invalid password). The system does the same work in either case, but the result occurs either in 1 or 10 seconds after the request. The throughput and CPU utilization remain the same. The latency increases in the 10-second case. While the transaction is outstanding, the system must store the information about the remaining work that needs to be done when it becomes active, which results in an increase in the amount of memory used to buffer the information while the transaction is idle.

Throughput and utilization are the key metrics used for scalability analysis and planning. Latency does not play an important factor in analyzing the performance of SBRC itself, except in managing failure conditions at the RADIUS level. Latency, however, is a critical factor in analyzing the performance of the external systems and directly impacts memory utilization and thread utilization levels. SBRC is impacted by latency on external systems such as the network connecting to back-ends or between SSR nodes, latency of external authentication or accounting databases, or latency to proxy targets.

## Performance Theory: Threads

Before the advent of multitasking operating systems (OSs), a single CPU ran one program to handle one task. If the program required an input (disk I/O or user input), the CPU waited for the input and did not perform any other task.

With the advent of multitasking OSs, the concept of processes arose. Resources of a CPU are time-sliced so that multiple processes can run at approximately the same time. While one process is waiting for an input (such as disk or network I/O), another process performs another task. Each process is encapsulated, so that one process does not see the memory used by other processes without special system calls to share it.

In recent years, processes have been split into smaller units sharing the same memory space. The term used for this is “thread,” also known as lightweight process (LWP). Two threads run the same groups of instructions in their program (although they could be running in different places at the same time on different CPUs) within one process. Multiple threads are executed simultaneously and manipulate the same memory (which may give rise to memory contention. See [“Performance Theory on Contention” on page 7](#) for more information.)

## Thread Models

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A thread can be thought of as managing a part of the total state of the system. Items managed by a given thread are grouped together with items managed by other threads. This means that passing items from one thread to another is quick and does not require inefficient cross-process calls, which would be required when crossing a process boundary.

For example, a thread with all its state makes an external request for information it needs (perhaps from the network) and goes idle. Another thread reads efficiently from the network and dispatches a task back to the requester thread.

Three thread models are typically used in SBRC.

- **Dispatcher**—One thread manages a resource and many threads wait for it to dispatch a request and return a result. This model is used, for example, in reading and writing to the network or the disk.
- **Buffering**—If task completion is of high priority and you are not concerned about the result of an operation before continuing to process the rest of the transaction, then that part of the task is placed in a queue (buffer) and the rest of the task can continue. This is how logging works: multiple threads write to that log buffer and another thread drains the log buffer in memory and writes it to the disk.
- **Worker thread**—Worker threads are managed by a manager. When a thread needs some other thread to do a particular task (for example, handling a new authentication request), the authentication worker thread manager assigns the task to a thread in an idle state, prompting the thread to execute the authentication code. The thread executes the authentication code while keeping the existing state of the transaction. If the manager cannot identify an idle thread, it creates a new thread and assigns the task. This model is often used in SBRC in a variety of cases.

The problem with too many threads is that only a certain number of tasks can be done on a system in a period of time. Starting new threads takes time and memory. Many threads means that a lot of state is being allocated. Too many threads (since each thread takes some amount of time to make) may lead to high memory and CPU overhead. This leads to memory contention, not enough CPU available to do the actual work, and the task may not be processed in time, which would not occur if the system had simply refused to start more threads and dropped the request, waiting for a retransmit.

The proper number of threads for an SBRC installation varies and has to do with the amount of external latency each thread needs to manage. In a lab environment, you can utilize an entire SBRC machine (to the limits of the CPU or disk speeds) with only 200 threads by doing normal user authentication and regular accounting. However, if you are using an external database that takes 200 ms to return, you might need 1000 threads or more to manage work for the latency of failover behavior.

## Thread Priority

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Similar to other operating systems, both Linux and Solaris provide a method to set the relative priority. Relative priority is the amount and frequency of a time slice for executing individual threads. In certain cases, setting the priority improves performance. The overall value of the priority and the types of scheduler modes vary.

- On Solaris 10, there are 160 priorities (0 through 159). The two key ranges of thread priority are the SYS range (60 through 99), in which most OS threads run, including network and socket buffer handlers; and the RealTime (RT) range (100 through 159). In the SYS range, the amount of time taken for activation is effectively infinite until interrupted or idle. In the RT range, threads are scheduled more frequently and preempt SYS threads, but operate on a fixed-time quantum, although they typically work until they return explicitly to an idle state. It is better to have only a few RT threads on a multi-CPU system. Starving SYS threads of CPU time may cause your network or disk to stop processing traffic into buffers for use by the rest of the system.
- On Linux, the real-time range is from 0 through 100, with the non-real-time “nice” range from -20 through 19 mapping into the priority range from 100 through 139.

In SBRC, you can set three threads to RT priority (see [“Thread Control” on page 48](#)): the threads are the ones that can receive network buffers from sockets, populate a packet cache, and dispatch the requests to other threads (authentication thread, the accounting thread, and proxy thread). These can be configured in the [Configuration] section of the radius.ini or the Proxy.ini file, respectively. See the *Juniper Networks Steel-Belted Radius Carrier Reference Guide* for more information.

### Locking Threads to a Processor

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SBRC does not require that a thread be locked to a processor because it primarily depends on external sources of data, such as the network and disk I/O, and few threads are critical to the performance of the system. The rare processor drift will not impact the overall performance of SBRC.

However, for performance, ndbmtd does require locking threads to processors and this relates to SBRC with SSR configuration. This mitigates the latency during processing for very high memory bandwidth workloads, as only a few threads are doing the bulk of the work. This is controlled by the LockExecuteThreadToCPU directive of the config.ini file, stored on each M node.

An increase in performance should only be relevant when the CPU for one thread on the ndbmtd node is within 20 percent of the maximum available CPU usage. On an M3000 with half the virtual CPUs disabled, **prstat -L** will report a thread at 20 percent out of the 25 percent maximum (which represents a fourth of the total cores on the M3000 processor). Other architectures vary radically. For instance, on Linux, “Irix” mode in **top** is similar to **prstat**’s default mode. See [“prstat” on page 22](#) for more information about the **prstat** and **top** utilities.

## Performance Theory on Contention

On a uniprocessor system, you can analyze the system performance with only a few variables (CPU speed, network bandwidth, memory speed, and disk I/O bandwidth). You can look at the metrics of a running system (CPU utilization percentage, bits per second on the network, or bytes per second to disk) and have a reliable idea of how much extra capacity will result in an overall performance increase. For example, if you are not constrained by the network bandwidth, memory speed, and disk I/O bandwidth, then doubling the CPU speed will give you approximately twice as much throughput, until you reach other bandwidth limits.

A known mode of contention is seen in what is called the “von Neumann bottleneck” (in the von Neumann architecture that most modern systems utilize). The faster CPU and memory subsystems are separated by a hardware bus of limited data rates. This bottleneck is limited with the addition of CPU caches at different levels of the hardware architecture. This is one source of memory contention.

With the advent of multiprocessing machines (with multiple CPUs and multiple cores per CPU, and even multiple virtual CPUs per core), what were single-use resources (such as a memory location or waiting for the cache to fill from memory) can become contended in real time.

For example, two CPUs might want to operate on the same memory location at the same time. If both CPUs do this operation at the same time when the operation is flushed from the CPU cache back to memory, an update will occur from one CPU but be ignored from the other. This leads to two processors having a different view of the underlying data. The same holds true of two processes attempting to update the same disk location, or two database systems attempting to be in sync, both attempting to update the same row.

There are two ways to handle this at a system level. The first is for operations to go in order. This is usually done by locking or using compare and swap (CAS) instructions and retrying if the result changes between the start and end of the CAS instruction. The second is to optimize into a given relative operation, such as a transaction that can be rolled back and re-executed, using a single-instruction locked increment or locked decrement that can be taken out of order and has a known result at the end. Most systems (including SBRC) use locking, as you usually want to execute several operations against a reliable amount of data, not just one.

A lock is an in-memory data structure that uses special instructions to tell the CPU to start the negotiation with other CPUs for locking, or to wait for a lock to be released. The lock instruction permits only one processor to execute a set of instructions, or operate against a single, consistent in-memory data structure at a time. Under the lock you read, calculate, and write the result, then release the lock so other processors can perform their tasks.



**NOTE:** A novel way of dealing with contention (widely used in the cloud computing paradigm) is eventual consistency. That is, for certain operations that do not need to be entirely accurate on a read of a single node, optimizations can permit a system to perform multiple inaccurate operations that will eventually produce an accurate result. SBRC does not presently rely on these semantics.

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Consider a case of a very large SMP (symmetric multiprocessing) machine with 128 virtual CPUs and 1000 instructions to execute under lock, compared to 2000 instructions that do not need to be executed under the lock, in a loop. In order to finish, processor 1 completes 2000 unlocked instructions, then under lock it completes 1000 instructions and releases the lock. During this time, processor 2 completes the 2000 unlocked instructions, and then under lock completes 1000 instructions. Processors 3 through 128 also complete the 2000 unlocked instructions and are waiting for processor 2 to finish



and release the lock so that processor 3 can complete the instructions. However, processors 4 through 128 and now processor 1 are also waiting for the lock. In effect, operations under the lock are executed as if there is only one CPU on the system. This is why faster CPUs are generally more preferable to more CPUs.

In most cases under lock, the processor completes a few instructions then releases the lock and spends most of its time performing unlocked work or locking other minimally contended resources. While one processor holds the lock, other processors can do some other task on other parts of the system, even if they are taking a different lock. However, even for small resources that are heavily used (for example, a global statistic that is incremented non-linearly but relatively often), you could run into contention. For long operations (for example, a locked read or write to a file system, or an update or insert of an SQL row by two SBRCs for managing IP addresses on a cluster), you could run into contention.

### Managing Contention

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In SBRC, there are many different ways to manage contention. Locking is limited, in most cases, to short duration operations. For large operations—for example, during a search of an internally indexed table—you can do a certain number of operations, release the lock and respond to the OS with the task completion status so the OS can schedule other tasks, and then reacquire the lock and continue with the longer operation. This permits other threads that have queued up to run with a much shorter delay.

In SBRC, with various use cases, you can run performance testing and attempt to optimize out the greatest sources of contention. One mitigation technique is caching. For profiles, SBRC can be configured to store an in-memory cache of profile information from the database since profiles are used more frequently than user information and there are relatively fewer profiles than users.

SBRC also uses sharding, or arranging large data structures so they can be split apart. The stripes of a RAID disk or NDB D nodes are examples of sharding. In the case of a four-D node system, two D nodes are mirrors of the other two for reliability, but the data is striped between the first two, such that every other row is reliably stored on one or the other D node (and mirrored to its pair). This means that when you are doing an insert, update, or get by the primary key, you are only involving one of the two D nodes. However, when a query is executed, all the D nodes are queried as to whether the row fitting the criteria exists and each D node must do some work to handle the query. Sharding makes some items much faster in a tradeoff that may increase the overall system performance.



**NOTE:** On both Solaris and Linux (Intel), the optimal thread count is defined based on the following cases:

- Case1—When threads are not waiting for an external network event, a thread count of two to three times (real, not virtual) the core count limits the amount of contention each thread experiences. External network event could be the regular Standalone CST and local accounting to file, or a native user authentication, or Max-Acct-Threads in proxy cases with block=0. Enabling the appropriate flood queues permits the SBR Carrier to respond to spikes in a timely manner.
- Case2—When the threads are waiting for an external network event (such as, authentication from or accounting to an external database, or any case that uses database accessors, SSR cases, and proxy cases with block=1), the number of threads can be much higher, taking into account downstream latency.
  - In a case of 10 milliseconds round-trip latency (inclusive of downstream processing), each thread will be able to handle a maximum of or slightly under 100 transactions a second. To handle 5,000 transactions per second, you would need certainly in excess of 50 threads, or probably closer to 100.
  - If the latency is 50 milliseconds in a proxy case, to handle 5,000 transactions a second, you need upwards of 1,000 threads.
  - In cases where there are excessive number of threads, decreasing the WorkerThreadStackSize might be required to avoid reaching the total memory utilization limit.

---

## CPU Utilization

Several cases are presented in the following sections.



**NOTE:** On Linux (Intel), the optimal CPU utilization is within multiple cores of one CPU (for example, the Intel Xeon E7-4870). The penalty for off-CPU thread execution is at least 12% of the throughput. For basic work such as native user authentication or local accounting to file, on a 10 core-count CPU, enabling the 11th core on a second CPU decreases the throughput by almost 40% owing to off-chip access. Enabling a 12th core returns to a 10% decrease from 10 core performance. Subsequently, enabling more cores decreases throughput mildly until adding more cores has no effect, but never returns to the maximum throughput at the 10 core per one socket rate.

In the TTLS/TLS and proxy cases, enabling two sockets worth of cores does give higher total throughput, but the increase is towards the addition of more sockets.

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### Case 1: More CPU versus More GHz per CPU

---

If you compare a 4 core (Quad Core) machine running at 3 GHz (for a total of 12 GHz) versus a machine with 12 cores each at 1 GHz (for a total of 12 GHz), you will generally see better performance on the higher GHz per CPU.

For example, consider the case for executing 1000 locked instructions. The machine running at 3 GHz executes these 1000 instructions three times faster than the machine running more CPUs at 1 GHz. The amount of time under lock will be one third, so another thread waiting for the resource will wait one-third of the time to do its locked work compared to the 1 GHz CPU.

### Case 2: Virtual CPU versus Physical Cores

---

The virtual CPU mechanism (known as CoolThreads in the Oracle SPARC Solaris-based system, controlled by `psrinfo` and `psradm`; and Hyper-Threading in an Intel-based system), in the broadest terms, is a way of getting more actual work done while waiting (for example, for memory latency) in much the same way threads wait and store state for disk and I/O latency. The state of a thread, in terms of registers and localized memory, is kept in a Layer 1 cache on the physical CPU while it is waiting for the memory to respond with the values from a particular location. This means that the pipeline inside a physical core that does the actual processing is kept as full as possible, at a minimum (but not zero) overhead. Switching registers in and out of the Layer 1 cache also takes time and sometimes threads migrate to different virtual processors, which takes longer, when the OS decides that a particular processor is underutilized. Threads usually stay with one processor unless there is a good reason for the OS to move them.



**NOTE:** On Linux, the overhead for thread processing (which is accounted for by %SY time) is somewhat higher than for Solaris for a similar workload.

Unless you are constrained by memory lookups and cache misses, you will not be able to utilize the extra time well. SBRC in a highly multithreaded system, where much more time is spent waiting for disk and network resources, will see only slightly increased performance utilizing virtual CPUs for each core. When handling high CPU utilization authentication types (for example, high-encryption cases such as EAP-T/TLS) with very limited use sets, you might not see a major improvement in performance (unless you get more total GHz in terms of cores).

In real-time transaction processing, especially in the `ndbmtd` threads, you might want to lock a particular thread to a physical CPU and not permit it to be swapped out for another thread to avoid the associated latency. In both cases, this mechanism provides some configuration to lock certain important threads to a virtual CPU.

In the case of `ndbmtd`, which is very real-time sensitive and optimized to use the CPU effectively, turning off the virtual CPUs gives a dramatic increase in performance as it decreases potential latency. Further locking the threads to certain CPUs gives an additional minor improvement in performance.

For NDB, you are presently limited to approximately eight cores (with no virtual CPUs), with the execute threads taking up two cores (such as the M3000 with quad core CPUs) or four cores (such as the M4000 with two quad core CPUs); additional cores beyond eight do not provide a benefit for NDB versions 7.1 and earlier. A future NDB version may provide additional threading capabilities.

**In general, more total GHz from your cores (with or without virtual processors enabled) is better, whether they come from many slow cores or fewer fast cores, until you reach a particular contention threshold for your use case, at which time faster is better.**

## Performance Theory on Memory Data Structures

The two most common underlying memory data structures are stack and heap.

- **Stack**—A stack is a continuous chunk of memory that is preallocated and utilized linearly. Every time a procedure call is made, more space is created on the stack to save the data from the registers and automatic storage. Recursive procedures, for example, are stack-intensive. Each time a recursive procedure is called, stack space grows. In general, you must preallocate enough stack space for your workload. You must also limit the amount of memory for the stack of any given thread, so it does not take up too much space, resulting in an out of memory error with many threads.

Stack memory does not leak. When you return from a procedure, the stack is unwound.

- **Heap**—A heap is a mixture of items allocated through operators in code such as `malloc` or `new`, or in JavaScript with any object creation. Allocating from heap takes time and can lead to contention, but is a reasonably efficient memory data structure.

On Solaris, `libumem` and `libmtmalloc` both do a good job at managing multiple threads, allocating and freeing information within the heap. On Linux, the default `malloc` offered by `glibc` is reasonably efficient, especially when the number of threads contended on allocation exceeds the number of CPUs.

But additional efficiencies might be available with specially crafted memory allocation schemes—for instance, Professor Berger's `HOARD` memory allocator, `tcmalloc`, and the commercially available "Lockless, Inc." memory allocators all show promise for various use cases.

Heap memory can leak. If you have allocated a piece of memory with `malloc` in C, or `new` in C++, and you lose the pointer to it by not storing it or never referencing it again, the memory remains blocked and will be unusable. The memory is erased only when the process is deleted.

Memory used by a process is rarely returned to the system until the process exits. After starting SBRC and running load against it, the SBRC process takes more memory for stack as the threads reach deeper into its call trees until a steady state is reached and the amount of memory allocated is sufficient to handle the load.

An increase in memory usage is often normal. For instance, as you add sessions and if you do not delete them with an accounting stop, you will use more memory to store the session information.

However, sometimes the memory continues to increase linearly, even on a steady state test, often by just a few bytes per transaction. Sometimes it is even less, increasing perhaps only on an error condition and these cases are more difficult to detect. This is an indication of a memory leak. In this case, you must contact JTAC and the engineering team for support.

The mechanisms of detecting these sorts of leaks are diverse and often difficult to implement. Enabling libumem “transaction” debug mode or the equivalent for other allocation schemes, followed by obtaining multiple cores over the course of a period of time, may be the only option in certain cases.



**NOTE:** Virtual and physical memory—In all SBRC servers and SSR nodes, the working set of SBRC and the ndbmtd should fit well within main memory and should not be at risk of being swapped out to virtual paging due to other activities on the system. Main memory sizes that are smaller than the working set size of any process are not supported.



## CHAPTER 2

# Understanding Performance Metrics

This chapter provides information about key utilities that you can use to analyze the performance of an existing or planned system. It also provides information about some of the terminologies used throughout this guide.

- [Metrics and Definitions on page 15](#)
- [Components of a Sample Use Case on page 17](#)
- [Average Peak Rates on page 20](#)
- [Spike Rates at Peak on page 21](#)
- [Utilities to Measure the Performance of an Existing System on page 21](#)

## Metrics and Definitions

[Table 7 on page 15](#) describes the key performance metrics of SBRC.

**Table 7: Key Performance Metrics**

| Acronym/Term | Definition  |
|--------------|---|
| Accts/s      | <p>RADIUS accounting per second.</p> <p>In SBRC, starts, stops, and interims have approximately the same load requirements. In certain use cases, starts can be marginally faster (a new session when a phantom was not generated), interims marginally slower (requiring an update, retrieval of existing values, and re-writing the record), and stops may be marginally more work (such as managing IP addresses and concurrency).</p> |
| Auths/s      | <p>RADIUS authentications per second.</p> <p>In general, auths/s refers to PAP authentication or CHAP authentication, which is the RADIUS Auth-Request.</p> <p>The performance characteristics of these auths are similar; the differences in simple authentication cryptographies are usually minor.</p>   |
| CPS          | <p>Calls per second.</p> <p>This can be one RADIUS authentication, one accounting start, and one accounting stop.</p> <p>This metric corresponds to a model where the sessions are transient, rather than of long duration where re-authentication occurs with each connection.</p>   |

Table 7: Key Performance Metrics (*continued*)

| Acronym/Term        | Definition  |
|---------------------|---|
| CSPS                | <p>Call setups per second.</p> <p>This is one authentication and one accounting-start.</p> <p><b>NOTE:</b> CSPS is rarely used by Juniper Networks, but is commonly used in other sources of reference.</p> <p>Adding 33 percent to CSPS equalizes the CPS metric, since CSPS ignores stops, whether generated by NAS, or autostops generated from the session timeout.</p>   |
| EAP                 | <p>Extensible Authentication Protocol.</p> <p>Most EAP-based authentication protocols require multiple round trips of RADIUS authentication requests and responses.</p> <p>The number of round trips is strongly influenced by the client and the number of protocols supported. The client can send negative acknowledgements (NAKs) for each authentication protocol until either the last authentication protocol or the server has attempted to serve all the protocols on the available list, after which the server should be configured to reject.</p> <p>If several types of EAP requests are supported, and the most likely ones are the preferred ones; this will under most circumstances decrease the number of transactions done at the negotiation stage.</p> |
| EAP-SIM and EAP-AKA | <p>Extensible Authentication Protocol method for GSM Subscriber Identity Module (EAP-SIM) and Extensible Authentication Protocol method for UMTS Authentication and Key Agreement (EAP-AKA).</p> <p>EAP-SIM and EAP-AKA require multiple round trips and less cryptography in the SBRC front-end application, some of which is pushed into the authGW and some to the Home Location Register (HLR).</p>   |
| EAP-TLS/TTLS        | <p>EAP-Transport Layer Security/Tunneled Transport Layer Security.</p> <p>In addition to multiple round trips, some of the packets that require much heavier cryptography to process can take many CPU cycles on each front-end application.</p>  |
| Proxy               | <p>The performance overhead of writing a request downstream and reading a response from downstream is similar to the equivalent auths/s or accts/s. This is in addition to the overhead of proxy processing of greater or lesser complexity.</p>  |
| SPS                 | <p>Sessions per second.</p> <p>This can be one authentication, one accounting start, three interim-accounting, and an accounting-stop.</p> <p>In certain use cases, the number of transactions can vary significantly, but the three interim-accounting transactions are in place in proportion to the authentications, starts, and stops for calls of average duration. In an average case, interims are sent to extend the session life three times in a varying period of time.</p> <p><b>NOTE:</b> CPS can also be referred to as SPS in other documents or in literature from other organizations.</p>   |



Table 7: Key Performance Metrics (*continued*)

| Acronym/Term | Definition   |
|--------------|--|
| TPS          | <p>Transactions per second.</p> <p>In SBRC, a transaction refers to a RADIUS input packet and its corresponding response packet.</p> <p>For example, a key TTLS transaction may take 100 CPU-milliseconds to execute. An interim accounting transaction might generate an ACK, but it might not perform an update, making it quicker. Thus, the “TPS” of a system is not a great metric for comparative performance.</p> <p>In general, TPS refers to any RADIUS transaction processing such as receiving a packet, turning the attribute-value pairs (AVPs) into an internal representation, doing minimal processing common to all transactions, turning the internal representation of AVPs back into RADIUS and calculating the authenticator, and sending simple responses.</p> |
| WiMAX        | <p>Worldwide Interoperability for Microwave Access.</p> <p>WiMAX is similar to EAP-TLS/TTLS for authentication in specific cases. In WiMAX, the session resumption keys and certain AVPs are stored within the NDB and use the WiMAX accounting flow functionality. This adds to the overhead for processing the accounting starts, interims, and stops.</p>   |

## Components of a Sample Use Case

Each use case can be considered as a collective work done by the components of SBRC, in terms of CPU, I/O, network, and latency.

For example, take the following medium, complex, and heavy utilization use case of a roaming WiMAX TTLS authentication, against an Oracle back end with foreign agent (FA) keying, IP address assignment, and using WiMAX accounting flows and an Oracle back end for accounting data.

[Table 8 on page 18](#) shows the breakdown of use case tasks done by the SBRC components.

Table 8: Sample Use Case Tasks

| Task Execution Sequence                  | Number of Transactions | Subtasks   | Description   |
|--|------------------------|--|---|
| EAP-TTLS authentication                  | 5                      | <ol style="list-style-type: none"> <li>1. SQL transaction validates the username and the TTLS password against an Oracle database.</li> <li>2. Profile AVP is assigned for internal SBRC processing.</li> <li>3. NDB phantom session is created with WiMAX attributes set for keying material.</li> <li>4. NDB insert to the TtlsResumptionCache and TtlsResumptionAttrs attributes.</li> <li>5. NDB insert to the WimaxMobilitykeys attribute.</li> <li>6. NDB update to the IP address table to mark an IP address as being used.</li> <li>7. Generated response is returned.</li> </ol> | <p>RADIUS transaction performs EAP-TTLS authentication.</p> <p>This is mostly a function of CPU utilization on the front-end applications, some of which have high CPU utilization.</p> |
| Foreign agent/gateway RADIUS transaction | 1                      | <ol style="list-style-type: none"> <li>1. Transaction read from the NDB WimaxMobilityKeys.</li> <li>2. Response is calculated.</li> </ol>  | Foreign agent or gateway RADIUS transaction queries the phantom session to return the generated keying material.  |
| WiMAX accounting start                   | 1                      | <ol style="list-style-type: none"> <li>1. NDB update to the CurrentSessions table.</li> <li>2. Insert to an Oracle schema for accounting the flow for the billing identity.</li> <li>3. ACK sent on success.</li> </ol>  | WiMAX accounting starts with the attribute WiMAX-Beginning-Of-Session set as true to start the flow accounting session.   |
| Accounting start                         | 1                      | <ol style="list-style-type: none"> <li>1. NDB update to the CurrentSessions table.</li> <li>2. Insert to the Oracle table for the session.</li> <li>3. ACK sent on success.</li> </ol>   | Accounting start updates the CurrentSession to turn a phantom session to a live session.  |

Table 8: Sample Use Case Tasks (*continued*)

| Task Execution Sequence                     | Number of Transactions | Subtasks   | Description   |
|---|------------------------|--|---|
| WiMAX interims                              | 3 (one per hour)       | <ol style="list-style-type: none"> <li>1. NDB update to the CurrentSessions table.</li> <li>2. Insert to the Oracle table for the session.</li> <li>3. ACK sent on success.</li> </ol>   | <p>WiMAX interims with the attribute WiMAX-Session-Continue set as true.</p> <p>This attribute updates both the CurrentSession, and the flow to which this session belongs.</p>               |
| Accounting request                          | 1                      | <ol style="list-style-type: none"> <li>1. NDB delete from the CurrentSessions table and WimaxMobilityKeys.</li> <li>2. Insert or update to the Oracle table for the session.</li> <li>3. Simple ACK on success.</li> </ol>   | Accounting request to stop the current session.   |
| EAP-TTLS re-authentication request/response | 2 to 3                 | <ol style="list-style-type: none"> <li>1. Profile AVP assigned as internal SBRC processing.</li> <li>2. NDB phantom session created with WiMAX attributes set for keying material.</li> <li>3. NDB insert to the WimaxMobilitykeys for the key.</li> <li>4. NDB update to the IP address table to mark an IP address as being used.</li> <li>5. Generated response is returned.</li> </ol> | EAP-TTLS re-authentication request/response pairs read from the NDB TtlsResumptionCache and TtlsResumptionAttrs attributes. In addition, performs cryptography to validate re-authentication. |
| Foreign agent/gateway RADIUS transaction    | 1                      | <ol style="list-style-type: none"> <li>1. Read from the NDB WimaxMobilityKeys.</li> <li>2. Response is calculated.</li> </ol>  | Foreign agent or gateway RADIUS transaction queries the phantom session to return the generated keying material.  |
| Accounting request                          | 1                      | <ol style="list-style-type: none"> <li>1. NDB update to the CurrentSessions table.</li> <li>2. Insert or update to the Oracle table for the flow.</li> <li>3. Simple ACK on success.</li> </ol>  | Accounting request to start a new session within the flow.  |

Table 8: Sample Use Case Tasks (*continued*)

| Task Execution Sequence | Number of Transactions | Subtasks  | Description  |
|-------------------------|------------------------|---|--|
| WiMAX interims          | 3                      | <ol style="list-style-type: none"> <li>1. NDB update to the CurrentSessions table.</li> <li>2. Insert or update to the Oracle table for the session.</li> <li>3. Simple ACK on success.</li> </ol>  | WiMAX interims with the attribute WiMAX-Session-Continue set as true update both the CurrentSession and the flow to which the session belongs (two NDB hits each). |
| Accounting request      | 1                      | <ol style="list-style-type: none"> <li>1. NDB delete from the CurrentSessions table and WimaxMobilityKeys.</li> <li>2. Insert or update to the Oracle table for the session.</li> <li>3. Simple ACK on success.</li> </ol>                  | Accounting request to stop the second session and delete the session.  |
| WiMAX stop              | 1                      | <ol style="list-style-type: none"> <li>1. NDB delete from the CurrentSessions table and WimaxMobilityKeys.</li> <li>2. Insert or update to the Oracle table for the session.</li> <li>3. Simple ACK on success closing the flow.</li> </ol> | WiMAX stop to end the flow.  |

From the above use case, you can see the complexity of scaling a single SBRC to support multiple use cases simultaneously, although they are additive when broken down into components. When applying complex use cases such as 3G and fixed TLS with DHCP, you will notice that scaling becomes extremely difficult to plan for due to the latency of external servers. However, by breaking the case down into component operations, you can estimate well. You can turn the above use case into a six-hour session:

- Approximate Oracle transactions = 13
- NDB hits = 23
- RADIUS transactions (of which 8 decompose into 1 TTLS and 1 resumption) = 22

## Average Peak Rates

This section describes the average peak rates.

For example, with one million subscribers, 20 percent of them operate the call model (as described in [Table 8 on page 18](#)) during the daytime peak hours. This is up to 200,000 sessions over 6 hours, or 33,333 sessions per hour, or 556 sessions per minute, or 10 sessions per second. To manage this load on average, you need to do 130 Oracle

transactions per second, 230 NDB hits per second, plus 10 TTLS and 10 resumptions per second, plus 140 accountings per second. However, the assumption of a constant task flow at an average rate is not entirely valid; you will generally see that the spikiness in call processing exceeds the low average figure (see [“Spike Rates at Peak” on page 21](#)).

## Spike Rates at Peak

---

This section describes the spike rates at peak.

For example, in a spike case, 20 percent of users attempt to begin the call model (as described in [Table 8 on page 18](#)) within 10 minutes from the start of day. Their focus is primarily on tasks 1 through 4, assuming that tasks 5 through 12 will even out over time as subscribers perform other operations.

- Oracle transactions = 3
- NDB hits = 7
- RADIUS transactions = 8, TTLS = 1, FA = 1, and accountings = 2
- 200,000 sessions over 10 minutes = 20,000 sessions per minute, or 167 sessions per second

This means you need to do 501 Oracle transactions, 1169 NDB hits, 167 TTLS, 167 FA, plus 334 RADIUS accountings per second.

This example is within the recommended base configuration guidelines for SBRC, but you can easily see that spike rates of shorter duration (for example, a GGSN reconnecting all its users), a larger subscriber base, or a higher than expected percentage of users attempting to connect at the same time (for example, call traffic generally spikes after notable public events) could easily push the rate even higher. Establishing a realistic call model and planning beforehand as to what limits you to consider the worst-case peak load for your use case will give you the flexibility you need when establishing and maintaining a reliable and performing solution.

## Utilities to Measure the Performance of an Existing System

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This section describes the following utilities available in the Solaris 10 operating system used to measure and view the performance of an existing system:

- [prstat on page 22](#)
- [sar on page 24](#)
- [iostat on page 25](#)
- [vmstat on page 26](#)
- [prtdiag and sosreport on page 26](#)
- [psrinfo on page 27](#)
- [psradm on page 28](#)
- [System Statistics on page 30](#)

## prstat

The **prstat** or **top** utility shows the current active processes information on the system and reports statistics based on the selected output mode and sort order. The following is a sample output with no arguments for an SBRC system under load for reference:

```
PID USERNAME  SIZE  RSS STATE PRI NICE      TIME  CPU PROCESS/NLWP
28193 root       248M  142M cpu0  42   0   0:23:26  94% radius_generic/285
27695 hadm      169M  129M sleep  59   0   0:00:17  0.1% mysqld/18
27609 hadm      131M   25M sleep  59   0   0:00:15  0.1% ndb_mgmd/10
28244 root     3888K 3248K cpu2   59   0   0:00:00  0.0% prstat/1
 1916 noaccess  166M   79M sleep  59   0   1:58:27  0.0% java/18
 1737 root     4968K 2160K sleep  59   0   0:28:51  0.0% nmbd/1
27947 root     6688K 4424K sleep  59   0   0:00:00  0.0% sshd/1
...
Total: 82 processes, 559 lwps, load averages: 12.43, 5.73, 2.29
```

The command on Linux is similar:

```
top - 11:40:40 up 5 days, 19:52, 1 user, load average: 0.09, 0.04, 0.01
Tasks: 101 total, 1 running, 100 sleeping, 0 stopped, 0 zombie
Cpu(s): 0.3%us, 0.8%sy, 0.0%ni, 97.8%id, 1.0%wa, 0.0%hi, 0.0%si, 0.0%st
Mem: 3923200k total, 1872928k used, 2050272k free, 147100k buffers
Swap: 6160376k total, 0k used, 6160376k free, 481212k cached

  PID USER      PR  NI  VIRT  RES  SHR  S  %CPU  %MEM    TIME+  COMMAND
 2631 root        -5   0 1871m 899m 8088 S   1.7 23.5 135:24.36 ndbmttd

 1858 root        20   0  727m  90m  12m S   0.7  2.4  23:51.54 radius

 1641 hadm        20   0  842m  60m 5652 S   0.3  1.6  24:30.98 mysqld

    1 root        20   0 19272 1456 1176 S   0.0  0.0   0:00.78 init
```

[Table 9 on page 22](#) describes the key fields of the **prstat** utility output.

**Table 9: prstat Output Description**

| Field | Description   |
|-------|---|
| CPU   | Shows the percentage of in-use CPU across the entire machine. The CPU time is regressed over the number of seconds, so this value does not show spike utilization, but is averaged over time.   |
| SIZE  | Shows the total working-set virtual memory size of the process (on some versions of Solaris, this reads as SWAP). In general, this should be less than the system memory size, and for the SBRC front-end application, as a 32-bit application, must be less than 4G. |
| RSS   | The resident set size (RSS) shows the amount of memory that is paged in. Some paging out of SBRC is tolerable, but if this value is less than the working-set size, check for other parts of the system processes using too much memory.                              |
| NLWP  | Number of light-weight processes (or threads).  |

Table 9: prstat Output Description (*continued*)

| Field | Description  |
|-------|--|
| TIME  | Shows the amount of CPU time that the process has been executing since the start.  |
| STATE | The information is not very useful in a multithreaded application in the thread roll-up display, but in <b>prstat -L</b> , it will show the state of the thread.   |
| PRI   | The information is not very useful in a multithreaded application in the thread roll-up display, but in <b>prstat -L</b> , it will show the thread priority. See “Thread Priority” on page 6 for more information. |

The following is an output of **prstat -L** showing per-thread utilization:

```

      PID USERNAME  SIZE  RSS STATE PRI NICE   TIME   CPU PROCESS/LWPID
28193  root      252M  146M sleep  51   0  0:01:20  2.2% radius_generic/65
28193  root      252M  146M sleep  53   0  0:01:21  2.0% radius_generic/28
28193  root      252M  146M sleep  53   0  0:01:00  1.3% radius_generic/66
28193  root      252M  146M sleep  54   0  0:00:14  0.8% radius_generic/156
28193  root      252M  146M sleep  58   0  0:00:19  0.8% radius_generic/122
28193  root      252M  146M cpu4   53   0  0:00:17  0.7% radius_generic/167
28193  root      252M  146M sleep  55   0  0:00:21  0.7% radius_generic/93
...

```

Size and RSS refer to the process and not to the specific thread. STATE, CPU and Time refer to the specific thread.



**NOTE:** The maximum CPU for a given thread is equal to 100 divided by the number of virtual CPUs active on the system. In this case, since SBRC runs on an M3000 with 8 virtual CPUs enabled, the maximum would be 12.5 percent. Since all CPU utilization is less than 12.5 percent and evenly distributed across multiple threads, you will get more than 90 percent of the total CPU on the system. In this case, SBRC works well under the load.

For more general usage information on the **prstat** utility, see the man page at <http://download.oracle.com/docs/cd/E19253-01/816-5166/6mbb1kqdk/index.html>.

On Linux, the **top** command accepts the uppercase “H” subcommand to switch between per-process (the default) and per-thread reporting:

```

top - 11:34:34 up 5 days, 19:46, 1 user, load average: 0.00, 0.00, 0.00
Tasks: 239 total, 1 running, 238 sleeping, 0 stopped, 0 zombie
Cpu(s): 0.5%us, 1.2%sy, 0.0%ni, 97.2%id, 1.0%wa, 0.0%hi, 0.2%si, 0.0%st
Mem: 3923200k total, 1873052k used, 2050148k free, 147100k buffers
Swap: 6160376k total, 0k used, 6160376k free, 481212k cached

      PID USER      PR  NI  VIRT  RES  SHR  S  %CPU  %MEM    TIME+  COMMAND
2631  root      -5   0 1871m 899m 8088  S   1.3  23.5  104:18.06 ndbmttd

2636  root      -5   0 1871m 899m 8088  S   1.0  23.5   54:27.83 ndbmttd

```

```

1681 hadm      20    0  842m  60m 5652 S  0.7  1.6 18:51.67 mysqld
2637 root      -5    0 1871m 899m 8088 S  0.7 23.5 67:02.36 ndbmt
1680 hadm      20    0  842m  60m 5652 S  0.3  1.6 18:12.45 mysqld
2624 root      20    0  727m  90m 12m S  0.3  2.4 15:55.08 radius
2625 root      20    0  727m  90m 12m S  0.3  2.4 16:52.83 radius
2634 root      -5    0 1871m 899m 8088 S  0.3 23.5  1:48.90 ndbmt
2638 root      -5    0 1871m 899m 8088 S  0.3 23.5 41:18.35 ndbmt
2639 root      -5    0 1871m 899m 8088 S  0.3 23.5 35:21.34 ndbmt
2666 root      -5    0 1871m 899m 8088 S  0.3 23.5  2:37.54 ndbmt

```

Unlike Solaris, the default %CPU on Linux totals to 100% times the number of processors. Thus, 100% utilization for a thread corresponds to one virtual CPU. It does not appear to be the case that 100% CPU utilization is realistic on a hyper threaded system. Further, in this calculation, %System time is not accounted for.

It is safe to assume, given that the highest CPU utilization threads for SBR are generally those involved with network I/O (which takes the bulk of the %SY time), that if the highest CPU utilization thread plus the overall %Sys time approximates to 100%, then that thread is at its maximum.

## sar

This is a system activity reporter utility. This Solaris command shows the overall activity of the system. The following is a sample output:

```

# sar 1 10 [every 1 second, display the results 10 times]
SunOS sbr-perf2 5.10 Generic_141444-09 sun4u 01/10/2011

15:14:10    %usr    %sys    %wio    %idle
15:14:11      70      25      0      5
15:14:12      71      26      0      3
...

```

For more general usage information on the **sar** utility, see the man page at <http://download.oracle.com/docs/cd/E19253-01/816-5166/6mbb1kqgf/index.html>.

The following is a sample output:

```

# sar -A 1 10 [every 1 second display all the results 10 times]
15:13:06    %usr    %sys    %wio    %idle
           device    %busy  avque  r+w/s  blks/s  await  avserv
runq-sz %runocc swpq-sz %swpocc
bread/s lread/s %rcache bwrit/s lwrit/s %wcache pread/s pwrit/s
swpin/s bswin/s swpot/s bswot/s pswch/s
scall/s sread/s swrit/s fork/s  exec/s rchar/s wchar/s
iget/s namei/s dirbk/s
rawch/s canch/s outch/s rcvin/s xmtin/s madmin/s
proc-sz  ov  inod-sz  ov  file-sz  ov  lock-sz
msg/s  sema/s

```



```

      atch/s  pgin/s ppgin/s  pflt/s  vflt/s slock/s
      pgout/s ppgout/s pgfree/s pgscan/s %ufs_ipf
freemem freeswap
      sml_mem  alloc  fail  lg_mem  alloc  fail  ovsz_alloc  fail
...
15:13:08      72      26      0      2
      nfs1      0 0.0 0 0 0.0 0 0.0 0.0
      nfs2      0 0.0 0 0 0.0 0 0.0 0.0
      nfs3      0 0.0 0 0 0.0 0 0.0 0.0
      nfs8      0 0.0 0 0 0.0 0 0.0 0.0
      nfs9      0 0.0 0 0 0.0 0 0.0 0.0
      sd0      0 0.0 0 0 0.0 0 0.0 0.0
      sd0,a     0 0.0 0 0 0.0 0 0.0 0.0
      sd0,b     0 0.0 0 0 0.0 0 0.0 0.0
      sd0,c     0 0.0 0 0 0.0 0 0.0 0.0
      sd1      2 0.0 3 1958 0.0 8.0
      sd1,a     0 0.0 0 0 0.0 0.0
      sd1,b     0 0.0 0 0 0.0 0.0
      sd1,c     0 0.0 0 0 0.0 0.0
      sd1,d     0 0.0 0 0 0.0 0.0
      sd1,e     0 0.0 0 0 0.0 5.8
      sd1,f     2 0.0 2 1956 0.0 9.0
      sd1,g     0 0.0 0 0 0.0 0.0
      sd2      0 0.0 0 0 0.0 0.0
      7.0      100 0.0 0
      0      7935 100 8 240 97 0 0
      0.00 0.0 0.00 0.0 143189
346430 26 22887 0.00 0.00 6541 3517768
      1      2 0
      0      0 1903 0 0 0
86/30000 0 32815/129797 0 615/615 0 0/0
      0.00 0.00
      0.00 0.00 0.00 0.00 0.00 0.00
      0.00 0.00 0.00 0.00 0.00
1548184 39927664
423872064 45155219 0 1032183808 911917808 0 165756928 0
...

```

The **sar** utility runs in the background to display metrics on the system, with an interval of every few minutes on a nominal system, or every 5 or 10 seconds on a system that is under examination or undergoing troubleshooting to help diagnose system anomalies that impact SBRC (for example, to identify periods of spikiness).

## iostat

The **iostat** utility reports I/O statistics such as terminal, disk, and tape I/O activity, as well as CPU utilization. The following is a sample output:

```

# iostat 1 10
      tty      sd0      sd1      sd2      nfs1      cpu
      tin tout kps tps serv kps tps serv kps tps serv kps tps serv us sy wt id
      0 55 11 1 7 93 2 14 0 0 0 0 0 0 6 2 0 91
      0 235 0 0 0 1021 1 13 0 0 0 0 0 0 72 25 0 3
      0 81 0 0 0 1026 1 10 0 0 0 0 0 0 72 25 0 3
      0 81 0 0 0 1024 1 13 0 0 0 0 0 0 72 25 0 3
...

```

If the CPU utilization from **prstat** is relatively low but the I/O utilization (kps on any device) is nearing the I/O bandwidth utilization, you may have a problem with I/O.

For more general usage information on the **iostat** utility, see the man page at <http://download.oracle.com/docs/cd/E19253-01/816-5166/6mbb1kq4q/index.html>.

## vmstat

The **vmstat** utility shows virtual memory usage statistics regarding kernel thread, virtual memory, disk, trap, and CPU activity. The following is a sample output:

```
# vmstat 1 10
kthr      memory          page        disk        faults        cpu
r  b  w    swap  free   re  mf  pi  po  fr  de  sr  s0  s1  s2  --   in   sy      cs  us  sy  id
0  0  0 19956200 13155320 43 379 11 26 26 0 4 1 2 -0   0 8658 31671 14768 6 2 91
11 0  0 19964120 12374728 9 40 0 0 0 0 0 0 1 0 0 60815 358620 149035 72 25
3
3 0  0 19963920 12374576 0 5 0 0 0 0 0 0 0 0 0 61047 352131 146928 72 25
3
```

The **vmstat** utility is useful to determine if the memory utilization is too high. For example, any high pi/po values indicate memory thrashing (that is, more memory is in use by the working set than is available on the system), and you should diagnose for stale sessions, leaks, or add more memory.

For more general usage information on the **vmstat** utility, see the man page at <http://download.oracle.com/docs/cd/E19253-01/816-5166/6mbb1kqms/index.html>.

## prtdiag and sosreport

The **prtdiag** and **sosreport** utilities displays system configuration and diagnostic information. The following is a sample output:

```
# prtdiag
System Configuration: Sun Microsystems sun4u Sun SPARC Enterprise M3000 Server
System clock frequency: 1224 MHz
Memory size: 16384 Megabytes
===== CPUs =====
      CPU          CPU          Run   L2$   CPU   CPU
LSB   Chip          ID          MHz   MB   Impl. Mask
-----
 00    0      0, 1, 2, 3, 4, 5, 6, 7 2750  5.0      7 161
===== Memory Configuration =====
      Memory  Available      Memory  DIMM  # of  Mirror  Interleave
LSB   Group   Size          Status   Size  DIMMs  Mode    Factor
-----
 00    A      8192MB          okay    2048MB   4 no    2-way
 00    B      8192MB          okay    2048MB   4 no    2-way
===== I/O Cards =====
...
```

For more general usage information on the **prtdiag** utility, see the man page at <http://download.oracle.com/docs/cd/E19253-01/816-5166/6mbb1kqdn/index.html>.

An equivalent of `prtdiag` on Linux is a `sosreport` (which may require an additional package, which can be installed with “`yum install sosreport`”). The `sosreport` generates a package of files in `/tmp`, which can be inspected or forwarded to JTAC.

```
sosreport
```

```
sosreport (version 2.2)
```

```
This utility will collect some detailed information about the
hardware and setup of your Red Hat Enterprise Linux system.
The information is collected and an archive is packaged under
/tmp, which you can send to a support representative.
Red Hat Enterprise Linux will use this information for diagnostic purposes ONLY
and it will be considered confidential information.
```

```
This process may take a while to complete.
No changes will be made to your system.
```

```
Press ENTER to continue, or CTRL-C to quit.
```

```
Please enter your first initial and last name [defaultusername]: juser
Please enter the case number that you are generating this report for: 12345
```

```
Running plugins. Please wait ...
```

```
Completed [51/51] ...
Creating compressed archive...
```

```
Your sosreport has been generated and saved in:
/tmp/sosreport-juser.12345-20120312121724-8658.tar.xz
```

```
The md5sum is: 68c7948130edf27d71ccc683ebe28658
```

```
Please send this file to your support representative.
```

```
The report can be viewed as follows:
```

```
# xz -d sosreport-juser.12345-20120312121724-8658.tar.xz
# tar xf sosreport-juser.12345-20120312121724-8658.tar
# cd %ltmachinename%gt-%ltdatetime%gt; ls
boot      etc          java         lspci        pstree       sos_commands  uptime
chkconfig free         lib          mount        root         sos_logs      var
date      hostname     lsb-release  netstat      route        sos_reports
df         ifconfig     lsmod        proc         sar12        sys
dmidecode installed-rpms lsof         ps           sestatus     uname
```

The preceding generated trees may be inspected freely and remotely, and are very valuable for debugging issues.

## psrinfo

The **psrinfo** utility displays information about virtual processors. The following is an example output:

```
# psrinfo
0      on-line   since 07/14/2010 18:36:36
1      on-line   since 10/04/2010 11:41:31
2      on-line   since 07/14/2010 18:36:36
3      on-line   since 10/04/2010 11:41:31
```

```
4      on-line   since 07/14/2010 18:36:36
5      on-line   since 10/04/2010 11:41:31
6      on-line   since 07/14/2010 18:36:36
7      on-line   since 10/04/2010 11:41:31
```

For more general usage information on the **psrinfo** utility, see the man page at <http://download.oracle.com/docs/cd/E19253-01/816-5166/6mbb1kqdt/index.html>.

## psradm

The **psradm** utility changes the status of the virtual processors. The following is a sample output:

```
# psradm -f 1
# psrinfo
0      on-line   since 07/14/2010 18:36:36
1      off-line  since 01/10/2011 15:19:20
2      on-line   since 07/14/2010 18:36:36
3      on-line   since 10/04/2010 11:41:31
4      on-line   since 07/14/2010 18:36:36
5      on-line   since 10/04/2010 11:41:31
6      on-line   since 07/14/2010 18:36:36
7      on-line   since 10/04/2010 11:41:31

# psradm -n 1
# psrinfo
0      on-line   since 07/14/2010 18:36:36
1      on-line   since 01/10/2011 15:19:47
2      on-line   since 07/14/2010 18:36:36
3      on-line   since 10/04/2010 11:41:31
4      on-line   since 07/14/2010 18:36:36
5      on-line   since 10/04/2010 11:41:31
6      on-line   since 07/14/2010 18:36:36
7      on-line   since 10/04/2010 11:41:31
```

For more general usage information on the **psradm** utility, see the man page at <http://download.oracle.com/docs/cd/E19253-01/816-5166/6mbb1kqds/index.html>.

## cpuinfo on Linux

On Linux, the equivalent of **psrinfo** is **/proc/cpuinfo**, which returns information like:

```
# more /proc/cpuinfo
processor       : 0
vendor_id     : GenuineIntel
cpu family    : 6
model         : 44
model name    : Intel(R) Xeon(R) CPU           X5687  @ 3.60GHz
stepping      : 2
cpu MHz       : 1600.000
cache size    : 12288 KB
physical id   : 0
siblings      : 8
core id       : 0
cpu cores     : 4
apicid        : 0
initial apicid : 0
fpu           : yes
```

```

fpu_exception    : yes
cpuid level      : 11
wp              : yes
flags            : fpu vme de pse tsc msr pae mce cx8 apic mtrr pge mca cmov pat
pse36 clflush dts acpi mmx fxsr sse sse2 ss ht tm pbe syscall nx pdpe1gb rdtscp
lm constant_tsc arch_perfmon pebs bts rep_good xtopology nonstop_tsc aperfmperf
pni pclmulqdq dtes64 monitor ds_cpl vmx smx est tm2 ssse3 cx16 xtpr pdcm dca sse
4_1 sse4_2 popcnt aes lahfm ida arat epb tpr_shadow vnmi flexpriority ept vpid
bogomips        : 7197.00
clflush size     : 64
cache_alignment  : 64
address sizes    : 40 bits physical, 48 bits virtual
power management:
processor        : 1
vendor_id        : GenuineIntel
cpu family       : 6
model            : 44
model name       : Intel(R) Xeon(R) CPU           X5687  @ 3.60GHz
...etc...

```

Please see the man page for “proc” for more information.

Summary information can be seen via the **lscpu** command.

```

# lscpu
Architecture:      x86_64
CPU op-mode(s):    32-bit, 64-bit
Byte Order:        Little Endian
CPU(s):            16
On-line CPU(s) list: 0-15
Thread(s) per core: 2
Core(s) per socket: 4
CPU socket(s):     2
NUMA node(s):      2
Vendor ID:         GenuineIntel
CPU family:        6
Model:             44
Stepping:          2
CPU MHz:           1600.000
BogoMIPS:          7197.24
Virtualization:    VT-x
L1d cache:         32K
L1i cache:         32K
L2 cache:          256K
L3 cache:          12288K
NUMA node0 CPU(s): 0,2,4,6,8,10,12,14
NUMA node1 CPU(s): 1,3,5,7,9,11,13,15

```

Please see the man page for lscpu for more information.

## Taskset on Linux

Taskset is used to set or retrieve the CPU affinity of a running process, given a PID or a command. This could be used to increase the performance in certain instances.

```
taskset -p -c <cpuset> <PID>
```

Example:

```
taskset -p -c 0-7 20320
```

Where `-p` option indicates the last argument is a PID, the `-c` option indicates the second-to-last argument is a list of CPU IDs (rather than, the default, a bitmap representing which CPUs). The effect of this command would be to make process 20320 bias to the first 8 cores.

## Disabling a CPU on Linux

To temporarily disable a CPU on Linux, use the following command:

```
# echo 0 >> /sys/devices/system/cpu/cpu[#]/online
```

Where `[#]` is the processor ID of the core to disable. It appears that disabling CPU 0 is not permitted. To enable, echo the value 1. It does not appear to persist between reboots.

## System Statistics

You use the **Statistics** page in Web GUI to display summary statistics for authentication, accounting, and proxy forwarding transactions. You can measure the current, average, and peak TPS values of authentication and accounting transactions.

Authentication statistics summarize the number of authentication acceptances and rejections, with summary totals for each type of rejection or retry (see [Figure 2 on page 31](#)).

Figure 1: Viewing Authentication Statistics

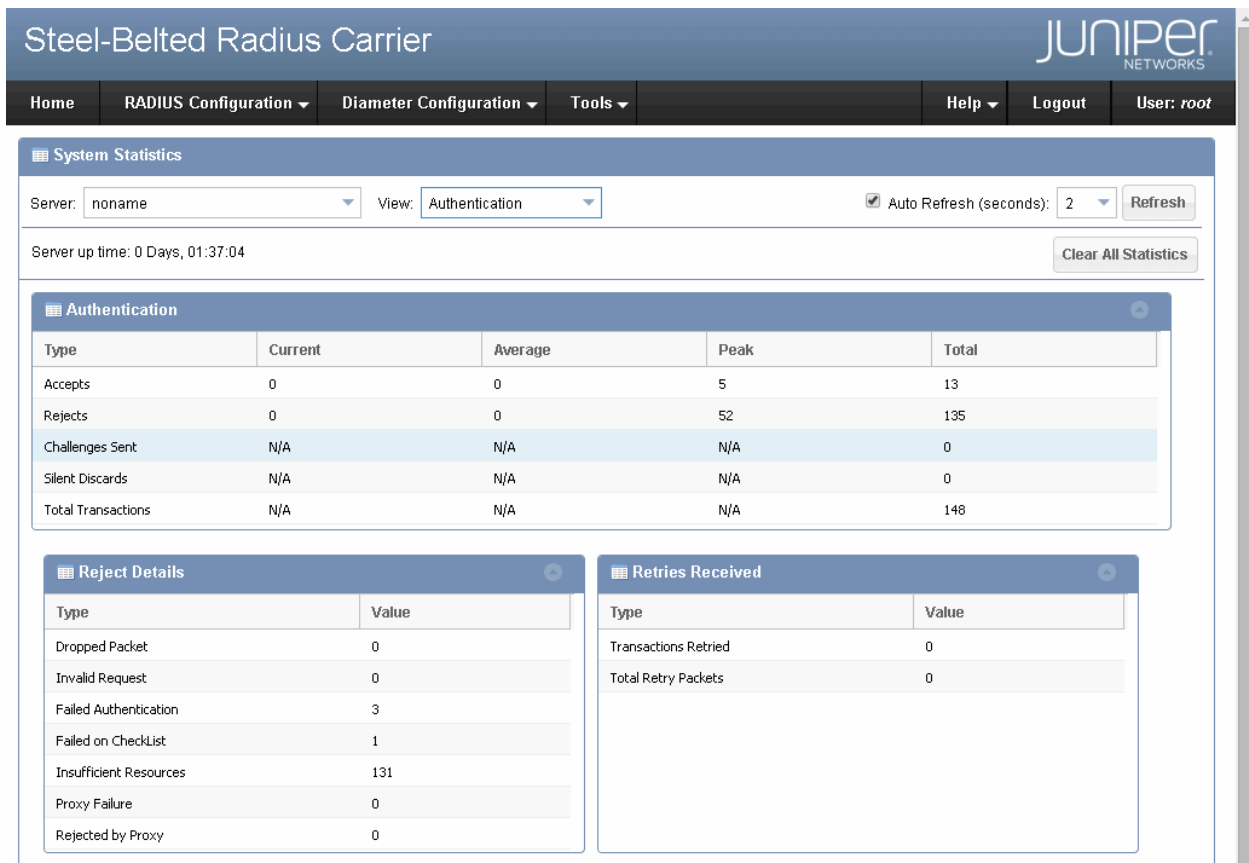
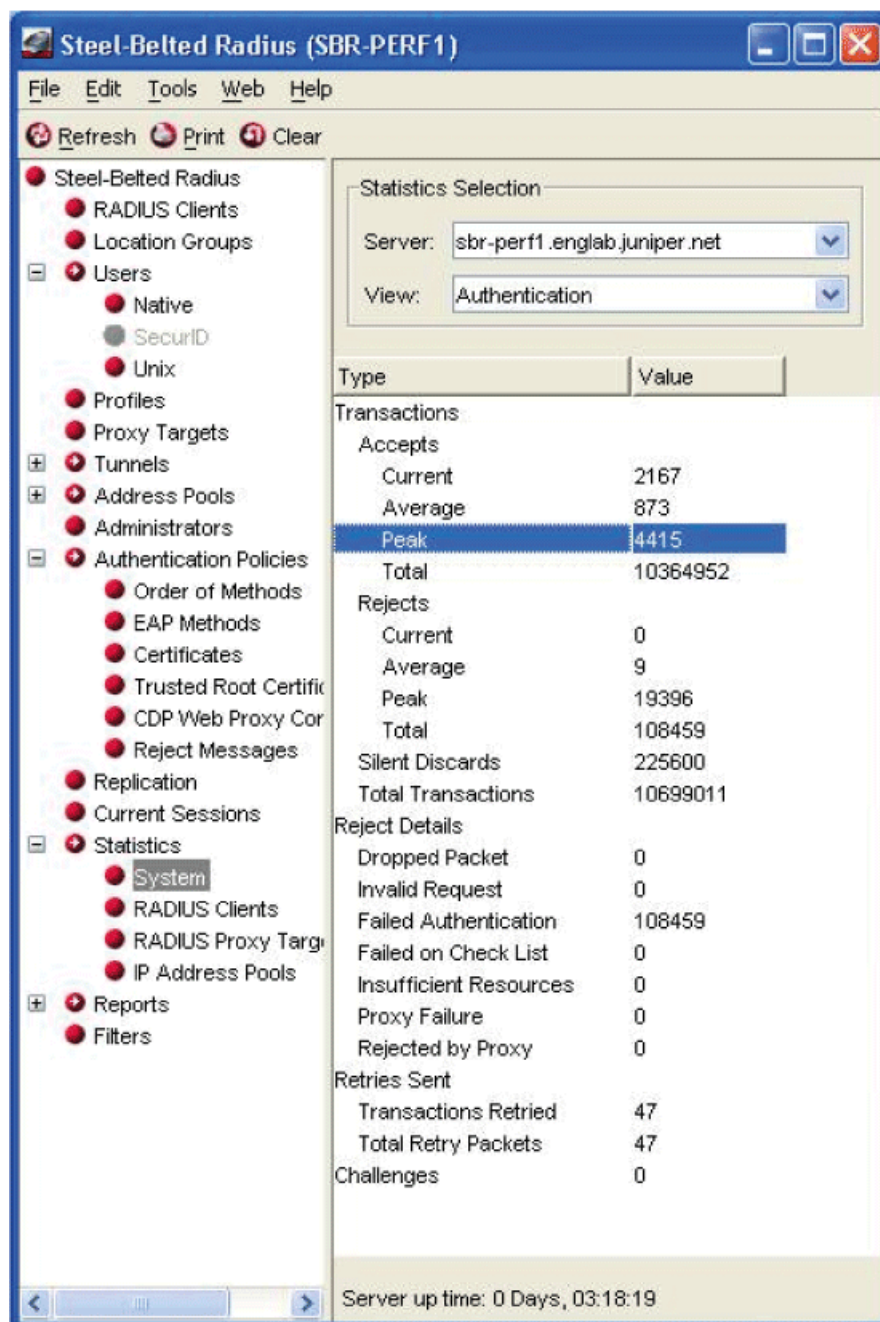


Figure 2: Viewing Authentication Statistics



Accounting statistics provide information such as the number of transaction starts and stops and the reasons for rejecting attempted transactions. The start and stop numbers rarely match, because many transactions can be in progress at any given time (see [Figure 4 on page 33](#)).

Figure 3: Viewing Accounting Statistics

The screenshot displays the Steel-Belted Radius Carrier web interface. At the top, the title "Steel-Belted Radius Carrier" is shown next to the Juniper Networks logo. A navigation bar includes links for Home, RADIUS Configuration, Diameter Configuration, Tools, Help, Logout, and the current user "root".

The main content area is titled "System Statistics". It features a "Server:" dropdown set to "noname" and a "View:" dropdown set to "Accounting". There is a checkbox for "Auto Refresh (seconds): 2" and a "Refresh" button. Below this, it shows "Server up time: 0 Days, 01:38:16" and a "Clear All Statistics" button.

The "Accounting" section is expanded, showing a table with the following data:

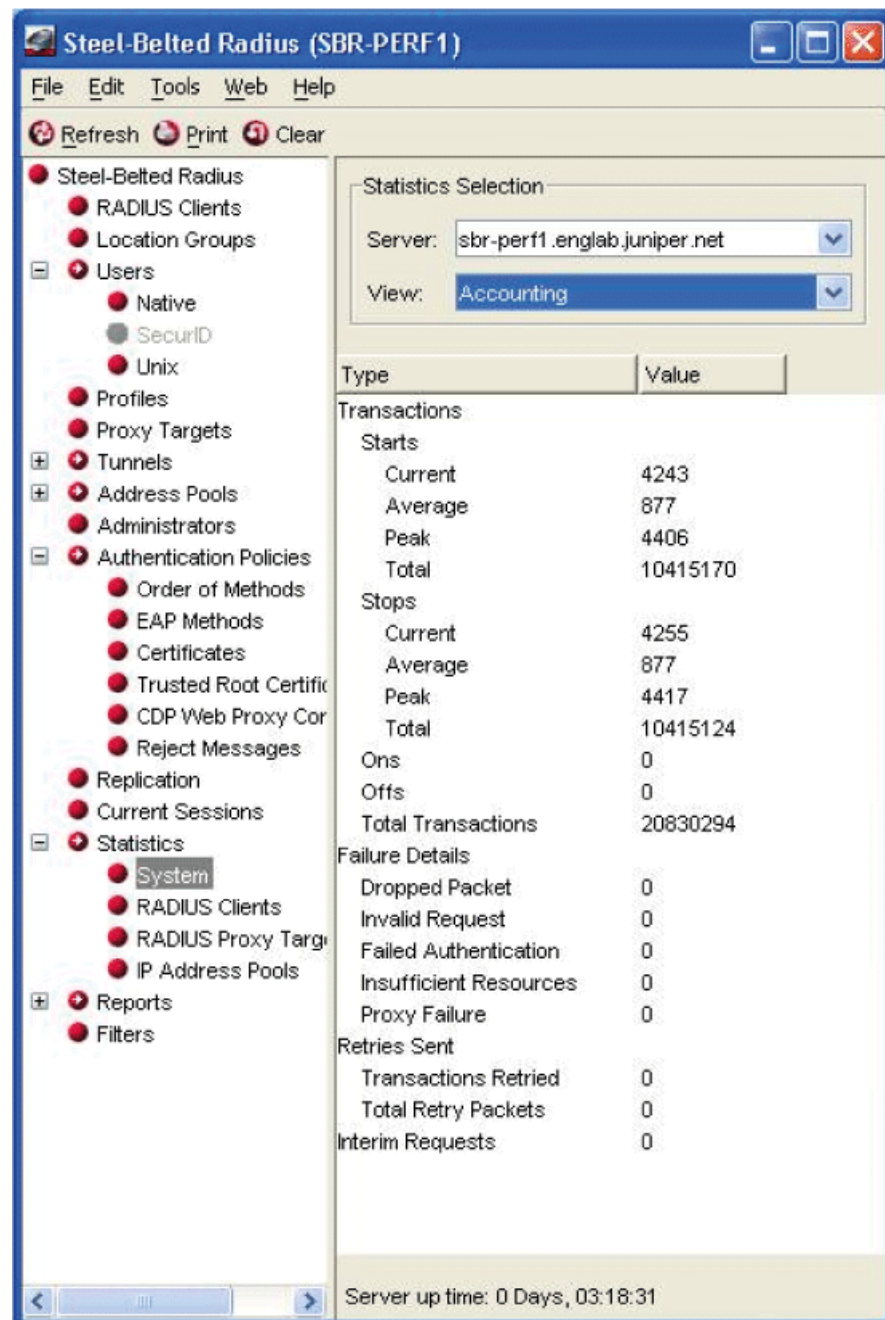
| Type              | Current | Average | Peak | Total |
|-------------------|---------|---------|------|-------|
| Starts            | 0       | 0       | 52   | 143   |
| Stops             | 0       | 0       | 0    | 0     |
| Total Start/Stops | N/A     | N/A     | N/A  | 143   |
| Ons               | N/A     | N/A     | N/A  | 0     |
| Offs              | N/A     | N/A     | N/A  | 0     |
| Interim Requests  | 0       | 0       | 0    | 0     |

Below the Accounting table are two smaller sections:

- Failure Details:** A table with two columns: Type and Value. The data rows are: Dropped Packet (0), Invalid Request (0), Insufficient Resources (0), and Proxy Failure (0).
- Retries Received:** A table with two columns: Type and Value. The data rows are: Transactions Retried (0) and Total Retry Packets (0).



Figure 4: Viewing Accounting Statistics





## CHAPTER 3

# Performance Planning

This chapter provides information that helps you understand the SBRC call models, memory utilization levels, CPU requirements, and load balancing on RADIUS front-end applications and downstream proxy devices.

- [Understanding SBRC Call Models on page 35](#)
- [Understanding the Memory Utilization Levels on page 37](#)
- [Understanding the CPU Requirements on page 40](#)
- [Retries on page 44](#)
- [Load Balancing on RADIUS Front-End Applications and Downstream Proxy Devices on page 45](#)
- [Handling Downstream Latency and Traffic Spikes on page 48](#)

### Understanding SBRC Call Models

---

A call model, also known as a session call model, is a logical description of the flow of information on the control plane of a carrier system, each part of which is termed a “leg” of the flow. It includes items such as authentication and authorization, service activation and provisioning, call and device control, and termination.

When you plan the sizing and expected performance of an SBRC as a system of systems, a key aspect to determine beforehand is the impact of the call models on the expected SBRC operation, that is, the scope and shape of the normal level of SBRC traffic.

Carriers often use the widely established call models, such as the reference models from networking working groups (such as 3G, WiMAX, and LTE) and modify them for their customer base to model their specific range of services. A subscriber base is often broken down into several key call models with subscribers (current and future), who either have or are expected to have certain classes of service, and statistically operate within identifiable patterns of system utilization. These call models and patterns of system utilization are further decomposed into the work that SBRC front-end applications and back ends (external DB, downstream proxies, and SSR) must do. This is usually done with the help of technical experts armed with existing data and statistics from the carrier or operator in consultation with the Juniper Network’s sales engineering force or value-added reseller. These often consult with Juniper Networks’ product engineering team for the latest information and to seek possible ways to optimize a specific use case.

An actionable set of call models and statistical information can include information like the following:

- 6 million total subscribers
- 2 million xDSL device address authentications, always on with an interim period of 4 hours and reauthentication period of 24 hours (+/- 1 hour), randomly occurring throughout the day
- 1.3 million fixed always-on WiMAX Device TLS with an interim period of 1 hour
- 30 percent of 500,000 subscribers, simultaneously using roaming WiMAX TTLS, each with:
  - An expected CPS of 3 per day with an interim period of 10 minutes
  - An expected regular peak of 200 CSPA for 20 minutes (at 9:00 a.m., 12:00 p.m., and 5:30 p.m.)
  - A tolerable absolute peak of 2000 CSPA during certain external events (for example, earthquakes or the Superbowl)
- Each GGSN supports 250,000 subscribers, which will reauthenticate at a limited rate of 2500 CSPA on restart; as well as attempt to support 2 GGSN simultaneous restarts, load balanced across both NOCs in normal operation, on a best-effort basis
- 100,000 heavy use commercial roaming WiMAX users with:
  - An expected CSPA of 1 per hour owing to cell movement
  - An interim period of 10 minutes
  - A peak of 800 CSPA (between 7:00 a.m. and 7:30 a.m.)
  - 35 percent simultaneous dormant subscribers
- 1000 foreign agent SPSs from recognized Wi-Fi relationships
- IP not assigned from the SSR and no concurrency checking

From the above, breaking the information into the respective use cases, you can measure the limits of CPS or CSPA that the system might simultaneously be called to do. You can derive the requirements for a system in terms of SSR hits, required SSR sharding (or splitting up the subscriber base over multiple SSRs), the amount of CPU power in GHz required, and SBRC front-end applications required to support the system that would need to be in each of the two NOCs, either of which might be required to handle the entire load in a failure condition.

After a thumbnail analysis of the above, you can see that scaling for authentication proves to be strongly related to the peak WiMAX rates (CPU intensive) on the front-end applications, and further closely related to the number of interims flowing through the system, up to the limits of SSR hits-per-second that one SSR can support.

There are multiple ways to optimize the system based on the performance results for specific hardware (see [“Hardware Used” on page 79](#) for more information). In addition to optimizing the behavior of SBRC, you need to consider such possibilities as decreasing the interim and fixed reauthentication periods to significantly reduce the background

load on the SSR to permit a wider bandwidth to support GGSN resets, or limiting spikiness through the use of flood queues and lengthening retry semantics. To maintain the expected security level, you can use a non-default cipher suite, smaller prime number generation for temporary Diffie-Hellman Ephemeral (DHE) Encryption keys, or a smaller TLS server certificate with more frequent certificate updates.

## Understanding the Memory Utilization Levels

This section provides information on the memory utilization levels for SBRC standalone and SBRC SSR cluster setups. It explains:

- [Memory Utilization on Standalone on page 37](#)
- [Memory Utilization on SSR Cluster on page 38](#)

### Memory Utilization on Standalone

[Table 10 on page 37](#) describes the memory utilization levels for the SBRC standalone setup. Remember, SBR standalone is limited to a maximum of 4G of memory utilization, in which the CurrentSessions as well as the operating memory for SBR transaction processing must be maintained.

**Table 10: Memory Utilization on Standalone**

| Parameter           | Data Memory                    | SA Overhead Bytes per Record (BpR)   | SA Maximum BpR | SA Reasonable BpR  |
|---------------------|--------------------------------|--|----------------|--|
| Current Sessions    | Memory for data (per session)  | 688  | 5294           | 1116   |
| IP Addresses        | Memory (per IP)                | $14 + (\#ips * 24 / 256)$  | –              | $14 + (\#ips * 24 / 256)$  |
| CDR Acct Records    | Memory (per session)           | LDAP CDR server for SS7, separate memory space, possibly separate machine, similar to cluster sizing | –              | LDAP CDR server for SS7, separate memory space, possibly separate machine, similar to cluster sizing |
| SimAkaPseudonymKeys | Memory (per key)               | 64   | 64             | 64   |
| SimAkaReauthCache   | Data memory (per cache)        | 228  | 1514           | 1514   |
| SMSAccounts         | Data memory (per Acct)         | N/A  | –              | –  |
| TtlsResumptionAttrs | Data memory (per TTLS session) | 104  | 8152           | Reasonable values vary widely with attribute stored  |
| TtlsResumptionCache | Data memory (per TTLS session) | 132  | 7620           | Reasonable values vary with key size and other items   |

Table 10: Memory Utilization on Standalone (*continued*)

| Parameter         | Data Memory                         | SA Overhead Bytes per Record (BpR) | SA Maximum BpR | SA Reasonable BpR |
|-------------------|-------------------------------------|------------------------------------|----------------|-------------------|
| UserConcurrency   | Data memory (per concurrency entry) | N/A                                | –              | –                 |
| WiMaxDHCPRootKeys | Data memory (per DHCP root key)     | 208                                | 208            | 208               |
| WiMaxHaRootKeys   | Data memory (per HA root key)       | 208                                | 208            | 208               |
| WimaxMobilityKeys | Data memory (per WiMAX session)     | 604                                | 2394           | Varies widely     |

## Memory Utilization on SSR Cluster

Table 11 on page 38 describes the memory utilization levels for the SSR cluster setup.

Table 11: Memory Utilization on SSR Cluster

| Parameter           | Data/Index Memory                            | NDB Overhead Bytes per Record (BpR) | NDB Maximum BpR | NDB Reasonable BpR |
|---------------------|--|-------------------------------------|-----------------|--------------------|
| Current Sessions    | Data memory (per session)                    | 344                                 | 4684            | 772                |
|                     | Data memory for unique indexes (per session) | 324                                 | 968             | 472                |
|                     | Index memory (per session)                   | 192                                 | 192             | 192                |
| IP Addresses        | Data memory (per IP)                         | 104                                 | 104             | 104                |
|                     | Index memory (per IP)                        | 32                                  | 32              | 32                 |
| CDR Acct Records    | Data memory (per session)                    | 296                                 | 2320            | 764                |
|                     | Index memory (per session)                   | 16                                  | 16              | 16                 |
| SimAkaPseudonymKeys | Data memory (per key)                        | 72                                  | 72              | –                  |
|                     | Index memory (per key)                       | 32                                  | 32              | 32                 |
| SimAkaReauthCache   | Data memory (per cache)                      | 600                                 | 1888            | –                  |
|                     | Index memory (per cache)                     | 16                                  | 16              | 16                 |

Table 11: Memory Utilization on SSR Cluster (*continued*)

| Parameter           | Data/Index Memory                    | NDB Overhead Bytes per Record (BpR) | NDB Maximum BpR | NDB Reasonable BpR |
|---------------------|--------------------------------------|-------------------------------------|-----------------|--------------------|
| SMSAccounts         | Data memory (per Acct)               | 360                                 | 1824            | –                  |
|                     | Index memory (per Acct)              | 16                                  | 16              | 16                 |
| TtlsResumptionAttrs | Data memory (per TTLS session)       | 104                                 | 8152            | ~3800              |
|                     | Index memory (per TTLS session)      | 16                                  | 16              | 16                 |
| TtlsResumptionCache | Data memory (per TTLS session)       | 120                                 | 7604            | ~4800              |
|                     | Index memory (per TTLS session)      | 16                                  | 16              | 16                 |
| UserConcurrency     | Data memory (per concurrency entry)  | 116                                 | 200             | 200                |
|                     | Index memory (per concurrency entry) | 16                                  | 16              | 16                 |
| WiMaxDHCPRootKeys   | Data memory (per DHCP root key)      | 56                                  | 120             | 120                |
|                     | Index memory (per DHCP root key)     | 48                                  | 48              | 48                 |
| WiMaxHaRootKeys     | Data memory (per HA root key)        | 112                                 | 112             | 112                |
|                     | Index memory (per HA root key)       | 16                                  | 16              | 16                 |
| WimaxMobilityKeys   | Data memory (per WiMAX session)      | 5760                                | 5760            | Varies widely      |
|                     | Index memory (per WiMAX session)     | 128                                 | 128             | 128                |

- Overhead—In standard model, this column includes zero-length data for each variable-length field.
- Reasonable—Include the most used AVPs with expected and usual length fields. In certain cases, adding customer-defined fields can increase the memory utilization for a particular use case over the defined reasonable values.
- Maximum—In certain cases, this column is entirely filled with data, and might go over this with customer-defined fields.



**NOTE:** The data memory and index memory mentioned in [Table 11 on page 38](#) for the SSR cluster refer to settings in the `/opt/JNPRhadm/config.ini` file.

You can accurately determine the reasonable values by examining a few instances of the live RADIUS traffic and determining the actual lengths of typical data in the fields

that are stored in the SSR. Add the actual length of data to the overhead column to construct a reasonable model of a session for your case. You can increase the data by 10 to 20 percent, as a margin of safety and for future expandability, and calculate the total usage.

The SSR memory requirement per D node for a system is calculated as follows:

1. Add the data memory and index memory values together for the expected values of sessions/addresses and other rows.
2. Multiply the value by the maximum number of concurrent sessions that will be supported.
3. Divide the value by the number of stripes (1, 2, or 3 for 2-, 4-, or 6-node SSRs, respectively).
4. Add 2G for the system overhead.
5. Round up to the next multiple of memory sizing (usually 2G or 4G increments).

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## Understanding the CPU Requirements

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**NOTE:** When analyzing the machine specifications for performance, you have to target throughput rates that take into account failure conditions.

For instance, to account for a GGSN reset that might attempt to reconnect 20,000 users in one minute after a failure, you would need to add the load for an Accounting-ON, which attempts to close 20,000 sessions (at approximately 1000 sessions a second, which equals to 20 seconds), plus 500 authorizations per second plus 500 accounts per seconds for 40 seconds, to whatever baseline in terms of authorizations, accounts, and interims you have as an average. Double each of those values to support two GGSNs restarting, for instance, after a power outage on a shared UPS.

When analyzing the expected performance of a given SBRC system, you must evaluate the following three items in terms of the CPU requirements:

- Number of CPUs (includes *cores*, as well as *virtual processors* [VPs])
  - A single chip may have multiple cores.
  - A *core* represents a single CPU unit and multiple cores on a chip often share a memory bus or I/O bus.
  - *Virtual processor* is a way to optimize the use of a core by permitting more threads to execute on the same core, while one thread is awaiting a memory or bus operation.



- Cores are an accurate metric of actual performance, as the VP's optimization is not constant, but depends on the workload.
- For example, the SPARC64 VII processor chip used in the M3000 has four cores and each has two VPs.
- Speed of single CPU or single core
  - Each core of a SPARC64 VII processor executes at 2.52 GHz, which means that one thread can execute 2.52 billion simple instructions per second.
  - This is the most important item for NDB, which has fewer execute threads (two or four Local Query Handlers to do most of the work) running simultaneously.
- Total CPU in terms of GHz.
  - This number represents the amount of work that the whole system can execute.
  - Multiply the clock-rate of the processor by the number of cores.
  - For example, the SPARC64 VII running at 2.52 GHz can execute 2.52 x 4 cores, or 10.08 GHz of work.
  - This is the most important number for SBR, which is well-behaved and generally scales to use all the CPU resources available until:
    - The I/O limit is reached
    - A single thread or other threads (such as the thread that reads RADIUS transactions from the network) utilizes all of one core's worth of CPU.

Table 12 on page 41 describes the SPARC processor models. For the latest information on SPARC processor models available for shipping, refer to your Oracle Sales Engineer.

**Table 12: SPARC Processor Models**

| SPARC Processor Model | Number of Cores | Number of Virtual Processors | Single-Core GHz Range | Total GHz   |
|-----------------------|-----------------|------------------------------|-----------------------|-------------|
| UltraSPARC T1         | 8               | 32                           | 1.0-1.4               | 8-11.2      |
| UltraSPARC T2         | 8               | 64                           | 1.2-1.4               | 9.6-11.2    |
| SPARC 64 VI           | 2               | 4                            | 2.15                  | 4.3         |
| SPARC 64 VII          | 4               | 8                            | 2.52-2.88             | 10.08-11.52 |
| SPARC T3              | 16              | 128                          | 1.65                  | 26.4        |
| SPARC T4              | 8               | 64                           | 3.0                   | 24.0        |

Table 13 on page 42 shows SPARC processors.

Table 13: SPARC Processors

| System Model Number | Processor Type            | Maximum Number of Processors |
|---------------------|---------------------------|------------------------------|
| M3000               | SPARC64 VI                | 1                            |
|                     | SPARC64 VII (recommended) |                              |
| M4000               | SPARC64 VI                | 4                            |
|                     | SPARC64 VII (recommended) |                              |
| M5000               | SPARC64 VI                | 8                            |
|                     | SPARC64 VII (recommended) |                              |
| M8000               | SPARC64 VI                | 16                           |
|                     | SPARC64 VII (recommended) |                              |
| M9000               | SPARC64 VI                | 32–64                        |
|                     | SPARC64 VII (recommended) |                              |
| T1000               | UltraSPARC T1             | 1                            |
| T2000               | UltraSPARC T1             | 1                            |
| T5120               | UltraSPARC T2             | 1                            |
| T5140               | UltraSPARC T2+            | 2                            |
| T5220               | UltraSPARC T2             | 1                            |
| T5240               | UltraSPARC T2+            | 2                            |
| T5440               | UltraSPARC T2+            | 4                            |
| T3-1                | SPARC T3                  | 1                            |
| T3-2                | SPARC T3                  | 2                            |
| T3-4                | SPARC T3                  | 4                            |
| T4-1                | SPARC T4                  | 1                            |
| T4-2                | SPARC T4                  | 2                            |
| T4-4                | SPARC T4                  | 4                            |

Using the total GHz, as explained in [Table 12 on page 41](#) and [Table 14 on page 43](#), you can estimate the expected performance based on the results in the current installation,

or on the expected results based on test results recorded in “SBRC System-of-Systems Performance Reference” on page 79.

For example, the results recorded in “SBRC System-of-Systems Performance Reference” on page 79 are for SBRC doing TTLS authentication with a cipher suite 0x002f on an M3000 2.75 GHz is 888 accepts per second.

- 2.75 GHz x 4 cores = 11 GHz.
- A SPARC T3-4 model (which can have 4 processors) can perform  $26.4 \times 4 = 105.6$  GHz total.
- Thus, the SPARC T3-4 model should be able to perform upwards of  $888 \times (105.6 / 11) = 8524$  TTLS accepts per second. This calculation should prove accurate, but might be limited by the single thread handling authentication network traffic as its utilization reaches the entirety of one 1.65 GHz core.
- T4 has special acceleration for single-thread throughput.

In a case of an existing SBRC system running WiMAX, for example, running on three T5120s (one SM node and two SSR D nodes), if you record an average transaction rate of 800 SPS, where the total average utilization of the SM node is 20 percent and the SSR's single maximum thread utilization is 1.0 percent out of a maximum of 1.56 percent ( $100\% / 64$  virtual processors = 1.56 % per VP from **prstat -L**), and you wish to upgrade to three M4000s with two CPUs:

- For the SBRC front-end application, you can expect a maximum of 8400 SPS [ $800 \text{ SPS} \times (20.16 \text{ total GHz}) / (20\% \times 9.6 \text{ total GHz}) = 8400 \text{ SPS}$ ].
- For the SBRC SSR, you can expect a maximum of 2995 SPS [ $800 \text{ SPS} \times 2.88 \text{ GHz} / (1.2 \text{ GHz} \times 1.0/1.56) = 2995 \text{ SPS}$ ].
- The back-end CPS will be slightly higher than these numbers due to decreased contention, as discussed in “Understanding Performance Metrics” on page 15, but this methodology allows a safe estimate.
- In this example, you are limited by the back-end utilization, and a greater overall increase will be noticed going to four D nodes of the M3000 with one processor running at 2.52 GHz (for approximately  $2 \times 2995 = 5990 \text{ SPS}$ ), versus two D nodes of the M4000 with two processors each.

Table 14 on page 43 describes some of the Intel processor examples.

Table 14: Intel Processor Examples

| Intel Processor Model | Number of Cores | Number of Virtual Processors | Single-Core GHz Range | Total GHz |
|-----------------------|-----------------|------------------------------|-----------------------|-----------|
| X5687                 | 4               | 8                            | 3.6                   | 14.4      |
| X5660                 | 6               | 12                           | 2.8                   | 16.8      |
| X5690                 | 6               | 12                           | 3.46                  | 20.76     |

Table 14: Intel Processor Examples (*continued*)

| Intel Processor Model | Number of Cores | Number of Virtual Processors | Single-Core GHz Range | Total GHz |
|-----------------------|-----------------|------------------------------|-----------------------|-----------|
| E7-4870               | 10              | 20                           | 2.4 <sup>1</sup>      | 24        |

<sup>1</sup> E7-4870 uses Intel “Turbo Boost Technology,” which can attain a maximum frequency of 2.8 GHz under heavy use.

In the Intel processor example servers described in [Table 14 on page 43](#), the following configurations are optional and there is no model number that references all the options specifically:

### Standalone or Front-End Applications

The following server example can be optimized for throughput:

HP DL380 2 x X5687, 8G, 200G fast (512 Mbps+) SSD (mirrored or RAID 1), or HDD (RAID 0, RAID 1, RAID 10 for highest performance). In the case of SSD, a 6 Gbps SATA with Sandforce-based SSDs (like the Intel 520) performs well for accounting and local CST because the data can be compressed. For long-term or compressed log storage, a separate HDD would be useful.

The following server examples can be used for better proxy and TTLS cases:

- HP DL580 2 x E7-4870, 8G, 200G fast SSDx4 (RAID 10), or 2xRAID 10 HDD
- HP DL580 2 x X5690, 8G, 200G fast SSDx4 (RAID 10), or 2xRAID 10 HDD

The following server example can be used for running four virtual instances of SBR:

HP DL580 4 x E7-4870, 36G memory, 2x (128G fast SSDx2), or RAID—one for each instance.

### Back Ends

The following server examples can be used for back ends:

- HP DL380 2 x X5687, 16-64G, 100G fast SSDx2, or HDD RAID 0 or 10 (mirrored or RAID 0)
- HP DL980 2 x E7-4870, 16-64G, 100G fast SSDx2, or HDD RAID 0 or 10

### Retries

The upstream RADIUS devices (such as NAS devices, load balancers, or SBRC sending to downstream proxies) must reattempt the same RADIUS transaction to the same SBRC front-end applications at least three times (with a 5-second retry period) before trying another front-end application. Another common method is five retries with a 3-second interval before trying another front-end application.

RADIUS is a UDP-based protocol with application-level retransmit semantics that can easily be configured and tuned in the client, unlike the TCP protocol retransmissions which are generally tuned at the system level.

Within the network, many network devices and operating systems drop UDP packets preferentially under certain cases of heavy traffic. Specifically, both Linux and Solaris may drop UDP packets if one of the buffers in its network stack is nearing full capacity. In a lab environment, under heavy load, you will often see some packet loss at the OS level, which occurs in accordance with the protocol design.

The retransmit semantics of three retries x 5 seconds each (3x5) or five retries x 3 seconds each (5x3) provide a good likelihood of avoiding traffic spikes on the network. This gives a reasonable amount of resilience, so that the underlying network protocols can reroute traffic and failure recovery semantics can occur in failure conditions.

A retransmit to one SBRC front-end application activates the RADIUS packet cache, which short-circuits the processing of the in-process or recently processed transactions. This means that a server receiving a second request generally returns the result immediately (with less overhead) without repeating the work, if the result has been returned already.

Using a retransmit time in hundreds of milliseconds conflicts with even the most ambitious failure recovery settings, turning what would otherwise be a recoverable failure scenario (for example, the outage of part of a cluster, or the loss of connectivity on one network adapter) into an unrecoverable one as far as the customer experience is concerned. This causes the system to do more work since the same work might be attempted over multiple front-end applications, and conflict resolution adds additional overhead with each retried attempt.

Three to four retries of 1 to 2 seconds each before trying a second front-end application (similarly for the third) is probably safe under most circumstances with sub-millisecond network latency and few-millisecond back-end DB latency. However, lesser values are entirely unsupported. Larger is better to the point where failures might seriously impact the user. Frequent failures of this mode, in any event, should be diagnosed.

In summary, the retry semantics are a function of the system resilience and should be set higher rather than lower. This avoids making a transient problem appear to be a more permanent one by, for instance, incorrectly failing an authentication and allowing a failure situation to become worse in the process.

Thus, three retries of 5 seconds each are nominal, human-level speeds that will permit wide latitude for successful failover scenarios.

## Load Balancing on RADIUS Front-End Applications and Downstream Proxy Devices

In high-end cases of multiple front-end SBRCs to one SSR, or multiple SAs operating in parallel, it is important that the load balancers in SBRC (whether they are commercial load-balancing devices or versions of SBR SA running proxy and doing round-robin) have the properties described in the following sections.

## Stateful and RADIUS-Aware

Load balancers should be stateful and continue to send packets of the same transaction cycle to the same SBRC front-end application. In the case of EAP over RADIUS, a single EAP stream under RADIUS Auth-Request Challenge-Response pairs must continue on the same front-end application until that front-end application returns a success, reject, or exhibits a failure, in which case the failover of authentication to another SBRC in the middle of an EAP negotiation will become a reject and the user must retry the connection.

The *State* attribute in the RADIUS request and response describes which front-end application processed the request. Alternately, the NAS-IP-address and port for most devices are unique identifiers, and the Calling-Station-ID can be used in some use cases.

In most cases, accounting should be processed on the same front-end application as authentication. If the load-balancing device can parse attributes, the class attribute can be used to route starts, interims, and stops to the originating NAS.

In some cases, for example, multiple SBRC SA front-end applications might be doing heavy authentication work (for example, TTLS with separate inner authentication proxying to SBRC cluster front-end applications), and the devices can send the accounting directly to the SBRC cluster front-end application, bypassing the unnecessary proxy step.

While TTLS may be cluster-enabled and thus reauthentication optimized across multiple nodes, TLS reauthentication optimization for a device, on the other hand, should attempt to use the front-end application that the previous device used, either by adding return attributes for server biasing, or using Calling-Station-Id or the User-Name, if it represents the device ID. If the front-end application fails, this reauthentication optimization does not need to occur and a full authentication cycle against any working front-end application can take its place.

FastFail is a failover mechanism in SBRC SA for proxy. It performs failover of the transactions from one downstream to another until a strobe of a failed target succeeds. This can be used to optimize performance under conditions of temporary failure. If failover might occur to SBRC front-end applications in a different NOC, you should scope your system so that each NOC can handle the work of the entire system.

## Network Configuration for SSR

A key source of contention within the SSR is the lock that must be in use to keep the two mirrored D nodes (data nodes) operating in lock step, related to the “two-phase commit” performance transaction in all redundant SQL systems. If a database node needs to update a piece of data in the row (for example, the SSR CurrentSessions table), it must request its mirrored pair to halt any other changes to that row, update both copies of the row in parallel, then release the lock. The amount of time taken to place the lock and update the data is partly a function of the CPU and the latency of the total operation from the first lock to the last release. Aggregate operations such as session deletes for multiple sessions, or IP address allocation, must take one lock for several ndb-level operations within it, and each will be slower due to latency.

## Why Latency Kills Performance: D-D and S-D

Latency between the data nodes (D) significantly reduces the overall throughput of the SSR. In any system that requires the highest levels of performance and reliability, latency of even multi-milliseconds cannot be recommended. Simple cases that look up by primary key, do not do database updates via interims, or have no phantoms, are more resilient to latency. Since each use case is different, testing for sustained throughput (in a lab environment) with latency while measuring the performance of the system is strongly recommended.

Similarly, the latency between S and D nodes (SBR and data nodes) decreases the throughput of the node due to the present NDB limitation of 120 ndb handles per API node. Each handle has a request outstanding, and these outstanding requests will take longer to process to completion when latency is high. In this case, additional S nodes are required to make up for the latency to meet the same bandwidth.

## Subscriber Scaling

Scalability for the SSR and SBRC front-end application is calculated based on the following dimensions:

- Inserts, deletes, and searches in the SSR indexes become slower as simultaneous sessions are added by a factor of approximately  $O(\log_2 n)$ .
- The number of TPS carried out by the system as a whole, required to sustain the user base, especially at the peak rates. Here, the number of auths, starts, and stops varies largely and is timed variably for mobile users, or items such as always-on devices, which may be rare.

The number of interim accounting transactions scales linearly with simultaneously connected subscribers and the interim period, and causes a significant amount of load especially with a short interim period. Reducing the interim period by half doubles the number of packets that must be managed; doubling the interim period reduces the amount of packets by half.

It is possible for devices that reconnect at set times (for example, at midnight or 2:00 a.m.) or otherwise manage to synchronize in time (due to, for example, a SGSN failure or a GGSN reset) to provide periodic spikes of traffic. Both the amount of traffic due to reconnection and the amount of traffic of future interims can match in time. You will often see something much closer to peak usage, as opposed to spreading the load out over the hour, which may prove an issue in deployment. Various solutions can be implemented, but the biggest benefit is seen by decreasing the interims that the SSR sees, followed by injecting a time skew in the reconnection process, either through the device, or through control points in SBRC.

## Why Are Interims Hard, and When Can They Be Thrown Away?

Interim accounting is an update transaction managed by the SSR. In most cases, stops only need a primary key search and a delete operation, with limited data transmitted to or from the SSR. Interim transactions include the work of a primary key search and the database row update of an accounting start, plus returning most or all of the data for

that row for reliable updating of indexed fields that changed, all under a row lock to keep the data consistent. Of all the per-RADIUS transaction operations against the SSR, the interim packet requires the most work to process.

Accounting interims may have been implemented as a way of doing a stop-loss for accounting purposes, in case the RADIUS server does not receive a stop. You can reliably bill the usage (for usage-based plans) for which you have received an interim and a stop was not received due to a failure. In this case, the SSR does not need to be updated by all interims, and the parameter **UpdateOnInterim** in **radius.ini** can be set to zero.

In certain cases, accounting interims are used to extend the session life. For example, if devices reauthenticate daily, by setting the Session-Timeout to a little over a 24-hour period, you can avoid the use of interims to extend the session life and also set the **UpdateOnInterim** parameter to zero. Interims will still be available for accounting-level processing, but need not hit the CST.

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## Handling Downstream Latency and Traffic Spikes

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This section explains the following:

- [Thread Control on page 48](#)
- [Flood Control on page 49](#)



**NOTE:** Proxy threads and proxy floods are used only when **Block=0** is set in the **[Acct]** section of the **RealmName.pro** file. See the *Juniper Networks Steel-Belted Radius Carrier Reference Guide* for more information.

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### Thread Control

This section provides information on the following thread control settings in the **[Settings]** section of the **radius.ini** configuration file:

- **Max-Auth-Threads** = 1 to 100,000 (default 100)
- **Max-Acct-Threads** = 1 to 100,000 (default 200)
- **Max-Proxy-Threads** = 1 to 100,000 (default 100)

Each thread setting controls the maximum number of threads allocated to handle the system load. The auth and acct thread settings manage the state and latency of the process as a whole, with the proxy threads coming into play for those proxies whose **Block=0**. Authentication and accounting, in this case, pass the work to another proxy thread and return a result immediately, and then wait for another transaction.

- **Auth-Receive-Realtime-Thread-Priority** (default value is 2,147,483,647, not real time) in the **[Settings]** section of the **radius.ini** file
- **Acct-Receive-Realtime-Thread-Priority** (default value is 2,147,483,647 not real time) in the **[Settings]** section of the **radius.ini** file



For *WorkerThreadStackSize* in the [Settings] section of the **radius.ini** file, the default value is 524,288 bytes (512K) for both Solaris and Linux. If a value is set for *WorkerThreadStackSize*, it overrides the system default stack size for worker threads (128K through 256K is sufficient in most cases); however if the value is too small, SBRC may core.

## Flood Control

When all the auth and acct threads are in use simultaneously and flood queues are enabled, packets received are placed in a queue to be processed on a best-effort basis, in a defined order.

To see the flood queue in action, turn on the Flood info parameter in the [Status] setting of the **radius.ini** file. See the *Juniper Networks Steel-Belted Radius Carrier Reference Guide* for more information.

## Settings

- Set the Max-Auth-Floods, Max-Acct-Floods, and Max-Proxy-Floods values to 0, which is the number of packets retained by the flood queue. The memory utilization overhead will be slightly higher than the average packet size times the number of floods.
- The value for Max-Auth-Threads-In-Flood, Max-Acct-Threads-In-Flood, and Max-Proxy-Threads-In-Flood by default is half the total threads for the type. The minimum value is 1 and the maximum value is the number of threads configured. This is the maximum number of threads that will be allowed to process packets in the flood queue, rather than taking new work.
- The value for Auth-Flood-Queue-Shape, Acct-Flood-Queue-Shape, and Proxy-Flood-Queue-Shape is FIFO, LIFO, or RAND. This is the order in which the queue is drained, as well as the order in which packets are dropped if the flood queue is filled.
  - FIFO (First-In-First-Out)—Drops the new packet if the queue is full; recommended for most instances.
  - LIFO (Last-In-First-Out)—Drops the oldest packet in the queue when the queue is full, always puts the new packet at the start of the queue, and always gets the last packet in the queue first. Recommended when you know you will have to throw packets away, in certain cases, to keep up with workload.
  - RAND (Random-in-Random-Out)—If the queue is full, drops either the first packet in the queue or the packet being received in order to get an item of work out of the queue. Pops a random packet in the middle of the queue as the next item. This is rarely recommended, but approximates random delays. For certain use cases, it helps to moderate the effects of DDOS attacks (for example, avoid one NAS being loaded with responses).



## CHAPTER 4

# Understanding the SBRC Network Architecture

This chapter provides a reference to a highly reliable network architecture for SBRC. It explains some existing error-handling techniques in SBRC which can be used to improve the overall performance and reliability of the system of systems.

SBRC cluster solution is architected based on principles which permit upwards of “5 9s” (99.999 percent) system uptime as a whole, outside of maintenance windows, making the system highly resilient to failures.

Redundancy is offered at multiple levels in SBRC:

- Within the RADIUS transmission structure, built on UDP, NAS devices at the application-level can retransmit to different devices after several attempts to the same device have failed before timing out the user.
- Within authentication, accounting, and proxy functionalities, multiple back ends or downstream RADIUS servers are attempted with appropriate retry semantics.
- Within the SSR, MySQL NDB is resilient to system outages of a single component (a machine or a network component) and some multi-component failures (for example, cluster splits).
- At the networking layer, utilizing techniques such as IP multipathing (IPMP), failures in hardware components such as network adapters, cabling, and switch outages, can be managed.
- At the machine layer, using RAID-5 or external storage with RAID mitigates the risk of disk failures. The implementation of Oracle's advanced system maintenance in terms of hot-swappable drives and power supplies limits the risk of total subsystem unavailability. The regular use of ECC (Error Correcting) memory helps to avoid memory corruption.

This chapter explains:

- [SBRC Architecture Overview on page 52](#)
- [Understanding “Geodiversity” Between the SSR D Nodes on page 54](#)
- [NDB Cluster Timeout Dependencies on page 55](#)

- [High Throughput Configurations on page 57](#)
- [Risks to Uptime within the Architecture on page 57](#)

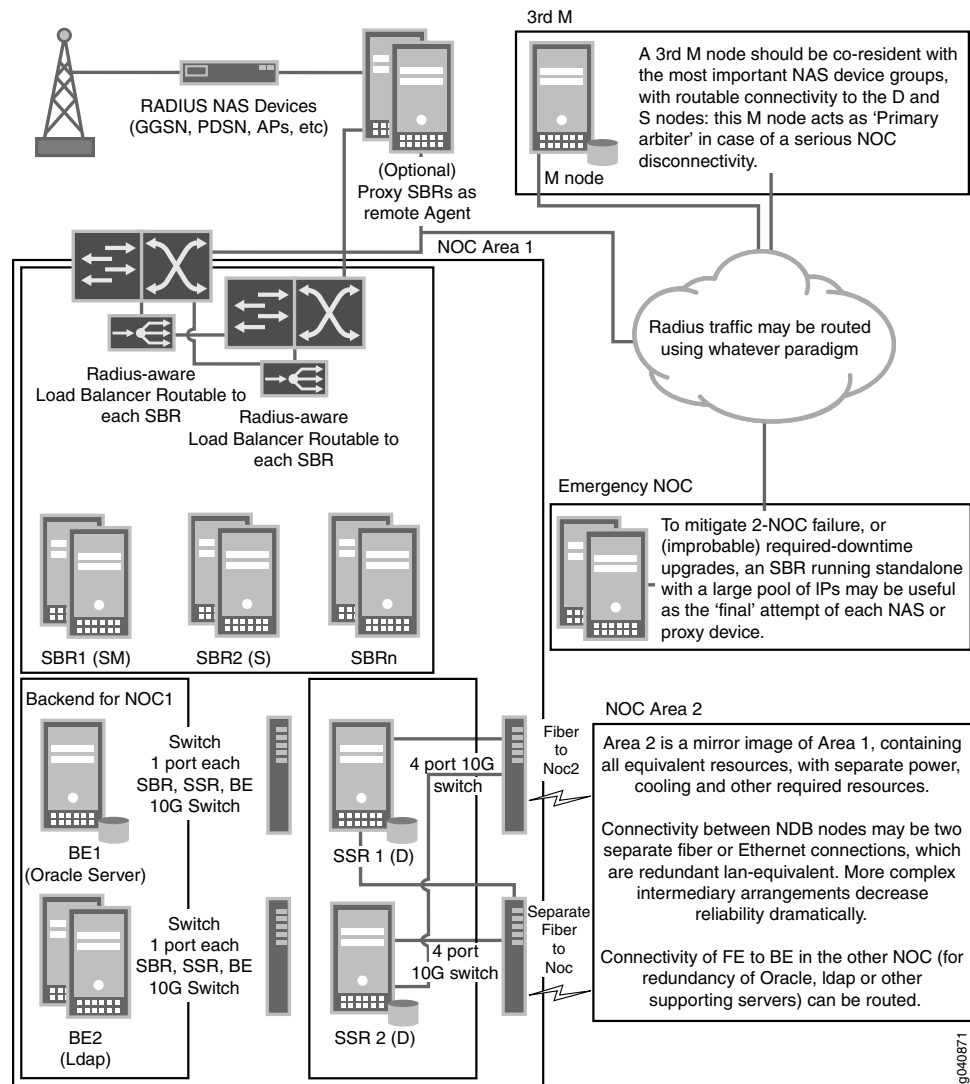
## SBRC Architecture Overview

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The following two key principles are primarily considered in a high availability system:

- **Redundancy**—The function of each network component and the subsystem should be replicated completely, both in terms of functionality as well as throughput. In case of a failure, half of the SBRC system or subsystem must be able to support the work of the entire system.
- **Separation**—Components that can fail individually should be permitted to fail individually. Thus, the NOC Area 1 and NOC Area 2, representing two different NOCs or two different sections of the same NOC (see [Figure 5 on page 53](#)) should function independently when an environmental failure occurs.

Figure 5: SSR Redundancy Architecture



Routing of the RADIUS traffic can be done using reliable networking techniques, either at OSI Layer 2 or 3. Since UDP traffic is retransmitted by the application layer at a comparatively slow retransmit rate, it is resilient to routing changes and packets being dropped during that reconfiguration.

In general, the Transmission Control Protocol (TCP) and Stream Control Transmission Protocol (SCTP) also have a relatively strong tolerance for additional latency due to routing changes, and traffic to the back-end servers (SBRC front-end application to authentication, accounting databases, or SSR) may be routed, although switching generally provides the lowest latency.

However, the intra-D node traffic, which attempts to keep two copies of the same data in lock-step, requires both low latency and high reliability, and should be managed through Layer 2.

IPMP, used to configure a single virtual address, which floats between one of the two physical adapters, is recommended. This is generally used in active-standby mode with active probing and failure detection time (which may be from 200 to 400 milliseconds), and can be varied based on the relevant heartbeat timeouts, in the case of NDB, and RADIUS retransmit semantics or database timeouts for other back ends.

See the *Oracle whitepaper Highly Available and Scalable Oracle RAC Networking with Oracle Solaris 10 IPM*

(<http://www.oracle.com/technetwork/articles/systems-hardware-architecture/ha-rac-networking-ipmp-168440.pdf>) for more information.

In a red-black network that separates the outward facing components from the inner “back-end” components, each SBRC S node will have a single virtual address on two physical adapters connecting to the two externally facing network devices. Each SBRC S node will also have a second virtual address connecting to the two physical adapters, which in turn connects to the back ends (SSR or authentication/accounting databases), the latter of which should generally be switched (and may provide Layer 2 routed access to a failover server in another NOC).

The emergency NOC can be placed in a separate location as a server of last resort to lessen the impact of critical, multi-system failures. A determination can be made on how promiscuous this server is: in many cases, where there is no response from the primary system (rather than a response with a reject), from a business point of view, a carrier can permit temporary access freely instead of being rejected due to these central failures.

The third M node used by the SSR must have at least low-bandwidth medium latency (less than 100 milliseconds round trip) routed connectivity, possibly via a firewall, to each D node and to the other M nodes. This M node serves as the final arbiter to determine which side of the cluster should be considered ‘alive’ if both fiber connections between the two NOCs split entirely. If there are only two M nodes in two different NOCs, then on a cluster split, one set of nodes survives and the other fails, but the surviving NOC might also be undergoing a connectivity failure to the rest of the system during the failure. This third M node should be collocated with the most important exterior devices, if any, with which you wish to preferentially maintain connectivity, in the event of certain major network failures.

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## Understanding “Geodiversity” Between the SSR D Nodes

---

Being the very core of the system's reliability, SBRC does not claim support for geodiversity among the SSR D nodes, since the underlying technology (Oracle MySQL NDB) does not claim such support. At the SBRC level, geodiversity can be supported at a split in the RADIUS layer with a second NOC installation with either its own SSR, or a load-balanced series of standalone systems to provide additional, perhaps limited, functionality through an unrelated SSR in a master/failover way.

That disclaimer made, as a matter of prudential and engineering judgment, a pair of single-mode fibers, each end connecting to switches at two different NOCs is a legitimate mechanism of providing LAN-equivalent functionality which should provide a similar level of uptime and supportability as a non-geodiverse solution.

However, in terms of network architecture, the further away from a literal pair of fibers you get, the further from optimal uptime you will achieve: each intervening piece of equipment, no matter on which network layer it operates and even if the device itself reaches 5 9s or greater, actually gives greater risk, from both a technical ( $99.999\% * 99.999\% = 99.998\%$ , and that is multiplicative for each device in series) as well as a human point of view. This is due to the possibility of inducing certain types of network latency (for example, when being reconfigured or reprovisioned) that will lead to a temporary outage and require additional recovery time, or an extended outage due to human or system error. It is often difficult to diagnose these transient latency increases, although with SBRC Release 7.4.0, logging within the SSR D nodes has been improved.

In any managed MPLS network, even rigorous SLAs can be written in such a way that jitter, packet loss, and latency might rise above the tolerances of the ndb transport, and as such, cannot be supported.

## NDB Cluster Timeout Dependencies

This section describes timeout dependencies between various SSR data nodes. A certain ratio must exist between each OSI stack-level failure condition, specifically between NAS clients and the RADIUS front-end applications, the RADIUS S node and the D nodes, and the ndb and dbapi nodes (M nodes and D nodes). This dependency is related to timeout values associated within the network and the NDB itself.

The network between the S nodes and the D nodes has the following timeout dependencies.

- If you are using IPMP, the IPMP probe value must be lower than twice the heartbeat timeout appropriate for the connection. Widely divergent values may impact performance in a failure case, leading to unexpected outage.



**NOTE:** Default values for the S or M nodes and the D nodes are controlled by the `/opt/JNPRhadm/config.ini` file on the M nodes. This value is set by **HeartBeatIntervalDbApi** and is 1500 milliseconds by default. The inter-D node timeout is set by **HeartBeatIntervalDbDb** and is 200 milliseconds by default.

- Heartbeats are implemented in and among the D nodes so that failures are more quickly detected than the underlying TCP failure mechanism can detect. The initial detection of fault happens after the interval of  $4 \times \text{HeartBeatInterval}$ . After initial detection, the D nodes attempt to repartition and form a valid cluster. This operation can take several to many seconds, depending on the type and mode of failure. Single D node hard failures or hard networking loss are quickest to detect. Complete cluster splits and serious network faults take longer to detect and compensate.

System overload affects fault-recovery performance. Many outstanding transactions take longer to roll back than a few outstanding transactions.

- During an extended loss of service due to a significant failure, such as loss of connectivity between two halves of a cluster, SBR Carrier might need to reconnect to the new cluster to continue processing. The failures of reconnection are managed by timers set by the

[Ndb] values— **DelayBetweenConnectRetriesSec** and **ReconnectRetriesin**—in the **dbclusterndb.gen** file. Setting these values higher than the defaults can make the system more resilient at the expense of a period of dropped RADIUS traffic. Setting the values of **TimeoutForFirstAliveSec** and **TimeoutAfterFirstAliveSec** lower may also increase resiliency.

- Some NDB operations are designed to retry the network to avoid lock contention. In cases where the underlying network is prone to latency or dropped packets, increasing the values of **Retries** and **DelayBetwenRetriesMillisec** in the [Database] section can improve performance and decrease delays.
- In cases where the underlying network is prone to short or long periods of latency, fault, or other unexpected cases, setting the value of **HeartBeatInterval** higher and setting all the proportionally related values appropriately can make the system more resilient. The trade-off is a fast detection of serious failures against the acceptance of temporary processing delays. The delays are due to minor faults that are otherwise survivable.
- In cases of NDB cluster failures due to extended one-way traffic failure between the inter-D and SM-D network, you need to automatically restart a node. A correct network design should not permit this failure to happen. IPMP probes with the correct values, for instance, cause this to fail over to a working link. The **HeartBeatOrder** fixes temporary instances of this type of failure. See the *SBR Carrier Reference Guide* for more information about the **HeartBeatOrder** parameter.
- Certain failure conditions may require you to perform a manual restart. These failure conditions are usually associated with serious, extended, and pathological network dysfunctions.
- The default settings of **CacheLowWater**, **CacheHighWater**, and **CacheChunkSize** may cause badly degraded performance. The defaults cannot be made higher because one S node can pre-cache all the addresses in a small pool if the **CacheLowWater** is set higher than the number of addresses in a pool. Default values of **CacheLowWater** and **CacheChunkSize** are related to the transaction rate of new address allocations for the installation. Hence, it is impossible to run out of addresses before the threads can fill up the cache, and you can use Per-Pool settings to set any small pools much lower than the default.

Set **CacheThreadVerbose=1** and inspect the logs for Emergency allocations. If **CacheLowWater** and **CacheChunkSize** are too low, then performance is degraded. Another indicator of degraded performance is low CPU utilization on the front-end applications and high CPU utilization on NDB.

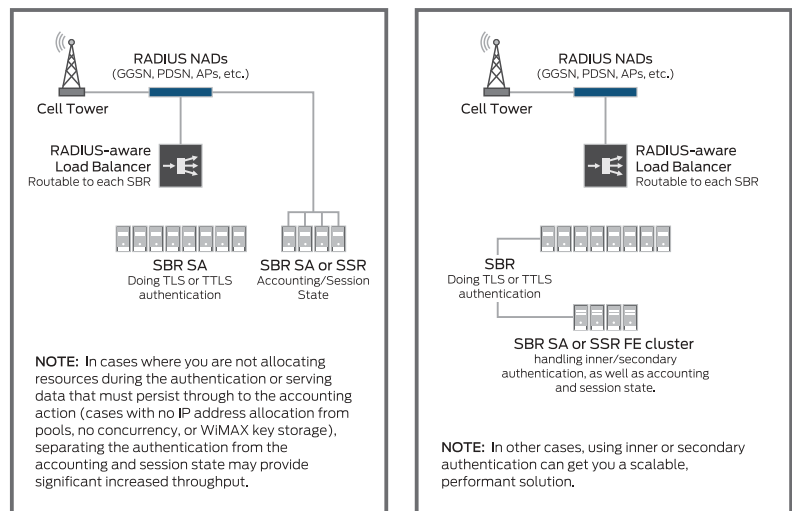
- The **ConnectCheckIntervalDelay** parameter comes into play when a heartbeat timeout occurs. At this time, the node will begin a connectivity check, pinging all nodes 3 times with the configured interval. The responses indicate whether the other nodes are trustworthy (that is, respond 100%), untrustworthy, or down (no response). Only messages from those nodes that are trustworthy will be considered during the regular election cycle. This feature helps protect against intermittent latency spikes.



## High Throughput Configurations

In cases that require lesser levels of redundancy, a system of SBRCs can be configured with a more standalone approach to provide scaling. The separation of authentication and accounting paths can be made when the RADIUS accounting (especially, the start) carries all the information that needs to be contained within the session state.

Figure 6: High Throughput Configurations



When the advanced cryptography load sufficiently outweighs the resource-allocation work (for concurrency and IP address allocation through the SSR), load-balancing the cryptography over multiple machines while doing the resource allocation in a central way can provide a total throughput increase.

## Risks to Uptime within the Architecture

Risks can be classified under the following three categories:

- Resources on which SBRC is dependent (such as external databases) can fail to function and cause the SBRC to do additional work to recover, extending the service outage until the entire system has reached a functional stasis again. For example, with a very large number of worker threads and a high transaction rate and high disconnect or reconnect rates, SBRC can take a longer time to process the backlogged transactions after a target back-end server recovers from failure than the duration of the initial outage.
- Partial hardware-based failures can cause unexpected broader problems. For example, networking among the D nodes, consistent latency transactions, especially those that are pinpoint or peer to peer (generated by an incorrect firewall rule, or router reconfiguration update operations) of certain values can cause a temporary cluster outage.
- Software errors:

- While most software errors are automatically recovered and affect one node only, being a complex system, there are a few forms of software errors that could cause an extended outage. To manage this risk, submit cases of transient errors with JTAC with the appropriate information as referenced in the troubleshooting section, as soon as possible, to avoid the problem being repeated or becoming worse.
- The most dramatic software errors are often termed a “packet of death.” invariably, in concert with a complex level of functionality, this form of software error involves a packet that is well-formed from a RADIUS perspective and malformed from a processing perspective. Items such as zero or single-byte null fields can cause poorly defended customer-defined SQL statements, stored procedures, or JavaScripts to error seriously. Other items might trigger unexpected side effects within packet processing. Since a great deal of processing is done and given the vast complexity of use cases, enough corner cases are tested for within Juniper Networks this form of software error is still possible.
- You can lessen these sorts of errors by keeping track of the uptime of the system, monitor and diagnose transient rejects and errors, and implement the recommended final failover emergency NOC. This could be an SBRC running with full logging, by default, to trap the unexpected packets that have failed other processing.

## CHAPTER 5

# Debugging Performance and Functionality Problems

This chapter provides information you can use to determine the scalability of an existing SBRC system and debug system performance issues.

- [Determining the Effective Performance and Peak Capacity on page 59](#)
- [Calculating Performance Scaling on an Existing System on page 60](#)
- [Debugging Performance Issues on page 62](#)
- [Notes on Debugging Performance Issues on page 68](#)

### Determining the Effective Performance and Peak Capacity

---

The key to determining the capacity of an existing or a planned SBRC system is not measured by average operational performance, but rather by expected or observed periods of peak activity. SBRC performance should generally be nominal during regular day-to-day system operations with significant unused capacity. The following exercise will help you determine how close the SBRC system is to possible peak performance for the hardware platform under evaluation.

For an existing SBRC system running continuously for a period of time and experiencing peak traffic, failures, and spike conditions, do the following:

1. Determine the “Peak” throughput in authentications, account starts, and stops using the **Statistics** page in Web GUI. Record these values and add them up.
2. Measure the system by simultaneously monitoring the following over a defined period (at least 5 to 10 minutes during “peak” user-level activity timeframes):
  - a. Average auths and accts/s for the period from the Web GUI (which you can clear before starting the test), and note the total interims done over the period.
  - b. Monitor the system using **prstat -L** to view the highest utilized thread for the period and its percentage utilization. This value is the strongest indicator of the overall scalability of SBRC, which in almost all cases performs well on multiple processors. The hard limit is often the utilization of one key thread that does slightly more work than other threads. This is more important on machines with more and slower

virtual processors, as compared to machines with fewer and faster processors such as the M3000.

- c. Use **prstat** to check and note the overall CPU utilization. This helps you determine the available CPU power to do the work of all the threads.
- d. Run **sar** with an interval of 5 minutes (**sar 300 1**). The result should be similar to **prstat**, but with information categorized based on `usr` and `sys`. A large amount of `sys` utilization means the system is processing more I/O and network work.
- e. Run **iostat** with an interval of 5 minutes (**iostat 300 1**) and note any devices that are heavily used. This gives you information about logging performance.

For example, executing our own load test tools for accounting on the M3000 may see a utilization of 3 Mbps, which is an average amount. You can also use (**iostat -E 300 1**) to obtain a utilization percentage number that you can use as a reference to maximum theoretical capacity calculated by the OS.

- 3. Calculate the expected utilization during peak performance by dividing each result obtained in Step 2a through Step 2e by the average TPS for the test period, and multiplying the value with the peak TPS. This gives you an estimate of the CPU resources and I/O resources that will be utilized during peak performance.
- 4. Record the following information of the results of calculations based on Step 3:
  - a. The projected highest single-thread utilization from **prstat -L**. If this is more than 90 percent of the single-CPU performance (determined by dividing 100 by the number of virtual processors), you will run out of CPU resources to handle the workload at peak.
  - b. The expected overall CPU utilization at peak. If this is more than 90 percent, you will run out of CPU resources.
  - c. The expected I/O utilization at peak. If this is more than 60 percent of the rated throughput on the drive, which varies by model, you will soon run out of resources. I/O utilization at 60 percent assumes activities such as “seek before writing” as a disk becomes full, which induces latency.

This is a good approach for calculating the existing nominal system usage and determining the performance characteristics at seen peak usages. With these calculations in hand, you can help ensure enough throughput to sustain peak usage for an extended period.

---

## Calculating Performance Scaling on an Existing System

---

Use [Table 15 on page 61](#) as a worksheet for calculating the performance scaling numbers of an existing SBRC system.

Table 15: Worksheet for Calculating Performance Scaling

| Category  | Front End 1 | Front End 2 | Front End 3 | Front End 4 | Total |
|---|-------------|-------------|-------------|-------------|-------|
| Before you start the test, you must gather the historical information of the SBRC system from the <b>Statistics</b> page in Web GUI.  |             |             |             |             |       |
| 1. Peak accepts/s.  |             |             |             |             |       |
| 2. Peak starts/s.   |             |             |             |             |       |
| 3. Peak stops/s.  |             |             |             |             |       |
| 4. Interims per start.<br><br>(Divide the interim requests by total starts.)  |             |             |             |             |       |
| 5. Challenges per accept.<br><br>(Divide challenges by total accepts.)  |             |             |             |             |       |
| Clear the results from the Web GUI and examine the system load at high usage for a defined period (5 minutes). This should not significantly impact the system performance. |             |             |             |             |       |
| 6. Average accepts/s.   |             |             |             |             |       |
| 7. Average starts/s.  |             |             |             |             |       |
| 8. Average stops/s.   |             |             |             |             |       |
| 9. Interims per start.  |             |             |             |             |       |
| 10. Challenges per accept.  |             |             |             |             |       |
| View the system statistics during the trial period.   |             |             |             |             |       |
| 11. Run <b>prstat</b> with average load during test.  |             |             |             |             |       |
| 12. Run <b>prstat -L</b> to view the highest thread utilization.  |             |             |             |             |       |
| 13. Run <b>sar 300 1</b> to calculate the usr percentage.   |             |             |             |             |       |
| 14. Run <b>sar</b> to calculate the sys percentage.   |             |             |             |             |       |
| 15. Run <b>iostat 300 1</b> for I/O utilization, in kps.  |             |             |             |             |       |
| 16. Run <b>psrinfo</b> to determine the virtual CPU count.  |             |             |             |             |       |

Table 15: Worksheet for Calculating Performance Scaling (*continued*)

| Category   | Front End 1 | Front End 2 | Front End 3 | Front End 4 | Total |
|--|-------------|-------------|-------------|-------------|-------|
| 17. One CPU as a percent of the system.<br><br>(Divide 100 by the value of #16.)   |             |             |             |             |       |
| Peak scaling is calculated by the result of #17 (assuming ratios of #4 and #5 are approximately equal to #9 and #10, respectively.)  |             |             |             |             |       |
| 18. Calculate the overall CPU utilization at peak.<br><br>(Divide the value of #11 by the value of #7 and multiply the result with the value of #2.)   |             |             |             |             |       |
| If the overall CPU utilization (result of #18) is nearing 90 percent, then the system is presently constrained by the CPU utilization.   |             |             |             |             |       |
| 19. Calculate the highest thread utilization at peak.<br><br>(Divide the value of #12 by the value of #7 and multiply the result with the value of #2.)  |             |             |             |             |       |
| If the highest thread utilization (result of #19) at peak is closer to the result of #17, then the system is presently constrained by the single-core CPU speed.   |             |             |             |             |       |
| 20. Calculate <b>sar</b> at peak.<br><br>(Add the values of #13 and #14, divide by the value of #7, and multiply by the value of #2.)  |             |             |             |             |       |
| If the result of #20 is nearing 90 percent, then the system is constrained by CPU utilization. If this trend continues and exceeds 90 percent, then the system will run out of CPU resources.<br><br>The result of #20 should be similar to the result of #18. |             |             |             |             |       |
| 21. Calculate <b>iostat</b> kps at peak.<br><br>(Divide the result of #15 by the result of #7 and multiply it by the result of #2.)  |             |             |             |             |       |
| If the result of #21 is nearing 60 percent of the rated speed of the drive, then the system will soon become I/O bounded.  |             |             |             |             |       |

## Debugging Performance Issues

This section describes the three common bounding scenarios of a live SBRC system, which can be verified using the tools listed in [Table 15 on page 61](#). They are:

- [CPU Bound on page 63](#)
- [I/O Bound on page 65](#)

- [Contended Systems on page 67](#)

Focus is primarily on Solaris tools, but the techniques of analysis apply to Linux as well.

## CPU Bound

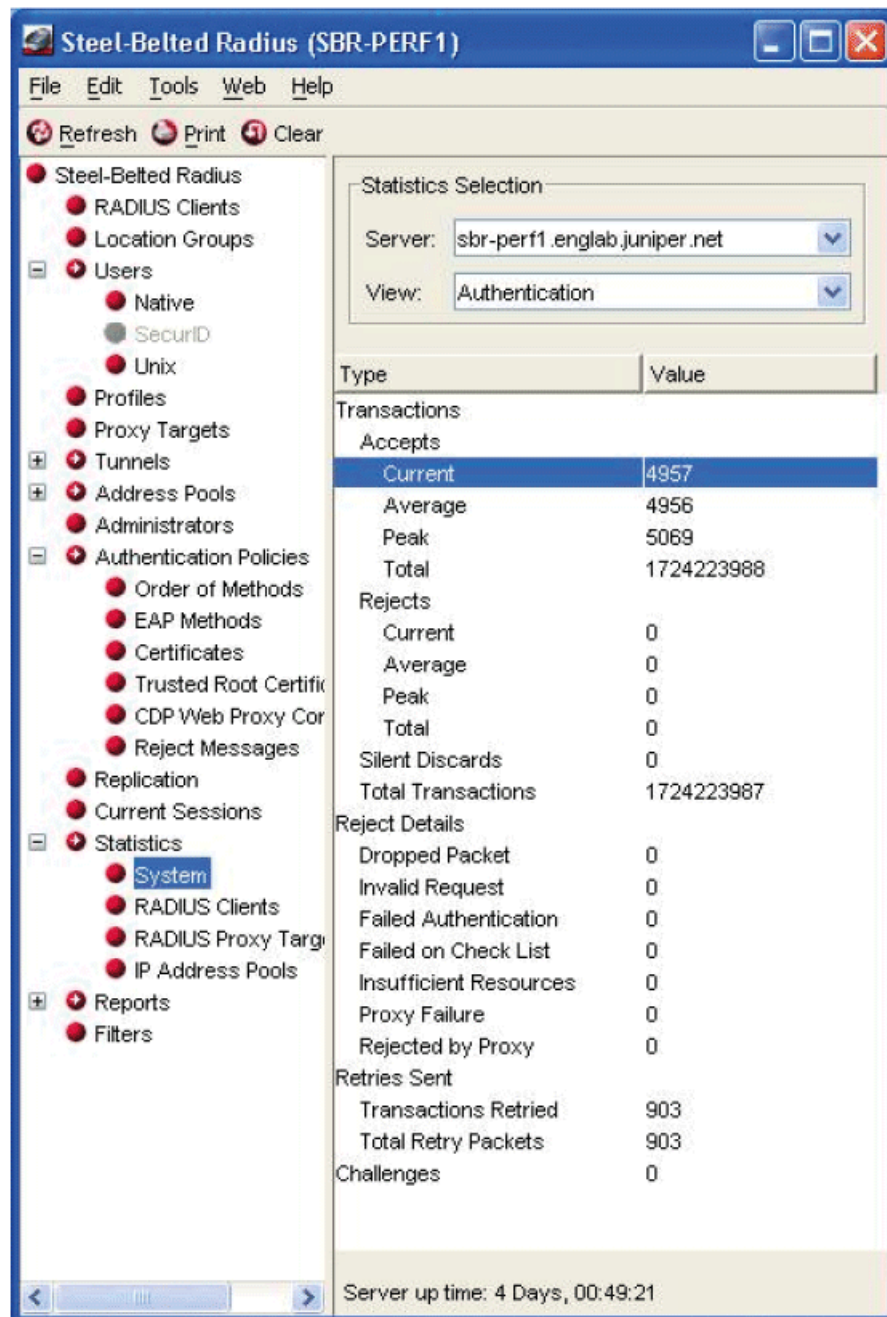
This section shows output in which the SBRC is well utilizing the available CPU and the CPU utilization is spread over many threads (see [Figure 7 on page 64](#)).



**NOTE:** The peak utilization rate is not much higher than the current rate.

---

Figure 7: CPU-Bound Utilization



## prstat output

```

PID USERNAME  SIZE  RSS STATE PRI NICE   TIME    CPU PROCESS/NLWP
1624 root       244M 129M  cpu6  33   0 686:11:58 88% radius_generic/252
29853 hadm       181M 141M  sleep 59   0 0:53:12 0.1% mysqld/18
29766 hadm       131M  26M  sleep 59   0 0:51:51 0.1% ndb_mgmd/21
2602 root       3808K 3072K  cpu0  49   0 0:00:00 0.0% prstat/1
19423 noaccess    174M   83M  sleep 59   0 3:31:37 0.0% java/18
2556 root       7456K 4744K  sleep 59   0 0:00:00 0.0% sshd/1

```



```

17497 root      3544K 1712K sleep  59    0   0:00:00 0.0% mountd/2
You can determine if any particular thread is taking up too much CPU by prstat
-L
  PID USERNAME  SIZE   RSS STATE PRI NICE   TIME   CPU PROCESS/LWPID
1624 root      244M  129M run   22    0  20:33:47 2.6% radius_generic/64
1624 root      244M  129M sleep 33    0   5:07:37 1.7% radius_generic/82
1624 root      244M  129M sleep 53    0   2:09:43 1.6% radius_generic/110
1624 root      244M  129M run   23    0   3:58:26 1.6% radius_generic/112
1624 root      244M  129M run   35    0   2:14:50 1.6% radius_generic/116
1624 root      244M  129M run   42    0  11:09:58 1.4% radius_generic/65
1624 root      244M  129M sleep 52    0   3:25:00 1.4% radius_generic/85

```

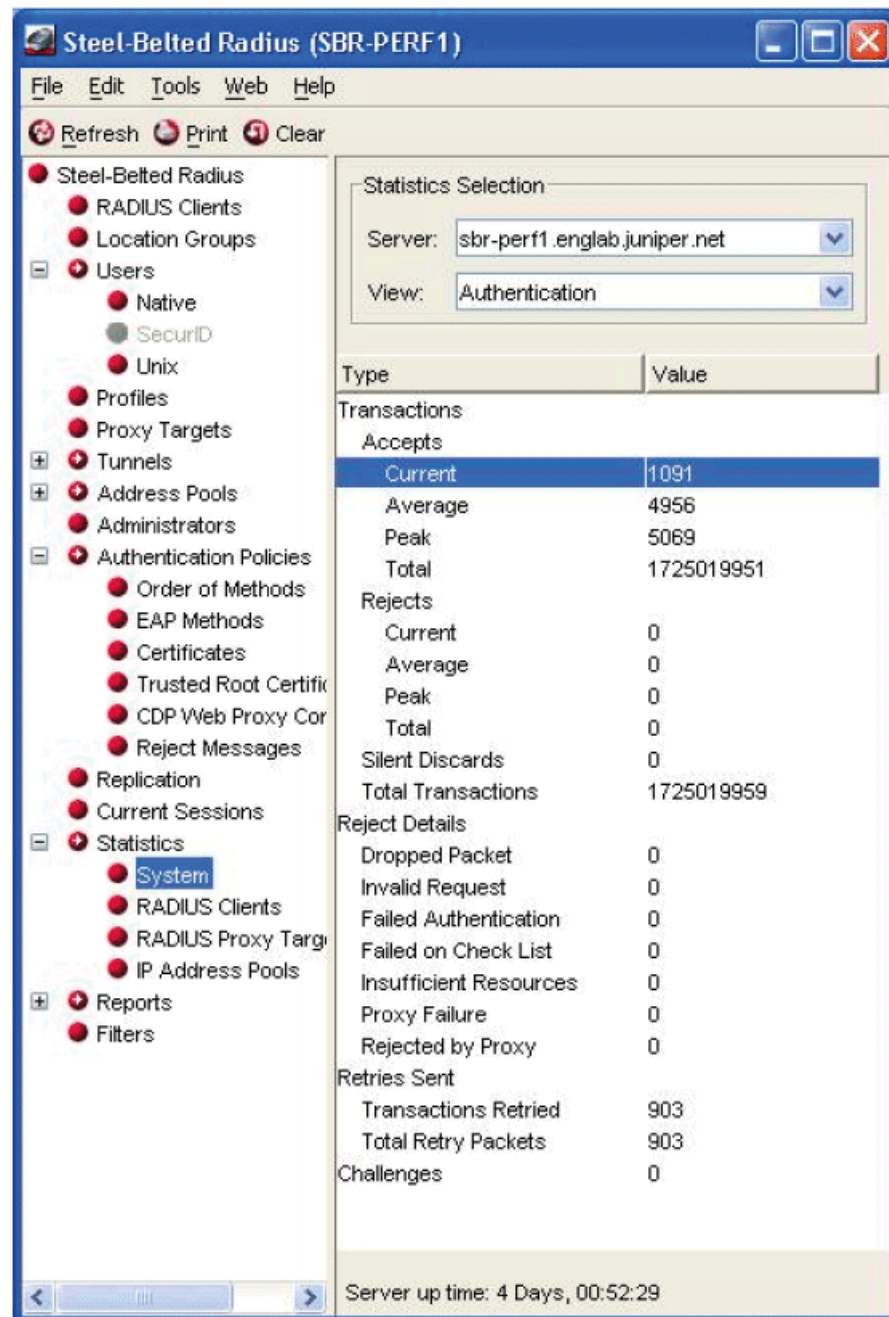
The following output shows no significant I/O usage:

| tty |      | sd0 |     |      | sd1 |     |      | sd2 |     |      | nfs1 |     |      | cpu |    |    |    |
|-----|------|-----|-----|------|-----|-----|------|-----|-----|------|------|-----|------|-----|----|----|----|
| tin | tout | kps | tps | serv | kps | tps | serv | kps | tps | serv | kps  | tps | serv | us  | sy | wt | id |
| 0   | 66   | 9   | 1   | 8    | 254 | 16  | 15   | 0   | 0   | 0    | 0    | 0   | 55   | 13  | 4  | 0  | 82 |
| 0   | 236  | 0   | 0   | 0    | 0   | 0   | 0    | 0   | 0   | 0    | 0    | 0   | 0    | 68  | 23 | 0  | 8  |
| 0   | 80   | 0   | 0   | 0    | 0   | 0   | 0    | 0   | 0   | 0    | 0    | 0   | 0    | 68  | 24 | 0  | 8  |
| 0   | 80   | 0   | 0   | 0    | 1   | 1   | 4    | 0   | 0   | 0    | 0    | 0   | 0    | 68  | 23 | 0  | 9  |
| 0   | 80   | 0   | 0   | 0    | 0   | 0   | 0    | 0   | 0   | 0    | 0    | 0   | 0    | 68  | 24 | 0  | 8  |

## I/O Bound

Figure 8 on page 66 shows output of a system that is more I/O bound (large packets being written to a long accounting file with LogAccept=1, LogLevel=2, TraceLevel=2). In this case, the CPU overhead of I/O is very high, and larger multiprocessor systems with more optimized I/O frameworks (such as Fibre Channel NASD devices and RAID5) will see higher rates and lower CPU utilization if they are I/O bound.

Figure 8: I/O-Bound Utilization



```

PID USERNAME  SIZE  RSS STATE PRI NICE   TIME    CPU PROCESS/NLWP
1624 root       248M 131M sleep 51  0 687:01:29 76% radius_generic/253
29853 hadm      181M 141M sleep 59  0 0:53:16 0.1% mysqld/18
29766 hadm      131M  26M sleep 59  0 0:51:54 0.1% ndb_mgmd/21
19423 noaccess  174M  83M sleep 59  0 3:31:37 0.0% java/18
2693 root      3808K 3072K cpu1  59  0 0:00:00 0.0% prstat/1
2556 root      7456K 4744K sleep 59  0 0:00:00 0.0% sshd/1
2609 root      3456K 2344K sleep 49  0 0:00:00 0.0% bash/1
17497 root      3544K 1712K sleep 59  0 0:00:00 0.0% mountd/2

```

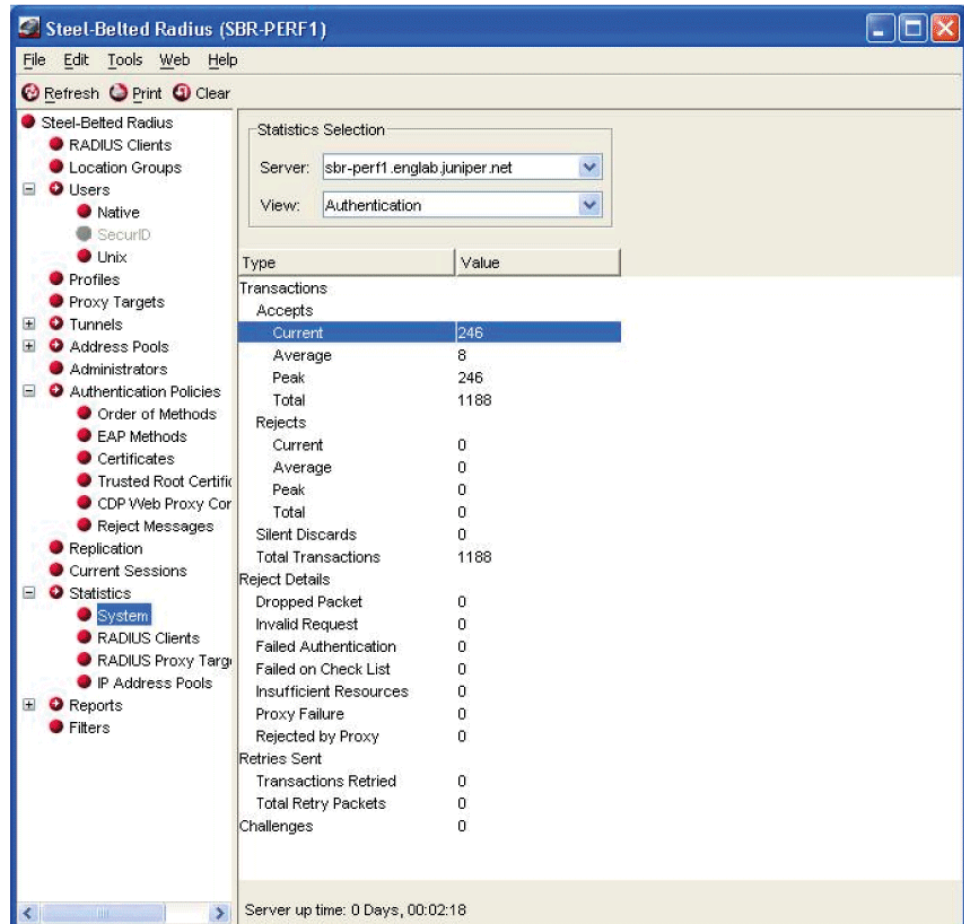
```
17499 daemon 2832K 1624K sleep 60 -20 0:04:46 0.0% nfsd/2
```

| tty |      | sd0 |     |      | sd1   |     |      | sd2 |     |      | nfs1 |     |      | cpu |    |    |    |
|-----|------|-----|-----|------|-------|-----|------|-----|-----|------|------|-----|------|-----|----|----|----|
| tin | tout | kps | tps | serv | kps   | tps | serv | kps | tps | serv | kps  | tps | serv | us  | sy | wt | id |
| 0   | 66   | 9   | 1   | 8    | 254   | 16  | 15   | 0   | 0   | 0    | 0    | 0   | 55   | 13  | 4  | 0  | 82 |
| 0   | 235  | 0   | 0   | 0    | 16333 | 17  | 12   | 0   | 0   | 0    | 0    | 0   | 0    | 58  | 24 | 0  | 18 |
| 0   | 82   | 0   | 0   | 0    | 17678 | 38  | 13   | 0   | 0   | 0    | 0    | 0   | 0    | 58  | 24 | 0  | 17 |
| 0   | 82   | 0   | 0   | 0    | 16693 | 18  | 12   | 0   | 0   | 0    | 0    | 0   | 0    | 58  | 24 | 0  | 18 |
| 0   | 82   | 0   | 0   | 0    | 16394 | 17  | 11   | 0   | 0   | 0    | 0    | 0   | 0    | 59  | 24 | 0  | 17 |

## Contended Systems

Figure 9 on page 67 is an example of a contended system with many (artificially induced) errors.

Figure 9: Contended Systems Utilization



| PID   | USERNAME | SIZE | RSS  | STATE | PRI | NICE | TIME    | CPU  | PROCESS/NLWP      |
|-------|----------|------|------|-------|-----|------|---------|------|-------------------|
| 3701  | root     | 199M | 83M  | sleep | 59  | 0    | 0:00:07 | 1.3% | radius_generic/80 |
| 29853 | hadm     | 181M | 141M | sleep | 59  | 0    | 0:53:19 | 0.0% | mysqld/18         |
| 29766 | hadm     | 131M | 26M  | sleep | 59  | 0    | 0:51:58 | 0.0% | ndb_mgmd/21       |

```
3717 root      3872K 3232K cpu6    59    0  0:00:00 0.0% prstat/1
2556 root      7456K 4744K sleep   59    0  0:00:00 0.0% sshd/1

  tty          sd0          sd1          sd2          nfs1          cpu
tin tout kps tps serv kps tps serv kps tps serv kps tps serv us sy wt id
  0   66   9   1   8 254 16 15   0   0   0   0   0   0 55 13 4 0 82
  0  236   0   0   0   0   0   0   0   0   0   0   0   0   0  2 1 0 97
  0   80   0   0   0   0   0   0   0   0   0   0   0   0   0  2 1 0 98
  0   80   0   0   0   0   0   0   0   0   0   0   0   0   0  2 1 0 97
  0   80   0   0   0  11 17 20   0   0   0   0   0   0   0  2 1 0 97
```

---

## Notes on Debugging Performance Issues

The following are some notes on debugging performance issues:

- If the amount of time taken to stop and start SBRC is more than two minutes, there might be too many sessions to be sustained through the current I/O bandwidth. You might also need to shard or move to cluster(s), or put the data files on a Fibre Channel storage device or similar devices. Also examine the CPU and I/O utilization at startup for added insight.
- The accounting and proxy thread usage is a function of downstream latency. Many threads will have low CPU utilization, since most of the time is spent waiting. Each thread has some overhead and takes a finite amount of memory. If the system requires more threads, it is trying to take in more packets than the downstream can receive, in which case you should consider if proxy spooling is a better solution.
- Accounting-ON and Accounting-OFF are work-intensive operations, as you can configure SBRC to generate AutoStops to be sent downstream or against the SSR. This generates a great deal of work for SBRC, the SSR, and downstream proxy targets to handle one RADIUS packet's worth of input. Taking this into consideration, the system may hit limits while processing these operations if there are many sessions to be terminated.

See [“Accounting-Off or Accounting-On with AutoStop Enabled”](#) on page 77 for more information.

## CHAPTER 6

# Special Topics in Performance

This chapter helps you understand some of the performance-related topics that affect SBRC.

- [Multifactor Authentication over EAP on page 69](#)
- [EAP-TLS, TTLS, and WiMAX on page 70](#)
- [EAP-SIM/AKA and authGateway on page 72](#)
- [External Authentication and Accounting on page 73](#)
- [JavaScript on page 74](#)
- [Proxy Radius on page 75](#)
- [Smart Static Accounting on page 75](#)
- [Spooled Accounting on page 76](#)
- [IP Pools through the SSR on page 76](#)
- [Accounting-Off or Accounting-On with AutoStop Enabled on page 77](#)

## Multifactor Authentication over EAP

---

Multifactor authentication is one of the most secure methods for authentication today. This authentication style is often transported by the Extended Authentication Protocol (EAP), which is embedded in multiple EAP-message attribute value pairs within a RADIUS packet.

Subscriber Identity Module (SIM) is another form of “something you have” authentication, as is Transport Layer Security (TLS), which uses client certificates to authenticate.

Tunneled TLS (TTLS) creates a cryptographically secure channel (either with just a server certificate, or both a client and a server certificate) through which other credentials can be sent (such as passwords or token cards) for greater data security for the single factor authentication, which protects against, for example, man-in-the-middle attacks.

EAP has its own negotiation protocol beneath RADIUS. One EAP negotiation can be encapsulated within many RADIUS packets, depending on the key size, the size of cryptographic material being transported, or even the number of EAP protocols supported (each protocol allowed by the server can be rejected by the client, requiring multiple round-trips in poorly optimized clients that disregard hints sent by the server). This, combined with the cryptographic complexity of the inner protocol, can severely impact

the required amount of CPU utilization to process a single-user request. There are many ways to lessen this impact while remaining cryptographically secure, which will be described in the following sections.

## EAP-TLS, TTLS, and WiMAX

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This section explains the following:

- [Reauthentication Cache on page 70](#)
- [Cipher Suites and Key Sizing on page 70](#)
- [Cipher Suite Scaling on page 71](#)
- [Reducing the Number of Round Trips on page 72](#)
- [Certificate Management on page 72](#)
- [Multiple TLS/TTLS-Only Front-End Applications on page 72](#)

### Reauthentication Cache

Instead of doing a full authentication for cryptographically complex processes, session keys can be established and made to persist, and a simpler reauthentication can take place instead. This requires between 200 and 2400 bytes of data per session (which mostly, in the SSR, varies due to stored attribute value pairs) to be stored on both the client and the server. Reauthentication caching optimizes the amount of CPU utilization required and is not a required functionality for any use case. Certain use cases may not see any benefits.

TLS resumption is currently handled on a per-server basis. The cryptographic material is stored on one local SBRC. To perform reauthentication, the source of the previous transaction must be routable (using load balancers or similar, see [“Load Balancing on RADIUS Front-End Applications and Downstream Proxy Devices” on page 45](#) for more information) to the correct target SBRC.

TTLS resumption, especially in the roaming WiMAX use case, can be propagated to the SSR, so that multiple servers can handle the reauthentication. The tradeoff is that heavy cryptography work is not done at the expense of another insert into the SSR for upwards of 2400 bytes of data, plus the read in a future attempted reauthentication. In cases of high throughput, where the performance of the SSR is the bottleneck, turning off reauthentication caching might allow you to scale more linearly (no longer limited by SSR transaction rates) by adding front-end applications.

### Cipher Suites and Key Sizing

The derivation of keying material for a tunnel is completed based on functions of the key (client and server keys for TLS or server certificate for TTLS) by using a set of cryptographic operations called a cipher suite. The default SBRC cipher suite cryptography is estimated on the strength of the suites and occurs in the order listed in [Table 16 on page 71](#).

Table 16: Cipher Suite

| Cipher Suite                        | Cipher Suite Code |
|-------------------------------------|-------------------|
| TLS_RSA_WITH_AES_256_CBC_SHA256     | 0x003D            |
| TLS_RSA_WITH_AES_128_CBC_SHA256     | 0x003C            |
| TLS_DHE_RSA_WITH_AES_128_CBC_SHA256 | 0x0067            |
| TLS_DHE_RSA_WITH_AES_256_CBC_SHA256 | 0x006B            |
| TLS_DHE_DSS_WITH_AES_128_CBC_SHA256 | 0x0040            |
| TLS_RSA_WITH_AES_256_CBC_SHA        | 0x0035            |
| TLS_DHE_RSA_WITH_AES_256_CBC_SHA    | 0x0039            |
| TLS_DHE_DSS_WITH_AES_256_CBC_SHA    | 0x0038            |
| TLS_DHE_RSA_WITH_AES_128_CBC_SHA    | 0x0033            |
| TLS_RSA_WITH_AES_128_CBC_SHA        | 0x002F            |
| TLS_RSA_WITH_3DES_EDE_CBC_SHA       | 0x000A            |
| TLS_RSA_WITH_RC4_128_SHA            | 0x0005            |
| TLS_RSA_WITH_RC4_128_MD5            | 0x0004            |
| TLS_RSA_WITH_IDEA_CBC_SHA           | 0x0007            |

The performance of the above algorithms is loosely related to their relative security, in the order shown in [Table 16 on page 71](#). RADIUS will always attempt to use the highest security cipher suite for which it is configured and that the client can also utilize. Removing the lower cipher suites increases the relative security of your system. Removing the higher cipher suites can result in a significant performance boost.

In the Diffie-Hellman Ephemeral (DHE)-based cipher suites, the temporary keys derived by the client and server are thrown away after the session is completed, providing perfect forward security—nothing directly derived from the server certificate is sent over the wire. However, using DHE keys is expensive and requires the creation of large relative prime numbers. Using the settings of DHE-based suites, the key generation is modified by the number of DHE prime bits of the field in which to search, which is the number of bits to look for in a relatively prime number on which to base the session keys.

## Cipher Suite Scaling

A few index values reproduced in Chapter 7 for the M3000 2.53 GHz should scale linearly with total CPU GHz. The relative cryptographic costs will be commensurate between

TLS and TTLS. With the default 1024 DHE bits using 0x39, the default cipher suite includes accounting to SSR but not reauthentication caching.

## Reducing the Number of Round Trips

SBRC can be configured to use a larger TLS fragment length per RADIUS transaction. Determine the expected length of the non-RADIUS attributes (with some buffer) in an authentication transaction and subtract that from 4000 (the maximum size of a RADIUS transaction). Set the TLS fragment length towards that length, preferably as a number evenly divisible by 255 (maximum RADIUS AVP length). The default of 1020 is intentionally short to emphasize operative safety in cases where many long AVPs might be sent from NAS equipment; 2040 may be a better value for many purposes.

## Certificate Management

The cryptographic keys of a TLS-based or TTLS-based server have a strong impact on the amount of work each server must process. A cryptographically secure system is one that has no known breaks or limitations on how long it would take to deconstruct the entire system (for example, in Triple-DES the key field is  $2^{168}$ , but an attack reduces that complexity to  $2^{112}$ , and because of that, cryptographers consider Triple-DES to be “broken”—although not completely so). Keys in such a secure system are cryptographically secure when the amount of time in which they are in use is less than the amount of time it would take to break the key using optimized brute force methods. One way of optimizing the CPU utilization is to generate shorter keys for the server certificate, and change them more often. If you have never changed your server certificates, then decreasing their size and changing them once a year may be both a security and performance improvement.

To give an appropriate reference point, in 2007 it was reported that by using a special number field sieve (filter), the equivalent operation of breaking a single 700-bit RSA key was executed on 400 computers over 11 months.

## Multiple TLS/TTLS-Only Front-End Applications

In cases using highly cryptographically secure algorithms and keys, running multiple standalone versions of SBRC, outside of use cases requiring cluster resumption, using TLS with secondary authentication to a cluster front-end application, or using TTLS inner-auth to a cluster front-end application provides linear scaling with hardware. Whether TLS or TTLS—since it all depends on CPU and scales well through higher end, massive multiple-CPU hardware—faster CPU is generally better than more CPU, GHz for GHz, but more total CPU among cores will always be a benefit to this case.

## EAP-SIM/AKA and authGateway

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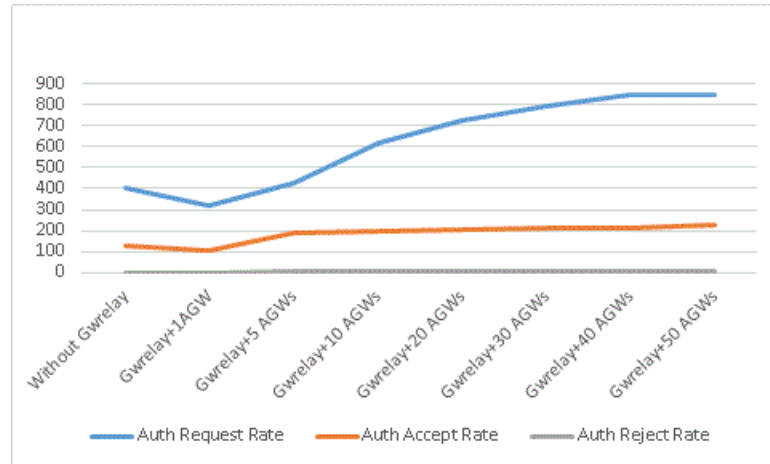
The authGateway functionality is implemented by multiple instances of finite state machines that accept SIM requests from the SBR Carrier simauth plug-in through the GWrelay application, and formats and transmits the requests to the HLR over the SS7 network or SIGTRAN. [Figure 10 on page 73](#) shows statistics of authentication rates with different numbers of authGateway instances on M3000 2.53 GHz.





**NOTE:** The graph is illustrative only, and the results may vary.

**Figure 10: Statistics of Authentication Rates on Solaris**



**NOTE:** These numbers are only for authentication and not for authorization, against an HLR with bearer codes, service type, and so on. We recommend that you use 5 to 10 authGateway instances for better performance results.

## External Authentication and Accounting

Much of the performance of a RADIUS system using external authentication and accounting is related to the latency and throughput of the back end. There is fixed overhead per transaction in terms of CPU utilization, but this should generally scale linearly with total CPU GHz of the system. The overhead for external server latency is accountable to additional memory utilization to keep a copy of the state of the in-process transaction in memory, along with the overhead for threads to manage that state.

The amount of processing increases if multiple external authentication servers must be tried in order. Setting the order so that the most utilized method is attempted first is the easiest way to increase the performance.

Most external authentication and accounting systems accept multiple concurrent connections. Increasing values such as the MaxConcurrent in `radsq.aut/acc` increases the throughput of the system towards the capacity of the back-end system. This value is closely related to the number of authentication or accounting threads that are in use, and there must be more threads than the MaxConcurrent (so that while concurrent transactions are processing on the back-end server, RADIUS-level processing for additional transactions can still be done within SBRC), often up to double or more, depending on latency. Beyond that point, you manage spike traffic using flood queues (see [“Flood Control” on page 49](#) for more information) to avoid having too many attempted concurrent transactions, which might cause the downstream server to stop processing efficiently.

LDAP, even more than SQL, can have poor performance with badly constructed searches (which might cause an unnecessary object tree walk) and filters, or with the use of functionality such as BindName (although the latter is sometimes necessary in some use cases of non-reversibly encrypted passwords with certain types of authentication protocols). Having multiple open connections to an LDAP repository can send more simultaneous requests.

Storing less data is usually better than storing more data. Selects, updates, and deletes by primary key are generally faster than by secondary indexes, which in turn are much faster than by non-indexed fields. Inserts into tables with many indexes outside the primary key are slower than inserts into tables with one or few indexes. Optimizing your back end to avoid extraneous indexes, querying regularly only on items that are necessary, and using well-optimized primary keys can produce a large throughput increase and latency decrease.

Other SQL items worth investigating include validating whether stored procedures are optimized and having no hidden table scans or other iterative behavior that could be optimized out with a different data model. In general terms, raw inserts into one table that might be subsequently batch-processed outside of the transaction path (by an external job) are faster than manipulated inserts into many tables within a stored procedure; however, the ability to do batch-processing depends greatly on the use case.

Measuring the performance of common inserts and selects with SQL analyzers and keeping tabs on the performance of back-end servers in terms of CPU and I/O (as recommended for SBRC) will help determine scalability issues with back-end servers, and can help reduce the extraneous overhead on the front-end applications as well.

Finally, load balancing between multiple back-end servers, as well as enabling failover behavior, can reduce performance issues caused by back-end throughput in a relatively linear manner.

See the *SBR Carrier Reference Guide* for information on configuring the following parameters:

- *Max-Auth-Threads*
- *Max-Acct-Threads*
- *MaxConcurrent* (radsq1.aut and .acc)
- SQL load balancing
- Ldapauth.aut

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## JavaScript

The number of JavaScript engines used at any one time is controlled by the **MaxEngines** setting in the **radius.ini** file. This need not be more than the number of total threads that will be running engines. See the *SBR Carrier Reference Guide* for information on configuring the **MaxEngines** parameter.



**NOTE:** Juniper Networks is not responsible for decreases in system performance that might have resulted due to the customization of JavaScripts implemented by the customer. Good programming can alleviate.

## Proxy Radius

Similar to external authentication and accounting, the fixed overhead per proxied transaction is approximately the value of one regular request/response pair, either authentication or accounting. This is because it takes about the same amount of time to parse the incoming RADIUS packet and generate a response as it does to generate a downstream packet and parse the response.

When the block is set as 0 in the .pro file [Acct] section, SBRC returns an ACK for the proxy accounting transactions and then passes the transaction state to a proxy thread (which is controlled by Max-Proxy-Threads). These functions are similar to MaxConcurrent. Unlike the relationship between Max-Acct-Threads and MaxConcurrent for external accounting, when it goes to proxy downstream, a RADIUS transaction is subsequently handled by the Max-Proxy-Thread pool for the response. So, the Acct Thread hands off the work to the Proxy Thread entirely, and the initial thread is free to handle another request. In general, the proxy threads may be larger than the Max-Acct-Threads, unless the external latency of the back end is higher than the external latency of the downstream, in which case they should be about equal.

When the block is not set to 0, the authentication or accounting thread handles everything and waits for the proxied response, and the number of threads must be related to the latency of the downstream (unless spooled accounting is used). See the *SBR Carrier Reference Guide* for information on configuring the Max-Proxy-Threads parameter.

## Smart Static Accounting

With smart static accounting, accounting requests can be sent to multiple downstream servers. As with the basic proxy case, the amount of work required for each request will also approximately equal one request/response pair. For example, with 10 downstream servers:

- With Block=0, proxying to 10 static accounting servers downstream occurs at the same time, up to the limit of proxy threads, which may be ten times the number of accounting threads to sustain the throughput (to the limits of memory).
- With Block=1, proxying to 10 static accountings downstream is serial, and has ten times the latency.

In both cases, the amount of CPU per transaction from downstream is ten times since the same work must be done, effectively ten times, with different encryption (for shared secrets).

## Spoiled Accounting

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When the throughput of the SBRC system might temporarily be greater than the throughput of the downstream, and you want reliable transport so that the accounting gets downstream eventually, you can use the spoiled accounting mechanism. In this efficient method, the packets are sent downstream synchronously about as fast as the downstream can go plus latency, but are sent outside of the transaction path. The overhead is in additional I/O to the local file system, which is approximately double the same throughput used for the equivalent network operation. For a 2000 RADIUS transaction, 2000 is written to the file, then later the file is read and the 2000 is written to the network. Currently, spoiled accounting logs are drained by one thread per realm and have one in-flight transaction outstanding. Contact the Juniper Network Sales Engineer or manager for additional throughput of multiple in-flight transactions or multiple threads per realm.

If the average performance requirements of the system are greater than the downstream realm can handle, the backlog can be significant, and delays in draining the local spool to the downstream proxy can reach a point where the downstream will never catch up. See the *SBRC Carrier Reference Guide*, [SpoiledAccounting] section, for more information.

## IP Pools through the SSR

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Because of the (well-known) problems in the ability of a SQL-derived system to implement efficient, reliable queuing across different processes, the current implementation of SSR has a performance limit with recovering addresses from very large IP pools on multiple threads. Multiple threads (running across multiple SBRC instances) attempting to pre-fetch possible lock-up keys to reclaim unused IP addresses can contend for the rows. This is a form of lock contention that can interfere with continued high-throughput SBRC operations. The semantics for lock back-off are controlled by the value for `TransactionDeadlockDetectionTimeout` in the `config.ini` file. One thread can wait up to this timeout value before retrying the reclaim operation, leading to a serious throughput limit.

There are several ways of managing this contention.

- Use different IP pools for different NAS devices, with different NAS devices biasing themselves (or being biased by a load balancer) to a given SBRC front-end application. This reduces cross-front-end contention.
- Shard the users or profiles so that different users have a *Framed-IP-Address* set from different pools. This evenly spreads the contention so that the usual case of random sleep used to manage contention (configured in `dbclusterndb.gen` as a period between *CacheThreadSleepMin* and *CacheThreadSleepMax*) will be sufficient to ensure adequate back-off for a request to reclaim a chunk of IP addresses. The added benefit is you can easily identify such items as class of service by linking given addresses to certain pools with well-defined ranges.
- Have enough addresses to set the *CacheLowWater* and *CacheHighWater* marks in `dbclusterndb.gen` very high, so that contended operations do not impact the effective throughput (so that you can take a multi-hundred millisecond pause in reclaiming

addresses without any transaction errors); however, values over 20,000 may cause SBRC to take longer to shut down in order to return the cached addresses to the available state. Also, a *CacheHighWater* value near the available size of the pool can cause one SBRC to cache all available addresses, leaving other SBRCs with none, which will lead to incorrectly failed authentications.

## Accounting-Off or Accounting-On with AutoStop Enabled

One of the few cases where a single RADIUS transaction can turn into an excessive amount of work on the back end is in processing an Accounting-Off or Accounting-On from a NAS device with many current sessions active. In this case, an accounting stop record is generated for each session. With high-end GGSN and similar devices, which can serve 100,000 users or more, the amount of work the SBRC must do and the number of operations made against an SSR are exceedingly high. In any SLA, this should be considered to be a “failure recovery” case, with the agreement that any transactions being processed during this time are processed on a best-effort basis.

Forwarding Accounting-Off and Accounting-On transactions to a server dedicated to handle such overflow operations can provide an optimal solution to avoid unnecessary user-level outage while the work is being executed.



**NOTE:** In general, Accounting-ON or Accounting-OFF typically is processed in one thread per transaction, reliably at approximately 1000 sessions per second on the highest single-CPU performing platforms (3–3.6 GHz). Retries of Accounting-ON or Accounting-OFF must be set so that the same SBR is tried multiple times for the length of the retry period required to terminate the sessions. For instance, if there are 20,000 sessions on a given NAS, the total retry length for the Accounting-ON or Accounting-OFF should be more than 20 seconds. Trying a second SBR in less than 20 seconds results only in duplicate work attempts, which results in conflicts and decreases the total throughput.

If multiple NAS devices may start in tandem—for instance, they are on the same UPS—load balancing each device with different primary and secondary starting points helps balance out the initial spike of work from processing an Accounting-ON.



## CHAPTER 7

# SBRC System-of-Systems Performance Reference

This chapter provides performance summary results of tests to estimate the SBRC load in a given use case or collection of use cases on a given system-of-systems. You can break down the effects of the tests and use them as a baseline to make reasonable estimates of expected performance. The tests represented in this chapter are not exhaustive, but are intended to give an indication of scalability.

This chapter also covers the limits of hardware performance. For example, disk I/O is rarely a limit for performance other than local file accounting or logging, and is ignored in most cases. This chapter focuses primarily on the following key performance measures:

- Overall CPU utilization (most relevant for SBRC)
- Per-thread CPU utilization (most relevant for SSR D nodes), with a focus on the single-highest thread

Throughout this chapter, the results are preceded by an explanatory text. Front-end application is an instance of SBRC and back end usually refers to a D node running `ndbmt`.

- [Hardware Used on page 79](#)
- [CPU Utilization on page 80](#)
- [Test Results Summary on page 80](#)

## Hardware Used

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The results shown throughout this chapter were tested on the following hardware:

- Two M3000 front-end applications with CPU 2.75 GHz, 16 G, running SBRC Release 7.4.0.
- Two or four M3000 back ends with CPU 2.52 GHz, 16 G, with half of the virtual CPUs disabled (unless otherwise specified) through `psradm`, running MySQL `ndbmt`
- M4000 Cluster, M9000 Standalone, and T3 standalone.

The focus primarily is on M3000 servers, as they are the recommended platform to run all the requisite tests.

The test clients used were executed with custom developed software, LoadTest, running between one and four VMs, executing on a 3.33 GHz XEON with 24 G.



**NOTE:** LogLevel and TraceLevel are set to zero and the local accounting is disabled unless otherwise specified.

## CPU Utilization

In most cases, the back-end CPU utilization percentage is a single percentage number, representing the highest single thread utilization, with the other threads being under control. In a few cases, the back-end CPU utilization percentage has multiple numbers (see [Table 17 on page 80](#)), which represents the order of thread execution—the top two (or four in the case of eight Execute Thread tests) are Local Query Handler (LQH) threads, which execute a major part of the work.

**Table 17: CPU Utilization**

| CPS  | Front-End CPU Utilization | SSR Node Max Single Thread Utilization |
|------|---------------------------|--|
| 4300 | 78 %                      | 2.3 %, 2.1 %, 1.2 %, 1.1 %             |

## Test Results Summary

This section provides a summary of the results tested in a given set of systems.



**NOTE:** All of the results shown in this section are for one front-end application unless otherwise stated.

- [Pap Authentication, Accounting Start, Accounting Stop on page 81](#)
- [Pap Authentication, Accounting Start, Accounting Stop—Sessions Preloaded on page 81](#)
- [Accounting Only—Sessions Preloaded, One Start and One Stop, Four D Nodes on page 81](#)
- [Accounting Only—Sessions Preloaded, One Start and One Stop, Two D Nodes on page 82](#)
- [Standalone: Auth/start/stop CPS on page 82](#)
- [Standalone: Accounting for 200 Threads on page 82](#)
- [Standalone: Authentication Only on page 83](#)
- [LDAP Authentication Only on page 83](#)
- [Oracle 11g on page 84](#)
- [LCI Queries against the SSR through SBRC on page 84](#)
- [IP Address Allocation on page 84](#)
- [IP Address Allocation with Eight Threads, Two D Nodes on page 85](#)



- IP Address Allocation with Eight Threads, Four D Nodes on page 85
- TTLS on page 86
- TTLS Plus Storing Resumption Context on page 87
- WiMAX on page 87
- 4D node system: M5000 on page 87
- Standalone: M9000 on page 88
- Standalone: T3 on page 88
- SSR and Standalone Performance: E4870 and X5687 CPUs on page 89

## Pap Authentication, Accounting Start, Accounting Stop

Tested on four D nodes with zero sessions preloaded.



**NOTE:** The number of test client threads is varied to show the effect of simultaneous operations.

**Table 18: Pap Authentication, Accounting Start, Accounting Stop**

| Client Test Threads | CPS  | Front-End Utilization | SSR Node Single Thread Utilization |
|---------------------|------|-----------------------|------------------------------------|
| 100                 | 4290 | 91 %                  | 3.8 %                              |
| 80                  | 4252 | 91 %                  | 3.8 %                              |
| 120                 | 4239 | 90 %                  | 3.8 %                              |

## Pap Authentication, Accounting Start, Accounting Stop—Sessions Preloaded

Tested on four D nodes with sessions preloaded.

**Table 19: Pap Authentication, Accounting Start, Accounting Stop—Sessions Preloaded**

| Number of Sessions Preloaded | CPS  | Front-End Utilization | SSR Node Thread Utilization |
|------------------------------|------|-----------------------|-----------------------------|
| 1M                           | 4210 | 89 %                  | 5.7-6.1 % <sup>1</sup>      |
| 4M                           | 4185 | 91 %                  | 6.5-6.8 %                   |
| 7M                           | 4064 | 89 %                  | 7.2-7.4 %                   |

<sup>1</sup>CPU utilization varied with Local and Global Checkpoints (LCP and GCP). Higher figures for other results are shown below.

## Accounting Only—Sessions Preloaded, One Start and One Stop, Four D Nodes

Tested on four D nodes with sessions preloaded.

**Table 20: Accounting Only—Sessions Preloaded, One Start and One Stop, Four D Nodes**

| Number of Sessions Preloaded | Accts/Sec | SSR Node Single Thread Utilization |
|------------------------------|-----------|------------------------------------|
| 0                            | 11,900    |                                    |
| 4M                           | 11,446    |                                    |
| 7M/100 threads               | 11,070    | 8.7 %                              |
| 7M/120 threads               | 11,160    | 8.8 %                              |

**Accounting Only—Sessions Preloaded, One Start and One Stop, Two D Nodes**

Tested on two D nodes with sessions preloaded, variation of accounting to local file.

**Table 21: Accounting Only—Sessions Preloaded, One Start and One Stop, Two D Nodes**

| Number of Sessions Preloaded        | Accts/Sec | SSR Node Single Thread Utilization |
|-------------------------------------|-----------|------------------------------------|
| 0 sessions/no account logging       | 13,900    | 4.2 %                              |
| 0 sessions/default account logging  | 12,280    | 4.4 %                              |
| 1M sessions/default account logging | 12,340    | 6.6 %                              |
| 4M sessions/default account logging | 12,300    | 7.5 %                              |
| 4M sessions/minimal account logging | 12,660    | 8.0 %                              |
| 4M sessions/no account logging      | 13,740    | 8.3 %                              |
| 7M sessions/no account logging      | 13,400    | 8.6 %                              |

**Standalone: Auth/start/stop CPS**

Tested on standalone SBR for Auth/start/stop CPS.

**Table 22: Standalone: Auth/start/stop CPS**

| Case        | CPS  | CPU Utilization |
|-------------|------|-----------------|
| 0 Sessions  | 6330 | 97 %            |
| 1M sessions | 5930 | 96 %            |
| 3M sessions | 5760 | 95 %            |

**Standalone: Accounting for 200 Threads**

Tested on standalone SBR for accounting only for 200 threads.



**NOTE:** Standalone being a 32-bit application, is limited to a 4 GB working set.

**Table 23: Standalone: Accounting for 200 Threads**

| Case   | Accts/s | CPU Utilization | Disk I/O |
|--|---------|-----------------|----------|
| 1M sessions  | 22,500  | 95 %            | 1.8 M/s  |
| 3M sessions<br>(This maximum varies with each use case, depending on data stored in the SSR compared to the 4G limit.) | 20,300  | 95 %            | 2.1 M/s  |
| 3M Sessions/Account.ini Enabled  | 15,200  | 96 %            | 6.0 M/s  |

### Standalone: Authentication Only

Tested on standalone SBR for authentication only.

**Table 24: Standalone: Authentication Only**

| Case        | Auths/s | CPU Utilization | Disk I/O |
|-------------|---------|-----------------|----------|
| PAP         | 14,800  | 98 %            | —        |
| CHAP        | 14,760  | 98 %            | —        |
| Rejects/s   | ~22,000 | 98 %            | —        |
| LogAccept=1 | 13,170  | 96 %            | 1.2 M/s  |
| LogLevel=2  | 3,890   | 77 %            | 6.8 M/s  |
| LogLevel=1  | 9,590   | 86 %            | 3.6 M/s  |

### LDAP Authentication Only

Tested for LDAP authentication.

**Table 25: Authentication Only**

| Case                                       | Auths/Sec | Front-End Overall | Front-End Single-Thread |
|--|-----------|-------------------|-------------------------|
| 1 client threads, maxconnect = 1           | 454       | 11 %              | 3.4 %                   |
| 10 client threads, maxconnect = 1          | 1030      | 26 %              | 6.2 %                   |
| 100 client threads/ 10 [server/*] sections | 10,175    | 39 % <sup>2</sup> | — <sup>3</sup>          |

<sup>2</sup> CPU on LDAP server maxed out—running 166 percent of two CPU VMware at 3.3 GHz.

<sup>3</sup> Evenly split, below the transport threads level.

## Oracle 11g

Tested on an Oracle 11g database running on an M3000, 2.52 GHz.

**Table 26: Oracle 11g**

| Case  | Auths/Sec or CPS                     | Front-End % | Oracle DB Process Max %                |
|---|--------------------------------------|-------------|--|
| Auth only—10 client threads                           | 9200 auths/sec                       | 24 %        | 22 % overall                           |
| Auth only—15 client threads                           | 12,500 auths/sec                     | 37 %        | 30 % overall                           |
| Directed realms, 20 client threads over two instances | 17,000–24,000 <sup>4</sup> auths/sec | 71 %        | 70 %                                   |
| Auth/start/stop, MaxConnections = 1                   | 2610 CPS                             | 37 %        | 4.6 %                                  |
| Auth/start/stop, MaxConnections = 10                  | 4255 CPS                             | 91 %        | 6.9 % (spread over 8 Oracle processes) |

<sup>4</sup> This result varied widely due to latency of the single Oracle DB processing requests from too many simultaneous connections.

## LCI Queries against the SSR through SBRC

The number of LCI server threads is hard-limited to eight by the server to avoid interference with regular RADIUS traffic processing.<sup>5</sup>

**Table 27: LCI Queries against the SSR through SBRC**

| Case                     | LCI Queries/Sec | Front-End CPU | SSR Node CPU |
|--------------------------|-----------------|---------------|--------------|
| 100 query client threads | 1452            | 53 %          | 3.7 %        |
| 200 query client threads | 1716            | 62 %          | 4.4 %        |

<sup>5</sup> SBRC 7.4.0 performance improvement permits greater throughput at less front-end CPU utilization.

## IP Address Allocation

Tested on two D nodes with IP address allocation.

**Table 28: IP Address Allocation with Two D Nodes**

| Case                             | CPS  | SSR Node CPU             |
|----------------------------------|------|--------------------------|
| 1M sessions, 1 pool, 1 front end | 3050 | 18 %, 18 %, 5.2 %, 3.5 % |

Table 28: IP Address Allocation with Two D Nodes (*continued*)

| Case   | CPS                | SSR Node CPU             |
|--|--------------------|--------------------------|
| 1M sessions, sharing 1 pool, 2 front ends          | 1600 + 1550 = 3150 | 19 %, 18 %, 5.3 %, 3.5 % |
| 1M sessions, 2 pools, each front end using its own | 1885 + 1857 = 3742 | 22 %, 20 %, 5.1 %, 3.5 % |
| 1M sessions, LCI queries, 1 front end              | 2650 + 550 LCI TPS | 17 %                     |
| 1M sessions, LCI queries, 2 front ends             | 3200 + 750 LCI TPS | 22 %                     |

### IP Address Allocation with Eight Threads, Two D Nodes

Tested on two D nodes with eight execute threads on eight virtual processors. This test case gives an indication of performance on the M4000. In this case, two threads are running on each physical processor for the M3000 case; it will be one thread per physical processor for the M4000.

Table 29: IP Address Allocation with Two D Nodes and Eight Execute Threads

| Case   | CPS                | Max Single Thread (out of 12.5 %) SSR Node | Front-End CPU |
|--|--------------------|--|---------------|
| 0 sessions, 1 front end                        | 3635               | 5.3, 5.1, 5.1, 5.1, 3.3, 2.0               | 75 %          |
| 0 sessions, 2 front ends, 2 pools              | 3270 + 3390 = 6660 | 8.3, 8.2, 8.2, 8.2, 4.0, 2.0               | 68 %          |
| 1M sessions, 2 front ends, 2 pools             | 2509 + 2492 = 5001 | 10.0, 9.7, 9.7, 9.6, 3.4, 1.9              |               |
| 1M sessions, 2 front ends, 1 pool <sup>6</sup> | 1853 + 1875 = 3728 | 8.4, 8.3, 8.0, 8.0, 3.3, 1.9               |               |

<sup>6</sup> In the two front end applications, one pool case, the limiting factor is the ndb lock collision associated with multiple threads reaping the old IP address at the same time.

### IP Address Allocation with Eight Threads, Four D Nodes

Tested on four D nodes with eight execute threads on eight virtual processors. This test case gives an indication of performance on the M4000. In this case, two threads are running on each physical processor.

Table 30: IP Address Allocation with Four D Nodes and Eight Execute Threads

| Case  | CPS                               | Max Single Thread (out of 12.5 %) SSR Node | Front-End CPU |
|---|-----------------------------------|--|---------------|
| No IP, 1M sessions, 2 front ends<br>(“No IP” is used as a baseline reference) | 5514 + 5472 = 10,986 <sup>7</sup> | 3.8, 3.8, 3.2, 3.0, 2.9, 1.7               |               |
| 1M sessions, 1 front end  | 3650                              | 4.0, 3.9, 3.7, 3.7, 2.2, 1.9               | 74 %          |

Table 30: IP Address Allocation with Four D Nodes and Eight Execute Threads (*continued*)

| Case                               | CPS                | Max Single Thread (out of 12.5 %) SSR Node | Front-End CPU |
|------------------------------------|--------------------|--|---------------|
| 1M sessions, 2 front ends, 2 pools | 2550 + 2600 = 5150 | 5.4, 5.3, 5.1, 5.1, 2.7, 2.1               | 45 %          |
| 1M sessions, 2 front ends, 1 pool  | 2300 + 2400 = 4700 | 3.9, 3.9, 3.8, 3.7, 2.0, 1.6               | 35 %          |

<sup>7</sup> 10 percent variation due to GCP and LCP.

## TTLS

TTLS with five RADIUS auth/challenge pairs per accept using various cipher suites and dh key sizes.

Table 31: TTLS with Five RADIUS Auth/Challenge Pairs per Accept

| Case               | Accepts/Second   | Front-End %            |
|--------------------|------------------|------------------------|
| 1024 dh bits, 0x39 | 565              | 95 %                   |
| 512 dh bits, 0x39  | 871              | 95 %                   |
| 1536 dh bits, 0x39 | 256 <sup>8</sup> | 73 %                   |
| 0x38               | 574              | (Maximum, around 95 %) |
| 0x33               | 575              | (Maximum, around 95 %) |
| 0x32               | 578              | (Maximum, around 95 %) |
| 0x16               | 575              | (Maximum, around 95 %) |
| 0x13               | 872              | (Maximum, around 95 %) |
| 0x66               | 886              | (Maximum, around 95 %) |
| 0x35               | 890              | (Maximum, around 95 %) |
| 0x2f               | 888              | (Maximum, around 95 %) |
| 0x15               | 575              | (Maximum, around 95 %) |
| 0x12               | 1112             | (Maximum, around 95 %) |
| 0x0a               | 1116             | (Maximum, around 95 %) |
| 0x05               | 1114             | (Maximum, around 95 %) |
| 0x04               | 1120             | (Maximum, around 95 %) |

Table 31: TTLS with Five RADIUS Auth/Challenge Pairs per Accept (*continued*)

| Case | Accepts/Second | Front-End %            |
|------|----------------|------------------------|
| 0x07 | 1116           | (Maximum, around 95 %) |
| 0x09 | 1117           | (Maximum, around 95 %) |

<sup>8</sup> The clients tested were out of CPU.

### TTLS Plus Storing Resumption Context

Tested with two D nodes on TTLS plus storing resumption context storage overhead.

Table 32: TTLS Plus Storing Resumption Context

| Case              | Accepts/Second | NDB SSR Node Thread Utilization |
|-------------------|----------------|---------------------------------|
| Resumption (0x38) | 575            | 0.7, 0.7, 0.4, 0.4              |
| Resumption (0x09) | 1117           | 0.9, 0.8, 0.5, 0.5              |

### WiMAX

WiMAX tested with TTLS plus one HA plus two starts and two stops. 10 RADIUS transactions = 6 NDB hits.

Table 33: WiMAX

| Case         | Accepts/Second | NDB SSR Node Thread Utilization | Front-End % |
|--------------|----------------|---------------------------------|-------------|
| WiMAX (0x38) | 355            | 3.5, 3.5, 1.3, 1.1              | 91 %        |
| WiMAX (0x09) | 475            | 4.7, 4.7, 1.6, 1.4              | 98 %        |

### 4D node system: M5000

These results were tested on the M5000 with four CPUs (virtual CPUs disabled) at 2.66 GHz and switch-connected with 10G networking.

Simple accountings per second = 49,200 (million per row stored):

- Network bandwidth (NB) for D nodes recorded upwards of 42 MBps = 336 Mbps
- Disk bandwidth 5 MBps = 40 Mbps

Realistic accountings per second (7M rows preloaded) and more data per transaction (approximately 512b per row stored):

- Accountings per second = 23,240
- Bandwidth (up to 7 MBps) = 56 Mbps
- Network bandwidth = 80 MBps

IP address allocations: 7701 CPS

WiMAX with resumptions: 3300 CPS

### Standalone: M9000

These results were tested on M9000 (16 CPUs x 8 cores) at 3.0 GHz running in one global zone, or six non-global zones.



**NOTE:** When SBR is running in non-global zones, the performance is limited because it is unable to set the RealTime priority on the receiving threads.

- Maximum authentications per second for one global zone = 31,000
- Maximum accountings per second for one global zone (with logging) = 38,000
- Maximum authentications per second across six non-global zones = 105,804
- Maximum accountings per second across six non-global zones = 91,470
- CSPA (without logging) across six non-global zones = 59,252
- TTLS (512RSA):
  - Maximums TTLS per second for one global zone = 3900
  - Maximums TTLS per second for six non-global zones = 11,900

### Standalone: T3

These results were tested on T3 (4 CPUs x 128 cores) at 1.65 GHz running in six non-global zones.



**NOTE:** Network bandwidth—disabling virtual CPUs decreases performance in all cases.

- Maximum authentications per second across six non-global zones = 69,850. Total CPU utilization is 18%.
- Maximum accountings per second across six non-global zones: 18,800. Total CPU utilization is 15.6%.



**NOTE:** Accounting and local session performance is excessively limited by single-CPU speed and spindle I/O performance. Consequently, T3 is not recommended for accounting performance, but has high ROI for TLS/TTLS and WiMAX cases.



- TTLS (512 DHE)—Maximum TTLS per second across six non-global zones = 12,100.  
Total CPU utilization is 78% and represents maximum server utilization available on this server.
- TTLS (1024RSA)—Maximum TTLS per second across six non-global zones = 17,000.  
Total CPU utilization is 66%.
- TTLS (1024 DHE)—Maximum TTLS per second across six non-global zones = 6300.  
Total CPU utilization is 52%.
- TTLS (2048 DHE)—Maximum TTLS per second across six non-global-zones = 2046.  
Total CPU utilization is 43.2%.

### SSR and Standalone Performance: E4870 and X5687 CPUs

These results were tested on E4870 CPUs and X5687 CPUs.

**Table 34: SSR Performance**

| Case  | 6D - E7-4870 x1 CPU | 4D - E7-4870 x1 CPU | 2D - E7-4870 x1 CPU | 2D X5687 x 2 CPU |
|---|---------------------|---------------------|---------------------|------------------|
| Accountings per second                                | 137,900             | 97,000*             | 78,100              | 89,000           |
| Accountings per second 512 byte sessions, 15M preload | 65,600              | 47,700              | 24,400              | —                |
| SBR 7.4.1 with new NDB optimizations                  | 140,700             | 120,000 *           | 107,000             | 107,000          |

**Table 35: Standalone Performance**

| Case   | X5687 x 2 CPUs | E7-4870 x1 CPU (2 for TTLS) | E7-4870 x 8 CPUs (with 6 to 12 Virtual machines) |
|--|----------------|-----------------------------|--|
| Pap Authentications per second                   | 44,900         | 48,000                      | 179,000  |
| Accountings per second (CST and logging to disk) | 42,000         | 40,000*                     | 190,000  |
| TTLS 512 DHE (0x39) authentications per second   | 3,800          | 4,300                       | —  |
| TTLS 1024 RSA (0x2F) authentications per second  | 4,700          | 5,400                       | 11,600   |
| TTLS 1024 DHE (0x39) authentications per second  | 2,900          | 3,000                       | —  |



NOTE: \*—These numbers are based on estimation.

Proxy authentications per second, accountings per second = 22,000. Round-robin is used for multiple downstreams.

JDBC/MySQL authentication = 18,800. Total CPU utilization is 15.6%.

JavaScript Engine Overhead = 10%.