



Performance Analysis:

Cisco Integrated Services Router (ISR)

ISR 4000 Family:

Models 4321, 4331, 4351, 4431 & 4451



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1 - Executive Summary

Miercom was engaged to conduct comprehensive performance tests of Cisco’s latest family of WAN-oriented Integrated Services Routers (ISRs): the 4000 family. Testing of five 4000 family models– the 4321, 4331, 4351, 4431 and 4451 – was conducted during the summer of 2015.

This report summarizes the results of the testing in these key areas:

- Aggregate throughput performance for each ISR and each licensed capacity level.
- The amount of still-available CPU processing capacity (headroom) in each scenario.
- Performance scalability of the ISR models and licensed capacity levels.

Key findings

Performance shaping allots processing capacity where needed	The same operating software runs on all 4000 ISR models, and effectively shapes performance, assuring ASIC-like resource allocation to specified features and services.
Delivers full licensed capacity, with plenty of CPU headroom	Testing confirmed the ISRs deliver every bit/s of advertised throughput when IP forwarding or running QoS, NAT or firewall, with 60+ percent of CPU capacity left for added features.
Near-peak performance while running multiple services	The ISRs all deliver impressive throughput even when running multiple services concurrently. From 50 to 90 percent of maximum licensed capacity was achieved while simultaneously running IP forwarding, IPSec encryption, NAT and firewall.
Linear step-up performance growth options	In grueling testing of WAN throughput in various demanding scenarios, the ISRs showed they offer near linear step-up options via licensed performance levels and model upgrades.

Miercom has independently tested key performance aspects of the Cisco 4000 family of Integrated Services Routers, including aggregate throughput and CPU utilization in various WAN network configurations, and while running services and features individually and concurrently. In light of these findings we proudly present the **Miercom Performance Verified** certification to the Cisco 4000 family of ISR models tested.

Robert Smithers
CEO
Miercom



2 - About the Cisco 4000 Family Integrated Services Routers

The five products tested comprise the latest Cisco family of routers, termed intelligent WAN platforms, which are designed for enterprise branch deployment. Their specialty: integrated support for the diverse applications and aspects of Wide Area IP networking – multiple diverse WAN access links, Ethernet, T1/T3, xDSL, VoIP, VPNs, encryption, Multi-Protocol Label Switching (MPLS), SIP trunking, firewall, NAT, and many other WAN-oriented protocols and processes – coupled with management tools for configuration, traffic monitoring, bandwidth usage and WAN optimization.

Architecturally, the 4000 family ISRs support various modules, which communicate with internal speeds up to 10 Gbps. Described as a distributed multicore architecture, the 4000 models support what has been called the industry's first internal services plane, distinguished from the logically separate data and control planes. The services plane embodies the software processing of a broad spectrum of WAN-oriented services, which can run concurrently, efficiently share the platform's memory and CPU, and perform as reliably as if running on dedicated appliances.

The models vary with regards to supported physical interfaces, rack width, performance levels, and other features, such as dual-integrated power supplies – supported by the higher-end 4431 and 4451 ISR models. But despite these differences, all models of the 4000 family are delivered with and run the same universal software image. IOS XE version 3.16 (15.5.3 in conventional IOS naming), which supports all features and services, was tested on all models.

The 4000 family models support concurrent aggregate throughputs up to 2 Gbps. The below chart highlights and compares some of the salient differences of the 4000 family ISR models.

ISR 4000 Family

Model	Cisco 4321	Cisco 4331	Cisco 4351	Cisco 4431	Cisco 4451
Rack width	1RU (1.75 in)	1RU (1.75 in)	2RU (3.5 in)	1RU (1.75 in)	2RU (3.5 in)
Onboard WAN or LAN ports	2	3	3	4	4
Enhanced service-module slots	0	1	2	0	2
Network Interface Module (NIM) slots	2	2	3	3	3
Default (max.) dedicated Control and Services Plane memory	N/A	N/A	N/A	4 GB (16 GB)	4 GB (16 GB)
Default (max.) dedicated Data Plane memory	N/A	N/A	N/A	2 GB (2GB)	2 GB (2GB)
Default (max.) combined Control, Data & Services Plane memory	4 GB (8GB)	4 GB (16 GB)	4 GB (16 GB)	N/A	N/A
Default (max.) flash memory	4 GB (8 GB)	4 GB (16 GB)	4 GB (16 GB)	8 GB (32 GB)	8 GB (32 GB)
Max power (Watts): without / with PoE	125 / 260	250 / 530	430 / 990	250 / 1000	450 / 1450
Base and license-upgradeable performance	50 Mbps, up to 100 Mbps	100 Mbps, up to 300 Mbps	200 Mbps, up to 400 Mbps	500 Mbps, up to 1 Gbps	1 Gbps, up to 2 Gbps

Evolution. The 4000 family of ISR and version 3.16 of the IOS XE operating software tested represent an evolutionary step up from the predecessor ASR 1000 router series and earlier ISRs. A major enhancement with the 4000 series is its ability to split into separate data plane, control plane and services plane.

- **Data plane** enables the platform to leverage the multi-core architecture most efficiently and provide dedicated performance.
- **Control plane** allows the router to manage all layer 3 protocols, most importantly routing protocols, even under heavy load, it is also reachable via management protocols like SNMP, Telnet and SSH.
- **Services plane** allows network administrators to host applications, like ISR-WAAS, directly on the router. Because the services plane has its own dedicated CPU and memory resources, applications installed in the services plane can't starve the resources of the control or data plane.

The data plane holds the Forwarding Information Base and routes packets by itself. It also executes features including Network Address Translation (NAT), Quality of Service (QoS), and Access Control Lists (ACLs).

The data plane is programmed with forwarding information by the control plane, which maintains the routing-control protocols (RIP, OSPF, etc.) and manages all components and modules in the system, including the user management interfaces. The services plane extends the ISR platform by handling additional pre-packaged services, like Cisco's Wide Area Application Services (WAAS).

The 4000 ISRs employ multicore processors, and cores can be allocated to the data, control and services planes. The ISRs include the Multi-Gigabit Fabric Architecture from earlier ISRs. This is an integrated backplane switch that moves traffic between modules at up to 10 Gbps without impacting the data plane or "control plane" processors.

The 4300 ISRs (4321, 4331 and 4351) have a single-socket CPU and schedule the CPU cores between the three different planes. Within the 4400 ISRs (4431 and 4451), the data plane uses a separate physical CPU socket with up to 10 cores. The control plane has its own memory banks and uses up to three cores for "service containers."

All software functionality included. As noted, the same IOS XE image encompassing all features and functions is delivered with each 4000 family ISR. In addition, performance capacity can be effectively tripled without having to upgrade to a bigger hardware platform.

Several software licenses are offered. The default feature package is IP Base. An additional license called Security adds zone-based Firewall, IPSec and VPN encryption and tunneling support. A voice license adds support for Cisco Unified Communications Manager Express and the local-branch-survivability version (SRST) of the IP-PBX package.

Many WAN-specific services and protocols are supported with an additional license called AppX, (Application Experience). These licenses are also offered in bundles. The AX bundle includes the Security and Application Experience license with a lot of features like MPLS, EoMPLS and L2TP, along with Cisco's Wide Area Application Services (WAAS) and Akamai Connect. Another licensed bundle, AXV, includes the full AX plus voice bundles.

ISR4300 and ISR4400 Series Architectural differences. A difference between ISR4300 and ISR4400 series is, the ISR4400 not only has a platform throughput shaper but also adds more cores to the data plane when the performance license is enabled. For example, on the ISR4451 the performance license increases the shaper throughput to 2 GBit/s and also adds 4 more data plane cores.

This increase in data plane cores, from 6 to 10, allows a doubling of throughput, regardless of the current throughput. The heavy service test profile (FW, NAT, QoS & IPSec) of maximum throughput for the ISR4400 series show this clearly.

3 - Performance Testing

The performance of every router platform varies with its configuration, which makes any test measurement heavily dependent on the router's particular configuration when tested. Routers have been traditionally tested by configuring them for a specific forwarding process – such as Layer-2 switching or basic IP routing – and delivering traffic at the maximum rate on all ports until data would be dropped. The result: Maximum throughput.

Throughput and CPU Utilization

The Performance Tests focus on deployments where one or a few features and services are enabled. These tests ascertain the throughput and data-plane CPU utilization for those particular feature/service configurations.

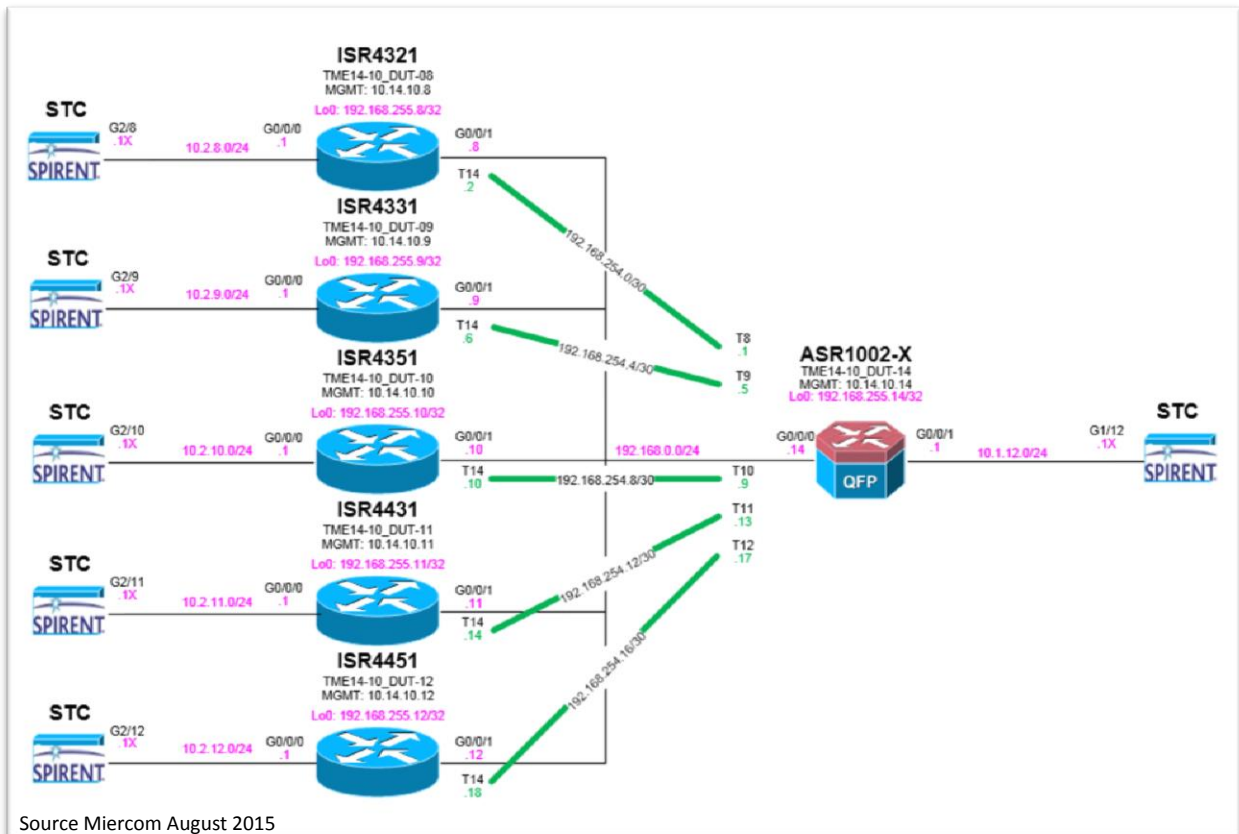
The 4000 family ISR platforms are designed to shape the overall traffic that is handled by the data plane, keeping the peak to a predefined amount (as determined by the performance license). This allows the router to deliver the advertised performance while running many features at the same time.

We also recorded the data plane's CPU utilization for each feature/service scenario that was tested, to see of how much additional CPU headroom was still available for additional features.

Performance Test Bed

All performance tests were done with traffic generated by, returned to and analyzed by a single Spirent Test Center (STC) running version 4.24 software. The STC chassis was configured with one 12-port, 10/100/1000, dual-media Rev B line card.

As shown in the test-bed diagram below, six ports of the Spirent Test System were used to verify the supported throughput of the five models in the ISR 4000 family tested: the ISR 4321, 4331, 4351, 4431, and 4451.



Test traffic was generated bidirectionally by the Spirent, at load levels set for the performance rating of each ISR 4000 model. Traffic was sent one-way directly from the STC test system to the ISR, which processed and forwarded the traffic onto and through a Cisco ASR1002-X, and then back to the return Spirent port. In the other direction, traffic was sent through the ASR1002-X, to the ISR, and back out to the return Spirent port, as shown in the diagram.

For IPsec and VPN tunneling services, data streams between the ISR and the ASR 1002-X were encrypted and decrypted, since the Spirent Test Center did not support encryption.

Initially, all tests were run in parallel for all the ISR 4000 models. Eventually, though, the traffic demand to fully load all five DUTs (devices under test) at their highest performance levels got too high for the Spirent, as configured. The remaining tests were then run one at a time.

Performance Tests – How We Did It

The performance tests assess each platform individually with one or multiple features enabled. Besides confirming the advertised throughputs, the tests also recorded the available CPU headroom.

IMIX distribution

To better represent real-world traffic, an IMIX distribution of test traffic was used in all performance tests. The IMIX breakdown is shown below:

IP length (bytes)	Total Ethernet length (bytes)	*Frequency weighting	Percent of packets	Percent of traffic volume
48	66	7	58.3	19.2
576	594	4	33.3	49.3
1500	1518	1	8.3	31.5

**Number of times this packet size appears in the IMIX stream.*

With this IMIX packet distribution, the average packet size for our tests was 378 bytes (including Layer-2 overhead). This equates to an average of 33,000 packets/second (pps) with a 100-Mbps aggregate throughput, and 330,000 pps with a 1-Gbps throughput.

Test Cases

Various features were enabled for this testing, individually and in combination. The features/services that were applied in our tests were:

- **IPv4 Forwarding:** the most basic service; no features besides IPv4 routing are enabled.
- **HQoS:** for Hierarchical Quality of Service, where there is a parent shaper configured that shapes the entire throughput to the advertised maximum limit. Within this parent shaper there is a child policy defined that describes how this available bandwidth is divided among different traffic classes.
- **NAT:** for Network Address Translation, where the ISR changes the source IP address of outgoing packets, both to conserve public IP addresses and to obscure internal addresses. This is done by almost all routers facing the Internet and therefore a very popular feature.
- **ZBFW:** for Zone-Based Firewall, Cisco's firewall implementation.
- **IPSec:** or IP Security, where all traffic traversing otherwise unsecure connections, typically WAN links, is encrypted outbound and decrypted inbound. The algorithms we used were AES-256 for encryption and MD5 HMAC (hash-based message-authentication code).

Before each test, all the ISRs were started in an unconfirmed state. A setup script was then run on each machine to configure it for the particular type of traffic, feature or service (e.g. IPv4, NAT, IPSec, FW, and combinations of these).

Each Spirent port was configured to deliver IMIX traffic up to the maximum advertised throughput capacity of each particular device under test (DUT). The Spirent traffic was checked for packets dropped by the DUT – traffic sent vs traffic received. If packets were dropped, the bandwidth level was reduced, the traffic was restarted and the test rerun.

The actual no-drop bandwidth was then recorded, along with the CPU utilization percentage. In most test cases, the ISR achieved its maximum advertised bandwidth (see results following this section).

The CPU percentage was taken from the last line of the Cisco CLI command output (see below). When the 5-second and the 1-min columns agreed (showed the same CPU percentage), then that CPU-load percentage value was recorded – 32 percent in this case.

Cisco CLI output, the last line showing CPU load for last 5 seconds, 1, 5 and 60 minutes.

```
TME14-10_DUT-08#show platform hardware gfp active datapath utilization
CPP 0: Subdev 0
Input: Priority (pps)      5 secs      1 min      5 min      60 min
      (bps)              0           0           0           0
      Non-Priority (pps)  14749      14749      14748      14740
      (bps)             46826576   46509888   46520416   46490256
      Total (pps)       14749      14749      14748      14740
      (bps)             46826576   46509888   46520416   46490256
Output: Priority (pps)      0           0           0           0
      (bps)              0           0           0           0
      Non-Priority (pps)  14749      14748      14747      14739
      (bps)             46850808   46533200   46543656   46514616
      Total (pps)       14749      14748      14747      14739
      (bps)             46850808   46533200   46543656   46514616
Processing: Load (pct)    32          32          31          24
```

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Results

The following pages show the results of the performance tests – aggregate throughput achieved, and the CPU utilization to achieve that throughput:

- For the five ISR models tested, from the low-end 4321, the 4331, the 4351, the 4431, to the high-end 4451.
- For five single-feature test cases – IPv4 Forwarding, Hierarchical QoS (QoS), Network-Address Translation (NAT), Zone-Based Firewall (FW), and IPSec – and three ‘combined-feature’ test cases: 1) QoS and IPSec, 2) FW, NAT and IPSec, and 3) FW, NAT, QoS and IPSec.

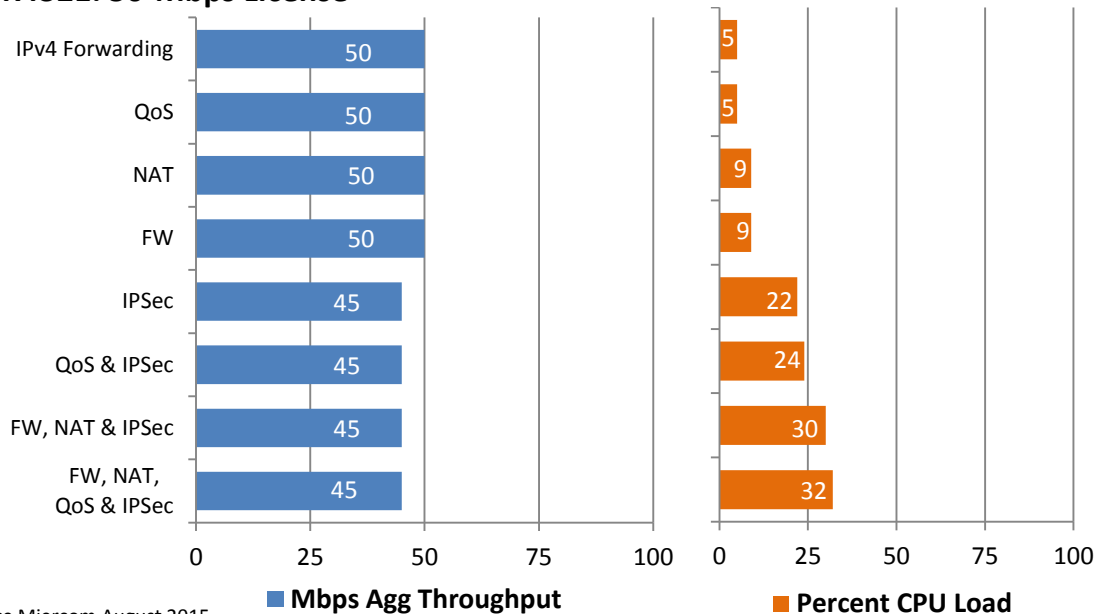
One note: The IPSec test cases were conducted with 10 percent less traffic in order to accommodate the added IPSec tunnel overhead (68 bytes per packet).

Each page shows the results for a single ISR model, the top chart for the lower aggregate-throughput license, and then with the higher capacity license for that model (lower chart).

Performance: Cisco 4321 – Throughput and CPU Headroom

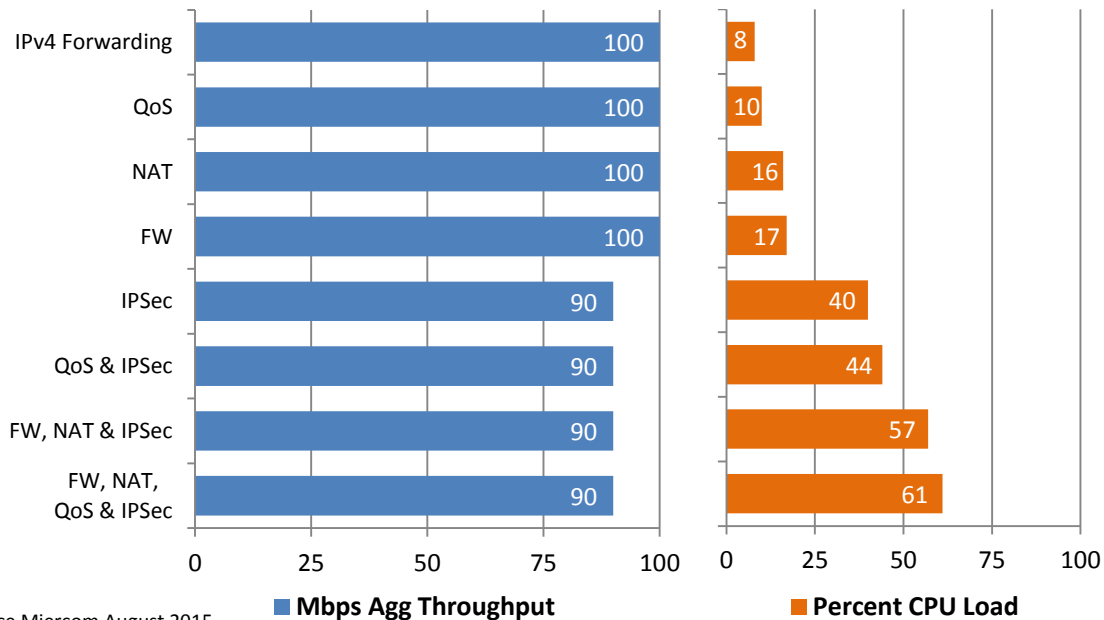
The aggregate throughputs achieved by the Cisco 4321 ISR, which can be licensed for 50- or 100-Mbps capacity performance. Each service configuration, the average CPU load for that throughput level is shown.

ISR4321: 50-Mbps License



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ISR4321: 100-Mbps License



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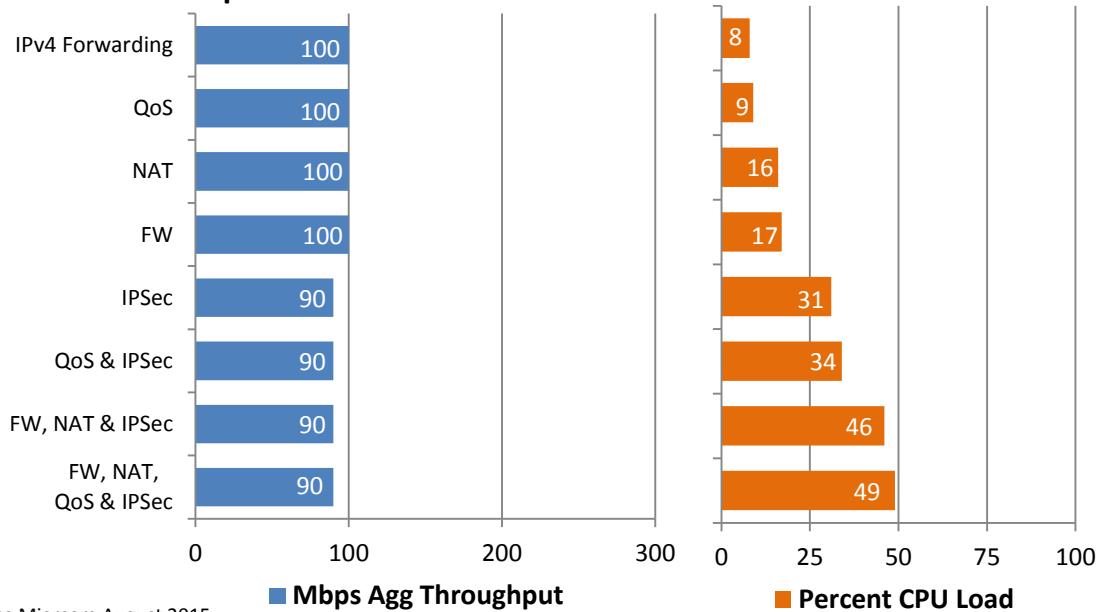
KEY: QoS = Hierarchical Quality of Service processing
IPSec = All data is sent/received via encrypted tunnels

FW = Zone-based Firewall
NAT = Network Address Translation

Performance: Cisco 4331 – Throughput and CPU Headroom

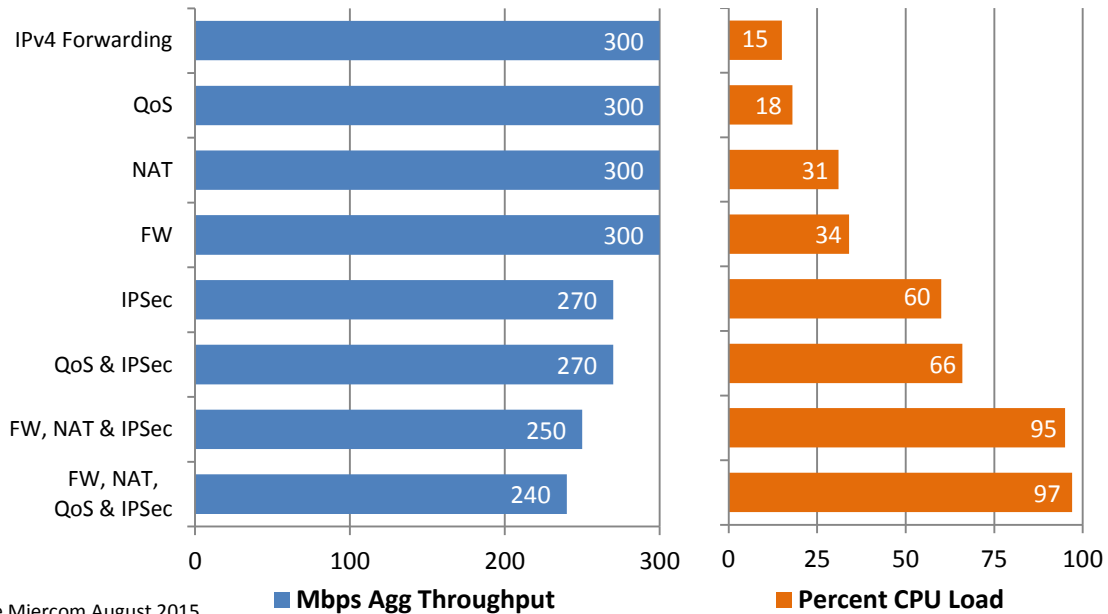
The charts below show the aggregate throughputs achieved by the Cisco 4331 ISR, which can be licensed for 100- or 300-Mbps capacity performance. For each service configuration tested, the average CPU load while achieving the particular throughput level is shown.

ISR4331: 100-Mbps License



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ISR4331: 300-Mbps License



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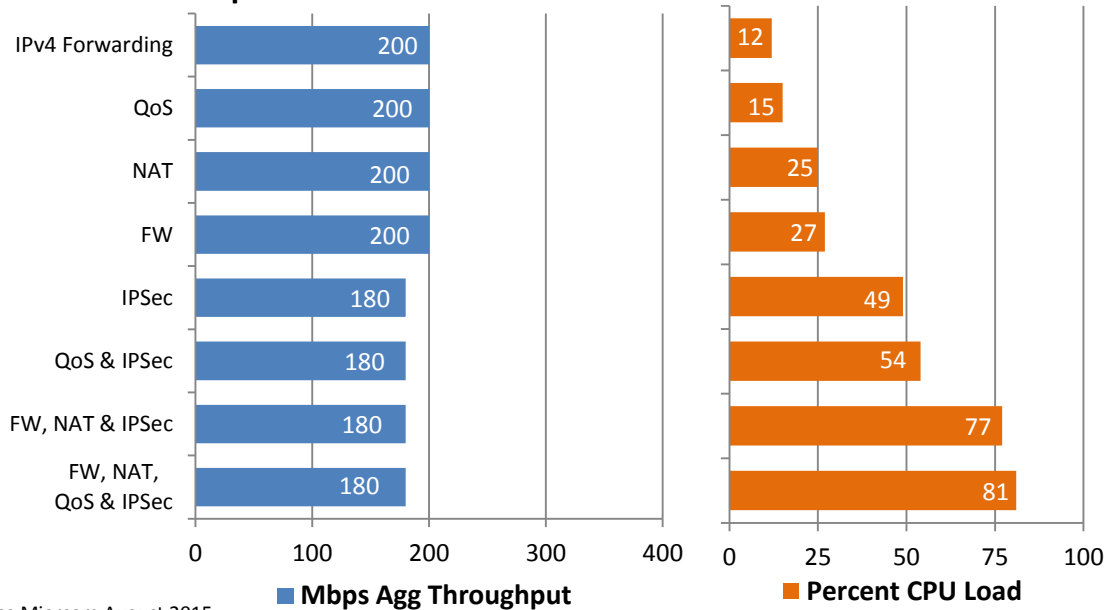
KEY: QoS = Hierarchical Quality of Service processing
 IPSec = All data is sent/received via encrypted tunnels

FW = Zone-based Firewall
 NAT = Network Address Translation

Performance: Cisco 4351 – Throughput and CPU Headroom

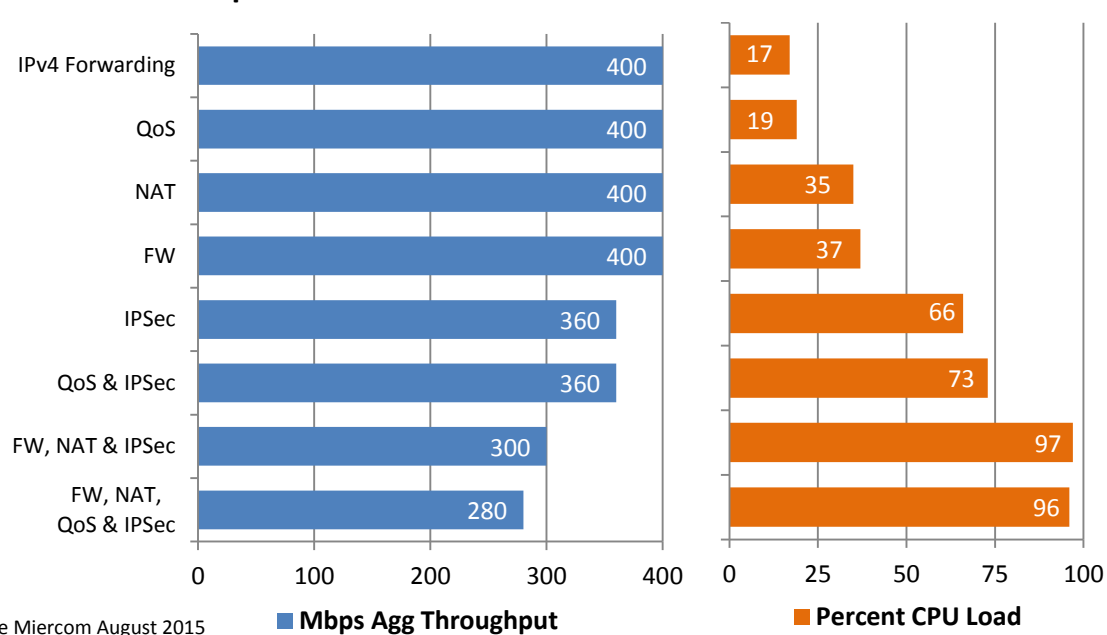
The charts below show the aggregate throughputs achieved by the Cisco 4351 ISR, which can be licensed for 200- or 400-Mbps capacity performance. For each service configuration tested, the average CPU load while achieving the particular throughput level is shown.

ISR4351: 200-Mbps License



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ISR4351: 400-Mbps License



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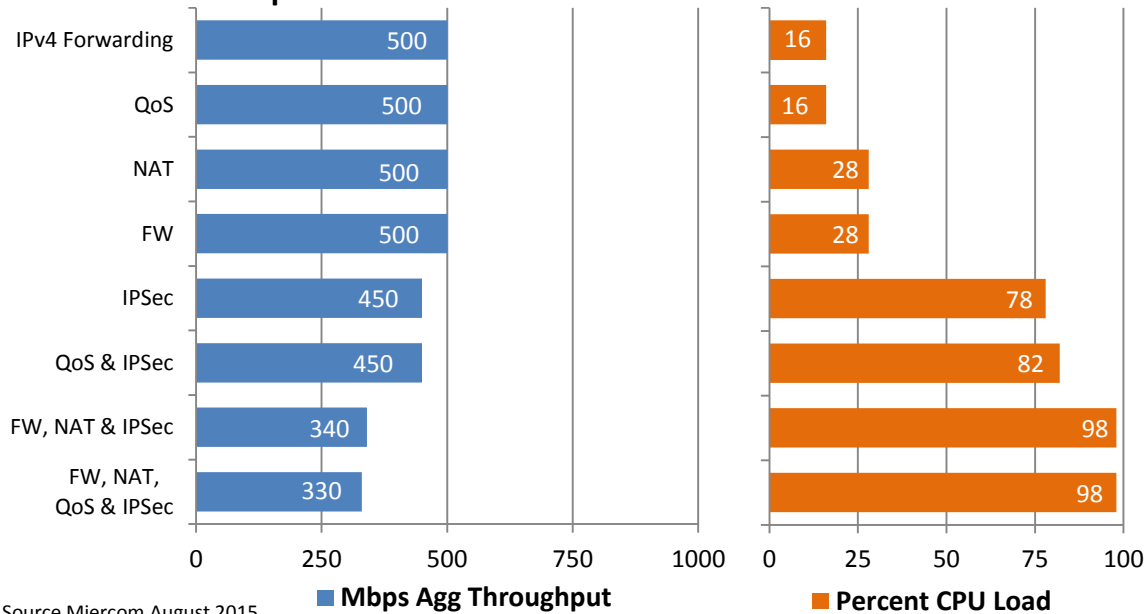
KEY: QoS = Hierarchical Quality of Service processing
 IPSec = All data is sent/received via encrypted tunnels

FW = Zone-based Firewall
 NAT = Network Address Translation

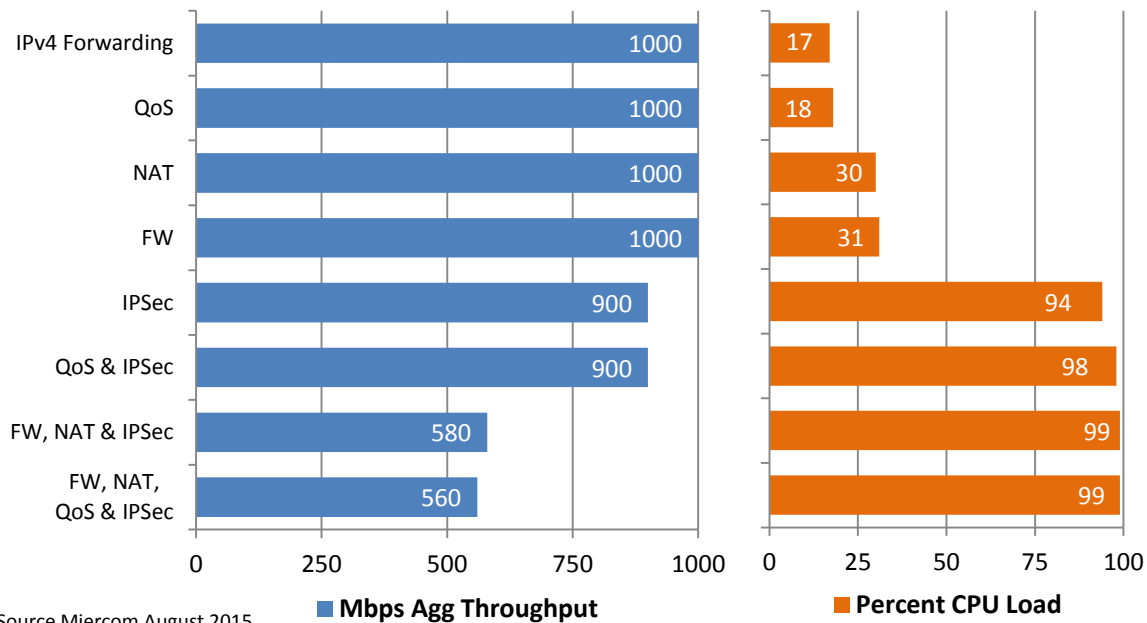
Performance: Cisco 4431 – Throughput and CPU Headroom

The charts below show the aggregate throughputs achieved by the Cisco 4431 ISR, which can be licensed for 500- or 1,000-Mbps capacity performance. For each service configuration tested, the average CPU load while achieving the particular throughput level is shown.

ISR4431: 500-Mbps License



ISR4431: 1,000-Mbps License



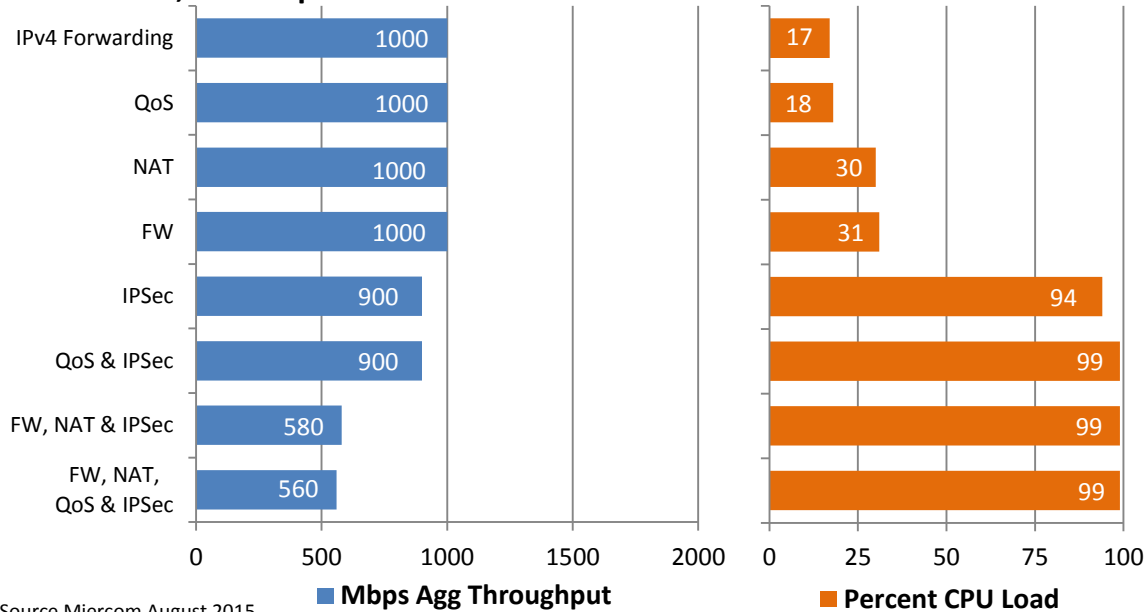
KEY: QoS = Hierarchical Quality of Service processing
 IPSec = All data is sent/received via encrypted tunnels

FW = Zone-based Firewall
 NAT = Network Address Translation

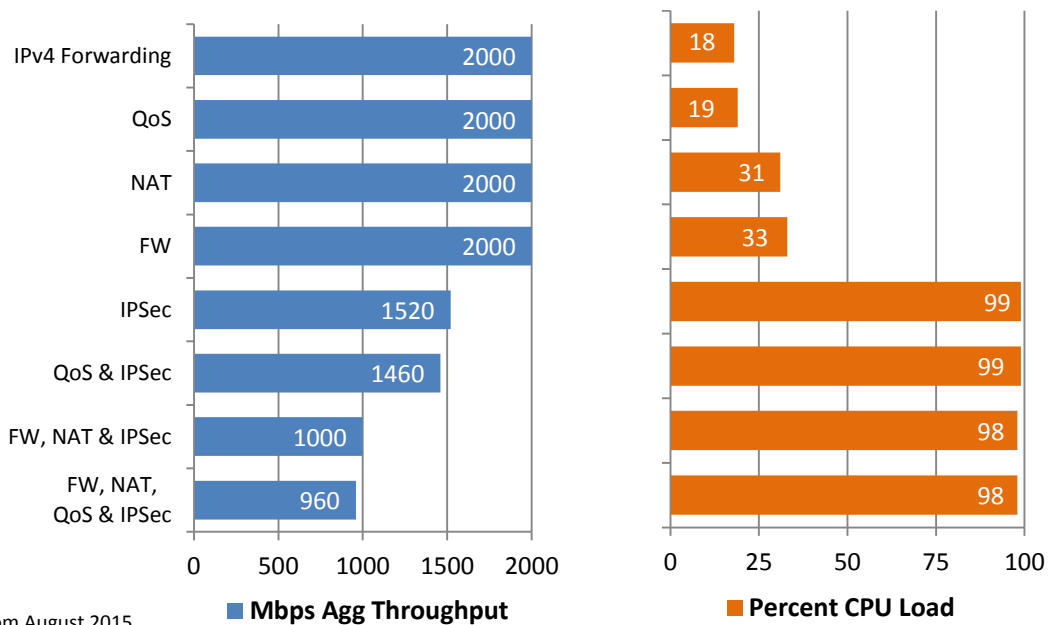
Performance: Cisco 4451 – Throughput and CPU Headroom

The charts below show the aggregate throughputs achieved by the Cisco 4451 ISR, which can be licensed for 1,000- or 2,000-Mbps capacity performance. For each service configuration tested, the average CPU load while achieving the particular throughput level is shown.

ISR4451: 1,000-Mbps License



ISR4451: 2,000-Mbps License



KEY: QoS = Hierarchical Quality of Service processing
 IPSec = All data is sent/received via encrypted tunnels

FW = Zone-based Firewall
 NAT = Network Address Translation

5 - Independent Evaluation

This report was sponsored by Cisco Systems, Inc. The data was obtained completely and independently as part of Miercom's network-product-performance analyses.

6 - About Miercom

Miercom has published hundreds of network-product-comparison analyses – many made public, appearing in leading trade periodicals and other publications, and many confidential, for internal use only. Miercom's reputation as the leading, independent product test center is undisputed.

Private test services available from Miercom include competitive product analyses, as well as individual product evaluations. Miercom test methodologies are generally developed collaboratively with the client, and feature comprehensive certification and test programs including: Certified Interoperable, Certified Reliable, Certified Secure and Certified Green. Products may also be evaluated under the Performance Verified program, the industry's most thorough and trusted assessment for product usability and performance.

7 - Use of This Report

Every effort was made to ensure the accuracy of the data in this report. However, errors and/or oversights can nevertheless occur. The information documented in this report may depend on various test tools, the accuracy of which is beyond our control. Furthermore, the document may rely on certain representations by the vendors that were reasonably verified by Miercom, but are beyond our control to verify with 100-percent certainty.

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