ACG RESEARCH

THE REQUIREMENTS AND ECONOMICS OF CORE ROUTING NETWORKS

EXECUTIVE SUMMARY

Internet traffic is projected to increase at a compound annual growth rate of 26% over the next five years. Much of this traffic is carried over service providers' core routing networks. The growth in internet traffic drives the need for highly scalable core routers with high-density 100GE and 400GE interfaces. As 5G networks rollout, smart cities proliferate, connected cars and AR/VR become more common, the need for scalable and cost-effective core networks is greater than ever. We are at a special time where long-term architectural and cost optimization decisions are more important than ever before. Rapidly scaling network demand and application latency requirements are driving the need for optimization of core network capacity and fully automated and intelligent network operations.

The Cisco NCS 5500 and Cisco 8000 Series routers are third-generation routers which are highly scalable and make full use of Cisco Crosswork Network Automation for network optimization and operations automation. This paper compares the total cost of ownership (TCO) of the Cisco NCS 5500 and Cisco 8000 platforms with the cost of first-generation and second-generation routers in the core, including comparisons in different size regions. The new routers have ultra-high capacity 100GE and 400GE interfaces allowing service providers to meet increasing demands and aggregate traffic volumes in smaller footprints. In addition, these routers have much lower power consumption per Gbps and operate with the Cisco Crosswork Network Automation suite.

The Cisco Crosswork Network Automation suite simplifies network operations, increases security posture, and optimizes traffic flows to help reduce network CAPEX and OPEX in all regions. Operation teams can be more proactive to deliver a superior network experience. Crosswork also reduces time to revenue and advanced analytics and telemetry allow engineers to make quicker and better decisions.

The analysis demonstrates that the Cisco 8000 Series routers are most cost-effective in large regions where high 100GE and 400GE port densities are required; the NCS 5500 Series routers are most cost-effective in medium and small regions and can scale to 400G in brownfield regions where the NCS 5500 is already deployed.

KEY FINDINGS

- TCO compares Cisco NCS 5500 and 8000 platforms with the cost of first-gen and second-gen routers in the core, including comparisons in different size regions.
- The Cisco NCS 5500 and 8000 Series provide unprecedented core network scalability
- 8000 and NCS 5500 Series have a five-year TCO savings of 87% over the first-gen routers and 66% savings over the second-gen routers
- Cisco Crosswork Automation reduces network OPEX by up to 80%

CORE ROUTING NETWORK CHALLENGES

Service providers' core routing networks provide the backbone of the internet. Designing, engineering, and operating core networks has been a challenge due to the rapid rate of traffic growth and high expectations by end users. The Cisco VNI projects that global IP traffic will reach 396 Exabytes per month by 2022, amounting to 85 GBytes per user per month. Traffic will increase at a compound annual growth rate of 26%. Additionally, IoT will drive a large increase in the number of devices connected to the internet. Globally, by 2022 there will be 3.6 networked devices per person or 28.4 billion networked devices. Consequently, core scalability continues to be a major challenge for service providers.

Some of the key drivers for traffic growth are:

- 5G mobile networks and applications
- Virtual reality (VR) and augmented reality (AR)
- Video game streaming
- Video surveillance
- Internet VoD and TV

The Cisco VNI predicts that globally, IP video traffic will be 82% of all IP traffic (both business and consumer) by 2022, up from 75% in 2017. The growth of video and other intensive bandwidth applications continues to drive the need for high bandwidth in the core.

Today, most legacy core routers are designed for high-density 10GE. However, the projected increase of internet traffic will overwhelm 10GE legacy routers. This means that the next-generation core needs to have high-density 100GE and 400GE interfaces to support the projected traffic growth.

In addition to capacity, security and trust is a key challenge in core network engineering and operations. Networks are critical infrastructure carrying data vital to many industries, imposing greater importance to maintain integrity of networks. This requires more trustworthy and secure solutions.

CISCO NEXT-GENERATION CORE ROUTERS

Given the enormous growth of traffic that is expected over the next five years, it's important for service providers to get ahead of the growth curve by deploying scalable 100G and 400G core routers. Large scale core networks also allow service providers to converge mobile, residential, and business networks which improves core network utilization and reduces cost.

Cisco has two families of core routers designed for high-density 100GE and 400GE interfaces. **The Cisco NCS 5500** is very cost-effective for 100GE port densities and also supports high-density 400GE. **The Cisco 8000 series** are new routers that are optimized for both 100GE and 400GE. The NCS 5500 will support projected traffic growth over the next five years in many locations. For high-density urban locations with very large traffic growth, the Cisco 8000 is a better choice because of its higher port densities. The 100GE and 400GE port densities are presented in Table 1. For chassis-based platforms, the port densities for 100GE and 400GE assume the chassis is fully loaded with either 100GE or 400GE but not both simultaneously. For the fixed form factors the total number of fixed ports are presented.

Platform	Slots	100GE Ports	400GE Ports
5508	8	288	192
5516	16	576	384
8201	Fixed Form	12	24
8202	Fixed Form	60	12
8808	8	384	288
8812	12	576	432
8818	18	864	648

Table 1. Cisco NCS 5500 and 8000 Port Density

NETWORK OPERATIONS STRATEGY

Worldwide, core networks carry most of the world's internet traffic. As these networks grow it is critical that they are secure, trustworthy, efficient, and reliable. Traditional network operations use point-and-click or scripted network automation which is inefficient and expensive. These problems increase in scope as networks grow larger. It is critical to modernize network automation and analytics to reduce the time and expense required to manage networks.

The Cisco Crosswork Network Automation improves planning, design, operations, and optimization of service providers' networks. It enables service providers to proactively manage their end-to-end networks with a suite of machine-learning, intent-based, and closed-loop solutions to ensure faster innovation, extraordinary customer experiences, and operational excellence. Crosswork reduces remediation time, reduces network OPEX, and accelerates time to revenue by:

- Simplifying network operations
- Optimizing network link utilization
- Reducing service assurance expenses
- Decreasing network security expenses
- Reducing test and certification expenses

The Cisco Crosswork Network Automation suite consists of multiple on-premise and cloud hosted products. On-premise products help operators optimize and reduce noise within their network and. cloud hosted products are simple to deploy and highly scalable. Data from Crosswork builds a collective knowledge base that can be used to improve machine learning algorithms and generally increase system intelligence.

Cisco Crosswork Network Insights

The Network Insights is a hosted application in Cisco Crosswork Cloud that provides rich analysis, visualization, and alerting on actionable network events. It provides real-time BGP route monitoring and rapidly detects routing issues caused from configuration issues or malicious intent. It identifies route leaks and other routing problems that can cause outages. Network Insights proactively alerts operation teams of these events, therefore reducing outage times that affect network service assurance expenses.

Cisco Crosswork Trust Insights

Network infrastructure security issues can be caused by malicious actions or simple procedural errors. Trust Insights checks the integrity of network hardware and software. It looks for alterations in

hardware, software boot images and run time processes that deviate from the norms. Trust Insights provides intuitive visualization, rich analytics, and alerts on devices to help your operation teams verify trustworthiness across the production network. The key benefits of Trust Insights are improving router security through integrity checks and reducing the time and expense for security compliance and audits. Trust Insights mitigates the risk of compromise which can cause loss of trust with customers and damage brands.

Cisco Crosswork Qualification Environment

Service providers must carry out a rigorous test and certification process before new hardware or software releases are deployed in a production network. The Qualification Environment provides a cloud-based test environment to improve the speed and reduce the cost of test and certification. Service providers can upload network topology, features, and test cases to the Crosswork Cloud and run a series of automated tests to produce a deployment score. Labor hours are reduced from weeks to days and network lab equipment expenses are eliminated.

Cisco Crosswork Optimization Engine

The dramatic traffic growth forecasted by the Cisco VNI challenges core network scalability. Although upgrading core networks with high-capacity 100GE and 400GE routers is important, it is equally critical to optimize the routing of network traffic. Underutilized links waste network resources and investments. The optimization engine uses closed-loop optimization in conjunction with segment routing and SDN to anticipate network traffic and optimize network resources. Some conditions addressed include automated bandwidth on demand and re-routing of traffic to lower latency paths for delay-sensitive applications. The optimization engine provides significant cost savings because it reduces the need for additional network capacity and support related to traffic issues.

Cisco Crosswork Situation Manager

IT and network operations teams are challenged with monitoring the amount of noise produced by dynamic network infrastructures, and the introduction of specialized tools to support these use cases has increased duplication of events, complicated correlation and increased time to remediate problems. Situation Manager is designed to assist IT and network operations teams in interpreting the events and streamlining the number of issues, so they can focus on resolving customer impacting issues collaboratively across workgroups. Combined with other Cisco Crosswork products, operators stay proactive with a closed-loop automation framework. The key benefit of Situation Manager is reducing the cost of network service assurance and accelerate root-cause analysis.

TCO MODEL FRAMEWORK AND ASSUMPTIONS

This paper presents the results of a TCO model showing the benefits of the Cisco NCS 5500 and 8000 Series routers in core networks and compares the TCO of these next-generation routers with first- and second-generation core routers that were optimized for 10GE interfaces. The TCO benefits of the Cisco Crosswork Network Automation suite also are presented in our TCO results.

Our TCO model assumes a converged core network for mobile, residential, and business services. The models for the converged core in a given region are presented in Figures 1 and 2. In a given region if two redundant core routers have enough capacity to serve the entire region, then the architecture in Figure 1 is used in our model. Alternatively, if additional capacity is needed in the core then a spine and leaf

architecture depicted in Figure 2 is used in our model. In both cases the core nodes are fed by aggregation networks that connect to the core using 100GE.

We determine that capacity required in the core using a demand model for mobile, residential, and business IP traffic. Core routers in each region connect to other core routers in other regions using 400GE trunks. For the first- and second-generation routers, we use 100GE trunks to interconnect core routers because these routers do not support 400GE. We also account for transit traffic passing through core routers. We assume that five times as much capacity is needed for transit trunks as opposed to service trunks, based on traffic data measured in real service providers' networks.

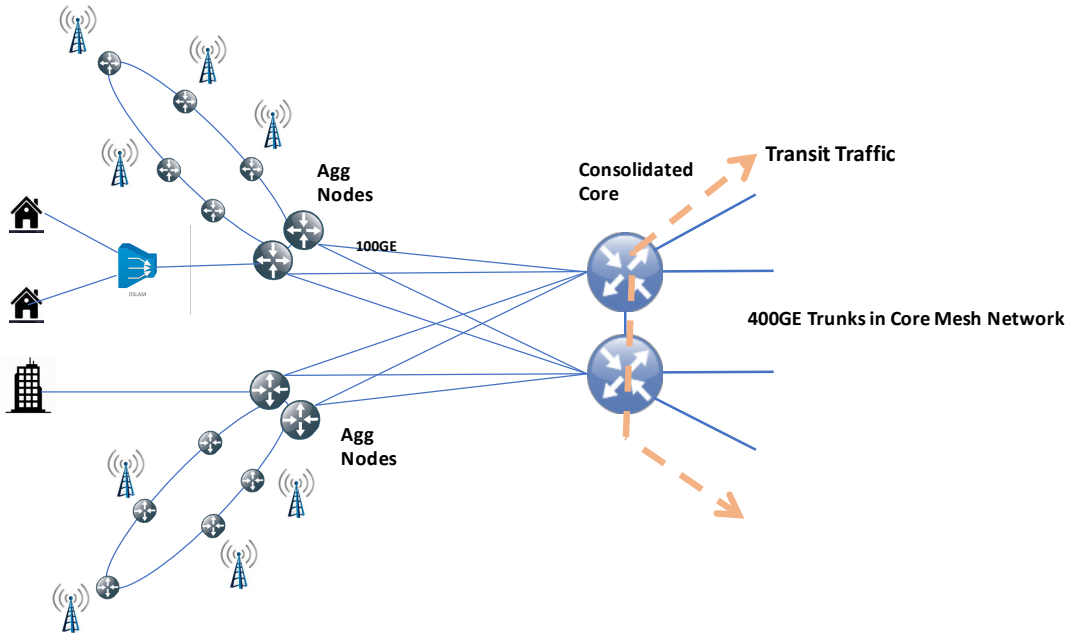

Figure 1. Consolidated Core in Region with Two Routers

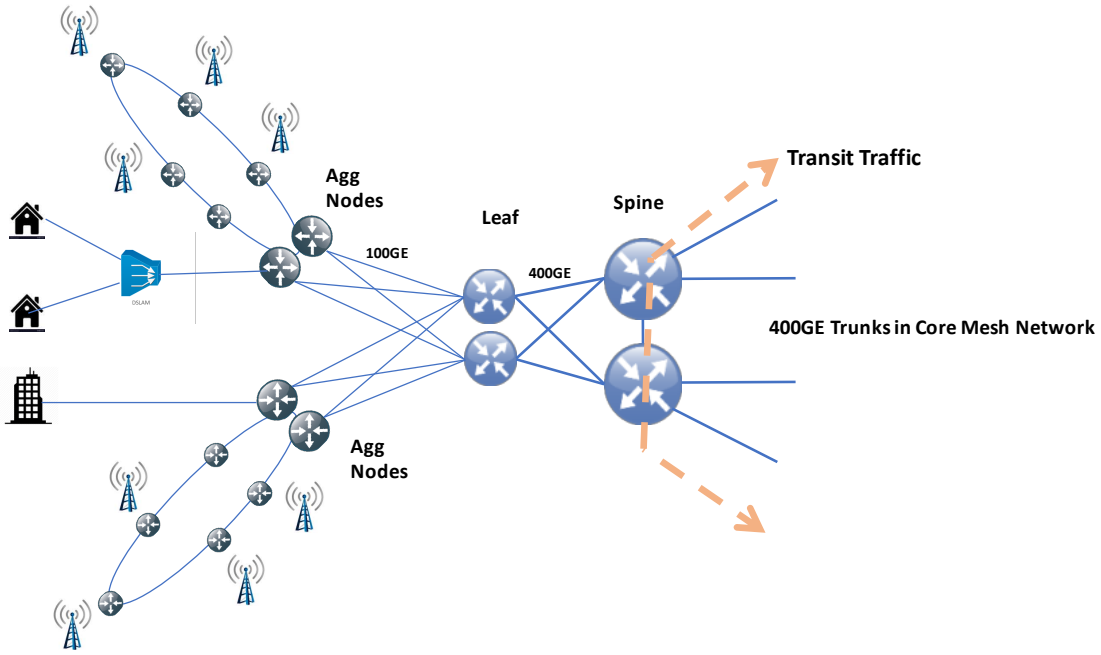

Figure 2. Leaf and Spine Core in Region with Multiple Routers

We consider three different types of regions: large, medium, and small. The demand modeling assumptions for these regions are presented in Table 2.

	Small	Medium	Large
Number of regions	10	10	10
Number of regional agg nodes	10	25	40
4G mobile traffic per base station (Mbps)	100	150	150
4G mobile traffic growth rate	20%	46%	46%
Number of 4G cell sites	1000	5000	10000
4G cell site growth rate	3%	3%	3%
5G mobile traffic per base station (Mbps)	500	800	800
5G mobile traffic growth rate	46%	46%	46%
Number of 5G cell sites	10	50	130
5G cell site growth rate	0.5	0.8	0.8
Residential subscribers	200,000	500,000	1,000,000
Residential traffic per subscriber (Mbps)	1.2	1.2	1.2
Residential traffic growth rate	20%	20%	20%
Business customers: 1GE CPE	500	1500	3000
Business traffic per CPE (Mbps)	2	2	2
Business traffic growth rate	42%	42%	42%

Table 2. Demand Assumptions in Regions

We assume that a core network connects 10 regions for each case of large, medium, and small regions. We use this comparison to identify the relative sweet spots for the Cisco NCS 5500 and 8000 series routers.

TCO RESULTS

The TCO model is a multi-dimensional model that calculates detailed router equipment expenses (CAPEX), router technical support expenses, environmental expenses, and many other operations expenses (OPEX). The results show that in large regions the Cisco 8000 Series is the most cost-effective platform, and in medium and small regions the Cisco NCS 5500 Series routers are more cost-effective. NCS 5500's are already deployed in many networks and are able to grow to support 400G. The 8000 is a new platform that is optimized for 400G. In all cases the new Cisco 8000 and NCS 5500 series routers with high 100GE and 400GE port densities are significantly more cost-effective than the first- and second-generation routers. The CAPEX, OPEX, and TCO results and the TCO differences between different routers are presented in Figures 3−5 and Tables 3−5. The figures show the relative CAPEX and OPEX of each alternative, and the tables show the values of CAPEX, OPEX, TCO expenses and the differences in TCO between the Cisco 8000 and NCS 5500 series routers and the first- and second-generation routers. For example, in Table 3 the TCO of the NCS 5500 is 31% higher than the 8000; the first-generation TCO is 749% higher; and the second generation is 212% higher than the 8000 series. In medium and small regions, the TCO of the NCS 5500 is lower than the 8000 by 1% and 2%, respectively.

The TCO model automatically selects the optimal routing configuration for each type of router based on the demand in the region. For example, if demand is high and a consolidated core of two routers is used in the model. Also, we select the optimal chassis to support demand. For example, we select either the 8808, 8812 or 8818 based on the demand over five years. Similar optimization is used to choose the NCS 5500 platforms and first- and second-generation router platforms.

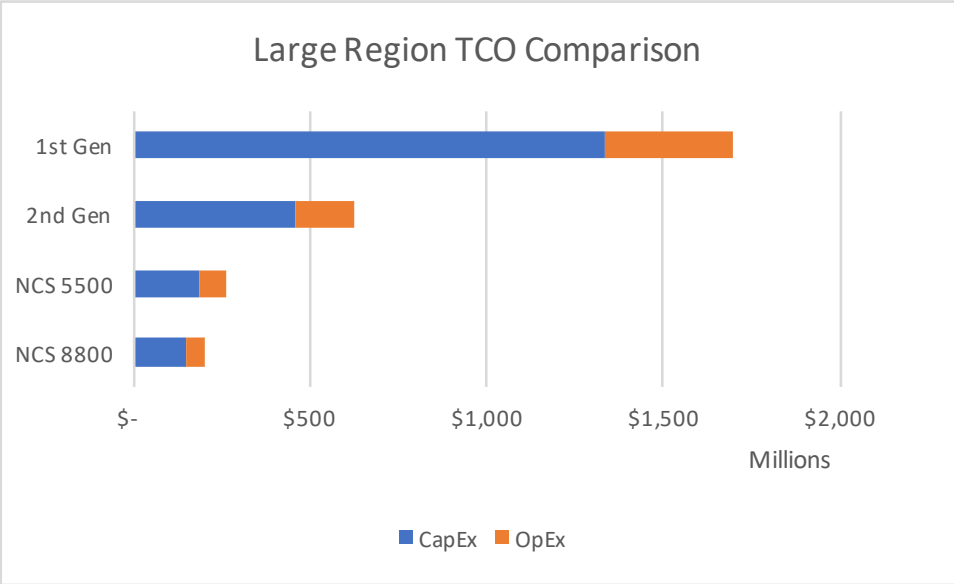

Figure 3. Large Region TCO Comparison

	CAPEX	OPEX	TCO	TCO Difference
8000	$144,638,800	$55,031,182	$225,045,752	N/A
NCS 5500	$186,265,600	$74,469,291	$260,734,891	31%
1st Gen	$1,334,035,200	$360,705,369	$1,694,740,569	749%
2nd Gen	$456,043,200	$166,527,130	$622,570,330	212%

Table 3. Large Region TCO Results

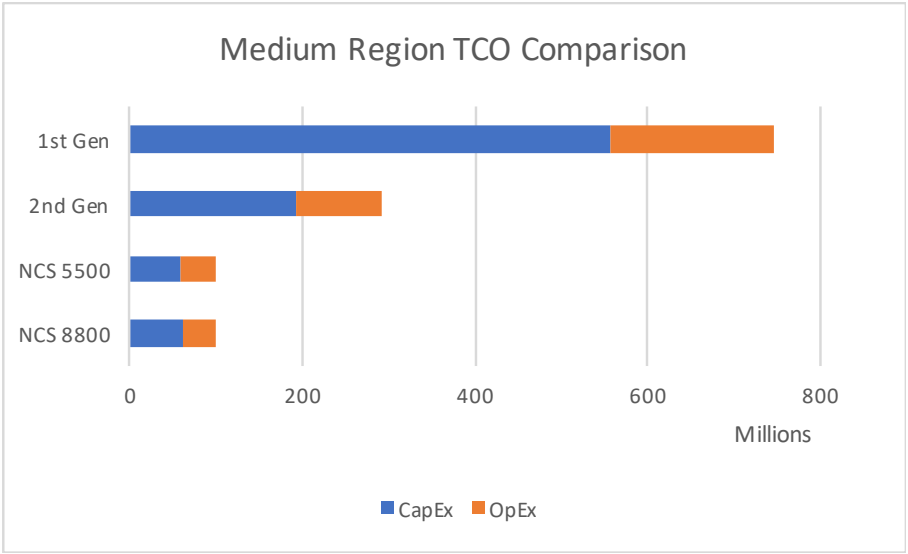

Figure 4. Medium Region TCO Comparison

	CAPEX	OPEX	TCO	TCO Difference
8000	$60,955,700	$38,886,269	$110,527,687	N/A
NCS 5500	$59,902,900	$39,142,760	$99,045,660	-1%
1st Gen	$556,298,400	$191,199,702	$747,498,102	649%
2nd Gen	$191,592,000	$100,156,461	$291,748,461	192%

Table 4. Medium Region TCO Results

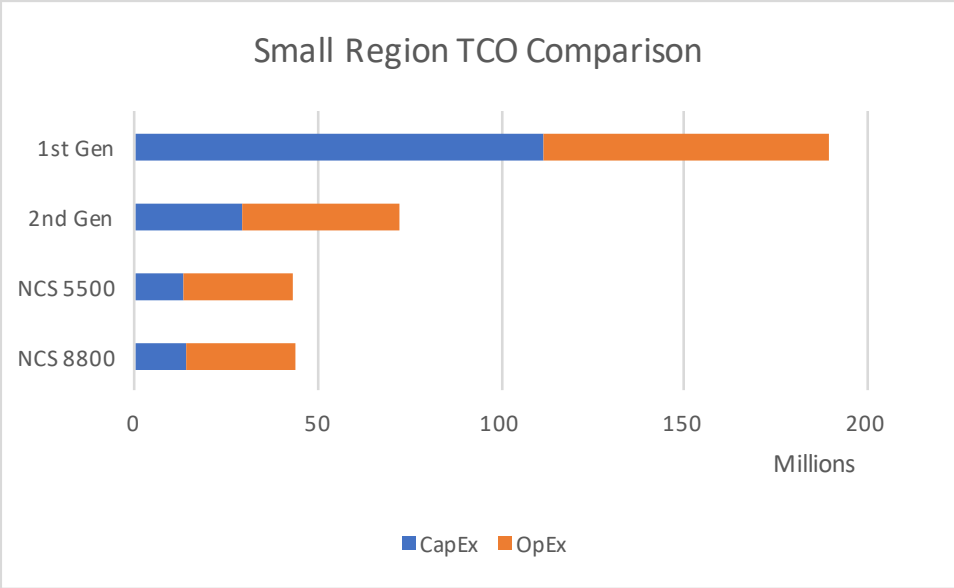

Figure 1. Small Region TCO Comparison

	CAPEX	OPEX	TCO	TCO Difference
8000	$14,210,900	$29,951,905	$46,412,430	N/A
NCS 5500	$13,464,500	$29,797,785	$43,262,285	-2%
1st Gen	$111,394,800	$78,204,987	$189,599,787	329%
2nd Gen	$28,896,200	$43,000,145	$71,896,345	63%

Table 1. Small Region TCO Results

The TCO model considers the categories of OPEX listed in Table 6. There are several areas where the Cisco 8000 and NCS 5500 Series routers have OPEX benefits over the legacy routers:

- Cisco Crosswork provides OPEX benefits in security, test and certification, network engineering, capacity planning, and service assurance
- Traffic drives a much higher number of legacy routers in the core, which increases many categories of OPEX
- The Cisco 8000 and NCS 5500 Series routers are more power efficient than earlier generation routers and lower power and cooling expenses

OPEX Category	Definition
Maintenance & Support	These are support expenses for hardware and software provided by the vendor
Security	Security management must be done for both the routing and optical network layers; involves security monitoring and patching
Test & Certification	Before any new hardware or software releases are deployed in production, they must go through a service provider's test and certification process
Software Upgrades	Network software upgrades require planning, monitoring, execution, and possibly rollbacks; labor expenses associated with software upgrades
Network Engineering & Capacity Planning	Network engineering groups are responsible for network architecture, detailed design, resiliency analysis, and capacity planning
Moves, Adds, Changes	Network operation requires constant changes in configuration, tuning, and management
Network Installation	One-time installation expenses for network equipment installation
Service Assurance Labor	Fault management, troubleshooting, and repair activities
Total Power (IT, Cooling, Aux) Cost per Kwatt/Hour	Power expenses for powering and cooling equipment

Table 2. Categories of OPEX

The five-year cumulative OPEX savings for medium regions is provided in Figure 6, and an annual comparison of power consumption is presented in Figure 7. The cumulative OPEX savings uses an average of the NCS 5500 and 8000 OPEX to compare with the 1st Gen and 2nd Gen routers. There are significant OPEX savings over five years which are due to Crosswork automation, less network nodes to manage, and lower annual support expenses. Power and cooling expenses are much lower for the Cisco 8000 and NCS 5500 as a result of lower annual power consumption (Figure 7).

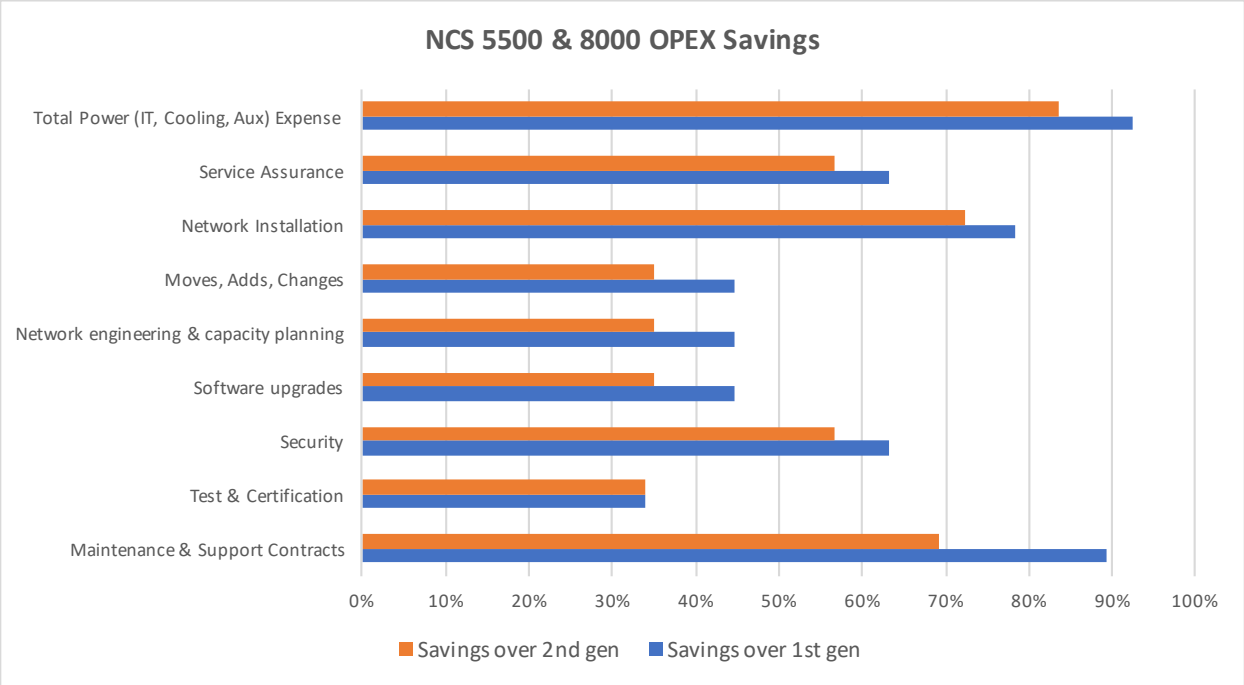

Figure 2. OPEX Savings in Medium Region

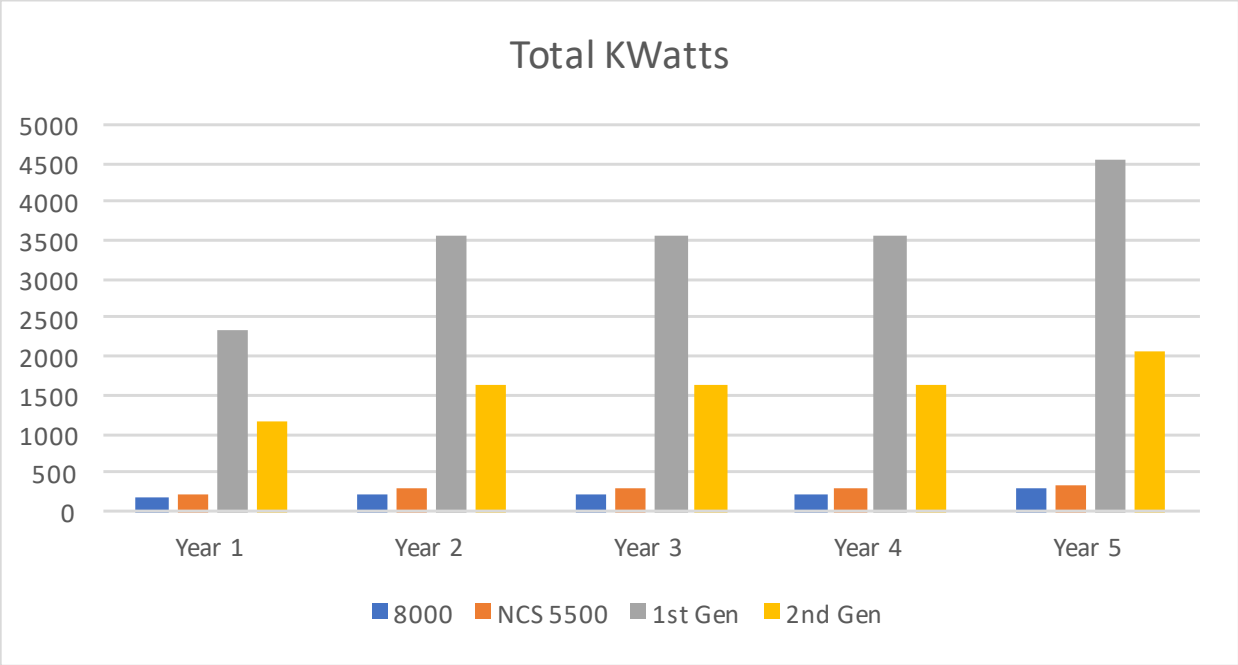

Figure 3. Medium Region Power Consumption Comparison in KWatts

Table 7 shows the CAPEX, OPEX, and TCO savings of the average of the Cisco NCS 5500 and 8000 routers over the first-generation and second-generation routers over five years for the medium size region.

	CAPEX	OPEX	TCO
1st Gen	89%	80%	87%
2nd Gen	68%	39%	66%

Table 7. CAPEX, OPEX, and TCO Savings of the Cisco NCS 5500 and 8000 Routers

CONCLUSION

As 5G networks rollout, smart cities proliferate, connected cars and AR/VR become more common, the need for scalable and cost-effective core networks is greater than ever. As a result, core routing networks are quickly moving from 10G to 100G and 400G. The Cisco NCS 5500 and 8000 series core routers allow service providers to scale and optimize their core networks to meet internet traffic requirements over the next five years. These routers are tightly coupled with Cisco Crosswork Network Automation to provide network optimization, intelligent automation, and analytics which improves capacity utilization, reduces network OPEX, and improves time to revenue. We have demonstrated that the third-generation NCS 5500 and 8000 routers have an 87% TCO savings over first generation routers and a 66% TCO savings over second generation routers. These savings are primarily due to the following factors:

- Smaller footprint
- Lower capital cost per Gbps
- Lower power consumption
- Crosswork network optimization
- Crosswork network automation and analytics

The sweet spot of the NCS 5500 are small and medium regions that need to increase link speeds to 400G. In large regions, the Cisco 8000 is the most cost-effective solution with unmatched 400G scalability. In addition to network scalability, network operations and engineering expenses are reduced with the Cisco Crosswork Network Automation suite. These products reduce the cost of security, test and certification, network engineering, capacity planning, and service assurance.

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