# Cisco Network Convergence System: Building the Foundation for the Internet of Everything

## Executive Summary

A third wave of Internet expansion, the Internet of Everything (IoE), is expected to come through the confluence of people, processes, data, and things. Cisco estimates the Value at Stake for the IoE is $14.4 trillion over the next 10 years. IoE requires a context-intelligent architecture in addition to massive scale. For IoE, service providers must deliver increasing security, reliability, and availability with networks that also provide greater service velocity and flexibility. In addition, they require network autonomics, process automation and the tools to meet the management challenges of a much more complex network.

Cisco Network Convergence System (NCS) is a family of integrated packet routing and transport systems designed to help service providers capture their share of the IoE Value at Stake. NCS is built on major innovations in silicon, optics and software and provides the building blocks of a multilayer converged network that intelligently manages and scales functions across its architecture.

ACG Research analyzed the business case for NCS and found it achieves massive scale via multichassis system architecture, the density and performance of its new chip set, and the extension of the control plane to virtual machines (VM) internally and externally. Fully virtualized software improves service velocity and asset utilization by creating a cloud model inside the platforms. Virtualization also supports orders of magnitude improvement in system availability and security through the isolation and independence of software operations. Optical innovations lower multichassis interconnect costs and optimize wavelength density and cost.

### KEY FINDINGS

NCS provides the architecture for building multilayer converged networks that intelligently split and scale functions to enable IoE:

- Providing a system with up to 66% lower TCO than competing solutions.
- Consuming up to 80% less power than competitive offers.
- Accelerating service velocity through fully virtualized software.
- Increasing system availability beyond five 9s by isolating software modules through virtualization.
- Opening the system to cloud-based innovations and cost levels by extending the NCS control plane to VMs, both internal and external.

## Introduction

A third wave of Internet expansion, the Internet of Everything (IoE), is expected through the confluence of people, processes, data, and things (Figure 1).

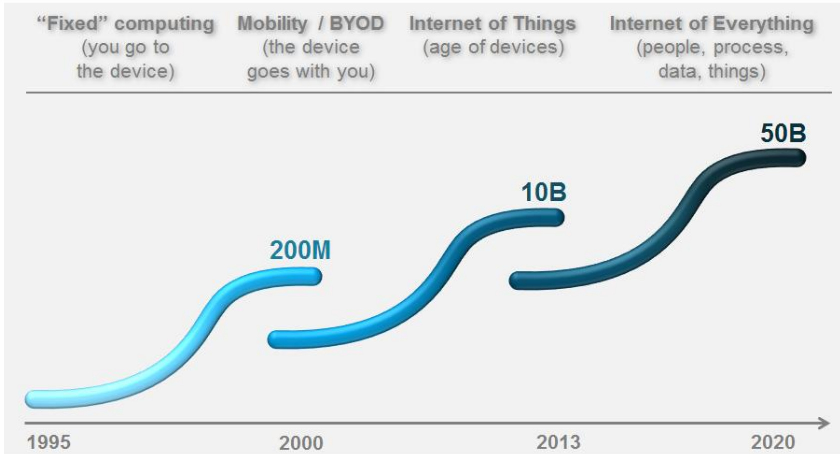


**Figure 1 – Third Wave of Internet Development**[1]

IoE opportunities are being driven by dramatic increases in processing power, storage, and bandwidth at lower cost; the rapid growth of cloud, social media, and mobile Internet; the capacity to analyze large quantities of data, transactions, and events and turn it into actionable intelligence (Big Data); and an improved ability to use hardware and software more powerfully and flexibly with capabilities such as virtualization, software-defined networking, and network function virtualization (NFV). IoE creates value by leveraging large numbers of interconnected information flows. Cisco estimates the global IoE Value at Stake[2] over the next 10 years will be $14.4 trillion. Service providers can gain a share in IoE Value at Stake by enabling the IoE.

***IoE Driven Requirements for Service Providers' Networks***

IoE requires an evolved, programmable, context-intelligent architecture in addition to massive and adaptive scale. Such a network must dynamically manage the complex interactions among traffic, business rules, and transactions. Network requirements created or amplified by IoE include:

- Interconnect trillions of things: About 10 billion high-function devices are connected to the Internet today. The addition of vast numbers of things (such as individual retail and commercial items) to the people on the Internet, the data they create and access, and the processes that manage, analyze, and respond to all the data and communications requires several orders of magnitude increase in connectivity.

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[1] See "Internet of Everything: Global Private Sector Economic Analysis," Cisco, January 2013.

[2] Cisco defines IoE Value at Stake as the total of private sector cost reductions and new revenue creation attributable to IoE initiatives. See "Internet of Everything: Global Private Sector Economic Analysis," Cisco, January 2013.

- Secure private data: IoE adoption requires that information owners trust the Internet to protect the owners' information. This trust level requires much safer security measures than those existing on the Internet today.

- Support exponential traffic growth: Video, mobile broadband, cloud computing, and IoE will drive global IP traffic to 1.4 zettabytes by the end of 2017 according to the Cisco Visual Networking Index. Traffic is expected to maintain a 23 percent annual growth rate through 2017.

- Increase network reliability and availability: IoE depends upon always-on networks. Today, the five 9s availability criterion is not adequate for such critical tasks as process control, public safety systems or medical monitoring.

- Increase service velocity and flexibility: Service innovation must be fast and flexible. Service introduction must be in days or minutes not months. Service instantiation must be low cost with fast and flexible service chaining.

- Meet increasing network management challenges: Managing huge numbers of devices, services and protocols; complex security requirements; and massive scalability requires new approaches. Automated network interactions will create self-managing and adaptive networks to enable growth far beyond the size of the Internet today. Such autonomic networks are analogous to the nervous system that regulates bodily functions and organs without conscious control.

## The NCS Family

The NCS family of integrated packet and transport systems positions service providers to capture a share of the IoE Value at Stake by meeting the new requirements for service providers' networks (See Figure 2).

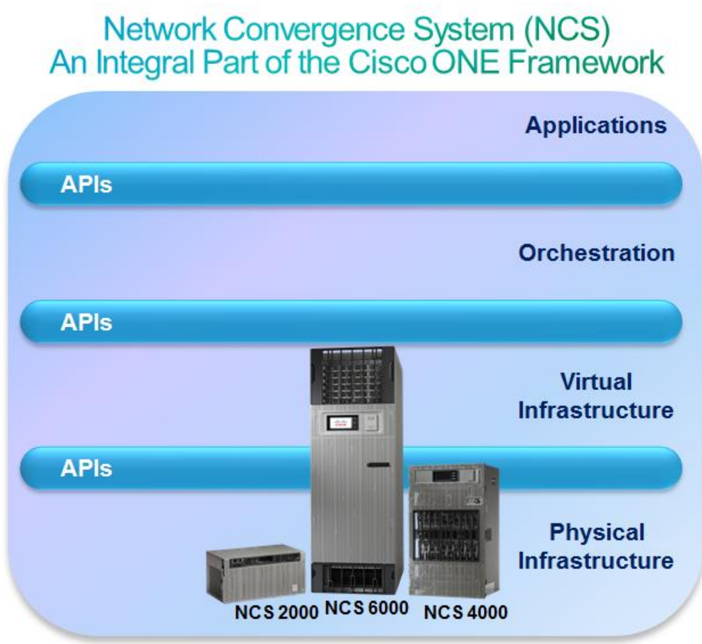


**Figure 2 – NCS Product Family**

NCS enables multilayer converged networks to split and scale functions intelligently across its system architecture. The NCS family consists of three products:

- NCS 6000: Integrated optical routing system
- NCS 4000: Integrated packet optical transport system
- NCS 2000: Agile DWDM system

NCS is built on major innovations in silicon, optics and software. A new level of silicon integration replaces 14 chips with two. It features common building blocks used in a variety of combinations for different applications, and all have programmable microcode. This enables rapid innovation and product delivery.

Optical innovations feature 100 Gbps coherent detection technology[3] and InfiniBand technology to lower multichassis interconnect costs. Silicon photonics is used to optimize wavelength density and power. The DWDM system is colorless, contention-less and omnidirectional. This simplifies network management, accelerates network reconfiguration, and improves asset utilization.

NCS creates a paradigm shift in network systems software architecture. For the first time full software virtualization extends down to the line card (See Figure 3).

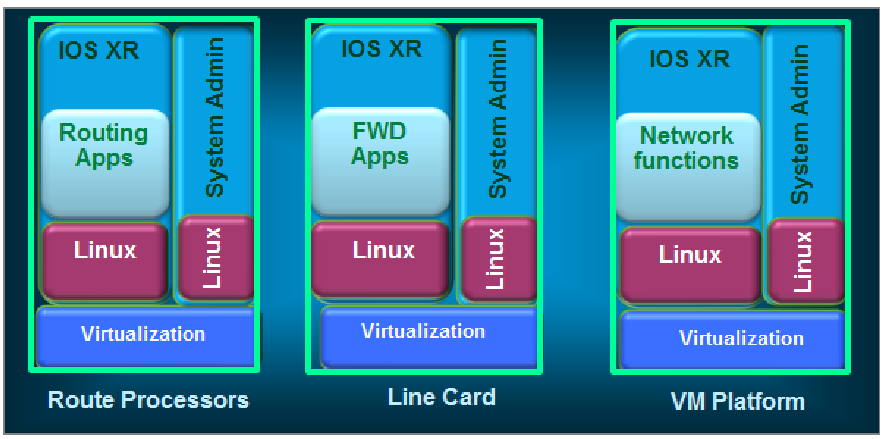


**Figure 3 – Fully Virtualized Software**

The virtualization feature of NCS allows more flexibility than solutions of previous generations. Hypervisors running VMs support a cloud model inside NCS. Figure 3 shows control plane, data plane and network services (IP mobile core, for example) deployed on identical system software infrastructure. Independent kernels and resources provide an isolated, scalable, and distributed owner-tenant model within the system and extend to any external VM platform.

The extension of the control plane to VM environments by NCS, including Cisco UCS, allows almost infinite flexibility and scalability of the routing control plane. This means new protocols, functions, and

[3] See ACG Research's "Why Service Providers Should Consider IPoDWDM for 100G and Beyond" for an analysis of the economic benefits of Cisco's coherent detection technology.

services can be deployed quickly, increasing service velocity and thus directly accelerating top-line revenue.

The ability to run multiple concurrent versions of software reduces security risks, increases service availability and service velocity. Virtualization also increases asset utilization, enables on-demand delivery and further enhances in-service software upgrades. Extension of the control plane to VM environments delivers the granular scale of customized services and low cost of data center-based systems. This allows the flexibility to add new protocols and services without needing to upgrade the hardware or adversely affecting performance. It provides a responsive low-cost platform for NFV, opening access to a large number of innovative applications from an ecosystem of third-party developers.

## NCS Meets IoE Driven Requirements for Service Providers

NCS delivers the scale to support massive and unpredictable traffic growth. It supports Terabit per second line cards with the highest 10 GE and 100 GE port densities in the industry, all providing line-speed data rates. The extensibility of its control plane to VM environments gives NCS the elasticity to respond to the dynamic demands of the IoE. Adding that to its network processing unit performance and programmability yields a system architecture built to support the transaction rates of trillions of connections and to evolve to meet future requirements.

***Massive Scale via Multichassis Network System Architecture***

The multichassis system architecture of NCS supports enormous traffic growth without additional systems and interconnects between them. The architecture also eliminates the time and cost required to reassign router ports when a new router is added to a cluster.

It is economically inefficient to accommodate traffic growth by adding single chassis routers to a router cluster. Some router port capacity is consumed to interconnect each existing router to the additional router. As more routers are added:

- Interconnect ports displace more revenue-generating service ports.
- Service ports need to be moved from one router to another, disrupting service and increasing operational complexity and cost.
- To meet traffic requirements, interconnect ports use between one-third and one-half of the port capacity of the routers.
- The interconnect architecture is a blocking-switching architecture and in some traffic conditions may not have enough bandwidth to serve demand.

NCS resolves these problems through use of multiple line card chassis to accommodate line cards (and first and third stage switch fabric cards) and a fabric card chassis that hosts the second stage of switch fabric cards. The NCS architecture delivers:

- No service disruption, no loss of service ports, and no rewiring when adding line card chassis

- Nonblocking fabric design using high-speed optical interconnect with cost-reduced, pluggable optics

- System scale that back-to-back or clustering solutions cannot match

***TCO and Power Comparisons with Leading Competitors***

A case study is used to compare the total cost of ownership (TCO) and power consumption of NCS 6000 with Vendor A's single router solution and Vendor B's multichassis router solution. Both vendors' solutions use their latest core routers. In the case study 2,000 10 GE ports and 500 100 GE ports are required in the initial study year, and total port requirements grow at 10 percent CAGR over the next five years. Figure 4 shows the TCO comparison; Figure 5 shows the power comparison.

Cisco NCS has 18 percent lower TCO than Vendor A and 45 percent lower TCO than Vendor B over six years. Over the same study period Cisco uses 42 percent less power than Vendor A and 59 percent less power than Vendor B. These savings are primarily attributable to the greater 100 GE and 10 GE port densities of the NCS 6000 and to the highly integrated and power-efficient design of the NCS chip set.

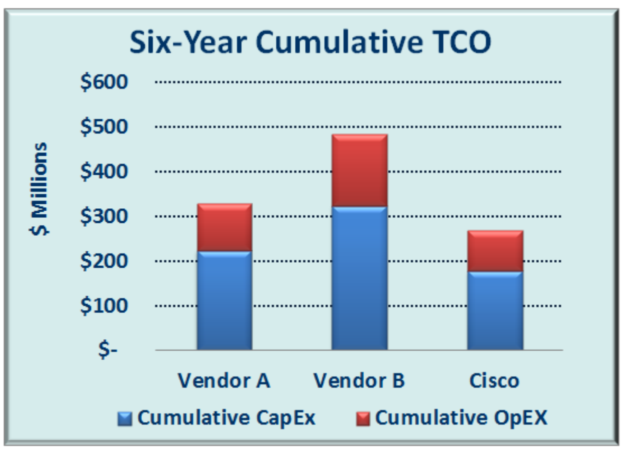


**Figure 4 – Core Router Six-Year Cumulative TCO Comparison**

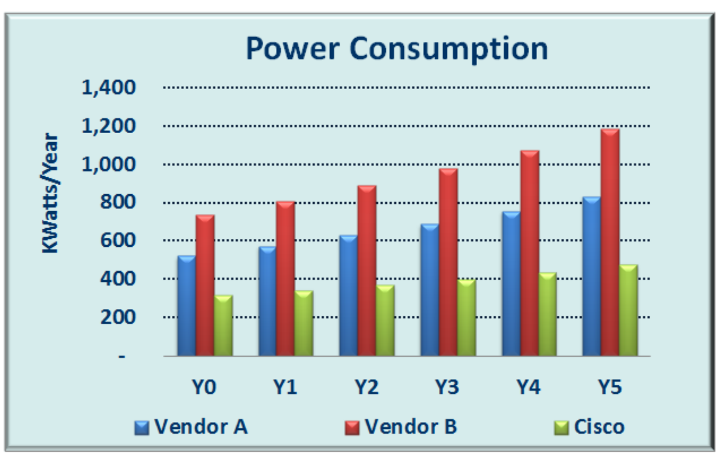


**Figure 5 – Core Router Annual Power Consumption**

***TCO Benefits of Scalable Control Plane***

NCS software virtualization combined with an extendable Ethernet control plane allows NCS networks almost infinite control plane scalability. This is very important because some network services require both control plane scalability and data plane scalability. A good example is the widely deployed MPLS VPN service. MPLS VPNs stress the control plane with multiple routing tables and eBGP sessions. Typical high-end routers cannot support more than 5,000 MPLS sessions per router. This is a limit imposed by the control plane. Therefore, while large routers can scale to terabits per second on the data plane, the control plane service limits can be exceeded long before the data plane limits are exceeded.

As an example, Figure 6 compares the NCS 6000 with core routers from Vendor A and B for a MPLS VPN use case.

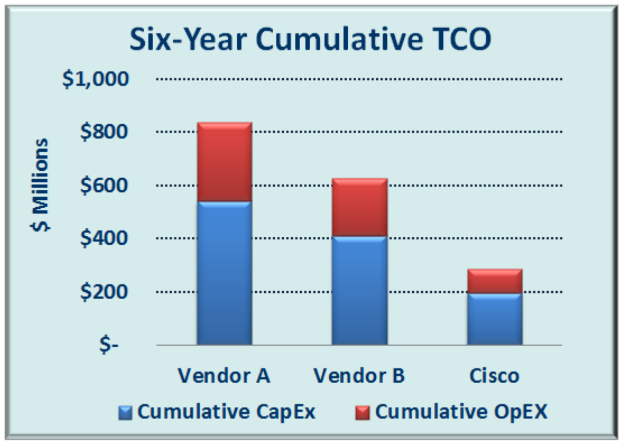


**Figure 6 – TCO Comparison for MPLS VPN Control Plane Use Case**

In this example each VPN customer's access point is assumed to generate 50 Mbps of traffic on average. The control plane limits for this service are exceeded long before the data plane limits are exceeded. Using the NCS 6000, servers are added to the control plane to continue to scale the MPLS VPN service without adding additional NCS chassis. Vendors A and B, however, require new chassis once the control plane limits are exceeded even though there are empty slots and unused capacity in the data plane. In this scenario the NCS 6000 solution is 66 percent more cost effective than Vendor A and 54 percent more cost effective than Vendor B. The NCS 6000 uses 80 percent less power than Vendor A and 65 percent less power than Vendor B.

***IP + Optical Convergence TCO Benefits***

Cisco nLight, a multilayer routing and optimization architecture focused on IP and DWDM integration and a Cisco ONE element, embodies the autonomics concept. nLight enables information flows between the optical and routing layers via control plane interworking, delivering an end-to-end protection and restoration solution. Compared to 1+1 optical protection nLight delivers savings of[4]:

- 26 percent fewer router interfaces
- 64 percent fewer optical transponder interfaces

[4] "The Economics of Cisco's nLight Multilayer Control Plane Architecture," ACG Research, 2013, provides the full analysis of the savings produced by nLight.

- Up to 50 percent savings in TCO for capacity planning

***Optical Port Density Benefits***

In addition to the TCO benefits of IP + optical convergence, there are additional operation (OpEx) benefits associated with the high DWDM port density in the NCS 4000. A single NCS 4000 shelf can support 32 100GE IPoDWDM interfaces compared with 16 or fewer 100GE interfaces provided by competing solutions. Additionally, power consumption per Gbps in the NCS 4000 is half that of the competition. This directly leads to 50 percent reductions in power, cooling, and floor space OpEx.

***Reliability, Availability, Flexibility, Security, and Network Management Advantages***

Full software virtualization allows software components to be isolated from each other. This protects each software component from failures or security events elsewhere in the system and provides more overall network reliability. Benefits are faster service velocity, including faster deployment of new software features and functions; zero packet loss and zero topology loss during software upgrades; and improved security.

Faster Service Velocity

Virtualization supports the rapid development and introduction of new services and software features by isolating the new software in production and by abstracting functions from the underlying physical infrastructure. An ACG Research study[5] found software virtualization significantly reduces time for testing and deploying new services and software. Substantial savings can be achieved by virtualizing only the testing process. For example, an ACG Research study found 30 percent time savings and 90 percent TCO savings by virtualizing a network test lab.

Zero Packet Loss, Zero Topology Loss and Network Availability

As IoE becomes more integral to business operations the need for more stringent service level agreements (SLA) will grow. Their value will increase because of the higher impact of outages, and remedies will escalate along with potential impact. Maintenance windows included in SLAs are typically two hours per month. This alone brings network availability down to 0.997 (24 hours per year): an availability level inadequate to meet the requirements of many IoE applications. Process control and monitoring applications require availability objectives with annual outage time in the second or subsecond range. Fault detection and isolation (protective relaying) used on the power grid is one such example. Grid performance requires faults to be isolated within three electric current cycles (50 ms) in order to minimize two catastrophic outcomes. First, faults across 500,000 volt transmission lines cause catastrophic damage if they are of longer duration. Second, faults of longer duration can cascade across the power grid, bringing down service over entire regions of a country[6].

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[5] See ACG Research's "Economic Benefits of Cisco CloudVerse," an analysis of how cloud techniques such as virtualization, abstraction, orchestration, and automation increase service velocity. These techniques are enabled by NCS's fully virtualized architecture.

[6] The 1999 southern Brazil blackout was caused by a lightning strike at a substation and cascading effect that affected 75 to 97 million people. The Northeast U.S. blackout of 2003 affected 55 million people in the U.S. and Canada and contributed to the deaths of 11 people. Water supply, transportation, communications and industry also were impaired due to power failure.

The high availability architecture of NCS will be an essential requirement in the era of IoE. Virtualization and isolation of software components eliminate packet and topology losses during software upgrades. This efficiency increases network availability, eliminates downtime costs, and eliminates the need to include maintenance window exceptions in SLAs.

Another way to assess the value of network availability is to observe the credits (remedies) service providers apply to enterprise service subscribers' accounts for violation of SLA network availability provisions. Table 1 provides some examples.

| SLA – Business Ethernet Service | Remedy |
|---|---|
| Availability 99.99% | 1% of MRC for each 1% below SLA |
| Latency 110 ms | 1% of MRC for every 4 ms above SLA |
| Packet Delivery 99.9% | 1% of MRC for each 1% below SLA |
| MRC = Monthly Recurring Charge | |

**Table 1 – Remedies for Violation of SLA Availability Provisions**[7]

Service providers can build networks to meet the SLA demands of IoE use cases with the innovative NCS architecture as their foundation.

<u>Improved Network Security</u>

The isolation of software modules and operating systems (OS) of NCS improves network security. If, for example, a hacker breaks into the data plane OS he does not have access to the control plane OS or the administrative OS, because these are separate virtual operating systems. Additionally, the software architecture of NCS allows many types of security software to run on the data, control, and administrative planes of NCS. Examples include anti-DDOS, firewall, and intrusion protection system services.

A simple probability model shows how software isolation decreases the chance that the entire network will be compromised by a security attack. A router might host three software modules and employ three operating systems. Assume there is a 0.01 probability that each of these modules and OSs can be compromised by a security attack. Under monolithic software design there is a 0.06 chance the entire router will be compromised. If each software module and OS is isolated, however, then there is only a $10^{-12}$ chance the entire router will be compromised[8].

The value of network security to service providers can be estimated by observing that recurring fees for managed security services make up 20 percent of total charges paid by enterprises.[9] This share of total revenue is likely to increase as security needs increase with the huge growth in connections and with more critical interdependent services riding the infrastructure.

[7] Source ACG Research survey 2013

[8] Under monolithic software probability that the entire router is compromised = $1 - (1 – 0.01)^6 = 0.06$. Under isolated software probability that entire router is compromised = $0.01^6 = 10^{-12}$.

[9] Source ACG Research survey 2013

***Benefits of NCS and Cisco ONE***

Cisco ONE provides a comprehensive framework of modular technologies and network programmability that allows networks to interact more meaningfully with applications to deliver on-demand response to their requests, accelerated service deployment, and improved customer experience. The NCS system is an integral part of the programmable network and its closed-loop communications path of analytics, applications and services orchestration. Through the Cisco Developer Network, Cisco is enabling a ONE ecosystem by helping developers create, test, and promote applications for their large customer base; more than 75 developers, including SAP and Citrix, are actively developing with Cisco APIs.

Autonomics

The aim of autonomic networking is to create self-managing networks with automated reprogramming and configuration of services in real time to overcome the rapidly growing complexity of the Internet (especially IoE) and to enable its future growth far beyond the size it is today. The virtualized architecture of NCS and the Cisco ONE ecosystem meet the challenges of creating autonomic networks.

IoE Applications

The Cisco ONE ecosystem provides a vehicle enabling service providers to enhance industry-specific IoE initiatives. Some of the most attractive use cases include:

- Smart factories: Adding connectivity to manufacturing processes and applications increases factory productivity, reduces inventories with real-time inventory supplies, and cuts average production and supply-chain costs.
- Connected marketing and advertising: Broad IT and social applications for marketing and advertising transform the way companies engage with customers, analyze their behavior, and optimize the impact of their interactions.
- Smart grid: An effective smart grid uses network connections—from production to customers—to better understand users' behaviors and improve the reliability, economics, and sustainability of the production and distribution of electricity.

Real-time Analytics

The IoE concept is tightly coupled to Big Data—data sets too big for traditional database tools or data processing methods. Network analytics increases the value of data when it can be used proactively in real time to drive actionable events for modern business processes (for example, policy management). Opportunities include marketing and sales for revenue-generating use cases, network management for root-cause analysis and fault prediction, and security for fraud detection.

Cisco ONE optimizes the use of network resources by integrating network analytics into the production network and enabling the network to adapt dynamically to application and user needs.

## Conclusion

The IoE is creating tremendous opportunity for service providers to share in a $14.4 trillion Value at Stake over the next 10 years. To do so service providers' networks must meet its many new and changing requirements:

- Interconnect trillions of things
- Secure private data
- Support exponential traffic growth
- Increase network reliability and availability
- Increase service velocity and flexibility
- Meet increasing network management challenges
- Support autonomics and process automation

Cisco NCS is a family of integrated packet and transport systems that help service providers capture a share of the IoE Value at Stake. NCS is built on major innovations in silicon, optics and software. Its new chip set provides the foundation to handle the traffic and transactions trillions of connections will bring. Optical innovations lower multichassis interconnect costs and optimize wavelength density and cost. The fully virtualized software system integrates cloud benefits into the solution, enabling elastic extension of the control plane, improving service velocity and asset utilization, and dramatically increasing system availability and security. The multichassis system architecture of NCS builds multilayer converged networks that intelligently manage, adapt, and massively scale functions to unlock IoE value for service providers.