# Cisco Software Innovations for Cloud-Scale Networking

E-Book

# Cisco Software Innovations for Cloud-Scale Networking

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# About This E-Book

To master the growing volumes of data and traffic in the digital economy, service providers need a new architecture for converging the data center and the WAN. An architecture that is designed for cloud computing operations, that is scalable in real time, with optimized performance and much greater operational efficiencies. Cisco has created such an operational solution for the demands of the digital economy. We call it **cloud-scale networking**.

### What does this e-book include?

The contents of this e-book explain how cloud-scale networking can be used to lower total cost of ownership; establish a scalable and resilient network; converge WAN and data centers; grow agility through automation and software-defined networking (SDN) programmability; and utilize end-to-end visibility for exacting control and management of services.

It includes an overview of the new software innovations available in Cisco IOS® XR Software that make these and other cloud-scale benefits possible. And it dives into real world scenarios that explain how hyperscale provider environments, service provider central offices, and content delivery networks can be transformed with cloud-scale networking.

### Designed for technical and operations-based audiences

This e-book provides a high level view of Cisco's cloud-scale networking technology and software innovations that simplify operations. It can be used by service providers interested in transforming their network through the principles of simplification, virtualization and automation, regardless of their business model or network architecture.

## Cisco IOS XR Software Innovations

Cisco has added services to Cisco IOS XR Software that enable networking at scale. They result in dramatically more efficient use of capital expenditures and lower operational costs through automation and economies of scale.

**Cisco has estimated these benefits from the cloud-scale network based on actual network deployments:**

- Reduction of network costs by 50 percent
- Doubling of network efficiency and performance
- 52 percent lower total cost of ownership
- 54 percent higher operational efficiency through automation
- 49 percent reduction in transport cost through data center and WAN convergence

The tidal wave of service demand based on digitization is on its way. Now is the time to retool to turn this transition into a tremendous opportunity rather than a liability.

DATA POINT

## Data Center Effects from Digitization

- "Our time series metric ingestion service handles more than 2.8 billion write requests per minute, stores 4.5 petabytes of time series data, and handles 25,000 query requests per minute." – Twitter blog, 2016
- Traffic traversing data centers will increase threefold to 10.4 Zettabytes by 2019. Inter-data center traffic is expected to grow by 31 percent due to cloud architectures and increased usage of data analytics. – Cisco Global Cloud Index
- A 60 percent increase in cloud workloads between 2014 and 2019 is forecast. – Cisco Consulting Services Survey

 

# The Need for Cloud-Scale Networking

You can't avoid it. Digitization is happening everywhere in our lives. And its effects are creating a sense of urgency among service providers. It's an exciting time with major opportunities – and challenges. Virtualization, automation, and orchestration tools and techniques have been promoted as the next big thing for service lifecycle operations. Just as cloud services moved from an idea to a strategy of choice for many businesses, programmability is now ready for service provider adoption.

Cloud-scale service providers pioneered an approach where they put the DevOps environment into production combined with an architectural approach for converging the data center and the WAN. This DevOps-based approach is highly automated and simplified. Optimized for cloud-scale in near real time. This approach delivers a consistently superb user experience.

These cloud-scale innovations provide quantifiable benefits:

- Tremendous scale and resiliency from decreased complexity, WAN and data center convergence
- Agility from automation and software-defined networking (SDN) programmability
- End-to-end visibility for exacting control and management of services
- A lower total cost of ownership from automation, higher utilization rates, and lower CapEx and OpEx costs

What are the specific characteristics that define a cloud-scale provider's environment? Here are some of the most important ones. Each is critical on its own yet all are interrelated and impart major, multidimensional effects on the future of provider network operations.

**Figure 1.** The Tenets of Cloud-Scale Networking

DATA POINT

## Digitization Forecast to Overwhelm Network Operations

Spiraling traffic volumes are flooding your resources. Service demands for various cloud and WAN offerings such as 4K/UHD video, the Internet of Everything, and 4G/5G threaten to stress your network architecture and service operations.

The old tried-and-true operational tools and workflows are too slow and outdated. Service provisioning, management, and troubleshooting fall behind demand. End-to-end network visibility is limited, which affects your ability to steer traffic along the most optimal and efficient paths at any point in time.

A more seamless, automated operational environment is desperately needed. A service environment that can scale to handle tremendous volumes of traffic and data. An environment that can spin up and take down services in real time while supporting a superb user experience. And an environment that can deliver economies of scale because of programmability, orchestration, and other new features.

 

## Scale and Resiliency

High scalability and resiliency are primary components of cloud-scale networking. To achieve these attributes, the data center and the network must be able to scale and tolerate runtime failures.

The amount of traffic from data centers to the Internet (for example, machine-to-user traffic) is large and increases steadily as consumers increasingly use cloud services. However, machine-to-machine (M2M) traffic is several orders of magnitude larger than what goes out to the Internet. This change in traffic patterns requires a different topology for data center networks that can scale more or less infinitely.

### Considerations for a cloud-scale network

- An unbalanced network infrastructure is not desirable. If one resource is scarce, it means other resources are sitting idle. That increases your costs
- Often cloud-scale networks are most constrained or least optimized with network resources. Either the network tends to be underprovisioned, leading to bandwidth bottlenecks, or the network tends to be overprovisioned, which is wasteful and expensive
- The fabric must be able to be upgraded continuously, with new servers added, server uplinks upgraded, and leaf and spine switches added. This should all be possible without the need to take the network fabric down

## The Clos Architecture: A Means to Scalability and Resiliency

Developed by Charles Clos, a researcher at Bell Laboratories in the 1950s, the Clos architecture delivers on both scale and resiliency in the cloud-scale network. Each layer has the same aggregated bandwidth. Clusters can be built to support up to line rate between endpoints within the same cluster. Equal-cost multipath (ECMP) routing enables next-hop packet forwarding to a single destination over multiple best paths to substantially increase bandwidth by load-balancing traffic over multiple paths. And when something breaks, only a small fraction of the bandwidth is effected, allowing applications to continue without even knowing about the failure.

To support Clos architecture and ECMP, the data center network should:

- Utilize dense, high-speed Ethernet devices
- Use cost-optimized switching
- Reduce complexity

## Agility

Speed is crucial for service providers competing in the digital economy. Providers that can move quickly to deploy, modify, and take down services have an advantage over others that cannot keep up with demand. Simplification and automation within the data center environments contribute to a high degree of agility.

For many years, applications have been built on clusters defined by virtual local area networks (VLANs) and subnets. This architecture limited an application's ability to scale beyond the physical cluster and made the application topology dependent. Scaling the application beyond these boundaries entailed a complex environment of network configurations and protocols.

DATA POINT

### Large Data Centers

**The Front Lines of Digitization**

Large data centers are on the front lines of digitization. Their challenges are dramatically clear. At a recent North American Network Operations Group (NANOG) Conference, one operator shared the daunting volume of operational data and issues they handle in their data centers:

- Over 30,000 configuration changes each month
- Over 20,000 CLI commands issued and scrapped every five minutes
- Over 4 million lines of configuration files under management at all times
- Eight million objects polled every five minutes

 

In a completely distributed architecture, the application has less or no dependency on the topology. The application can be spun up to operate anywhere. It can scale as wide as the application architecture instead of being bound by the network architecture. Providers can offer on-demand services based on this type of distributed architecture with much greater flexibility. And, using automation, services can be deployed, modified, scaled up or down, or taken down in seconds or minutes instead of hours or days. This is how service agility is defined in the cloud-scale network.

## Visibility

Achieving cloud scale requires exacting control and management of services. This is impossible without visibility into how applications and network behavior interact. Understanding where and why network hot spots occur is critical. A continual overview of the environment allows the system to make adjustments necessary to provide high priority for jobs that must run in real time while handling lower-priority ones with otherwise available capacity.

When issues occur, heightened visibility contributes to reduced mean time to resolution. Visibility provides the basis for automated fault isolation and problem remediation in the cloud-scale network, contributing to higher uptime. It provides application architects with a rich body of data to use in analytical analyses of system behavior to find areas that can be improved.

## Automation

A primary characteristic of the cloud-scale networking environment is automation. Automation accelerates processes, minimizes errors, and reduces operational costs throughout the service lifecycle. It does so in the provisioning of new systems and services. In configuration management. In problem resolution. In data collection for system analytics. In tasks both major and minor that currently slow down your entire operation.

Automation at scale is made possible by open APIs that promote common methods to retrieve data and set object values. Simplifying what objects are read and written through a common set of data models furthers the development of automated processes. These models let your application developer query for well-known constructs or capabilities without having to understand a device's underlying hardware and software architecture.

For developers, the cloud-scale network is an incredible DevOps platform, offering the ultimate in scale, resiliency, agility, and visibility. In the end, the line between developer and operations team starts to blur. Partnerships are strengthened based on the focus on a common use case rather than getting waylaid by disparate development and operational challenges. Customer satisfaction increases with faster service activation and improved SLAs. This helps you to better retain existing customers and attract new ones.

 

# Cisco Cloud-Scale Networking Innovations in Cisco IOS XR Software

Cisco has added services to Cisco IOS XR Software that enable networking at scale. They result in dramatically more efficient use of capital expenditures and lower operational costs through automation and economies of scale.

**These cloud-scale features are grounded on three main pillars:**

- Evolved networking stack
- Self-driving network
- Platform for open innovation

The new features were developed to help service providers address the performance and operational challenges that have been heightened by the increasing pressures on networks caused by digitization.

## Evolved Networking Stack

New features in Cisco IOS XR software represent an exciting evolution of the networking stack. They include structured, data model–driven, high-performance APIs; software modularity; centralized, policy-driven programmability; and automation.

### Open APIs

Cisco IOS XR software now includes integration with the industry's broadest set of structured, data model–driven, high-performance APIs to provide automation at scale and move beyond CLIs. Our motto is "any model, any encoding, any transport." In addition, we provide developers with a YANG development kit (YDK) that lets them autogenerate model-driven APIs from any YANG model for Python and C++. They can also get access to a model-mapping SDK that enables any model, including customer-specific ones, to be mapped to native XR models.

## Software Modularity

Cisco IOS XR Software is modular, with major features delivered as independent packages. Each package can be installed and updated individually on your current major software release to test and validate their respective features. No need to go through a full, lengthy software release qualification. Just get the code you need and put the new features to work more quickly. Most packages don't require a system reload, which reduces downtime.

Additionally, we've moved to industry-standard RPMs, which align update and upgrade procedures with the ones used in the data center. With its built-in dependency management, the RPM package format gives you the transparency and automation you require in cloud-scale networking.

## Automation

With the automation of new device onboarding there should be no more manually intensive, sequential processes that take different teams hours or days to complete. With Cisco cloud-scale networking, the boot and day-zero provisioning processes are fully automated.

 

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## IOS XR Open APIs

The new software features include:

- **Models:** An extensive set of more than 100 native YANG-based data models allows you to control the rich feature set in Cisco IOS XR Software. The list of supported models includes native, OpenConfig, and IETF models. In addition, YANG provides a modeling language optimized for network devices with a growing number of tools and utilities.
- **Encoding:** The decoupling of encodings from the model provides the flexibility to deploy based completely on your specific requirements and preferences. Data can be encoded in JSON, XML, or Google protocol buffers (GPB) format. Although encoding and transports are sometimes coupled, the XR programmability infrastructure is designed to support different encodings of the same data model if the transport protocol supports it.
- **Transport:** The decoupling of transports from the choice of encoding provides further flexibility. You can control the network using NETCONF, RESTCONF, or Google RPC (gRPC). Your protocol choice will be influenced by your networking, programming, and automation background and the tooling available.

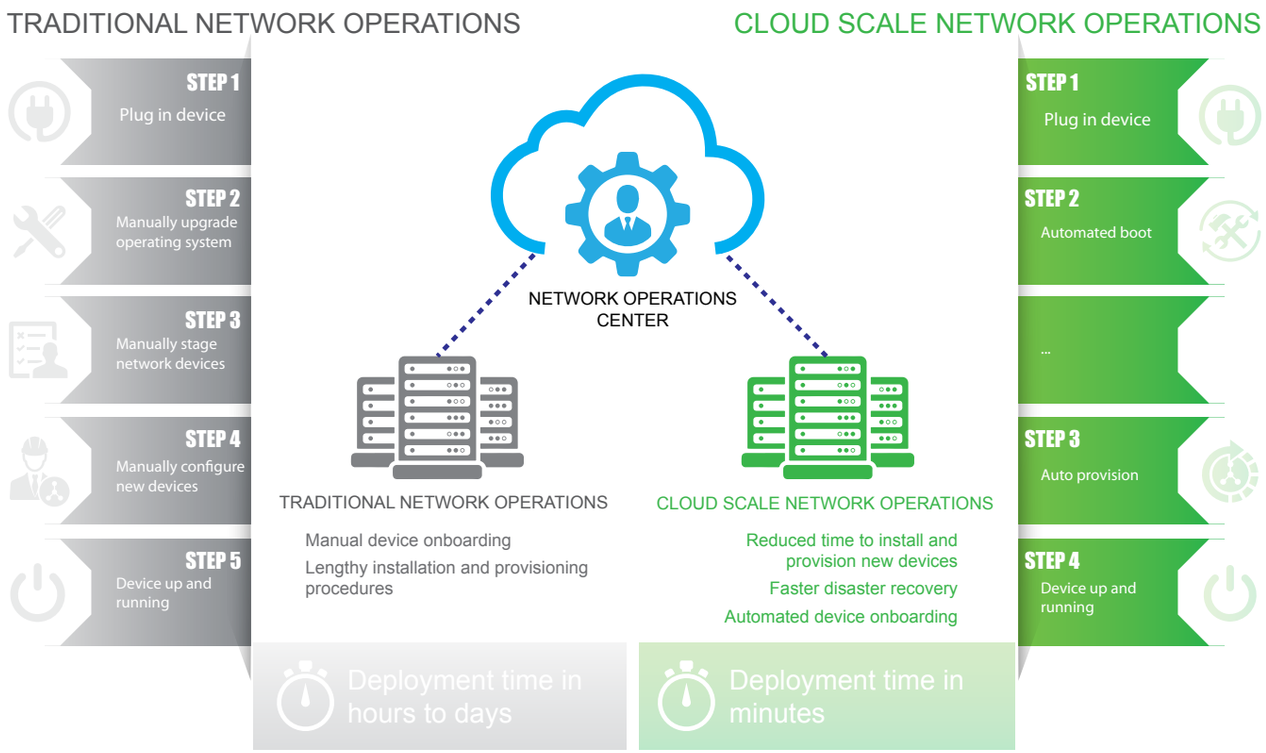


**Figure 2.** Automated Day-Zero Provisioning

You can use the same tools you currently use for bootstrapping servers and standard Linux scripting for autoprovisioning. Cloud-scale networking techniques reduce the time to bring devices online from hours to minutes.

Traditional networking operations are now also heavily reliant on manual configuration using CLI scripting. This results in many errors because CLI scripts are complex to develop. And they are highly sensitive to CLI changes between one OS software release and another, leading to script failures following an upgrade. That cumbersome, time-consuming, failure-prone solution doesn't work in cloud-scale networks. Instead, automation at scale is required.

As in DevOps, we provide automation for day-two management with the industry's widest set of structured, data model–driven, high-performance APIs and programmability. All of these features in the enhanced Cisco IOS XR Software let you dramatically fast-track and simplify operations.

## Self-Driving Network

With cloud-scale networking, end-to-end visibility into network infrastructure is a required feature. Until now, visibility has been limited to sections of network topologies. And it hasn't been available to administrators in real time. But with the demands of a quickly digitizing world – including massive scale, stringent security, strict service-level agreements (SLAs) with high uptime, and optimal cost efficiency for profitability – you need to see what is going on in all facets of your network at all times. Visibility must be continual and automated to support the scale and agility required today and increasing in the future.

 


DATA POINT

### The Growth and Impact of IP Video Usage

Multimedia content delivery has become a huge part of provider businesses over the past few years.

Globally, IP video use is surging. It's expected to account for 82 percent of all traffic by 2020, when almost one million minutes of video will traverse networks every second.

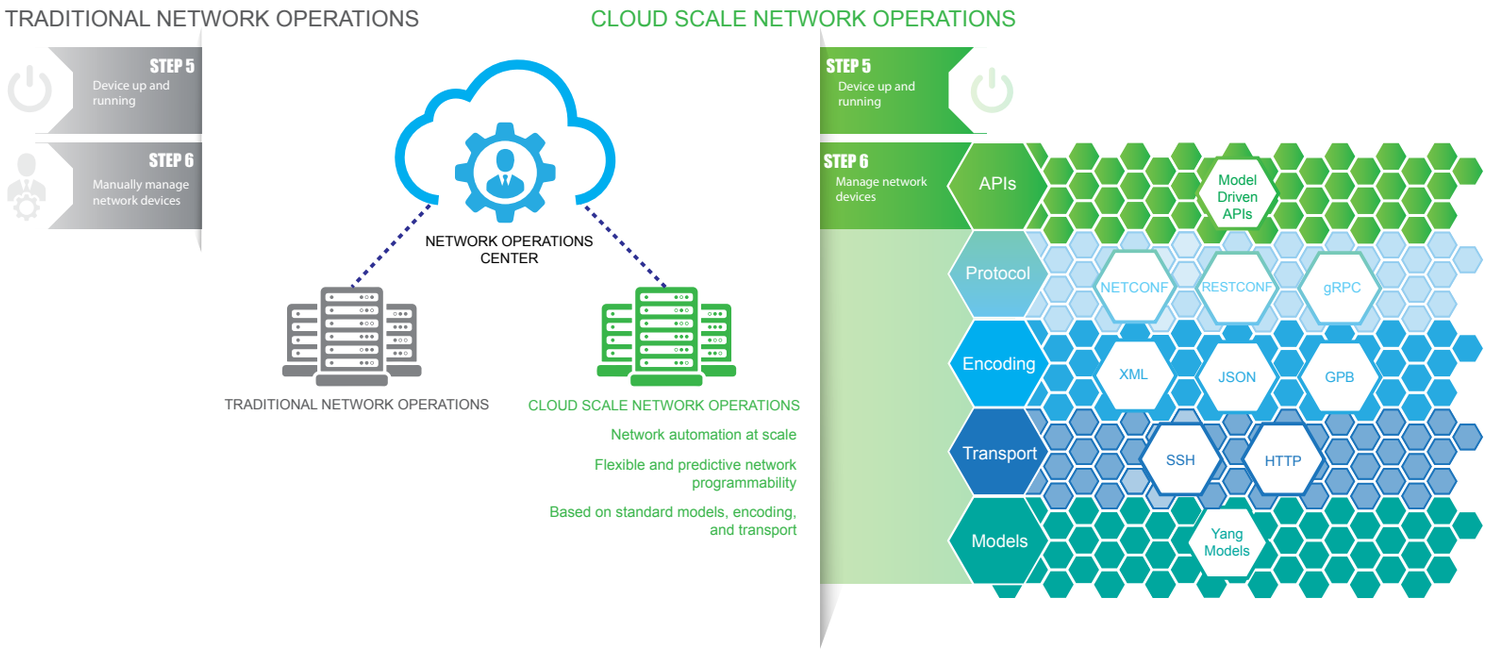


**Figure 3.** Network Infrastructure Programmability

Cisco model-driven telemetry is the answer for cloud-scale networking. Available with Cisco IOS XR Software, it's a new approach to network monitoring. Data is streamed and captured continuously from devices with efficient, incremental updates.

**In addition to pushing vast quantities of data, model-driven telemetry uses the power of data models in two important ways:**

- First, model-driven telemetry is fully configurable using YANG-based telemetry models. You can precisely specify what data to stream, to where, and with what encoding and transport using just the models; no CLI is required
- The second way that model-driven telemetry uses YANG data models is in the specification of the data to be streamed. With model-driven telemetry, you simply specify the YANG model that contains the data you want

**Why use model driven telemetry?**

- Model-driven telemetry opens up your entire operational space for fine-grained control
- It is your first step in a journey that will transform how you monitor and operate networks. With the power of telemetry, you'll discover things you never imagined and learn how to take your network to the next level
- The increased visibility provided by the streaming telemetry push model enables the highly efficient techniques of segment routing for near real-time network optimization and Cisco Application-Engineered Routing

DATA POINT

## Simple Network Management Protocol (SNMP) Isn't the Answer

Simple Network Management Protocol (SNMP) isn't the answer. It doesn't scale to collect the growing volumes of operational data needed to align network performance with application performance and optimization. It has very limited extensibility. Neither does screen scraping in the CLI. Increasing polling frequency isn't practical; it is slow and consumes too much network device CPU. So administrators have a fragmented, incomplete set of operational data that limits their ability to manage their networks proactively.

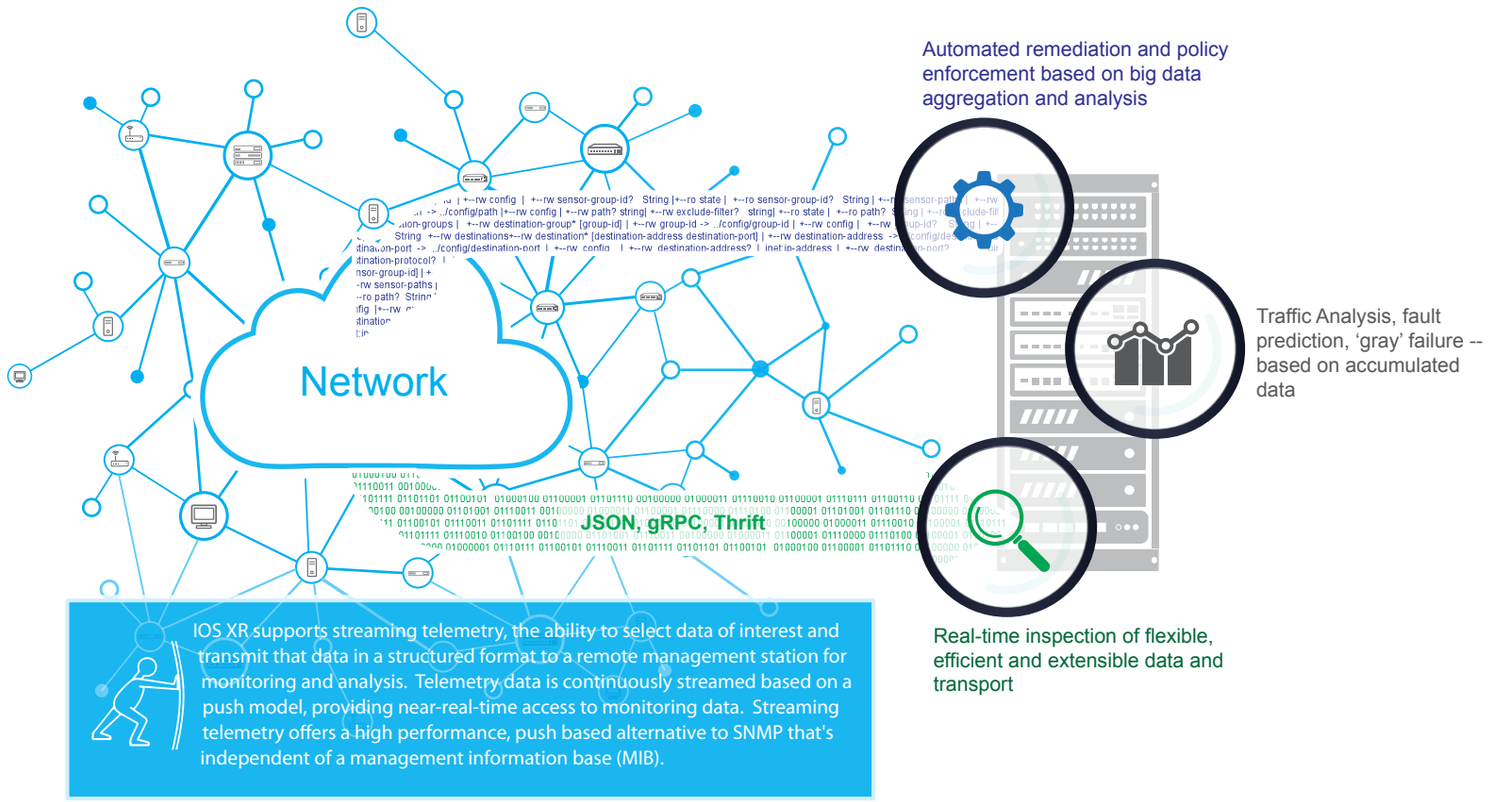


**Figure 4.** Cisco Model-Driven Telemetry

Streaming telemetry outputs from the network, captured in a data collector, together with solutions such as segment routing, allow for a closed loop of data capture, analytics, and control. These features allow cloud-scale networks to make decisions based on real-time information and real-time traffic engineering.

Applications can express that they need more bandwidth or lower latency, for example, and the system can respond. Path optimizations can be pushed to the network and implemented as needed.

With the actionable insights from streaming telemetry, you can run your cloud-scale network at much higher utilization rates, with stringent SLAs and a better customer experience.

## Open Innovation

The need for innovation in business is mentioned so often that it risks sounding like a cliché. Here's what it means in cloud-scale networks.

Digitization is coming so quickly that service providers won't be able to transform their environments, business models, and offerings in time by going it alone. Emerging scalable systems take advantage of open interfaces and APIs in order to integrate disparate systems into one complete system. And that's where the openness of Cisco IOS XR Software comes in.

CISCO INNOVATIONS

## Segment Routing

**Segment routing** provides the cloud-scale network with enhanced packet forwarding. You can use it to transport packets through a specific forwarding path rather than the shortest path that a packet usually takes. This flexibility is beneficial in many use cases related to different application requirements.

Though not required, the segment routing solution optimally works with an SDN controller that has a complete picture of the network topology and flows. The controller performs centralized optimization, including bandwidth admission control. A router can request a path to a destination with certain characteristics such as minimum latency, degree of availability, or sufficient bandwidth. The controller computes an optimal path and returns the corresponding segment list to the requesting endpoint. Then the requesting endpoint can inject traffic with the segment list without any additional signaling in the network.

With Cisco IOS XR software, you can implement centralized or distributed policy-driven network control through open-source or other SDN controllers or path computation elements (PCEs). Enjoy full path programmability of the network and network optimization from real-time control of forwarding paths. With programmable networking, you can achieve the right balance between centralized and distributed intelligence across your network equipment and the controller. It optimizes capacity. And it enables tight, end-to-end integration between applications and the network.

 

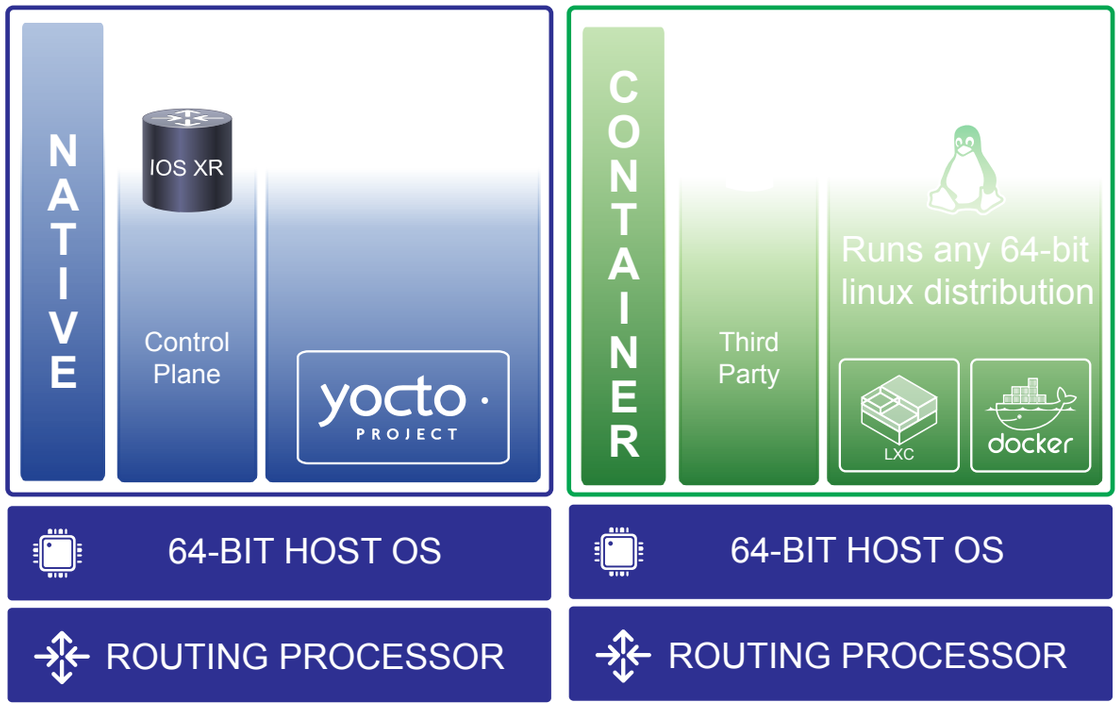


**Figure 5.** Cisco IOS XR Application Hosting

### Full-featured SDK

Cisco IOS XR Software has opened up to support third-party applications and containers with a full-featured SDK. This allows you to take advantage of the kind of extensibility and open innovation for networking enjoyed by server DevOps. And we provide Chef and Puppet support for integration of server DevOps with the networking stack.

But while opening up Cisco IOS XR Software features, we have maintained a clear separation between the Linux kernel networking stack and the Cisco IOS XR Software stack. Cisco IOS XR Software, unlike competitive OS products, has not fully opened up the Linux kernel stack to avoid security vulnerabilities. All of the protections built to mitigate distributed-denial-of-service (DDoS) attacks are available transparently to the Linux application, so Cisco IOS XR Software is not compromised while supporting third-party Linux applications.

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## Application Hosting in Two Variants: Native and Container

The choice you make is a function of the use case associated with the utility or app. If you're looking to use greater visibility into XR processes and file systems, then putting your app inside the XR process space container is the way to go. This is what we call native app hosting, in our parlance.

In contrast, if the choice of distribution and isolation from XR processes is the primary requirement, then using LXCs or Docker to isolate your application is what you're looking for. This is what we refer to as container-based app hosting.

## The Hyperscale Data Center

Designing a hyperscale data center network is all about making the entire data center behave as a high-performing network fabric. Rapid network deployment and performance scalability are strong requirements that do not require any dismantling of massive previous infrastructures every time more capacity is required.

Gradual scalability and resiliency can be achieved by breaking up the data center into small, identical clusters and setting high-performance connectivity between these clusters. This modular design enables hyperscale service providers to quickly scale capacity in any dimension. When more compute capacity is required, clusters are added. When more intra-cluster network capacity is required, additional spine switches are added. When external connectivity to the fabric is required, uplinks are added on existing edge switches.

### Features of the Hyperscale Data Center

**ECMP routing:** For most traffic, the network fabric makes heavy use of ECMP routing to utilize all available bandwidth, and to provide performance survivability when individual optics or devices fail.

**Zero-touch provisioning:** Provisioning and changes to the network fabric should be fast and easy. Automated day-zero capability can automatically deploy configurations on the devices depending on the role they play in the fabric. This way, large-scale deployment can be achieved very expediently, leading to an agile infrastructure.

**Automation:** The standardized topology facilitates easier programmability, and SDN approaches can help introduce more automation and more modularity to the network, furthering our goal to be agile.

**Streaming telemetry:** The scale of the network fabric necessitates a shift in the way the fabric is monitored and troubleshooting is handled. That's where streaming telemetry plays a major role by collecting a wealth of statistics from the network on a near real-time basis. This data can be used to provide visibility to enable quick problem identification and remediation as well as to manage actionable policy on the network.

You can transform your networks and services by introducing cloud-scale networking. Cloud-scale features and technologies let providers of all sizes and types build network fabrics that converge WAN and data center resources. You can turn your network into a cloud-scale platform to provide a superb customer experience with no downtime window.

## Transforming the Central Office

Many service providers have a network architecture composed of a national core network backbone and different regional networks. In addition, they usually have tens of data centers, thousands of central offices and some even have a separate IP TV network. These different locations are full of special purpose, dedicated infrastructure that operates in silos. Service provider link utilization is commonly below 40 percent. Total cost of ownership is high, based on deployment of single purpose hardware and manual operational processes from a highly complex environment. Time to market for new services, network troubleshooting, and mean time to repair (MTTR) are far slower than desired.

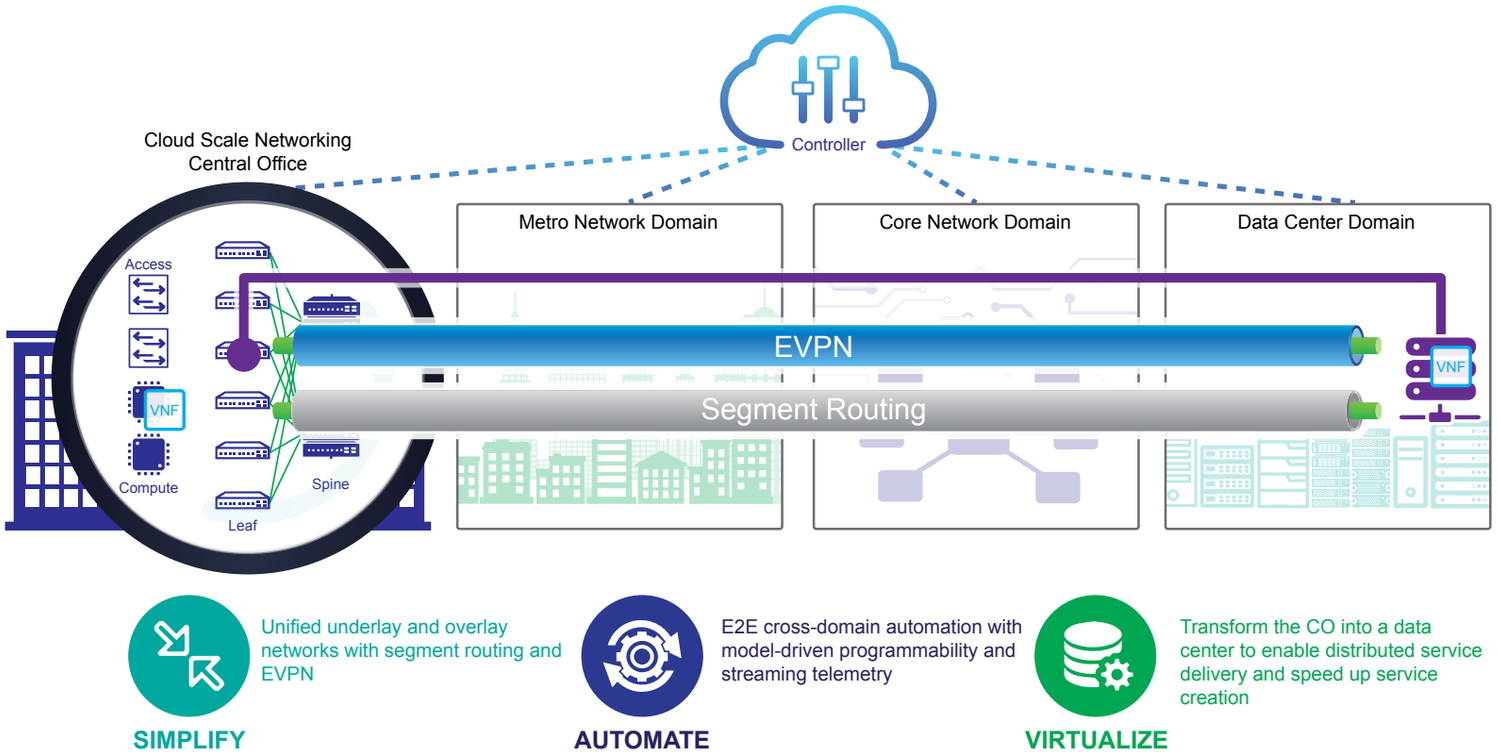


Figure 6. Logical Cloud-Scale Network Node for WAN and Data Center Convergence in the Central Office

### Integrating diverse networks into one cloud fabric

Traditional appliance functionality can be integrated into the fabric by placing them at the fabric edge. Increasingly popular, these appliance functions can be moved to virtual network functions (VNFs) on compute infrastructure. As software-based tools rather than packaged appliances, VNFs tend to be more cost-effective and provide way more agility – no more physical boxes to move around and less concern with physical topology. Further, the on-demand nature of VNFs provide true cloud scalability by enabling simple mechanisms to scale up and out.



 

That's exactly what you can do to transform your central offices. Each cloud-scale central office might include leaf and spine layers with a mix of physical and virtual resources and technologies. Designs may vary widely. Some might have only one or two layers, for example, and provide high oversubscription. Others might have many more layers with lower oversubscription based on much greater service, workload volume, and performance requirements. This highly modular, flexible architecture is a hallmark of cloud-scale design.

### A common computing and network infrastructure

With cloud scale, your network infrastructure becomes a fabric consisting of a common compute and networking infrastructure that is modular and allows for integration of best-in-class components. It extends from the edge of your network through the core to your data centers with a simplified data forwarding plane powered by segment routing. Augmented with Cisco IOS XR Software innovations, it gives you the flexibility, the agility, and the automation to optimize the location where services are delivered to increase customer experience.

The preceding cloud-scale solution might include multiple hardware form factors, ranging from fixed to modular and spanning across multiple product lines: the Cisco Network Convergence System (NCS) 5500/5000 Series and the Cisco ASR 9000 Series Aggregation Services Routers.




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## Content Delivery Networks

The effects are already being felt by global content providers. High costs and operational problems with IP video services are affecting revenues and leading to high customer churn. If you are one of these providers, you can adopt the Cisco cloud-scale networking architecture, including model-driven telemetry, and use segment routing to transform your content delivery network into a highly efficient environment that optimizes your users' experience.

### Right-sizing the cloud-scale fabric

The cloud-scale network fabric can be deployed at just the right size across as many regional or global sites as needed to provide the capacity required to deliver your content. Streaming telemetry within the cloud-scale network fabric, in combination with other sources of performance and availability data (for example, clients on the Internet), gives you a detailed composite of each application's experience. This provides a better understanding of how to deliver the content in the most optimal way, including which Internet paths should be selected for given clients. From this data, segment routing can be used to signal which direction to send the content (for example, which transit network to use), based on the very best path, whether that means the lowest latency path, the cheapest path, or the one with the most capacity.

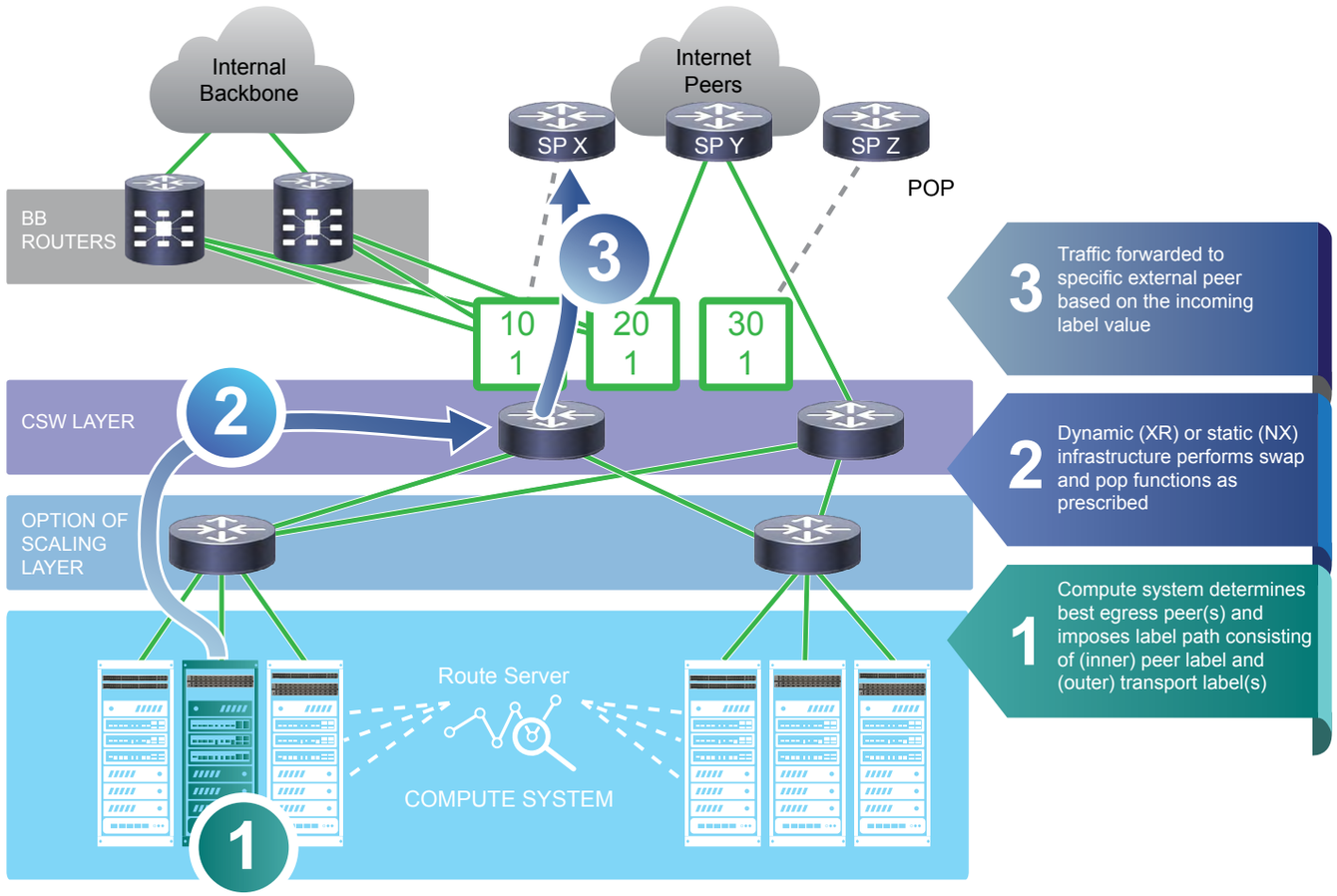


**Figure 7.** Cloud-Scale Network Fabric for Content Delivery

For example, a system that collects information about the Internet and clients can then be queried by a content delivery application for the best way to deliver specific content to specific users. After the constraints (such as the need for lowest latency) are known, the system can instruct the content delivery server to send the content to individual users using specific segment routing paths.

As shown, the segment routing path expresses which peering router should be used to send the content to the user. But it goes even one step further. This same path can even suggest the correct peer (the transit provider's router) to use. Or, in the case of a cache miss, this same technology can be used to instruct the system how to route queries to the content origin. In scenarios where user experience is of critical importance, this is an extremely important capability.

**The efficiency of content delivery routing**

This is content delivery routing at its most efficient. It utilizes the end-to-end visibility, automation, and control features of the cloud-scale network to implement segment routing over the Internet. Applications now participate in networking decisions. Content delivery can scale up or down quickly as needed.

Beyond the content delivery network, the provider sees segment routing as the foundation of tomorrow's end-to-end SDN. It will be the basis of operations for every app, not just media, because it provides much more granular routing for a much better user experience.



 

# Cisco Services

## Unmatched Industry Experience

Implementing cloud-scale networking technologies can get complex. Ensuring that you're adding them in a way that will enable the simplified, automated, programmable networks of the future—even more so. Fortunately, you don't have to go it alone.

Cisco Services has decades of professional services experience helping service providers plan, build, and manage network migration projects. We have industry-leading expertise across the full range of technologies, as well as next-generation orchestration platforms. We can help you capitalize on new cloud-scale innovations more quickly and easily, at a lower cost and with less risk.


## Implementation Tailored to Your Business

Cloud-scale networking evolution paths can be different for each service provider. We have the flexibility to understand and help you achieve your specific business goals. Our services can help you evolve your network to support new customer experiences, simpler and less expensive operations, faster time-to-market, and more profitable growth. Cisco Services uniquely deliver innovative solutions, unmatched expertise, and smart service capabilities using a collaborative partner approach.

Our intellectual capital, tools, experience and expertise set Cisco Services apart from the competition. We have delivered successful plan, build, and manage services to all types of service providers around the world. Trust the success of your network operations to the worldwide leader in networking services and solutions.

# Summary

Cisco Cloud-Scale Networking is an exciting operational solution to the daunting challenges posed by digitization. It is based on new enhancements to Cisco IOS XR Software that include software modularity and extensibility, large-scale automation, and fine-grained routing visibility and control.

These capabilities enable more efficient performance because service providers can run their networks at much higher utilization rates with full, near real-time visibility into resources. Scalability on demand is simpler. Operations run more quickly. DevOps can be opened to an ecosystem of ISVs for faster time to market of competitive services. SLAs can be provided, monitored, and guaranteed with greater confidence. And customers can enjoy a better service experience.

**Cisco has estimated these benefits from the cloud-scale network based on actual network deployments:**

- Reduction of network costs by 50 percent
- Doubling of network efficiency and performance
- 52 percent lower total cost of ownership
- 54 percent higher operational efficiency through automation
- 49 percent reduction in transport cost through data center and WAN convergence

Find out more about how Cisco Cloud-Scale Networking can deliver specific new features and benefits to enhance your own environment for the coming digital tidal wave.

## Next Steps

For more information:

- Cisco Application-Engineered Routing: http://www.cisco.com/c/en/us/solutions/service-provider/application-engineered-routing/index.html
- Cisco Network Convergence System (NCS) 5000 Series: http://www.cisco.com/c/en/us/products/routers/network-convergence-system-5000-series/index.html
- Cisco Aggregation Services Routers (ASR) 9000 Series: http://www.cisco.com/c/en/us/products/routers/asr-9000-series-aggregation-services-routers/index.html
- Cisco Network Convergence System (NCS) 1000 Series: https://www.cisco.com/c/en/us/products/optical-networking/network-convergence-system-1000-series/index.html
- Cisco Network Convergence System (NCS) 5500 Series: https://www.cisco.com/c/en/us/products/routers/network-convergence-system-5500-series/index.html
- http://segment-routing.net