WHITE PAPER

Ciena's Adaptive IP™

IP is the universal language of the internet—the glue holding everything together. Historically, network design was IP-centric. Applications were limited to what was supported by existing IP capabilities, and evolution meant more protocols added to the existing IP software stack.

During the first three decades of the internet, there were no significant changes to this approach. It was a highly competitive game, in which IP equipment vendors dictated a provider's ability to support new applications within closed and proprietary protocols. In doing so, these vendors controlled the market. The consequences of this model were quite clear: a slow innovation pace, high infrastructure refresh rate, vendor lock-in, limited supply chain, limited choice, and fast-growing operational cost and complexity for the network provider.

Within the last decade, the balance of forces has started to change. Internet Content Providers (ICPs) have disrupted the traditional notion of a network. ICPs have emerged in force, with different views on the existing network ecosystem. ICPs have no predefined bias about how to design, deploy, or manage their networks. They are focused on creating the most efficient content delivery mechanism leveraging the most advanced, best-in-breed, connectivity technologies in conjunction with storage and computing capacity. In addition, end-customers' perception of value has shifted—from connectivity to overall Quality of Experience (QoE). This has increased pressure on incumbent service providers to deliver a faster time-to-market and QoE, albeit at a much lower cost.

These changes require moving from a multi-protocol to a multi-cloud service delivery approach. IP-based flexibility is required to move service delivery closer to the network edge, to reduce the transport cost, and improve performance. All of which will result in a significant increase in the number of IP nodes and protocols. The traditional, IP-centric way of building networks is simply unsustainable. Associated revenues no longer support the cost of constant capacity and platform upgrades. The ever-increasing inefficiency of continually adding more IP protocols makes network operations overly complex and unmanageable. A dense, siloed IP infrastructure has simply become too big an obstacle for operators to cost-effectively scale to new and emerging demands.

Service providers and enterprises already face an enormous challenge to support current services and applications while cost-effectively addressing ever-increasing user demands. As the speed of innovation accelerates, technologies such as 5G, IoT, Edge Cloud, and AI create different network requirements that simply can result in increased operational complexity with a direct negative impact on Operational Expenses (OPEX), Time-to-Market (TTM), and Time-to-Revenue (TTR).

In legacy IP architectures, each IP platform needs a full stack of IP protocols to handle different applications. It also needs to interact with many different nodes to identify an optimized route to deliver the content. This box-centric approach is extremely inefficient, as the platform wastes a lot of capacity processing outdated protocols and signaling to many nodes. This makes performance and ability to scale difficult. The monolithic approach makes all routing decisions, with a limited view of the network and the requirements of the applications running on top of it. Legacy IP routing decisions are usually far from optimal. Any new application can require massive networkwide software and hardware upgrades to support it.

The new IP network must be open, programmable, disaggregated, and virtualized in a way that allows resources to be reconfigured rapidly, without physical intervention, to enable both existing and emerging services. It must support

open, standards-based Application Programming Interfaces (APIs) such as NETCONF/YANG and provide rich telemetry for software-defined control to self-diagnose, self-optimize, and self-heal. It must also allow for intelligent, data-driven, intent-based automation and an increased level of dynamic decision-making and subsequent actions.

Network transformation is not about adding more protocols or upgrading IP boxes. It is about how to connect users most efficiently to content in a multi-domain/multi-cloud distributed application world, and the speed at which the network can adapt to new application requirements. It is about flexibility, cost-efficiency, and performance—a network with capabilities that are adaptive.

What is Adaptive IP?

To address the new IP network requirements, Ciena has introduced Adaptive IP, an innovative approach that offers the essential IP capabilities required to support new applications while allowing network operators to benefit from cloud-like scale, disaggregated functionality, and AI.

Adaptive IP leverages Ciena's Adaptive Network™ architecture vision, which unites Ciena's optimized routing, switching, coherent optics, and virtual infrastructure with software-based control and automation driven by Machine Learning (ML)-based analytics, founded on network telemetry. Adaptive IP is Ciena's Routing and Switching Portfolio's approach to supporting existing services, applications and traffic profiles while setting the stage for new—and emerging—broadband, mobile, and cloud use cases, such as 5G, cell site routing, IP and optical convergence, virtualized business services, peering deeper, and telco edge cloud.

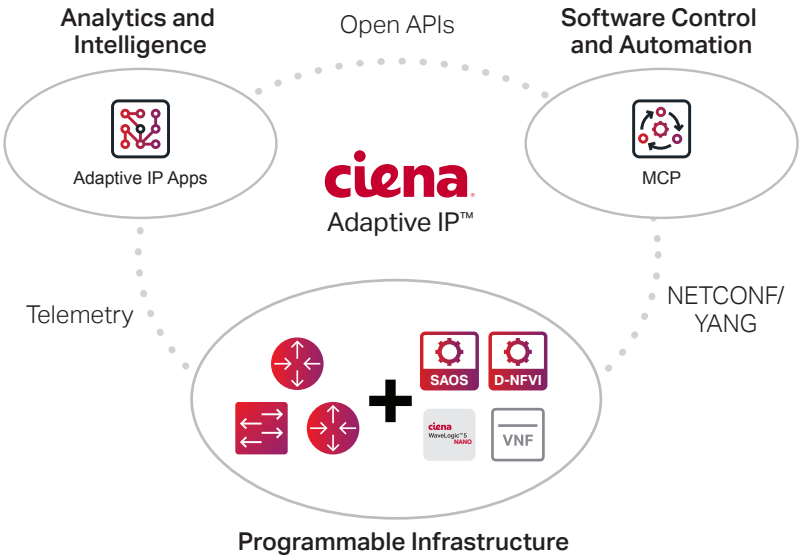

Figure 1. Ciena's Adaptive IP Architecture

The Adaptive Network
Learn more

Adaptive IP is much more than a traditional standalone, router-based implementation. It is a new and unique architectural approach that anticipates the next stage of IP-based network transformation and the industry as a whole.

Ciena's Adaptive IP incorporates the following components:

1. Programmable Infrastructure—Ciena's routing and switching portfolio presents the ideal infrastructure to evolve toward an open, flexible, and scalable Adaptive IP network via the company's state-of-the-art Operations, Administration, and Management (OAM) and Quality of Service (QoS) capabilities, which eliminate significant cost and complexity. Ciena's purpose-built platforms are designed for specific applications via a broad selection of features and capabilities targeted specifically at access, aggregation, edge, and metro networks.

These routing and switching platforms are powered by Ciena's unique and field-proven Service-Aware Operating System (SAOS). SAOS is a common software architecture that provides operational efficiency and consistent system and service attributes for Ciena's routing and switching platforms. SAOS provides automation-friendly intelligence and streaming operational data to enable network-level programmability supported by open standards, such as IGP, BGP, segment routing, NETCONF/YANG, and gRPC. As a disaggregated collection of functions, SAOS enables new functions and platforms, including third-party hardware and COTS x86 servers, to deploy functions as containers. This allows for rapid service creation, deployment, and modification to maintain pace with user demands.

Ciena's Adaptive IP approach easily supports IP and optical convergence. As service providers capitalize on advances in system architecture, Ciena's purpose-built coherent routing platforms support hyper-converged data plane network architecture designs and utilize coherent 100G, 200G, and 400G optics to decrease costs and increase QoE. Adaptive IP software control and

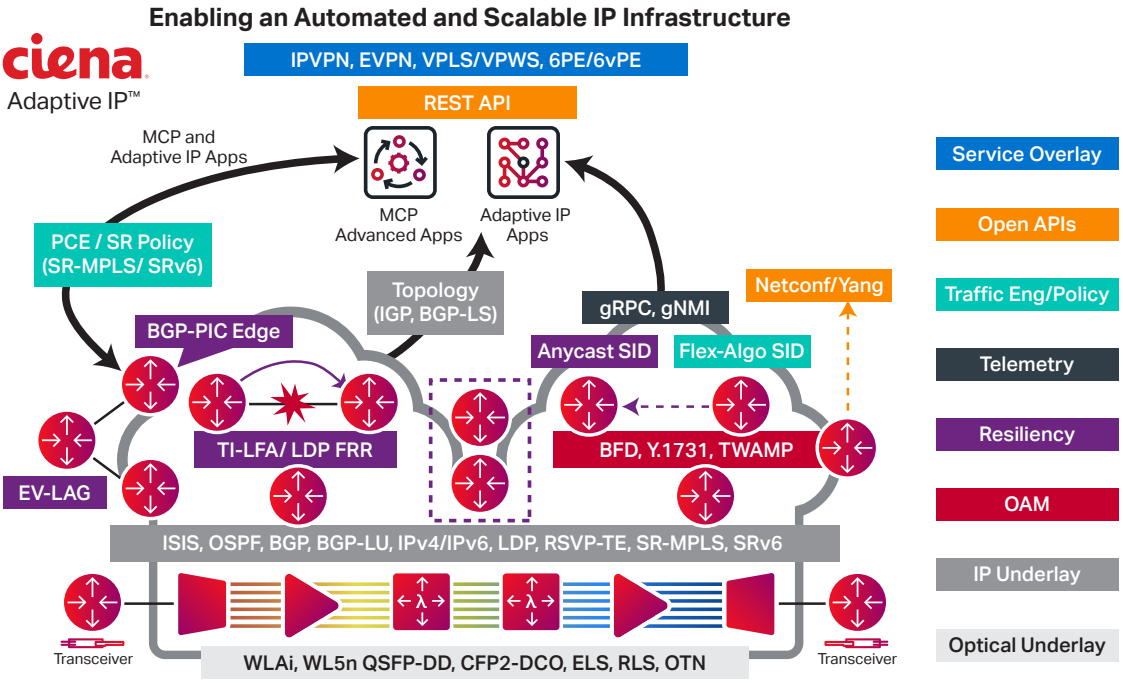

Figure 2. Ciena's Adaptive IP disaggregated programmable infrastructure

automation, analytics, and intelligence support a seamless converged IP and optical operational experience.

Support for open API architectures, such as NETCONF/YANG and Border Gateway Protocol (BGP) extensions, enables connectivity to Software-Defined Networking (SDN) and Network Functions Virtualization (NFV) layers. This provides simplified end-to-end management and automation of network services across multi-vendor and hybrid networks, while promoting the creation of a rich virtual service portfolio via support for third-party Virtual Network Functions (VNFs), such as vFirewall, vEncryptors, vSD-WAN, and many more.

With Adaptive IP, part of the IP control plane function is moved from the decentralized platform (router) to the centralized SDN layer. This significantly simplifies network deployment to increase performance and capacity in support of new applications and use cases. This enables a leaner IP protocol stack in the platform, as the software control, automation, and intelligence layers handle any additional service flexibility requirements. Ciena's Routing and Switching Platforms are highly instrumented, with the ability to export real-time service and network performance data using open protocols and APIs, such as OpenConfig streaming telemetry and high-performance Remote Procedure Call (gRPC), to detect and report network status to the analytics and intelligence layer. The network can also extract other information from the network through Link State BGP (BGP-LS) or PCE to make forwarding decisions.

To offer differentiated 5G services, mobile and wholesale network operators must optimize their transport infrastructure to provide guaranteed end-to-end 5G service performance with network slicing with network guarantees for latency. Ciena's Adaptive IP offers efficient transport for IP routing SR-MPLS, Carrier Ethernet, and is SRv6 ready.

This enables the network to proactively self-diagnose, self-optimize, and self-heal by intelligently adjusting its resources, as needed, to meet the ever-changing demands of emerging applications.

2. Software Control and Automation— Adaptive IP takes full advantage of Ciena's Manage, Control and Plan (MCP) domain controller, with its centralized, software-defined control of multiple IP domains.

MCP allows for the rapid creation, deployment, and automation of end-to-end service delivery, across both physical and virtual domains. MCP facilitates network evolution toward supporting emerging digital services for businesses and consumers—and serves as a core element of Ciena's Adaptive IP approach.

New applications will require computing power to be located at the edge of the network, delivering scale and performance dynamically as needed while significantly increasing the number of deployed IP router nodes. This associated complexity makes intelligent automation a critical network requirement.

Ciena's SDN-based software platform is a vital component of Ciena's Adaptive IP approach, effectively and efficiently handling the intricacy of new applications and services. In a legacy IP solution, an ever-increasing number of costly deployed hardware-based router platforms perform this task. In contrast, the software control and automation layer reduce node-based control plane signaling, making deployments far simpler and more cost-effective. Adaptive IP operates in a multi-vendor, hybrid network environment, making it easy for any network provider to start their journey from a box-centric legacy IP approach to a simple, automated network design, efficiently supporting legacy services most while preparing for the next wave of applications requirements.

3. Analytics and Intelligence—The Adaptive IP approach leverages Adaptive IP Apps, which fill a fundamental IP/MPLS management gap. While SNMP, Syslog, NetFlow, Deep Packet Inspection (DPI), Application Performance Monitoring (APM), and other tools are ubiquitous, only Adaptive IP Apps provide real-time visibility into how routing behavior affects service delivery. Adaptive IP Apps capture real-time telemetry from network devices, as well as from domain controllers and service orchestrators such as Ciena's MCP, to provide network forensic capabilities.

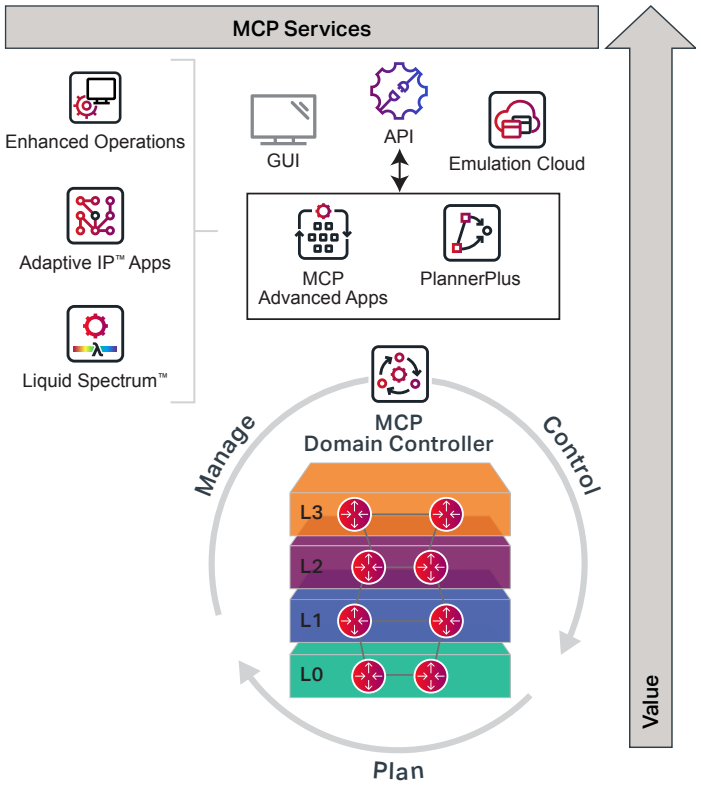

Figure 3. Adaptive IP Apps

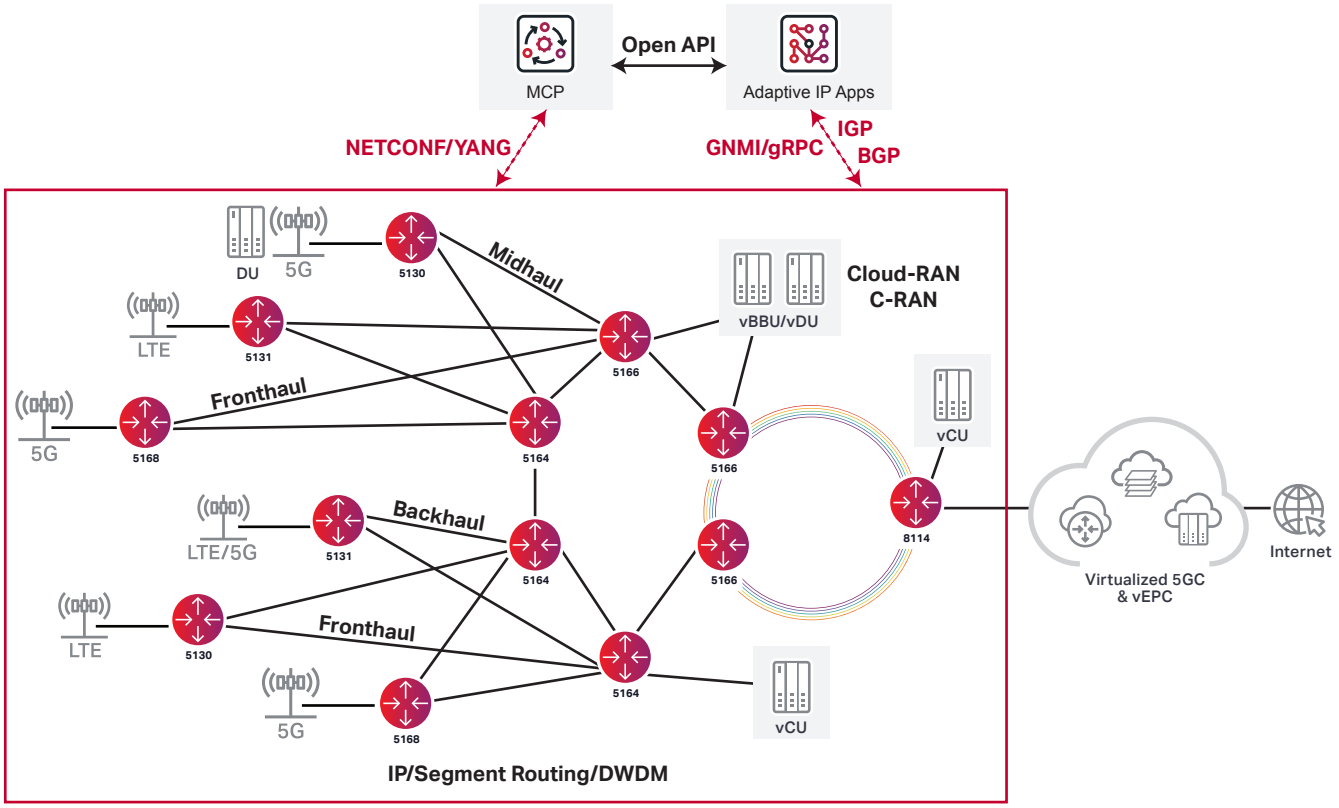

Figure 4. Adaptive IP supporting 5G Evolution

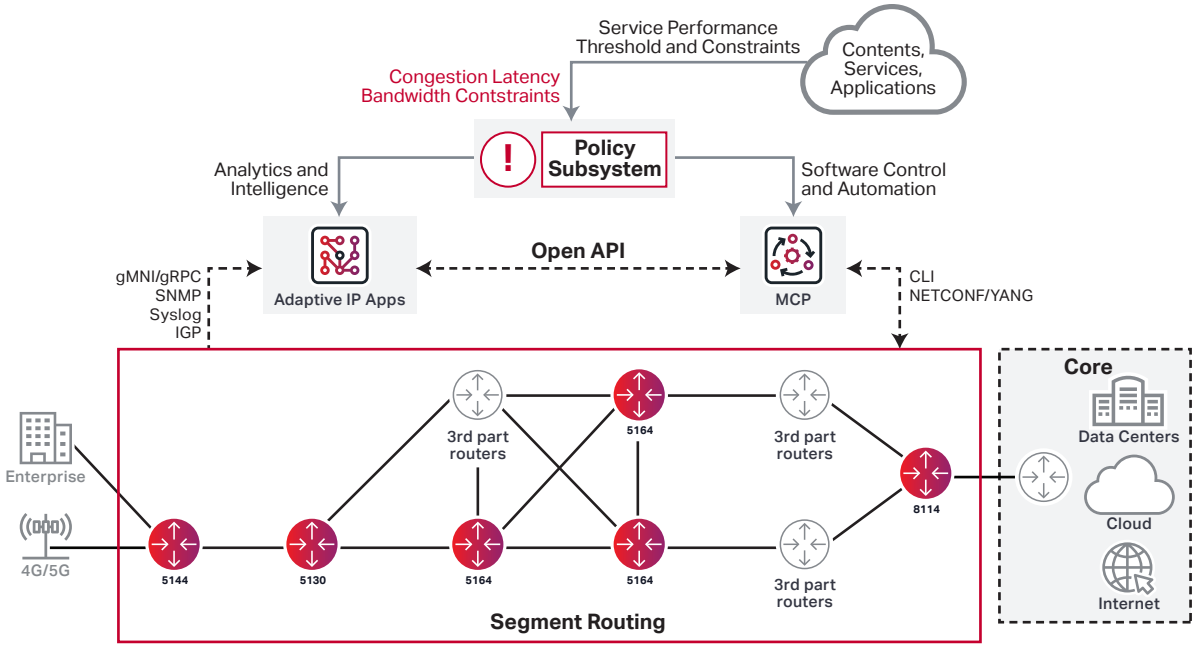

Figure 5. Programable closed-loop automation

What you need to know
Adaptive IP use cases

This visibility into the IP/MPLS network control plane allows operators to see precisely how specific traffic traverses the Layer 3 IP network, and where performance can be optimized on an ongoing basis. Suboptimal conditions missed by traditional tools can be identified quickly to correct service delivery issues and use network resources more cost-effectively to reduce overall operating costs. Engineered for intelligent network automation, Adaptive IP Apps integrate with MCP to provide powerful analytics and orchestration capabilities and accelerate the transition toward an Adaptive IP network.

Adaptive IP can be used alongside legacy IP environments to improve visibility, network performance, and automation as the network operator transitions to the Adaptive Network.

Adaptive IP is an innovative architecture that addresses current and future application requirements based on what is needed now, unlimited by the past.

Delivering this impending network transformation using legacy IP devices is inefficient overkill. The amount of power, space, cost, and processing capacity required to support the incredible number of devices is not compatible with current mobile network designs. Some IP applications, such as mobile packet core Mobility Management Entity (MME), are already embedded into many routers and are now virtualized in data centers.

Adaptive IP creates a lean, flexible, and scalable infrastructure with minimal required resources, significantly reducing cost and eliminating inefficiencies. A centralized SDN layer handles the exponential number of anticipated endpoints and unprecedented growth of network requirements to significantly reduce the signaling between network nodes (routers) while providing intelligent automation. AI and ML-based capabilities use information provided by applications and telemetry, allowing the network to continually self-diagnose/optimize/heal. Ciena's Adaptive IP creates an SDN-based, cloud-like, future-proof network infrastructure to support the ongoing evolution of mobile networks.

Cell site routing

Routing multiple Base Band Units (BBUs) to Remote Radio Heads (RRH) has never been more efficient and simpler, with Ciena's Cell Site Routers (CSRs), enabled by Ciena's Adaptive IP. Ciena's CSRs are purpose-built to not only aggregate traffic from multiple Mobile Network Operators (MNOs), something Ciena has been leading the industry for many years, but also offer advanced software (SR-MPLS) and hard (FlexEthernet [FlexE]) service isolation. With Layer 1/Layer 2/Layer 3 (L1/L2/L3) low-latency, operators can offer wave services for native and non-native Ethernet or eCPRI connections at 5 Gb/s granularity. Operators can choose from Carrier Ethernet, IP routing, SR-MPLS, or SRv6-ready platforms.

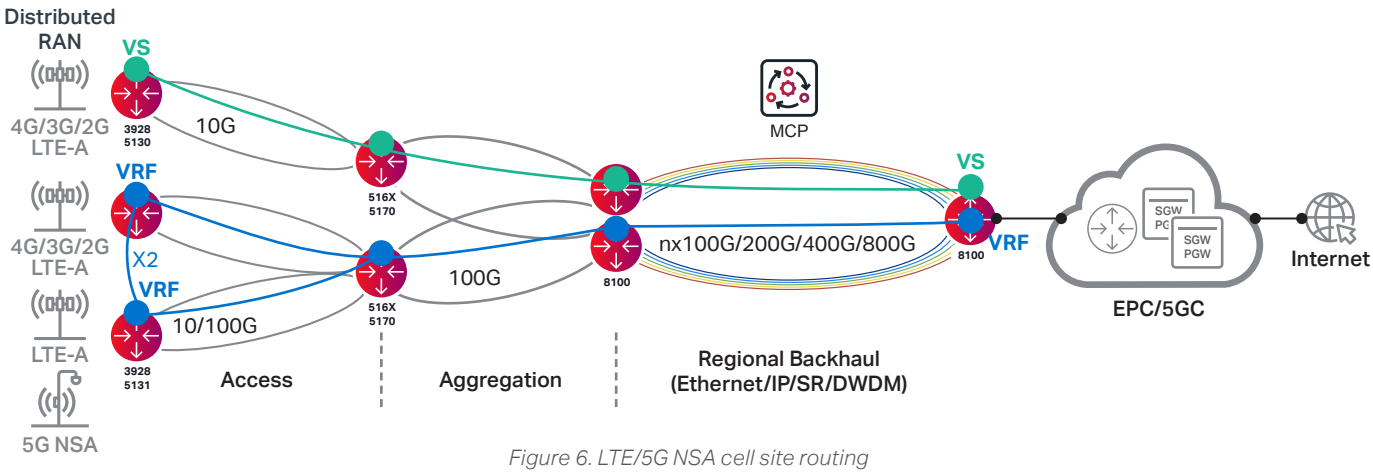

Figure 6. LTE/5G NSA cell site routing

Enterprise business services

Enterprises are looking for technologies to continually improve their business outcomes by maintaining their high customer QoE on an ongoing basis. They need to create better products and solutions while tightly controlling their operational costs. The network infrastructure that supports their business must be highly adaptive and aligned with their changing strategic objectives.

Legacy IP networks were built around speeds and feeds providing the same type of service and capacity for long periods of time. Overly complex, proprietary, and monolithic infrastructures will not be flexible enough for agile, on-demand network services. Legacy access networks based on single-function physical devices simply do not have the required level of flexibility or agility.

Ciena's 5132 Router is purpose-built for 100 GbE service and demarcation—with support of WaveLogic™ 5 Nano (WL5n) – in a variety of business and wholesale environments. Multiple native and non-native Ethernet services are supported using FlexE service isolation and transported using Adaptive IP.

Adaptive IP unites the capacity of an SDN intelligent automation layer, open protocols, and analytics with the flexibility of open VNFs to provide the connectivity solution enterprises require to take full advantage of the new cloud-based technologies. It can readily adapt to new and changing application requirements by adjusting capacity and network functions as required over time.

Ciena's Adaptive IP
Learn more

Broadband

For years network operators had to decide between dedicated and shared fiber last-mile access topologies, which meant having to deploy multiple vendors and multiple platforms for different types of services.

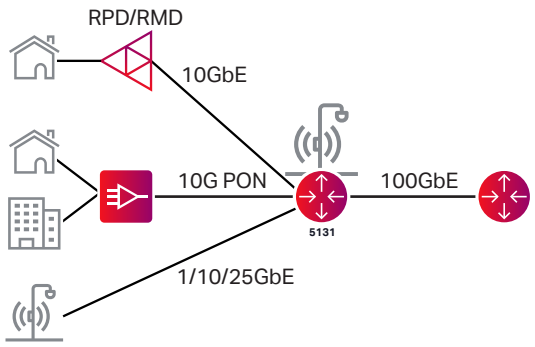

Figure 7. Broadband and 5G on a pole

Ciena has simplified that decision, with XGS-PON-enabled Adaptive IP routers. Simply plug the XGS-PON micro-Optical Line Terminal (uOLT) into one of Ciena's 10+ Adaptive IP routers, up to 128 of Ciena's or third-party XGS-PON Optical Network Units (ONUs), with multiple devices can be connected to each uOLT. Or use one of Ciena's 1/10/25G ports to connect fiber nodes. With a variety of purpose-built Adaptive IP routers, operators can choose where (building, pedestal, pole/strand/wall) and when (pay-as-you-grow). Traffic can then be routed using simple, secure, and efficient Adaptive IP. Operators can also take advantage of extensible features like FlexE for PON customers as well, greatly improving latency and jitter.

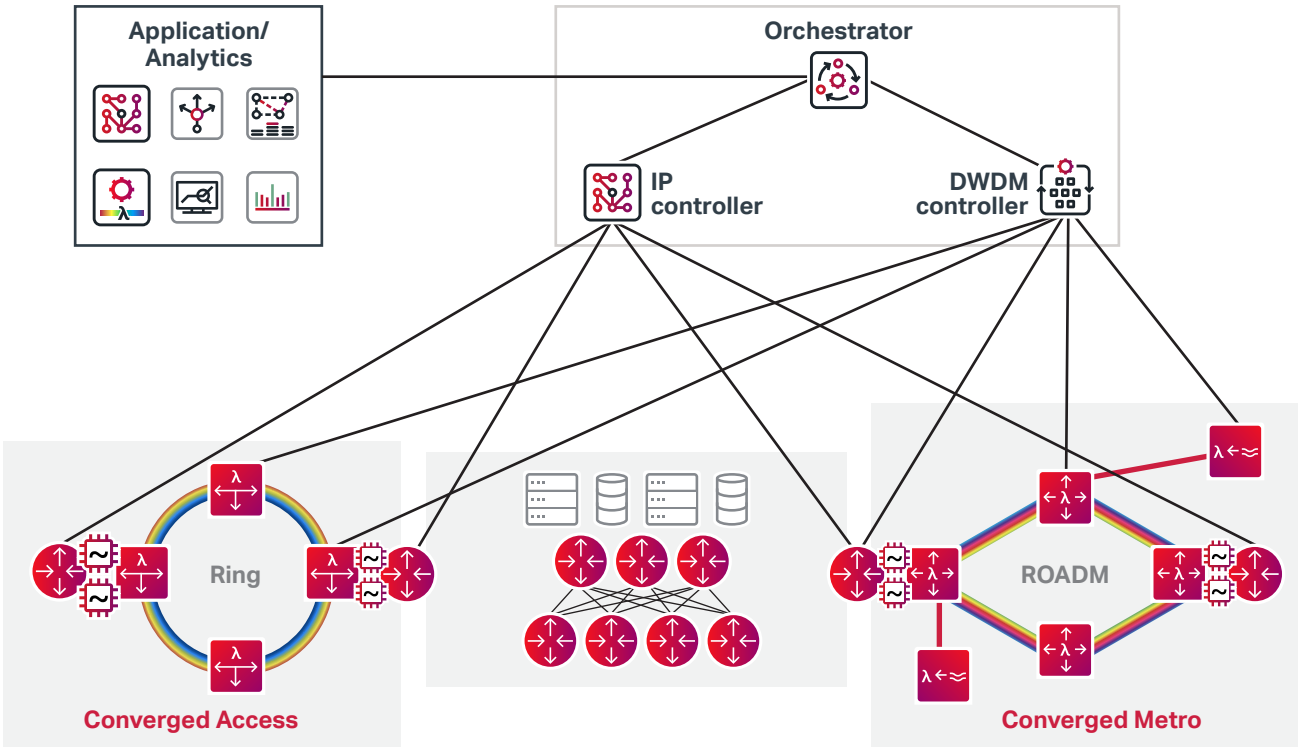

Figure 8. IP/Optical infrastructure

IP and optical convergence

Applications are becoming increasing distributed and virtual. As applications and compute get pushed to the network edge to deliver customer low latency and high QoE, residential services have become the new 'home office', and enterprise workloads continue to accelerate to the cloud. 5G is enabling new applications with massive amounts of intelligent devices as well as the need for wireline like speed and scale.

To effectively manage the massive growth, operators need IP and optical convergence, while simplifying the network with a common transport layer and service protocols, like segment routing and EVPN.

Ciena's Routing and Switching Platforms enable operators to transform their networks by streamlining the network and simplifying of network, optical (L0) and IP (L3) layers, to take advantage of the new digital economy and support the past.

Peering deeper

Video and cloud have pushed content closer to the customer, increasing the need for deeper peering while reducing the reliance on core 'Tier 1' interconnection markets. Adaptive IP routers, like the 8114, have deep packet buffers, large routing tables, and Internet Group Management Protocol (IGMP) version 3 capabilities that enable localized peering at the metro and cloud on-ramp locations while improving QoE for users by reducing the latency to application sources. QoE can be improved by dynamically aligning application preferences with tactical Segment Routing Traffic Engineering (SR-TE) policies.

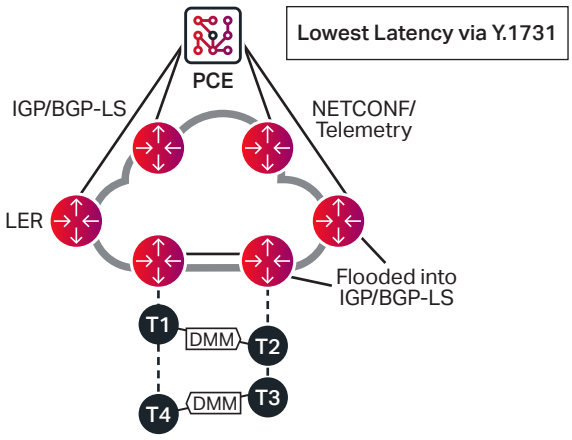

Figure 9. Router service and aggregation

Telco Edge Cloud

Cloud-native applications are changing the network edge. They have become part of the everyday experience—tracking ride-share providers, package deliveries, and more via a smart phone app. These cloud-native apps use the compute function on phones to make deliver QoE and make life much easier, convenient, and safe.

Edge Cloud can be defined many ways, by many different users, providers, and vendors. Ciena defines the Edge Cloud as an interchangeable cloud ecosystem that encompasses storage and compute assets located at the edge and interconnects by a scalable, applications-aware network that can sense and adapt to changing needs, securely and in real time.

Ciena's Adaptive Network vision can provide an effective framework for the evolution to a distributed Edge Cloud Architecture.

Depending on the customer service QoE expectations, storage and compute functions can or may need to reside in a local or regional data center, and even on the customer premise or device where latency is critical.

Ciena's Adaptive IP plays an important part, enabling the most efficient and secure cloud access and on ramps for mission-critical, latency-aware traffic.

Getting the most from the network

Successfully competing in a hyper-competitive market requires more than simply adding additional nodes and protocols to the existing legacy IP architecture—it will need a full network transformation. Users are willing to pay to access their content and applications, and for the end-to-end connectivity that makes it all possible. They are not paying for IP networks or IP protocols.

5G, AI, and IoT applications will require computing power to be located at the edge of the network, delivering high scale and performance. The legacy IP approach does not offer a viable solution to address the challenges and opportunities of the future. It keeps the network closed, costly to scale and expand, highly manual, and vendor dependent. It also lacks the critical element of choice.

Ciena's broad selection of market-leading Routing and Switching Platforms are purpose-built hardware platforms offering support for coherent optics, telemetry-powered analytics, intelligent network automation, and a broad suite of professional services. These components make Adaptive IP a unique approach to enable a network provider's evolution from an obsolete, inefficient box-based legacy IP network to a new architecture that is open, flexible, scalable, and highly cost-effective to align to ever-changing application and use case requirements.