



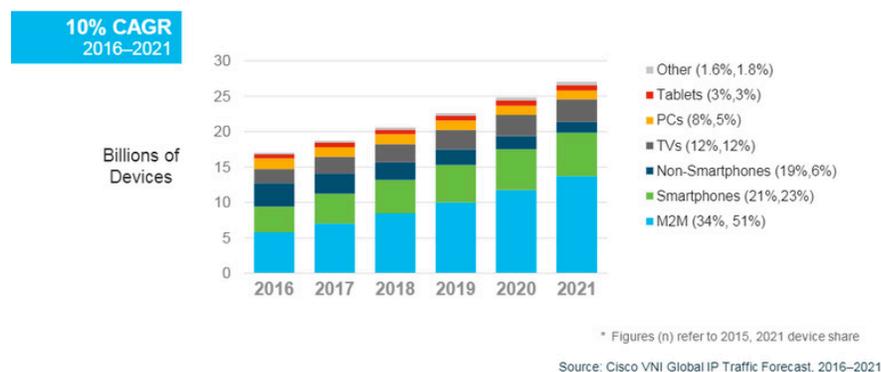
Critical Trends Shaping the Communications Market



The Imperative for Change

CSPs compete in a rapidly changing market to deliver a range of services to their residential and business subscribers. Subscribers now purchase an array of services from providers, starting with basic voice and data through advanced broadband services such as high-speed Internet, Internet protocol television, (IPTV), mobile broadband, high-definition and ultra high-definition video, and over the top (OTT) video and online gaming from a variety of CSPs. Consumers are also rapidly adding devices that require high bandwidth, low latency services (e.g., virtual and augmented reality) as well as IoT devices that bring significant complexity to the premises network. In the near future, it is likely that adoption of autonomous technologies such as self-driving cars will dramatically increase demand and complexity.

The rapid growth in new technologies is generating increased network traffic and putting pressure on CSPs to cost effectively upgrade and enhance their networks to meet demand. For example, Cisco Systems, Inc. estimates that global IP traffic will grow at a compound annual growth rate of 24% per year from 2016 to reach approximately 278 exabytes per month in 2021. At the same time, the proliferation of new technologies creates a tremendous opportunity for CSPs to offer new services and revenue streams by mastering the complexity of the smart home and business for their subscribers.





The Emergence of Web-Scale Players As a Competitive Force

The level of competition among CSPs - wireline and wireless service providers, cable MSOs and other CSPs – has increased over the last decade as traditional service boundaries have fallen. All providers are now competing for the same residential and business subscribers using similar types of IP-based services. The explosion of new technologies in the subscriber premises creates significant new opportunities for all CSP's. Innovators of every type and size are moving aggressively to seize that opportunity. Perhaps the most significant recent change in the competitive dynamic across the communications space is the aggressive entrance of web-scale players into subscribers' homes and businesses. These entrants, such as Google and Amazon, are extending their current business models (e.g., data driven search, e-commerce) into the subscriber premises with new devices and services that are helping to reshape the home environment. Their extensive use of data enables them to rapidly deploy new services and command a central place in the subscriber's daily life. The level of insight that they generate by mining subscriber data, coupled with their DevOps business model, positions them to offer and deploy services to subscribers at pace that few, if any, traditional CSPs can match today.

To address this challenge and establish control of the device-enabled subscriber, CSPs must respond by leveraging analytical tools that mine network data and subscriber behavioral data to target individual subscribers with services that meet their needs. These services include high-bandwidth packages, managed Wi-Fi, whole home Wi-Fi and smart home services. These new services represent the CSPs' greatest opportunity to create new revenue streams and higher average revenue per user (ARPU) while reducing churn. CSPs must also mine network and subscriber data to streamline and automate subscriber facing functions such as customer service. These data-driven approaches can significantly reduce service costs, improve profitability and support investment in new services and technologies. Increasingly, the winners in the communications space will embrace strategies that apply machine learning and artificial intelligence

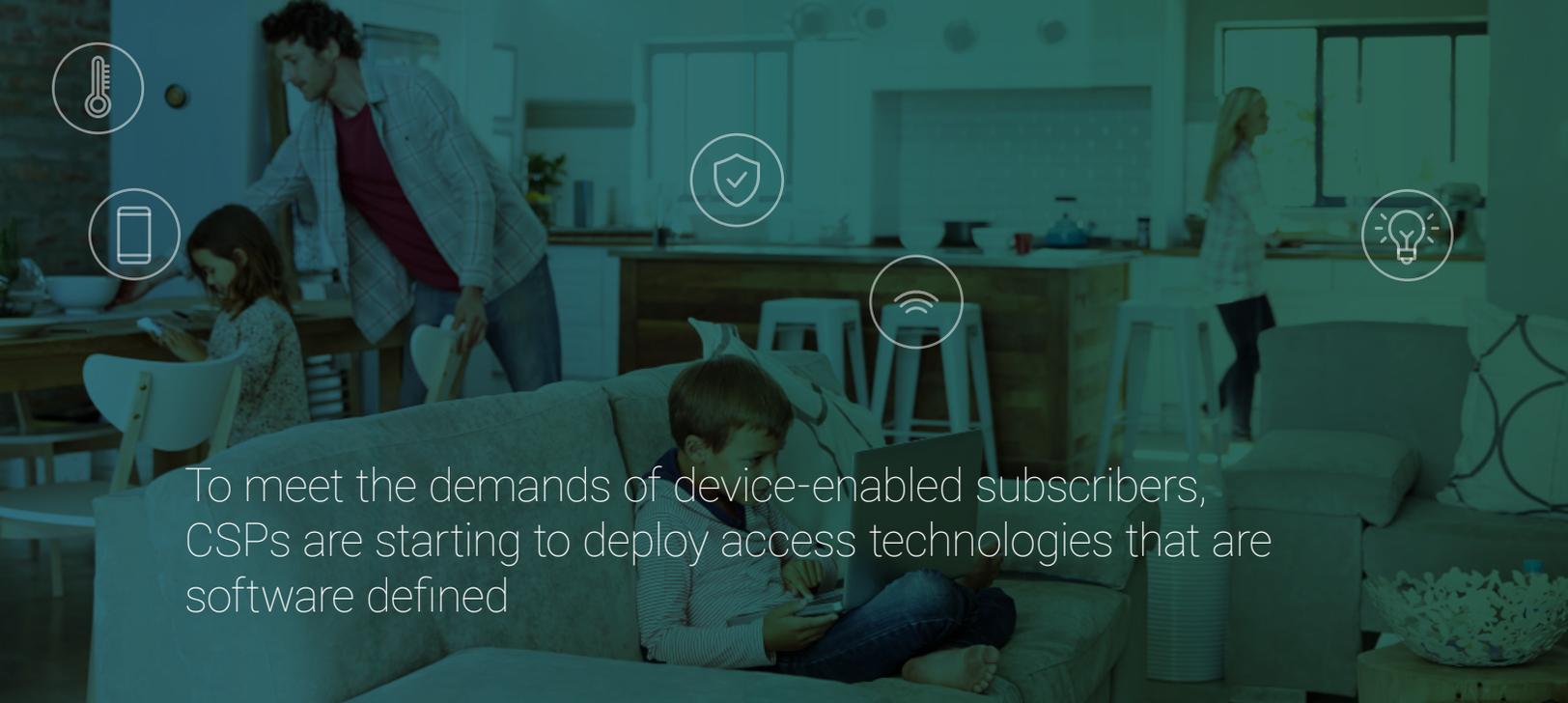
A close-up photograph of a hand holding a black game controller, with a teal overlay. The controller has several buttons, including a prominent yellow one. The background is dark and out of focus.

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technologies that promise to dramatically improve the subscriber experience, build subscriber intimacy and loyalty while increasing ARPU. By leveraging data to build a tighter bond with their subscribers and deliver high-value services, CSPs can more effectively meet the challenge presented by web-scale players.

The Rise of Smart Premises

In many ways 2017 was a significant inflexion point for the smart home market. The Amazon Echo was the top selling item on the entire Amazon marketplace – reaching 22M units sold and selling-out during the holiday season. IoT, VR and other connected devices have become mainstream for many consumers and they are flooding subscriber premises. Parks and Associates estimates that the proliferation of connected home devices has led to an average of 9.1 connected devices per US broadband home and projects annual sales of all connected home devices reaching 442 million units by 2020. This device proliferation is happening in markets across the globe. McKinsey



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and Company, Incorporated, estimates that globally the total IoT market will grow at a 32.6% CAGR through 2020. These connected devices are already creating complexity and management challenges for the CSPs who are often contacted by their subscribers when performance issues arise. Increasingly, subscribers view any device that is connected to home network as the purview and responsibility of their CSP. As the number and type of devices continues to expand, CSPs must develop strategies and adopt technologies that help them manage the complexity.

In a quest to improve performance and coverage throughout their homes, many subscribers are also purchasing Wi-Fi routers and gateways via consumer channels and introducing them into the home network. These devices simply compound management challenges for CSPs as the subscribers generally contact their CSP when issues arise with the Wi-Fi performance. Since these consumer devices don't provide carrier class management capabilities that enable remote diagnostics, management, and trouble-shooting, performance issues can create a tremendous cost burden for the provider who might need to send a technician to fix the issues or create customer satisfaction issues if they choose not to address the issues.

Recognizing that many subscribers see the CSP as the logical source of insights and services that enable the smart home and business, innovative CSPs are developing strategies and business models that embrace these new technologies via carrier-class premises systems. Over the last 12 months, several of the largest and most innovative CSPs have announced

strategies that incorporate the latest technologies (e.g., voice interaction, IoT connectivity). By leveraging cloud management technologies and developing a proactive strategy for smart device connectivity, voice interaction, security, and premises system instrumentation, CSPs can position themselves as the critical enabler of the smart home and business. Winners will embrace software platforms that enable all of these capabilities and premises systems that provide a foundation for turning the burden of the smart home into new services and revenue streams.

The Required Shift to a DevOps Business Model

Access networks, traditionally known as the local loop or last mile, directly and physically connect the residential or business subscriber to the CSP's data center, central office or similar facilities and create the onramp to the Internet. The access network is critical for service delivery as it governs the bandwidth capacity, service quality available to subscribers and ultimately the services and experience CSPs can provide to subscribers. Providing differentiated, high-quality, high-speed connectivity has become increasingly critical for CSPs to retain and expand their subscriber base and launch new revenue-generating services. To meet the demands of device-enabled subscribers, CSPs are starting to deploy access technologies that are software defined and leverage next generation Passive Optical Network (PON) architectures such as NG-PON2, XGS-PON and 10gig EPON. In doing so they will address many of limitations of legacy access systems:



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- Limited capacity of outdated access architectures
 - Network architectures have physical limitations in their ability to scale bandwidth, avoid latency issues and deliver the advanced broadband services subscribers demand today and are expected to increasingly demand in the future.
- Inflexible networks constraining subscriber offerings
 - Networks were designed to support a narrow range of services, and as a result, they limit the ability of CSPs to deploy the advanced broadband services increasingly demanded by their subscribers.
- Expensive to Deploy and Operate – With a wide variety of equipment installed, networks require significant downtime and labor for maintenance and upgrades, thereby placing a significant and recurring capital and operating expense burden on CSPs
- Back-office systems slow deployment of new services - Traditional methods for operationalizing new products and services often require significant testing and lengthy back-office integration activities. This often places CSPs at a competitive disadvantage relative to emerging service providers that are leveraging agile management practices.

By replacing traditional hardware functions with software defined networking, CSPs can overcome these operational challenges and bring new products and services to market faster. Many CSPs are embracing SDN and SDA to help accelerate innovation, deploy automation, bring agility to their network and eliminate service disruptions. By embracing standards-based, modular software platforms that abstract software functions from hardware, CSPs can free themselves from a dependence on specific hardware technologies and upgrade their access network to enable a DevOps business model. The winning service providers of the future will embrace software defined access platforms and transform their access networks from a burden to competitive weapon. Ultimately, this new model will enable CSPs to manage a complete range of access systems across nearly every deployment scenario (e.g., Central office, Head-end, Cabinet, mounted on a pole) in a consistent manner. With this shift they will introduce services at a pace that can then match the speed of the web-scale players.

The imperative to develop lean operating models

CSPs in nearly every market will face a dual challenge in the coming years – mounting competitive pressure and the requirement to increase their investments in technologies that can deliver the new services that their subscribers will demand. The stark reality is that many CSPs are ill prepared to survive this squeeze. Most will need to make dramatic shifts in their operating models to survive in the coming decade. They must implement a lean operating model that dramatically reduces the cost to run the business and deliver services to subscribers at an accelerated pace and at a significantly lowered cost.

The adoption of new technologies that provide automation and intelligence, such as Software Define Access (SDA), will help service providers adopt agile operating models and reduce the burden of network and back-office operations. Winning CSPs will invest in these technologies and shift their resource mix from a back-office dominant to a front office dominant model. For many, however, technology alone will not be sufficient to drive the required scale and scope of change. Many CSPs will need to seek help from third parties who possess deep expertise in new methods

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for evolving and managing operations. By partnering with services firms who can bring the scale and skills required to rapidly transform or even outsource aspects of their operations, CSPs can focus their resources and investment on business process that will deliver differentiable value to subscribers.

The role of governments in supporting technology investment

As CSPs face increasing competitive pressure, they must accelerate their investments to upgrade their access networks and deploy new subscriber facing technologies. Governments around the world recognize the importance of expanding broadband networks and delivering advanced broadband services to more people and businesses. As a result, many governments have established stimulus programs or other incentives for broadband investment.

In the United States, programs like the Connect America Fund (CAF) and E-Rate provide billions of dollars each year to CSPs in the form of capital investment incentives, grants and loans to encourage broadband network investment in unserved or underserved communities and schools. For example, in 2015 the

CAF program was authorized to distribute \$3.8 billion through 2020 to offset the costs of installing and operating CSP operated broadband and voice networks for Tier 1 and Tier 2 service providers in the United States. In 2017, this program was extended to the Tier 3 service providers to distribute \$10.0 billion over the next ten years to offset the costs of installing and operating broadband and voice networks. In addition, the E-Rate program was authorized to offer \$1.5 billion in grants to build gigabit capable network connections to schools. The E-Rate program targeted at networks is funded at its current level indefinitely. The Canadian Radio-television and Telecommunications Commission in 2016 created a \$750 million fund targeted at increasing broadband coverage and speeds, and the European Commission is pursuing similar goals via its Connecting Europe Facility and other programs.

With the increasing importance of broadband connectivity and the evolution of the smart home and business market, we expect this investment focus to continue and even increase. World-class connectivity and service is becoming an essential capability for individuals, as well as businesses and nations who strive to remain economically competitive in an increasingly global market place.

At Calix, we recognize the imperative for change and we are dedicated to helping our customers succeed. We have built a software platform, cloud, systems and services portfolio that is designed to provide our customers with the capabilities and expertise that is required to meet these challenges and turn them into opportunities. By partnering with each customer, we help them master and monetize the complexity between the cloud and the device enabled subscriber. To ensure that our customers win in their markets, we are helping them transform their business models, rapidly deploy new services, and make the promise of the smart home and business a reality.



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