EXECUTIVE SUMMARY

Stimulated by the opportunity for new 5G enabled service offerings, many service providers around the globe have announced, if not launched, 5G services. Although 5G technology provides a platform to initiate a myriad of new consumer and business services, it will also drive new scaling challenges as the number of devices, their bandwidth and performance demands reach higher expectations.

Many service providers are challenged to find a way to deploy 5G with stalled growth, mounting competition and regulatory pressures. While the desire to drive top-line growth with new services, and reduce operating costs through the adoption of automation, many service providers are sidelined by their inability to free up budget due to the burden of numerous purpose-built networks. For many years, service providers have been rolling out purpose-built stand-alone networks to deliver specific services (mobile, residential or enterprises). These siloed networks require specialized skills, dedicated resources, unique operational processes and tools. Delivering services across these network boundaries is extremely cumbersome and expensive.

To free up budget and resources to implement 5G, service providers need to converge services onto one transport network to handle the amalgamation of service offerings. With this converged strategy, service providers can significantly change the economics and lower their total cost of ownership (TCO) while benefitting from the latest technology advances to enable service innovation and velocity.

This paper presents the results of a TCO analysis comparing the economics of a converged IP/MPLS transport network with more traditional dedicated networks. **The results of the analysis demonstrate significant savings with an overall TCO savings. of 62%, capital expense (CAPEX) savings of 60%, and operations expense (OPEX) savings of 66%.** The analysis asserts the financial advantages of a converged future mode of operation and elaborates on the benefits of the higher price performance of Cisco's 5G ready routing portfolio and the benefits of segment routing, network programmability and automation.

KEY FINDINGS

- 5G services drive new network requirements for high data rates, low latency, high reliability, high security, and network slicing.
- 5G ready routers must support SDN, segment routing, open APIs, and advanced network orchestration and automation.
- Cisco's 5G ready routers provide the features and functions required for 5G while lowering TCO by 62%, CAPEX by 60%, and OPEX by 66%.
- Cisco's 5G Converged SDN Transport network provides significant financial advantages to change the economics and lower the TCO of the 5G transport network.

5G TRANSPORT NETWORKS

As service providers around the world plan, test, and/or roll out new 5G service offerings, the expectation is that 5G will transform the world with innovative service offerings ranging from enhanced mobile broadband to critical and massively connected IoT devices. To deliver these new use cases, mobile transport networks must support higher capacity, lower latency, enterprise class reliability, and end-to-end security.

A critical part of the 5G architecture is the any-to-any, highly scalable, and flexible transport network to deliver a vast and diverse set of these 5G mobile, business and residential service offerings. It is critical that we acknowledge these 5G use cases and their associated demands on the network to thoroughly understand their impact on the 5G TCO model. Service providers need to ensure that 5G services are both scalable and profitable. To achieve this goal, they must minimize network TCO while meeting 5G requirements for scalability, reliability, security, and latency. The following section provides an overview of these 5G use cases, associated 5G mobile technologies and IP transport network requirements.

5G Use Cases

There is a myriad of 5G use cases, and the expectation is that new applications will evolve at a rapid pace as the 5G ecosystem develops organically. To address key 5G technical requirements, the 3GPP standards body has defined three primary use cases that define requirements for thousands of actual use cases and applications (Table 1).

USE CASE	APPLICATIONS	TECHNICAL REQUIREMENTS
Enhanced Mobile Broadband (eMBB)	HD & 3D video, AR & VR, next-generation social media	Peak data rates of 20 Gbps, user experience data rate of 100 Mbps, area traffic 10 Mbit/s/m^2
Ultra-Reliable Low Latency Communications (URLLC)	Tactile Internet, telehealth, smart utility control	User plane latency up to 1 msec, control plane latency up to 10 msec, high reliability
Massive Machine-Type Communications (mMTC)	Massive IoT, smart city, vehicle tracking & control	1M devices per km^2

Table 1. 3GPP 5G Primary Use Cases

These 5G use cases and requirements will drive massive network scale, ultra-low latency requirements and large increases in end-points and associated services. It is also anticipated that because of the organic nature of service evolution, network traffic patterns will also become more diverse and difficult to predict. As new applications enter the 5G ecosystem the network must be flexible, reliable, and able to provide strict quality of service (Q0S) to these applications.

5G Transport Network Requirements and Key Technologies

The 5G use cases and supporting technologies and architectures are driving the need for a flexible and robust transport networks. Unlike previous generations of RAN transport networks where almost all traffic flow is between cell sites and centralized DC, 5G mobile network have much higher sets of requirements. These includes:

- Massive increase in bandwidth
- Ultra-low latency for selected traffic
- Multi-Access Edge Compute for infrastructure and enterprise workloads
- Network Slicing

End to end IP is the best option for 5G transport network. Some of the key IP technologies that are necessary for 5G:

Software Defined Networking (SDN): SDN allows separation of the routing control plane and user plane. It provides the framework for more advanced routing and traffic engineering to satisfy requirements for both bandwidth and latency. SDN enables advanced traffic engineering, which reduces average link utilizations which in turn reduces network TCO.

Segment Routing: A source-based routing technology that enables IP/MPLS and IPv6 networks to run more simply and scale more easily. Segment routing eliminates resource-heavy signaling protocols of MPLS and moves intelligence to the source/edge of the traffic thus removing complexity from the network. The key benefits are:

- Networking protocol stack simplification (LDP, RSVP-TE are no longer needed)
- Network programmability
- Integrates with SDN controllers
- Advanced traffic engineering and lower network TCO
- 50 msec link and node protection
- Unified fabric across access, metro, core, and data centers

Network Programmability: The requirements for 5G transport drive the need for network flexibility and program control. Network elements and management systems must have open APIs to allow various systems to control networks and to extract data from them. APIs allow for automation, which reduces labor expenses thus decreasing network OPEX.

Automation and Orchestration: Network orchestration provides a framework for easily provisioning new services and facilitating DevOps. Network elements must support NetConf protocols and Yang models and use orchestration systems to automate network configuration, fault, and performance management. Automation reduces labor expenses thus reducing network OPEX.

Converged Networks: Many service providers' IP networks have grown up in silos. For example, service providers traditionally built separate networks for mobile, business, and residential services. This is because traditional IP networks have lacked flexibility, and various products and software were required by different applications and services. Additionally, it was easier for organizations to fund, build, and maintain their own networks. 5G networks are designed to support multiple types of customers, services, and technologies on the same network infrastructure. Therefore, as service providers move to

5G they should converge their network infrastructures to obtain the full benefits of 5G. A converged network reduces TCO because a common infrastructure is shared for all services.

TCO ANALYSIS

An important consideration in migrating to a converged 5G transport network is the total cost of ownership (TCO). The next-generation network must not only meet the requirements previously specified but must also change the economics so that the TCO is reduced over time. Since bandwidth demand is likely to grow faster than revenues, the converged IP transport network must be more cost effective than previous networks. The following sections describe the TCO model and assumptions and present the results.

> The converged 5G transport network must not only meet the requirements previously specified, but it must also reduce the network total cost of ownership.

TCO Model Definition and Assumptions

Our TCO analysis compares the **present mode of operation (PMO)** with the **future mode of operation (FMO)** for a typical mobile market segment depicted in Figures 1 and 2, respectively. In both scenarios, we analyzed networks carrying concurrent mobile, residential, and business service traffic with projected growth in bandwidth demand over five years. In the PMO model we make the following assumptions:

- Dedicated IP transport networks are used for mobile, residential, and business services.
- A common core network is used for all services.
- Current Cisco routers are used in the TCO model.
- MPLS is implemented.
- Segment routing is not implemented.
- Cisco advanced automation and orchestration functionality is not implemented.

For the FMO model the following assumptions are used:

- Converged IP transport network is used for all services at the preaggation, aggregation, and core layers of the network.
- Cisco's 5G ready routers are deployed.
- Segment routing is implemented using MPLS or IPv6.
- Cisco NSO is used for intent-driven configuration and orchestration.
- Cisco Crosswork provides full network automation and intelligence.

For both the PMO and FMO the following network and traffic assumptions are used in our model:

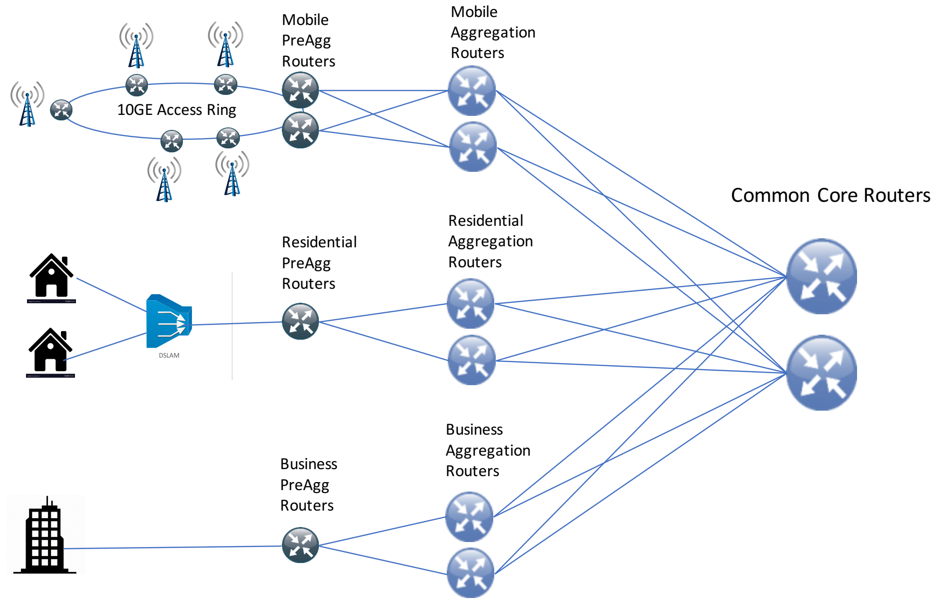

Figure 1. Present Mode of Operation

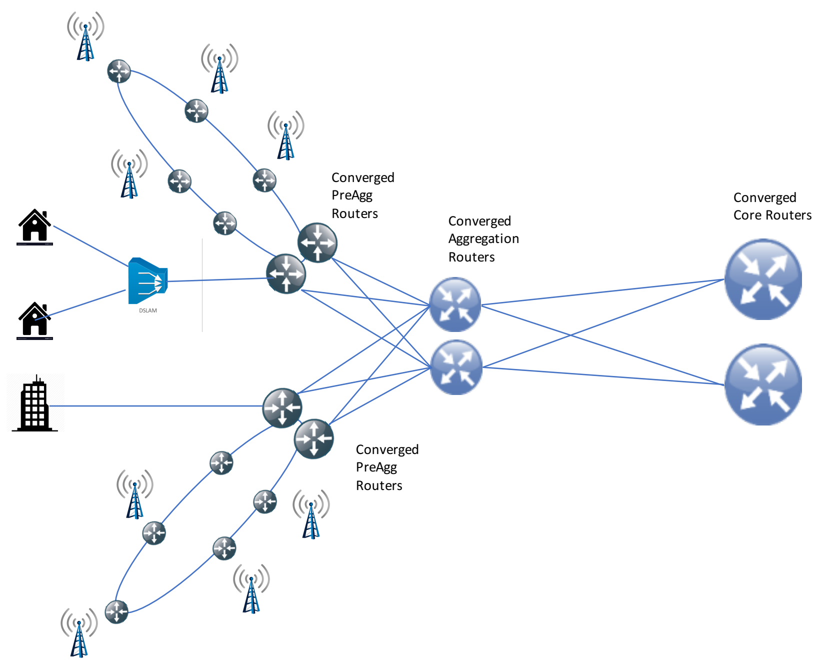

Figure 2. Future Mode of Operation

Mobile Service Assumptions

To support 5G services with improved coverage and increased bandwidth, transport networks will need to be densified. By using both macro and small cells, operators can address the need for increased coverage and higher capacity more economically. These trends are characterized by the following technical assumptions used in our TCO models:

- Number of cell sites served by the aggregation network emulated in the two models grows from 2,000 to 3,500 over five years.
- Average traffic is modeled at 800 Mbps per cell site with 40% annual growth rate over five years.

- A ratio of five cell sites per access ring, 10 access rings per pair of preaggregation nodes, and 28 aggregation routers are modeled to emulate the market segment evaluated.

Residential Service Assumptions

We assume that residential broadband is provided with DSL or cable. Residential traffic is highly bursty typically because of Internet activity, streaming, and long periods of downtime. Consequently, the technical assumptions used in our TCO model are:

- 10,000 subscribers are assumed per pre-aggregation node.
- A density of 288 subscribers per DSLAM/CMTS is modeled in the analysis.
- The DSLAM/CMTS directly connects to the pre-aggregation routers in the model.

Business Service Assumptions

The TCO model also assumes that business services were provided over Carrier Ethernet emanating from the pre-aggregation router. It is projected that business service traffic is growing at a rapid rate with the following assumptions:

- 1000 business CPE are assumed per pre-aggregation router,
- Average traffic of 2 Mbps per CPE with a 42% annual growth rate over five years emulated.

TCO RESULTS

A comparison of the cumulative TCO over five years is presented in Figure 3. The cumulative TCO includes both CAPEX and OPEX. CAPEX includes the cost of purchasing routers, automation software, and any other one-time investments made in the network infrastructure. OPEX is the on-going cost of operating the network. Figure 3 shows that the TCO of a 5G ready network (FMO) is significantly lower than the PMO network.

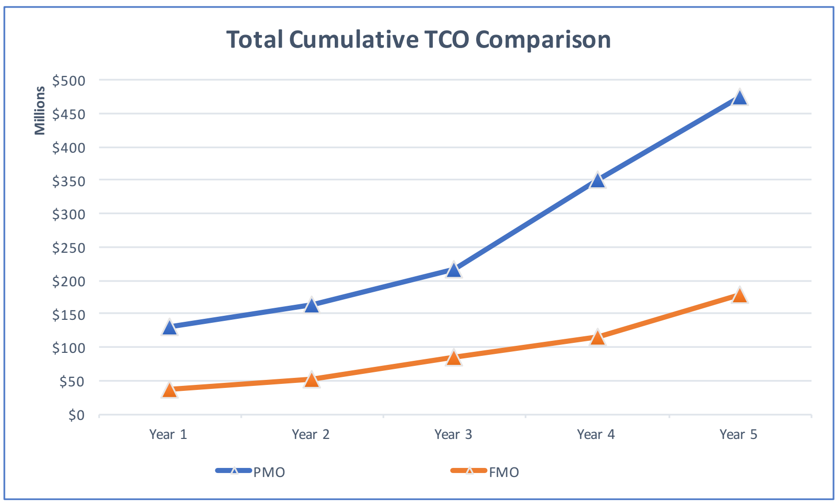

Figure 3. PMO versus FMO Cumulative TCO Comparison

The overall savings of the 5G ready FMO network are:

- 60% CAPEX savings
- 66% OPEX savings
- 62% TCO savings (CAPEX and OPEX)

The drivers of the CAPEX and OPEX savings are explained in the following sections.

CAPEX Savings Analysis

The procurement costs for routers constitute network CAPEX. 5G traffic is growing at a rapid rate and in order to maintain or improve profit margins it is essential to continually reduce the cost per bit of IP transport. Cisco 5G ready routers are highly scalable and have a significantly lower cost per bit than earlier generation routers. The converged network architecture depicted in Figure 2 allows the IP transport network to be shared among multiple services, which increases resource utilization and therefore reduces cost. Additionally, segment routing provides optimized traffic engineering and load balancing that allow the transport network to run more simply and scale more easily than traditional hop-by-hop routing protocols. Segment routing eliminates resource-heavy signaling protocols of MPLS and moves intelligence to the source/edge of the traffic thus removing complexity from the network. . The CAPEX comparison of the PMO and the FMO 5G ready network are depicted in Figure 4.

In summary, the primary sources of the CAPEX savings are:

- Converged network reduces the number of routers and improves router utilization.
- Cisco's 5G ready routers have better price performance.
- Segment routing allows the transport network to run more simply and scale more easily.

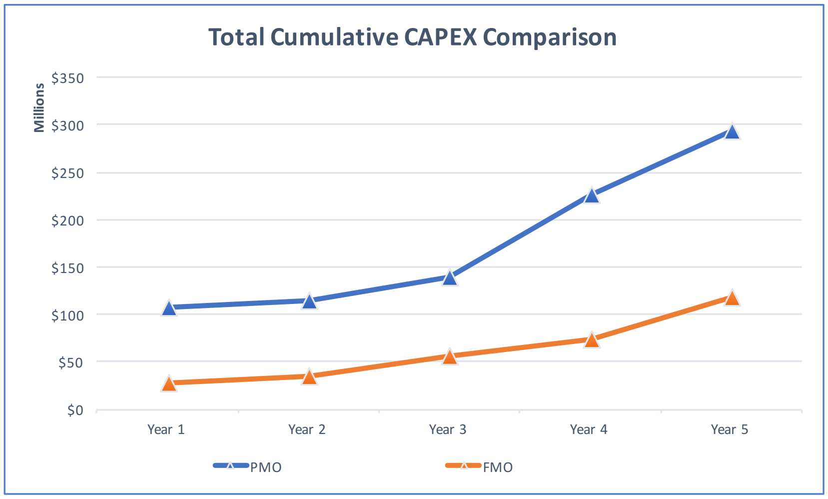

Figure 4. PMO versus Cumulative CAPEX Comparison

OPEX Savings Analysis

Operations expenses are the on-going costs associated with running the network. The categories of OPEX analyzed in this model are defined in Table 2. Our analysis shows significant 66% OPEX savings. The cumulative OPEX comparison of the PMO and FMO are presented in Figure 5. It should be noted that as time goes by the cumulative OPEX savings increase. Some of the OPEX savings are directly due to consolidating the three separate networks (mobile, residential, and business) into a converged 5G IP transport network. There are also reduced labor costs that are a result of network orchestration and automation provided by the Cisco NSO and Crosswork. Power consumption in the FMO network is lower, resulting in lower environmental expenses. A significant component of OPEX is the technical support expenses that are tied to network CAPEX. Technical support is usually priced as a percentage of the cost of router hardware and software. The key drivers of OPEX savings are:

- Converged networks result in consolidation and reduction of staffing requirements.
- Converged transport networks have fewer routers to manage.
- 5G ready routers are more power efficient (64%).
- Segment routing simplifies network engineering, configuration and fault-management tasks by reducing number of protocols.
- Network programmability and enhanced automation reduce cost of network installation (77%), time to perform move, add and changes by 87%, and service assurance MTTR by 71%.

A detailed OPEX breakdown is provided in Figure 6.

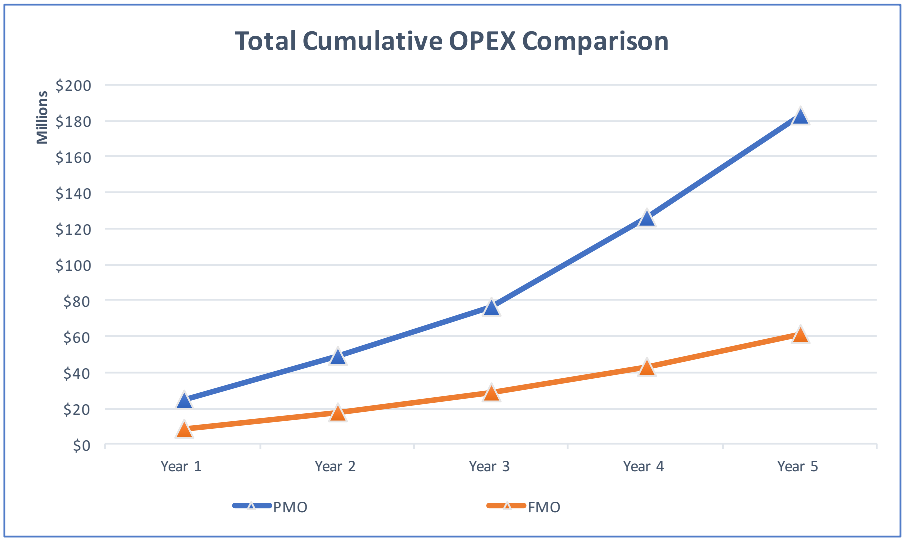

Figure 5. PMO versus FMO Cumulative OPEX Comparison

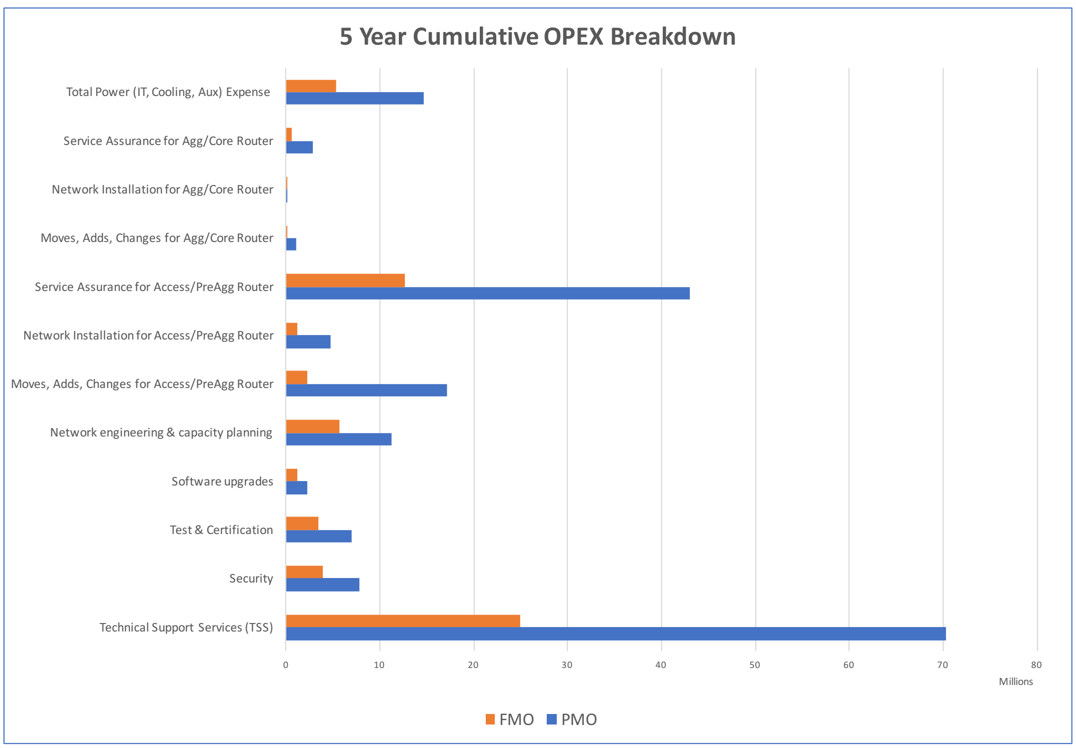

Figure 6. OPEX Breakdown

OPEX CATEGORY	DEFINITION	SAVINGS
Technical Support Services	These are support expenses for hardware and software provided by the vendor	65%
Security	Security management must be done for both the routing and optical network layers; involves security monitoring and patching	50%
Test & Certification	Before any new hardware or software releases are deployed in production, they must go through a service provider's test and certification process	50%
Software Upgrades	Network software upgrades require planning, monitoring, execution, and possibly rollbacks; labor expenses associated with software upgrades	50%
Network Engineering & Capacity Planning	Network engineering groups are responsible for network architecture, detailed design, resiliency analysis, and capacity planning	50%
Moves, Adds, Changes	Network operation requires constant changes in configuration, tuning, and management	87%
Network Installation	One-time installation expenses for network equipment installation	75%
Service Assurance Labor	Fault management, trouble shooting, and repair activities	71%
Total Power (IT, Cooling, Aux) Cost per Kwatt/Hour	Power expenses for powering and cooling equipment	64%

Table 2. OPEX Definitions

Service Velocity Considerations

5G networks allow service providers to offer many new services that will provide new revenue streams. Because mobile and wireline services are saturated in most markets, the ability to offer new services is critical for revenue growth. Examples of new applications and services enabled by 5G are:

- 4K/8K & 3D mobile video
- Virtual reality and augmented reality
- Self-driving car communications and control
- Vehicle tracking and control
- Video monitoring and analysis
- Variety of IoT services
- Smart city services

Although there are many potential 5G services, it is not yet clear which services will gain market traction. Therefore, service providers need the ability to deploy and test services quickly to determine which services will get traction and ultimately generate profitable revenue growth.

The new capabilities of the 5G transport network are key to increasing service velocity or increasing the speed at which service providers can deploy and test new services. A fundamental component of service velocity is reducing the time required for network configuration, moves, adds, and changes, and decreasing MTTR. Some of the specific benefits of the 5G transport network are:

- Automation and orchestration facilities will reduce time to instantiate customer services by 78%.
- Automation and orchestration facilities will reduce time to perform move, add, and changes by 80%.

- Service assurance can reduce the MTTR faults by 55%.
- Savings in deploying services reduce overall TCO and increase time to revenue.

CONCLUSION

5G services and use cases place a new set of requirements on networks, driving the need for higher bandwidth, lower latency, higher reliability, better security, and network slicing. To deliver on this 5G promise while meeting these heightened expectations, service providers must fundamentally change the economics of their infrastructure. To address the demands of 5G technologies, service providers need to converge services onto one transport network. 5G ready transport networks are converged and designed to handle the amalgamation of fixed and mobile, consumer, residential and business service offerings. Service providers need to migrate to the next generation mobile transport which is best addressed by IP. The latest routers from Cisco provide significant hardware and software advancements to address the needs of 5G networks. A critical aspect of the new network are open network APIs, network orchestration, service assurance, and network automation. The results of our study show that Cisco's 5G transport network meets the demanding requirements of 5G while lowering TCO by 62%, CAPEX by 60%, and OPEX by 66%.

Peter Fetterolf (pfetterolf@acgcc.com) is CTO with ACG Research. His primary focus is developing business models for next generation networks which includes IP transport, SDN, NFV, vEPC, vRAN, other mobile network functions, and optical transport networks. He is also responsible for software development of the Business Analytics Engine (BAE) software network economic simulation tool.