The TCO Benefits of Distributed Broadband Services with CUPS

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EXECUTIVE SUMMARY

Mobile networks have captured much of the market's attention over the last several years, but communication service providers (CSPs) have continued to see a consistent and steady increase in demand for fixed broadband services for consumers, small businesses, and enterprises. Even with continued steady growth in wireline broadband, many CSPs are struggling to maintain the status quo. In many cases, changing customer requirements, along with rising performance demands for new applications and cloud services, are pushing traditional Broadband Network Gateway (BNG) architectures to the limits. Growth in 4K video, gaming, web conferencing, AR/VR, and other applications are increasingly driving stringent bandwidth and latency requirements, compelling CSPs to innovate new architectures so they can maintain or improve the economics. As a result CSPs are pursuing emerging technologies to:

- Simplify network operations where feasible
- Separate and distribute BNG user planes to the edge of the network
- Align network investments with business growth

In order to address these requirements, the Broadband Forum (BBF) are developing standards with the goal of making broadband networks more distributed, cloudified, converged and software driven. Among the most important early products of these efforts is the BBF TR-459 standard, which defines BNG Control and User Plane Separation (BNG CUPS).

BNG CUPS separates the BNG architecture into the user plane (UP) and control plane (CP). This allows the CPs to be centralized and UPs to be distributed as requirements demand. It also allows the CP and the UP functions to scale and be innovated independently. Some of the key motivations and benefits of BNG CUPS are:

- Distributed BNG user planes to support edge computing requirements
- Distributed BNG user planes can support low latency and high throughput requirements
- Separate BNG control and user planes can optimize network costs
- Increased resilience with 1:N redundancy on UPs for greater resiliency at lower cost
- More cost-effective allocation of BNG subscriber licenses by enabling license pooling
- CPs can scale efficiently with a Kubernetes-based, cloud-native architecture
- Reduces OSS interfaces to BNG control planes, lowering maintenance and integration costs
- Time to market for new services is improved with BNG CUPS
- BNG CUPS can be a platform for innovative use cases to improve service and resiliency

ACG Research has developed a total cost of ownership (TCO) model to compare a traditional BNG architecture with an BNG CUPS implementation as prescribed by the BBF. This whitepaper compares the TCO of traditional BNG deployments with an BNG CUPS architecture to quantify the economic advantages/disadvantages of each approach.

The following TCO models comparing a traditional BNG deployment model (the present mode of operation [PMO]) with an BNG CUPS based approach (the future mode of operation [FMO]). The traditional PMO architecture uses 1:1 redundant BNG service nodes in regional central offices. The FMO architecture, on the other hand, leverages BNG CUPS to distribute BNG user planes while centralizing the BNG control plane. In the FMO model, BNG user planes are located in both regional and edge central offices. The FMO also uses a spine-leaf architecture to interconnect access nodes with BNG user plane nodes as represented in our previous **Distributed Broadband Access Solution**[1]. Our TCO model compares the PMO and FMO scenarios for a medium-size CSP broadband network. The five-year cumulative TCO results are presented in Table 1. The benefits of the distributed BNG CUPS architecture show significant CapEx and OpEx savings, resulting in a five-year TCO savings of 64%.

	Cumulative Five-Year TCO Comparison			
	CapEx	**OpEx**	**TCO**	**TCO Savings**
FMO-BNG CUPS	$101,278,555	$ 68,039,399	$169,317,954	64%
PMO-Central BNG	$305,156,000	$164,510,437	$469,666,437	N/A

Table 1. Five-Year Cumulative TCO Comparison of PMO and FMO

[1] https://www.acgcc.com/reports/he-economic-benefits-of-distributed-broadband-serv/

The paper also describes the drivers for distributed broadband services with BNG CUPS, the key benefits of the BNG CUPS architecture, and the results of the ACG TCO analysis.

Drivers of Distributed Broadband Services with CUPS

Fixed broadband services for consumers and enterprises continue to evolve and grow. Much of the traffic growth is driven by video and new bandwidth-intensive applications. One of the major trends in broadband networks is that more traffic is concentrated at the edge of the network. CSPs are building out edge computing infrastructure to reduce latency and increase bandwidth for edge applications. Some examples of edge applications that require low latency and/or high bandwidth are:

- Video CDN networks moving closer to edge to improve streaming
- Video upload: security, event recording, and live streaming
- Cloud gaming
- IoT applications
- AR/VR and the metaverse
- Connected vehicles
- Real-time control for drones and robots

Broadband average data rates are also increasing. ACG Research projects residential average broadband traffic to grow from an average busy hour data rate of 13 Mbps in 2021 to 21 Mbps in 2025 with an annual growth rate of 12%[2]. This traffic growth is primarily due to video streaming growth (HD and 4K), cloud gaming, and more video calls. Traffic growth is also due to new access technologies that are increasing residential bandwidth, for example, 10G PON, G.Fast, and 5G FWA.

ACG has recently completed a global traffic study that shows more traffic will stay in the local metro area due to the growth in edge computing applications [3]. Figure 1 presents the results of this study, showing the distribution of network traffic in 2021 and projections for 2027. This analysis reveals that most traffic stays within the metro network today and projects a larger percentage of traffic will stay in the metro area in 2027. These results are driven by traffic growth and edge applications hosted in metro edge data centers.

[2] https://www.acgcc.com/reports/middle-mile-networks-capacity-requirements-for-fix/

[3] https://www.acgcc.com/reports/next-generation-cloud-metro-network-requirements-a/

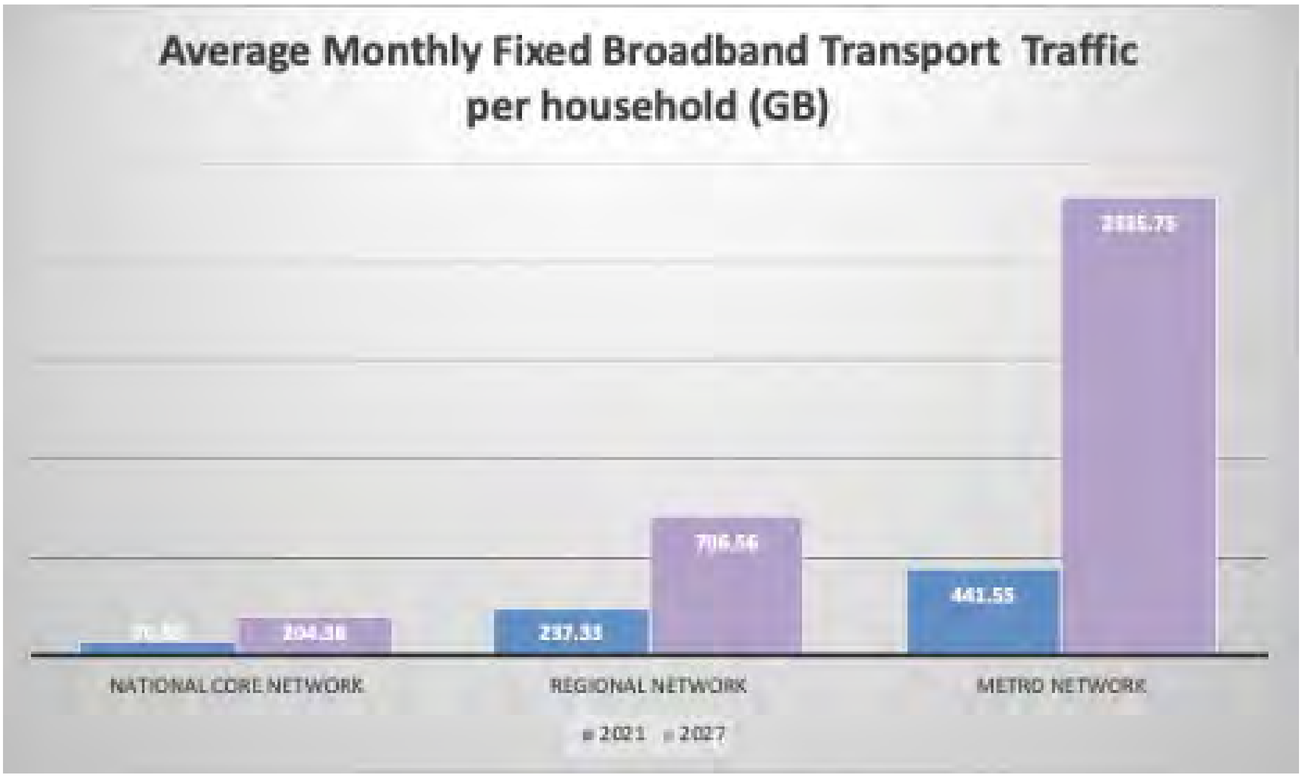

Figure 1. Global Distribution of Fixed Broadband Traffic between the National Core, Regional, and Metro Networks

These trends will increasingly drive the need for distributed broadband services with CUPS. Because traffic is terminating and/or originating at the edge of the network, it is advantageous and potentially necessary to collocate BNG user planes with edge servers. This prevents traffic from needlessly traversing the WAN to/from a central BNG node, reducing WAN bandwidth consumption and guaranteeing performance expectations can be met on the edge of the network.

Challenges of Legacy Centralized and Integrated Broadband Services Architectures

Traditionally, BNG nodes have been located in regional central offices with both control plane and user plane functions integrated on each node. In these circumstances all network traffic must travel to the centralized BNG node before it can access services. Edge applications, on the other hand, require a BNG node to be collocated with edge servers to guarantee customers' quality of experience expectations can be met. There are additional challenges with a traditional/centralized BNG architecture:

- Integrated BNG ports are more expensive and not optimized for aggregating access nodes as compared to high-density switching ports
- Service resilience can be relatively more expensive to deploy and maintenance windows costly to execute
- 1:1 stateful redundancy is required for high availability hitless switchover
- BNG resource demand varies with services, consequently when scaling BNG services some resources can be underutilized while others are overutilized, examples of resources are signaling, memory, throughput
- Separate interfaces and OSS integrations are required for each BNG router

The next section describes how these problems are addressed with distributed BNG CUPS.

Distributed Broadband Services with CUPS

The distributed BNG with CUPS (Figure 2) addresses many of the problems associated with the centralized and integrated BNG service nodes. This architecture uses a central BNG cloud-native control plane and distributed user planes. Additionally, a spine-leaf architecture and cost-effective access switches are utilized to interconnect access ports to the BNG user plane. This allows access ports to scale independently of BNG user plane and control plane nodes. The independent scaling and use of cost-effective access ports allows CSPs to minimize their TCO for BNG deployments.

Another benefit of this approach is a single interface from each BNG control plane to the OSS back office. In legacy BNG deployments a separate OSS interface is needed for each integrated BNG node. Consequently, distributed broadband services with BNG CUPS have the added benefit of reducing OSS integration and management expenses.

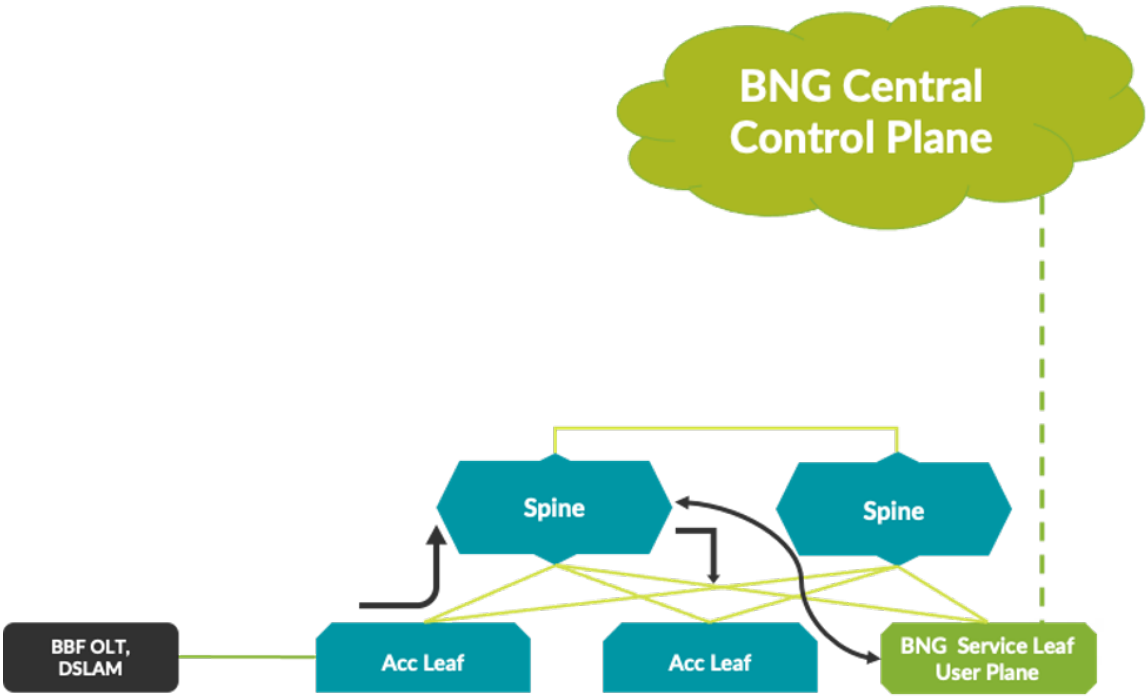

Figure 2. Distributed BNG with CUPS

Benefits of Distributed Broadband Service CUPS Architecture

The following summarizes the key benefits of the distributed BNG with CUPS:

- Distributed BNG user planes support edge computing requirements
- Distributed BNG service edges provide low latency and high throughput
- BNG user planes are interconnected with access ports using spine-leaf switching, which allows for cost-effective scaling of access ports and BNG user plane
- Independent BNG control and user planes allow independent scaling and cost optimization
- Increased resilience with N:1 stateful redundancy on BNG user planes provide greater resiliency at lower cost than 1:1 BNG redundancy required in legacy systems
- A network-wide pool of BNG subscriber licenses adds a cost-effective allocation of BNG software licenses
- BNG control planes are highly scalable using cloud-native architecture with Kubernetes
- A smaller number of OSS interfaces are required to the BNG control planes reducing OSS integration and management expenses
- Time to market for new services is improved with BNG CUPS due to independent scaling of functions

TCO Model Framework and Assumptions

ACG Research has developed a TCO model comparing the PMO with the FMO. The PMO architecture uses 1:1 redundant BNG service nodes in regional central offices, depicted in Figure 3. The FMO architecture uses a distributed BNG user plane and a centralized BNG control plane, represented in Figure 4. BNG user planes are located in both regional and edge central offices. The FMO also uses a spine-leaf architecture to interconnect access nodes with BNG-UP nodes, represented in Figure 2. Our TCO model compares the PMO and FMO scenarios.

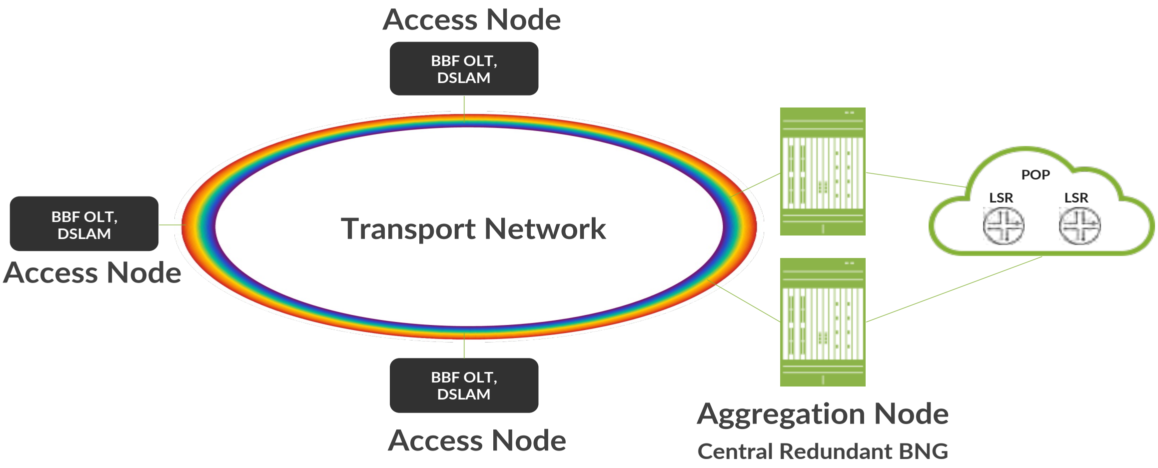

Figure 3. PMO with Centralized 1:1 Redundant BNG Nodes

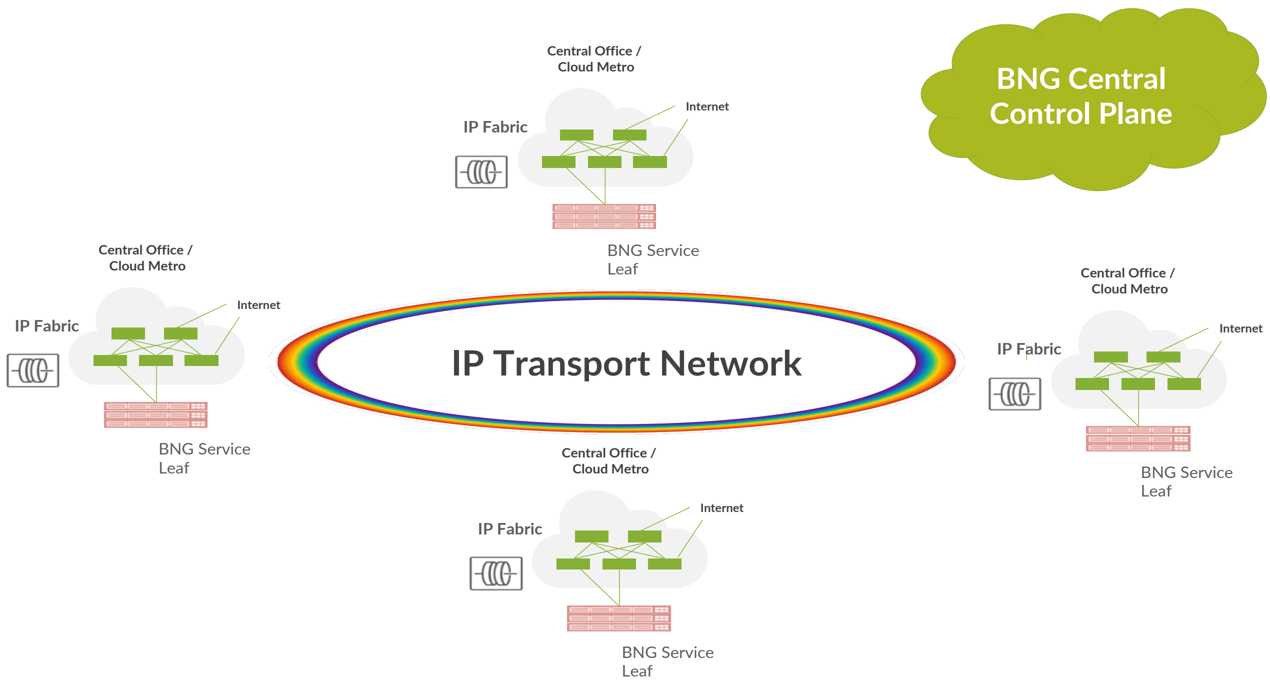

Figure 4. FMO with Distributed BNG UP and Centralized BNG CP

For each of the comparisons we assume a medium-size network with:

- 10 large central offices
- 100 medium-size central offices
- 1000 small central offices

The number of residential and business subscribers and average traffic per subscriber are presented in Table 2. These assumptions are used to configure the PMO and FMO BNG solutions for both scenarios.

	Cumulative Five-Year TCO Comparison				
Network Demand	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Residential subscribers per large CO	18000	23400	30420	39546	51410
Residential subscribers per medium CO	10000	13000	16900	21970	28561
Residential subscribers per small CO	1500	1950	2535	3296	4284
Residential subscriber traffic (Mbps)	13	15	17	19	21
Business subscribers per large CO	4000	5200	6760	8788	11424
Business subscribers per medium CO	2000	2600	3380	4394	5712
Business subscribers per small CO	300	390	507	659	857
Business service traffic (Mbps)	5	7	10	12	15

Table 2. Residential and Business Fixed Broadband and Demand

The TCO model considers both CapEx and OpEx associated with the BNG solutions. The FMO CapEx includes:

- Leaf nodes
- Spine nodes
- BNG service nodes
- BNG control plane, Kubernetes, and servers
- Software licenses
- Pluggable optics

The PMO CapEx includes:

- BNG chassis
- BNG line cards
- Software licenses
- Pluggable optics

The OpEx assumptions for both the PMO and FMO include:

- Equipment technical support services
- Power and cooling
- Floorspace
- Labor expenses:
  - OSS Integration expenses
  - Annual software upgrades
  - Annual BNG management expenses

TCO Results

The results of a five-year cumulative TCO comparison of the FMO and PMO are presented in Table 3. The total TCO savings over five years is 64%.

	Cumulative Five-Year TCO Comparison			
	CapEx	OpEx	TCO	TCO Savings
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Table 3. Five-Year Cumulative TCO Comparison of PMO and FMO

A breakdown of the five-year cumulative expenses is presented in Figure 5. The key drivers of TCO savings are reduced equipment CapEx and support followed by reduced labor expenses. The FMO solution has higher power, cooling, and floorspace expenses because it is a distributed BNG edge solution versus a regional BNG deployment. The distributed nodes are located in many edge central offices and therefore take up more real estate and power than a regional BNG solution. However, the increased environmental expenses are small compared to the savings in equipment CapEx and OpEx.

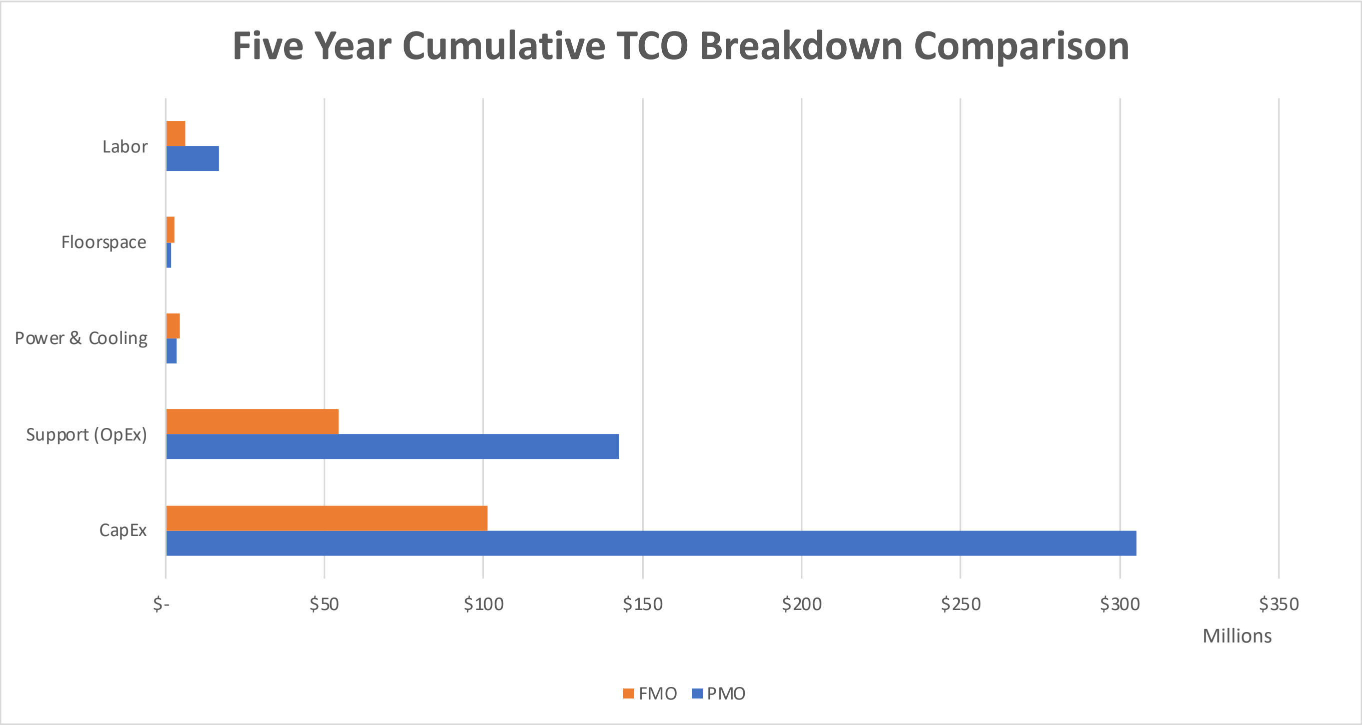

Figure 5. Five-Year Cumulative Breakdown of PMO and FMO TCO

The annual TCO comparison of the PMO and FMO solutions is presented in Figure 6.

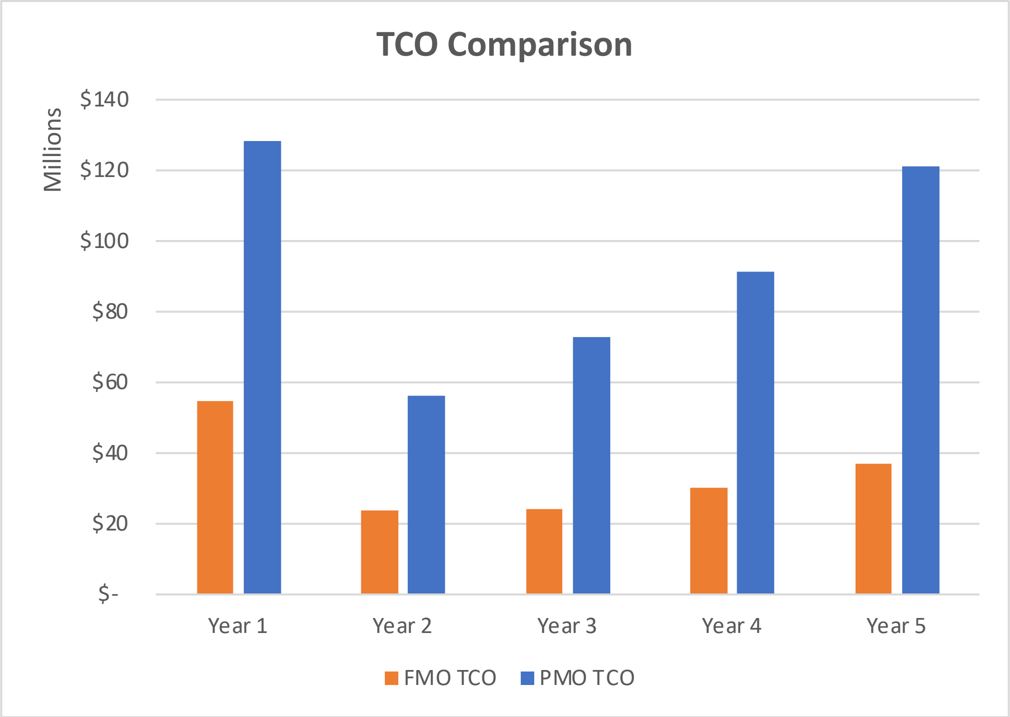

Figure 6. Annual TCO Comparison of PMO and FMO over Five Years

There are many TCO benefits of the distributed BNG CUPS architecture. Some of the key drivers of TCO benefits are described in the following sections.

Network-Wide Pooling of BNG Subscriber Licenses

Because subscribers' licenses are allocated from a centralized pool, the BNG licensing cost is significantly lower than the licensing costs in centralized BNG nodes. This is because legacy BNG subscribers' licenses are allocated to a single node and not shared throughout the network. The central BNG control plane allocates licenses as needed throughout the entire network, which increases costs. Additionally, adding UPs to scale network throughput does not increase BNG licensing costs.

Spine-Leaf Architecture

The spine-leaf architecture allows cost-effective scaling of the BNG user plane. Access ports from OLTs, DSLAMs, and CMTS connect to access switches with cost-effective 10GE ports. BNG user plane service-leafs connect to the switches with 100GE interfaces and scale based on traffic demand as opposed to scaling based on access-port connectivity. This lowers both CapEx and OpEx.

Reduced Labor Expenses

The central BNG control plane reduces labor expenses because there are a small number of central BNG-CP nodes. Some of the expenses considered in our model are:

- OSS integration expenses
- Annual software upgrades
- Annual BNG management expenses

Conclusion

The emergence of edge computing combined with continued broadband traffic growth is driving the need for a new broadband services network architecture. This paper makes the business case for CSPs to deploy BNG CUPS with a centralized BNG control plane and distributed BNG user planes. ACG's TCO analysis shows that BNG CUPS provides a 64% TCO savings over legacy BNG network architectures. It should be noted that CSPs can enable BNG CUPS on top of their existing centralized BNGs and migrate to distributed BNGs over time.