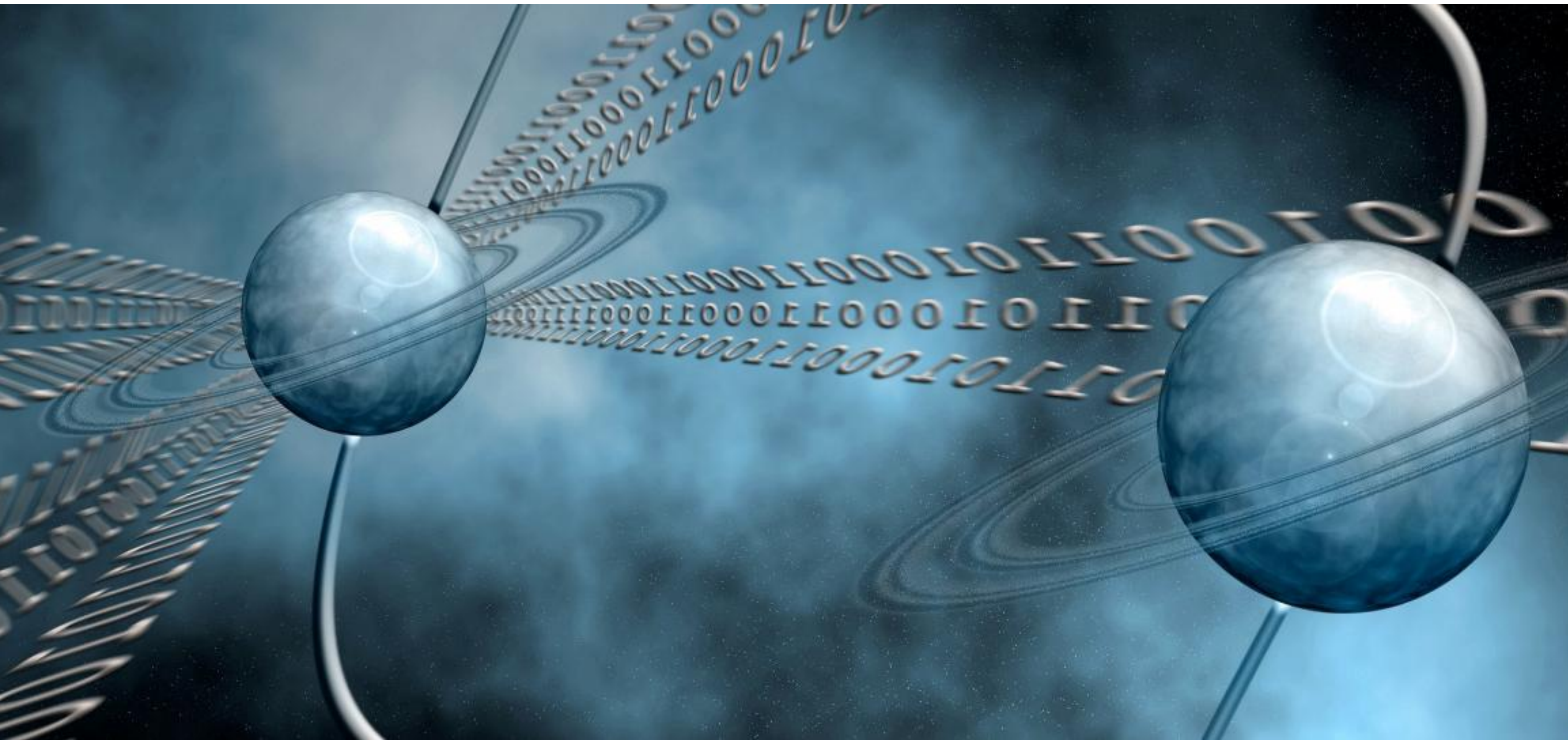

Executive Summary

The dramatic rise of multimedia applications in residential, mobile, and business networks is continuing to drive the migration from legacy TDM and ATM to Carrier Ethernet and IP/MPLS networks. Ethernet/IP is the dominant switching and routing technology in next generation networks. The key reasons for widespread adoption of Ethernet/IP technology are its superior scalability, service layer flexibility, and lowest Total Cost of Ownership (TCO).

One of the key challenges faced by service providers today is finding the right approach to scale the network while providing new services to both new and existing customers. Wireline and wireless customers expect a full range of multimedia services (voice, Internet, video) and are not tolerant of network outages or service degradation. However, CapEx and OpEx burn rates are a major concern — service providers must find a solution that meets customer expectations at a minimum TCO to ensure on-going profitability of their businesses.

This study examines the TCO of a Carrier Ethernet/IP metro network. The results show that the TCO of Brocade's Ethernet/IP metro network is significantly less than the TCO of Ethernet/IP metro networks built with equipment from three market leading competitors. The study uses a comprehensive TCO model developed by Network Strategy Partners to compare the TCO of each alternative solution. The model characterizes traffic generated by:

- Residential broadband services (Voice, Video, and Internet)
- Business broadband services (Carrier Ethernet and MPLS VPN)
- 4G Mobile backhaul

Traffic is projected over a five-year period and four alternative networks are designed: a Brocade network and networks for three market leading switch/router vendors. These vendors are denoted as Vendor A, Vendor B, and Vendor C. Figure 1 shows the five-year cumulative discounted TCO for Brocade and the three alternative networks. Annual TCO amounts are discounted at a 10% rate.

The key reasons for the Brocade cost advantage are:

- Brocade has the lowest price per port for both 1 GbE and 10 GbE ports
- Brocade has the highest 10 GbE port density in a single platform
- Brocade has the lowest power consumption which reduces power, cooling, and space operational expenses
- Brocade has the lowest cost of spares because the same cards are used in aggregation and core routers

The body of this paper presents a detailed description of the NSP TCO model assumptions and analyzes the TCO findings.

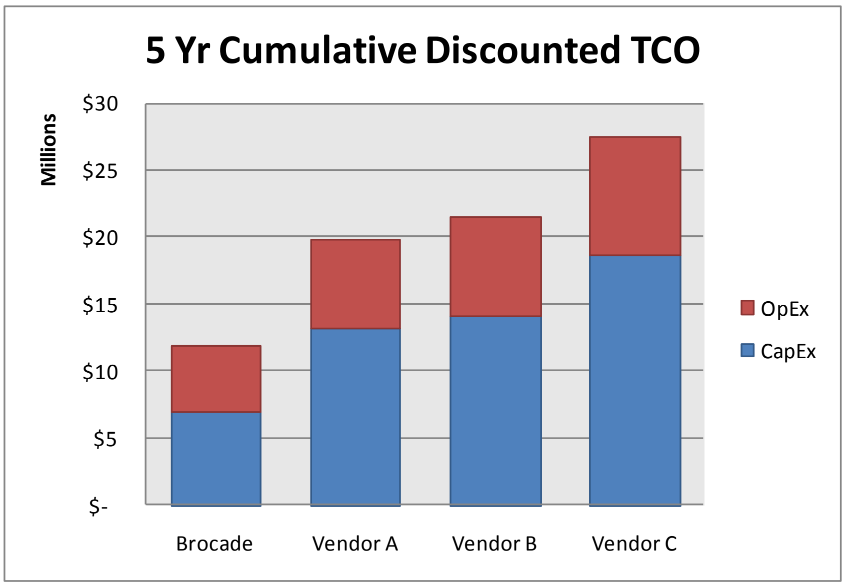

Figure 1. Five-year cumulative discounted TCO for four alternative network designs

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Overview of the Ethernet/IP Network TCO Model

The analysis presented in this paper is based on a comprehensive Ethernet/IP TCO model developed by Network Strategy Partners. A high level diagram depicting the model's structure and logical flow is presented in Figure 2. The model begins with a set of assumptions regarding network architecture, central office dimensions, and parameters for residential, mobile, and business traffic. Using these assumptions, a five-year service level traffic forecast and network traffic engineering for the access, aggregation, and core networks is computed by the model. Traffic engineering addresses traffic utilization levels, redundant paths, network topologies, IP multicast, and IP unicast data streams. The number of 10GbE rings and links, 1GbE and 10 GbE ports counts, and equipment configurations are derived from the traffic forecast and traffic engineering. The port counts are used to configure network equipment and compute CapEx. OpEx is computed as a function of the number of chassis and cards in the network and uses a comprehensive OpEx model developed by Network Strategy Partners.

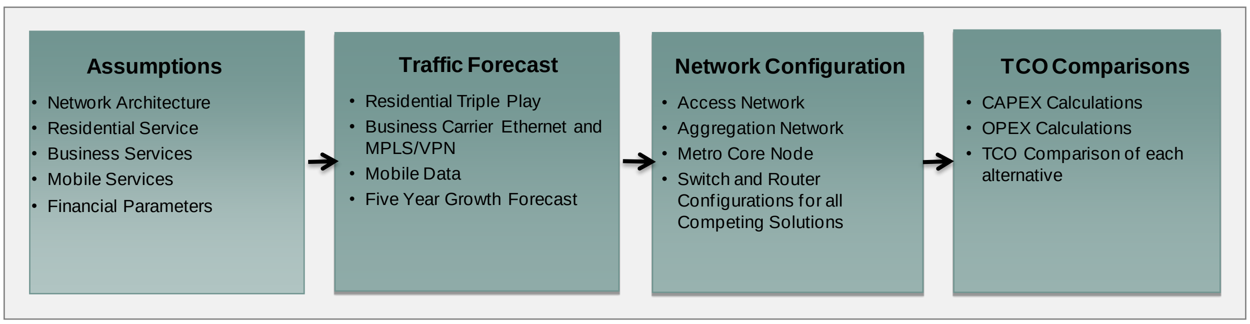

Figure 2. Overview of the NSP TCO Model Logic

TCO Model Assumptions

The TCO modeling process begins with network architecture, and service and traffic assumptions as follows:

Network Architecture Assumptions

This study focuses on metro access and aggregation networks. Three types of central offices (CO) are modeled:

- Access CO
- Aggregation CO
- Core CO

Each type of CO provides Ethernet/IP transport for residential services, business services, and 4G mobile backhaul. Residential services are provided by IP DSLAMs connected to access switches using 1 GbE interfaces. Business services are offered using 10/100/1000 Ethernet interfaces. 4G Mobile backhaul interconnects 4G cell sites with 1 GbE Ethernet links. The network architecture is illustrated in Figure 3. Access COs are interconnected using a 10 GbE access ring. Aggregation COs interconnect with one or more Access Ring and are themselves interconnected using a 10 GbE network. Core COs use redundant core routers to connect the aggregation network with the core IP/MPLS network. The Brocade solution uses the following products in each central office:

- Access CO: **CES 2048FX**
- Aggregation CO: **MLX 16**
- Core CO: **MLX 32**

Equivalent products for the Vendors A, B, and C are selected from each vendor's product portfolio. Cost effective 1 RU or 2 RU switches for Access COs are selected from each vendor's product line, Carrier Ethernet routers are selected for the aggregation network, and core IP/MPLS routers are selected for the core network. Products that each vendor has targeted for service provider Carrier Ethernet and IP/MPLS network installations are used in all cases.

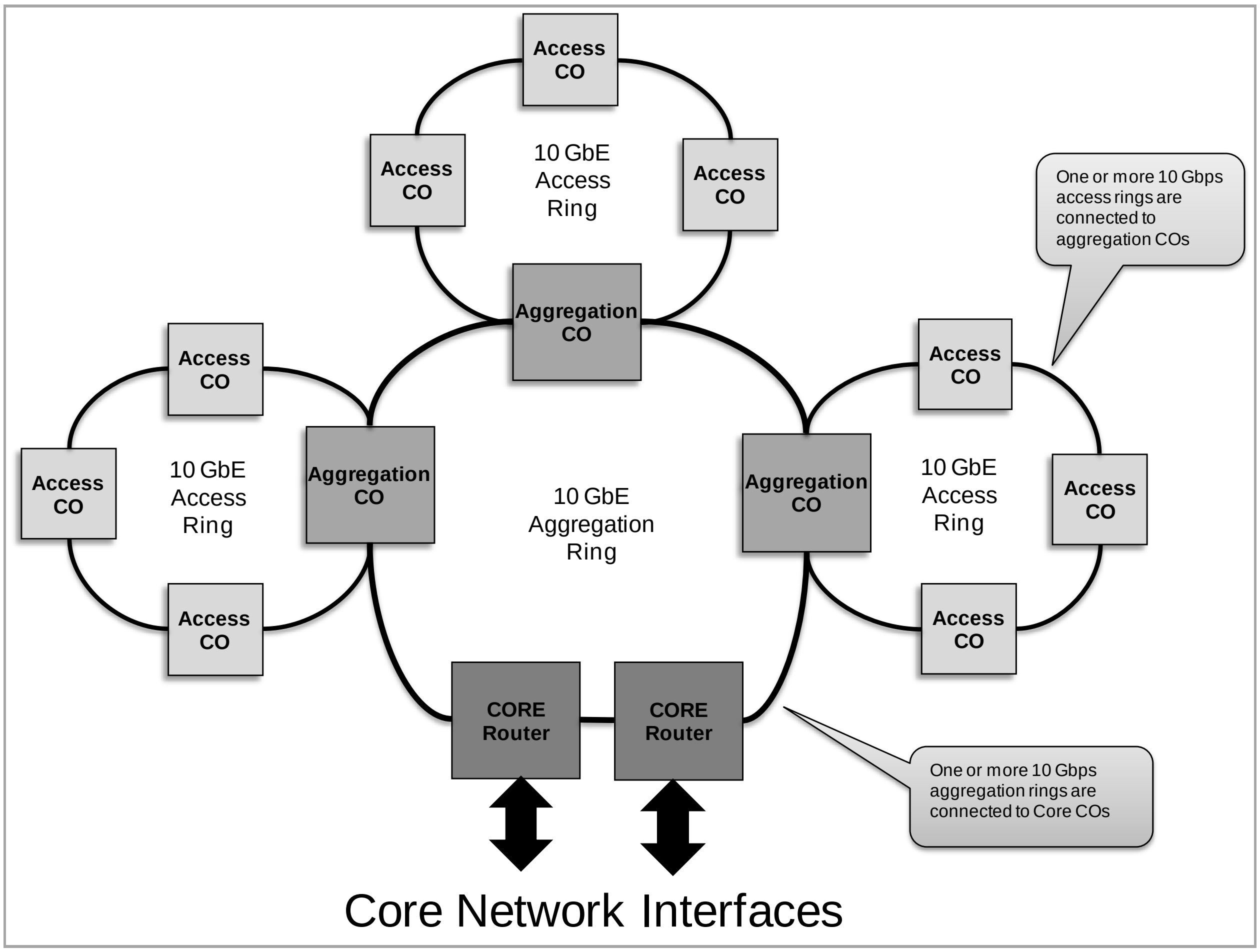

Figure 3. Metro Network Architecture

The TCO model is flexible, allowing users to specify networks of varying sizes. Table 1 and Table 2 summarize the dimensions of the network being modeled. The total residences and businesses passed by the network is a measure of the number of potential subscribers. Penetration rates are applied to the residences or businesses passed to determine actual subscribers.

This is a hypothetical network; the network dimensions approximate real networks in medium sized metropolitan areas. The areas of lowest population density are served by access central offices, aggregation central offices are located in areas with higher density, and the core central office is located in the center of the metropolitan area with the highest population density.

Table 1. Network Architecture Input Assumptions

Input Assumptions	Values
Residences passed by Access CO	1,500
Residences passed by Aggregation CO	3,000
Residences passed by Core CO	10,000
Business Establishments passed by Access CO	25
Business Establishments passed by Aggregation CO	100
Business Establishments passed by Core CO	500
Number of Access COs per Access Ring	5
Number of Access Rings per Aggregation CO	2
Number of Aggregation COs per Aggregation Ring	5
Number of Aggregation Rings per Core CO	2

Table 2. Summary of Metro Network Dimensions

Network Dimensions	Values
Total Access COs in Network	100
Total Aggregation COs in Network	10
Total Core COs in Network	1
Total Residences Passed	190,000
Total Business Establishments Passed	4,000
Total Cell Towers	470

Service and Traffic Assumptions

A converged network providing residential, business, and mobile services is modeled. Residential services consist of broadband triple play services, specifically:

- Broadband Internet
- Broadcast IPTV (both SD and HD)

- Video-on-Demand (both SD and HD)
- Voice (VoIP)

Business services consist of:

- Carrier Ethernet Layer 2 Service
- MPLS VPN Layer 3 Service
- Business Internet Service

Mobile services consist of 3G and 4G backhaul traffic. Only Ethernet backhaul is considered - no legacy mobile traffic using T1/E1 circuits or ATM backhaul is modeled.

The five-year traffic forecast used to design and configure the network is based on a detailed set of assumptions regarding network services, data rates, and growth rates. These assumptions are characterized in the tables below. Table 3 specifies the market penetration rates for both residential and business services. The actual number of customers served by the network is calculated by multiplying the market penetration rates in Table 3 by the homes and businesses passed specified in Table 1 and Table 2. Mobile traffic is driven by the number of 3/4G cell sites connected to the network as specified in Table 4. The traffic engineering process used to assign capacity, dimension the network, and configure routers uses a combination of the number of subscribers, data rates, concurrency rates, growth rates, and network traffic engineering rules. The average data rates for each type of service is specified in Table 5 and the parameters used to estimate growth and bandwidth are specified in Table 6. It should be noted that average data rates are usually much lower than peak data rates. Users are idle for a large percentage of time—no data is transferred during idle periods—therefore average data rates are significantly lower than the peak data rates. Average concurrency is specified in Table 5. This is the percentage of time that a given customer is using the service (for example watching VoD or using the Internet). All these values are used in network traffic engineering.

Table 3. Market penetration rates for residential and business services

Residential Subscriber Penetration Rates	Year 1	Year 2	Year 3	Year 4	Year 5
High Speed Internet	30%	40%	50%	60%	70%
Video Services	10%	15%	20%	25%	30%
Voice Services	10%	15%	20%	25%	30%

Business Subscriber Penetration Rates	Year 1	Year 2	Year 3	Year 4	Year 5
Carrier Ethernet L2 Service	2%	4%	6%	8%	10%
Carrier Ethernet Internet Service	5%	7%	15%	20%	25%
MPLS VPN L3 Service	2%	4%	6%	8%	10%

Table 4. Number of 4G cell sites served by each type of Central Office

Number of 3/4G Cell Sites Served	Year 1	Year 2	Year 3	Year 4	Year 5
4G Cell sites served by Access COs	4	4	4	4	4
4G Cell sites served by Aggregation COs	6	6	6	6	6
4G Cell sites served by Core COs	10	10	10	10	10

Table 5. Data and concurrency rates for each type of service

Service Data Rates	Data Rate (Mbps)	Concurrency
Residential Internet	1	25%
Residential HD IPTV	9	N/A
Residential SD IPTV	2	N/A
Residential HD VoD	9	15%
Residential SD VoD	2	15%
Residential VoIP	0.032	25%
Business Carrier Ethernet Service	10	N/A
Business Internet Service	10	N/A
Business MPLS VPNService	5	N/A
Mobile 4G Data Service from cell site	20	N/A

Table 6. Service forecast parameters for each service

Service Forecast Parameters	Value
Annual growth rate of Internet traffic to the home	25%
Total Number of TV Channels	300
Percent of Video that is HD	10%
Annual growth rate of HD content	5%
Growth in Average Data Rate for Carrier Ethernet	20%
Growth in Average Data Rate for Business Internet	30%
Growth in Average Data Rate for MPLS VPN	20%
Growth in Average Data Rate for 4G Cell Sites	75%

Traffic Forecast

Traffic engineering is carried out on the access, aggregation, and core network nodes. Traffic engineering uses the assumptions characterizing traffic, accounts for both unicast and multicast traffic, and allows for link restoration in the case of a single link failure. Figure 4 presents total network traffic and Figure 5 depicts a breakdown of residential traffic by application category. Significant growth in video services on wireline and wireless networks is forecast. This creates large growth in total network traffic over the five-year period. Traffic growth drives the requirement for scalable and cost effective Ethernet/IP access and aggregation networks.

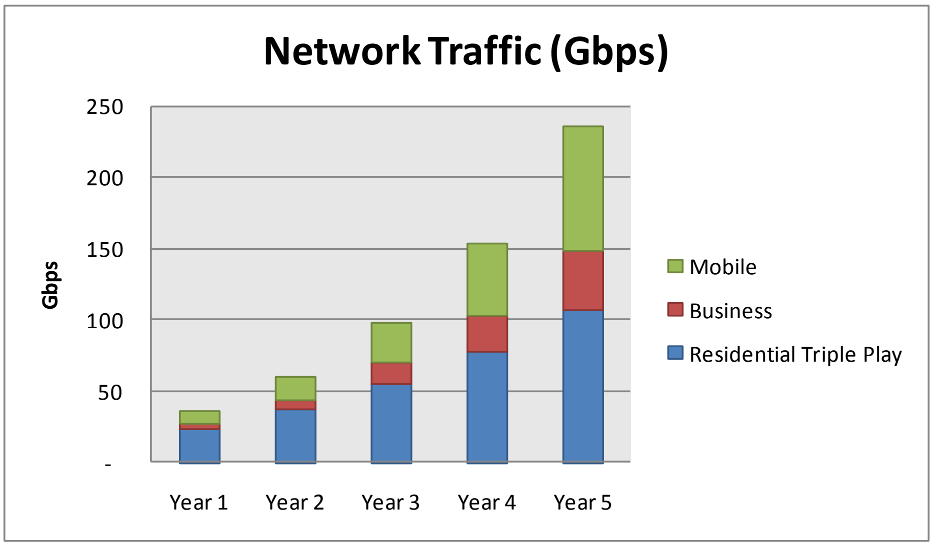

Figure 4. Total metro network traffic for residential, business, and mobile services

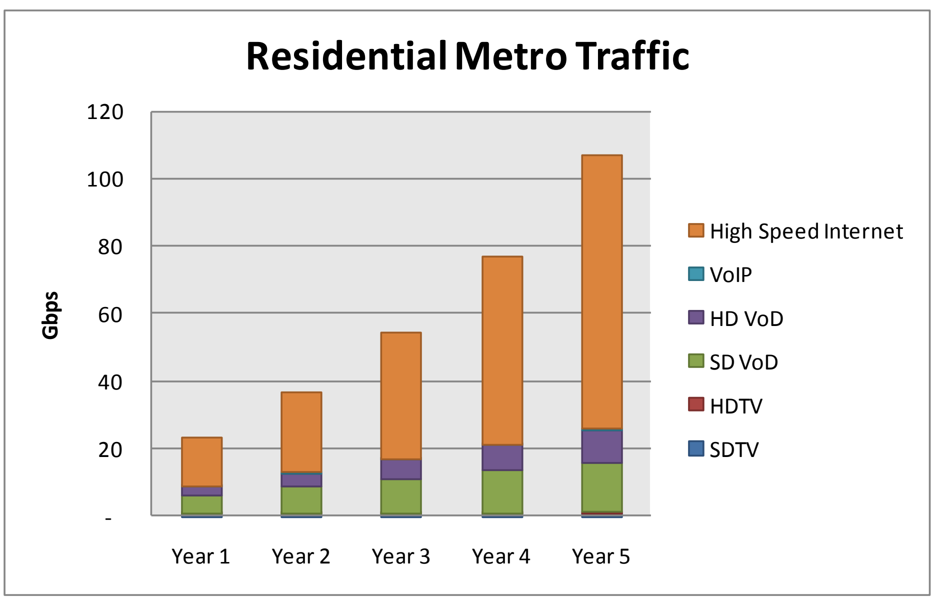

Figure 5. Traffic breakdown for residential services

TCO Results and Analysis

The TCO of the alternative solutions is computed by first designing four separate networks—all networks are designed using the assumptions, requirements, and traffic forecasts specified in the preceding sections. CapEx and OpEx of each solution then is calculated by costing out the resulting designs an system configurations. Brocade's network solution has a significantly lower TCO than all the other solutions because:

- Brocade has the lowest cost per port for both 1 GbE and 10 GbE Ethernet ports
- Brocade has the highest 10 GbE port density in a single platform
- Brocade has the lowest power consumption
- Brocade has the lowest cost of spares due to the fact that cards are reused on both the MLX 16 and MLX 32 platforms

Figure 6 presents a summary of the five-year cumulative discounted TCO for each solution. The cumulative TCO consists of CapEx and OpEx over the five year period of study. The cumulative TCO for each year is discounted at a 10% rate to account for the time value of money. The cost of capital is the rate of return that capital could be expected to earn in an alternative investment of equivalent risk. Since network capital investments have higher than average risk, a rate of 10% is used to account for this level of risk. Brocade's solution is significantly less expensive than the alternative solutions. Figure 7 illustrates this cost advantage as the percentage savings for TCO, CapEx, and OpEx. This chart shows that the Brocade CapEx advantage is greater than the OpEx advantage. Figure 8 presents the annual cumulative discounted TCO for each alternative.

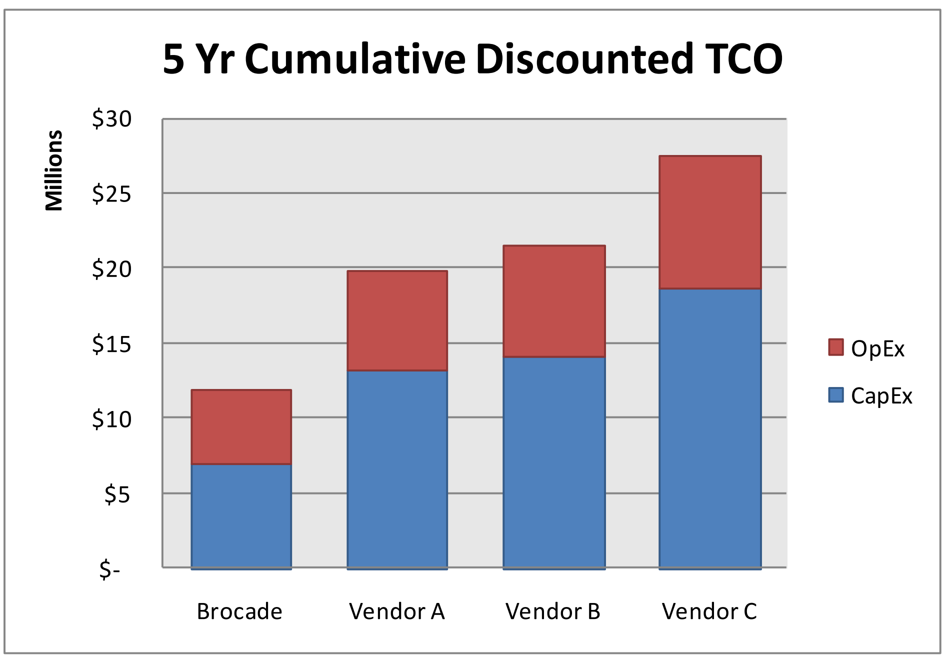

Figure 6. Five-year cumulative discounted TCO for each alternative

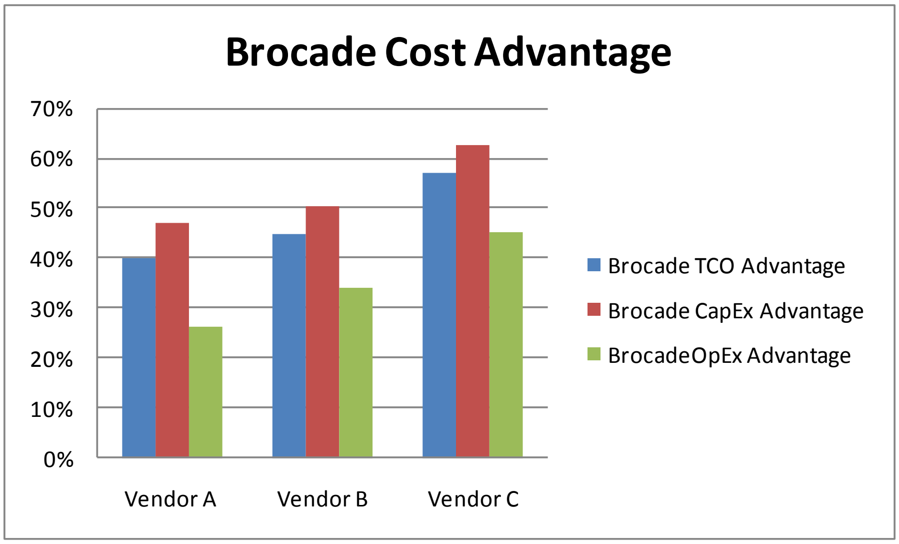

Figure 7. Brocade's TCO and CapEx advantage over the alternative solutions

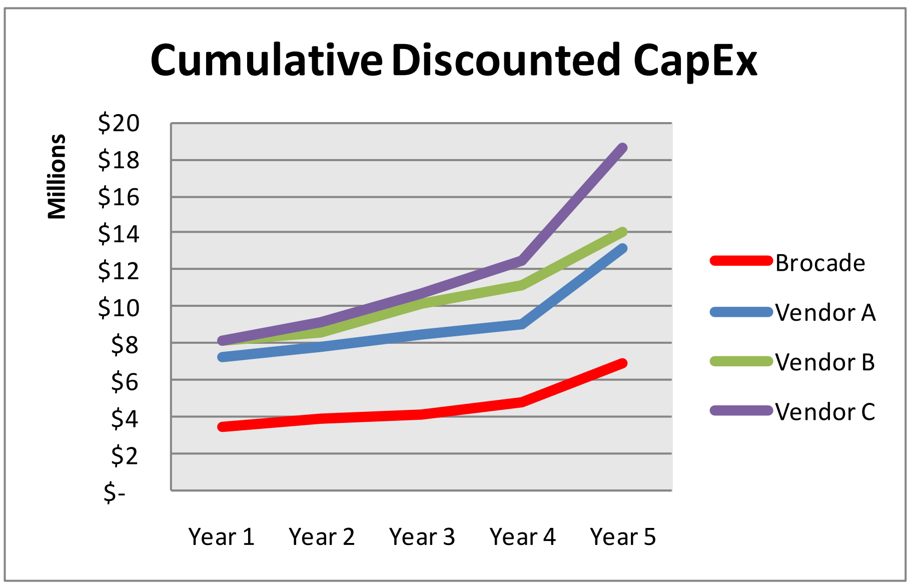

Figure 8. Comparison of the cumulative discounted TCO for each alternative

The primary reason for Brocade's CapEx advantage is that Brocade has the lowest cost per port. Brocade, additionally, has a cost advantage in sparing because the MLX 16 and MLX 32 share the same line cards. Since the same line cards are used in both the aggregation and core network solutions, less spares are needed in Brocade's network. The alternative solutions use different platforms and line cards in the aggregation and core networks and therefore have a higher cost of spares. Figure 9 presents a comparison of sparing costs between the four alternatives.

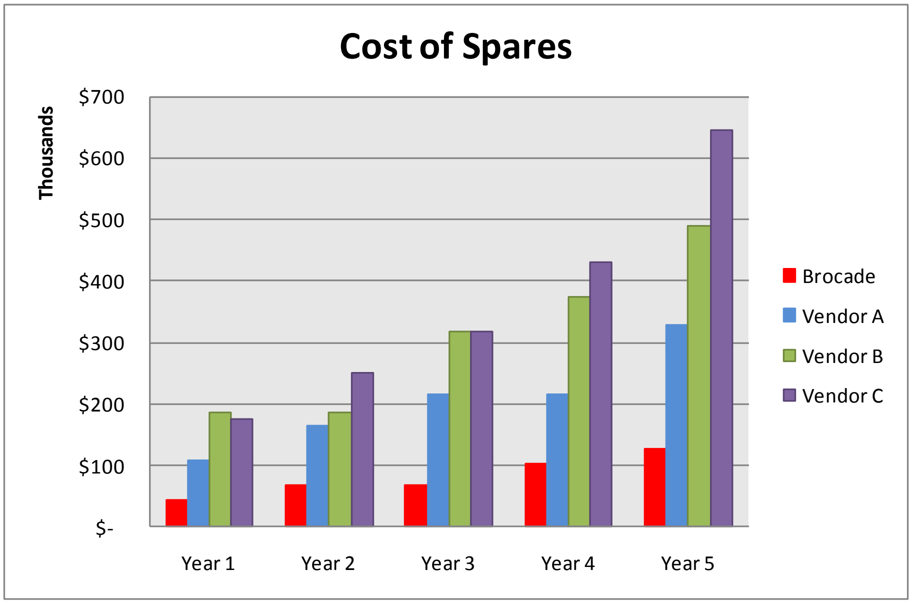

Figure 9. A comparison of the cost of spares over a five year period

The Network Strategy Partners TCO model captures the fundamental components of OpEx as represented in Table 7. This model uses assumptions regarding hours of labor per chassis and line card for various engineering and operations activities. Three categories of labor: hands on technicians, NOC technicians, and NOC engineers are modeled. OpEx for engineering and operations activities is calculated using these parameters in combination with the number of chassis and the number of line cards in the network. Environmental expenses are calculated directly from network configurations by adding up the total power consumption for each chassis and line card. Power consumption contributes to power expenses, cooling expenses, and floor space expenses. Floor space is estimated using a Telecordia standard for the maximum heat dissipation power density allowed in a Central Office. Figure 10 displays a breakdown of OpEx for the four alternatives. This figure includes all the service provider operational expenses except vendor service charges. Vendor service charges are tied closely to CapEx because the charges are linked to the associated equipment prices. Since Brocade's CapEx is lower than the alternatives, service charges are also lower. Some of the operational expenses such as training, testing, and certification of new releases are similar for all vendor solutions. However, environmental expenses are lower for Brocade's solution as a result of power savings (see Figure 11) in Brocade's network.

Table 7. Description of OpEx components of the TCO model

Operations Expense	Definition
Engineering, Facilities, and Installation (EF&I)	This is the cost of engineering, facilities, and installation of network equipment.
Network Upgrades & Patches	This includes both hardware and software upgrades to the network.
Network Care	This includes network provisioning, surveillance, monitoring, data collection, maintenance, and fault isolation.
Testing and Certification Operations	Testing and certification is needed for all new hardware and software releases that go into the production network.
Training	Training expenses are required initially and also on an on-going basis.
Service Contracts	These are vendor service contracts required for on-going support of network equipment.
Floor Space Cost	These costs are associated with the floor space cost/square meter in the CO.
Power Cost	This is the electric utility bill to power equipment.
Cooling Cost	This is the cost of cooling the equipment.

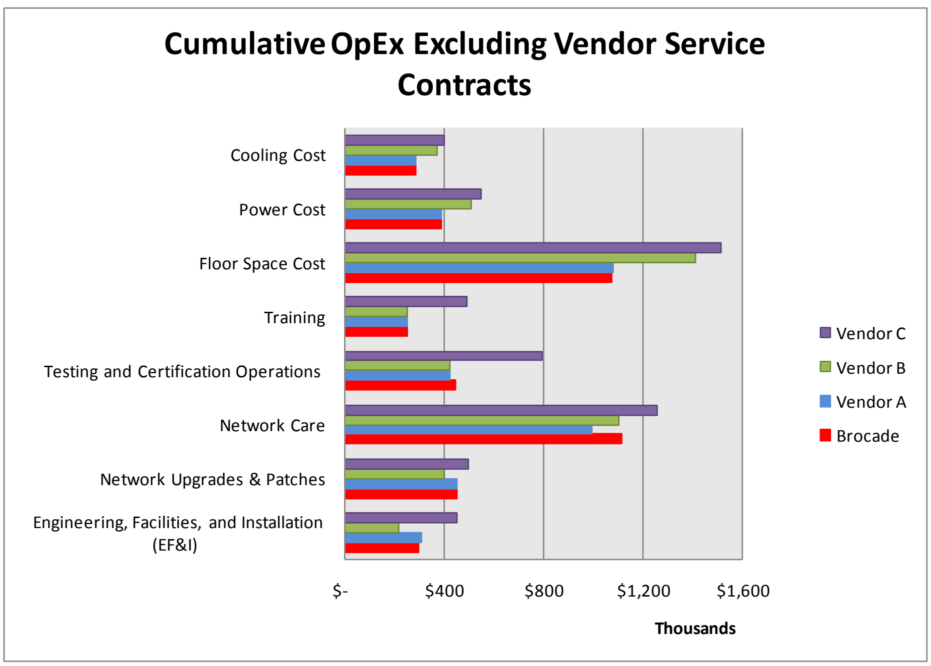

Figure 10. Breakdown of OpEx expenses excluding vendor service contracts

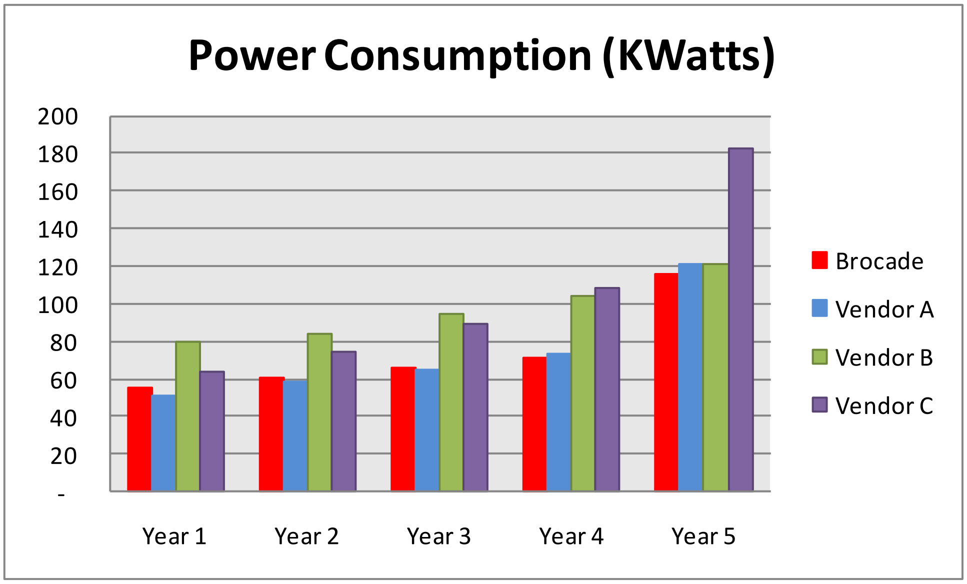

Figure 11. A comparison of the total network power consumption for each alternative

Brocade's multiyear TCO advantage leads to a substantially lower cost of Ethernet transport. Figure 12 presents the monthly unit cost of Ethernet transport ($/Gbps per month) for each alternative. This estimate is made by dividing the TCO (CapEx + OpEx) for each year by the total traffic demand in the metro network in the same year (Total traffic demand is the sum of the demand from all subscribers.) This annual value then is divided by 12 to get the monthly amount. As network traffic increases due to various multimedia and video applications, it is essential that the on-going cost of Ethernet transport is minimized. Brocade's solution allows service providers to effectively scale their networks while minimizing the cost of transport, thus maintaining service profitability.

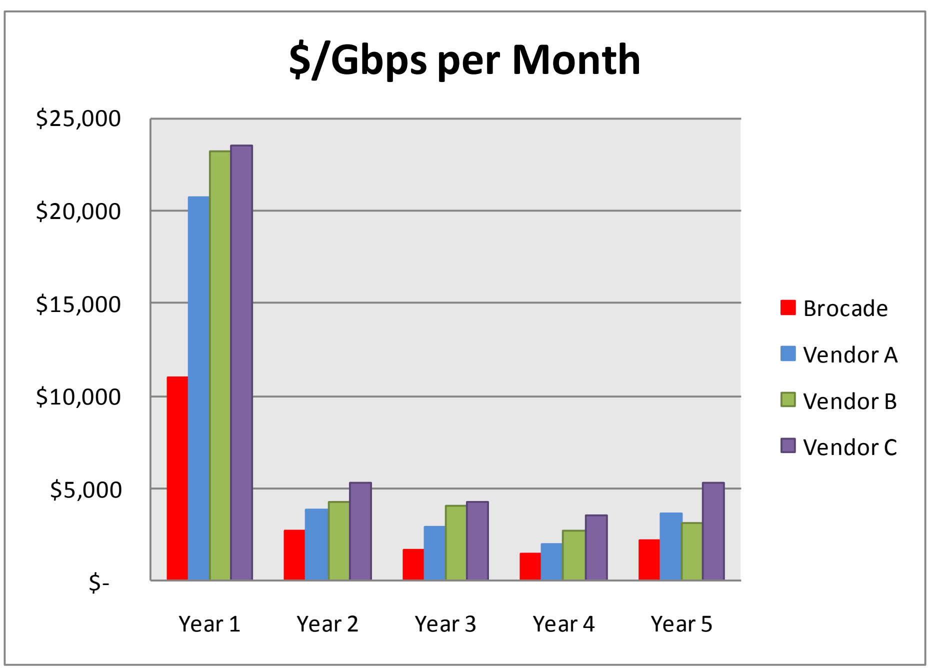

Figure 12. Ethernet transport costs in $/Gbps per month for each alternative network solution

Conclusion

This paper uses a comprehensive TCO model to analyze a hypothetical Metro Ethernet network, comparing four alternative solutions: Brocade, Vendor A, Vendor B, and Vendor C. Brocade has significant CapEx and OpEx advantages over the other three vendors, leading to much lower costs for Ethernet transport and routing. The primary reasons for this advantage are Brocade's:

- Lowest price per port (1 GbE and 10 GbE)
- Highest port density
- Lowest power consumption
- Lowest cost of sparing

Service providers need to reduce the on-going expenses of Ethernet transport and IP routing in order to maintain service level profitability in the face of exponential traffic growth. Brocade's solution helps service providers achieve this important objective.

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ACG Research

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