A TCO COMPARISON OF PRIVATE WANS VS MANAGED NETWORK SERVICES FOR ENTERPRISES

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EXECUTIVE SUMMARY

Private enterprise networks typically use MPLS, SD-WAN or Carrier Ethernet services. Managed network services are ubiquitous and easy to deploy; however, in some cases it makes sense for an enterprise to consider building a private network with dark fiber. Specifically, enterprises with one or more of the following requirements should consider a Private WAN employing dark fiber:

- Link speeds greater than 70 Gbps
- Ultra-low latency requirements
- Requirements for high-availability network topologies

Private WANs leveraging dark fiber allow enterprises to build highly-scalable, low-latency, and high-availability networks. Although the cost of managed network services is typically based on the port speed and guaranteed bandwidth of the connections, the cost of dark fiber is based on the location of the fiber and the distance between end points. This means that the cost of managed network services continues to rise as bandwidth increases while the cost of a private WAN with dark fiber is relatively flat as bandwidth increases. Therefore, these private networks can scale to exceedingly high bandwidth without dramatic increases in expenses. Additionally, dark fiber can provide extremely low latency because there is no carrier equipment between enterprise end points, and enterprises can choose fiber routes to minimize latency. Enterprises can also design fiber networks in ring or mesh topologies to create high-availability networks. The financial analysis in this paper uses North American pricing data; however, the results can be applied globally. If network demand and requirements justify the use of dark fiber then an enterprise needs to access the availability and pricing of fiber in its own regions and cities.

The types of enterprises that might be candidates for private WANs with dark fiber are:

- Financial services and program trading firms
- Hyperscalers and large web services companies
- Government organizations

This paper provides an overview of Private WANs and presents the results of a total cost of ownership model comparing a Private WAN with dark fiber to a managed network service (Carrier Ethernet). We use Carrier Ethernet as a comparison because it is the most cost- effective network service for sites that need very high bandwidth (10Gbps or greater).

ENTERPRISE NETWORK BACKGROUND

Enterprises have been building private networks for many years. Private networks started with leased T1 lines and Frame Relay virtual circuits in the 1990s and have moved to MPLS, SD-WAN, and Carrier Ethernet services. The requirements for enterprise networks are driven by the type and size of the organization and specific application and use-case requirements. Requirements for enterprise networks fall into three categories:

- Security
- Guaranteed bandwidth, jitter, and latency
- Network availability

The relative levels of bandwidth and security for various network services are depicted in Figure 1. Broadband internet for residential and small business service is the least expensive and least secure service, operating at low to medium bandwidth levels (1 Gbps or less). Direct internet access is a high-speed commercial internet offer providing higher levels of bandwidth (up to 10Gbps) with best-effort traffic delivery and low levels of security. Traditional MPLS and SD-WAN services offer low to medium bandwidth with high levels of security. Carrier Ethernet service can scale to higher bandwidths with medium levels of security. For enterprises with extremely high bandwidth and/or security requirements, Private WANs with dark fiber are another option. Dark fiber allows enterprises to build a private network on top of existing fiber that they lease from one or more service providers.

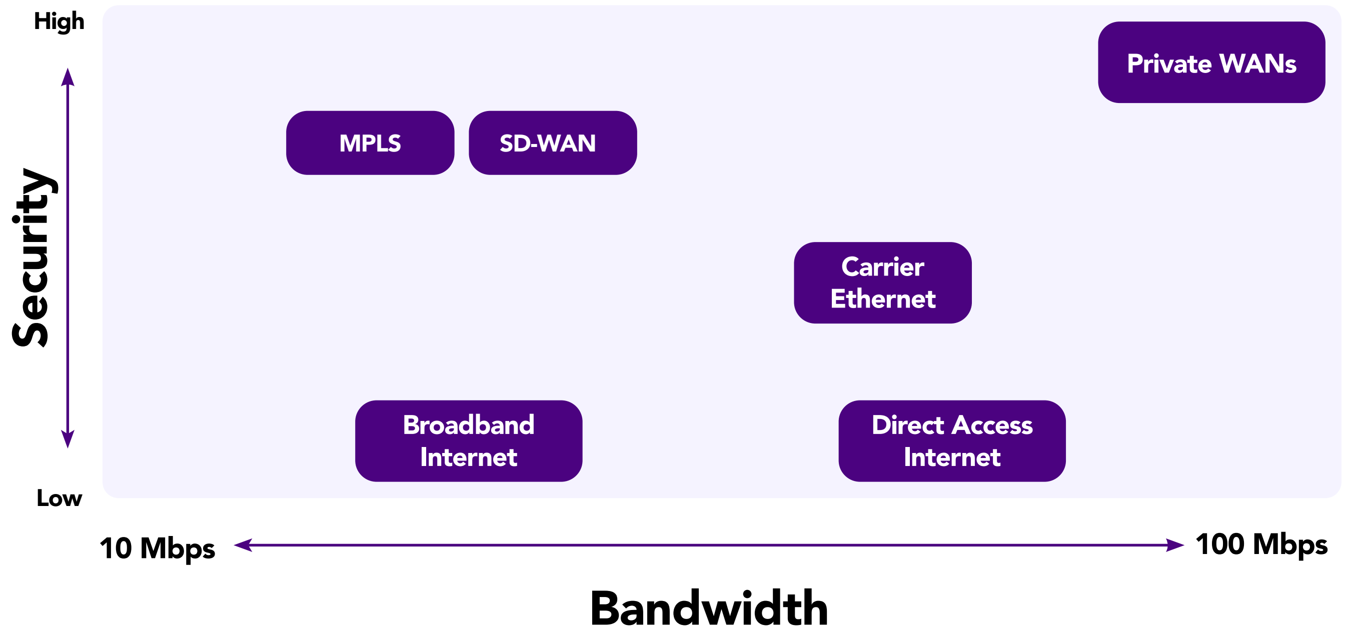

Figure 1: Network Services on the Spectrum of Bandwidth and Security

Building a Private WAN with dark fiber is an expensive undertaking and is only applicable to enterprises with one or more the following network requirements:

- Very high bandwidth
- Ultra-low latency
- High availability

Some examples of organizations that build Private WANs with dark fiber are presented in Table 1.

Organization	Network Requirements
Program Trading Firms	Program trading requires ultra-low latency for program algorithms to work effectively. These firms have built private fiber networks to minimize latency. Financial networks require precision record keeping and need to have an accurate Time-Of-Day timestamp.
Financial Services Firms	Financial services firms can have very large bandwidth requirements and high security requirements especially when connecting to partners, such as Moody's. Some firms have used Private WANs with dark fiber to address these requirements while lowering network expenses for extremely high bandwidth connections.
Hyperscalers	Hyperscalers have enormous bandwidth requirements and have been building private networks on dark fiber for many years to allow for exponential bandwidth growth.
Department of Defense	High security, low latency, and high bandwidth are requirements for some organizations in DoD.
Intelligence Agencies	High security, low latency, and high bandwidth are requirements for some organizations in intelligence agencies.

Table 1. Examples of Organizations with Requirements for Dark Fiber

Decisions regarding network services are highly dependent on the type of organization, use cases, and application requirements. In the following sections we provide an overview of dark fiber-based Private WANs, explain the sweet spots for their consideration, and present an economic comparison of Private WANs to managed Carrier Ethernet services.

Private WAN with Dark Fiber

Enterprises that need exceedingly high bandwidth, low latency, and security should consider building a private network with dark fiber. Dark fiber is extra fiber in a conduit that is unlit and unused and available for lease. The reason there is a plethora of dark fiber is that a large part of the cost of building fiber networks is construction. The cost of fiber pairs in cables is much lower than the cost of digging trenches and conduits and pulling fiber cables. Fiber cables can have up to 864 fiber strands in a single cable. Each fiber pair (two strands) can carry up to 96 wavelengths with each wavelength able to provide up to 400 Gbps transport capacity. The bandwidth in a single fiber pair is 38.4 Tbps, which is virtually unlimited. In many developed and developing nations network operators normally have a great excess of fiber strands that are unused, and they are usually willing to lease fiber pairs to enterprises or other operators that require private fiber networks.

Examples of network operators that lease dark fiber are:

- Large national and global service providers that have extensive fiber networks, for example, AT&T Telefonica, Eurofiber, and euNetworks
- Wholesale service providers
- Electric, gas, and water utility companies that have built fiber networks on their right of way
- Municipal and state government organizations that have built fiber in certain regions
- Local service providers that own fiber networks in local regions
- Railroads than have laid fiber next to their tracks over the railroad right of way

The key benefits of dark fiber are presented in Table 2.

Dark Fiber Benefit	Description
Scalability	A single fiber pair can scale to extremely high data rates. Routers can connect to a fiber pair at 100 Gbps or 400 Gbps. If additional bandwidth is needed, DWDM, which offers virtually unlimited scalability, can be used. C-Band DWDM supports up to 96 wavelengths on a fiber pair with each wavelength able to carry up to 400 Gbps. That amounts to 38.4 Tbps per fiber pair. The lease cost of a fiber pair is the same price regardless of the bandwidth required for network transport.
Predictable Cost Structures for Increasing Network Bandwidth	The primary cost for leasing a dark fiber pair is dependent on the location of the fiber and the distance between the end points that need to be connected. The lease cost of a fiber pair is the same price regardless of the bandwidth required for network transport. There is some additional cost for network equipment as bandwidth is increased, but this is fairly small in comparison with the cost of the fiber lease and also the cost of comparable Carrier Ethernet or MPLS services.
Low Latency	Any connection across a managed network service, such as MPLS, Internet or Carrier Ethernet, traverses multiple hops with active network equipment such as routers, switches, and DWDM ROADMs. In contrast a dark fiber connection has no active network equipment; therefore, latency is reduced. Enterprises building Private WANs with dark fiber can choose fiber routers to minimize network distance and latency.
Security	Dark fiber-based networks inherently have high security because there are no service provider's routers or switches in between enterprise's end points. The enterprise controls its routers, and fiber cannot be monitored unless it is cut, which would alert the enterprise network operator.
Redundancy and Reliability	Enterprises can increase network redundancy and reliability with dark fiber because they can use fiber in different conduits with diverse routes. They can also design ring and mesh networks, which are inherently fault tolerant to fiber cuts. Enterprises also do not need to worry about a service provider's equipment failing and disrupting service because there is no service provider's equipment in the network. Enterprises need to manage their own equipment, but they have greater visibility and control.

Table 2. Benefits of Private WAN with Dark Fiber

TCO Comparison of Private WAN with Dark Fiber and Carrier Ethernet

In this section of the paper we compare the total cost of ownership (TCO) of a Carrier Ethernet service with a private WAN dark fiber network. At higher levels of bandwidth Carrier Ethernet service is more cost effective than MPLS or SD-WAN; therefore, we use Carrier Ethernet as the comparison with dark fiber. The price of both Carrier Ethernet and private WAN dark fiber can vary greatly depending on local regions and service providers. We use an average cost for these services in North America. The enterprise uses high-speed routers to connect to both the Carrier Ethernet and private WAN dark fiber services. Although the routers are the same, the configurations and cost of the router varies for each network architecture.

Carrier Ethernet service pricing is based on port speeds and committed information rates (CIR). Because we are comparing costs for high-bandwidth connections we assume Carrier Ethernet uses 10 GE ports with 10 Gbps CIR. This is typically the maximum port speed and CIR for most Carrier Ethernet services. We also assume a discount on Carrier Ethernet service as the number of 10 GE ports increases. This is a volume discount. Dark fiber pricing varies between metro networks and long-haul networks. The price of dark fiber pairs is typically per mile. Using North American industry averages the assumptions for service pricing are presented in Table 3.

Transport Technology	Price
Monthly Carrier Ethernet: 10Gbps CIR and 10GE Port (3 year term)	$1,300
Carrier Ethernet Discount per Port for Extra 10GE Ports	2%
Monthly Price per Dark Fiber Pair per Mile: Long-Haul	$9
Monthly Price per Dark Fiber Pair per Mile: Metro	$29

Table 3. Service Pricing Assumptions

It should be noted that the price of both Carrier Ethernet and dark fiber varies between regions and cities in North America and worldwide. Although the financial analysis in this paper uses pricing data from North America the results can be applied globally (dark fiber is available in abundance in Europe, Japan, and Korea). If network demand and requirements justify the use of dark fiber then an enterprise needs to access the availability and pricing of fiber in its own regions and cities.

Another important component of the TCO analysis is network topology and link-data rates. To simplify and normalize the analysis we consider a simple three-node network, and we assume that the traffic between all nodes is identical. The topologies for Carrier Ethernet and dark fiber are depicted in Figure 2 and Figure 3, respectively. In the Carrier Ethernet network we assume that each router is connected to a Carrier Ethernet service using one or more 10 GE ports. All three nodes are connected with Ethernet Virtual Circuits using a CIR of 10 Gbps. The dark fiber network using a physical fiber ring connects routers in each of the three nodes.

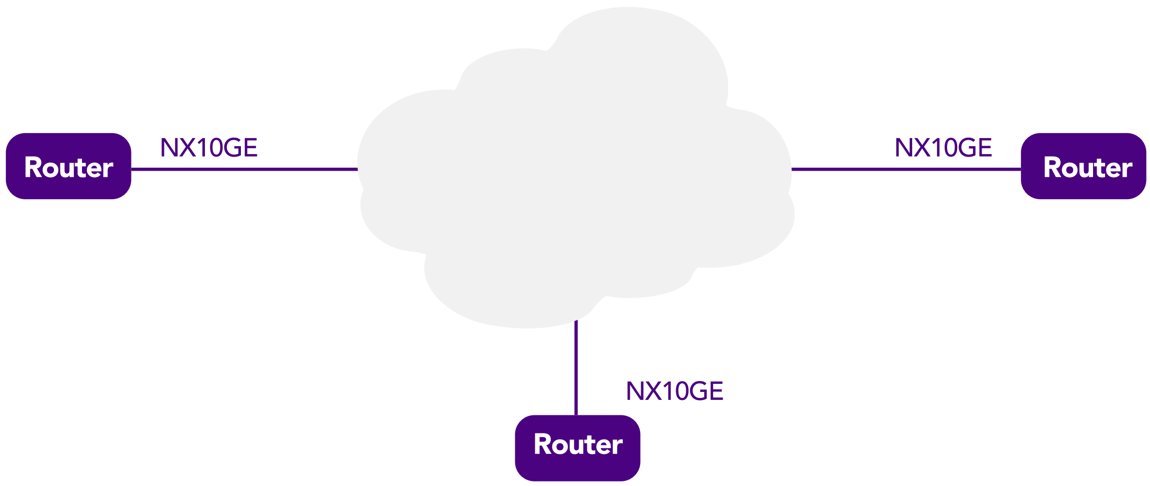

Figure 2. Carrier Ethernet Network Topology

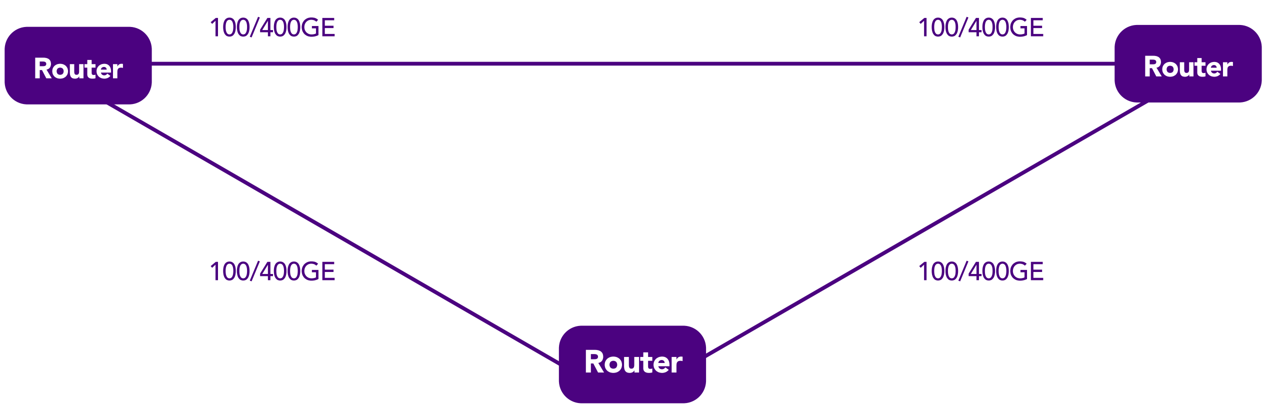

Figure 3. Dark-Fiber Network Topology

We also consider the router expenses in our TCO model. The Juniper MX 240 routers are used in the analysis. For the Carrier Ethernet network we use multiple 10 GE ports on an MX 240. For the dark fiber network we use either 100 GE or 400 GE ports, depending on the data rate required on the link. We also consider MPLS software license expenses.

Another component of the TCO analysis is labor operation expenses (OpEx) We assume that the labor expenses are higher for managing a dark fiber network than managing a Carrier Ethernet network. For the small three-node network in this example our labor expense assumptions are presented in Table 4.

	Price
Annual Fully Loaded FTE Expense	$150,000
FTEs Required for Carrier Ethernet Service	0.25
FTEs Required for Dark Fiber Service	1

Table 4. Labor Operation Expense Assumptions

Clearly, most enterprise networks are more complex than the simple network used in our TCO model; however, the results will apply to larger, more complex networks because the benefits of dark fiber are on a particular link that has high bandwidth and/or low latency requirements. Many networks might be hybrid architectures where some links might use dark fiber, and other connections will use more traditional managed network services such as Carrier Ethernet or MPLS.

TCO RESULTS

The TCO includes the following components:

- Cost of transport (Carrier Ethernet or dark fiber)
- Cost of routers
- Cost of labor (OpEx)

We compare two scenarios over three years:

- Metro network with link distances of 75 miles
- Long-haul network with link distances of 500 miles

The cumulative three-year TCO of the metro network is presented in Figure 4. The analysis shows the TCO of both the dark fiber and Carrier Ethernet scenario for varying levels of link bandwidth. The range of the link bandwidth is 5 Gbps to 400 Gbps. In our model we assume that this is the bandwidth required between all three routers. The TCO model shows that the crossover point is at 70 Gbps for each link in the network. This means that in a metro network links with bandwidth above 70 Gbps are more cost-effective running on dark fiber networks. A breakdown of transport expenses and routing expenses is depicted in Figure 5 and Figure 6, respectively. The crossover point of Carrier Ethernet versus dark fiber transport expenses (not including routers or labor expenses) is at 20 Gbps. Router expenses are always higher for the Carrier Ethernet network above 5 Gbps, but the difference is small until the bandwidth increases beyond 75 Gbps. We also include the difference in labor expenses in the TCO, which is not depicted in a chart but drives the TCO crossover point to a higher bandwidth than the transport expense crossover.

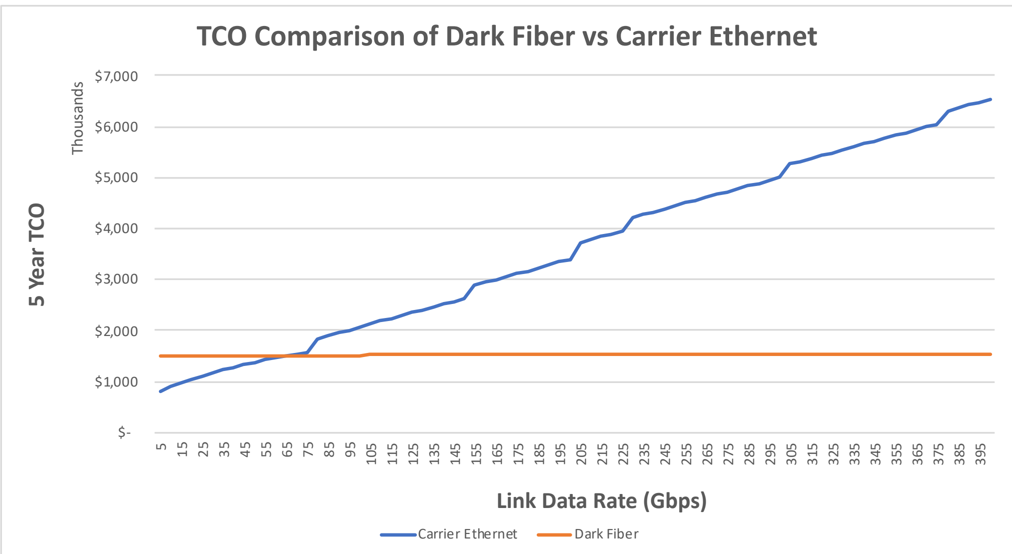

Figure 4. Metro Network Three-Year TCO Comparison of Dark Fiber vs Carrier Ethernet

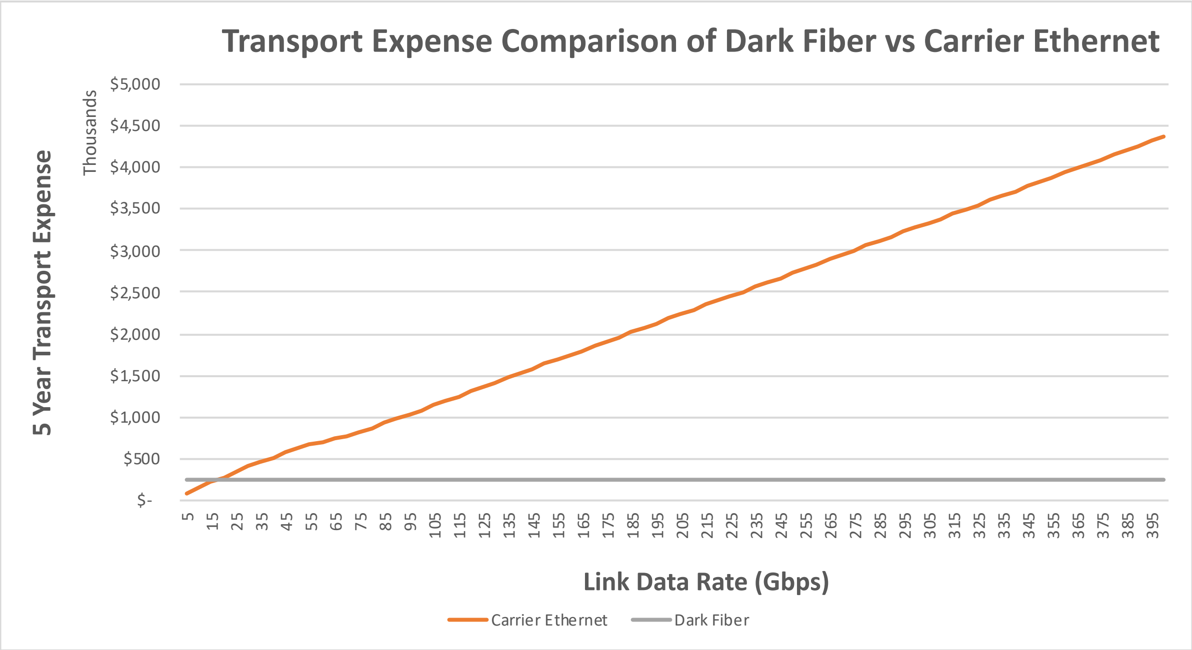

Figure 5. Metro Network Three-Year Transport Expense Comparison of Dark Fiber vs Carrier Ethernet

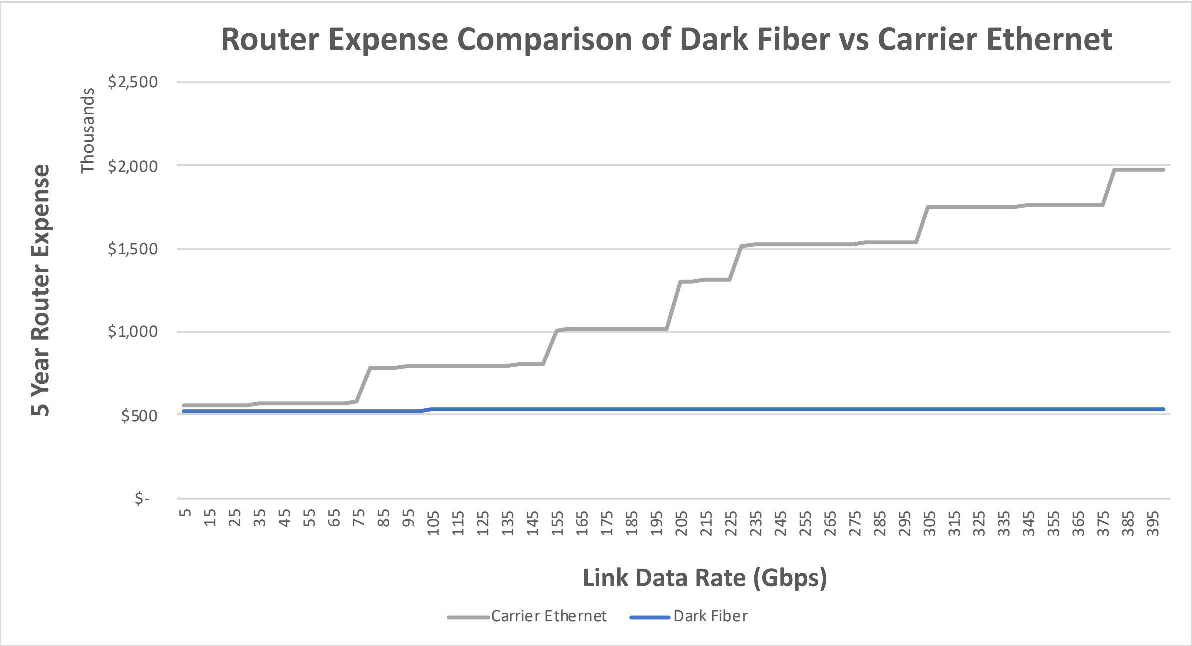

Figure 6. Metro Network Three-Year Router Expense Comparison of Dark Fiber vs Carrier Ethernet

The cumulative three-year TCO of the long-haul network is depicted in Figure 7. The results are not vastly different from the metro network. The crossover point where dark fiber becomes more cost-effective than Carrier Ethernet is 75 Gbps. The three-year TCO of transport and router expenses is depicted in Figure 8 and Figure 9, respectively.

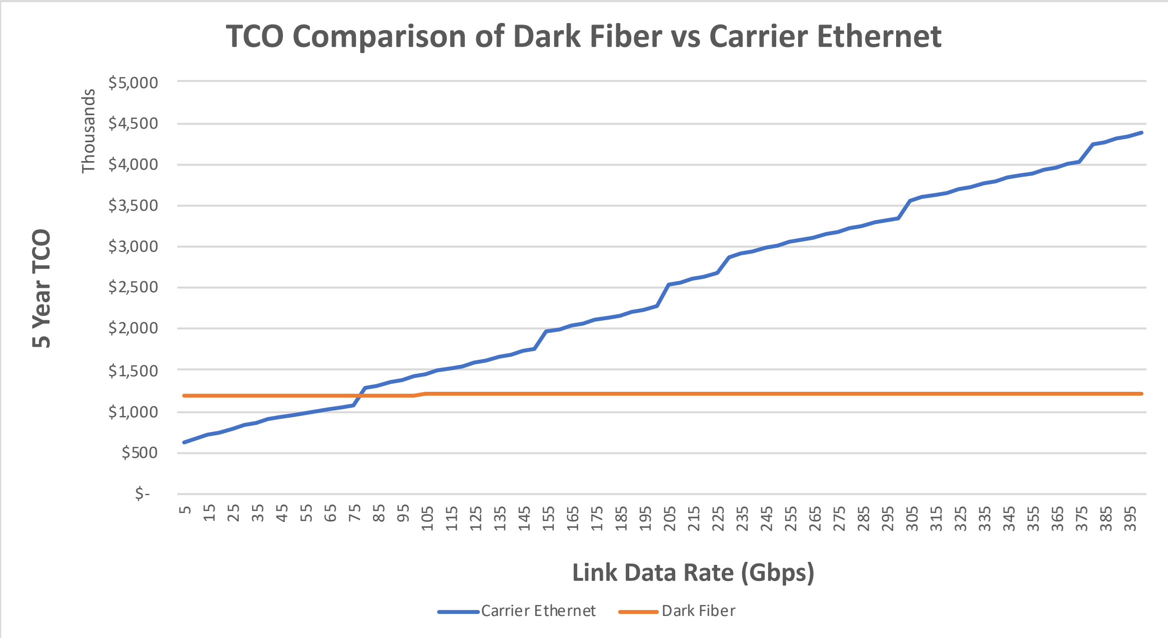

Figure 7. Long-Haul Network Three-Year TCO Comparison of Dark Fiber vs Carrier Ethernet

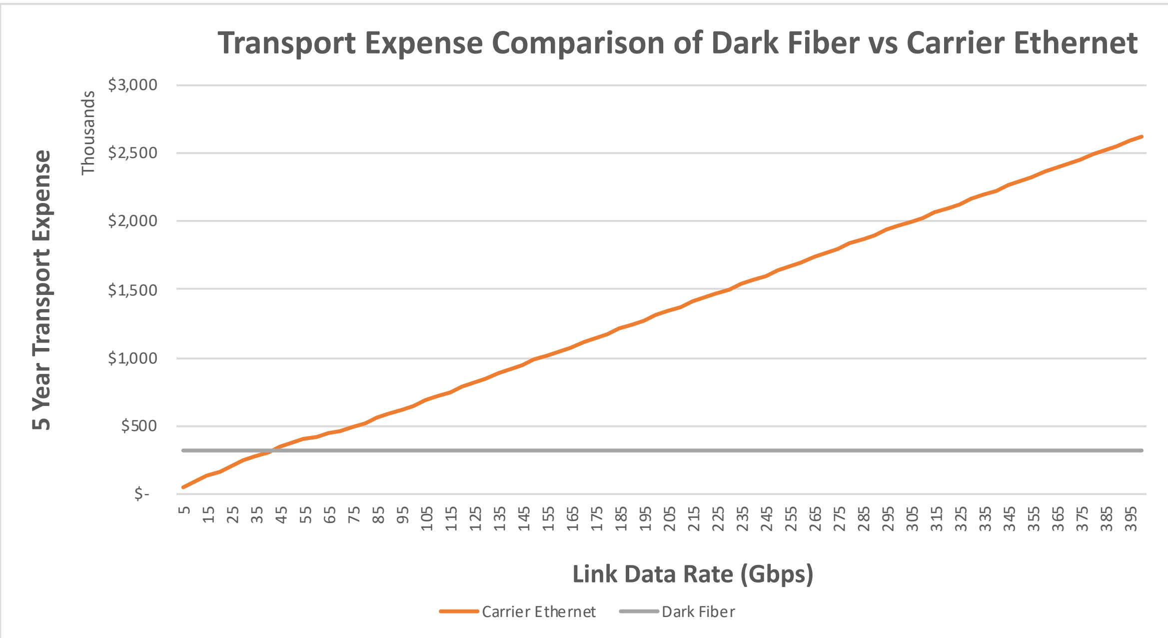

Figure 8. Long-Haul Network Three-Year Transport Expense Comparison of Dark Fiber vs Carrier Ethernet

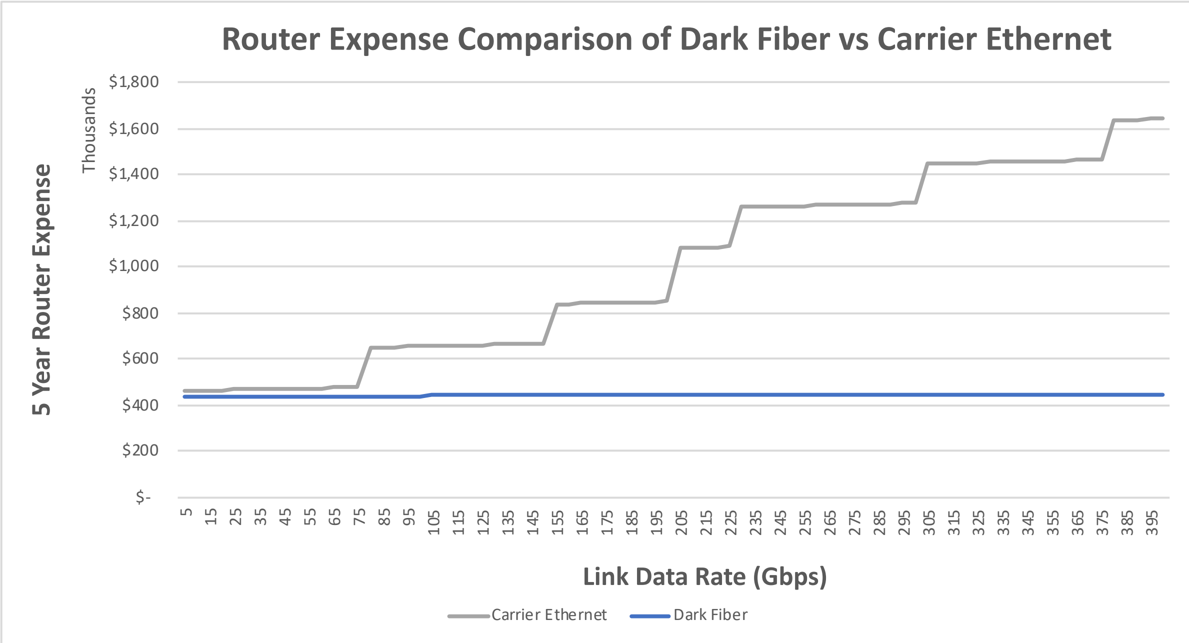

Figure 9. Long-Haul Network Three-Year Router Expense Comparison of Dark Fiber vs Carrier Ethernet

Conclusion and Summary

Although most enterprise networks are suited to standard network services such as MPLS, SD-WAN, and Carrier Ethernet, there is a class of enterprise networks that have specific requirements that could justify building a private network on top of dark fiber. The key drivers for a private dark fiber network are one or more of the following:

- Link speeds greater than 70 Gbps
- Ultra-low latency requirements
- Requirements for high-availability network topologies