MIGRATION TO 100G CAMPUS CONNECTIVITY
THE ECONOMICS AND APPLICABILITY OF INPHI'S COLORZ-LITE® TECHNOLOGY

SUMMARY

Campus environments have utilized 10 Gb/s pluggable optical technology to interconnect buildings and data centers for more than 10 years. The technology is mature, cost effective and flexible with wavelength division multiplexing enabling multiple 10 Gb/s wavelengths to share a common pair of fibers.

With enterprise bandwidth growing, workloads becoming increasingly virtualized and distributed and inter-eXchange providers (IXP), such as Equinix, EdgeConneX and DigitalRealty, hosting compute and storage pods in distributed facilities across town, the need for high-speed campus connectivity has outgrown 10 Gb/s optical links. Enterprises and IXPs are increasingly looking to deploy 100 Gb/s optical links to deliver a step-function in performance and flexibility. However, a question remains as to what 100 Gb/s technology is appropriate and least cost for such deployments.

ACG Research conducted a total cost of ownership economic analysis of three 100 Gb/s optical technology alternatives: 100 Gb/s grey optics, Inphi's ColorZ-Lite technology and 100 Gb/s coherent DWDM. Not unexpectedly, coherent is generally the most expensive alternative to operate at 10–20 km campus distances. Grey light is the least-cost alternative if the enterprise has easy access to fiber and/or the bandwidth demands are low. ColorZ-Lite is the least-cost alternative if connectivity demands are large (Nx100 Gb/s) or fiber is scarce. Our analysis demonstrates that ColorZ-Lite delivers up to 68.5% TCO savings and 89% lower operation expenses over five years. Enterprises migrating campus connections to 100 Gb/s should consider ColorZ-Lite.

REPORT HIGHLIGHTS

- ColorZ-Lite provides a new option for Nx100 G campus connectivity
- ColorZ-Lite delivers **43.9% to 68.5% TCO savings** vs. a 100G grey optic alternative
- ColorZ-Lite delivers up to **89% lower opex** than a 100 G grey optic alternative
- Inphi is working with partners to deliver a 1RU, plug-n-play multiplexer/ amplifier/dispersion compensator for enterprise applications
- Beyond 10 km distance, deploying ColorZ-Lite has the least cost due to the higher cost of eLR4 or ER4 optics today

INTRODUCTION

The 10 Gb/s Ethernet standard has been available since 2002[1]. Since that time, vendors have been developing pluggable 10 Gb/s modules with increased performance, lower power and smaller size. Today, one can purchase 10 Gb/s XFP or SFP+ pluggable optical modules with grey light compatibility (10G-BASE-LR or 10G-BASE-ER) for hundreds of dollars or CWDM/DWDM compatible ones for well under $1,000 each. For more than a decade, enterprises have used 10 Gb/s technology to connect two devices across the room or across town. With bandwidth continuing to grow and 100 Gb/s optical technology maturing, many are making the leap to 100 Gb/s connectivity.

In 2016, Inphi announced its ColorZ technology, which delivers 100 Gb/s, 100 GHz, fixed-dense wavelength division multiplexing (DWDM) in a 4.5 watt, QSFP28 pluggable package. In 2017, the technology is actively being deployed to interconnect sub 80 km metro-distributed data centers using coherent DWDM technology for longer distances.

Inphi is now introducing ColorZ-Lite, a derivative of the ColorZ technology optimized for 10–20 km campus connectivity. To deliver a comprehensive enterprise-deployable solution, Inphi is also working with a technology partner to introduce a plug-n-play 1RU mux/amplifier/dispersion-compensation network element for deployment by enterprise customers in campus connectivity applications.

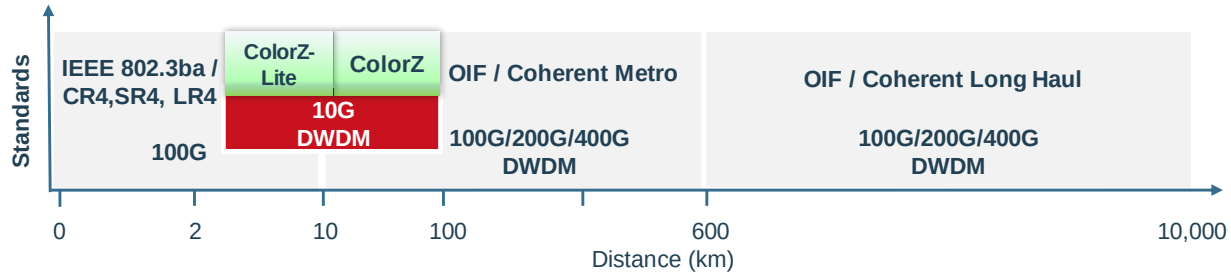

Figure 1. Interconnect Technology by Distance

This report analyzes the economics of deploying ColorZ-Lite in the 10–20 km campus connectivity environment where an enterprise may be considering grey light alternatives such as 100G-BASE-LR4 with 10 km reach or 100G-BASE-eLR4 with up to 20–25 km reach. For completeness, we also consider 100 G coherent DWDM solutions, but these solutions are generally overkill for such a relatively short transmission distance.

ADVENT OF HYBRID NETWORKS AND WORKLOAD DISTRIBUTION

There are multiple forces impacting enterprise optical network connectivity. First is continuous bandwidth growth. According to Cisco, global IP traffic will continue to grow at 24% CAGR through 2021[2]. Global cloud IP traffic will grow even faster at 30% CAGR through 2020. Enterprise workloads are also shifting from traditional to cloud data centers and from private to public. By 2020, 92% of

[1] 2017 The Ethernet Alliance.

[2] 2017 Cisco Visual Networking Index.

workloads will be processed in cloud data centers, and 68% of cloud workloads will be in public cloud data centers with 32% remaining in private cloud data centers[3]. The increased availability and presence of inter-eXchange providers (IXP) or carrier neutral providers (CNP) means that enterprises do not need to own their own facilities to create a seemingly local presence in a metro area or across town. Enterprises can install a pod into an existing IXP/CNP location and deliver a local presence with the same infrastructure and software as at the headquarters or branch office. With infrastructure as a service (IaaS), many enterprises are hosting their private applications on public compute and storage platforms such as AWS and Microsoft Azure. With the increased popularity of software as a service applications (SaaS), such as Microsoft 365 and Salesforce.com, enterprises are replacing proprietary, on-site applications and workloads with third-party solutions hosted in public cloud data centers. Enterprises are thus not only delivering optical connections among their own private buildings and data centers but also among external locations where workloads and applications are being processed. This hybrid environment with shifting workloads and connections is effectively creating a virtual enterprise campus with fast, reliable and cost-effective optical connectivity playing a critical role for IT departments and the enterprise customers they serve.

Network Architecture

In our economic analysis, we focused on point-to-point optical connections. These interconnections are needed between physical buildings of the enterprise as well as to virtual or hybrid extensions of the enterprise, including IXPs/CNPs hosting the enterprise's pods or public data center companies hosting IaaS or SaaS applications the enterprise is using.

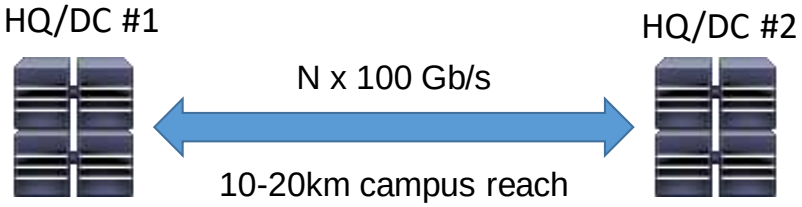

Figure 2. Campus Connectivity between Buildings

Economic Measures Included in the Analysis

We developed an economic modeling tool with 50+ input variables, including initial bandwidth, annual bandwidth growth rate, labor rates and installation costs. The duration of the model is five years and the outputs include capital expense (capex), operation expense (opex) and total cost of ownership (TCO) over that time. We analyzed three technical alternatives: 100 G grey optics, 100 G ColorZ-Lite and 100 G/200 G coherent DWDM. At present, there is a significant price difference (at minimum 2x) between 10 km 100 G grey pluggable modules (100G-BASE-LR4) and those that cover 20+ km distances (for example, 100G-BASE-eLR4 or 100G-BASE-ER4). The heavy price-delta results in the ColorZ-Lite product always being more cost effective for the 20 km reach. Our analysis focuses on 10 km reach scenarios where grey 100 G module pricing is more cost effective today.

[3] 2016 Cisco Global Cloud Index.

Cumulative Total Cost of Ownership

Total cost of ownership is the sum of capex and opex for a given solution. Both capex and opex have their own components and methods of calculation. Cumulative TCO sums TCO components over a period. In this analysis, we considered the TCO over five years.

Capital Expenditures

Capex is the cost of purchasing the elements for an optical connectivity solution. In addition to typical equipment costs, we have also included the cost for an enterprise to provide its own fiber when existing fiber capacity is exhausted. If leased fiber is available at reasonable rates, then an enterprise would avoid the capital cost of supplying its own fiber. Fiber construction costs can vary wildly, for example, including as much as $100,000 per mile on the high end where trenching is required. However, there are also situations where existing conduits are available and fiber can be pulled through the existing path. In such situations, construction costs may be only a few thousand dollars per mile. Our modeling tool supports three options: leased fiber (a portion of annual opex), trenched construction fiber and conduit pulled construction fiber (capex). Although construction costs are input variables in the model, we used $2,000 per mile for conduit pulled fiber construction costs and $20,000 for trenched fiber construction costs. Our goal is to be realistic but also utilize relatively conservative construction costs as to not unduly burden the economic model.

Operational Expenditures

Opex includes the costs of deploying and running the solution. In this analysis, we focused on engineer, furnish and install (EF&I) labor costs and electrical power utilization over the analysis period. Every component of a deployed solution is assigned rack space costs (zero for pluggable optics), EF&I labor costs and power utilization costs. We purposefully left out any recurring software maintenance or support fees for the solutions as these can differ considerably among service providers and vendors. We also included a monthly fiber lease rate as a variable to calculate the recurring cost of leased fiber.

CAMPUS CONNECTIVITY RESULTS

The following section discusses the results of our analysis. We examine scenarios where leased fiber is readily available as well as ones where construction is required by the enterprise.

Scenario #1: Leased Fiber, 400 G Initial Bandwidth

In this scenario, we assume that the enterprise is leasing fiber and that the initial bandwidth is 400 Gb/s. The significant input variables impacting the analysis are outlined in Table 1.

Scenario #1 Key Input Variables	Value
Bandwidth per Interconnect (Gb/s)	400
Bandwidth Growth Rate (per Annum)	30%
Connection Distance (km)	10
Leased Dark Fiber for Interconnect	Yes
Monthly Lease Rate (per Fiber Pair)	$300

Table 1. Scenario #1 Input Variables

Cumulative TCO and Capex

It becomes readily apparent in the analysis that annual bandwidth growth combined with a recurring monthly lease disadvantages the 100 G grey optic solution over time. In this scenario both coherent DWDM and ColorZ-Lite only require a single fiber pair throughout the five-year analysis compared to 12 fiber pairs in Year 5 for the 100 G grey optics solution. Although the ColorZ-Lite solution has 42% higher capex due to the deployment of the integrated 1 RU, mux/amplifier/dispersion-compensation network element and the higher priced ColorZ-Lite module, the efficiency improvement from utilizing a single fiber pair usurps the capex differential to deliver 43.9% TCO savings over five years versus grey optics.

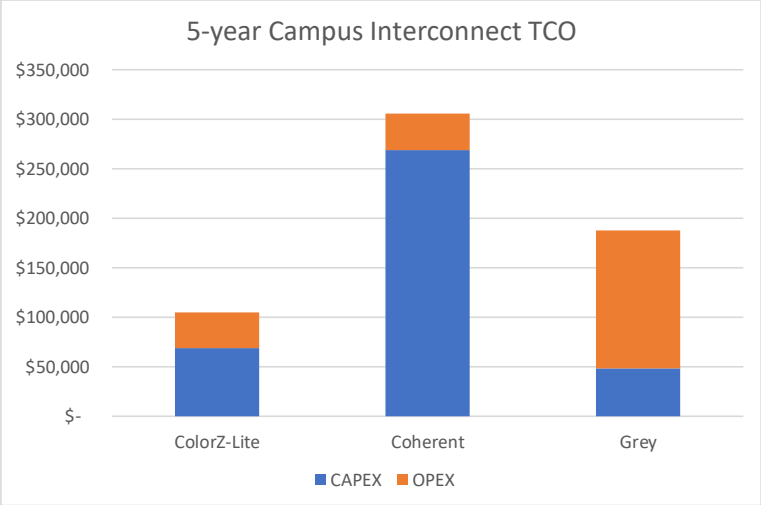

Figure 3. Cumulative TCO for Scenario #1

Opex Comparison and Analysis

Figure 4 depicts the complete opex comparison for the three technologies. The total opex cost for ColorZ-Lite and coherent DWDM is almost identical given that both utilize a single fiber pair for transmission. However, the leased fiber cost overwhelms the opex analysis with 100 G grey optics, requiring 3.8x the opex of the competing alternatives.

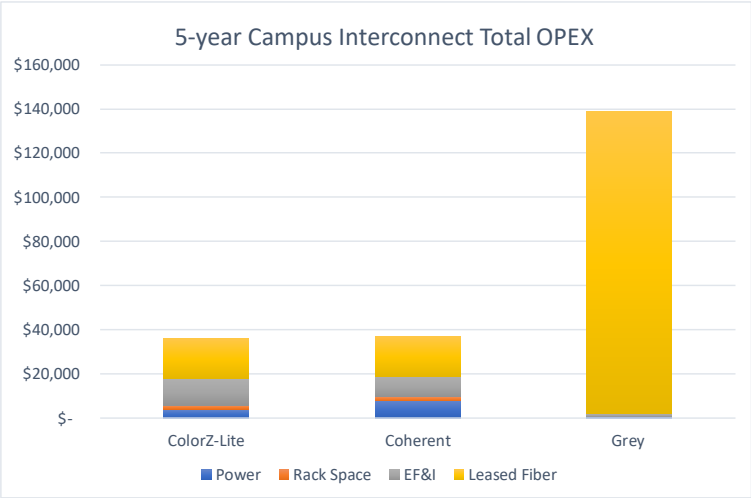

Figure 4. Cumulative Opex for Scenario #1

Scenario #2: Leased Fiber, 1 Terabit per Second Initial Bandwidth

In this scenario, the initial bandwidth is assumed to be 1 Tb/s between the two networking locations. All other parameters including 30% annual traffic growth rate and $300 per month per fiber pair lease rate remain the same as in scenario one.

Cumulative TCO and Capex

In this scenario, the total bandwidth remains below the 4 Tb/s total capacity of the ColorZ-Lite pluggable module family. Thus, ColorZ-Lite and coherent DWDM provide adequate transmission bandwidth throughout the five-year analysis over a single fiber pair. In contrast, the 100 G grey solution requires 29 fiber pairs. Capex for ColorZ-Lite is 28% higher than the grey optics solution, but ColorZ-Lite delivers 55.9% TCO savings when opex is considered.

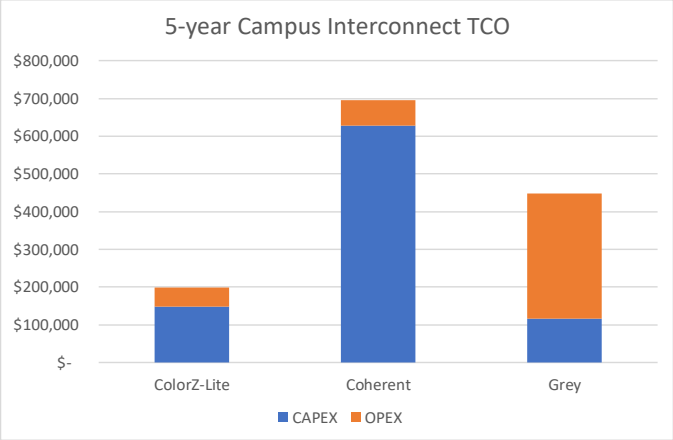

Figure 5. Cumulative TCO for Scenario #2

Opex Comparison and Analysis

Given that we are starting at 1 Tb/s initial bandwidth and retain 30% annual traffic growth, opex is exacerbated in this scenario versus the first scenario, which started at 400 Gb/s. Five-year total opex for the 100 G grey optical solution is more than 6.5x that of the ColorZ-Lite solution. Once again, the monthly fiber lease rate dominates the analysis.

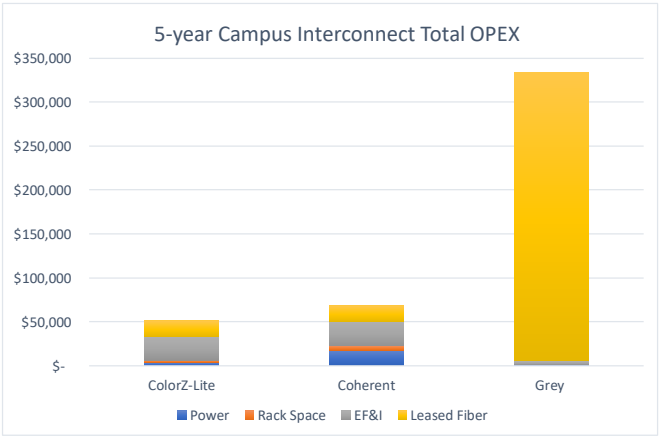

Figure 6. Cumulative Opex for Scenario #2

Scenario #3: Leased Fiber, 1 Terabit per Second Initial Bandwidth, $500 Monthly Lease

As fiber leasing rates vary widely, including confirmed instances of enterprises paying more than $1,000 per month, we demonstrate a range of situations that enterprises may encounter. Scenario three keeps all input parameters from scenario two but the price of the monthly fiber pair lease rate is $500.

Cumulative TCO

The fiber inefficiency of the grey optics solution is magnified with a higher monthly lease rate. Although higher in capex, ColorZ-Lite delivers 68.5% TCO savings and 89% lower opex than grey optics alternative.

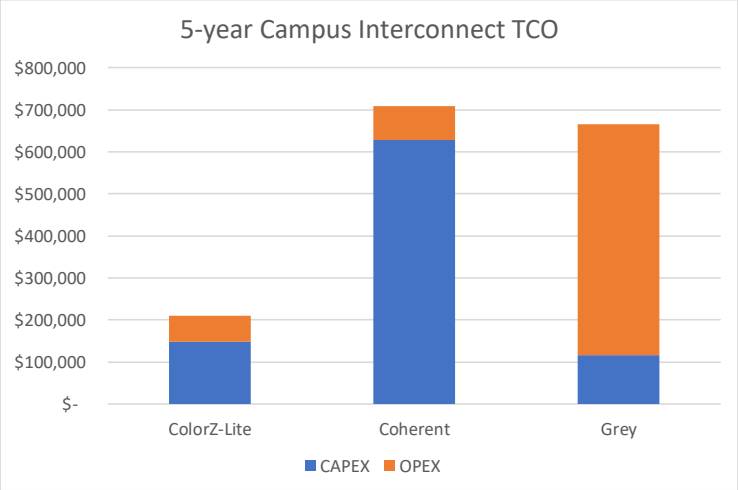

Figure 7. Campus Interconnect TCO

Leased Fiber Sensitivity Analysis

To determine an equivalent five-year TCO value for 100 G grey optics and ColorZ-Lite solutions, we created a curve with total initial bandwidth on one axis and the monthly fiber lease rate on the other axis. The solid line represents the TCO equivalence curve or break-even point. Above the curve, ColorZ-Lite produces a lower TCO for the enterprise, but below the curve, the 100 G grey optics solution produces the least cost.

As one example, if the initial interconnect bandwidth is only 100 Gb/s, a monthly lease rate below $365 results in TCO savings for the 100 G grey optics solution. If the leasing rate is above $365, then the ColorZ-Lite solution is more economical. As the bandwidth increases, more fibers are needed for the 100 G grey optic solution, and thus the lease rate per fiber pair must decline to retain an equivalent TCO value between the two solutions.

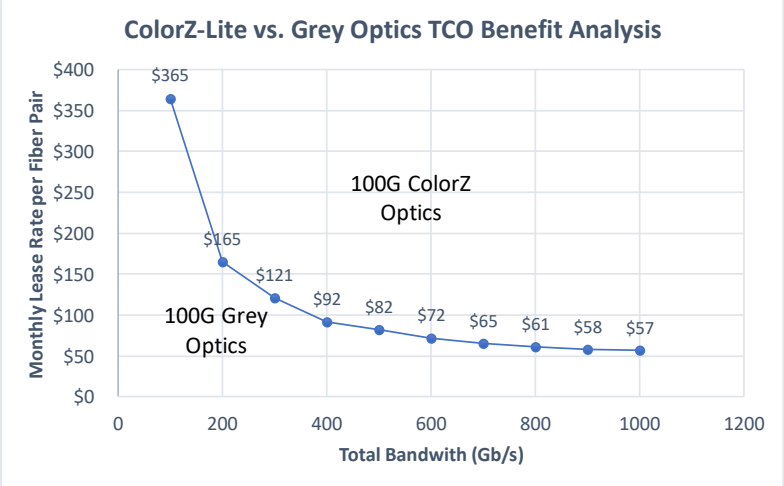

Figure 8. Leased Fiber TCO Equivalence Curve

Scenario #4: Fiber Build with Existing Conduit, 1 Tb/s Initial Bandwidth

There are cases where leased fiber may not be available. This case requires an enterprise to obtain its own fiber. Since construction costs vary wildly and the initial capital investment can be extensive with costs as high as $100,000 or more per trenched mile of fiber, we acknowledge that many enterprises will want to avoid this scenario. We also acknowledge an enterprise would generally not pursue this path unless the bandwidth demands are considerable (terabit and beyond). However, the analysis does provide some interesting perspectives especially if existing conduit can be used to keep construction costs to a minimum. Keep in mind that with ColorZ-Lite and with coherent DWDM there are 4 Tb/s and 18.2 Tb/s (assuming 200 Gb/s wavelengths) per fiber pair, respectively. If the total interconnect bandwidth remains below these respective capacities for the analysis period, a single fiber pair can service the solution (two pairs with a backup path for resiliency).

Scenario #4 Key Input Variables	Value
Bandwidth per Interconnect (Gb/s)	1,000
Bandwidth Growth Rate (per Annum)	30%
Connection Distance (km)	10
Leased Dark Fiber for Interconnect	No
Fiber Pull Cost per Mile Using Existing Conduit	$2,000
Cost per Foot of 144 Count Fiber Bundle	$1.88

Table 2. Scenario #4 Conduit Build Input Variables

Cumulative TCO and Capex

The high monthly fiber leasing costs for the 100 G grey optics solution is eliminated. However, the grey optics solution requires increased capital costs to pull the fiber through the existing conduit. The increased capital cost burdens the grey optics solution, but the TCO benefit for ColorZ-Lite solution shrinks to 7.6% versus 55.9% TCO savings in the leased fiber analysis in Scenario 2. The investment in fiber for the grey optic solution puts grey optics and ColorZ-Lite TCO within 10% of each other.

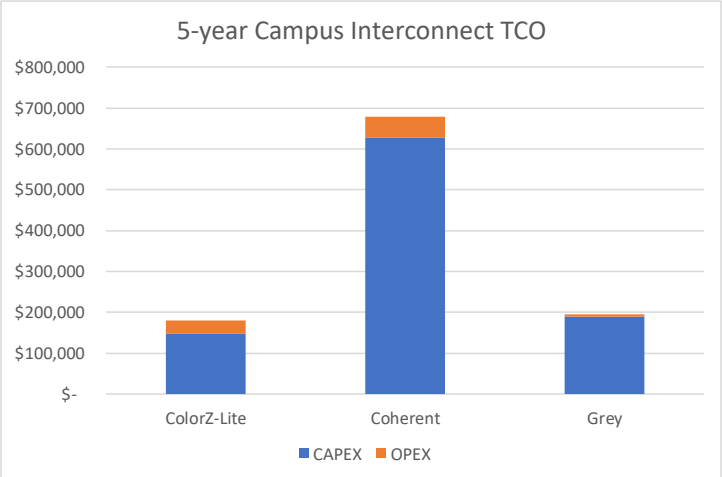

Figure 9. Cumulative TCO for Conduit Build with 1 Tb/s Initial Bandwidth

Opex Comparison and Analysis

By eliminating the monthly recurring fiber lease fees, the opex for the 100 G grey solution is drastically reduced under a build scenario. The modest operational costs that remain are tied to installation and power utilization.

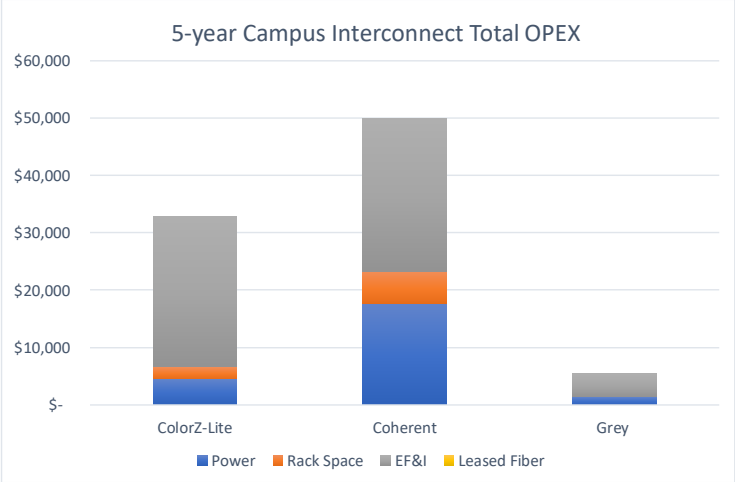

Figure 10. Cumulative Opex for Conduit Build with 1 Tb/s Initial Bandwidth

If the total bandwidth demand of the connection exceeds the capacity of the ColorZ-Lite solution (4 Tb/s) over the analysis timeframe, the ColorZ-Lite solution will also require fiber construction. Under this scenario, both the 100 G grey optics solution and the ColorZ-Lite solution will incur the same cost of pulling fiber through the conduit. After fiber construction, we will have the equivalent of a fiber-rich scenario with zero monthly fiber leasing costs. As seen in Figure 8, the grey optics solution will have the lowest TCO in this scenario (below the curve).

ADDITIONAL CONSIDERATIONS

We identify some additional considerations and items we did not include in the analysis to enable enterprise customers to make an informed optical connectivity decision. We did not include the cost of:

- Operationalizing or integrating ColorZ into the service provider OSS/BSS. There are ColorZ Simple Network Management Protocol Management Information Bases that need to be read/written. Although we believe this integration work to be modest, each operator will need to take this into consideration when making an informed data center interconnect decision.

- Annual software maintenance fees for the three alternatives. These can vary significantly among providers and vendors, and we did not want software maintenance to distort the analysis.

CONCLUSION

Enterprises are outgrowing 10 Gb/s optical solutions for 10–20 km campus connectivity. Enterprise bandwidth growth, the rise of hybrid networks and migrating application workloads are increasing the demand for 100 G campus connectivity solutions. Enterprises are looking for high performance and least cost. Where fiber leasing costs are extremely low or bandwidth demands are light, 100 Gb/s grey optics solutions deliver a least-cost approach. However, if fiber is scarce, leasing costs are high and/or bandwidth is significant, then Inphi's ColorZ-Lite technology provides an economical solution with up to 68.5%, five-year TCO savings that enterprises will want to consider when selecting a technology for campus connectivity deployments.

Analyst Biography: Tim Doiron is principal analyst for ACG's Intelligent Networking practice which includes Packet Optical solutions, Data Center Interconnect, Transport/Multi-Layer SDN, Mobile Anyhaul and enterprise services virtualization with NFV. Doiron has more than 25 years of telecommunications industry experience. In addition to previous general manager, product planning and product management posts at Coriant and Tellabs, Doiron has held a variety of leadership positions in software engineering, product management, business development and marketing at ARRIS, Cadant, Ericsson, and Southwestern Bell Wireless. Doiron holds a Bachelor of Science degree in electrical engineering from Southern Illinois University, a Master of Science in electrical engineering from Virginia Polytechnic Institute and State University and a Master of Business Administration from Webster University. Doiron also holds eight patents and is a member of IEEE, OSA and the Electrical and Computer Engineering Industrial Advisory Board at SIU.