Introduction

Once upon a time - Data Centers were unique and recognizable places, known for their glass walls, humming machinery, as well as special heating, vacuum and air-conditioning equipment. Those simplistic times are quickly coming to an end. Today's Data Centers are undergoing rapid change, driven by 24x7x365 global business operations, significant use and depth of business intelligence (BI) and predictive analytics (Big Data), and the "Internet of Things". In fact, the entire Data Center environment—server, storage, and infrastructure networking are moving towards virtualization and automation. These changes are taking place in all types of Data Centers, including:

- Mega Data Centers
- Enterprise-oriented Data Centers
- Distributed Data Centers
- Communications Network Operators Data Centers
    - Mobile Cloud-RAN Data Centers
    - Fixed landline Central Offices utilizing CORD principles

The Data Center of the future has the potential of not only lowering operations and capital costs, but also dramatically improving services delivery speeds, while simultaneously reducing the complexities of services delivery and infrastructure operation, administration, maintenance and provisioning (OAM&P). It is impossible to predict exact technology directions even over a two to three-year horizon given the acceleration of IT Hardware and Software R&D. But the industry is starting to form a good, high-level framework for the future centered on Applications driving automated Data Center network re-configurations. This type of Applications driven automated network OAM&P is commonly referred to as *"Software Defined"*, and *Software Defined Infrastructure* (or SDI) when applied to Layer-0 infrastructures.

Full data center automation requires a much deeper intelligence about the state of applications, nodes and the interconnect cabling infrastructure, which include cable cross-connections. In this paper, we explore several aspects related to automated fiber cross-connects within the Data Center environment.

Fiber Takes Over

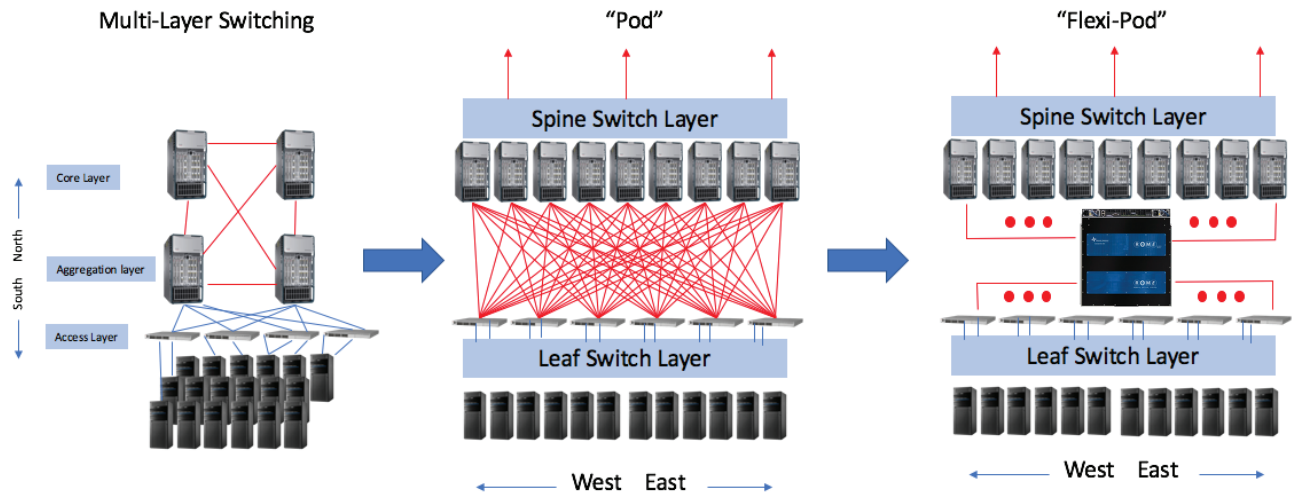
The use of fiber optic cable throughout data centers is quickly becoming a reality. Organizations that once considered 1-Gigabit Ethernet (1GE) or 10GE sufficient bandwidths are being driven to deploy 40GE, 100GE, 200GE and beyond. Fiber optics cabling is the best medium to support these always increasing speeds, so as not to require an infrastructure refresh before full depreciation of the Layer-0 infrastructure. Fiber also provides longer runs than copper with lighter cable weights, can resist electromagnetic interference (EMI), and deters hacking.

In fact, horizontal cabling within the Data Center is also increasingly fiber optic. Although copper is gaining capacity with Cat-7 and the soon-to-come Cat-8, the Cat-7 and Cat-7a tops out at 10GE, and is still a bottleneck when looking to move data at 100GE or faster speeds. Therefore, a fiber optic cabling infrastructure are widely seen as a solid long-term bet because it can outlast multiple generations of IT processing equipment. To help simplify fiber deployments, advanced Data Center products such as Robotic Optical Cross-Connects, support either single-mode or multi-mode fiber plants.

In addition to bandwidth and depreciation schedules, there are several other factors to consider when determining the Layer-0 infrastructure components such as:

- Time the end-user will occupy a facility
- The Expected installed lifetime of the cabling plant
- Types of applications that will run on the cabling plant over its useful life
- Timeframe during which standards, applications and electronics manufacturers will support the cabling plant
- Cost of active electronics
- Warranty length and covered components
- Price as it relates to performance

Adoption of network architectures such as spine and leaf are driving the scale of the fiber cabling infrastructure, requiring greater fiber counts. For spine-and-leaf architectures, each leaf switch in the network connects, using a mesh, to every spine switch in the network. As this architecture is deployed in Data Centers, fiber counts multiply very quickly when compared with traditional three-layer distribution architectures. The only sure way to manage the exponential growth in fiber counts is by using an automated fiber cross-connect, inserted as an eco-system component of a Data Center POD within the deployment architecture, creating a "Flexi-Pod" deployment approach, as shown in the following diagram:



Even without Spine-Leaf architectures, the increasing number of parallel optics that use eight fibers per port instead of the traditional two fibers per port is also creating unprecedented growth in fiber cabling. Therefore, Data Center fiber counts will increase regardless of spine-and-leaf or traditional three-layer architectures, requiring enhanced Layer-0 management capabilities to keep pace with growth.

Cloud Service Data Center Costs

Where does the cost go in today's Cloud Scale Data Centers?

To quantify Mega Data Center costs, consider a Data Center that houses 50,000 servers, and the Data Center is constructed based on currently well-understood techniques, using good quality and highly available equipment. Table 1 provides a rough guide to associated costs.

Amortized Cost	Component	Sub-Components
~45%	Servers	CPU, memory, storage systems
~25%	Infrastructure	Power distribution and cooling
~15%	Power draw	Electrical utility costs
~15%	Network	Links, transit, equipment

Table 1. Cloud Services Data Center Relative Costs

Costs are amortized, i.e., one-time purchases are amortized over reasonable lifetimes, assuming a 5% cost of money. By amortizing, we obtain a common cost run rate that we can apply to both one-time purchases (e.g., for servers) and ongoing expenses (e.g., electrical power). Details may vary somewhat by site or by moment in time, but these are the major costs. While Layer-0 networking is not the largest cost category, networking and Layer-0 innovation is the key to reducing costs and getting the most out of each dollar invested. A properly designed and deployed Layer-0 infrastructure should last a customer 10 to 15 years, and support 2 to 3 refresh iterations of active equipment and applications. A costly factor in these calculations is labor, which may vary depending on geographic location.

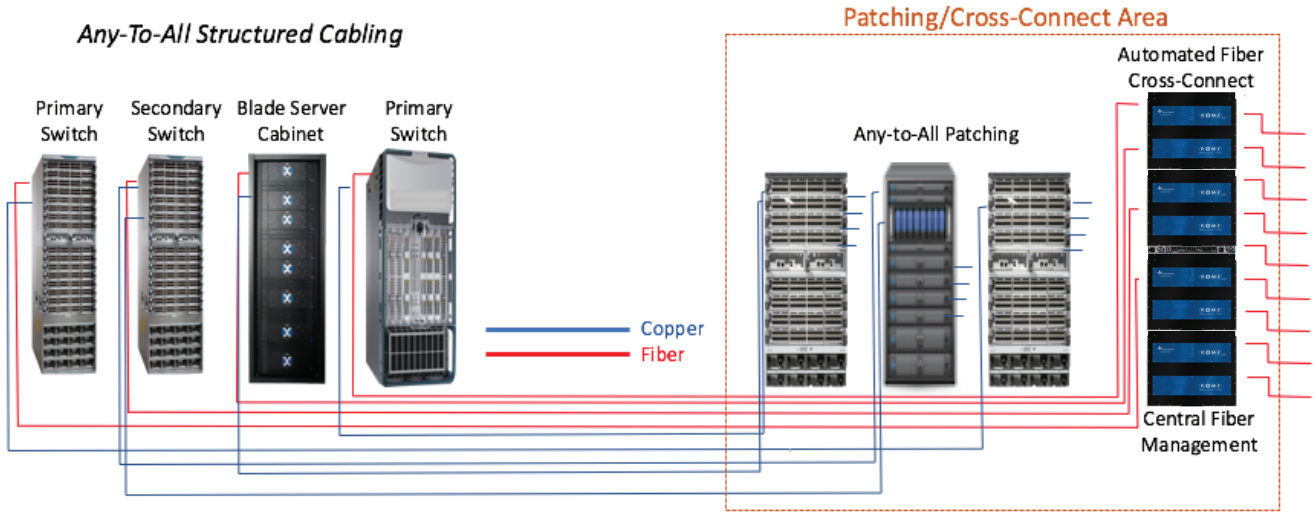
The Optical Cross-Connect

Given the depreciation and desired life-cycle of Layer-0 implementations, the automated optical cross-connect is emerging as a key component of well-designed Layer-0 infrastructures. Its purpose is to provide network administrators ultimate flexibility of the optical fiber infrastructure layer, so as to better utilize Layer-1 and upper Layers network equipment assets, and adapt to changing demands.

Incorporating an automated optical cross-connect with ultra-low latency enables the instant delivery and provisioning of any-to-any physical fiber optic connections, and automation provides the ability to virtualize these connections via software. An automated connectivity fabric makes Data Center Layer-0 networks dynamically reconfigurable, with security, speed and accuracy that traditional manual processes cannot match. This on demand connectivity opens the door to a broad range of new applications within the Data Center ecosystem. Data Center administrators and engineers are looking to reduce space and power consumption, while increasing flexibility and control. This requires newer more agile Layer-0 architectures, and a next generation automated optical cross-connects will play an integral role.

For example, many Data Centers today are victims of historical point-to-point cabling practices. Direct connections - "Point-to-Point" (i.e. from switches to servers, servers to storage, servers to other servers, etc.) are problematic and costly for a variety of reasons. The "from" point and "to" point are a mystery, making cable management problematic at best. Compounding this problem is a lack of naming conventions. If the cables were labeled at both ends, the labeling may not make sense anymore. For instance, a cable may be labeled "Unix Row, Cabinet 1." Years later, the Unix row may be replaced, and new personnel may not even know where the Unix row was located.

A recommended architectural approach to guard against these future issues is shown in the following diagram. The red lines (fiber connections) all arrive in the central automated cross-connect area. This allows any piece of equipment requiring a fiber connection to be connected to any other fiber equipment port. For instance, if a cabinet has a switch that requires a fiber connection for a Storage Area Network (SAN) on day one, but needs to be changed to a different fiber switch connection at a later date, all that is required to connect the two ports is a software command at the central robotic Cross-Connect Area.



The inherent programmability of SDI ensures that robotic automated cross-connects are dynamic and—unlike physical cross-connects or switches—device connections can be modified quickly. A wide variety of use cases—including network monitoring and security applications—are well suited to the robotic cross-connect approach. This functionality is currently available today, from next generation products such as Wave2Wave's ROME product family.

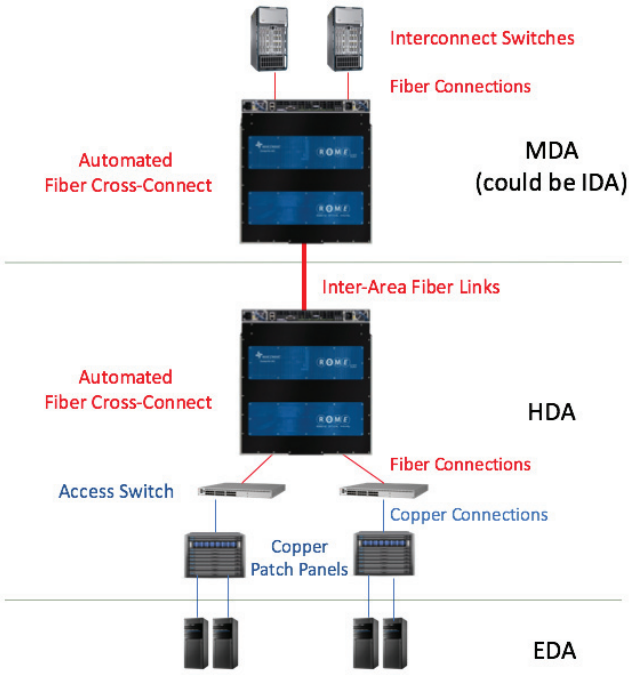
Know Your Areas: MDA – HDA - EDA

Data Center Leaf-Spine switching fabrics support the use of Horizontal Distribution Areas (HDAs) for housing Access Switches that connect to servers and storage equipment placed in Equipment Distribution Areas (EDAs). In this scenario, the HDA can be located at the end of row (EoR) or middle of row (MoR) position to serve the equipment in that zone, or an HDA can serve multiple rows of cabinets in larger zones. By zoning switches, unused ports are kept to a minimum because Leaf switches are purchased and installed based on the number of servers that require connections, rather than on the number of cabinets as seen in ToR architectures.

Another advantage of the EoR or MoR approach is that any two servers in a zone that need to "talk" to each other can be connected to the same switch for low-latency wire speed port-to-port communications, rather than being connected to separate switches that result in higher latency switch-to-switch uplink communications. A disadvantage with this zoned approach is the need to run point-to-point cabling in pathways from the access switch to each server in the zone, which can lead to "spaghetti" cabling over time without some form of automated cross-connect fabric.

However, the spaghetti issue can easily be alleviated by deploying a robotic automated optical cross-connect in the HDA that serves the entire zone. Structured cabling allows for an "any-to-all" approach within the zone where any switch port can be connected to any server port within the zone. Another benefit to using structured cabling with a robotic automated optical cross-connect is that the access switches in the HDA can remain separate and secure. The robotic optical cross-connect can reside in a separate cabinet, so there is no need to access the switch cabinet. Some Data Center managers prefer to deploy traditional structured cabling for switch-to-switch connections with optical cross-connects at the interconnection switch and/or access switch for manageability, flexibility and/or keeping switches separate and secure.

Robotic Automated Optical Cross-Connects can be deployed for ease of manageability, flexibility and/or keeping switches secure. Ideal for larger Data Centers or when optical fiber is distributed to multiple zones, the use of robotic automated optical cross-connects can allow for one-time deployment of fixed high-fiber count cabling from the Main Distribution Area (MDA) to another robotic automated optical cross-connect at the Intermediate Distribution Area (IDA) and/or HDA as shown in the following figure:



This allows optical fiber backbone cabling to be used for various purposes (e.g., SAN or uplink ports) without multiple moves, adds and changes. A key consideration of deploying optical cross-connects between the Interconnect Switches and the Access Switches is optical insertion loss budget restraints. Each connection point in a channel adds loss, and Data Center managers need to carefully calculate the insertion loss to ensure they stay within the optical loss limitations that ensure maximum performance.

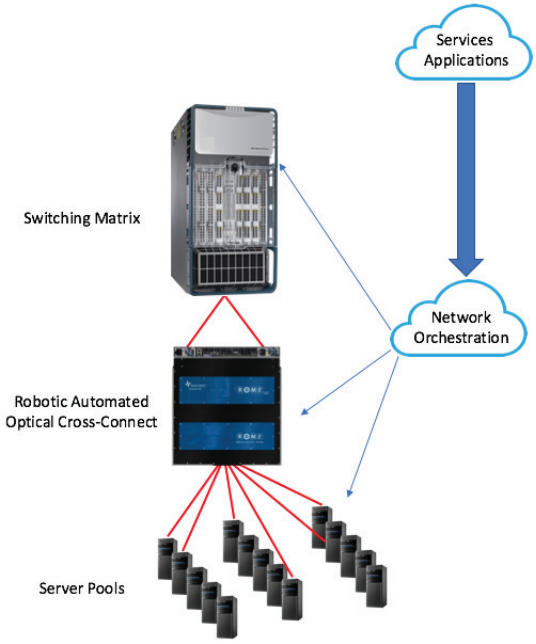
Did You know? - Hidden Benefits of Robotic Optical Cross-Connects

Current studies show that electrical power alone represents from 15-20% of overall data center budgets. In order to have the most efficient cooling, Layer-0 cabling must be properly designed, remediated and routed to allow the air to flow in an unobstructed manner. Data Center standards suggest eliminating adverse effects due to Moves-Adds-Changes (MAC) work, while also assuring that pathways are run in a manner that will allow the flow of cold air in cold aisles to be unobstructed by cabling.

However, older Data Centers have suffered from ill-managed MACs (moves, adds and changes) over the years, leaving abandoned cabling channels behind. These unused channels often create air dams which obstruct air flow that result in higher energy consumption, since air conditioning equipment work less efficiently. While that problem alone should be enough to commission the removal of abandoned cabling and installing a robotic automated optical cross-connect flexibility point, there may also be issues with the older cabling jackets not meeting current RoHS (Reduction of Hazardous Substances) requirements. In many cases, these older cables carry significant fuel load which can pose additional fire threats, and can release toxins such as halogens if ignited.

While the ability to keep cabling channels in check will reduce cooling power consumption, intelligent Layer-0 infrastructures using Robotic Automated Optical Cross-Connects will also reduce power needs of active network equipment. When designed with a central robotic automated optical cross-connect zone, an intelligent Layer-0 infrastructure architecture can help ensure that all switch ports are utilized — decreasing the power needs for electronics by keeping unused ports to a minimum. The ability to patch into unused ports rather than purchasing and installing additional switches provide energy savings which in turn translates into further cooling savings.

On is Better than Off: Given the steep fixed costs for a server installed in a Data Center and the server's three-year lifetime, it is always better for the server to be on and engaged in revenue producing activities – much like a commercial plane makes no money sitting on the ground. This is optimizing operation per investment dollar. The challenge is achieving agility, so that any server can be applied to any Application need, and when needed. Robotic Automated Optical Cross-Connects, such as the ROME product line, enables the creation of "server pools" which minimize over-deployments that lead to low server utilization and excess power cooling as shown in the following figure:



Conclusion

Designing the Layer-0 optical-cabling infrastructure for Data Centers requires consideration of many factors, including network architecture and physical planning of white spaces, and Data Center operations Areas. Traditional Data Center multi-tier switching architectures have limited scalability and cannot keep up with growing internal Data Center traffic demands. Ethernet equipment and traditional Optical-to-Electrical-to- Optical (OEO) switches alone cannot economically or physically scale to meet projected Data Center requirements. In addition, the logistics of deploying and managing dedicated point-to-point optical fiber cable to replace existing copper cabling is not considered feasible without multiple flexibility cross-connect points. That's because Data Centers need scale, and low-latency automated Optical-to-Optical-to-Optical (OOO) cross-connect eco-system solutions that better utilize the strengths of OEO switches and Ethernet equipment is ideal to position today's Data Centers for tomorrows' needs. The resulting order-of-magnitude efficiency gains translate into Opex savings, faster service time to revenue, and lower energy costs. By inserting Wave2Wave's ROME automated Robotic Automated optical cross-connects products into existing Data Center architectures, operators can simplify Layer-0 infrastructures, reduce operational costs, and improve redundancy and resiliency.

