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Navigating the Pros and Cons of Structured Cabling vs. Top of Rack in the Data Center

Executive Summary

There is no single end-all cabling configuration for every data center, and CIOs, data center professionals and IT managers need to examine the pros and cons of each solution based on their specific needs. This paper focuses on the many factors to consider when evaluating top of rack (ToR) and structured cabling configurations. The discussion includes the impact of those configurations on total management; scalability and upgrades; interoperability; equipment, maintenance and cabling costs; port utilization; power consumption and cooling requirements.

Bandwidth demand and scalability, server virtualization, high-performance switching capabilities and higher densities necessitate taking a careful look at the various configurations available for cabling a data center. Today's data center cabling configuration choices are also impacted by the need to lower power consumption and ensure efficient cooling of critical equipment, as well as by budget constraints and management structure.

Introduction

As data centers become more complex, cabling system design and topology become critical.

When the first data centers were built, end user terminals were connected via point-to-point connections. This was a viable option for small computer rooms with no foreseeable need for growth or reconfiguration. As computing needs increased and new equipment was added, these point-to-point connections resulted in cabling chaos with associated complexity and higher cost.

In response, data center standards like TIA-942-A and ISO 24764 recommended a hierarchical structured cabling infrastructure for connecting equipment. Instead of point-to-point connections, structured cabling uses distribution areas that provide flexible, standards-based connections between equipment, such as connections from switches to servers, servers to storage devices and switches to switches (see Figure 1).

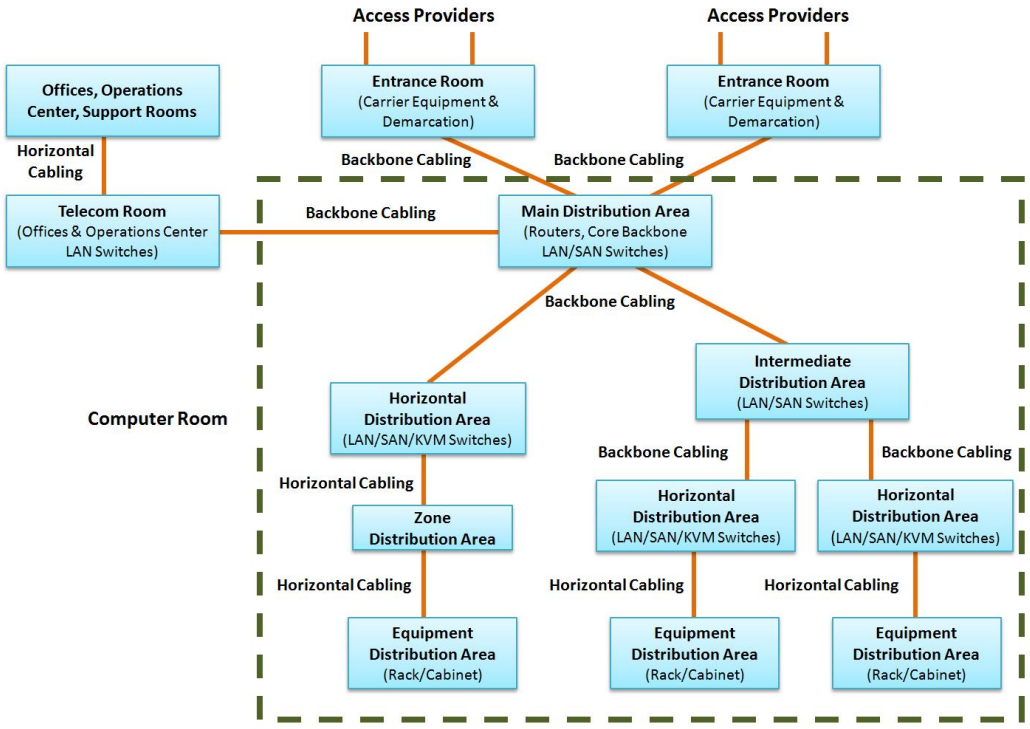

Figure 1: TIA-942-A Data Center Topology (similar to ISO 24764)

With today's high-performance servers and virtualization, more applications can be delivered from a single rack of servers than ever before. In response, several switch manufacturers recommend a Top of Rack (ToR) configuration where smaller (1RU to 2RU) edge switches are placed in the top of each server rack (or cabinet) and connect directly to the servers in the rack via short preterminated small form-factor pluggable (e.g., SFP+ and QSFP) twinaxial cable assemblies, active optical cable assemblies or RJ-45 modular patch cords.

ToR significantly increases the number of switches and reduces the initial amount of structured cabling. It is often recommended for its rack-at-a-time deployment, ability to limit the use of copper cabling to within racks, support for east-west (i.e., server-to-sever) traffic and rack-level management capabilities. Both TIA 942-compliant structured cabling and ToR have advantages and disadvantages. When selecting the cabling configuration to best meet the needs of the data center, it is important to examine the impact that structured cabling and ToR have on overall total cost of operations, as well as other trade-offs.

Manageability Considerations

Before choosing a cabling infrastructure, data center professionals should consider operational structure and policies.

With structured cabling, patch panels that mirror switch ports and server ports connect to corresponding panels in one or more central patching areas or zones via permanent (or fixed) links. Also referred to as distribution areas, these patching areas may be located at the end or in the middle of a row of cabinets. Moves, adds and changes (MACs) are accomplished by repositioning patch cord or fiber jumper connections at the central patching area. The fixed portion of the channel remains unchanged and switches and equipment are left untouched and secure. This creates an "any-to-all" configuration where any switch port can be connected to any equipment port. Furthermore, structured cabling can be field terminated to any length to maintain a clean, slack-free appearance.

In a ToR configuration, switches at the top of each rack connect directly to the servers in the same rack, requiring all changes to be made within each individual rack (or cabinet). This eliminates the use of central patching and reduces the amount of structured cabling in the data center (see Figure 2). MACs in a ToR configuration can be more complicated and time consuming—especially in large data centers with hundreds of cabinets. Changes must be made in individual racks or cabinets, rather than at one convenient central patching area. Identifying the specific rack or cabinet requiring the change can be a complicated process.

ToR can be a solution for data centers where individual racks of servers and their corresponding switches need to be managed as their own entity or segregated by application. ToR does not allow network administrators to keep switches separate from server administrators, which can be problematic when these groups manage switches and servers separately and when switches must remain protected for security purposes.

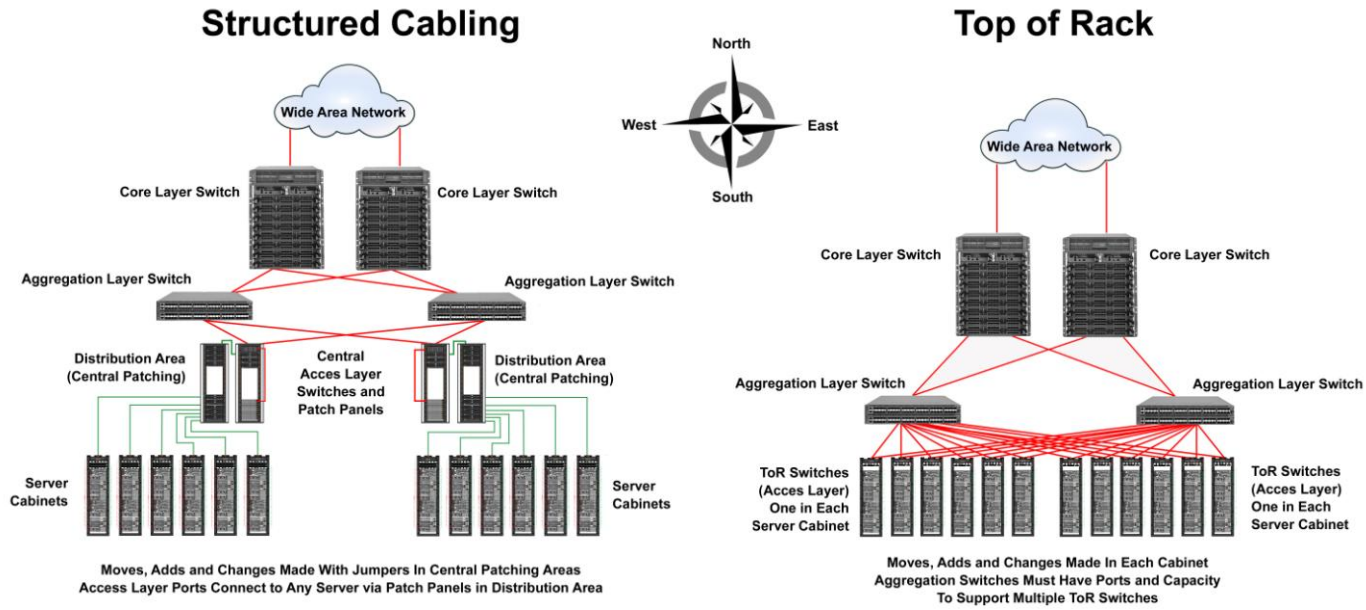

Figure 2: Structured Cabling vs. ToR Topology. ToR eliminates central patching in the distribution area.
Note: Designs based on a three-tier switch architecture.

Scalability and Upgrade Considerations

Cabling system design can limit or enhance squeezing the most from racks, servers and ports.

A widespread switch upgrade with ToR impacts many more switches than with structured cabling and requires equipment at the network core to have the port densities and bandwidth capacity to support the increased number of switches. An individual switch upgrade with structured cabling can increase connection speeds to multiple servers across several racks in the data center. An upgrade to an individual ToR switch improves connection speed to only the servers in that rack.

ToR switches using short-distance small form-factor pluggable twinaxial cable assemblies cannot support autonegotiation. Because the twisted-pair cabling used with structured cabling is backwards compatible, it supports autonegotiation where individual ports can switch between a 10 and 1 gigabit operation depending on the connected equipment. Autonegotiation enables partial switch or server upgrades on an as-needed basis, enabling a cost-effective migration over time. Without autonegotiation, a switch upgrade requires all equipment connected to that switch to be upgraded simultaneously, incurring full upgrade costs all at once.

Because ToR small form-factor pluggable twinaxial cable assemblies are typically more expensive than copper patch cords in a structured cabling system, costs can escalate even further during upgrades as some equipment vendors require use of their cable assemblies and force cable upgrades with equipment upgrades. The core physical layer infrastructure or the fixed portion of the cabling channel is typically installed once, as long as the minimum standards recommended fiber and copper cabling are used.

In a ToR configuration using small form-factor pluggable twinaxial cable assemblies, distance between the switches and the servers is limited to a length of 7 meters in passive mode. While this is not a problem if each rack will always be managed as an individual unit, these short lengths can restrict the location of equipment if needs change. Structured cabling lengths can be up to 100 meters, allowing flexible equipment placement.

Interoperability Concerns

Open systems enable more choices and a competitive market place.

Interoperability and the open systems concept is the "bedrock" of cabling industry standards. Data center managers expect and value interoperability to fully leverage their existing cabling investment by ensuring performance and a competitive market regardless of which vendors' equipment and cable designs are selected.

Unfortunately, some switch vendors now require their proprietary cable assemblies for connecting ToR switches to servers when using small form-factor pluggable twinaxial cable assemblies. Some ToR switches are designed to check vendor security IDs on cables and either display errors or prevent ports from functioning when connected to an unsupported vendor ID. While this helps ensure that vendor-approved cable assemblies are used with corresponding electronics, it can limit data center design options by locking data center managers into a proprietary solution. This is a substantial change from the industry standards-based fiber connectivity and copper connectivity successfully deployed in data centers for decades.

Third-party independent testing by University of New Hampshire's Interoperability Lab (UNH IOL) proves that passive small form-factor pluggable twinaxial cable assemblies from cabling vendors pass interoperability testing with several vendors' ToR switches that are designed to display errors. These tests demonstrate that proprietary cables are not necessarily required. This may not be the case for switches designed to actually prevent ports from functioning altogether when connected to an unsupported vendor ID.

Maintenance, Equipment and Cabling Cost

The choice of cabling system has a major impact on cost.

With a ToR switch in every cabinet (or two for dual primary and secondary networks), the total number of switch ports depends on the total number of cabinets in the data center, rather than on the actual number of switch ports needed to support the equipment. This can nearly double the amount of switches and power supplies required, compared to structured cabling. Unlike passive structured cabling, ToR switches require power and ongoing maintenance. For example, based on an actual 39-cabinet data center using separate dual networks, the cost for equipment and maintenance for ToR is more than twice that of structured cabling (see Figure 3).

The use of distribution areas with structured cabling also impacts cabling costs. ToR saves on structured cabling costs, but the added cost of cabling assemblies can negate that savings, especially when switch vendors require their proprietary cable assemblies. As shown in Figure 3, the cost of the ToR cable assemblies for each used port is more than twice the cost of structured cabling. Even if the cost of ToR cable assemblies is not a consideration, structured cabling costs represents only about five percent of the total equipment and maintenance savings realized with structured cabling. Structured cabling also typically carries a 15 to 25 year warranty (depending on manufacturer) as opposed to the average 90-day warranty on cabling assemblies offered by most electronics vendors.

Equipment and Unit Price	ToR		Structured Cabling		Total Savings
	Units	Price	Units	Price	
32-port 10G ToR Switches ($15,000)	78	$1,170,000	35	$525,000	$645,000
Redundant Power Supplies ($500)	78	$39,000	35	$17,500	$21,500
SFP+ Uplink Ports ($1500)	312	$468,000	140	$210,000	$258,000
32-Port Aggregation Switches ($25,000)	10	$250,000	5	$125,000	$125,000
SFP+ Modules ($5000)	80	$400,000	40	$200,000	$200,000
Redundant Power Supplies ($500)	10	$5,000	5	$2,500	$2,500
Core Switches ($80,000)	2	$160,000	2	$160,000	0
Redundant Power Supplies at ($7,500)	2	$15,000	2	$15,000	0
Fiber Cards for Uplinks at ($70,000)	4	$280,000	2	$140,000	$140,000
Cabling Total		**$240,000**		**$110,000**	**$130,000**
Equipment Total (not including software)		**$2,787,000**		**$1,395,000**	**$1,392,000**
3 Years Maintenance		**$1,200,000**		**$570,000**	**$630,000**
TOTAL		**$4,227,000**		**$2,075,000**	**$2,152,000**

Figure 3: ToR vs. Structured Cabling Cost Comparison (based on MSRP at time of print) for an actual 39-cabinet data center (assumes average 5 to 6kW per cabinet, dual network, redundant power supplies, 14 servers per cabinet, four uplinks per switch, 2.5-meter SFP+ direct attach cable assemblies for each used ToR port, and category 6A UTP for structured cabling).

Furthermore, a ToR design can add to server costs. Servers with twisted-pair network interface cards (NICs) are typically less expensive than those with SFP+ or QSFP NICs. Many server platforms also ship with twisted-pair copper NICs native to the motherboard. With ToR deployments supported by small form-factor pluggable twinaxial cable assemblies, SFP+ or QSFP NICs would need to be purchased for those connections, which can range from about $400 to $800 per NIC.

Switch Port Utilization

Structured cabling maximizes port accessibility and utilization.

Studies by DataCenter Dynamics and the Gartner Group show that the average power supplied to a server cabinet ranges between 5 and 6kW. Using this assumption, the number of servers in a cabinet is approximately 14. Server switch port demand is therefore typically lower than the switch ports available on a ToR switch. For example, with only 14 ports of a 32-port switch used, 18 ports will remain unused. Other assumptions using a higher number of servers and higher power supplied to the server cabinet would improve the switch port utilization on a ToR switch. The relative economics would need to be determined based on the actual design and type of servers that are deployed.

When using separate dual networks with 14 servers per cabinet where each server connects to two 32-port switches, 28 of the 64 ports are used for the 14 servers, leaving 36 unused. When applied across the actual 39-cabinet example used in Figure 3, this scenario results in 1,404 unused ports, which equates to nearly 44 unnecessary switch purchases (see Figure 4).

With structured cabling, virtually all active ports can be fully utilized because they are not confined to single cabinets. Instead, the 32 switch ports that would be dedicated to a single cabinet in the ToR configuration can now be divided up, on demand, to any of several cabinets via the distribution area. Even if edge switches are used to accommodate east-west (i.e., server-to-server) traffic, structured cabling allows the switches to be centrally located in distribution areas, which decreases the number of unused ports and reduces the amount of north-south traffic to and from aggregate and core switches.

Equipment	ToR				Structured Cabling			
	Units	Total Ports	Used Ports	Unused Ports	Units	Total Ports	Used Ports	Unused Ports
32-port 10G ToR Switches	78	2496	1092	1404	35	1120	1092	28
32-Port Aggregation Switches	10	320	312	8	5	160	140	20
Fiber Cards for Core Uplinks	4	128	40	88	2	64	20	44
TOTAL PORT USAGE		**2944**	**1444**	**1500**		**1344**	**1252**	**92**

Figure 4: Switch port utilization for ToR vs. Structured Cabling for an actual 39-cabinet data center (assumes average 5 to 6kW per cabinet, dual network, redundant power supplies, 14 servers per cabinet and four uplinks per switch).

While the number of unused ports will be less in high-density server environments where the power supplied to server cabinets is now reaching upwards of 20kW to support a full complement of servers, they can still add up. For example, in a 200-cabinet high-density server farm with 40 servers and a 48-port switch per cabinet, the number of unused ports reaches 1600 (i.e., 8 unused ports per cabinet) at a cost of about $735,000. Using structured cabling can save nearly 85% even in these high-density environments. Being able to effectively manage unused switch ports is therefore a key consideration when selecting a ToR configuration. It is worth noting that some data centers use a switch fabric architecture, which may have a different outcome on the number of unused ports and amount of equipment and cabling compared to a three-tier switch architecture. However, the benefits of a structured cabling system remain.

Increased Power Consumption

Port utilization and equipment have a major impact on power consumption.

Power consumption is one of the top concerns among today's data center managers as energy costs continue to rise, power becomes more costly and green initiatives take center stage. As shown in Figure 5 below, the ability to use all switch ports with structured cabling lowers the number of switches and power supplies required by more than half. This helps cut equipment and energy costs while contributing to "green" initiatives such as LEED, BREEAM or STEP. With structured cabling requiring fewer power supplies, future upgrades to more efficient power supplies are easier and more cost effective.

Equipment	ToR	Structured Cabling
32-port 10G ToR Switches	78	35
Redundant Power Supplies	78	35
SFP+ Uplink Ports	312	140
32-Port Aggregation Switches	10	5
SFP+ Modules	80	40
Redundant Power Supplies	10	5
Core Switches)	2	2
Redundant Power Supplies	2	2
Fiber Cards for Uplinks at	4	2
TOTAL SWITCHES	**90**	**42**
TOTAL POWER SUPPLIES	**90**	**42**

Figure 5: With structured cabling, the number of switches and power supplies required is less than half that of ToR, thereby reducing power consumption

When switches reach full utilization in a ToR configuration, adding a new server to the cabinet requires an additional switch in the cabinet as well as additional power supplies. This can take away from potential power that

can be allocated for servers. There may not even be enough power provisioned to the cabinet to support the additional load. Even with virtualization reducing the number of servers and related power and cooling, the increased number of power supplies required with ToR can potentially negate some virtualization savings.

It is important to remember that even in an idle state, unused switch ports can consume power. Furthermore, edge switches like those used in ToR process more instructions in their central processing units. This can cause potential unanticipated power spikes. Regardless of the configuration and technologies deployed, power consumption varies by switch model and manufacturer and actual port consumption or power draw should be examined across the entire data center.

Cooling and Failure Rate Considerations

Improper placement of equipment can wreak havoc on the best data center cooling and uptime plan.

While a ToR switch can technically be placed in the middle or bottom of a cabinet, they are most often placed at the top for easier accessibility and manageability. According to the Uptime Institute, the failure rate for equipment placed in the top third of the rack is three times greater than that of equipment located in the lower two thirds. In a structured cabling configuration, the passive components (i.e., patch panels) are generally placed in the upper position, leaving the cooler space for the equipment.

ToR designs can also land-lock equipment placement due to the short cabling lengths available and data center policies that do not allow patching from cabinet to cabinet. This can prevent placing equipment where it makes the most sense for power and cooling. For example, if the networking budget does not allow for outfitting another cabinet with a ToR switch, placement of a new blade server may be limited to where network ports are available. This can lead to hot spots, which can adversely impact neighboring equipment within the same cooling zone. Structured Cabling systems avoid these problems.

Conclusion

Many factors impact the choice of which cabling configuration to deploy, and there is no single end-all solution. ToR configurations can make a lot of sense for small server rooms, when self-contained cabinets are required or where a higher number of unused ports can be managed. However, data center managers should carefully consider the pros and cons as outlined in Figure 6.

ToR Pros	ToR Cons
• Reduced amount of structured cabling • Lower cabling infrastructure costs • Rack-based cable management and changes • Rack-based access for application segregation • Rack-based switch upgrades	• Significantly higher equipment, maintenance and cabling costs • Poor port utilization • Increased power consumption • Scalability and upgrade limitations – may not support interoperability and autonegotiation • Time consuming MACs in large data centers • Limited equipment placement and potential hot spots

Figure 6: ToR Pros and Cons

When selecting a cabling configuration for the data center, an overall study that includes total management; scalability and upgrades; interoperability; equipment, maintenance and cabling costs; port utilization; and power and cooling requirements should be undertaken by facilities and all networking departments to ultimately make the best educated decision. ToR is often positioned as a replacement for structured cabling, but in many instances, structured cabling must coexist with ToR to support central switching for KVM or other in-band or out-of-band management and data center monitoring.