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Top of rack network switches

This article provides a close examination and comparison of two popular physical data center designs, rack top, and end of line. We will also explore a new alternative design using fabric extensioners, and finish with a quick look at how Cisco Unified Computing could fit into this image. Start! Top Rack Design At the top of Rack design servers connect to one or two Ethernet switches installed inside the rack. The term rack top was coined for this design but the actual physical location of the switch doesn't necessarily need to be at the top of the grid. Other switching locations might be at the bottom of the grid or in the middle of the rack, but the top of the rack is most common due to easier accessibility and cleaner cable management. This design can also sometimes be called In-Rack. The top Ethernet rack switch is usually low profile (1RU-2RU) and fixed configuration. The key feature and appeal of the top of rack design is that all the copper wiring for the servers stays in the rack as the server's relatively short RJ45 patch cables to the rack switch. The Ethernet switch connects the rack to the network of data centers with fibers running directly from the rack to a common aggregation zone connecting to redundant modular ethernet switches Distribution or Aggregation. Each rack is connected to the data center with fiber. Therefore, there is no need for a large and expensive copper wiring infrastructure operating between racks and throughout the data center. Large amounts of copper wiring put an additional burden on data center facilities because bulky copper cable can be difficult to deliver, can obstruct airflow, and generally requires more racks and infrastructure dedicated to just patching and cable management. Long series of twisted pair copper wiring can also put limits on server access speeds and network technology. The design of the Top of Rack data center avoids these problems because there is no need for a large copper wiring infrastructure. This is often the key factor for which a Top of Rack design is selected over End of Row. Each rack can be processed and managed as an individual, modular unit within the data center. It is very easy to change or upgrade rack-by-rack server access technology. All network upgrades or problems with rack switches will usually only affect servers in this rack, not a row servers. Since the server connects with very short copper cables inside the rack, there is more flexibility and options in terms of what this cable is and how fast a connection it can support. For example, a 10GBASE-CX1 copper cable could be used to provide a 10 gigabit server connection at low cost and low power. The 10GBASE-CX1 cable supports distances of up to 7 meters, which works very well for a top of rack design. Fiber to each rack provides provides Better flexibility and investment protection than copper due to the fiber's unique ability to carry higher bandwidth signals at longer distances. Future transitions to 40 gigabit and 100 gigabit network connectivity will be easily supported on a fiber infrastructure. Given the current 10 Gigabit power challenges on the copper twisted pair (10GBASE-T), any future support of 40 or 100 Gigabit on twisted pair will likely have very short distance limitations (distances in the rack). It is also another key factor for which Top of Rack would be selected on End of Row. The adoption of blade servers with built-in switch modules has made fiber-connected racks more popular by moving the Top of Rack concept inside the blade enclosure itself. A blade server speaker can contain 2, 4, or more ethernet switching modules, multiple FC switches, resulting in an increasing number of switches to manage. A significant removal from the top of rack design is the increased management domain with each rack switch being a single instance control plan that needs to be managed. In a large data center with many racks, a Top of Rack design can quickly become a management burden by adding many switches to the data center that are each managed individually. For example, in a 40 rack data center, where each rack contained (2) Top of Rack switches, the result would be 80 switches on the floor simply providing server access connections (not counting distribution and basic switches). This is 80 copies of switching software that needs to be updated, 80 configuration files that need to be created and archived, 80 different switches participating in layer 2 covering the topology of trees, 80 different locations a configuration can go wrong. When a Top of Rack switch fails, the person replacing the switch needs to know how to properly access and replace the archived configuration of the failed switch (assuming it was correctly and recently archived). The individual may also be required to perform verification tests and shooting problems. This requires a higher skill set that may not always be available (or if so comes at a high price), especially in a remotely hosted lights off facility. The top of the rack design usually also requires higher port densities in the aggregation switches. Going back to the 80 switch example, each switch has a unique connection to each redundant aggregation switch, each aggregation requires 80 ports. The more ports you have in the aggregation switches, the more likely you are to face potential scalability constraints. One of these constraints could be, for example, the logical ports STP, which is the product of aggregation ports and VLAN. For example, if I needed to support 100 VLANs in a single L2 domain with PVST on the 80 ports of aggregation switches, this would result in 8000 STP logic ports by aggregating aggregation Most robust modular switches can handle this number. For example, the Catalyst 6500 supports a total of 10,000 PVST instances, and 1,800 per line card. And the Nexus 7000 supports 16,000 PVST instances worldwide without card-by-line restrictions. However, this is something that will need to be paid attention to as the data center increases in the number of ports and VLAC. Another possible scalability constraint is raw physical ports - does the aggregation switch have enough capacity to support all the switches at the top of the rack? What about supporting 10 Gigabit connections with each top rack switch, to what extent the aggregation switch scale in 10 gigabit ports? Summary of the benefits of Top of Rack (Pro's): Copper remains In Rack. No large copper wiring infrastructure is required. Reducing wiring costs. Less infrastructure dedicated to wiring and patching. Cleaner cable management. Modular and flexible by rack architecture. Easy rack upgrades/modifications. Future fiber infrastructure to the test, supporting transitions to 40G and 100G. Short copper wiring to servers allows low power, low cost 1oGE (10GBASE-CX1), 40G in the future. Ready for unified fabric today. Summary of the disadvantages of Top of Rack (Con): More switches to manage. More ports required in aggregation. Potential scalability problems (STP logic ports, aggregation switch density). No more Layer 2 server-server traffic in aggregation. Racks connected to layer 2. More STP instances to manage. Single control aircraft by 48 ports (per switch), higher skill set needed for switch replacement. End of Row Design Server cabinets (or racks) are usually lined up side by side in a row. Each line can contain, for example, 12 server cabinets. The term End of the Line was coined to describe a rack or cabinet placed at each end of the server line to provide network connectivity to servers in that line. Each server cabinet of this design has a bundle of twisted pair copper wiring (usually Category 6 or 6A) containing up to 48 (or more) individual cables routed to the End of the Line. End of Row network media may not necessarily be located at the end of each actual line. There may be designs where a handful of network racks are placed in a small row of their own collectively provide End of Row copper connectivity to more than one row of servers. For a redundant design, there may be two copper packets at each rack, each running at End of Row network racks. In the server cabinet, the copper package is usually wired to one or more patch panels attached to the top of the cabinet. Individual servers use a relatively short RJ45 copper patch cable to connect the server to the patch panel in the rack. The copper beam of each support can be routed through over the head cable troughs or scale ladder that carry dense copper beams to the End of Row network media. Copper beams can also be transported under an elevated floor, to the detriment of the obstruction of fresh air flow. Depending on the amount of copper required, it is common to have a support dedicated to patching all the copper cable adjacent to the grid that contains the End of Row network switch. Therefore, there may be two network racks at each end of the line, one for patching, and one for the network switch itself. Again, an RJ45 patch cable is used to connect a port on the network switch to a corresponding patch panel port that establishes the link to the server. The large amount of RJ45 patch cables at the end of the line can cause a cable management problem and without careful planning can quickly result in an unmanageable ugly mess. Another variant of this design can be called Middle of the Row which involves transporting the copper cable from each server rack to a pair of racks placed next to each other in the middle of the row. This approach reduces the extreme lengths of the terminal cables of the server cabinets end, but potentially exposes the entire line to a localized disaster in the middle of the row (such as a water leak from the ceiling) that could disrupt both server access switches at the same time. The End of Row network switch is usually a modular chassis-based platform that supports hundreds of server connections. As a general rule, there are redundant supervising engines, power supplies and, overall, better high-availability features than those usually found in a Top of Rack switch. The modular end-of-row switch is expected to have a longer lifespan of at least 5 to 7 years (or even longer). It is rare that the end-of-line switch is frequently replaced, once its in - it's in - and all other upgrades are usually component level upgrades such as new line cards or supervisor engines. The end-of-line switch provides connectivity to the hundreds of servers in this line. Therefore, unlike Top of Rack where each rack is its own managed unit, with End of Row, the entire series of servers is treated as a holistic unit or Pod in the data center. Network upgrades or end-of-line switch problems can impact the service across the entire server line. The network of data centers in this design is managed by line, rather than rack. A top of rack design extends the topology of layer 2 of the aggregation to each individual support, resulting in a larger overall footprint of layer 2, and therefore a larger topology of the tree that extends. The end-of-line design, on the other hand, extends a layer 1 wiring topology of the End of Line switch to each support, resulting in smaller and more manageable layer 2 footprint and fewer STP nodes in topology. End of Row is a line management model in terms of data center In addition, End of Row is also per line in terms of network management model. Since there are usually two modular switches per line of servers, the result of this is by far few switches to manage compared to a high rack design. In my previous example of 40 racks, let's say there are 10 racks per line, which would be 4 rows each with two end of line switches. The result is 8 switches to manage, rather than 80 in the top of rack design. As you can see, end-of-line design generally has an order of magnitude advantage over Top of Rack in terms of the number of individual switches that require management. This is often a key factor for which end-of-line design is selected on Top of Rack. Although End of Row has far fewer switches in the infrastructure, this does not necessarily equate to much less capital costs for networking. For example, the cost of a 48-port line map in a modular line switch end can only be slightly less than the price (if not similar) to a 48-port equivalent Top of Rack switch. However, maintenance contract costs are generally lower with End of Row due to the much lower number of individual switches with maintenance contracts. As mentioned in the Top of Rack discussion, the large amount of dense copper wiring required with End of Row is generally expensive to install, cumbersome, restrictive for airflow, and brings its share of cable management headaches. The long twisted pair copper cable poses a challenge for the adoption of higher-speed server network I/O. For example, a 10 gigabit server connection on the twisted copper even cable (10GBASE-T) is difficult today due to the current power requirements of the silicon 10GBASE-T currently available (6-8W per end). As a result, there is also little availability of dense and cost-effective 10GBASE-T network switching ports. As the adoption of dense computing and virtualization platforms accelerates rapidly, servers limited to 1GE network I/O connections will pose a challenge to achieve larger-scale consolidation and virtualization capable in modern servers. In addition, the adoption of a unified fabric will also have to wait until 10GBASE-T unified tissue switch ports and NBAs are available (not expected until the end of 2010). The 10GBASE-T silicon will eventually (over the next 24 months) reach lower power levels and switch providers (such as Cisco) will have dense 10GBASE-T line cards for modular switches (such as Nexus 7000). Manufacturers of will also begin shipping 10GBASE-T (LAN) triple-speed LOMs - 100/1000/10G, and NIC/HBA suppliers will have unified fabric NPAs with 10GBASE-T ports. All of this should work on the existing Category 6A copper cable. However, all bets are off for 40G and beyond. Summary of End-of-Line Benefits (Pro): Fewer switches to manage. Potentially lower switching costs, lower maintenance costs. Fewer ports required in the Racks connected to layer 1. Fewer STP instances to manage (by line, rather than rack). Longer life, high availability, modular platform for server access. Single control aircraft by hundreds of ports (by modular switch), lower skill set required to replace a 48-port line map, as opposed to replacing a 48-port switch. Summary of end-of-row disadvantages (Con): Requires an expensive, cumbersome, rigid copper wiring infrastructure. Loaded with cable management challenges. More infrastructure needed for patching and cable management. Long twisted pair copper wiring limits the adoption of lower server power at higher speed I/O. More future questioned than future evidence. Less flexible per-line architecture. Platform upgrades/modifications affect the entire line. Unified Fabric is not a reality until the end of 2010. Top rack extender fabric Extension is a new data center design concept that allows the Top of Rack placement of server access ports as a layer 1 extension of a main upstream switch. Just like a line card in a modular switch, the fabric extension is a data-only plane device that receives all its control plan intelligence from its main switch. The relationship between a fabric extender and its main switch is similar to the relationship between a line card and its supervisor engine, only now the fabric extender can be connected to its main switch (supervisor engine) with fiber remote connections. This allows you to efficiently decouple the line cards from the End of Row modular switch and distribute them throughout the data center (at the top of the rack), all without losing the management model of a single End of Row switch. The main switch and all this if its remotely connected fabric extenders are managed as a single switch. Each fabric extender simply provides a remote extension of the ports (acting as a remote line map) to the single master switch. Unlike a traditional top of rack switch, the top of the rack fabric extender is not an individually managed switch. There is no configuration file, no IP address, and no software that needs to be managed for each fabric extension. In addition, there is no layer 2 topology from the fabric extender to its main switch, it is rather the whole layer 1. Therefore, there is no spanning tree topology between the main switch and its fabric extenders, as if there was no spanning tree topology between a supervisor and his line cards. The topology of the tree covering layer 2 exists only between the main switch and the upstream aggregation switch to which it is connected. The fabric extender design provides the physical topology of Top of Rack, with the logical topology of End of Row, offering the best of both designs. There are far fewer switches to manage (a bit like End of Row) without the need for a large copper wiring infrastructure, and and fiber connectivity at each rack. There is also a cost advantage. Because the fabric extender doesn't need the processor, memory and flash storage to operate a control aircraft, there are fewer components and therefore less cost. A fabric extender is about 33% cheaper than a top of rack equivalent switch. When a fabric extender fails, there is no configuration file that needs to be retrieved and replaced, no software that needs to be loaded. The stranded fabric extender simply needs to be removed and a new one installed in its place connected to the same cables. The skill set required for replacement is someone who knows how to use a screwdriver, can unplug and plug the cables, and can watch a state light go green. The new fabric extender will receive its configuration and main switch software once connected. In the design above show in Figure 6, top rack fabric extenders use the fiber of the grid to connect to their main switch (Nexus 5000) somewhere in the aggregation area. The Nexus 5000 is linked to the Ethernet aggregation switch like any normal End of Row switch. Note: Up to 12 fabric extensions can be managed by a single master switch (Nexus 5000). In Figure 7 above the top of the rack fabric extenders, use fiber that extends from the grid to an End of Row cabinet containing the main switch. The main switch, in this case a Nexus 5000, can also provide 10GE unified fabric server access connections. It is more common for fiber to run from the rack to a central aggregation area (as shown in Figure 6). However, the design shown above in Figure 7 where the fiber also runs to the end of a row may begin to focus on tissue extension deployments as a means of preserving the logical grouping of lines by physically placing the main switch in the row of fabric extensions associated with it. Summary of the benefits of top of rack (Pro) fabric extension: Fewer switches to manage. Fewer ports required in the aggregation area. (End of row) Racks connected to layer 1 via fiber, extending the copper layer 1 to rack servers. Fewer STP instances to manage. (End of row) Single control aircraft by hundreds of ports, lower skill set required for replacement. (End of row) Copper remains In Rack. No large copper wiring infrastructure is required. (Top rack) Reducing wiring costs. Less infrastructure dedicated to wiring and patching. Cleaner cable management. (Top rack) Modular and flexible architecture by ». Easy rack upgrades/modifications. (Top rack) Future fiber-proof infrastructure, maintaining transitions to 40G and 100G. (Top of Rack) Copper wiring runs to servers allows low power, low cost 1oGE (10GBASE-CX1), 40G in the future. (Top rack) Summary of disadvantages top of rack fabric extender (Con's): New design concept only available sinus January 2009. Not yet a widely deployed design. Link to Learn more about fabric extenders. Cisco Unified Computing Pods The Cisco Unified Computing solution provides a tightly coupled architecture of blade servers, unified fabrics, tissue extenders and integrated management within a single consistent system. A multi-rack deployment is a unique system managed by a redundant pair of Top of Rack fabric interconnection switches providing integrated device level management, procurement and the link between the pod and the Ethernet and Fibre Channel data center aggregation switches. Above, a 3 rack pod is a system. Each blade enclosure is connected to a unified fabric - fabric extender - to fabric interconnection switches with fiber optic 10GBASE-CX1 or USR 10GE (ultra-short range). A single unified computer system can hold up to 40 blade cases than a single system. With such scalability, there could be designs where an entire row of blade speakers is linked to the End of Row or Middle of Row fabric interconnection. As shown below... These are not the only possible designs, rather than a few simple examples. There are many more possibilities because the architecture is as flexible as it is scalable. Summary of the Benefits of Unified Computer Systems (Pro): Takes advantage of the Top of Rack physical design. Takes advantage of Fabric Extender technology. Fewer management points. Unique system of calculation, unified fabric and integrated management. Very scalable as a single system. Optimized for virtualization. Summary of the disadvantages of the Unified Computer System (Con): Cisco UCS is not yet available. :-(Ask your local cisco representative for more information. UPDATE: Cisco UCS is available and shipping to customers since June 2009 Link to learn more about Cisco Unified Computing System. Deploying data center designs in physical designs Pods choosing Top of Rack or End of Row is not a matter of all or nothing. The only thing all the above drawings have in common is that they bind to a common area of aggregation with fiber. The common aggregation area can therefore serve the End of Row pod area no differently from a Top of Rack pod. This allows flexibility in the design choices made as the data center grows, Pod by Pod. Some pods may use end-of-row copper wiring, while another pod may use the top of the support fiber, with each pod connecting to the common aggregation area with fiber. Conclusion This article is based on a detailed presentation of more than 30 slides that I developed from scratch for Cisco covering Data Center Physics, Top of Rack vs End of Row. If you would like to see the entire presentation with a one-on-one discussion about your specific environment, please contact your local Cisco representative and ask to see Brad Hedlund's Top of Rack vs End of Row Data Center Designs presentation! What can I say, a shameless attempt at self-promotion. ;-) ;-)

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