The Case for 25GbE vs. 40GbE

SUMMARY
Application workloads continue to surge, forcing cloud providers to already consider an upgrade for their 10GbE top-of-rack switches. We believe an upgrade to 40GbE is an overkill currently and doesn't offer investment protection for the eventual 100GbE cycle, requiring two switch upgrade steps and full cable "rip-and-replacement." We believe 25GbE offers a cost-efficient, linear migration path to 100GbE. With 25GbE, cloud providers can skip 40GbE, extend the life of their 100GbE switches and reuse much of the cable infrastructure. Google and Microsoft are on board, and other cloud providers could follow suit. We see the 25GbE upgrade as a net positive to the vendors as they are given an opportunity to defend from white box vendors with new 100GbE solutions. Longer term, as enterprises adopt 25GbE after IEEE standardization, a faster upgrade cycle in 25GbE vs. 40GbE offers accelerated data center spending. We view Cisco and Arista as key beneficiaries.

KEY POINTS
- **The problem.** Over the past three years, cloud providers have migrated from 1GbE to 10GbE switching in their data centers seeking higher throughput and faster performance. The continued surge in application workloads will soon prove 10GbE insufficient yet 40GbE seems an overkill for most apps and doesn't offer a smooth migration path to 100GbE down the road. We believe 25GbE offers a more economical path to 100GbE as it reuses switching and cabling elements.
- **40GbE complications.** When factoring in the high cost of 40GbE (switching and cabling) and considering that most apps don't yet need 4x the capacity of 10GbE, the economic benefits of 40GbE might not be what they seem. Moreover, 40GbE doesn't scale linearly toward 100GbE and requires a complete rip-and-replacement of ToR switches and the entire cable infrastructure. As a result, cloud providers are considering 25GbE as an alternative.
- **Enter 25GbE.** With the availability of 25GbE on the server, cloud providers could upgrade immediately to 100GbE ToR switches and bypass the 40GbE upgrade. 25GbE allows cloud providers to gain higher throughput, scale linearly toward 100GbE and future-proof environments by extending the life of switches and reusing cables/optics. Google and Microsoft have already committed to 25GbE, and Cisco and Arista have expressed their support.
- **Enterprise to join.** Enterprise adoption of 25GbE isn't likely until IEEE standardization, suggesting adoption in 2018 or after. The transition nevertheless would probably be faster than 40GbE and could hasten 100GbE adoption in the core. Vendors are likely to beef up their 100GbE offerings, and eventually introduce native 25GbE switch ports, in preparation for the upgrade.
- **Bottom line.** We believe 25GbE offers a more compelling upgrade path to 100GbE for cloud providers and later enterprises. The vendors will gain an opportunity to engage with the cloud providers and work to protect their footprints from white box vendors while enterprise uptake could drive accelerated overall spending. We see Cisco and Arista as key potential beneficiaries.

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The Case for 25GbE vs. 40GbE

Executive Summary

Cloud providers have migrated from 1Gb Ethernet (1GbE) port connections to 10GbE over the past three years in demand for higher throughput and faster performance. But just as 1GbE connections proved inadequate three years ago, the continued surge in application workloads and the resulting rise in cloud traffic have spurred an initial move toward 40GbE/100GbE. One would think that faster is better, but most cloud applications actually don’t need 40GbE yet and won’t need 100GbE for some time. When factoring in the high cost of 40GbE (hardware and cabling) and considering unutilized throughput, the economic benefits of an upgrade might not be what they seem. Making matters worse, a move to 40GbE does not future-proof environments for the eventual move to 100GbE.

Enter 25GbE, a simpler, cost-effective way for cloud providers to gain higher throughput. On July 1st, the 25GbE Consortium was formed with founding members including Arista, Broadcom, Google, Mellanox, and Microsoft with Cisco and Intel joining as well. Broadcom announced it would ship 25GbE server controllers and Microsoft announced it would use 25GbE (and not 40GbE) in new cloud deployments. As detailed in this note, we believe 25GbE provides a more flexible and cost-efficient switch and cabling upgrade path on the way to 100GbE. This is achieved by reusing cabling and switching elements in the 100GbE upgrade cycle, something that can’t be done when upgrading first to 40GbE.

Cloud providers have long struggled to keep equipment cost low and have only recently upgraded from 1GbE to 10GbE. Scaling to 100GbE could cost 2x-3x more. With 25GbE, cloud providers can wire their entire data center once leveraging 100GbE switch ports at the top of the rack and using discrete cabling elements (two transceivers and a cable). This design could later scale up 16x (to 100GbE to 400GbE to the server) while reusing many of the cable and switch components first installed at the 25GbE upgrade. On the other hand, moving from 10GbE to 40GbE would require complete rip-and-replacement again when moving into 100GbE down the road. With cabling costs running at around 20%-25% of deployment, the savings could be material.

Google and Microsoft already announced plans for 25GbE, and we expect other cloud providers to learn quickly from one another and it’s likely that others will follow suit and are already looking at 25GbE starting in 2015/16. While we expect cloud SPs to be the first movers, we believe enterprise needs are modest and would likely be addressed only after IEEE standardization (2018 and beyond) before moving forward more aggressively.

As for the vendors (Cisco, Juniper and Arista), we believe 25GbE provides an opportunity to engage with the cloud providers and convince those that are considering white box solutions to stick with vendor-based solutions. We believe some cloud providers would keep an open mind. As for the enterprise, we expect adoption to take longer and begin only in 2018 after IEEE standardization. Nevertheless, we believe the transition could drive upside as we expect 25GbE uptake to be faster than what a 40GbE upgrade cycle would be. It could also accelerate the adoption of 100GbE solutions. Longer term, optics and cable revenue could come under pressure as they could be purchased discretely from third parties. That said, cables and optics are more often than not bundled with switches. Thus, we believe most would enterprises would still stick with vendor-based solutions.

Bottom line—We see 25GbE as an attractive alternative to 40GbE in cloud environments, providing material cost savings and future-proofing environments for 100GbE deployments. Switch vendors could leverage 25GbE to protect strongholds from white box vendors at cloud providers and benefit later as enterprise adoption begins. Slight positive to Cisco, Juniper and Arista.
Faster is better, but one step at a time...

In demand for higher throughput and faster performance, Cloud provider data centers have migrated from 1Gb Ethernet (1GbE) port connections to 10GbE over the past three years, driving strong growth in 10GbE port shipments and revenue from 1Q10 to 2Q14. Consequently, 10GbE revenue in 2Q14 accounted for nearly ~40% of the overall switching market’s revenue, up from ~25% in 1Q10 while 10GbE port shipments accounted for over 8% of total port shipments or nearly 4x 1Q10 levels (~2%). But just as 1GbE connections proved insufficient years ago, the continued surge in application workloads, social media and content consumption and the resulting rise in cloud providers’ data center traffic has left them looking to upgrade again, spurring an initial move toward 40GbE and 100GbE.

Exhibit 1: 10GbE and 100GbE Switching Revenue

![10GbE Switching Revenue Chart]

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10GbE Switching Revenue

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Revenue (in Millions)</th>
</tr>
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<tbody>
<tr>
<td>1Q10</td>
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YoY Growth

<table>
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</tr>
<tr>
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<td>2Q13</td>
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<td>4Q13</td>
<td>100%</td>
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<tr>
<td>2Q14</td>
<td>100%</td>
</tr>
</tbody>
</table>

Revenue Contribution

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Contribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Q10</td>
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<td>4Q13</td>
<td>100%</td>
</tr>
<tr>
<td>2Q14</td>
<td>100%</td>
</tr>
</tbody>
</table>
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Naturally one would think that faster is better; just put in 40GbE/100GbE connections and the rising traffic challenge is solved. However, we believe that most cloud applications and environments do not require 40GbE throughput just yet and won’t need it for some time.
And when factoring in the high cost of 40GbE (new hardware and cabling) and considering that currently 40GbE throughput largely goes unutilized for most cloud applications, the economic justification of such an upgrade cycle is questionable.

As an alternative, we believe that most cloud provider data centers are using multiple 10GbE connections between the servers and switches instead of new switches that accommodate 40GbE connections. The same holds true for 100GbE: most current 100GbE deployments are simply ten lanes of 10GbE connections. To date, most “true” 40GbE switch ports are deployed as uplinks on top-of-rack (ToR) switches as a connection to end-of-row or aggregation layer switches rather than downlink server-facing ports. By using multiple 10GbE ports as opposed to deploying true 40GbE or 100GbE downlink connections, cloud providers can scale throughput in a linear way.

Nevertheless, while multiple 10GbE connections can scale in a linear fashion, smoothing out speed and cost increases associated with higher throughput, most cloud data center operators know what is to come (the need for “more”) and thus are thinking about the best way to scale in the future with 100GbE in mind as an end goal. The dilemma could be considered in the following way:

*At this rate, my 10GbE server ports could become throughput restrictive by the end of next year. But do I really need 4x the capacity now? And if I buy 40GbE switches, can I eventually scale from 40GbE to 100GbE later without ripping-and-replacing everything? Do I need to buy new switches again? Replace all my cables?* – CIO/CTO dilemma.

We believe 40GbE deployments can be somewhat cost-prohibitive for cloud providers as they introduce a costly intermediate upgrade step between 10GbE and 100GbE with limited hardware and cabling reuse. This, we believe, makes 40GbE deployments cost-prohibitive for large cloud providers that already today need to think about future 100GbE deployments. What to do? 25GbE to the rescue…

**Where did 25GbE come from? A brief history**

In 2008, Broadcom introduced its first 10GbE server controller. In servers, the controller is the chip that essentially acts as the connection point for servers with the network. The product was successful, and Broadcom quickly landed HP’s blade server business and Google as its first key customers. Leveraging its relationship with Google, Broadcom was able to land not only the server controller business but also won Google’s switch silicon business. Utilizing commodity hardware and Broadcom silicon, Google replaced its old Force10 (acquired by Dell) ToR switches with its own custom-made ToR switches. The result was the formation of what the industry now refers to as “white box” switches.

Fast-forward to 2Q14, white box switches have grown to account for roughly ~3% of the overall switch market, driven largely by cloud provider deployments. Broadcom dominates the white box market, having nearly 100% share in this category after growing its share of the ToR white box switch market nearly every quarter since inception. Given the advantages that Broadcom’s merchant silicon brings, switching vendors have taken notice, adopted the silicon as well as pushing Broadcom’s share to nearly 50% of the silicon in the total ToR market (Cisco being the other dominant silicon vendor with a few others in the 1% range).

As Broadcom focused more on switching silicon, it slowly lost its high-end sever controller business (10GbE+), which deteriorated to only 21% of 10GbE server port shipments in 2013, down YoY in a growing market and well off peak share of 37% in 2010. With its controller business no longer best-in-breed, Broadcom decided to divest its 10GbE and higher speed server controller business to QLogic in January of 2014 (keeping its 1GbE controller segment, where it still maintains competitive share).
Even though Broadcom had lost share in cloud and high-end server controller chips, the sale of the controller business appeared odd to many industry participants considering cloud and high-end enterprises data centers were the wave of the future. But six months later Broadcom had its answer—it announced its plans for 25GbE server controller chips that could scale to 100GbE linearly offering smaller incremental bandwidth steps and hardware/cabling investment protection when moving to 100GbE down the road. Suddenly, the 40GbE upgrade cycle appeared redundant in cloud provider data centers.

On July 1st, the 25GbE Consortium was formed with founding members including Arista, Broadcom, Google, Mellanox and Microsoft. Cisco and Intel joined the party shortly thereafter, adding credibility, and momentum started to build when Broadcom announced plans for 25GbE server controller chips and as Microsoft announced it would be using 25GbE (and not 40GbE) in all of its new cloud deployments.

As we will later explain, we believe a 25GbE connection speed offers a more flexible and cost-efficient upgrade point from 10GbE for cloud providers on the long-term path to 100GbE connections. We believe the technology could be attractive to enterprises as well but believe this would take time and a more established standardization process.

### An easier 100GbE migration path

Cloud providers have always struggled with the task of keeping equipment cost low given their massive build plans and the need for high-performance servers, switches and lots of storage in support. In recent years, they upgraded their switching infrastructure from 1GbE to 10GbE, replacing not only switches but also the cabling (from 1G Base-T to SFP+). We estimate that scaling to 100GbE could be two or three times more expensive than the upgrade cycle to 10GbE.

We believe that with 25GbE, cloud providers can wire their entire data center once with the ability to scale up 16x (from 25GbE to 400GbE), leveraging the same cabling down the road. This would extend the life of cable infrastructure from 3-5 years to 10 plus years. On the other hand, we believe that moving from 10GbE to 40GbE would require multiple cabling and switch upgrades to get to higher 100GbE+ down the road. This is important as we estimate that cabling costs could account for ~20%-25% of deployment cost.

Let’s examine first the current state of cloud provider data centers. Most common deployments today are of 10GbE server to 10GbE switch connections (SFP+ to SFP+) or 4x10GbE server to 40GbE switch connections (4xSFP+ to QSFP). As Exhibit 2 shows, these cables represent one integrated connection composed of two transceivers and a cable in between. These elements cannot be separated and are purchased as one unit.

### Exhibit 2: Current Cloud Server-Switch Connection

<table>
<thead>
<tr>
<th>Server Side</th>
<th>Switch Side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Speed</td>
<td>Transceiver</td>
</tr>
<tr>
<td>10GbE</td>
<td>SPF+</td>
</tr>
<tr>
<td>40GbE (4x10GbE)</td>
<td>4x SFP+</td>
</tr>
</tbody>
</table>

One Cable Element

Source: Oppenheimer & Co.
The first upgrade path is the traditional one with 40GbE on the server. In this case, if the cloud provider didn’t use 40GbE ToR switches, new switches would need to be installed. In addition, new cabling supporting 40GbE server connections and 40GbE switch connections (QSFP to QSFP) would need to be installed. As Exhibit 3 shows, here too the cables represent one integrated connection composed of two transceivers and a cable in between. These elements cannot be separated and are purchased as one unit and thus require a complete rip-and-replacement of the cabling infrastructure.

The complication comes when a further upgrade to 100GbE on the server is contemplated down the road. Again, the switch infrastructure would need to be upgraded to support 100GbE connections and, in addition, new cabling supporting 100GbE server connection and 100GbE switch connection (QSFP28 to QSFP28) cables would need to be installed. As Exhibit 3 shows, these cables are separate elements composed of two QSFP28 transceivers and one cable in between. Nevertheless, all of them would need to be purchased, and nothing of the existing cable infrastructure would be reused.

Exhibit 3: Traditional Cloud Upgrade Path to 40GbE, Later to 100GbE

<table>
<thead>
<tr>
<th>Server Side Port Speed</th>
<th>Transceiver</th>
<th>Switch Side Transceiver Port Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>40GbE</td>
<td>QSFP</td>
<td>40GbE QSFP</td>
</tr>
<tr>
<td>100GbE</td>
<td>QSFP28</td>
<td>100GbE QSFP28</td>
</tr>
</tbody>
</table>

Exhibit 3 shows the cable elements in both the server and switch side. The cables are one integrated connection composed of two transceivers and a cable in between. In the suggested 25GbE upgrade path there is some switch and connection reuse in the second 100GbE upgrade step. At first, cloud providers would deploy 25GbE on the server. Here, 100GbE switches would be used at the top-of-rack facing the servers instead of 40GbE. To accommodate for 100GbE, cloud providers would need to update their cable infrastructure to the three-piece cable setup mentioned above, with an SFP+ transceiver on the server side of the fibre cable and QSFP28 transceiver connecting to the 100GbE port on the switch side. Thus far, the upgrade is similar to the first step 40GbE upgrade—both a switch and cabling replacement.

In the suggested 25GbE upgrade path there is some switch and connection reuse in the second 100GbE upgrade step. At first, cloud providers would deploy 25GbE on the server. Here, 100GbE switches would be used at the top-of-rack facing the servers instead of 40GbE. To accommodate for 100GbE, cloud providers would need to update their cable infrastructure to the three-piece cable setup mentioned above, with an SFP+ transceiver on the server side of the fibre cable and QSFP28 transceiver connecting to the 100GbE port on the switch side. Thus far, the upgrade is similar to the first step 40GbE upgrade—both a switch and cabling replacement.

The difference compared to the 40GbE path comes at the second upgrade from 25GbE to 100GbE on both the server and the switch side. First, the cloud provider has already deployed 100GbE switches at the first upgrade to 25GbE. Thus, the switching infrastructure could be largely reused. Second, because the cloud provider already deployed a three-piece cable infrastructure (two transceivers and one cable), the only piece in need of replacement would be the SFP+ transceivers on the server side (replaced with QSFP28, see next page), reusing the transceiver on the switch side and the cable. This allows the cloud provider to scale to 50GbE on the server more easily as an intermediate step if needed.
Exhibit 4: New Cloud Upgrade Path to 25GbE, Later to 100GbE

While new switches supporting higher throughput will still have to be purchased, IT operators can move directly to 100GbE server-facing (top-of-rack) switches, bypassing the 40GbE upgrade altogether—thus extending the life cycle of switching hardware. In the spine and aggregation layers where greater throughput is needed, a similar upgrade can occur as 100GbE uplink ports can scale linearly toward 200GbE and 400GbE speeds.

We also believe 25GbE can assist cloud providers in cabling their data centers for greater distances. Many cloud providers are now so large that the original specs for many fiber options are just too short. The original fiber specs were designed when data centers measured a hundred servers, not for cloud providers that measure in the few hundred thousand servers. Cloud providers have outgrown the distances supported by much of the existing multi-mode fiber and need to move to a single-mode fiber cabling infrastructure to support the distances inside the mega-size cloud data centers.

Our checks suggest that several cloud providers have already started down the road to 25GbE migration, including Microsoft (Microsoft currently utilizes 32-port 40GbE boxes from Arista and Cisco for both the server access and aggregation layer, utilizing cable splitters to connect 10GbE servers to 40GbE ToR switches). The new 25GbE infrastructure will likely utilize a new chip set (“SerDes”) that can support multiple 25GbE server connections (linking to 100GbE switch ports) and 100GbE uplinks as well—similar to the way Trident II silicon supported 10GbE server connections and 40GbE uplinks.

What about enterprise adoption of 25GbE?

So far we have focused the discussion on cloud providers which struggle with scale and are at the cutting edge of technology. But what about the general enterprise market? As history tells us, enterprise migration to 25GbE will take a different route than cloud. As 25GbE technology stands today, it has yet to be adopted by the IEEE as a true standard, and it isn’t a purpose-built switch port (reminder: 25GbE is a server controller chip set that allows for an easier migration path to 100GbE switch connections). As enterprises typically wait for standards to develop before mass deployments are considered, we don’t expect enterprise adoption to occur until 2016 or beyond.

Looking at enterprise adoption today, most environments are still dominated by 1GbE with 10GbE still in infancy stages. We estimate that only 1 of 8 servers ships with 10GbE connections today with the majority shipped into cloud environments. We expect enterprises to begin the migration to 10GbE in 2015 leveraging cheaper 10G Base-T which was not available to cloud providers until now. While cloud providers are in need of higher speeds at incremental cost and investment protection on the path to 100GbE,
enterprises do not. We believe 10GbE would be sufficient for most needs for a long period of time. Thus, we do not expect enterprises to evaluate 25GbE until a formal standard is adopted. It is likely enterprises will stick with 10GbE well into 2016, considering 40GbE or 100GbE (in prep for 25GbE adoption) only at the spine/aggregation layer.

A conservative estimate for 25GbE entering the enterprise is likely two silicon cycles away, putting adoption closer to 2017-2018. By this time, we expect enterprises will need server connections above 10GbE. And given that nearly half of servers will be in cloud provider environments, enterprises are likely to take the cloud route and adopt 25GbE as well. We recognize it’s still early and 40GbE remains a viable and more widely adopted alternative. However, with Broadcom pushing 25GbE, we believe it’s safe to bet that other controller vendors would adopt 25GbE server-switch connection chip sets as well rather than outline a strategy alternative to Broadcom’s and push 40GbE adoption instead.

**Vendor thoughts**

The vendor impact of 25GbE would be minimal and limited to cloud providers through 2016. To put things into perspective, 25GbE was first announced in January of 2014. It typically takes 18-24 months until products ship. Thus, we believe 25GbE will hit production networks only in late 2015 with first substantial volumes in 2016. By 2017, 25GbE could reach parity in port volumes with 40GbE for server access and the introduction of 50GbE into production networks could also occur. By 2018, 40GbE could be relegated to a niche technology with 25GbE server access port shipments far exceeding 40GbE as enterprises adopt 25GbE after it is a formal standard with unique purpose-built 25GbE ports.

If we look at products for server access (downlinks), Arista, Juniper, and Cisco all had significant product launches to support 10GbE server access and 40GbE spines/aggregation layers for their cloud and enterprise customers. While we may see modest enhancements, the form factors will stay similar until the next generation of switching silicon is available. Cloud spend will remain robust, but it remains our view that these vendors will benefit the most by the enterprise upgrade to 10GbE kicking into high gear in 2015 and their current portfolios all support this transition very well.

Given that first deployments of 25GbE will not use a true 25GbE switch port but rather split 100GbE ports, much of the vendors’ current R&D and product roadmap remains unchanged. Vendors are already developing 100GbE spine/aggregation switches, and modifying them slightly to support 25GbE will not be a significant change in R&D cost. Looking past 2016, vendors will likely experience fragmentation as enterprises begin to look at 25GbE, but require a true 25GbE port supported by a standard. At the same time, cloud providers will be demanding 50GbE speeds for server access. Therefore, vendors will have to support a wider range of SKUs. We do not believe this increase in SKUs will impact Arista, Juniper, and Cisco as their volumes can easily support it, but it could cause other vendors in the market to struggle or pick on select end-markets to compete in. Regardless, until 2016, time is on the side of the vendors as cloud customers thinking of adopting 40GbE in 2015 for server access will likely remain at 10GbE or only use 40GbE for mission-critical applications until they fully evaluate 25GbE.

The greatest potential impact on the vendors from 25GbE could come from the opportunity to impact cloud providers’ white box roadmaps. We believe a 25GbE migration could spur some vendor displacement, but white box is not a sure guarantee at any cloud provider. Large cloud providers typically use an upgrade to new silicon or a higher speed as an insertion point for new vendors or white box (true of both Google and Amazon). Yet outside Google and Amazon, most large cloud providers are either in the very early stages of white box deployment (primarily in test and development environments) or are still using vendors as key suppliers. An upgrade to 25GbE is an opportunity for switching vendors to
get in front of their cloud customers with new 100GbE solutions and either defend their footprint or even displace some white box suppliers.

Google and Amazon, already white box customers, are optimized in their white box designs and are unlikely (but not completely) to move toward a vendor in the transition to 25GbE. Microsoft, however, is a wild card. While it currently uses Arista and Cisco, we believe it is evaluating white box switch options and could potentially go down that road. This holds true for Facebook, Apple and Century Link as well. We believe the list of cloud providers picking white box and those picking vendor-based solutions for this transition will not be straightforward, and there could be quite a few surprises. The upgrade to 25GbE actually provides the vendors with an opportunity to reengage with cloud customers that were considering white box solutions and potentially convince some to remain with vendor-based solutions or come to another beneficial agreement that avoids white box (low cost, non-vendor OS support, etc.).

The impact to vendors from enterprise adoption of 25GbE represents a more interesting opportunity. We believe that once 25GbE is standardized, enterprises would be open to more aggressively upgrade to 25GbE than they would have 40GbE. This means an accelerated upgrade cycle in the data center as well as higher 100GbE uptake for spine and core (aggregation layer) switch deployments. We also expect enterprises to consider adopting 25GbE in campus environments as uplinks.

The one risk to the vendors could come from incrementally lower revenue from proprietary optics and cables as those could potentially be purchased discretely from third parties instead of as one integrated solution from the vendors themselves. This issue is limited to enterprise customers as many cloud providers are already buying optics directly from the open market away from the vendors. Nevertheless, cables and optics are more often than not bundled with switches. Thus, even though enterprises could look for third-party cable/optics solutions, we believe most would stick with vendor-based solutions.
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Juniper Networks, Inc. (JNPR - NASDAQ, $22.63, OUTPERFORM)
Microsoft Corporation (MSFT - NASDAQ, $47.52, OUTPERFORM)

All price targets displayed in the chart above are for a 12- to 18-month period. Prior to March 30, 2004, Oppenheimer & Co. Inc. used 6-, 12-, 12- to 18-, and 12- to 24-month price targets and ranges. For more information about target price histories, please write to Oppenheimer & Co. Inc., 85 Broad Street, New York, NY 10004, Attention: Equity Research Department, Business Manager.

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**Oppenheimer & Co. Inc. Rating System as of January 14th, 2008:**

**Outperform(O)** - Stock expected to outperform the S&P 500 within the next 12-18 months.

**Perform (P)** - Stock expected to perform in line with the S&P 500 within the next 12-18 months.

**Underperform (U)** - Stock expected to underperform the S&P 500 within the next 12-18 months.

**Not Rated (NR)** - Oppenheimer & Co. Inc. does not maintain coverage of the stock or is restricted from doing so due to a potential conflict of interest.

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**Oppenheimer & Co. Inc. Rating System prior to January 14th, 2008:**
Buy - anticipates appreciation of 10% or more within the next 12 months, and/or a total return of 10% including dividend payments, and/or the ability of the shares to perform better than the leading stock market averages or stocks within its particular industry sector.

Neutral - anticipates that the shares will trade at or near their current price and generally in line with the leading market averages due to a perceived absence of strong dynamics that would cause volatility either to the upside or downside, and/or will perform less well than higher rated companies within its peer group. Our readers should be aware that when a rating change occurs to Neutral from Buy, aggressive trading accounts might decide to liquidate their positions to employ the funds elsewhere.

Sell - anticipates that the shares will depreciate 10% or more in price within the next 12 months, due to fundamental weakness perceived in the company or for valuation reasons, or are expected to perform significantly worse than equities within the peer group.

### Distribution of Ratings/IB Services Firmwide

<table>
<thead>
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<th>Rating</th>
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<th>Percent</th>
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