

Case Study

# The Philadelphia Stock Exchange

Meeting Performance Requirements While Saving Time and Money with Juniper

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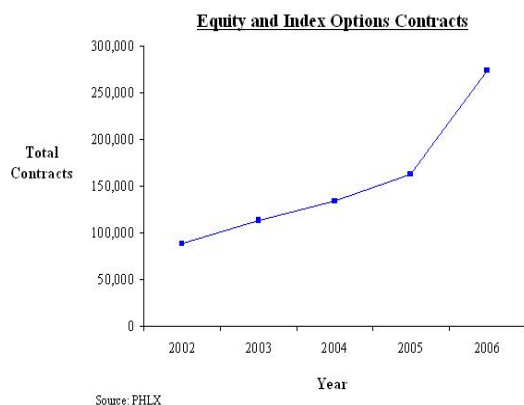
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## Introduction

Since its inception in 1790, the Philadelphia Stock Exchange (PHLX) has prided itself on a tradition of using innovative technology to augment its business. As the first organized securities exchange in the U.S., and the first exchange to have its own site on the World Wide Web, the PHLX has always been at the forefront of trading technology.

Like other stock exchanges, the PHLX provides IP-based systems for stock brokers and traders to trade company stocks and other securities. Currently it lists over 7,000 stocks, more than 2,600 equity options, 17 index options and multiple currency pairs. Through the PHLX, member firms can access and execute trades on three different trading platforms for equities, options, and futures. Within each of those marketplaces, firms can choose from many different products. As Figure 1 shows, the overall transaction volume has increased significantly with a jump of over 70% in just the last two years. The PHLX options trading accounts for 15% of all equity options trades executed in the U.S. (#3 ranking in the U.S., #5 in the world).



*Fig. 1: Growth of equity and index options contracts traded on the Exchange*

## Drivers for Network Upgrades

For the PHLX, staying competitive means providing trading systems that are at the cutting edge of technology in terms of speed, reliability, and accessibility. With other highly competitive exchanges in the market, providing electronic trading platforms that meet clients' needs is vital to the PHLX's success.

Along with the inherent business need to provide high-performance networking for its clients, several factors drove the PHLX's need for a network upgrade:

1. An industry-wide paradigm shift to electronic trading that supports virtual transactions from remote locations
2. The SEC's overhaul of the national market systems (Reg. NMS) and customer demand for improved transaction speed (latency)
3. The planned shift to "Penny" priced options that would lead to significant growth in options messaging and trading traffic
4. Significant organic growth in network transactions resulting in latency slowdowns and the need to improve overall performance

To proactively address these capacity issues, the PHLX decided that a network upgrade was needed. It was the Exchange's hope that a network upgrade would also allow them to expand the usability of its multiple trading platforms and capture increased trading volumes ahead of demand.

## Customer Requirements

To accommodate its objectives for a network upgrade, the PHLX identified several buying criteria. Specifically the PHLX required:

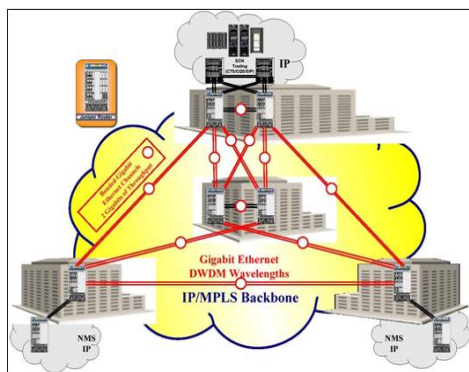
- Ultra low latency
- Carrier class reliability and stability
- High availability

In support of meeting these criteria, the PHLX designed bench tests that would measure hardware performance in three critical areas:

- Performance
- Throughput
- Latency

After running over 1,200 test scenarios on different brands of network hardware, the PHLX concluded that Juniper Networks hardware best fit its network needs.

*"We took normal traffic levels and tripled them for testing. With Juniper we saw no deviation of the latency of the platform. This was simply not the case for other equipment we tested,"* said Frank Ziegler, VP of Communications at the PHLX.



Source: JNPR

Fig. 2: PHLX Network diagram.

The PHLX then teamed up with Juniper and AboveNet to create an Institutional Regional Optical Network (IRON). The architecture of the IRON is shown in Figure 2 above. The IRON not only helps the PHLX meet its customers' latency requirements but also addresses the need for increased network performance, reliability, operational efficiency and flexibility.

The switched IP backbone of the IRON creates multiple universal access options for all of the PHLX's trading systems and increases connectivity between the exchanges' multiple locations in Pennsylvania, New Jersey and New York. At each co-location site the PHLX has deployed Juniper Networks M320 routers each with multiple parallel GB Ethernet links in the MPLS backbone.

One of the benefits of the IRON architecture is the ability to run Multiprotocol Label Switching (MPLS). MPLS operates between layers 2 and 3 in the OSI stack, and enables more efficient application management. By explicitly identifying routes that traffic can take through a TCP/IP network, an MPLS system increases the speed of information transfer. With Juniper's MPLS the PHLX can run two unprotected optical lines over diverse paths. By doing this, it is able to utilize both lines concurrently for load balancing. "Because of Juniper's MPLS capabilities, we can leverage our optical infrastructure better. We no longer have half of it sitting in insurance mode – so we have effectively doubled our capacity," said Ziegler.

## Network Performance Results

Following the deployment of the IRON, the PHLX enhanced its already efficient network in the following areas:

- **Reliability** - reduction in duration and frequency of unplanned outages as well as reduction of healing time to improve network availability
- **Performance** - combination of throughput and latency, which improves scalability
- **Flexibility** - the ability to easily add capacity, services, and customers to the network

The specific benefits realized by the PHLX are as follows:

**Reliability – 99.999887% network reliability, system healing between 5 and 10 ms**

For the PHLX, minor deviations in reliability are unacceptable. Business success hinges on the client's ability to rely on lightning fast transactions to execute trades. To optimize their performance, member firms monitor the exchanges' latency seeking out the fastest trading exchanges. Exchanges are often chosen based on raw transaction speed and reliability. If a network slowdown occurs, member firms automatically switch to trade through another exchange. A client switch could result in the exchange losing its business for a day or multiple days. For the PHLX, there is "an almost immeasurable cost to us for reliability – we have to be 100% reliable all the time," said Ziegler.

With the addition of Juniper to the network, the PHLX achieved 99.999887% reliability not just from each router individually, but from the entire coupled IRON chain.

In addition to reliability, lab tests from the PHLX demonstrated that Juniper's MPLS with fast-reroute can self-heal (i.e. re-route and re-converge) in between 5 and 10 milliseconds - a considerable improvement over Open Shortest Path First (OSPF) which typically takes 10-40 milliseconds to re-converge.

### Performance – 50% reduction in latency

The creation of the IRON helped the PHLX meet its customers' need for ultra-low latency. Prior to the network expansion, the Exchange's latency ranged from 4-6 milliseconds. Post network upgrade, latency through the entire network (Juniper MPLS and IRON) ranged from 2.8-3.1 milliseconds (through the Juniper components in isolation the latency was 12 $\mu$ s). (See Figure 3). "We live and die based on our ability to provide access and low latency trading to our clients," said Ziegler.

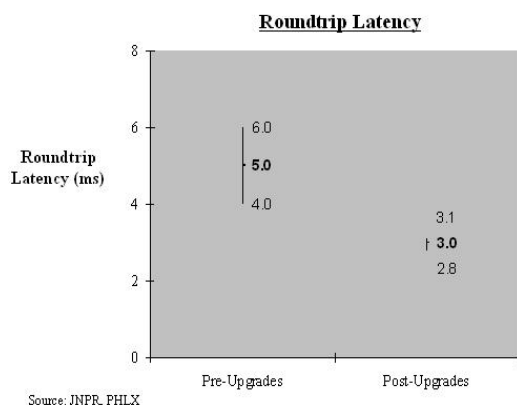


Fig. 3: Roundtrip latency with JUNOS software

For the PHLX, it was critical that regardless of network load and services running on the routers, it could rely on the same latency through all routers on all ports. According to Ziegler, Juniper routers' architecture is the key component that enables such low latency: "What sets Juniper routers apart from a latency standpoint is the switching fabric embedded in their routers." In addition, placement of Juniper Networks M320 routers at co-location sites closer to the New York metro area reduced the delays over distance and made roundtrip latency significantly faster.

### Flexibility – achieving "capacity on-demand"

From a network perspective, flexibility is the ability to easily add infrastructure without loss of network stability or reliability. It enables networks to scale efficiently without additional capital expenditure or a network redesign.

With the IRON, the PHLX can take advantage of increased bandwidth capacity using Dense Wavelength Division Multiplexing

(DWDM) technology. In contrast to multiple OC12c services through a traditional carrier, DWDM combines multiple optical signals from routers and carries them over fiber links. By using DWDM technology, the PHLX can easily add capacity to its existing network to support customers as needed. "The flexibility with Juniper comes from the fact that when we want to add bandwidth, we don't need a network engineer to sit in a room and work on a network redesign," said Ziegler.

Juniper's single code train across core network hardware components enables incremental infrastructure hardware to be added easily as capacity thresholds are reached. With JUNOS software on its network hardware, the PHLX found that it could scale quickly by upgrading line cards. "Having Juniper hardware means capacity on demand...we can have incremental growth without a network infrastructure overhaul. We have future-proofed our capacity needs," said Ziegler.

### Network Operations Results

The improvements in reliability, performance, and flexibility that the PHLX achieved with the Juniper-based network also created meaningful enhancements in network operations efficiency. Operational efficiency means that network operations teams can spend less time on routine network administration and daily maintenance and can focus their time on more critical network tasks. The most common (and time consuming) tasks for the PHLX network operations team were:

- Monitoring and upgrading
- Managing unplanned events
- Troubleshooting

With JUNOS software, the network operations team at the PHLX could more efficiently and effectively manage these specific network tasks. Specific results will be discussed in the following sections.

### Monitoring and Upgrading – significant productivity gains, 75% less time spent upgrading

Like many financial institutions, the PHLX spends a significant amount of time monitoring its network. Since deploying Juniper network hardware, they have realized significant productivity gains – staff that was formerly devoted

entirely to monitoring can now work on other operational projects in tandem. *“Now that we have JUNOS software in place we spend virtually no time monitoring network performance. Because those monitoring requirements have gone down, we can give operations personnel other projects to do concurrently,”* said Ziegler.

Ziegler points to JUNOS software’s features that allow for proactive monitoring so problems can be preempted before they impact the entire network. For example, JUNOS software’s custom operation scripts and event policies allow network operations teams to identify and proactively resolve issues automatically so the network can stay up and running at all times. *“With JUNOS software we are no longer in reactive operations mode – we are now in proactive tactical mode,”* said Ziegler.

Before the PHLX implemented JUNOS software, the upgrading process was sometimes cumbersome. *“To do even routine upgrades, someone on the network operations team had to touch every single device,”* said Ziegler. Since the network upgrade, Ziegler reports that upgrading with JUNOS software is more intuitive and takes approximately 75% less time than with other operating systems. *“Because of JUNOS software’s single code train we can automatically configure all the routers in the network,”* said Ziegler.

**Unplanned Incidents - 72% reduction in frequency of unplanned incidents**

Though the PHLX rarely has network outages, it can experience incident events that have the potential to reduce services levels. Accordingly, incidents are carefully tracked and monitored. Due

in part to having Juniper network infrastructure and JUNOS software running, the frequency of unplanned incidents has decreased by 72%. (See Figure 4)

With JUNOS software running, the PHLX realized overall improvements in performance and service levels. Since the deployment of Juniper routers in 2007, the PHLX has not had a single network outage. In contrast, before the network upgrade it suffered several network outages that resulted in lost revenue.

**Troubleshooting – significant reduction in time spent resolving trouble tickets**

For the PHLX, one of the most significant benefits of upgrading to JUNOS software is the reduction in time spent dealing with moderate and severe trouble events. Prior to the network changes, trouble events often required manual intervention by the network operations teams. Though extremely rare, the most extreme events required the complete shutdown of backbone class devices.

*“If there was a network service problem, it was all hands on deck. I would have to grab a team, go to the NOC and try to figure out what had happened. It was a reactive process to an event that already occurred,”* said Ziegler.

With its advanced troubleshooting functions and self-healing capabilities, JUNOS software better enables the PHLX to handle severe events remotely, often without manual intervention. *“With JUNOS software we are able to be proactive and most of the time someone knocks on my door and says ‘hey, there was a problem, but it is already fixed,’”* said Ziegler.

Before the network upgrades, resolving and closing one of these trouble tickets would typically take two hours. With JUNOS software running, the network operations team can close a trouble ticket in an average of 30 minutes – a 75% reduction in time spent troubleshooting. (See Figure 5).

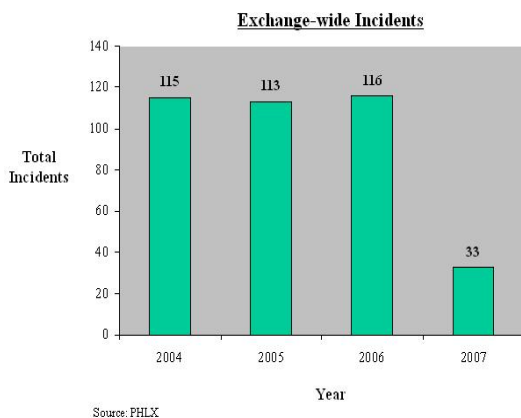
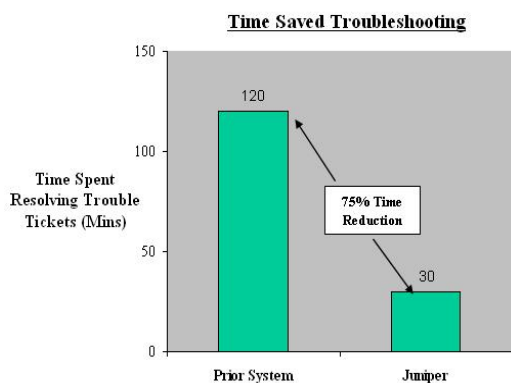


Fig. 4: Frequency of unplanned network-wide incidents



Source: Lake Partners' Research

Fig. 5: Estimated time saved troubleshooting with JUNOS software

### Financial Results

In addition to network performance and operational benefits, the PHLX realized the following improved financial results:

- Reduced OpEx due to increased staff productivity and moving away from OC12c services
- Lower CapEx stemming from better scalability of deployed infrastructure
- Increased customer satisfaction and loyalty

#### Savings - \$10.2M OpEx savings, \$1M CapEx

A combination of decreased connectivity costs, improved operational performance, and improved staff efficiency contributed to an expected total of \$10.2M OpEx savings over the next five years. Somewhat surprisingly, it was more cost-effective for the PHLX to deploy their own proprietary optical network than to continue to partner with a traditional carrier. The IRON not only keeps the cost of ownership low but also provides additional bandwidth to support increased transaction volume and messaging rates.

Juniper's reliability helped the PHLX to avoid additional operating costs from having full-time staff at remote sites. Typically, the PHLX would have required 3 full-time employees to manage remote sites. Because JUNOS software enables network operations teams to get preemptive network anomaly reports, having staff at each site is unnecessary. "JUNOS software is so reliable that we don't have to staff the remote sites. This saves us a lot of money," said Ziegler.

By planning in advance for capacity issues, the PHLX preempted the need for additional infrastructure and capital expenditures. Because of its proactive capacity planning and network expansion, the PHLX expects to realize savings of ~\$1M in 2008. In part, this CapEx savings is due to the scalability of the Juniper routers deployed by the PHLX. The Juniper Networks M series routers deployed by the PHLX can run at high line rates without packet loss or delay thus enabling the PHLX to take full advantage of its 320Gbps fabric speed. By deploying Juniper hardware, the PHLX eliminated the need to purchase more capacity near-term, instead relying on its ability to increase the capacity through each Juniper router.

#### Potential Revenue Increases – renewed customer loyalty

In part by creating the IRON and deploying Juniper routers, the PHLX enhanced the satisfaction and loyalty of its existing customers. "If we had not upgraded, it is possible customers would have taken their business elsewhere. Now that we have a faster, more reliable network, we are pretty confident they will stick with us," said Ziegler. By increasing customer confidence in the system, the PHLX hopes that it can continue to capture additional trading volumes going forward.

The IRON generates savings for the Exchange's customers as well due to co-location. Having network hardware close to its member clients creates savings by reducing the need for duplicate customer hardware at connection points. By deploying hardware at co-location sites, Ziegler estimates that the PHLX's customers may be able to realize savings up to \$100,000 per year in OpEx and as much as \$120,000 in CapEx.

#### Juniper Differentiators

The benefits realized by the PHLX are consistent with other Juniper customers' experiences. In line with previous research conducted by Lake Partners Strategy Consultants, the operational results the PHLX experienced are also reported by other customers using Juniper network hardware and software. The research done by Lake Partners focused on understanding the efficiencies created by different operating systems and indicated that operating systems play an important role in network availability (reliability) and operations.

Based on interviews with over 100 network operations team leaders, significant improvements in network availability were recognized by those who used JUNOS software. Compared to other vendor solutions, Juniper customers reported JUNOS software significantly reduced the frequency and duration of unplanned events by an average of 24% and 30% respectively (see Figure 6).

Network Availability Metric	Avg. Reduction With JUNOS
Frequency of Unplanned Events	24%
Duration of Unplanned Events	30%

Fig 6: JUNOS software impact on frequency and duration of unplanned events

In addition, those who used Juniper were able to quantify meaningful improvements in routine network operations as a result of using JUNOS software. Figure 7 below shows the average network operations efficiencies created by JUNOS software.

Network Operations Task	Avg. JUNOS Efficiency
Adding Infrastructure	29%
Upgrading & Planned Events	23%
Troubleshooting & Unplanned Events	54%
Monitoring & Optimizing	24%
<b>Avg. Time Saved With JUNOS Software</b>	<b>25%</b>

Fig 7: Average time saved with JUNOS software in key operational areas

The features of operating systems that contribute most to high reliability are:

- Modular and redundant architecture
- Independent control and forwarding planes
- Commit check functions
- Advanced troubleshooting tools

The modular architecture of Juniper hardware contributes to high reliability by preventing a failure of one process to necessarily affect the entire system. Even during control plane restarts, forwarding continues. In addition, Juniper Networks M series routers all have independent control and forwarding plane processors to allow for the separation of functions. Built-in redundancy enables quick recovery from unplanned events and

graceful switchover means networks can stay running during planned, or unplanned, outages.

Coupled with the modularity of Juniper’s architecture, JUNOS software’s advanced functionality helps maintain high network reliability. JUNOS software’s commit check functions reduce the frequency of unplanned events by catching configuration errors prior to implementation. Troubleshooting tools allow configuration changes to be checked and compared to previous settings before network-wide implementation.

In addition to reliability, Lake Partners’ research found that operating systems allow for increased network flexibility and operational efficiency by having the following characteristics:

- A consistent operating system
- Interoperability with existing network infrastructure
- Advanced monitoring tools
- Multiple supported IP protocols

Lake Partners’ research highlights several ways in which JUNOS software improves operational efficiency. First, JUNOS software’s single code train across core network components makes planning for, and carrying out, routine tasks quick and easy. Second, JUNOS software is interoperable with a wide variety of other brand hardware so new components can be added incrementally as capacity thresholds are reached or new services are necessary. Third, Lake Partners’ research indicates that JUNOS software’s advanced monitoring tools allow customers to more effectively monitor performance levels of network hardware. Finally, they found that because JUNOS software supports multiple IP protocols, handling network growth is less complicated.

Given the results of Lake Partners’ previous research, it is not surprising that the PHLX has experienced similar benefits after its network upgrade.

**Summary**

In the end, the Philadelphia Stock Exchange’s network upgrade resulted in increased performance, more efficient network operations, and financial savings. By working with Juniper Networks to create a reliable, flexible and cost-effective network, they have been able to maintain a technical competitive edge and remain one of the premier exchanges in the country.

*Lake Partners is a Seattle based strategy consulting firm. We blend data and analysis with expertise and experience to help mid to large sized companies achieve their financial and business goals. For more information please visit our website (<http://www.lakepartners.com/>).*

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