the Availability Digest

Nasdaq Taken Down by Software Flaw
September 2013

Thursday, August 22, 2013, was a bad day for the stock market. The Nasdaq stock exchange went down for most of the afternoon, halting trading in major stocks such as Microsoft, Apple, Google, and Facebook. 3,200 stocks were paralyzed. The outage is being called the "flash freeze" after the 2010 "flash crash" during which high-frequency computer trading dropped the Dow by 1,000 points for a few minutes

Initially, Nasdaq offered no explanation for the outage. Then, over the next several days, there was active fingerpointing between Nasdaq and its major competitor, the New York Stock Exchange (NYSE). Finally, Nasdaq admitted that the outage was caused by a software failure in one of its systems, but one that was aggravated by the NYSE. A heavy burst of messages from the NYSE electronic trading system overwhelmed Nasdaq's market reporting system, and Nasdaq suffered a failover fault as it tried to switch to its backup system.

The Outage

The problem began when Nasdaq's Securities Information Processor (SIP) became overloaded. SIP drives the data feed that delivers pricing information to the "consolidated tape," the national record of all securities quotes that ensures that trades occur at the most competitive price.

When it became apparent to Nasdaq that SIP was unable to report Nasdaq price quotes on a timely basis, it decided to halt all trading until the problem could be resolved in order to ensure a fair and orderly market. Trading was halted at 12:14 PM. The Nasdaq markets finally reopened at 3:25, just thirty-five minutes prior to closing. Stock prices were stable when the Exchange reopened.

Apple stock during the flash freeze

Nasdaq shared little information during its outage, sowing confusion among traders and investors. Nasdaq traders weren't immediately aware that Nasdaq had stopped trading. It took almost two hours for Nasdaq to send a message acknowledging the outage. This message is critical to automated trading systems that use it to stop trading in halted stocks.

Ultimately, Nasdaq blamed the NYSE's Arca electronic trading system for sending heavy blasts of messages to SIP that overloaded SIP and caused its failure. SIP was restored in thirty minutes, but it took almost three hours to return it to service.

The Fingerpointing

The SEC immediately asked Nasdaq and the NYSE to come up with a timeline of the outage. It took almost a week to do so because Nasdaq and the NYSE could not agree on details. They each had a

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different view as to what happened before and during the outage and blamed the other party for the failure.

What they did agree on was that Arca experienced difficulties connecting with SIP during the morning of August 22. Arca tried over twenty times to connect with SIP, each attempt requiring that significant resources be expended by SIP.

With each attempt came a blast of messages from Arca. Nasdaq characterized these messages as containing inaccurate symbols to which it had to respond with quote rejects. The NYSE countered that connectivity problems were common. When it has connectivity problems, its common practice is to send out "zero quote" messages to ensure that no stale trades would be sent to the market.

Nasdaq believed that Arca's connectivity problems and consequent message floods led to a potential freeze in SIP as its memory reached capacity. It shut down the Arca connection before the SIP froze. Its servers were overwhelmed, and it was unable to switch over to its backup system.

NYSE's view of the outage was that Nasdaq inadvertently shut down the Arca connection for fifteen minutes. Connection was reestablished and ran properly for 45 minutes. Nasdaq then requested that Arca voluntarily shut down the connection. The NYSE believed that this exposed a flaw in the Nasdaq system. No matter what, SIP should not be going down.

Nasdaq's Admission

About a week after the outage, Nasdaq concluded its study and published the results in its newsroom.[1] It concluded that the outage was partly its fault due to a software bug, but that the outage was mostly the fault of Arca.

According to Nasdaq's findings, the problems started around 10 AM when Arca could not connect to SIP. Arca tried more than twenty times that morning to connect. Between each attempt, it sent out a mass of zero-dollar quotes to ensure that no stale trades would be reported. SIP had to respond with quote rejects to each of these messages.

The problem was the rate at which Arca was sending these messages – about 1.3 million messages per second! SIP had been designed to handle the expected peak traffic from its member exchanges with ample extra capacity. It has fifty communication ports, and each port can handle 10,000 quotes per second for a grand total of 500,000 quotes per second. This capacity had been verified by Nasdaq in a test conducted the previous January.

A normal rate for an August day is about 1,000 quotes per second per port, one-tenth of the port's capacity. The Arca message rate amounted to 26,000 quotes per second per port – 2.6 times the capacity of the SIP ports.

Nasdaq turned off Arca's access to SIP around 11 AM. By 11:17, Arca seemed to be working properly. However, the immense amount of data sent by Arca overwhelmed SIP. The Nasdaq attempted to recover by switching over to its backup, but a latent software flaw made the failover ineffective. With the backup system in operation, there were long delays in reporting quotes. The combination of large system inputs and delayed outputs ultimately degraded the ability of the SIP to process quotes to such an extent that shutting down the system was in the broader public interest to prevent information asymmetry and to ensure fair conditions for all market participants. Nasdaq decided to halt trading at 12:14 PM.

Within a half hour, Nasdaq had SIP up and running. However, it took another three hours to test the system and to evaluate scenarios with its SIP committee members and market participants to reopen the market for fair and orderly trading. The Nasdaq market reopened at 3:25 PM and performed properly until its normal closing time at 4 PM.

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[1] NASDAQ OMX Provides Updates on Events of August 22, 2013, *NASDAQ OMX Newsroom*; August 29, 2013.

Nasdaq said that it was "deeply disappointed" in its performance and called it unacceptable to its members, issuers, and the investing public.

A major Nasdaq failure was in not keeping the trading and investment community informed as to what was happening. Nasdaq is studying ways to post information in real time, including social media such as twitter, and opening up additional phone lines for market participants to hear directly from Nasdaq officials.

This outage exposed serious flaws in the design of SIP. It was not designed to throttle, or forcefully slow down, the flow of data to prevent overload. Nasdaq is studying plans to make SIP more resilient, including architectural improvements, information security, disaster recovery plans, and capacity parameters.

Summary

Of concern to many, especially after the flash crash of 2010, was the extent to which high frequency computerized trading played a role in this outage. Nasdaq concluded that such trading was not a factor.

However, this outage highlighted the fragility of the world's financial backbone. Last year, Nasdaq was bruised by the botched initial public offering of Facebook. Today's financial systems are so complex and so interactive that it may be impossible to envision every failure scenario. Outages such as this flash freeze are likely to become more common as exchanges and brokerage firms compete to offer the fastest and most comprehensive services.

Nasdaq and the NYSE are currently the top exchanges in U.S. securities. However, that is about to change. The BATS Global Market and Direct Edge exchanges have said that they would merge, creating an exchange larger than Nasdaq in U.S. stock trading. The NYSE is the number one U.S, exchange operator. After merging with Euronext to form NYSE Euronext, it is now merging with the Intercontinental Exchange (ICE).

Exchange systems are only going to get more complex, with more opportunities for headline-setting failures.

Acknowledgements

The information for this article was taken from the following sources:

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SEC reviews Nasdaq as rivals blame each other for outage, *Reuters*; August 27, 2013.
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NASDAQ OMX Provides Updates on Events of August 22, 2013, *NASDAQ OMX Newsroom*; August 29, 2013.
Nasdaq blames rival NYSE Arca for 3-Hour trading outage, *The Register*; August 30, 2013.