UTP SIP MIGRATION AND LATENCY REDUCTION PLAN

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UTP SIP MIGRATION AND LATENCY REDUCTION PLAN

- Performance and Reliability Improvements
- High Level Project Plan
- Acceptance Testing
- Step by Step Migration
- Latency Reduction Plan



INET SIP OBJECTIVES



REDUCE LATENCY

Use the latest INET technology to reduce latency below 50us Go-Live





INCREASE RESILIENCY & RELIABILITY

Industry proven robust architecture offering active/active redundancy, dynamic failover, and active/active disaster recovery



INCREASE CAPACITY

Distributed system which will handle a minimum peak rate of 2 million messages/sec per data feed upon launch

IMPROVE SCALABILITY

Highly scalable architecture allowing for addition of computing assets when additional customer ports or processing capacity is required

SYSTEM IMPROVEMENTS PROTOCOL IMPROVEMENTS

By improving the protocols we aim to increase reliability, resiliency, and introduce efficiency

Binary Protocol Improvements	Legacy Behavior	
Binary values	Ascii values	Lower latConsumeBinary va
Use Nasdaq standard network protocol, MoldUDP64.	Session layer and application layer information is comingled in the same protocol.	 Battle tes efficient Supports level Provides missed p
Participant Consolidated High, Low, Last and Volume.	This information is not disseminated in legacy UTDF	 Data Fee needing Provides
Removal of OTC Montage Data Feed (OMDF). FINRA ADF Participant quotes will be included in UQDF	Top of book quotations for each FINRA ADF participant, disseminated on a separate data feed (OMDF).	 UTP data ADF Parti connecti

Rationale

tency e less bandwidth alues more efficient to read and write

sted Nasdaq standard networking protocol that allows and scalable transmission of data

blocking of messages, so no need at the application

a mechanism for listeners to detect and re-request backets

ed clients can use the calculations statistics without to calculate themselves.

uniformity with CTS feed.

feed recipients that wish to receive the individual Finra icipant BBOs will no longer need to secure and support a on to a separate feed, saving them connectivity costs.

SYSTEM IMPROVEMENTS

OUTBOUND FEEDS REDUNDANCY & FAILOVER



Legacy SIP:

- DR not disseminating simultaneously
- Backend process failover to DR is manual
- Republishers send spoof source IP

INET SIP:

- Disseminate in both Carteret and Chicago simultaneously
 - No failover action required
 - Clients can be ready for failover before it occurs
- New MC group addresses
 - Allows for parallel production and cleaner migration
- No Republishers
 - Less network hops reduces latency
 - Different source IPs will be apparent
- Consensus will automatically promote standby Distribution Channels
 - 2 active, 2 standby in Carteret
 - 2 active, 2 standby in Chicago

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SYSTEM IMPROVEMENTS AUTOMATIC GAP FILL

- Legacy SIP Retransmission Request
 - Email is not reliable
 - Requested messages are broadcasted to all clients
 - Requires manual intervention
- New SIP Automatic Gap Fill
 - Request and response protocol
 - Requested messages are sent only to the requester
 - No manual process

LEGACY SIP Manual Gap Fill







SYSTEM IMPROVEMENTS AUTOMATIC GAP FILL

- Gap fill request sent over UDP to re-request server
- Missed packets sent UDP Unicast to client
- Resent packets may be handled by the same socket on the client side
- Gap fill procedure:
 - 1. Client receives sequence 110, but the last seen sequence is 99.
 - 2. Request packet sent with sequence of 100.
 - 3. Data Persistence Agent A sends requested messages starting at requested sequence number in a Mold64 packet via UDP Unicast



INET SIP PROJECT PLAN

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INET SIP UPGRADE PROJECT PLAN PROJECT TIMELINE

				2016			
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
		SIP Buildo	out				
				Ea	rly Customer Test in NTF	Acceptance Te	st in NTF and Pr
Weekend Estimated	Production Tes	st Dates				<u>Step 1</u> - Paralle Comparison Te	el st <u>Step 2</u>
Apr – Jun 2016	Internal and ECT needed	Integration Test as	0-0-				
7/9/16	UAT – Connectivit	y Only				γ 	
7/23/16	UAT – Full Functio	onality		Weekend Production Tests Internal Test Customer Test		ts	
8/6/16	UAI – Full Functio	onality					
9/10/16	UAT - NON-FUNCTIO	onal Testing					
9/24/16	UAT – Migration F	allback Test					
10/8/16	Confidence Test			Nasdaq M	larket Technolog	y – Confidential 1	rade Secret



INET SIP UPGRADE PROJECT PLAN KEY DATES

- 1 Month Early Customer Test
- 3 Months Acceptance Testing & Parallel System Test
- Final Confidence test before Go/No-Go Call

Event

Binary Message Format Test Early Customer Test NTF Acceptance Test Period (UATs) Parallel Comparison Test (1 moi Parallel BETA Production (2 mor Go/No-Go Call with Exchanges Saturday Confidence Test Go-Live All Channels INET Binar Two Week Fallback Availability Migration Complete

	Expected Start Date	Expected End Date	
	May-16	Jun-16	
	25-May-16	24-Jun-16	
	24-Jun-16	22-Sep-16	
nth)	9-Jul-16	8-Aug-16	
nths)	8-Aug-16	7-0ct-16	
		7-0ct-16	
		8-0ct-16	
y SIP	10-0ct-16		
	10-0ct-16	22-0ct-16	
		24-0ct-16	

ACCEPTANCE TESTING

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ACCEPTANCE TESTING OVERVIEW

Early Customer Test Period (Test Facility & Production)

- Provides Participants early access to new system before acceptance testing begins
- Test Facility (NTF) will be available
- New SIP Carteret and Chicago production hardware will be available on weekends
- Internal testing will be performed, and the system will be restarted as needed without notice

Acceptance Test Period (Test Facility & Production)

- Participants will perform Regression, Connectivity, Functional/Acceptance, and Disaster Recovery testing
- Industry Testing will be performed by Participants and Data Feed Clients
- Testing will occur in the Test Facility (NTF) during the week and production on weekends
- NTF will be available for exchange participants and <u>NTF connected</u> clients

Go/No-Go Call & Confidence Test (Production)

• Following a Go call, and weekend confidence test, the migration will begin on the agreed upon dates

ACCEPTANCE TESTING

TEST DETAILS

- Connectivity testing
 - Each Participant confirms its connectivity via all inbound connections.
 - Verify data is being disseminated out all extranet switches.

Functional/Acceptance testing

- Ensure that the specified functionality is consistent with the observed results.
- Each Participant will perform a full end-to-end test and validate the system delivers their expected results.
- Regression testing
 - Ensure that a change has not introduced new faults.
 - Each Participant will confirm their ability to submit all inbound messages via their connections

- Industry/Integration testing
 - Recipients for testing
 - access.
- Capacity/Performance testing
 - load.
- Disaster recovery testing
 - requirements.

Nasdaq SIP will make available the new INET Binary data feeds to both Participants and Data

Ensure that the System delivers the defined results as detailed in the specifications with respect to Participant and Customer use and

Determine the upper limits of the System's capacity and its robustness under an extreme

Participants will participate in a failover test, coordinated by the SIP, to ensure successful and timely failover consistent with the new

MIGRATION Strategy

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MIGRATION STRATEGY OBJECTIVES

- Low Risk Phases lacksquare
 - No impact to legacy system

- **Extensive Parallel Period**
 - Inputs and outputs run in parallel —

- Fallback Options ${\color{black}\bullet}$
 - Option to fallback available for each step

- - —

 - outputs
- Production Parallel for 2 Months
- No changes before Go-Live
 - in place

Internal Parallel Comparison Test

An adapter forwards the production SRO input transactions into new platform SRO inputs will be processed by the new platform as if it were live Processing end of day results to UTP SIP

Legacy system remains live Participants send inputs to both systems Clients test outputs from both systems

Participants and clients leave configurations

MIGRATION STRATEGY HIGH LEVEL OVERVIEW





MIGRATION STRATEGY

STEP 1: PARALLEL COMPARISON TEST

- Parallel comparison test with production data
- No Production Impact No software or hardware changes to legacy SIP
- Transition Handler forwards production SRO input transactions to INET SIP
- SRO inputs will be processed by the new platform as if it were live
- Results of this processing will be compared at the end of each day to the outputs from the UTP SIP
- Nightly replay of old & new formats



Parallel Comparison Test Procedure

- 1. Participants continue to send to legacy SIP.
- 2. Legacy SIP process and provides a sequenced stream of quotes and trades
- 3. Transition Handler converts the sequenced stream of quotes and trades to input to the new system Customer Ports as regular input.
- 4. Customer Ports consume quote and trade data in the exact same order as Legacy system, allowing the new SIP to perform the exact same calculations.
- 5. Legacy and New output are recorded separately for comparison. A comparison tool will validate the output is logically equivalent.

MIGRATION STRATEGY STEP 2: PARALLEL SYSTEMS

- Active participants send quote and trade data to **both** Legacy and INET SIP
- Legacy SIP remains live
- New SIP uses new multicast groups and new binary format
- Participants and Datafeed clients should use new feeds for beta testing
- No Fallback required
- Legacy SIP output may not correlate 100% due to new functionality and improved efficiencies with the INET SIP (i.e. NBBO and Price Bands may be different between systems)



Prerequisites:

- Successful parallel comparison test
- Successful connectivity and functional tests performed by participant testing in NTF and weekend prod tests

MIGRATION STRATEGY STEP 3: GO-LIVE ALL CHANNELS

- All channels live on new multicast groups and binary format
- Legacy data feeds still disseminating for Fallback
- Completes migration



MIGRATION STRATEGY FALLBACK OVERVIEW

- In the event that a failure can not be resolved on the new system we have a plan for fallback to the legacy system.
 - o Fallback not required for steps 1 & 2.
 - o In Step 3, fallback all Quote and Trade channels



MIGRATION STRATEGY FALLBACK PROCEDURE

Fallback procedure:

- 1. Issue statement to Fallback to legacy feeds. Inform participants we will be performing quote wipeouts for each symbol. This will ensure fresh quotes will be disseminated, even for thinly traded stocks.
- 2. Shutdown INET SIP dissemination
- 3. Increment outbound sequence numbers +100k on quote and trade feeds, to avoid confusion.
- 4. Perform quote wipeout using the Admin UI.
- Participants continue submitting quotes and trades throughout. No Fallback is required, as connections have already been made.
- Trades which were not disseminated will be retransmitted after 4PM. In addition, a flat file of all trades will be provided EOD.
- If any trades data was disseminated incorrectly or corrupt, AS-OF corrections will be sent.
- LULD bands are published every 30 seconds, correcting the case where any LULD bands were not disseminated, or were corrupt.





MIGRATION STRATEGY DR SITE AVAILABILITY



STEP 182 PARALLEL SYSTEMS

- DR and Failover will remain as they today with • no changes.
- Legacy SIP system will only be used for ulletproduction purposes

STEP 3 Go-Live: All Channels

- DR and Failover will now be on the NEW • system.
- The NEW system will only be used for • production purposes





	CHICAGO		
		NEW	
EW	ASHBURN		
		OLD	

LATENCY **REDUCTION PLAN**

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LATENCY REDUCTION PLAN
GOALS

- 1. Reduce end-to-end latency to 50 microseconds at the median by Go-Live
- 2. Reduce end-to-end latency to 25 microseconds at the median by one year post Go-Live



End-to-End Latency

LATENCY REDUCTION PLAN GO-LIVE

Goal: Reduce latency below 50 microseconds



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Upgrade network

10 G network

Lowest latency switches available (200 nanoseconds)

Improve architecture, reducing network hops

Upgrade servers

More Cores, More Cache

More Memory, Faster Memory

Accelerated Network Cards

LATENCY REDUCTION PLAN ONE YEAR POST GO-LIVE

Goal: Reduce latency below 25 microseconds

Software performance tuning

- Live data will identify bottlenecks
- Software modifications will remove bottlenecks, improve efficiencies

Leverage hardware acceleration technology

- Lower level messaging may be a source for improvement
- FPGA technology will allow us to offload processing from software to hardware

Upgrade server and network hardware

- Intel adding cores, improving memory speeds
- More cores allow for greater parallelism
- Faster memory will improve overall performance