

Usage of Exchange Simulators and Test Exchanges as Tools for Ticker Plant Systems Testing

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Abstract—Ticker Plant systems are widely used in modern day trading. They allow collecting in real-time quotes from several markets, present the data in a unified format, and disseminate it electronically depending on requests and goals of external clients, traders. This paper presents a view on the possibility of using market simulators for testing such systems. A set of main functional and non-functional test scenarios required to control the quality of quote dissemination has been identified. A comparison of market simulators and real test markets has been presented. **Keywords:** Ticker Plant, Market Data, exchange, test market, market simulator, functional testing, non-functional testing.

I. INTRODUCTION

It is impossible to imagine modern day trading without up-to-date information about financial instruments, orders, and trades. Highly loaded exchange and brokerage systems provide market data concerning traded financial instruments by means of their own components called Market Data Feeds. Every financial instrument comprises a fair amount of information generated every second. Therefore the ability to disseminate the entire stream of market data and the speed of disseminating market data for each financial instrument are the main characteristics for this type of components of highly loaded trading systems.

1.1. The Main Parameters of Market Data

Normally market data includes the following set of parameters that are specific for a certain financial instrument: Ticker Symbol, Last Trade Price, Best Bid & Offer, ISIN, exchange code, Trade Time, Close Price. Depending on the complexity of highly loaded exchange systems, market data can be processed by the electronic exchange’s internal components and enriched with additional information: e.g., daily turnover, VWAP, and more detailed information about the stock or derivative, i.e. Reference Data including, for instance, parameters of traders, market, trading sessions, and instruments. Reference Data or Static Data is instrument information, which does not change real-time: e.g., International Securities Identification Number (ISIN), price at the close of previous day’s trading session (Close Price), Currency, the parameters of so called “Circuit Breakers” that

are normally presented as percentages of last trade price (Dynamic or Static Circuit Breaker Tolerances (%)), and so on [1].

There is a number of standard quote dissemination protocols, such as, for instance, FIX/FAST [2], the so called quote dissemination protocols with fixed length of messages (e.g., ITCH [3]), or coded data dissemination protocols (e.g., HTTPS (HyperText Transfer Protocol Secure) [4], [5]) for providing the above mentioned information.

To transmit quote information, many electronic exchanges use both standard and bespoke protocols. Often traders cannot afford developing computer applications that would collect quote information required for their work. Therefore there is a need of creating systems allowing collection and aggregation of market data from various exchanges disseminated by using different financial data transmission protocols.

1.2. The Main Functionalities of Ticker Plant Systems

A Ticker Plant is a system of aggregating market data information from various electronic trading platforms (or exchanges) and its dissemination. The system provides market data to the traders in a normalized or unified format [6]. Based on accumulated market data, Ticker Plant systems often calculate additional parameters, i.e. it enriches the static data about stock and derivatives. One other characteristic of Ticker Plant systems is the ability to unite homogeneous values of disseminated quotes - Price Levels, real-time quote data provision based on requests from clients (e.g., such widely used services as Level 1, Level 2, Index, T&S, News) - and storing of disseminated market data.

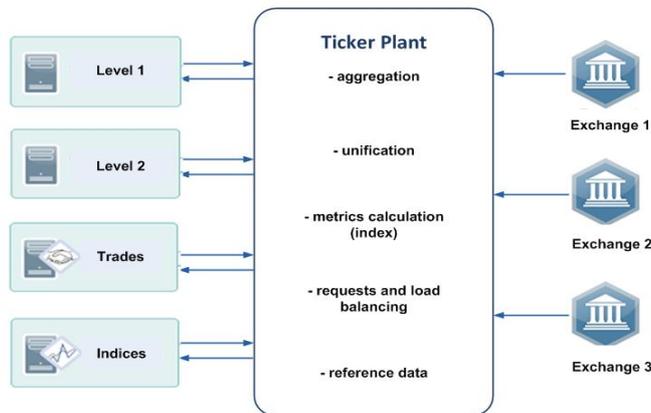
The types of market data services mentioned above are widely used in the electronic financial instruments trading industry. Let us take a look at each one in more detail:

- *Level 1* is information about last Bid/Ask, OHLC (Open, High, Low, Close), Volume;
- *Level 2* is information about Level 1 + Order Book (5-10 depth levels of order book, Bid/Ask Px&Qty). Level 2 can contain attributed or anonymous orders and use models, such as MBO (Market by Order, i.e. when all orders within a separate price level are reflected individually) and MBP

(Market by Price, i.e. aggregated reflection of orders within a separate price level) [7];

- *Level 2* – Total View is more complete information compared to Level 2;
- *News* is the latest news about a company [8];
- *Index* is indices-related data [9].

A schematic representation of a Ticker Plant system is provided below as Picture 1.



Picture 1. A Ticker Plant system schema

II. THE MAIN REQUIREMENTS FOR A TICKER PLANT SYSTEM

Based on the description of a Ticker Plant system and its main characteristics noted above, we provide a set of requirements the system should comply with. We will follow this set of characteristics when testing it. In order to make the assessment of each of the characteristics easier, we have divided them into functional and non-functional ones.

A Ticker Plant system should:

- *From a functional standpoint*

1. Collect quotes information from several sources (the suppliers of market data: exchanges, banks);
2. Process reference data provided by the exchanges;
3. Process quotes information disseminated via various data transmission protocols in real-time;
4. Convert the collected information into one format;
5. Aggregate quotes information according to various methods described above;
6. Process this data in order to enrich the system's functionality: e.g., provide statistics (VWAP, Turnover, Trade High/Low, 52 week Trade High/Low);

7. Provide data according to clients' requests: Level 1, Level 2, T&S, News, Index, Option chains, etc.;

8. Provide recorded historic data about quotes.

- *From a non-functional standpoint*

1. Provide fast processing of quotes data streams received from the exchanges in real-time;

2. Provide fast processing of requests received from clients and quotes data depending on the type of a client request (e.g., separately for a traded instrument, or a group of instruments, or the entire market);

3. Provide continuous working efficiency of the system;

4. Provide system operability;

5. Provide the ability of system monitoring (i.e. the availability of applications to monitor the system and operate its components);

6. Provide throughput;

7. Provide latency;

8. Provide fault tolerance.

Having defined a set of functional and non-functional characteristics of Ticker Plant, we need to understand the process of testing each of the characteristics. The following two approaches to testing such systems become obvious.

The first approach is testing with real test environments (e.g. CDS – customer development service [10]). Usually the exchanges provide their clients with test environments similar to the real trading platform. Often it's done to enable a certification process or provide the clients with an opportunity to adjust the clients' software.

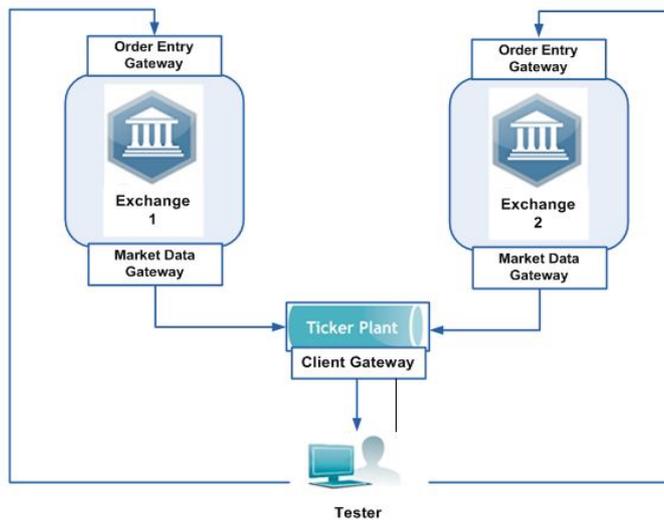
The second approach is testing by using trading platforms simulators developed based on public information about an exchange.

III. A TEST EXCHANGE: DESCRIPTION AND MAIN FEATURES

A "Test" Exchange is in essence a replica of a real trading exchange [11]. Such a replica must have the fullest possible range of functionalities that are specific to a real electronic platform. Test exchanges are provided to clients who need to verify the correct work of trading and informational software developed by them [12]. Orders and trades on such test exchanges are generated as a result of interaction between the clients verifying their software.

Ideally, the test exchange consists of the same components as the real exchange system [13]. Trading sessions, the main parameters of traded instruments, trading rules graphical applications for controlling reference data parameters, and so on – all of these characteristics fully apply to the components of the real exchange system. Therefore such test environment allows verifying the software having in mind that the settings in the real system are the same.

Picture 2 below provides a diagram of Ticker Plant testing using a test exchange.

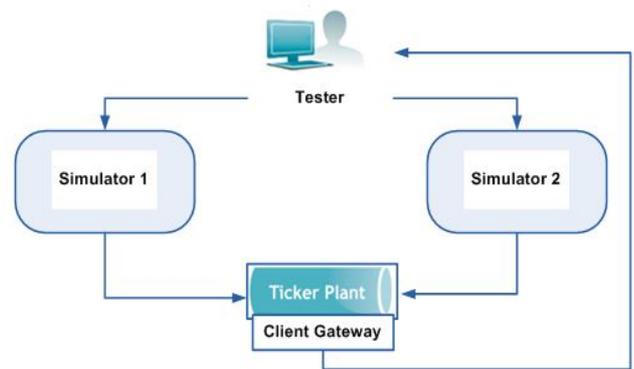


Picture 2. Ticker Plant testing using a test exchange as a tool.

IV. AN EXCHANGE SIMULATOR: DESCRIPTION AND MAIN FEATURES

A Market Simulator (or Exchange Simulator) is an interactive computer program developed in order to simulate the possibilities and features of real market models [14]. An Exchange Simulator must emulate real events that take place on an exchange: the trading itself (order placement, trades generation, changes in instrument status, etc.), exchange trading monitoring and the introduction of changes (market operations: cancelling and changing of orders and trades, halting of trading, etc.), market changes (transition of market from one status to another – market open, auctions (Opening / Closing / Periodic Auction Calls), the calculation of auction prices and closing price publication, market close, etc. An Exchange Simulator has an API similar to one for a real exchange with elements of controlling responses sent to clients [15]. Such exchange simulators allow having fuller control over generated events for Ticker Plant, which expands testing coverage. Simulators allow creating the necessary load comparable with data streams characteristic of real highly loaded exchange and broker systems.

Further we are providing a diagram of Ticker Plant verification done with the help of a simulator.



Picture 3. Ticker Plant testing using an exchange simulator as a tool

V. CREATING A LIBRARY OF SCENARIOS AND CASES FOR TESTING MARKET DATA AGGREGATION AND DISSEMINATION SYSTEMS (TICKER PLANT)

Based on main requirements for Ticker Plant systems we have developed a library of test scenarios suitable for the verification of their work. Table 1 below provides a short description of each area of Ticker Plant test coverage. The table also shows a scale of testing areas depending of their priority. For example, priority 1 shown against an area of testing denotes that errors in such area mean that Ticker Plant will not perform its main function in full. Priority 3 against an area denotes that errors in it mean that Ticker Plant will perform its main function, although with certain deviations.

Table 1. Ticker Plant Areas of Testing and Their Priority

#	Area of Testing	Description	Priority (1 - 3)
1	Technical connectivity to exchanges – streaming quotes and trades data in real-time) <ul style="list-style-type: none"> ▪ UDP (User Datagram Protocol) ▪ TCP/IP (Transmission Control Protocol (TCP) и Internet Protocol (IP)) ▪ HTTPS (HyperText Transfer Protocol Secure) 	<ul style="list-style-type: none"> - possibility to connect to primary channels; - connectivity to secondary channels; - fault tolerance; - disaster recovery testing; 	1

#	Area of Testing	Description	Priority (1 - 3)
2	Technical connectivity to exchanges – Replay/Recovery channels	- possibility to connect to primary channels; - connectivity to secondary channels; - fault tolerance; - disaster recovery testing;	1
3	Testing of exchange to Ticker Plant system protocol (real time + replay/recovery)	- verification of administrative messages initiated by Ticker Plant (Login Request, Replay Request, Snapshot Request, Logout Request); - verification of administrative messages initiated by a channel (Heartbeat, Login Response, Replay Response, Snapshot Response, Snapshot Complete); - verification of application messages (Time, System Event, Symbol Directory, Symbol Status, Add Order, Add Attributed Order, Order Deleted, Order Modified, Order Book Clear, Order Executed, Order Executed with Price/Size, Trade, Auction Trade, Off-Book Trade, Trade Break, Auction Info, Statistics); - verification of mandatory tags and values; - verification of optional tags and values; - verification of various possible combinations of tag values (Order Type, TIF, etc.); - verification of negative values (unsupported values, negative values, special characters, etc.)	1
4	Recovery of a small	- possibility to connect	1

#	Area of Testing	Description	Priority (1 - 3)
	amount of lost data (Replay channel)	to primary channels; - connectivity to secondary channels; - verification of received data sequence; - verification of correctness of received data; - verification of buffering data volumes	
5	Recovery of a large amount of lost data (Recovery channel)	- possibility to connect to primary channels; - connectivity to secondary channels; - verification of received data sequence; - verification of correctness of received data; - verification of volume of transmitted data	1
6	Verification of Reference Data	- the possibility to upload financial instruments data provided by the exchange; - correctness of data processing; - using reference data to calculate various parameters	1
7	Testing of Ticker Plant behavior when exchange components fail (Failover under data stream from the exchange)	- recovery of data after failure of primary and/or secondary channels; - correct sequence of messages; - the possibility of further data processing after recovery	1
8	Testing of Ticker Plant behavior when its components fail (Failover under data stream from Ticker Plant)	- verification of work of Ticker Plant components when primary and/or secondary channels fail; - correct sequence of messages; - the possibility of further data processing after recovery	2
9	Testing of full Daily Life Cycle (DLC) of	- verification of correct sequence of starting the	1

#	Area of Testing	Description	Priority (1 - 3)
	Ticker Plant	Ticker Plant components; - verification of correct sequence of stopping Ticker Plant components	
10	Testing of full Daily Life Cycle (DLC) of the exchange	- verification of correct sequence of messages coming throughout the day; - adding a new instrument, changing its parameters, deleting the instrument; - changing instrument status; - transition of orders from one trading phase into another; - transition of orders from one day into another	1
11	Verification of various trading statuses of the market	- verification of presence of given types of statuses in the Ticker Plant system: e.g., Halt, Opening auction call, Pre-mandatory quote period, Continuous trading, End trade reporting, Closing auction call; - verification of processing of transition from one instrument status into another; - verification of correctness of message processing during mass changing of financial instruments statuses	1
12	Measuring the width of used network data transmission channel (Bandwidth measuring)	- load tests are performed to measure the volume of data transmitted per time interval	1
13	Measuring of throughput of channels per time interval (Throughput measuring)	- load tests are performed to measure the average number of messages guaranteed to be delivered through data transmission channels	1

#	Area of Testing	Description	Priority (1 - 3)
14	Latency measurements	- verification of system components with latency of data transmission	1
15	Verification of system capacity – load created with incoming data flow	- verification of correct work of Ticker Plant with significant incoming data flow	2
16	Verification of system capacity – load created from the client side of Ticker Plant	- verification of processing by Ticker Plan of a large number of client requests	2
17	Verification of Ticker Plant system with incorrect client requests and system response for Replay/Recovery channels	- attempts of client connections (CompID) with insufficient amount of privileges; - attempts to connect with a non-existent user; - verification of maximum number of connections; - verification of maximum number of requests	1
18	Verification of correct processing by Ticker Plant of incorrect messages from exchange	- response to nonexistent message types; - incorrect number of tags; - incorrect order of tags; - incorrect checksum	2
19	Verification of correct work of the system as a whole – from the trading client to Ticker Plant system (End-To-End testing)	- adding orders; - changing orders; - cancellation of orders; - adding aggressive orders leading to a trade	1
20	Complex scenarios to verify the functionality of the exchange	- verification of processing the sequence of events (e.g., multilevel trades with Iceberg orders); - auction price calculations; - Stop / Stop Limit orders behavior depending on trading day phase; - verification of GTC orders behavior over the course of several days	2

#	Area of Testing	Description	Priority (1 - 3)
21	Reconciliation testing	- verification of incoming and outgoing data flows (a detailed check that every event that came into the system was processed and got reflected in the outgoing flow)	1
22	Market by Order (MBO) and Market by Price (MBP) service testing	- functional verification of services provided by the Ticker Plant system	1
23	Indices calculation verification	- verification of correctness of indices calculation depending on the trades flow	2
24	Verification calculation of statistical data	- verification of VWAP, Turnover, Trade High Low, 52 week Trade High Low, etc. calculation	2
25	Work with historic data	- collection of historic data; - sorting depending on type of data; - response generation according to client requests; - possibility to replay recorded historic data	2
26	Verification of receiving and transmitting news from exchanges	- News testing; - client Announcements testing	3
27	Verification of actions by exchange operator	- trade cancellation; - amendment of trade parameters	2
28	Verification of complex client requests	- provision of derivative instrument data (option chains) for a requested underlying instrument	2
29	System monitoring	- verification of applications that serve as a means of system monitoring and operating system components	1

VI. A METHODOLOGY OF TICKER PLANT TEST COVERAGE ANALYSIS AS RELATED TO PRIORITY OF TESTS AND USAGE OF TEST TOOLS

In order to assess and analyze the completeness of functional testing coverage of a Ticker Plant system, we have developed a methodology based on defining the priority of tests and comparing test coverage as described in various test scenarios pertaining to a certain functional or non-functional area, and deriving percentages of test coverage that can be achieved by utilizing available test tools (in our case, a test exchange and an exchange simulator). Based on testing experience accumulated on Exactpro Systems projects [17], we have arrived at priority values presented in Table 1 above.

The next part of this paper describes the experience of applying the methodology of test coverage analysis in order to assess the completeness of Ticker Plant testing both when using real test exchange environments and when using exchange simulators.

6.1. Comparative Characteristics of Ticker Plant Testing Assessment Data: Testing Performed by Utilizing a Real Test Exchange Environment vs. Testing Performed by Utilizing a Simulator

Table 2 below provides comparative characteristics that include assessment data accumulated during testing of a Ticker Plant system with the help of a real test exchange environment and a simulator. Detailed explanation of accumulated data is also provided.

Table 2. Comparing Test Coverage Achieved Using a Test Exchange vs. Test Coverage Achieved Using an Exchange Simulator as Test Tools

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
1	Technical connectivity to exchanges – streaming quotes and trades data in real-time <ul style="list-style-type: none"> ▪ UDP (User Datagram Protocol) ▪ TCP/IP (Transmission Control Protocol (TCP) и Internet Protocol (IP)) ▪ HTTPS (HyperText 	100	40	Our assessment provided here is based on the fact that an exchange simulator, by its nature, is not capable of fully simulating all technical details of connecting to an exchange. We are estimating that,

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
	Transfer Protocol Secure)			provided a technical specification is available, correct gateway emulation is possible with 40% completeness based on a set of exchange connectivity test scenarios.
2	Technical connectivity to exchanges – Replay/Recovery channels	100	40	Our assessment provided here is based on the fact that an exchange simulator is not capable of fully simulating all technical details of connecting to an exchange. We are estimating that, provided a technical specification is available, correct gateway emulation is possible with 40% completeness based on a set of exchange connectivity test scenarios.
3	Testing of exchange to Ticker Plant system protocol (real time + replay/recovery)	100	100	This functionality (testing of an external gateway) is isolated from the exchange. We therefore believe that the usage of a

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
				simulator or the usage of a test exchange provide the same test coverage with the available set of test scenarios.
4	Recovery of a small amount of lost data (Replay channel)	100	100	This functionality (testing of an external gateway) is isolated from the exchange. We therefore believe that the usage of a simulator or the usage of a test exchange provide the same test coverage with the available set of test scenarios.
5	Recovery of a large amount of lost data (Recovery channel)	75	100	Despite the fact that the functionality is isolated from the exchange, its testing requires a significant flow of quotes data from the exchange. Based on our experience, it is not always possible to achieve that when testing with a test exchange, and there are a number of significant limitations.

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
				The data flow from the test exchange usually meets the expectations, but it's almost impossible to control it. When a Simulator is used, control is in the hands of testers.
6	Verification of Reference Data	100	5	The focus of this testing is verification of system parameters, financial instruments parameters, etc. This testing needs to be performed via a connection with real test markets.
7	Testing of Ticker Plant behavior when exchange components fail (Failover under data stream from the exchange)	100	10	Testing via a simulator is possible, but a significant amount of tests verifies the connection between the Ticker Plant and exchanges. Our assessment provided here is based on the fact that an exchange simulator is not capable of fully simulating all technical details of connecting to an exchange. Provided a

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
				technical specification is available, correct gateway emulation is possible with 40% completeness based on a set of exchange connectivity test scenarios.
8	Testing of Ticker Plant behavior when its components fail (Failover under data stream from Ticker Plant)	100	40	Testing via a simulator is possible, but a significant amount of tests verifies the connection between the Ticker Plant and exchanges. Our assessment provided here is based on the fact that an exchange simulator, by its nature, is not capable of fully simulating all technical details of connecting to an exchange. We are estimating that, provided a technical specification is available, correct gateway emulation is possible with 40% completeness based on a set of exchange connectivity test scenarios.

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
9	Testing of full Daily Life Cycle (DLC) of Ticker Plant	40	100	Due to the significant limitations as to the possibility to control the trading day on test exchanges, a simulator provides more opportunities to execute such test scenarios.
10	Testing of full Daily Life Cycle (DLC) of the exchange	100	40	Although the explanation provided for the previous area of testing is true here as well, test scenarios in this area are more influenced by the fact that incoming messages are created on a test exchange according to the Reference Data settings on the exchange. Our assessment is based on the fact that a simulator, by its nature, cannot emulate all technical details of full trading Daily Life Cycle (DLC) of system under test. Therefore our assessment of testing coverage is only 40% for use of a simulator.

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
11	Verification of various trading statuses of the market	50	100	Due to the limitations as to the possibility to control the trading day on test exchanges, a simulator provides more opportunities to execute such test scenarios.
12	Measuring the width of used network data transmission channel (Bandwidth measuring)	75	100	Testing with a simulator is possible; test exchanges have a significant dependency on their hardware and capacity settings. A simulator has an advantage for this area.
13	Measuring of throughput of channels per time interval (Throughput measuring)	75	100	Testing with a simulator is possible; test exchanges have a significant dependency on their hardware and capacity settings. A simulator has an advantage for this area.
14	Latency measurements	75	100	Testing with a simulator is possible; test exchanges have a significant dependency on their hardware and capacity settings. A simulator has an advantage for this area.
15	Verification of	75	100	Testing with a simulator is

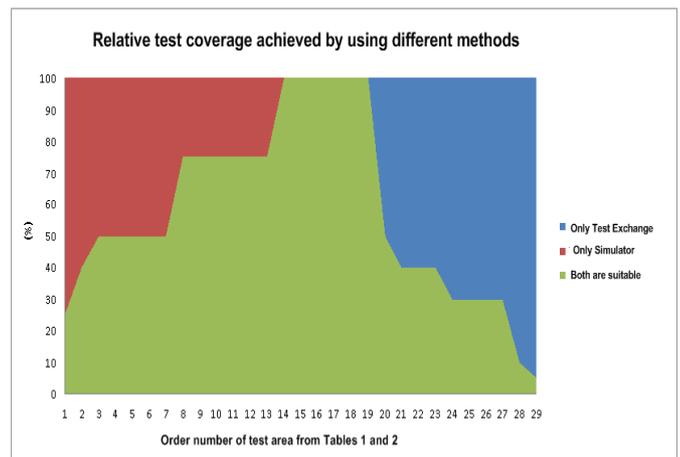
#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
	system capacity – load created with incoming data flow			possible; test exchanges have a significant dependency on their hardware and capacity settings. A simulator has an advantage for this area.
16	Verification of system capacity – load created from the client side of Ticker Plant	75	100	Testing with a simulator is possible; test exchanges have a significant dependency on their hardware and capacity settings. A simulator has an advantage for this area.
17	Verification of Ticker Plant system with incorrect client requests and system response for Replay/Recovery channels	100	100	This functionality (testing of an external gateway) is isolated from the exchange. We therefore believe that using test exchanges or a simulator provide the same testing coverage.
18	Verification of correct processing by Ticker Plant of incorrect messages from exchange	25	100	A simulator can provide the ability to send to the Ticker Plant a flexible set of negative test scenarios, which provides a wide coverage. However, almost all of the test scenarios are impossible to

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
				reproduce based on the exchange specification only.
19	Verification of correct work of the system as a whole – from the trading client to Ticker Plant system (End-To-End testing)	90	85	This testing comprises a combination of all available trading scenarios and can be achieved either by using test exchanges or a simulator. Our percentage assessment is therefore almost identical for both approaches.
20	Complex scenarios to verify the functionality of the exchange	50	100	Either of the approaches provides flexible opportunities for emulating complex scenarios. Due to the fact that the testers are in control of the simulator, it provides more opportunities to emulate really extraordinary events.
21	Reconciliation testing	100	50	This testing area is about comparing data flows from the exchange and those from the Ticker Plant. Testing with a real test exchange is preferable and

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
				more correct as the exchange is by default an independent source of quotes data.
22	Market by Order (MBO) and Market by Price (MBP) service testing	100	100	This functionality (testing of an external gateway) is isolated from the exchange. We therefore believe that using test exchanges or a simulator provide the same testing coverage.
23	Indices calculation verification	50	100	This functionality must be performed with full control of the market. A simulator has an obvious advantage and hence the assessment we have provided for this area.
24	Verification calculation of statistical data	50	100	This functionality must be performed with full control of the market. A simulator has an obvious advantage and hence the assessment we have provided for this area.
25	Work with historic data	50	100	For testing this area it is necessary to emulate of artificial

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
				historic events. To make the tests repeatable, a simulator is necessary. In case of a test exchange, other users can influence the events.
26	Verification of receiving and transmitting news from exchanges	50	100	This area of testing requires emulation of artificial news. To make the tests repeatable and in order to have full control, a simulator is necessary.
27	Verification of actions by exchange operator	100	30	Verification of market operating functionalities must be performed via a connection to real systems that will eventually be operated in production. Test exchanges have an advantage for this area.
28	Verification of complex client requests	100	100	This functionality (testing of an external gateway) is isolated from the exchange. We therefore believe that using test exchanges or a simulator provide the same testing coverage.
				Verification of

#	Area of Testing	Test Coverage when Testing with a Real Test Exchange (%)	Test Coverage when Testing with a Simulator (%)	Detailed Explanation of Comparative Data
29	System monitoring	100	30	market operating functionalities must be performed via a connection to real systems that will eventually be operated in production. Test exchanges have an advantage for this area.



Picture 4. Comparative analysis of test coverage achieved through usage of a test exchange and an exchange simulator as test tools

One can get an impression that full test coverage for Ticker Plant systems is only possible with the help of simulators (as follows from Table 2). In reality it is not the case. The main obstacle is the fact that the emulation of a trading platform with 100% accuracy is impossible. It is specifically true for the interaction between the Ticker Plant and various markets. The reason for this is that any exchange connectivity protocol specification only contains a limited description of system behavior under various circumstances. Hence even a simulator built with 100% precision according to a specification, including the smallest nuances, will still have logic implemented “at the discretion” of its developers.

For clarity, we will illustrate the point by an example. Let us suppose that a trade takes place and the exchange sends two events to its clients: the first event contains the trade volume and price, while the second event contains the changes in HIGH and LOW price parameters of the financial instrument. If an index calculation algorithm uses the information from both of the events, it is highly possible that for the algorithm to continue working the sequence of the events will be important. It is unlikely that the exchange specification will contain any requirements specifying the order of messages and events. Moreover, in the absence of such a requirement in the specification, the exchange can easily change the order of the events. Thus we have an example of a scenario that cannot be emulated precisely. Given that, a significant amount of testing should be performed on a test exchange, the closest possible replica of behaviors observed on real markets. This conclusion is also based on our experience with Ticker Plant systems testing.

Picture 4 below provides a visual representation of the comparative analysis of test coverage achieved by utilizing various types of test tools.

The analysis of data provided in Table 2 and Picture 4 shows that both methods of testing – by utilizing exchange simulators and by utilizing real test exchanges (during a reasonable time period) - each have their upside and downside. Overall, data obtained by applying our comparative methodology shows fairly equal results.

The following formula was used to assess test coverage achieved for each of the functionalities by utilizing one of the test tools (an exchange simulator or a test exchange):

$$\text{Summ}(\text{CovN}^*(1/\text{PriorN}))/\text{Summ}(1/\text{PriorN}) \quad (1)$$

Where *Summ* is sum (Table 2), *CovN** is relative coverage of a specific functionality by utilizing a corresponding test tool (Table 2), *PriorN* is priority of a specific functionality.

CONCLUSION

This paper provides the description of a market data aggregation and dissemination system (Ticker Plant), the list of its main characteristics, the description of a reference test scripts library encompassing the entire functionality of a generic Ticker Plant system. The paper also contains definitions of an exchange simulator and a real test exchange. By utilizing a developed methodology for assessing test coverage of market data aggregation and dissemination system (Ticker Plant), two possible approaches for testing - by utilizing a test exchange and an exchange simulator as test tools - were analyzed and quantified. Based on data presented in two summary tables conclusions were made as to the advantages of both approaches.

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