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Order Routing System for Stock Brokers connected to multiple exchanges

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Abstract - *In the past, traders had to place orders through the trading desk and the options were limited. Routing orders through a trading desk causes delay in order execution, putting traders at a disadvantage. In an Electronic Trading Platform or Online Trading Platform both buyers and sellers use the internet to connect to a trading platform such as an exchange-based system or electronic communication network (ECN). In recent years, the Smart Order Routing(SOR) system has become a topic of interest in the financial industry. Order routing is the process by which a buy or sell order in the stock market is placed. Order Routing is the ability to correctly and efficiently route an order by choosing the best execution destination based on factors like price, costs, speed, quantity, etc. Order Routing takes decisions based on certain rules that are defined by the broker or the brokerage firm.*

Key Words: **ORS (Order Routing System), FIX (Financial Information Exchange) Protocol, QuickFIX Engine, SOR (Smart Order Routing), VWAP (Volume Weighted Average Price)**

1. Introduction

Large investment banks, hedge funds and institutional investors are investing money in building High Frequency and Low Latency trading platforms to use powerful computers and servers and connectivity technology like FIX (Financial Information Exchange) Protocol [5],[8],[11] to trade large numbers of orders at extremely high speeds. The vast majority of exchanges and brokers use the FIX protocol for accepting orders from third party systems or brokers. FIX has become the de-facto standard in broker-exchange connectivity. Order routing server will send orders received from clients to a best execution venue through FIX engine which utilizes FIX messages. FIX messages reduce time and complexity involved in connecting to multiple trading partners and exchanges around the world[1],[3]. This is because FIX Protocol has been developed through the collaboration of banks, exchanges, brokers and information providers from around the world.

1.1 Objectives

The main idea behind the Order Routing System is to scan the markets and find the best deal to execute a customer's order, based on price, cost, execution speed and liquidity. It is the process of automatically taking advantage of the best price available across multiple exchanges and liquidity to optimize the outcome of an order.

Main Objectives:

- Broker can set rules for order routing
- Automatic search for the best Price
- To create Rule-based Order Routing System
- Fast and efficient routing of orders
- Brokers will be able to see order execution status.

In this project, we intend to achieve a platform that can handle many exchanges and select the one with best price, cost and liquidity.

1.2 Scope

The scope of this project is to get the input from users (brokers) like select Stock ticker, quantity of shares, order side i.e. buy or sell, type like market, limit, stop. The system will focus on routing market orders efficiently and brokers can see order execution status. The order routing server will route broker's orders to the best venue i.e. to the best exchange by comparing the market data prices from multiple connected exchanges[1]. Final product will also have a UI where brokers can see order execution status. Some of the Steps in order routing systems are receiving incoming orders through different channels, processing the orders inside the order routing system, taking into account, routing the orders to one or several venues according to the decision made by the order routing system. Using the order routing system we get simultaneous access to several venues, automatic search for the best Price.

2. Literature Survey

Sr. No.	Year and Name of Journal	Author	Title	Key Findings
1	IEEE Symposium Series on Computational Intelligence-2016	Andrew Todd, Peter Beling and William Scherer	Order Routing and Arbitrage Opportunities in a Multi-Market Trading Simulation	In this paper the authors present a simple multimarket trading model. The same security trades in private pairs trading platforms. Prices and ratings are linked only by strategic behavior of traders.
2	Journal of Finance, Vol. 63, 2008	Thierry Foucault and Albert Menkveld.	Competition for Order Flow and Smart Order Routing Systems	In this paper, the authors study the changes in liquidity after the introduction of a new electronic limit order market. Since before its introduction trading was centralized in a single limit order market.
3	The Journal of Trading Winter-2010	Dhiren Rawal	Bringing Intelligent Decision-Making to Order Routing	This paper discusses the fragmentation and how it speeds up the exchange of funds between territories or venues, making it necessary for the second generation of smart order routing (SOR) to bring real-time intelligence to the decision-making process.
4	Quantitative Finance Journal, Volume 17, 2017	Rama Cont, Arseniy Kukanov	Optimal order placement in limit order markets	In this paper it discusses stochastic algorithms that combine optimal route policy and learning. This algorithm uses data in the latest order that completes the transition to the numerical use of the algorithm to obtain this information through a supervised learning process.
5	4th International Multi-Conference on Engineering and Technological Innovation(IMET) - 2011	Shweta Swarnka and John Jenq	Implementation of FIX Engine and Order Management Systems using ASP.NET and C	In this paper, a FIX engine is integrated and linked to an Order Management System (OMS) for brokers and one FIX engine with an exchange server. The paper talks about the benefits of FIX engine in Stock Exchange and Order Routing.
6	IEEE 14th International Conference on Intelligent Computer Communication and Processing (ICCP)-2018	Claudia Pop, Cristian Pop, Antal Marcel, Andreea Vesa, Teodor Petrican, Tudor Cioara, Ionut Anghel, Ioan Salom	Decentralizing the Stock Exchange using Blockchain	This paper addresses the shortcomings of medium-term stock trading systems, such as high transaction costs, centralized risk-taking control and a lack of openness about market actions and algorithms, by proposing new formats using blockchain to improve stock trading and the ongoing open market.

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7	Quantinsti Blog-2019	Rekhit Pachanekar	Automated Trading Systems: Architecture, Protocols, Types of Latency	This was based on the development of an automated trading system that provided a more intuitive knowledge of the components involved and the various challenges architects needed to address / overcome in order to build a robust automated trading system.
8	Conference Society and Technology, 2008	Emilija Vuksanovic and Borislav Josanov	The Belgrade Stock Exchange: The Success Story of FIX Protocol Implementation	The purpose of this paper is to introduce a new Belgrade Stock Exchange trading system based on the FIX protocol. This paper talks about the features of the Belgrade Stock Exchange, specific aspects of the FIX protocol and implementation of the FIX protocol on the Belgrade Stock Exchange.
9	Journal of Risk and Financial Management(JRFM) - 2021	Suchismita Mishra and Le Zhao	Order Routing Decisions for a Fragmented Market	This paper reviews the latest theoretical, evidentiary, and experimental books related to choosing a trading platform in the context of different stock markets. It discusses the direct and indirect effects of market segregation on market quality in a variety of ways, including financial prowess, flexibility, and price efficiency.
10	Journal of risk management in financial institutions-2010	Jan Fraenkle, Svetlozar T. Rachev, Christian Scherrer	Market Impact Measurement of a VWAP Trading Algorithm	They proposed a market impact model for algorithmic trading. They show that this VWAP algorithm is the perfect solution to the problem of efficiency using market impact models presented.

3. Proposed Order Routing System Architecture

3.1 Requirements

(1) QuickFix Engine[12]
(2) JAVA
(3) Java virtual machine (JVM compatible with Oracle JRE Java 1.7.x or higher.)
(4) Java swing
(5) MySQL
(6) JDBC

3.2 Project Architecture

This Paper presents Order routing system architecture which contains following contents with figure

The whole system can be broken down into 4 components:

(1) Client - side application (GUI)
(2) Order Routing Server
(3) Connector (Connects Order Routing System to multiple Exchanges)
(4) Stock Exchanges (3rd party market data vendors)

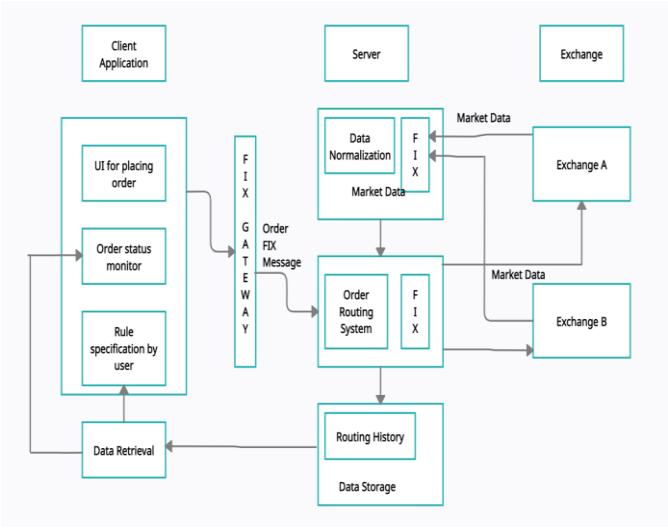

Figure 3.1 Order Routing System Architecture

1) Client-side

GUI application for placing orders. Brokers will be able to select stock ticker, Quantity of shares, order side(Buy or Sell), etc. Broker(client) can also add rules with respect to the type of order (limit order, stop order, stop limit order, etc.) Clients can also monitor the status of order whether an order has reached a desired exchange.

2) Server

The Server block contains the data normalization, order routing server, data storage. This block directly communicates with different Exchanges in the stock market.

- **Data normalization Block**

FIX (Financial Information Exchange)[5,8,11] is used extensively in broker-exchange connectivity.

As there are multiple destinations (Exchanges) connected to the order routing server there is a need for data normalization. Hence data normalizer block is added to convert the market data from multiple exchanges to standard form(i.e. FIX message). This normalized market data is constantly provided to the order routing system.

- **Order Routing Server**

Order Routing server will be provided with Market data from mock exchanges. The incoming order from the client is fed into the ORS as a FIX message. Server will use this market data and apply certain rules defined by the end user (broker) to route incoming orders to the stock exchange with the best price.

- **Data Storage**

All the event history / order routing history is stored in a database. When an order reaches a particular destination the record of routed order will be stored in a database. These records can be retrieved by the client-side to monitor the status of an order.

3) Connector

As the Order Routing System is going to interact with multiple exchanges, the server will have to handle multiple FIX sessions. The Connector component will handle these FIX sessions between ORS and multiple connected exchanges.

4) Exchanges

We are using a simulator destination for testing purposes instead of an actual exchange.

5) FIX Protocol

FIX protocol is a messaging standard for electronic communication for financial information or trade - related messages. A FIX message contains tag and value pairs. Each FIX tag represents a specific field and is denoted by numbers.

Sample FIX message
8=FIX.4.4 | 9=284 | 35=8 | 34=61 | 49=TEST | 52=20180822-08:10:35.644 | 56=TESTSESSION | 57=testuser | 6=0 | 11=Order1 | 14=0 | 15=USD | 17=testsession-testuser-0asd-U-0 | 22=1 | 37=sdsda3-sds3-67ju-629d-18caf14bb34a | 38=3000000 | 39=0 | 40=2 | 44=100 | 48=26054abcd | 54=1 | 55=[N/A] | 60=20180822-08:10:35.452 | 150=0 | 151=3000000 | 423=1 | 10=117 |

The above FIX message is a type of FIX message called “Execution Report” and it’s the acknowledgement message from the server to show that the order has been placed on the market. For example , tag 54=1 means the trade placed a BUY side order , 38=3000000 means that broker wants to buy 3 million shares.

We are using QuickFIX/J which is a java version of an open source FIX engine. QuickFIX addresses the session level messaging of the FIX protocol. It also supports logging to multiple destinations.

FIX is a session based protocol. Session is a communication or information exchange between two parties. FIX communication involves two parties:-

1) Initiator / Client - initiates the communication
2) Acceptor / Server - receives connection request from initiator and validates client request using login message.

The Order Routing System will act as an acceptor for receiving orders from a broker and at the same time for routing orders to a particular exchange it will act as an initiator.

The Order Routing System is going to connect with multiple exchanges simultaneously so that it can route orders received from brokers to the desired exchange. So in this case we will have one initiator and multiple acceptors.

QuickFIX engine requires all these details about the sessions so that it can read the configurations and initiate sessions accordingly. There is a separate session for receiving market data via FIX protocol.

Configurations for Order Routing System to connect to multiple exchanges:

[DEFAULT] ConnectionType=initiator ReconnectInterval=60 StartTime=00:00:00 EndTime=00:00:00 SenderCompID=ORS FileStorePath=data	[SESSION] BeginString=FIX.4.2 SenderCompID=ORS TargetCompID=NYSE HeartBtInt=20 SocketConnectHost=127.0.0.1 SocketConnectPort=9823	[SESSION] BeginString=FIX.4.2 SenderCompID=ORS TargetCompID=NASDAQ HeartBtInt=30 SocketConnectHost=127.0.0.1 SocketConnectPort=8323

Table 3.1 shows the configurations that are required to create a FIX sessions

Session	
ID	**Description**
BeginString	Shows FIX protocol version in the use
SenderCompID	ID of the party who is sending message
TargetCompID	ID of the party who is receiving message
ConnectionType	Defines if session will act as an acceptor or an initiator
StartTime	FIX session activation time
EndTime	FIX session deactivation time
HeartBtInt	HeartBeat Interval in seconds.(Only used for initiators)
ReconnectInterval	quickFIX engine Attempts to reconnect after certain interval (in seconds)(only for initiators)
SocketConnectPort	Used with a SocketIntiator. Socket port for connecting to a session with the acceptor

Table 3.1 Configurations

4. Result Analysis

There are a variety of algorithms used by brokerage firms, hedge funds and large investment banks to guide their decision or to route their orders to the exchange where they will get the best execution price. VWAP and TWAP are two such algorithms. For the scope of this paper, we will understand how VWAP works.

4.1 Proposed Order Routing Algorithm

VWAP (Volume Weighted Average Price)[10] :

Volume is important and it has an impact on the financial markets. Trading volume also helps investors identify the trend and momentum in a security. VWAP was created so that investors would make a decision by taking into account both volume and price.

$$\text{VWAP} = \frac{\sum_{i=1}^{n} Vi*Pi}{\sum_{i=1}^{n} Vi}$$

(1) First step for finding VWAP involves calculating the average price at which a security was traded for a given period

Average Price = (high + low + close)/3

= (3815.95 + 3757.60 + 3784.20)/3

Average price = 3785.91

(2) For the second step, multiply the average price with the volume for that period and we need to add the cumulative total of the previous period

For example, Let's say at a particular time period (t) volume traded was 105003.

(Price * Volume) = 397,351,907.73

For x+1, with volume at 57668

The cumulative average price = ((Avg. Price at t+1) * (volume at t+1)) + cumulative total at t

The cumulative average price = (3786.42 * 57688) + 397,351,907.73 = 615,782,904.69

(3) For the third step, find the cumulative total volume.

Volume at time t = 105003

Volume at time t+1 = 57668

Cumulative total volume = 105003 + 57668 = 162671

(4) In the final step simply find VWAP by dividing cumulative price* volume by the cumulative volume.

VWAP = (Cumulative(Price*Volume)) / (Cumulative Volume)

For time t, VWAP = 397,351,907.73 / 105003 = 3784.1957

For time t+1, VWAP = 615,782,904.69 / 162671 = 3785.449

Below Figure shows the results calculated using the above four steps involved in VWAP Algorithm on 1-minute interval.

Time	Close	High	Low	Open	Volume	Typical Price	Price*Volume	Total P*V	Total Volume	VWAP
05:30:00	38.9	38.96	38.9	38.96	59550	38.93	2318281.5	2318281.5	59550	38.93
05:31:00	38.94	38.97	38.86	38.92	31237	38.92	1215744.04	3534025.54	90787	38.92656
05:32:00	38.91	38.96	38.91	38.94	20102	38.93	782570.86	4316596.4	110889	38.92718
05:33:00	38.89	38.94	38.88	38.92	11290	38.91	439293.9	4755890.3	122179	38.9256
05:34:00	38.9	38.94	38.9	38.9	14350	38.91	558358.5	5314248.8	136529	38.92396
05:35:00	38.97	38.97	38.9	38.9	9187	38.93	357649.91	5671898.71	145716	38.92434
05:36:00	38.92	38.96	38.92	38.96	6584	38.94	256380.96	5928279.67	152300	38.92501
05:37:00	38.9	38.93	38.86	38.93	13212	38.91	514078.92	6442358.59	165512	38.92382
05:38:00	38.9	38.92	38.89	38.89	14890	38.9	579221	7021579.59	180402	38.92185
05:39:00	38.92	38.92	38.91	38.91	17890	38.91	696099.9	7717679.49	198292	38.92078

Figure 4.1 VWAP Sample Calculation

Many 3rd party market data vendors and API also provide this VWAP value so that traders can make their decision and it also helps them to determine the trend for a particular security.

5. Conclusion

This paper overcomes problems of an existing system which requires more time for executing an order and because of this delay there is a decrease in efficiency or performance of the system. In this paper, we tried to overcome this problem. Smart Order Routing System can quickly find the best execution of an Order based on some parameters. This system increases the flexibility, customizability, efficiency and becomes more fast and secure because of the FIX engine. FIX engine will increase efficiency between brokers for provision and completion of trading services. It is popular within the Exchanges community over the last several years all exchanges surveyed supported a FIX interface. Currently, FIX is being used for equities, fixed income and foreign exchange trading which can be very helpful in the stock market. In future, along with the transport layer the FIX network will become more integrated with the trading ecosystem. This will help save time and also eliminate errors or inaccuracies making the trading ecosystem more efficient.

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