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December 2007

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Abstract

Electronic trading venues are autonomous and equal in their basic functionality providing a platform for trading of stocks, where prices are generated and transactions are performed. They can be seen as peers. Electronic trading venues in the United States are linked together through the central National Market System (NMS) and a set of rules enabling communication on this network, the Regulation NMS. Although in Europe regulation is not forcing the linkage of venues, regulatory actions encourage the development towards a single European capital market. One already established mechanism among European trading venues is the reference price principle. In this conceptual work, a peer-to-peer network of trading venues is presented together with economic algorithms enabling communication among peers as a decentralized alternative to a central market system aiming at integration of venues.

Keywords

peer-to-peer, electronic trading venues, equities trading, reference price

Introduction

A peer-to-peer network, often depicted as the setup of the very early Internet, describes a system of autonomous, equated network participants where nodes are both information providers as well as consumers. The nodes need not be homogenous, as they can provide comparable functionality on varying infrastructure and different performance levels.

Electronic trading venues, i.e. exchanges, electronic communication networks (ECN), alternative trading systems (ATS) or multilateral trading facilities (MTF), are autonomous and equated in their basic functionality of providing a platform for the trading of stocks. Orders to buy or sell securities can be send to each venue, where they are matched against each other or against quotes. After the matching, trade prices are determined and transactions are performed. This autonomy and decentralization allows seeing venues as peers. Additionally, authorities more and more take the approach of equal regulation for equal functions, further bringing the electronic trading venues in line. The electronic trading venues in the United States are linked through the National Market System (NMS) and a set of rules enabling communication on this network, the Regulation NMS (SEC 2005). The information flowing on the network consists of the two entities orders and market data.

The European 'Markets in Financial Instruments Directive' (MiFID 2004) does not implement comparable links between European markets. However, several articles of the directive promote market-driven solutions in this direction, e.g. intermediaries' obligation to execute client orders on most favorable terms across Europe (Best Execution). The Best Execution obligation requires that an order is send to a venue which has been chosen based on an evaluation of the available execution venues, which requires data from several venues to be compared.

[1] I thankfully acknowledge the support of the E-Finance Lab, Universities Frankfurt/M. and Darmstadt, for this work.

One already existing scheme which can foster the integration and organization of European markets is the reference price mechanism, where one venue pulls market data from another reference venue and offers execution on related terms e.g. executing retail-sized orders for a net price better than the displayed price on the reference venue. The United Kingdom's Financial Services Authority defined best execution for the national UK market as such a reference price model, where the best price equated at least the London Stock Exchange's SETS quote. In Germany, several floor exchanges have established links to the electronic exchange system Xetra by defining their own rules for reference prices and markets. Currently, the scheme is used only in one direction, which is similar to free riding in peer-to-peer networks, but could be utilized bidirectional and contribute to the economically important price discovery function of electronic trading venues.

This conceptual work presents peer-to-peer as an alternative approach to the central U.S. NMS for achieving integration of financial markets. It enables a market solution through self-organization in contrast to regulatory enforcement. The remaining article is structured as follows: Section 2 gives a brief overview of related work regarding peer-to-peer and finance. Section 3 checks the prerequisites, whether electronic trading venues meet peer-to-peer criteria and thus such solutions are applicable. Section 4 refers to economic algorithms for a peer-to-peer electronic trading venue network as an approach towards market integration. Finally section 5 looks at peer-to-peer techniques which can be used as an alternative for market consolidation and concludes.

Related Work

Peer-to-peer technology and its applications have been in focus of information system research for some time. Oram (2001) describes various aspects and forms of peer-to-peer networks. Topologies of peer-to-peer networks have been addressed by Schlosser et al. (2002a,b) examining the hypercube topology or by Brankovic et al. (1997a,b) examining Cayley graphs. Efficient content distribution and retrieval among peers has been addressed by the Chord Network (Stoica et al. 2001), Pastry (Rowstron and Druschel 2001) or in context of semantic networks e.g. by Tempich et al. (2004). Self-organization of peer-to-peer networks (Flake et al. 2002), the small-world effect (Kleinberg 2000) and scale-free characteristics (Albert et al. 2000) have also been investigated.

Electronic trading venues are a major topic in economic research, including their comparisons and measurement of execution quality. Werner (2003) evaluates execution costs, price impact, spreads and information content for different NYSE order types. Among the results is the information content of Intermarket Trading System (ITS, a component of the U.S. National Market System) orders. Boehmer et al. (2006) investigate whether past execution quality affects order-routing decisions and Boehmer and Wu (2006) provide evidence that order flow is related to prices. Subsuming, venue services, e.g. the degree of liquidity, is awarded through investors. Price discovery of markets has been investigated by Hasbrouck (1995) or Yan and Zivot (2006). Hallam and Idelson (2003) describe today's technology in financial markets and deal with the technological premises for pan-European best execution.

The interaction between computer science and economics has been investigated e.g. by Schneidman and Parkes (2003) addressing rationality of peers and the questions resulting from utility-maximizing behavior. Fuqua et al (2003) present a game-theoretic model for peer-to-peer storage networks investigating the preferences regarding space offering. Eymann (2001) proposes a market mechanism for coordination of distributed agents based on bilateral bargaining. Gomber et al. (1997) propose the Vickrey auction as an adequate mechanism for the coordination of agents within a multi-agent system. Padhy et al. (2006) demonstrate a utility-based auctioning scheme for multi-sensor networks with an incentive mechanism for nodes to relay data from others to the base station. A payment and earnings scheme has been used as an incentive mechanism in the Mojo Nation System (Oram 2001, p. 262). The literature in this area shows the contribution of economics to the coordination of networks or agents, while the economic algorithms in this work aim at communication and sharing.

Securities trading supported by peer-to-peer technology is thinly researched yet. Scientific work regarding financial networks has been contributed by Economides (1993, 2001) investigating e.g. network exter nalities and the impact of the Internet on financial markets. Further work deals with trading between investors without utilization of central markets. Despotovic et al. (2004) propose a double auction mechanism that does not rely on the existence of central authorities. Usunier (2002) proposes a form of electronic bargaining which does not require complex cognitive elaborations from agents to achieve satisfactory matchmaking and price setting. Gehrke and Schumann (2003) address the construction of electronic marketplaces and Gehrke et al. (2004) propose to organize securities trading on a peer-to-peer basis utilizing the Chord protocol.

Maxemchuk and Shur (2001) describe a distributed architecture together with a modification of the reliable multicast protocol which can be technically utilized for trading within a peer-to-peer network. Liquidnet (2001) represents an implemented peer-to-peer trading system among institutional investors demonstrating that peer-to-peer is suitable for stock trading.

This work expands the current research by proposing the application of the peer-to-peer paradigm on electronic trading venues rather than on investors using economic algorithms for communication purposes instead of resource allocation. The goal is to offer an alternative to a central market system in order to integrate markets, focusing on European trading venues, where regulation enables a local, non-central solution.

Peer-to-peer and electronic trading venues

In order to apply the peer-to-peer paradigm to electronic trading venues, it is necessary to show that trading venues can be seen as peers. From the information system perspective, there are various definitions of a peer-to-peer network or system. In Oram (2001), it is a self-organizing system of autonomous, equated nodes. The definition prefers systems without central services and a central instance. However, hybrid systems (Yang and Garcia-Molina 2001) possessing a central hub also comply with the definition, like e.g. the original Napster or the SETI project. Schoder et al (2005) highlight shared provision of distributed resources, decentralization and autonomy as peer-to-peer characteristics. Typically, peers co-operate and share their resources for a given goal of the network. Thus, in the following, electronic trading venues will be checked for equated functionality, autonomy, resource sharing, decentralization and bilateral communication among peers.

The relative small number of electronic trading venues (the European Union (2007) currently lists around 70 regulated markets in 29 countries) has potential to organize these into an efficient topology as already discussed for peer-to-peer networks, e.g. a hyper cube (Schlosser et al. 2002a,b). In the following, a brief analysis of the suitability of electronic trading venues for the peer-to-peer paradigm is performed.

Key Peer-to-Peer characteristics

The characteristic of equated nodes refers to the functionality and services offered by the various peers. It does not mean that all peers have to be equal and homogenous but that the infrastructure in terms of processing power, storage space and available bandwidth can vary from node to node. This heterogeneity of peers is often reflected in the underlying protocols or applications of the peer-to-peer network allowing peers to set own constraints or dynamically determine parameters.

From a functional and data viewpoint, electronic trading venues meet the characteristics. They are heterogeneous regarding the market model and technical capacity, but any venue has the ability to receive investor orders to buy or sell securities, to match orders and quotes according to the market model and to determine trade prices for which securities are exchanged between buyers and sellers. Typically, pre-trade prices are displayed either in form of an open limit order book (order driven markets) or as quotes (firm or indicative) of a market maker (quote driven markets). Venues also generate post-trade tick data following each transaction.

Among electronic trading venues, particular exchanges are so-called Self Regulatory Organizations (SRO) which autonomously set and supervise their own rules. Additionally, national regulatory authorities monitor their activities. Thus, there exists a high degree of own regulation and methods to prevent fraudulent action by peers. The SRO bodies also adopt schemes such as the reference price principle or the definition of the reference venues. They can define dynamic rules for reference market selection and thus lead to a self regulation of the network by local actions, such that a failure or halt of one peer can be compensated and the network can be reconfigured.

The function of sharing is another characteristic of a peer-to-peer network. This can be either resource sharing among users, e.g. files, or contribution of own resources for a common goal, e.g. computational power. Electronic trading venues are competitors for order flow and thus typically do not share resources, although they contribute to an efficient allocation of investments and to the functioning of the capital market as a whole. Here, regulation and incentives can enable sharing, as is done by the NMS and its order handling rules. In this context, the difference between market fragmentation and liquidity fragmentation is worth to mention. Market fragmentation fits well into peer-to-peer characteristics, where any single market is responsible for a distinct subset of stocks. Liquidity fragmentation, on the other hand, means that one stock is tradable at several venues and thus, there is no single allocation of investment interest. If liquidity is fragmented, it is theoretically possible that buy or sell orders are placed on different venues and therefore cannot be executed against each other, even if it were possible on a single venue. If such locks occur in the U.S., some mechanisms of the NMS resolve the problem. As stated by McCleskey (2004), the problem of liquidity fragmentation is a barrier to achieve market integration and free flow of capital.

In Europe, electronic trading venues are decentralized and operate under national rules. No central instance is allocating orders to venues or is dictating specific bilateral or multilateral communication. U.S. venues are decentralized only to some extent, because the regulation authorities have a global view of the network and define the multilateral communication between peers, fitting more into the class of hybrid peer-to-peer networks (Yang and Garcia-Molina 2001).

An obvious requirement for peer-to-peer networks is communication between peers. This typically exceeds the simple linkage through a common network like the Internet by an own peer-to-peer protocol enabling bilateral communication.

The requirement of bilateral communication between electronic trading venues is fulfilled on various levels. While some markets have no links to their competitors, others are fully connected. U.S. electronic trading venues are widely interconnected through the NMS. Here, pre-trade data from all involved trading venue peers is available for all other NMS venues through the Consolidated Quotation System. Additionally, post-trade data is shared through the consolidated tape association. Lastly, the Intermarket Trading System and the regulation, e.g. Best Execution obligations, foster the flow of orders between the competing venues. The Regulation NMS as a kind of specification determines content and timing of communication between peers.

A further indication of venue suitability for peer-to-peer approaches is characteristic of resource concentration on leaves of the network. Electronic trading venues are leaves being not the origin of orders, but the source of market data, which is incorporated through investors e.g. for their next trading decisions. The matching or trading capacity is located within the decentralized venues. They also hold investor orders at a specific time within their order books aggregating these resources from investors.

Discussed problems in peer-to-peer networks include free riding and fraud. Free riding describes the effect of peers being consumers of the shared resources without own contribution, e.g. getting files from a file sharing network while offering none. Fraud has various occurrences depending on the network and the self-regulation system in place. This can be the rising of own reputation through usage of malicious peers, not routing of queries and answers, manipulation of queries or a kind of plagiarism, where answers from other peers which should only be routed to the querying peer are rewritten such that the own peer gets awarded for them within the reputation system.

Electronic trading venues are also subject to free riding problems, whereas fraud is suppressed by the legal system. The venues are not anonymous to each other, thus a peer with malicious behavior, if detected, can be sanctioned.

Subsuming, electronic trading venues meet the characteristics and requirements for peers and can be organized in a peer-to-peer network. The next section identifies economic algorithms enabling the communication among trading venues.

Economic Algorithms for Peer-to-Peer Electronic Trading Venues Networks

This section presents two already existing economic algorithms enabling communication within a network of venues: the reference price scheme and intra-peer order routing. Additionally, a new algorithm is presented for consolidation of venue liquidity substituting the consolidation tasks already performed by brokers as intermediaries.

An overall driver for the algorithms and one of the key issues in market microstructure is the processing and incorporation of the information about an asset from various sources into its market price. The corresponding process is known as price discovery (O'Hara 1998, Frijns and Schotman 2005) and is tightly related to venue liquidity[2]. Especially limit orders carry information about the value an investor assumes or has estimated for a given stock. Other sources of information are news, reviews or analyst comments. To gain this information, a trading venue can either get the prices from other venues or from orders carrying the information or both.

Reference price scheme

The first algorithm enabling communication is the reference price scheme describing a practice where displayed prices are pulled from reference venues and used to adjust own bids and offers. It is common to improve the own displayed prices by one tick when the spread (the difference between highest bid and lowest offer) is at least two ticks (one tick is usually one cent). Figure 1 shows the situation where venue I imports reference prices from two venues R_1 and R_2, taking the highest bid and the lowest offer from them (bid at 63.12 and offer at 63.18, respectively). Venue I improves its displayed prices by one tick, leading to a bid at 63.13 and an offer at 63.17. The American Stock Exchange once started with this scheme, getting New York Stock Exchange (NYSE) prices by telephone and offering trading at these with lower commissions (Stoll 2006). The NYSE could not prohibit the communication necessary to limit this behavior. The concept of reference prices can either contribute to the own price discovery or even substitute the process.

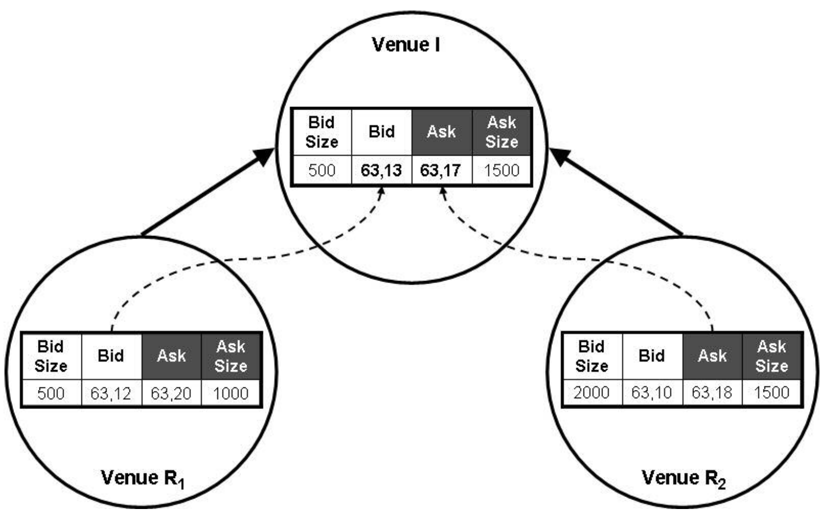

Figure 1: Venue I importing reference prices from two venues R_1 and R_2 and improving own display prices

In the first case, the imported prices help to correct price discovery bias due to lower liquidity. A high level of liquidity, regardless of the measure used, represents a high amount of trading interest and thus carries valuable information. As a result, the generated prices reflect the cumulated information and reduce the risk to trade with better informed investors. Participants like market makers compensate less for taking this risk - leading to tighter spreads both in quote and order driven markets.

In markets with low liquidity, the compensation for the various trading, information and inventory costs leads to inferior bids and offers and therefore to worse trade prices. The import of reference prices uncovers the information carried by trading

[2] Schwartz and Francioni (2004) define liquidity as the ability to trade stocks in arbitrary quantity whenever one wants to trade

interest on the reference market and helps to improve the estimation of asset prices. Publication of own prices enables other peers to gain the same benefits, too. In this case, information is shared among the markets and underpins the peer-to-peer view.

An example for the second case is the model of internalization, where the reference price is imported and the internalizer offers to trade with the investor at an improved price. Here, the investor's trading interest does not contribute to the price discovery of the reference venue and the information remains proprietary.

Importing prices from one trading venue without own contribution is free riding (Stoll 2006) as it can be found in peer-to-peer networks. The effect can be comparably negative for electronic trading venues as for peer-to-peer networks, leading to questions regarding the value of market data and market prices. Here, solutions from peer-to-peer networks could be utilized, e.g. reputation systems or a payment scheme algorithm, where import requires a positive balance earned through own contribution (Oram 2001, p. 262). Such self-organizing scheme is already present in online brokerage, where brokers offer cheaper or free access to real-time market data to those customers making a certain number of trades per month.

Intra-peer Order Routing

The second algorithm already implemented for U.S. electronic trading venues is the routing of orders between markets. Basically, an order has to be routed to the market offering the best displayed prices, the National Best Bid or Offer (NBBO). This is motivated by investor protection such that investors should not pay inferior prices if better ones are available elsewhere. It also rewards the peer for offering the best pre-trade prices without questioning the origins of this bids and offers. At first, this mechanism is consistent with the one used in various peer-to-peer networks, where e.g. good service (for instance quality or amount of content, information or files) is rewarded based on a reputation system or virtual payments. It can also be compared to organization in semantic networks, where queries are routed to peers from whom best answers are expected (Tempich et al. 2004) based on learning and own valuation. Routing of orders is a second step after displaying bids, and offers, as the market data is necessary to make the routing decision.

In Europe, routing of orders among venues is not required and thus not present. Electronic trading venues are typically unwilling to route their orders away, as they earn commissions based on orders and trades, but exceptions exist. The exchange based internalization system Xetra BEST requires the internalizers to compensate for the orders executed through this system by liquidity provision into the displayed Xetra central limit order book (Deutsche Börse 2006). Here, however, both markets are maintained by the same organization.

Request for Consolidation as ad-hoc linkage proposition

As a third, future algorithm, the request for consolidation is presented (see Figure 2). There are various possibilities to enable full execution of an executable customer order in case the client order size exceeds the displayed and hidden liquidity on one venue. At first, intermediaries like brokers can split an order across trading venues to gather the required liquidity. Another possibility is automated Smart Order Routing, where an algorithm splits an order across venues – a computer mapping of the broker's manual work. Athuman intermediated quote -driven venues, a further possibility is that a market maker replenishes the liquidity either by acting as dealer or by purchasing the liquidity elsewhere. Finally, the development of intermarket sweep orders can solve the task to gather liquidity.

In a peer-to-peer network of electronic trading venues, the solution could be achieved by an ad-hoc consolidation of books across market centers (see Figure 2). Here, the trading venue without enough liquidity (venue A) would request another trading center (venue B) for an ad-hoc consolidation of their books to gather the necessary liquidity (request for 1000 shares). If venue B agrees, the necessary liquidity would be virtually transferred to venue A into an ad-hoc consolidated book and the investor's order (for 2000 shares in the example) could be executed. The resulting price (63.175) for the investor can be superior to the one (63.18) achievable at the venue with enough liquidity (venue B). This needs adequate rules regarding handling of different commissions, compensation of the sharing market in form of priority rules for execution or other incentives. Especially electronic trading venues within a single group, e.g. NYSE and Archipelago Exchange (NYSE Arca), have fewer barriers from competition to implement such techniques. A request for consolidation algorithm substitutes the task performed by intermediaries.

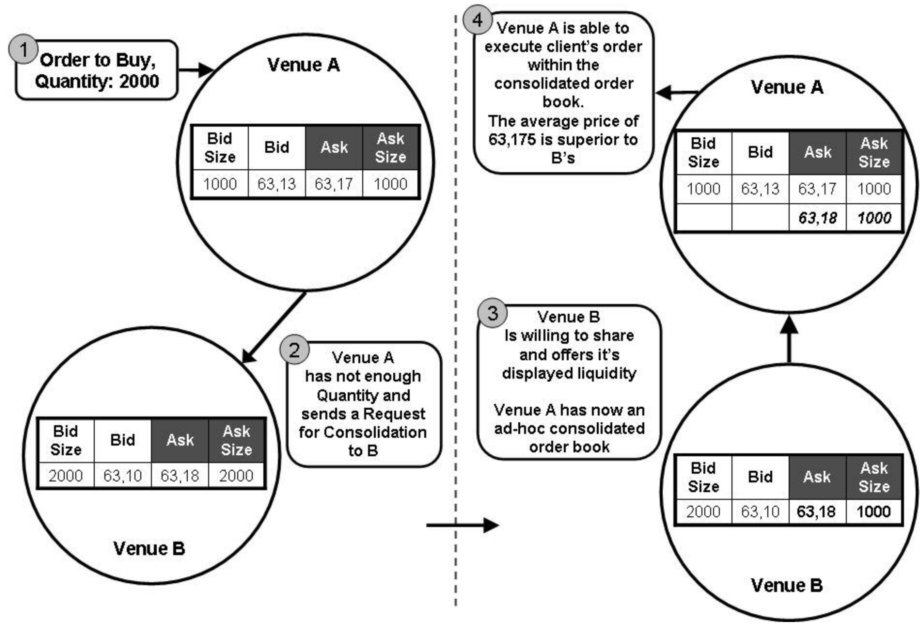

Figure 2: Request for Consolidation as a peer-to-peer algorithm

Outlook and Conclusions

By modeling electronic trading venues as peers, an integrated capital market can be achieved by the adoption of peer-to-peer technology instead of using a central approach like the U.S. NMS. European authorities have not defined a central system while encouraging the creation of a pan-European capital market. Thus, a peer-to-peer solution represents an alternative for Europe. Electronic trading venues show the core characteristics of peers and can be organized in this way.

The self-regulating nature of peer-to-peer systems is already reflected by reference price schemes utilized by some European electronic trading venues. The possibility of order interaction across multiple venues, however, which has been centrally implemented within the U.S. NMS, is missing, although the basic algorithm does not need a central instance. Today's technology (Hallam and Idelson 2003) can overcome arguments regarding speed of decentralized systems. Additionally, Regulation NMS Access Rule "enables the use of private linkages offered by a variety of connectivity providers, rather than mandating a collective linkage facility (SEC 2005, p.37501)" and offers the opportunity to introduce the peer-to-peer concept into the NMS. Peer-to-peer can also counter the failure risk of formal links between markets, as they have no incentives to maintain them (Stoll 2001).

A peer-to-peer approach offers the possibility to adopt solutions from other peer-to-peer systems, e.g. the reputation or reward scheme utilized, but unfortunately, problems of misbehavior and unwillingness of peers require a tailored solution.

Investors' search for liquidity might be supported by adopting search algorithms from semantic peer-to-peer networks (e.g. a seeking order) as well as learning methods to improve routing tables of venues, where liquidity should be first searched.

Overall, this article shows that electronic trading venues can be modeled as peers and that the peer-to-peer paradigm is not only suitable to interconnect individual investors, but can also be applied to electronic trading venues. Already existing and new algorithms to link venues together have been presented. Peer-to-peer can contribute to the pan-European discussion regarding the future organization and structure of the capital market.

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