A Multi-Agent System with Negotiation Agents for E-Trading of Securities

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Master of Science Thesis

Stockholm, Sweden

June 2014
Abstract

The financial markets have been started to get decentralized and even distributed. Consumers can now purchase stocks from their home computers without the use of a traditional broker. The dynamism and unpredictability of this domain which is continuously growing in complexity and also the giant volume of information which can affect this market, makes it one of the best potential domains to take advantage of agents. This thesis considers the main concerns of securities e-trading area in order to highlight advantages and disadvantages of multi-agent negotiating systems for online trading of securities comparing to single-agent systems. And then presents a multi-agent system design named MASTNA which considers both decision making and negotiating. The design seeks to improve the main concerns of securities e-trading such as speed, accuracy and handling complexities. MASTNA works over a distributed market and engages different types of agents in order to perform different tasks. For handling the negotiations MASTNA takes advantage of mobile negotiator agents with the purpose of handling parallel negotiations over an unreliable network (Internet).

Keywords: Multi-Agent systems, Negotiation Agent, Securities e-trading
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Chapter 1: Introduction

Whether business-to-consumer (B2C) or business-to-business (B2B), e-commerce effectively provides all the products or services one might ever want or need, often times with free shipping (Lai & Meng-Wen, 2004). One of the more recent industries to capitalize on the benefits and business potential of e-commerce is finance, particularly with regard to securities trading. Although consumers now have the opportunity to buy, sell, trade, and manage their own stock and securities portfolio, the majority of trading is done through investment firms, brokerage houses, and private equity venture capital firms, which indicates that the negotiating for this type of business needs to be predominantly B2B (Wang, Wong, & Wang, 2011).

While companies act as the members of these broker firms, they get charged by each action and also their trading area is somehow limited. These issues start the intendancy to surmount this centralized securities trading market structure and move toward distributed trading (see figure 1). Respectively companies need to have strong and efficient systems to manage this independency (Wang, Wong, & Wang, 2011).

The first concern would be about decision making in this domain. Which security (e.g. a share) is the best one to buy? What is the best time to buy/sell a security? So buying and selling decision suggestions would be the first step, for which a giant volume of information and data should be considered. Even simple break news can affect the decision, considering that these data are continuously changing and decisions should be made rapidly. And since different companies and people have different trading strategies, they need some systems to act on behalf of them (Luo & Liu, 2002).

There are also a number of critical factors that come into play regarding negotiating in securities trading using e-commerce. In particular, the system must be able to handle a large volume of traffic, while they should also manage to process and match bids in fractions of a second. Furthermore, the system must have a maximum of a six sigma error rate, adhere to all relevant federal and international regulations, and be highly secure with a strong and virtually impervious infrastructure (Aknine, 2012). Due to these critical factors, the development and design of successfully functioning negotiation systems for an internet based securities trading firm is a very challenging and arduous task, which requires a great deal of expertise, planning,
collaboration, insight, and testing to be successfully accomplished (Bala, Sheetal, & Mukhopadhyay, 2013). Further, due to the fact that each online securities trading organization is different, the specific design of the negotiation systems must be different, so as to fit the particular business specifications of each firm (Bala, Sheetal, & Mukhopadhyay, 2013).

This project will further examine the roles of decision making and negotiation agent based systems in facilitating securities trading in the realm of e-commerce in a B2B setting based on the securities trading environment, from an international perspective.

![Figure 1: Different market types](image)

1.1 Background

Agents are defined as software programs that act on behalf of human users or other systems in order to carry out desired tasks. These desired tasks can be ranged from simple single tasks to complicated multi-tasks, such as accessing and integrating information from distributed heterogeneous information sources, resolving inconsistencies in the retrieved data, filtering out irrelevant or unwanted data and summarizing complex data (Luo & Liu, 2002). Agents have

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1 Graham & Cook 3
been applied in different areas in order to automate repetitive tasks and notify users on upcoming events or system changes. Agents have the ability to learn from historical behaviors and act as a consultant to suggest alternative solutions to the user (Luo & Liu, 2002).

There are different types of agents which have a specific set of capabilities. A complex task can be divided among several agents of a same type or different types to be executed. Each agent can do its own sub-task and then cooperate with other agents in order to complete the whole task (Moreno, 2010).

Considering these abilities of agents, it has been proven that agent technology can fulfill the demands on dynamic domains such as portfolio management which is the base for securities trading (Sycara, Deckar, & Zeng, 1998). To act successfully in securities trading, user should have an integrated and updated financial picture from the current situation which can be extracted from enormous amount of continuously changing and weakly organized data. These data itself should be gathered from various information resources, even the ones which seem not to be related directly.

There have been several multi-agent system designs for supporting information gathering and decision making in stock trading area such as the system suggested by Hu and Lio which supports dynamic information and knowledge exchange among the cooperating agents (Luo & Liu, 2002). Garcia et al. reported a framework for implementing a deliberative multi-agent system (Garcia, 2000) and Cingiser et al. introduced a real-time multi-agent system based on CORBA (DiPippo, Fay-Wolfe, Nair, Hodys, & Uvarov, 2001).

While there have been several attempts in decision making part of this domain, the lack of such effort in negotiation part is felt obviously. According to available literature, the activity of negotiation in the realm of e-commerce is defined as the process by which two or more entities/parties multilaterally bargain resources for mutual intended gain, by using the tools and techniques of electronic commerce (Beam & Segev, 2009). As an example, a process in which two intelligent software agents negotiate a solution electronically and then present it to the executives would fall under the definition of e-commerce negotiation (Beam & Segev, 2009). In addition, available literature identifies negotiation as the process in which two or more parties with different criteria, constraints, and preferences jointly reach an agreement on the terms of the transaction (Rahwan, Kowalszyk, & Pham, 2002). This serves as a broader definition, as it would apply to any type of negotiation including those relating to e-commerce, and those that do not.
Importantly, many current automated negotiation systems support one-to-one negotiation; although the need for more complex one-to-many automated negotiations have become increasingly prevalent within e-commerce, particularly within the business to business realm of e-commerce (Abrahams, Bellucci, & Zeleznikow, 2012). To date, one-to-many negotiation has been mostly automated using limitations, such as the lack of the ability to perform two-way communications of offers and counteroffers, which indicates a distinctive need for greater emphasis in development in this area (Rahwan, Kowalszyk, & Pham, 2002). Despite this need for further development, e-commerce agents have become more powerful tools for buying, selling and searching for products through the Internet over the past two decades (Fathey & Moawad, 2005).

Over these decades, organizations engaging in online trading e-commerce have found that automated negotiation agents have facilitated much more effective and efficient trading (Acheson, Dagli, & Kilicay-Ergin, 2013). One of the most important new additions to the area of automated negotiation agents is the concept of multi-agents (Rahwan, Kowalczyk, & Pham, 2002). Specifically, one-to-one negotiation is common among certain e-commerce businesses, particularly in retail, but e-commerce geared towards securities trading requires a more complex one-to-many type of automated negotiation in order to facilitate effective and successful trading of securities between thousands of buyers and sellers nearly simultaneously (Li & Sheng, 2011).

As such, it is the concept of one-to-many negotiation agent systems that serves as one of the primary focuses of research and study in the realm of e-commerce as it relates to B2B business operations from an international perspective (Kim, Hong, & Yong, 2007). This thesis project seeks to explore the advantages and disadvantages of the multi-agent system for securities e-trading by focus on including negotiation as well, examining the most important issues that should be concerned in this area. Then, a potential system solution will be proposed to address some of these issues.

1.2 Problem

As described in previous sections, securities e-trading is one of the potential areas to take advantage of e-commerce and respectively agents in order to act successfully in this area; however most of the efforts in this area are related to centralized markets. While the other types of agents have been used previously in this domain, considering negotiation agents, in order to trade on distributed networks and facilitate high volume securities trading data and
transactions, has become increasingly prevalent in the realm of e-commerce (Lai & Meng-Wen, 2004).

Available literature appears to indicate that a multi-agent approach may represent one of the most promising approaches to ensuring adequate negotiation support in all securities transactions regardless of current volume (Renna, 2011). Despite this, a single agent approach, one-to-one negotiation represents the method that has traditionally been employed by e-commerce based securities trading firms (Ren, Zhang, & Fulcher, 2012).

As such, the problem which this study seeks to resolve is to provide a comparison framework between single-agent and multi-agent system to see what they provide to address main issues with regard to B2B securities e-trading in the international distributed market. Then it should be determined that which of these approaches fits better the domain requirements for negotiating. In addition, considering the limited work in the area of negotiation agents for this business, this thesis will suggest a system design including negotiation based on the selected approach which considers the crucial factors of the business.

Ultimately considering the fact that negotiation agent systems play a crucial role in e-commerce B2B based securities trading throughout the world (More, Vij, & Mukhopadhyay, 2013); identifying and addressing relevant problems that may arise with regard to negotiation agent system will help to facilitate more effective and efficient securities trading in the future.

1.3 Purpose

The purpose of this thesis is to present the advantages and disadvantages of the multi-agent system over the single-agent system for one to many negotiations in online securities trading and then present a multi-agent system design for this domain named MASTNA (Multi Agent Securities Trading Negotiation Assistant) which considers negotiations. This design engages different types of agents based on their abilities in order to perform different tasks. It will also present ways in which the multi-agent system can be improved so that it meets the demands that will be placed on online securities trading in the future.

1.4 Goal, Benefits, Ethics and Sustainability

The goal of this project is to define a comparison framework in order to determine which agent approach, multiple or single, fits the demands of securities e-trading negotiations
considering the facilities and weak points for each approach. Furthermore, based on the selected approach, the negotiation part of the system is designed and added to the whole design of MASTNA which is a multi-agent system for securities e-trading. This design tries to take advantage of the right agent type in the right place, by recognizing different types of agents and their abilities.

There are a number of critical factors that should be considered in designing agent based systems for securities e-trading such as volume of the transactions and data, speed, accuracy and also security. Since these critical factors get even more important considering the selected business area which is B2B e-trading of securities, this project tries to consider them in the design and also suggest some improvements. The suggestions may also be used to upgrade existing systems to make them consistent with the need to process higher volumes with increasing speed, accuracy, and security.

The benefits that can be realized upon the achievement of the project goals can be extensive and far-reaching as this project has aimed a specific domain—securities e-trading—within e-commerce. Importantly, the e-commerce business sector has become increasingly prevalent in recent years (Kim, Hong, & Yong, 2007).

In addition, the e-commerce business sector represents one of the largest users of negotiation agents in order to facilitate effective e-commerce operations (More, Vij, & Mukhopadhyay, 2013). This requirement is significantly higher among firms engaging in B2B e-commerce business operations. Essentially, providing e-commerce organization with the necessary information technology, to support smooth digital business operations, will enable businesses operating within this sector to achieve organizational goals and strategies, as well as growth and expansion in the future (Yeung, 2011).

Moreover, the availability of highly effective and appealing negotiation agent solutions, designed to support e-commerce business operations, will motivate other organizations to enter the e-commerce market in order to reap the fiscal benefits that have been realized by existing firms within the sector (Wong & Fang, 2010). The increase in competition will effectively benefit the customer as prices remain in equilibrium with supply and demand, and increased selection provides customers with a better choice of product and service options (Wong & Fang, 2010). Based on this, the benefits associated with the identification and development of an enhanced negotiation agent primarily geared toward supporting B2B e-commerce enterprise
can impact a number of relevant stakeholders, although most importantly, the organization itself and the firm’s customers.

Narrowing the discussion down to this case which is securities e-trading, existing applicable and efficient e-trading systems will encourage different companies dedicated or even interested in securities investments to develop and apply their own systems rather than dealing with broker firms. In this way, instead of paying fees to the broker or exchange firms, they can invest their money to employ their own systems based on their own preferences. They will be able to trade securities more globally and by replacing the brokers, the results would be more reliable.

Although it seems that the brokers are eliminated, but the fact is that they are replaced by software agents. So the main ethical issue which is common in this filed, is that to what extent should decisions be delegated to computational agents? Of course this ethical issue would be more important in other domains such as medical area, but we cannot omit the importance of financial area in today’s lives.

Furthermore, replacing the broker firms and humans by agents can also lead to some other ethical considerations, such as the increasing possibility of misusing agents caused by non-existence of controls. Agents are supposed to act as humans, but they are not able to consider moral and ethical issues; in the other words “They will do what user wants them to do”. Lacking double controls and overall monitoring which was the responsibility of the broker firms may cause some illegal manipulations of agents to act on behalf of one user’s benefits. For example an agent may broadcast invalid data which can affect pricing of a specific stock.

Sustainability as it relates to the topic of negotiation agents in the e-commerce business sector is an extremely important concept in which to examine. As is the case with any business related function, changes within the marketplace, such as technological advancements, innovation, and consumer preferences will require corresponding changes and adaptations to these business functions. This appears to be especially true in the e-commerce business sector as it continues to emerge as an increasingly popular platform for business operations throughout the international marketplace.

One of the biggest issues that could impact sustainability of the solutions resulting from this study may involve the different cultural business ideologies that exist within the various nations that actively participate within the international business world (Hofstede, Jonker, & Verwaart, 2012). Specifically, cultural beliefs with regard to business can differ significantly
from one nation to another. Certain nations have developed extensive legislative frameworks to protect intellectual property and to govern acceptable business practices, while other nations have very little in the way of legislation to govern these areas. Further, in some countries, corporate corruption through bribery is a standard business practice, yet in other nations, this type of practice would be considered illegal (Phokha & Nonsrimuang, 2013).

It is critical that the outcomes of this project take into account the various cultural differences that may exist across the international marketplace, as fluctuations in such may require further changes and adaptations to the negotiation agent framework. Sustainability may also be negatively influenced by technological advancements and innovations in the realm of e-commerce and information technology. As such advancements emerge, negotiation agent solutions will have to adapt and change in order to support the enhanced technology in an effective manner (Rouff, 2006). If this is not done, the negotiation agent system may become ineffective or obsolete. Ultimately, due to the fact that technological advancements and innovations occur on a continuous basis, particularly in the realm of information technology, sustainability of the negotiation agent solution will be limited as continued changes and improvements will need to be made in order to reflect technological advancements within the area of e-commerce and online business operations.

Lastly, sustainability would need to be more basic and related to the local infrastructure. For example, in some countries, the possibility of losing electrical power should be considered. This issue gets more significant when it comes to security trading business, since even micro seconds can be crucial. Infrastructure is more critical in some areas than in more advanced industrialized nations with a modern electrical grid.

1.5 Methods

When conducting an academic study, there are a number of factors that should be considered in order to ensure the study flows properly and that it effectively explores the subject in the manner that was anticipated and desired by the researcher. Importantly, there are a variety of different research methods that can be used to direct a research study, each of which possessing their own framework of defining characteristics that focus on a specific type of data and philosophical approach to facilitate usable outcomes.

The two most fundamental categories that research methods are divided into are that of qualitative and quantitative research (Håkansson A., 2013). As such, it is typically the first step
of the research process to determine which methodology will be taken (Håkansson A., 2013). While in the quantitative method a phenomenon is proving by means of a large data set, in qualitative method phenomenon is studying in order to create theories, products and inventions. Put in simplest terms, quantitative research is numeric based while qualitative research is not (Håkansson A., 2013).

The method that will be used in this study is qualitative, since the project is studying the different approaches of designing agent systems and takes advantage of comparative analysis in order to come up with a new system design in the area. For this purpose the project is not dealing with a highly structured data set, so the qualitative method seems more relevant.

Philosophical assumption can be considered as the start point of the project, since it affects the whole project (Håkansson A., 2013). Among the core assumptions which are Positivism, Realism, Interpretivism and Criticalism, the philosophical assumption of this master thesis can be mostly classified as Interpretivism while in some parts it is realism.

Positivism mostly focuses on testing theories via deductive manner, while in Criticalism the focus is on oppositions and conflicts. Interpretivism assumption is used in the projects which are based on opinions, perspectives and experiences, while realism is not dependent on a person and studies a known or perceived fact. In realism researchers try to develop the knowledge by observing a phenomenon. (Håkansson A., 2013).

The main purpose of the project is to introduce a system design for securities e-trading which is not existing yet and is based on personal experience and knowledge, so the main assumption of this thesis in interpretivism. On the other hand, a comparison of single-agent and multi-agents systems will be conducted in general which is studying an existing fact and is based on general understanding rather than personal. This comparison can be fallen into realism area.

A more detailed explanation of the methods will be reviewed in chapter 3.

1.6 Delimitations

When preparing to conduct a comprehensive research project into a particular area of study, it is very important and potentially useful to identify and examine the various delimitations that researchers will face, as well as limitations to the study itself which may limit the overall applicability of study findings.
The first delimitation of this study involves the fact that available literature and examples for single agent systems are a few and rather old comparing to multi-agent systems which makes the general comparison restricted. On the other hand current research and development in the area of multi-agent systems for negotiation are far more limited than that of single agent systems (Fathey & Moawad, 2005). Although the multi-agent approach to automated negotiation represents one of the most promising areas of future research, the fact remains that the research, conducted in this area is still within the early stages. As a result, the research conducted in this study will ultimately be underpinned by this limited research, which may become somewhat obsolete in the near future as additional research in the area is completed. However, the research conducted in this project will hopefully serve as a valuable addition to the current body of knowledge in the area of multi-agent automated negotiation systems, and as a result, help to facilitate future research in this area.

The second delimitation of this research is that the negotiation agents, focused on in this study, will be designed for the broadest applicability within the international marketplace, which requires the consideration of numerous laws and regulations in order to ensure the negotiation agent is capability of maintaining operations from the e-commerce platform in accordance with the law. As such, the development and ratification of some sort of international legislative framework that outlines the rules and regulations governing e-commerce and business activity on an international scale would be particularly useful in simplifying the negotiation agent processes while widening its applicability (Fisher, 2010). Although there have been a number of multi-nation commerce agreements developed in recent decades, such as those of the European Union, the world lacks a universal standard by which international commerce must adhere to.

Ultimately, if such a standard was developed and adopted throughout the world, this study would be able to provide negotiation agent solutions that are further enhanced to provide additional benefits to both e-commerce organizations and their customers.

The last and somehow most important delimitation of the study is the time and scope of a master thesis project. It leads the project to be limited in the abstract and mostly conceptual level rather than exploring implemental details which lies further than the scope of a master thesis.
1.7 Outline

In the following of this report, Chapter 2 will consist of a literature review of the research that has been conducted on the topic up to this point. It will examine the current body of knowledge and identify any existing gap in the knowledge. A short description of the terminology to be used in this project will be also mentioned in this chapter. Chapter 3 will provide the rationale for the selected research methods and will provide the research procedures. Chapter 4 will consist of the comparison between single and multi-agent systems based on the concerns of the area and then selection of the proper approach for the desired domain. Chapter 5 will present the suggested design and architecture based on the selected approach in chapter 4. Chapter 6 includes evaluation of the design regarding to the same concerns for comparison in chapter 4 in addition to suggestions and discussions. Chapter 7, states the conclusion of the work and suggest some further works.
Chapter 2: Literature Review

This chapter presents relevant literature on the topic of this research study. The first task of the literature review is to provide an understanding of agents in the trading industry. It will explore the use of single and multi-agent systems, as well as what is currently known about their advantages and disadvantages. The literature review will rely on authoritative current sources to derive its information. It will explore the current state of information on the topic, as well as any gaps that may need to be filled in the knowledge base.

2.1 Background of E-commerce Negotiation Agents of the 21st Century

E-commerce stands among the brightest blossoming business platforms of the 21st century as increased emphasis has been placed on automation and computers to facilitate virtually every business activity from marketing to sales, from supply chain to distribution chain (Li & Sheng, 2011). In addition, the e-commerce platform has helped to support a veritable boom in service based businesses that rely of various services as their primary offerings rather than tangible goods such as those in the grocery store. In response to this rise in service based businesses that are utilizing the e-commerce platform as the mechanism to run their enterprise, technological advancements have been pursued in order to provide these businesses with the technology and computer solutions they need to conduct business operations almost entirely through a virtual storefront (GreySpark, 2013).

Of course, the software used to support service firms that offer traditional or straight forward products, such as banking, car insurance, tax service, and the like, the software needed is relatively simple. These firms generally have a plethora of solutions at their disposal so that they can select the one that most closely meets the needs of the firm, both from a financial perspective and a business perspective. Importantly, there are other e-commerce based businesses that require software that is far more sophisticated and highly technical that those used in traditional service businesses.
A perfect example of an e-commerce firm that would require such sophisticated software solutions are those within the securities trading industry (GreySpark, 2013). Essentially, according to Purch², securities trading offered through an e-comerce format has gained considerable popularity in recent years as a result of successful advertisement campaigns for e-commerce based investment firms such as T. D. Ameritrade, Scottrade, E*Trade, and others. The number of proprietary e-trading sites continues to grow at a steady pace. Competition is becoming increasingly tough. Companies must continue to improve their trading systems to work more efficiently in response to this increased competition.

As previously stated, the tech support needed to operate a securities trading firm through an e-commerce platform would be considerably sophisticated requiring a wide range of capabilities to ensure the firm remains in compliance with all relevant regulatory frameworks, as well as established industry standards. Perhaps the most important of these highly sophisticated technical solutions is known as the negotiation agent. It is actually the negotiation agent that is used to facilitate the trades that are made between the firm and entities within the securities market, all on behalf of the firm’s clients. In particular, a negotiation agent based on the context of being used within a securities trading e-commerce firm is known as automated negotiation, which represents a powerful and critical method used to allocate scarce resources among self-interested autonomous software agents (Rahwan, Sonenberg, Jennings, & McBurney, 2007).

When conducting securities trading from an e-commerce platform, the firm’s software system will be required to interface with other software agents that are associated with other agencies and firms, each having their own set of goals and objective that are often divergent from the other firms involved in the transaction. Prevailing research indicates that automated negotiation as it is used within e-commerce based securities trading, is focused primarily on theory relating to negotiation protocol and strategy (Cao, Chi, & Liu, 2009). One major problem that has plagued firms seeking to develop negotiation agents involves overcoming the obstacle of designing the negotiation strategy, which is the mechanism that is utilized by an agent to facilitate decision making and dictate its negotiation behavior.

Within recent years, a substantial amount of research has been focused toward multi-agent systems, much of which being directed at examining the various aspects of intelligent

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² Purch.com
negotiations while using a variety of different methods in differing domains. The most prevalent of these include game theory, decision theory, and economic paradigms (Aknine, 2012). Much of this research falls short of examining the complexities associated with negotiation systems that have been developed in recent years, which represent an entirely new generation of system applications.

Despite the scant research in this area, there have been a few key studies conducted that outline specific problems that are faced by designers seeking to develop multi-agent systems within the current e-commerce environment that is full of the newest generation technological solutions. What is perhaps one of the loudest messages delivered from the prevailing literature is that the increased complexity associated with negotiation paradigms used within the 21st century, as well as the complex strategies that accompany them, illustrates that multi-agent systems are an essential business tool to e-commerce based securities trading firms operating within today’s e-commerce landscape (Abu-Draz & Shakshuki).

In the end, despite considerable efforts to design a negotiation agent system that utilizes a sound strategy, problems can continue to persist, requiring frequent interventions by designers and administrators.

One problem that can emerge involves addressing behavioral issues that arise within the system, such as deadlocks between agents within a multi-agent system. Fortunately, research has been conducted on this issue, which has facilitated the development of effective interventions that can address this problem and enhance the overall strength and integrity of the multi-agent system. The most widely accepted solution to behavioral problems found within multi-agent systems is known as formal verification. Specifically, when one tries to determine the optimal values of timing parameters based on simulation results, formal verification can assist in refining the results by confirming whether deadlocks among the various agents within the multi-agent system are possible for particular established parameter values (Yeung, 2011).

2.2 Terminology

There are several concepts associated with this project that are critical enough to merit further discussion and detailed definition. The specific concepts that will be discussed here include the terms agent, different type of agents, negotiation agent, the different types of agent systems, as well as how each compares to the other as they are used in the securities e-trading
industry. In addition, to ensure total clarity and understanding, relevant terms associated with securities trading will be defined as well.

### 2.2.1 Agent

Agent is a term that has a number of different meanings depending upon the context in which it is being used (Rasmusson & Janson, 1999). Within the context of this study, the term ‘agent’ refers to a computer software program that is designed to respond on behalf of the user or organization to conduct certain transactions (Rasmusson & Janson, 1999). There are a number of different ways in which a software agent can respond on behalf of an organization.

One common example of this would be when someone places an order through an e-commerce based retailer's web site. The software agent will work to collect the appropriate information that is necessary to complete the order and alert the customer if relevant information is not provided. In addition, the agent facilitates the placement of the order automatically, and immediately sends the order to the appropriate department while generating an automatic e-mail to the customer indicating that the order has been processed. This is a typical example of a software agent as it functions independently yet on behalf of the organization based upon the parameters set forth by the user.

### 2.2.2 Software Agent vs. Intelligent Agent

As described above, a software agent is software which acts on behalf of other party which is computer user in this case. Of course to act on behalf of other party, a software agent needs to be intelligent enough, so the terms “Software Agent” and “Intelligent Agent” are used interchangeably.

However, in some literatures, these terms have been used as separate terms. Intelligent agents are the agents that have the ability of learning from previous decisions and actions, while the software agents do not need to have this ability (Håkansson A., 2011).

### 2.2.3 Different types of agents

There are many different classifications of agents which have been done based on the employed criteria. None of them is an exact division which can be applied in the general sense. However, there is a more common classification of agents applied in the computer science field suggested by BTLab researchers (Moreno, 2010), (Mahmoud, 2000):
Collaborative agents

- These agents typically operate in Multi-Agent Systems (MAS) since their main characteristic is to communicate and cooperate with other agents while saving autonomy in their tasks.
- These agents negotiate with their peers to reach mutually acceptable agreements during cooperative problem solving.
- The best application of these agents is in distributed problem solving caused by distributed problems, data sources or even expertise such as air-traffic control.
- By applying these agents the system can act beyond the abilities of any of its members.

Interface agents

- As it is obvious from their name, these agents are in contact with the user and try to perform tasks for their owners.
- Their aim is to support and provide proactive assistance to the user who is using a particular application or trying to solve a problem. So they act as a personal assistant.
- They have limited cooperation with other agents and normally they do not need reasoning capabilities.
- They are also used for notifying the user about any system event or change.

Mobile agents

- Mobile agents are able to migrate from host to host to work in a heterogeneous network environment (e.g. Internet)
- In most of the applications the idea is to go to other system to perform a given task and then come back to the initial host with the obtained results
- The environment in which mobile agents exist, is a software system distributed over a network of heterogeneous computers and its primary task to provide an environment in which mobile agents can run.
- The areas which are most attracted to use this type of agents are the ones including data process over on unreliable network.
- E-commerce is an interesting area which attracts lots of effort in using mobile agents.
Information/Internet agents

- Explosive growth of information in World Wide Web increases the interest in applying such agents
- These agents can manage the access to multiple heterogeneous information sources which are distributed over the world
- Their main task is to acquire, meditate and maintain the relevant agent for user or other agents dynamically.
- They are able to retrieve, extract, fuse, analyze, summarize and filter the data, in addition to monitoring and updating relevant data sources on behalf of the user.

Reactive agents

- These agents act and response in the stimulus-response manner to the current state of the environment.
- They are viewed as a collection of modules which operate autonomously and responsible for specific tasks (e.g. sensing, computation and etc.)
- The area of interest for this type of agents is entertainment domain such as 3D animations.

Hybrid agents

- The configuration of these agents is a combination of other agent types gathered into one single agent.
- It is difficult to see where, when and whether to use this type of agents.

2.2.4 Negotiation Agent

The term ‘negotiation agent’ refers to software agents that have been given the capability to perform negotiation functions with other agents on the user or organization’s behalf. As such, this type of negotiation is regarded as automated negotiation as the negotiation process is generally left up to the software agent to complete while acting on the behalf of the organization.

When used in the context of online securities trading, negotiation agents are considered intelligent agents, as they are required to respond accurately to a variety of different transactions that require the use of logical progression in order to ensure the appropriate response is taken within the negotiation process (Rasmusson & Janson, 1999). This requires extensive programing that will prepare negotiation agents to respond accurately to any scenario.
or set of circumstances that may occur so that negotiation agents act in conjunction with what is most desired for the organization.

When negotiation agents are used within securities e-trading organizations, the negotiation agent will be charged with completing the negotiation process by interfacing with a number of other negotiation agents on a competitive basis as each negotiation agent will be designed to protect their self-interests and facilitate the best possible set of outcomes for the organization (Rasmusson & Janson, 1999). This indicates that extraordinary complexity goes into designing competitive negotiation agents as they must be able to stand up against the negotiation agents that it interfaces with to facilitate the best outcomes.

Importantly, there are two main types of negotiation systems available for firms to utilize, which include single agents and multi-agent systems (Rasmusson & Janson, 1999). Each of these systems possesses a unique set of capabilities and characteristics that cause them to be best suited to the needs of certain organizations based on their individual set of requirements and business activity.

In order to better understand how single agent and multi-agent systems are implemented and utilized within today’s organizations, the following will provide a brief discussion that defines each system, as well as a comparative analysis that will establish the appropriate context and environment in which each should be used to garner maximum results.

### 2.2.5 Single-Agent Systems

Single-agent systems are those that are centralized in that the power and influence of the agents is concentrated into a single agent rather than distributed throughout a number of agents. As a result, the single-agent system is far more complex than multi-agent systems as it is charged with conducting a wider array of functions and tasks. The functionality of the single agent system is unique and of itself, as well as it models itself, the environment and interactions (Stone, 1997).

With a single-agent system, the goals, actions, and domain knowledge are centralized into a single agent, which results in a less flexible agent. This is demonstrated in the figure below, which illustrates the environment associated with single agent systems.
A single agent system adapts to the environment in which it interacts. Every agent is independent, with their own goals and knowledge set. They are not aware of any other agents or interactions. They do not recognize the goals of any other agent in the environment. They are simple considered part of the environment (Stone, 1997).

A single agent system operates as a single, self-contained entity. This differs from a multi-agent environment where every agent recognizes the other agents in the environment. As such, for systems that are complex and require substantial flexibility, the single agent system is likely not the best option to pursue. In order to fully understand why this is the case, it is important to define and explore the multi-agent system for comparison.

2.2.6 Multi-Agent Systems

A multi-agent system refers to a network of software agents that are coupled together in order to facilitate problem solving that is beyond the capabilities of the individual agent (Cao, Chi, & Liu, 2009). In the other words, a multi-agent system is a heterogeneous system...
consisting of two or more agents which belong to two or more different agent types (Moreno, 2010).

Just as was described in the discussion regarding single-agent systems, multi-agent systems function as a decentralized unit with authority and capabilities distributed among several agents rather than consolidated into one. This allows for each agent to be focused on one particular task or problem solving element in order to facilitate greater simplicity in the design of each agent. Importantly, when all of the agents are linked in a network, the complexity of the agent process is far beyond what is found in any single agent system as the capabilities provided by the various agents in the multi-agent system are extraordinarily extensive (Weiss, 2013). Put in simpler terms, a multi-agent system is a system comprised of a number of different agents where each has the capability to perform divergent yet critical tasks necessary to facilitate an organization’s operations.

There are two different architectures for multi-agent systems (Moreno, 2010):

- Flat: Each agent can talk directly to any other agent in the system
- Federated: There are facilitator agents that manage the connections and communications among the agents

Based on the preceding discussion, one can infer that there are some systems that would be best suited to a single-agent system, while there may be others that would benefit more from a multi-agent system. The system being explored in this study involves e-commerce based securities trading, which is a highly complex function that requires the negotiation agent to interface with a number of entities in order to facilitate a myriad of trade decisions that meet the set requirements and parameters of the system (Weiss, 2013). Due to the complexity inherent in the securities trading process, the multi-agent system appears to be more suitable for e-commerce firms engaging in this type of business. This is the discussion which needs to be more clarified.

Importantly, prior to conducting an in-depth examination of why this is the case, it is first necessary to briefly cover the most commonly used securities trading terminology relevant to the e-commerce securities trading industry. Providing a cursory explanation of the definition and context of this terminology will ensure easier and more accurate interpretation of the study and its findings.
The most common securities trading terminology involves terms such as trader, trading, securities, stocks, risk, margin, and a lot of other terms.

2.2.7 Trade/Trading

The simple definition of a trade which can be found in any dictionary is “The action of buying and selling goods and services”. The more detailed and finance-related definition can be found in Investopedia as “A basic economic concept that involves multiple parties participating in the voluntary negotiation and then the exchange of one’s goods and services for desired goods and services that someone else possesses. The advent of money as a medium of exchange has allowed trade to be conducted in a manner that is much simpler and effective compared to earlier forms of trade, such as bartering.”

The term trading is used to describe the action of one firm trading securities with another firm in exchange for some sort of equitable compensation, which is most typically monetary. For firms within the securities trading industry, the rules of economics apply in that these firms seek to engage in trade where they will be able to obtain the highest possible value at the lowest possible cost. Ultimately, the action of trading is what powers the securities trading market, and thus, what is used to generate revenue among securities trading firms.

2.2.8 E-Trading

The process of conducting market transactions (buy and sell orders) using an electronic platform that transfers the orders to a physical person to complete. Electronic trading has become a popular method due to its ability to conduct transactions quickly and effectively (BusinessDictionary, 2014).

2.2.9 Trader

Within the context of the e-commerce based securities trading firm, the trader is referred to the specific parties that are engaged in trading a specific security that each party is mutually interested in exchanging. Typically, a securities e-trading firm represents one trader in this arrangement, while the other traders may include other securities firms, brokerage houses, and individual people (Investopedia, 2014).
2.2.10 Trade Parameters

There are some concepts or parameters which are linked to each trade (Simmons M., 2002):

- **Trade Date**: It is the date of trade execution. In the other words, trade date refers to the date on which the trade parties agreed to trade.

- **Operation**: It determines the type and direction of the trade, which can be whether buy or sell, lend or borrow.

- **Quantity**: Quantity specifies the number of units of the goods being exchanged.

- **Goods**: It refers to specific goods or commodities being exchanged in a trade. When it comes to Securities Trading, Goods are referred to as Securities.

- **Price**: This price refers to the price of each unit being exchanged.

- **Supplier**: Supplier is a party that supplies goods or services, according to BusinessDictionary or the entity with whom the trade gets executed. (The one who deliver the goods and receive the cash) In Securities Trading, the party with whom the trade is conducted is known as counterparty.

- **Delivery Date**: It refers to the agreed intended date of delivery (of goods) by the supplier and payment (of cash) by the buyer. Delivery date in Securities Trading is known as value date or settlement date.

- **Risk**: This concept will be described more detailed later.

2.2.11 Securities

The term security, as it is used in the context of this project, is defined as a financial instrument that represents an owner share in a publicly traded corporation (Investopedia, 2014). The most common forms of this ownership share are known as stock, and bonds (Simmons M., 2002). In particular, stocks represent the type of security that provides owners with a small ownership stake in the organization. As a result, the individual will maintain this ownership stake until such a time as they sell or trade their ownership stake in exchange for some sort of compensation. In contrast, bonds represent a type of security that is regarded as debt (Simmons M., 2002). As such, when an organization is in financial straits, bond holders are typically given priority of repayment before stockholders.

In addition, bonds typically have a fixed rate of interest that will be earned by the bond owners, which often makes bonds a safer and more desired type of security by some investors.
Ultimately, a security is a negotiable and fundable financial instrument that is assigned a specific financial value. In the securities trading process this financial value that is assigned is universally observed by all those engaged in the securities trading market (Simmons M., 2002).

2.2.12 Risk

Risk has been generally defined as a probability or threat of damage, loss, or any other negative result caused by external or internal vulnerabilities. Risk may be avoided through preemptive actions (BusinessDictionary, 2014).

Risk in finance domain is defined as the probability that the actual return of an investment be lower than the expected return at the investing time. Finance is fundamentally based on the relationship between risk and return, the greater the potential return, the greater amount of risk that an investor should take on. The reason for this is that investors need to be compensated for taking on additional risk (Investopedia, 2014). Different types of risk are usually measured by calculating the standard deviation of the historical returns or average returns of a specific investment. A high standard deviation indicates a high level of risk.

In securities trading, the risk is referred as the probability of a loss or drop in value. This trading risk can be categorized as market risk which is caused by overall market system and affects all the securities from the same class, and nonmarket risks.

2.2.13 Risk Management

Risk management is the process of identification, analysis and either acceptance or alleviation of uncertainty in investment decision-making. Risk management process is consisted of two general steps: determining the existing risks in an investment and then handling those risks in a way best-suited to investment objectives (Investopedia, 2014).

2.2.14 Portfolio

Portfolio refers to a grouping of financial assets such as stocks, bonds and cash equivalents, as well as their mutual, exchange-traded and closed-fund counterparts. Portfolios are held directly by investors and/or managed by financial professionals (Investopedia, 2014). Risk measurement determines how the value of a portfolio will change as market factors change, while portfolio construction requires a measure of the accuracy of the manager's forecasts (Smithson & Wilford, 2000).
2.2.15 Portfolio Management

It is really important to understand the difference between risk and portfolio management, as in many cases these concepts have been confused.

Essentially, risk management is not a substitute for portfolio management. Risk management is all about measuring and controlling the risks of an existing portfolio. On the contrary, portfolio construction is about selecting a set of risky positions designed in order to maximize return subject to the amount of risk that is considered to be appropriate (Smithson & Wilford, 2000).

2.2.16 Margin

In general context of the business, margin refers to the difference between the original cost of a good and its selling price. In securities trading, it refers also to the difference between the loan (borrowed money for trading securities) and the current value of the deposited securities (BusinessDictionary, 2014).
Chapter 3: Methodology

The purpose of this research study is to suggest an agent based system design for use in an e-trading environment within the online e-commerce world. Selecting an appropriate methodology for conducting the research is of utmost importance to the success of the project. The following will explore the rationale for choosing the selected research method, as well as the research procedures to achieve the desired results.

3.1 Rationale

Qualitative research is generally regarded as the research method used to answer the how and why behind human behavior based on opinion, perception, and experience (Creswell, 2012). The qualitative research method is usually used when the research seeks to gain a deeper understanding of meanings and opinions among a population in order to develop sound theories that can be used to define a particular behavioral phenomenon or belief system (Ploeg, 1999). Importantly, qualitative research generally uses data sets that are quite a bit smaller than those used in other methods (Neill, 2007).

Unlike qualitative research, a quantitative research approach focuses heavily on numerical data facilitated through experiments and rigorous testing of identified variables in order to prove or disprove established hypothesis (Håkansson A., 2013). Another characteristic of the quantitative research method that differs from qualitative research involves the size of the data sets that are used which are also highly structured (Creswell, 2003). In particular, quantitative data deals with much larger data sets than qualitative research which makes it the best approach for particular areas such as performance testing.

As it was mentioned in the first chapter as well, qualitative method can better fits the demands of this project, since it seeks to deeply understand a specific domain and its concerns and try to choose the more suitable approach to suggest a new system design. Although, this study includes a comparison between two existing approaches, the comparison would be more based on conceptual analyses rather than numerical ones. The data sets used in this research are limited and low level structured.
It is important to note that qualitative and quantitative research represents the broadest classification of research methods, and as such, additional analysis must be done to narrow the methodology to a level where it supports the unique parameters of the study being conducted (Neill, 2007). Importantly, there are a number of levels that must be examined when pursuing a qualitative research method, as each level requires a decision that defines the direction that the researcher intends to pursue. These levels include philosophical assumption, research methods, research approaches, research strategy/design, data collection, data analysis, quality assurance, and presentation (Håkansson A., 2013).

The philosophical assumptions associated with qualitative research include mostly interpretivism and partially realism. Interpretivism generally combines qualitative methods, i.e. empirical analytical data with inductive reasoning and logic (Payne & Payne, 2004). Realism accepts the existence of the external world, yet relies solely on research and experimentation to explore and better understand this external world without the use of personal assumptions, and deductive logic (Payne & Payne, 2004). Essentially, realists observe a phenomenon in order to gain creditable data and facts and then try to understand this data to be able to develop the knowledge (Håkansson A., 2013).

Considering these characteristics and as it was stated before, both interpretivism and realism assumptions can justify the scope of this study. In particular, designing a system to facilitate massive volumes of electronic negotiations for a securities trading firm will require emphasis on the actual environment as it exists in reality in order to extract the main concerns of the environment. Then these concerns should be matched to an approach for design, and ultimately suggest a system design which can fulfill the environment’s demands.

3.2 Research Method

The next step to consider after determining the appropriate philosophical assumption involves selecting the appropriate research methods, which have been identified as analytical, non-experimental, empirical, fundamental, and applied (Håkansson A., 2013). Essentially, each of these research methods serve a particular purpose to researchers, which is what differentiates them from other methods as a mechanism to help researchers achieve their research goals and objectives.
Among these methods, analytical, fundamental and applied research methods seem to be more applicable for this project.

Fundamental research primarily focuses on establishing generalizations that facilitate the development of a theory that can be used to explain the existence of a particular phenomenon or set of outcomes. Within this context, conducting research for the main purpose of gaining knowledge is considered fundamental research. As such, research devoted to examining natural phenomenon, such as weather patterns, virus propagation rates, and star luminosity, represent different types of fundamental research (Creswell J. W., 2012).

Applied research is different in that seeks to answer real-world issues. In particular, the primary aim of applied research is to determine a particular solution to a specific problem (Creswell J. W., 2012). As such, applied research is used quite frequently in a number of discipline areas, including economics, business, politics, and social sciences.

Analytical research method uses the collected data in order to analyze and evaluate the material and is one of the best research methods that can be applied for product and process design researches (Håkansson A., 2013).

Although it is difficult to decide which of these methods can best fit the current project, the analytical would be the possible choice considering the result of this project which is a system design.

3.3 Research Approach and Strategies

The approach of the research is inductive, since the data collected via qualitative methods as described above would be analyzed in order to achieve a better understanding of the phenomena. The research strategies used for this research includes Action Research as this project is planned, designed, observed and evaluated (Håkansson A., 2013). Explanatory research strategy has been also used in some parts of the project.

3.4 Data Collection and Data Analysis Methods

The major part of the needed data for conducting this research is gathered through Language and Text method, while some other parts are provided via unstructured interviews.
The documents and source material that have been chosen for inclusion in this project were gathered from only reputable areas, including the EBSCOhost online library and Google Scholar. In addition, the resource material that was generated through searches relevant to the topic of this project was screened to ensure they met strict accuracy and reliability guidelines. As such, mostly source material that was created within the last 10 years was considered for inclusion in this project.

In addition, the sources of literature that were considered for this project were limited to peer-reviewed journals and periodicals, academic literature, university studies, international reports, and government source data.

In order to achieve a comprehensive understanding of the selected domain which is securities e-trading, several unstructured interviews are conducted with the people working in this area. These people are working in a Financial IT company named Cinnober which develops exchange market systems.

These collected data are analyzed and discussed using the Narrative Analysis method.

3.5 Research Process

After conducting some informal interviews with the people involved in securities e-trading business and extracting the main concerns of the domain, the related literatures in the area are reviewed in order to gain more understandings about agent-based systems design for e-trading. According to the literature, there are two different approaches for designing an agent-based system: single-agent and multi-agent approaches. For designing an agent based system first it should be decided that which approach fits the target domain requirements.

In order to come up with a proper design for securities e-trading negotiation, the first step would be carrying out a general comparison between these approaches based on the concerns for the area and then narrowing down the comparison to the domain of securities e-trading negotiation. The framework of this comparison has been provided via interviews and literature studies. The factors which are using in this comparison include the concerns relevant to agent systems and also the factors which are mainly considered for any software system evaluation such as the ones stated in ISO/IEC 9126.
Afterwards, the selected approach will be the base for designing the agent-based system supporting decision making and negotiating for securities e-trading. The design tries to consider the main concerns of the business. Later on, the design would be evaluated via the same concerns as comparison in order to make sure that the concerns of the domain are improved.
In chapter 2, single-agent and multi-agent systems were introduced and the application of each system has been discussed shortly. In this chapter, a general comparison between these systems will be explained in relation to various system requirements and parameters in the online trading sector of the e-commerce market. As stated before, these factors consider both agent systems’ concerns as well as general software quality parameters. Afterwards the application of these systems will be narrowed down to the selected domain which is securities e-trading.

This should be mentioned that this comparison is based on the understanding gained after studying several literatures, and also the limitation of shortage and oldness of the literature related to the single agents systems should be considered as well.

4.1 Comparison of Single-Agent and Multi-Agent systems

Following is the comparison of single and multi-agent systems categorized based on some of the main concerns in the area of agent-based systems and software quality including speed, accuracy, simplicity, cost, availability, flexibility, scalability, security, trust, communication and efficiency.

4.1.1 Speed

A main key disadvantage of the single-agent system is that it is slow. The singe agent each time starts to fill a request. If unsuccessful, it must then return and try to fulfill the request again. In an application where speed is of the utmost importance, this system is slow and cumbersome. It is while the multi-agent systems allow doing the tasks in parallel which suggests a higher speed in task execution.

It has been discussed that in multi-agent systems, agents should wait for each other to complete their tasks, and it is in addition to the latencies which should be considered during communications between agents. However, it does not sound as a valid discussion, since in
single-agent systems, functions are done step by step as well, so a new function cannot be started until the previous one has been completed. In the multi-agent systems the results produced by some agents can be used by other agents several times and if a failure happens in one agent’s task, other agents do not need to repeat their tasks from beginning.

4.1.2 Accuracy

Accuracy is one of the concerns that needs more effort to be correctly compared among the systems, such as real use case testing on already developed agent systems in order to compare the results, which is out of the scope of this project. Analyzing the accuracy should also be conducted in the context. Of course it can be discussed that using single agents for complex problem solving areas, would not lead to accurate results, and it would not be easy even to trace the problem solving process.

By narrowing down the context into e-trading in which speed is one of the main factors, it can be justified that more accurate results can be achieved via multi-agent systems. Considering that there are several possible offers for a request, a single agent starts with analyzing them one by one, when one is rejected or failed, the next one will be taken until the match is achieved. Then the single agent would not analyze the rest of possible offers in order to save time. A single agent has come up with a match, but is it really the best possible match? If this analyzing gets done in a parallel manner suggested by multi-agent systems, a better offer will be matched within a shorter time.

4.1.3 Simplicity

The simplicity, or on the other hand complexity is a general concept which should be considered at least in 2 different scopes when dealing with agent based systems. This concept should be examined both from deployment factors and functional factors view-points.

Deployment Simplicity: Single agent systems are relatively simpler to build and install than the platforms for multi-agent systems. They are centralized, which means that the entirety of the information in the system can be accessed and viewed quickly and easily. A single user can quickly access and view the information in the system. They can easily retrieve the information that they want, or they summarize and compile the information easily. Moreover since single agents do not need to recognize and communicate with the other agents in the environment,
many complex concerns which are related to multi-agent systems such as trust, cooperation and communication are out of the discussion for single agent systems.

*Functional Simplicity:* Although it can be claimed that the key advantage of single agent systems is the simplicity of the infrastructure, platform and frameworks on which this systems run, the interest for this simplicity may lead to a high level of complexity in algorithm, modules and data which should be feed to this single agent, in order to accomplish its tasks. So the main factor in selecting of such systems is trying to weigh and balance these outcomes.

### 4.1.4 Cost

With the respect to simplicity, this factor should be also examined through two sub factors which are deployment cost and maintenance cost.

*Deployment Cost:* As a result of simplicity in deployment platform, the initial cost for single agent systems is relatively lower than multi-agent systems. Any other agent which gets added to the system, an extra cost would be added to the project, since this agent needs to be in cooperation with other agents.

*Maintenance Cost:* On the other hand, it should not be ignored that developing a complex function for a single agent, may consume more time and effort. Especially in the area of complex problem solving, using a single agent instead of decomposition tasks between multiple agents, may lead to produce non creditable or incorrect results which would be a large waste in the costs of the company. Another point to be considered is the lower cost of maintenance and repair of the system in multi-agent systems which will be discussed later in flexibility.

### 4.1.5 Availability

One of the key disadvantages of the centralize single-agent system is that if the central system goes down, all activity on the system ceases. The entire system can easily go down at once due to the failure of one component (Gehrke, Daldrup, & Seidenfaden, 2004). Any software or hardware issue can cause a complete system failure.

This is not the case in a multi-agent system. Each agent in the system operates both independently, yet still remains dependent on the other agents in the system. If one part of the system goes down, the rest of the system can continue to function. It is just that the options and
resources of that agent will not be available to the system for consideration. This makes the multi-agent system more stable than the single-agent system. If a component or several components break, the entire system is not lost. The efficiency of the system may be compromised by having fewer agents, but the system can still function. This is not the case with the single agent system. When a key component goes down in the single-agent system, there is no other function choice, which results in a system failure.

The multi-agent system has another advantage too. It has built in redundancy. Many agents may offer the same terms as each other. If one component of the system fails, the system will simply switch to one of the available replacements. The built in redundancy of the multi-agent system assures that there is little likelihood that the entire system will crash. One example where this may be relevant is in the case of a wide scale natural disaster. The agents within the area of the disaster will go down for a time, but the remainder of the system not affected by the disaster will remain operational. As the damaged agents are repaired, they can easily be added back into the system.

### 4.1.6 Flexibility

Multi-agent systems are completely more flexible than single-agent systems. If there is a need to change functionality, it is enough to change it only on the relevant agent. Agents are like black boxes for each other, so any update on their functionalities would not affect other agents. In contrast, a single agent system holds all the functionalities in a single agent, so any change or update needed for a single functionality would affect the whole functionalities in the agent. A good example for clarifying this issue is how component based programming has improved the flexibility.

It is the same for adding or removing functionalities and consideration to the system. In the multi-agent system this can be easily done via adding new agents, removing agents or replacing them, while in single agent systems this kind of improvements would not be easy.

### 4.1.7 Scalability

The decentralized approach allows for increased scalability that is superior to the single-agent approach. Additional interface agents can easily be added to the system without having to reprogram the central server (Gehrke, Daldrup, & Seidenfaden, 2004). In terms of the ability to
expand to meet future needs, the multi-agent system adds almost endless possibilities. The multi-agent system is not limited in the number of users that it can admit to the system. The single-agent system is limited by the size of the server and can only be expanded so far without having to add another server to the network. There is a limit to the number of servers that can be added without compromising the efficiency of the single-agent system.

4.1.8 Security

Security is also another concern which needs more attention in multi-agents systems especially in the case using mobile agents in the system. The issue of Authentication and Encryption require to be clarified in agent-based systems.

4.1.9 Trust

Trust means to what extent can an agent trust on other agents in the system. It is obvious that this concept is on question especially for multi-agent systems. In single-agent systems, the only existing agent in the system is aware of whatever happens in the system, while in multi-agent systems agents are aware of the other existing agents in the system, but they do not know much about them, instead they should trust them only.

The multi-agent system has the disadvantage that a single user does not have access to the entirety of the information on the system as a whole. It would next to impossible for a single user to gain a view of the entire network and see all of the transactions that are taking place simultaneously. Such massive amounts of the information would be so large that they would no longer be useful to the user.

4.1.10 Communication and Cooperation

One of the other concerns which should be considered in multi-agent systems and seems not easy to handle, is managing communications and cooperation among different agents. The more the number of agents in the system is, the more difficult to handle the cooperation. Considering standardization and developing communication languages and protocols is one of the concerns which are not the issue of single-agent systems. Considering facilitator agents is another possible solution for multi-agent systems.
4.1.11 Efficiency

Based on all the points mentioned above, it can be theoretically discussed that multi-agent systems work in a more efficient manner, since the idea behind these systems is to the better usage of the resources by decomposition of tasks among different agents. However, efficiency should be also measured in a more practical way which is not a part of this project.

The following table suggests a summarization of the comparison results for the considered factors. As it is stated, the dark green conforms to the general comparison while the light green refers to the context comparison. Yellow color has been used to show that less effort is needed in this area.

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<thead>
<tr>
<th>Factor</th>
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<th>Multi-Agent</th>
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<td>Accuracy</td>
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<td>Efficiency</td>
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</table>

- Totally better
- Better on the context (depends on...)
- Less effort needed so better!

Table 1: Summarization of the comparison results
4.2 Selecting the right agent system approach for securities e-trading negotiation

When choosing a negotiating system for online trading, one must consider the key needs of the user. One of the key factors in online trading is speed. The system needs to be able to initiate, complete, and process the results of the transactions in fractions of a second. Although the single-agent system is simple, its key disadvantage is that it is slow. The importance of online trading is expected to continue to grow in the business world. This means that systems will need to develop even greater speed than is required at the present time. The limited ability of the single-agent system to increase speed makes it obsolete in the application of online security trading.

Securities trading is a dynamic environment in which the market data is continuously changing. Considering this dynamicity, speed would be the main factor that should be considered in this domain. The negotiations need to be done in parallel in order to achieve the best possible solutions in a short time frame.

The inability of the single-agent system to meet the speed demand of the emerging peer-to-peer and one-to-many negotiating systems makes it inappropriate as a choice for the development of improved architecture that will meet the demands of online securities trading. This leaves multi-agent systems as the only other choice at the present time.

Another point that should be considered in this domain is that the accuracy of the gained results has a high level of importance in investment domains such as securities trading. The ideal situation would be considering all the possible investments, negotiate for them and then select the best possible one within the shortest possible time. This kind of accuracy can be gained through multi-agent systems as discussed above.

The availability of the system in order to conduct negotiations is a crucial requirement for this domain due to the rapid market change. Unavailability of the system is a huge risk in this area which nobody dares to take it on.

The multi-agent systems will be able to allow for the increased speed needed. In addition, one of their key stated advantages in this chapter was their scalability. They can easily be expanded to add new agents and new users without having the reconfigure the central architecture of the system. This is one of the key advantages, and reasons for the choice, of
multi-agent systems as the backbone of systems of the future. This will become increasingly important as peer-to-peer systems replace the multi-agent systems that are currently in use today.

Considering the dynamicity and the high rate of changes required in this business to be applied on the functionality of the agents, flexibility is another key concern in this business. These changes can be caused by changing trading strategies, risk calculation algorithms or any other possible change in the domain.

As systems become considerably larger, so will maintenance costs to keep them operating smoothly. The multi-agent system has lower maintenance costs than large, centralized single-agent systems. This can be considered as another key reason for choosing multi-agent systems over single-agent systems.

Speed, accuracy, scalability, flexibility and lower maintenance costs are the main factors which lead to selecting multi-agent approach as the base for agent based systems for securities e-trading negotiation domain. Speed and accuracy are the first concerns in the business while scalability, flexibility and low maintenance costs can be expanded to meet the demands of increasing numbers of users and higher trading volumes in the future.
Chapter 5: System Architecture and Design

According to the earlier discussions in chapter 4, it has been concluded that multi-agent systems are the proper choice for handling negotiations in securities e-trading area. In this chapter, a multi-agent system design will be introduced which supports both decision making and negotiating in securities e-trading. Although this design is more focused on securities e-trading, the ideas can be extended to any other B2B e-trading area. The key issues which are related to this domain have been considered in this design as much as possible, while for the other ones some suggestions will be made.

5.1 General view

The system design which is introduced in this master thesis named MASTNA (Multi-Agent Securities Trading Negotiation Assistant) which is a middle system between user and Internet. MASTNA is able to handle a range of requests which are crucial for this domain’s users, such as retrieving information about particular securities (query search), monitoring user’s preferred securities and notify the user about changes, making suggestions for buy and sell to the user by applying risk management functions and negotiation handling which is the most important in this thesis. Figure 3 shows the scope in which MASTNA works:

![Figure 3: MASTNA functionalities](image-url)
5.2 Pre-assumptions

MASTNA is a multi-agent system which acts as a middle layer between the user and the market. As stated before the main goal of using e-commerce is to decentralize or distribute the market by replacing brokers. Thus, the securities market considered in this design is a distributed market whose peers can be diffused over the world. There would be some conditions for each peer to be able to trade in this market, for example it is assumed that the environment has the ability for hosting and running mobile agents.

Considering the complexity of the domain, such as a huge amount of relevant data and complicated process for risk calculations and decision makings, it is natural that an agent system designed for this domain should take advantage of different agents. There are several agents in this system design assumed for executing different tasks; so not all of them get engaged for performing a request. There are different scenarios that can be handled via MASTNA, for each of which a set of agents are involved. For example the process of suggesting the beneficial buys and sells to the user, is completely separate from the negotiation process which is the main focus of this thesis. However, the results gained from decision making process can be a potential input for starting negotiation. Thus, this system design can also partially be used, for the companies who are interested only in some specific functionalities.

It is also considered that the agents communicate via standard protocols and by using a standard language such as Knowledge Query Manipulation Language (KQML).

5.3 System Architecture

MASTNA’s architecture consists of several agents from different types each of which is responsible for performing specific tasks. According to the categorization introduced in chapter 2, the agents constructing MASTNA can be classified as:

- Interface agents: Interface Agent, Monitor Agent
- Collaborative agents: Facilitator Agent, Negotiation Agent
- Information agents: Finance Information Agent, Securities Information Agent
- Mobile agents: Negotiator Agents
- Reactive agents: Risk Manage Agent
Figure 4 shows the whole architecture of MANSTA including all the agents, data bases and the connections among them.

Another categorization for the system agents is:

- Dedicated agents: Negotiator agents are the only dedicated agents in this design. It means that for each concurrent negotiation, a Negotiator agent is assigned. This part of the design will be completely explained in further sections.
- Shared agents: The other agents in the design are shared through the system. It means that there is only one of each of these agents, which is shared among different requests, or different users of a single system.

All the data bases are shared within the system and the only data base which is dedicated to each user is User Profile DB.

Each system component has been considered to execute specific tasks. As mentioned before, not all the components will be engaged to fulfill a request. Moreover, the communication between the agents is limited as well. There is no need for an agent to be in communication with all the other existing ones. Even some considered communications in the architecture will be used rarely and only on demand cases.
**Interface Agent (IA):** This agent is the only agent which interacts with the user directly. It receives the user’s request and specifications as well as user preferences and returns the results to the user. This agent is responsible for creating user profiles and updating User Profile DB. The only agent which is in the direct contact with IA is the Facilitator Agent (FA).

**Facilitator Agent (FA):** This agent is a collaborative agent which has the main coordination task in this system. This agent maintains a precise view of the system agents’ capabilities. Based on this view, whenever a user request arrives from IA side, FA plans how to fulfill the request and engage relevant agents. FA decomposes a request to smaller tasks and assigns each sub-task to the capable agent. After fulfilling the sub-tasks, FA is the responsible for returning the result to the IA. FA is the only agent in the system which has a direct contact with all the agents except Negotiators.

**Monitor Agent (MA):** MA is an interface agent which monitors the state of desired securities on behalf of the user. This agent notifies user as it notices any abnormal changes, such as price shifts or abnormal trading volume. This agent uses mainly the data gathered by Securities Information Agent in Real Time Securities Information Data Base (RTSI DB) based on user profile and communicates with Risk Management Agent in order to gain a view about the risk of portfolios. MA receives its task from FA and sends the results (notifications) to FA.

**Risk Management Agent (RMA):** RMA uses User Profile DB information for helping MA and Decision Support Agent in order to analyze the risk levels of the user’s desired or deposited securities. It has an important role when deciding about the time to sell the deposited securities.

**Securities Information Agent (SIA):** SIA is an Information/Internet agent which is the responsible for updating RTSI DB. It has all the abilities of information agents, such as retrieving data from multiple heterogeneous data sources over internet and then extracting, analyzing, summarizing, filtering and maintaining this data. This agent is the main resource of information in this system design. It gathers the information related to the securities which is the feed for almost all the other agents.
Finance Information Agent (FIA): FIA is another Information/Internet agent used in this design, but its data is not as crucial as SIA. This agent is used less frequently and is involved mainly in decision supporting process by gathering some forecasting data. These data would be some more general data which can affect the finance field even indirectly, such as company profiles, financial events, opinion of financers and even breaking news. This agent is the responsible for updating Finance Information data base (FI DB).

Negotiation Planning Agent (NPA): This agent is another collaborative agent via the system and is the main actor in negotiation process. Whenever user decides to do some negotiations or some Opposing Negotiator Agents move to the host, NPA plans the negotiations that should be done and creates an instance of Negotiator Agent for any of them. It manages the process of negotiating and receives that negotiation results. NPA is the responsible for updating Repository and User Profile DBs since it is the only first agent which gets aware of successful trades. The role of this agent will be discussed more in negotiation process.

Negotiator Agents (NA): These agents are mobile agents initiated by NPA in order to conduct separate negotiations. These agents are feed by the required components for the negotiation such as negotiation model and parameter table. They move to the other host defined by NPA for conducting the negotiation on site. In this way, the advantage of parallel negotiation can be extracted from the system. Opposing Negotiator Agents are the same as Negotiator Agents which are created by another host. The naming differs in order to clarify the user’s point of view.

5.4 Possible Scenarios

In this section, the possible scenarios requested by user will be discussed and engaged agents for each scenario will be identified.

5.4.1 Securities Information Retrieval

This scenario is the simplest scenario which can be requested by the user in the system. This scenario can also be considered as a simple query. Handling such scenarios does not need involving several agents as it is shown in Figure 5. Here are the steps for this scenario:
- User submits the request of information retrieval via IA about some desired securities, in addition to the information about these securities
- IA send the user request to FA
- FA analyzes the request and engages only SIA to provide the information
- SIA retrieves the relevant information from the Internet and tries to filter out the irrelevant information. Then analyzes the remained data and summarizes it to represent in the desired format.
- SIA returns the results to FA who submits them to the user through IA.

![Diagram of the system](image)

Figure 5: Securities Information Retrieval

### 5.4.2 Monitoring specific securities

This scenario happens when the user is interested in some securities or has them already deposited. The user needs to keep track of these securities and gets notified in occurrence of any abnormal manner.

- User submits the request of monitoring some specific securities via IA, in addition to the information about these securities
- IA send the request to FA and updates the User Profile DB
- FA analyzes the request and engages SIA, MA and RMA in some cases (on demand)
SIA retrieves the relevant information from the Internet in a real-time manner and keeps the RTSI DB updated for these securities.

MA monitors the data retrieved by SIA from now on and communicates with RMA on demand in order to have a risk level view, until user stops the monitoring process.

- MA sends a notification to user via FA as soon as observing an abnormal manner related to these securities.
- IA shows the notification to the user.

The engaged agents for this scenario are shown in Figure 6.

**Figure 6: Monitoring process**

**5.4.3 Decision Support Process**

This scenario can occur in two different cases. One is when the user does not have any specific security in mind to decide about and wants to retrieve system suggestions about the proper action on deposited securities or any other new security. The second case happens when the user wants to know the right action and right time for acting on some specific securities.
- User submits the request of decision support process via IA, whether by mentioning any specific securities or not
- IA sends the request to FA and updates the User Profile DB if specific securities have been mentioned
- FA analyzes and plans the request and engages DSA, SIA, FIA and RMA agents
- DSA starts communicating with SIA and FIA and RMA in order to obtain all the required data. The communication with SIA continues until all the needed data gets provided in the right format.
- DSA analyzes the data and uses its forecasting and reasoning abilities in order to come up with the suggestions
- DSA submits the suggestions to FA
- FA passes the suggestions to IA in order to present them to the user
- IA presents the suggestions to the user

Figure 7 shows the involved agents and their connections in this scenario.

5.4.4 Negotiation Process

Negotiation process starts whenever a trade request is received by the system. There are two possible scenarios:
1. User submits the request for starting negotiation in order to make a trade
2. Some other hosts send in some NAs (Opposing Negotiators)

User is more likely to use the decision making process results for initiating a trade request consisting of negotiations.

In both scenarios, both sides of the negotiation set some attributes (parameters) when requesting a trade. More common parameters in securities domain are: price, quantity, value date, margin, risk, and market sector preferences. These parameters can be classified in two main groups:

- **Constraints**: The ones which are strict and not negotiable and cannot be compensated.
- **Preferences**: The ones that are negotiable and can be changed during negotiation.

In addition to these parameters which are related to the security which is going to be negotiated, each side set a time limit for the negotiation. Otherwise IA would set it as the default value. This time limit I considered in this area, regarding the significant importance of timing and the change rate of the market data.

Considering the scenario 1, when the user submits a trade request, IA passes this request to FA. FA plans the task. First of all SIA is engaged in order to find the hosts which are available for the negotiation (have the security available in their repository for sell, or are interested in buying a security). SIA can limit the results by filtering out some hosts by comparing the constraints. If both of the sides set the same parameter as a constraint, but with different values, then these hosts should not be included in the possible choices.

One of the key points in this design is to restrict the available options as much as possible, since for each available negotiation option, one NA will be created by NPA in order to conduct parallel negotiations. SIA returns the compressed and targeted data to NPA, and afterwards the main task of NPA starts. NPA should have a high level of intelligence, since it should come up with the best possible set of options. NPA interacts with other agents such as SIA and RMA in order to find the best fits. NPA evaluates each situation by valuing the offers’ parameters.

If the number of possible solutions is limited and manageable, NPA stops the selection process and goes to the next step. But if the number of possible solutions is more than the
acceptable limit, NPA tries to classify them into prioritized groups and start with sending NAs to the first group. If no trade is achieved, then it continues with the second group and so on.

After coming up with the list of destinations, NPA initiates instances of NAs and feeds each of them with the negotiation model and parameters as well as the address of the destination host. Negotiator agents are consisted of two main modules, as it is shown in Figure 8.

![Figure 8: Negotiator Agent architecture](image)

Each NA moves to its determined host in order to start the negotiation. Once it is hosted the Negotiation module of the agent submits its offer to the opposing negotiator (negotiator agent of the destination host). The response from the opposing negotiator will be received and processed by the Negotiation module and it will either submit its own response or request further information from the real-time attribute adjuster. The sub-system between the real-time attribute adjuster and the Negotiation modules is designed to be able to handle negotiations with the opposing negotiator until an agreement has been reached. A virtue of this subsystem is that it can receive a response from the opposing negotiator and immediately processes the response and offer a counter response, as the subsystem continues working even while it awaits a response from the opposing negotiator.

The “real-time” aspect of the real-time attribute adjuster means that it is constantly updating the values of securities as the negotiation process is occurring, as it frequently communicates with the Negotiation module. The main task of real-time attribute adjuster module is to convert the actual attribute values of a given offer into numerical values and then calculate the overall utility of an offer based on the attribute values. If this overall utility of the
offer is out of the utility range given by the user, then this offer will be rejected and a new offer should be generated which is the responsibility of the Negotiation module.

The negotiations are in progress until an agreement is achieved within the time limit set by user or system. Otherwise the negotiation process will be cancelled.

There are two strategies for handling parallel negotiation processes from the same type for example user wants to buy 100 (not more) of security A and three NAs have been sent to three different hosts with 100 quantity available of security A:

1. Three NAs progress their negotiations within the time limit, and as soon as any of them achieves the agreement, makes the trade and notify NPA. Then NPA notifies other two agents to cancel the process. Although this strategy is fast, but it can cause some risky cases such as the case in which two NAs achieve an agreement at the same time and 200 securities get bought. Another problem is about the accuracy of the result. While the made trade is one of the best options, it cannot be guaranteed that it is the best possible one.

2. For resolving the problems mentioned in strategy 1, NAs can send a notification about the achieved agreement before making the trade to NPA and wait for its acknowledgement about making the trade. In this case NPA can get an overview of the achieved agreements of each NA within the time limit, and then send the ACK to the best one. This solution may add some delays to the process due to overloaded communications which may cause risky situations, such as missing the time limit while waiting for the ACK from NPA.

In order to apply any of these strategies users should be determined about their main concern in the current situation. Do they want to have one of the best solutions in the shortest possible time? Or do they want to have the best possible solution?

After making the trade, NA notifies NPA about the made trade and NPA returns the trade logs to FA in order to inform the user via IA. NPA also updates the Repository and User Profile DBs respectively.

The second scenario is the reversed version of the first scenario, in which the opposing negotiator agents comes to the host in order to conduct negotiations. The agent which is
responsible for serving these agents is NPA. NPA engages other agents in order to analyze the offer and initializes new NAs based on User Profile DB information about the negotiating security. In this scenario NAs are executing in host and do not need to move to remote hosts.

Figure 9 presents the agents involved in negotiation process.

![Figure 9: Negotiation Process](image)

There are two possible implementation alternatives for handling the negotiator instances after they are done with their job. One idea is to terminate them which can be done in the destination host right after sending the negotiation results or in the resource host after coming back. And another idea is to pool the instances in order to reuse them in other negotiations.

Ultimately, it should be mentioned that the main reason of applying mobile agents in the negotiations process is trading over a distributed market on the Internet which is not reliable for sending and receiving messages. In addition, since the negotiation is a process which may need several number of messages, it would take a long time to pass these messages from host to host over the network. Thus, mobile agents seem to be the proper solution to be applied in this area.
Chapter 6: Evaluation, Discussion and Suggestions

In the previous chapter, a multi-agent design for securities e-trading domain has been suggested and described in details. In this chapter an overall evaluation of the suggested systems will be directed based on the factors mentioned in chapter 4 ordered by priorities of the context. And some discussions will be made regarding security, trust and data accuracy.

6.1 Evaluation

Speed

The main concern of the domain is speed which was the first consideration of the design. Conducting parallel negotiations improves the speed of negotiation significantly. Several negotiations can be performed in the same time which leads to fast trade making. On the other hand, using mobile agents which move between hosts in order to execute their tasks on site eliminates passing messages between two sides of negotiation on the network. This elimination decreases the latencies and improves the speed of the system noticeably.

Accuracy

Accuracy was the second concern of this design after speed. Many attempts have been done in order to improve accuracy of the results in this design. Some of these attempts are:
- Using facilitator agents
- Introducing different strategies for selecting the possible set of solutions
- Creating one agent for each possible negotiation
- Suggesting different strategies to handle parallel negotiation
- Applying real time agents and data bases
- Using mobile agents in order to eliminate connection misses or message losses

However, the accuracy of the system is relied on the accuracy of algorithms used in the engaged agents.
**Simplicity**

Regarding the deployment, as mentioned earlier, multi-agent systems need more complex installation platforms. In this design the market is distributed and several agents have been used, in addition to using mobile agents which imposes more requirements to the platform such as standard protocols. However, in this design most of the agent to agent communication has been eliminated by using collaborative agents. Particularly by applying strategy 1 for parallel negotiations there would not be any needed communication between the hosts’ agents outside the host.

Regarding the functionality, this design has improved the simplicity by decomposition of tasks between different agents and using facilitator agents which identify the agents that should be emerged for each request.

For example one of the biggest complexities of this domain is a giant amount of data which should be considered in problem solving. In this design, two separate Information agents have been considered in order to decompose this huge task. One of the agents deals with the directly relevant data and the other one with indirect data which may affect the decision making. The second agent is being used not as frequent the first one. On the other hand the first one which is the main provider of the relevant data does not need to drown in a huge amount of data which are less relevant.

**Cost**

Considering the application of multiple agents in order to decompose the task, and also using the coordinator agents which match tasks to agents, the maintenance cost of this design will be low. Moreover, most of the agents are shared in this design via the system and only some agents are dedicated, it has been tried to use the resources in the best way which decreases the cost.

**Availability**

The best effort in improving the availability can be noticed in the multi-agent negotiation process, in which even if some negotiator agents break, the other negotiators are still available to conduct the negotiation.
Flexibility

The design is task decomposition oriented between agents, so updating the functionalities and adding new agents can be handled easily in this design. Taking advantage of facilitator agents also increases this flexibility.

Scalability

The design is completely scalable. Since the market is distributed, there is no limit for the number of hosts in this market.

On the other hand, other agents can be added simply to a single host design without affecting the other agent’s tasks, while considering coordinator agents simplifies this development.

Security

Security is one of the key issues in this design due to usage of mobile agents. It would not be easy to accept a mobile agent on your computer. How can it be differed from viruses? Later on the security and trust issues will be discussed more.

Trust

Trust means to what extent can an agent trust on other agents in the system. This design is working based on trust. For example all the agents should trust on the information provided by SIA. Using facilitator agents increases the trust in multi-agent systems, since these agents take the responsibility of coordinating the other agents and making sure about their task fulfillments.

Communication and Cooperation

As stated in other factors as well, this design tries to eliminate the agent communications over the network by using mobile agents. Inside the system, facilitators simplify the cooperation and communication among agents. However, same as any other multi-agent system, MASTNA needs to define communication protocols and follow of world-wide standards.
**Efficiency**

Based on all the points mentioned above, it can be theoretically discussed this design work in an efficient manner, since it tries to take best advantage of the resources by decomposition of tasks among different agents and using coordinator and mobile agents. However, efficiency should be evaluated after developing and testing a system.

In addition to this evaluation, it should be mentioned that the design of MASTNA and the level of its applicability were discussed with the people who were interviewed at the beginning of the project, and fortunately the overall feeling about applying MASTNA was completely positive.

**6.2 Discussion**

**6.2.1 Security and Trust**

Security is a key issue with multi-agent trading systems which is not easy to be separated from Trust issue in this domain.

Several systems have been developed to ensure online trust is essentially a security issue and the establishment of online reputation is closely linked to security. These include information gathering systems, scoring and ranking systems, and response based systems. Many different versions of these trust and reputation systems exist.

One of the key challenges in online trading systems is that every company has its own set of proprietary software, system, and methods for conducting agent negotiations and transactions. In the development of a whole system, these elements must be able to communicate with each other in a way that establishes trust in the source of the information.

Establishing uniformity in system security represents one of the key challenges for system designers and engineers. One of the key challenges in system design is that as greater layers of security are added to the system, the slower and less efficient the system will become. Every time information is exchanged between the two systems, handshake and security protocol must be conducted. This adds considerable processing time to the transaction. More processing time in the transaction means a greater chance that that agent's time limit will be reached and the system will fail.
This problem is further complicated by the fact that agents from different organizations use different architectures as the backbone of their system. For instance, the process of authentication can be cumbersome when going from a Linux based system to a Windows driven operating system. At this point, special steps can be taken to ensure compatibility, but this adds another layer to the security protocol that must be addressed before a transaction can take place. Each addition of a security layer means more time taken away from the negotiating processes of the agents. As time increases, the potential for a failed transaction due to a timeout error, rather than due to an actual failed negotiation between retrieving agents increases.

As systems become increasingly complex, it will create more potential entry points for users who would wish to exploit or harm the system integrity. This means stricter enforcement and development of security protocols. If this trends continues, the efficiency of the system will decrease due to traffic congestion caused be differing security protocols. The need for increased security protocols has the potential to create significant bottlenecks in the system. A solution to this problem must be developed so that this does not continue to be increasingly problematic in the future.

One solution to help resolve the dual problem of creating a secure environment while maintaining system efficiency is to develop a standard set of handshake protocols that would be required to be used system wide. If every agent were using a standard set of handshake protocols, the need for compatibility packs and failures of handshake due to system compatibility would be eliminated. The idea is to make certain that if a handshake fails it is for a true failure and potential system breech, rather than for technical issues involving system compatibility.

The development of industry wide security and handshake security protocols would ensure the integrity of the system, would allow members to quickly and assuredly move through the authentication process, establish trust, and move to the negotiation stage of the transaction. The key to making the system work more efficiently and to be able to handle higher trading volumes and users is in standardization of systems and the security protocol that they use.

In the development of these standardized protocols, a survey of the systems being currently used and their security systems must be conducted. The idea would be to develop a uniform system that is compatible with the greatest number of systems in use today. However, this must be conducted with the acknowledgement of the next generation of systems that is being developed and the foreseeable issues that they will face. The development of uniform
security protocol with the eventual goal of increased network security without compromising efficiency will need to be a key focus in the development of the uniform system. The system should take into consideration both the current and future needs of online e-Trading.

6.2.2 Data Accuracy and Replication

The success of a multi-agent system depends on the explicability and accuracy of data in the systems of the various users. This means that every time a user makes a change in their inventory, the items in the inventory must be updated on all of the units in the system. Otherwise, other agents will not have accurate information and will initiate negotiation processes based on old, outdated information. This sets the scenario for failed transactions and can create a significant problem with the system, potentially even a crash. If this happens, it could create a situation where none of the agents could complete a transaction. The system must be able to update the inventories of all of the agents in real time.

One might notice that many trading platforms of today state that the information provided is so many minutes old. This is due to the need to update all of the information in the systems of the agents. This creates a considerable time lag. In addition, one must make certain that a set of checks and balances is in place to ensure data accuracy when the data is being transferred.

The transfer of data between the various agents in the system creates redundancy. This can be advantageous in the event of a system crash. The data may be lost in one location, but it can be recovered from another. According to SQL Server official website, Peer-to-Peer Transactional Replication is used to achieve this function in near real time. This type of redundancy increases the accuracy of the information being passed from system to system.

Transactional replication has another key advantage in the world of e-trading. The information across all agents and nodes is continually updated across the various nodes. This means that the information is available from more than one location. The agent does not have to continually refer back to the central server for the most current information in the system. It can quickly obtain the information by accessing another node of the system. This helps to increase the speed of the system, which will allow it to process a high volume of transactions faster.

Transactional redundancy allows queries to be spread accord multi-agents in the system. This increases consistency in the system. All of the nodes of the system will have the same
information. This means that the results of the negotiation process will be the same, regardless of where they take place in the system. The information does not have to travel back and forth to a centralized server using a redundant system. Using transactional redundancy in the design of future systems for e-Trading will ensure that increasing the number of users or nodes in the system will not decrease the accuracy of the transactions. Redundancy in the system will also lead to increased availability of the information to all users of the system.

Transactional redundancy means that if one unit goes down, the information in that unit is not lost. The retrieval agents can simply be redirected to a functioning node, with the assurance that the information contained on this node would be identical to that on the failed node (SQL Server, 2014). This increases the reliability of the system, regardless of the number of users and new nodes that will be added in the future. The availability of the information across various nodes will also decrease the latency involved in accessing updated information. However, as the number of nodes that need to be updated increase, the latency time of the entire system will increase. There will be more nodes for the information to propagate across as the number of user's increases.

6.2.3 Limitations

In addition to security, trust and data accuracy which need more considerations in this design, there were other limitations for conducting this master thesis which could have done in a more dedicated way, however, they were out of the scope of this project.

One of the early faced limitations in this project was related to unavailability of developed typical single-agent and multi-agent systems in a domain of e-trading, which could have been used for practical comparison of some factors, such as accuracy of the results and efficiency of each system. This limitation restricted the comparison to be a theoretical analysis of the systems’ behaviors based on their characteristics.

The other limitations are mostly related to the design which are caused by time and scope limits of the project and can be further continued. Scoping the project in a complex domain such as securities e-trading and in a vast area of agent systems was the first challenge for this master thesis.

In order to finish the project in the time frame and scope of a master thesis, several potential areas for more investigation have been omitted or left in a conceptual level. These areas are mostly related to the agents’ behaviors and their used algorithms. For example, risk
management is a complex area on which several researches have been conducted. Deeply investigation of the Risk Management area and required algorithms and data for its responsible agents can be a separate master thesis topic.

Another potential area was related to the technical discussion of algorithms and modules used by negotiator agents, such as attribute valuing and utility calculations. In addition to agents’ modules and algorithms, concerns related to their communications introduce another field of study. These concerns are the ones related to platforms, developing communication languages, communication protocols and standardization of them.

All these mentioned areas which are partially or conceptually stated in this master these can be considered as further possible works related to thesis, which are discussed separately in the next chapter.
Chapter 7: Conclusion and Further Work

7.1 Conclusion

This master thesis has been scoped based on studying agent-based systems and applying them in securities e-trading by the focus on negotiating. The scope has been defined regarding to the importance and growing intendancy of engaging e-commerce in different B2B areas, with a particular attention to one of the most potential and recent industries which is securities e-trading. Considering the specific characteristics of this business and the significance of negotiation in handling securities e-trading which is not investigated adequately through previous works, this thesis attempts to answer these questions:

- What are the main concerns in securities e-trading?
- Which agent system approach – single or multi – is suitable for negotiation in securities e-trading?

And then according to the answers of these questions, the study presents a system design for securities e-trading by highlighting the negotiation part which tries to improve the main concerns of the business.

In pursuance of conducting this master thesis, the scope of qualitative research for data collection and research process has been selected. With regard to answer the first question in addition to literature review, some informal and unstructured interviews with some people working in the area have been conducted. The main concerns of the business extracted from this step are mainly:

- Speed due to the rapid and unpredictable market data changes
- Accuracy of the gained results, since we are dealing with investments and risks in this domain
- Huge amount of data that can affect the market and should be considered while working in this domain and also high volume of transactions
- Security and trust
In order to answer the second question, a comparison framework has been suggested based on the mentioned concerns of the business and also other factors related to agent based systems or any other software systems such as the ones stated in ISO/IEC 9126. The considered factors in this framework are: speed, accuracy, simplicity, cost, availability, flexibility, scalability, security, trust, communication and efficiency.

According to the analytical comparison of single-agent and multi-agent systems based on this framework which is explained in chapter 4, single-agent systems are simpler and more cost effective regarding to their build, installation and deployment and they also need less effort for security, trust and communication. On the other hand, multi-agent systems are the choice regarding availability, flexibility and scalability which can lead to less maintenance cost in complex domains. Narrowing down the comparison to the context, it has been theoretically discussed that multi-agent systems are faster and can provide more accurate results while they are also more efficient.

Considering the main concerns of the business, multi-agent approach seems to be the proper choice for negotiation systems in securities e-trading since they can fulfill the demands of speed, accuracy and complexity of the domain; however this approach requires more effort in the security area.

After recognizing the suitable approach for designing the negotiation process and by considering different types of agents and their capabilities, MASTNA is introduced as a solution for e-trading of securities which seeks to facilitate the domain’s concerns. As described in chapter 5, MASTNA is a multi-agent system which tries to apply different types of agents in a right place for doing specific tasks. It works on a distributed market and performs different functionalities in the securities e-trading area including securities information retrieval, monitoring specific securities, decision support and negotiation for trading.

The securities trading area requires very quick decisions to be made accurately and quickly, given the limited time and tons of information involved in securities trading. The systematic design presented here seeks to address these particularities of securities trading. This design is multi-agent so that it can assign different roles to different agents and process information more quickly and effectively. Although the design is consisted of several agents, not all of them are involved in execution of a request. Each scenario in the system engaged only a subset of relevant agents.
The key points in the design are taking advantage of coordinator agents, mobile agents and shared/dedicated agents. Applying coordinator agents improve the flexibility and scalability of the system, in addition to handling the communication among the agents. Using shared agents among different scenarios or different users improves the efficiency of the system while dedicated agents improve the availability and speed of the negotiation process. Ultimately, the main point in this design is taking advantage of mobile agents which can negotiate in parallel over the unreliable network (Internet) in order to improve speed and accuracy of the results as well as reducing the message passing over the network.

Moreover, for handling the huge amount of information needed for analyzing in securities e-trading two separate information agents have been applied. Each of these agents is the responsible for a group of information which makes the search and analyzing easier for them and helps to decrease the complexity in this area.

The main part of the design is about handling the negotiation which is almost missing in most of the existing suggested systems for this domain. The negotiation process is performed mainly via a coordinator agent named Negotiation Planning Agent which plans and manages the negotiation by initializing dedicated Negotiator agents for each planned negotiation. Negotiator agents are mobile agents consisted of two main modules which can move to other hosts over the network in order to start negotiation in parallel with the other Negotiator agents. In order to manage parallel negotiations two possible strategies have been introduced; one with the focus on the time and the other with the focus on the accuracy of the results.

As it is mentioned above and also evaluated in chapter 6, this design fulfills the domain’s demands by improving speed, accuracy, simplicity, availability, flexibility, scalability and efficiency while it may need to spend more effort in security, trust and communication areas. However, there are some suggestions about applying standard hand shake protocols and platforms which can help to improve these factors as well.

There were of course some limitations for conducting this study; however some of them provide potential fields for further investigations and research. The available literature limitations and also the lack of developed single and multiple agent systems, was one of the limitations for doing the comparison. On the other hand the time limit and scope of a master thesis constrained the study to do further investigations in the areas of security, communication and agents’ algorithms. However, there are still many other areas related to this research that
can be improved more in the future, such as the speed for which no one can claim that there is an end.

### 7.2 Further work

There are several related works that can be suggested to be followed based on this thesis context. One of the fields which need further investigation is the quantitative measurement of performance, accuracy and efficiency of agent-based system designs which first needs the development of the designs.

Another possible further work proposed by this project is the improving of security and trust in multi-agent e-trading systems and on distributed markets, as it was discussed in chapter 6. As systems become more and more complicated, it can be more difficult to detect and fix security threats. There are many concerns related to the security of distributed agent based systems, such as developing and applying worldwide standard protocols which needs further attempt and exploration.

The other limitation of this design which can lead to possible further studies is that it relies on other aspects for accuracy. The accuracy of the system as a decision maker and negotiator will be mainly determined by the accuracy of processes and algorithms used in the local databases and by the agents. If such the methods of decision-making are good, then the decisions making by the decision supporting agent will likely be accurate. Likewise, if the ways that the agents sort and analyze information from the local database and from other agents work properly, then the system is much more likely to produce accurate decisions.

There are still a large number of further works that can be conducted in this area, such as improving the speed of the negotiations, improving the evaluation of the attributes, improving the strategies for parallel negotiation handling and etc.
References


