Ramifications of Gift Exchange in a Multiagent System

Master Thesis

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Eidesstattliche Erklärung

Hiermit erkläre ich an Eides statt, dass ich diese Arbeit selbständig verfaßt, nur die im Literaturverzeichnis zitierten Quellen benutzt und sie noch keinem anderen Prüfungsamt vorgelegt habe.

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Dedicated to

My Parents

Abstract

We explore in this thesis the implications of applying the idea of gift-exchange mechanism inspired from Pierre Bourdieu's sociological theories into a market-based multiagent system. Our work is directed in the continuation of investigations by Knabe, which addressed the formation of different organizations structures between providers in a profit-oriented market [Knabe, 2002]. We nevertheless scrutinize various hypotheses centered to gift-exchange in which an agent sacrifices its profit for a long-term binding relationship. The idea is to aim larger profit through alliances that are formed as consequences to gift-exchange.

The market in our case comprises of customers and providers agents; the former places call for proposals for tasks in the market, while the latter proceed with the execution of tasks based on their abilities and other circumstances. In our work, the agents are profit-oriented and the ones who prefer exchanging gifts and are in pursuit of others who also practice this mechanism. We examine particular interesting scenarios that include preservation or repetition of hierarchical structure in the market where less powerful agents use gift exchange as means of their survival, situations when two providers decide to form an alliance and share their abilities and profits, and hypothesize split of agents in terms of profit-oriented and gift-exchanges ones.

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Chapter 1

Introduction

This thesis investigates the integration of *gift* exchange, a sociological concept into multiagent systems. Scientific studies of the sociological theories via techniques from Distributed Artificial Intelligence have been part of the ongoing research in the interdisciplinary field of Socionics. The motivation is to exchange concepts and theories so that both the disciplines benefit from each other. In the first section we present an introduction to the problem and motivation behind this thesis, followed by an overview of the main observations covered in the second section. The third and last section provides an outline of how this thesis is structured.

1.1 Problem Introduction

While the idea of gift giving in real-world is very ancient, it is found to be an important sociological concept even today, especially in the corporate world. The very essence of reciprocity and the accompanying sense of gratitude are pivotal in societies where gifts are exchanged. In his Habitus-Field Theory, Pierre Bourdieu explained the sociological basis of gift exchange in the real-world where individuals as well as organizations exchange gifts; the main motivation behind this practice is to build reliable partnerships in order to survive and accumulate capital in the market where competitions are fierce. The practice of gift exchange motivates the agents to bear smaller losses in order to build a stable and long-term relationship with one another. Another motive behind gift giving, also explained by Bourdieu, is to attain supremacy of other individuals or organizations keeping them indebted to the favor granted in the form of a gift.

In this thesis we introduce gift exchange in an artificial society modeled through a multiagent system in a market-based scenario. The agents are self-interested and compete with each other to accomplish tasks introduced in the system and consequently earning profits. Gift Exchange is modeled to the tenets of Bourdieu's idea of time-lag; a concept discussed in the next chapter. To investigate the effects of gift exchange in our system, we test the model on the hypotheses that center upon the performance of agents who practice gift exchange, and those who are only interested in earning profits. Social systems, like other complex systems, are full of intricacies. Nevertheless, one is able to build simple models focusing on a certain aspects we are interested and can test the ramifications of the phenomenon one attempts to model. We implement our testbed for the gift exchange and report our observations obtained out of the experiments.

1.2 Contributions

This thesis contributes to a model for gift exchange in a market-based multiagent system. We identify the major parameters surrounding the phenomenon of gift exchange based on Pierre Bourdieu's Habitus-Field Theory. Our model provides the mechanisms for building of relationships among agents who practice gift exchange. We also present the interaction diagrams for gift exchange that maybe helpful in understanding the system and for future extensions. Several hypotheses were tested in order to investigate the effects of gift exchange. Gift exchange was found to be an important means for agents to build long-term associations due to the reciprocal nature of gift giving. The performance of such agents was found to be better than the others. Practices of gift exchange not only provide less powerful agents a better chance of survival in the market, it also helped them to accumulate more wealth than they had earned without it.

1.3 Outline of the Thesis

In Chapter *2*, we cover the background research work upon which this thesis is based. Moreover, we review significant related work concerning modeling of exchange of gifts in multiagent systems presented by researchers in MAS and Socionics. Chapter *3* further elucidates the problem statement and the motivation behind this work along with the targets that we attempt to achieve. Hypotheses are stated and a few applications are discussed. Following, Chapter *4* encompasses of the specification of our gift model. We introduce the assumptions, setting and important parameters of the model followed by a discussion of the exchange mechanisms and representation of agents' interaction in the system. Implementation highlights and a brief overview to the graphical user interface (GUI) are presented in Chapter *5*. Chapter *6* covers the experimental setting together with the results and their discussion. Finally, Chapter *7* provides a summary of this work and concludes with potential future work in the direction of this thesis.

Chapter 2

Background and Related Work

This thesis is inspired from *Socionics* which is an emerging field, and contributes to the understanding the phenomena surrounding it. The term itself is Germany primarily used among German computer scientists and sociologists as an interdisciplinary discipline, "a kind of *tertium quid*" between Sociology and Distributed Artificial Intelligence (DAI) [Malsch, 2001]. Computer simulations of sociological theories have been in practice for quite some time and have significantly assisted in better understanding of the social behavior and organizations in the social world [Gilbert and Troitzsch, 1999]. Nevertheless, recently researchers in multiagent systems have been able to use some of the ideas from sociology and have used them quite successfully in solving their own problems concerning the design of DAI systems. The driving force behind this input from sociology is the cultural value, social roles, norms, power structures and authority etc. concepts that have provided fair hope to the MAS researchers in helping them design robust, adaptive and scalable systems.

In this chapter we cover the background and related work concerning this thesis. Initiating with coverage of agents and multiagent systems, we discuss relevant issues regarding applying techniques from AI to social simulation with an overview of some pertinent methods. Last but not the least, we introduce the notion of gift exchange, its sociological basis and a review on some related work in formalizing this concept.

2.1 Intelligent Agents & Multiagent Systems

Even though the term 'agent' has no single definition, there has been in recent past enormous growth of literature related to research in agent-based methodologies and development of industry applications ranging from real-time embedded systems to crawlers making the most of AI technologies.

Russell and Norvig define a *rational agent* as one picking the right course of action such that it is supplemented with a performance-measure together with its prior knowledge of the environment (if any) and its percept to date [Russell and Norvig, 2003]. The agent's rational choice thus depends upon the information gathered through its percepts as well as its ability to learn from what it senses.

Wooldridge defines agent with respect to its being autonomous and adaptable to its environment.

Definition 1 (Agent according to Wooldridge, 1997)

[An] agent is an encapsulated computer system that is situated in some environment, and that is capable of flexible, autonomous action in that environment in order to meet its design objectives.

In the next section, we briefly present the engineering aspect of agent-based methodology followed by our discussion to agent-based computing related to artificial intelligence (AI) and multiagent systems (MAS); as they provide the base for our work in this thesis.

2.1.1 Agent-Oriented Software Engineering

For researchers in software engineering, agent-based software engineering is a subject of high interest as it can be perceived as a next-step after the object-oriented approach, in the design of complex and intricate software systems. As Herbert Simon explained, due to the fact that software are built upon parts (or modules) that have many interactions complexity is inherent to the development of large software systems [Simon, 1996].

However, agent-oriented software has a modular structure like that of objects in the object-oriented paradigm, but both differ in quite a few ways. Objects are by design passive to their environment, need external control to be activated, and they do not have their behavior (choice of action) encapsulated like their states. Agents on the other hand are *autonomous* with respect to their actions as well as *proactive* within their environment [Wooldridge and Jennings, 1995].

2.1.2 Agent Architecture

Distributed AI (DAI) as a sub-field of AI is concerned with the design of interacting agents; it's the interest of DAI researchers to build such networks that has made much in this field relevant to social sciences [Gilbert and Troitzsch, 1999]. Different approaches exist for describing the properties and structure of agents, two of which we present here.

Belief-Desire-Intentions (BDI) Architecture

BDI Agents are agents with percepts at any given current state, reasons to achieve it in the best possible way by creating a plan based on their reasoning and following the plan accordingly. They are supplemented by functions through which they are able to estimate the quality of their action of reaching a state. The three structures of the BDI agents represent their state, viz. their beliefs (model of the domain), desires (the ordering of possible states according to their preferences) and intentions (actions they choose to satisfy their desires concordantly) [Rao and Georgeff, 1995].

The Wooldridge and Jennings's Classification

Another way of explaining properties of intelligent agents was put forward by Wooldridge and Jennings. According to them agents generally exhibit the following properties [Wooldridge and Jennings, 1995].

- *Autonomy*: Agents choosing their actions on the basis of their own percepts and not by external controlling authority.
- *Social Ability*: There exist formal protocols (communication language) via which agents interact with their environment and with each other.
- *Reactivity*: Agents are able to observe their environment and able to respond consequently.
- *Proactivity*: Not only are the agents reactive, they engage in action driven by their aspiration to achieve their goals.

2.1.3 Multiagent Systems

The other half of DAI, multiagent systems represent a system where agents cooperate in an environment to solve a distributed problem solving (DPS) which constitutes the first half. In MAS, agents are (usually) different entities that can possess different motives individually (or collectively in case of groups of agents), can adopt different strategies, cooperate and collaborate to facilitate their goals which could be self-centered or group-based. Jennings et al. define MAS as consisting of four properties:

Definition 2 (A Multiagent System according to Jennings et al., 1998)

A Multiagent system is a system that has these four properties:

- *each agent has incomplete capabilities to solve a problem*
- *there is no global system control*
- *data is decentralized*
- *computation is asynchronous*

How MAS become a natural choice for modeling human societies will be discussed in the next section in detail. Before we conclude our discussion on intelligent agents it is worthwhile to present here an interesting example of MAS, the *MANTA* system based on "ants' colony"; not only does it reflects the crux of MAS modeling, it is also a motivation for the following discussion.

MANTA: "Modelling an Anthill Activity"

MANTA is the simulation of birth of an ant colony, where ants in MANTA are modeled as agents carrying out (different) tasks assigned to them [Drogul and Ferber, 1994]. An ant (agent) can only take on one task at one time, the nature of task being dependent upon parameters such as the task's weight etc. Not only ants are modeled as agents, the environment itself is represented by means of agents such as *food agents*, *light agents* etc. As reported by Drogul and Ferber, the simplicity of MAS was found to be appropriate for modeling the behavior of ants and have been found to be extremely handy in conducting experiments effectively [Drogul and Ferber, 1994].

2.2 Computer Simulation of Social Phenomena

How individuals organize themselves in a society to form groups with various types of organizations leading to clusters and community structure has being studied by sociologists and DAI researchers in the recent past [Carley and Gasser, 1999]. A more recent work by Schillo et al. describe organizations as both "autonomous social fields" and "corporate agents" which compete with other organizations within the same domain [Schillo et al., 2002]. Actions taken by individuals within a group, ascertained by preferences and interactions of members give rise to complexity. It's the interaction of individuals and their cumulative efforts for their community that connects social sciences and MAS as we society evolving as a result of autonomous interactions of agents. Additionally, the sense of locality and no essential need for knowing the network globally makes MAS an appropriate platform to express complexity of social systems and organizations.

2.2.1 Simulation in Social Sciences

Simulation as a particular type of modeling has been used in order to obtain a better understanding of the world we try to model or to be able to predict outcome of the model in 'future' or even used as means to substitute human-capabilities, e.g. in expert systems. Gilbert and Troitzsch define social simulation as

Definition 3 (Social Simulation according to Gilbert and Troitzsch, 1999)

Social Simulation is the idea that one can build a computer program that models the behavior of some social phenomena.

Modeling in social sciences means aiming at an abstraction to a real-world phenomenon which in the case of a computer simulation might be a computer program used as a test-bed. Such a simulation can be viewed as an *artificial society* which we develop and investigate not only to look into our existing society, but also scenarios where possible social structures can be examined as one of the ways of developing social theories.

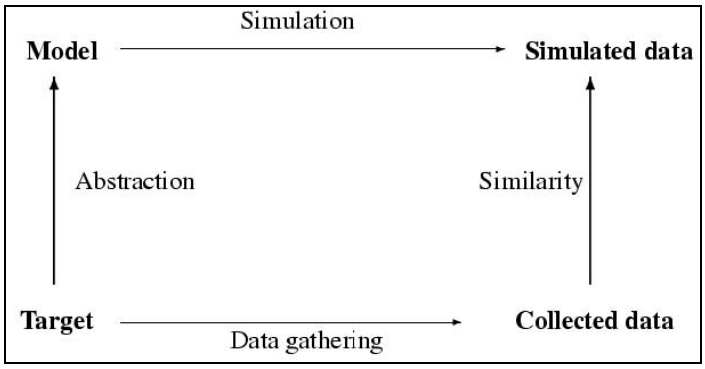

Figure 2.1: Logic of Simulation as Method [Gilbert and Troitzsch, 1999]

There is a whole range of techniques used in social simulation from micro-analytical simulations to the use of evolutionary models. We review the role of MAS in social simulation in the following section.

2.2.2 MAS and Social Simulation

Application of the agent-based methodology in computer simulation of social phenomenon can be traced back to mid 1980. As argued by Axelrod the goal of this modeling approach was to exploit the simplicity of assumptions that appear in a wide range of applications [Axelrod, 1987]. With the advent of multiagent models, social simulation benefited from it most as these models provided the provisions of simulating social behavior of autonomous individuals and the interactions between them. Agent-based models have been found to be most appropriate for decentralized scenarios especially when individual interactions lead to the emergence of social structures such as organizations, social networks etc.

Davidsson outlines agent-based simulation of social phenomena as an interdisciplinary activity based on the intersection of three fields, i.e. social science, agent-based computing and computer simulation [Davidsson, 2002]. This thesis can be viewed as an example of such an intersection.

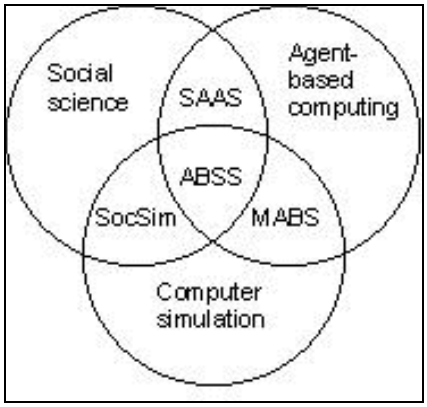

Figure 2.2: Intersection of three fields [Davidsson, 2002]

2.2.3 DAI and Sociology

The growing interest in socionics lies in the fact that both sociology and DAI have benefited from each other. For a sociologist, DAI techniques have been found to be effective with regards to modeling the complexity of human societies; as put forwarded by Rouchier, the ability of MAS to express this complexity at several scales of agent-interactions makes it a preferred tool for representing them [Rouchier, 1998].

The idea that intricate problem could be solved by means of the cooperation of many autonomous entities (agents) have inspired vast research opportunities concerning with the investigation of human societies which are versatile, stable and fault-tolerant as surveyed by Malsch [Malsch, 2001]. By the same token, sociologists are motivated for using MAS for testing and elaborating their concepts, models and theories; more importantly in connection with dynamic interactions between the micro-, meso- and macro-level on which societies can be described.

2.3 Agents Interaction & Social Structures

As Gasser stresses, MAS are social in character; thus he calls researchers in DAI to seek inspiration from social foundations, which are the observed practical strategies of human societies practiced in order to survive as active participants in a highly competitive market. Sociological theories thus provide the specification of relevant scenarios that researchers in Socionics are usually interested to investigate. For example, the Habitus-Field Theory (HFT) of Pierre Bourdieu has already been employed effectively in MAS assignment of tasks in market-based scenarios [Knabe, 2002; Schillo et al., 2003].

Economic exchange is the archetypical mode of interaction in market-based scenarios. In its crux lies the contractual commitment between customers who offer tasks to providers who win tasks by competing (e.g. in an auction) and receive payment in exchange of their labor. Agents are self-interested to maximizing their own profits and to their organization if they are part of any.

Orthogonal to the economic exchange is gift exchange, which we shall describe later in this chapter.

2.3.1 Bourdieu's Habitus-Field Theory (HFT)

The sociological basis of this thesis draws its stimulus from Bourdieu's concept of habitus and social fields. In his habitus-field theory, Pierre Bourdieu defines a "field" as an objective structure developed historically and consisting of objective relations between positions, setting aside inter-subjective links. A position is characterized by the determinations imposed upon the agents, by the present and potential composition of all sorts of capital (i.e., economic, cultural, social and symbolic) and by its relation to other positions. According to Bourdieu, an agent is the force behind the development, change and reproduction of social structure of any field [Bourdieu and Wacquant, 1992].

Schillo et al. provide valuable insight to consider organization and social interactions of agents as social fields [Schillo et al., 2002]. According to them "The social structure of an organization as a field is a cultural as well as a political construction of dominant and dominated agents." In a dynamic environment like market, some agents are more powerful with respect to their assets and use of their economic, cultural and social capital. Social structures would then be agents' objectives, the use of their capital helping their interests and the rules of interaction which constrain their activities [Köhler et al., 2000].

2.3.2 Agents' Task Delegation Mechanisms

Delegation of tasks in MAS is no more a novel notion for DAI researchers and has undergone scrupulous studies recently and several strategies have been studied. Nonetheless in scenarios where agents vary their decisions on a case-by-case basis, task-delegations become a complex concept and calls for more attention in MAS research; the idea is highlighted by Bourdieu for human societies where delegation assumes a central role.

Traditional treatment of task delegation mechanisms focus upon the distribution of tasks in systems where the agents are designed sharing common goals, or when they are structured hierarchically simulating authority relationship for instance in distributed problem solving. Nonetheless as Castelfranchi and Falcone elucidate, task delegation is a highly relevant complex concept in especially in open or semi-open MAS where the archetypical delegation mechanisms do not apply [Castelfranchi and Falcone, 1998]. This follows from the fact that agents take decision about delegating a task and the agent to whom it be delegated on depending upon the circumstances.

Definition 4 (Task Delegation according to Schillo et al., 2001)

Task Delegation is the delegation of a sequence of (autistic) goals to be achieved

There has to date no single task-delegation mechanism for MAS, which is not a surprise as delegation mechanisms vary with scenarios. Four different mechanisms have been observed [Schillo et al., 2001], i.e.:

- *Voting:* decisions made by plurality of votes.
- *Authority:* Use of hierarchical structure for distributed problem-solving.
- *Economic Exchange:* Some agents offer tasks to other agents who compete for their acquisition and are paid on completion of the assigned task.
- *Social Exchange:* As put forward by Bourdieu this concerns the exchange of favors as gifts; the idea is to accumulate social capital which is an important resource in the HFT.

Definition 5 (Social Capital according to Bourdieu and Wacquant, 1992)

[Social Capital] is the sum of the resources … that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition.

We confine ourselves to *economic exchange* and *social (gift) exchange* in our market-based MAS, where agents accumulate wealth through the former and as collaboration becomes vital use the latter to be able to know other participants in the market. Later in this chapter, we introduce the 'delegation matrix' as the theoretical basis for investigating gift exchange in MAS. We adjourn our treatment to the above two mechanisms and the description of our testbed to the Chapter *4* of this thesis, where we specify our modus operandi.

It is useful to present the auction mechanisms briefly, Guttman and Maes provide a comprehensive review for market-based scenarios [Guttman and Maes, 1998]. Figure 2.3 on the next page illustrates a classification scheme for such scenarios.

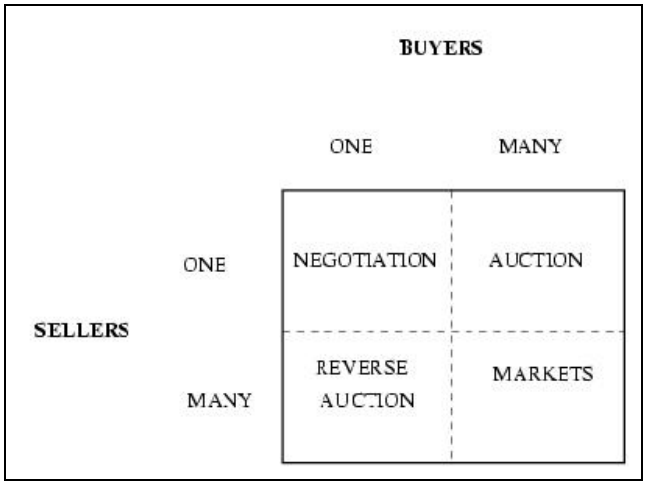

Figure 2.3: Market Framework [Guttman and Maes, 1998]

Following are the most common auction mechanisms [Sandholm, 1999]; the first of which is being applied in this thesis:

- *English auction:* Each bidder is free to raise their bids; in case no more bids are raised, the bidder with the highest bids wins with the last offered bid.
- *Dutch auction:* Prices are lowered continually until a bidder procures at the current price.
- *Vickrey:* Bidders submit their bids without knowing what others have proposed; the highest bidder wins the auction at the highest losing bid.

2.3.3 FIPA Interaction Protocols

A non-profit international organization, FIPA™ (Foundation for Intelligent Physical Agents) is a pivotal contributor to the promotion of intelligent agents industry by openly developing specification to facilitate interoperability among agents, by means of open collaboration among universities, research organizations and companies. Such specifications published by FIPA provide standards to researchers and professionals, followed in the development of agent-based applications and test-beds for agent-based simulations.

The way conversation or interaction between agents have been modeled in the past have spawned typical patterns emerging as outcome of practices followed by researchers in agent-based computing. As defined in the FIPA specification, *Interaction Protocols* are such patterns of message sequences which are exchanged between agents during conversation, serving as standard course of action. In Chapter *4*, we describe our use of the FIPA protocols in this thesis; in this section we restrict ourselves to FIPA 'Agent Communication' (for details to FIPA specifications, see [FIPA, 2003].

FIPA Agent Communication Language (ACL)

The FIPA ACL lay down specified format for the negotiation, communication and information exchange among agents, consisting of five levels, i.e.:

- *Protocol:* Social rules for formalizing agents' communication. For example the FIPA Contract Net Protocol (introduced in Chapter *4*).
- *Communicative Act:* This defines the 'performative' of the message for example 'propose', 'request', 'inform' etc.
- *Messaging:* Contains the meta-level information regarding the message besides identifying its sender and receiver.
- *Content Language:* Specifying the grammar and semantics of the message content's language, such as LISP etc.
- *Ontology:* Defines the message content's lexicon and definition for terms.

```
(call-for-proposal
        : sender (agent: name i)
        : receiver (set(agent: name j))
        : content
            "task(task-name, deadline)"
         : language Prolog
)
```

Figure 2.4: Example of FIPA ACL Message

2.3.4 Using UML to Model Agent Interaction

In recent years, object-oriented approach for the analysis and design of complex software has led the practices used by the software industry. The Unified Modeling Language (UML) unifies and formalizes various object-oriented approaches through its models (static, dynamic and implementation) and use cases diagrams which are specifications of actions that can be performed (for details, see [OMG, 1999]). UML itself was found to be insufficient for modeling agent-based systems, as agents are not controlled from external sources like objects in the object-oriented paradigm. Moreover, in MAS the action of agents are not independent but are related with other agents in the system. AgentUML was introduced as an extension to UML for the specification of interaction protocols [Bauer et al., 2000].

Albeit AgentUML solves the problem, agent interactions can be specified with respect to *activity diagrams* of UML, which, as claimed by Lind is a major advantage as one circumvents the 'diversification' of UML [Lind, 2000]. There are however limitation to this approach, which we shall present in our discussion for using this methodology for modeling interactions in our test-bed.

2.4 The Gift Exchange Phenomenon

The Oxford Dictionary defines the term 'gift' as "thing given", where the act of giving is willingly in essence [Oxford, 2001]. Nevertheless, in a sociological sense, the meaning of gift-giving spans a whole procedure where there is a need for returning the gesture from the one receiving it, providing the basis for mutual familiarity between the two parties involved in such exchange.

Definition 6 (Exchange according to Hutchins, 1980)

Every exchange event is a communication from one person to another of both an artifact (item exchanged) and a social message. The movement of artifact makes exchange important economically. The participant's interpretation of social messages makes exchange important symbolically.

For researchers in the social sciences notably the sociologists and anthropologists, gift-giving is more than merely being bighearted, the crux lies in the notion of 'sacrifice'; which is an offering of something dear in order to gain long standing relationship and intimated social bonds built out of reciprocity, obligation and indebtedness in returning the favor subsequently. Such social sentiments have been explained by the social scientists and have been a favorite theme of literary figures for many years, as they play an important role in the social interactions of human beings. For instance the famous short story "The Gift of the Magi" by O. Henry, gives account of two lovers who sacrifice their greatest belongings for each other with both losing; ironic it may seem, but they achieve a lasting acquaintance as a long-term benefit [Henry, 1963]. Expecting reciprocity is the backbone to gift exchange; which as explained by Gouldner, is one of only two social agreements that have been found to be universal among societies throughout in the history of culture and civilization (the other being the incest taboo) [Gouldner, 1961].

The idea of exchanging gifts in a society has remained theoretical with not many attempts to formalize it, some of which we shall state shortly; this thesis also takes a step-forward in this respect. We shall now present the theoretical detail of this phenomenon followed by recent work in this respect.

2.4.1 Sociological Basis of Gift Exchange

If it is true that the lapse of time interposed is what enables the gift or counter-gift to be seen and experienced as an inaugural act of generosity, without any past or future, i.e. without calculation, then it is clear that in reducing the polythetic to the monothetic, objectivism destroys the specificity of all practices which, like gift exchange, tend or pretend to put the law of self-interest into abeyance [Bourdieu, 1977].

A very important aspect of gift exchange is the giver's expectation of receiving a return; it should be emphasized that the return or 'counter-gift' must be different than that of the actual one, which could even be a token of gratitude. As explained by Levi-Strauss, exchange of goods is not only economic commodities but facilitate social ties such as influence, sympathy, maintaining of status quo [Levi-Strauss, 1965]. Hence, paying by the same token implies a "tit for tat" behavior in which exchange becomes that of an economic signaling a refusal to participate in exchange gift exchange thereafter. An exact return according to Marcel Mauss is "the equivalent of a declaration of war; it is a refusal of friendship and intercourse" [Schwartz, 1967].

Temporal Aspects

One of the major aspects of Bourdieu's idea of exchange is to highlight the temporal aspect, which unlike mere reciprocation, leads to a cycle of unconscious obligations to give and to give in return. Hence failure to respond with a counter-gift at some point possibly abolishes any chance of exchange of gifts in future [Acciaioli, 1981]. Furthermore as Bourdieu accentuates, for a gift exchange to get underway the counter-gift must be delayed and different. An immediate return of gift (though different) would be a signal of no further gifts being given or returned.

This thesis takes into account time considerations as agents observe time lag for the gift to be conceived. As argued by Bourdieu, a proper time-lag is essential which is concealed by agents from others and so it remains for the receiver to choose the course of future interactions [Bourdieu, 1985]. Choice of the time-lag is of immense importance as there would be no social gain for an immediate counter-gift and is an important research issue. We present the strategies used by agents in our case to determine the time-lag.

Dyadic Relationship

Gift exchange is not a global activity in a society and is a highly local process. It becomes interesting to incorporate and to study its ramifications in a multiagent system testbed, where agents exchange gifts in a pure dyadic fashion but one could look forward to an overall emergent behavior. As explained by Schwartz, a dyadic gift exchange always leads to a situation where one of the participants comes in debt of the other [Schwartz, 1967]. Sociologically equilibrium between the two participating agents must never be realized as the dyadic relationship would be reduced to an economic one rather than exchange of social capital.

One can view the notion of 'indebtedness' as a range of choices bounded by complete and inadequate reciprocity; it's 'somewhere' within this range that an agent giving a counter-gift must decide to choose the value for its gift.

Building Trust and Showing Sacrifice

Definition 7 (Trust according to Goecks and Mynatt, 2002)

An individual's trust is the degree of belief that, for a particular situation, an entity (an individual or a system) has the capacity to harm the individual but is not expected to exercise this capacity.

Offering a gift to another agent in the society[1] reflects the identity of the giver (and the receiver) of the gift. With respect to DAI, offering a gift serves as a 'signaling device' that reveals the identity of the giver as an agent who exchanges gifts in addition to mere economic exchange. Certainly this revelation remains private to the receiver. On the contrary, it imposes a challenge on the receiver who is compelled to show its own interest in building an enduring mutual relationship.

[1] Here by society we mean the population of agents in MAS at any given time.

In MAS, trust can be regarded as an expectation an agent 'ascribes' to an other agent that the latter will cooperate with the former in a certain situation and thus let agents decide whom to cooperate and with whom not [Marsh, 1994]. Besides trust, a related but different concept of 'reputation' has also being studied by researchers in DAI and socionics. To put in plain, reputation is an agent's perception about another agent or agents. Our notion of gift exchange relies on building trust as compared to reputation. Mui et al. provide an across-the-board review of the concept of reputation in MAS [Mui et al., 2002]. Trust is a central sociological concept investigated by evolutionary biologists, economists and DAI researchers. Fley and Florian provide a comprehensive review of trust-based approach used in DAI, we however restrict ourselves to the relationship of trust with gift exchange [Fley and Florian, 2003].

For Bourdieu, trust is intertwined with an agent's accumulated social capital based on symbolic exchange of commodities (e.g. gift exchange) [Bourdieu, 2000]. Nevertheless, on one hand Bourdieu assumes agents to be self-interested in maximizing their profits and thus achieving a higher rank in the society, thus taking a selfish role; but intriguingly on the other hand, they presume long-term mutual relationships (both symmetric and asymmetric) through exchange of symbolic goods. Hence, agents sacrifice their profits momentarily anticipating larger profits in a longer run as a result of building stronger relationships; the self-interested nature of agents remains intact.

In our work, agents evade from making high expectation in terms of gift exchange initially, as exchanging gifts require economic capital; however as time passes agents looking for gift exchange partners broaden their quest. It should be accentuated that in our case, agents remain unaware of the number of rounds (time-steps) the market remains active, making the scenario more interesting. Moreover as maintained by Fley and Florian, agents must be able to recognize a gift with respect to MAS. Our notion of gift follows from what is described as "process-based trust" by them [Fley and Florian, 2003].

In the context of MAS, the dyadic gift exchange is advantageous as first the initial gift is marked as a signal of trustworthiness and the risk the giver of the gift has undertaken. In our case the initial gifts serve a gesture and thus are of size that does not cause any significant gift to the agent offering it; as there always remains the chance that the receiver of the gift is opportunistic in nature and does not return a gift. In case of an exchange however, there is a symmetric transfer of trust for a future exchange.

2.4.2 The Delegation Matrix

While discussing the delegation mechanisms in MAS, we introduced the two modes of delegations, i.e. task delegation and social delegation. The former works on economic logic and is well-known in DAI, whereas the latter incorporates the long-term standing relationship among agents and entails trust and power. Four distinct mechanisms were also defined for the delegation of these two modes. We now present the most important basis for modeling gift exchange which is the *delegation matrix* that defines the relationship between the modes and the mechanisms. As Schillo maintains, in principle all possible combinations of the two modes and the four mechanisms are possible in dealing with organizations in multiagent systems [Schillo, 2002].

	Task Delegation	Social Delegation
Economic Exchange	X	X
Gift Exchange	X	X
Authority	X	X
Voting	X	X

Figure 2.5: The delegation matrix, with Task Delegation and Social Delegation as the two modes and the four mechanisms on the left [Hillebrandt, 2004]

Figure *2.5* presents the matrix introduced by Hillebrandt that not only allows decentralized coordination of task assignment, but also provides the basis for the propagation of cooperation between agents in carrying out tasks jointly [Hillebrandt, 2004]. Though the above-shown mechanisms may possibly be not the only ones for task and social delegation, the matrix nevertheless, provides the plausibility for introducing gift exchange to multiagent systems.

2.4.3 Related Work in Gift Exchange Modeling

Gift exchange was investigated by economists like Kenneth Arrow and others in the past. However, their idea of gifts are not orthogonal to the notion presented in the previous section, they remained more or less related to research in area of macro economics and game theory [Heijden et al., 2001]. Only recently computer scientists and sociologists began investigating the possibilities of modeling gift exchange with the social perspective. As argued earlier, MAS is well-suited to serve as the means for simulating such social phenomena and finding out whether the outcome of analyses could be beneficial in the area of DAI. Modeling gift exchange is an open field for MAS and DAI researchers, although there have been some contributions to formalizing it. We review some of such attempts in this chapter.

In his paper, van de Van presents various theories that lead to motivation behind gift exchange mechanism [van de Van, 2001]. These theories center on market-oriented economics guided by gift exchange but it does not pursue a MAS approach. An important contribution is the presentation of scenarios where reciprocating a gift is not necessary and more importantly the possible gift exchange models presented along with their explanation in the context of economics theories. We discuss here only the models of gift exchange as explained by van de Van.

Motivation	*Aim*
Altruism	making others happy
Egoism I	exchange
Egoism II	warm glow, social approval
Strategical	signaling, building trust
Fairness	norms, reducing inequity
Survival	selection

Figure 2.6: Models of Gift Exchange [van de Van, 2001]

In this thesis, we make use of these mechanism illustrated in Figure 2.6 with respect to the time-lag aspect of Pierre Bourdieu's view of gift exchange. Roughly this idea can be envisaged as rational as the motives of an agent offering a gift can be explained by the time-factor it sets for its gift. We elucidate its relevance in Chapter *4.*

Another significant related work is by Rouchier et al. which is interesting in the sense it employs an agent-based methodology in investigating certain aspects of gift exchange [Rouchier et al., 2001]. For building their artificial society they used MAS approach as they found this methodology "to be effective in representing agents and for observing the result of the repetition of their interactions in time".

The society modeled by Rouchier et al., consisted of gift-giving agents who are either giving gifts when they have the capital to do so, or (exclusively) work when they lack such resources. Gift-giving is controlled by two parameters, 'esteem' and 'prestige'; the former being self-confidence of an agent while the latter being its motivation to enhance its reputation. Agents observe reputations of every other agent and choose their actions accordingly. A major assumption of this model is that *each agent does not worry about to whom its gift is going to go or whether it will get one in return.* Our model in this thesis strictly circumvents such assumption one does not find justification for it in terms of sociological theories. Another aspect of their approach to which we differ, is the global nature of gift-giving phenomena; as argued earlier, the dyadic nature of gift exchange is more rational and has a strong sociological basis.

The model by Rouchier et al. aims at the hierarchical ranking of agents in the society with the assumption that a gift is given at each time-step. Two types of gifts are defined 'sharing gifts' and 'prestige gifts' with agents choosing either of the two. It would be useful to explain that these two types of gifts are essentially different from our notion and treatment of gift. Figure 2.7 illustrates how agents test their attribute with "Rd" meaning a unit random number.

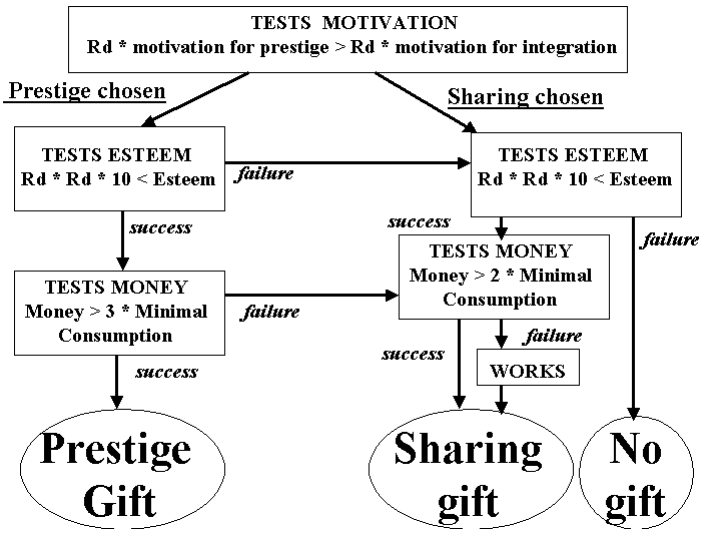

Figure 2.7: Agents' testing of attributes [Rouchier et al., 2001]

As claimed by Rouchier et al. their model successfully represents the ethnologists' viewpoint of gifts as gift exchange is the only means of communication in their society and serves as a signaling device serving as a novel way for representing reputation in MAS. Although our case differs in several aspects, this work is important as it's one of the few attempts to model gift exchange in MAS-based artificial societies.

2.5 Summary

This chapter introduces the notion of an agent with respects to AI and the basic characteristics that define the concept of intelligent agents. The multiagent systems methodology is presented which supports a modular and extensible approach for modeling complex systems consisting of multiple autonomous agents with possibly variable skills. Complex problems are therefore solved through the collaboration of participating agents who interact via well-specified protocols. The FIPA Agent Communication Language and use of Unified Modeling Language are briefly discussed.

Social simulation has attracted the attention of AI researchers especially those from its sub-field Distributed Artificial Intelligence (DAI). How social scientists view social simulation and the use of computational models is discussed, especially MAS, which has become the definitive choice in Socionics (an emergent discipline that bridges sociological theories and DAI). An important observation is the relation between agents-interaction and social structures. Agents in MAS are typically able to collaborate and communicate with other agents, for instance, the sharing of resources and skills for solving complex tasks in case a single agent in unable to complete it on its own. An overview to Pierre Bourdieu's Habitus-Field Theory is presented, which provides the sociological basis for this thesis and has inspired several agents' task delegation mechanism successfully.

Finally, the notion of a gift is explained taking into account the essence of exchanging gifts as explained by social scientists. The idea behind gift exchange in a society where agents need the cooperation of other agents in order to survive and levitate their capital is presented. Temporal aspects of gift exchange, i.e. maintaining reasonable delay when reciprocating with a counter-gift, along with its dyadic nature are presented as key features of Bourdieu's idea of exchanging social capital. The *delegation matrix* is introduced that presents the relationship between the two modes, viz. task and social delegation and the four mechanisms of delegation. The matrix shows the possibility of every possible combination of the modes and mechanisms.

Practicing gift exchange thus motivates MAS researchers as a means of building trust among agents. There have been a few attempts to model gift exchange in multiagent systems but the models do not reflect the sociological basis which is the crux of this concept. We show in the Chapter *4* how our model takes care of the idea of gift exchange in accordance to the sociological theories.

Chapter 3

Problem Description

In this chapter we present the research questions of the relevant field to which this thesis addresses. We begin by outlining the central ideas and the relevant concepts that we focus upon, followed by the stipulation of the research goals of this work. The chapter concludes with a sketch of a few examples where the contributions of this thesis may find application in the real-world systems and complex scenarios.

3.1 Problem Statement

Socionics as an interdisciplinary field has its basis in three fundamental guiding principles as highlighted by Malsch: *Social Reference* which takes into consideration the use of computational models such as MAS in formalizing sociological theories and probing into them; the *Computational Reference* which focuses on the use of sociological theories and ideas into the design of efficient DAI models and problem-solving strategies and last but not the least, the *Praxis Reference* dealing with the impact hybrid artificial societies comprising of human and artificial agents impose in social terms [Malsch, 2001]. This thesis being in the field of socionics primarily concerns with the first of the three above-mentioned tenets, albeit the research questions raised serve as the motivation for applying new sociological concepts (viz. gift exchange) in the contemporary DAI research.

In this thesis we investigate the implications of applying the idea of gift exchange mechanism inspired from Bourdieu's sociological theories into a market based multiagent system. Our work is directed in the continuation of investigations by Knabe who studied the formation of different organizations structures between providers in a market comprised of self-interested agents who delegate tasks by means of economic exchange [Knabe, 2002]. In contrast, we are keen into scrutinizing various hypotheses centered to gift exchange in which an agent sacrifices its profit for a long-term binding relationship in a market multiagent system. The idea is to aim larger profit through alliances that are formed as consequences to gift exchange.

The market in our case comprises of customers and providers agents; the former places call for proposals for tasks in the market, while the latter proceed with the execution of tasks based on their abilities and other circumstances. The provider agents are divided into two classes: profit oriented and the ones who prefer exchanging gifts and are in

pursuit of others who also practice this mechanism. Unlike a typical market scenario where there is no room for a long-term relationship, gift-giving provider agents get engaged into dyadic exchange and therefore one expects interesting scenarios that include preservation or repetition of hierarchical structure in the market. In such setting more powerful providers dominate the less powerful ones. Moreover, one anticipates situations when two providers decide to form an alliance sharing their abilities and profits; also the split of provider agents in terms of profit oriented and gift-giving ones.

The primary goal therefore remains to find novel concepts to be introduced in MAS as researchers in socionics believe agents constructed in line of sociological theories could better cope with complex decentralized systems [Hillebrandt, 2004].

3.2 Research Questions

So as to embark upon the target mentioned-above we set three milestones, viz. specifying the model of gift exchange in accordance with the Habitus-Field Theory, formalizing the mechanism through standard approaches such as those laid down by FIPA and UML etc and finally testing and evaluating hypotheses related to the problem statement.

3.2.1 Specification of Gift Exchange Mechanisms and Relative Parameters

The foremost task in investigating gift exchange is the formalization of the mechanism. In order to have our notion of gift exchange consonant with the Habitus-Field Theory, we delineate what a gift is, and how social delegation can be achieved in the market via exchange of gifts. This thesis introduces two new concepts, viz. *Weak Gift Exchange* and *Strong Gift Exchange* that help capture the different circumstances a gift-giving agent goes through during the run. The following chapter explains the two mechanisms and the rationale behind them.

Having established the mechanism, we introduce the parameters central to our model of the gift (or reciprocal) exchange. Time is the most important aspect of Bourdieu's idea of gift-giving phenomenon and several parameters take care of it; for instance 'initial rounds', expected time to wait for any gift offer from another provider and calculation of deadline to await a counter-gift once a gift is offered etc. Various gift-giving strategies suggested by sociologists are used by the providers in making a rational choice for calculation of time lags. Several other parameters related to the performance measures of agents and contribution of gift exchange and profit oriented agents are also set up.

3.2.2 Development of Protocols

The FIPA standards for agents' interaction protocols and the *Contract Net Protocol with Confirmation (CNCP)* enhanced by Knabe et al. cover the delegation of tasks between the agents when the mechanism of delegation is economic exchange [Knabe et al., 2002]. Nonetheless for the gift exchange mechanism as means of task and social delegation, we develop two new protocols that represent the interaction of two provider agents

exchanging gifts. These protocols are developed in accordance with the FIPA performatives and can be used for any multiagent system following the FIPA standards.

3.2.3 Testing of Hypotheses

An extension to the JTOM (Java Testbed for Organization in Multiagent System) has been implemented that simulates our model for the gift exchange mechanism. Our market-based testbed encase the model parameters that can be varied so that a variety of interesting scenarios can be run and the ramifications can be investigated. We test the hypotheses that encompass the crux of gift exchange mechanism and most relevant to our problem statement.

The hypotheses we present are:

1. In scenarios where the message-limit (number of call for proposals sent by an auctioneer) and the market size are low, the number of gift exchanges among the gift-giving agents is reduced.

2. In homogenous market scenarios where all agents are gift-giving, there is no long-term distinct grouping of the agents.

3. In heterogeneous market scenarios, introduction of gift exchange partitions the provider agents into two groups over a long run.

4. In heterogeneous market scenarios, if the population of GE agents is greater, the EE agents will not be as successful as in the case when the population of GE agents is low. The higher the populations of GE, the higher are the chances of GE agents of being successful.

5. If the survival of provider agents with lesser capabilities is difficult, the practice of gift exchange will be intensive. Such GE agents would build buddies in order to gain more capital even though they suffer early losses from the gifts they give.

3.3 Promising Areas of Application

The most direct application of gift exchange mechanism is in the holonic approach in the design of multiagent systems. Gift exchange as an eminent sociological concept is well-suited for task and social delegation among agents and hence can contribute to the overall efficiency of the entire system. As Hillebrandt points out, the very nature of gift exchange as a device for long-term relationship can possibly help in the make of flexible holons [Hillebrandt, 2004]. In real-world trade where companies compete in a highly complex and dynamic market, the inter-relationships among the participants depends heavily on the creation of trust, and gift exchange has been founded as well-practiced strategy. It therefore helps emergence of various organizational structures in the market. Moreover as the research in the properties of complex networks have sprung in the recent past, the formation of clusters and cliques, especially in eastern family networks can be explained in terms of gift exchange; as we previously studied the clustering effect within such networks due to arranged marriage systems [Alam, 2003].

From the sociological point of view, having a testbed to study gift exchange and its effects provides a wide gamut of application where artificial societies are studied. Gift exchange as reciprocal exchange potentially helps to investigate how social networks emerge, the development of trust-based systems, countering epidemic or security threats by means of collective effects etc. We present the translation of a quote by J.J. Rousseau as the canonical social observation:

Eventually we separated very pleased, and that afternoon was one out of my life that I remember with most satisfaction. The party turned out not to be ruinous, for the thirty penny that it cost me at most, one had satisfaction for more than hundred thalers J.J. Rousseau - Les rêveries du promeneur solitaire, 1782; translated by Klundert and van de Van [1999].

3.4 Summary

Investigating the outcome of gift exchange mechanism in a market-based multiagent system is the purpose of this thesis. As a new sociological concept, we formalize and develop our model of gift exchange and outline its parameters. In order for the agents to exchange gifts, protocols have been developed in accordance with the standards laid down by FIPA for agents' interaction. Hypotheses are presented which are tested within the testbed developed in this thesis.

Chapter 4

Model Specification

In order to investigate a phenomenon e.g. gift exchange, a simulation model is the requisite. As Gilbert and Troitzsch explain, having a simulation model is analogous to an experimental methodology which can be run many times with varying configurations and exploring the effects of different parameters of the model [Gilbert and Troitzsch, 1999].

In this chapter we elucidate the model conceived in order to tackle the problem statement and be able to test the hypotheses presented in the preceding chapter. We begin with the foundation settings and basic assumptions of our model followed by the specification of the parameters. We introduce the relationships and subsequently the gift exchange mechanisms. Finally, we provide the specification of protocols concerning gift exchange.

4.1 The Gift Model

Understanding the meaning of gift is trivial, albeit one needs to define it in the percepts of the agents in our testbed and concordantly with our model.

Definition 1 (A 'gift' in the context of our model)

A 'gift' is a utility, e.g. a task (or subtask) or capital entrusted by a gift-giving provider to any another provider it chooses in the system.

Defined as a utility, a gift facilitates the design of a model where agents may send gifts in the form of a task such that the profit earned through it remains with the receiver. Similarly, a gift can also be given as some proportion of an economic capital earned by the sender of the gift; by the same token, the idea of gift can be extended to any form of an agent's capital it possesses. It becomes pertinent to have definite way of sending a gift so that the agent receiving it is able to distinguish a gift from an economic exchange. As explained by Fley and Florian, it's vital in MAS that agents possess abilities to recognize a gift as a gift in their common meaning [Fley and Florian, 2004]. Specific protocols and exchange mechanisms are presented that facilitate agents to recognize a gift such that the idea expressed above remains intact. In the following sections, we present the model settings, the controlling parameters and performance measures taken into consideration.

4.1.1 Assumptions and Settings

The basic setting stems from the auction-based MAS stated by Knabe; this thesis augments upon that idea [Knabe, 2002]. A similar mechanism has been used by Hahn and Schillo in their work respectively [Hahn 2004; Schillo, 2004]. We present in this section, an overview of the setting highlighting the essentialities. The market framework for the investigation of sociological theories has been central to the researchers of socionics; Mauss defends a market scenario for sociological investigations as follows, *We will describe the phenomena of exchange and contract in societies that are not (as some have inaccurately claimed) deprived of economic markets – for a market is a human phenomenon to which no society is a stranger* [Mauss, 1967].

The market in the MAS consists of two distinct sets, one consisting of customers and another comprised of providers. The customers are characterized with respect to the complexity of tasks that put on auction in the market; a task may be atomic, for example of types *A*, *B* or *C* etc or a compound of distinct atomic tasks such as *AB*, *BC*, or *ABC* etc. A customer offering a particular task also specifies the volume of the task and the time it takes to accomplish the task once it's delegated. Time is modeled in terms of number of rounds and customers taking part in a particular round send calls for proposals for their respective tasks to providers in the market. Providers are selected on the basis of economic exchange and their ability to carry out the task successfully. Provider agents who are assigned a task and cannot accomplish it on their own, begin their own auction in which they delegate the part of task beyond their capabilities to other providers; in our model the mode of delegation can be both economic exchange and gift exchange. The exchange mechanism is the Contract Net Protocol with Confirmation (CNCP). We explain the delegation via gift exchange later in this chapter; Knabe et al. describe the CNCP and other related issue concerning task delegations via economic exchange [Knabe et al., 2002]. An agent initiating an auction is referred as *initiator*, while those taking part in the auction in response to the calls for proposals are referred to as *participants.* The market is unpredictable for agents in terms of its finality, i.e. the number of rounds the simulation runs; moreover, no future order to be placed by customers can be guessed in advance.

In our work the auction-based market is defined with two types of providers, i.e., those that are only keen in economic exchange and earning profit, and those who besides making profits, look for other agents with whom they can exchange gifts. The former may be called economic exchange providers abbreviated as (EE), and the latter as the gift exchange providers abbreviated as (GE). Given the population of providers as *Providers*, we have, $|Providers| = |EE| + |GE|$ such that $\forall p \in Providers, p \in EE \cup p \in GE$ and $EE \cap GE = \emptyset$. Beginning with the simulation, providers are aware of each other in terms of the ability of doing a task. However, the providers' type which is either of the two mentioned above is private in the beginning.

GE providers seek the type of other providers by means of delegating subtasks as gift sporadically. It's expected that after a number of experiments, a GE provider able to delegate subtasks, gains information about the types of several of the providers in the market, i.e., it had discovered a subset of providers who are also GE. A major part of this search takes place during the initial rounds, which is a parameter introduced in the next subsection. Once some providers are found to be gift giving as well, a GE selects receivers for an exclusive gift-exchange with them. An immediate return of a gift or a counter-gift with almost the same worth implies end of any further gift-exchange. A

sender of a gift expects reciprocation later on as a signal indicating that the provider receiving the gift is also a GE; and a possibility of future gift-exchanges between them may be anticipated.

The GE provider gains the knowledge during the initial rounds (a parameter), where it acts 'carefully' earning profits via economic-exchange but also putting gifts at auction, albeit seldom. Following, X knowing some agents as GE, selects gift-givers for an exclusive gift-exchange with them, which we call as the 'strong' mode of gift-exchange. An immediate return of a gift or a counter-gift with almost the same worth implies end of any further gift-exchange. Once a GE provides gives a gift to another provider, it expects a return later as a signal indicating that the provider receiving the gift is also a GE and thus anticipating a possibility of future gift-exchanges between the two.

Given the case when a task is delegated as a gift, a sender of a gift is not allowed to delegate the entire task; instead a proportion of a task is delegated while the remaining is carried on by the sender itself. In case such restriction is not imposed one may possibly encounter a situation which does not exist in reality. Supposing $X_0 \ldots, X_{n-1}$ are gift giving agents in the market. Assuming X_0 chooses X_1 and delegates some task T to it as a gift which is accepted by X_1. It could be the case that X_1 now gives gift the same task T to X_2 and this continues. Since the task T has to be completed within its deadline, so if X_{n-1} sends gift to X_0, it would be perceived as a gift from X_{n-1} and so on. The outcome would be formation of a ring; however, allowing the delegation of only a proportion of a task prevents such situation.

4.1.2 Gift Exchange Parameters

The model provides the basis for gift exchange and thus a number of controlling parameters are introduced that govern the behavior of the system. The values of these parameters are varied so that a satisfactory number of experiments could be performed in order to accumulate statistical measures. We present here the parameters that control the gift exchange mechanism globally for the system followed by the local parameters that influence a gift giving provider's behavior. Some parameters are introduced later on when the relevant context is explained.

Proportion of Provider Agents

This is the parameter that determines the proportion of gift giving and profit-oriented provider agents specified in the beginning of the simulation before the agents are configured with respect to their *provider-types* and *resources*, the latter being the abilities of provider to carryout particular tasks or subtasks. The parameter can be varied to introduce a heterogeneous population of both types of providers, or a homogenous population of either of the two types.

Initial Rounds

The motive of GE agents as presented in the preceding subsection was to try out with other provider agents at the earliest. The rationale is as to know their preference for gift exchange is influenced by time, which as we explained earlier plays a vital role with

respect to the Habitus-Field Theory. This parameter thus defines the time limit during which the GE agents experiment gift exchange via CNCP and after which they build up their behavior and future course as a result of these experiments. It is pertinent that the agents remain unaware of the number of rounds the simulation runs as this information can distort the sociological ideas of reciprocity and building of trust. For one may not rule out agents maximizing their profits and be self-interested; exploiting the knowledge of how long the simulation would run. It is possible that the simulation ends within the initial rounds or continue for a very long time beyond this threshold.

Chance of Gift through CNCP

This provides the chance for a GE provider to pick a committed participant of an auction as recipient of the gift. Since the GE providers need to earn profits besides gift exchange initially, the parameter controls the frequency of delegating a subtask as a gift or earning profit via economic exchange especially during the initial rounds.

Gift Receiver Selection Strategies

While selecting a committed bidder as recipient of its gifts, a GE provider picks one or more participants of its auction based on the following strategies:

Counter-Gift Receiver Strategy: A GE agent in our model is conscious of reciprocating a gift that it had received from another provider in the past, especially if it hadn't sent any counter-gift at all. Having such a provider to whom it's indebted participating in its auction provides the chance to reciprocate a gift and therefore, prove it a gift giving agent as well. Care is taken when choosing a GE participant among the bidders for a counter-gift, that the value of the gift should be different and that 'some' time has passed since the gift was received. Since the CNCP auction is an opportunity to offer gifts to providers in order to know their types, this strategy is not selected always, and either of the following two is selected otherwise.

Best-Bidder Strategy: This is a probability parameter that gives the chance of picking among the committed participants, the provider with the highest bid.

Random-Bidder Strategy: If the best-bidder is not chosen, any of the bidders is selected uniform randomly.

Preference of Bidders

A GE auctioneer selects from the population of providers, bidders to whom it sends call for proposal (*cfp*). This chance parameter allows the extension of the list of the bidders including those providers who had sent the auctioneer a gift previously. This parameter operates during the initial rounds and thus, the need for such extension is seldom. The idea is to give chance of participating in the auction to those providers who have sent a gift, so that there remains some possibility of a counter-gift during the initial rounds. On the other hands, the participants make use of this parameter in prioritizing the cfps they receive, when sending their proposals. The prioritization is based on the relationship providers develop among themselves, which we present later in this chapter.

Deadline Strategies

The deadline set when a gift is offered is dependent upon the gift sender's status that in turns means the level of surge to look for a GE partner. It also depends upon the size of task allocated to the recipient in case a task is offered as a gift. For instance, a very highly resourceful GE agent may offer gift in order to maintain the structure in the society which we introduce later on, and hence does not need a partner for its survival. In such case a longer deadline is set. On the contrary, a GE provider with limited resources who cannot afford to wait long for a counter-gift, require a response to its gift soon. Resources of a GE provider can be explained in terms of the ability it has to conduct a particular task together the profit it had earned till then.

Several different motivations for giving a gift were explored by van de Van, together with the cases where the dyadic nature of gift giving is imminent and where gift giving is asymmetric with no reciprocation [van de Van, 2000]. We model four of such motivations as strategies when a gift is offered and a deadline is set till which a counter-gift is anticipated. As introduced previously, this methodology is in accordance with Bourdieu's idea of a time-lag. The four strategies are as follows:

Altruistic: This gives a maximum possible deadline and selected as the strategy, when asymmetric gifts are offered.

Egoistic: Much lesser than altruistic but higher than strategic, chosen when there is a strong dyadic gift exchange between the sender and receiver of the gift.

Strategic: Mostly chosen during the initial rounds, when GE providers attempt to build upon relationships upon their exchange of gifts.

Survival: Picked when a sender of a gift desperately needs a reliable partner and time when the gift is sent within the initial rounds.

Value of Gift

A gift defined as a utility as a task or profit earned etc, has its worth is calculated based on the size of the task delegated and the bid offered by the receiver of the gift. Three types of gifts are defined, i.e., *Minimum-Gift, Medium-Gift, and Maximum-Gift* in terms of its value. During the initial rounds, a *Minimum-Gift* is preferred with lesser economic worth, but used as a gesture of offering future gift exchange. The idea is to circumvent bigger loss initially in case the recipient of the gift is an EE and thus does not send a counter-gift at all. Larger gifts are exchanged once a relationship is established.

Send Further Gift

A sender of a gift keeps track of the gifts it sends and information of the gift offered to a particular provider is recorded. It expects a counter-gift as the gift is delivered. Typically, no further gift is sent to a provider whose type is unknown unless it reciprocates or the deadline is passed. This parameter provides a bound to the number of gifts a GE provider sends to a provider before it receives a counter-gift or loses its hope.

Maximum Gift Per Round

This parameter bounds the maximum number of gifts offered by a GE agent in a single round when the simulation is within the initial rounds.

4.1.3 Performance Measures

In order to test the model many runs of the model are made so that data are generated for evaluation. As such multiple runs of the same model may differ from each other as a result of differences in the configuration setting and stochastic variations, some measures are taken into account to gain insight from the generated data. As Axelrod explains, while a single run may be sufficient to described an outcome, it is important too to perform statistical analyses so as to determine whether the inferences drawn from simulation are well founded [Axelrod, 1997]. We used the following performance measures to investigate various aspects of the model.

Profit per Provider

Although the tasks are introduced to the market by the customers, it is the providers that attempt to accomplish it either on their own or through collaboration of others. Since the providers build coalitions on the basis of gift exchange or economic exchange, the most important criterion is the difference in profit they earn through their collaborations over a longer run.

Earning of Providers per Type

As we can distinguish the population of providers into two disjoint groups of EE and GE, this performance measure investigates the wealth distributed to the two kinds. This measure is important since, the EE form a partnership only for a current task and distribute among them the money via economic exchange. On the other hand, the GE providers look for longer term relationships with their collaborators via gift exchange and also perform economic exchange given the circumstances.

Statistical Measures for Gift Exchange Parameters

Besides comparing the data generated through multiple runs from identical parameters, we also probed the influence of changing value of parameters. By changing the parameters together with stochastic variations, the effects were studied by means of complete runs of the model. The differences in the data were addressed to know whether they are being statistically significant, i.e. unlikely to have been caused by mere chance.

Dominance of Powerful Providers

From the sociological point of view one needs to investigate the differences between the agents that result in the emergence of hierarchical structure in the system. Inequality between agents on the basis of the ‘Theory of Capital’ by Bourdieu and the modeling of

such structure are introduced later in this chapter. Most interesting measure in finding the dominance of powerful agents over lesser powerful ones is the making of asymmetric gifts be it altruistic or to maintain the hierarchy of provider agents in the market.

4.2 Relationships

The relationships built by a GE provider reflect its intentions and the choices it makes under the given circumstances. It can be conjectured that after sufficiently many rounds, all GE provider agents gain self-reliance among themselves implying isolation from the profit oriented agents in terms of accomplishing tasks. This can be explained as an intention of a GE provider. For a GE provider with limited abilities long-term binding relationships is vital, while for a powerful agent knowledge of providers' types provides opportunities for asymmetric gifts and thus maintaining hierarchy in the system.

In the beginning no provider knows about the type of other providers and as the rounds proceeds, their knowledge increases resulting in a grouping of the providers in various relationships. The following figure depicts a GE provider's perception about others in the market after some time $t \geq 1$.

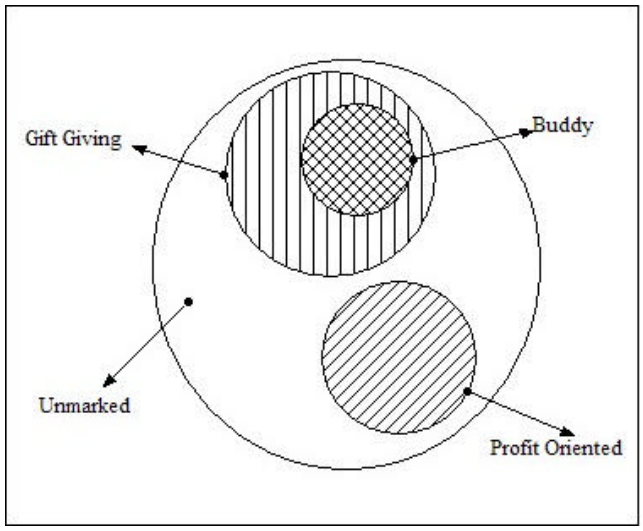

Figure 4.1: A GE provider's perspective of other providers in the market

At any time during the simulation, the GE provider maintains two distinct set of the agents, the gift giving, profit oriented and unmarked. As the pursuit of a GE provider is to gain as much knowledge about other providers being GE or not, a two-way search is carried out where the first two sets increase in size and the third reduces. On the one hand the search for GE provider agents is carried out, while on the other hand the estimate of EE provider agents in the market is also being improved. The search is expected to be narrowed down so that after many rounds each GE agent develops its own perception of the market, partitioned into two sets of GE and EE providers with the best possible estimate. In this section, we discuss the four relationships as shown in Figure *4.1*.

4.2.1 Potential Gift Giving and Buddies

The basis of building relationship among GE provider agents is recognition of the inclination for gift giving via gift exchange. We model this exchange as a two-way process; i.e. the behavior of a GE provider offering a gift to another, and that of a GE provider who is a recipient of a gift. We introduce the two relationships through which a gift giving provider agent acknowledges another gift giving provider.

The *Potential Gift Giving* Relationship

This is the set of providers that contains GE providers who are included if at least one gift is received from them, or had sent a counter-gift at least in reciprocation to a gift offer. When a GE provider participating in an auction initiated by a provider receives a gift from the auctioneer, it includes the sender of the gift in this set. A thorough record keeping is performed keeping track of all the gifts which are received during the simulation; given the fact that a GE receiver of a gift is conscious of sending counter-gifts.

A gift received is assessed whether it is a counter-gift; in case affirmative, the sender is added into the list of gift giving agents. The sender of the counter-gift is thus recognized as one to be considered for future gift exchange. With the handling of this counter-gift, the return is not awaited any further and the records are updated. On the other hand, if the received gift is found to be an opening gift from an agent, this implies that the sender of the gift has shown itself to be worthy of trust by identifying itself as a gift giving agent, taking the risk of losing a profit. In such case the receiver acknowledges the sender in this set and tries to reciprocate the gift later on. For the sender, the receiver of its gift is not marked as a member of this group unless a counter-gift is made.

Finding the maximum number of gift giving agents implies that a GE agent constructs that actual partition of provider types in the market during the runs and is able to utilize this information. More significant is the following relationship built from those present in this group as an exclusive subset with whom stronger ties are developed. A proposal from a gift giving agent is preferred when a counter-gift is due to be sent by the GE auctioneer.

The *Buddy* Relationship

A GE provider agent acknowledges another a buddy, as the one with who stable gift exchange is established; this is ensured with consistent fulfillment of reciprocating the gift. Moreover, the number of gifts exchanged between the two GE providers must be at least higher than a threshold before they acknowledge each other as buddy.

The relationship ‘buddy’ is specified as a dyadic relationship and for simplicity sake kept as boolean. This implies that an agent can exclusively be a buddy or not with no scalar value attached characterizing the level of being a buddy. Not only this specification is simple and straightforward, it allows the relationship to be defined as *symmetric* and *dyadic*.

That is, given two GE providers X and Y we can define the relation *buddy* as:

$$X \ buddy \ Y \quad = \quad \left\{ \begin{array}{l} true, \quad if \ (\#received \ gifts + \#sent \ gifts) \geq threshold \\ false, \quad otherwise \end{array} \right\}$$

More intricate definitions for this relation can be presented, albeit the essence remains unaltered. The relation is symmetric since the condition is just the total number of exchanges; however, in order to introduce the dyadic nature, a minimum number of gifts (say, *n*) need to be sent to the other such that both agents contribute fairly to the establishment of the relation.

Hence we have, $X \ buddy \ Y \quad \Leftrightarrow \quad Y \ buddy \ X$

It may be noted that the relation can be extended as *transitive* which is plausible due to the boolean nature of the relationship; sociologists identify such phenomenon as 'a friend of a friend, is a friend'. Such transitivity has been exploited by researchers, like Terry et al. in their project *Social Net* designed as social-acquaintance application, requiring the sharing of friends' list by agents among each other [Terry et al., 2002]. Gift exchange, in particular does not build upon sharing list of buddies as agents choose which relationship to form with whom distinctively. As Fley and Florian explain a dyadic gift exchange provides continuity of relationship among two GE agents, though the mutual obligations of reciprocation remains with the two parties and the resulting trust cannot be generalized to third parties [Fley and Florian, 2003]. On the other hand, when such dyadic exchange of gifts among agents increase, a network emerges separating the gift giving agents (having dyadic reciprocal relationship) from others; concordantly, the *buddy* relation can be generalized when agents are grouped in a network. For such case the transitivity holds,

$$X \ buddy \ Y \quad \wedge \quad Y \ buddy \ Z \quad \Rightarrow \quad X \ buddy \ Z$$

If there is a proposal from a buddy, it is accepted with highest preference and kept in the current solution to the original task. In case the proposal from a buddy is not among the highest received, the loss incurred is viewed as the gift that a GE auctioneer offers to that buddy. This relationship facilitates in the pursuit of a peer for collaboration where both agents linked fulfill each other's need for a partner. There remains, nonetheless the case where one GE provider dominates over the other; we discuss such phenomenon later in this chapter.

4.2.2 Profit Oriented and Unmarked

The remaining classifications of providers in the market as perceived by a GE provider agent are those that are profit oriented and those whose identity is yet to be identified.

The *Profit Oriented* Relationship

Besides looking for building stable relationships with other GE providers, a gift giving agent attempts to identify as many profit oriented or EE agents as possible at the earliest. Gift giving strategy helps in this search as GE agents experiment with unknown providers via CNCP. An agent is attributed as profit oriented if no gift sent to them is reciprocated at all within the deadline. To such agents no further gift is offered though economic exchange remains open. Given the fact that our model permits gift exchange

via CNCP during the initial rounds; an agent marked as profit oriented is removed from this set and recognized as gift giving if it returns the gift after the deadline passed. This choice is made only when the gift was offered during the initial rounds, as the recipient of the gift may well possibly fail to reciprocate via the CNCP even though it had desired to send a counter-gift. The idea is to gain some knowledge of the market during the initial rounds so that when gifts are made exclusively, so that a gift sent is particularly aimed at the receiver and none else.

Unmarked Agents

The group represents the providers whose type is yet to be guessed. Initially every other agent is regarded as an unmarked and thus the set is equal to the providers in the market for each GE agent. As the knowledge about providers is gained, the size of this set reduces as the number of agents whose types are guesses increases. A GE provider able to interact with every other provider via gift or economic exchange is able to guess the types after many runs implying that no agent remains unmarked.

4.3 Weak Gift Exchange Mechanism

In this section, we present the gift giving mechanism that uses the contract net protocol with confirmation (CNCP) mode and is the only way of sending a gift and counter gift during the initial rounds. For economic exchange we follow the CNCP mechanism as outlined by Knabe et al. in their work [Knabe et al., 2002]. In this section, we restrict to the discussion of incorporating gift exchange within CNCP as an augmented mechanism we refer to in this thesis as *Weak Gift Exchange (WGE).*

4.3.1 Task Delegation via Gift Exchange

This form of gift-exchange is the augmented version of the auction-based mechanism we have used for economic-exchange. The primary distinction is that gift exchange is made possible through the CNCP protocol. This mechanism facilitates both making gifts and counter-gifts, in which the gift is a subtask on the auction. We first argue that only a gift giving provider can practice gift exchange revealing the sender's provider type to the recipient. Moreover, it introduces a challenge for the receiver to disclose its identity as well by sending a counter-gift which is both different and sent at some time later. Figure 4.2 provides the basic procedures for the weak gift exchange mechanism.

Proposition 1: *If the task is marked as gift, then the auctioneer is a gift giving agent.*

Since the auctioneer communicates with every participant separately, the bidders responding to the *cfp* with proposals are unaware of the bids proposed by other participants, if any. We conjecture that the profit oriented agents are only interested in maximizing the profits and would not bear any loss when they are the auctioneer. Therefore a provider agent receiving a gift offer identifies the auctioneer as a gift giving agent without any doubt. The gift through this mechanism has to be offered as a higher price than originally proposed by the receiver of the gift. Even if the receiver of the bid

were the highest bidder, it would receive an offer of a greater value as a gift. Since profit oriented do not suffer losses by offering a higher price as a gift to their bidders, a subtask contains an offer of a gift if and only if the auctioneer is a gift giving provider.

A GE provider when receiving a *cfp* from a customer evaluates what can be done on its own and in case it is able to perform only a part, it initiates a new auction for the subtask which is beyond its capabilities and *cfp* are sent to the providers. This follows from the approach used by Knabe for task delegation via CNCP [Knabe, 2002]. In the beginning of the simulation, the gift giving auctioneer has little or no knowledge of other providers' type. As this knowledge increases, a GE auctioneer further sends the *cfp* to the providers from whom a gift had been received in previous rounds; within the initial rounds, this case occurs only occasionally. The idea is to give chance of participation to the known GE providers so that their wealth increases; more importantly, the motive is to introduce the possibility for reciprocating a gift when the simulation is in the initial rounds. Since the weak gift exchange is the only channel through which GE providers communicate during the initial rounds, the model provider a parameter *Chance-Offering-Gift* which restricts a GE provider to offer a gift each time it is an initiator of an auction.

For picking a receiver for its gift, the model provides a GE auctioneer three strategies, one of which is selected. The first is *Weak-Counter-Gift* strategy, which provides a chance for selecting a bidder from whom a gift had been received earlier. In the following section, we discuss how the weak gift exchange is used for sending a counter-gift. The second is the *Best-Bidder* strategy which provides the chance of picking among the committed bidders, the provider with the best proposal. Finally, if the best bidder is not picked, any of the bidders is selected with uniform probability.

Once a provider is chosen, a gift offer is made and the response is awaited. For the weak gift exchange mechanism, the gift as a utility is a subtask whose value is calculated based on the size of the original task and the bid offered. A gift is only delivered when the payment is made since for various reasons, a committed bidder may fail to accept the auctioneer's request. The gift's size also depends upon whether the market is in the initial rounds during which a small gift is preferred. Such gifts do not have much value instead they serve as gestures for future binding relationships. This prevents a GE auctioneer from big losses in the initial rounds, in case the recipient of the gift turns out to be profit oriented and does not reciprocate at all. A deadline is set depending upon the auctioneer's current status; i.e. the need to find another GE provider. In addition, the size of subtask allocated to the gift recipient is also taken into account. The various strategies for deadline have been introduced in the previous section of this chapter. A comprehensive record of the sent gift is maintained and a return is awaited especially if the recipient's identity is unknown.

A GE participant receiving the gift through the weak gift exchange acknowledges the sender as gift giving and keeps record of the incoming gift to be used for sending a counter-gift later on. During the initial rounds a GE receiver of a gift attempts to reciprocate the gift through weak gift exchange and on gaining such opportunity sends a counter-gift with a different value after some time lapse. Since not every GE provider who receives some gifts during the initial rounds is able to use this mechanism, it paves way for a special communication channel which we introduce in the next section. A GE receiver also checks whether the gift received is a counter-gift or not; in case true, it identifies the sender of the counter-gift as gift giving, i.e. one to be considered for later gift exchange, stops waiting and keeps record of the gifts being exchanged and further

ones. A GE provider earlier identified as profit oriented due to the fact that it failed to send a counter-gift within the deadline, is removed from this relationship and recognized a gift giving if it sends a counter-gift later on. This occurs only when initially the gift was sent during the initial rounds. If the number of gifts exchanged between GE provides passes the buddy criterion, a GE provider is promoted to buddy and is informed; the same holds for the former agent.

```
Algorithm 1 Picking receiver through Weak Gift Exchange
procedure ChooseGiftReceiver (task: subtask delegated)
if giftsSentThisRound = MAXIMUM-GIFTS then
     exit procedure
committedBidders ← ComputeSolution (task)
if counterGift? != true
     for all agent in committedBidders do
          if agent in profitOriented? != true
               potentialGiftReceivers.add(agent)
          receiver ← call GiftSelectionStrategy
else
     receiver ← call CounterGiftStrategy
call SendWeakGift
exit procedure

Algorithm 2 Sending gift through Weak Gift Exchange
procedure   SendWeakGift   (task:   subtask   delegated,
receiver: agent who receives the gift from this agent)
gift ← call CalculateGift
if counterGift? = true then
     gift ← call CalculateDifferentGift
deadlineStrategy ← call returnDeadlineStrategy
deadline ← call CalculateDeadline
counterGift ← waiting
giftPackage ← prepareGift.add(receiver, gift, gift-
deadline, counter-gift)
call AddGiftPackage
call RecordOutGoingGift
exit procedure

Algorithm 3 Handling gift through Weak Gift Exchange
procedure  HandleGift  (task:  subtask  delegated,  sender:
agent who sends the gift, gift: gift received)
if call CheckCounterGift? = true and
     sender in profitOriented? = true then
          profitOriented.remove(sender)
GiftGiving.add(sender)
if call IsQualifyBuddy? = true then
     call SendBuddyInform
call RecordIncomnigGift
exit procedure
```

Figure 4.2: Pseudocode for Weak Gift Exchange procedures concerning task delegation.

4.3.2 Counter-Gift and Preference Criteria

Being conscious of reciprocating the gift, a GE auctioneer checks if a counter-gift is due or not. It is possible that it had earlier received a gift from a provider and chooses to reciprocate the gift. Therefore, on receiving and evaluating proposals, a GE auctioneer

searches if there exists a proposal from someone to whom a counter-gift is due. If a bidder if found, it is preferred over other providers and its bid is placed in the latest solution of the task entrusted to the auctioneer; for others, the bids are kept as backup and are considered only if the current bidder declines the job. Special care is taken when choosing a GE provider to who is a counter-gift is to be sent, with regards to the fact that the value of the counter-gift be different and in a different round than when the gift was received by the auctioneer.

The preference criteria set by a GE provider when handling proposals follows an ordering in which a bid from a buddy provider is most preferred; i.e. if there is a proposal from a buddy, its proposal is accepted anyway and kept in the current solution. If the bid is not the best among those who had responded to the call, the loss is calculated as the gift to be given to the buddy. Next, a proposal from a gift giving provider who is not a buddy is preferred given preference if it proposes the highest bid. In case the proposal is not among the best, preference is given when the auctioneer owes a counter-gift to the GE bidder. An unmarked bidder is always preferred over a profit oriented bidder and the latter is only considered to be given the task when neither of the above preference criteria exists. In that case, the weak gift exchange reduces to economic exchange task delegation via CNCP.

4.4 Strong Gift Exchange Mechanism

In sociological sense gift exchange carries special gestures of individuals sending gifts to others. A gift taking the route through an auction has profound advantages with regards to problem-solving abilities in artificial societies; there remains a need for an additional mechanism separate from a mechanism which in its basic structure commences economic exchange. We introduce such channel where gifts can be exchanged as utilities, i.e. as tasks or profits earned etc, and call this mechanism *Strong Gift Exchange (SGE).*

Availability of an exclusive channel through which GE providers interact is in accordance with the model presented by Smith based on the contract net [Smith, 1980]. As Smith explains, out of the three methods of information transmission, one is the direct transmission of information form one agent to another; which may be interpreted as an exchange of a gift as a utility between two GE providers. Thus a strong gift can be given via a special channel without CNCP. The strong gift exchange mechanism comes into action when the market passes through the initial rounds since gift giving agents are required to build strong and stable *buddy* relationships in order to practice gift exchange via this mechanism. In the following proposition, we argue that this mechanism is also suitable for sending a counter-gift in post initial rounds.

Proposition 2: *Strong Gift Exchange facilitates sending of a counter-gift.*

When a GE provider receives a subtask as a gift via weak gift exchange from another GE provider, it comes into the obligation of returning it with a counter-gift some rounds later. Assuming that the weak gift exchange is the only justifiable channel for sending a gift, a GE receiver of a gift would strive to take on the role of an auctioneer later on in order to be able to return a gift suitably. Since each time an auction is initiated by a customer, a limited number of agents are chosen to participate, it becomes quite likely

that the GE receiver may not be delegated the task by the customer. Making a gift offer in the weak gift exchange can only be possible if the subtask delegated is a complex one and not atomic. Since during the initial rounds, only the weak gift exchange is the means of delegating gift as explained earlier; it is plausible that a special channel is introduced after the initial rounds through which a counter-gift can be sent.

The strong channel or strong gift exchange mechanism is meant to pave way for strong and regular relationship between two GE providers through gift exchange. In our model, the counter-gift triggers this mechanism in the market with the assumption the most GE providers have gained some knowledge about other providers.

4.4.1 Modeling Formal Structures

The practice of making gifts does not always entail the element of reciprocation in societies; the entities in real and artificial societies (e.g. individuals in extended families or clans, business organizations in a corporate environment etc) can be classified with respect to a hierarchical system. This inequality among the agents emerges as a result of the differences in the capital (e.g. economic, social, symbolic etc) that the agents earn during the course of their interactions. Usually it is the desire of powerful entities in a market or in other words those who rank high in the hierarchy, to maintain their status of being strong and dominating over lesser powerful agents. In his treatise on the sociology of gift, Mauss [1967] refers this phenomenon as a general fact whereby people belonging to the upper class in a society distribute gifts as a means of sustaining prestige to their kith and kin lower in status. In most cases the counter-gifts by the dominated agents are outnumbered by the gifts sent by the dominating ones.

The asymmetric nature of the above-mentioned scenario is explained by Bourdieu in his theory of capital by means of existence of formal structures in a society [Bourdieu, 2000] where social fields are dynamic with agents interested in improving their relative positions and are not just oriented towards a common goal. As Hillebrandt explains, in a social field some agents dominate others with respect to their earned capital in order to maintain the structures and regularities in the society. A formal structure may either be an objective of some agents such as prestige, their use of capital for self-interested goals or any other constraints.

In our model such phenomenon is handled by means of the strong gift exchange. In scenarios when the gift is delivered asymmetrically, we refer it to as a strong gift, while when this channel is used as means of reciprocation; we call it a *strong counter-gift*. The strong gift messages are exchanged using the 'tick' approach similarly to the mechanism used for weak gift exchange messages. The tick approach consists of two phases, the *send phase* and the *run phase*; where a message is sent in the first step and handled by the concerned receiver(s) in the latter. This approach was employed in MAS by Turner and Jennings in their various experiments [Turner and Jennings, 2000].

For the SGE to take place the market should have passed the initial rounds and any participating agent of SGE must have earned some profit until then. Hence when defining powerful agents, power does not simply mean the ability to carry on a task but also the ability to give a gift and the economic capital earned. Since even for an asymmetric form of a gift, the receiver must be known as a GE by the sender, there should be at least one gift from the receiver so that its type is confirmed.

The objective of powerful provider agents is to maintain the structure in the society and make the less powerful agents obliged to receive their gifts during the simulation. Hence when they receive a task from either a customer or another provider, they offer a portion of it, i.e. a subtask to a lesser powerful GE provider using the strong gift exchange channel. In order to ensure that a task taken by a powerful GE provider through CNCP is successfully done and that practicing a strong gift does not result in a ring or endless recursion, the sender of a SGE must do some portion of the task itself. A receiver of a strong gift checks if it is able to conduct the subtask or not and either accepts or refuses. If the sender of SGE receives a refusal to its SGE offer, it either offers to another provider or does the task on its own; nevertheless, it offers a SGE to another agent. Figure 4.3 illustrates this process.

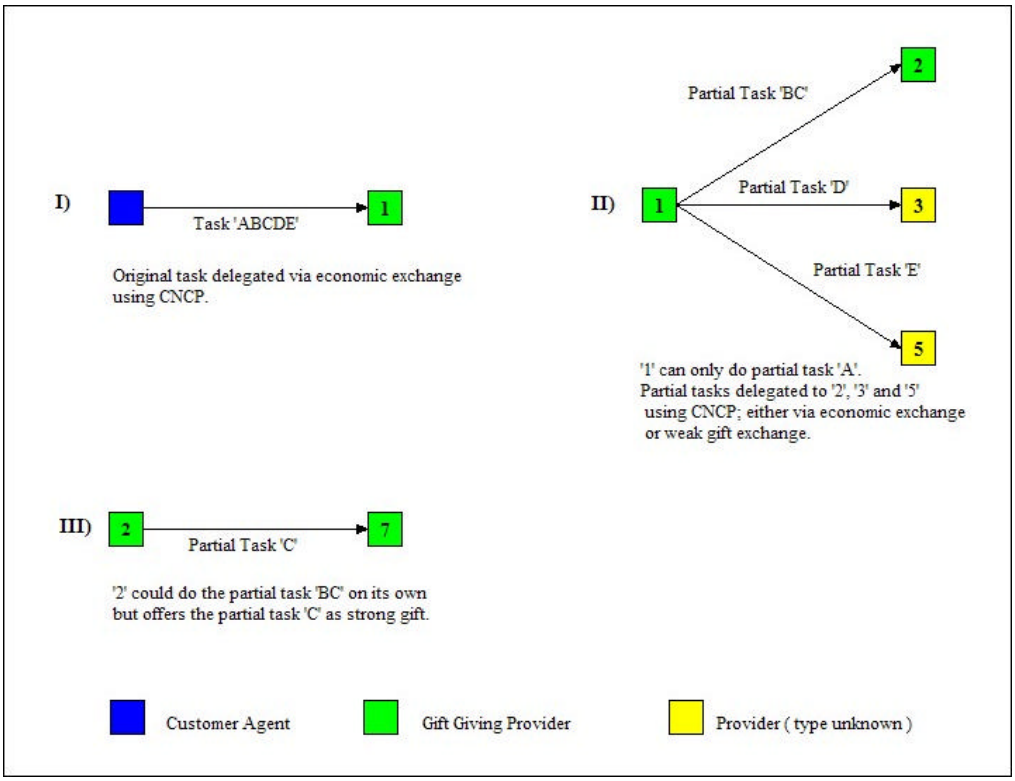

Figure 4.3: An illustration of triggering of strong gift exchange

A gift giving provider receiving a strong gift makes a decision whether to remain dependent upon a powerful agent for tasks or not. This decision relies upon the number of tasks the receiver acquired via CNCP, the number of buddy relationships it developed earlier on and the frequency of the subtasks it receives from the powerful agent. Occasionally, the regular receiver of a SGE sends a counter-gift which is some proportion of the economic capital earned taken care that the counter-gift is different in terms of time and worth.

Finally, when a GE provider initiates an auction and it receives proposals to its call for proposals from two or more providers such that at least two of them are its buddies; one buddy is preferred over another if and only if the number of strong gifts sent by one is greater than that sent by the other. In case of a tie, the buddy is preferred randomly. In the context of dominance of agents created through one-sided gifts, this approach may be found as reasonable.

4.4.2 Counter-Gift via Strong Gift Exchange

Sometimes a GE provider is unable to send a counter-gift to an agent from whom it had received a gift and it is likely that the sender marks it as a profit oriented agent if the deadline passes. Sociologically it is unfair that an agent is unable to reciprocate constraint by the process which requires task delegation, in spite of the fact that the agent desires it most. The purpose of the counter-gift via the strong gift exchange is to provide such GE providers a chance to send a counter-gift if they had received a gift earlier but could not reciprocate. It is likely that the GE providers unable to get a chance to reciprocate at least one gift are better than many in terms of capability and can contribute to better relationships with other gift giving providers. Strong gift exchange facilitates this process through a parameter *Counter Strong Gift Exchange*; which limits the possibility and number of occurrences of sending counter-gifts in a round. Various settings of this parameter have been used in the testing of hypotheses which we present in Chapter *6* of this thesis.

4.5 Protocols Specification

In the recent past, MAS researchers have contributed and used a variety of modeling tools for agent technology. There has been a considerable interest of research in this area, and various protocols for agents' interactions have been proposed. For the delegation of tasks and re-allocation of sources, Smith proposed the contract net protocol; a framework for distributed problem solving specifying communication, control and knowledge organization mechanisms [Smith, 1979; Smith 1980]. The MAS community has been using the FIPA Contract Net Protocol (CNP), an adaptation of the original contract net protocol widely regarded as a standard for most agent-based platforms. FIPA provides a complete specification for this protocol with numerous applications [FIPA, 2002].

4.5.1 CNCP Interaction Diagrams

In this section, we present sequence diagrams for agents' interactions based on the Contract Net Protocol with Confirmation (CNCP) as discussed by Knabe [2002] in their work. As explained by Knabe, one of the advantages for a CNCP based approach is that a commitment to task delegation by a participant is made only when a request is sent by the auctioneer. In case of the request being declined or the deadline is passed, the next agent in an already sorted list is sent the request.

Following an agreement to a request by a bidder, the rest are sent a reject-proposal message. The process ends when the bidder to whom the task is delegated informs about a *failure* or a successful completion of the task. A major advantage of this approach is that a bidder needs only to commit for a task when it is offered a request; it is free to take calls for proposal (*cfp*) from other agents and can send its proposals accordingly. This as Knabe demonstrates improves the efficiency of task delegation in a market comprising of providers and customers, as the providers need not allocate their resources in the earlier stages of the auction. Knabe et al. provide a detailed analysis of this approach [Knabe et al, 2002].

In Figure 4.4 we present the protocol for weak gift exchange mechanism based on the CNCP using the Unified Modeling Language (UML) sequence diagrams. We follow the FIPA nomenclature and call the GE provider offering the gift and the provider taking part is the auction as *GE Initiator* and *Participant* respectively. The sequence of events follow from sending the *cfp* after which a participant either responds with a proposal or refusal; in case of no response and the deadline passes, the communication ends.

In the sequence diagram of our weak gift exchange protocol, we follow the standard so that all messages exchanged are under the FIPA performatives. Hence, the gift offer is modeled so that it is enclosed within the request and is easily distinguished. Since an offer of a gift requires acceptance of the request, the chosen receiver must send agree or refusal. In case the participant is run out of resources, another provider may be picked up. The protocol ends with the gift receiver giving final status of the task either informing completion or failure.

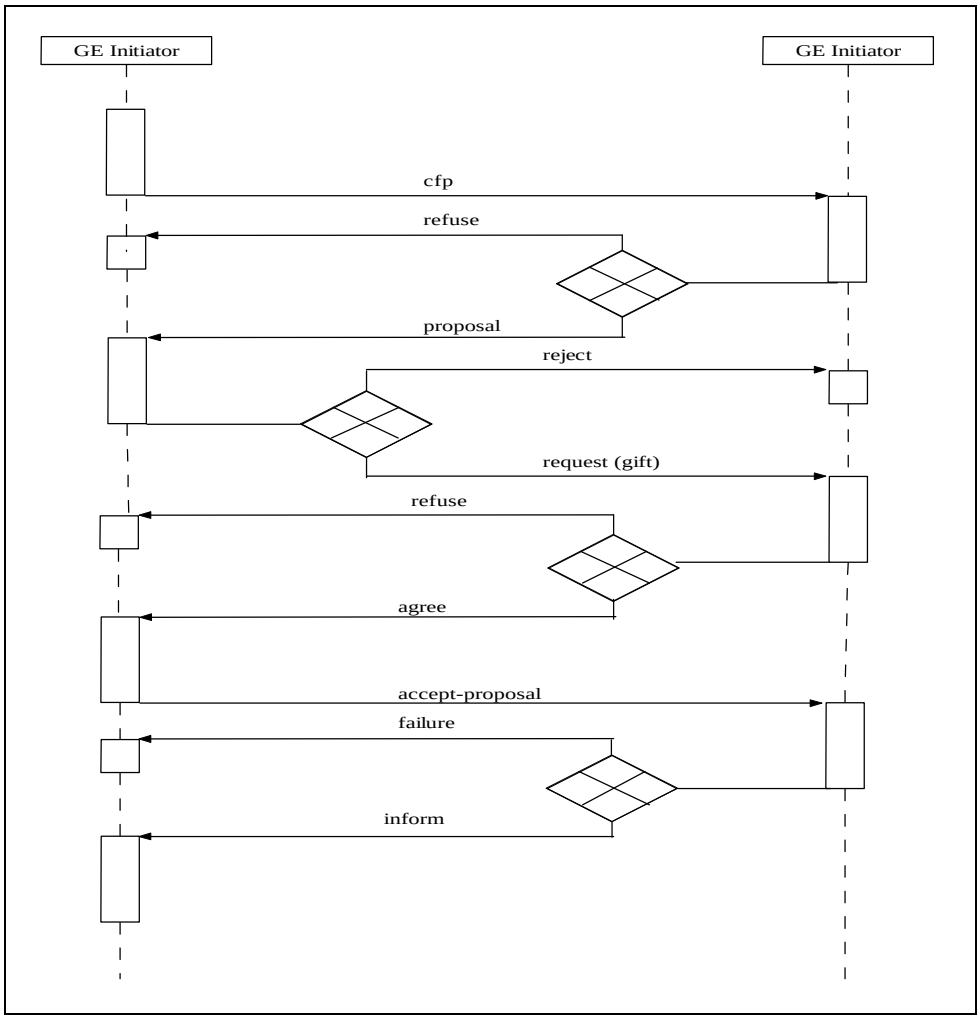

Figure 4.4: CNCP interaction protocol for Weak GE Mechanism

Figure 4.5 shows another protocol in which a GE provider informs another when they meet the buddy criterion as explained previously in the chapter. This protocol is based on the history of gift exchanges between the two and provides a special channel through which the two buddies communicate. The FIPA performative *inform* is used by the two GE providers for acknowledging each other as buddies.

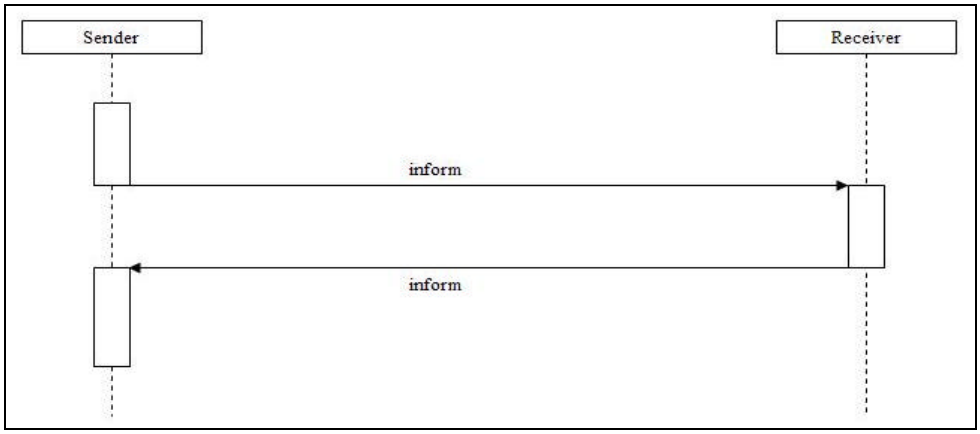

Figure 4.5: Buddy Inform Protocol

4.5.2 Using UML Activity Diagrams

One difficulty faced by the MAS research community is the unavailability of a single methodology that not only shows the control flow of agents' interaction but also captures the role-internal aspects that arise during the design process; furthermore, there is a need for comprehensive software engineering support for the interaction protocols. Several protocol specifications languages have been used by the MAS community, but as Lind argues, most of them provide a text-based representation scheme making it difficult when the intricacies of protocols grow [Lind, 2000]. The Unified Modeling Language (UML) has grown popularity in the recent past mainly due to its graphical representation schemes and a coherent framework facilitating design of complex software systems. Booch et al. provides the complete specification for UML and modeling with object-oriented methodology [Booch et al., 1999].

In this section, we present the interaction of agents in our work modeled through UML Activity Diagrams; an approach proposed by Lind in a couple of their presentations [Lind, 2000; 2002]. This modus operandi neither proposes major enhancements or entirely new diagrams, but relies on the standard diagrams available in the UML specification. One of the advantages is therefore, providing a useful alternative for modeling agents' interactions, adhering to the existing standards without proposing a variant of UML.

Preliminary Overview of the Scheme

UML provides several building blocks or structural elements used in activity diagrams, in order to describe a program flow. Booch et al. provides a complete specification for UML diagrams along with a description of object-oriented modeling technique [Booch et al., 1999]. We present below an outline of those symbols that are employed in our work with a pictorial representation of these symbols are presented in the Figure 4.6 (a).

- *Action States:* Atomic entities that cannot be decomposed any further.

- *Activity States:* Represent possible collection of atomic states that can be decomposed, e.g. modules for specific tasks.

- *Branching:* Represents a non-linear control flow, i.e. a decision point at which the path of the flow is decided.

- *Swimlanes:* Partitioning of an activity diagram in two or more related parts. Within an activity diagram, each swimlane is identified with a unique name and an activity must belong to exactly one swimlane.

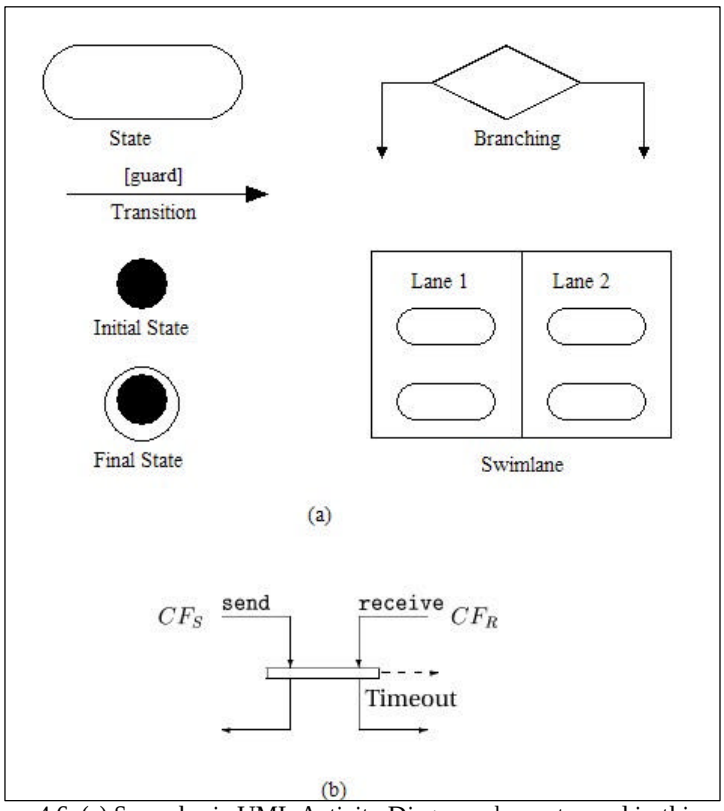

Figure 4.6: (a) Some basic UML Activity Diagram elements used in this work; (b) A *syncrhonization point* with timeout.

In their work, Lind proposes a few slight modifications to the basic entities of UML Activity Diagrams [Lind, 2002]. The swimlanes, for instance, are interpreted as physically distinct flows and are referred as *Control Flow Spaces*. These control flow spaces interact with each other by means of explicit communication channels that manage the message exchange. As Lind explains, the message exchange itself is modeled in *synchronization points* that denote the sending and receiving of the message. Each synchronization point can have several incoming transitions with exactly one out of them labeled with the keyword *send*, which indicates the sender of the message. The rest refer to the receivers of the message such that each time the control flow of a receiver enters a synchronization point, other activities are in abeyance; caused when the control flow of the sender reaches the synchronization point. The control flows of the sender and the receiver resume after the message is delivered. In order to prevent the receivers waiting ad inifinitum for a message that never arrives, Lind introduces an additional transition referred as *timeout* attached to synchronization. When a timeout is reached, the control flow of a receiver resumes its activity from the state pointed to by the timeout transition. Figure 4.6 (b) shows a graphical representation of a synchronization point where CF_S and CF_R denote the control flows of the sender and the receiver respectively along with a timeout transition.

Activity Diagrams for Gift Exchange

We present the representation of the gift exchange mechanisms using the above-mentioned approach. One of the contributions of this thesis is that it takes a step ahead in using this modeling approach. In Figure 4.7, beginning with the roles that we assign to the agents for the weak gift exchange, we have the initiator and the participant where a provider participating in an auction may assume the role of an initiator at a different situation. In any case, the initiator is a GE provider, while the participants may belong to any of the two providers' types. Since a control flow represents a process, the inception of initiating an auction begins with the initializing the necessary data structures and fulfilling the conditions; the first activity state shows this stage. A major advantage of this approach is that a whole module can be represented as an activity state so that the diagram is easy to comprehend without losing significant functional representation.

Once the initialization is done, the auctioneer prepares the bid that involves computing the capacity, price, deadline for a task and preparation of the list of providers to whom a *cfp* is to be sent. The control enters the first synchronization point when a *cfp* is sent to the participants. At this point, the participants who had already been prepared to handle a *cfp* receive this message while the initiator awaits their responses. Since a response from all receivers of the *cfp* is required for the resumption of activities, we introduce a timeout so that any participant failing to respond within a timeframe is not looked for any further. The participants in the meantime examine the *cfp*, evaluate their own prices and prepare proposals for their bids. As the initiator receives the proposals it checks if all the pending responses have been received; in case the control for the initiator moves to the next state. Picking a receiver of the gift may be based on any of the strategies introduced earlier in this chapter; the state in the diagram encapsulates it all. One can collapse this state to into several to show the process of picking a receiver of a gift into detail, nevertheless, the essence of the process is not lost. A gift is intended and offered for the chosen participant. The participant receiving this offer re-evaluates and its ability to conduct the task and decides whether to commit or not. An agreement or refusal response is prepared based on the decision and is sent to the initiator.

If the participant declines the request, the next bidder is picked following by a decision for it to be chosen for the gift or not. If the next bidder is an EE and the only remaining choice no gift is offered with the request. This also follows if no response is received from the participant and the timeout expires. On the contrary, an acceptance to the offer by a participant prompts for the participant to keep record of the gift sent which means a counter-gift is expected from the participant in later rounds. The process terminates when both the control flows reach their final states. For an initiator this is reached when the participant notifies for the successful completion of the task or failure. There are two ways by which a control flow ends for a participant; when it declines an offer for a gift and quits the auction or when it finally notifies the initiator about the outcome of its task.

Figure 4.8 is another example employing this modeling approach where we represent the process of sending a counter-gift via strong gift exchange mechanism. The diagram shows the flow where both the sender and the receiver are gift giving providers. The scenario represented is that of sending a counter gift via strong gift exchange. The approach does not require unnecessary details and just following the states and the flows in both the swimlanes the idea can be easily perceived. The control flow of the sender enters the first synchronization point when a gift is reciprocated through the channel of strong gift exchange which if not handled by the intended receiver and the timeout

expires, terminates the process. When acknowledged by the receiver, the control flows of both the agents enter the respected final states.

In this section, we have demonstrated the application of this approach for agents' interaction in a gift exchange. Use of this method employs best use of existing UML elements, serving as an effective tool for modeling and understanding agent communication. Although it explains the essence within a process, the sequence diagrams are more useful when it comes to following the sequence of events. We observe that both methodologies have advantages of their own, and it is best to use both techniques when representing agents' interactions.

4.6 Summary

A market based model for the multiagent system is presented consisting of two types of agents, customers and providers. The former introduce tasks in the market and do not interact within their types while the latter contend for the tasks and interact among them to accomplish complex tasks through collaborations. The providers are further classified as profit oriented (EE) and gift giving (GE), the profit oriented interact and collocate by means of economic exchange. For the gift giving providers we present a set of parameters that control the gift exchange between them along with primary performance measures.

Each gift exchange builds its own percept of the market and group providers through various relationships; the strongest being the buddy relation whereas profit oriented providers are also looked for and identified. Two mechanisms for gift exchange have been introduced, referred to as weak gift exchange and strong gift exchange mechanism. The weak gift exchange is in essence based on the auction-based mechanism and is practiced during the initial rounds of the simulation. The strong gift on the other hand uses a special channel for sending a gift without *CNCP*; carrying the gesture of a strong affinity for the recipient with whom a stable gift exchange is established. We argue that the strong gift exchange is more suitable for maintaining hierarchical structures in the market where the powerful players attempt to maintain their positions as the domineering ones.

Interaction between the GE provider agents is represented through sequence diagrams which are simple and easy to comprehend. Another modeling technique is also used which makes use of UML Activity Diagrams and thus do not require a major modification to the existing standards. This approach by Lind captures the flow of the processes and is valuable for interactions in MAS.

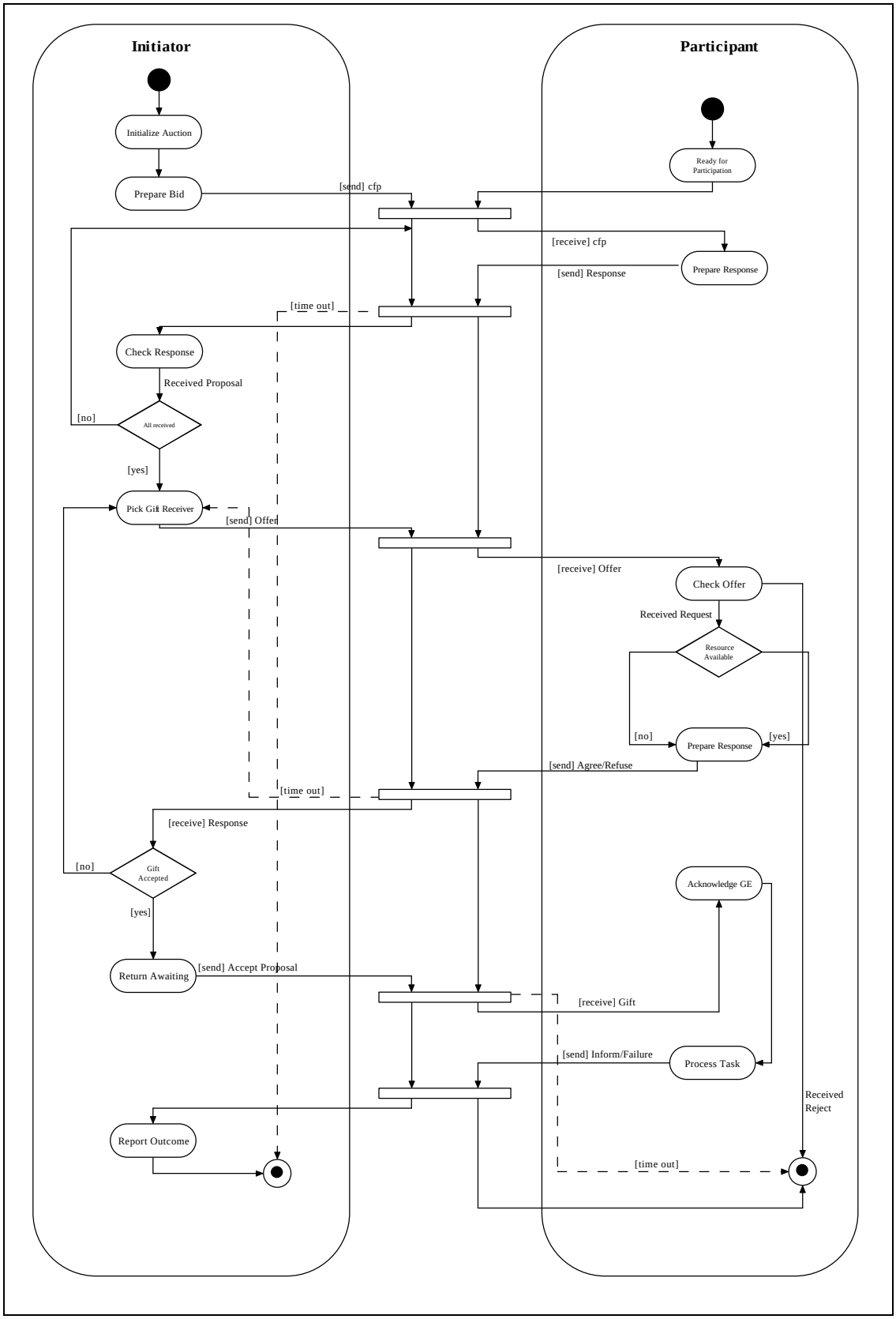

Figure 4.7: Weak Gift Exchange Mechanism

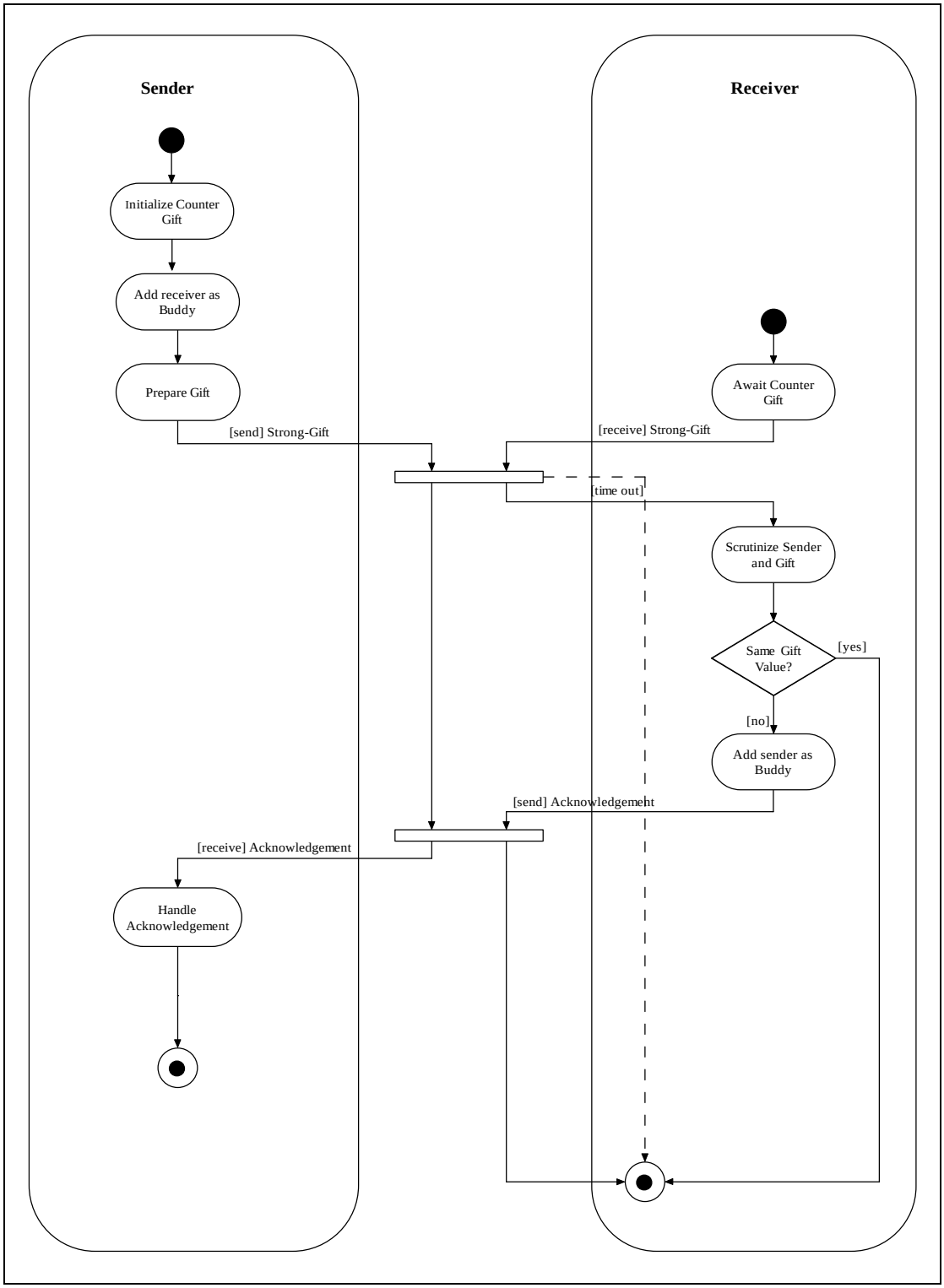

Figure 4.8: Counter-gift via Strong Gift Exchange

Chapter 5

Implementation Highlights

In this chapter we outline the pertinent implementation issues that were taken care of for this thesis. We present briefly our choice of the programming environment and introduce the foundation testbed on which the model was implemented. In addition to that, we provide a synopsis of the Graphical User Interface (GUI) developed to provide visualization of the simulation along with exploratory data analysis.

5.1 The Testbed and Programming Environment

The Java programming language was used for the implementation in this thesis developed using the NetBeans[1] IDE. The basis using Java is to be consistent with JTOM, the foundation testbed used in the Socionics Project of the Multiagent Systems Group at the DFKI in collaboration with the Technical University of Hamburg-Harburg. The JTOM (Java Testbed for Organizations in Multiagent System), originally developed by Knabe, presents the basic structure for the economic exchange in a market-based environment where agents form various organizations as a result of self-organization processes [Knabe, 2002]. The purpose of this testbed was to investigate the properties of different organizational models for the grouping of agents in a scheduling domain.

Care has been taken while implementing the gift exchange model so that it augments with JTOM implying more features and flexibility is added to the existing system.

5.1.1 Augmented JTOM

The gift exchange mechanisms described in the previous chapters is implemented with the agents' interaction modeled with respect to the interaction diagrams. For task-delegations, the agents use the CNCP protocol introduced and implemented by Knabe et al. and follow similar mechanism with regards to economic exchange [Knabe et al., 2002]. This work provides augmentation to JTOM with Java classes concerning the behavior and operations of gift giving agents and related issues designed and implemented using inheritance and other features of the object-oriented methodology.

[1] The Java technology and NetBeans IDE are the trademarks of Sun Microsystems, Inc.

5.1.2 Hardware Used

The simulation was run and tested on an Athlon[2] 1.6 GHz machine with 512 MB RAM and Pentium[3] III 800 MHz machine with 256 MB RAM.

5.2 The Graphical User Interface (GUI)

In large and complex scenarios, a lot of data is generated during a simulation run and merely a console output is quite cumbersome to manage and hard to analyze. Not only an exploratory data analysis helps in analyzing the performance measures of the agents both local and global, visualizing the agents' interaction dynamics helps reveal those characteristics that might remain concealed under large data. As this thesis contributes to the modeling of sociological concepts, the GUI helps sociologists to investigate in the behavior of the system without bothering the technicalities. Figure *5.1* shows a screenshot of the main window of the GUI.

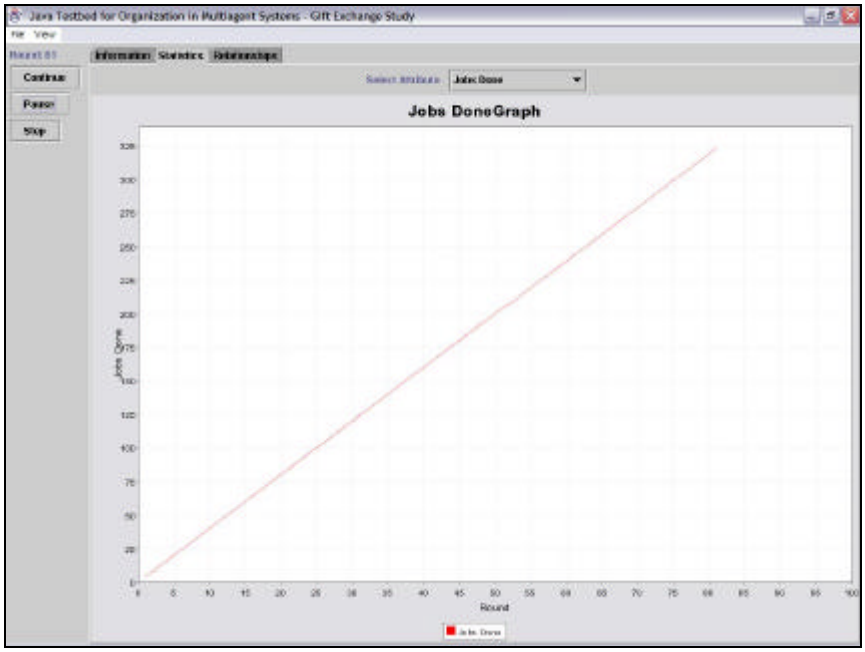

Figure 5.1: Screenshot of main window of the GUI with active statistic panel

The core of the GUI is based on the JAVA Swing API, a set of classes that provides powerful and flexible GUI components with up-to-date render capabilities. A great advantage of using Swing components is that they are written entirely in Java and are therefore platform independent. The API allows a Java-based GUI to be designed in such a way that all elements contained in the main GUI panel adjust their sizes whenever the user changes the screen layout. The pluggable look and feel of Swing allows elements to substitute another appearance dynamically. The Sun Java website provides complete specification of the Swing system [Sun, 2004]. The scalability of the interface is guaranteed independent of the platforms and user's settings. In the following sections,

[2] Athlon is the trademark of Advanced Micro Device, Inc.
[3] Pentium and Pentium III are the trademarks of Intel Corporation.

we present the key features of the GUI of our system followed by an overview of the library used for displaying graphs.

5.2.1 GUI Features

The main panel of the GUI is based on a stack *cardbox* design where each card displays distinct features related to their titles. The *Statistics* panel of the GUI which displays dynamic time-series plot of various performance measures such as gift giving provider's income, numbers of jobs done per round, etc. are plotted as the simulation proceeds. The design is generic enough to add as many such plots without any modification to the GUI class. Any chart may be selected any time from the selection box which is rendered on the main panel. Figure *5.1* shows the statistics panel with the *Jobs Done* chart displayed. The *Information* panel displays information about the configuration and setting of the current simulation along with values of the important parameters; Figure *5.2* shows a screenshot of this panel. Any change in the configuration during the simulation is updated on the panel during runtime.

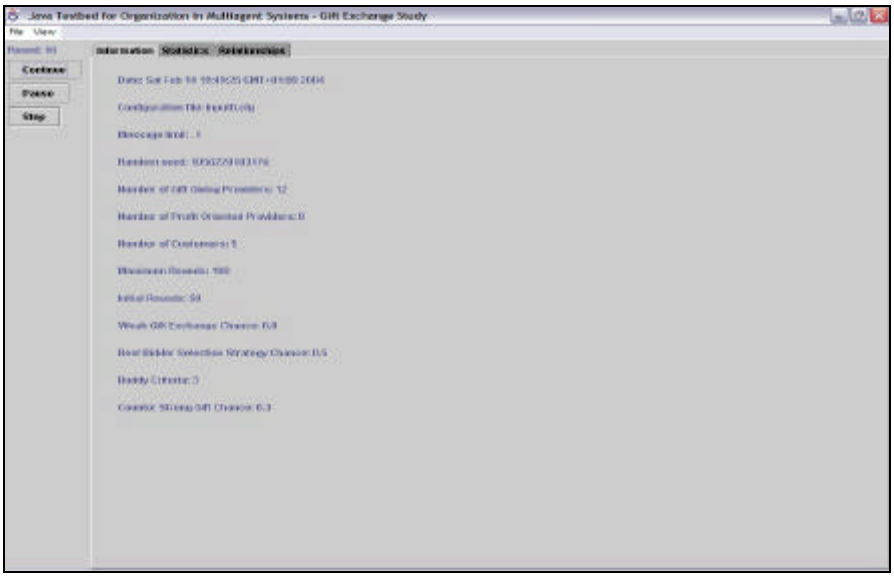

Figure 5.2: Screenshot of the Information panel

The third panel is the *Relationship* panel that displays agents' interaction during the simulation. Each of the three agents groups, i.e. gift giving providers, profit oriented providers and customers are labeled with different colors and with agents name on the nodes as well. The network of interaction among agents provides insight into how agents group themselves as the simulation proceeds and collaborate with each other. Figure *5.3* gives a screenshot of the network during the process.

In addition to the above-mentioned panels, our GUI allows to save and retrieve the time-series plots on storage devices once a simulation ends. Moreover, many already saved simulation runs can be retrieved and superimposed on the current simulation plots; each run is specifically distinguished by unique color coding. This feature is helpful in analyzing different runs and understanding the behavior of the system. Other features of the GUI include pausing and round-by-round run of the simulation.

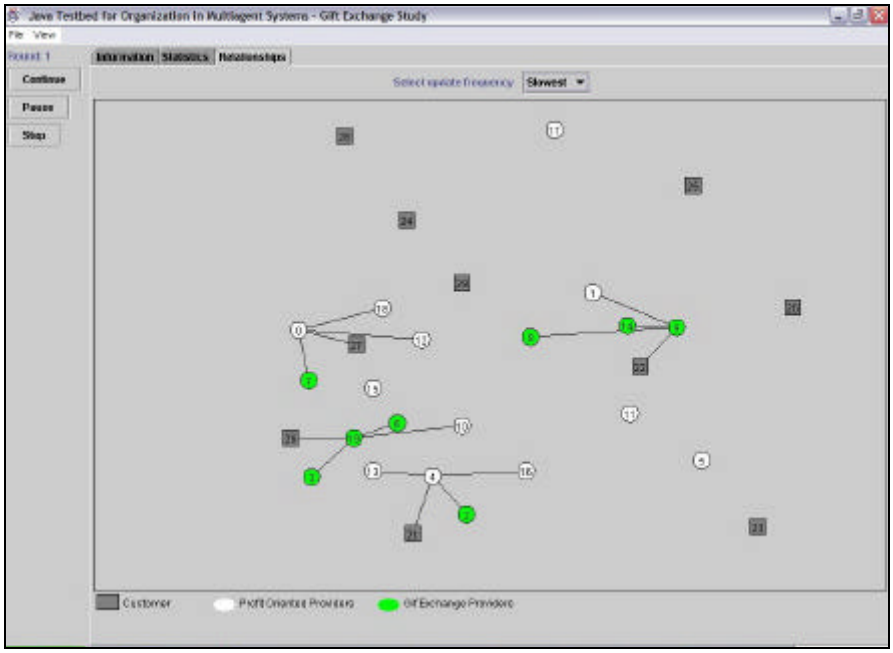

Figure 5.3: Screenshot of the Relationship panel

5.2.2 The *JFreeChart* Library

For the time-series graphs we used the JFreeChart[4] library, a Java class library for generating charts, available free along with complete source code under the GNU License[5]. The library provides interfaces thorough which a variety of charts may be generated. This includes pie charts, bar charts, time-series plots, scatter plots, line charts, Gantt charts etc; a comprehensive set of example of charts that can be produced via the library are available at their website.

Besides plotting facility, the JFreeChart offers access to data from any source via dataset interfaces, and support for multiple secondary axes and datasets. Tool tips, zooming and printing facilities are also available, and it is a valuable package for Java based software.

5.3 Summary

The testbed has been developed using the Java development environment. It can also be augmented to the JTOM (Java Testbed for Organizations in Multiagent System). Hypotheses have been tested within the testbed on several terminals available at the Multiagent Systems Group of DFKI. A graphical user interface (GUI) was designed for the testbed that enables users to control the simulation rounds, view dynamical time-series charts and network of agents' interaction during the simulation. The time-series graphs corresponding to a number of performance measures can be saved and retrieved later on for analyses.

[4] JFreeChart is the copyright of Object Refinery Limited www.object-refinery.com
[5] The GNU Lesser General Public License is issued by the Free Software Foundation.

Chapter 6

Testing of Hypotheses

We report in this chapter the description of a number of experiments that were performed for testing our hypotheses within the model. We begin with a discussion of the hypotheses in conjunction with our arguments for choosing them. Following, we introduce the scenarios chosen for the respective hypotheses from which the gathered data have been tested. The third section deals with the analysis of the observations for each hypothesis.

6.1 Hypotheses

In this section we elaborate upon the hypotheses which we introduced in Chapter *3* of this thesis. These hypotheses correspond to the various ramifications one may anticipate in introducing gift exchange in a multiagent system based on the market-based scenarios. A variety of other hypotheses may be tested related to both the sociological issues and computation and several interesting scenarios may be conceived. A handful of such prospective hypotheses are introduced in the final chapter of this thesis where the intended future work is discussed.

We state each of the hypotheses followed by their respective discussions:

Hypothesis – I: *In scenarios where the message-limit (number of call for proposals sent by an auctioneer) and the market size are low, the number of gift exchanges among the gift-giving agents is reduced.*

This hypothesis is primarily concerned with the computation aspect of the effects of gift exchange. The idea that the number of gifts exchanged is proportional to the market-size is not very surprising and intricate; albeit, it is helpful in testing the workflow of the system. The incentive behinds the testing of this hypothesis is to be sure that the practice of gift-giving can be scaled in terms of message limits as well as in terms of proportion of GE providers in markets of varying size.

Hypothesis – II: *In homogenous market scenarios where all agents are gift-giving, there is no long-term distinct grouping of the agents.*

The idea of grouping arises from the scenario whereby a GE provider initiating an auction and receiving proposals, prefers a buddy over other respondents to its call for proposals. Since each of its buddies has such relationship of its own with others, one can expect GE agents to have tied up with their buddies. For a homogenous environment, i.e. where all provider agents are gift giving stable and long-term ties among the providers is not expected to persist permanently. Since a stable and regular relationship of delegation of tasks depends upon the exchange of gifts between two agents, a homogenous environment does not permit such phenomenon to occur. When such stability is achieved, it is expected to be limited to a smaller proportion of the providers.

Hypothesis – III: *In heterogeneous market scenarios, introduction of gift exchange partitions the provider agents into two groups over a long run.*

We deal with a market-based scenario in which the provider agents are essentially either profit oriented or gift giving types. The model does not impose any sanction on the selection of provider agents by a provider initiator of an auction ab initio; thus, at the time the simulation starts any provider may be delegated a subtask by another provider type. Nevertheless, the gift giving agents prefer those of their own types as they build up their relations and try to circumvent dealings with the profit oriented agents. We hypothesize that the agents split into two major cliques comprising of GE and EE agents respectively.

Hypothesis – IV: *In heterogeneous market scenarios, if the population of GE agents is greater, the EE agents will not be as successful as in the case when the population of GE agents is low. The higher the populations of GE, the higher are the chances of GE agents of being successful.*

Whereas this hypothesis seems related to the computation load within a system due to gift exchange, it is quite concerned with the sociological aspect of the simulation. As Ruth et al. report, the practice of gift exchange may often be seen among the financial players in the real world who are familiar with its influence in the strategic decision-making situations [Ruth et al., 2003]. In a market-based scenario where both types of providers exist, GE providers are expected to be more successful when they are in majority. Given that the gift giving agents try to avoid dealings with the profit oriented agents, they are expected to find GE providers for task delegation more often when the GE providers are in greater number.

Hypothesis – V: *If the survival of provider agents with lesser capabilities is difficult, the practice of gift exchange will be intensive. Such GE agents would build buddies in order to gain more capital even though they suffer early losses from the gifts they give.*

The primary motivation behind this hypothesis is that gift exchange could be perceived as a means by which the GE agents with lesser abilities build *buddy* relationships with other GE providers. Since the *buddy* relationship is dyadic in nature as introduced in Chapter *4*, we expect gift exchange to be practiced as a survival strategy of agents with lesser abilities. Not only does one expect an intensive exchange of gifts in such scenarios, the practicing agents are also likely to accumulate good wealth. This conjecture seems justifiable as symmetric form of the gifts gives rise to the preference of buddies over other agents when tasks are delegated via weak gift exchange.

6.2 Experimental Design

Prior to discussing the observations obtained through testing of the hypotheses, we state briefly the experimental layout in this section. First the independent and dependent variables are presented, followed by the introduction of constant factors stated separately. We present an overview of the scenarios chosen for the hypotheses respectively upon which the experiments have been carried out. Isolating the variables and constant factors helps in understanding their effects and in focusing upon a limited number of selected factors, while keeping the rest unchanged.

6.2.1 Variables and Constant Factors

We first introduce the independent variables which have been varied so that the simulation runs with different configurations. Next we present the variables whose values are assessed depending on the agent's local choices and the system's overall performances. Lastly, we give an overview of the factors whose values were being kept constant during the experiment runs.

Independent Variables

The major independent variables are presented below; most of them are discussed in Chapter *4* of this thesis:

Population Configuration: This variable deals with the size of the population, i.e. the number of provider agents and customers involved in the manner as used by Knabe [Knabe, 2002]. For provider agents their respective atomic tasks are assigned which may be varied. Likewise, for customers the respective atomic or complex tasks types are configured which they introduce to the providers at the beginning of a round.

Providers Proportion: From the population of providers, the proportion of the gift giving and profit oriented providers can be set, which have been varied in the various scenarios tested.

Initial Rounds: This is the threshold that determines the number of rounds required for the initial rounds to pass away. Usually the initial rounds have been set as between *40-60%* of the maximum number of rounds.

Sending Further Gift: We have varied this factor from *1-3* in the testing of the hypotheses.

Buddy Criteria: This is also being varied during the experiments. Setting a larger value for this variable compels the gift giving agents to put more efforts in building the *buddy* relationships.

Preference for Bidders: The value for this chance parameter has been regulated for testing some hypotheses. Since this parameter influences the chance for accepting a buddy's call for proposal and other model's attribute, experiments were carried out with regular variation of its values.

Chance of Counter Strong Gift: This chance factor is usually kept low between *10-20%*.

Dependent Variables

The most pertinent dependent variables are the performance measures of our model which are discussed in the Chapter *4* of this thesis. In addition to those, we present a few significant dependent variables below:

Gifts per Tasks Ratio: At anytime during the simulation, the number of tasks (or subtasks) successfully done by a gift giving provider is updated along with the number of gifts sent till then. This ratio is used by a provider agent in evaluating its performance until then and consequently deciding whether to give a strong gift or not.

Isolated GE Providers: This is a numerical value that gives the number of those gift giving agents who fail to build a long-term relationship with any other gift giving agent throughout the simulation run. The number is used in analyzing how successful the gift giving agents have been in establishing gift exchange and isolating themselves from the profit oriented agents.

Successful Strong Gift: This variable is attributed with each gift giving agent and keeps track of the successful delegation of the strong gift attempted during the simulation.

Constant Factors

There has been a number of factors kept constant throughout the runs, albeit the following presented below are the most related:

Message Limit: This imposes a bound on the number of call for proposals sent by the initiator of an auction. This has been kept at *30%* of the providers' population size.

Initial Capital of Providers: The simulation starts with each provider allocated an initial capital which is kept fixed and equal for all providers in the market.

Number of Rounds: For our experiments we kept the maximum number of rounds for the simulation fixed at *200* rounds.

6.2.2 Scenarios for Hypotheses

We present a synopsis of the respective scenarios chosen for the testing of the hypotheses. The setting of the independent variables is presented as well as the values of the constant factors can also be laid down. The results are discussed in the subsequent section of this chapter.

Scenario for Hypothesis I

We setup three sets of provider agents' population with sizes 20, *30* and *60* respectively. For each of the three sets three separate configurations were designed, i.e., where the gift giving agents are in minority, same number as that of profit oriented agents and where the number of gift giving agents is in majority. The experiments were run for *100* rounds

and the numbers of gifts exchanged were calculated at the message limits ranging from *10-30%* of the population size with *1%* step for each experiment.

Scenario for Hypothesis II

For the second hypothesis, we selected three different configurations of provider agents each of size *20*. All providers were initialized as gift giving agents. A number of experiments were carried out for each of the three configurations and the maximum number of rounds was set to *100*. The initial-rounds parameter was set fixed to *50%* of the simulation rounds. The hypothesis was tested for three different criteria for buddy selection.

Scenario for Hypothesis III

Three distinct sets of providers' population were used of sizes 20, *30* and *60*. Likewise in the first hypotheses, we set three distinct configurations for gift giving proportions in the market. The message limit was set fixed to *30%* of the population size and the experiments were run for *100* rounds. The number of customers was set to be *20%* of providers' population with each customer emitting orders of type *ABC* in the market. Also we kept the *Bias-Bidder-Preference* parameter to *100%*, i.e., with maximum preference by the gift giving agents for agents of their own type. The *Buddy-Criterion* was set as moderate while the agents used *CNCP* to send counter gifts *70%* time.

Scenario for Hypotheses IV – V

For the fourth and the fifth hypotheses, we set a heterogeneous population of providers. The experiments were conducted varying the *Chance-Weak-GE* and the *Initial Rounds* parameters. The message limit was fixed to *30%* of the population and the simulations were run for *100* rounds. The number of customers was configured to be *25%* of the providers' population. We tested the hypotheses with two customers' configurations; one emitting same type of orders, while the other with orders of heterogeneous types.

6.3 Results and Discussions

In this section we discuss the results obtained from the experiments conducted. These experiments for each of the hypotheses have been based on the respective scenarios expressed in the preceding section of this chapter. We present the summary of the experiments along with the graphs and remarks upon their outcomes.

6.3.1 Hypothesis I

Figure *6.1* summarizes the experiments conducted for this hypothesis based on the scenario discussed in the previous section. For the two cases when the gift giving agents are not in minority, the number of gifts exchanged increases with respect to the message

limits. One can observe that being in almost equal number or in greater number, provides the gift giving agents sound opportunity to practice gift exchange as the search for other gift giving agents becomes less difficult. Also for the weak gift exchange, there are better chances to return a gift within the initial rounds. On the other hand, when the gift giving agents are in minority, one does not observe an increasing behavior, although for higher value of the message limit, the number of gifts exchanged increases. The opportunity for gift exchange is inhibited when there are more profit oriented agents in the market and therefore the practice appreciates only when the gift giving agents are able to acquire more tasks than the others during the simulation.

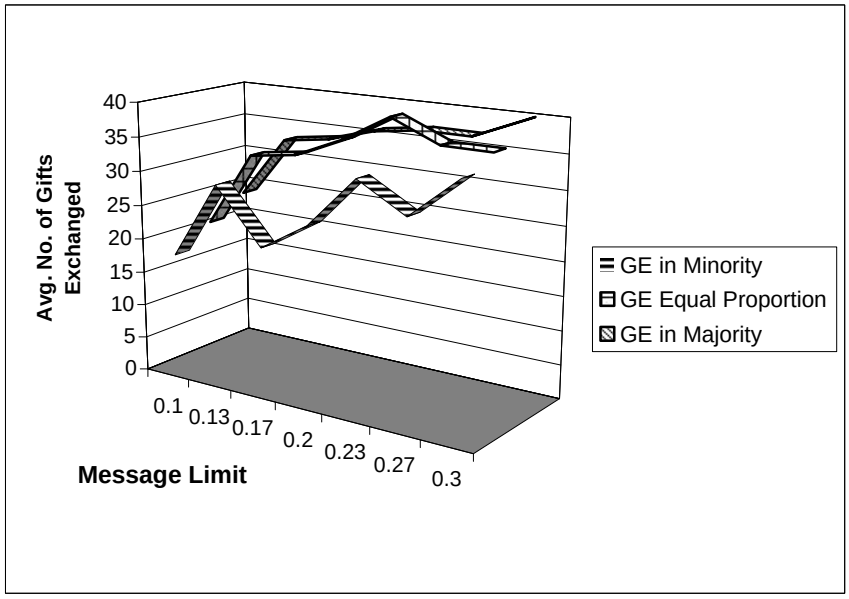

Figure 6.1: Series plot showing average number of gifts for the three cases with varying message limit.

6.3.2 Hypothesis II

We build the graph over the *buddy* relationship which the gift giving agents build among after some gifts are exchanged. Since this relation is symmetric, the graph constructed is a undirected and so there is less overhead for updating the graph after each round and calculating its connected components. The standard algorithm for calculating the strongly connected components presented by Cormen et al. requires two depth-first traversals of the graph and thus the time complexity is $O(|GE\text{-}Providers|)$, which does not put significant burden on the simulation [Cormen et al., 2001].

Figure *6.2* presents the outcome of the experiments based on the scenario discussed in the previous section. The simulation begins with all gift giving providers isolated with each other and thus the forest built has $|GE\text{-}Providers|$ disjoint single node trees. The number of strongly connected components decreases very gradually during the initial rounds for all the three criteria. Nevertheless we observe a sharp decline in the number of isolated gift giving agents once the simulation enters beyond the initial rounds; the prime factor behind this increase in the connectivity is the *strong gift exchange*. As the population is homogenous, i.e. all providers are gift giving the number of distinct groups decreases further as the simulation approaches the end and the trend continues. Most of the agents are therefore able to build the *buddy* relationship with each other.

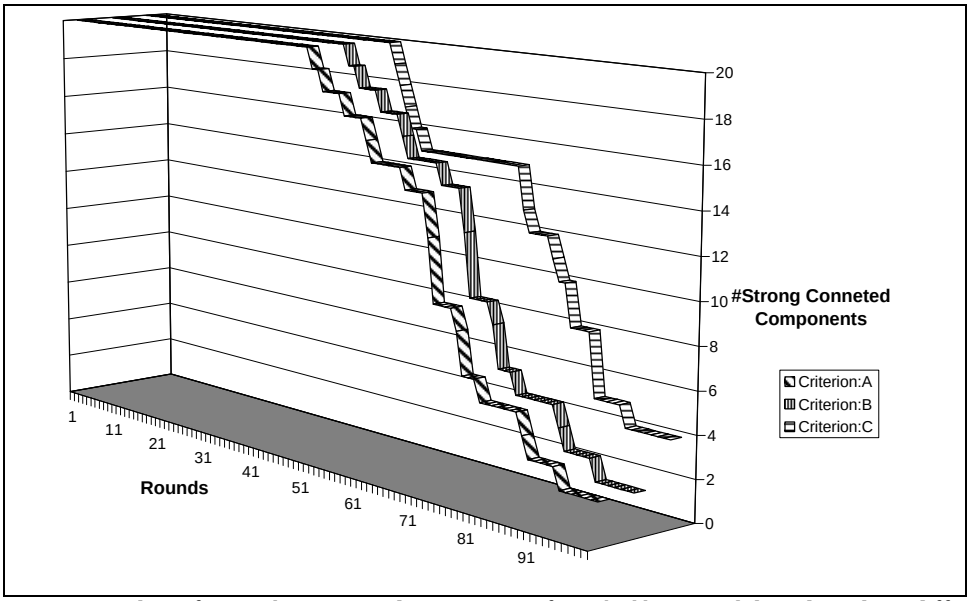

Figure 6.2: Number of strongly connected components from *buddy* network based on three different criteria for buddy selection.

6.3.3 Hypothesis III

We attempt to investigate how well the gift giving agents perform in relying more on other gift giving agents in the market and less on those known to be as the profit oriented ones. Since the gift giving agents look for providers of their own types throughout the simulation, their reliance on agents of their own types is expected to increase. Although each gift giving agent attempts to prefer interactions with other gift giving agents, they practice economic exchange with others when there is no other option. Figures *6.3* and *6.4* show the plots of two series, the first series represents the average number of interactions of the gift giving agents among themselves; while the other denotes the average interactions of the gift giving agents with the providers who they know as the profit oriented ones.

In Figure *6.3*, the graph represents the experiments in which the gift giving agents were in greater number than the profit oriented ones. It may be noticed that in the beginning agents do not know about the types of others and this knowledge is expected to increase during the simulation. With a greater number of GE providers in the market, a majority of gift offers turned out to be successful due to the fact that the gift giving agents had ample opportunities to return gifts. Thus on average, the knowledge about the other GE providers increased throughout the simulation rounds. On the other hand, it took some rounds for the GE providers to know about the presence of profit oriented agents in the market. It is pertinent to mention here that the gift giving agents interacted with the profit oriented agents right from the start, but they marked them as the EE agents when they did not receive a counter-gift within the anticipated deadline. With a greater proportion, the interaction of the gift giving agents among themselves continued to increase as well as their knowledge about the profit oriented agents, with the rounds. Nonetheless, the former clearly outperformed the latter, that is, the GE agents kept on increasing their interactions among each other.

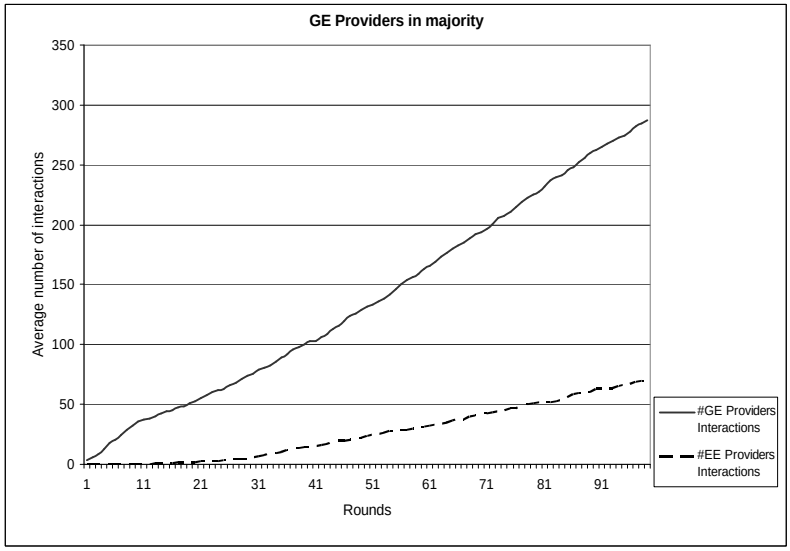

Figure 6.3: Interactions of GE agents with providers of both types with the GE providers in majority.

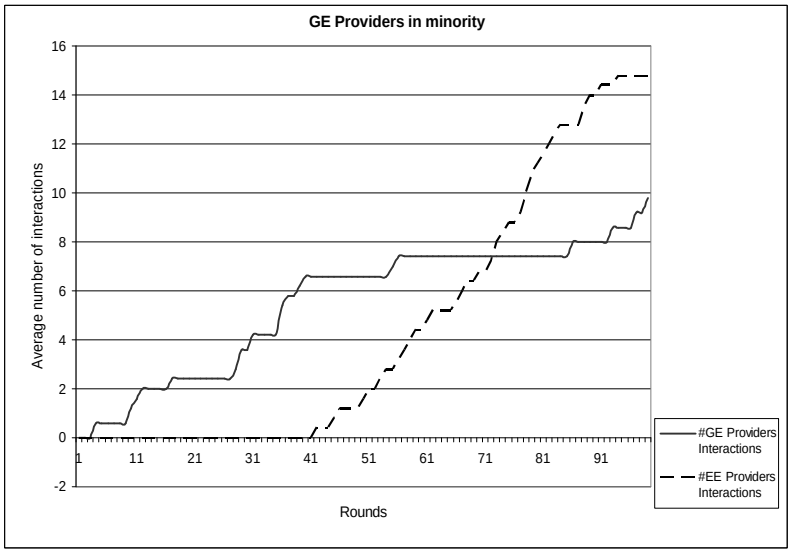

Figure 6.4: Interactions of GE agents with providers of both types with the GE providers in minority.

When the gift giving providers were in fewer than the profit oriented ones, their knowledge about other gift giving providers increased during the rounds; albeit gradually, as show in Figure *6.4*. It is understandable that with lesser number of GE providers in the market, the number of interactions among themselves is expected to remain low. One also sees a sharp rise in the second series, which shows the increase in the knowledge of GE agents about the profit oriented providers; similar to the previous case, when the agents who did not return a gift were marked as EE. Being in minority the gift giving agents had fewer opportunities to interact with each other. In contrast, they practiced economic exchange with the profit oriented providers knowing the latter's type.

With a greater or equal proportion, the gift giving providers were able to interact with each other more frequently than in the scenario when the market had more profit oriented provider agents. However in both cases, their knowledge about the types of other agents increased with subsequently during the simulation.

6.3.4 Hypothesis IV

We carried out the experiments in two phases; first we compare the performance of the gift giving providers (GE) with the profit oriented ones (EE) and then deepen our evaluation in the second phase.

Figure *6.5* shows the first part of the experiment in which the parameters *Counter Gift Strategy* and *Strong Gift* were kept low and the message limit was set fixed to *30%* of the population's size. The performance was evaluated in terms of the average profit earned by the two types of the providers at the end of each simulation and are shown in the graph as the two series, corresponding to the varying proportion of GE agents. Figure *6.5(a)* show the graph with an intense criterion for *buddy* selection, while in Figure *6.5(b)* the criterion is set to be moderate. It maybe noticed that in a heterogeneous population and limited number of rounds, not all GE providers can be expected to build the *buddy* relationship with others. In the experiments represented by Figure *6.5*, we maintain no distinction within the GE agents.

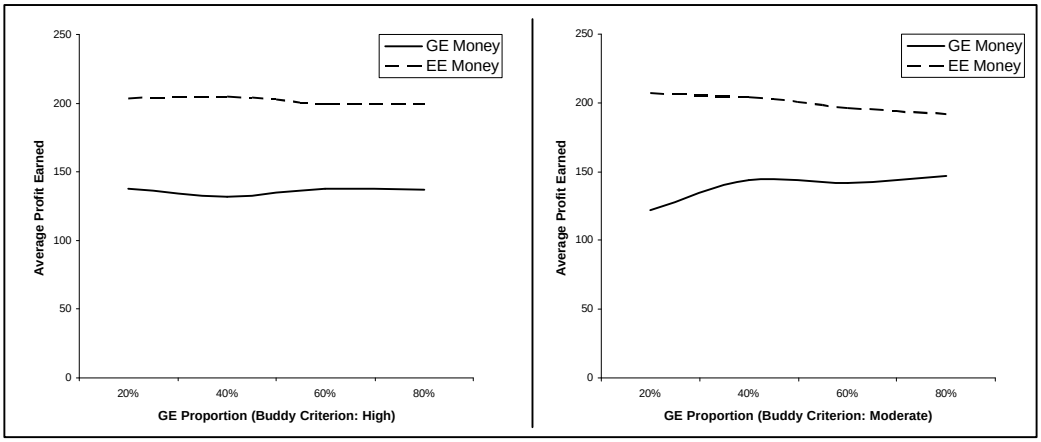

Figure 6.5: A comparison of average profit earned by GE and EE provider agents with varying proportion of GE agents: (a) with high criterion for *buddy* selection; (b) with moderate criterion.

In the first example with high criterion, we observe a steady profit gain by the GE providers with a slow increase in the average wealth as their proportion increases in the market. At the same time, the average wealth of the EE agents declines though at a slow rate. Since we keep a stricter criterion for the *buddy* relationship, the number of GE providers unable to find buddies is more, especially when the GE proportion is in minority. It is due to such GE providers that the average wealth of all the gift giving agents is pulled back. Consequently, we repeated the experiments with a moderate criterion such that more GE agents find opportunities to build up the *buddy* relationship; Figure *6.5(b)* shows the graph for the second example. With more gift giving agents having long-term gift exchange with others, the increasing trend of their average wealth is more vivid than in the first example. Not only does the chances for gift giving agents to accumulate wealth increases with respect to their proportion, the profit oriented agents lose their average wealth at a faster rate. As the experiments were carried out for a limited number of rounds, one may expect better performance from the gift giving agents when the number of rounds goes higher.

In the second phase, we go in further details by analyzing the average performances of the gift giving agents with and without buddies separately. Once again, we split the experiments into two cases: i.e., with intense and moderate buddy selection criteria. The *Counter Gift Strategy* for *weak gift exchange* was set high and the *Initial Rounds* were set to *40%* of the total number of rounds. Likewise in the first phase, we set the message limit to *30%* of the population size, while the customers introduced heterogeneous types of orders to the market. Figures *6.6* and *6.7* summarize the experiments for the second phase.

In both Figures *6.6* and *6.7*, three series are shown; the first *GE Money* refers to the average wealth of those GE providers successful in making some buddies during the simulation. The second, i.e. *Buddyless GE* corresponds to those GE providers without any *buddy* at all through the simulation. Finally, the third series shows the average wealth attained by the EE providers.

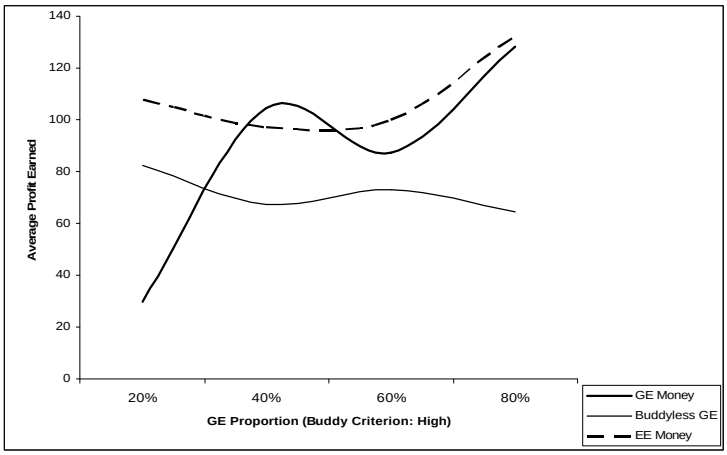

Figure 6.6: A comparison of average wealth earned by the GE providers classified into two groups and EE agents with a high criterion for *buddy* selection.

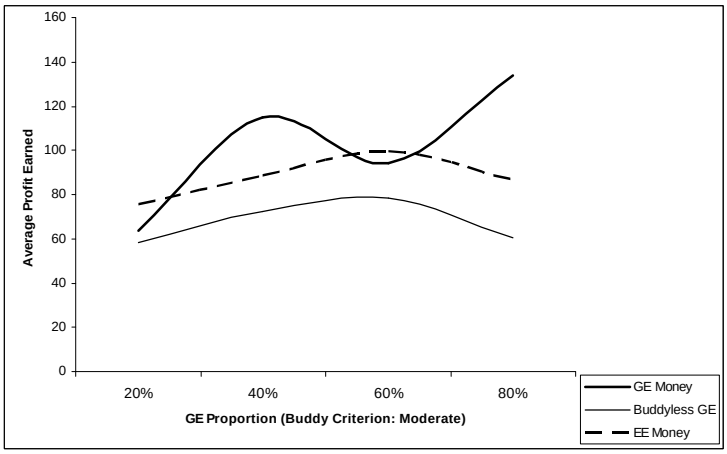

Figure 6.7: A comparison of average wealth earned by the GE providers classified into two groups and EE agents with a moderate criterion for *buddy* selection.

In experiments represented in Figure *6.6*, the *Buddyless* GE providers were found to be more successful than those with buddies when the GE providers were in lesser proportion. This is due to the fact that the GE providers had very few opportunities to practice gift exchange and thus a larger fraction of the gift giving agents remained without any buddy relation; also because the criterion was set to be high. Nevertheless

with steady increase in the proportion the GE providers outperformed the *Buddyless* GE subsequently. Between the GE proportions of *40-60*, the gap between the first and the second series is less while for the third series the average wealth remained less than the others. One also observes a decreasing trend for the *Buddyless* GE agents mainly due to the fact that the average wealth of the EE and the GE agents with *buddy* relations increases at a rapid rate.

With more GE providers able to build the *buddy* relationships, they performed better than the others in most of the cases as shown in Figure *6.7*. When the market is composed of the GE agents in majority, their chance for success are greater than otherwise. The rise and fall of the average wealth for the first series in the middle is possibly because of the change in the number *Buddyless* GE providers within that interval. Moreover, success of the GE agents also depends upon their ability to build stronger ties with each other; those without such were found to gain lesser wealth than others.

6.3.5 Hypothesis V

We look into the proportions of the less powerful GE agents among the total gift giving agents and their corresponding share in the number of gifts exchanged. Three different sets of experiments were conducted for different values of the initial rounds, i.e. *40*, *50* and *60%* of the total number of the rounds. We assume less powerful agents as the ones whose abilities were of atomic task types *A* and *B* whereas the powerful agents as those with abilities of types *C* and *D*. For each set, different proportions of the less powerful GE agents were tested. Figure *6.8* shows the series plots for the three sets of the experiments with respect to the respective values of the initial rounds.

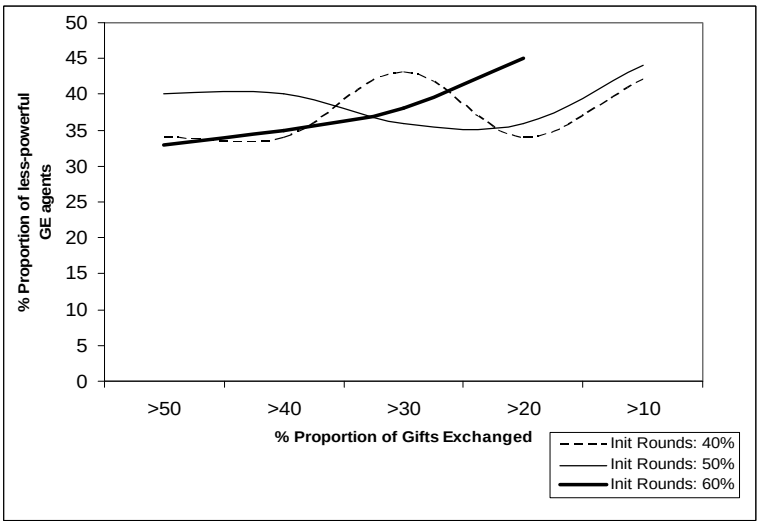

Figure 6.8: Series plots for percentage proportion of less powerful agents versus their contribution to total gifts exchanged, for different initial rounds.

Since the less powerful GE agents are in much need for buddies than those with greater abilities, they are expected to practice gift exchange more often especially when they are in lesser proportion. Furthermore, the gifts offered by them also reflect the surge for their search for long-term relationships. Consequently, the deadline set by them for expecting a counter-gift is also shorter than others; i.e., either a *Survival* or *Strategic* strategies are chosen for the deadline in most cases. For the first two sets of experiments one does not see an increasing trend, though for the smaller proportions the number of

gifts exchanged does rise. On the other hand when the value for the initial rounds was highest in the third set of experiments, a clear increasing can be seen as predicted. As the proportion of less powerful GE agents was reduced, their contribution to the overall gifts exchanged went higher; supported by the higher value for initial rounds. Not only the less weak GE agents could wait longer for a counter-gift, they also had better opportunities to return gifts within the initial rounds than the other two preceding cases. However, more experiments may be required to test this hypothesis comprehensively.

6.4 Summary

The hypotheses selected for investigating the various effects of the introduced gift exchange in a multiagent system were tested via our testbed developed for this thesis. Gift exchange as expected, was found to be more intense when the message limit in the system was high. Most gift giving agents were able to build *buddy* relationships with others in a homogenous environment. Although this was not found to be the case for each provider, very few agents were found isolated when the simulation runs ended. For a heterogeneous provider population, the gift giving agents did tend to successfully avoid interactions with the profit oriented agents when they were at least half the proportion of the total population. However the result was unexpected when the gift giving agents were in lesser number and they remained dependent on interactions with the profit oriented ones.

Gift giving agents able to build stable gift exchange relationships with others were found to be more successful than those who could not. Moreover, their chances of being accumulating more profit increased with respect to their proportion in majority of the tests. Gift exchanged by the less powerful agents only seemed to have increased steadily with respect to the reduction in their proportion in the population when the value for initial rounds was set as high. For lesser values, the results were found not in accordance with the hypothesis.

Chapter 7

Conclusions

This thesis concludes with this chapter in which we present briefly the inferences drawn from our investigations. Next, we provide a summary to the contributions made by this thesis to the ongoing research work. Finally, the second section presents prospective directions for future research.

7.1 Conclusion and Contributions

For a market-based multiagent system, gift exchange was implemented and tested on various scenarios. Gift exchange was used by the gift giving providers to build trust and long-term relationship with others, making use of its reciprocal nature. Not only was gift exchange used to search for other gift giving agents in the market, it also helped singling out the profit oriented agents; i.e. those agents who do not practice gift exchange at all. The time-lag between a gift and a counter-gift was crucial and agents used various strategies to estimate such time-lag depending upon their strength. Moreover, gift giving agents able to build stable relationships earned as much wealth as the profit oriented agents and in several cases outperformed the others.

A major contribution of our work is that it provides a model for gift exchange among providers in a market-based framework, together with a testbed through which many other hypotheses maybe tested; besides the one investigated in this thesis. We also devised mechanisms through which agents could interact in order to exchange gifts. These mechanisms have been specified through the interaction protocols which help in understanding the agents' interactions in the system. These protocols have been specified according to the FIPA standard. Also the control flow of the gift exchange mechanisms have been presented through UML Activity diagrams using an approach developed at the German Research Center for AI (DFKI).

The outcome of our experiments show that gift exchange as a sociological concept is important for the emergence of inter-relationships among agents and can provide the synergy for the agents to remain committed to each other on a long-term basis.

7.2 Future Work

In this section we outline some of the directions in which this work maybe used for future research. As a testbed is developed, quite a few ramifications of the gift exchange can be investigated with sociologically interesting scenarios.

Testing Asymmetric Gift Exchange

We have already implemented in our testbed the mechanism through which powerful agents could dominate the less powerful agents by means of asymmetric gifts. The gift giving agents can use the available mechanism in order to preserve hierarchical structures within the system. Preliminary testing of this phenomenon provide basis for in-depth study as future research work.

Further Sociologically Interesting Hypotheses

As mentioned above, a number of hypotheses maybe tested using the testbed. We however present two of such hypotheses we intend to test in the near future.

a) If there is a high population of very strong profit oriented agents, the gift giving agents especially those who are less powerful would try to build co-operations with agents of similar power. The rate of gift exchanged turns to get high in such case.

b) If there is a high population of strong gift giving agents together with a high population of weak profit oriented agents, the rate of exchanged gifts would not be that high as in the case above.

Incorporating Multiagent-based Organizations

Having dealt with gift exchange for the market-based scenario, the model maybe used to apply gift exchange in more complex multiagent organizations. The framework specified by Schillo et al. support gift exchange and the model can be augmented to investigate further, the social characteristics of the various organizational forms [Schillo et al., 2002]. Gift exchange among provider agents may also be integrated to the research work by Hahn which provides a detailed analysis for organizations in a holonic multiagent system [Hahn, 2004].

Utilizing Reinforcement Learning

Hogg and Jennings propose a framework for making decisions based on the agents' social welfare function that combines their collective and individual perspectives in a flexible manner [Hogg and Jennings, 2001]. A realization of such framework was shown successful via *Q-learning*, a method used for reinforcement learning. The choice for the *deadline strategies* maybe based on this method, i.e. each GE agent improves its reasoning by exploiting the available information and estimating the response from the others.

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