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A FRAMEWORK FOR MULTI-AGENT INTERBANK PAYMENT AND SETTLEMENT

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A FRAMEWORK FOR MULTI-AGENT INTERBANK PAYMENT AND SETTLEMENT

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ACCRONYMS AND ABBREVIATIONS

AACO	Addis Ababa Clearing Office
ACL	Agent Communication Language
ACPS	Automatic Cheque Processing System
ACPSIA	Automatic Cheque Processing System Interfacing Agent
AMS	Agent Management System
AOSE	Agent-Oriented Software Engineering
B2B	Business to Business
B2C	Business to Customer
BA	Borrower Agent
BA	Bankers' Acceptance
BAT	Banking Agent-based Transaction
CA	Collection Agent
CBS	Core Banking System
CBSIA	Core Banking System Interfacing Agent
CD	Certificate of Deposit
CDA	Continuous Double Auction
CFP	Call For Proposal
CHPA	Claiming HOA Processing Agent
CPA	Claim Processing Agent
CPO	Cashiers Payment Order
CSP	Constraint Satisfaction Problem
DCSP	Distributed Constraint Satisfaction Problem
DD	Demand Draft
DF	Directory Facilitator
DGS	Differed Gross Settlement
DNS	Differed Net Settlement
E-Banking	Electronic Banking
E-Cheque	Electronic Cheque
E-Commerce	Electronic Commerce
ETB	Ethiopian Birr
FAT	Financial Agent-based Transaction
GUI	Graphical User Interface
HOA	Head Office Accounts

ILMA	Intraday Liquidity Managing Agent
IP	Interaction Protocol
JADE	Java Agent DEvelopment
LA	Lender Agent
LCA	Liquidity Coordinating Agent
LRA	Lender Roaming Agent
LRPA	Loan Re-Paying Agent
MAILS	Multi-Agent Interbank Lending System
MAIPS	Multi-Agent Interbank Payment and Settlement
MAS	Multi-Agent System
MAUT	Multi-Attribute Utility Theory
NBE	National Bank of Ethiopia
OBC	Outward Bills for Collection
OD	Over Draft
RDA	Request Decomposer Agent
RHPA	Responding HOA Processing Agent
RMI	Remote Method Invocation
RPA	Response Processing Agent
RRA	Request Receiver Agent
RTGS	Real-Time Gross Settlement
SEC	Securities and Exchange Commission
SPA	Settlement Processing Agent
SRA	Standard Repurchase Agreement
T-Bill	Treasury Bill
TC	Travelers' Cheque

ABSTRACT

Interbank payment and settlement systems automate transfer of fund from one bank to another bank on the order of a customer. The communication between banks involved in interbank payment and settlement is automated. Moreover, few agent-based payment systems tried to simulate the trend of incoming and outgoing payments so as to manage liquidity requirement. However, interbank payment and settlement systems developed so far are living with critical problems like gridlock, intraday liquidity management, and interfacing with autonomous legacy systems.

Hence this thesis proposes a framework for Multi-Agent Interbank Payment and Settlement (MAIPS) system, which improves interbank payment and settlement system, and extends its coverage. The proposed framework interfaces autonomous banking systems with the interbank payment and settlement system. Besides, MAIPS provides solution for intraday liquidity management and gridlock problems through automated interbank lending. Thus the thesis develops a Multi-Attribute Utility Theory (MAUT) based interbank lending model. In order to secure liquidity through interbank lending, the system floats bid to borrow liquidity, evaluates bidders' proposal, selects the best lender and agrees with the winner. This interbank lending model is simulated through the prototype called Multi-Agent Interbank Lending System (MAILS), which is developed using Java Agent DEvelopment (JADE) Framework and uses FIPA English Auction Interaction Protocol. Finally the prototype is tested using relevant information so as to clearly visualize interaction of participating banks and check correctness of the prototype.

The result of this thesis will bring breakthrough in improving interbank payment and settlement systems. It will also pave the way for multi-dimensional complex auctions to use decision aid techniques.

Keywords: Interbank Payment and Settlement, Cheque Clearance, Multi-Agent System, Gridlock, Intraday Liquidity Management, Collateralized Credit, and Interbank Lending.

1. INTRODUCTION

1.1 MOTIVATION

Traditionally a bank provides a variety of automated or manual services such as deposit, payment, transfer, loan, etc. These services are provided in different forms of money, i.e., cash (notes and coins) and negotiable instruments (cheque, DD, TC, etc.). The advent of Internet technologies and intelligent electronic devices, such as personal digital assistant (PDA) and automated teller machines (ATM) are revolutionizing the way banking services are provided and paves the way for the introduction of E-banking.

E-banking is automated delivery of banking products & services directly to customers through interactive electronic communication channels. E-banking enables customers of financial institution (individuals or organizations) to access their accounts, effect payments, deposit cash, process credits, buy goods/services, view account information, obtain new financial products and services, and open and close accounts. Besides, they can get banking services from banks where there account doesn't actually exist [1, 2, 3].

E-banking plays a substantial role in increasing productivity and thereby profitability of customers/organizations, facilitating e-commerce, increasing virtual market places, securing cash, and environmental protection. Some of the benefits of e-banking for both the customers and financial institutions are conserving energy, saving time, preserving the environment, improving public safety, significant productivity increase, better cash management, etc. [13, 14].

Although e-banking has enormous benefits, there are a number of banking operations that are not fully automated. Among such operations, interbank payment and settlement is the one. Interbank payment and settlement involves fund transfers and payments through negotiable instruments such as cheque, DD, TC, etc. between banks. In order to convert a negotiable instrument to cash, it needs to be cleared. Clearance involves activities such as scrutinizing for the genuineness of instrument, verifying signatures, availability of balance in the payer account that can cover the amount it contains, written date, etc.

The second step is settlement, which deals with the actual transfer of fund from responding bank to claiming bank. Thus interbank payment and settlement process is complex as it involves a number of independent and complex legacy systems and requires considerable human involvement. Besides, the responding bank may face liquidity shortage to settle the payment. In such situation the responding bank needs to look for possible options to increase liquidity. Hence the operation intraday liquidity management that facilitates interbank payment and settlement activities needs huge involvement of human being and analysis to find fund from credit providers, negotiate with them, etc. This nature of the problem makes interbank payment and settlement difficult to be fully automated using traditional software technology. However, this problem could be solved through the use of intelligent software agents, which are capable of analyzing and decision making.

A software agent is a piece of software that works (acts) on behalf of a user or other program, i.e., it decides and responds to the request by its own. Agents are autonomous, intelligent and dynamic entities that can consume or provide service by themselves. They are distinguished from programs, objects and expert systems by their reactive & proactive behavior to the environment, autonomy, goal-orientation, social ability, distributedness and persistence [7, 8, 23]. Hence agents seem ideal to deal with problems like interbank payment and settlement.

1.2 STATEMENT OF THE PROBLEM

As stated in [15] though the rate of online banking is increasing, usage of cheque is significant throughout the world. For instance, the relative importance of cheques as payment instrument in Singapore was (73.3% in 2006), Turkey (66.6% in 2005), the United States (54.7% in 2006), Brazil (40% in 2005) and Canada (35.0% in 2006). The study in [21] also mentioned that cheques accounted for 60% of the non-cash transactions in 2001 in the United States. These indicate that cheque processing, clearing and settlement is one of the major tasks in interbank payment and settlement. This in turn leads to the

need to simplify, expedite and above all secure the cheque clearance and settlement process.

Although the statistics regarding the relative importance of cheque as payment instrument in the case of Ethiopia is not mentioned in any literature; one can safely conclude that its relative importance as payment instrument is larger than those countries because of the absence of alternative payment instruments like credit card, e-cheque, and others in Ethiopia.

As stated in [16] the interbank cheque clearance and settlement directive of Ethiopia has set maximum time required for a cheque to be cleared and settled, i.e., within 48 hours in Addis Ababa city branches. However, the memorandum in [20] disclosed that contrary to the interbank cheque clearance and settlement directive currently in place, the average time for a cheque to be cleared and settled has reached 8 (eight) days.

According to the regulation of payments market in [18] paper cheque is widely used than digital cheques for its advantages of being used offline, and easy for inventory. The common problem for paper cheque and digital cheque is that both of them cannot be instantly settled. Hence taking into account such situation, it is crucial to implement intelligent agents that can enhance instant payment and settlement of cheques.

In connection with this the study in [19] has concluded that the process of writing and depositing cheques would remain unchanged for consumers, but the processing of cheques would be made more efficient through the help of Information Technology. That is the cheque can be captured and transferred electronically (digitally) than physically (in person) to the cheque writer's (reimbursing) institution and clearing agents (bodies responsible to clear cheques on behalf of member banks). However, the settlement process problem still persists. This indicates that there is a need to improve overall interbank payment and settlement process.

Banks participating in interbank payment and settlement have their own independent banking solution that supports part of e-banking services. The scope of these e-banking services is limited to transactions made between

customers and their base bank. However, interbank payment and settlement involves Commercial Banks, Central Bank and branches of participating banks whose levels of automation vary significantly. Thus it requires high interaction among legacy systems of participating banks. Moreover, the task requires considerable human intervention. It also involves dynamic attributes such as shortage of liquidity, change of balance, stop cheque orders, and change of signatories, etc.

Considering this nature of interbank payment and settlement, the existence of gap and the emergence of agent technology, it is essential to provide banking application developers a way to structure the banking application around autonomous, communicative components and lead to the construction of software tools and infrastructure to support the design metaphor. This helps to view complex and independent banking systems to communicate with each other in order to clear and settle interbank payments. Accordingly, banking software will be able to act as user preferences, provide response for cheque in transit, checking court cases, auto cheque clearance, deal with money laundering, perform interbank lending, etc. In connection with this, different scholars [2, 3, 28, 29, 30] have agreed that on-line businesses in general and e-banking in particular requires agent-based systems as they involve complex interactions between diverse systems owned by different organizations.

Real-Time Gross Settlement (RTGS) Systems are being used by different countries for interbank payment and settlement. RTGS has two finality options: Delayed Finality and Immediate Finality. As the immediate finality option of RTGS system is almost impossible to realize, the delayed option is commonly used. However, the delay needs to be minimized through intraday liquidity management. The approaches of intraday liquidity management depend on the central bank's policy of interbank payment and settlement. The policy of most central banks allows interbank lending, intraday credit, etc. The interbank lending can be collateralized or uncollateralized. The problem is interbank lending cannot be automated using traditional software technologies.

Therefore, the target of this study is assessing the contribution and appropriateness of Software Agents on secured, timely and cost effective interbank payment and settlement process. Then it ends up with developing Multi-Agent-Based framework for interbank payment and settlement, Multi-Attribute Utility Theory (MAUT) based interbank lending model, and prototype for interbank lending.

1.3 OBJECTIVES

General objective

- To develop Multi-Agent based framework for interbank payment and settlement that can significantly reduce gridlock, human involvement, clearance and settlement cost, enhance security, improve efficiency, and increase customer satisfaction.

Specific Objectives

- ✓ To study if software agents are better than other tools in interbank payment and settlement in general, and in intraday liquidity management in particular.
- ✓ To reduce interbank payment and settlement time and cost.
- ✓ To analyze components of Multi-Agent based Interbank Payment and Settlement (MAIPS) system.
- ✓ To design Multi-Agent based intraday liquidity management model.
- ✓ To filter out determinant factors in interbank lending for the purpose of intraday liquidity management.
- ✓ To develop multi-attribute utility theory based model for interbank lending.
- ✓ To develop Multi-Agent based collateralized interbank lending prototype.

1.4 SCOPE & LIMITATIONS OF THE RESEARCH

In general interbank payment and settlement refers to transfer of funds in the form of cash or negotiable instruments between claiming and responding banks. Negotiable instruments include cheque, Demand Draft (DD), Travelers' Cheque (TC), Cashiers Payment Order (CPO), Clearance Vouchers, and other items that may be approved as negotiable instrument. These negotiable instruments need to be cleared before the payments get effected.

Since the nature of negotiable instruments is similar, the research considers only cheque clearance in the process of interbank payment and settlement. The study will also emphasize only on interbank payment and settlement for banks having common clearance house. Hence the result of the study is applicable for payment and settlement among foreign and local banks providing that they possess the common clearance house. However, the current practice of foreign cheque clearance and settlement is being handled through third party. This third party based cheque clearance among foreign and local banks requires knowledge on how foreign banks handle cheque clearance such as role of their central bank, establishment of common clearance house and others. Thus cheque clearance and settlement between local and foreign banks is considered beyond the scope of the thesis.

The scope of this thesis is limited to study and improve interbank payment and settlement by allowing autonomous banking systems to interface with. Besides, gridlock reduction will be considered.

1.5 MAJOR RESEARCH ACTIVITIES

Activities of the research have begun with studying target domain, i.e., interbank payment and settlement, and agent technology. Then it is followed by reviewing related researches, reports and others.

These preliminary activities helped us to determine the remaining activities of the research. Accordingly, the following major research activities are pin pointed.

- **Payment System Characterization:** Components of payment system are identified. These components are characterized in relation to agent technology.
- **Development of Agent-Based Payment System Framework:** After characterization of payment systems, the framework is developed addressing issues like determining interacting protocols, identifying usable agents, and stating required infrastructures.
- **Interbank Lending Model Development:** One of the major limitations of traditional interbank payment and settlement systems is gridlock, which requires intelligent intraday liquidity management. As a solution, MAUT based interbank lending model is introduced.
- **Multi-Agent Based Interbank Lending Prototype Development:** In this activity tasks of interbank lending are actually implemented using MAS technology.

1.6 APPLICATION OF RESULTS

The final users of Multi-Agent Interbank Payment and Settlement Systems are commercial banks, central bank and clearing house. Nevertheless, the scope of this thesis is to develop a prototype for multi-agent based interbank lending, which focuses on intraday liquidity management. Hence the usable final product of this thesis is the framework, and the model for intraday liquidity management. The framework and the model will be applicable in agent-based payment systems development. Moreover, the model can be adopted independently and implemented in any collateralized credit service between different parties.

1.7 ORGANIZATION OF THE THESIS

This section provides a bird's eye view as to how the rest of the thesis is classified into different Chapters, and highlights on what the Chapters contain. Accordingly, the organization of this thesis is as follows:

- ✓ **Chapter 2** provides the details of interbank payment and settlement process in general and interbank cheque clearance in particular. It also presents overview of multi-agent systems. This helps the reader to clearly understand interbank payment process and multi-agent systems.
- ✓ **Chapter 3** deals with related literature review. This Chapter presents summary of literatures relevant to this thesis and identifies the limitations of the literatures, which will be addressed by this thesis.
- ✓ **Chapter 4** presents the core component of this thesis, i.e., framework for multi-agent based payment system focusing on cheque clearance.
- ✓ **Chapter 5** designs MAUT based interbank lending model, which will be used in the prototype of this work.
- ✓ **Chapter 6** provides the prototype of the multi-agent based interbank lending, which is the main component in payment system. The Chapter is aimed to demonstrate technical feasibility of Multi-Agent based interbank payment and settlement system. The prototype in this thesis implements the core part of interbank payment and settlement system that avoids gridlock.
- ✓ **Chapter 7** concludes the thesis and identifies future works.

2. BACKGROUND

This Chapter describes interbank payment and settlement, and the target technology. It provides an overview of interbank payment and settlement in general and cheque clearance process in particular. Besides, it describes Multi-Agent Systems and Agent Technology.

2.1 INTERBANK PAYMENT AND SETTLEMENT

The study in [31] showed that fund transfer is initiated by the payer through transmission of payment order request to the payee. To effect payment to the payee the payment order is processed according to the predefined rules, which incorporate identification, verification, and effecting payment. This transmission and processing is followed by settlement. Settlement is the actual transfer of funds between the payer's and payee's bank that takes place under the central bank. Settlement can be divided into two: (1) Net Settlement, and (2) Gross Settlement. In the case of net settlement, the participating bank's net position is calculated i.e., all transfers it has received minus all transfers it has sent, and the bank is credited or debited for the net settlement position. On the other hand, in a gross settlement system, the settlement of funds occurs on transaction-by-transaction basis. Such categorization of settlement leads to classification of settlement systems into Net Settlement System and Gross Settlement System. These interbank fund transfer systems are subdivided into Real-Time (Continuous) Gross Settlement (RTGS), Differed (Designated-Time) Gross Settlement System (DGS), and Differed Net Settlement (DNS) Systems based on the timing. These RTGS and DNS systems use the same transfer and processing mechanisms, which is transaction-by-transaction. These systems can also be classified into central bank owned and private bank owned where central bank plays coordinating role.

According to [32] Payment system (or interbank fund transfer and settlement systems) is a system, which enables to effect payment between payer and payee, and includes clearing and settlement. It has tremendous impact on speed of transfer, financial risk, reliability, cost of processing, widening customer base and maintaining competitiveness. The core principles that the

payment system should satisfy are legal robustness (being synthesized with country's legal environment), clarity of accountability and responsibility of participants, clear definition of procedures for management of risks such as liquidity, credit, legal, operational and systematic risks, swift settlement, feasibility, reliability, and security. In this paper RTGS system is chosen as payment system between banks in India for its reduction of time between instruction process and settlement. This scenario lets the customer to receive the fund during the day. There are three RTGS structures: (1) **V**-Shaped where claiming branch directly sends documents to central bank and the central bank to responding branch, (2) **Y**-Shaped Where document flow follows: Claiming Branch->Claiming Bank Central Processor->Central Bank->Responding Bank Central Processor->Responding Branch, and (3) **L**-Shaped, which is similar to Y-shaped, but with different message content. Among the three RTGS structures, Y-shaped is chosen by Reserve Bank of India (RBI) as it retains confidential information of customers and sends only relevant particulars to the RTGS, creates single contact point for each bank, provides single RTGS account for each participating bank, manages transaction priority per bank, and manages liquidity. Finally the paper concluded that RTGS system is an effective platform for inter-bank payments with adequate supporting devices, and the success largely depends on the adaptation to compatible systems by all the participants, i.e., all participants need to have compatible banking systems in order to implement RTGS, otherwise they need an intermediate infrastructure and system, which is compatible to the RTGS.

The above studies recommended the need of intermediate system for different bank systems to understand each other. Hence developing a framework for self- initiated intermediate system that maintains autonomy of participant banks will bring quantum leap in payment systems.

2.1.1 INTERBANK PAYMENT AND SETTLMENT CONCEPTS

Interbank payment and settlement concepts deal with ideas and policy issues to be considered in designing interbank payment system. These concepts are:

Clearance Policy: refers to directives and guidelines used in interbank cheque clearance and settlement.

Identification, Verification, and Authentication: Identification is the process of identifying drawer and payee. Verification deals with scrutinizing the cheque and other documents so as to check their validity, correctness of drawer signature, date, etc. Authorization refers to allowing someone to take action either debit or credit on accounts.

Liquidity Requirement: Liquidity refers to cash or ability of an asset to be converted (bought or sold) into cash without loss of value. In general the liquidity requirement of the bank refers to the cash requirement of the bank in the process of interbank payment and settlement. If net intraday liquidity of a bank is negative, it is considered as illiquid and will not be able to settle responded cheques. Generally there are four sources of fund: (i) balances maintained in reserve account at the central bank (NBE in the case of Ethiopia), (ii) funds received from other banks, (iii) credit facility of central bank, and (iv) money market (or credit facility from other banks).

Intraday Liquidity Management: The intraday liquidity management mainly deals with issues like a bank's reserve account balance requirement to determine equilibrium position of liquidity; and injection of cash (credit) to its settlement account. There are different approaches to address these issues. For instance the liquidity requirement of the bank can be randomly determined or it can be determined in some sort of intelligent way through simulation. Likewise the equilibrium position of liquidity can be ignored or decided based on game theory. The second issue deals with funding, i.e., increasing balance of the settlement account from different sources of funds and how to get cash from these sources.

Reserve Account Balance: is the main source of fund, where each bank should have a pre-set minimum balance to participate in interbank payment and settlement process. This balance is changed in transferring and receiving funds.

Incoming Fund Transfer: is the second important source of intraday liquidity. The reliability of this source of intraday liquidity depends on the volume and predictability of incoming and outgoing payment flows.

Central Bank Credit: Intraday liquidity can be provided by the Central bank. The central bank provides credit with or without interest. Such credit facility could be collateralized or uncollateralized overdraft facility.

Money Market: Money market is a means of borrowing and lending in short term through trading of financial instruments with high liquidity and short period of maturity. Money market securities consist of the following negotiable instruments:

A. **Purchase Agreement (Repo):** is a form of short-term borrowing to raise the capital. The dealer sells government securities on daily or overnight basis, and buys them back. For the party selling the security (and agreeing to repurchase it in the future) it is a repo; for the party on the other end of the transaction, (buying the security and agreeing to sell in the future) it is a reverse repurchase agreement. [67]

B. **Commercial Paper (CP):** is short-term debit investment issued by corporation for financing of accounts receivable and meeting short-term reliabilities. It is unsecured debit investment, because it is not backed with any collateral. Besides it doesn't need to be registered with Securities and Exchange Commission (SEC) as long as it matures before 270 days (nine months).

C. **Bankers' Acceptance (BA):** is a short-term credit investment created by non-financial firm and guaranteed by a bank.

D. **Treasury Bill (T-Bill):** is short-term debit obligation backed by the government with a maturity of less than one year. T-bills are sold in denominations of ETB 5,000 up to a pre-set maximum purchase limit and commonly have maturities of one month (four weeks), three months (13 weeks) or six months (26 weeks). T-bills are issued through a competitive bidding process rather than paying fixed interest payments.

E. Certificate of Deposit (CD): is saving certificate, which bears interest, has maturity date, can be with any denomination and issued by bank. Though it is possible to withdraw the money before its maturity date, the action will incur penalty.

Credit risk is the risk of loss of principal or loss of a financial reward stemming from a borrower's failure to repay a loan or otherwise meet a contractual obligation. Credit risk is calculated based on the borrowers' overall ability to repay the loan, i.e., it includes the borrowers' collateral assets, revenue-generating ability, etc.

Gridlock: is a situation that happens when settlement requests are queued due to insufficient fund. It is considered as a case of system illiquidity, because it occurs when the aggregate liquidity is insufficient. Gridlock mainly occurs due to a participating banks, which deliberately delay sending of its payments [63].

Monitoring System Liquidity: According to the study in [31] central banks monitor the system liquidity regularly so as to avoid gridlock. Likewise the central bank in Ethiopia (NBE) manually checks reserve accounts of banks and advises them to deposit if the fund in the account is less than the minimum requirement or insufficient to cover a given payment request.

2.1.2 INTERBANK CHECQUE CLEARANCE, PAYMENT AND SETTLEMENT

Negotiable instrument is transferable, signed document that promises to pay the bearer a sum of money at a future date or on demand. Among the negotiable instruments Cheque is commonly and widely used instrument. Cheque is paper-based payment instrument, which takes some days to be changed into cash. The bearer of a cheque can cash it on its base branch, or on other branch of same bank or other bank. Cheque as a payment instrument has standard features to enhance security and provide legal protection to create trust between transacting parties.

When the bearer of the Cheque deposits the Cheque to his/her account at his/her branch instead of cashing it at the drawer's account holding branch the process of cheque clearance is invoked.

Interbank cheque clearance process takes 2-5 working days within a country and 8-15 working days across countries in normal clearance. This is mainly due to the fact that the cheque should be transferred physically between the involved banks or branches for clearance. Alternatively to speed up the clearance process, cheque particulars are transferred electronically (called e-cheque), but cheque as payment instrument remains paper-based [4, 6].

Interbank cheque clearance and settlement in Ethiopia takes place through Addis Ababa Clearing Office (AACO), which functions under the supervision of the National Bank of Ethiopia (NBE) and has other commercial banks as members. The eligibility criterion for membership is that the bank should be located in Addis Ababa. Each of the eligible banks has representative at the AACO. The cost of running the AACO is shared among member banks in accordance with criteria set by NBE. This office is established with the objective of speeding-up the settlement process and creating an efficient & reliable payment system [16].

Each member bank of the AACO is required to maintain an account at NBE and must have a balance of greater or equal amount to the reserve requirement in order to cover the payments in the clearance process. NBE has also authorization to debit or credit this account [16].

2.1.2.1 INTERBANK CHEQUE CLEARANCE, PAYMENT AND SETTLEMENT PROCESS IN ETHIOPIA

In Ethiopia, interbank cheque clearance process is categorized in to two: (i) special interbank cheque clearance and (ii) ordinary interbank cheque clearance. Ordinary interbank cheque clearance is a type of Cheque clearance that ought to have been cleared within the pre-set time-limit, which is two consecutive working days within Addis Ababa. Special interbank cheque clearance is a type of Cheque clearance, which takes reasonably short period of time to clear when compared to ordinary interbank cheque clearance. This type

of clearance within the city takes a maximum of one day to clear, but the customer should pay extra payment. In fact, all tasks in ordinary cheque clearance are also handled in special cheque clearance type. But customer's account is credited with involvement of the two banks disregarding other clearing offices like AACO and NBE. Interbank cheque clearance and settlement processes in Ethiopia can be depicted using Triangular-shape and Y-shape structures as shown in Figures 2.1 & 2.2.

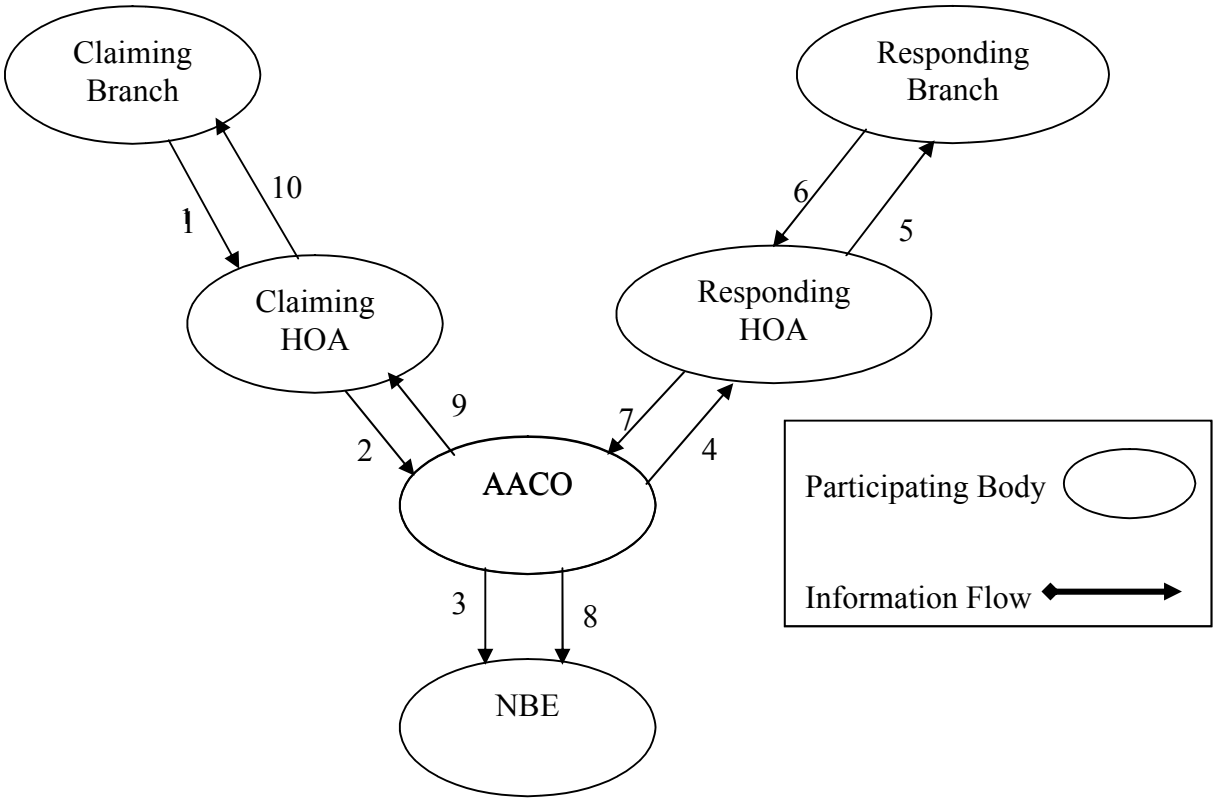

Figure 2.1: Interbank Ordinary Cheque Clearance Structure

Interbank cheque clearance, as depicted in figure 2.1, involves AACO and the two HOAs, i.e., the claiming Bank branch that originates the process and the responding Bank branch that holds the drawer's account HOAs. The claiming Bank branch sends (1) the credit summary to its HOA. The claiming Bank HOA upon receipt of the summaries from its branches go through the usual checking of the summaries totals and split the summaries if it satisfies the cheking purpose. Then it will sort out the cheques by Bank, prepare a credit

summary and forward (2) to the AACO. The AACO again checks for the correctness of the summary totals against the attached individual cheques and forwards it to NBE and the responding branch Bank HOA respectively (3 & 4). The responding branch Bank HOA also goes through the checking and split the summary and sorts the cheques by branch and prepares a summary that is forwarded (5) to the responding branch. The responding branch upon receiving the summary checks the credit summary total by comparing with the individual cheques total and split the summary and go through the verification and other process, then it will debit each cheque from the respective customer's account by crediting the branche's HOA Account with it. After completing the process the responding branch sends (6) the summary total confirming its acceptance to its HOA. The responding branch Bank HOA upon the recipt of the summary acceptance confirmation will debit the responding branch Account with it by crediting the AACO clearing account and responds (7) the claim. As the AACO recives the response of the responding Bank, it forwards (8) the response to NBE. Then NBE will credit the claiming Bank by debiting the responding bank with same amount and acknowledges AACO. Then after AACO sends (9) the action performed to the claiming Bank HOA. The claiming Bank HOA as it receives the response from AACO will credit the claiming branch Account by debiting the AACO account with it and sends (10) the summaries acceptance message to the claiming branch. As the claiming branch recives the final message from its HOA, it will credit the individual payee accounts by debiting its HOA account with the branch.

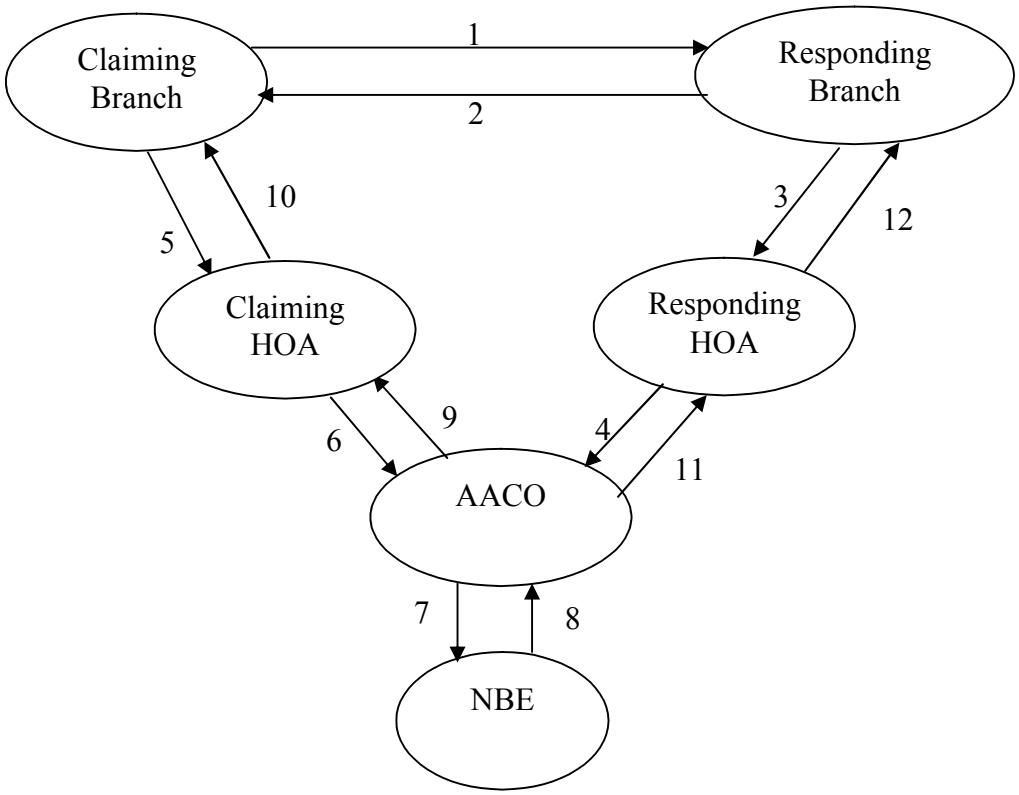

Figure 2.2: Interbank Special Cheque Clearance Structure

In the interbank special cheque clearance process, the beneficiary's account is credited without passing all the steps of interbank cheque clearance process. As shown in Figure 2.2, the claiming branch directly sends (1) the credit summary along with the cheque to be cleared directly to the respective responding branch. Upon receipt of the summary, the responding branch goes through the usual process of cheque verification. As it ascertains the verification process, the branch will debit the customer account and credit the HOA account with branch and responds (2) to the claiming branch summary by confirming its action. The responding branch also sends (3) the copy to the responding HOA informing its action so that the responding HOA debits the branch's account with it and sends (4) to AACO. Upon receipt of the response, the claiming branch will credit the customer account by debiting the HOA account with it. Then it will send (5) its claim to the claiming HOA to inform its action so that HOA credits its account and sends (6) to AACO. As the AACO receives the copy of the claims from both the HOAs, it sends (7) to NBE. Then

NBE will debit the responding bank account with it by crediting the claiming bank account. Then it will send its confirmation action to both branches (8-12).

2.1.3 INTRADAY LIQUIDITY REQUIREMENT AND MANAGEMENT

Intraday liquidity requirement is associated with national policies and procedures of interbank clearance and settlement. According to NBE's clearance policy [16] all participating banks are obliged to have fixed minimum amount in their reserve account at NBE. Moreover, the policy allows banks to get credit from any participating bank or central bank in case of deficiency. However, the usual practice for such situation in Ethiopia is advising the responding bank to deposit cash into its reserve account. Deficiency in liquidity may occur at any time in the process of clearance and settlement. Hence the fund availability needs regular monitoring and resolution mechanism if the available fund is less than the minimum requirement or not enough to cover the payment requested.

Intraday liquidity management refers to the administration of liquidity of participating bank. It is supposed to monitor and manage the four sources of liquidity, i.e., reserve account balance, incoming transfer, central bank credit and other bank credit (money market). Intraday liquidity management is important for both participating banks and central bank, because it helps central bank to have stable clearing process. Besides it benefits the claiming bank to get cash on time and credit customer's account. It also avoids gridlock of interbank payment system.

The intraday liquidity management considers multi factors like the structure of financial markets and systems (e.g. the adequacy of private sector sources of liquidity, the amount of collateral/securities available, reserve requirement) and central bank's policy.

When the balance in reserve account of responding bank is not enough to cover the requested payment, traditional interbank payment systems process the settlement using any of the three options: (i) queuing centrally, (ii) rejecting the request and (iii) settling with credit facility of central bank. Since the solution

depends on the central bank policy or agreed up on directive, these different options are adopted by different countries payment systems [31]. These settlement options for the case of insufficient balance have their own advantages and disadvantages as follows.

Rejecting the request queues payment requests on responding bank side and advises the bank to deposit onto the reserve account, which increases delay and unsettled cheques. Queuing on central bank may cause delay on processing speed of clearance and settlement system. The third option; settling with central bank's credit is preferable, because once the payment is effected, the claiming bank can credit the funds to its customers, use the funds for its own settlement purposes, etc. It is also helpful for smooth operation of the system by avoiding queue management in the settlement process, and reducing gridlock. In fact this credit is normally provided for a period of less than one business day (called intraday credit). The mode of intraday credit provision can be performed in different terms such as collateral based or non-collateral based, free or interest based, overdraft, etc. In order to lessen complexity, credit provision based settlement uses only OD facility of the central bank.

The issue of how to provide credit needs due attention as mechanisms and terms of credit require thorough decision and management. Participating banks may need to make analysis on liquidity cost and delay costs. Liquidity costs include direct funding costs such as interest, charges, tying up collateral etc., and delay cost includes penalty, customer dissatisfaction, etc. Intraday liquidity management requires banks to be actively involved in the management of their payment flows in order to use intraday liquidity effectively. This could require huge investment in the internal systems, controlling staff, etc.

Many central banks adopt RTGS in large-value fund transfers to reduce systemic risk, because it lowers intraday interbank risk exposure, avoids possibility of multiple unsettled payments, and settlement pressures are not concentrated at particular points in time. Thus this principle can be adopted in our MAIPS system that can handle interbank payment and settlement on real-

time basis to reduce interbank risks, because the duration of credit and liquidity risk is reduced. However, settlement possibilities are limited with fear of credit and liquidity risk.

In order to extend the traditional interbank payment systems to use any credit facility or money market, the core thing to be considered is credit risk analysis. Hence the system to be proposed should consider credit risk before determining the settlement option. Moreover, the system should be able to limit or avoid all risks associated with interbank payments like liquidity risk. The main reason of insufficient fund problem of many interbank payment systems to be resolved through OD facility or queuing mechanism is a limitation of risk management. Because other solutions like all types credit facility and interbank lending need detail analysis and decision. Therefore, our work recommends agent technology to extend the payment system to use all possible options to resolve the problem. This recommendation will be analyzed and realized through negotiation, which is one aspect of the three interaction level components (coordination, negotiation, and communication) in agent technology. The new extension to traditional interbank payment systems is that these self-interested software agents can also perform direct fund transfers from one autonomous system to another system by negotiating credit with different involving parties. As stated earlier the setup of interbank payment system allows credit facility among participating banks provided that they agree on interest rate or other deal. Hence software agents can play substantial role in negotiating credit facility so as to avoid gridlock in settlement process. The agent will take action as per the chosen mode of settlement and report to the monitoring personnel. The system is extensible to link other fund transfer and settlement systems on real-time basis, and unconditional fund transfers from this system to the other autonomous systems would be possible. Thus the use of agent based systems is helpful to interface cheque clearance and settlement system with other fund transfer systems that can share the same source of fund, i.e., the reserve account of the participating bank at NBE.

2.1.4 INTERBANK LENDING

Interbank lending also called interbank money market is process by which one commercial bank borrows cash from other commercial bank so as to maintain the desired level of liquidity or achieve the minimum reserve requirement. Mostly it is short-term transfer of fund between banks, mainly used as a remedy for shortage of balances in interbank payment and settlement [56, 62, 68]. The interbank market is helpful for banks to monitor other banks and achieve competitive advantage in the market [61, 68].

Interbank lending has two distinctive characteristics, i.e., completeness and interconnectedness. In the case of complete interbank market, each bank is directly linked to all other banks by financial contract as shown in Figure 2.3. On the other hand incomplete and interconnected interbank market connects only some of participating banks directly, and others may have indirect relationship through others, called their correspondent bank. The third form of interbank market structure is incomplete and disconnected where there may be fragmented interconnections [64].

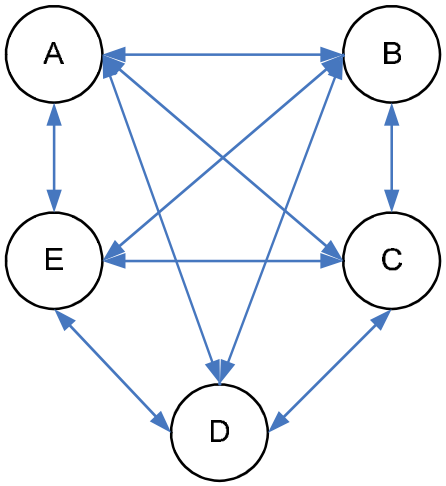

Figure 2.3: Complete Interbank market structure

The research in [56] argued that in interbank lending, both borrower and lender banks are exposed to credit risk. Hence the two commercial banks should negotiate about the collateral asset to be used, the haircut and the interest rate so as to make their risk analysis. For instance the lender reduces

the risk through having highly liquid and safe asset as collateral along with higher haircut and higher interest rate. On the other hand, the borrower is benefitted on lower haircut and lower interest rate along with illiquid asset as collateral. In fact in order to reach an agreement on a transaction, the two counterparties are required to share the risk; otherwise, they may not be able to agree on a transaction at all. Hence, they should negotiation to balance their interest and reach an agreement on a transaction. Accordingly the paper developed a model for different assumptions based on three defaulting conditions: (1) Neither the borrower nor the lender defaults, (2) Both the borrower and the lender defaults, and (3) Either the borrower or the lender defaults. Of course to mitigate credit risks, the borrower and the lender banks might in principle write a complicated agreement. Specifically these counter parties sign a standard repurchase agreement (SRA) C=(y, h, r), which is composed of a collateral composition y, a haircut h, and interest rate r. Commonly accepted collaterals are repos, Treasury bond, secured & non-secured assets, etc. and their associated haircut or margin varies on the number of days of credit are stated in [57, 66].

2.2 AGENT TECHNOLOGY AND MULTI-AGENT SYSTEM (MAS)

According to [47] a software agent is a software entity that functions continuously and autonomously in a given environment. Such continuous and autonomous functioning of software agents avoids human involvement. Mostly it interacts with other software agents for the change of the environment. Hence the term software agent generally refers to the different types of agents that performs distinct functions.

Studies in [7, 8, 22, 47] explicitly stated that software agents can be classified based on their abilities or characteristics. Such variation on property helps to determine the type of agent required in a given domain. Major characteristics of software agents are the following:

- **Adaptive:** Agent's behavior may be changed after it has been deployed, i.e., it can adapt to the changing environment and reconfigure itself.
- **Autonomous:** An agent can be considered as being self-contained as it is capable of making independent decisions and taking actions to satisfy internal goals based upon its perceived environment. Hence it can be considered as goal-oriented, self-started and proactive entity.
- **Collaborative**: Agents communicate and work cooperatively with other agents to form multi-agent systems working together to solve complex problems.
- **Knowledgeable:** An agent is capable of reasoning about its goals and has knowledge to make decisions, i.e., it has inferential capability using prior knowledge of general goals and preferred methods. Hence, its decision can be more like a human being than simple software code. It can make flexible decision and its decision can consider the information that is not given by the interacting body.
- **Mobile:** An agent can have ability to move from one environment to another. A mobile agent that moves itself includes its execution state to continue execution on another processor, which is referred to as mobile code.
- **Persistent:** Agents are able to retain knowledge and state over extended periods of time. This behavior is also called temporal continuity.
- **Distributed:** Agents can be designed to be very loosely coupled and to be executed as independent threads and on distributed processors.
- **Reactive:** Agents have the ability to selectively sense and act, i.e., it reacts to the change in its environment or to the request of another agent.
- **Personality:** Agents have a capability of manifesting the attributes of a real world object such as emotion.
- **Communication ability:** Agents are able to communicate with persons and other agents with language more resembling human being.

Based on the aforementioned characteristics of agents, the works in [47, 48] have classified agents into different types and described their major area of application as follows:

- **Collaborative Agents:** These agents emphasize on autonomy and cooperation with other agents to perform a given task. They negotiate so as to reach an agreement. These agents are mostly required to solve too large distributed problems, and allow interoperation of multiple legacy systems.
- **Interface Agents:** Interface agents focus on autonomy and learning. They provide interface to users and other applications. These agents can learn by collecting feedback from users and by requesting other systems. They are helpful for systems interacting with users or other non-agent applications.
- **Mobile Agents**: Mobile agents are capable of roaming wide area networks to collect information from other hosts and come back to their owner. These agents are required to reduce communication cost by bringing processed data, save local computational resource by minimizing unnecessary local processing, and enhance collaboration.
- **Information Agents**: Information agents are also called Internet agents. They filter out the refined information from the existing bulk of sources of information. These agents may be mobile or static, non-cooperative or social, and adaptive or non-adaptive depending on the information required.
- **Reactive Agents**: Reactive agents are agents that do not have internal symbols of their environment; instead they act to changes in the present state of the environment in which they are embedded.
- **Hybrid Agents**: Hybrid agents are those agents that merge properties of different types of agents and create new agents to maximize benefits of agent technology. Hybrid agent is different from Heterogeneous Agent System (HAS) or Multi Agent System (MAS), because HAS/MAS uses multiple types of agents without changing them in solving the problem.

According to the roadmap in [7] Agent Technologies are considered in three perspectives: (1) Agents as Design Metaphor, (2) Agents as source of Technology, and (3) Agents as Simulation.

- **Agents as a design metaphor** provide application developers a way to structure the application around autonomous and communicative components. This helps to view complex and independent systems to communicate with each other.
- **Agents as a source of technology** makes agents to act as user preferences, finding ways to negotiate, analyze and make decisions.
- **Agents as simulation** deals with representing complex real-world systems like economics, biological environment, and others.

The Agent Roadmap in [7] also groups agent technologies, tools and techniques into three levels based on the scale at which they apply:

1) *Organizational Level*: is the top level where technologies and techniques related to agent society that deals with issues of organizational structure, trust, norms and obligations, and self organization. Issues to be dealt at this level are those studied in disciplines of sociology, anthropology, biology, etc.

2) *Interaction Level*: are those technologies and techniques concerned with communications between agents, which addresses the issues of communication languages, interaction protocols, resource allocation mechanisms, negotiation between involving parties, and decision making. Real world issues that are dealt at this level include those studied in the discipline of economics, political science, philosophy and linguistics.

3) *Agent Level*: These are technologies and techniques concerned only with individual agent that deals with its reasoning and learning procedures. Hence problems at this level focus on artificial intelligence to build machines that have capability of learning and reasoning.

As stated in [8, 9, 10, 11, 23] agents are assumed to be autonomous, smart, sociable, proactive, reactive, and capable of making independent decisions in a distributed environment. Characteristically agents have no full information or all methods to achieve an objective (this can be referred to as "limited viewpoint"). Besides, an agent has little or no global control of systems. In case of distributed agents, data is decentralized and execution is asynchronous. Thus agents have to collaborate with other agents to solve complex problems. They also need mechanisms to synchronize and coordinate their effort to solve complex problems. Collection of autonomous software agents that interact and work together for a common goal are called Multi-Agent Systems (MAS).

A Multi-Agent System (MAS) contains a number of agents where each agent has its own goals. These agents can interact in a given environment to build-up a team, to negotiate, or to compete with each other. A MAS is required to provide answer to the following questions:

- How can autonomous agents coordinate their activities so as to cooperatively achieve a goal?
- How can cooperation be achieved in societies of self-interested agents?
- How can self-interested agents recognize conflict?
- How can agents reach an agreement?
- What kinds of communication languages can agents use?

The study in [23] stated that agents are autonomous, problem-solving computational entities capable of effective operation in dynamic and open environments. Mostly they are deployed in environments in which they can interact and collaborate with each other to solve a problem. Hence most agent-based systems are MAS. The paper emphasized that MAS is appropriate for distributed and complex systems.

As stated earlier, interbank payment and settlement involves various complex systems, which can provide service by their own. Moreover, the owners of these complex systems are spatially distributed. Hence a multi-agent system is very

important for interbank payment and settlement because of the following reasons:

- **Lack of Centralized Solution**: The knowledge and information required for interbank payment and settlement is spatially distributed among claiming branch, responding branch, claiming clearance office, responding clearance office, central clearing house, drawee, drawer and central bank.
- **Need to Maintain Independence**: All the involved parties are highly in need of maintain their autonomous behavior.
- **Need to receive information and advice proactively**: Claiming branch needs response immediately and thereby take action on drawee's account.
- **Need of Coordination**: Involving entities should communicate and coordinate their effort to effect payments and settle them.
- **Complexity**: Interbank payment and settlement process is too complex and can be decomposed into different sub processes that can work autonomously.
- **Dynamicity**: Interbank payment and settlement is dynamic in its nature as balance changes frequently, incoming and outgoing payments are non-deterministic, signatures change, cheque expires, etc.

MAS Structure and Agent Architecture

As stated in [39] there are two types of MAS structure: Mesh and Hierarchical as illustrated in Figures 2.4 and 2.5.

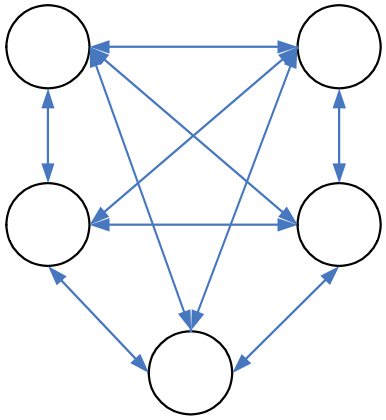

Figure 2.4: Mesh MAS Structure

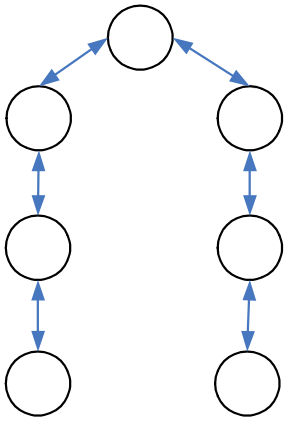

Figure 2.5: Hierarchical MAS Structure

According to [39] Agent architectures are classified into Deliberative, Reactive, and Hybrid or layered architectures.

Deliberative: Symbolic world vision, i.e., it develops plans and makes decision as per the plan.

Reactive: Situations and embodiment, i.e., it deals with perceptions and actions.

Hybrid: Is a layered architecture with both reactive and deliberative features.

2.3 SUMMARY

Interbank payment and settlement is a conceptual and practical structure that mainly deals with clearance policy, clearance categorization, liquidity requirement, and fund transfer and the like among the involved banks and central clearing authority. As it mainly involves payment or transfer of funds in cash or in the form of a negotiable instrument, it entails a great deal of risks for the involving parties to require a well thought fund management system. This fund management system bases on a national policy of the central clearing authority that determines the liquidity requirement of the involving parties in the form of intraday liquidity requirement. The liquidity requirement of the involving parties can be satisfied through deposit to the settlement account by its own or through borrowing from other parties involving in the interplay. As the process of transfer and settlement involves a number of hands, it is to large extent manual, lengthy and requires a high level of human interaction.

Interbank cheque clearance, payment and settlement is an interbank payment and settlement process, which involves customers, different banks, clearing offices of respective banks, central clearing house, and central bank. In order to help the reader to clearly visualize the process of interbank cheque clearance, payment and settlement, it is summarized in the Ethiopian context as shown in Figure 2.6.

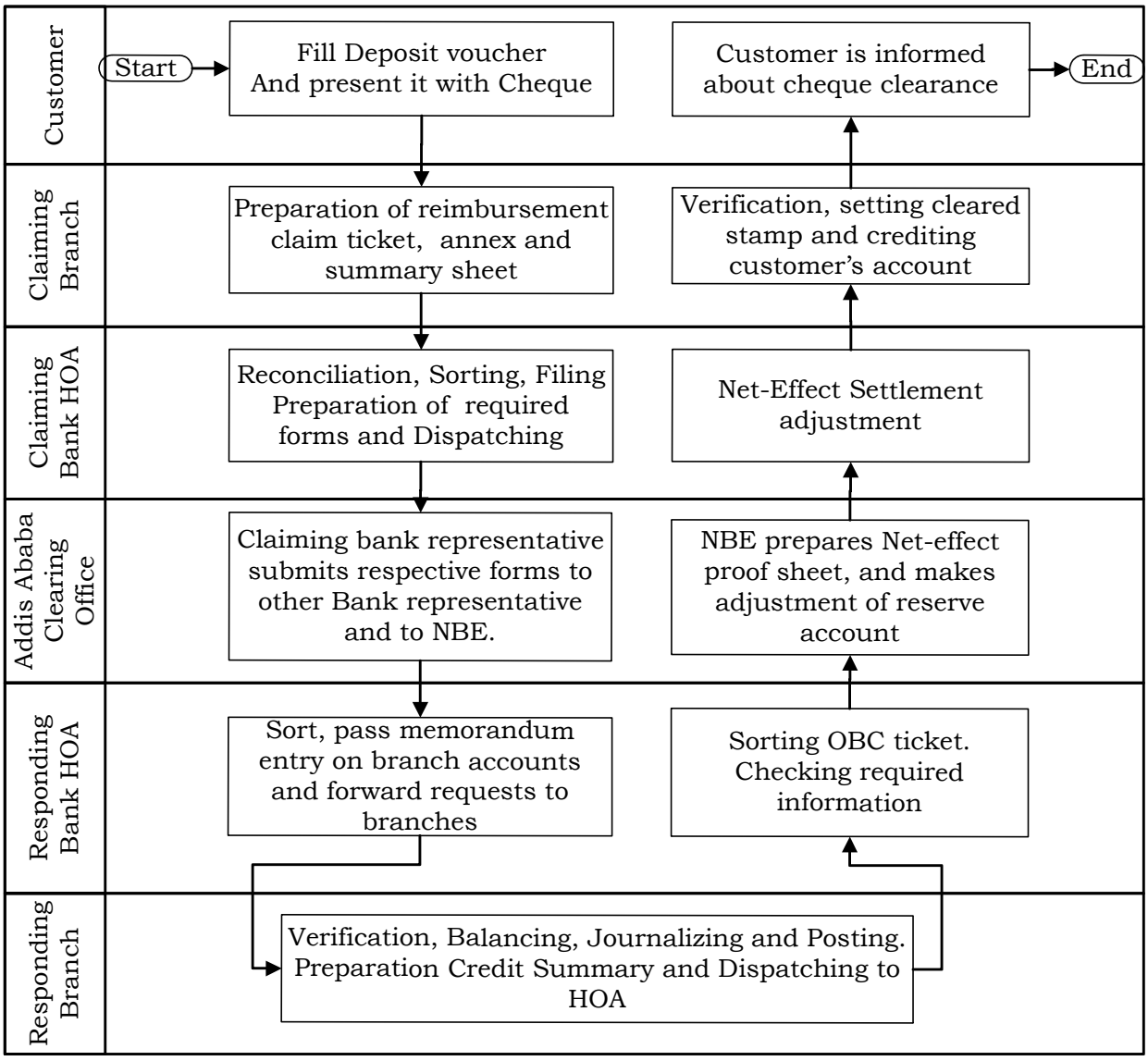

Figure 2.6: Process Flow of Interbank Cheque Clearance and Settlement.

Based on the nature of interbank payment and settlement process, Multi-Agent System (MAS) is proposed, because MAS has abilities to automate complex systems, maintain autonomy of systems, coordinate efforts, and is capable of decision making. Accordingly MAS is detailed in this Chapter and summarized as follows.

Multi-Agent System deals with collaboration of software agents to solve a given problem. These collaborative agents can have their own plans to perform so as

to achieve the common goal. Software agents are considered in three perspectives: (i) as design metaphor, (ii) as source of technology, and (iii) as simulation. Moreover, agent technologies, tools and techniques are grouped into three levels: (i) Organizational level, (ii) Interaction level, and (iii) agent level. Our study considers agents as design metaphor and as source of technology in the perspective of agent technology, and deals with interaction level.

3. RELATED WORK

This Chapter summarizes contributions of different study reports, articles, journals, associations, and any other relevant materials on Software Agents, payment systems and E-Banking in general and software agent related interbank payment systems in particular. Then each summary is followed by comments with respect to our work. For simplicity and readability, the Chapter is structured into banking and agent technology, and payment systems, Agent-based payment systems and automatic cheque processing. Each section is followed by critiques so that the gap can be identified so that it is filled by this thesis and to use their products for this work (if required). Finally the Chapter is concluded by summary.

3.1 BANKING AND AGENT TECHNOLOGY

According to the research in [2], Internet is playing a key role in changing the banking process radically. It helped people to make transactions electronically, providing that the person entered the right code through the graphical user interface. However, in the near future people will neither go to their financial institution branches physically, nor log on to the Internet to deal with banking service. They just want to delegate software agents to perform transactions. The trend of technology is changing banking service from customer self-service to self interested software service. Having this trend in mind the researchers have developed a framework called Banking Agent-based Transactions (BAT) framework, which has different types of agents to handle banking tasks such as making/receiving payment, and creating/maintaining/closing accounts. According to the paper, the security of BAT should be envisaged in two levels: the first is authentication of an agent itself and the second is specific security policy as the service type. The research has also pointed out requirement for further studies in the development of agent communication framework, integration of agent and non agent-based environments, and security of agent-based interactions. Finally the research concluded that agents are applicable for Internet-based transactions only if agents are properly characterized for the

domain, and the current deployment of agent technology can influence the way services are provided.

As stated in [3] e-banking service is a fundamental component in electronic commerce, but the degree of automation requires considerable human interactions for authorization, payment processing, etc. On the other hand humans need to delegate managers of their bank account, which is not yet coping up with increasing service demand, growing needs of flexibility and service integration. Hence using self-interested software entities is inevitable in automating complex real world problems. Even if the increasing development of agent technologies, tools and techniques in various fields indicate their feasibility and appropriateness for e-financing, Financial Agent-based Transactions (FAT) System is required to evaluate agent-based e-financing framework. E-Finance is the final service to be provided to customers and businesses in B2C or B2B transactions. E-finance incorporates banking, insurance, investment, mortgage loan, and wealth management. Agent-based e-finance framework tackles challenges like integration of agent infrastructure with non-agent environment, development of agent communication framework and security of agent based interactions. As a result, the paper defined required ontologies (bank ontology and insurance ontology), interaction protocols (FIPA-request, FIPA-query and FIPA-contact-net), appropriate agents (Personal Assistant Agent, Service Provider Agent and Bank Agent), and all required for insurance service provisioning.

Ontology broker and interpreter agents could allow applications to understand each other even though they use different terminologies. Hence, banking applications with different databases and terminologies can understand each other to clear cheques through the use of ontology broker and interpreter agents [17].

The study in [12] stated that one of the basic components of health care system is electronic referral system, which incorporates need of referral determination, service identification, provider selection, and communication. Agent-oriented approach is recommended for electronic referral system as the nature of data is

distributed, several autonomous entities need to communicate, and the problem needs to be decomposed into different sub-problems. Accordingly the paper developed multi-agent referral decision support framework for the Ethiopian referral system. Decision support of the framework focuses on provider selection, but the overall referral decision-making process (referral indication decision, required service, and appropriate provider selection) are addressed in multi-agent architecture design. Finally a multi-criteria decision making based provider selection model is built up and the multi-agent based prototype, which defined required agents along with inter-agent communication, is designed and implemented.

The papers reviewed so far indicate that MAS is an ideal technology for problems whose nature of data is distributed; participating parties need independence, and the problem is too complex to be solved using conventional technologies. The nature of problems mentioned in these papers aligns with the nature of interbank cheque clearance and settlement. Some of the studies reviewed above show that using software agents in the banking industry can dramatically change the way services are provided in the sector. The improvement of banking service has positive impact on investment, customer satisfaction, and e-commerce. Besides, the papers indicate the need of a framework in order to develop an agent-based system. However, the above studies clearly indicate that we should overcome the following challenges before developing Multi-Agent-based System (MAS):

- ✓ Integration of Agent Infrastructure with existing non-agent based environments.
- ✓ Development of usable agent communication framework.
- ✓ Security of agent based interactions. The notion of trust has to be redefined so that the main characteristics of the problem domain and agent technology are taken into account to build appropriately secured framework.
- ✓ Defining intra-agent and inter-agent infrastructures that enable software entities to participate in solving a problem.

- ✓ Designing technical facilities for enabling specific agent-to-agent interactions, i.e., protocols.
- ✓ Defining common knowledge representations and ontologies.
- ✓ Defining security policies regulating the agent-based system.

3.2 COLLATERALIZED INTRADAY CREDIT

According to the studies in [49, 50, 51] intraday credit is the remedy for liquidity shortage in RTGS systems. Whether the intraday credit is provided by central bank or other participating banks, credit risk and other associated costs require due attention. Usually the central bank reduces credit risk through controlling measures like imposition of quantitative limit (or "cap"), charging high interest (not necessarily market rate), and the requirement of collateral or intraday repos. All these measures impose cost on the use of intraday credit, i.e., penalty for violation of cap, considerable interest charges and opportunity cost of collaterals or repos. Among different intraday credit options, collateralized credit is the preferable and prevailing option.

As stated in [50, 51] the intraday liquidity management uses economics game theory to choose effective way of settlement. Among the different intraday liquidity management options, the generic intraday liquidity management game in relation to costs of settlement is shown in Table 3.1.

Table 3.1: Intraday Liquidity Management Game

		Bank B	
		Morning	*Afternoon*
Bank A	*Morning*	$C^A(m,m), C^B(m,m)$	$C^A(m,a), C^B(a,m)$
	Afternoon	$C^A(a,m), C^B(a,m)$	$C^A(a,a), C^B(a,a)$

The Intraday liquidity management game in Table 3.1 assumes that there are two banks participating in interbank payment and settlement: Bank A and Bank B, and two periods per day: Morning and Afternoon. Since each bank can play morning or afternoon strategy of settlement, there are different associated costs. The first element of each cell denotes the settlement cost of Bank A and the second element denotes cost of Bank B. In order to minimize cost of settlement, participating banks perform cost benefit analysis through the help of this game. Accordingly they choose their Nash equilibrium strategy. Nash Equilibrium or strategic equilibrium is one of the strategies from list of strategies in a game involving two or more players where one player has nothing to gain by changing only his or her own strategy unilaterally (According to the definition in [58, 59]). In the case of collateralized intraday credit regime, the intraday liquidity management game and the Nash equilibrium strategies can be discussed as follows:

In the real working environment, the maximum allowed delay is defined for a given period. If a given bank delays to settle payments more than the allowed period, it will be charged delay cost D. Thus in order to avoid the delay cost, the bank searches credit for the cost of C. The cost C includes opportunity cost of collateral and associated interest. Suppose Bank A and Bank B have engaged in collateralized intraday credit regime for interbank payment and settlement. If both banks have shortage of liquidity but with collateralized credit option, the settlement cost can be stated in collateralized credit game as shown in Table 3.2.

Table 3.2: Collateralized Credit Game

		Bank B	
		Morning	*Afternoon*
Bank A	*Morning*	C,C	2C,D
	Afternoon	D,2C	C+D,C+D

Table 3.2 shows that the (*morning, morning*) option incurs cost C for both banks. In the (afternoon, morning) option Bank A incurs cost D as it has received incoming payments and Bank B incurs cost 2C as it has no any incoming payments and is forced to extend credit. Conversely the (morning, afternoon) option costs Bank A 2C and Bank B D. The fourth option; (afternoon, afternoon) option costs both banks C+D for one period delay of settlement and the need of credit extension for the afternoon settlement. To put it in a nut shell, the Nash equilibrium of collateralized credit game depends on the values of D and C. If D>C, then banks have no incentive to delay and the (morning, morning) strategy will be preferable and it is the only Nash equilibrium. On the other hand if C>D (or D is insignificant), then the (afternoon, afternoon) strategy is also candidate Nash Equilibrium.

The above studies indicate that collateralized interbank lending is a solution for intraday liquidity management. However, interbank lending takes days as it requires negotiation among counter parties. This indicates that developing agent based interbank lending will make it possible in short period of time. However, the interbank lending model is the pre-requisite to develop Multi-Agent Interbank Lending System (MAILS).

3.3 AUTOMATIC BANK CHEQUE PROCESSING

As stated in [5] Check 21 ("Cheque Clearing in the Twenty-First Century Act") is signed by the US President Bush on October 28,2003. Cheque 21 is cheque processing tool aimed to eliminate movement and handling of paper cheques by sending electronic images of cheques. This in turn improves customer satisfaction, payment system, cost, clearance time, risk of human error, and helps banks to focus on back-office operations. Check 21 allows corporate customers, banks (at the teller window) to capture cheques and transfer to the processing center (clearing house). Consequently the clearing house can receive cheque images on the other end and cheque 21 takes care of verification process. Then the clearing house continues the clearing process, which is beyond the scope of the system.

The paper in [27] argued that cheque system is inexpensive payment system in high-credit business. Paper cheque system incorporates a rigid type of cheque called authorized cheque or certified cheque. Nevertheless, rapid growth of e-commerce is forcing these cheap paper based payment systems to be changed in to electronic ones. Accordingly, a mirror of paper cheque called electronic cheque is introduced. Like paper cheques, electronic cheques face default risks either intentionally or accidentally. As a solution this paper proposed a new type of electronic cheque system called safeCheck system, which avoids default risk, cost of authorization and permit credit based payment. This system is agent based system consisting of three types of intelligent agents: Cheque Book Agent, Cheque Receipt Agent, and Banker's Control Agent. The system is made agent-based to gain benefit of intelligent agents' behaviors, i.e., autonomy, communication ability, and reasoning and learning capability. Besides, agents are applicable in financial decisions such as personal banking, electronic payment, and budgeting. In SafeCheque system, each agent comprises of two basic components: (1) problem solver, which retrieves data, classifies data, performs reasoning, and generates outgoing messages, and (2) communication controller that is responsible to control messages, interpret incoming messages, and manage outgoing messages. It also incorporates security algorithms.

The work in [33] stated that many customers rely on their banking institution to verify cheque transaction details. Transfer of cheque as image or any form from one institution to another makes it vulnerable to fraud. Hence a system called Extr@i, which issues a cheque on pre-printed cheque paper, is developed. The cheque is produced in the form of Encrypted Pre-Defined Format containing all relevant information (like payee, amount, cheque number, etc.). Extr@i incorporates bank customers in secured cheque processing system. Hence it indicates that multi-agent based system for electronic cheque clearance can extend to corporate customers.

According to the study in [34], manual cheque processing is expensive, labor intensive, and subject to fraud. In fact this situation has pushed banks and

cheque using customers to electronic form of cheque processing. In connection with this there are a number of electronic cheque processing solutions such as point of purchase, back office conversion and Check 21. Cheque processing comprises the three sub processes of cheque processing: Authorization, Back-office/Settlement, and Collection. The paper stated the weaknesses and strengths of each electronic cheque processing solution.

The above discussed studies indicate that software agents can handle all interbank cheque clearing activity without human involvement because these papers avoided manual transfer and verification of cheques. Moreover, there is an indication for the appropriateness of agent technology (or MAS) in cheque based payment systems as the knowledge is highly distributed, and processing is too complex. However, the settlement is not considered. Hence there is a need to extend such works to accommodate cheque clearance and settlement.

3.4 AGENT-BASED PAYMENT SYSTEMS

According to [25] payments between banks are settled through interbank payment systems. Various types of payment systems in different countries such as TARGET in Europe, FedWire in USA, and CHAPS in UK play pivotal role for the financial marketing. Since most interbank systems in use are RTGS, settlement takes place as soon as payment is submitted into the system. RTGS modality imposes high liquidity demands on banks, making it vulnerable to liquidity risk. Accordingly liquidity-short banks are unable to send their own payments, creating delays and possible grid locking the whole system. Thus RTGS payment systems require due attention of central bank, and requires more researches. Liquidity in payment system is resulted from complex interaction between system's participants. To cover the liquidity problem banks rely on two sources: reserve account balance and funds received from other banks. Since the later source is beyond control of the bank, it causes delay on bank's payment activity. Hence studying behavior of banks in payment system is crucial so as to forecast payments. Accordingly this paper studied and modeled liquidity management game through adoption of dynamic behavior of

banks in order to keep them at equilibrium. The model developed by this paper is described in terms of payment requests presented, delays and liquidity costs. To find equilibrium of the liquidity, a game called Fictitious Play Tatonnement is used for its simplicity and it is a tool to compute equilibria. The results of the experiment are (1) delays decrease exponentially as liquidity increases and vice versa (2) equilibrium outcome roughly coincides with collective-cost-minimizing choice for extreme values of delay costs.

The research works in [24, 26] explained that the usual practice of interbank payments for paper based payment instruments is through central clearing house with the aim of multilateral net settlement at the end of the day. But, the increase of size and volume of payments made those end-of-day activities difficult and led to the introduction of Real-Time Gross Settlement (RTGS). Still the problem to settle immediately persists as payee banks deliberately hide queues of cheques to make the delay of response so as to reduce liquidity of their collateral at central bank. Banks attempt to handle the trade-off between liquidity and delay costs by reordering payments for submission to the central clearing house, i.e., they provide low priority to large payments. This is happening because banks delay settlement in anticipation that other banks will make payments to them first. In effect performance of RTGS degrades radically. To alleviate this problem these researches have considered Agent as Simulation. Then the papers proposed a model to simulate banks to behave autonomously and faced by asymmetric information through the help of adaptively (learning) intelligent agents. This helps banks to have efficient and stable point of the 'good' equilibrium; that is, they can operate in balancing liquidity and delay.

The papers reviewed in this section (or papers in [24, 25, 26]) have dealt with one of the perspectives of agent technology, i.e., simulation, which shows that the problem (interbank payment) is dynamic and complex that needs support of agent technology. Indeed this is good indication of usage of agent technology in payment systems. However, the papers considered and simulated only one source of liquidity, i.e., incoming payments to determine liquidity requirement.

Being dependant on incoming payments may cause gridlock, provided that all participating banks follow the same strategy. Hence, other sources of liquidity such as interbank lending; need to be considered in order to avoid gridlock. Interbank lending can be automated through self-interested software components that decide by themselves so as to find lenders, call them for proposals, analyze their proposal and make borrowing decision. In order to develop fully agent based RTGS that can manage intraday liquidity, multi-agent based framework and interbank lending model are required. This idea thoroughly exploits the first two agent technology perspectives: agents as design metaphor and agents as source of technology. This notion helps complex and independent banking systems to communicate each other as well as to make agents to act as user preferences.

3.5 MULTI-AGENT NEGOTIATIONS

Negotiation is a form of interaction by two or more parties with conflicting interests in order to reach a mutually acceptable agreement. Economics Game Theory describes such interactions in terms of protocols and strategies. In multi-agent negotiations, each agent uses its strategy to fulfill its interest and maximize its benefits. According to the study in [52] decision making analysis tools are used to help agents to identify the optimal strategies.

3.5.1 COMPETITIVE NEGOTIATIONS

Competitive negotiation is a type of multi-agent negotiation where decision making process revolves around resolving conflicting interest of multi-parties over a single mutually exclusive goal. Such type of negotiation is called a zero-sum game in Game Theory because there is only single dimension shift, i.e., one side is better off and the other is worse off. Particularly doing such type of negotiation in a market relieves a seller from determining price of a product priori [52].

As per the survey in [29], software agents have competitive negotiation skills. Hence they can be used to automate human-based negotiation in buying and selling goods/services.

In electronic commerce, multi-agent based competitive negotiations are implemented in three forms: (i) Classified Ad Negotiations, (ii) Stock Market Negotiations and (iii) Retail Auction Negotiations [52].

Classified Ad Negotiations

As shown in [35, 52, 53, 65] web-based multi-agent classified ad systems allow users to create either buying or selling agents and send to centralized marketplace (such as Kasbah). These agents can automate buyer's or seller's negotiation in transacting goods. Kasbah buying and selling agents negotiate in bilateral, competitive and straightforward way. Buying agents follow one of the three strategies: anxious, cool-headed and frugal corresponding to a linear, quadratic or exponential function respectively to increase its bid value over time.

Stock Market Negotiations

The central server like AuctionBot [60] allows users to create a seller or a buyer agent that creates new auction for sale or purchase respectively. Then buying and selling agents competitively negotiate in a Continuous Double Auction (CDA) manner. Unlike Kasbah's multi-agent bilateral negotiation, AuctionBot agents negotiate multilaterally [52, 60].

Retail Auction Negotiations

Retail auctions are called first price, open cry auctions where the highest bid wins the good for that price. In retail auction negotiation; merchants compete each other through product differentiation than price. These auctions have the following inherent problems [52, 55]:

a. Bids are non-retractable.

b. Products are non-returnable

c. Long delay between starting negotiations and purchasing the product

d. Bidder should continuously bid for the product

e. After providing a given price, each bidder should wait to restart negotiation until the good is auctioned again

f. Usually goods are sold more than their market price

g. Forces the sellers to set minimum starting price, and compete with others.

3.5.2 COOPERATIVE NEGOTIATIONS

Cooperative negotiation is a type of multi-agent negotiation where involving parties cooperate for a common goal, and it is a win-win type of negotiation. In fact parties involving in competitive negotiations also cooperate so as to engage themselves in negotiation and reach an agreement. However, competitive negotiation is concerned with only single dimension like price, and cooperative negotiation considers multi-dimensions. In cooperative negotiation the principle non-zero-sum game is applicable because values of multiple dimensions may shift in different directions to allow all parties to be better off. Hence cooperative negotiations can be described in terms of decision making process whose analysis is made through Multi-Attribute Utility Theory (MAUT). In cooperative negotiation merchants try to produce products that satisfy all needs of individual customers, and customers need to converse with retailers that can provide a product satisfying their interest with hassle-free shopping experience [52].

Multi-Attribute Utility Theory

Multi-Attribute Theory (MAUT) is an evaluation scheme or decision analysis tool that evaluates objects quantitatively from perspective of a single decision maker. It analyzes preferences of decision maker with multiple attributes, i.e., value V of an object x (or V(x)) is defined as a weighted sum of its evaluation with respect to its relevant dimensions. For example value dimensions of a given product can be price, delivery time, size, warranty, payment options, loan options, etc. [52, 55].

Distributed Constraint Satisfaction

Constraint Satisfaction Problem (CSP) analyzes decision problems qualitatively. CSP is defined in terms of three components: Variable, Domain and Constraint. Variable refers to a feature to be considered, and is associated with a domain. Constraint deals with relationships among variables and their value restrictions. These constraints can be classified into hard and soft constraints. Hard constraints are those mandatory constraints or features and soft constraints are optional ones. The variation of CSP is Distributed CSP (DCSP) whose variables and constraints are distributed over two or more agents [52, 54].

Papers reviewed in multi-agent negotiation section are critical to determine the type of multi-agent negotiation to be used in interbank lending. Among the type of negotiations stated above, cooperative negotiation is appropriate for interbank lending as interbank lending has the following characteristics:

- ✓ Both lending and borrowing are concerned with multiple dimensions.
- ✓ Though borrowing and lending banks posses independent goal that each tries to maximize, they share common goal of avoiding gridlock

3.6 SUMMARY

Literature reviewed so far commonly agree that multi-agent systems are very appropriate for complex problems whose data is distributed. They also stated that a framework is required before developing agent-based systems so as to overcome challenges like interaction of agents, integration of agent and non-agent systems, and security issues. Particularly papers related to interbank payment systems have clearly described interbank fund transfer and settlement. Though there are a number of payment systems with different approaches, still there is a gap to be filled. The major gaps that this thesis should overcome are extending the coverage of interbank payment and settlement and intraday liquidity management.

The works reviewed in Collateralized Intraday Credit section have shown that intraday liquidity can be increased through interbank lending. This intraday liquidity management option has different factors to be determined using game theory. This in turn indicates that multi-agent systems are appropriate for such dynamic problems.

Studies in the area of automatic cheque processing are driving forces to develop secured agent-based payment systems, which avoids involvement of human beings in any point of interbank payment and settlement process.

Those works entitled as Agent-based payment systems are not really payment systems, rather they are using agents to simulate and forecast payment flows in the current non-agent based payment systems. These studies help participating banks to determine their liquidity requirement. After liquidity requirement determination, workers are forced to find out fund and increase liquidity. Hence actual agent based system that can handle these tasks and fill the gap of non-agent based payment systems should be constructed. However, the pre-requisite is to develop a framework for multi-agent based interbank payment and settlement system.

The two types of multi-agent negotiations, i.e., competitive and cooperative multi-agent negotiations are evaluated. Basically, in both types of negotiation, cooperation is required so as to engage agents in negotiation. Competitive negotiation deals with a single dimension, whereas cooperative negotiation deals with multiple dimensions. Furthermore the two approaches of cooperative negotiation, i.e, Multi-Attribute Utility Theory (MAUT), and Distributed Constraint Satisfaction Problem (DCSP) are also discussed. These negotiation types are the base for intraday liquidity management in general, and interbank lending model development in particular. As interbank lending involves multi-dimensions, it entails MAUT based cooperative negotiation.

4. A FRAMEWORK FOR MULTI-AGENT INTERBANK PAYMENT AND SETTLEMENT

This Chapter deals with the design of Multi-agent based interbank payment framework that uses intelligent agents in interbank payment and settlement. According to [38] a **Framework** is a basic conceptual structure used to solve or address complex issues. Hence, in this study, the reusable agent-based framework for interbank payment and settlement system that uses hybrid architecture is proposed among the existing agent architectures.

The Chapter is organized into four sections. The first section presents design considerations that are taken into account while designing Multi-Agent based Interbank Payment and Settlement (MAIPS) framework. The second discusses goals of the MAIPS system. The third section presents the proposed framework for Multi-Agent Interbank Payment and Settlement. The last section deals with overall summary of the chapter.

4.1 DESIGN CONSIDERATIONS

The design considerations of multi-agent based interbank payment and settlement framework focus on the design of reusable agent-oriented framework for interbank payment and settlement system. According to [39], Agent-Oriented approaches help to model, design and build complex (distributed) software systems, which are mainly solved using multi-agent systems. Thus multi-agent system design particularly considers agent-oriented software engineering methodology.

In designing MAIPS System we assumed the following.

- **Target Interbank cheque clearance and Settlement System:** though the characterization of interbank cheque clearance and settlement primarily targets the context of Ethiopian cheque clearance and settlement, the overall interbank payment and settlement system is generic. Hence, the interbank payment and settlement model mentioned

in Figure 2.1 that inherits the properties of Hierarchical MAS structure depicted in Figure 2.5 with be dealt in our framework.

- **Network Infrastructure**: this design assumes network infrastructures of each bank are connected to the central clearing house network infrastructure.
- **Automatic Cheque Processing:** the cheque processing, i.e., cheque scanning, cheque validation, and signature verification system is assumed to be implemented by participating bodies.
- **Core Banking System:** Each participating bank is assumed to have core banking system that can provide account information and take action on accounts as per the order of agents.
- **Transaction Security:** The framework to be proposed is supposed to use existing Secured Electronic Transaction (SET) mechanisms.
- **Messaging Middleware**: the system is thought to use existing messaging mechanisms like FIPA ACL Messaging, RMI, HTTP, etc. as appropriate for any of its communication requirements.

4.2 GOALS OF MAIPS SYSTEM

According to the study in [43], goal represents actor's strategic interests. There are two types of goals: hard and soft goals. Hard goals (also called goals in short) are those, whose satisfaction level can be measured and verified, and soft goals are those whose satisfaction level can be set relatively and verification is difficult. To the perspective of a system hard goals are used to model functional requirements and soft goals are typically used to model non-functional requirements.

The main goal of MAIPS System is to improve interbank payment and settlement system that fills the gap of traditional interbank payment systems by the help of agent technology. To achieve this main goal the system should support the following:

A. Intraday Liquidity management through Interbank Lending

B. Automated interbank cheque clearance, payment and settlement communication

C. Interfacing the interbank payment system with autonomous legacy systems.

The intraday liquidity management facility of the system monitors liquidity by itself and makes decision, i.e., either increasing liquidity or leaving as it is after doing thorough cost benefit analysis. When it is required to increase the liquidity, it floats bid to borrow liquidity and collects proposals of bidders. Finally, it analyzes the proposals of bidders and borrows liquidity from the winner bank. This is a breakthrough in interbank payment and settlement.

The interbank cheque clearance, payment and settlement communication facility of the system generates claims automatically on behalf of a branch and sends the claim to the respective HOA. Then the HOA passes appropriate entry automatically and sends to AACO so as to help it to automatically pass necessary entries and send to both the central bank and responding HOA. Accordingly the responding HOA passes necessary entries automatically and pass to responding branch. The responding side will also do this automatic entry passing, automatic cheque verification, authentication and communication. This mechanism would radically change the interbank payment and settlement system in terms of time, cost, customer satisfaction, accuracy, etc.

Interfacing interbank payment system with legacy banking systems will help banks with different core banking and signature verifications systems to interact with the interbank payment system. Hence the interaction level of interbank payment system will cover end-to-end process. Moreover, the human involvement to maintain autonomy and manage intraday liquidity will no more require.

The aforementioned features of MAIPS system provide the following benefits in the banking sector:

- Provides automatic Intraday liquidity management
- Helps participants to view their independent systems as a single system.

- Facilitates cash circulation
- Improves customer satisfaction significantly
- Saves time, and cost of clearance process
- Introduces cost-effective and reliable system of communication in negotiable instruments clearance
- Relieves banks from huge paper works
- Relieves central bank from monitoring and administering all banks.

So as to clearly visualize MAIPS System, its high level hard goal diagram is depicted in Figure 4.1. The circle represents an actor and rounded rectangles represent hard goals.

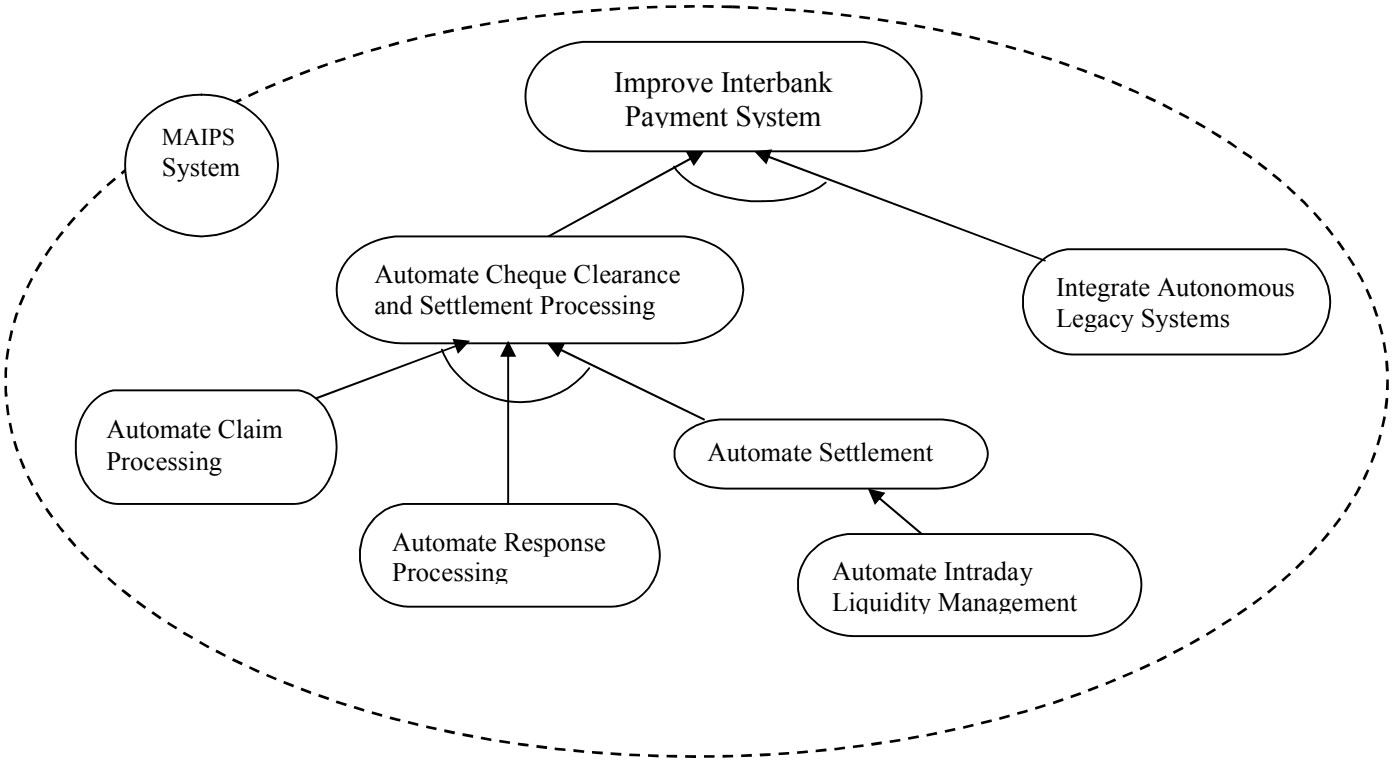

Figure 4.1: High-Level Hard Goal Diagram for MAIPS System

Figure 4.1 shows the set of high-level hard goals that *MAIPS System* should achieve. The main goal of *MAIPS System* is to *Improve Interbank Payment and Settlement System.* The *Improve Interbank Payment Process* goal is decomposed (AND Decomposition) into two sub goals: *Automate cheque Clearance, payment*

and Settlement, and *Integrate Autonomous Legacy Systems.* The hard goal analysis of *MAIPS System* revolves around the two sub-hard goals: *Automate Intraday Liquidity Management and Integrate Autonomous Legacy Systems,* which are the focus of this thesis. The first sub goal, *Automate cheque Clearance, payment and Settlement* is concerned with preparing and filling valid forms and reports required in clearance, effecting payments, settling payments and communicating to the concerned organ. It is also responsible to manage intraday liquidity. The second sub goal; *Integrate Autonomous Legacy Systems* helps autonomous complex systems to communicate with each other through the interbank payment and settlement system.

4.3 FRAMEWORK FOR MAIPS SYSTEM

The objective of this framework is to develop an architectural design of MAIPS System, which extends the capability of traditional interbank payment systems by the help of agent technology. The architectural design defines global architecture of the system in terms of participating actors in relation to their inputs/outputs, their capabilities and overall control flow. The framework is critical component in the process of agent-based system development as it alleviates the challenges in MAS development, and reduces design complexity. According to Sycara (as cited in [37]) there are six challenges of Multi-Agent System Development:

i. How to decompose problems and allocate tasks to individual agents.
ii. How to coordinate agent control and communications.
iii. How to make multiple agents act in a coherent manner.
iv. How to make individual agents reason about other agents and the state of coordination.
v. How to reconcile conflicting goals between coordinating agents.
vi. How to engineer practical multi-agent systems.

Our work overcomes the indicated challenges by defining a framework for multi-agent based interbank payment and settlement system. Particularly the following issues are addressed.

i. Defining overall architectural organization of MAIPS System.
ii. Identifying set of required agent types and their roles.
iii. Stating Capabilities of individual agents.
iv. Interaction between agents in the same organ and communications between agents in different organs. The organs in this work refer to branches, HOAs, AACO and NBE.
v. Mapping of identified actors, goals, plans, etc. to the architectural design.
vi. Interaction between agent-based and non-agent components.
vii. Refining the demarcation of capabilities in the case of agents competing for same goal.
viii. Engineering practical multi-agent systems.

4.3.1 REQUIRED AGENTS AND THEIR CAPABILITIES

In this section software agents required in the process of interbank payment and settlement process are identified. The target of MAIPS system is to allow agent based clearance, payment and settlement of negotiable instruments between branches of different banks. As stated in the previous Chapters interbank payment and settlement is complex as it involves various organs with complex and autonomous systems, and needs huge involvement of human being. Taking into account overall concepts of interbank payment and settlement process, policies and procedures, and the nature of interbank payment and settlement, the following agents are identified and roles are assigned to these agents according to the requirement of interbank payment and settlement process.

1. **Request Receiver Agent (RRA)**: is an interface agent that receives scanned cheque and cheque particulars from a person (front office bank

clerk) who receives deposit voucher and cheque from customer. The front office bank clerk is supposed to receive cheque along with the deposit slip, and validate the information filled on both cheque and deposit slip.

2. **Request Decomposer Agent (RDA)**: is an agent that receives information from RRA and decomposes the information provided. This agent decomposes the request for clearance information into two: (i) Cheque Information, and (ii) Transaction Information. The cheque information contains issuing bank, security feature of the cheque, signature of the drawer, cheque number, limited static information of the drawer and the payee, and scanned image of the cheque. Transaction information component contains static information like full name of the drawer and the payee, cheque account number, transaction date, amount, charges, etc.
3. **Claim Processing Agent (CPA)**: is an agent designed to process claim on the claiming branch side. It is responsible to prepare and fill claiming forms. This agent prepares claim ticket for each request individually. Hence there is no need of summary sheet preparation. Then it transports OBC claim from claiming branch to claiming bank HOA. Note that it doesn't carry batch of OBC claims as each cheque deposit request is processed individually. It is because the settlement is supposed to be made continuously (on real-time basis), rather than on the pre-set time interval.
4. **Claiming HOA Processing Agent (CHPA):** is an agent, which receives OBC claim from branch, saves copy of claiming form and sends it to AACO. This agent should digitally sign on the form so as to provide it an approval of the message, which is passed through HOA. The proposed framework is supposed to work in the manner of Real-Time Gross Settlement (RTGS), i.e., transfers are settled individually without netting credits against debits. Hence, banks could receive the money immediately and no need of passing single entry. This mechanism

avoids the task of sorting claims and preparation summary of claims. Moreover, there is no need of reconciliation of claim total against cheque total and comparison of cheque total with that of clearance voucher total is not required. Then CHPA transports claim from claiming HOA to other bank representative at AACO. CHPA submits claiming requests to other bank representative. NBE should involve only on acknowledgments. Hence NBE should not receive copy of a message sent to responding bank. On receiving response, this agent processes credit summary and send appropriate information to claiming branch.

5. **Responding HOA Processing Agent (RHPA):** is an agent, which receives OBC claim from CHPA, saves copy of claiming form and sends it to responding branch. On the other hand it receives claim response from responding bank, processes it and provides the response to AACO.
6. **Core Banking System Interfacing Agent (CBSIA):** is an agent that passes the transaction to the core banking system. On the responding side, this agent will be initiated only if the RPA receives acceptance of the cheque from ACPSIA. It translates data from agent-based system to non-agent based system and vice-versa. Hence it is an integration agent that integrates non-agent based system with agent-based one. It interfaces with the core banking system of responding bank and receives the acknowledgment of the core banking system about the transaction of the drawer cheque account. The acknowledgment on the core banking system side might be “Transaction Passed Successfully”, “Insufficient Fund”, “Non-Resident Account”, “Stopped Cheque”, “Account Closed”, etc. After CBSIA communicates with the banking application that performs the transaction, it reports information about the transaction to the response processing agent. On the claiming bank side, CBSIA works to receive response to a claim from claiming HOA and takes action as per the response, i.e., it might credit customers account or store in the returned cheque processing system.

7. **Automatic Cheque Processing System Interfacing Agent (ACPSIA):** is an agent that interfaces with the ACPS (Automatic Cheque Processing System) and gets the response from the system. The acknowledgement of the ACPS could be either accepted or returned for one or more of the returning reasons. This agent transfers its response to RPA.
8. **Response Processing Agent (RPA):** is an agent that prepares response to claim and sends to HOA. Since claims are coming individually in a real-time manner the agent prepares response to single claim. Hence it doesn't acknowledge for receipt of batch of claims. Besides the task of balancing, journalizing, summary preparation, etc. can be avoided. In the case of returned cheque, RPA clearly states the reason of returning cheque.
9. **Settlement Processing Agent (SPA):** is an agent that performs the tasks of central bank in the process of interbank payment and settlement. This agent passes transactions to the reserve account of participating banks. In doing so it checks whether each participating bank has account at the central bank core system or not. And if the account exists it should also check the minimum balance to effect payment or set penalty (as required). When the responding bank does not have sufficient fund in reserve account to cover the payment, the agent consults Intraday Liquidity Managing Agent.
10. **Liquidity Coordinator Agent (LCA):** is an agent designed to coordinate overall liquidity requirements of participating banks. It maintains central certified information about validity of securities, collaterals, etc. of a document to be purchased. Besides, it maintains information about eligible banks that can participate in interbank such as bank code, name, capital, trust level, ROI, NPL position, market share, etc. It also maintains the available guarantees of credit requesters at specific point. Since there is two-sided risk, i.e., risk of lending and risk of borrowing, both banks need to have detail information of the counterparty.

11. **Intraday Liquidity Managing Agent (ILMA):** up on insufficient balance for settlement, this agent manages liquidity of illiquid bank. It checks all possible sources of fund to increase the balance of reserve account so as to cover the requested payment. Finally it either increases the liquidity by getting fund through money market or leaves as it is. The later decision is made provided that a cost of getting extra fund is greater than the liquidity cost. In order to manage liquidity requirements of an illiquid bank at specific point, this agent continuously monitors the need of extra fund to settle payments. This agent helps to maintain the minimum required balance at the reserve account. Even though the available balance meets the minimum requirement, it may not be able to cover a given payment request. In such situations, this agent queues the request until the required amount of fund is found. When this agent concludes to increase available fund through interbank lending, it consults the Borrower Agent.

12. **Lender Agent (LA):** is an agent implemented on the Lender's side. It avails its excess fund ready for lending. When borrowing agent request calls it for liquidity borrowing proposal. This agent calculates the credit worthiness of credit requesting bank by considering collateral, other sources of repayment, credit history, management ability, lending relationship index, etc. After performing credit risk analysis, it sends proposal to participate in bid. Finally if it is found winner, it receives the award and sends an agreement message to the borrowing agent.

~~5.~~13. **Lenders Roaming Agent (LRA):** is an agent that searches for available and eligible credit providers. It brings the information of remote agents that can provide credit to the requirement of credit seeking agent. The factors that LRA considers are amount of available fund, terms of payment, eligibility of lender, etc. After collecting credit facility information from list of Lenders along with their terms of credit, it filters out, and provides shortlisted Lenders to the Borrower Agent.

~~13.~~14. **Borrower Agent (BA)**: is an agent on the borrowing bank side. It floats bid to borrow liquidity, receives proposals of bidders, makes analysis to select appropriate lender based on information about lenders by consulting LCA, offers of haircut and interest rate received from lenders, relationship between lender and borrower, etc. Based on the collected information it selects the lender, and then sends award to the winning Lender Agent. This agent also negotiates with a selected Lender and signs contract with it. Finally ownership of collateral will be transferred to lender and the liquidity will be transferred to borrower.

~~14.~~15. **Loan Re-Paying Agent (LRPA):** is an agent that checks availability of enough fund from the borrower account. If there is enough fund to cover the previously borrowed amount, this agent requests Collection Agent to return the collateral back by paying the loan. This agent is required to handle the Standard Repurchase Agreement (SRA).

~~15.~~16. **Collection Agent (CA):** is an agent implemented on the lending bank side. This agent listens to the request of LPA to involve in repurchase process. If the LPA avails the amount of fund it borrowed, CA checks terms of payment, calculates interest and other deductions. Accordingly CA receives all required amount from LPA, and provides the collateral.

~~5.1.1~~4.3.2 HIGH LEVEL ARCHITECTURAL ORGANIZATION OF MAIPS FRAMEWORK

This section provides the high-level architectural design or framework of MAIPS System. It deals with the organizational structure of interbank payment and settlement process, and proposed architecture of the MAIPS framework. In designing the MAIPS Framework the goal-oriented Multi-Agent System Architecture approach presented in [46, 47] is taken into account.

The overall architectural organization depends on the model depicted in Figure 2.1, which is generated from the ideal organizational structure for interbank cheque clearance, payment and settlement in Ethiopia as shown in Figure 4.2. The organizational structure depicted in this figure is deemed to be

hypothetical as it is formed only for the sake of facilitating clearance, and there is no managerial interdependency.

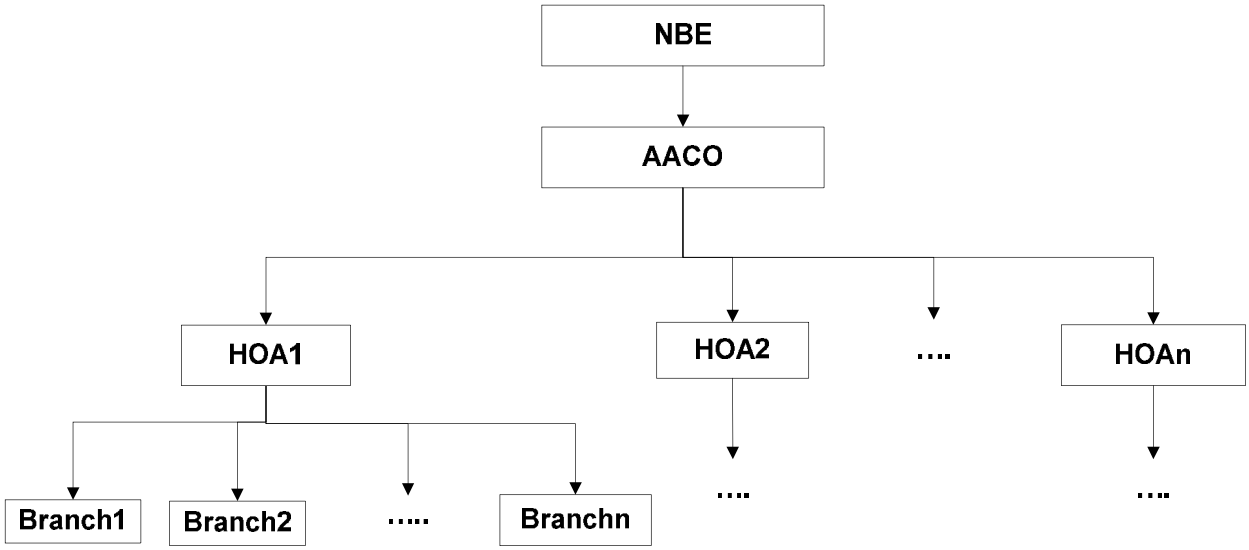

Figure 4.2: Organizational Structure of interbank Payment and Settlement in Ethiopia

The proposed high-level MAIPS framework deals with the request, processing, delivery and interaction between organs in the overall process of clearance, payment and settlement. As per the classification of MAS architecture in [39], features of MAIPS framework fulfill the definition of layered MAS architecture. MAIPS architecture is reactive in nature as it reacts to users' requests and other system requests or responses such as invalid cheque, incorrect signature and insufficient balance. On the other hand MAIPS architecture is deliberative as it executes planned actions. Hence the MAIPS architecture is **Layered architecture**.

The proposed MAIPS framework has the following layers and these layers are diagrammatically represented in Figure 4.3.

A. **Request Decomposition Layer**: In this layer cheque particulars are decomposed into Cheque Information, and Transaction Information.

B. **Interfacing Layer**: This layer provides interface for external organs interacting with the system. It provides an interface for system users and

other systems. Thus this layer is sub-layered into *User Interfacing* and *System Integration.*

a. **User Interfacing:** Provides an interface for system users such as entering cheque image and cheque particulars.

b. **System Integration:** In this sub-layer the agent-based and non-agent based components will be able to communicate with each other. For instance the non-agent based system that verifies cheque provides cheque verification information to the agent based system. On the other hand the agent-based system provides responses to the core banking system.

C. **Processing Layer**: Internal tasks like claim preparation, response wrapping, intraday liquidity management, and other appropriate decisions take place in this layer. The layer has a capability to provide end-to-end solution for clearance and settlement process. The core component of our Multi-Agent System resides in this section.

D. **Communication Layer**: In the process of clearing and settling a cheque between banks, different agents will coordinate their efforts. Thus the communication layer deals with interactions made between agents. Communicating agents may reside in the same or different organ. Organ refers to branches, HOAs, AACO and NBE. Hence this layer is divided into *Inter-Agent* and *Intra-Agent Communication.*

a. **Intra-Agent Communication**: The communication between agents in the same domain.

b. **Inter-Agent Communication**: The communication between agents in different domains.

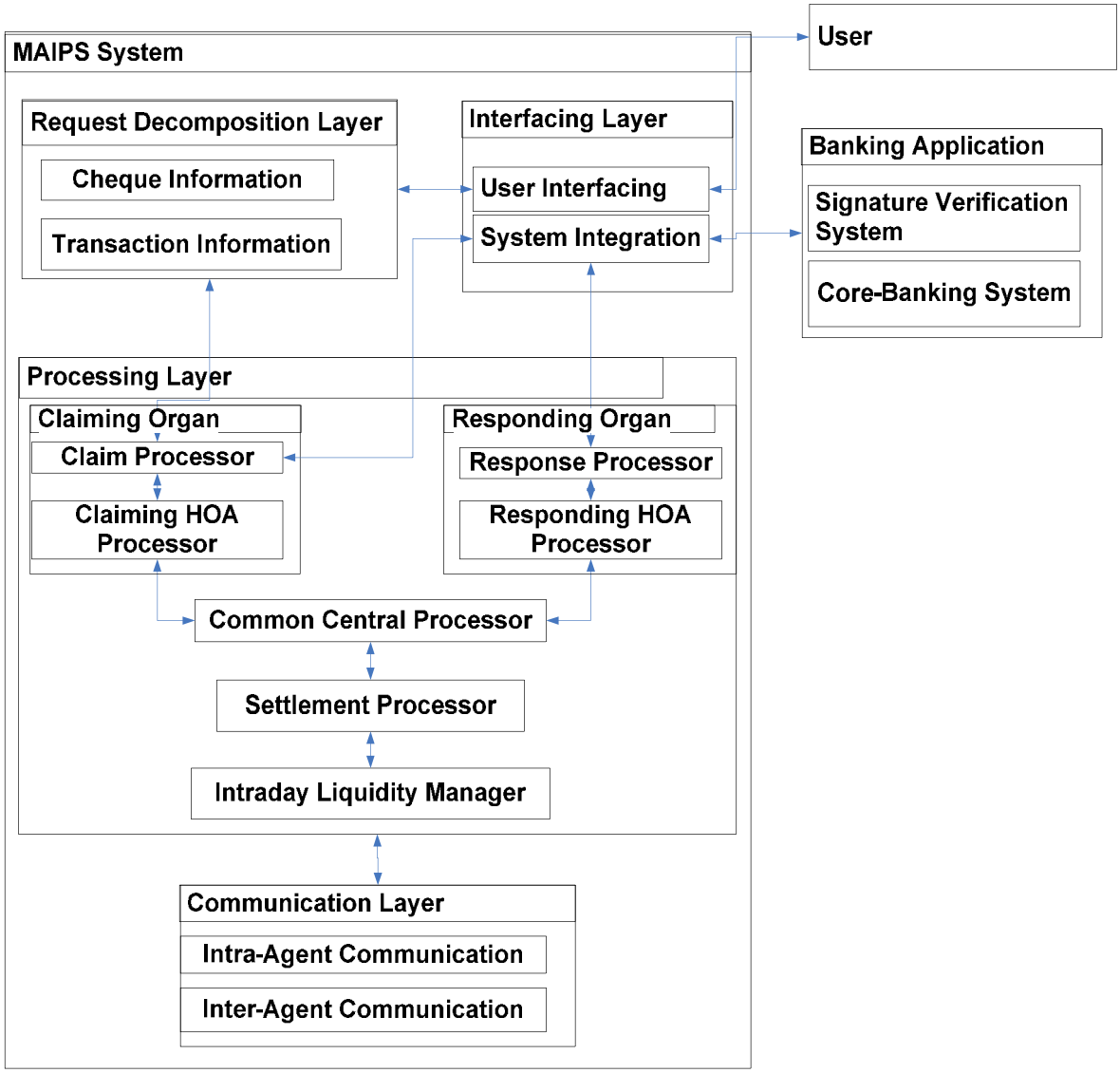

Figure 4.3: Layered MAIPS System Architecture

~~5.1.2~~4.3.3 AGENT CATEGORIZATION

Agent Categorization deals with the classification of agents proposed in our work. The types of proposed agents in agent-based interbank payment and settlement system are categorized as per their capabilities with respect to the proposed MAIPS framework. According to the definitions and classifications of agent types stated in [47, 48], the set of agent types that involve in MAIPS System are the following:

Interface Agents (Personal Agents): are those agents interacting directly with a user so as to capture user's preferences, and automate interbank payment

and settlement. These agents also interface with other systems like core banking or branch banking software, automatic cheque processing systems, and other applications involving parties to fetch required information. It is also responsible for grasping information that is not included in banking applications like cheque on transit, delinquent list, etc.

Hence the following are agent in this category:

i. Request Receiver Agent (RRA)
ii. Request Decomposer Agent (RDA)
iii. Automatic Cheque Processing System Interfacing Agent (ACPSIA)
iv. Core Banking System Interfacing Agent (CBSIA)
v. Settlement Processing Agent (SPA)

Collaborative agents: are required to maintain autonomy of participating organs in cooperating to clear and settle cheques. They also negotiate to reach an agreement. Since these agents are mostly required to solve too large distributed problems, our framework mainly exploits the features of them. Hence list of collaborative agents are used to communicate and interact in groups, representing signature verifiers, claim processors, response processors, supervisors, managers, other officials and service providers. These agents exchange messages to share information required for interbank payment and settlement. In doing so there are a number of correspondences within a given organ or from one organ to another as follows:

- From claiming bank clearing office to AACO and vice versa
- From claiming to endorsing/responding bank clearing office and vice versa
- From AACO to responding bank clearing office and vice versa
- From responding bank clearing office to responding branch and vice versa

Moreover, collaborative agent types involve actively in the process of intraday liquidity management so as to search credit facility providers, negotiate with them and sign contract. Agents in our work that fall under this category are the following:

i. Claim Processing Agents (CPAs)
ii. Claiming HOA Processing Agent (CHPA)
iii. Responding HOA Processing Agent (RHPA)
iv. Response Processing Agent (RPA)
v. Intraday Liquidity Management Agent (ILMA)
vi. Lender Agent (LA)
vii. Borrower Agent (BA)
viii. Loan Re-Paying Agent (LPRA)
ix. Collection Agent (CA)

Information Agents: are used to maintain information about credit providers, collaterals, etc. In our framework Liquidity Coordinator Agent (LCA) is an information agent.

Decision Agent: This is a type of agent that analyzes the available information in relation to predetermined parameters, associated risks, etc. and makes decision. Some user defined agents may possess characteristics multiple agent types. Hence our framework has associated decision agent properties to some of collaborative agents mentioned above. Agents in our work that have decision agent's capability are the following:

i. Lender Agent (LA)
ii. Borrower Agent (BA)

Mobile Agents: are required to collect credit providers' information from other hosts and bring for the one that can negotiate with them. Mobile agents are required to reduce communication cost as it brings filtered information and avoids short listing process on the credit requesting side. The only mobile agent in our framework is Lender Roaming Agent (LRA).

5.24.4 SUMMARY

A framework for Multi-Agent Interbank Payment and Settlement is a conceptual structure, which deals with the required agents and their

capabilities to pay and settle interbank fund transfers along with clearance of negotiable instruments such as cheques. Our framework extends the capability of traditional interbank payment and settlement systems in general, and RTGS in particular by adding the capability of agent-based intraday liquidity management, and interbank payment system integration with autonomous legacy systems. In the process of this framework development, we have assumed the existence of core banking system, transaction security, network infrastructure and others, which can be simply used without the need of analysis.

This framework has layered MAS architecture. The layers of the framework are: (i) **Interfacing Layer**, (ii) **Processing Layer**, and (iii) **Communication Layer**. The interfacing layer provides interface to system users and allows other legacy systems to be integrated with. The processing layer performs actual works of the interbank payment and settlement. The last layer deals with inter-agent and intra-agent communication.

In order to realize Multi-Agent Interbank Payment and Settlement System, the following Agents are required:

i. Request Receiver Agent (RRA)
ii. Request Decomposer Agent (RDA)
iii. Automatic Cheque Processing System Interfacing Agent (ACPSAIA)
iv. Core Banking System Interfacing Agent (CBSIA)
v. Claim Processing Agents (CPAs)
vi. Claiming HOA Processing Agent (CHPA)
vii. Responding HOA Processing Agent (RHPA)
viii. Response Processing Agent (RPA)
ix. Settlement Processing Agent (SPA)
x. Liquidity Coordinator Agent (LCA)
xi. Intraday Liquidity Management Agent (ILMA)

xii. Lender Agent (LA)

xiii. Lender Roaming Agent (LRA)

xiv. Borrower Agent (BA)

xv. Loan Repaying Agent (LRA)

xvi. Collection Agent (CA)

According to the classification of agent types, the aforementioned agents can b categorized into Interface Agent, Collaborative Agent, Mobile Agent and Decision Agents.

5. INTEBANK LENDING MODEL

As described in the previous Chapters, most interbank payment and settlement processes are automated using either DNS or RTGS systems except intraday liquidity management and interfacing these systems with those autonomous banking systems. Thus this Chapter deals with development of model that can automate intraday liquidity management through software agent based interbank lending.

The Chapter is organized into three sections. The first section deals with goals and criteria of lender and borrower banks in interbank lending. The second section presents the proposed Multi-Criteria Interbank Lending Model. The last section summarizes the Chapter.

5.1 GOALS AND CRITERIA OF INTERBANK LENDING

Interbank lending is fragmented in nature, and its overall marketing strategy and interaction lies on the monetary policy. The central bank has a goal of facilitating, securing, and monitoring of cash flow among banks and other markets as long as the predetermined criteria are fulfilled. It finds different alternatives to alleviate fund shortage of banks in interbank payment and settlement process. Such alternatives are intended to avoid gridlock in interbank payment and settlement systems. Particularly in interbank lending, the central bank is responsible for processing and settlement of transactions made between the borrower and lender banks.

5.1.1 GOALS OF INTERBANK LENDING

Banks participating in interbank payment and settlement systems have common goal of avoiding gridlock. In general each bank has goals like reducing delay costs, receiving incoming payments as soon as possible, satisfying customers, etc. In particular banks have their own different goals, when they play borrower and lender roles in interbank market.

Goals of Lender:

A. Getting highly liquid and safe collateral.

B. Securing high hair cut

C. Assuring higher interest rate

D. Assuring good lending relationship: expressed in terms of lender preference index, borrower's status in interbank lending, borrower's financial status, etc.

Goals of Borrower:

A. Providing illiquid and relatively unsafe collateral.

B. Securing lower hair cut

C. Getting lower interest rate

D. Assuring good borrowing relationship: expressed in terms of borrower preference index, lender's status in interbank lending, etc.

5.1.2 INTERBANK LENDING CRITERIA

The most important solution that plays substantial role to achieve both the lender and borrower goals is interbank lending. However, interbank lending is practicable provided that both the lender and the borrower fulfill the required criteria as shown in Figure 5.1. Such criteria requirement and analysis in interbank lending is helpful to minimize risks on both side.

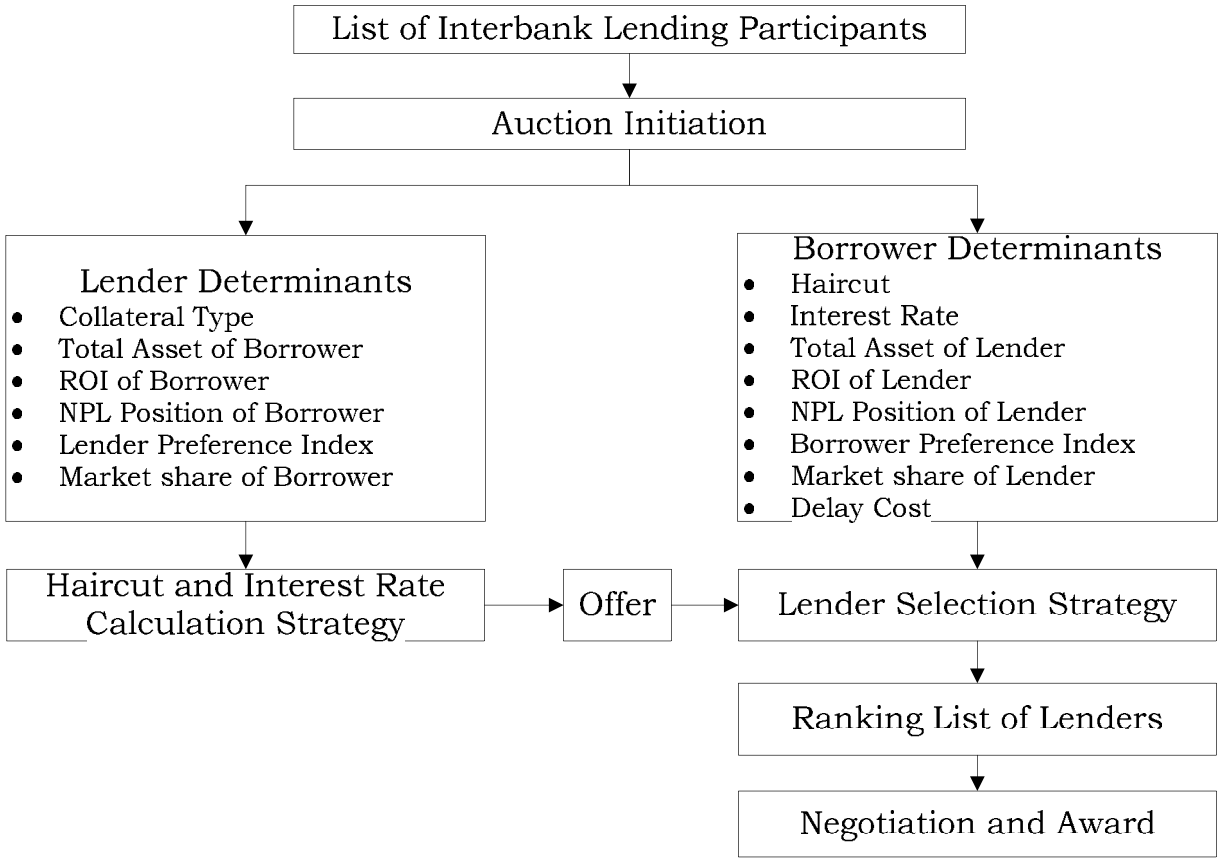

Figure 5.1: Lending and Lender Selection Criteria

Collateral Type: this criterion is related to the lender determinants and indicates the type of collateral that a borrower presents on requesting credit. Acceptable collaterals include treasury bills, bonds, copons, etc. as indicated in [66]. Collaterals have preset margins (or a percentage of fair market value) in interbank lending. Collaterals, which are highly liquid and safe, get higher market value.

Total assets size of the lender: According to the study in [68] larger banks obtain favorable interest rates when borrowing or lending. Hence if the lending bank's total asset size increases, its lending rate increases. On the other hand if the borrowing bank's total asset size increases, its borrowing rate decreases because its bargaining power increases with asset size.

Total Asset of Borrower: Larger banks receive lower interest rate [68]. It is because of the fact that larger banks take considerable time to fail ("too-big-to-

fail"). Hence lenders want to have relationship with borrowers, which have high total asset size.

NPL Position of Borrower: NPL Position is a criterion on both lender and borrower determinants. Borrowers with higher NPL position get higher interest rate in the interbank market [68].

NPL position of the lender: Lenders with higher proportion of NPL tend to receive lower interest rate on the loans in the interbank market [68].

Return on Investment (ROI) of Lender: More profitable lending banks tend to receive a higher interest rate, than less profitable ones.

Return on Investment (ROI) of Borrower: more profitable borrowing banks pay lower interest rates than less profitable ones [68].

Lender Preference Index (LPI): is a ratio that indicates total funds that lender L has lent to the borrower B during the year/quarter over the total amount of funds that L has lent in the interbank market during that same year/quarter [68]. This ratio is more likely high if L relies on B more than other participating banks in the interbank market. Lenders receive higher interest rate on loans to borrowers with whom they have a lending relationship.

Borrower Preference Index (BPI): is computed as total funds that borrower B has borrowed from lender L in a given year/quarter over the total amount of funds that B has borrowed in the interbank market during that same year/quarter [68]. This ratio is more likely high if L relies on B more than other participating banks in the interbank market. Borrowers pay a lower interest rate on loans from banks with which they have a lending relationship. This logic opposes with the LPI, but the research result [68] proved it.

Market share of the Lender: its computation is based on total amount lent over borrowed by all banks in the market [68]. This is positively correlated with bank's size. The study in [68] found that lenders/borrowers with larger market share receive better rates.

Market share of the Borrower: is computed as total amount lent over borrowed by all banks in the market. This is positively correlated with bank's size. Lenders/borrowers with larger market share receive better rates [68], i.e., interest rate, repo, available amount, haircut, maturity, etc.

Delay Cost: is the penalty to be imposed for the delay of settlement. This cost will be compared with the total cost associated with borrowing from the bank, and the bank will choose either delay or proceed with borrowing fund.

Haircut: Haircut is magnitude to be discounted on the initial value of the collateral proposed in interbank lending [45]. Haircut is the spread in a repurchase agreement, or the difference between the amount advanced by a lender and the market value of collateral used to secure the loan [36]. For example, if a lender makes a loan equal to 90% of the dollar value of marketable securities, the difference (10%) is the haircut. Haircuts for all possible collaterals in interbank lending are stated in [66].

Interest Rate: is the price that the lender proposed to lend liquidity for the given collateral.

5.2 MULTI-CRITERIA INTERBANK LENDING MODEL

The liquidity shocks give rise to borrowing and lending. Hence, the interbank lending is initiated just after a liquidity shock. Liquidity shock is said to be existing when the reserve account balance is less than the minimum requirement or a requested payment is greater than the existing amount in the account. If there is a liquidity problem, the system announces an auction for the needed level of liquidity by identifying the collaterals it has and amount of fund required. Bidders waiting for such bid provide their offer. Finally the bank in need of liquidity analyzes the offers, selects the winner of the bid, awards the winner and negotiates with the winner. Up on getting enough fund to cover the borrowed amount, the borrower pays the loan and repurchases the collateral. The overall Multi-Agent based interbank lending model passes the following basic phases.

5.2.1 PHASE 1: INITIATION

This phase characterizes that there is liquidity shock in a bank; the illiquid bank is in need of fund from interbank market. In our model, interbank lending is initiated by a borrower. In order to initiate interbank lending, the **Intraday Liquidity Management Agent (ILAM)** continuously monitors the reserve account balance, and the amount of outgoing interbank payments. Up on checking these two components, the ILMA may receive one of the following four outcomes: (1) reserve amount is less than the minimum requirement, (2) requested outgoing payment is greater than the existing amount (3) both outcomes (1 & 2) are true and (4) none of them are true. The first three conditions indicate that there is shortage of liquidity and the fourth outcome shows that there is enough fund, and no need for interbank lending. In the case of liquidity shock, Borrower Agent (BA) injects a bid to interbank lending pool, i.e., it approaches other banks by identifying itself along with the collateral it has, and asks others to participate in the bid requested for borrowing.

5.2.2 PHASE 2: BIDDING

Once the borrower identified need of liquidity and aired bid to borrow liquidity, lenders analyze the bid and offer their bidding proposal that states interest rate and haircut. In the course of participating in the bid, lenders pass the following steps.

Step 1: Banks with excess liquidity listens for bids in the interbank market through an agent called **Lender Agent (LA)**. Whenever LA gets bid for borrowing it collects information about the liquidity amount, collateral, other static information about the bank and starts analyzing the credit worthiness.

Step 2: The Lender Agent (LA) queries LCA (Liquidity Coordinating Agent) about the bank in need of liquidity, and itself. Then LCA returns standard collateral margin based on the given collateral, total asset of borrower, NPL position of the borrower, LPI, market share of borrower, etc.

Step 3: In this step LA uses decision making tool to provide proposal. MAUT is applied to determine credit feasibility, appropriate haircut, and interest rate.

According to MAUT rules stated in [55], the overall evaluation of an object is weighted sum of values of its relevant dimensions. In our case credit analysis can be made based on the aforementioned criteria, i.e., LPI, borrower's size, borrower's NPL position, ROI of borrower, and borrower's market share. Hence the overall evaluation of credit analysis is defined by the following overall value function V (B), where V is overall value function and B is borrower.

$$V(B) = \sum_{i=1}^{n} w_i v_i(B)$$

Here, $v_i(B)$ is the evaluation of the borrower on the i^{th} dimension d_i, w_i refers to the relative weight of i^{th} value dimension on the overall evaluation, and n refers to the number of different dimensions. In this model, we deal only with six dimensions of the borrower. Hence n is 6, and proposed relative weights of each value dimension are shown in Table 5.1.

Table 5.1: Proposed Borrower Evaluation Criteria and Their Relative Weights

Counter (i)	**Evaluation Criteria (Dimension)**	**Relative Weight (w_i)**	**Actual Value ($V_i(B)$)**	**w_i $V_i(B)$)**
1	Collateral Type	60%	$v_1(B)$	0.6 x $v_1(B)$
2	Lender Preference Index	15%	$v_2(B)$	0.15 x $v_2(B)$
3	Total Asset of Borrower	10%	$v_3(B)$	0.1 x $v_3(B)$
4	ROI of Borrower	5%	$v_4(B)$	0.05 x $v_4(B)$
5	Market share of Borrower	5%	$v_5(B)$	0.05 x $v_5(B)$
6	NPL Position of Borrower	5%	$v_6(B)$	0.05 x $v_6(B)$
V(B)				$\sum_{i=1}^{6} w_i v_i(B)$

In our work static haircut is proposed as stated in [66]. The interest rate to be offered depends of the overall value function of the aforementioned criteria. For this work we propose the interest rate r as follows:

$$r = r_{0+(100-V(B))\%}$$

Where r is the proposed interest rate, r_0 is the minimum interest rate set by the central bank, and V(B) is the overall value function.

Step 4: Finally LA offers the above haircut and interest rate for the bid. The LRA takes proposal of LA to BA.

5.2.3 PHASE 3: LENDER SELECTION

In this phase the bank in need of liquidity compares the offers of all bidders according to their static information and their offers. In order to minimize risk the borrower should analyze the information provided, rank bidders and decide to borrow from the one which scores best according to MAUT. Lender selection phase passes the following steps:

Step 1: In this step, **Borrower Agent (BA)** prepares decision matrix as shown in Table 5.2 based on lender selection criteria collected from **Lender Roaming Agent (LRA)** and **Liquidity Coordinating Agent (LCA)**.

Table 5.2: Decision Matrix for Lender Selection

Counter (i)	**Evaluation Criteria (C_i)**	**Weight (w_i)**	**Actual Value ($V_i(L_j)$) of Lenders**				
			L1	**L2**	**L3**	**…**	**Lm**
1	C_1	w_1	$V_1(L_1)$	$V_1(L_2)$	$V_1(L_3)$	…	$V_1(L_m)$
2	C_2	w_2	$V_2(L_1)$	$V_2(L_2)$	$V_2(L_3)$	…	$V_2(L_m)$
3	C_3	w_3	$V_3(L_1)$	$V_3(L_2)$	$V_3(L_3)$	…	$V_3(L_m)$
…	…	…	…	…	…	…	…
N	C_n	w_n	$V_n(L_1)$	$V_n(L_2)$	$V_n(L_3)$	…	$V_n(L_m)$
$V(L_j)$			$\sum_{i=1}^{n} w_i v_i(L_1)$	$\sum_{i=1}^{n} w_i v_i(L_2)$	$\sum_{i=1}^{n} w_i v_i(L_3)$	…	$\sum_{i=1}^{n} w_i v_i(L_m)$

In Table 5.2 L_j represents j^{th} lender participating in the bid, C_i is the i^{th} evaluation criteria, and w_i represents the relative weight of C_i in evaluating lenders participating in the bid. The borrower makes decision by comparing overall value function of lenders.

In our work seven evaluation criteria are proposed to select appropriate lender. This list of criteria and their proposed relative weights are shown in table 5.3.

Table 5.3: Proposed Lender Selection Criteria and Their Relative Weight

No	**Evaluation Criteria (C_i)**	**Weight (w_i)**	**Actual Value ($V_i(L_j)$) of Lenders**				
			L1	**L2**	**L3**	**…**	**Lm**
1	Haircut	30%	$V_1(L_1)$	$V_1(L_2)$	$V_1(L_3)$	…	$V_1(L_m)$
2	Interest Rate	40%	$V_2(L_1)$	$V_2(L_2)$	$V_2(L_3)$	…	$V_2(L_m)$
3	Lender's Total Asset	5%	$V_3(L_1)$	$V_3(L_2)$	$V_3(L_3)$	…	$V_3(L_m)$
4	ROI of Lender	5%	$V_4(L_1)$	$V_4(L_2)$	$V_4(L_3)$	…	$V_4(L_m)$
5	NPL of Lender	5%	$V_5(L_1)$	$V_5(L_2)$	$V_5(L_3)$	…	$V_5(L_m)$
6	BPI	10%	$V_6(L_1)$	$V_6(L_2)$	$V_6(L_3)$	…	$V_6(L_m)$
7	Market Share of Lender	5%	$V_7(L_1)$	$V_7(L_2)$	$V_7(L_3)$	…	$V_7(L_m)$
$V(L_j)$			$\sum_{i=1}^{7} w_i v_i(L_1)$	$\sum_{i=1}^{7} w_i v_i(L_2)$	$\sum_{i=1}^{7} w_i v_i(L_3)$	…	$\sum_{i=1}^{7} w_i v_i(L_m)$

Step 2: BA (Borrower Agent) computes overall value function $V(L_j)$ for each participating bank. Then it ranks all bidders based on the computed overall value function.

Step 3: In this step BA computes the cost of borrowing and compares with the delay cost. Besides, it checks the settlement agreement in the intraday liquidity

management game. If the computed delayed cost is greater than the cost of borrowing, BA awards the winner of the bid to start negotiation and sign contract.

5.2.4 PHASE 4: NEGOTIATION

During negotiation phase, the borrower and the lender deal with terms of transaction settlement. Since the details of negotiation such as credit risk analysis on the lender side, borrowing risk analysis on the borrower side, ranking of bidders, MAUT based decision making, etc. are done in the previous two phases, the negotiation phase deals with the contractual agreement to be made between the borrower and the selected lender. It is the termination of auction, which transfers the fund to the borrower and collateral to the lender, and there by solve the liquidity problem.

Commonly used agreement in interbank lending, is the Standard Repurchase Agreement (SRA) [56]. As Per the SRA, the Borrower Agent performs the contractual Agreement with the Lender Agent.

5.2.5 PHASE 5: COLLECTION

This phase is the post interbank lending phase. It deals with repurchase of the collateral. In this phase the borrower bank receives the collateral back upon paying the loan. Collection phase passes the following steps:

Step 1: Loan Re-Paying Agent (LRPA) checks available fund in borrower account, and if there is excess fund, it approaches the Collection Agent (CA) to get back the collateral.

Step 2: Upon receiving repurchase request from CA, Lender Agent (LA) checks terms of payment, calculates interest and other deduction. Then it receives the cash and provides the collateral.

5.3 SUMMARY

Since the problem of intraday liquidity management requires interaction and negotiation of participating banks, it falls in the interaction level of agent technologies and techniques. Besides, as stated in related literature review Chapter, the automation of interbank lending requires cooperative multi-agent negotiation because interbank lending possesses multi-dimensions. Hence MAUT is chosen as decision analysis tool, and MAUT based MAILS model is developed. The approach followed in the development of interbank lending model is illustrated in Figure 5.2.

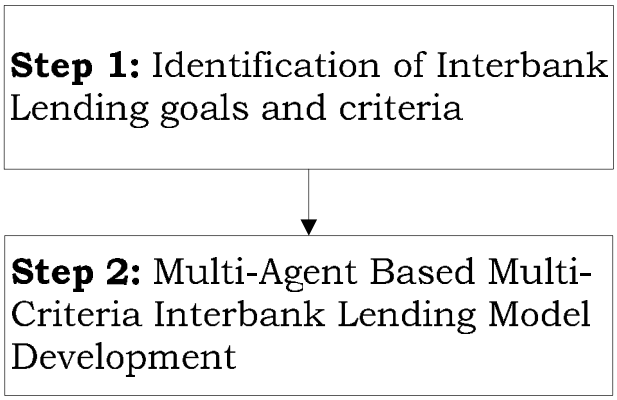

Figure 5.2: Interbank Lending Model Development Approach

Among different approaches of intraday liquidity management, collateralized interbank lending regime is chosen and dealt in our model for its main advantage that it is safe. The model development steps we followed are described as follows:

The first step explains goals and criteria in interbank lending. These goals and criteria are helpful to determine the type of agent negotiation to be used in interbank lending model. According to the interbank lending criteria, cooperative type of negotiation is required to develop interbank lending model. Specifically Multi-Attribute Utility Theory is deployed in multi-criteria interbank lending model development.

The second step states the interbank lending model. Interbank lending involves two-sided credit risk, i.e., a lender risk and a borrower risk for which banks are

exposed in lending and borrowing respectively. Hence the proposed interbank model tries to reduce risks through a thorough analysis of lending and borrowing. The proposed interbank lending model uses Multi-Criteria Utility Theory (MAUT) to make lending and borrowing decisions.

6. IMPLEMENTATION

This Chapter presents a prototype for Multi-Agent Interbank Lending System (MAILS). To this end the Chapter is organized into four sections. The first section presents scope of the system that is implemented in our work, and deals with development tools used in the implementation. The second section describes development process of Multi-Agent based Interbank Lending System (MAILS). The third section presents running examples that demonstrate the results of the system for a given input. The last section summarizes the Chapter.

6.1 SCOPE AND DEVELOPMENT TOOLS

6.1.1 SCOPE OF THE PROTOTYEPE

This thesis implements only the interbank lending portion of the framework. The two interbank lending triggers, i.e., shortage of liquidity to meet the minimum requirement and comparing of outgoing payments with the existing amount are not implemented. Instead the user is provided Graphical User Interface (GUI) to initiate borrowing bid. On the other hand the information about lender banks are taken as input from the user through Lender Agent GUI. Our prototype of MAILS deploys two agent types, i.e., Borrower Agent and Lender Agent.

The prototype (MAILS) has the following basic functionalities:

Information Maintenance: MAILS provides an interface to maintain information about borrowers. It also allows recording of information about lenders, who have idle fund. The information recorded about borrowers and lenders includes static information about a bank, and borrowing or lending factors. The information to be maintained here is assumed to be authenticated by third party; central bank.

Bid Floating: This functionality helps the borrowing agent to locate lenders, and send CFP to all of them. Then the borrower expects lending proposals from lenders. The proposal should contain information that is helpful to evaluate the

lender. The information includes haircut, interest rate, total asset, ROI, NPL position, market share, etc. of a lender participating in a bid. Up on receiving all proposals from lender banks, MAILS starts bid evaluation.

Proposal Preparation: Lender banks evaluate borrowing request and propose haircut and interest rate that can make them profitable. In doing so bidders require information about the borrower like bank code, bank name, total asset, ROI, NPL position, LPI, etc.

Bid Evaluation (Lender Selection): This is the core functionality provided by MAILS. It is evaluation of lenders based on multi-criteria and choosing the winner. After receiving proposals from all eligible lenders, the borrowing agent evaluates each lender based on multi-criteria and selects the one with highest score.

Award Provision: After choosing the winner of borrowing bid, MAILS sends award notification to the winner bank in order to start negotiation.

Award Reception: After providing lending proposals, lender banks expect bid evaluation result. When one of the lenders receives an award, it sends negotiation message.

Negotiation: The prototype concludes at this point, i.e., after receiving the agreement from award winner.

6.1.2 DEVELOPMENT TOOLS

Development tools used to implement MAILS are the following.

JADE 3.5 (Java Agent DEvelopment) Framework: is a framework to develop multi-agent systems in compliance with the FIPA specifications. JADE is a middleware fully implemented in Java language. It simplifies the implementation of multi-agent systems that complies with the FIPA specifications. The agent platform can be distributed across machines and the configuration can be controlled via a remote GUI. The configuration can be even changed at run-time by moving agents from one machine to another one.

NetBeans IDE 6.1: NetBeans IDE is a modular, standard-based integrated development environment (IDE), written in the Java programming language. NetBeans IDE runs on the J2SE (Java SE Development Kit) JDK 5.0 and higher, which consists of the Java Runtime Environment plus developer tools for compiling, debugging, and running applications written in the Java language.

6.2 SYSTEM DESIGN METHODOLOGY

In designing MAIPS system, a Framework for Evaluating Agent-Oriented Methodologies in [40] is reviewed to choose the one that spans all phases of agent-oriented software design. Accordingly the surveys and comparisons on Agent-Oriented Software Engineering Methodologies made in [41, 42] are also referred for final decision of the design methodology. These papers surveyed and compared some of the existing AOSE methodologies like i*, Kaos, Tropos, Gaia, AUML, Prometheus, MASE, SODA and PASSI. As a result of which, Tropos is found to be a preferable methodology as it has high building blocks coverage, high analyzability, high complexity management, better modularity, best life cycle coverage and good domain applicability. Moreover, its modeling and notation is clear, easy to use and easy to learn. Thus the Tropos Agent-Oriented Software Engineering Methodology is adopted in designing the MAIPS System.

The Tropos Methodology is intended to support all analysis and design activities in agent-oriented software development [43]. Even if the first two phases belong to Requirement Analysis, Tropos methodology incorporates four major development phases namely, Early Requirements Analysis, Late Requirements Analysis, Architectural Design, and Detailed Design. Hence, in designing the MAIPS system, we have followed the Tropos Methodology approach as shown in Figure 6.1.

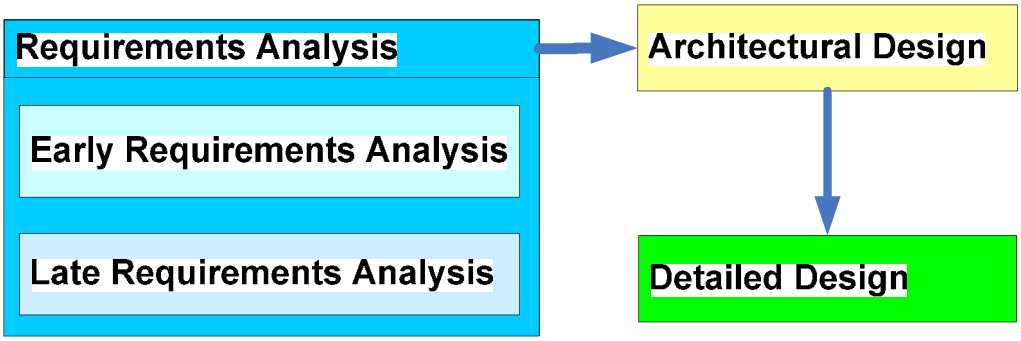

Figure 6.1: Phases of the system design process

Requirements Analysis represents the initial phase and in Tropos it provides functional and non-functional requirements of the system-to-be. Tropos splits this phase into two, i.e., Early Requirements Analysis and Late Requirements Analysis.

During **Early Requirements Analysis** phase, domain stakeholders are identified and modeled as social actors who depend on one another for goals to be achieved, plans to be performed, and resources to be furnished. Defining these dependencies helps to state the **why** of the system, beside to the **what** and the **how** of the system.

In the **Late Requirements Analysis** phase, the conceptual model is extended to include new actors representing the system and dependencies with other actors of the environment.

Architectural Design phase defines global architecture of the system in terms of subsystems, interconnected through data and control flows. Subsystems are represented as actors, and data/control interconnections are represented as dependencies. Architectural design also provides mapping of system actors to set of software agents.

The Detailed Design phase aims at specifying agent capabilities and interactions.

6.3 DEVELOPMENT PROCESS

The Development process deals with the steps accomplished in developing Multi-Agent based Interbank Lending System (MAILS). In developing MAILS, the AOSE methodology of Tropos is adopted.

6.3.1 EARLY REQUIREMENTS ANALYSIS

In our prototype, involving stakeholders and their intentions are stated as follows:

Central Bank: is a government agency whose objective is to create reserve account for participating banks, maintain collaterals of banks, and maintain standard margins of collaterals.

Lender Bank: is a licensed bank with excess liquidity and can provide cash to other banks.

Borrower Bank: is a licensed bank with shortage of liquidity, which searches liquidity from borrowers by availing acceptable collateral.

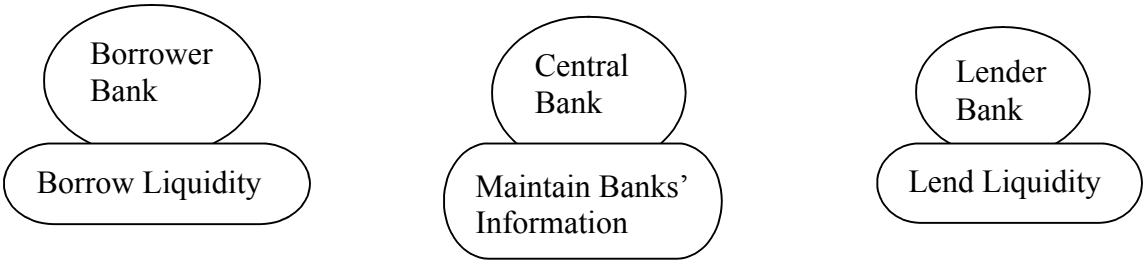

Figure 6.2: Actor Diagram Modeling of MAILS

Figure 6.2 shows Actor Diagram Model of MAILS, where actors and their intentions are represented. The representation of each symbol used in this Chapter such as circle for actor, rounded rectangle for hard goal, etc, is detailed in Annex A. The description of the above diagram is as follows:

Central bank has hard goal *Maintain Banks' information*, which stores the reserve amount of participating banks, their collaterals, their balance sheet, NPL position, etc.

Lender bank has hard goal of *Lending Liquidity* for banks and earn profit.

Borrower bank has hard goal of *Borrowing Liquidity* to fulfill the minimum requirement of fund and effect outgoing payments.

6.3.1.1 MEANS-END ANALYSIS AND GOAL/PLAN DECOMPOSITION

After the identification of stakeholders with their goals and social dependencies, the analysis takes place so as to analyze the rational of each goal with respect to the associated stakeholder. This analysis is done through means-end analysis and goal/plan decomposition. The means-end analysis is used to identify plans, resources and soft goals that provide means for achieving the hard goal.

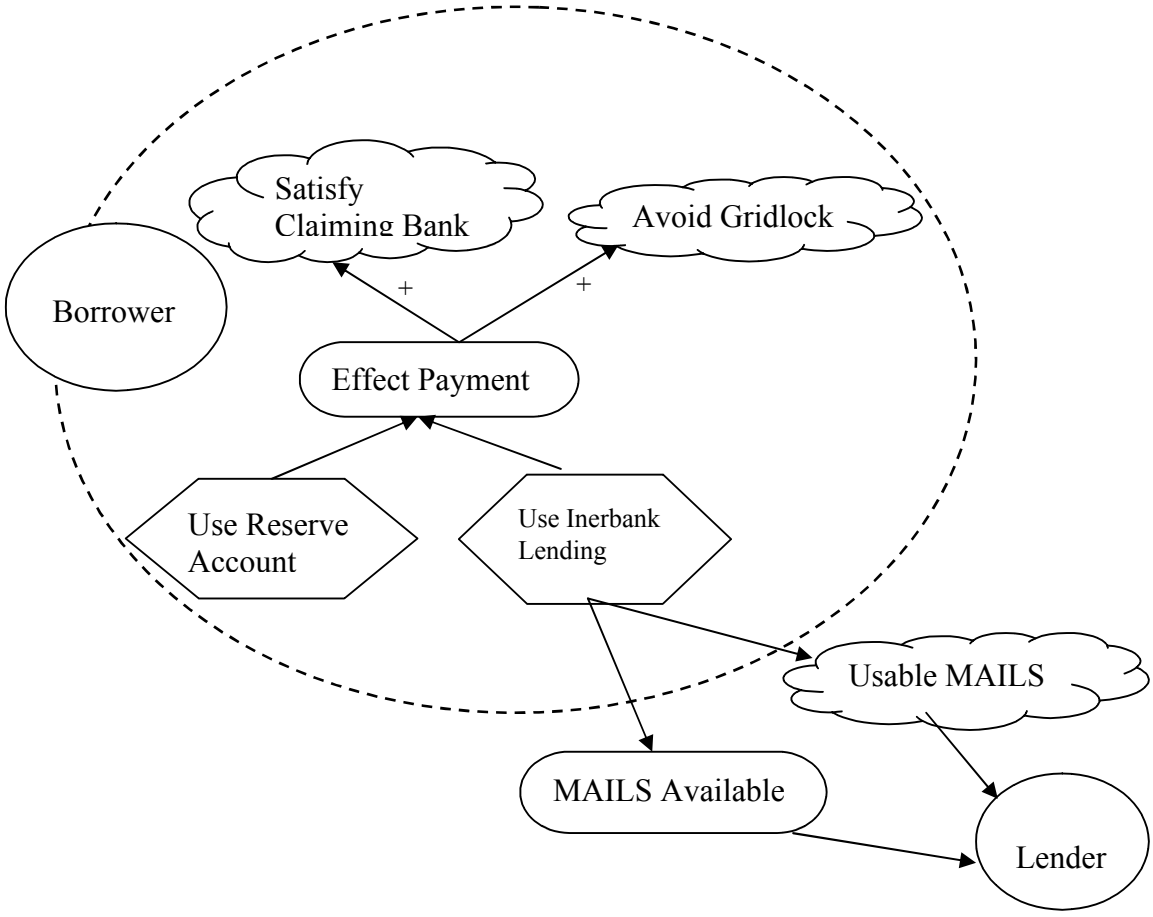

Figure 6.3: Goal Diagram for Borrower

Figure 6.3 shows the perspective of actor **Borrower**. In the perspective of actor Borrower, the goal *Effect Payment* can be fulfilled through either of the two means, i.e., using reserve account if it has enough fund to cover or through

borrowing from other banks. These two sub plans are means to achieve the goal: *Effect Payment*. The sub plan *Use Interbank Lending* is the one to be dealt with in this study, and it is a reason for interdependency between Borrower and Lender: *MAILS Available* and *Usable MAILS*.

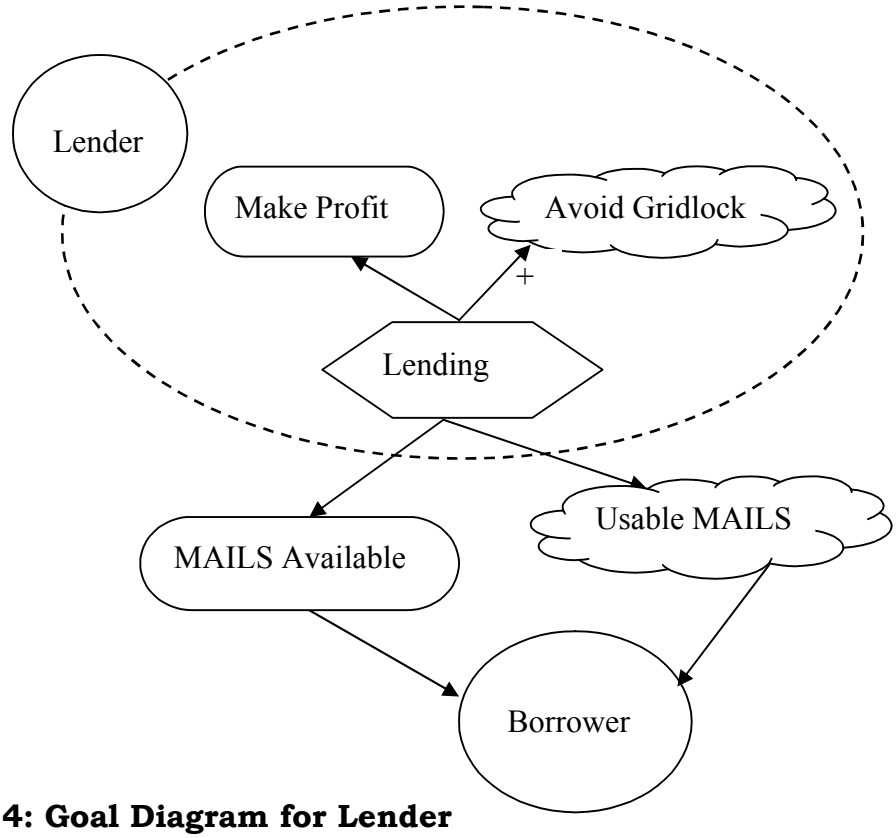

Figure 6.4: Goal Diagram for Lender

Figure 6.4 shows the perspective of actor Lender. In the perspective of actor Lender, the goal *Make Profit* can be achieved through plan *Lending* to banks. *Lending* to banks in interbank market is fulfilled by the help of the two goals: *MAILS Available* and *Usable MAILS*. These two goals are means for interdependency between lender and borrower.

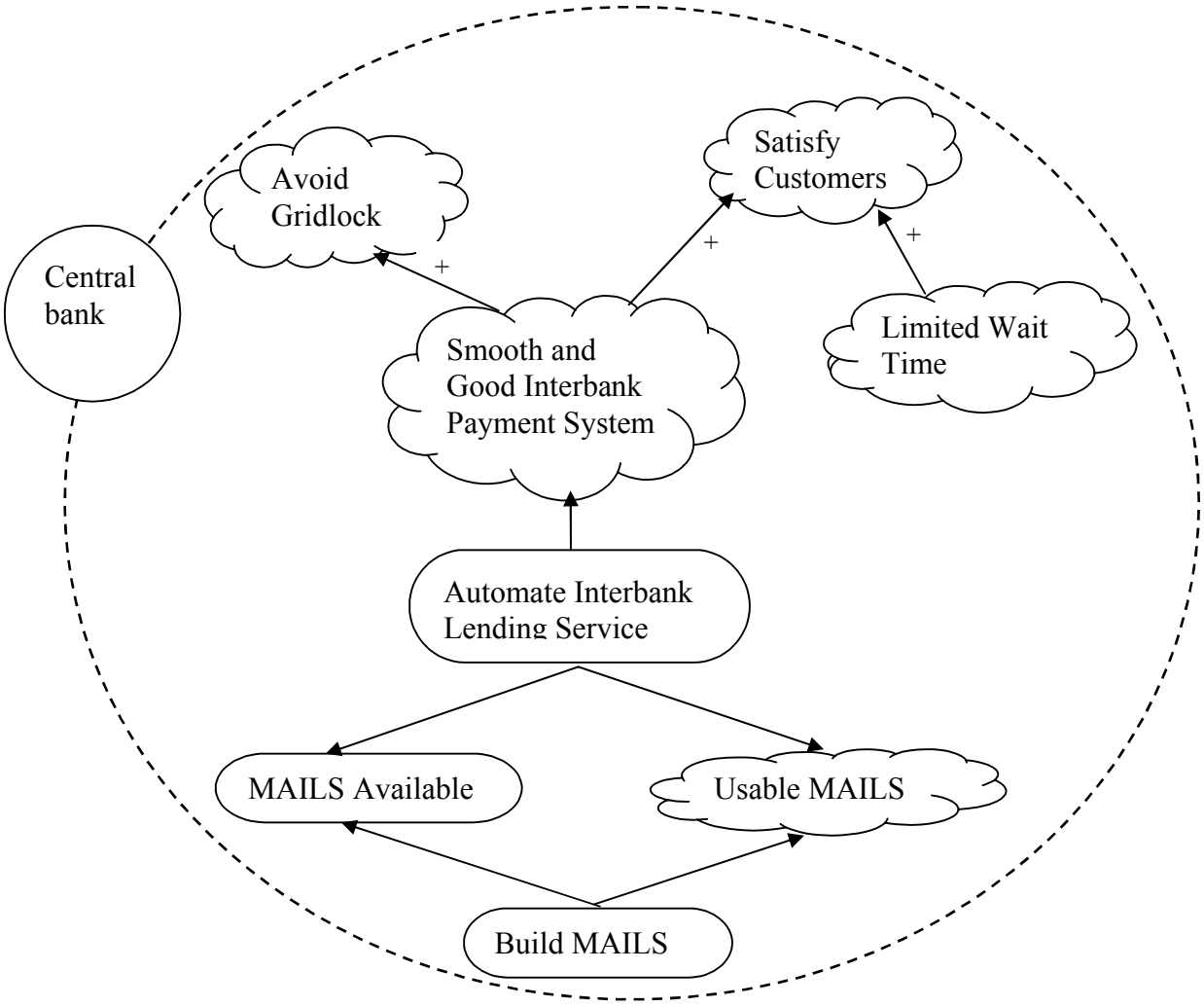

Figure 6.5: Goal Diagram for Central Bank

Figure 6.5 shows the perspective of actor Central Bank. In the perspective of actor Central Bank, the goal *Automate Interbank Lending Service* is achieved through sub goals: *MAILS Available* and *Usable MAILS.* The goal *Build MAILS* is motivated by soft goal *Usable MAILS and* goal *MAILS Available.* In this goal diagram soft goals *Smooth and Good Interbank Payment System* and *Limited Wait Time* positively contribute to the soft goal *Satisfy Customers*. Moreover soft goal: *Smooth and Good Interbank Payment System* positively contributes to the soft goal *Avoid Gridlock*.

6.3.2 LATE REQUIREMENTS ANALYSIS

This phase focuses on the system-to-be within its operating environment. In this regard MAILS is represented as an actor, and its actor diagram is drawn including all required goals, plans, and dependencies with other actors. So as to clearly visualize *MAILS*, its goal diagram is depicted in Figure 6.6. The soft goals of the system are not stated here as they are beyond scope of this prototype.

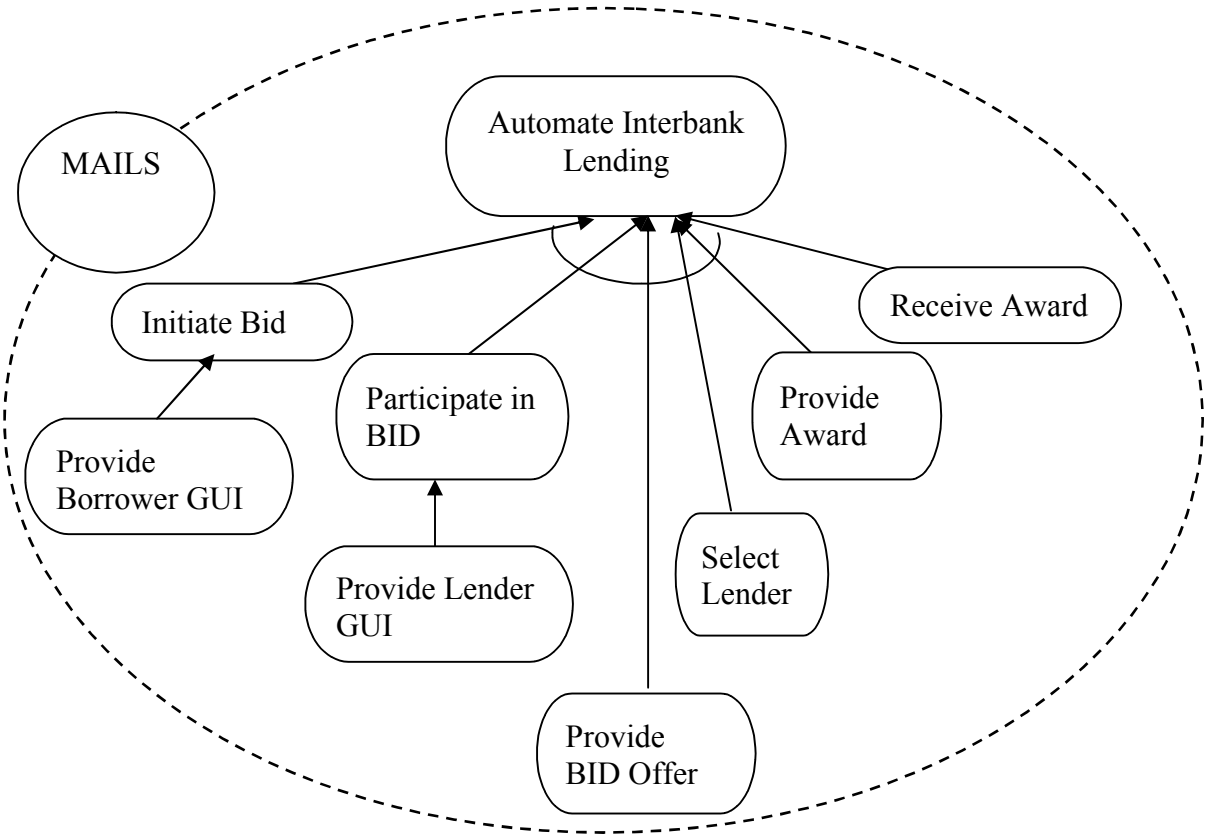

Figure 6.6: Goal Diagram of MAILS

Figure 6.6 shows the set of hard goals that *MAILS* should achieve. The main goal of *MAILS* is to *Automate Interbank Lending.* The hard goal analysis of *MAILS* revolves around this main goal. The *Automate Interbank Lending* goal is decomposed (AND Decomposition) into six sub goals: *Initiate Bid*, *Participate in Bid, Provide Bid Offer, Select Lender, Provide Award* and *Receive Award.*

The sub goal *Initiate Bid* is concerned with the need of borrowing liquidity. As it is mentioned in the scope of the prototype, it is initiated by the user. Hence

this goal is achieved through providing user interface to float bid regarding need of liquidity. It is responsible to achieve the following goals:

i. Preparation of bid form that shows the name of bank, amount of liquidity, duration, collateral, borrower total asset, borrower NPL, etc.
ii. Searching for available lenders
iii. Floating Bid, i.e., sending CFP to lenders

The goal *Participate in Bid* is concerned with availing fund for lending. In order to participate in bid, the sub-goal: *Provide Lender GUI* is required. The sub goal *Provide Lender GUI* is concerned with receiving information about the lender.

The goal *Provide Bid Offer* is concerned with continuously listening for CFP, and performs feasibility analysis provided that the bank has idle fund that can cover the requested amount. And if it is feasible, it proposes haircut and interest rate.

The *Select Lender* deals with evaluating bidders based on pre-set multi-criteria and selecting the one that wins the bid.

Sub-goals *Provide Award* and *Receive Award* are concerned with communication between the winner and the borrower.

6.3.3 ARCHITECTURAL DESIGN

In this phase MAILS global architecture is defined as shown in Figure 6.7. The phase also identifies capabilities of agents needed to fulfill their goals and plans. This shows the behaviours of agents, triggering events for change of behaviours, interdependency relationships of agents, etc.

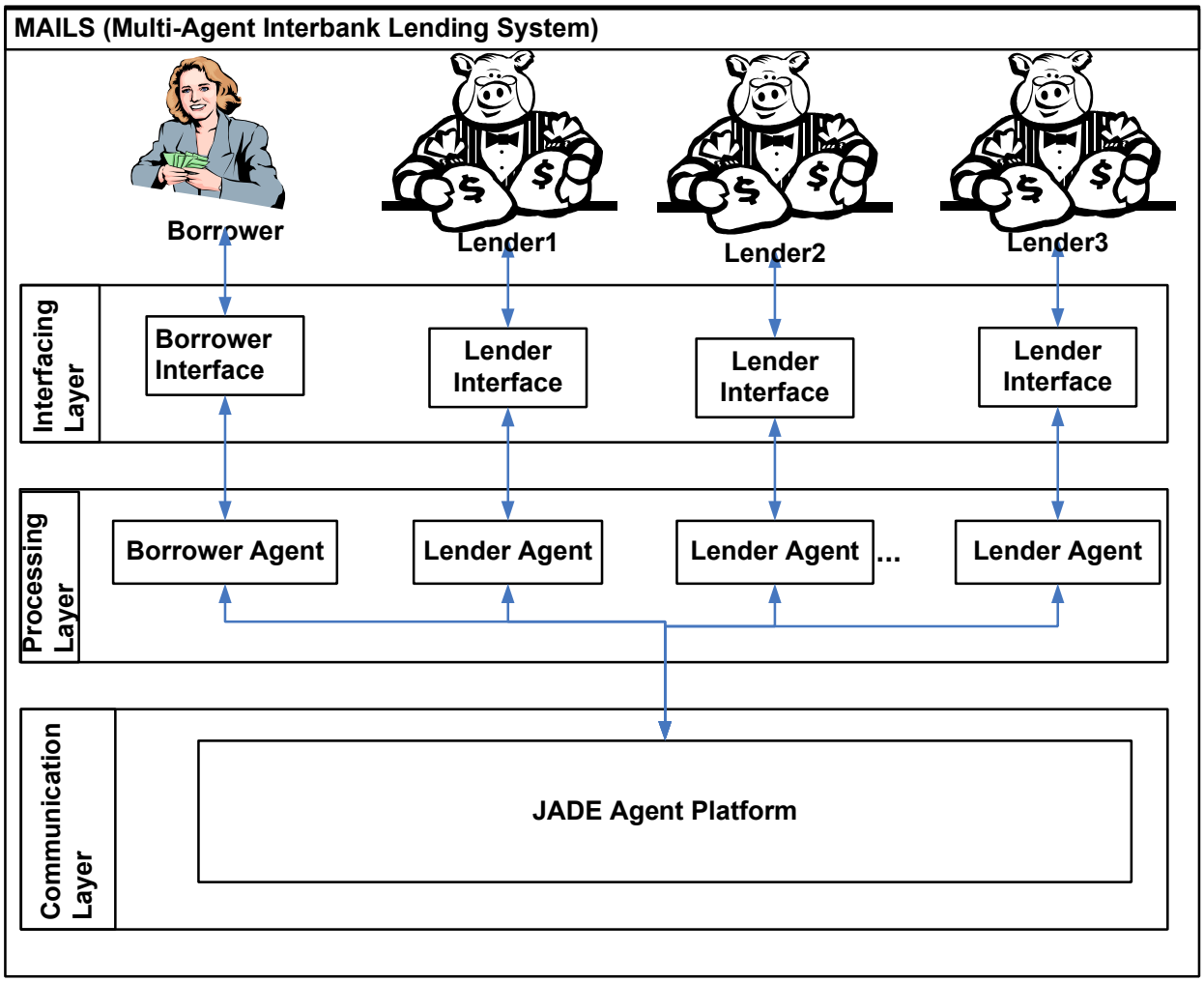

Figure 6.7: Architectural Design of MAILS

Figure 6.7 depicts layers of the framework demonstrated in our prototype. As stated in our framework the *Interfacing Layer* provides an interface for system users and other systems. The *Interfacing Layer* provided by MAILS implements *BorrowerAgentGui* as user interface of borrower and *LenderAgentGui* as user interface of lender bank. These two interfaces also simulate *Central Bank's Database* that integrates with MAILS. The central bank's database provides facts about banks in interbank lending. The *Processing Layer Implements* actual agents required in the prototype. These agents interact with the simulator of central bank database, i.e., user interface to retrieve information required to make lending or borrowing decision. The third layer: *Communication Layer* implements agents' interaction. The implementation issues in each layer are discussed as follows:

A. Interfacing Layer

BorrowerAgentGui: This GUI simulates components of the *Interfacing Layer*, i.e., *User Interfacing* and *System Integration.* In simulating the *user interfacing* sub-layer, it allows the borrower to enter its code, name, collateral type, liquidity amount required, and duration. In the case of simulating *System Integration,* it acts as *Central Bank's Database* that provides reliable information like market share of borrower, ROI of borrower, NPL position of borrower, registered collateral, etc. to the lending bank.

LenderAgentGui: Like BorrowerAgentGui, this GUI simulates components of the *Interfacing Layer* on the lender bank side. In simulating the *user interfacing* sub-layer, it allows the lender to enter its code, name, and liquidity amount availed. In the case of simulating *System Integration,* it acts as *Central Bank's Database* that provides reliable information about the lender such as market share of lender, ROI of lender, NPL position of lender, etc. to the borrowing bank.

B. Processing Layer

This layer implements actual workers of interbank lending. It is composed of two types of agents: **Borrower Agent** and **Lender Agent**. Detailed capabilities of these agents are stated as follows:

Lender Agent: This agent simulates the roles of lending bank. It is initiated by the user. It takes lender bank information from the user and avails its liquidity for lending. When borrowing bank sends CFP, it analyzes and sends proposal. Finally it receives award provided that it won the bid.

Borrower Agent: This agent simulates the roles of borrowing bank. It is initiated after the liquidity shortage is identified. However, in this prototype the user explicitly invokes this agent, instead of Intraday Liquidity Managing Agent (ILMA), as implementation of ILMA is beyond the scope of this prototype. The Borrowing Agent (BA) is supposed to invite potential lenders to participate in bid, compare their offer and select appropriate lender. It performs the following to secure liquidity.

a. Bid floating (or sending CFP to potential lenders)
b. Receiving bid offers
c. Bid Evaluation
d. Award Provision
e. Negotiation

6.3.4 DETAILED DESIGN

The detailed design phase deals with the specification of agents' capabilities, behavior, interaction, communication etc. This phase depends on the agent development environment, agent communication language and other related specifications. Thus our work of implementation deals with interaction diagram, agent communication, and agent tasks.

6.3.4.1 AGENT INTERACTION DIAGRAM

The interaction diagram helps to visualize behavior of the system when it exchanges message with different involving objects. It is modeled using UML sequence diagram. In the diagram agents correspond to objects, the long narrow rectangle represents life-line of objects, and the communication between agents correspond to asynchronous message arcs. The agent interaction diagram of MAILS is illustrated in Figure 6.8. But note that lender agents need to be created before the interaction gets started.

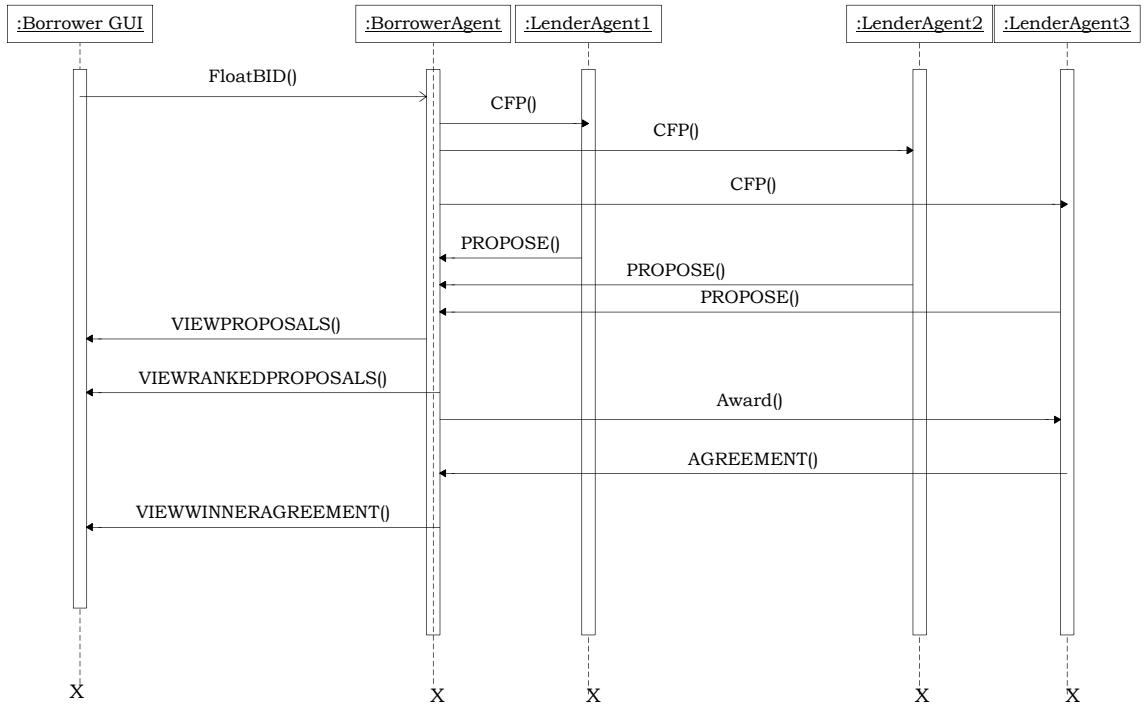

Figure 6.8: Agent Interaction Diagram of MAILS

In figure 6.8 the user first fills information of borrower, i.e., static information of borrower, rated information of borrower, and other loan information. This initiates the Borrowing Agent (BA) to float bid of liquidity borrowing. BA sends Call For Proposal (CFP) (or bid document) to all ready Lender Agents (LA). Then these LA makes analysis and proposes their haircut and interest rate. Up on receiving the proposal from Lender Agents, the Borrower Agent performs bid evaluation and communicates the winner. Finally the winner sends its agreement message.

6.3.4.2 AGENT COMMUNICATION

Agent communication is the fundamental characteristic of multi-agent systems. According to FIPA specifications [44], agent communication deals with Interaction Protocols (IPs), Content Languages (CLs) and Communicative Acts (CAs). The Interaction Protocol (IP) is concerned with the pre-agreed message exchange format for ACL messages. The Communicative Act describes different

utterances for ACL messages. The third component, content language deals with different representations of ACL messages.

Our prototype uses the following among different approaches in agent communication.

Interaction Protocol: There are different types of interaction protocols such as Request Interaction Protocol, Query Interaction Protocol, Recruiting Interaction Protocol, English Auction Interaction Protocol, Dutch Auction Interaction Protocol, etc. Among these interaction protocols English Auction Interaction Protocol is chosen as it satisfies most of the interactions in MAILS.

Content Language: There are three basic types of content representations: (1) **Ontology,** (2) **Java Serialized Objects,** and (3) **String (Simple Message).** As the communication in interbank lending requires independent weighted fields, Java serialized object is chosen for its simplicity.

Communicative Acts: Communicative Acts required in MAILS are the following:

- **Call For Proposal**: The action of calling bidders for proposals to borrow liquidity.
- **Propose**: The action of submitting a proposal to participate in interbank lending bid, given certain preconditions like availability of enough fund to lend.
- **Accept Proposal**: The action of accepting a previously submitted proposal to perform an action.
- **Inform**: The sender informs the receiver that a given proposition is true.
- **Refuse:** The action of refusing to perform a given action, and explaining the reason for the refusal.

6.3.4.3 AGENT TASKS

Agent tasks refer to the actual job that an agent has to do. An agent may have different tasks that should be carried out in parallel or phase by phase. In order to handle such tasks, JADE introduced a concept called **Behaviour**.

Behaviour represents a task that an agent handles when change of state occurs. It is implemented as an object with two methods: *action()* and *done()*. The method *action()* defines operations to be performed, and the *done()* method specifies whether or not a behavior is completed. Among different types of behaviours, the following behaviours are used in the implementation of MAILS.

A. **One-shot Behaviour**: It completes immediately and its *action()* method is executed only once. In MAILS, three operations are implemented using one-shot behaviour: (i) Bid floating, (ii) Award provision, and (iii) Agreement reception from the winner bidder.

B. **Cyclic Behaviour**: It never complete and whose action() method executes the same operations each time it is called. Bid offer provision, and Bid award reception operations of MAILS support cyclic behaviour.

C. **Generic Behaviour**: It embeds a status and execute different operations depending on that status. MAILS implemented generic behaviour bid processing operation. This generic behaviour invokes award provision and agreement reception.

6.3.4.4 INTERFACE DESIGN

This section presents the GUI that helps the users to interact with the system.

Lender Agent GUI: It provides interface to the lender. It helps the user to enter static and weighted information of lender as shown in Figure 6.9.

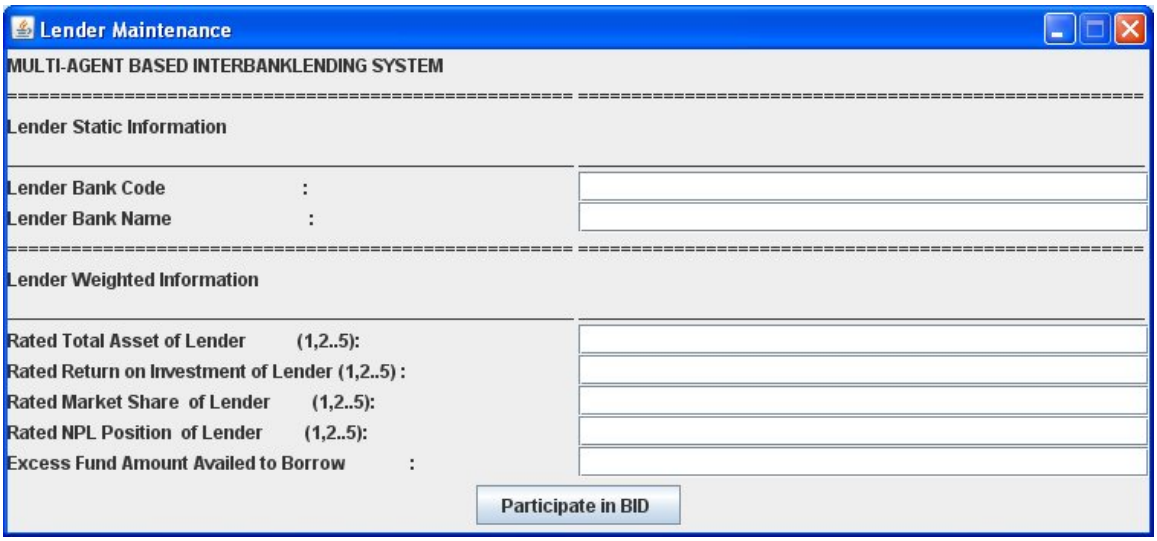

Figure 6.9: Lender Agent GUI

Borrower Agent GUI: It provides interface to borrower. It helps the user to enter static and weighted information of borrower as shown in Figure 6.10.

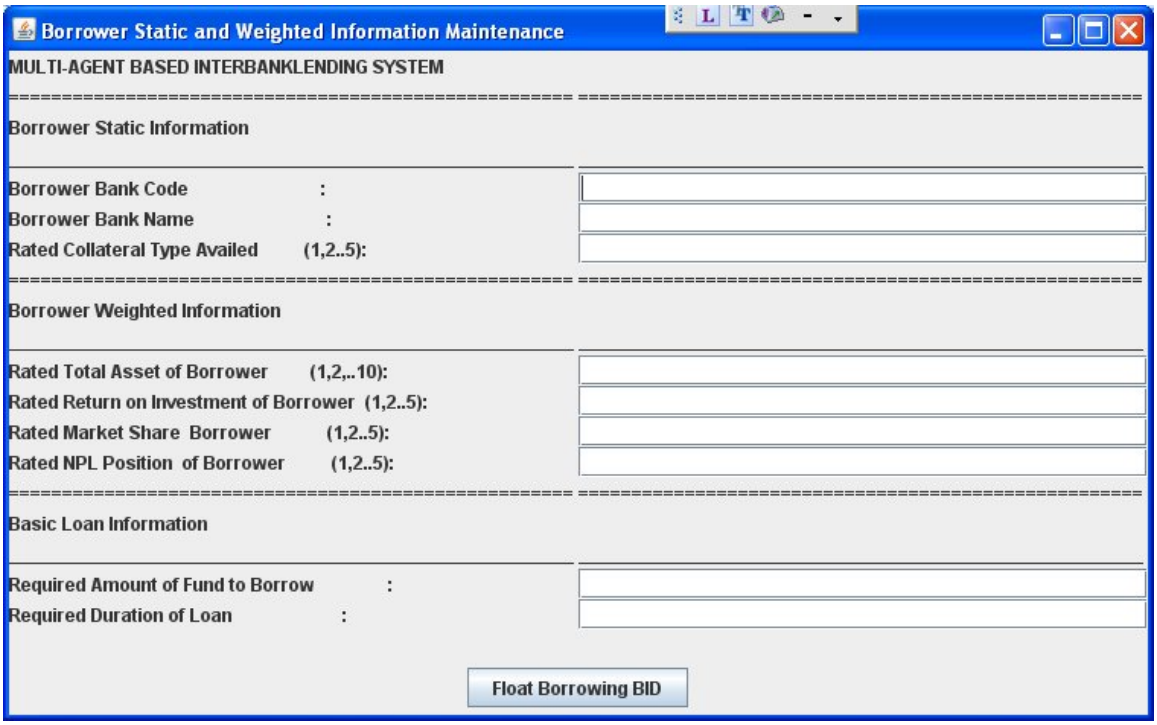

Figure 6.10: Borrower Agent GUI

6.4 RUNNING EXAMPLES

This section demonstrates MAILS using sample data about borrowing and lending banks.

6.4.1 INPUT INFORMATION

The input information for interbank lending comes from both the user and the central bank's database. In our prototype, the central bank's database is simulated by the user and hardcoded information. Input data that cannot be common for a given body like BPI, and LPI are hardcoded. Others that can be read from keyboard are presented as follows:

In order to participate in interbank lending bid, eligible banks should present their static information, weighted information and amount of fund available for lending as shown in table 6.1.

Table 6.1: Lender Banks' Input Data

No.	Code	Name	TA (/5)	ROI (/5)	MS (/5)	NPL (/5)	Fund Availed
1	AIB	Awash International Bank	3	4	3	5	1,500,000
2	BIB	Birhan International Bank	3	4	1	5	500,000
3	CBE	Commercial Bank of Ethiopia	5	4	5	3	4,000,000
4	DB	Dashen Bank	4	5	3	5	2,000,000
5	DBE	Development Bank of Ethiopia	4	3	2	1	1,200,000
6	WB	Wogegen Bank	3	2	3	2	800,000

Borrower bank floats bid by presenting its static information, weighted information and amount of fund to borrow as shown in table 6.2.

Table 6.2: Borrower Bank Input Data

Parameter	Value	Remark
Bank Code	AB	
Bank Name	Abyssinia Bank	
Collateral Type (/5)	5	
Total Asset (/10)	8	
Return On Investment (/5)	4	
Market Share (/5)	3	

Parameter	Value	Remark
NPL Position (/5)	4	
Amount to Borrow	1,000,000	
Duration	5	

6.4.2 PROCEDURE

In order to demonstrate MAILS for the aforementioned input data, one should do the following

1) Install and Configure JADE
2) Copy "InterbankLending" Package to "C:\JADE"
3) Start Command Prompt
4) Change the directory to "C:\JADE\InterbankLending>"
5) Type java jade.Boot –gui and press Enter. Then you will see the JADE Remote Agent Management GUI
6) Expand AgentPlatforms
7) Expand the "Local Name"
8) Activate **Main Container**, and click **Start New Agent** from **Action** menu. The dialog box as illustrated in Figure 6.11 will be displayed.

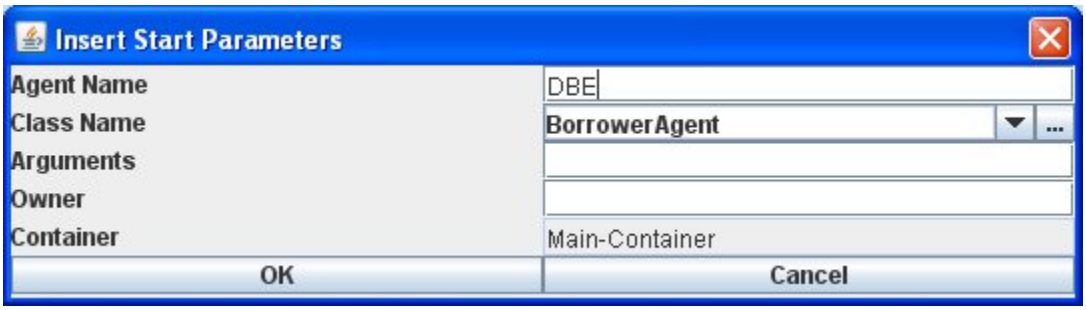

Figure 6.11: New Agent Creation GUI

9) Type Agent Name. In our case use bank code as agent name.
10) Type Class Name. In MAILS there are two agent classes, i.e., **BorrowerAgent,** and **LenderAgent.** If the agent to be created is

borrower agent use class name BorrowerAgent; and if the agent to be created is lender agent use class name LenderAgent.

11) Click OK. The GUI for the created agent will be viewed as shown in Figure 6.9 and 6.10.

12) Insert required parameters into the displayed GUI.

13) Finally click on the respective command button.

6.4.3 OUTPUT

After creating all required agents, and entering the respective input information, the output of MAILS for the aforementioned input will be displayed as illustrated in Figures 6.12-6.14.

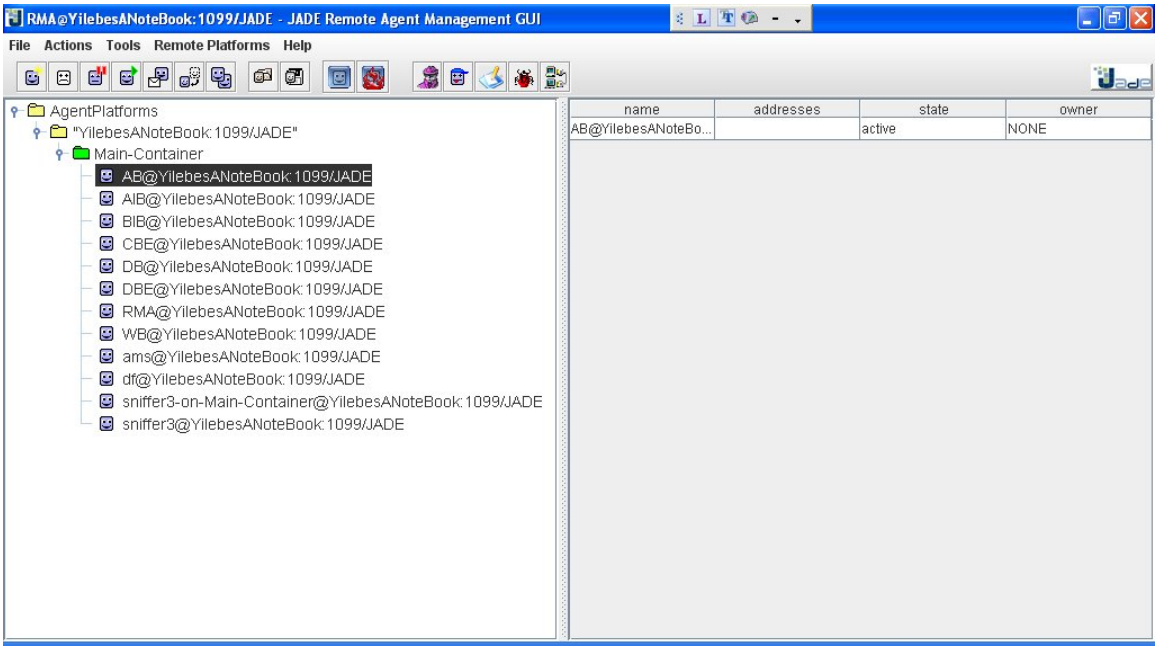

Figure 6.12: Screen shot of built-in and MAILS agents

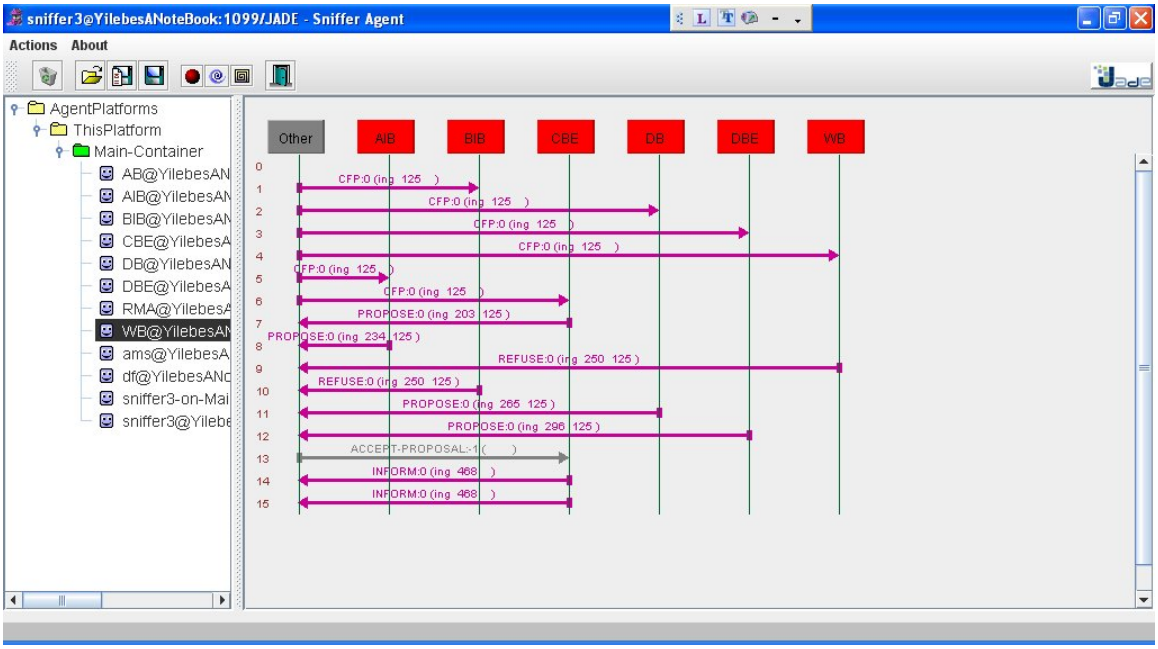

Figure 6.13: MAILS Inter-Agent Interaction

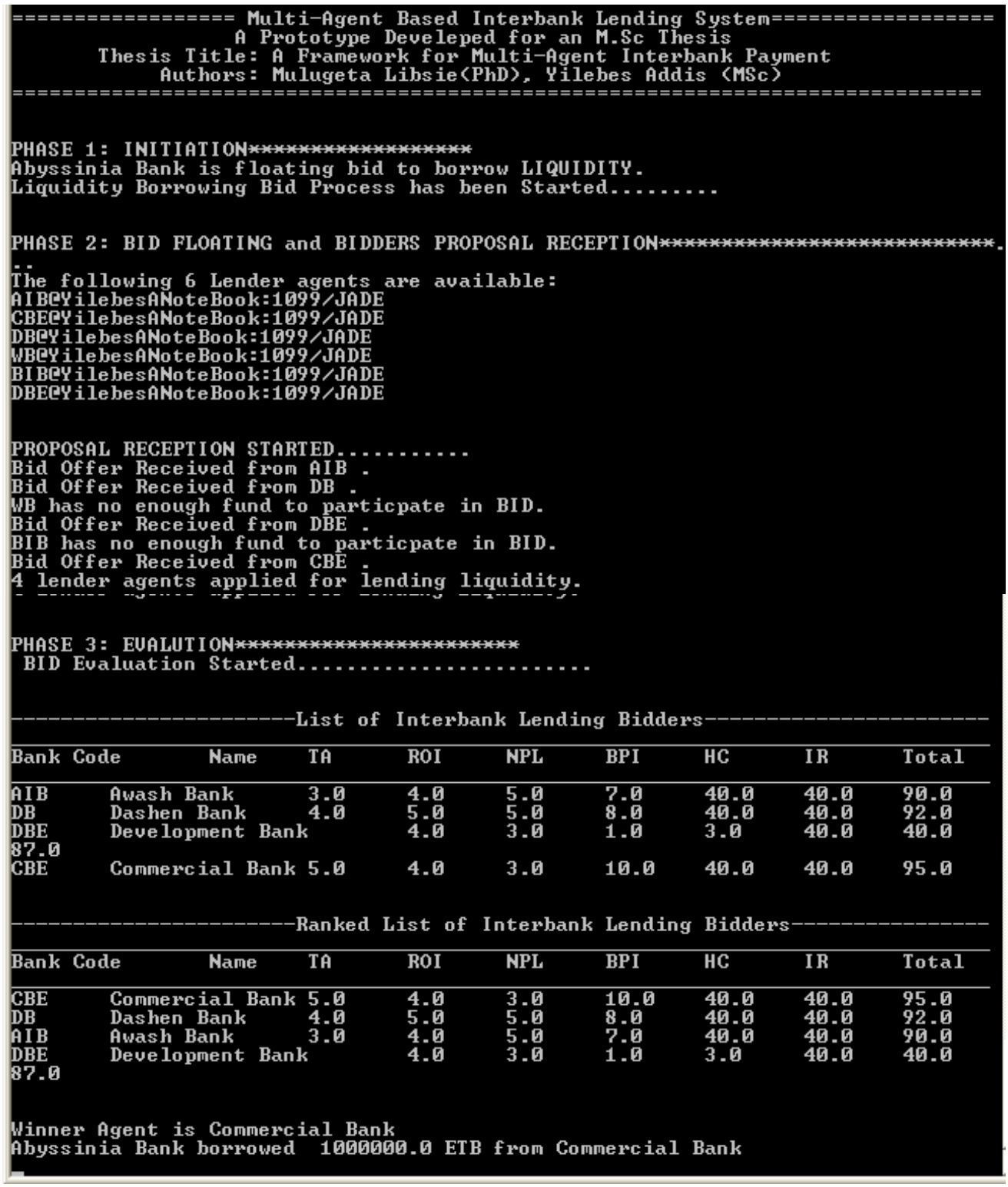

Figure 6.14: MAILS Output

7. CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

The advent of Internet technologies and intelligent electronic devises and their application in the financial sector particularly in banking business has paved the way for the emergence of new type of service provision called e-banking. E-banking has changed the customary way of doing banking business. Among others e-banking has enabled customers to open and manage their account remotely without the need to travel where banks and their branches are physically located. The banking sector and its users, both customers and employees, are widely beneficiaries from this opportunity as this new way of doing business improves the sector's productivity. However, customers are still in need to get service without providing inputs now and then. Service providers are also requiring automation of all their tasks, including those tasks requiring workers' analysis and decision.

Interbank payment and settlement system is one of e-banking services, which transfers funds, and settles them including different negotiable instruments such as cheque, DD, TC, etc. between banks. Interbank payment and settlement process includes transfer of messages, clearance of negotiable instruments, and settlements. Interbank payment and settlement as a process involves different, autonomous and distributed bodies with quite different levels of automation or use of independent legacy systems. Besides, parties involving in interbank payment and settlement face liquidity shortage that leads to the delay of settlement process. When all participating bodies are forced to delay the settlement due to liquidity shortage, gridlock is said to be occurred.

In its attempt to define and present existing interbank payment and settlement process and the associated problem so as to come up with a viable way out, the thesis came up with a conclusion that interbank payment and settlement is a process which needs keeping the autonomy of each involving party on the one hand and the need to facilitate and improve the interbank payment and settlement process on the other.

In order to solve the problems involved in interbank payment and settlement, software agents that are dynamic and intelligent, which can act on behalf of users or other programs by their own are suggested. This final conclusion is concretized through a review of related literatures whose analysis has led to the appropriateness of Multi-Agent System (MAS) to the current problem of the thesis. However, in order to apply this idea in our problem area, there is a theoretical gap as well as MAS development challenges that should be dealt with. Hence this thesis proposed development of framework to fill the gap, reduce design complexity and lay the foundation for multi-agent interbank payment and settlement system developers. Furthermore, we proposed interbank lending model to realize interbank lending automation, and avoid gridlock.

In doing so the thesis has affirmed why software agents are better than other tools for interbank payment and settlement and analyzed and presented components of Multi-Agent based Interbank Payment and Settlement (MAIPS) System. To this end the thesis work has involved in such major tasks as payment system characterization, development of agent based payment system framework, design of interbank lending model and implementation of multi-agent based interbank lending.

Finally, the research has defined and presented the required framework for this appropriate MAIPS system. Accordingly, the thesis developed interbank lending model, which avoids the gridlock problem and intensive human involvement in interbank payment and settlement process. The framework is believed to keep the autonomy of the involved legacy systems while handling intraday liquidity management, and interbank payment system efficiently. Based on the proposed framework and the developed model, the interbank lending prototype is implemented, to show technical feasibility of our recommendation.

7.2 CONTRIBUTIONS OF THE THESIS

The main contributions of this thesis are the following:

A Framework for Multi-Agent Interbank Payment and Settlement Systems is proposed. This framework improves the existing interbank payment and

settlement systems by extending its coverage and avoiding is inherent problems, i.e., intraday liquidity management and gridlock.

The proposed framework states the suitable MAS architecture, which is layered MAS architecture in our case. Three basic layers are proposed: the first layer helps to interface users and integrate other autonomous systems with the interbank payment and settlement system. The second layer performs actual tasks of interbank payment and settlement process. The third layer deals with inter-agent and intra-agent communication in interbank payment and settlement. This framework simplifies design complexity of interbank payment and settlement systems as it provides components to be included, and features of agents to be used.

The other core contribution of this thesis is gridlock avoidance in interbank lending. In interbank lending, both borrowing and lending banks are exposed to risk. Hence both banks should do risk analysis. The proposed interbank lending model filtered out interbank lending goals and criteria. Then lending criteria and borrowing criteria along with their relative weights are proposed. Finally the model for interbank lending is proposed based on Multi-Attribute Utility Theory (MAUT) and FIPA English Auction Interaction Protocol.

Besides this developed model paves the way to use agent based cooperative negotiations with decision analysis tools to automate complex auctions.

7.3 FUTURE WORKS

The thesis has shown that agent technology is applicable in interbank payment and settlement systems development. However, further researches are required for realization of Multi-Agent Interbank Payment and Settlement system. Major areas of research to complement this work are summarized as follows:

Enhancement of FIPA English Auction Interaction Protocol: The protocol specification covers four steps: (i) starting auction, (ii) sending CFP, (iii) Response to CFP (or Proposal), and (iv) Accepting or rejecting proposal. This specification is adopted for interbank lending, and covered starting auction to

loan imbursement (award response reception) phases. However, interbank lending incorporates post lending phases called loan repayment and collection. Hence further study is required to modify the aforementioned interaction protocol.

Improvement of MAILS Model: The proposed interbank lending model requires improvements to fully avoid uncertainties of lenders and borrowers. Particularly, haircut and interest rate determination requires scientific approaches. Therefore, further researches are required to improve lending and borrowing determinants, and decide haircut and interest rate. Besides extra works are required on decision analysis tools appropriate for interbank lending, because we just used MAUT for its simplicity.

Upgrading the Prototype: In our work there are a lot of proposed agents and agent types that can be used to realize MAIPS system. But only few agents are simulated in a limited environment. Hence additional works are required to develop a prototype to implement all proposed agents in distributed environment.

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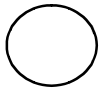
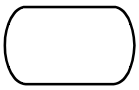
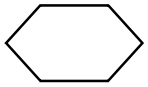
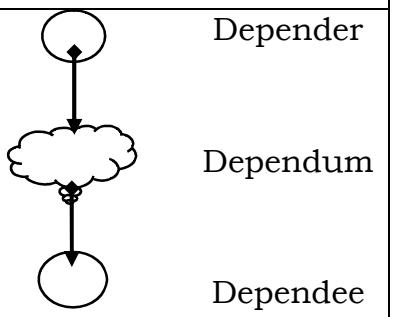
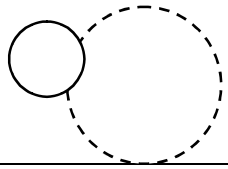
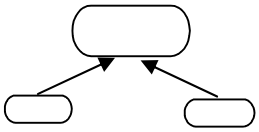
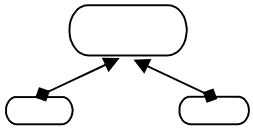
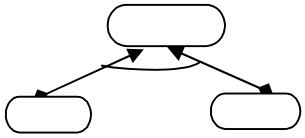
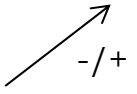
ANNEX A: SYMBOLS USED IN AOSE DEVELOPMENT

Concept	**Symbol**
Actor	
Hard goal	
Soft goal	
Plan	
Soft goal Dependency	
Actor Perspective	
Means-End Analysis	
OR Decomposition	
AND Decomposition	
Contribution	

Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for a degree in any other university, and that all sources of materials for the thesis have been duly acknowledged.

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Yilebes Addis

This thesis has been submitted for examination with my approval as an advisor.

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Mulugeta Libsie (PhD)

Addis Ababa

November, 2009