Modeling Intelligent Decision Making on Electronic Mail Distribution Systems

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Abstract

This paper presents and discusses an economic decision model for electronic mail distribution systems. In order to apply economic decision approaches to an user mail agent community, made of intelligent agents with the aptness to reach lower mail transfer costs, we have imported concepts, adopted parts of a mail system model, designed new components and proposed an Electronic Mail Distribution System based on Multi-Agent Systems technology.

Keywords: Electronic Mail Distribution Systems Modeling, Economic Decision Making, Multi-Agent Systems, Concurrent Engineering, Negotiation.

1 Introduction

Actual *Electronic Mail Distribution Systems* (EMDS) assume a relevant role in most organizations. Activities related to information exchange, product ordering, enterprises' personnel communication, or thematic discussion zones use them as a primer form of communication. Their simplicity of use, low communication costs, easy installation, and the ability to deal with almost every kind of system's information (e.g. text, images, sound) make them powerful and useful tools in human daily activities. There are cases where commercial viability of enterprise's products are affected by the availability, qualification and effectiveness of the EMDS installed, making them critical resources.

EMDS's activities are supported by a very diversified group of computational resources. Host computers, routers, gateways, and high sophisticated communication lines are examples of some of those resources. Their permanent availability, although not strictly necessary, ensures EMDS's best operation and guarantees correct message deliverance inside organizations and worldwide.

2 Electronic Mail Distribution Systems Models

Several EMDS models were designed and developed. However, it is possible to find a generic (sub-)model that all of them have included in their functional structures. Such model is basically made of two subsystems: [1]:

- a *Message Transfer System* (MTS), which integrates one or more *Message Transfer Agents* (MTA) responsible for message transportation;
- the *User Agents* (UA), that act on behalf of the users and ensure interface to the local MTA.

Additionally, we may add a third subsystem constituted by the *Administrative Agents* (AA), that controls and supervise MTA's activities.

In our case we designed a EMDS model (Figure 1) based on the *MH* system - a "Multifarious" User Agent [6] - to which we added some new features. MH is a little more than an UA, it is an electronic mail message handler with several user interface facilities. MH's model considers a group of small programs, designed as agents, that have associated well determined functions. Beyond the user interface agent, basically it is organized into four components:

- a *Database Agent* (DBAg)- that manages the mail messages that the user received;

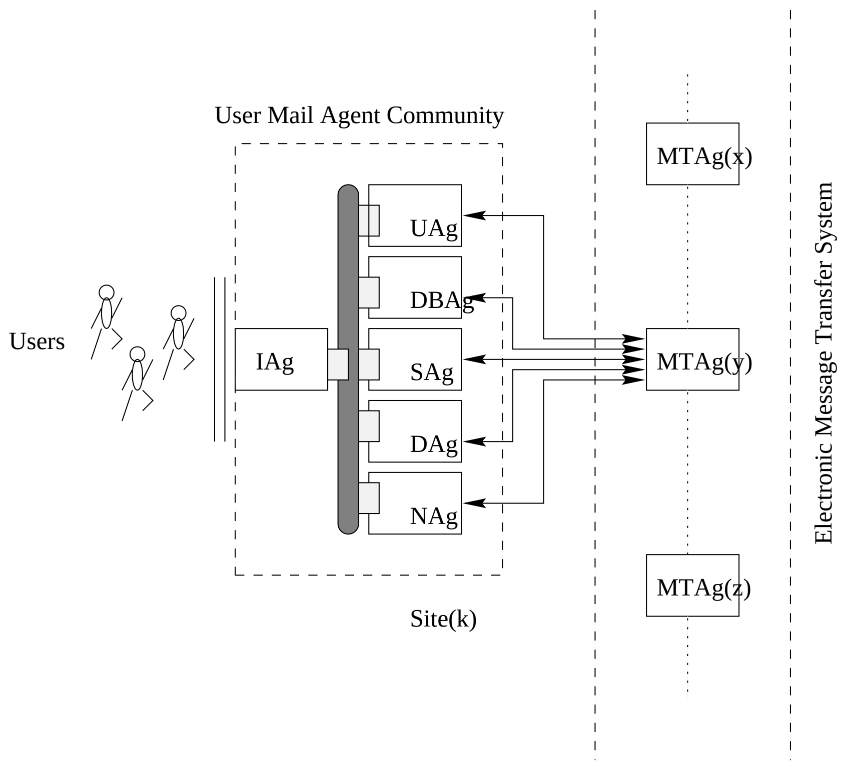

Figure 1: An Electronic Mail Distribution System Model.

- an *User Agent* (UAg) - that provides submission and delivery services;
- a *Directory Agent* (DAg) - that provides for name to address mapping;
- a *Security Agent* (SAG) - that implements authentication and privacy services over mail messages if required.

All these agents were considered in our model. However, they are now included in a user mail agent community sharing a common environment with two other agents:

- a *Negotiation Agent* (NAg) - responsible to develop negotiation processes with the MTA in order to obtain better transportation conditions at lower prices, according to the user mail agent community status and needs of transportation;
- a transformed *Interface Agent* (IAg) - that basically acts as the MH's one but now having conditions to operate as an autonomous agent

integrated in a cooperative agent community.

The agents communicate with each other through messages. They act according their own competences, cooperating with each other every time they have inter-related tasks. The reasons that lead to the design of an user mail agent community, or an user mail *Multi-Agent System*(MAS) [7] [5], are related to the high levels of modularity, decentralized control, scalability and opportunistic behavior that any conventional MAS allows.

3 Applying Economic Decision Approaches

In this paper we do not intend to analyze and discuss the advantages or disadvantages of the presented model. We have imported concepts, adopted parts of a model, designed new components and proposed an EMDS model based on MAS technology with a simple idea in mind: to apply economic decision approaches, conciliated with the ones related to contract net protocols, in order to get an user mail agent community made of intelligent agents with the aptness to reach lower mail transportation costs. Thus, this paper focus on the characterization of the negotiation processes that NAg is able to develop with its local MTA on the MTS. The remaining agents are necessary to support ordinary mail processes and to deliver to NAg the information it needs.

3.1 The Message Transfer System Scenario

The MTS usually involves several *Service Providers* (SPs). Although the connection between a MH system and a MTA is controlled by just one SP, we assume that the NAg can contact any of the other SPs in order to determine dynamically the best provider to deliver a particular mail message. The protocol that is used by the NAgs when choosing the best SPs is the *Contract Net Protocol* (CNP) [10, 4]. This protocol tries to reproduce the negotiations that occur in real markets when a particular entity wants to find the best partner to execute a task. In this protocol we may find two kinds of agents:

- *Managers* - the agents that announce the tasks to be executed (in the *announcing* phase) and afterwards select the best partners according to the bids received (in the *awarding* phase);

- *Contractors* - the agents that execute the tasks and that answer to the announces with a bid that reflects their suitability to their execution (in the *bidding* phase).

In this particular instance of the protocol the *manager* roles will be assumed by the NAgs and the *contractor* roles by the SPs.

The economic principles are applied in the decisions that must be made in the *announcing*, *bidding* and *awarding* phases of the CNP. The use of economic principles in this problem can be justified by the fulfillment of the following conditions [11]:

- the fundamental problem to be solved is one of resource allocation;
- all the involved agents act rationally in order to achieve their most preferred outcomes;
- the decision making is inherently decentralized.

We not address the *bidding* phase of the protocol, i.e., this paper only focus on how the MH system is designed. The approach followed in modeling the *announcing* and *awarding* phases is based in our previous work in the area of resource allocation in multi-enterprise environments [3, 2], which in turn was based in Sandholm work in the area of automated contracting using extensions of the CNP [8, 9].

3.2 An Utility Based Agent

The NAg is modeled as an utility-based agent. The definition of an utility-function provides the ability to quantify the monetary compensation that the NAg is willing to tradeoff for the delivering of a particular message. Let $C(t)$ be a function that represents the available cash at instant t. Let $P_i(t)$ be a function that assesses the value of a specific parameter i that influences the level of satisfaction of the NAg's owner (a possible parameter is, for example, the average time of message delivery). Let $U(C(t), P_1(t), ..., P_{Np}(t))$ be the utility function of a particular NAg. This function is specified by the NAg's owner and should be defined according to its preferences.

When the NAg's owner submits a new message to be delivered, it is necessary to define precisely to which SPs the announce should be sent , or, in other terms, it is necessary to define the extent the message's market. This decision depends mainly on two factors: the communication costs of sending the announces and the results of past interactions. The market of a set of messages T is defined as $M(T)$. This set results from the maximization of the expected return of an announcement and is determined as

$$\max_{M(T) \subseteq SPs} \mathcal{E}(\Delta U^{M(T)}(T)),$$

where SPs is the set of involved service providers and $\mathcal{E}(\Delta U^{M(T)}(T))$ is the expected change in utility if the messages in T are announced to the set $M(T)$.

3.3 The Economic Model

Let $\mathcal{E}(\Delta U^{O}_{with\_off}(T))$ be the expected change in utility if the set of SPs O make a valid offer and $\Delta U^{M(T)}_{comm}(T)$ be the change in utility caused by the communication costs of sending announces to all the SPs in $M(T)$. Then, for any message set T and for any set of entities $M(T)$, $\mathcal{E}(\Delta U^{M(T)}(T))$ is bounded below by

$$\mathcal{E}^{-}(\Delta U^{M(T)}(T)) = \min_{O \subseteq M(T), O \neq \emptyset} (\mathcal{E}(\Delta U^{O}_{with\_off}(T)) + \Delta U^{M(T)}_{comm}(T)),$$

and above by

$$\mathcal{E}^{+}(\Delta U^{M(T)}(T)) = \max_{O \subseteq M(T), O \neq \emptyset} (\mathcal{E}(\Delta U^{O}_{with\_off}(T)) + \Delta U^{M(T)}_{comm}(T)).$$

The value of $\Delta U^{M(T)}_{comm}(T)$ is easily assessed by the NAg, since that the cost of sending an announce to a SP is previously fixed.

The final value of $\mathcal{E}(\Delta U^{M(T)}(T))$ is determined by

$$\mathcal{E}(\Delta U^{M(T)}(T)) = \mathcal{E}^{+}(\Delta U^{M(T)}(T)) - \alpha \times (\mathcal{E}^{+}(\Delta U^{M(T)}(T)) - \mathcal{E}^{-}(\Delta U^{M(T)}(T))).$$

where α ($0 < \alpha < 1$) stands for the NAg attitude. A low value for α leads to a optimistic NAg, that always expects high returns from the announces. High α values will cause the NAg to act in more pessimistic fashion. This parameter should be tuned by the NAg's owner according to its own preferred attitude.

The expected change in utility if the set of SPs O make a valid offer is determined by

$$\mathcal{E}(\Delta U^{O}_{with\_off}(T)) = \max_{Winner \in O} \mathcal{E}(\Delta U^{Winner}_{ex}(T)) \tag{1}$$

where $\mathcal{E}(\Delta U_{ex}^{Winner}(T))$ is the expected change in utility if the message is delivered by $Winner$ (i.e., the negative value that corresponds to its cost), which is estimated based on past values stored in the database of the MH system. Equation 1 gives a hint about how the NAg should proceed in the *awarding* phase: just choose the SP that offers the lower cost.

4 Conclusions and Future Work

The application of a economic decision making approach to the previous model brought the ability to determine intelligently and dynamically the best SP to deliver a particular electronic mail message. The possibility to define the utility function and the level of optimism of the NAgs gives to this model the necessary flexibility to adapt it to the requirements of almost every user or organization.

In the future we intend to apply some of the ideas presented in this paper to the development of negotiation mechanisms inside the MTS. Taking into account that this system is controlled by several SPs, each one controlling different sets of MTAs, it is frequently necessary to select communication channels controlled by foreign MTAs. This implies, necessarily, a study of different proposals from different SPs and consequently to negotiate them in order to minimize operation costs.

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