Mobile Agents in E-Learning Resource Management

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Abstract - This paper is devoted to mobile agents and their use for E-learning resource management. We provide a brief overview and an elaborate case study. The overview introduces the concept of mobile agent, enumerates the claimed benefits, and discusses the state of the art of application in this domain. In the case study, we use mobile agents with Learning Object Metadata and Rights Expression Language description information to achieve a whole resource management process. The process shows how the prototype we have made works. We also contrast the performance to the client/server paradigm, which we have built for comparison purposes. At last, we conclude with a summary, lessons learned, and items for future work.

Index Terms – Aglets, E-learning resource management, mobile agent, rights expression language

INTRODUCTION

Mobile agents have raised considerable interest in the research community. In the past few years several platforms have been developed and mobile agents have been used in applications ranging from network resource management to automatic software distribution. Several benefits are associated with their use and the successful applications in electronic commerce are given to back the claimed benefits. This article is devoted to mobile agents and their use for E-learning resource management. We provide a terse overview and an elaborate case study.

The overview introduces the concepts of mobile agent and mobile agent platform, enumerates the claimed benefits. It also discusses the state of the art of resource management in E-learning, including the existing problems and new demands. To every situation referred in problems and demands, we present a short solution using mobile agents and carry out it in our case study.

In the case study, we begin with a scenario which is encountered commonly in E-learning resource management. In order to solve the problems, mobile-agent-based system including the process procedures is introduced step by step. Then we discuss the expected benefits by using mobile agents. And in the last part of the section, the whole prototype is described with its three layer structure. The whole E-learning resource management system runs on the IBM Aglets, which is a well-known mobile agent platform.

We also contrast the system to the client/server paradigm, which we have built for comparison purposes. The measurements show clearly that the mobile-agent-based approach outperforms the client/server counterpart. Although the case study is on E-learning resource management for our multilayer distributed system, the results can be transposed to most E-learning resource management applications for the same basic functions. It demonstrates the performance benefits associated with the use of mobile agents for the specific application domain.

This paper is organized as follows: The next section is devoted to the overview and covers both mobile agents and the state of the art of resource management in E-learning. Section 3 presents our prototype of the mobile-agent-based application, describing how it works in the process of E-learning resource management. The comparison with our prototype of the client/server counterpart is given in section 4. In the last section of this paper, we conclude with a summary, lessons learned, and items for future work.

A BRIEF OVERVIEW: MOBILE AGENTS AND E-LEARNING RESOURCE MANAGEMENT

An introduction to mobile agents and mobile agent platform is provided first. The state of the art of E-learning resource management is reviewed after that. Then we point out the existing problems and new demands in E-learning resource management.

1. Mobile Agents and Platforms

From references [1-3] which have been published on mobile agents, we can easily define the concepts of mobile agent and mobile agent platform.

Mobile agent is a software entity that:

• Works for another entity: Mobile agent acts on behalf of another entity (e.g., a person, another software entity) to finish some works. Usually, mobile agent is created by another entity. During the constructing, the final goal of the work is given.

• Migrates between physical nodes: Mobile agent can be suspended and move to another physical node (e.g., another computer). It can resume its work when the migration finished. This usually occurs when mobile agent needs to interact with the internal software entity in another physical node.
• **Reacts to external changes:** Mobile agent usually has some listeners to monitor the external changes. When the external changes affect the running work, mobile agent can protect the data immediately.

• **Is autonomous:** Mobile agent can control its internal working state by its autonomous strategy to achieve the final goal. The autonomous strategy indicates how to handle the internal messages.

The primary characteristics of mobile agent are mobility and autonomy. The mobility borrows a lot from process migration which consists of transferring a process from one computer to another. The code, the data, and the running state of the mobile agent are all moved to the destination when migration occurs. The autonomy also gives mobile agent some artificial intelligence features. Mobile agent not only decides what to do next according to its autonomous strategy, but also can change its autonomous strategy to fit in with the new situation that some external changes cause.

Mobile agent platform is the special environment for mobile agents’ execution. It is also called MAE (Mobile Agent Environment). Generally, it consists of several basic models such as: [3-4]

• **Agent model:** This model gives an internal structure of the mobile agent in the platform, indicating how to build a mobile agent that can act on behalf of another entity.

• **Autonomy model:** This model indicates how to handle the internal messages to manage the mobile agents in the platform.

• **Migration model:** This model presents how a mobile agent moves to another platform in different physical nodes.

• **Communication model:** Communication model cares how the mobile agents in the platform communicate with the external world.

• **Naming and locating model:** Every mobile agent in the platform must have a unique name to be identified. The model cares how to name the mobile agent and how to locate it form the name.

• **Security model:** Security model not only protects mobile agents against the platform, but also protects the platform against mobile agents.

• **Service locating model:** Some mobile agents can provide some services in the internet. This model provides the location and the interface of the services.

In the past few years, a lot of mobile agent platforms have been built. But most of them are implemented as Java applications. Famous platforms commonly used today include Aglets [5], Grasshopper [6], and Voyager [7]. The prototype we present in our case study runs on Aglets which is built by IBM.

Here are several benefits which are associated with mobile agents: [8]

• **Concurrency:** A lot of mobile agents can achieve one goal at the same time. Each mobile agent has its own process.

• **Asynchrony:** Mobile agents can migrate between physical nodes autonomously to finish the work. If there is no synchronous requirement, the result can be an asynchronous feedback. User need not trace the process and wait for result.

• **Reduce network usage:** Mobile agents can continue roaming and working on behalf of users even when users are disconnected. User need not connect to the internet all the time.

• **Better performance:** Compared to the number and length of messages exchanged in a traditional client/server application, performance is improved when the mobile agent’s transferred code is small in size.

• **Dynamic interface upgrades:** Mobile agents can upgrade their interfaces easily when they are running, while the client/server approaches are too static to adapt to rapid changes.

Although mobile agents have several advantages, they have so far been used in experimental settings. In our opinion, deployment has been hindered by the security problem. Although a lot of researches have been given on mobile agent security, the problem has not yet been solved in a satisfactory manner. In our case study, we introduce the DRM (Digital Rights Management) mechanism, the license which is based on REL (Rights Expression Language) is used to protect the data thus make the system safer.

### II. E-learning Resource Management

The main aim of the E-learning resource management is to share the E-learning resources. A lot of standards and specifications are devoted to this purpose. And some E-learning resource management applications followed them have been developed, such as Learning Resource Metadata Management System [9]. Usually, they use Learning Object Metadata Schema to describe the E-learning resources, and use client/server pattern to build the system. In the past few years, these applications generated a lot of attention, but there are still some problems left.

• **The lack of interoperability standards implementation:** Although a lot of E-learning standards and specifications have been issued, a lot of nonstandard E-learning resources still remain in the different E-learning resource management platforms. We need some standardization applications to solve this problem, and we build one called Resource Creator in our case study. User can use Resource Creator to create standard E-learning resources and transform the nonstandard E-learning resources into standard ones.

• **The hardness in distributed query:** Different E-learning resource management platforms have different databases to store the resources. And no interoperability interface has been provided between these platforms. Therefore distributed query is very hard to implement. In our case study, we use mobile agents as a ‘changeable interface’ to solve this problem. We add a MAE to every E-learning resource management platform, and dispatch mobile
agents to do distributed query. Since mobile agents can be reloaded in different MAE, the query data and the results carried by the mobile agents can be easily transferred from one platform to another.

- **Unsafe resource access:** It is noticed that most of the applications in this domain care little about the resource access. They always give all the rights to the user who can gain the resources. So user uses the resources without limitation like copying the resources or changing the resources data anytime. But this is not what the resource author wanted. REL in DRM provides a license to solve this problem. In our case study, user can use Resource Creator to add REL information to every resource and dispatch mobile agents to register the REL information to the E-learning resource management platform. When user asks to use the resource in the platform, a DRM certificate (e.g., a license) is required. The platform verifies the certificate and gives user relevant rights to the resource, according to the REL information comparison.

With the development of E-learning resource management, some new demands have been given directly and indirectly by the users. In rear part, we briefly discuss some of them.

- **Intelligent retrieval:** Nowadays, the quantity of E-learning resources online is so huge that we can hardly use keywords to get the proper resource we need. Lots of useless results are given by the search engines. Users must check each return resource to see whether it is useful or not. This takes a lot of time. But if the platform has the function of intelligent retrieval, which only returns the suitable E-learning resources to user, things will change a lot. In our case study, we use mobile agents to search the resources. During traveling in the network, mobile agents collect the resources information from different physical nodes, identifying the suitable resources by their autonomous strategies.

- **Individuation Study:** People always want to study the things that they are interested in. But current E-learning platforms only provide defined route of study. They give the same E-learning resources to their users, ignoring whether users like the resources or not. The demand of individuation study proves that some students want to get the resources fit their tastes. In our case study, we let user dispatch a mobile agent to select resources by given the predilection. Mobile agents can change their strategies to return different resources by different predilections.

- **Evaluation Procedure:** The current applications in E-learning resource management are weak in Evaluation Procedure. To monitor the quality of E-learning resources, the platforms should have the evaluation procedure to the E-learning resources. In our case study, each mobile agent who carries the resource to user will come back to the platform with the evaluation information given by user.

**THE ELABORATE CASE STUDY: MOBILE-AGENT-BASED APPLICATION**

Our application is designed to solve the problems referred in Section 2 and make some progress for the new demands. In this section, we first present a scenario to show how mobile agents can be used in E-learning resource management. The expected benefits are presented afterward. Then the whole prototype is described.

I. The Scenario in E-learning Resource Management

Figure 1 depicts the scenario. We assume that:

- The teacher in the Figure 1 lives in Wuhan, while the student in the Figure 1 lives in Shanghai.
- The university, where the teacher works, has an E-learning platform A which is different in physical location and storing databases from E-learning platform B, providing services to the student.

![Diagram](image)
• The student wants to use the e-learning resource made by the teacher. Since the resource is stored in the database A, which is located in platform A, the student can not query and access the resource directly.

• The resource is created by an application called Resource Creator which can create standardization E-learning resource with LOM & REL description information.

• The student uses the resource based on a DRM certificate (e.g., a license).

Then our mobile-agent-based E-learning resource management system begins its work. We use mobile agents to help the student and the teacher. The whole mobile-agent-based system not only refers to the Resource Management Application in the Figure 1, but also includes the Resource Creator and the E-learning platform. Actually the Resource Management Application in the Figure 1 describes a distributed resource management application which consists of several E-learning platforms. The processes are as follows:

• **Step 1**: The teacher uses mobiles agents provided by the Resource Creator application to send the standard resource and its LOM & REL description information to E-learning platform A. The corresponding steps showed in Figure 1 are 1, 2 and 3.

• **Step 2**: E-learning platform A stores the resource to the database and use mobile agents to register the resource’s LOM & REL description information to Web Server A, which provides the resource retrieval and resource access services. The corresponding step showed in Figure 1 is 4.

• **Step 3**: The student asks Web Server B to send a retrieval mobile agent to find the resource. Then Web Server B creates the retrieval agent according to the requirement and individual predilections from the student to search the resource. Since the retrieval agent can not find the resource in E-learning platform B, it travels around. The corresponding steps showed in Figure 1 are 5 and 6.

• **Step 4**: The retrieval agent migrates between different E-learning platforms. Every time when it lands on the platform, it resumes its retrieval work. Since the query strategies are different in every platform, some additional information, like LOM description information, is used to achieve intelligent retrieval. The corresponding steps showed in Figure 1 are 7 and 8.

• **Step 5**: When the retrieval agent moves to E-learning platform A, where the requirement from the student is met, it collects the LOM & REL description information and carries them back to E-learning platform B. The corresponding steps showed in Figure 1 are 9 and 10.

• **Step 6**: E-learning platform B analyses the LOM & REL description information and sends response to the student. If the student has the rights described by the REL description, the resource access pointing to the Database A will be given to the student. Then the student can use his DRM certificate to use the resource legally. The corresponding steps showed in Figure 1 are 11 and 12.

II. Benefits from Mobile Agents

We use a lot of mobile agents in the process of sharing the resource, and the expected benefits from mobile agents are briefly discussed below:

• Mobile agents can improve performance over the client/server approach, especially in the situation that the registration data and agent’s code are small in size.

• Mobile agents can react to the changeable situations to protect the learning resource. So the whole system will be more robust.

• Mobile agents can work locally. It is more convenient to cooperate with the internal subsystems of the platform.

• Mobile agents can compare and select the suitable resources to the student, during traveling around online.

• Mobile agents can give an asynchronous feedback. Student can disconnect to the network while the agent is working, instead of connecting to the network to wait the result. The agent can return the learning resources back to the student when he connects to the network later.

III. Three Layers’ Prototype

From reference [10] we learn that Aglets is a very robust platform, which is the only one passed all the tests without crash. So we choose it as our experiment platform. Described in Figure 2 We divide the whole system into three layers:
• **Layer 1**: This layer is the creating layer. The subsystem in this layer is an application called Resource Creator. The main function of this application is to make standardization resources. There are two ways to implement the resource standardization. One is to create a new resource by this application, which is followed the standards. The other is to import a nonstandard E-learning resource and fill the essential information by the guide of the system to let the resource become standardization. The resources coming out form this application have two main elements which are LOM & REL description information. And the application has well-defined interface that can communicate with Aglets platform. When the process of creating standardization resource is over, the application can transfer the resource data to Aglets and create a mobile agent whose task is to upload the data. And the successful notification given to user will be an asynchronous feedback.

• **Layer 2**: This layer has several functions. The first one is to save the data to the database for resource access, not only the resource itself, but also the LOM & REL description information. The second function is to push the LOM & REL description information to register the web server which is in the layer 3. The third function is the access control, using DRM. The second function and the third function all depend on mobile agents. We use mobile agents’ mobility to transfer the LOM & REL description information to the web server. And we exam the DRM certificates carried by the mobile agents which are referred in the previous part to implement access control.

• **Layer 3**: In this layer, there are some web servers who provide retrieval service. Each web server has a resource list and they can receive registration agents or repealing agents to update its resource list. They also can create and receive the retrieval agents. The retrieval agent can implement resource retrieval locally in the web server and travel around to enumerate the adjacent web servers. Retrieval mobile agents can use their artificial intelligence features to do intelligent retrieval. In order to make a convenient retrieval, each web server collects some parts of the adjacent resource lists. So in this layer, synchronization agents are necessary to synchronize the information between these adjacent platforms. They move from one web server to another quickly to update the resource list.

### The Comparison with the Client/Server Counterpart

In order to show the advantages of the mobile-agent-based prototype, we build a client/server counterpart for comparison purposes. The client/server paradigm is also designed with the three layers patterns, for the convenience of contrast. In the first layer it use socket to transfer the resource and the relative data packed by SOAP (Simple Object Access Protocol). The second layer still uses SOAP to register the resource to the web server. In the third layer, we use web application to search the resource, and use EJB (Enterprise Java Beans) to synchronize the resource list. The results of the comparison are given as follows:

• **Layer 1**: The client/server counterpart is 2 to 10 times faster than the mobile-agent-based prototype in the transplantation period. But the mobile-agent-based prototype is more robust and can receive the asynchronous result.

• **Layer 2**: The mobile-agent-based prototype is 1.5 to 4 times faster than the client/server counterpart when the size of the data is less than 360k. If a big size registration agent (about 1 M) appears, the mobile-agent-based prototype will take much longer time than the client/server counterpart.

• **Layer 3**: The time to search the resource by two prototypes in this layer are very close. But the mobile-agent-based one adopted intelligent retrieval which is more efficient than ordinary search by the client/server counterpart.

Although the performance of the mobile-agent-based prototype in layer one make us very unsatisfied. When all comes to all, the mobile-agent-based prototype has its advantages in registration and resource retrieval. In order to show the benefits of mobile-agent-based system, we conclude time statistics from the experiments carried out in three different layers as Table I. In the table, Registration not only indicates the time spent on register process, but also includes the resource’s transfer time. And Query in the table means the time spent on searching resources from two platforms.

<table>
<thead>
<tr>
<th>Round</th>
<th>Mobile agents</th>
<th>Client/Server</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Registration</td>
<td>Query</td>
</tr>
<tr>
<td>1</td>
<td>0.797s</td>
<td>0.250s</td>
</tr>
<tr>
<td>2</td>
<td>0.747s</td>
<td>0.222s</td>
</tr>
<tr>
<td>3</td>
<td>0.829s</td>
<td>0.187s</td>
</tr>
<tr>
<td>4</td>
<td>0.752s</td>
<td>0.154s</td>
</tr>
<tr>
<td>5</td>
<td>0.770s</td>
<td>0.137s</td>
</tr>
<tr>
<td>6</td>
<td>0.782s</td>
<td>0.156s</td>
</tr>
<tr>
<td>7</td>
<td>0.733s</td>
<td>0.154s</td>
</tr>
<tr>
<td>8</td>
<td>0.763s</td>
<td>0.159s</td>
</tr>
<tr>
<td>9</td>
<td>0.722s</td>
<td>0.184s</td>
</tr>
<tr>
<td>10</td>
<td>0.734s</td>
<td>0.172s</td>
</tr>
<tr>
<td>Average</td>
<td>0.763s</td>
<td>0.178s</td>
</tr>
</tbody>
</table>

The same conditions of our comparison experiments are as follows:

• 100 Mbps Offices’ LAN
• Two platforms different in physical location and storing databases
• Above 10000 different records stored in every databases

### Summary, Lessons Learned and Future Work

This article provides a terse overview of mobile agents and their use for E-learning resource management. The overview introduces mobile agents, and reviews their usage in E-learning resource management. It is extended by an elaborate study of the mobile-agent-based prototype application. The
comparison with the client/server paradigm reveals that mobile agents are more suitable for the conditions we met in the E-learning resource management.

Although the mobile agents have a good performance in the E-learning resource management, we still have learned lessons from the case study. The first lesson is that the way that is using REL to avoid the security problem, which we tried in the case study, may not be a successful way. Although the resources protected by the REL are very safe, the agents who carrying them are not robustness. The result is that the legal user may not acquaint the resources for the weak protection of mobile agents. The second lesson is that the cost of an intelligent mobile agent is too high. The cost comes from two factors. One is the intelligent design, which takes a long time to make agent well-defined and adds a lot of codes to the agent for handling strategies. The other is migration, which gives convenience to communication but costs a lot of time for reloading the agent, especially the heavy agent.

In spite of these, the benefits from mobile agents show that using mobile agents to manage E-learning resources is a desirable way. We will continue our work to form a more perfect E-learning resources management system in the future and add more intelligent mobile agents to the platform. An extended KQML (Knowledge Query and Manipulation Language) will be used in the future to reduce the cost of migration also. And we will try to make the agent data much safer. Our ultimate goal is that using all mobile agents’ advantages to improve the performance of E-learning resources management, building a robust intelligent platform.

REFERENCES