A Security Framework for Mobile Agent Systems

Omer Mansoor Paracha
Abstract

Agent technology is a novel approach for the development of distributed systems. In particular, mobile agents can provide much greater flexibility and robustness than the traditional distributed system methodologies since they provide mobility from platform to platform. Thus, they form a vast area of research. One key problem faced by the mobile agent systems is security. A migrating agent can face many threats while migrating to a host/agent platform. Similarly the platform can be maliciously affected by an agent. A number of different approaches have been suggested in the literature to deal with security of mobile agents. In this thesis, we present an overview of such threats and present an "agent threat model" for mobile agent systems. Based on this model we survey and evaluate the techniques that provide countermeasures to the mobile agent systems. Based on the techniques surveyed, a state-of-the-art is evaluated and the security of certain mobile agent systems is discussed. The thesis presents a proposed framework to provide mobile agent system security from both malicious mobile agents and platform. The idea is to provide a solution to the requirement of a security framework that provides security as a combination of components based on techniques for mobile agent system security and protection. The proposed framework is comprised of various components that are studied in the light of operation scenarios. An implementation of the system is discussed and the evaluation of the proposed framework as well as a comparison with the state-of-the-art mobile agent systems is provided to highlight the strengths and weaknesses.
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# Mobile Agent Security Framework

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Chapter 1

Introduction

Software systems have advanced immensely with the technology march with special regard to expansion of systems over a distributed concept. Various approaches for development of software systems especially distributed systems have come into existence. This advent of distributed system application and performance has lead to many research dimensions and topics. Since distributed systems require immense communication between its components or subsystems and the information that they share is considerably large in amount, approaches to access, search and access of this is vital. So, for this, various theories for communication and information retrieval exist.

Distributed systems came into existence so that a wider network could be used for information sharing and also for service access. A large number of applications were derived from this ability to scale a large area and distribute information and service. Distributed systems become vitally important due to their function. However, the function and capabilities are vast and the requirement from such systems becomes larger. Features of such systems make the system different in construction and operation. Performance issues include the issues of extensive reliability, like fault tolerance, safety and security. Of these, one important issue is the security of software. When software
goes distributed, it becomes potentially more prone to network insecurity and threats. Thus, it is very important to assess the threats and insecurities that the system might undergo during its lifetime and, that the system can somehow prevent the occurrence of attack.

Mobile agents are an innovative idea in the field of distributed system research (Kotz, Gray & Rus, 2002). They are basically autonomous units of code and state data that can migrate from host to host for remote processing. Their capabilities are immense in comparison to normal remote procedure calls and remote processing as they themselves carry the process and data but use the remote host’s capability to carry out the execution.

The uses of agents are many as their prime propose is in their name. They are actually representatives for cyber-users.

Mobile agents may be characterized as “good” agents that carry out tasks for us on our behalf remotely, for example an agent to purchase a book online. The agent looks for the book on different hosts and purchases the one that fits the criteria like its cost or its required stock. Also, there may be “bad” agents, like viruses and worms that can go online and travel to hosts to damage them or spy on them. As agents are composed of code and data it can use this for virus like activity.

Mobile agents and their activity may be malicious or it may be attacked by the host it is supposed to execute on, meaning that the host is malicious. Also, both agent and host may be “good” but the network may be comprised of hackers. This means that the network is insecure and liable to attacks in its route.

Our aim is to create a framework to insure secure agents and hosts (Jansen & Karygiannis, 1998). The framework that has been suggested deals with primarily the security. The prime aim in abstract is to allow “good” mobile agents and disallow “bad”
mobile agents on the host and to protect the mobile agent from the host’s activity. The agent has to send its processed information back to the host from where it came from along with its execution log containing the entire trace of its execution on the host. Also, the use and access of resources has to be taken into consideration. The framework accommodates the protected resource use by the visiting mobile agent.

The thesis is arranged as follows: Chapter 2 covers the background to Mobile agents, their theories and to their applications as well as giving the concepts of security that is required in mobile agent systems. Chapter 3 presents the Threat Model that accommodates the various threats that occur in a mobile agent system i.e. to the agent and the agent platform. Chapter 4 surveys the countermeasures and techniques in the literature on mobile agent security and is evaluated to see what threats are protected by these measures using the threat model. Chapter 5 covers the various state-of-the-art mobile agent systems and describes their security architectures and evaluates these on the basis of the techniques that are used for security from Chapter 4. Chapter 6 details our proposed framework and describes its components and subcomponents. Chapter 7 describes the various operation scenarios to check their security of our proposed framework. Chapter 8 describes the implementation issues of our proposed system. Chapter 9 evaluates our system and lists down the benefits and limitations of the proposed system using the threat model and also a comparison with other state-of-the-art mobile agent systems. Chapter 10 concludes the thesis and provides some research directions.
Chapter 2

Mobile Agent Systems

Security: A Background

This chapter gives the background that is required for mobile agent system security. It covers the different theories that are available in the literature on mobile agents and mobile agent systems in general.

2.1 Remote Code Execution

Taking the generic client server model, a set of traditional approaches to remote processing can be discussed. The client server model generically contains a client that issues a request to be processed by the server on its behalf. The server then processes the request and responds as required. For this kind of communication model, approaches for remote code execution were developed (Aneiba & Rees, 2004; Picco, 2001). The approaches for remote code execution are Remote Procedure Calls and Remote Evaluation (Lange, 1998; Rothermel & Schwehm, 1998).
Code can be accessed simply by calling the procedures like through RPC (Remote Procedure Calls) and through REV (Remote Evaluation). In RPC, the methods are invoked by the agent through method calls. Client is the caller whereas the server is the callee. The server responds by sending the results of the procedure execution back to the client. In REV, the method is downloaded to the client by the server and it executes there. Here, there are two further approaches; one is that the client may call the code for download and execution. The other is that the code may be sent by the server to be executed on the client according to the server. The first approach is remote execution whereas the second is code-on-demand.

In contrast we have software agents that can be mobile, i.e. mobile agents that can carry out remote code execution and overcome the limitations that traditional approaches have (Rothermel and Schwehm, 1998).

2.2 Software Agents

To understand what software agents are, we have to understand what agents are. As defined in various papers, agents are best defined by Franklin and Graesser (Franklin & Graesser, 1996) that highlights the notion of what agents are according to various definitions that people defined. However, the best understanding was found in the definition that was derived in (Lange, 1998) that the definition of an agent is based on which perspective we are elucidating its nature. Generally, an agent is a representative for a user that has been delegated some work. As stated before the debate becomes rather immense (Franklin & Graesser, 1996) and the requirements of an agent and its actual meaning becomes too narrow. Thus, the definition needs to be broadened and the definition from (Lange, 1998) is rather complete by which we adapt our definition of an
agent; an agent is a delegate or a representative that can operate in an environment, is reactive, autonomous, goal-driven, continuous, communicative, mobile, learning and believable. Agents may possess all of these or some of these characteristics (Sundsted, 1998).

From this definition of an agent, we can define what a software agent is. A software agent is basically an object possesses all of the aforementioned characteristics. Rothermel and Schwehm in (Rothermel & Schwehm, 1998) classify software agents. From this classification and the classification done in (Franklin & Graesser, 1996) we understand that due to the features of a software agent, the agent can assume a number of forms. In this thesis, we take the mobile agent class of software agents.

2.3 Mobile Agents

After explaining software agents, the class of mobile agents does not require much of a formal definition. However, we do explain mobile agents and their context in the rest of this thesis. A mobile agent is an agent that can simply carry out our tasks for us as users remotely. By remotely, we can mean many other remote locations. A mobile agent is thus simply one that is created at one place, carries its code and state over to another place and resumes its execution. It does not require the remote code execution approaches for this; instead it propagates itself over the communication network to carry out its tasks (Lange, 1998).

To explain what a mobile agent is, we have to understand certain basic concepts. As explained by (White, 1998) and (Milojicic, LaForge & Chauhan, 1998) a mobile agent system has agents and places. A place is where the agent visits in its journey. At each of these places, there exists an agent environment to allow its execution. The environment
allows processing on the basis of a policy. Of course, the underlying features that define the agent and the place implementation differ in its state-of-the-art as various mobile agent systems implement the features differently.

(Marrow & Ghanea-Hercock, 2000) define the mobile agent computing approach and give the features of the actual setup and features that are required. Traced from what has been discussed and by (Marrow & Ghanea-Hercock, 2000) mobile agents have certain fundamental features. Taking a general idea that a mobile agent moves from place to place, a mobile agent requires the elements of mobility, communication and task association. A mobile agent is fundamentally mobile and can migrate from place to place as specified. Similarly, a mobile agent needs to communicate and co-ordinate with agents and the execution environment to execute. Lastly, an agent needs to be associated with a specialized task to perform on the behalf of the creator of the agent that it is representing.

2.4 Mobile Agent Benefits

Mobile agents along with their features can thus provide a number of benefits to distributed and component based systems and technology (Kotz & Gray, 1999). Their applications due to these benefits are thus numerous. As explained in a lot of papers, mobile agents have large potential. To assess this we highlight the benefits from mobile agents that are mentioned in the literature. As expressed by (Lange & Oshima, 1999), there are several good reasons for mobile agents. These are listed as follows:

1) Network load is reduced because multiple interactions are not required between the server and the client like in traditional approaches. Instead, a mobile agent carries the
complete set of interactions to the server. The agent executes the commands locally and thus reduces the set of instructions that had to be sent. Also, for a large amount of data, transmission over channels is rather expensive; hence the mobile agent using the data locally reduces the network load.

2) No delays are witnessed as the mobile agent executes at the point of execution. For example, in the traditional approaches, a large amount of wait had to be done for a command to be processed and responded to. In the case of mobile agents, an agent is actually sent there and the wait time is reduced.

3) Protocols do not need to be enhanced for mobile agents that are migrating and they can utilize the protocols at hand as for other mechanisms the protocols need to be upgrade according to the specification of the communication required.

4) Autonomous execution makes the mobile agent independent of the creator. This is favorable for the example of limited devices like mobile devices. The agent moves to the server, executes and the device collects the agent later.

5) Dynamism is enhanced as the mobile agents can be adapted according to the environment that is given to them.

6) Heterogeneity is provided because the underlying specification is independent to the mobile agent allowing better integration of heterogeneous systems and environments.
7) Robustness is achieved because dynamism allows agents to be configurable as the environment suggests, this also makes them fault-tolerant if required.

2.4.1 Mobile Agent Applications

Now we discuss the applications that are possible because of mobile agents.

2.4.1.1 Telecommunication

In the field of telecommunication, mobile agents can use their advantage in reduction of network bandwidth and can enhance these for several network services that future or next-generation telecommunication networks (Pham & Karamouch, 1998).

2.4.1.2 Network Management

Mobile agents can be used to evolve current client/server based network management approaches to a more distributed approach (Pham & Karamouch, 1998).

2.4.1.3 Information Retrieval

Mobile agents can be used for retrieval of information over a network and the Internet. The mobile agents can carry queries and can retrieve particular information (Pham, 2001). This can be extended for cache management and searching as well.

2.4.1.4 Others

There is other work in progress in many dimensions as seen in the literature on them. Mobile agents can be used in Global Information Systems for tracking, in Grid Systems,
in Intrusion detection systems, for distribution of multimedia and so on. Also, agents have a broad research potential (Kotz, Gray & Rus, 2002).

2.5 Mobile Agents Limitations

Mobile agents have their immense applications and there are several benefits because of them but they still have their limitations. Their possibilities are hindered by several challenges (Schoder & Eymann, 2000). Some of these are limitations to the technology and some are because there are missing solutions to numerous issues that arise in mobile agent systems concepts and design (Rothermel, Hohl & Radounikilis, 1997; Kotz & Gray, 1997).

Various authors have written about the mobile agent dimension limiting and the reasons that cause the limitations to their adoption (Gray, 2004). Also, the reason has been highlighted as because of applying it in the wrong regard despite having a clear concept to their use (Johansen, 2004). For this the reasons listed in (Vigna, 2004) define the limitations and their reasons quite well. The listed reasons are:

1) Performance issues can be limiting. A generalization states that agents may reduce network bandwidth consumption and so on, but this is not true in every scenario.

2) There is a lack of a systematic approach to design a mobile agent, making it difficult to develop.
3) Implementing agents is also hard work as so many unpredictable interactions are present in its journey to so many places consisting of adverse environments.

4) The testing and debugging of such systems are extremely complex. This is due to the fact that the approaches become so unpredictable.

5) Authentication can be based on so many things the agent is associated with. For this the authentication mechanism may be weak.

6) Corruption of the agents is possible as the agent transfers over the various places it visits. This means an agent can lose its information or actually deviate from its goal.

7) Since information might be lost, the agent cannot be trusted with secret information either. The information can be leaked on its way.

8) A mobile agent requires a setup or an infrastructure to actually perform. A system that bases itself on mobile agents would require that all the places can execute the mobile agent.

9) Mobile agents in order to interact require a sort of mechanism, a means to interact and to collaborate; there is a lack of such an approach, such a language that supports this mechanism.
10) Mobile agents remotely execute at one place and go to the next; this is very much like a worm that actually can cause so much damage to the system if they are allowed to process.

2.5.1 Mobile agent security

Of all the above, security is one of the greatest weaknesses to a mobile agent. Security alone is a large reason for the lack of use of agents for providing the solutions they promise (Li, Zhang, Sun & Yin, 2004).

A huge amount of research material is available that has either raised the notion of security of mobile agents or has tried to solve it in one way or another. The notion of mobile agent security is because the mobile agents that are roaming a network can be used as malicious objects for accessing private or confidential information and resource, for causing corruption like viruses and worms and so on. Similarly, in this regard if an agent is supposed to be correct and non-malicious, we are never sure that the place it is visiting may be malicious to it or not and may also leech information from the agent, corrupt it or even use it for its malicious purpose.

The lack of security has been highlighted mainly because of a lack in approach to so many things that have to be secured about a mobile agent system. A mobile agent system thus lacks approaches because of a lack of a security providing framework that will fulfill the end to end security requirements of the agents and the places.
This chapter looks into various security threats and the aspects that may be malicious in
a MAS. Also, a MAS threat model is presented that denotes the threats that an MAS
may comprise.

3.1 Overview of MAS Security Threats

Threats to a mobile agent are an area of fond interest as they stand out to the acceptance
of mobile agent systems for various applications. The vulnerabilities alone have cause
immense interest in the field of security of distributed systems. Various goals have been
highlighted to protect a system out of which some have a substantial solution and some
do not (Abdalla, Cirne, Franklin & Tabbara, 1997). This chapter identifies the threats
that occur in a mobile agent system so that a MAS can be evaluated according to the
threat that they countermeasure.
The threat model has been derived from the various papers discussing the countermeasures to the threats. However, (McDonald, Yasinsac & Thompson, 2005) derived threats to the MAS. In this model, we generalize the threats to the MAS and create our own threat model. Also, the threat model includes threats from a malicious network not present in (McDonald, Yasinsac & Thompson, 2005).

The security of mobile agent systems encompasses protection of the mobile agent, the platform and the network (Greenberg, Byington & Harper, 1998). Thus, the work on security in mobile agents can be classified into three broad categories (Gray, 1997; Brooks, 2004):

- Malicious Agent Platform and environment
- Malicious Agent
- Malicious Networks

### 3.1.1 Malicious Platform

Malicious platform security is necessary so as to defend the agent and the spawning host from any platform to which the agent is transferred to. This includes various security threats like spying on the agent and its data, masquerading or posing as a correct platform and also the corruption or misuse of the agent (Farmer, Guttman & Swarup, 1996b; Kun, Xin & Dayou, 1999).

Similar to this, other agents may harm the incoming agent(s) and so may the environment (Kun, Xin & Dayou, 1999).
3.1.2 Malicious Agent

The protection of the platform on which the agent is executing has to be protected as well (Farmer, Guttman & Swarup, 1996b). This is because the agent may act like a virus and may corrupt the platform or can act as a Trojan and can spy on the platform and its resources (Kun, Xin & Dayou, 1999).

3.1.3 Malicious Network

This security deals with the network on which the mobile agent is transferred to other platforms (Farmer, Guttman & Swarup, 1996b). The networks can be tampered and insecure channels may be created luring agents and corrupting them and may also allow the spying on the agents themselves (Kun, Xin & Dayou, 1999). The framework supposes that the network being considered is secure.

3.2 The MAS Threat Model

The different types of threats that the MAS would encounter according to 1) malicious platforms, 2) malicious agents and 3) malicious networks are as follows. Like (Jansen & Karygiannis, 1998; Jansen, 2001; Jansen & Karygiannis, 1998), we use simple mobile agent architecture to identify the threat model shown in Figure 3.1. The arrows indicate an underlying network that carries the mobile agent. The host O spawns a mobile agent A to an agent platform X for execution. The mobile agent A continues its execution to agent platform Y and so on. The three major security considerations can be expressed here, the malicious platform, malicious agent and the malicious network. This threat