Mobile Agents - an Overview

Shalini Diana Reddy
Dept of Computer Science and Engineering
University of Texas at Arlington
shalinidianareddy@yahoo.com

ABSTRACT

Mobile IP is an Internet protocol with enhancements to support host mobility. Mobile IP works even better with the use of Mobile Agents which is a mobile object that moves from host to host under the control of its own will in order to achieve some task. This paper aims at describing the motivation, advantages and functionalities of the mobile agents. The working of a Mobile Agent including the state diagrams is described here, followed by an assessment for Mobile Agents. Challenges like security threats posed by Mobile Agents have also been addressed which make their deployment difficult. A solution proposed by [5] to deal with security issues has also been discussed.

Introduction

In response to the increasing popularity of palm-top and other mobile computers, Mobile IP was developed to enable computers to maintain Internet connectivity while moving from one Internet attachment point to another. Mobile IP is an Internet protocol designed to support host mobility. Its goal is to provide the ability of a host to stay connected to the Internet regardless of their location. The term "mobile" in this context implies that a user is connected to the Internet, that the user's point of attachment changes dynamically, and that all connections are automatically maintained despite the change. Mobile agents are programs that can be dispatched from one host and delivered to another (remote) host for execution.[12 & 13] A mobile agent has the unique property that during its lifetime it can be halted, its state and code moved to another system on the same network and then resume executing the code from where it stopped. The mobile agent comprises of the code, the agent execution thread and the data.

Mobile agents were not discovered to do something new but because their use enabled things to work out better. The main motivation for mobile agents was from network management bottlenecks because of unnecessary bandwidth utilization.[11] Mobile agents work with low bandwidth connections because users allow the agents to roam on their behalf and wait for the results. In addition to these mobile agents have asynchronous transaction capabilities and they may be allowed to have intelligence in order to make decisions, process information and communicate with other agents.

Mobile agents encompass message passing and object passing. Message passing allows synchronization and asynchronous communication but it makes debugging very tough. Mobile agents also include static and mobile objects [8].

The mobile agents has the discretion to make the decision when and where to move. It moves by first saving its current state, transporting the saved state to the next system and finally resuming the execution of the saved state [13].

Every mobile agent is described by two things namely the agent and the place where the agent executes. The agent is characterized by:

- **State:** This is required to resume computation after agent migration.
- **Implementation:** This is required for location-independent agent execution.
- **Interface:** This is required for agent-agent communication.
- **Identifier:** It is required in order to recognize and locate the traveling agents.
- **Principals:** This is required to determine legal and moral responsibilities of the agent.

The place where the agent executes is characterized by the following:

- **Engine:** Workhouse and virtual machine for one or more place.
- **Resources:** The databases, processors and other services provided by the host.
- **Location:** The network address of a given place or host.
- **Principles:** Those legally responsible for the proper execution of operations.

Mobile agents have many advantages that's makes them very suitable for mobile computing applications.[14]

- Every node is a server: The agent can execute on any host which contains an agent execution environment. The agent also treats all hosts as servers because at an arbitrary point of time the mobile agent may require any node in the network to provide information to it for execution.
- Communication efficiency where code-size is greater than data size: It is much more efficient to execute a large piece of code at a single host in a batch rather than at the mobile host which has limited resources like storage, battery power and computational capability.
- Network fault tolerance: The operation of mobile agents is fault-tolerant of the network because once the required information is collected the agent executes locally on one host and till it decides to migrate it does not need any information from any other node in the network, so even if some links in the network are broken it does not cause concern to the execution of the agent.

Why are Mobile agents used? [3,15,13,10]

- ***Reduce network load:*** Mobile agents reduce the need for bandwidth. Instead of individual interactions between hosts, mobile agents package multiples interactions and execute at one host locally. The network bandwidth is thus saved because the packaged interactions are sent as a discrete piece of network traffic. The bandwidth utilization can be improved by deploying the mobile agent onto the service agents so that the mobile agent needs to perform the necessary operations. The service agent reports the intermediate results back to the client host.
- ***Overcome network latency:*** Mobile agents reduce network delays because they reduce network traffic by moving the processing to the raw data. They also reduce communication latency and connection time.
- ***Encapsulate protocols:*** Mobile agents encapsulate all the required data within themselves and so when a mobile agent arrives for execution at a host it does not

need any more interaction from any other host because it contains every piece of data required for execution.

- ***Execute asynchronously:*** A mobile agent's operation is asynchronous because no wait is required once it is dispatched. The mobile agent executes and moves at its own will and it also decides when to terminate.
- ***Execute autonomously:*** A mobile agent is autonomous because it decides for itself where it needs to move next and what it needs to do at the new destination and also how long it will exist before moving on or terminating. The exception to this is that a mobile agent's environment may control its decision.
- ***Adapt dynamically:*** Mobile agents are easily cloned and dispatched in different directions which allows them to work in parallel because of which agents are very active.
- ***Fault-tolerant:*** A mobile agent is quite fault-tolerant in the sense that even if some of the existing agents are destroyed the ones remaining have a positive impact and the ones which were destroyed would have benefited every host upto the point they were executed.

Where are mobile agents used? [13]

- Network management systems
  - Discovery agents & Configuration Agents
- Distributed information retrieval
  - Best price, monitoring stock markets and telecasting news
- Data mining
- Search engine
- Telecom network service
- Personal assistance and E-Commerce technology

Requirements of the Mobile Agent and its host[13]

Agent host requirements:

- An agent host must allow multiple agents to co-exist and execute simultaneously.
- An agent host must allow agents to communicate with each other and the agent host.
- An agent host must be able to negotiate the exchange of agents.
- An agent host must be able to freeze an executing agent and transfer it to another host.
- An agent host must be able to thaw an agent transferred from another and allow it to resume execution.

Agent requirements:

- An agent must have its own unique identity.
- Agents must be able to determine what other agents are executing in the agent host.
- Agents must be able to determine what messages it needs to accept and what to send.

Mobile agent-agent communication [6,7,9]

A mobile agent can be uniquely identified through its ID and it has the ability to find out whether other agents are interacting with the host on which it is currently executing. It also knows what information can be shared to allow effective and fruitful execution. The connection is established initially by sending a 'Hello' message. Each mobile agent executes in a temporary workspace initially and performs its functions which help it to interact with several other agents. The host also cooperates with the agents to exchange information and share resources. Intra-agent communication is based on message passing. An optimal way of mobile agent-agent communication with minimal communication delays would be to limit the number of mobile agents co-existing at a node.

Mobile agent-based computing [3]

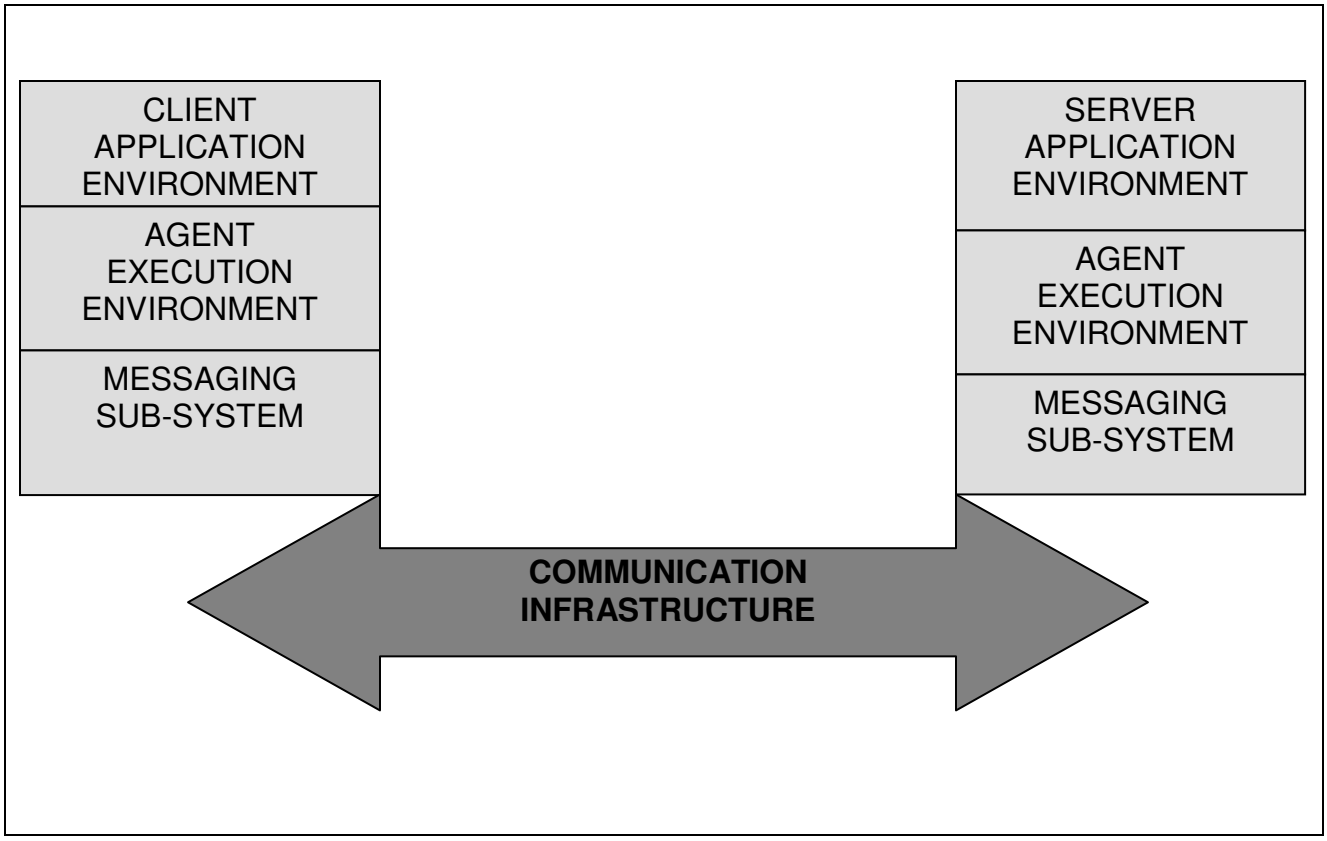

Figure 1 – Mobile Agent Infrastructure and Communication [3]

Figure 1 shows the concept of a mobile agent. Both the client and the server systems have their respective application environments, an agent execution environment and the messaging sub-system. The application environment consists of an operating system like Windows which allow execution of applications desiring to interact with the server. The agent execution environment binds to

- various operating system functions at the client side such as timer, memory manager etc.
- message transport service in order to send and receive mobile agents via the communication infrastructure.
- interface libraries of the client device in order to collect information directly from the client on which it is executing.

The agent execution environment has access to different agent programs which provide numerous varying services to clients. For example there may agents for database

retrieval requests, or agents to collect updates on stock markets. The agent program could be a virtual machine language or even just machine language. Using interpreted languages are preferred as they come with the inherent advantage of late binding enabling the agent to contain references to code not present at the system when it is initiated but are available at the destination. Managing security using interpreted languages is easier.

The messaging sub-system sends and receives messages and agents via the communication interface.

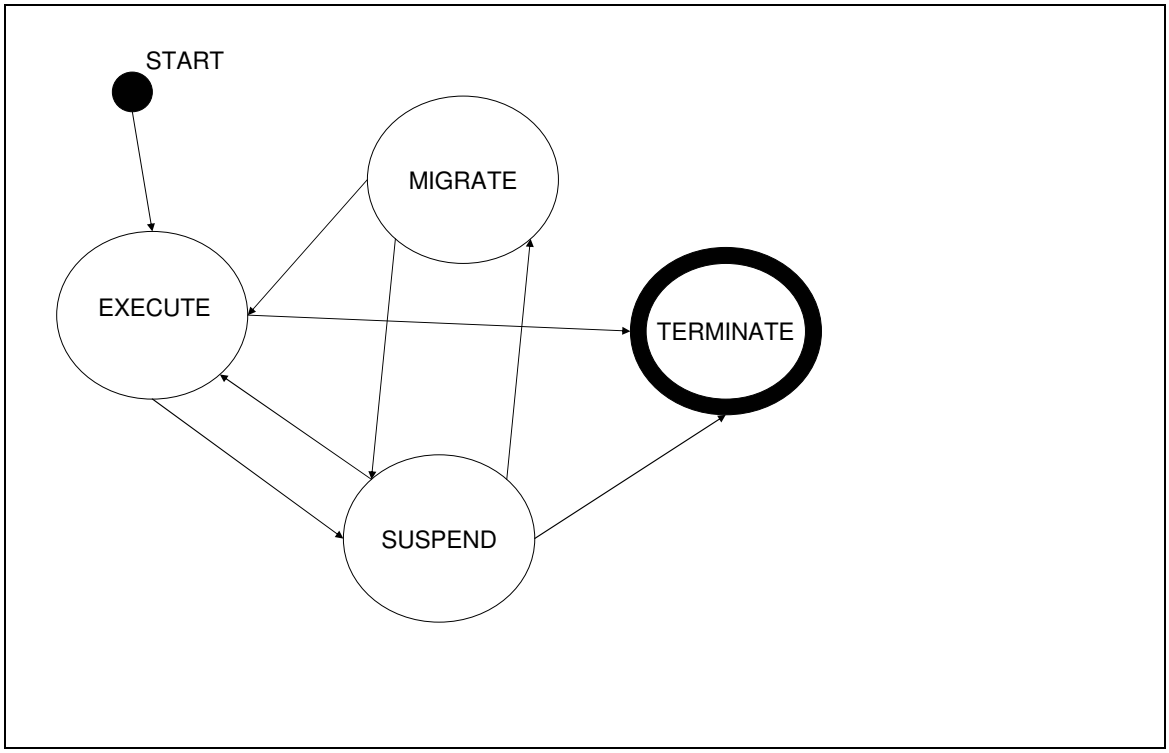

Figure 2- State Diagram for Mobile Agent

Once an agent gathers all the information it needs for initiating its execution an instruction is executed by the agent which may cause it to migrate to another machine. The following occur during agent migration:

- A new child agent gets created and is ready for execution or the current agent gets suspended.
- The state, stack, heap and list of external references of the current agent which is suspended or the child agent is gathered and processed into a machine-independent form. This is done because the agent may need to propagate to another host for its execution later or may have some required data items at the

destination specified in its list of references. In this case the agent is just a set of object references.

- The agent is routed to its destination by sending a message either explicitly or by using a post office function which performs the address resolution or even through some intermediate nodes which route the agent based on the content in the message.
- The message used to route the agent to its destination is first handed to the messaging sub-system which on reaching its destination server is delivered to the servers messaging sub-system which in turn delivers the agent to the server's agent execution environment.
- The agent now begins executing the next instruction after converting its code into an executable.

The agent executes at the server and while it is executing, it gives all the information it gathered at the client application at the previous host to the current host that is the server. After execution is complete the following may take place:

- The agent may decide to terminate its execution.
- The agent may decide to suspend itself for a while at the server perhaps waiting for some event to be delivered from the server application. Such agents could be said to have become 'permanent residents' at the server primarily because the user at that host may have some service preferred quite often.
- The agent may choose to migrate itself as in the process described before.

Assessing mobile agents [3]

- ***Mobile agents provide good support for mobile clients:*** This works because the mobile host is not always connected to the network and so it can start the execution of an agent for itself when it gets connected and in its subsequent connection to the network the host can collect its result. Another reason is that the host even if connected to the network has a very low bandwidth available for itself to carry out the operations hence if the agent performs the operation in a

- batch for the host the information to be transmitted over the network is reduced by a great amount and hence reduces cost. The storage and battery power available at most hosts may be limited hence if an agent is used to perform the entire operation that is collecting the information, processing it and returning the result to the client would work most efficiently in terms of saving on power and storage at the host.
- ***Mobile agents perform semantic information retrieval:*** Semantic information retrieval deals with gathering information in an orderly fashion from users as well as multiple servers, filtering it and possibly indexing the result. The host can perform information retrieval from the client very well but this interaction is not a major part. The main information comes from interaction with multiple servers which is not possible for a host due to limited bandwidth, battery power and storage, and network latency. A mobile agent can perform this job very well because it can gather all the information at once and execute in a batch. A good searching, filtering and indexing scheme could be applied for an agent to format the result in the best possible way for its client.
- ***Mobile agents carry their state as they move:*** As compared to client server computing where the state of the executing process needs to be saved at each client and server, mobile agents carry their state along wherever they go.
- ***Queries based on mobile agents are robust:*** Mobile agents provide reliable transport between client and server since they do not require any communication from any host while executing. Incase a mobile agent propagates to a server and that server is unavailable at that point of time, the mobile agent knows the alternatives available for it. It does not burden the client with routing decisions for it.

Problems with Mobile Agents [13]

- ***Security threats:*** Mobile agents require a highly secure execution environment. The performance and functionality of mobile agents is limited because of security problems which come along with the concept of mobile agents. They also need to incorporate virus scanning and epidemic control mechanisms.
    - Security for hosts: We cannot ensure that an agent is not 'evil'.
    - Security for agents: There is need for protection against hostile hosts that would seek to dissect or modify them.
- ***Mobile agents carry their state:*** Wherever they move, mobile agents carry their state along. This incurs overhead.

Mobile agents have many commercial disadvantages like problems in propagating the agent execution environment to third party servers and trust from third party server providers for allowing the execution of agents. The third party server must be willing to support the computational load which the mobile agent brings along with itself.

Mobile Agent Security [5]

Using mobile agents make the hosts and the agents very vulnerable to security threats from malicious users.

- ***Firewalls:*** Using firewalls also does not work well in this case because agents breach assumptions made by firewalls. Firewalls assume that there is no security threat from within the network, but incase of mobile agents the attack may originate from inside the network, hence there is no protection offered from a firewall.
- ***Cryptography:*** Cryptography offers little or no resistance to malicious mobile agents when they arrive as attachments with electronic mail or to web pages because they can reinstall themselves and continue execution and they could attack the internet pretending to be regular users.

- ***Digital Signatures:*** Digital Signatures can only be used to certify that the origin of the mobile agent was authentic but it cannot ensure that the mobile agent was not tampered with in transit.

[5] offer two mechanisms for solving the security threats by mobile agents namely bidirectional security and layered security.

Bidirectional security for Mobile Agents [5]

Ensuring security for mobile agents requires the security mechanism to be applied to both the host and the agent. The host can be made secure from attacks by using the following methods:

- ***Authentication:*** This involves ensuring that the agent originated at a trustworthy host.
- ***Verification:*** This involves checking the mobile agent's code for any operation that does not adhere to the principles defined. A method called 'safety proof' can be used to ensure that the code carried by the mobile agent is authentic and safe for execution. This comprises of attaching a safety proof to every piece of code in the agent and when a mobile agent arrives for execution this safety proof can be examined by the host before it allows execution.
- ***Authorization:*** This involves checking the mobile agents access rights on resources at the host where it executes.
- ***Payment for services:*** This involves the mobile agent's ability to pay for the services.

Implementing security mechanisms for the mobile agent is tougher compared to hosts. They are listed as follows:

- ***Authentication:*** This involves validating the host the agent migrates to for execution.
- ***Pretty Good Privacy (PGP):*** This is an encryption algorithm to avoid snooping eyes when mobile agents travel.
- ***Digital Signatures:*** They are used to identify malicious messages which could have not possible been sent by the receiver.

- ***Secure key encryption:*** This is single key mechanism which is shared by both the sender and receiver.
- ***Public key encryption:*** The algorithm used is RSA and is very suitable to mobile agents as they execute in an open environment.

Layered Security for Mobile Agents [5]

Providing a secure environment for the mobile agents to execute is a herculean task. In the layered approach there are several layers at which security measures need to be implemented in order to ensure the whole environment to work safely.

- File, user and process security is provided by network operating systems like UNIX. The task of security should not be limited to the application layer but should be expanded to the network operating system layer.
- The mobile agent needs to protect itself for which encryption algorithms should be used to ensure that the agent and its data do not become compromised.
- There should be mutual authentication services in mobile agents which are invoked when agent-agent communication occurs because malicious data could be exchanged causing harm.

Conclusion

Mobile agents do not have strong individual advantages but when considered as an aggregate they seem quite plausible and effective. Alternatives to mobile agents exist when compared to the complete set of advantages offered by mobile agents they seem weaker. Information retrieval, finding services and empowering individual users could form the major reason for mobile agents to be so appealing to the internet [3]. There are many competing technologies like message passing systems, remote method invocation (RMI), and common object request broker architecture (CORBA).[8] The security mechanisms if implemented, mobile agents work very well in most scenarios [5]. Future work is possible in the area of improving the existing security measures for mobile agents.

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