ABSTRACT
Mobile agents require access to computing resources on heterogeneous systems across the Internet. This demo illustrates how agents can negotiate terms and conditions of resource access with one or more mediators representing virtual organizations of autonomous hosts, before migrating to a new location. Time-limited resource contracts are the result: contracts between agents and mediators, and contracts between mediators and hosts. The negotiation protocol and language are based on the WS-Agreement Specification, and have been implemented and tested within the AgentScape framework. The demonstration shows in detail how this negotiation framework has been implemented for resource access on remote, distributed systems.

Categories and Subject Descriptors
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General Terms
Experimentation, Standardization

Keywords
mobile agents, resource management, agent-based negotiation, WS-Agreements

1. INTRODUCTION
One of the assumptions behind the mobile agent paradigm in open, heterogeneous environments is that agents have access to computing resources across the Internet. However, little thought has been given to the way in which this is implemented. Not only do agents need access, they need to be able to plan coordinated resource usage across multiple domains. Recently, in service-oriented approaches negotiation of the conditions and quality of service of resource access has become identified as an important capability. The AgentScape demonstration focuses on negotiation of resource access for mobile agent applications deployed on Internet-scale, open distributed systems. The resources required by agents can vary from CPU type, bandwidth, to the provision of specific services (e.g., databases, web servers, etc.), and level of security required, depending on the task at hand. Well-defined, open protocols and mechanisms are necessary for agents to negotiate their resource access requirements with heterogeneous hosts.

Mobach et al. [3] present a negotiation infrastructure in which individual agents acquire time-limited contracts for the resources they need, through negotiation with one or more system domain coordinators: mediators representing multiple autonomous hosts. The protocols with which agent applications, domain coordinators, and hosts interact, are based on the WS-Agreement Specification [1] with application dependent domain ontologies for specific resources.

2. NEGOTIATION INFRASTRUCTURE
The overall goal and use of the negotiation infrastructure is to allow for the negotiation of terms of conditions and quality of service of resource access by agents. The negotiation model includes exchange of agreement offers and acceptance of offers between different parties. The negotiation infrastructure has been designed to deal with (i) large numbers of heterogeneous agents, and (ii) dynamic groups of heterogeneous hosts each with their own specific sets of requirements. From the agent’s perspective, the negotiation infrastructure defines a straightforward interface to acquire resources, but hides specific allocation details. On the other side, hosts need to keep full control over the use of their resources by agents. Negotiation policies spanning multiple hosts, allowing specification of resource access and usage policies over a set of hosts (e.g., for load balancing or virtual organization-wide policies) are also facilitated.

In our negotiation model, hosts (H) are autonomous entities that provide resources (R) to agents (A) under specific usage and access policies. Hosts are aggregated into virtual domains. Domain coordinators (DC), represent hosts within virtual domains in the negotiation process, negotiating with both agents and hosts.

Negotiation is a two-layered process: Agents negotiate resource access with domain coordinators, and domain coordinators, in turn,
negotiate with groups of host managers in virtual domains to obtain the resources agents require. The results of negotiation are time-limited contracts specifying which resources may be accessed during the time span of the contract, and under which conditions they may be used. Agents can negotiate with multiple domain coordinators. Figure 1 shows an overview of the model.

In our demonstration, a domain coordinator hides the individual resources from the agents. The task of selecting one appropriate offer (based on the available resources at a specific point in time) has been delegated to the domain coordinator. Alternatively, a domain coordinator could return a set of possible offers, letting a requesting agent choose the most appropriate. The model supports both options, but only the first will be demonstrated.

The negotiation protocol and language in our negotiation model are based upon the WS-Agreement Specification [1]. The specification defines an XML-based language for agreements between resource providers (hosts) and consumers (agents), and a protocol for establishing these agreements. An agreement contains terms and a context. Agreement terms describe the (levels of) service involved. The context contains meta information about the agreement, such as the parties involved or the duration. The specification of domain-specific term languages is explicitly left open.

In the proposed negotiation protocol, agents request agreements from domain coordinators, coordinating the resources made available by hosts (resource providers) by issuing an agreement request based on available agreements templates, which, if accepted, result in new agreements.

Hosts, the actual resource providers, also provide an agreement interface to the domain coordinator. The domain coordinator aggregates the templates offered by the hosts into composed templates. The domain coordinator makes these combined templates available to agents. Agreement requests made by agents are received by the domain coordinator. The domain coordinator negotiates an agreement with the hosts for the requested resources.

![Figure 2: Extended WS-Agreement protocol.](image)

Figure 2 shows the interaction model between an agent and Domain Coordinator. This model extends the original WS-Agreements protocol with two extra interactions: the request for templates at the start and the explicit accept/reject interaction at the end. The initial request for templates allows for the initial exchange of information between agents and a domain coordinator, for example for authentication purposes. The final accept/reject interaction allows agents to negotiate with multiple domain coordinators simultaneously, and accept the best offer from the set of offers received.

3. AGENTSCAPE

The negotiation architecture described above has been implemented in AgentScape [2, 4], a framework for heterogeneous, mobile agents. The AgentScape middleware creates a distributed environment that supports multiple, mobile agents. Middleware processes running within AgentScape provide services to agents. For example, agent servers provide a run-time environment for agents, a Message Center enables agents to communicate with other agents, and a Web service gateway enables agents to communicate with web services using the SOAP/XML protocol. In AgentScape, virtual domains are called locations. An AgentScape location consists of one or more hosts running the AgentScape middleware, typically within a single administrative domain.

In addition to the middleware processes described above, each host has a host manager middleware process, which is responsible for managing the middleware components running on the host, and implementing the required negotiation functionality. Furthermore, each AgentScape location runs a location manager process on one of its hosts. This process manages the AgentScape hosts, and implements the functionality of the domain coordinator, enabling applications to enter into resource negotiations with locations. Figure 3 shows an overview of an AgentScape location.

![Figure 3: Overview of an AgentScape location.](image)

Agents can start negotiations with a number of locations, and given the offers the locations provide, select the location offering the best options. The agent then migrates to the location with which agreement has been reached. A domain specific ontology used during negotiation describes the resources that can be allocated and used by agents in AgentScape. These resources include: CPU-time, communication bandwidth, memory, web service access, and disk space.

4. REFERENCES