Java Agent DEvelopment Framework (JADE)

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JADE and the Agent Abstraction

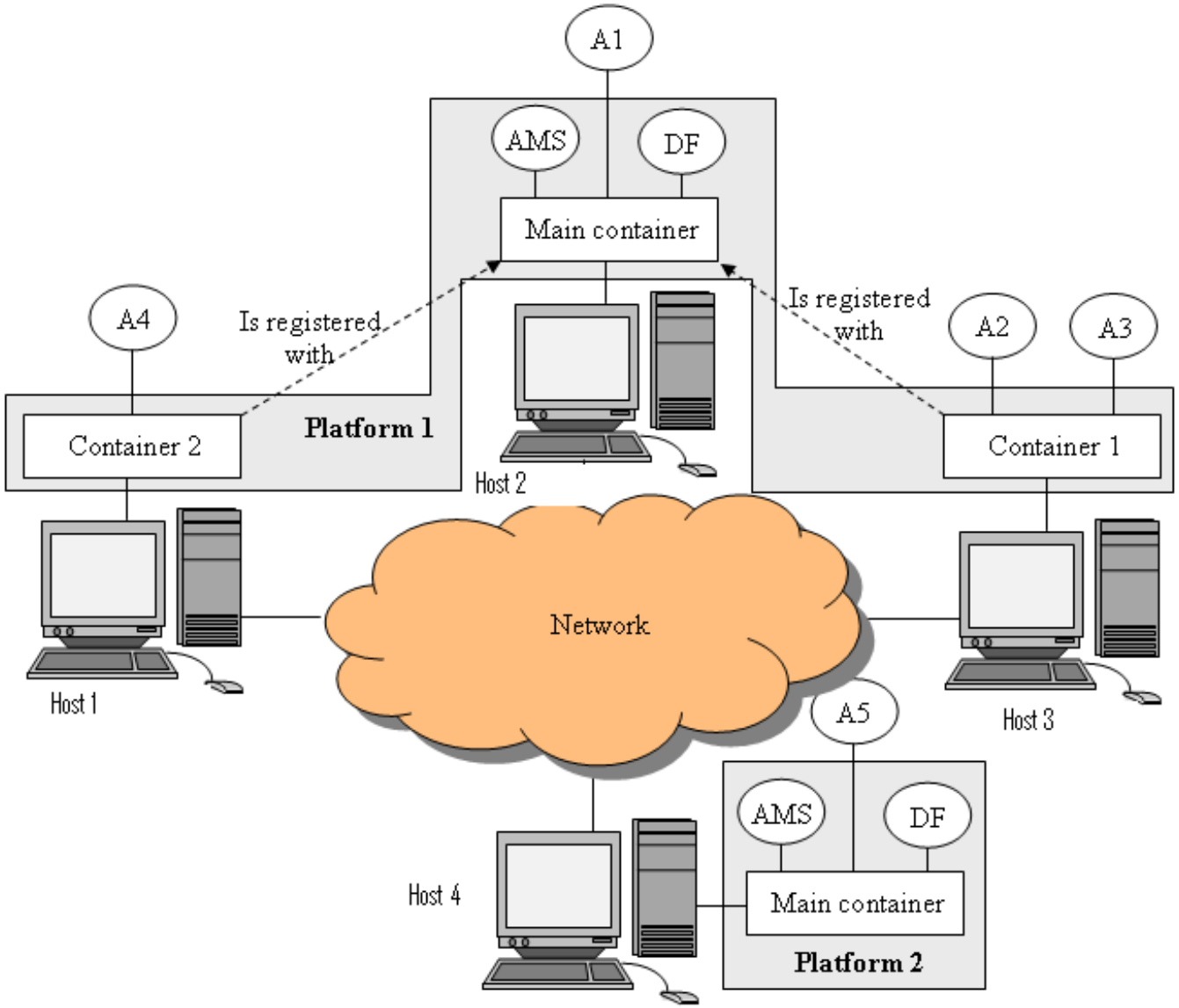
JADE Main Features

- Software platform providing basic middleware-layer functionalities for the realisation of distributed application by exploiting the agent abstraction
- Full compliant with *FIPA specifications*
- Provides graphical tools to support programmers when debugging and monitoring

JADE Agents

- Identified by a globally unique name: *AgentIdentifier* or *AID*
- Can join and leave a host platform at any time and can discover other agents through both *white-page* and *yellow-page* services
- Can initiate communication with any other agent at any time and can equally be the object of an incoming communication at any time
- Can be mobile

JADE Architecture



JADE Architecture

Agents and Containers

- A JADE platform is composed of *agent containers* that can be distributed over the network
- Agents live in containers
- A container is a Java process providing the JADE run-time and all the service needed for hosting and executing agents

Main Container

- Is a special container representing the bootstrap point of the platform
- All the containers must join to a main container by registering with it
- By default the *Main Container* contains two agents:
  - *Agent Management System* (AMS) that supervises the entire platform
  - *Directory Facilitator* (DF) that implements the yellow pages service

Admin & Debugging Tools

Complexity in Multi-agent Applications

- Often distributed across several hosts
- Composed of perhaps hundreds of multi-threaded processes
- They are dynamic in that agents can appear, disappear and migrate

→ Difficulties in management and especially debugging

→ JADE has an event notification service which forms the basis of

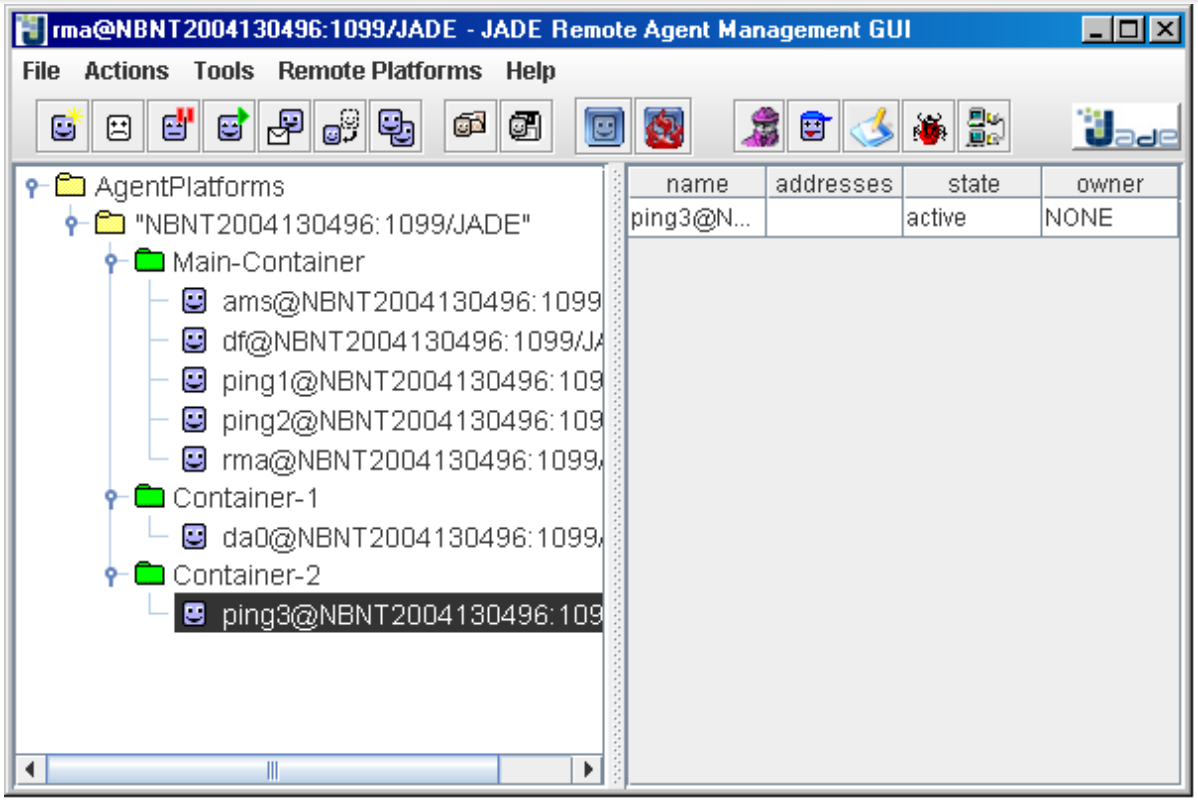
  - The *JADE RMA* management console
  - A set of graphical tools

  → They are provided to help in the management and debugging phase

Admin & Debugging Tools

JADE RMA (Remote Monitoring Agent)

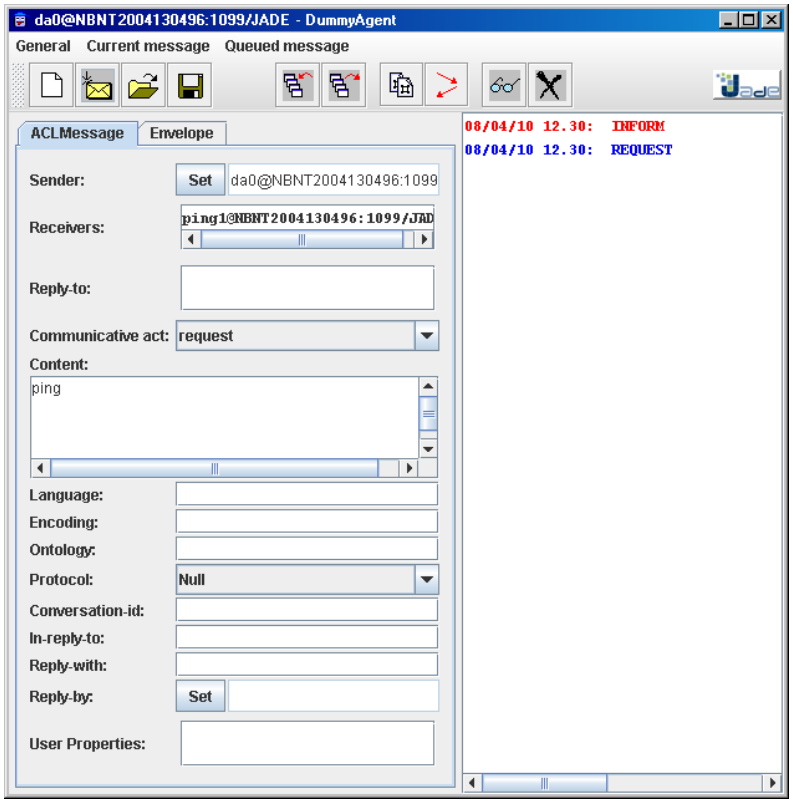
- Implements a graphical platform management console
- Provides a visual interface to monitor and administer a distributed JADE platform composed of one or several hosts and container nodes
- It includes a "Tools" menu through which other tools can be launched



Admin & Debugging Tools

Dummy Agent

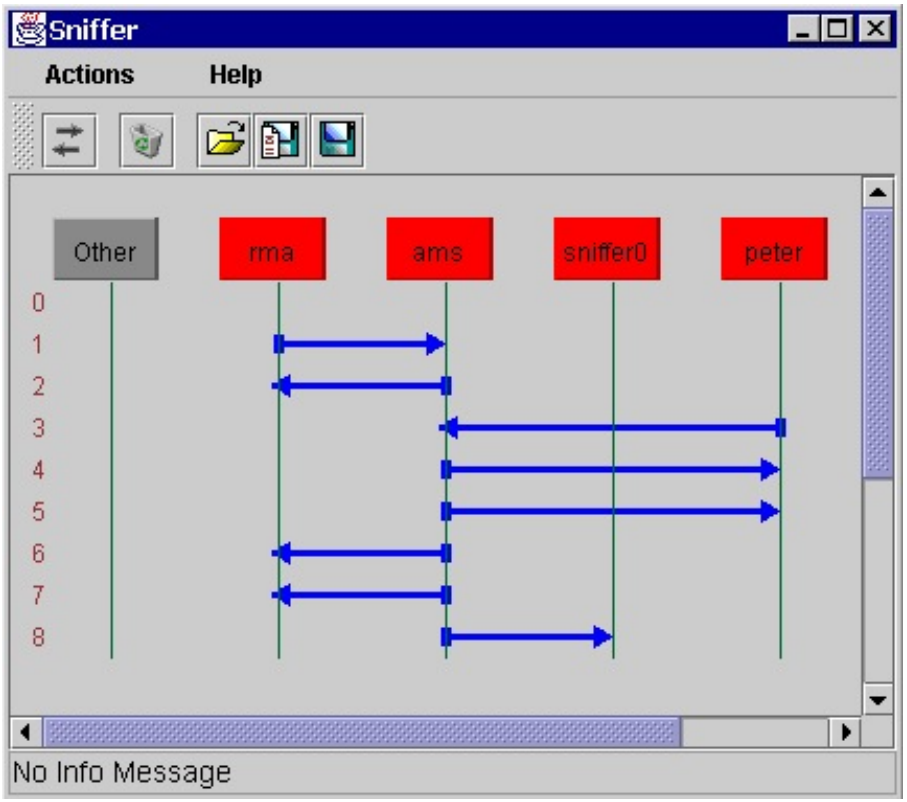
- A simple tool that is useful for sending stimuli, in the form of custom ACL messages, to test the behaviour of another agent



Admin & Debugging Tools

Sniffer Agent

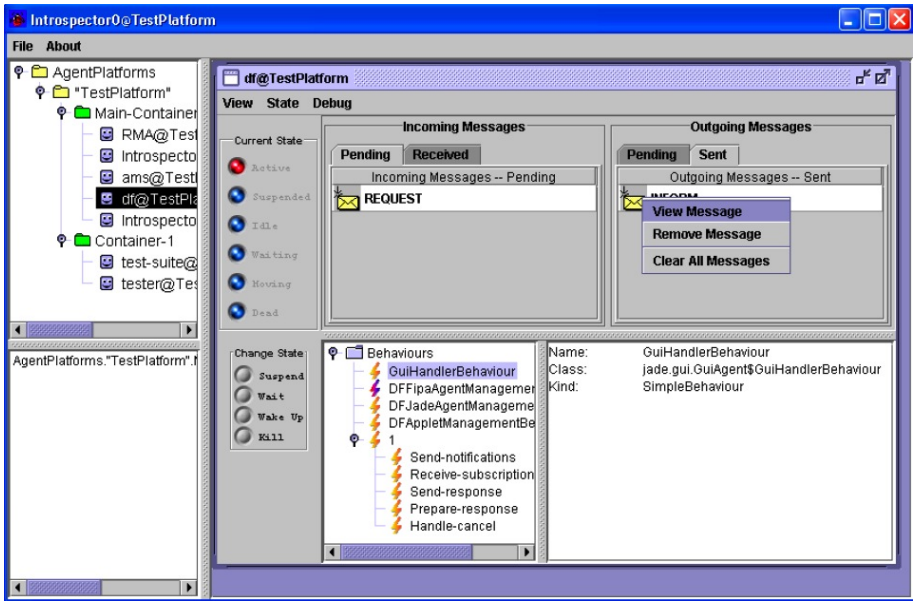
- A tool used for debugging or, simply documenting conversations between agents



Admin & Debugging Tools

Introspector Agent

- While the Sniffer Agent is a tool useful to sniff, monitor and debug conversation between agents, the Introspector Agent should be used to debug the behaviour of a single agent
- In fact, it allows an agent's life cycle, and its queues of sent and received messages, to be monitored and controlled



Admin & Debugging Tools

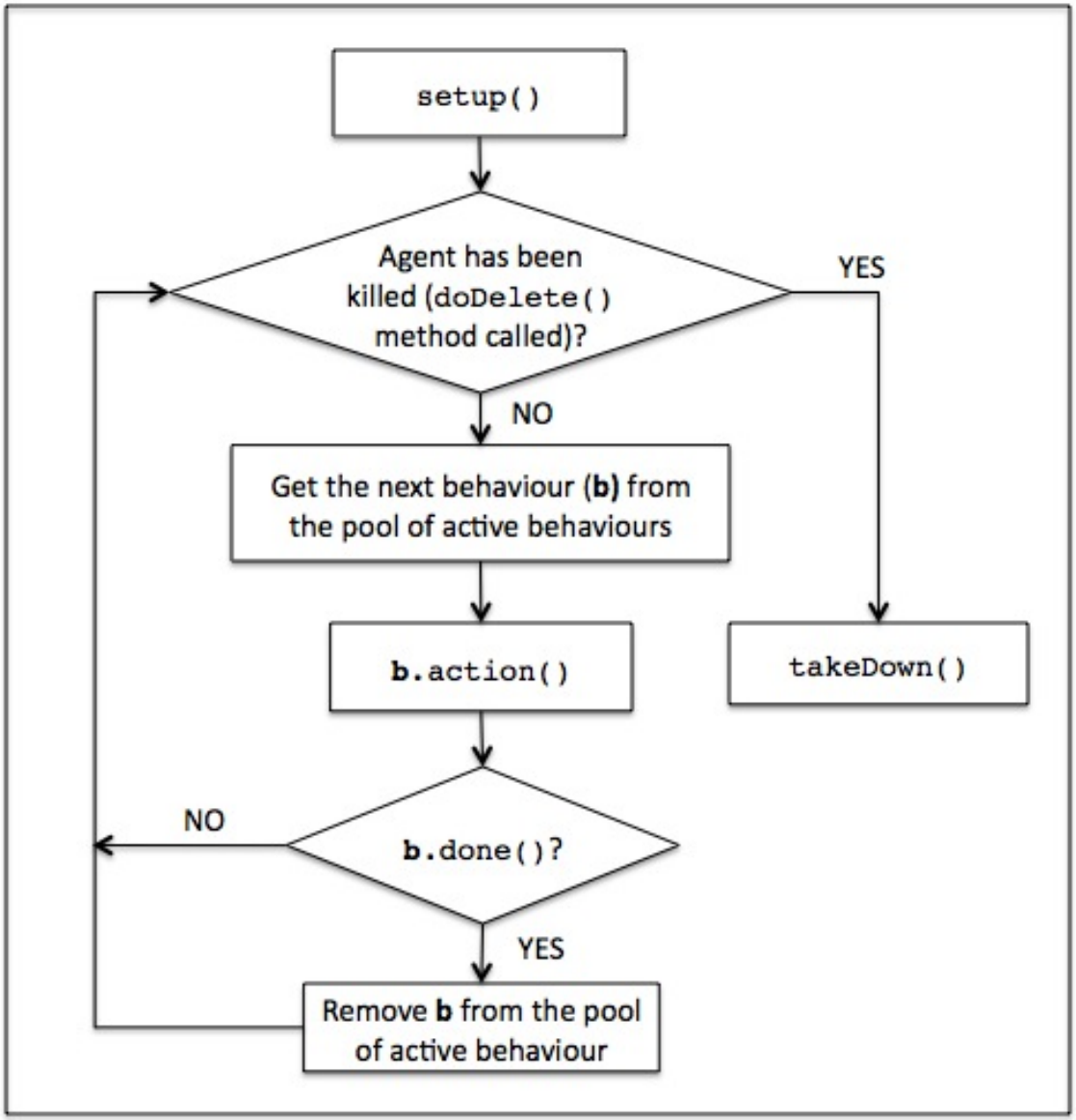
Log Manager Agent

- Is a tool that simplifies the dynamic and distributed management of the logging facility by providing a graphical interface that allows the logging levels of each component of the JADE platform to be changed at run-time

log0@hpi11170:1099/JADE - LogManagerAgent

Logger Name	Set Level	Handlers	Set log file
	INFO	java.util.logging.ConsoleHandler...	
global	INFO	java.util.logging.ConsoleHandler	
jade.content.lang.sl.SL0Ont...	INFO	java.util.logging.ConsoleHandler	
jade.content.lang.sl.SL1Ont...	INFO	java.util.logging.ConsoleHandler	
jade.content.lang.sl.SL2Ont...	INFO	java.util.logging.ConsoleHandler	
jade.content.lang.sl.SLOntol...	INFO	java.util.logging.ConsoleHandler	
jade.content.onto.BasicOntol...	INFO	java.util.logging.ConsoleHandler	
jade.content.onto.Ontology	INFO	java.util.logging.ConsoleHandler	
jade.content.onto.Serializabl...	INFO	java.util.logging.ConsoleHandler	
jade.content.schema.AgentA...	INFO	java.util.logging.ConsoleHandler...	logFile.txt
jade.content.schema.Aggreg...	INFO	java.util.logging.ConsoleHandler	
jade.content.schema.Conce...	INFO	java.util.logging.ConsoleHandler	
jade.content.schema.Conte...	INFO	java.util.logging.ConsoleHandler	
jade.content.schema.Conte...	WARNING	java.util.logging.ConsoleHandler	
jade.content.schema.IRESc...	INFO	java.util.logging.ConsoleHandler	
jade.content.schema.Object...	CONFIG	java.util.logging.ConsoleHandler	
jade.content.schema.Predic...	FINE	java.util.logging.ConsoleHandler	
jade.content.schema.Primiti...	FINER	java.util.logging.ConsoleHandler	
jade.content.schema.TermS...	FINEST	java.util.logging.ConsoleHandler	
jade.content.schema.Variabl...	ALL	java.util.logging.ConsoleHandler	
jade.core.AgentContainerImpl	OFF	java.util.logging.ConsoleHandler	
jade.domain.DFGUIManage...		java.util.logging.ConsoleHandler	
jade.domain.DFMemKB	INFO	java.util.logging.ConsoleHandler	
jade.domain.FIPAAgentMan...	INFO	java.util.logging.ConsoleHandler	
jade.domain.FIPAAgentMan...	INFO	java.util.logging.ConsoleHandler	
jade.domain.JADEAgentMan...	INFO	java.util.logging.ConsoleHandler	

Agent Cycle


setup()
Agent has been killed (doDelete() method called)?
YES
NO
Get the next behaviour (b) from the pool of active behaviours
b.action()
takeDown()
NO
b.done()?
YES
Remove b from the pool of active behaviour

Agent Example

```
import jade.core.Agent;
import java.util.Iterator;

@SuppressWarnings("serial")
public class HelloWorldAgent extends Agent
{
    @SuppressWarnings("unchecked")
    protected void setup()
    {
        System.out.println("Hello World! I'm an agent");
        System.out.println("My local name is " + getAID().getLocalName());
        System.out.println("My GUID is " + getAID().getName());
        System.out.println("My addresses are: ");

        Iterator it = getAID().getAllAddresses();

        while (it.hasNext())
            System.out.println("- " + it.next());

        System.out.println("My addresses are: ");
        Object[] args = getArguments();

        if (args != null)
            for (int i = 0; i < args.length; i++)
                System.out.println("- " + args[i]);

        doDelete();
    }
}
```

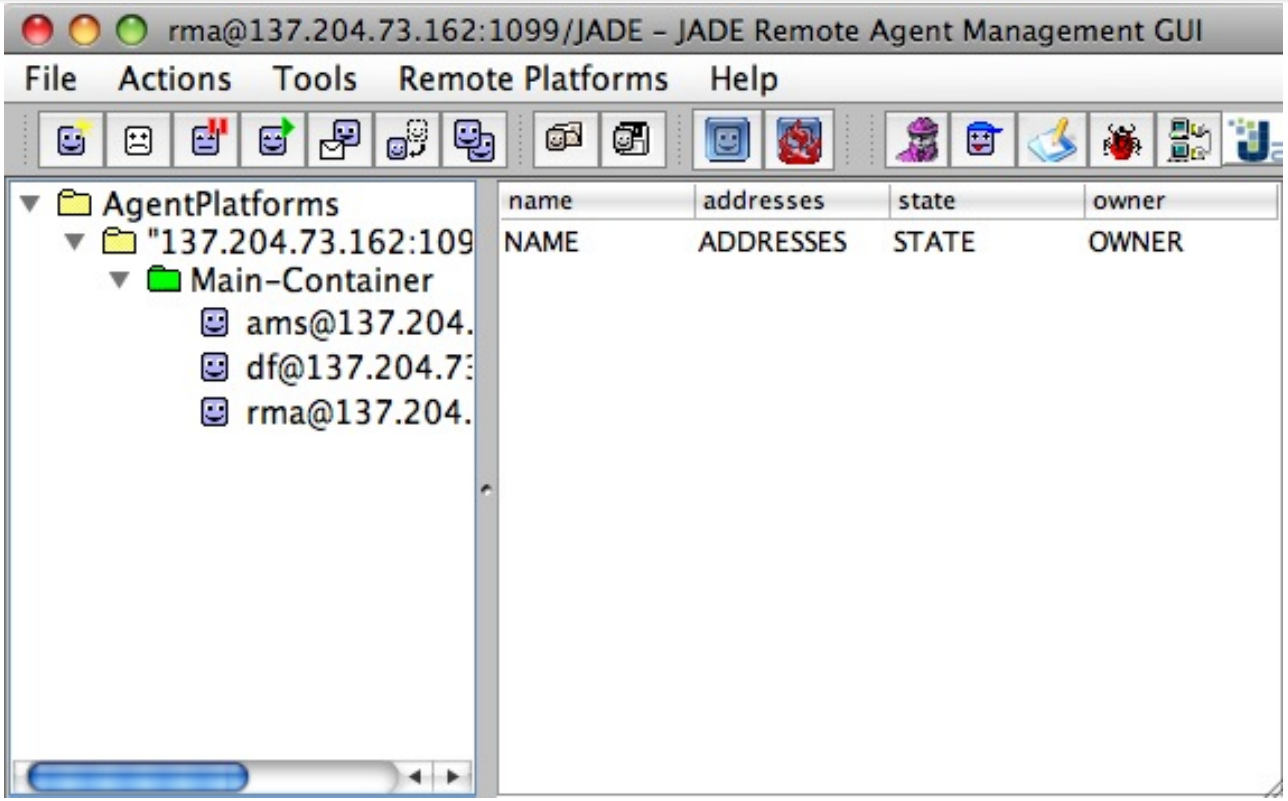
Agent Execution

- Compile the Agent HelloWorldAgent with the command

  ```
  javac -cp jade.jar *.java
  ```

- Run the *Main Container* with the command

  ```
  java -cp .:jade.jar jade.Boot -gui
  ```



Agent Execution

- Run the Agent with the command

  `java -cp .:jade.jar jade.Boot -container Pet:HelloWorldAgent`

```
Hello World! I'm an agent
My local name is Pet
My GUID is Pet@137.204.73.162:1099/JADE
My addresses are:
- http://polo-port03.polocesena.dir.unibo.it:7778/acc
My arguments are:
```

- Run the Agent with the command

  `java -cp .:jade.jar jade.Boot -container "Pet:HelloWorldAgent(arg1,arg2)"`

```
Hello World! I'm an agent
My local name is Pet
My GUID is Pet@137.204.73.162:1099/JADE
My addresses are:
- http://polo-port03.polocesena.dir.unibo.it:7778/acc
My arguments are:
- arg1
- arg2
```

Agent Behaviour

- Three primary behaviour types are available with JADE
  - One-shot. Designed to complete in one execution phase
  - Cyclic-shot. Designed to never complete
  - Generic-shot. Embed a status trigger and execute different operations depending on the status value

Example of Behaviour Implementation (From BOOK-TRADING Project)

```
private class OfferRequestsServer extends CyclicBehaviour
{
    public void action()
    {
        MessageTemplate mt = MessageTemplate.MatchPerformative(ACLMessage.CFP);
        ACLMessage msg = myAgent.receive(mt);
        if (msg != null)
        {
            // CFP Message received. Process it
            String title = msg.getContent();
            ACLMessage reply = msg.createReply();

            Integer price = (Integer) catalogue.get(title);
            if (price != null)
            {
                // The requested book is available for sale. Reply with the
                // price
                reply.setPerformative(ACLMessage.PROPOSE);
                reply.setContent(String.valueOf(price.intValue()));
            }
            else
            {
                // The requested book is NOT available for sale.
                reply.setPerformative(ACLMessage.REFUSE);
                reply.setContent("not-available");
            }
            myAgent.send(reply);
        }
        else
        {
            block();
        }
    }
```

Example of Behaviour Definition (From BOOK-TRADING Project)

```
// Add the behaviour serving queries from buyer agents
addBehaviour(new OfferRequestsServer());

// Add the behaviour serving purchase orders from buyer agents
addBehaviour(new PurchaseOrdersServer());
```

Agent Communication

- Agent communication is implemented in accordance with the FIPA specifications
- The communication paradigm is based on *asynchronous message passing*:
  - A *mailbox* associated to each agent
  - An agent is notified whenever a message is posted in the mailbox

Messages

- Compliant with FIPA-ACL message structure
  - The *sender* of the message
  - The list of *receiver*
  - The *communication act* (or *performative*) indicating what the sender intends to achieve by sending the message
  - The *content* containing the actual information to be exchanged
  - The *content language* indicating the syntax used to express the content
  - The *ontology* indicating the semantic used to interpreter the content
  - Some additional fields...

Example of DF Usage: Registration (From BOOK-TRADING Project)

```
// Register the book-selling service in the yellow pages
DFAgentDescription dfd = new DFAgentDescription();
dfd.setName(getAID());
ServiceDescription sd = new ServiceDescription();
sd.setType("book-selling");
sd.setName("JADE-book-trading");
dfd.addServices(sd);

try
{
    DFService.register(this, dfd);
}
catch (FIPAException fe)
{
    fe.printStackTrace();
}
```

Example of DF Usage: Searching (From BOOK-TRADING Project)

```
DFAgentDescription template = new DFAgentDescription();
ServiceDescription sd = new ServiceDescription();
sd.setType("book-selling");
template.addServices(sd);
try
{
    DFAgentDescription[] result = DFService.search(myAgent, template);
    System.out.println("Found the following seller agents:");
    sellerAgents = new AID[result.length];
    for (int i = 0; i < result.length; ++i)
    {
        sellerAgents[i] = result[i].getName();
        System.out.println(sellerAgents[i].getName());
    }
}
catch (FIPAException fe)
{
    fe.printStackTrace();
}
```

Example of Message Sending (From BOOK-TRADING Project)

```
// Send the cfp to all sellers
ACLMessage cfp = new ACLMessage(ACLMessage.CFP);
for (int i = 0; i < sellerAgents.length; ++i)
{
    cfp.addReceiver(sellerAgents[i]);
}
cfp.setContent(targetBookTitle);
cfp.setConversationId("book-trade");
cfp.setReplyWith("cfp" + System.currentTimeMillis()); // Unique
                                                      // value
myAgent.send(cfp);
```

Example of Message Reception and Blocking (From BOOK-TRADING Project)

```
private class OfferRequestsServer extends CyclicBehaviour
{
    public void action()
    {
        MessageTemplate mt = MessageTemplate.MatchPerformative(ACLMessage.CFP);
        ACLMessage msg = myAgent.receive(mt);
        if (msg != null)
        {
            // CFP Message received. Process it
            String title = msg.getContent();
            ACLMessage reply = msg.createReply();

            Integer price = (Integer) catalogue.get(title);
            if (price != null)
            {
                // The requested book is available for sale. Reply with the
                // price
                reply.setPerformative(ACLMessage.PROPOSE);
                reply.setContent(String.valueOf(price.intValue()));
            }
            else
            {
                // The requested book is NOT available for sale.
                reply.setPerformative(ACLMessage.REFUSE);
                reply.setContent("not-available");
            }
            myAgent.send(reply);
        }
        else
        {
            block();
        }
    }
} // End of inner class OfferRequestsServer
```

JADE for Usage

- Homepage: `http://jade.tilab.com/`
- Download JADE-all-4.0.1.zip containing
  - bin
  - doc
  - examples
  - src
- We need jade.jar in bin, the documentation in doc and examples

Jason with JADE

- It is possible to use Jade as communication infrastructure for Jason
- It is possible to integrate Jade agents with Jason agents
- See `http://jason.sourceforge.net/mini-tutorial/jason-jade/`

Outline

Thermostat Agent with JADE

Requirements

- Check the environment temperature T.
- Until T is not: > 18 and < 22:
  - Decrease T of one unit if the temperature is 22
  - Increase T of one unit if the temperature is 18

Constraint

- ThermostatAgent interacts with the environment to sense and change the temperature
- The environment can be simulated by an agent

Outline

Thermostat Agent with Agent Interaction

New Constraints

- There are three agents:
  - ThermostatAgent interacts with the environment to sense and change the temperature
  - ManagerAgent publish the service JADE-themperature-checking in the DF
  - ThermostatAgent searches the service JADE-themperature-checking in the DF and obtain the Agent ID (AID) of ManagerAgent
  - ThermostatAgent asks to ManagerAgent the new value of the temperature

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