

JADE: Java Agent DEvelopment Framework Advanced

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- 1 Directory Facilitator
- 2 FIPA Interaction Protocols in JADE
- 3 JADE Agents & Java Swing



Disclaimer

All the material presented in these slides is rearranged by the author from a collection of documents kindly made available by the JADE team.

Credits for all the stuff (text & images) go to the JADE team, in particular to Giovanni Caire.

Credits for all the mistakes go to the author.



Outline

- 1 Directory Facilitator
 - API
 - Syntax
 - Usage
- 2 FIPA Interaction Protocols in JADE
 - Achieve Rational Effect
 - Contract Net
 - More on Responders
- 3 JADE Agents & Java Swing



Recap

What we already know

By default, a singleton **Directory Facilitator** (DF) exists for each JADE platform, which:

- provides the **yellow pages** service by keeping track of published services provided by advertising agents—be them local or remote
- should be *explicitly* contacted by JADE agents who wish to advertise their capabilities—both to submit an advertisement and to remove it
- supports the **publish/subscribe pattern** by offering a *notification service*
- can be *federated* with other DFs to implement a *truly distributed* yellow pages service

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DF API I

What's new

The DF service is implemented as a JADE agent – as the AMS – in class `jade.domain.DFService`

! being JADE DF FIPA-compliant, *all interactions with the DF must follow FIPA's standards*:

- interaction protocols taken from package `jade.proto`
- *ACL* messages must adhere to the `FIPAMangementVocabulary` (ontology) in package `jade.domain.FIPAAgentManagement`
- *ACL* messages content must adhere to the `SLOVocabulary` in package `jade.content.lang.sl`

...

DF API II

JADE helps us

...

- static methods are provided to automatically build *semantically-correct* *ACL* messages:
 - `createRequestMessage()` to request the execution of a `fipa-agent-management` ontology action by the DF
 - `createSubscriptionMessage()` to request subscription for a given `DFAgentDescription` template
 - `decodeResult()` to process the content of the final message received as a result of `search()` operation
 - `decodeNotification()` to process the content of a notification message received as a consequence of a previous subscription

...



DF API III

JADE helps us even more

...

- to ease developer's work, a set of static methods embedding such interaction protocols are provided by class DFService
 - `register()` called by an agent wishing to advertise a service
 - `deregister()` called by an agent who no longer offers a previously advertised service
 - `search()` called by *client* agents looking for a service to exploit
- ! be careful 'cause all these methods are **blocking calls**, therefore *every activity of the agent is suspended* until success or failure of the call
 - if you need *asynchronous* interactions, go for the FIPA protocols approach

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DF Entries Syntax I

The DFAgentDescription class (DFD)

The DFD is an entry in the DF, thus must contain (at least):

- the agent ID
- the set of services the agent wishes to advertise, in the form of *ServiceDescription*
- the set of *ontologies*, *protocols* and *languages* the agent is able to support/understand



DF Entries Syntax II

The ServiceDescription class (SD)

The SD is a descriptor of the service the agent wishes to publish to the DF, thus must contain (at least):

- the service *name*
- the service *type*
- the set of *ontologies* and *languages* whose knowledge is required to exploit the service
- a number of *service-specific* properties



DF Entries Syntax III

```
DFAgentDescription {  
  Name: AID (mandatory)  
  Protocols: set of strings  
  Ontologies: set of strings  
  Languages: set of strings  
  Services {  
    Name: String (mandatory)  
    Type: String (mandatory)  
    Protocols: set of strings  
    Ontologies: set of strings  
    Languages: set of strings  
    Properties: {  
      Name: String  
      Value: String  
    }  
  }  
}
```

Figure: Pseudo-code view of a DF entry

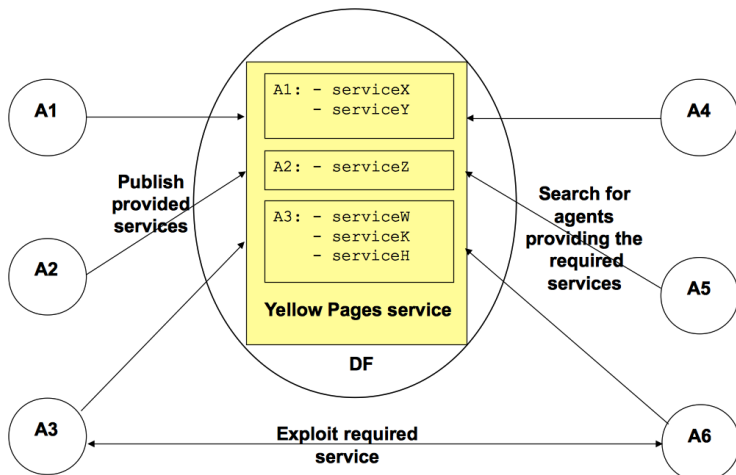


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DF API Usage I



DF API Usage II

Registering to the DF

- ❶ instantiate a `DFAgentDescription` object
→ `DFAgentDescription dfd = new DFAgentDescription();`
- ❷ fill in (at least) its `Name` field with the advertising agent AID
→ `dfd.setName(getAID());`
- ❸ instantiate a `ServiceDescription` object
→ `ServiceDescription sd = new ServiceDescription();`
- ❹ fill in (at least) its `Name` and `Type` fields with meaningful strings
→ `sd.setType("buyer");`
→ `sd.setName("online trad");`
- ❺ add the `ServiceDescription` to the `DFAgentDescription`
→ `dfd.addServices(sd);`
- ❻ call `DFService.register(this, dfd);`

DF API Usage III

Deregistering from the DF

Since dead agent's AIDs are automatically removed *solely from the AMS*, it is a good practice to deregister agents upon death

- a good place where to do so is in `takeDown()` callback method
 - `DFService.deregister(this);`

! keep in mind that each agent is allowed to have *only one entry* in the DF

- each attempt to register an already registered agent throws an exception



DF API Usage IV

Browsing the DF I

Client agents may query the DF to know if any agent offers the services they are looking for and then acquire their AIDs:

- ❶ create a DFD (with no AID, obviously...) filling its fields with the properties you look for
 - `DFAgentDescription dfd = new DFAgentDescription();`
`ServiceDescription sd = new ServiceDescription();`
`sd.setType("buyer");`
`dfd.addServices(sd);`
- ❷ specify as SearchConstraints that you want to get *all* the agents offering the service (skip this if you need only one)
 - `SearchConstraints all = new SearchConstraints();`
`all.setMaxResults(new Long(-1));`

...

DF API Usage V

Browsing the DF II

...

- 1 launch the search process (skip last parameter if skipped previous point)

→ `DFAgentDescription[] result = DFService.search(this, dfd, all);`

- 2 extract the AID(s) from the results set

→ `AID[] providers = new AID[result.length];
for (int i = 0; i < result.length; i++) {
 providers[i] = results[i].getName();
}`

Check the `ds.lab.jade.bookTrading` example for the whole code.

DF API Usage VI

Subscribing to the DF I

JADE agents can ask the DF to **notify** them *as soon as* a given service is advertised:

- 1 as usual, create a DFD suited for the service you wish to be notified about...

```
→ DFAgentDescription dfd = new DFAgentDescription();  
   ServiceDescription sd = new ServiceDescription();  
   sd.setType(...);  
   dfd.addServices(sd);
```

- 2 ...configure your chosen SearchConstraints (if you please)...

```
→ SearchConstraints sc = new SearchConstraints();  
   sc.setMaxResults(new Long(1));
```

...



DF API Usage VII

Subscribing to the DF II

...

- 1 ... then, perform your subscription

```
→ send(  
    DFService.createSubscriptionMessage(this, getDefaultDF(), dfd, sc)  
);
```

Now the DF will send an `ACLMessage.INFORM` to the subscribed agent *whenever* an agent matching the supplied description registers



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Interaction Protocols I

FIPA definition

“Predefined sequences of messages that can be reused in different domains to implement a given interaction”—some kind of “design pattern” for communications

The jade.proto package

`jade.proto` contains behaviours implementing both the **initiator** and **responder roles** in most common interaction protocols

- managing the flow of messages and checking that it is *consistent to the protocol*
- providing *callback methods* that can be overridden to take the necessary actions when a message is received

Interaction Protocols II

(Some) Protocol classes I

AchieveRE[Initiator/Responder] factorization of all the FIPA *Request-like* interaction protocols^a, that is, those in which the initiator aims to achieve a **RE (Rational Effect)** and needs to verify if it has been achieved or not

ContractNet[Initiator/Responder] allows the initiator to send a *Call for Proposal* to a set of responders, evaluate their proposals and then accept the preferred one (or even reject all of them)

... ..

^asuch as FIPA-Request, FIPA-query, FIPA-Request-When, FIPA-recruiting, FIPA-brokering.



Interaction Protocols III

(Some) Protocol classes II

... ..

Propose[Initiator/Responder] allows the initiator to send a PROPOSE message to the participants indicating *its will to perform some action if they agrees*. The participants responds by either accepting or rejecting such proposal, then the initiator either carries out the action or not accordingly

Subscription[Initiator/Responder] allows the initiator to *subscribe* to a target agent for certain kind of events. If the participant agrees, it communicates all content *matching the subscription condition* using an INFORM-RESULT

... ..

... refer to JADE API for the others

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AchieveRE I

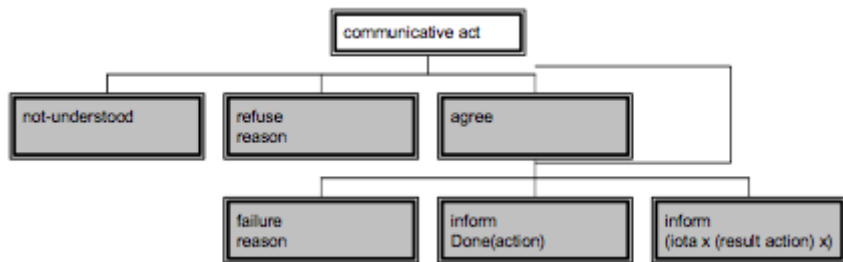


Figure: FIPA AchieveRE protocol message flow

AchieveRE II

AchieveREInitiator

Initiator role for FIPA request-like protocols

- constructed by passing the protocol-starting *ACL* message
 - ! be sure to set the `protocol` field of the `ACLMessage` with the proper constant taken from `FIPANames.InteractionProtocols` in package `jade.domain`
- to be extended by overriding its `handle[...]` *callback* methods, which provide hooks to handle all the states of the protocol
 - e.g. `handleAgree()`, `handleInform()`, ...
 - ! be aware of the functioning of callbacks such as `handleOutOfSequence()`, `handleAllResponses()`, `handleAllResultNotifications`—refer to JADE *programmer's guide*
- manages an *expiration timeout* expressed by the value of the *reply-by* slot in `ACLMessage`
 - ! as defined by FIPA, such timeout refers to the *first response*: second response timeouts can be managed “by hand”

AchieveRE III

AchieveREResponder

Responder role for FIPA request-like protocols

- constructed by passing the `MessageTemplate` describing *ACL* messages we'd like to manage
 - ! method `createMessageTemplate` is provided to create templates for each interaction protocol
- to be extended by overriding its `handle/prepare[...]` *callback* methods, which provide hooks to handle all the states of the protocol
 - `handleRequest()` to reply to first initiator message
 - `prepareResultNotification()` to send the final response about the RE achieved
 - ...



AchieveRE IV

```
ACLMessage msg = new ACLMessage(ACLMessage.REQUEST);
msg.setProtocol(FIPANames.InteractionProtocol.FIPA_REQUEST);
addBehaviour(new AchieveREInitiator(this, msg){
    @Override
    protected void handleAgree(ACLMessage agree) {

    }
    @Override
    protected void handleFailure(ACLMessage failure) {

    }
    @Override
    protected void handleInform(ACLMessage inform) {

    }
    @Override
    protected void handleNotUnderstood(ACLMessage notUnderstood) {

    }
    @Override
    protected void handleRefuse(ACLMessage refuse) {

    }
});
```

Figure: JADE AchieveREInitiator



AchieveRE V

```
MessageTemplate template = AchieveREResponder.createMessageTemplate(  
    FIPANames.InteractionProtocol.FIPA_REQUEST);  
addBehaviour(new AchieveREResponder(this, template){  
    @Override  
    protected ACLMessage handleRequest(ACLMessage request)  
        throws NotUnderstoodException, RefuseException {  
        return new ACLMessage(ACLMessage.AGREE);  
    }  
    @Override  
    protected ACLMessage prepareResultNotification(ACLMessage request,  
        ACLMessage response) throws FailureException {  
        return new ACLMessage(ACLMessage.INFORM);  
    }  
});
```

Figure: JADE AchieveREResponder

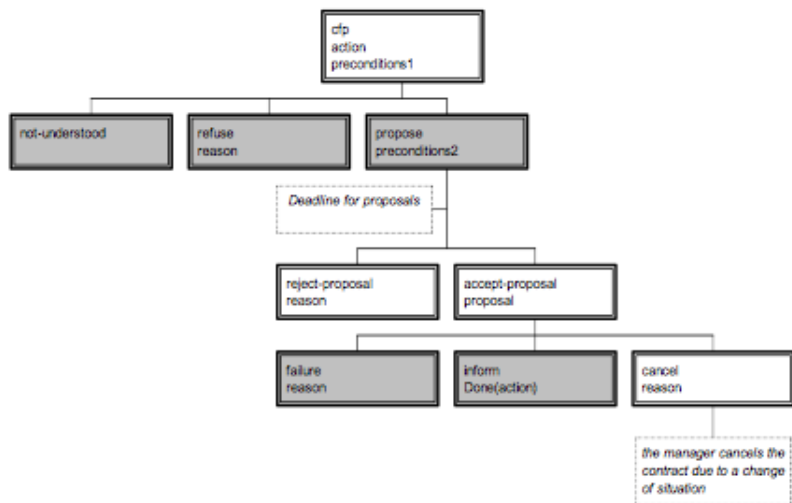


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ContractNet I



ContractNet II

ContractNetInitiator

Initiator role for FIPA contract-net protocol

- constructed by passing the protocol-starting *ACL* message
 - ! again, use `FIPANames.InteractionProtocols` to set the protocol field of the `ACLMessage`
- to be extended by overriding its `handle[...]` *callback* methods
 - e.g. `handlePropose()`, `handleInform()`, ...
 - ! be sure to implement `handleAllResponses()` by adding to the `acceptances` Vector all the `ACLMessage.ACCEPT_PROPOSAL` *ACL* messages to send
- manages the *expiration timeout*
 - ! again, reply-by timeout refers to the *first response*
 - ! late answers *are not consumed*, thus remain in the agent message box

ContractNet III

ContractNetResponder

Responder role for FIPA contract-net protocol

- constructed by passing the proper `MessageTemplate`
 - ! again, use method `createMessageTemplate`
- to be extended by overriding its `handle[...]` *callback* methods
 - `handleCfp()` the initial CFP message
 - `handleAcceptProposal()` when an `ACCEPT_PROPOSAL` message is received from the initiator
 - ...

Check the `ds.lab.jade.bookTrading.contractNet` example for the code.



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Responder Behaviours I

Cyclic vs. single-session responders

Responder behaviours may have two forms:

Cyclic Serve interactions initiated by different agents **sequentially**

- ① wait for the protocol initiation message
- ② serve the protocol
- ③ go back waiting for a new protocol initiation message

Single-Session Serve interactions initiated by different agents **in parallel**

- ① get the protocol initiation message in the constructor
→ requires an external behaviour to be used
- ② serve the protocol
- ③ terminate

Check the `jade.proto` package to learn more.

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Java Swing Troubles I

What's the problem?

Whenever developing JADE agents which need to interact with a Java GUI, the *thread-per-agent* concurrency model of JADE agents must work together with the Swing **Event Dispatcher Thread (EDT)** concurrency model



Java Swing Troubles II

More in detail

- as you should know, the Swing framework *is not thread-safe*, so any code that updates the GUI elements must be executed within the EDT
 - since modifying a *model object* triggers an update of the GUI, model objects too have to be manipulated just by the EDT
- the **SwingUtilities** class exposes two *static methods* to delegate execution of Runnable objects to the EDT

invokeLater() puts the Runnable into the System Event Queue (SEQ) (accessed by the EDT only) and returns immediately—*asynchronous* call

invokeAndWait() puts the Runnable into the SEQ and blocks waiting its completion—*synchronous* call

JADE Solution I

GuiAgent class

To develop JADE agents interacting with a GUI, simply extend **GuiAgent** class in package `jade.gui`

onGuiEvent(GuiEvent e) may be viewed as the *equivalent* of the `actionPerformed()` method in Java Swing, that is, a callback invoked by JADE platform as soon as a **GuiEvent** is generated

postGuiEvent(GuiEvent e) used by the agent's GUI to *queue GUI events* for later processing—similar to queueing *ACL* messages in its mailbox



JADE Solution II

GuiEvent class

A GuiEvent object has:

- two *mandatory* attributes
 - source** the Object source of the event
 - type** an integer identifying the kind of event generated
- an optional list of parameters eventually used for events processing
 - addParameter()** takes the Object to add as a GuiEvent parameter
 - getParameter()** gets the *i-th* parameter
 - getAllParameter()** returns an Iterator to browse all parameters



JADE Solution III

One advice

From JADE programmer's guide:

*"In general, it is not a good thing that an external software component maintains a **direct object reference** to an agent, because this component could directly call **any public method** of the agent, skipping the asynchronous message passing layer and turning an **autonomous agent** into a server object, **slave to its caller**. The correct approach is that to gather all the external methods into an **interface**, implemented by the agent class, then an object reference of that interface will be passed to the external software component (e.g., a GUI) so that only the external methods will be available from event handlers."*

Check the `ds.lab.jade.bookTrading.gui` example carefully.

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