JADE: Java Agent DEvelopment Framework Overview

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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

JADE in Short I

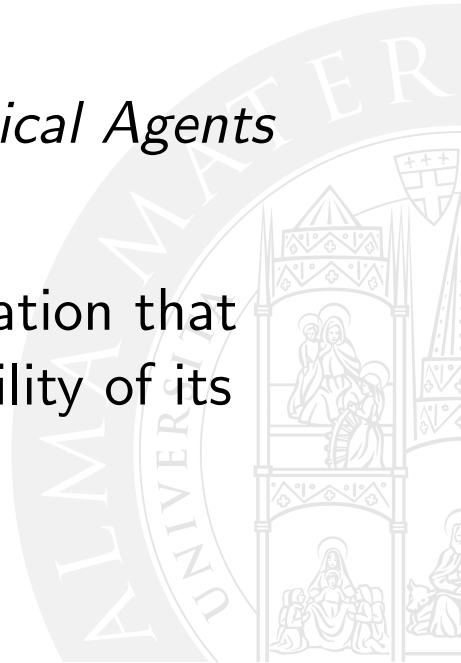
- JADE stands for *Java Agent DEvelopment Framework*

  `http://jade.tilab.com/`

- JADE is a Java-based framework to develop agent-based applications in compliance with the FIPA specifications for interoperable, intelligent, multi-agent systems
- where FIPA stands for *Foundation for Intelligent Physical Agents*

  `http://www.fipa.org/`

- FIPA is the IEEE Computer Society standards organisation that promotes agent-based technology and the interoperability of its standards with other technologies



JADE in Short II

JADE Goals

As an agent-oriented middleware, JADE pursues the twofold goal of being

- a full-fledged FIPA-compliant *agent platform*. Hence, it takes charge of all those application-independent aspects – such as agent lifecycle management, communication, distribution transparency, etc. – necessary to develop a MAS
- a simple yet comprehensive *agent development framework*. Therefore, it provides Java developers a set of APIs to build their own customisations

JADE Main Ingredients

Java

Being fully implemented in Java, JADE is a notable example of a distributed, object-based, agent-oriented infrastructure, hence an interesting example about how to face a design/programming *paradigm shift*

FIPA

Being compliant to FIPA standards, JADE is a *complete* and *coherent* agent platform providing all the necessary facilities to deploy MASs

JADE Main Features

JADE offers (among many)

- a distributed agent platform, where "distributed" means that a single (logical) JADE system can be split among different networked hosts
- transparent, distributed message passing service
- transparent, distributed naming service
- white pages & yellow pages discovering facilities
- intra-platform agent mobility (code & context, to some extent)
- debugging & monitoring graphical tools
- . . . much more. . .

Outline

JADE Architecture Overview

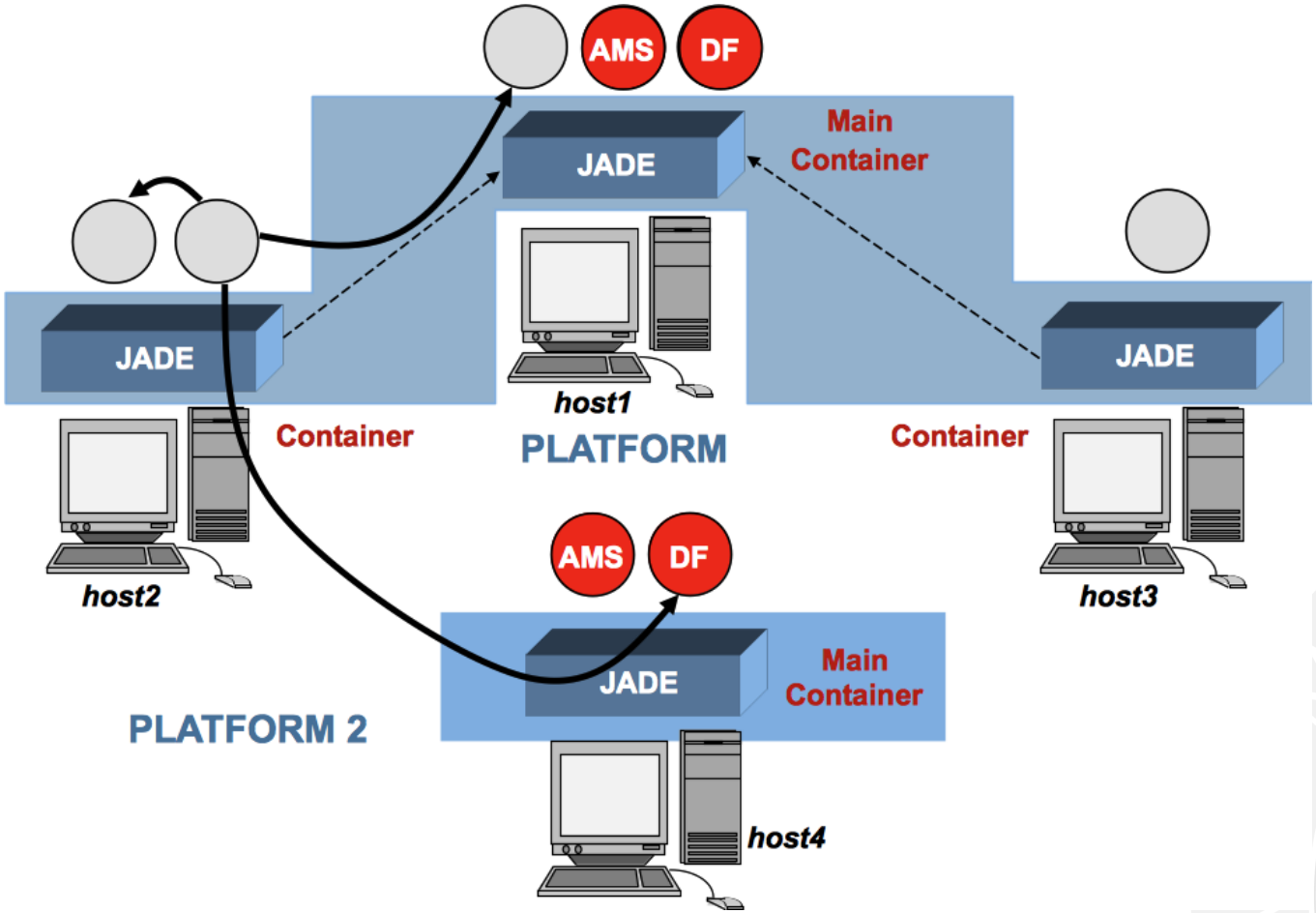


Figure: JADE system overview

Outline

FIPA Architecture I

According to FIPA, the agent platform can be split on several hosts given that:

Containers

- each host acts as a container of agents, that is, provides a complete *runtime environment* for JADE agents execution—lifecycle management, message passing facilities, etc.
- (at least) one of these containers is the main container (actually, the first started), responsible to maintain a *registry* of all other containers in the same JADE platform—through which agents can discover each other

Hence, JADE promotes a *P2P* interpretation of a MAS.

FIPA Architecture II

Agent Management System

For a given JADE platform, a single Agent Management System (AMS) exists, which:

- keeps track of all other agents in the same JADE platform—even those living in remote containers
- should be contacted by JADE agents prior to any other action (they do not even exist until registered by the AMS)

Hence, the AMS provides the white pages service—that is, a *location-transparent* naming service.

FIPA Architecture III

Directory Facilitator

A singleton Directory Facilitator (DF) exists for each JADE platform, that:

- keeps track of all advertised services provided by all the agents in the same JADE platform
- should be contacted by JADE agents who wish to publish their capabilities

Hence, provides the default yellow pages service—*publish/subscribe* paradigm.

FIPA Architecture IV

Agent Communication Channel

For a given JADE platform, a distributed message passing system exists—which is called Agent Communication Channel:

- it controls exchange of messages within the JADE platform, be them local or remote
- it implements all the needed facilities to provide *asynchronicity* of communications
- it manages all aspects regarding FIPA $\mathcal{ACL}$ ($\mathcal{A}$gent $\mathcal{C}$ommunication $\mathcal{L}$anguage) message format, such as serialization and deserialization

FIPA Architecture V

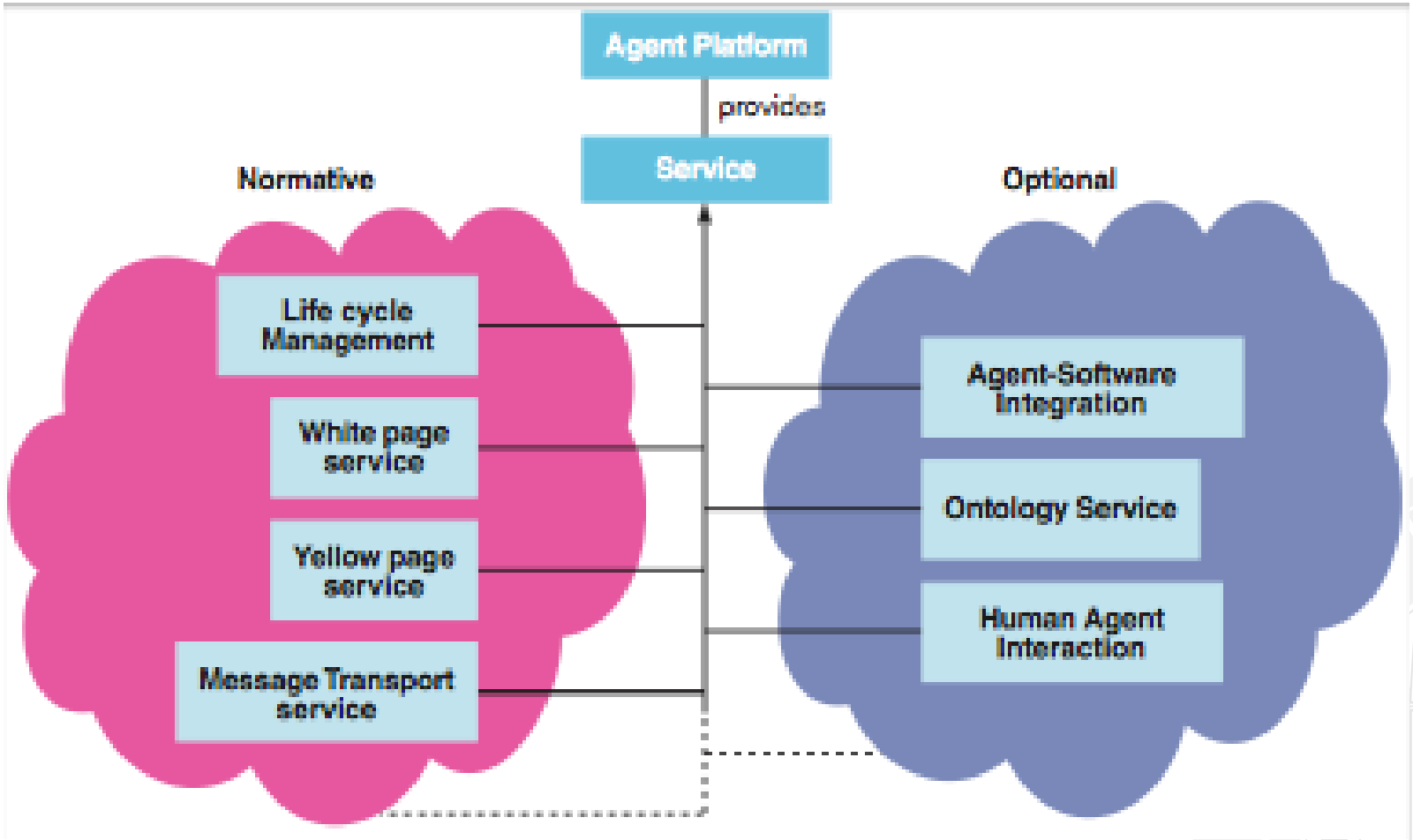


Figure: FIPA required services

Outline

What Is An Agent In JADE I

An agent is a Java object executed by a Java thread

Being an *object-based middleware*, JADE agents are first of all Java objects:

- user-defined agents must extend `jade.core.Agent` class, inheriting some ready-to-use methods
- a JADE agent is executed by a single Java *thread* (there is an exception, though)

What Is An Agent In JADE II

An agent is more than a Java object

JADE agents have a wide range of features enabling their autonomy—despite being still Java objects

- all JADE agents must have a *globally unique name* (aid), which is (by default) the concatenation – by symbol '@' – of their *local name* and of the JADE platform name
- agents *business logic* must be expressed in terms of *behaviours*
- JADE agents can communicate by exchanging FIPA $\mathcal{ACL}$ messages

FIPA Agents Lifecycle I

Agent Life Cycle I

According to FIPA, a JADE agent can be in one of several states during its lifetime:

Initiated the agent object has been built, but cannot do anything since it is not registered to the AMS yet—it has no *aid* even

Active the agent is registered to the AMS and can access all JADE features—in particular, it is executing its behaviour(s)

Waiting the agent is blocked, waiting for something to happen (and to react to)—typically, an $\mathcal{ACL}$ message

⋮ ⋮

FIPA Agents Lifecycle II

Agent Life Cycle II

⋮ ⋮

Suspended the agent is stopped, therefore none of its behaviours are being executed

Transit the agent has started a *migration* process—it will stay in this state until migration ends

Unknown the agent is dead—it has been deregistered to the AMS

FIPA Agents Lifecycle III

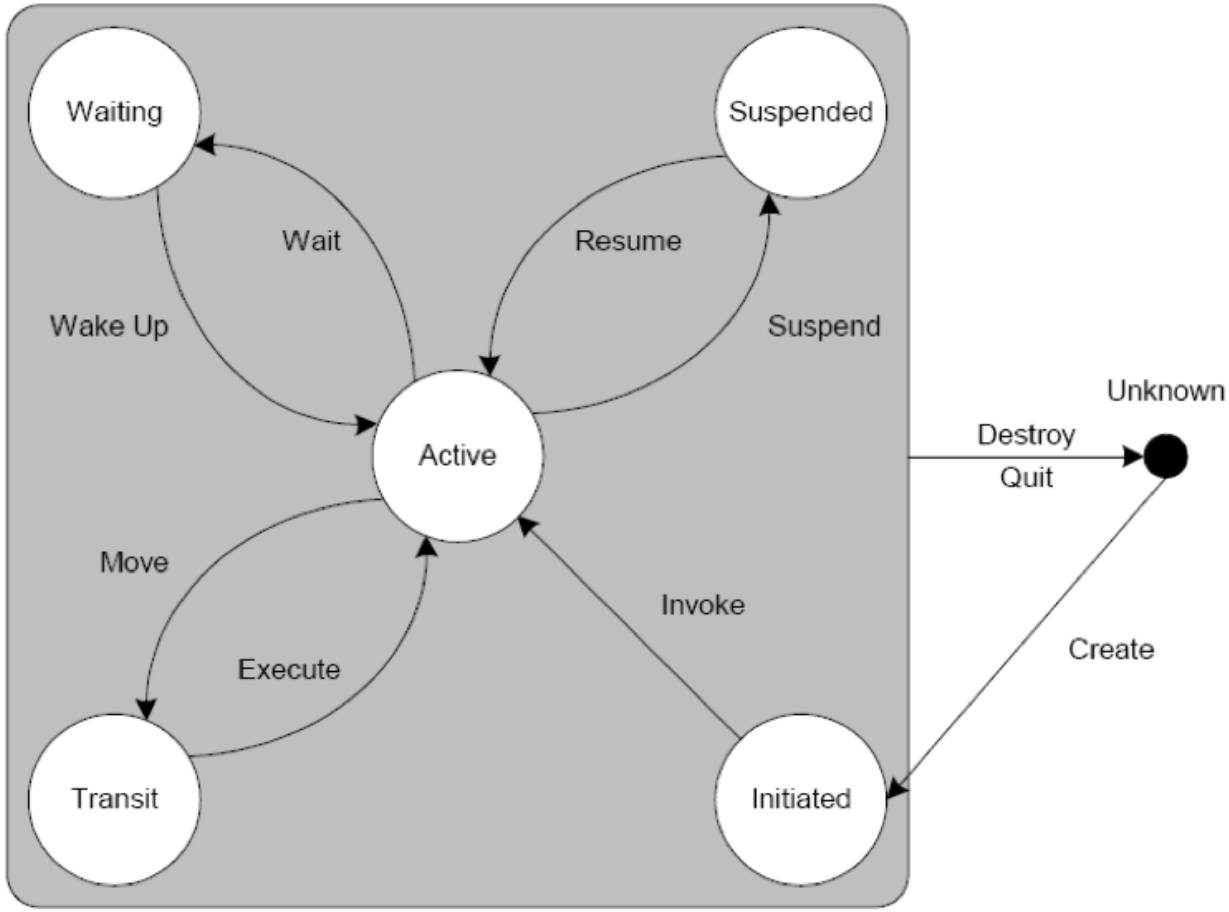


Figure: FIPA Agent Life Cycle

Agent Behaviours I

Why behaviours?

- By definition, agents are autonomous entities, therefore they should act independently and in parallel with each other
- The need for *efficiency* drives toward the execution of JADE agents as a single Java thread each
- ! However, agents need to perform complex activities, possibly composed by multiple tasks—even concurrently

How to conciliate this contrasting needs?

Agent Behaviours II

With behaviours!

What are behaviours?

- A behaviour can be seen as *an activity to perform with the goal of completing a task*
- A behavior can represent both a *proactive* activity – started by the agent on its own – as well as a *reactive* activity—performed in response to some events (timeouts, messages, etc.)

! JADE implements behaviours as Java objects, which are executed concurrently (still by a single Java thread) using a non-preemptive, round-robin scheduler (internal to the agent class but hidden to the programmer)

Agent Behaviours III

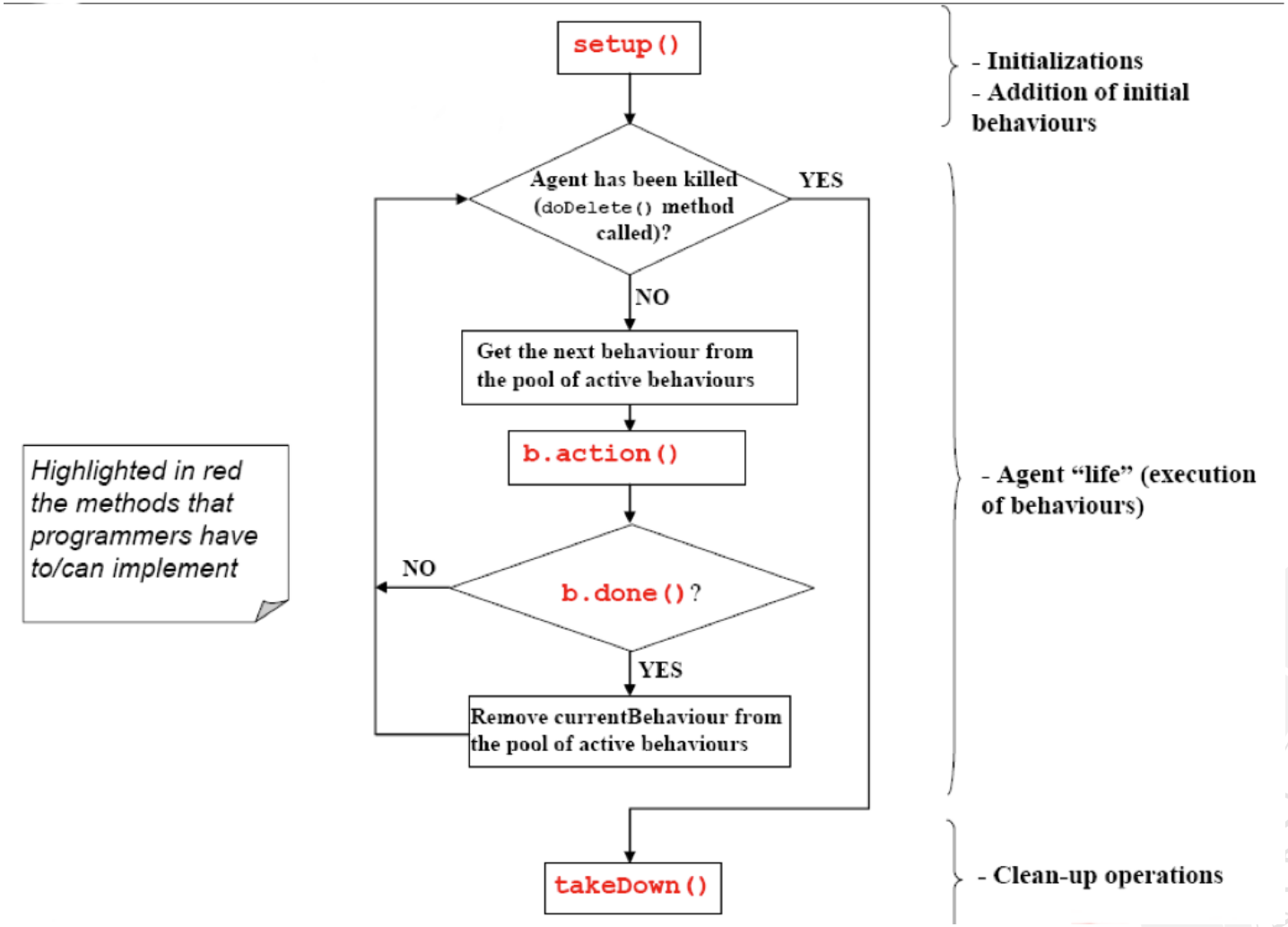


Figure: JADE non-preemptive scheduling policy

Outline

The Agent Communication Channel I

JADE messaging runtime

According to the FIPA specification, JADE agents communicate via asynchronous message passing:

- each agent has a *message queue* (a sort of mailbox) where the JADE ACC delivers $\mathcal{ACL}$ messages sent by other agents
- whenever a new entry is added to the mailbox, the receiving agent is *notified*—it does not need to block nor to continuously ask either

! *if* and *when* the agent actually processes a message is up to the agent itself (or the programmer)—for the sake of agents autonomy

The Agent Communication Channel II

$\mathcal{ACL}$-compliant messages

- To *understand* each other, it is crucial that agents agree on the format and semantics of the messages they exchange
- Hence, an $\mathcal{ACL}$ message contains:

`:sender`	who sends the message—automatically set
`:receiver`	who the message targets—may be many
`:performative`	the name of the communication act the agents want to carry out—constrained by a FIPA ontology
`:content`	the actual information conveyed by the message
`:language`	the syntax used to encode the `:content`
`:ontology`	the semantics upon which the `:content` relies
⋮	⋮
others	fields...

The Agent Communication Channel III

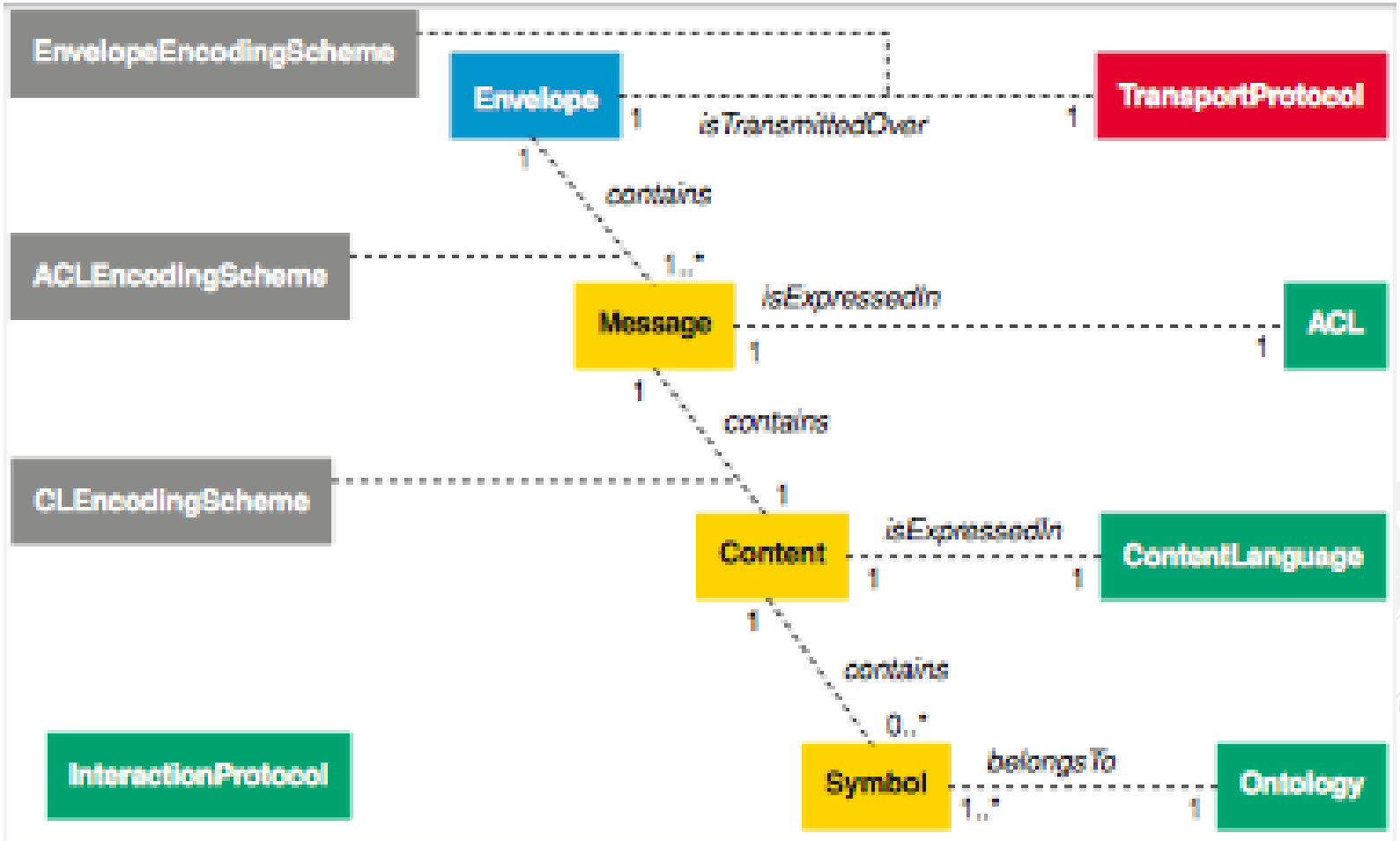


Figure: FIPA communication model abstractions

The Agent Communication Channel IV

JADE communication primitives

To interact, JADE agents have a number of ready-to-use methods:

- **send** to send a message to a recipient agent
- **receive** to asynchronously retrieve the first message in the mailbox (if any)
- **timed receive** to perform a *timed*, synchronous receive on the mailbox—timeout causes agent to resume execution
- **selective receive** to retrieve a message from the mailbox which *matches* a given *message template*—message queue order is bypassed

All these methods are distribution-transparent, that is they choose the proper address and transport mechanism based upon sender and receiver locations.

Outline

JADE Management Tools I

RMA

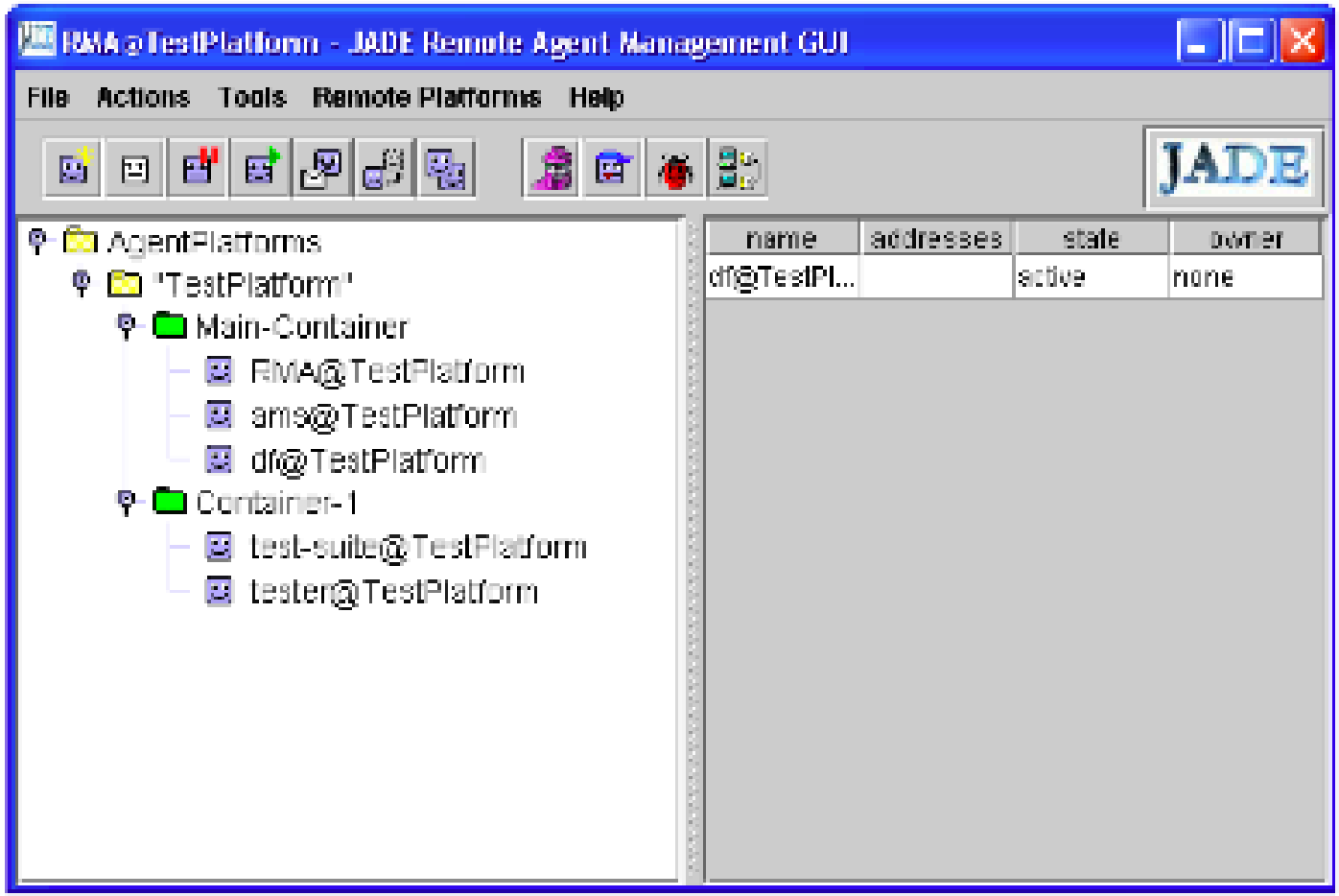
The Remote Monitoring Agent (RMA) allows to control the life cycle of the agent platform and of all the registered (possibly, remote) agents.

RMA features

RMA allows to:

- start, stop, kill agents
- send them messages
- clone and/or migrate agents
- add, remove, shutdown (remote) platforms
- . . . much more

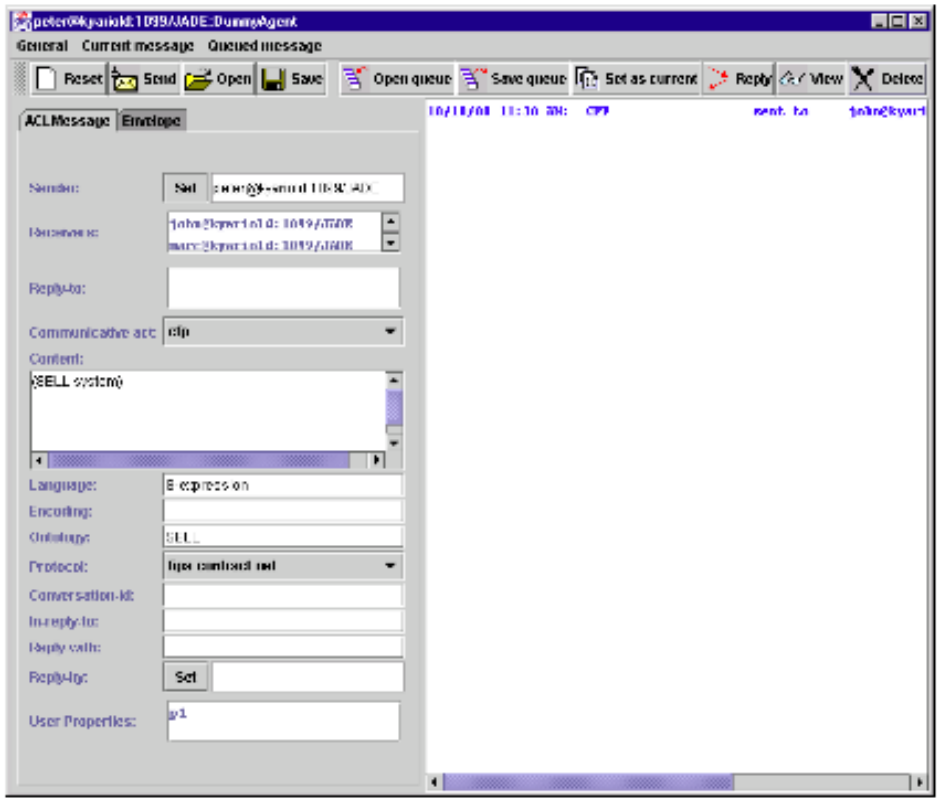
JADE Management Tools II



JADE Management Tools III

Dummy Agent

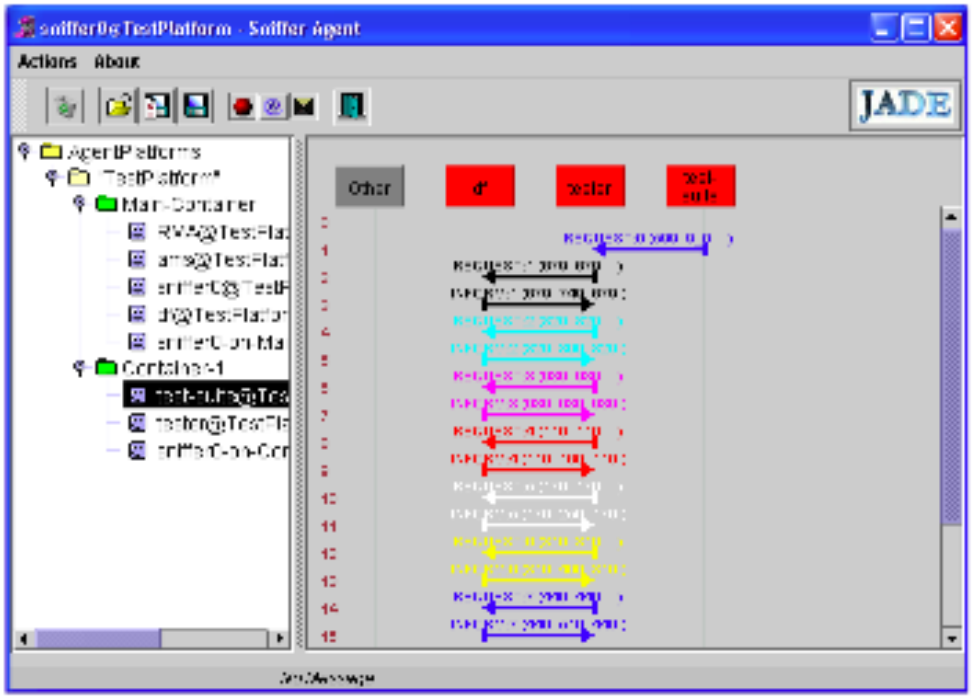
The Dummy Agent allows a human user to interact with JADE agents by sending, inspecting, recording custom $\mathcal{ACL}$ messages.



JADE Management Tools IV

Sniffer Agent

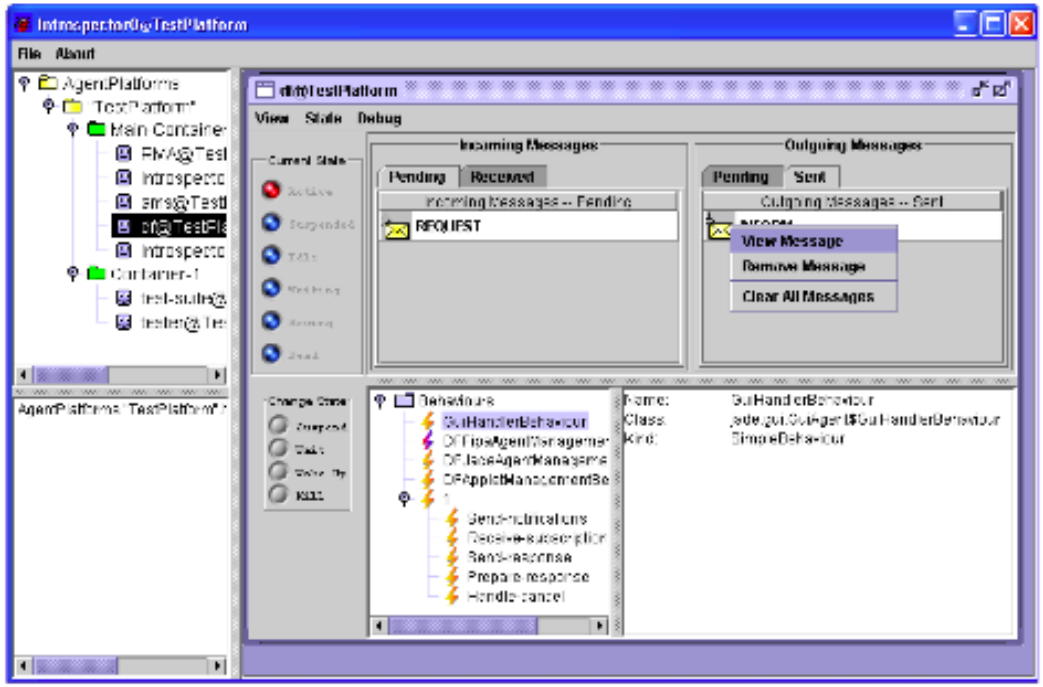
The Sniffer Agent allows a user to *sniff* an agent or a group of agents, which means that every message directed to/from that agent / agent group is tracked and displayed.



JADE Management Tools V

Introspector Agent

The Introspector Agent allows to monitor and control both the queue of sent and received messages as well as the queue of behaviours—including executing them step-by-step.



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