JADE: Java Agent DEvelopment Framework Basics

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Disclaimer

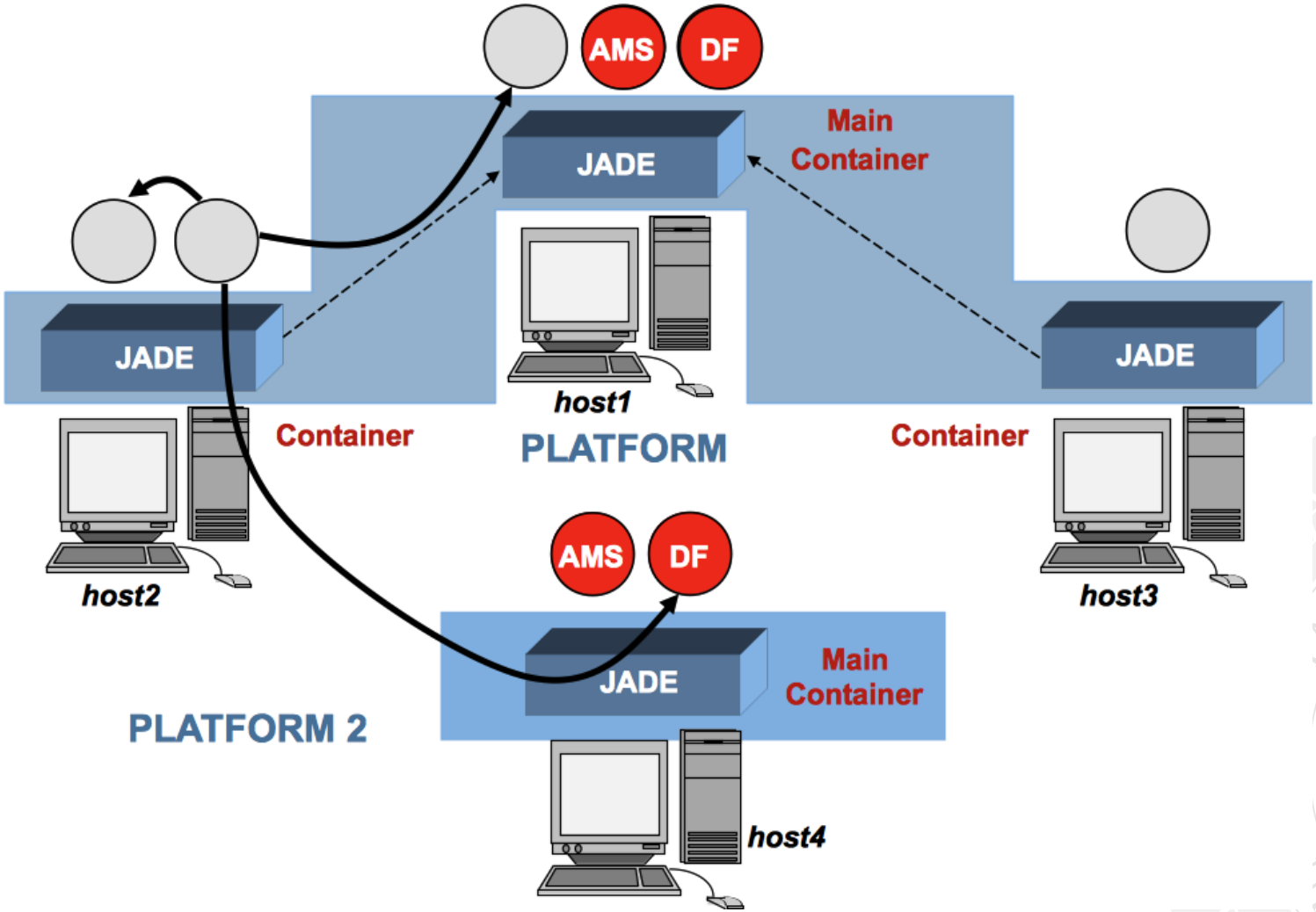
All the material presented in these slides is rearranged by the author from a collection of documents kindly made available by the JADE team.

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

Recap on JADE Architecture I



Recap on JADE Architecture II

Containers

- agents runtimes, the *environments* without which agents cannot exist
- *one* main container for *each* JADE platform...
- ...but many peripheral containers may coexist in the same platform and in the same host too
- they automagically register themselves to the (default/given) main container
- one single JVM executed per host/platform (2 JADEs on the same host are 2 JVMs)

Recap on JADE Architecture III

Agent Management System (AMS)

- JADE white pages service
- *one* AMS service (agent) for *each* JADE platform
- always runs in the main container
- is contacted (automagically) by every JADE agent upon start...
  - AMS `register()` method called prior to agent `setup()` abstract method being called by the container
- ...and death
  - `deregister()` called after `takedown()`

Recap on JADE Architecture IV

Agent Communication Channel (ACC)

- JADE *distributed*, *location-transparent* messaging service
- asynchronous by default (agents autonomy)...
- ...but, can also provide for synchronicity (if required)
- compliant to FIPA $\mathcal{ACL}$ message format

Directory Facilitator (DF)

- JADE yellow pages service
- similar to the AMS agent...
  - *one* DF service (agent) for *each* JADE platform
  - always runs in the main container
- ...but, should be explicitly contacted by *advertising* and *client* agents upon need—*public/subscribe* pattern

Outline

Brief Recap

JADE agents

- instances of `jade.core.Agent`-derived classes
- single-threaded, *multitasking* computational model based on concurrent behaviours
- *asynchronous* communication model based on FIPA $\mathcal{ACL}$ messages
- FSM-like lifecycle with public methods to perform state transitions
- `jade.core.AID` class implements the globally unique naming service
  - agent name of the kind `<localname>@<platformname>`
  - pool of platform addresses, only used for *inter-platform* communications

Agents Lifecycle

Lifecycle methods

`doActivate()` from SUSPENDED to where it was when `doSuspend()` was called

`doDelete()` from either state to UNKNOWN

`doWait()` from ACTIVE to WAITING

`doSuspend()` from ACTIVE or WAITING to SUSPENDED

`doWake()` from WAITING to ACTIVE

`doMove()` from either state to TRANSIT

`doClone()` same as `doMove()`

Agents Execution I

Starting agents

Agents are launched with command

```
$> java -cp ...  jade.Boot ...  -agents <name>:<class>
```

(or, from the RMA GUI)

1. the agent constructor is executed
2. the proper AID is given by the platform
3. registration to the AMS is done calling `register()` method
4. the agent is put in the ACTIVE state
5. `setup()` is executed...
6. ...then, behaviours scheduling begins

Agents Execution II

Stopping agents

Agents can be stopped by any of their behaviours calling the `doDelete()` method

1. prior to go into UNKNOWN state, the abstract method `takeDown()` is called by the platform to allow application specific clean-up
2. upon its completion, the agent is deregistered from the AMS calling `deregister()` method
3. the agent is put into the UNKNOWN state
4. the thread executing the agent is destroyed

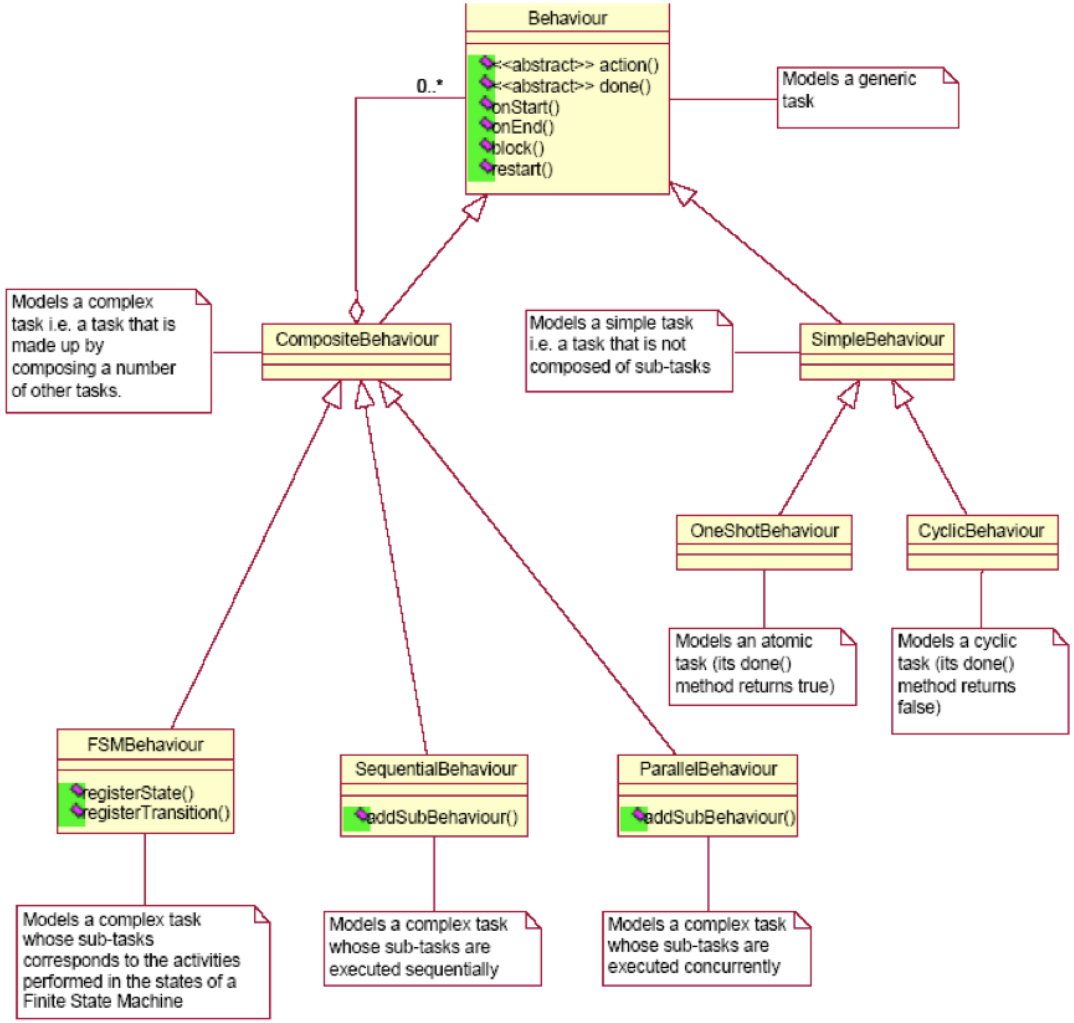
Outline

Brief Recap

JADE behaviours

- instances of jade.core.behaviours.Behaviour-derived classes
- executed concurrently according to a round-robin, non-preemptive scheduler internal to agents—thus, hidden to programmers
- everything is still *single-threaded*. . .
  - → method `action()` should be overridden to carry out the application-specific task
  - → method `done()` should be overridden too to check such task termination condition

(Simplified) Behaviours Hierarchy



Behaviour APIs I

All behaviours are in package `jade.core.behaviours`

SimpleBehaviour

- `OneShotBehaviour`
  - method `action()` is executed only once...
  - ...hence, method `done()` always returns `true`
- `CyclicBehaviour`
  - method `done()` always returns `false`...
  - ...hence, method `action()` is executed forever—until agent death

Behaviour APIs II

CompositeBehaviour I

- SequentialBehaviour
  - method addSubBehaviour() to add *child* behaviours...
  - ...to be scheduled *sequentially*—method done() drives progress
  - the whole behaviour ends when the last child ends
- ParallelBehaviour
  - method addSubBehaviour() to add *child* behaviours...
  - ...to be scheduled *concurrently*
  - two termination conditions provided by default—through constants
    - WHEN_ALL children are done
    - WHEN_ANY child is done

  Other conditions may be implemented by the programmer exploiting JADE APIs—see checkTermination() method

... ...

Behaviour APIs III

CompositeBehaviour II

... ...

- FSMBehaviour
  - method `registerState()` to add a child behaviour to the FSM
    - each child represents the activity to be performed within a state of the FSM
  - method `registerTransition()` to add a transition
    - the value returned by the `onEnd()` *callback* method is used to select the transition to fire
  - some of the children can be registered as *final states*...
  - ...hence, the whole behaviour terminates after the completion of any of them

Behaviour APIs IV

Other behaviours

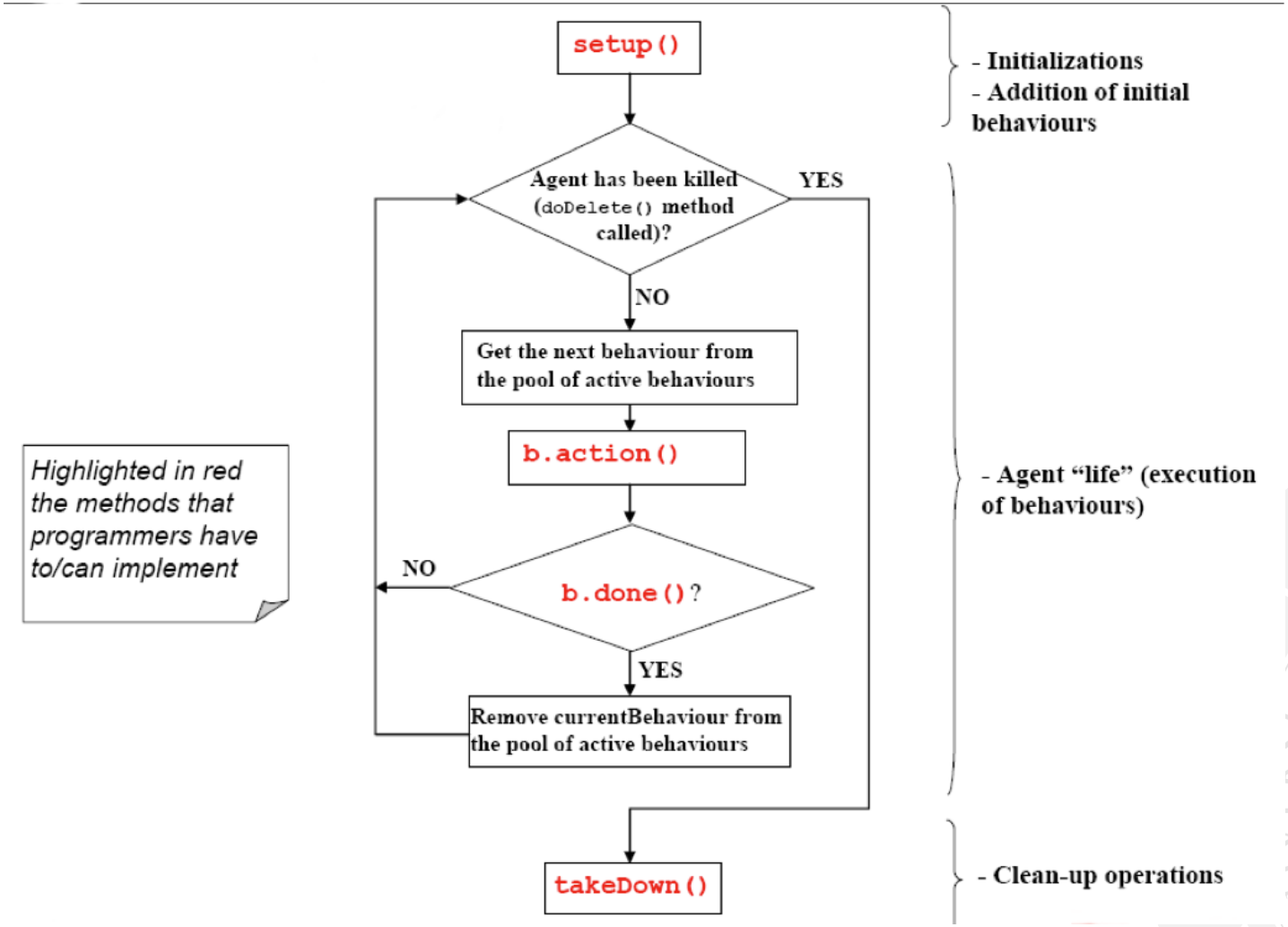
Many other very useful abstract behaviours exist, such as:

- `WakerBehaviour`
  - methods `action()` and `done()` are already implemented, so to execute abstract method `onWake()` when specified, then terminate
- `TickerBehaviour`
  - methods `action()` and `done()` are again already implemented, so to execute abstract method `onTick()` periodically as specified, then terminate when abstract method `stop()` is called
- ...

...refer to JADE APIs for the others.

Outline

Behaviours Scheduling Recap



Round-Robin, Non-Preemptive Scheduling I

The `setup()` method

By overriding the `setup()` method, JADE programmers ensure their agents have an initial pool of *ready-to-schedule* behaviours

- method `addBehaviour()` to add a behaviour (also usable elsewhere)
- method `removeBehaviour()` to remove one (better use it elsewhere...)

`setup()` serves to create instances of these behaviours and *link* them to the owner agent.

Round-robin

After initialisation, first behaviour from the *active behaviours* pool (ready queue) is scheduled for execution.

Round-Robin, Non-Preemptive Scheduling II

Some remarks

- ! Behaviours switch occurs only when the `action()` method of the currently scheduled behaviour returns
  - → hence, when it is running *no other behaviour can execute*
- ! Behaviour removal from the scheduler pool occurs only when `done()` returns `true`
  - → thus, if it returns `false` the behaviour is re-scheduled for next *round*
- ! `action()` is run *from the beginning every time*: there is no way to "stop-then-resume" a behaviour
  - → therefore, the computational state must be explicitly managed by the programmer in instance variables

Round-Robin, Non-Preemptive Scheduling III

One more remark

- Programmers may need their agents to wait for something to happen—typically, a message to arrive
- Programmers may be lured to use method `doWait()` for the purpose...

! ...don't do it!

  ! `doWait()` moves the agent to the WAITING state, where none of its behaviours can be executed!

→ Use method `block()` provided by any behaviour class instead, which allows to *suspend only the calling behaviour*

  → *as soon as* `action()` *returns*, the behaviour is moved to a special queue of blocked behaviours...

  → ...from which can be restored in the ready queue *whenever any message arrives* or by explicitly calling `restart` method

Outline

Outline

More on $\mathcal{ACL}$ Messages I

FIPA performatives

Performatives identify the type of *communicative act* carried out by the message—thus its semantics and expected response

`CFP`	(Call For Proposal) to obtain proposals about something
`INFORM`	to let someone know something
`PROPOSE`	to propose something
`REQUEST`	to ask for a service
`SUBSCRIBE`	to subscribe for notification about something
`AGREE`	to express consensus about something
`REFUSE`	to refuse a request
`...`	...

They are constants to be set for any $\mathcal{ACL}$ message exchanged by agents.

More on $\mathcal{ACL}$ Messages II

FIPA message syntax

The syntax of an $\mathcal{ACL}$ message is defined by FIPA to enable interoperability

`addReceiver()` to add a value to the `:receiver` slot

`setContent()` to fill in the `:content` slot

`setConversationId()` to fill in the `:conversation-id` slot

`setEncoding()` to fill in the `:encoding` slot

`setInReplyTo()` to fill in the `:in-reply-to` slot

`setLanguage()` to fill in the `:language` slot

`setOntology()` to fill in the `:ontology` slot

`setSender()` to fill in the `:sender` slot

... ...

Outline

Agents Communication Basics I

Sending messages

To send a message, an agent should:

1. create an $\mathcal{ACL}$ message
   - `ACLMessage msg = new ACLMessage(ACLMessage.<performative>);`
2. fill its (mandatory) fields
   - `msg.addReceiver(new AID(receiver));`
   - `msg.setContent("<content>");`
   - `...`
3. call the `send()` method
   - `send(msg);`

Agents Communication Basics II

Replying to messages

To simplify answering, the `ACLMessage` class provides method `createReply()` to automagically set a number of $\mathcal{ACL}$ fields:

- `:receiver`
- `:language`, `:ontology`
- `:conversation-id`, `:protocol`
- `:in-reply-to`, `:reply-with`

Anyway, the programmer is free to overwrite such slots.

Agents Communication Basics III

Who to talk with?

? How to find agents to talk to? When sending messages we must know the receiver AID

→ should we necessarily know it at compile-time?

! JADE provides several ways to get an agent ID:

- by using the agent local name (whenever known)
- from the RMA GUI
- by asking to the AMS
- by asking to the DF (we'll see how to next lesson)

Agents Communication Basics IV

JADE local names

The simplest way to identify an agent is by its local name:

```
...
msg.addReceiver(new AID("myAgent", AID.ISLOCALNAME));
...
```

JADE ACC will automagically associate to the given agent name its AID.

JADE RMA

By simply launching the RMA with `$> java -cp ... jade.Boot -gui` you have a gui which displays all agents in the monitored JADE platform along with their AIDs.

Agents Communication Basics V

Using the AMS

A much more comprehensive and flexible way to query JADE about existing agents is by interacting with the AMS service:

1. prepare a placeholder for agents with `AMSAgentDescription [] agents = null;`
2. configure some kind of "template" on agents with `AMSAgentDescription template = new AMSAgentDescription (...);`
3. configure search parameters with `SearchConstraints c = new SearchConstraints(...);`
4. launch the search process with `agents = AMSService.search(this, template, c);`
5. collect AIDs with `AID aid = agents[i].getName();`

More on Agents Communication I

JADE communication primitives

`send()` to asynchronously send a message—recipient is implicit

`receive()` to asynchronously retrieve the first message from the mailbox (if any)

`receive(MessageTemplate)` to perform a *selective receive*

`blockingReceive()` to perform a *synchronous* receive

`blockingReceive(long)` to perform a *timed* synchronous receive

`blockingReceive(MessageTemplate)` to perform a selective, synchronous receive

`blockingReceive(MessageTemplate, long)` to perform a timed, selective, synchronous receive

More on Agents Communication II

Receiving messages

Be careful when receiving messages:

- ! Method `blockingReceive()` *suspends all agent behaviours*, not only the calling one—due to synchronicity
  - → call `receive()` then `block()` instead, so to resume the behaviour whenever any message arrives
  - → call `blockingReceive()` only when you actually need to suspend all behaviours—e.g. during `setup()`
- ! Method `receive()` *removes* the first message from the mailbox, therefore it may "steal" someone else's
  - → use `jade.lang.acl.MessageTemplate` within a `receive()` to get only messages *matching a given pattern*

More on Agents Communication III

Selective receive

`jade.lang.acl.MessageTemplate` allows JADE agents to perform receive operations only *on a subset of their mailbox*, which is the subset with only those messages matching the given template.

Hint

When your agent should have *parallel negotiations* with several other agents, you should:

- create a `:conversation-id` string to *uniquely* identify messages
- by using the proper `MessageTemplate`, set-up a behaviour which only responds to messages with that particular `:conversation-id`

More on Agents Communication IV

MessageTemplate APIs I

A set of static, *factory methods* are provided to build different kinds of template objects...

`matchAll()` matches any $\mathcal{ACL}$ message

`matchContent()` match checked on `:content` slot

`matchCustom(ACLMessage)` template built so to match the given $\mathcal{ACL}$ message

`matchConversationId()` match checked on `:conversation-id` slot

`matchOntology()` match checked on `:ontology` slot

`matchSender()` match checked on `:sender` slot

... ...

More on Agents Communication V

MessageTemplate APIs II

. . . along with elementary boolean operators to combine them into more complex patterns. . .

- `and()` to build a template which is the *intersection* of two given templates
- `not()` to build a template which is the *union* of two given templates
- `or()` to build a template which is the *negation* of a given template

. . . and a non-static method to actually check matching:

- `match(ACLMessage)` returns `true` if the given message matches the template upon which it is called

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