Advanced Techniques in Artificial Intelligence

Curso 2021-2022

German Rigau

german.rigau@ehu.eus

Grado en Ingeniería en Informática

Topics

- Intelligent Agents
- Multiagent Systems
- Planning

2 Multi-agent Systems

1. Introduction
2. Communication between agents
3. Platforms: FIPA
4. JASON
5. JGOMAS

Introduction

- Many problems are essentially distributed
- The knowledge needed to solve a problem may be distributed
- An individual agent could solve the problem but: we concentrate all responsibility on that agent ...
- Distributed Resolution of problems (?)
- Multiagent systems (MAS) are Agent Based Systems oriented for distributed problem solving

Introduction

- MAS: System consisting of a set of (semi) autonomous components that have the following characteristics:
  - Individually, they do not have complete information or ability to solve the problem. It has a limited point of view.
  - There is no global control system.
  - The data is decentralized.
  - Asynchronous computing.

Introduction

- Distributed problem solving
  - Division of the problem into subproblems
    - Assigning subproblems to specific agents
  - Solving subproblems
    - Agents can operate independently or share tasks or results
  - Combination of sub-solutions
    - Establishment of responsibility at this stage => need for coordination agent

Introduction

- Distributed problem solving in multi-agent systems is only appropriate when agents have communication capabilities on which cooperation and negotiation strategies can be established.

Introduction

- How to formulate, describe, decompose problems and synthesize results among a group of intelligent agents?
- How to allow agents to communicate and interact?
- What communication languages and protocols can be used?
- Which architecture is most suitable for building practical multi-agent systems?
- What languages and development tools can be used?
- How to build tools to support development multi-agent based methodologies?

Introduction

- Main issues so far:
  - Decomposition of the problem
  - Communication between agents
  - Coherence in the proceedings
  - Representation of the knowledge of other agents
  - Coordination of actions
  - Manage the use of resources
  - Avoid unwanted global behaviours
  - MAS Design: methodology and development

2 Multi-agent Systems

1. Introduction
2. Communication between agents
3. Platforms: FIPA
4. Aplications
5. JADE
6. JASON

Communication between agents

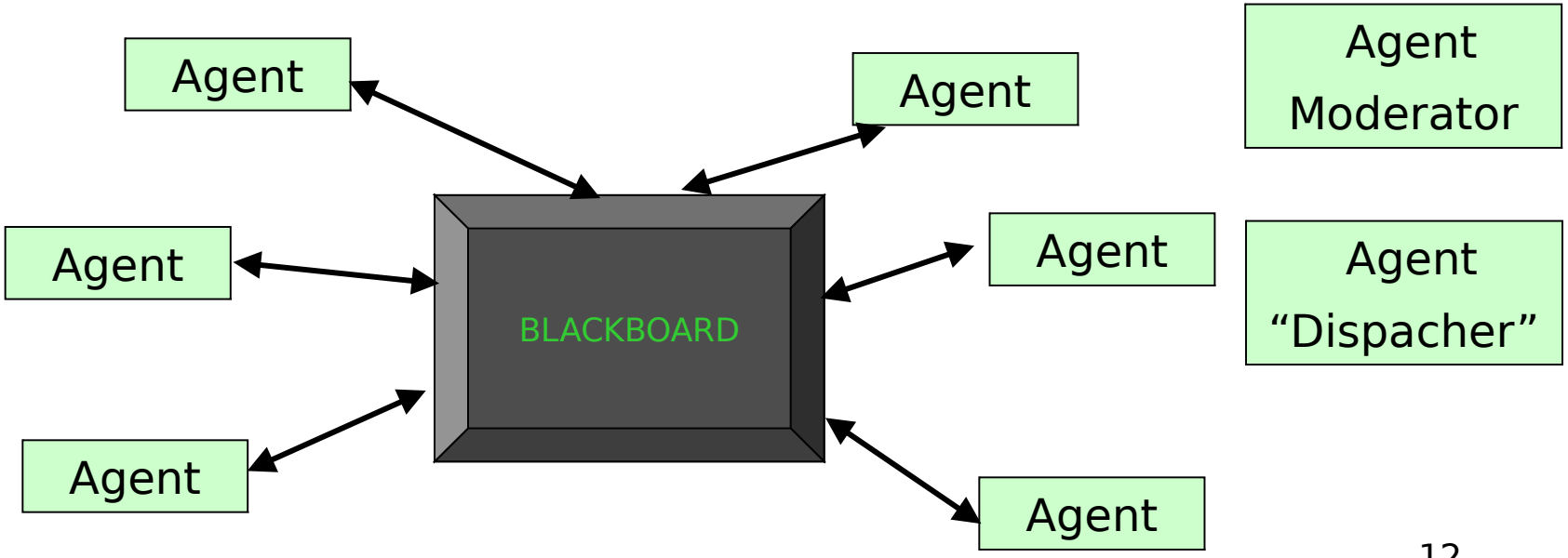
Communication skills are the basic tools for building mechanisms of cooperation and negotiation between agents.

- Methods
  - Blackboard systems
  - Message passing
- Languages
  - KQML, Knowledge Query and Manipulation Language
  - FIPA ACL:
    - Foundation for Intelligent Physical Agents
    - Agent Comunication Language

Communication between agents

Method: Blackboard systems

- A common working area that allows agents to share all kinds of information.
- A MAS may have several boards with different agents registered in each.
- No direct communication between agents



Comunication between agents

Method: Message passing

- Communication protocols:
  - Language of communication, based in the Theory of *Speech Acts*:
    - Common and known semantics.
  - Communication process
  - Message formats

Comunication between agents

Method: Message Passing: Speech Acts

- The main purpose of traditional linguistics is to understand the meaning of sentences:
  - combination of meaningful words

- Speech acts designate intentional actions in the course of a conversation
  - Denotative function of language determining the truth or falsity of a sentence
  - Conative function is used to modify the environment or transmit orders

Comunication between agents

Method: Message Passing: Speech Acts

- The speaker does not only declare true or false sentences
- The speaker performs speech acts:
  - requests, suggestions, promises, threats, etc.
- Each statement is an speech act

Comunication between agents

Method: Message Passing: Speech Acts

- Locution: production of sentences using a grammar and a lexicon
- Ilocution: act performed by the speaker for the recipient through the utterance
  - Illocutionary force (F):
    - affirmation, question, request, promise, order
  - Propositional content (P):
    - object of the illocutionary force ~ F(P)
- Perlocution: effects that can have illocutionary acts in the state of the recipient and in their actions, beliefs and judgments
  - to convince, to inspire, to persuade, to frighten

Comunication between agents

Method: Message Passing: Speech Acts

- Classification of illocutions
  - Assertives (report)
  - Directives (ask)
  - Commissives (promise)
  - Permissive, prohibitive and declarative (cause events)
  - Expressive (emotions and evaluations)

Comunication between agents

Method: Message Passing: Levels of Communication

- Low level: interconection
  - Physical communication and basic protocols (eg TCP / IP)
- Medium level: formats
  - Sintactic: Standard KQML, FIPA ACL
    - Speech acts (tell, ask, deny, perform, …)
    - Implementations (JAT, LALO, …)
- High level: meaning
  - Semantics: KIF, Ontologies
    - Ontolingua
    - Pre-trained Language Models?

Comunication between agents

Method: Message Passing: Levels of Communication

- Low level: transport mechanism
  - Messages must be able to be:
    - Planned or served by events
    - Synchronous or asynchronous
    - Physical addresses or role-based
    - Unicast / multicast / broadcast
  - Implementations
    - CORBA, Common Object Request Broker Architecture
    - RMI, Remote Method Invocation
    - DCOM, Distributed Component Object Model

Comunication between agents

Method: Message Passing: Levels of Communication

- Medium level: Lenguage of the communication
  - Must have well-defined syntax
  - Formal semantics
  - Implementations
    - KQML
    - FIPA ACL
    - XML-based

Comunication between agents

Method: Message Passing: Levels of Communication

- High level: Ontologies
  - Issues
    - Different terms for the same concept
    - The same term for different concepts
    - Different class systems
  - Common ontology to represent the knowledge
    - Semantic Web
  - Implementations
    - OIL
    - Ontolingua
    - KIF, Knowledge Interchange Format
    - RDF / Esquemas XML / DTD

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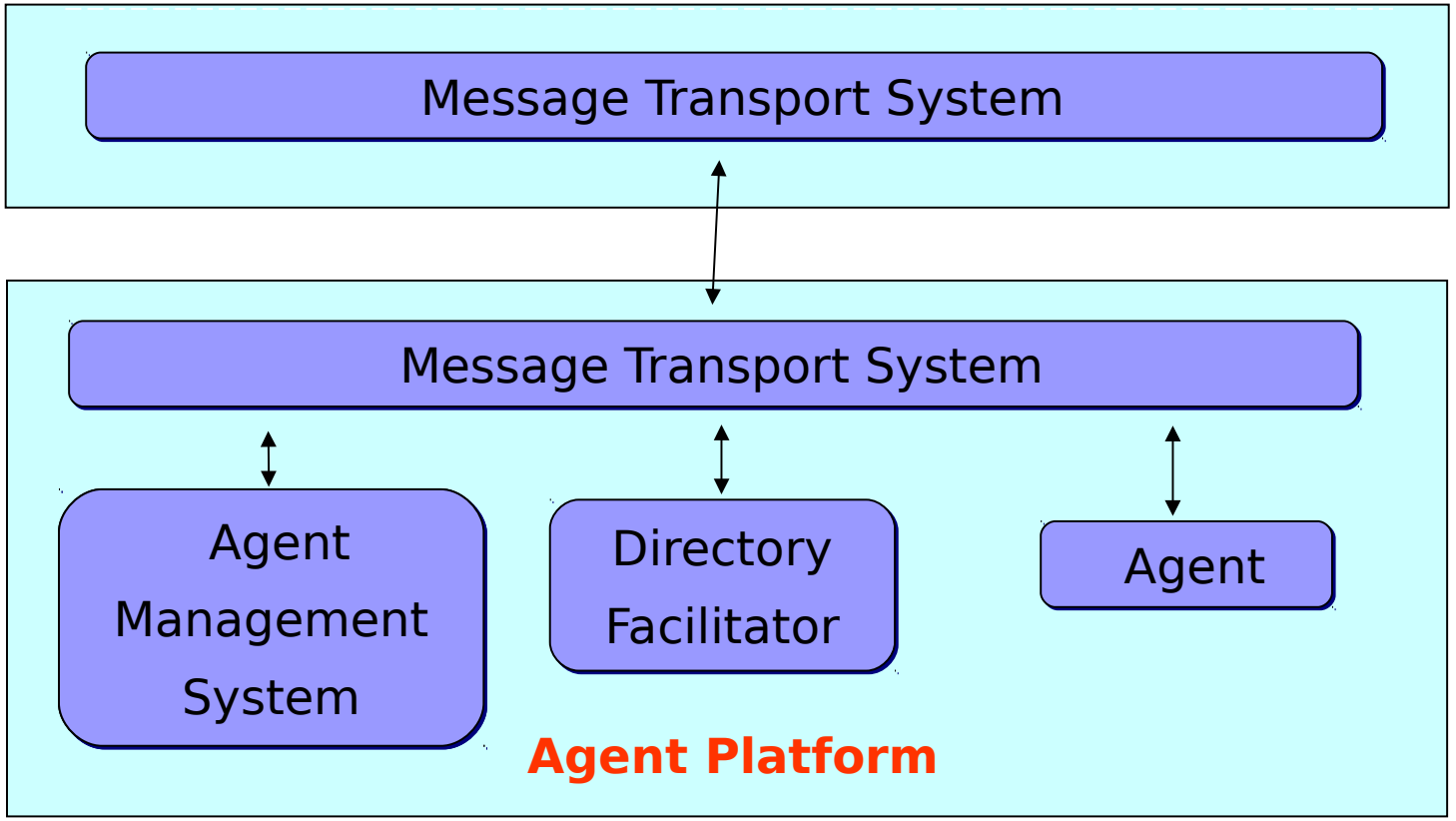
FIPA platform

- Foundation for Intelligent Physical Agents
- Industrial consortium founded in 1996
- http://www.fipa.org
- Objetives
  - Accelerate the development of intelligent agent technologies by producing internationally agreed specifications
  - Specification of the behavior and external capabilities of generic subsystems: agent resources (for migration, execution, etc.), interaction and cognitive
    - Agents, multi-agents, and agent societies
    - Selection and adaptation of existing technologies

FIPA platform

- Agent platform: Determines the basis of the infrastructure on which agents can be developed and used. Hw and Sw.



FIPA platform: AMS

- Agent Management System
- Primary management element
  - Platform Status
  - State of the agents of the platform
- Services offered
  - Creation, destruction and control of the change of state of the agents.
  - Monitor permissions for new agents to register (valid AIDs).
  - Control of the mobility of agents.
  - Management of shared resources.
  - Management of the communication channel.
  - Service of Names (ANS) or White Pages (Name - Address)

FIPA platform: DF

- Directory Facilitator
- Yellow pages service
- Services offered
  - The agents are registered indicating the services they offer
  - Agent asks for a service
    - Result: agents offering it

FIPA platform: MTS

- Message Transport System
- Communications infrastructure that allows two agents to communicate
- Services offered
  - Send messages between agents of the same or different platform.

FIPA platform

- Communications model
- FIPA communication specifications between agents deal with:
  - ACL messages (Agent Communication Language)
  - Message exchange protocols (communicative acts based on speech acts)
  - Content Language Representation

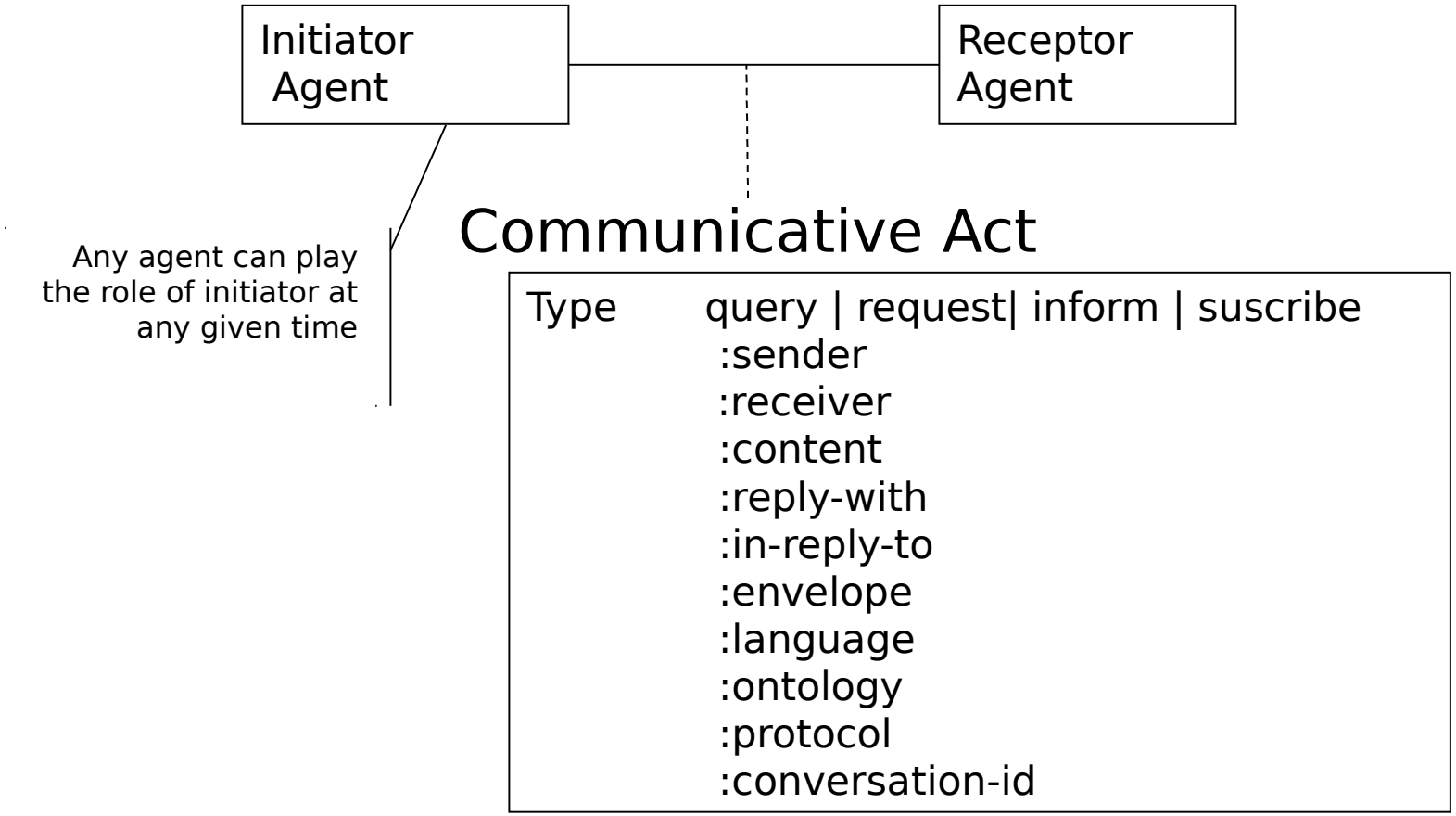
FIPA platform

- Communication model: Example of message

```
(request
  :sender an-agent
  :receiver df-agent
  :content
   (action an-agent
    (search
     (:df-agent-description
      (:services
       (:service-type email)))))
  :language SL0
  :ontology fipa-agent-management
  :protocol FIPA-request
)
```

FIPA platform

- Communication model



FIPA platform

- Communicative acts
- *FIPA Communicative Act Library Specification*
- http://www.fipa.org/specs/fipa00037/SC00037J.pdf
- Interoperability is achieved through an agent communication language
  - well defined
  - unambiguous
  - with a solid formal framework
- The basis of an ACL is composed of communicative acts

FIPAplatform : Communicative Acts (CA)

- Each of the FIPA directives is defined by:
  - the summary of the message
  - the type content of the message
  - the description with a detailed explanation of the communicative act
  - the formal model that is a description in SL (Semantic Language) that defines mental states
  - an example of a message with the communicative act

FIPA PLATFORM: Communicative Acts (CA)

- Notation for the definition of an CA
- A model of communicative act (CA) will be represented as follows:

  < i, act(j, C) >,
  FP : φ1
  RE : φ2
- where i is the agent that executes the CA, j is the receiver, act is the name of the performative, C refers to the content of the message and φ1 and φ2 are logical propositions.
- FP : Feasibility Preconditions
- RE : Rational Effect
- The message is:

  (act
  :sender i
  :receiver j
  :content C)

FIPA platform

- Types of Communicative Acts
  - Information
  - Realization
  - Negotiation
  - Intermediation

FIPA Platform: Communicative Acts (CA)

- Types of Communicative Acts: Information
- Sending agent: REQUEST information
  - query-if:
    - Ask another agent if a given proposition is true.
  - query-ref:
    - Ask another agent for the object referred by a referential expression.
  - subscribe:
    - The act of requesting a persistent intention to notify the sender of the value of a reference, and to notify again whenever the object identified by the reference changes.

FIPA platform: Communicative Acts (CA)

- Types of Communicative Acts: Information
- Sending agent: OFFERS information (1)
  - inform
    - The sender informs the receiver that a given proposition is true.
  - confirm
    - The sender informs the receiver that a given proposition is true, when it is known that the receiver is not sure about the proposition.
  - disconfirm
    - The sender informs the receiver that a given proposition is false, when it is known that the receiver believes, or believes that the proposition is likely to be true.

FIPA platform: Communicative Acts (CA)

- Types of Communicative Acts: Information
- Sending agent: OFFERS information (2)
  - not-understood
    - Agent i informs the receiver that he does not understand what j has just done. For example, when i does not understand the message sent by j.
  - inform-if (macro)
  - inform-ref (macro)

FIPA platform: Communicative Acts (CA)

- Types of Communicative Acts: Information
- Example:
  - Agent i asks agent j if j has been registered on domain server d1.

```
(query-if
    :sender (agent-identifier :name i)
    :receiver (set (agent-identitfier :name j))
    :content "((registered (server d1) (agent j)))"
    :reply-with r09
    ...)
```

  - Agent j answers no.

```
(inform
    :sender (agent-identifier :name j)
    :receiver (set (agent-identifier :name i))
    :content "((not (registered (server d1) (agent j))))"
    :in-reply-to r09)
```

FIPA platform: Communicative Acts (CA)

- Types of Communicative Acts: Realization
- Sending Agent: REQUEST an action
  - request
    - The sender requests the receiver to take some action. For example perform another communicative act.
  - cancel
    - An agent informs another that he no longer intends to do a particular action.
  - request-when
    - The sender asks the receiver to perform an action when a proposition is true.
  - request-whenever
    - The sender asks the receiver to perform an action whenever a proposition is true.

FIPA platform: Communicative Acts (CA)

- Types of Communicative Acts: Realization
- Sending Agent: PERFORMS an action
  - agree
    - The action of agreeing to carry out some kind of action, perhaps in the future.
  - refuse
    - The action of refusing to perform a particular action, and explain the reason for the denial.
  - failure
    - The action of telling another agent that an action was attempted, but the attempt failed.

FIPA platform: Communicative Acts (CA)

- Types of Communicative Acts: Negociation
- Sending Agent: NEGOCIATE for an action
  - cfp (call for proposals)
    - The action of requesting proposals to carry out a particular action.
  - accept-proposal
    - Accept a previously submitted proposal for action.
  - reject-proposal
    - The action of rejecting a proposal to carry out some type of action during a negotiation.
  - propose
    - Submit a proposal to carry out a certain action, given certain preconditions.

FIPA platform: Communicative Acts (CA)

- Types of Communicative Acts: Intermediation
- Sending Agent: INTERMEDIATE for an action
  - propagate / proxy
    - The sender intends that the receiver propagates the embedded message to other agents indicated by a given description.

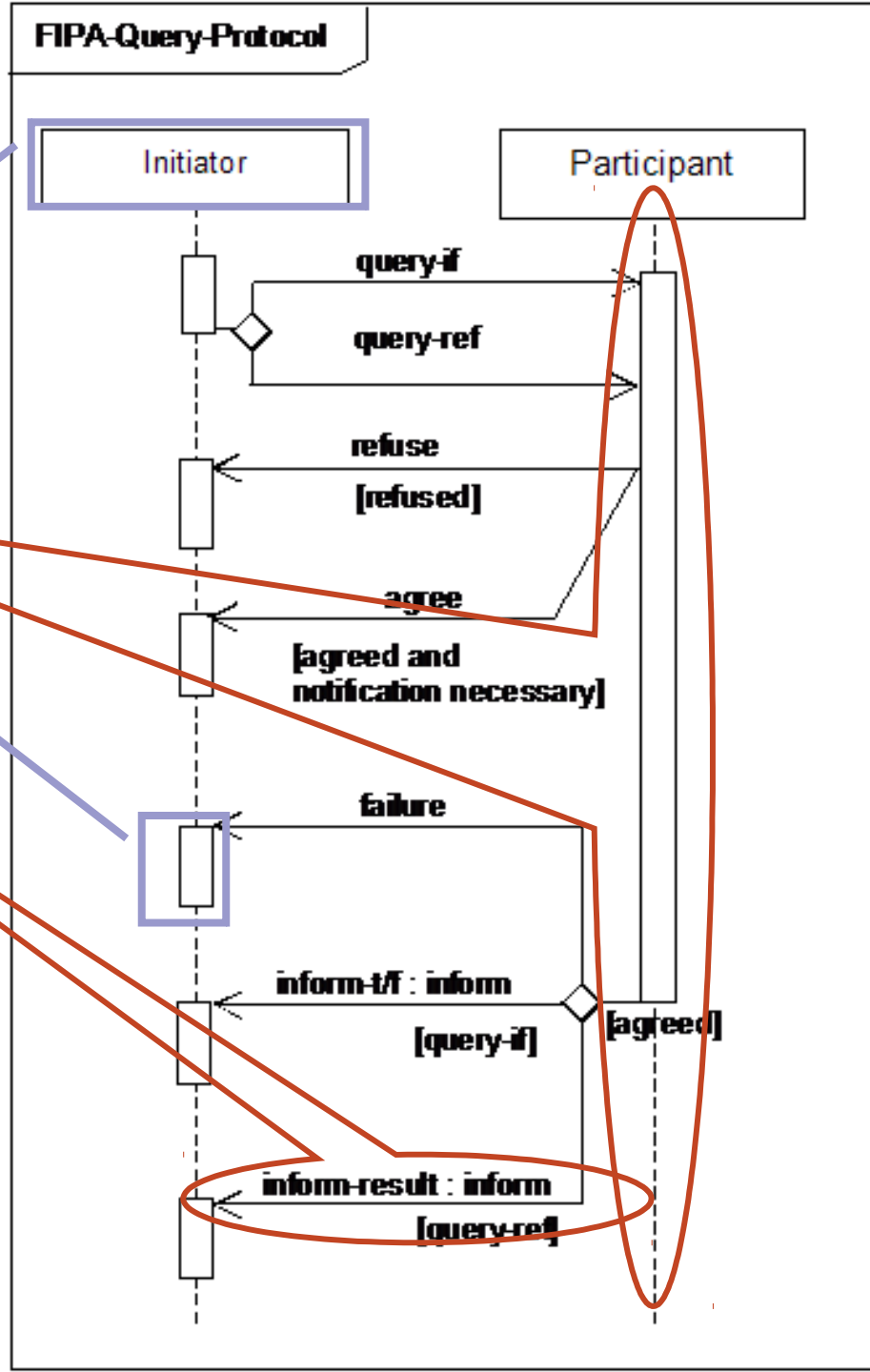
FIPA platform: Interaction protocols

PROTOCOL	Description
Request	An agent is required to perform some action
Request when	An agent is required to perform some action as long as the precondition is met
Query	An agent is asked to report something
Contract net	An agent requests the performance of a certain task to a set of agents. These give their proposal based on costs and the initiator chooses who finally realizes it.
Brokering	An agent (broker) offers the functionalities of other agents or forwards the requests to the appropriate agent
English auction	Several agents participate in an auction that starts with the lowest price and progressively goes up
Dutch auction	Several agents participate in an auction that starts with the highest price and progressively goes down
Recruiting	Similar to Brokering but the answers about the service go directly to the agent who needs it (do not go through the broker)
Propose	The initiator proposes to a series of agents the accomplishment of a task and these they accept or not.
Subscribe	The initiating agent requests to be notified when a certain condition is true

FIPA Platform: Interaction protocols

AUML language:

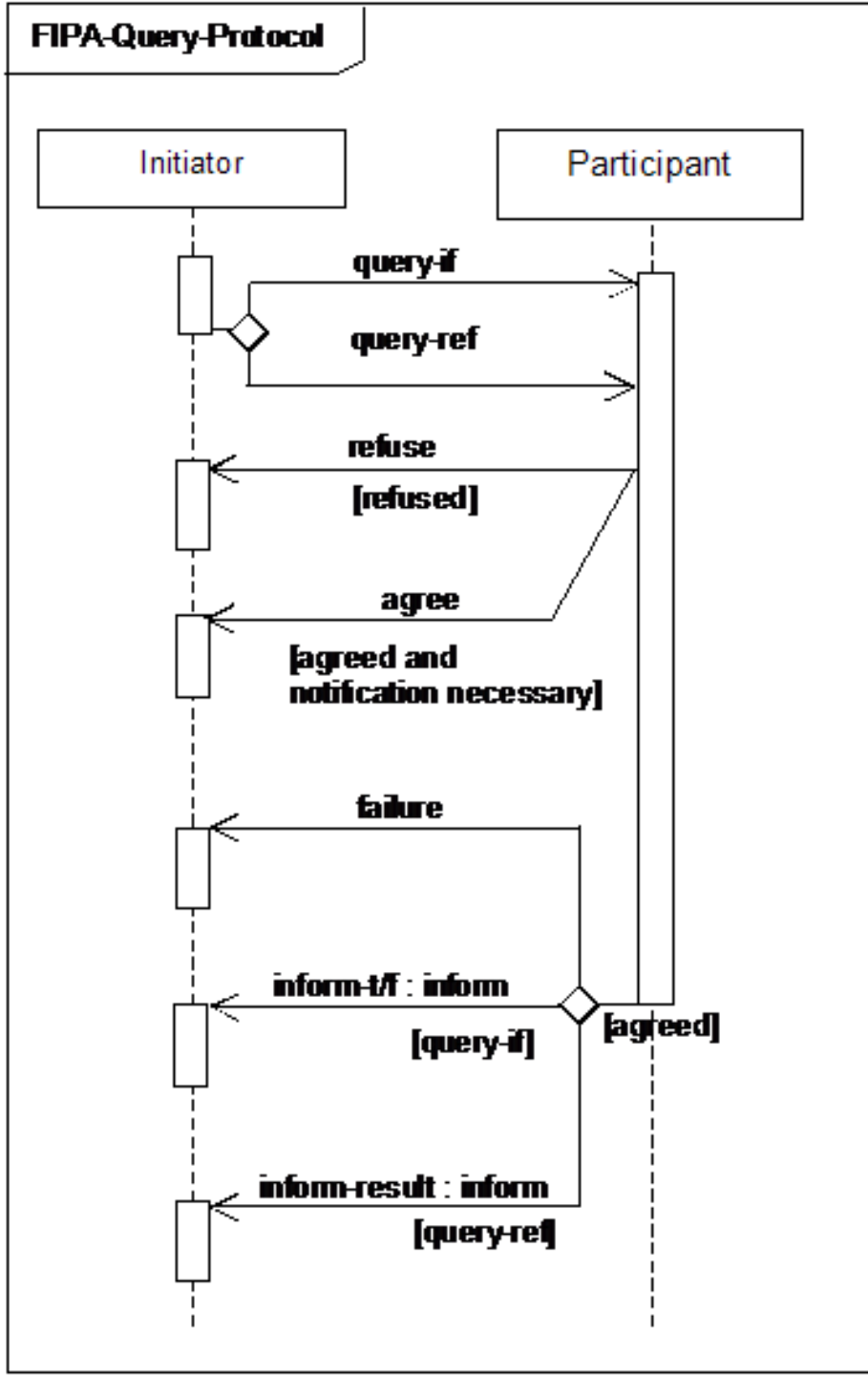
- Agent roles
- Life line
- Interacting threads
- messages



FIPA Platform: Interaction protocols

FIPA query:

- An agent ask for information
- Two types:
  - query-if: truth value of a proposition
  - query-ref:value of some identified object



FIPA platform: IP FIPA-query

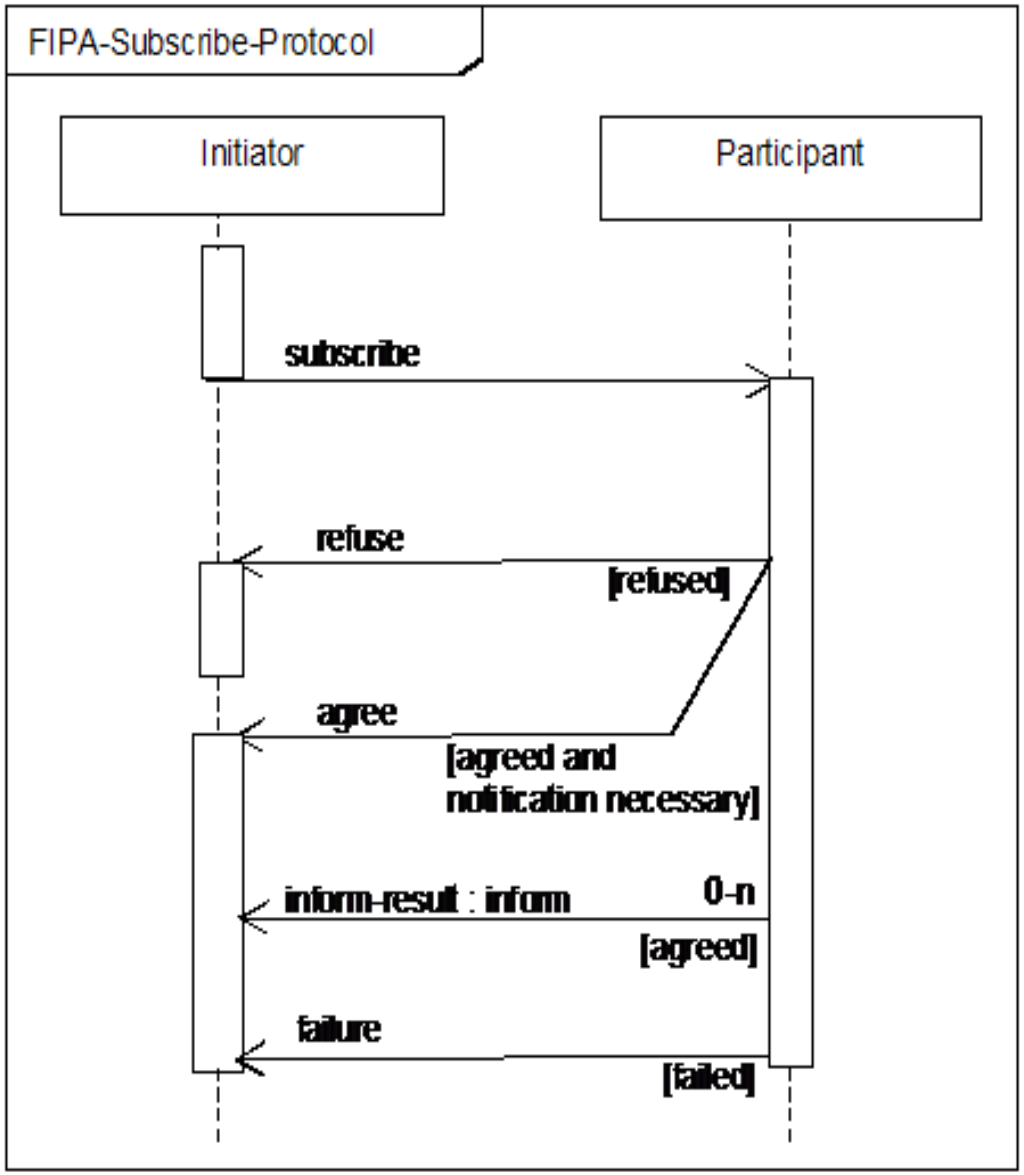
- example:
  - Agent i asks agent j if j has been registered on domain server d1.

    (query-if
    :sender (agent-identifier :name i)
    :receiver (set (agent-identitfier :name j))
    :content "((registered (server d1) (agent j)))"
    :reply-with r09
    ...)
  - Agent j answers no.
    (inform
    :sender (agent-identifier :name j)
    :receiver (set (agent-identifier :name i))
    :content "((not (registered (server d1) (agent j))))"
    :in-reply-to r09)

FIPA Platform: Interaction protocols

FIPA subscribe:

- the initiator requests to be warned each time the condition is met indicated in the message



FIPA platform: IP FIPA-subscribe

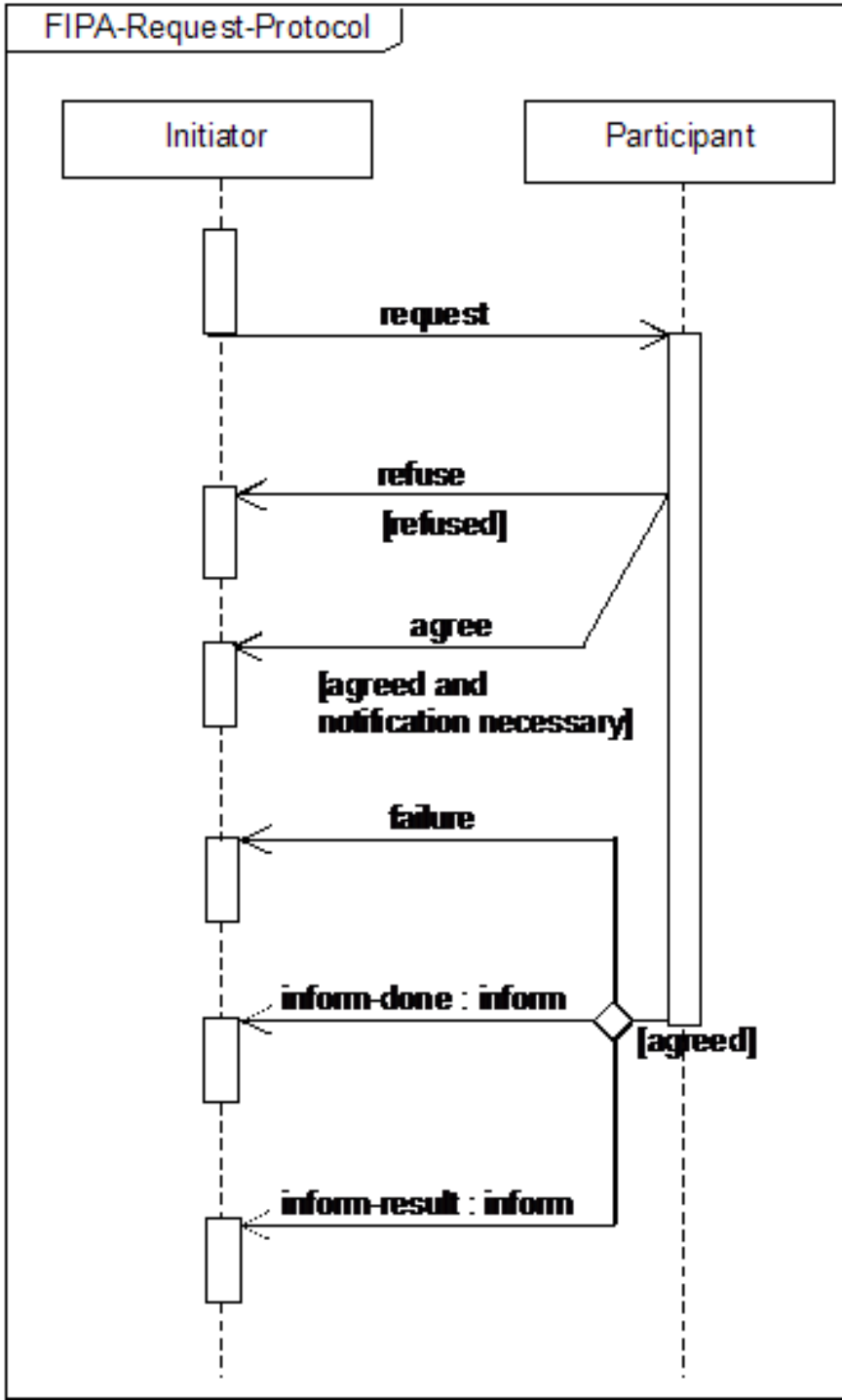
- Example:
  - Agent i wants to be informed of the exchange rate changes between Francs and Dollars, and makes a subscription with j.

```
(subscribe
  :sender (agent-identifier :name i)
  :receiver
       (set (agent-identifier :name j))
  :content
       "((iota ?x (= ?x (xch-rate FFR USD)))))“
...)
```

FIPA Platform: Interaction pr

FIPA request:

- One agent requests another agent to performs an action.
- The receiver must indicate his agreement or respond that refuses to do it.



FIPA platform: IP FIPA-request

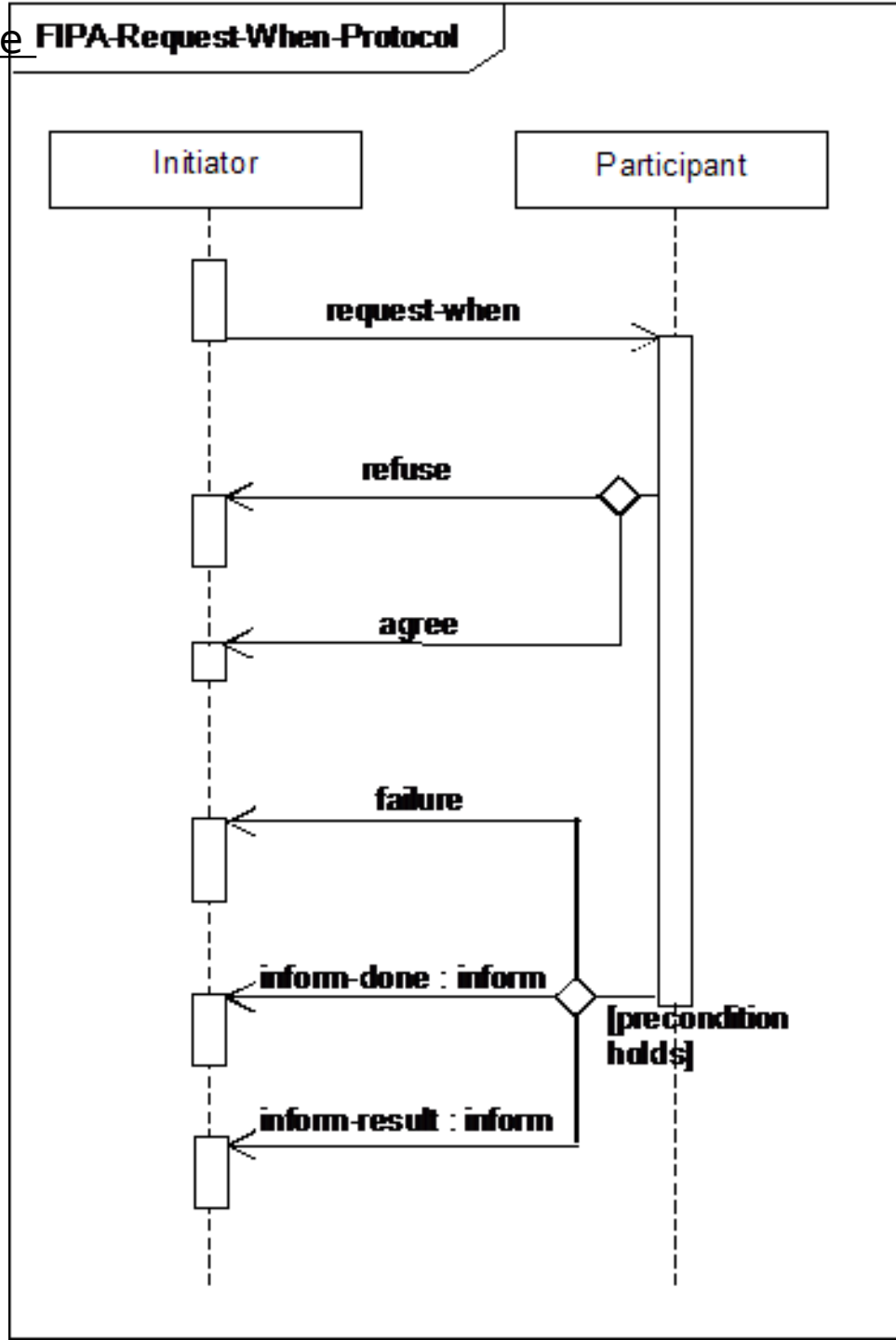
- Example:
  - Agent i asks j to open a file

```
(request
  :sender (agent-identifier :name i)
  :receiver (set (agent-identifier :name j))
  :content  "open \"db.txt\" for input"
  :language vb)
```

FIPA Platform: Interaction protocols

FIPA request-when:

- analogous to FIPA-request.
- The initiatior wants the receiver to do some action as soon as some precondition holds
- the receiver must wait to comply with the precondition to respond



FIPA platform: IP FIPA-request-when

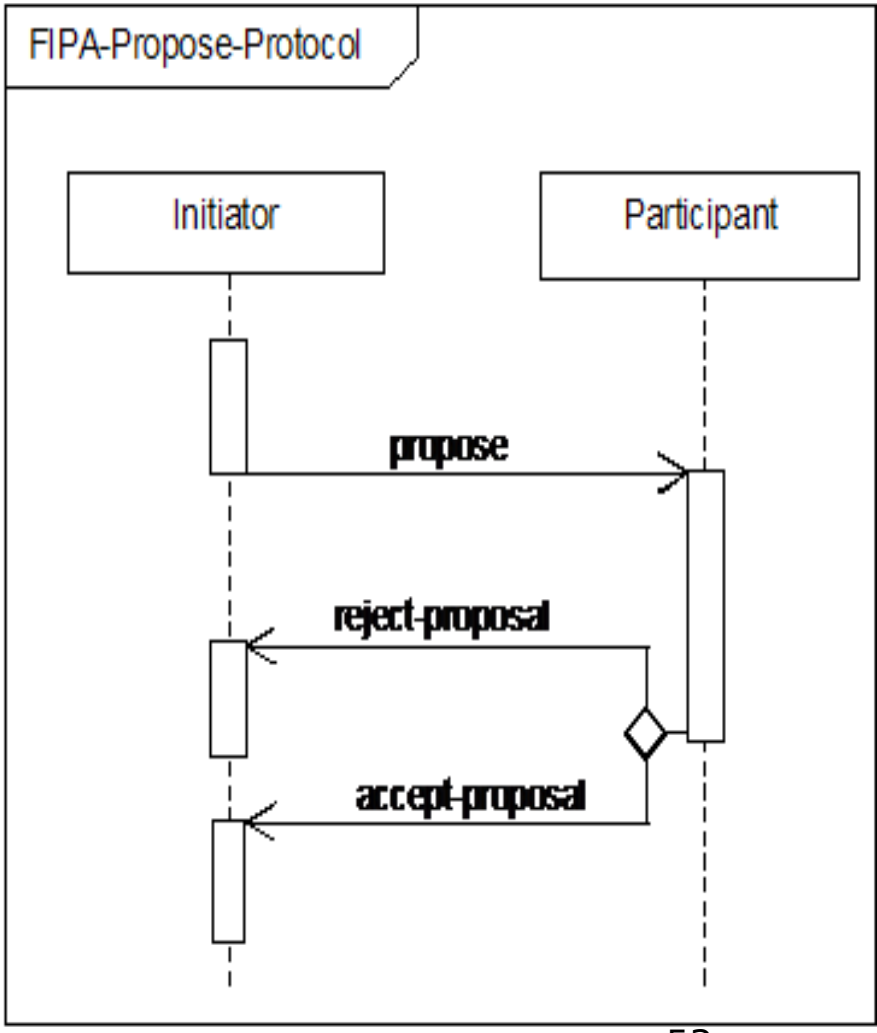
- Example:
  - Agent i requests agent j to notify him of an alarm jump as soon as occurring.

```
(request-when
  :sender (agent-identifier :name i)
  :receiver (set (agent-identifier :name j))
  :content
    "((action (agent-identifier :name j)
      (inform
        :sender (agent-identifier :name j)
        :receiver (set (agent-identifier  :name i))
        :content \"((alarm \"something alarming!\"))\"))
      (Done ( alarm )))"
  …)
```

FIPA Platform: Interaction protocols

FIPA propose:

- the sender sends a message to the participant indicating that he will take some action if the participant agrees
- usually follows the implementation of the action and state notification



FIPA platform: IP FIPA-propose

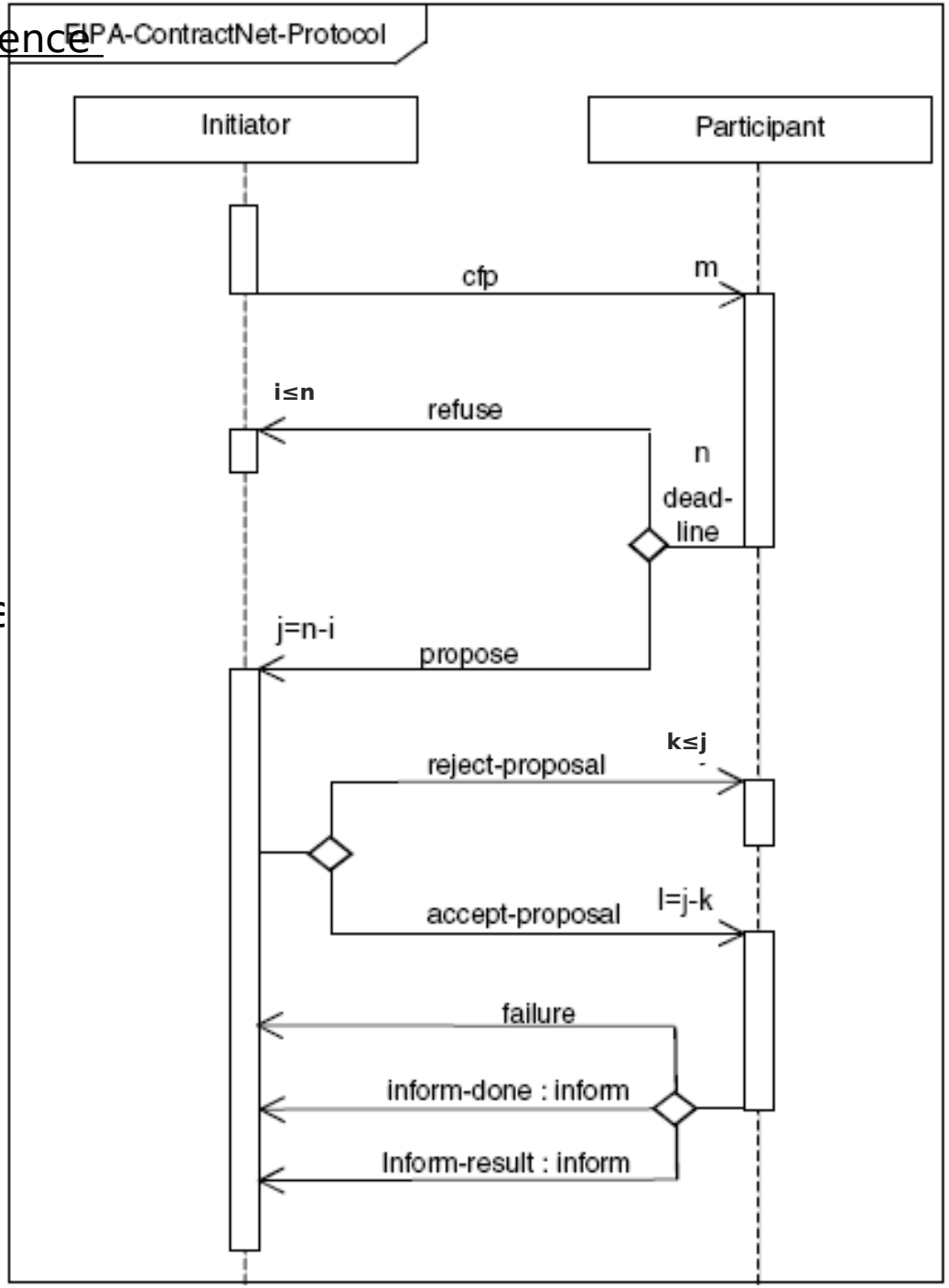
- Example:
  - Agent j proposes agent i to sell 50 boxes of plums for 5€

```
(propose
  :sender (agent-identifier :name j)
  :receiver (set (agent-identifier :name i))
  :content
    "((action j (sell plums 50))
      (= (any ?x (and (= (price plum) ?x) (< ?x 10)))
      5)"
  :ontology fruit-market
  :in-reply-to proposal2
  :language fipa-sl)
```

FIPA Platform: Interaction protocols

FIPA contract-net:

- an agent wants to be take action
- there are several candidate
- you want to minimize a feature that characterizes the task (price)



FIPA Platform: Interaction protocols

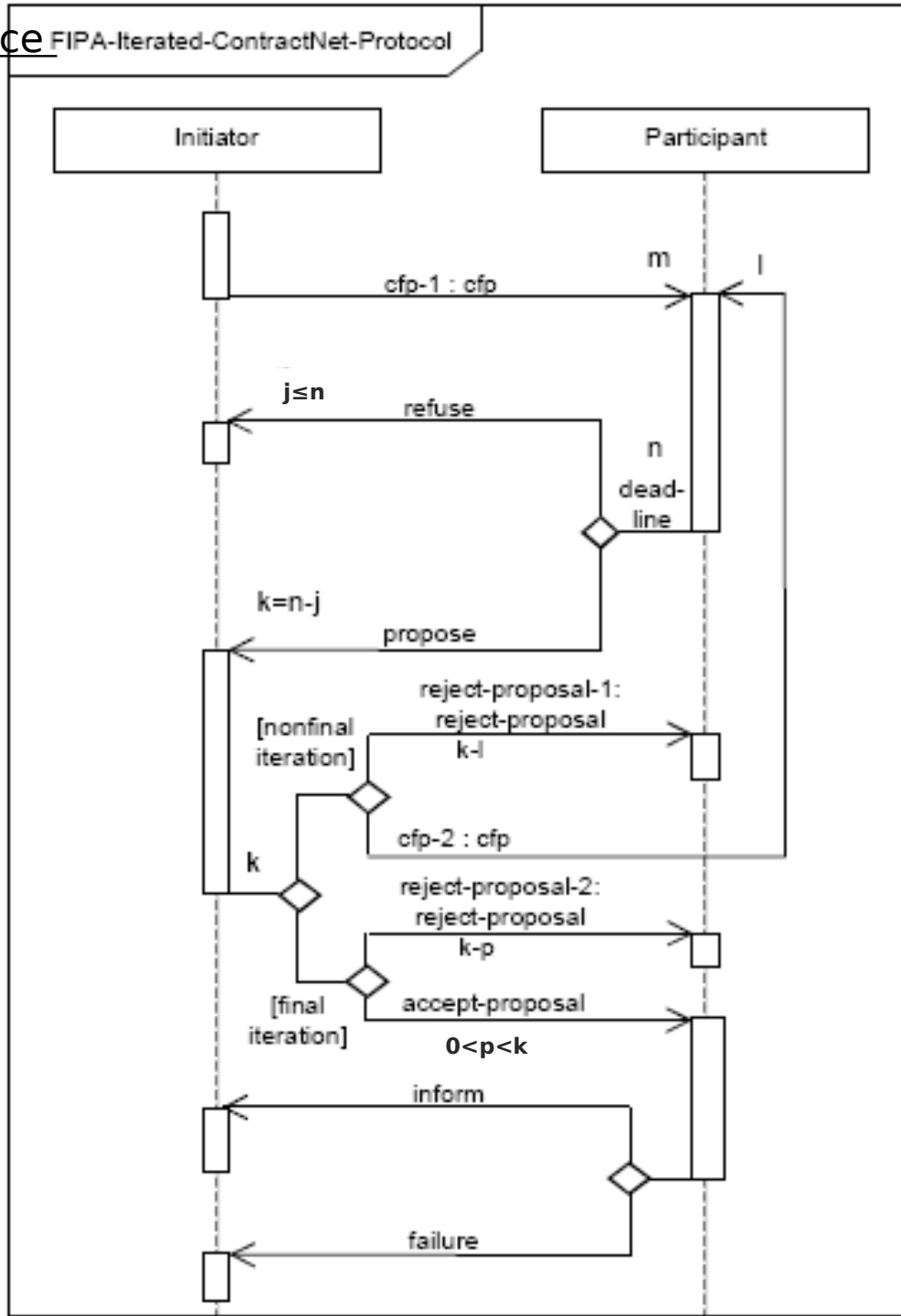
FIPA contract-net:

- Initially, the manager, with the initiator FIPA role, generates m cfp (call for proposal) messages and is waiting certain time, after which it will not receive any messages (a total of n received)
- Let i be the number of messages of type refuse, We will then have j = n - i messages of the type propose
- For each of the messages, send later either an accept-proposal or a reject-proposal
- The result is reported with a failure, with an inform without result or with an inform with a the result.

FIPA Platform: Interaction protocols

FIPA iterated-contract-net:

- contract-net with several rounds
- starts with a cfp
- each participant releases his offer
- the initiator can accept one, reject them all,
- release a revised cfp



FIPA Platform: Interaction protocols

FIPA iterated-contract-net:

- Initially, the agent with the initiator role of the conversation generates m cfp messages
- After a waiting deadline, the initiator picks up n offers
- a total of j refuse to perform the task through refuse
- We then have k = n - j agents offerings that are willing to perform the task with propose
- If the iteration is not the last one, from the total of k received offers, some will be rejected directly, k - l, and will be accepted as many l.
- Among those accepted, a counter-offer is made for each agent and wrapped in a new cfp

FIPA Platform: Interaction protocols

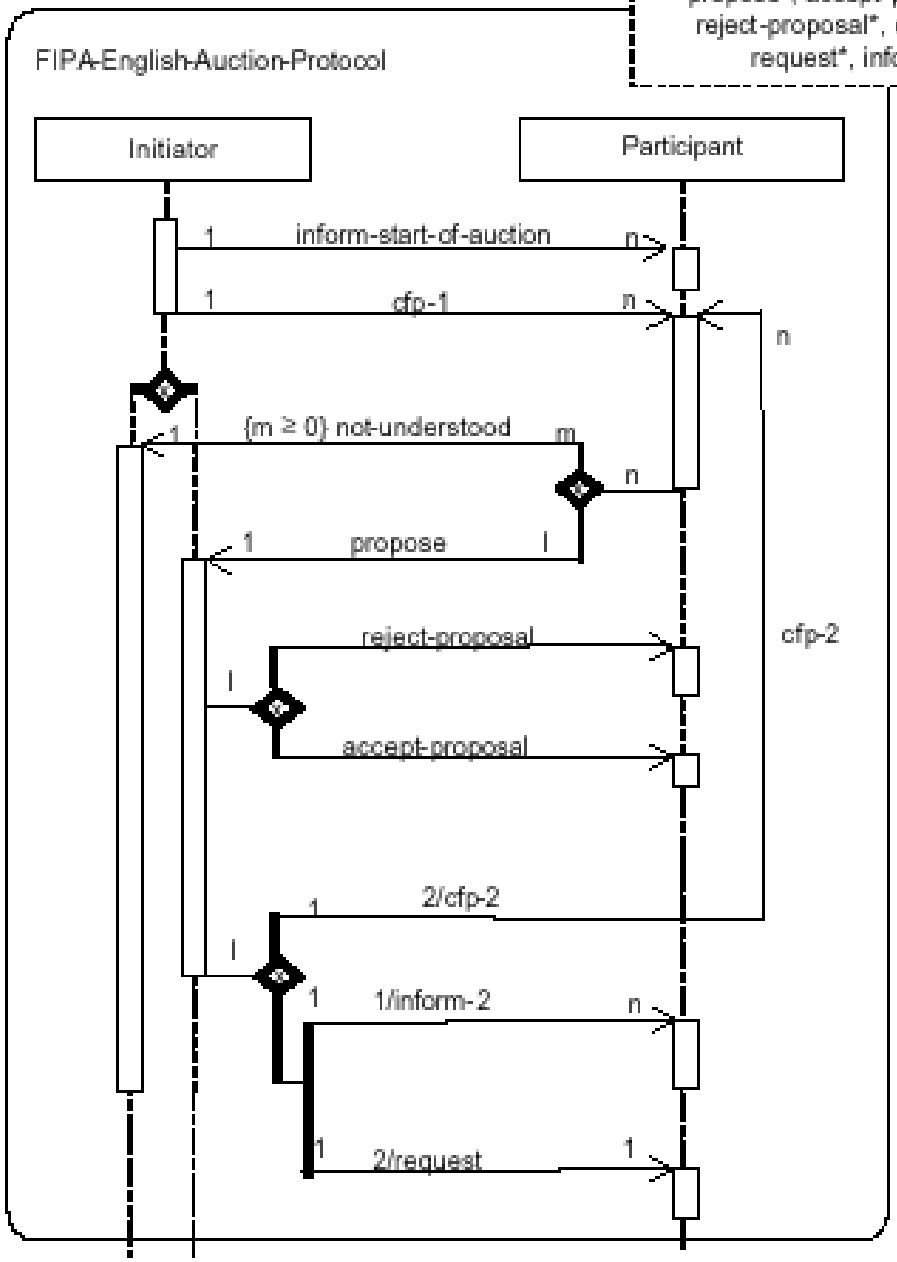
FIPA English auction:

- Upward auction method
- when an offer is issued, the initiator generates a cfp with the new price
- The auctioneer seeks to find the market price of a commodity by proposing an initial price lower than the assumed market value so that the price gradually increases.

FIPA Platform: Interaction protocols

FIPA English auction:

-



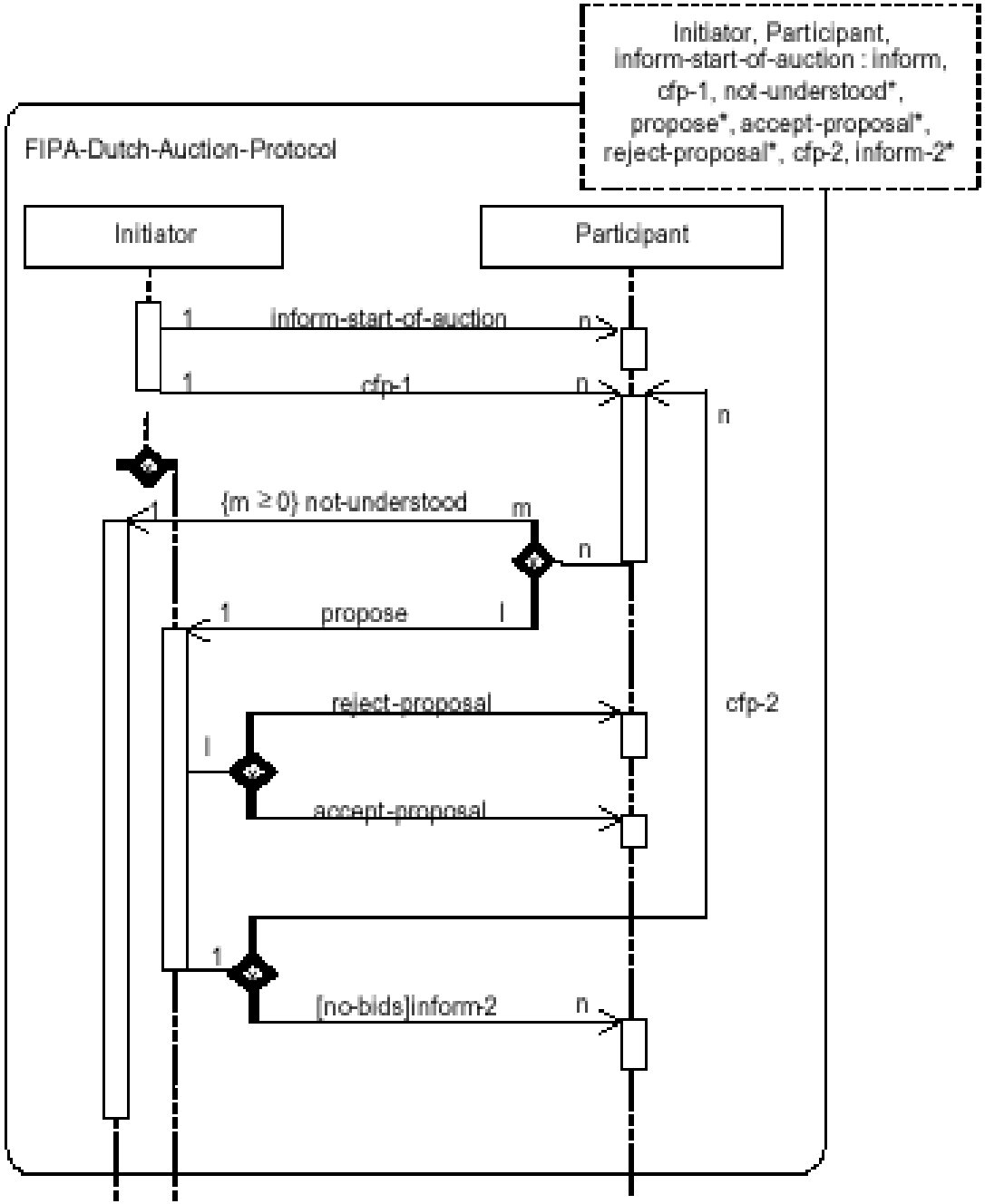
FIPA Platform: Interaction protocols

FIPA Dutch auction:

- Downward auction method
- there is usually a minimum price below which the sale is not made

FIPA Platform: Interaction protocols

FIPA Dutch auction:



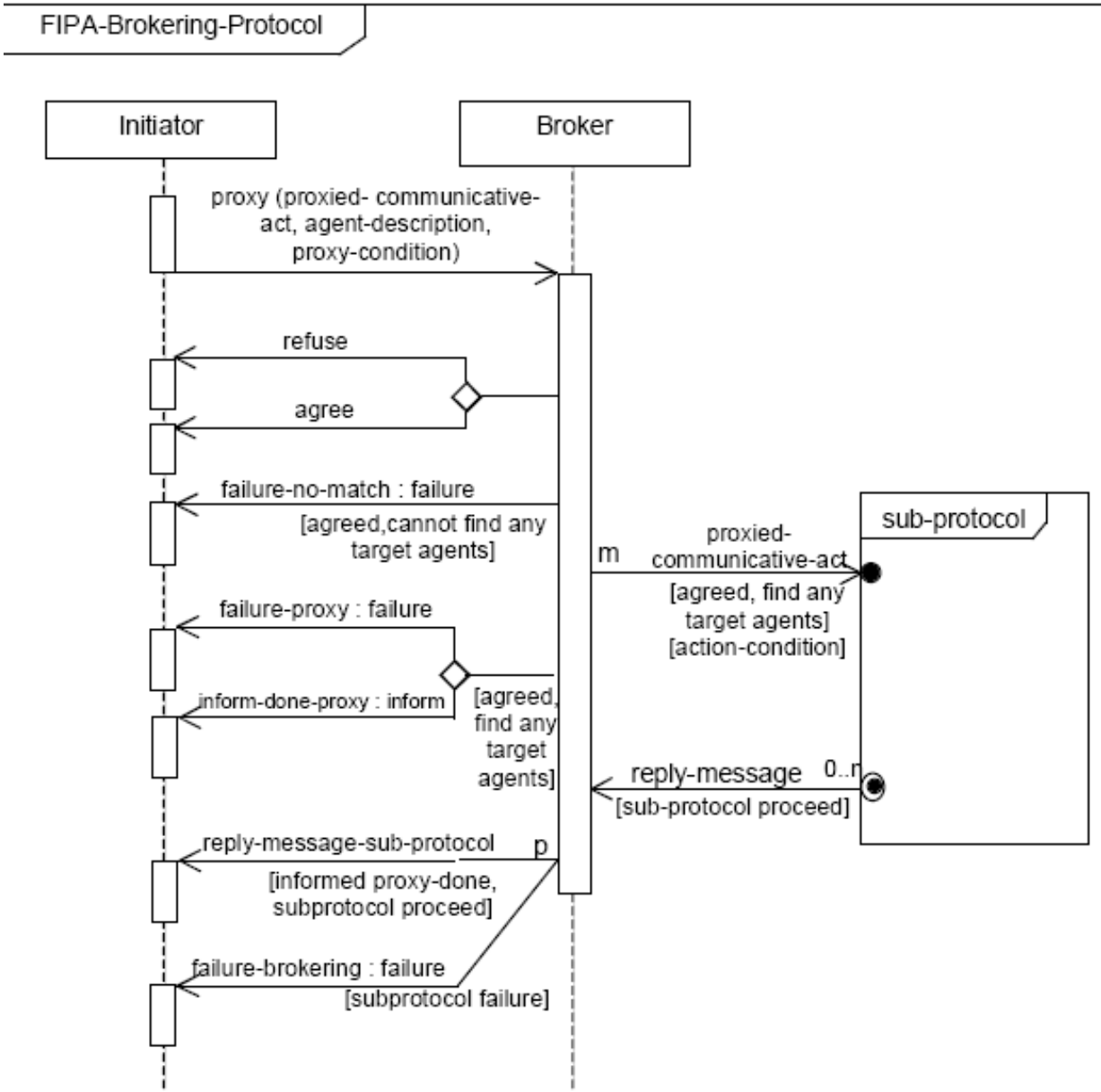
Plataforma FIPA: Protocolos de Interacción

FIPA brokering:

- Diseñado para soportar la intermediación entre agentes
- el broker envía la petición a un conjunto de agentes
- el broker proporciona las respuestas

Plataforma FIPA: Protocolos de Interacción

FIPA brokering:



FIPA Platform: Interaction protocols

FIPA brokering:

- Its purpose is to allow interaction with other agents through a mediator (the broker)
- proxy is a macro (includes another communicative act that the broker must make arrive at the selected or selected)
- The broker returns the results through reply-message-sub-protocol (i.e. a reply with the response in the body of the message)

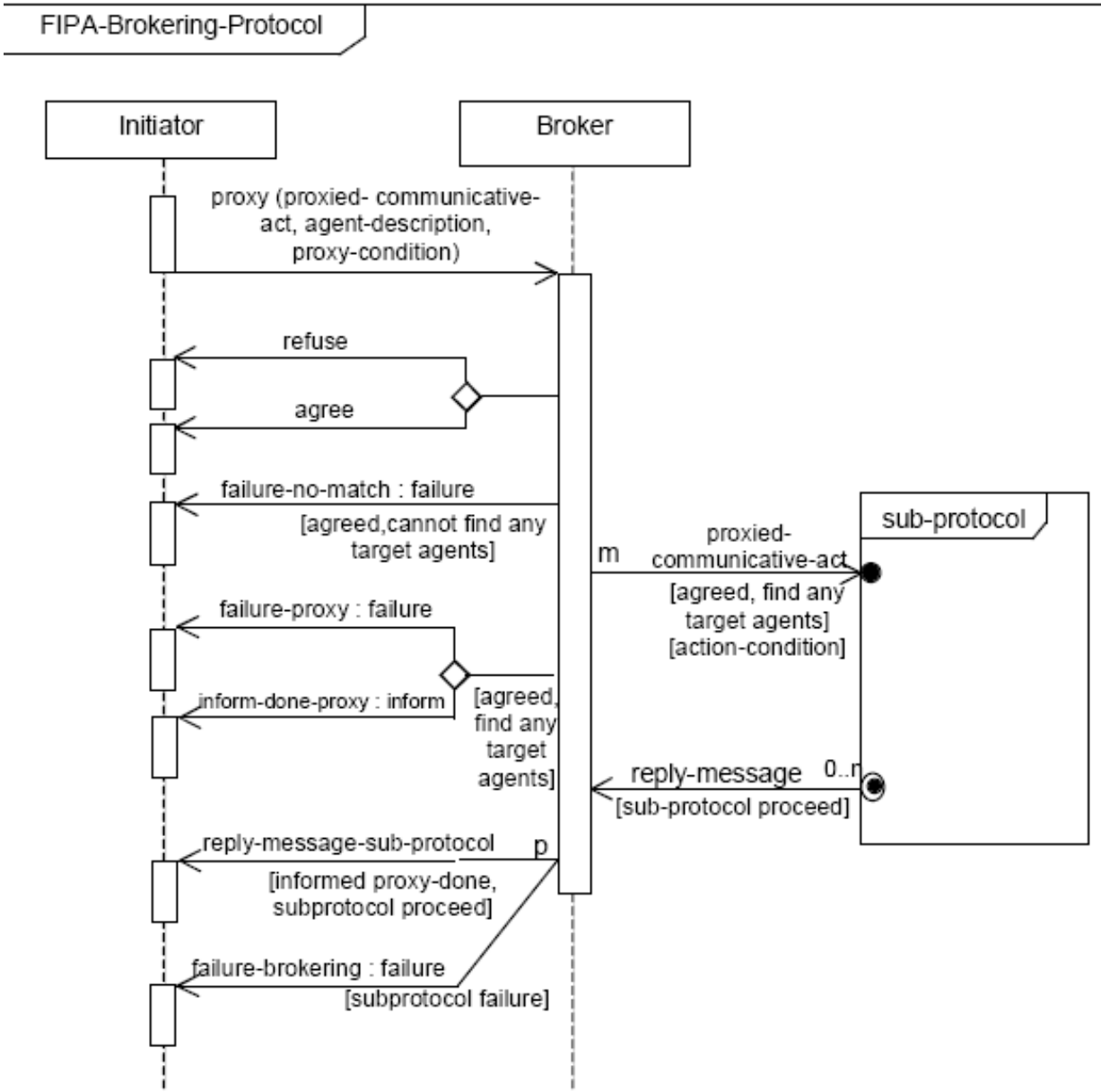
FIPA Platform: Interaction protocols

FIPA recruiting:

- analogous to FIPA-brokering
- the broker sends the request to a set of agents
- the agents are the ones who send the response to the initiator

FIPA Platform: Interaction protocols

FIPA recruiting:



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Advanced Techniques in Artificial Intelligence

Curso 2021-2022

German Rigau

german.rigau@ehu.eus

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