Agent and Multi-Agent Systems: architectures and reasoning

Interaction mechanisms : models and implementation

Wassila Ouerdane

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CentraleSupélec –SAFRAN Training

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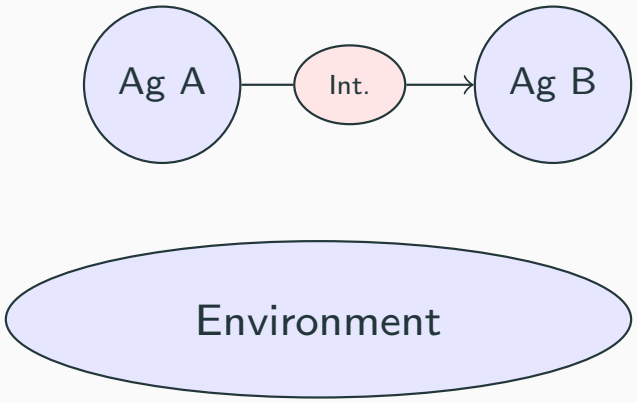
Interaction Mechanisms

Interaction Mechanisms

Interaction

- An interaction occurs when two or more agents are brought into a dynamic relationship through a set of reciprocal actions.
- Interactions develop out of a series of actions whose consequences in turns have an influence on the future behavior of agents.



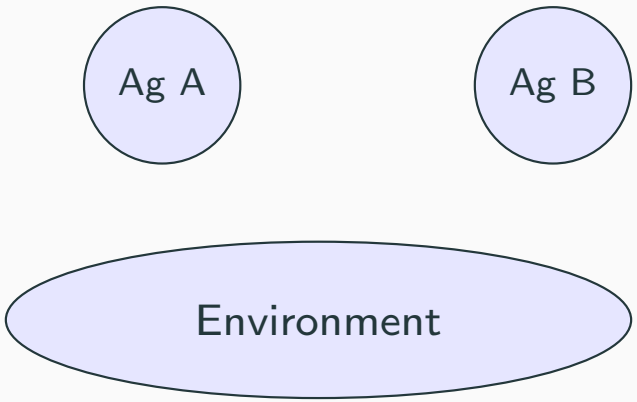
Asynchronous interactions

Problems in MAS

- Agents run asynchronously
- Method invocation is synchronous

PRS Architecture

- Actions modify the environment
- (Asynchronous) perception of the modification



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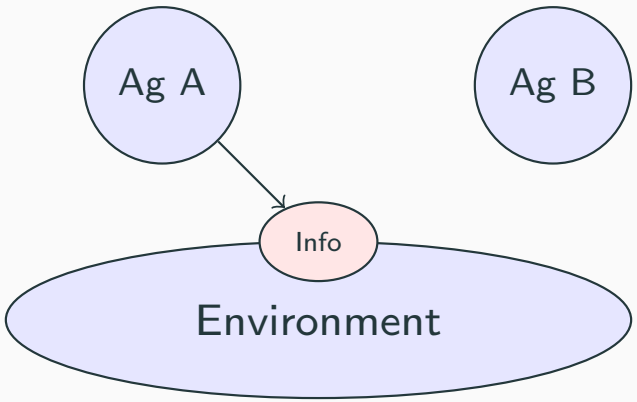

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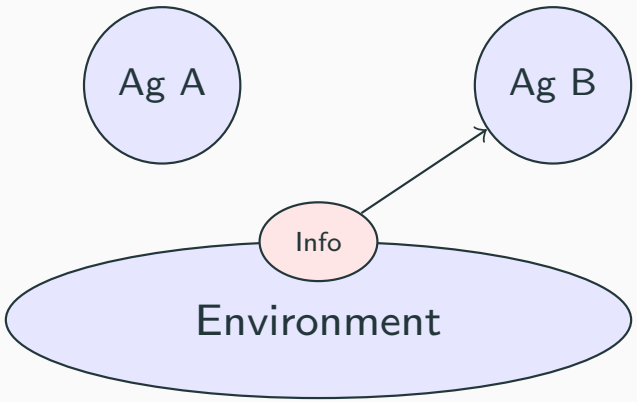

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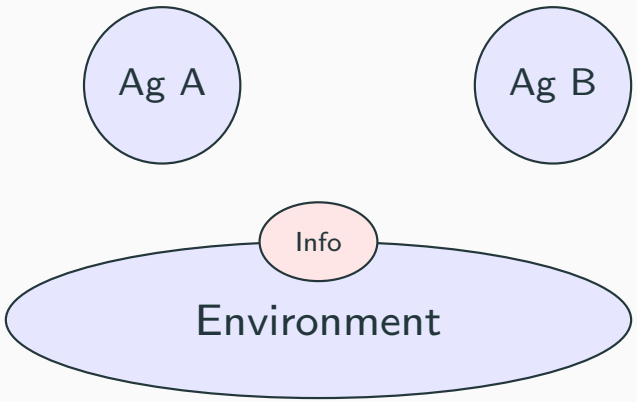

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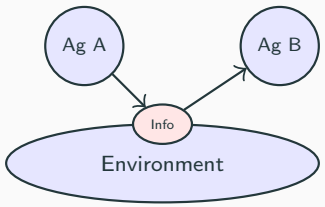

Example from session 1

➜ Alice and Bob manipulate a shared variable.

The action of each agent is triggered by the fact that the other agent modified the variable

Interactions

Two sorts of interactions

- Indirect interactions

  ➜ The agents act on the environment, the interaction is a side-effect of the actions

  See Alice and Bob's example

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Two sorts of interactions

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  See Alice and Bob's example

- Direct interactions

  ➜ The agents have explicit communication actions (message sending)

  + for cognitive agents : communication goals/intentions

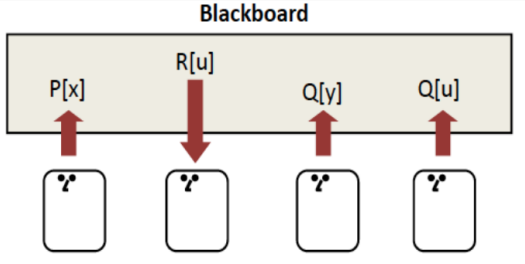
Indirect interactions

Indirect interactions

- No intention to communicate to a specific agent
- Agents interact through an intermediate entity
- This medium supplies specific interaction mechanisms and access rules
- These rules and mechanisms define agent local context and perception

Artifact-mediated interaction: Blackboard systems

- Agents access a shared artifact (stores data) that: they can observe and can modify
- Such artifact is a communication channel characterized by an intrinsically broadcast transmission.
- Specific laws regulating access to this medium
- It represents a part of agents' environment.



For more details

`https://en.wikipedia.org/wiki/Blackboard_system`

Blackboard: implementation

Environment

```
class Environment:
    blackboard = {}
    def act(self,name,value):
        self.blackboard[name] = value
    def perceive(self,name):
        if name in self.blackboard:
            return self.blackboard[name]
        return None
```

Blackboard: implementation

Agents (Alice and Bob with their preferred value)

```
1  class Agent(Thread):
2      def __init__(self, name, preferred_value, env):
3          Thread.__init__(self)
4          self.name = name
5          self.env = env
6          self.pv = preferred_value
7
8      def run(self):
9          while True:
10             self.procedural_loop()
11
12     def procedural_loop(self):
13         if self.env.perceive("v") != self.pv:
14             self.env.act("v",self.pv)
```

From Blackboard to Stigmergy

Blackboard's limitations

- Centralized mechanism $\rightarrow$ possible failures
- All agents perceive the whole environmeent!

From Blackboard to Stigmergy

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Local view on the environment

e.g.: Money model or prey-predators

- Agents are spatially situated

  $\rightarrow$ localization variables in relation to the environment, *e.g.* a grid)
- Each position in the grid is associated to a mini-blackboard

Direct interactions

Direct interactions

Principle

- Intention to communicate to a specific agent
  - Messages with sender & recipient
  - Control over the communication
- Information exchange
  - Structured content → content models and languages
  - Ontologies

Norms

- Agent Communication Language (ACL)
- Communication/Conversation rules ("protocols")

Speech Acts Theory I

Searle, 1969

Communication is an action

Communicate $\rightarrow$ change interlocutor's mental state

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Communication is an action

Communicate $\rightarrow$ change interlocutor's mental state

Three aspect of a speech act

- Locutionary: the act of saying

  What was said: "*Is there any salt?*"

- Illocutionary: the intention behind the speech

  What is expected to be the result: *get the salt*

- Perlocutionary: the effect of the speech

  What happened as a result, what was understood

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Sucessful communication

$$\text{Illocutionary} = \text{Perlocutionary}$$

Speech Acts Theory II

Searle, 1969

Illocutionary act

Performative Verb (Propositional Content)

Speech Acts Theory II

Searle, 1969

Illocutionary act

Performative Verb (Propositional Content)

Examples

Content = 'the door is closed'

- Performative = request — *please close the door*
- Performative = inform — *the door is closed*
- Performative = question — *is the door closed?*

Speech Acts Theory II

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Illocutionary act

Performative Verb (Propositional Content)

Examples

Content = 'the door is closed'

- Performative = request — *please close the door*
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Categories of performatives/speech acts

- Assertive (send information)
- Directive (send orders. . . or ask questions!)
- Commissive, Declarative, Expressive. . .

Agent Communication Language (ACL)

➜ Standard for messages exchanged among agents *e.g.* FIPA-ACL, KQML...

Message structure

- Sender of the message (agent ID)
- Receivers (agents IDs)
- Performative (predefined list of possible values)
- Propositional content in some content language (*e.g.* KIF)
- Conversation IDs
- Ontology

FIPA-ACL is the *de-facto* standard `http://www.fipa.org`

- FIPA: Foundation for Intelligent Physical Agents
- KQML: Knowledge Query and Manipulation Language
- KIF: Knowledge Interchange Format

FIPA-ACL standard

Example – KQML-based syntax

```
(inform
   : sender agent 1
   : receiver agent 5
   : content (price good200 150)
   : language sl
   : ontology hpl-auction
 )
```

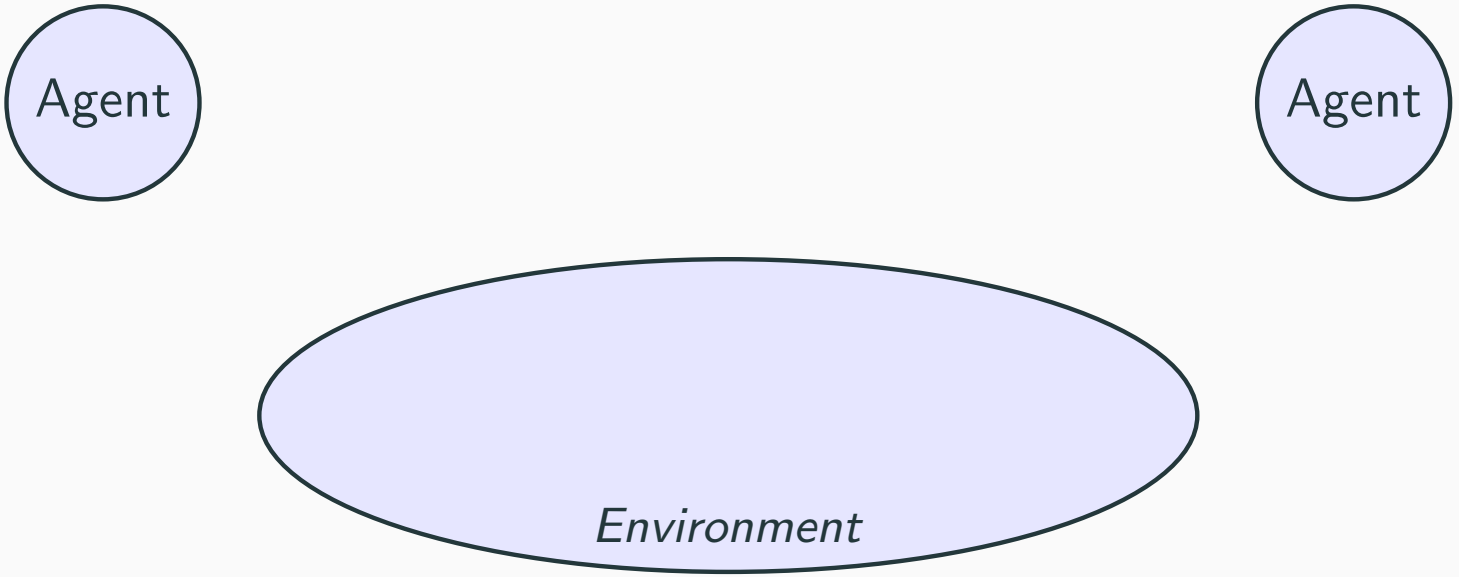
Note that the performative is the leader element!

FIPA-ACL standard

FIPA ACL Performatives

performative	passing info	requesting info	negotiation	performing actions	error handling
accept-proposal			x		
agree				x	
cancel		x		x	
cfp			x		
confirm	x				
disconfirm	x				
failure					x
inform	x				
inform-if	x				
inform-ref	x				
not-understood					x
propose			x		
query-if		x			
query-ref		x			
refuse				x	
reject-proposal			x		
request				x	
request-when				x	
request-whenever				x	
subscribe		x			

How does this work? Asynchronous message sending



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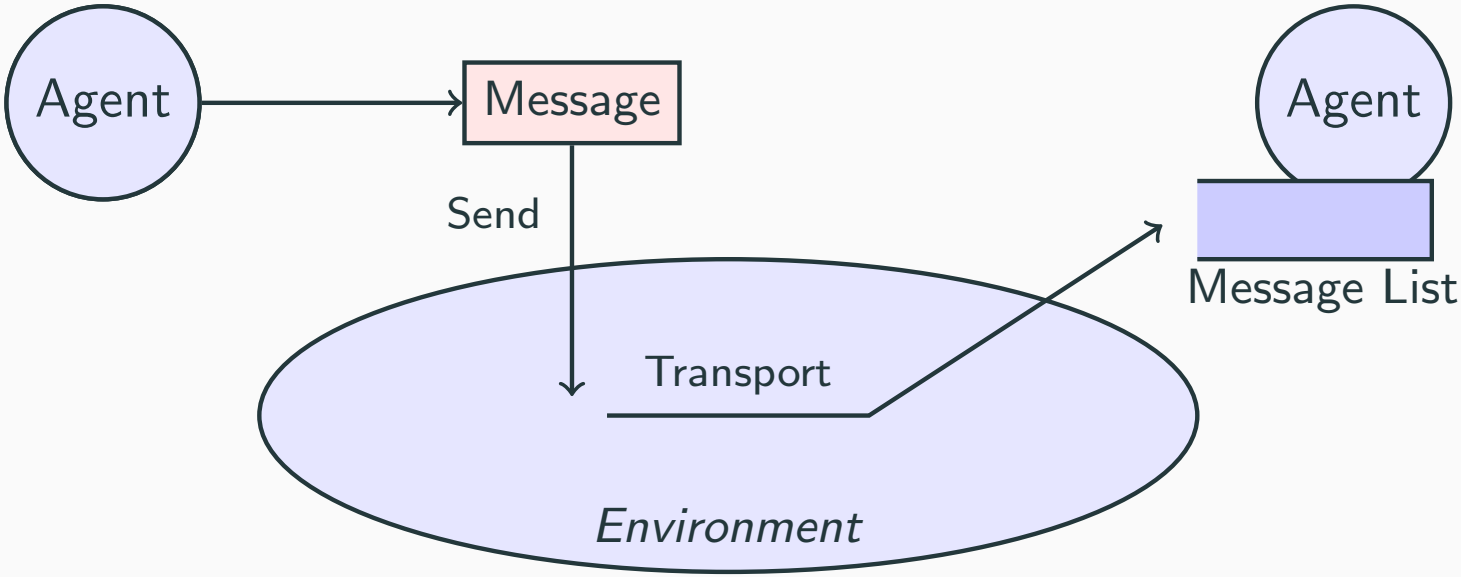
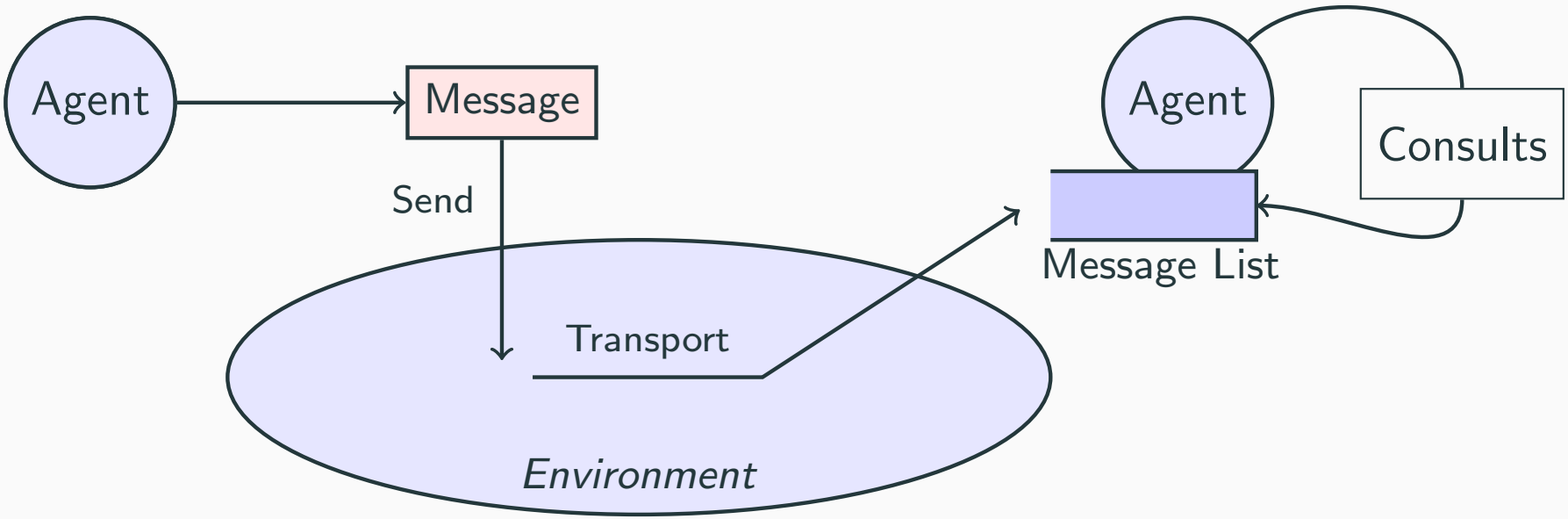


Synchronous method calls

How does this work? Asynchronous message sending



Synchronous method calls	Asynchronous

Practical Work

Alice-Bob with direct interaction

- Agent Charles has a value
- Agent Alice and Bob have preferred values for Charles
- On their turn, they ask Charles its value (message)

```
m = Message("ask",self.id,"value")
m.addReceiver(charles_id)
self.environment.send(m)
```

- Depending on the answer, they ask Charles to change the value (message)

```
m = self.receive() # look in the msg box
if m.get_sender()==charles_id
  and m.get_performative()=="assert"
  and m.get_content()!=self.preferred_value: ...
```

➜ Build a model that is generic enough

Messages

```
1  class Message:
2    def __init__(self,performative,sender_id,content=
       None):
3      self.receivers = []
4      ...
5    def add_receiver(self,agent_id): ...
6    def get_content(self): ...
7    def get_performative(self): ...
8    def get_sender(self): ...
9    def get_receivers(self): ...
10
```

Practical Work

Environment

```
class Environment:
    ... # has a list of agents
    def send(self,message):
        for id in message.get_receivers():
            self.agents[id].append_message(message)
```

Agents (generic)

```
class Agent(Thread):
    ... # has a mailbox
    def append_message(self,message):
        self.mailbox.append(message)
    def receive(self):
        l = self.mailbox.copy()
        self.mailbox.clear()
        return l
```

Practical Work

Alice & Bob

```
class AliceBob(Agent):
    def procedural_loop(self):
        m = self.receive()
        if m==None: # ask Charles' value
          m = Message(...)
          self.env.send(m)
        else: # react to Charle's answer
```

Charles

```
class Charles(Agent):
    def procedural_loop(self):
        m = self.receive()
        if m!=None:
          if m.get_performative()=="ask": # answer
          elif m.get_performative()=="order": # change
```

What else?

We have

- A more or less generic Agent, Environment, Message architecture
- Code for Alice/Bob agents and Charles agents

What is missing?

What else?

We have

- A more or less generic Agent, Environment, Message architecture
- Code for Alice/Bob agents and Charles agents

What is missing?

- At the implementation level: IDs
  Agents need to know the ID of their interlocutor(s)
  ➜ Yellow Pages in the environment

```
ids = self.env.get_ids(role="charles")
for id in ids:
  m.add_receiver(id)
```

- At the conceptual level: protocols
  ➜ Define how agents should exchange information!

Interaction protocols

Interaction protocols I

Protocols

Describes how agents can interact in the MAS

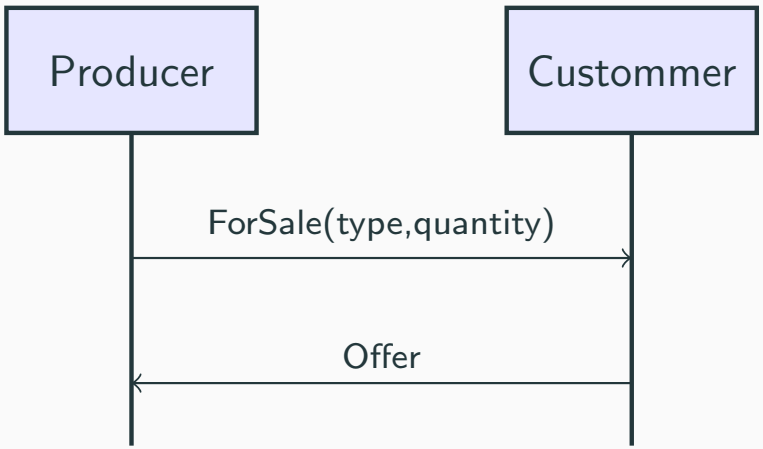
Interaction protocols I

Protocols

Describes how agents can interact in the MAS

AUML (Agent Unified Modeling language) standard

- Inspired from UML sequence diagrams
- Describes message exchange between roles
  - An agent can adopt several roles
  - A role can be fulfilled by several different agents



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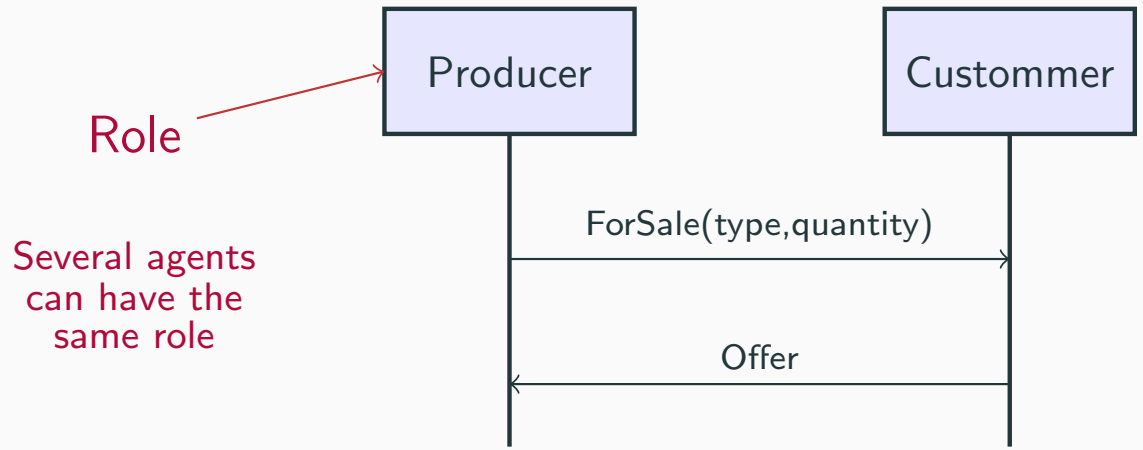

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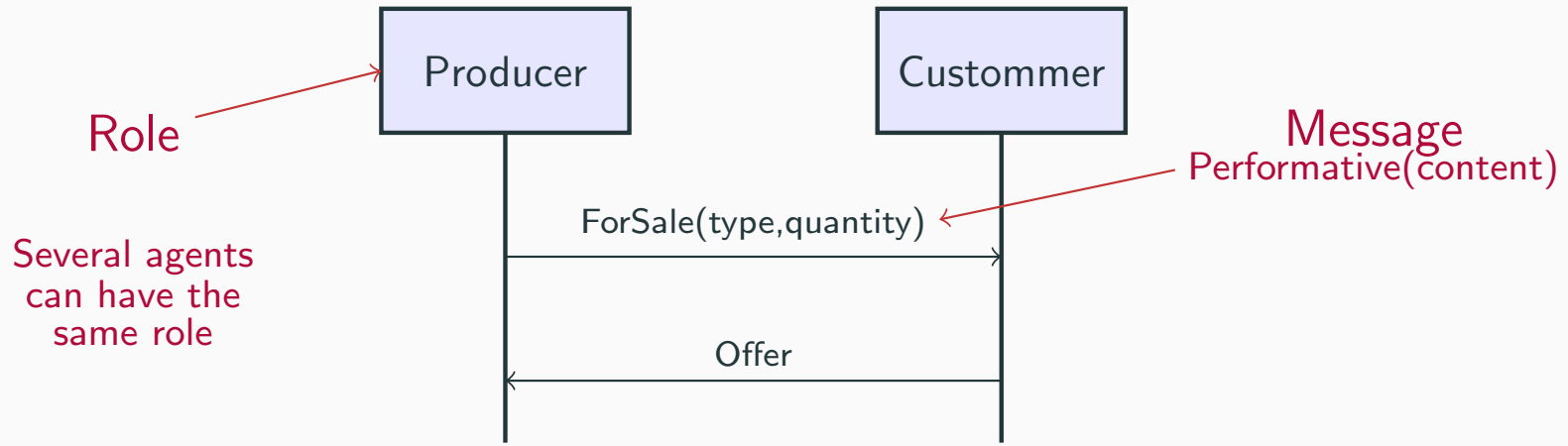

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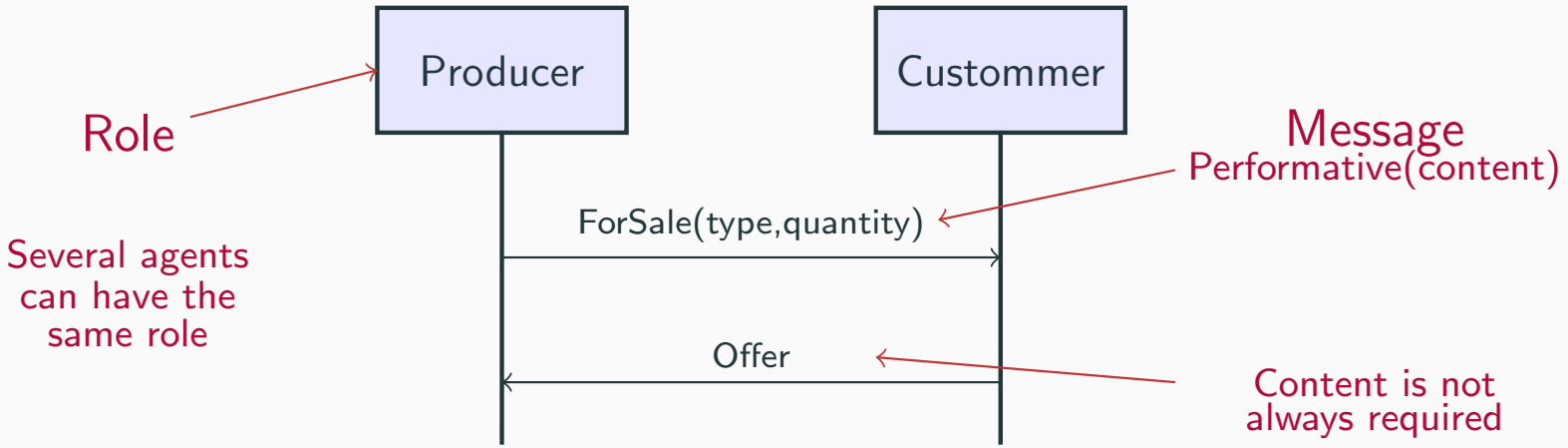
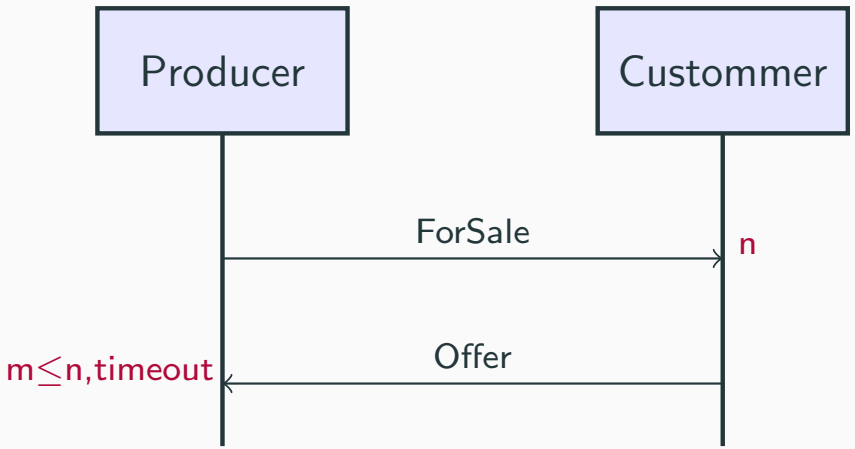


Interaction protocols II

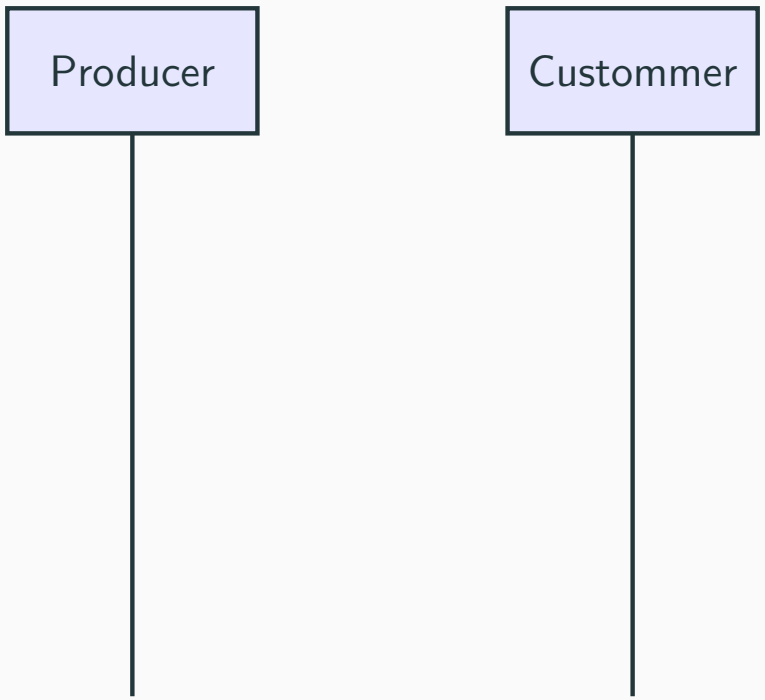
Conditions

- Number of messages sent (arrow end)
- Timeouts
  - Messages received after timeout are considered out of the protocol



Interaction protocols III

Operators



Interaction protocols III

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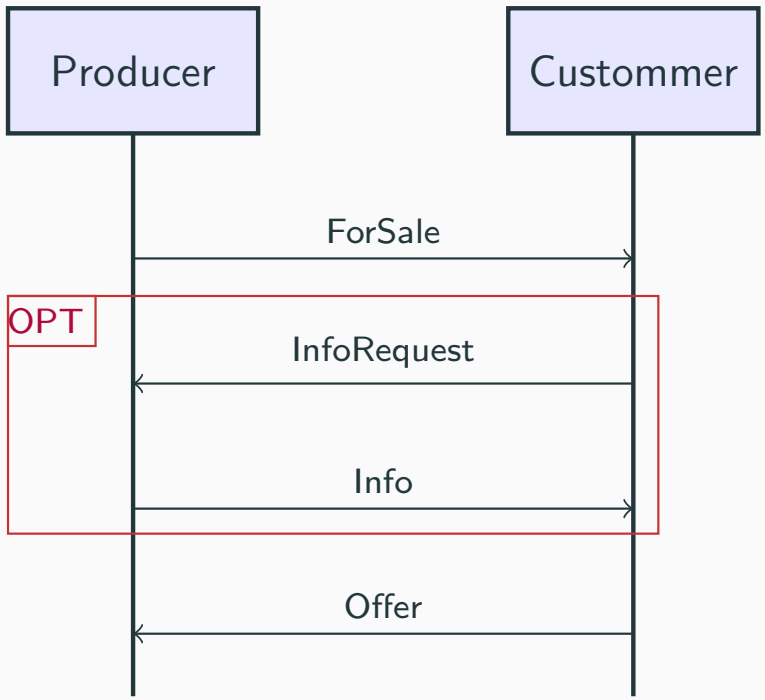
- OPT $\rightarrow$ some parts can be optional



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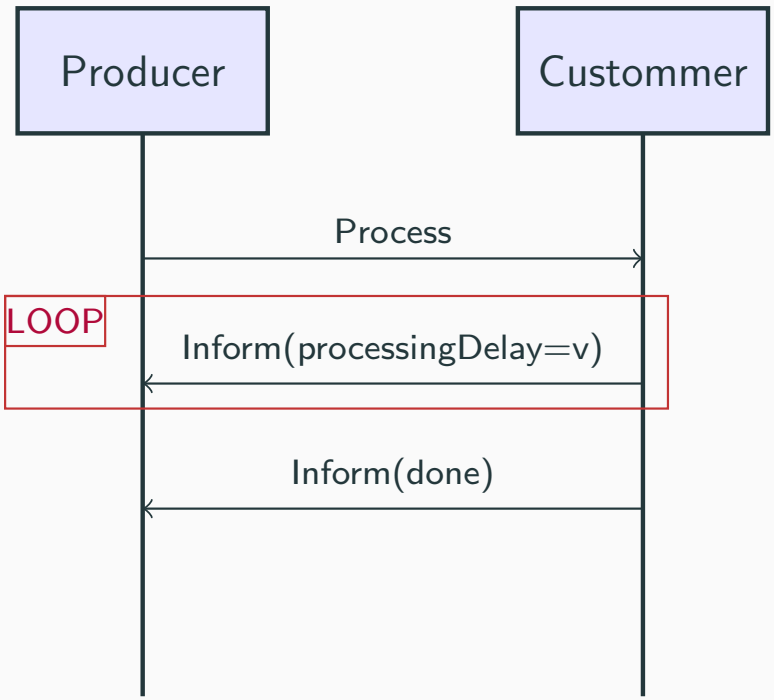
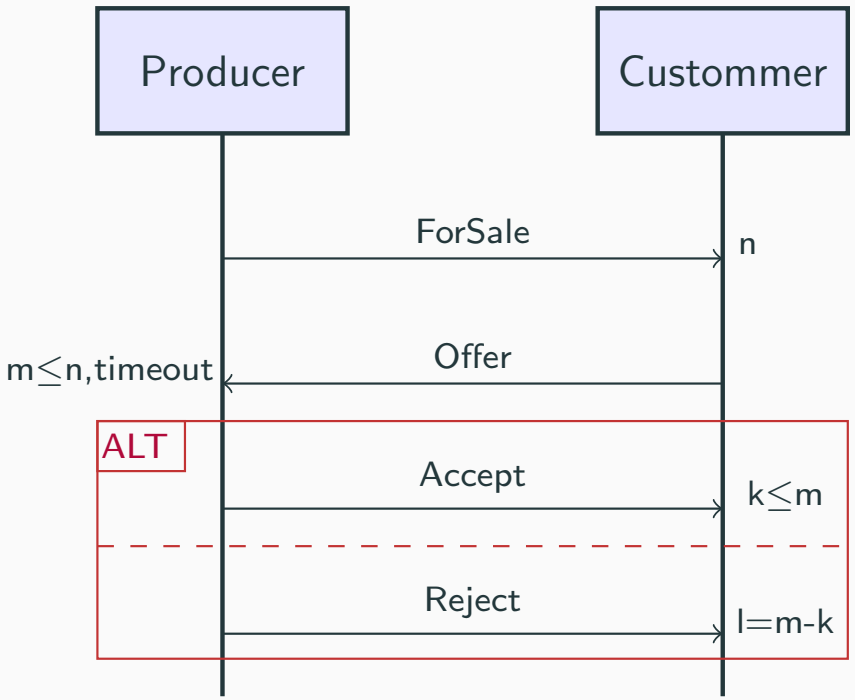
- OPT $\rightarrow$ some parts can be optional
- LOOP $\rightarrow$ some parts can be repeated randoml



Interaction protocols III

Operators

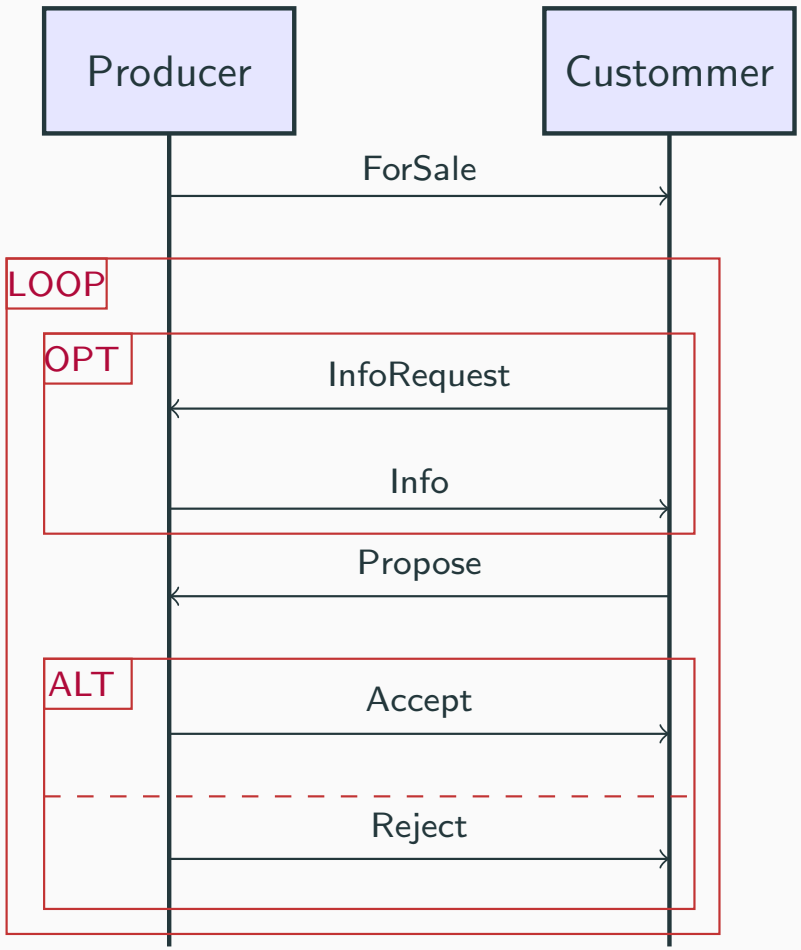
- OPT $\rightarrow$ some parts can be optional
- LOOP $\rightarrow$ some parts can be repeated randoml
- ALT $\rightarrow$ one or the other



Interaction protocols IV

Operators

- Operators can be combined



Interaction protocols

Contract-Net Protocol (CNP)

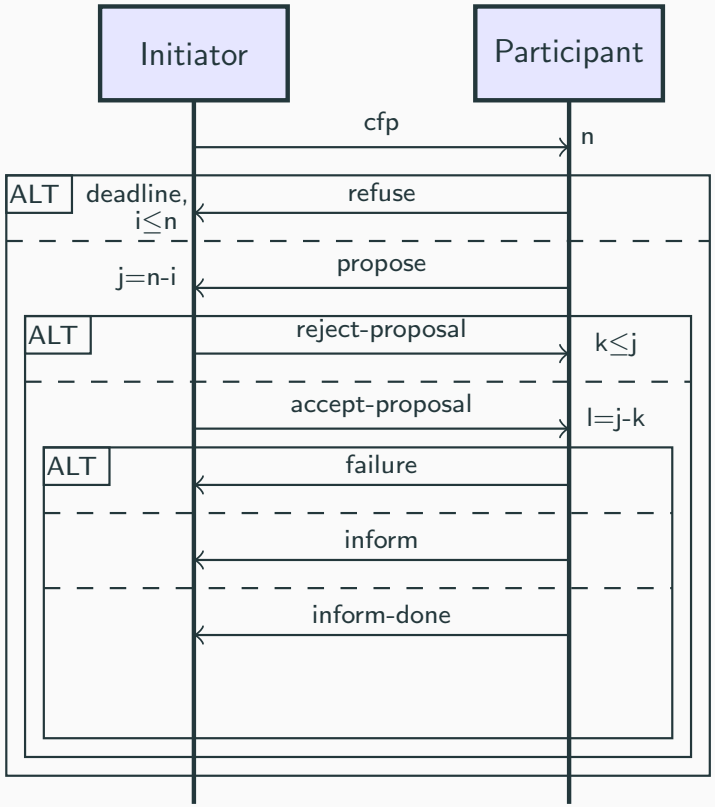
- One of the oldest, most widely used agent interaction protocols
- A manager agent announces one or several tasks, agents place bids for performing them
- Task is assigned by manager according to evaluation function applied to agents' bids (e.g., choose cheapest agent)
- Idea of exploiting local cost function (agents' private knowledge) for distributed optimal task allocation
- Even in purely cooperative settings, decentralization can improve global performance
- Successfully applied to different domains (e.g. transport logistics)

Interaction protocols V

Contract-Net Protocol (CNP)

Standard for agents to agree on a transaction.

- FIPA standard
- The "must-know" protocol



Communication in Mesa

Using of messaging communication in Mesa

open and explore mesa.zip

with the help of the file PW3_ExploringMesa.pdf

(correction provided, but you need to understand the mechanism)