Modelling Agent Services for Open Environments

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Theory & Practice

- "In theory there is no difference between theory and practice.
- In practice there is." Yogi Berra
- In this tutorial, we emphasise simple MAS theories that we can realise in practice.
- We will use the FIPA MAS specifications as the agent landscape for the theory & practice.

Outline

1. **Introduction to MASs based on speech-act communication √**
2. **Specifying MAS communication: FIPA approach**
3. **Designing FIPA MAS applications**
4. **Implementing MAS applications**

Motivation: resource access problem

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Web access problems …

Error 404 – Web Page Not Found

Motivation: resource access problem

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Error 404

Motivation: resource access problem (error handling)

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"The requested page …**/helpme** is not available via this web server.

Check that you have typed the address of the web page correctly.

Otherwise, please report to us the URL of the referring page as well as the URL of the missing page.

The Web site you seek cannot be located, but Countless more exist.", for example:

Try http://foo.yyy.zzz/bar or ….

Vision of an Agent Centric World?

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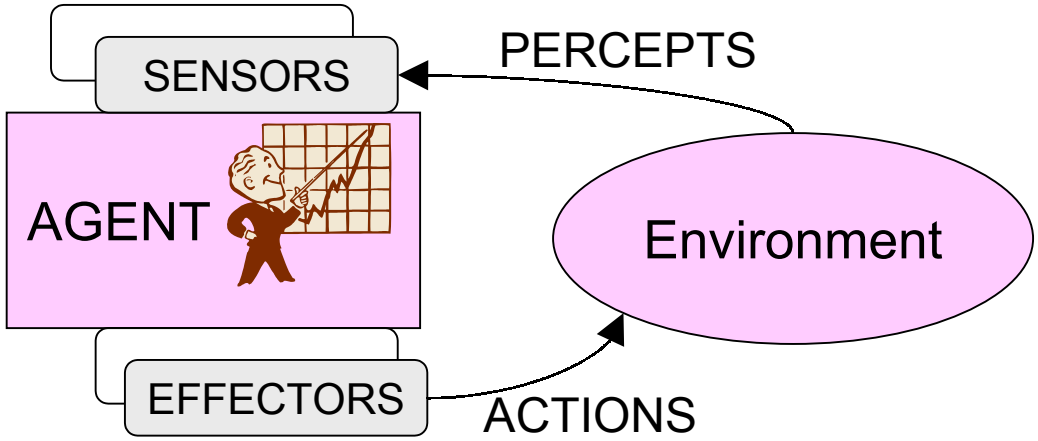
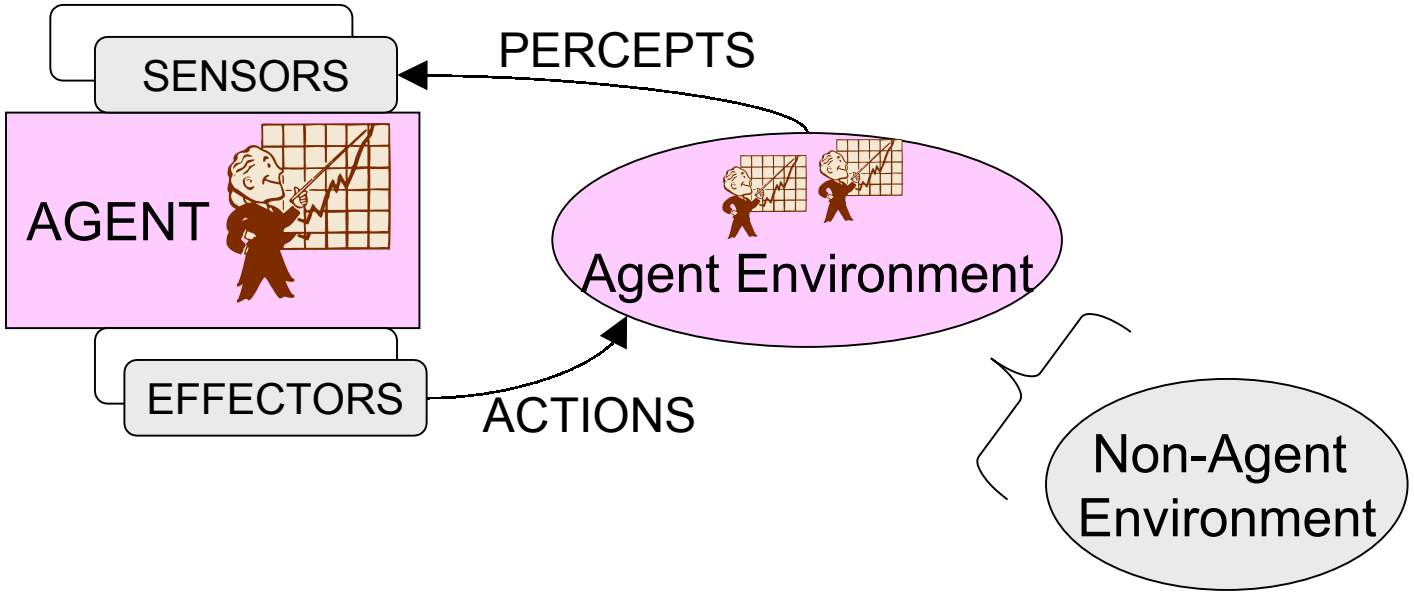
- We don't currently live in an agent centric world
- We won't in such an agent centric world for the foreseeable future
- We live in a heterogeneous information technology world
- We need to position agents w.r.t to existing non-agent models & technology and we need interoperability -> FIPA

Agent System

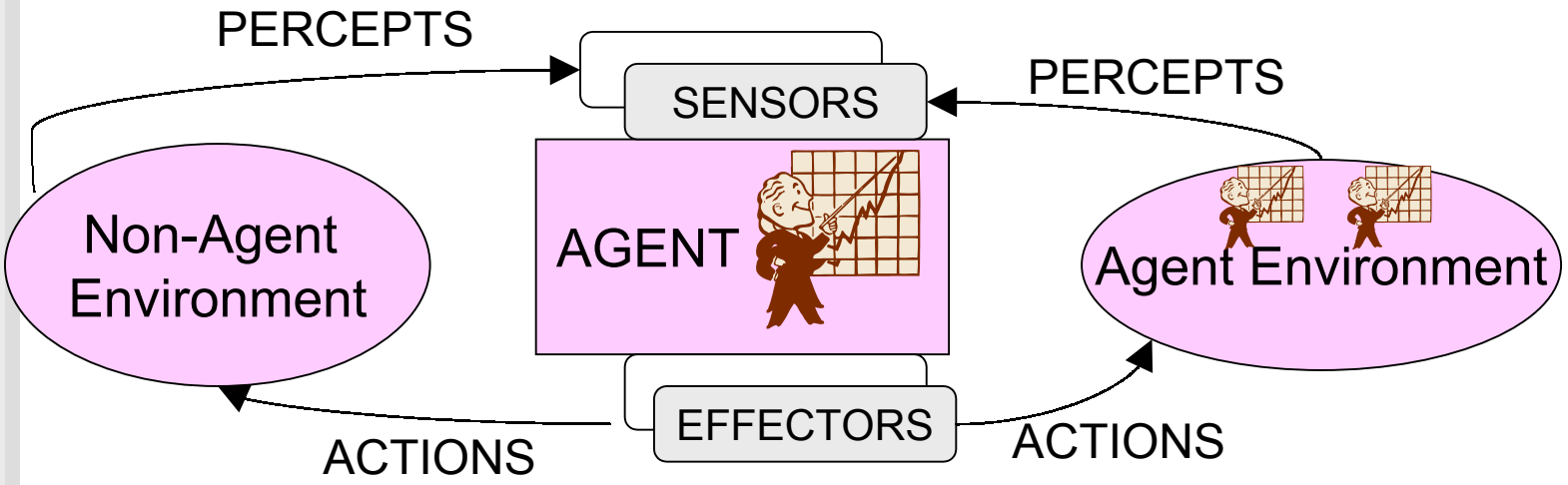


Multiple Agent System



Can we assume the non-agent environment is rational?

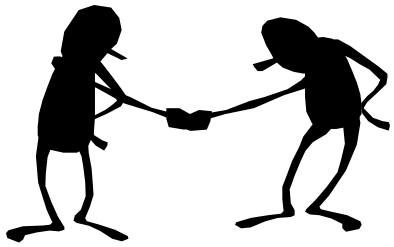
Multi-Agent System: situated in a non-agent environment



MAS Agent Properties

- Genesereth,1994, regards the use an Agent Communication Language (based on speech acts) as the key property of an agent.
- Others such as Wooldridge & Jennings, 1995, specify other properties:

- Reactive
- Proactive
- Autonomous
- Social ability
- Cognitive



- Agent can follow
- Agent can say ‘go’
- Agent can say ‘no’
- Agent work-flow
- Agent know-how

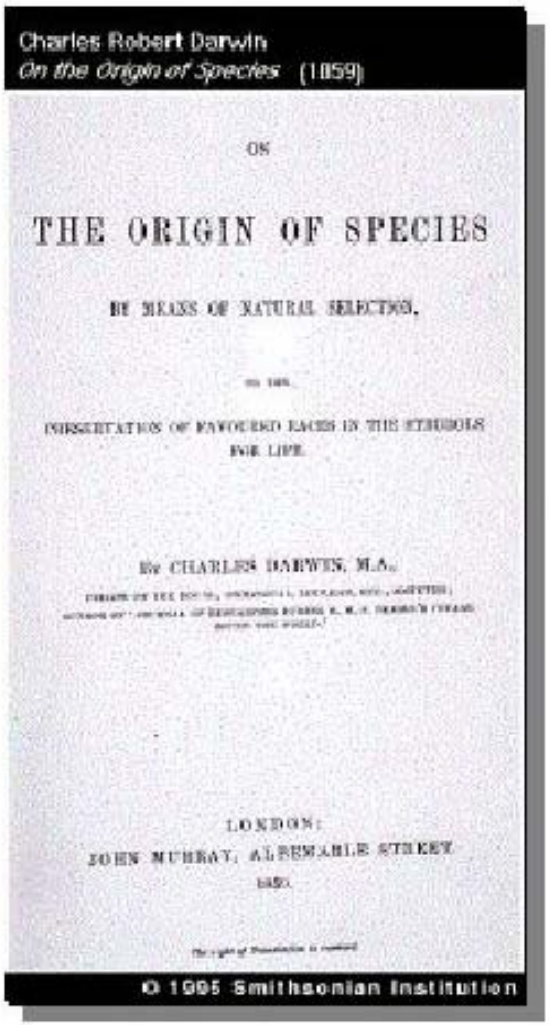
Multi-Agent System: adaptivity

"It's not the strongest of the species that survive ….

Nor the most intelligent

But the one most adaptive to change"

Charles Darwin 1809 – 1882.



MAS: Adaptivity through social interaction & deliberation

Adaptivity through combining:

1. Richer communication / social interaction (FIPA):
   - Generic Communication Protocols: Speech act
   - Communication patterns: Interaction protocols
   - Knowledge exchange
     - Domain knowledge independent of task – Ontology /or conceptual framework
     - Semantics: interpretation of concepts within a given conceptual framework
2. Goal-directiveness / deliberation
   - Agents have specific goals
   - They make plans and can re-plan to achieve these goals

MAS: Adaptivity through social interaction & deliberation

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- Combining social interaction & deliberation
  - How long should it take to complete the deliberation?
    - World is likely to change the longer it takes to reason about it
  - How much knowledge, what type of patterns do we need to understand to socialise?

Motivation for communicative agents: e.g, handling unavailable resources

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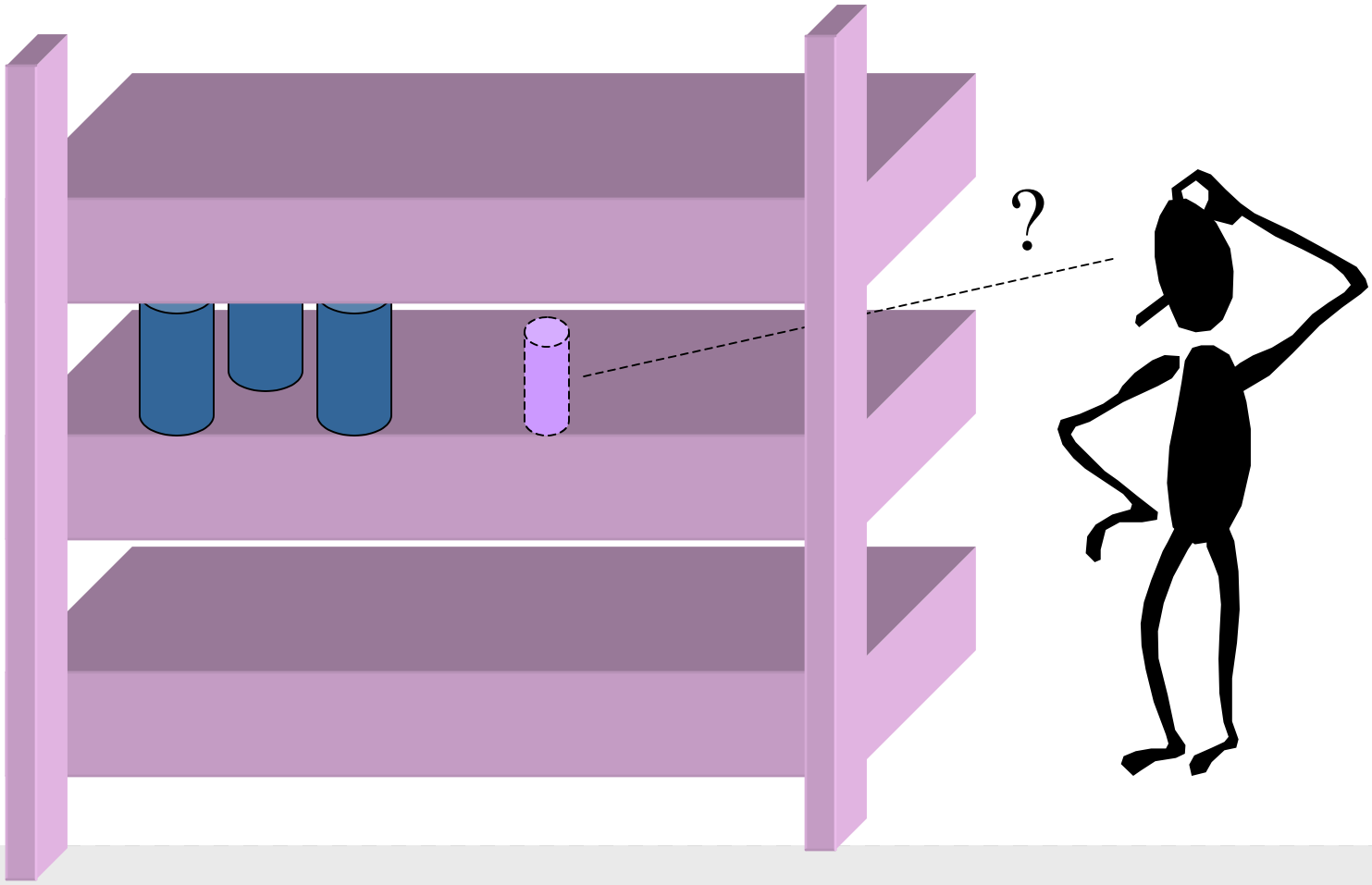

Handling unavailable resources

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It's no longer there, panic!

- What do we do next? Some options ….
- Change the goal (of retrieving the item in the known place)
  - e.g., give up, go back later
- Keep the goal, change the plan
  - Reason internally - single agent approach
- Keep the goal, change the plan
  - Social interaction - multi-agent approach

Handling unavailable resources: brute force search

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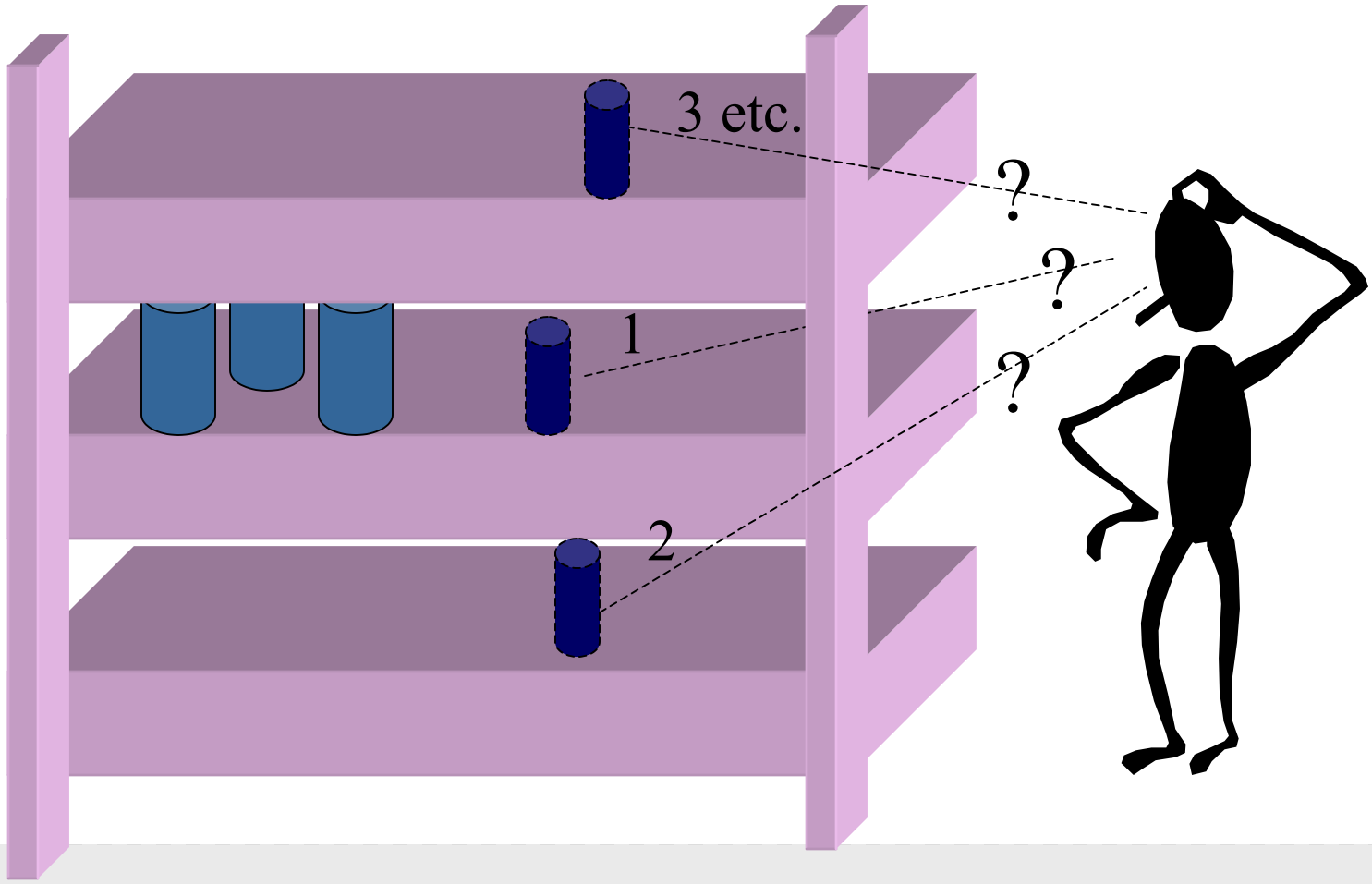

Handling unavailable resources: using generalised search engines

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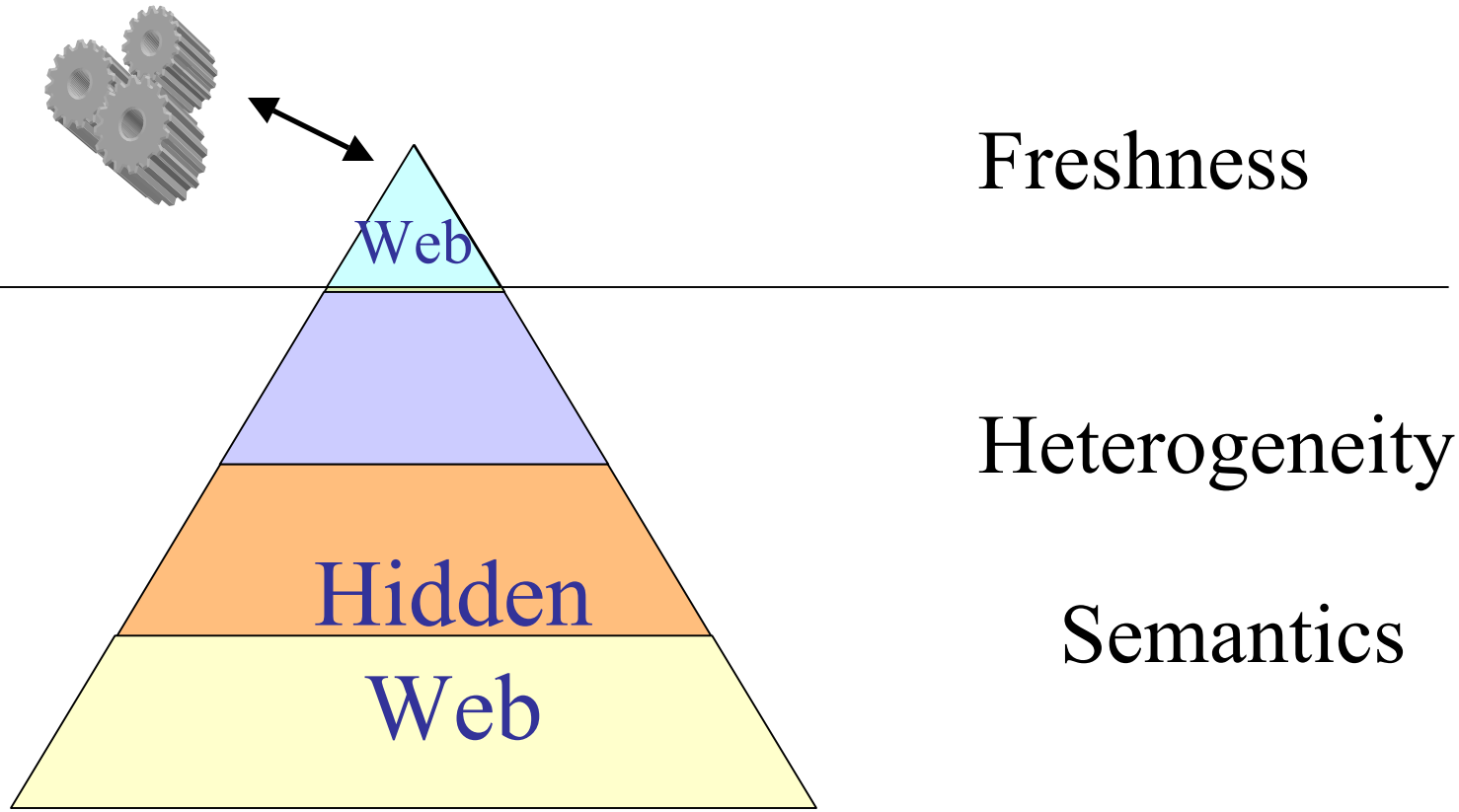

Handling unavailable resources: using a domain assistant

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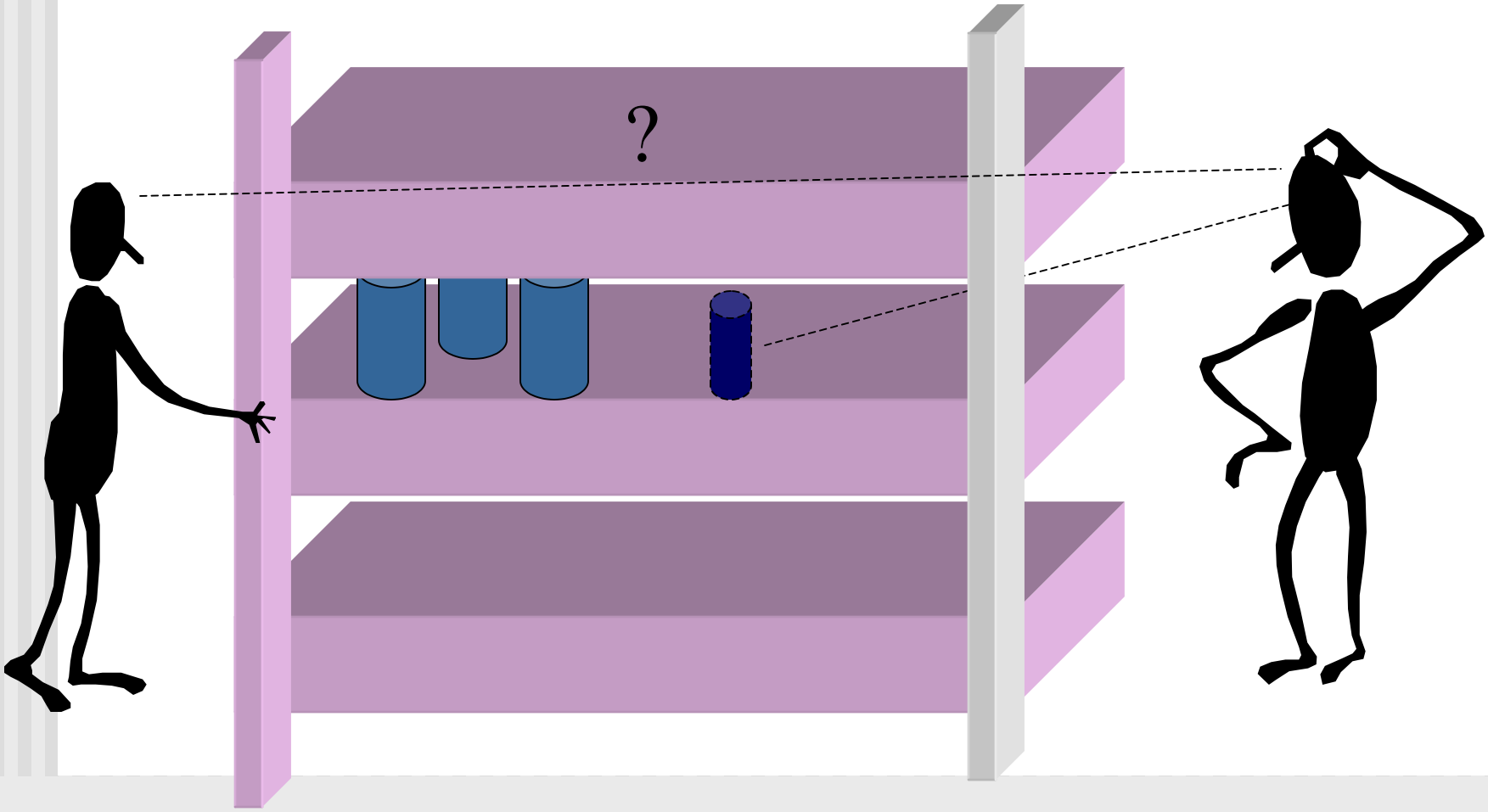

Generic Communication Protocols

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- Most application level communication protocols are application specific
  - What is the semantics of HTTP request message in my application domain?
  - Which application protocol do I choose for security?
- How can we get interaction within multiple domains using multiple protocols?
- Can we have a domain /application (standard?) neutral protocol?

  Yes we can! – a Speech act based protocol !

A communication protocol based on human speech acts

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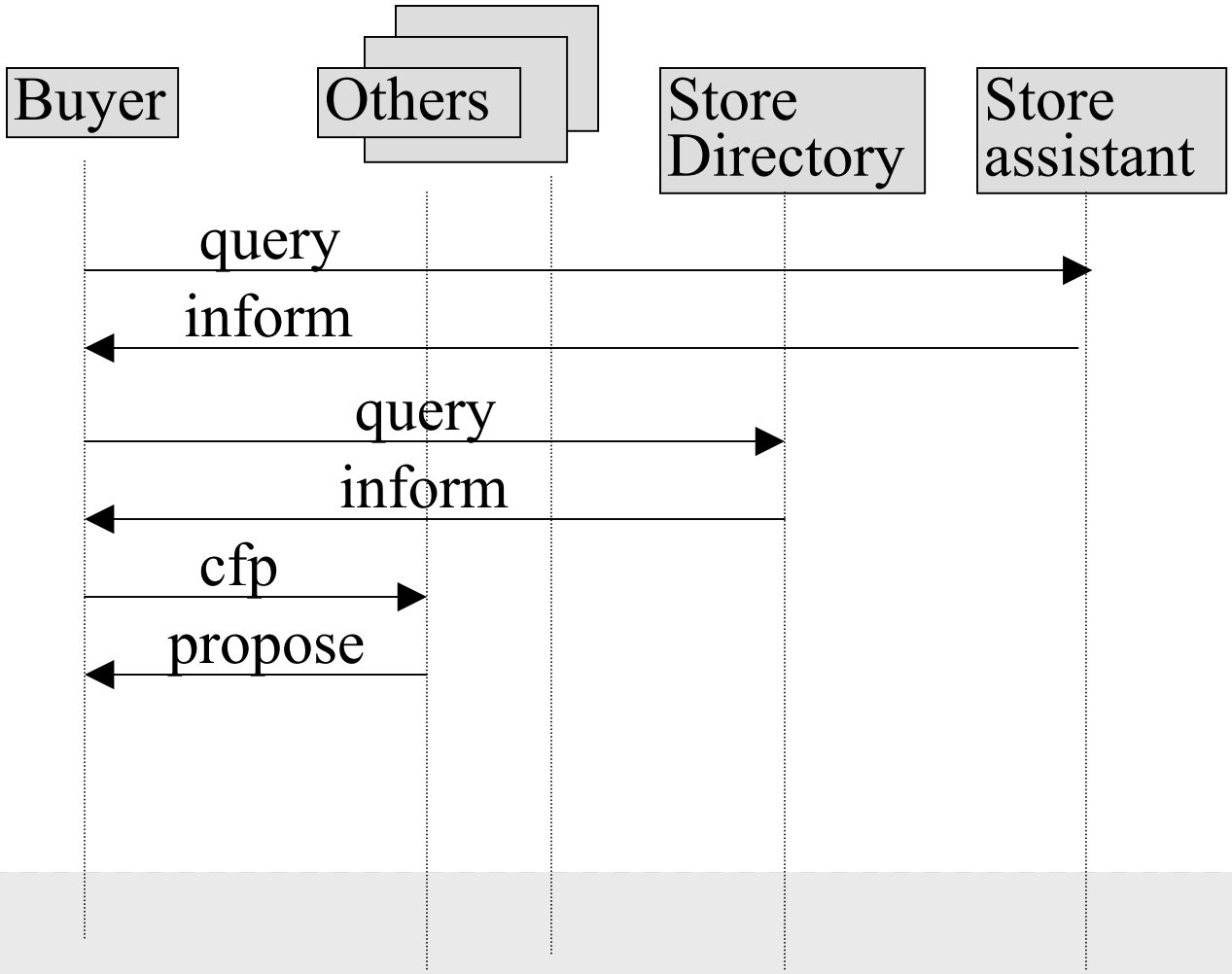
- The door is open?
- The door is open!
- Open the door (for me)
- OK! I'll open the door
- I am unable to open the door
- I will not open the door
- Tell me when the door becomes open
- Anyone want to open the door?
- I can open the door for you … at a price
- Etc

- Query
- Inform
- Request
- Agree
- Failure
- Refuse
- Subscribe

- Cfp
- Propose

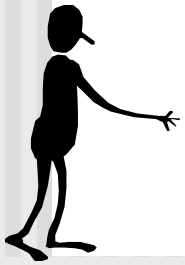
- Etc

Example: socialising to get help



FIPA Speech Acts

Accept-proposal	Agree	Cancel	Cfp
Confirm	Disconfirm	Failure	Inform
Inform-if	Inform-ref	Not-understood	Propose
Query-if	Query-ref	Refuse	Reject-proposal
Request	Request-when	Request-whenever	Subscribe



Speech acts: often used within interactions & with agreeing a priori shared knowledge

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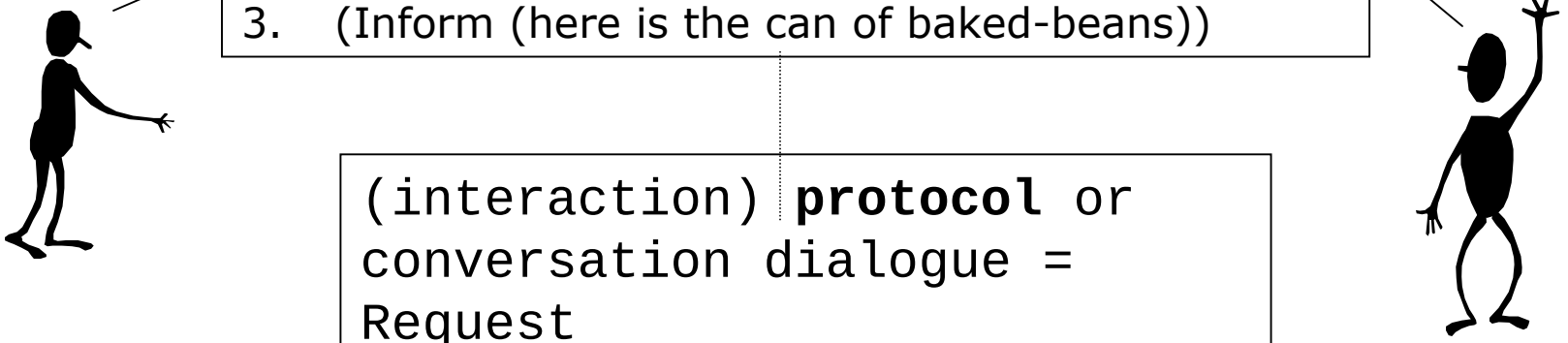

(interaction) **protocol** or conversation dialogue = Request
Speech or communicative act = Request, agree (or refuse or failure), inform
content = The location of the baked-beans (content or ontology)
language = English
ontology = food-shopping

Standard [FIPA] Interaction Patterns

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- Request, Request-when
- Query
- Contract-Net, Iterated Contract net
- English Auction, Dutch Auction
- Broker
- Recruit
- Subscribe
- Propose

A common understanding

- Buyer --- [Query] “Where can I find a small can of baked-beans?” --> in this store!
- Is a “tin” a can?
- Is a jar equivalent to a can?
- Is “small” less than 300g?
- Are black-beans equivalent to “baked beans”?
- Is one instance of baked-beans equivalent to another one?
- Do you request delivery here? Now? At home? within 2 min.s?
- Is “Where” defined in absolute terms as an Aisle No. or defined in relation to another product?

Formalisms & modelling for MAMD communication

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Requirements

- Logic model independent of the domain
  - Speech acts & interaction protocols need to be independent of the domain [ontology]
- Multiple formalisms for a heterogeneous world
  - Predicate -> Modal -> ?? Multi-modal
- Multiple semantics
  - BDI, Institutional, ….
- More or less formalism & semantics – we can get more efficient interoperability with weak formalisms
  - May want to trade-off the deliberation & expressiveness of the formalism against engineering, maintenance & performance

Varying the degree of Intention in communication

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Ferber 1999 has classified MAS communication at 3 orders of intention:

- Intentional order 0: no intention, incidental communication
- Intentional order 1: intention for the sender to get the receiver to respond
- Intentional order 2: sender A wishes to get a belief from receiver B relating to the state of the world (BDI)
- Intentional order 3: sender wishes to get a belief from receiver B about a particular belief of a 3rd party C (BDI)

Intentional communication order 0: Reactive behaviour

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- Agent A informs Agent B that A perceives a resource's location is not known, e,g, transmits a "no resource at location X" cry for help.
- Consider the production of the inform message that is based purely on reactive (stimulus – response behaviour).
  - A informs B "no resource available" because it perceives "no resource at location"
  - This does not depend on any deliberation by the sender
  - It is just based on the sender perceiving a certain state
- This is called
  - **incidental communication** or
  - **intentional communication of level 0**

Intentional Communication order 1

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- Agent A perceives a resource's location to be unknown
- Consider the production of the query message that is based on some simple reaction but with little deliberation
- A queries B because it wants a response from B
  - A queries B "for resource location of X" because it wants B to inform it of the location
- This is called intentional communication of level 1
- For example the FIPA MAS interaction protocols can be explained at this level

Intentional Communication order 2

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- Consider the production of an inform message that is based on greater deliberation
  - E.g., B informs A (of the location of resource X)
  - B informs A because it believes the proposition that A does not know the location of resource X and it wants to change B's belief
  - In theory, individual FIPA speech acts are modelled at this level (2) in a language called SL (Semantic Language)
  - But in practice, many FIPA applications do not use this order 2 intentional model but use the previous order 1 intentional model

Intentional Ping Service

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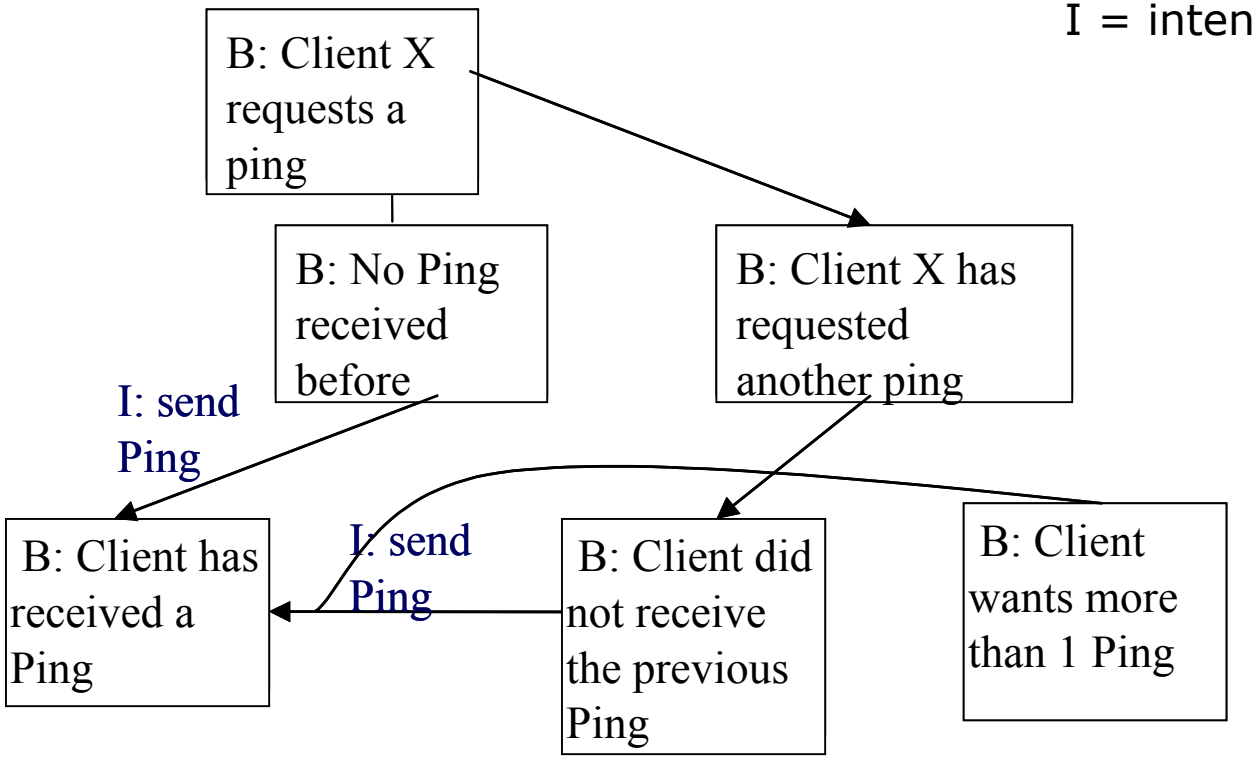
B = belief

I = intent



Outline

1. Introduction to MASs based on speech-act communication
2. Specifying MAS communication: FIPA approach
3. Designing FIPA MAS applications
4. Implementing MAS applications

FIPA approach to MAS: overview

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- About FIPA, FIPA scope
- FIPA models, representation, abstractions
- Overview of the core specifications

The leading Agent Standard: FIPA

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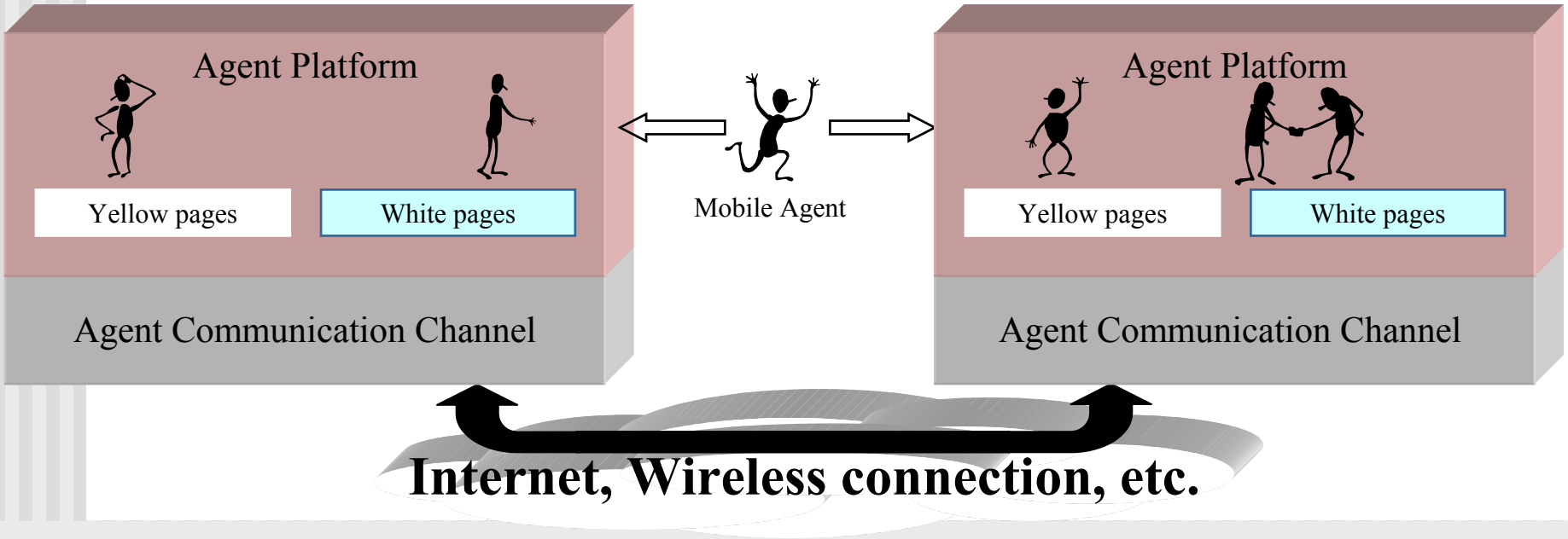
Foundation for Intelligent Physical Agents

16 implementations
5 open source implementations
JCP called JAS
50 members
EU & other projects



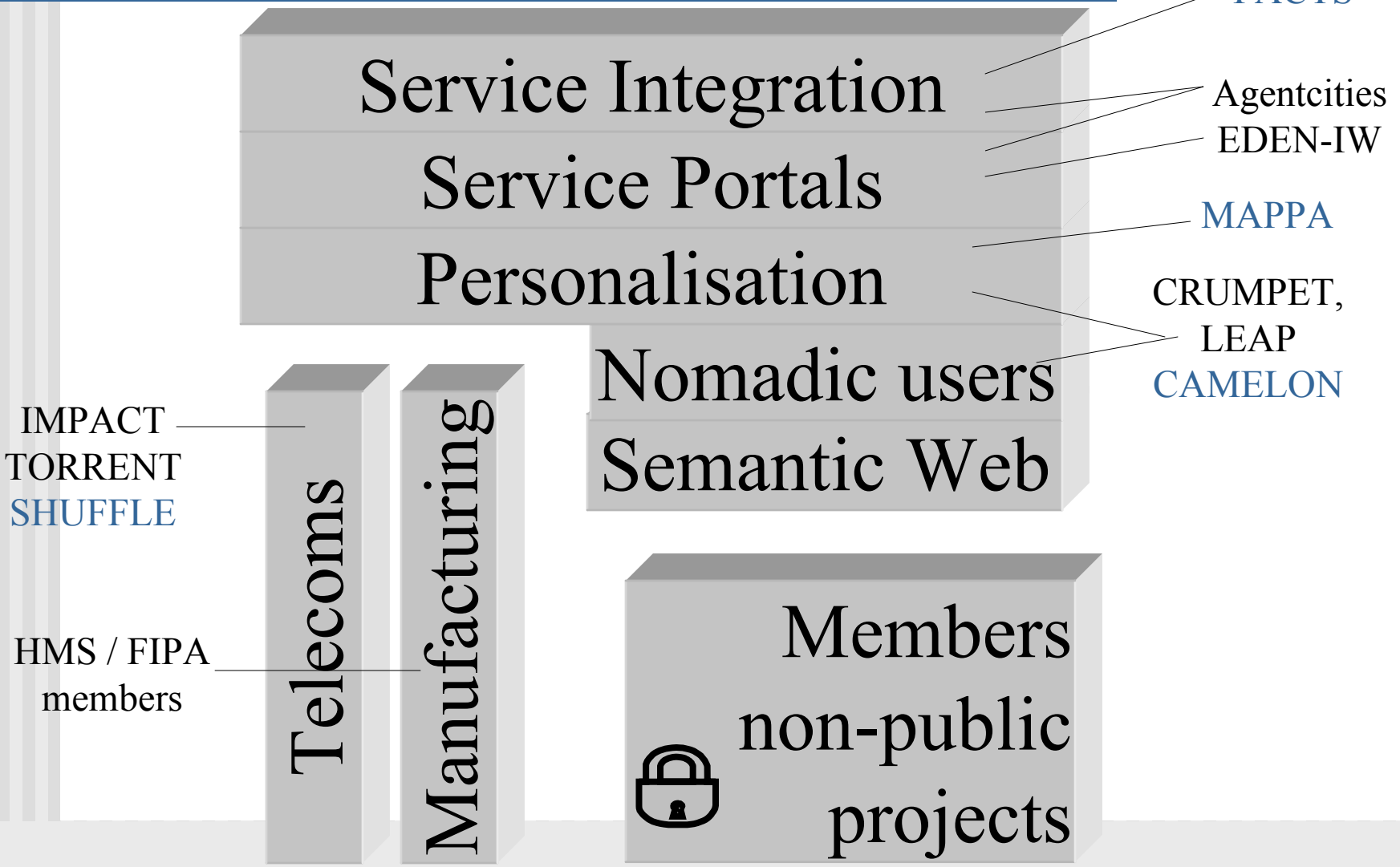
FIPA's Goal

- FIPA's official mission statement: **the promotion of technologies and inter-operability specifications that facilitate the end-to-end inter-working of intelligent agent systems in modern commercial and industrial settings**.
- FIPA was established in 1996 **to identify and select usable specifications of agent technology in a timely fashion**

FIPA: What's in a Name?

- **F**oundation for **I**ntelligent **P**hysical **A**gents
- Key focuses:
  - **software** agents but initial vision was physical agents (robotics)
  - specifying communication and **interoperability** between agents
  - specifies **external behaviour** not internal behaviour - don't specify how agents process and reason about the information they receive.
  - Use in **heterogeneous** environments
- **F**oundation for **I**ntero**P**erable **A**gents

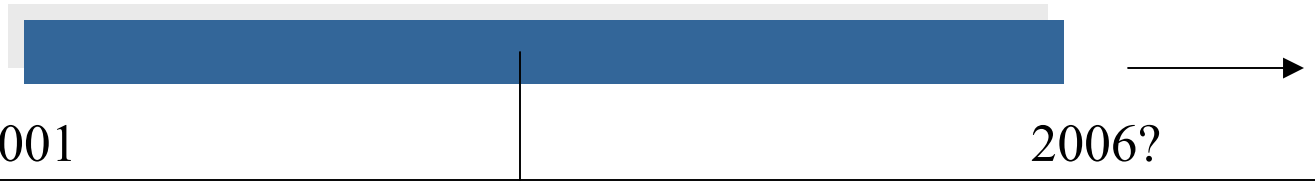
FIPA market focus



Focus & achievements: 1st 5 years

- Theory & research driven initiative
- Set of specifications & abstractions were produced
- 1st phase trials to test the specifications: (EU projects included FACTS, IMPACT, MAPPA etc)
- Domain & technology neutral

FIPA Focus: 2nd phase



- Market, user-driven: may lead to theory alterations
- Domain specific focuses
- 2nd phase projects: portals, nomadic, manufacturing ..
- Management will become more important: abstractions for security, policies, mobility etc.
- Improved ACL & ontology framework for more practical knowledge exchange and management
- Persistence & personalization …

Agent standards: a driver for scaleable agencies

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- Many incompatible, proprietary agent systems exist
  - Used for niche opportunities, clusters of agents are unable to communicate with each other
  - Difficult to scale up (e.g., across the Internet)
- Interoperability and Openness as driving forces
  - customers strive for simplicity and universality when accessing multiple services
  - service providers can act in unison to attain a critical mass for a sustainable customer-base
- There is a need for agent standards that standardize agent interoperability, that are public

Agent standards: issues

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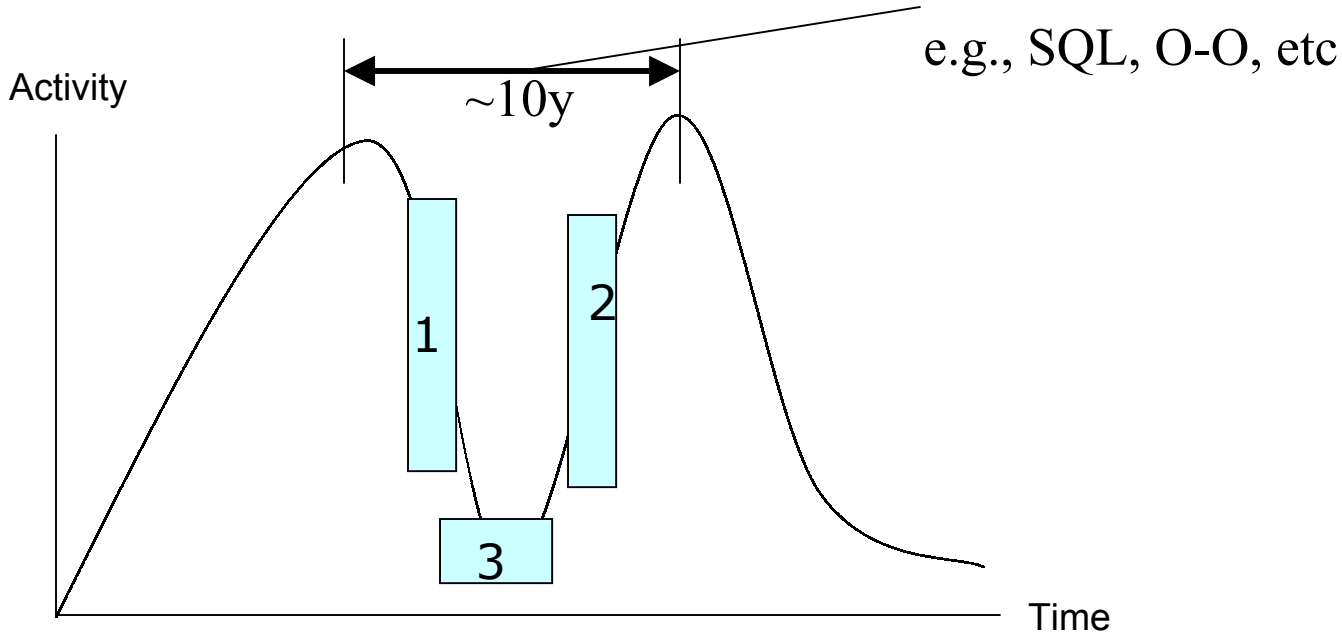
- Timing
  - "Camel Model"
- Defining a core
  - set of speech acts,interaction protocols, ontologies? etc.
- Scope and interfaces to infrastructure
  - ACL, facilitator agents? HCI / PA agents? General agent - software interfaces? Type of persistence, transport, mobility
- Competition and resuse standards
  - FIPA vs. KQML, OMG, W3C (XML,DAML)

Standardisation & Timing: Camel model



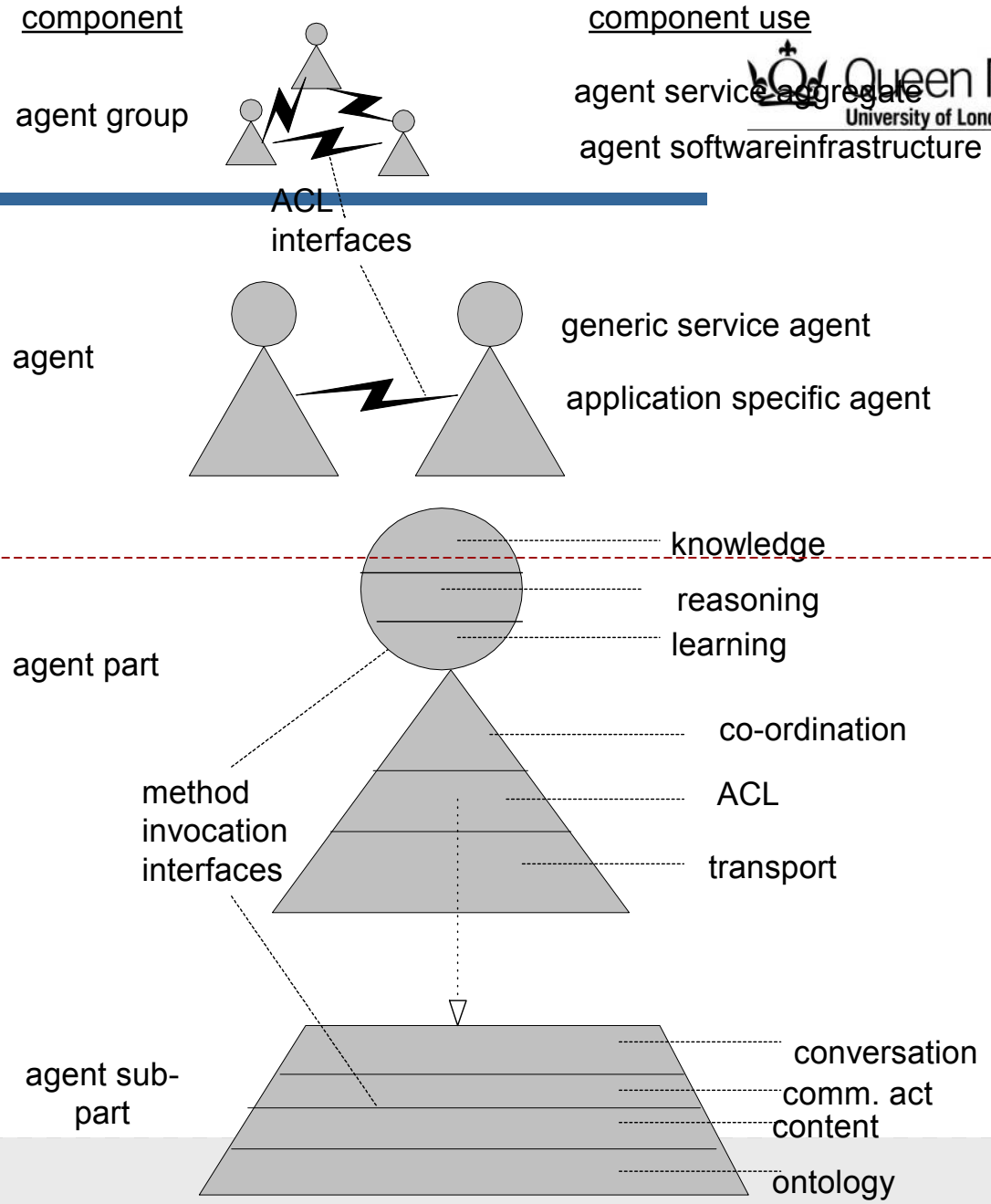
Timing of the standardization is important

1. Not too early
2. Not too late
3. Just right

MAS standards (1): scope

FIPA specifications

FIPA toolkits & implementations



Vertical vs. Horizontal layer MAS architectures

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- In theory it seems that a vertical layered model, where all of the functionality to support such complex communication is in each agent, is a good model to support autonomy.
- In practice, generic functions are factored out into shared agent components and shared services, i.e., a horizontal layered MAS architecture
  - The autonomy of agents is limited in practice
  - You don't have to design agents in a horizontal layered system but it's the usual way.

what features should be modelled as agents vs. non-agent parts?

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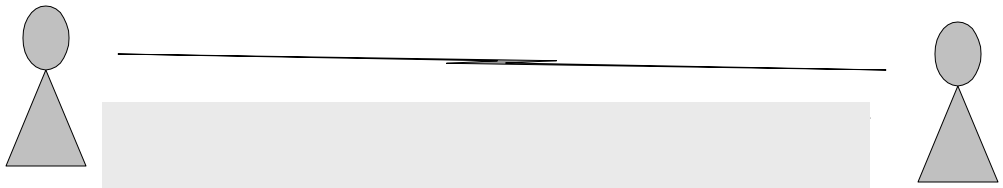
e.g., should a message transport service be an agent?



FIPA Models and Representation

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- For interoperability, it is not enough to have a de facto standard
  - Standards needs to be verifiable?
    - theoretical / formally vs. practical
  - In practice, a reference system is built, sets of conformance points are specified and tests between another system against the ref. system at those points are preformed
- FIPA Agent Specifications exist as a combination of:
  - Descriptive Models
    - Prescriptive Models
  - Formal Models

Overview of the specifications

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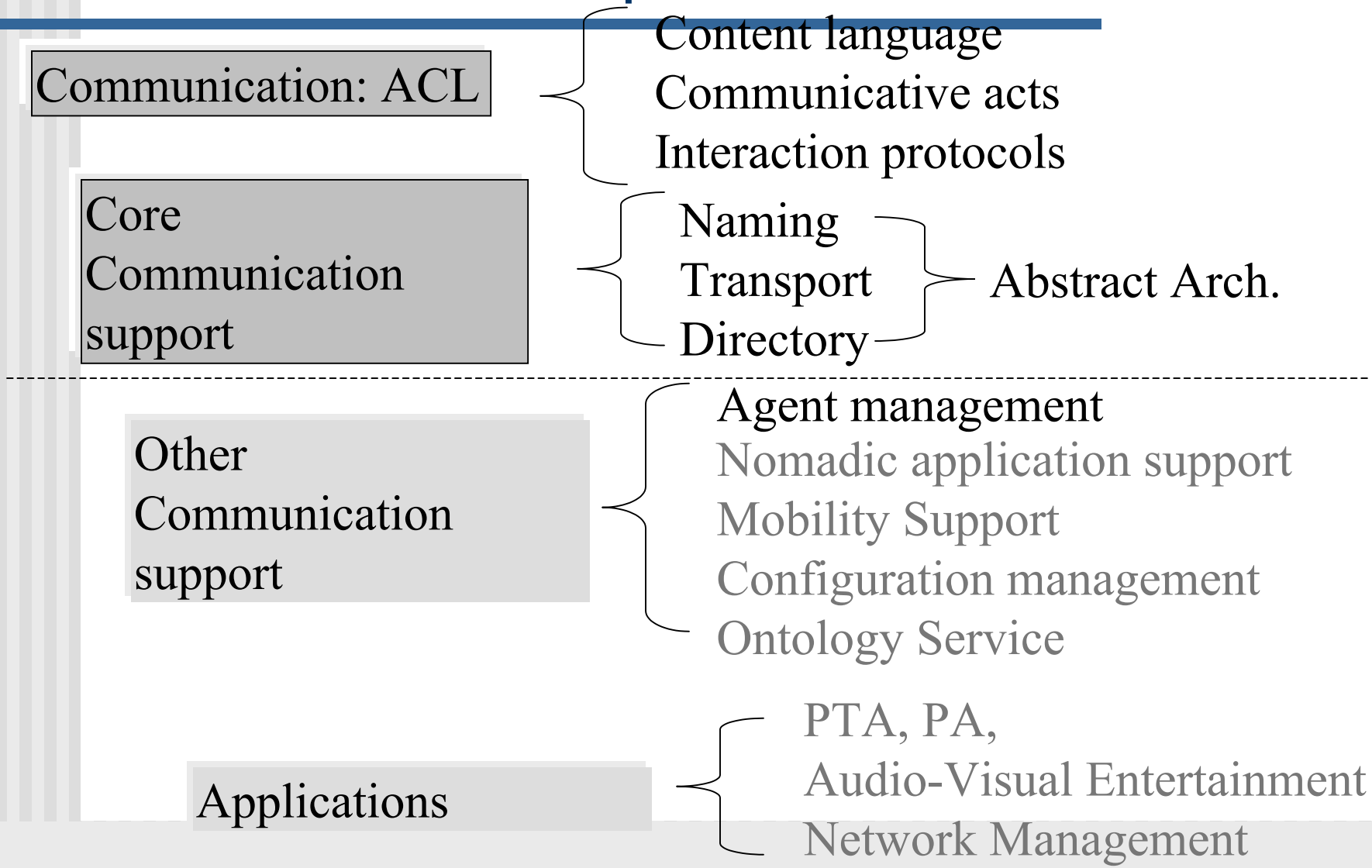
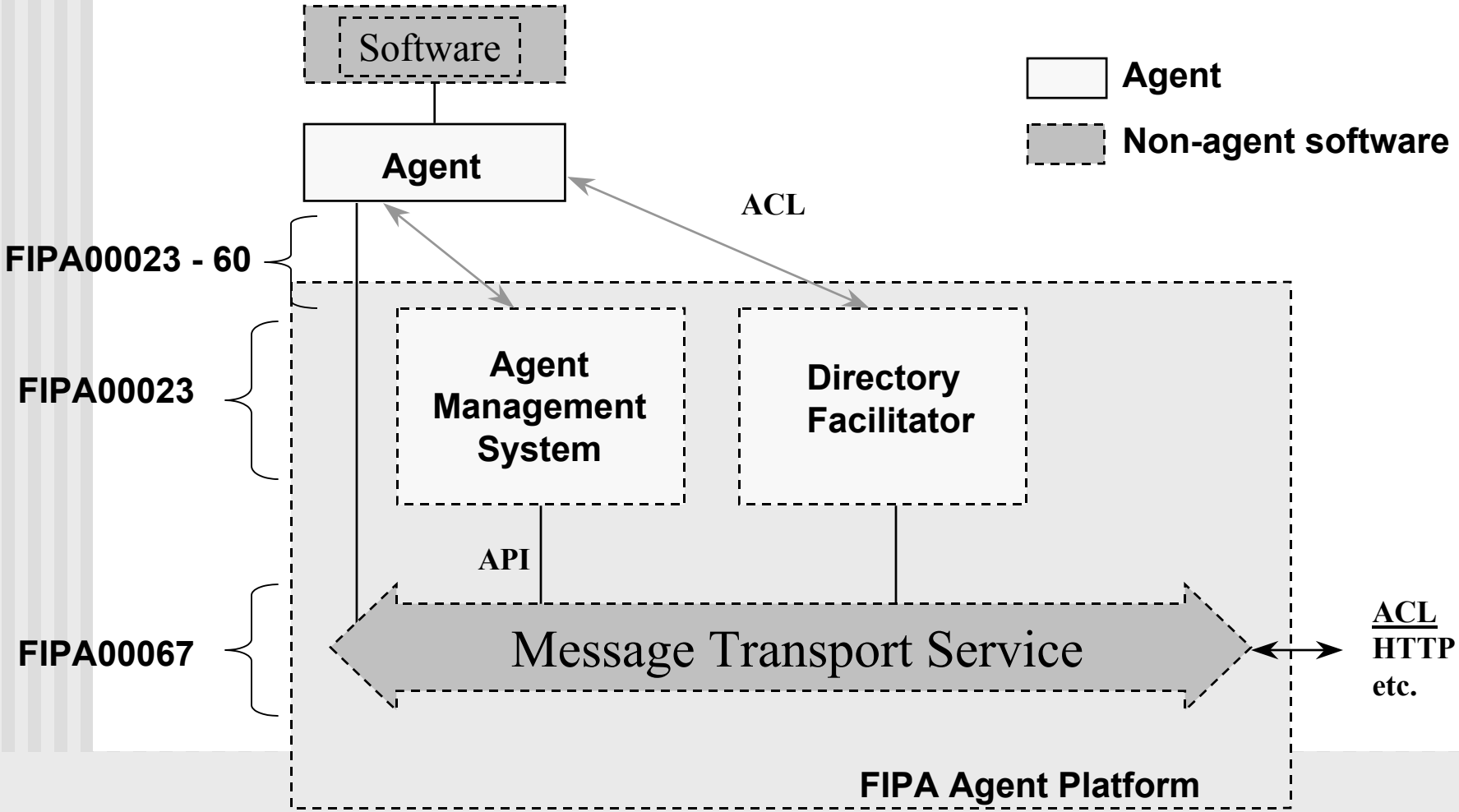
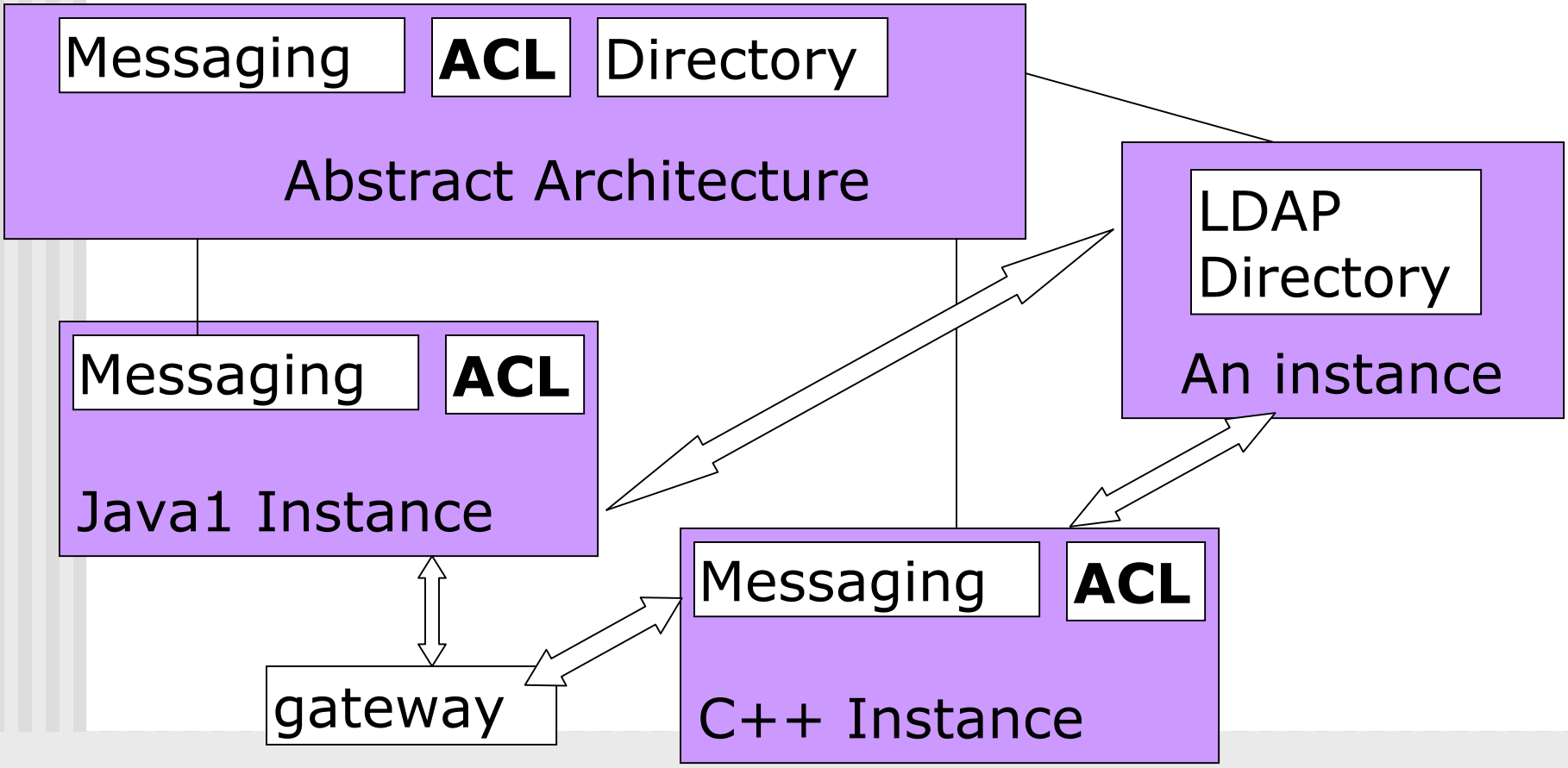


FIPA Agent Platform



Abstract architecture and Interoperability



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AOSE Models & Methodologies

- Focus on extensions of O-O methodologies
  - E.g., Massive (Jurgen Lind), UML, Tropos etc.
- Can have multiple Models (views)
  - Massive Views: task, environment, role, interaction, society, architectural,system
- These views fall into 2 basic categories:
  - Organisational vs. Operational
  - These 2 types may be Static vs. dynamic
  - Organisational: agents, roles
  - Operational: message exchanges, goals, plans, tasks

Goals & Tasks

- A **goal** is application specific, declarative, end-state of a set of tasks
  - E.g., transfer [pay in] sum of money to bank account
- A **task** is a lower-level step towards achieving the goal
  - E.g., visit bank, hand-over cheque, etc.

Plans & Roles

- A **plan** is an organisation of tasks and sub-tasks, done to achieve a goal
  - A tree organisation of tasks is often used
  - Multiple plans to achieve same goal (e.g., pay in cheque)
  - E.g., visit bank, use automatic machine, mail it etc
- A **role** is an organisational constraint on goal & plan
  - Defines a relationship and interaction between different members of the organisation
  - Roles are dynamic

A simplified AOSE methodology for FIPA applications: overview

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- Focus on two views: organisational & Operational
- Organisational view based on roles and assigning roles to agents
- Operational view based on tasks (& plans & goals)

Simplified AOSE Operational View

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- Simple plans are defined by the FIPA interaction protocol sequences.
- More complex plans are combinations of FIPA interaction protocol sequences
- FIPA interaction sequences define roles for different parties in the organisation
- Relates (sub) goals to end-point of the interaction protocol sequence for each party
- A (sub) Task handles part of the interaction sequence, e.g., initiate a an interaction protocol, handle an incoming speech act message etc.
- Interaction and co-ordination is achieved by different parties playing complementary roles in the same interaction protocol
- Communication semantics determined by the interaction protocol & not the semantic definition of the individual speech acts: (intentionality of order 1 not 2)

Simplified Organisational view

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- Identify the agents for the organisation:
  - Determined by the application
  - Determined by the MAS architecture, e.g., use of FIPA agent model requires DF and AMS agents
- Identify application specific roles that need to be played and distribute these amongst the agents.
- Distribution of roles is determined in part by the application, i.e., often user and provider are geographically distributed.
- Think about adding interaction redundancy, i.e., achieving the same goal using different interaction sequences possibly with different agents
  - This is the basis for adaptive behaviour and supporting more sophisticated plan options

An Operational View driven by the use of interaction protocols

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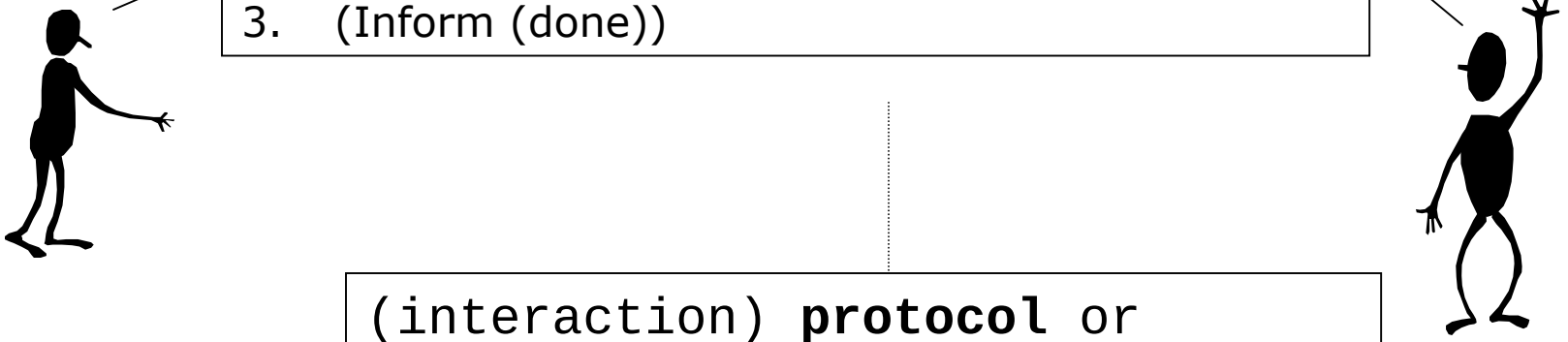
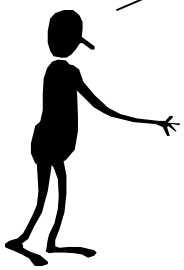


(interaction) **protocol** or conversation dialogue = Request
Speech or communicative act = Request, agree (or refuse or failure), inform
content = shut the door
(content or ontology) **language** = English
ontology = indoor-environment

Semantics of speech acts (2)

1. (Request … shut the door (?)…)
2. (Agree (to the request))
3. (Inform (done))

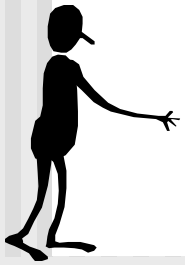


Logic of speech acts

- Message Header specifies:
  - predicates modelled using model logic, plus generic parameters such as sender, receiver
- Message body specifies
  - predicate parameters such as the action of a request, the result of a query
  - the semantics of these parameters are expressed in an ontology
- The next slide shows an example

FIPA Speech Acts

Accept-proposal	Agree	Cancel	Cfp
Confirm	Disconfirm	Failure	Inform
Inform-if	Inform-ref	Not-understood	Propose
Query-if	Query-ref	Refuse	Reject-proposal
Request	Request-when	Request-whenever	Subscribe



Standard FIPA Interaction Patterns

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- Request, Request-when
- Query
- Contract-Net, Iterated Contract net
- English Auction, Dutch Auction
- Broker
- Recruit
- Subscribe
- Propose

FIPA Contract-Net interaction protocol (1)

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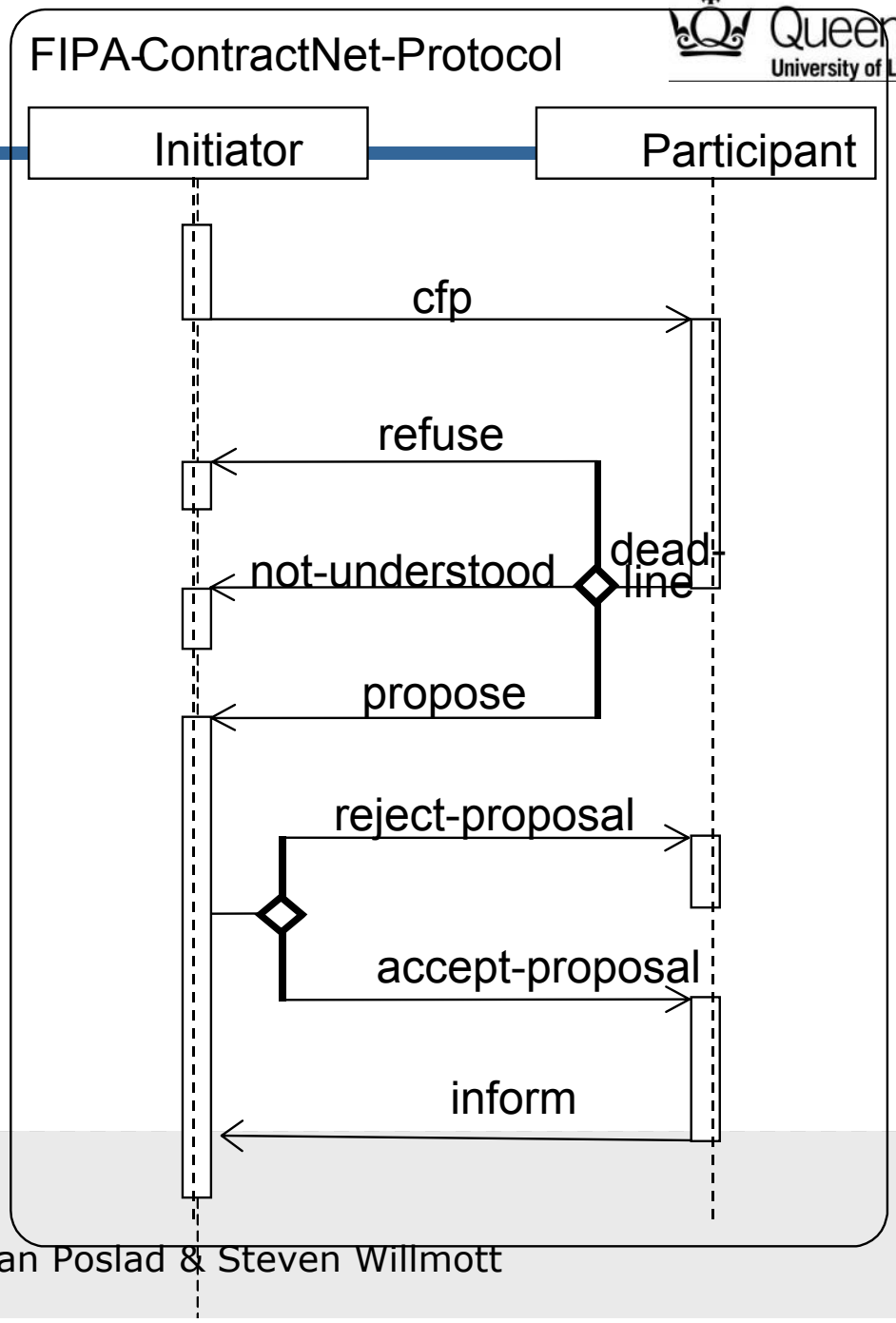
- In the contract net protocol, there are 2 main roles: manager (or initiator) and contractor (or participant)
- The manager wishes to have some task performed by one or more other agents.
- This task may need to be optimised w.r.t 1 or more parameters such as price and deadline
- The manager solicits *proposals* from other agents by issuing a *call for proposals*, which specifies the task and any conditions the manager is placing upon the execution of the task.
- Etc.

FIPA Contract-Net (2)



Plans as interactions

- Plans can be 1 or more interaction patterns, e.g., a simple plan for a typical service user:
  - A user agent searches for a service provider agent
  - A user agent sends a query to a provider agent
  - The provider agent may delegate a request to another provider agent
  - Etc.

Agents determined by the application and the MAS type

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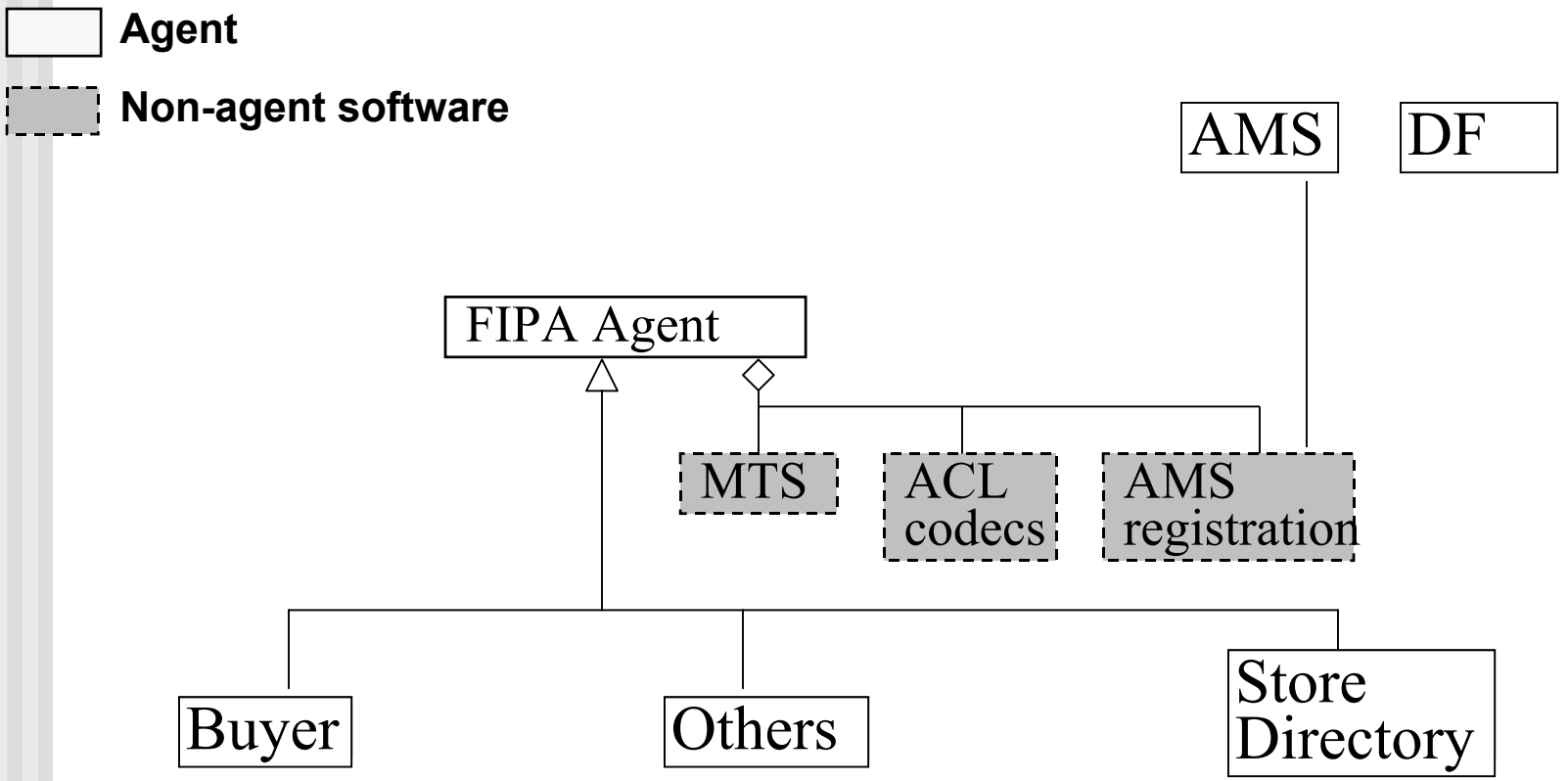
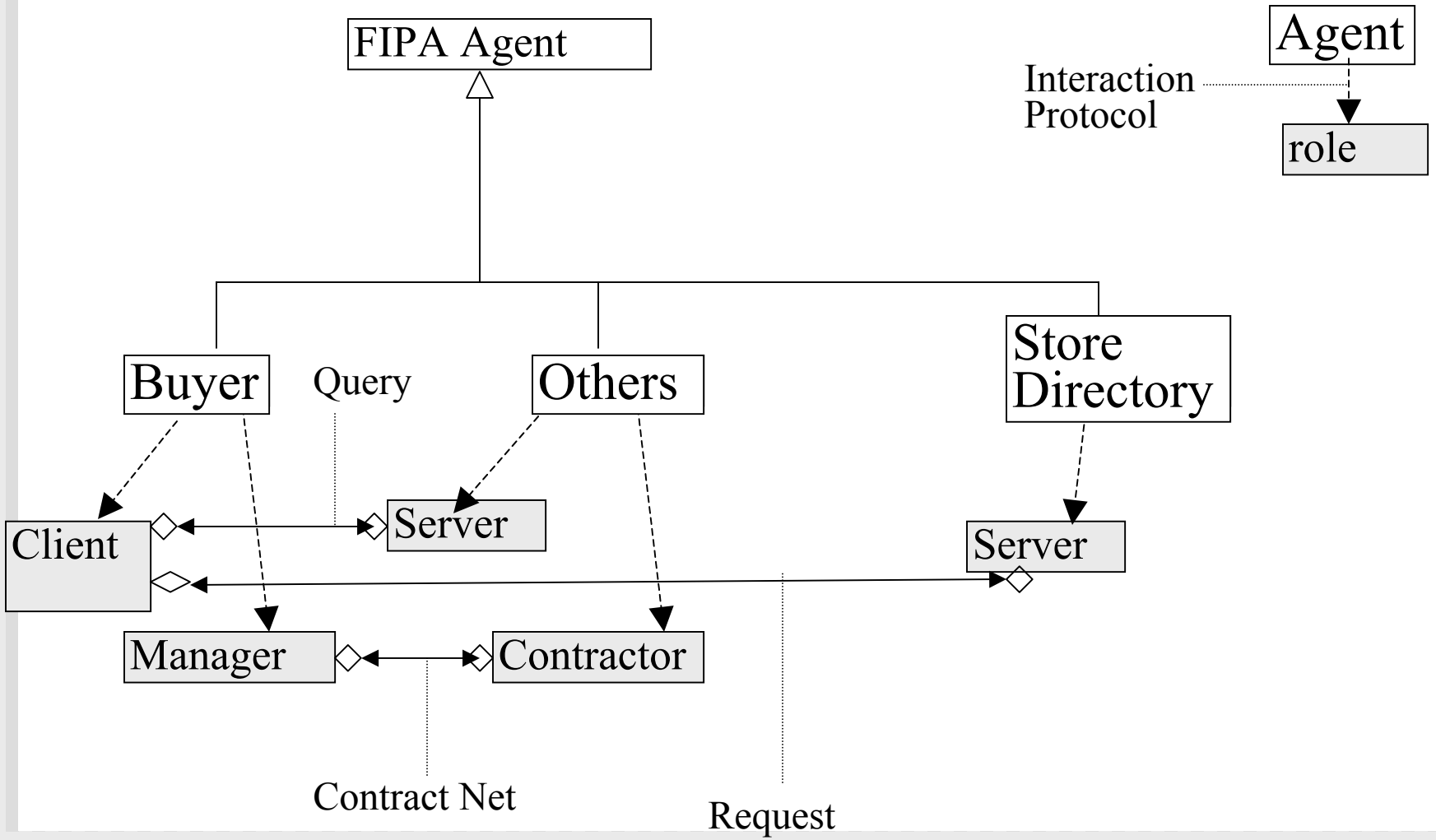


Agents with roles assigned



Hierarchical Task Analysis or HTA

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- Describes the task in terms of a hierarchy of operations and plans based on structure chart notation.
- This method produces a hierarchy of three levels of task analysis:
  - **Goals** (end-state): system state that the human or agent wishes to achieve,
  - **Tasks**: simple actions having no control structure
  - **Plans**: structured set of tasks in some specified sequence to achieve goal(s),

HTA for directory assistance (1)

Task 0: Retrieve item X.

Plan 0:

1: Retrieve Item X at known Location Y

2: Check if Item X at location Z

3: Retrieve Item X at location Z

4: Locate assistant

Plan 4:

4.1: Search ..; 4.2: Broadcast … 4.3: Query Directory

5: Check if assistant available / able to help

6: Ask Assistant about Item X

Plan 6:

6.1: to retrieve; 6.2: to locate; 6.3: Retrieve from new

7: Modify Search for Item X

Plan 7:

7.1: Check for substitute; … 7.3 Wait for item

HTA for directory assistance (2)

Plan 0:

Do 1 (retrieve item)

If result of 1 = yes, then finish

If result of 1 = no, then do 2.

If result of 2 = yes, then do 3

If result of 2 = no, then do 4, 5

If result of 5 = yes, then do 6

If result of 6 = no, then do 7

N.B. this is not complete, just representative

Outline

1. Introduction to MASs based on speech-act communication
2. Specifying MAS communication: FIPA approach?
3. Designing FIPA MAS applications
4. Implementing FIPA MAS applications

Implementing FIPA MAS applications: overview

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- FIPA tool-kits & MAS overview
- Installation
- Using a FIPA MAS: run the demos
- Developing your own MAS agents

FIPA open source implementation

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Company	*Implementation*
Comtec (Jp)	***Comtec AP***
TiLabs (It)	***JADE***
Fujitsu Labs (USA)	***AAP***
Emorphia Ltd (UK)	***FIPA-OS***
BT Exact (UK)	***ZEUS***
JCP (Fujitsu, IBM)	***JAS***

Basic issues in using the specs. to develop agents & services

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Event driven programming

- Specify message handlers to receive & Parse ACL messages
- Offer mandatory services
  - Naming, directory, transport
- Set transport encoding, content languages

Use an existing open source platform to help do these

- Run example projects and applications
- If MMAS, Interlink agent platforms
- Test platforms (Motorola test agent on the Web)
- Developed and Offer new services using the example ones as a template

Using the FIPA specifications

In theory

- The core specifications that must be implemented are the speech act or communicative act specifications and the abstract architecture specification

In practice, most FIPA applications use (but you don't have to) the

- FIPA defined Interaction protocol specifications
- FIPA Content language specifications
- FIPA Agent Management specification
- FIPA Transport Specifications specification

Using the FIPA specifications (2)

- You don't have to implement these specifications yourself in practice, you use a FIPA agent toolkit that has already implemented them.
- For Example, the following are Open Source Implementations written in Java:
  - FIPA-OS: http://fipa-os.sf.net
  - JADE: http://jade.cselt.it/
  - ZEUS: http://www.labs.bt.com/projects/agents/zeus/
- All you need to do is to develop some agents using the APIs they provide

To run & test your (Java) agent

1. Compile your Java agents
2. Add classes to the Java class-path
3. Start agent platform (assuming it's already installed)
4. Start agents from the command-line or using a GUI.
5. For some agents, you can just develop the server agent and use a standard dummy user agent to send messages to the server to test it.
6. Use JADE Sniffer Agent or FIPA-OS IOtest agent to fire off messages to test agents (but no support for replays, plans etc).

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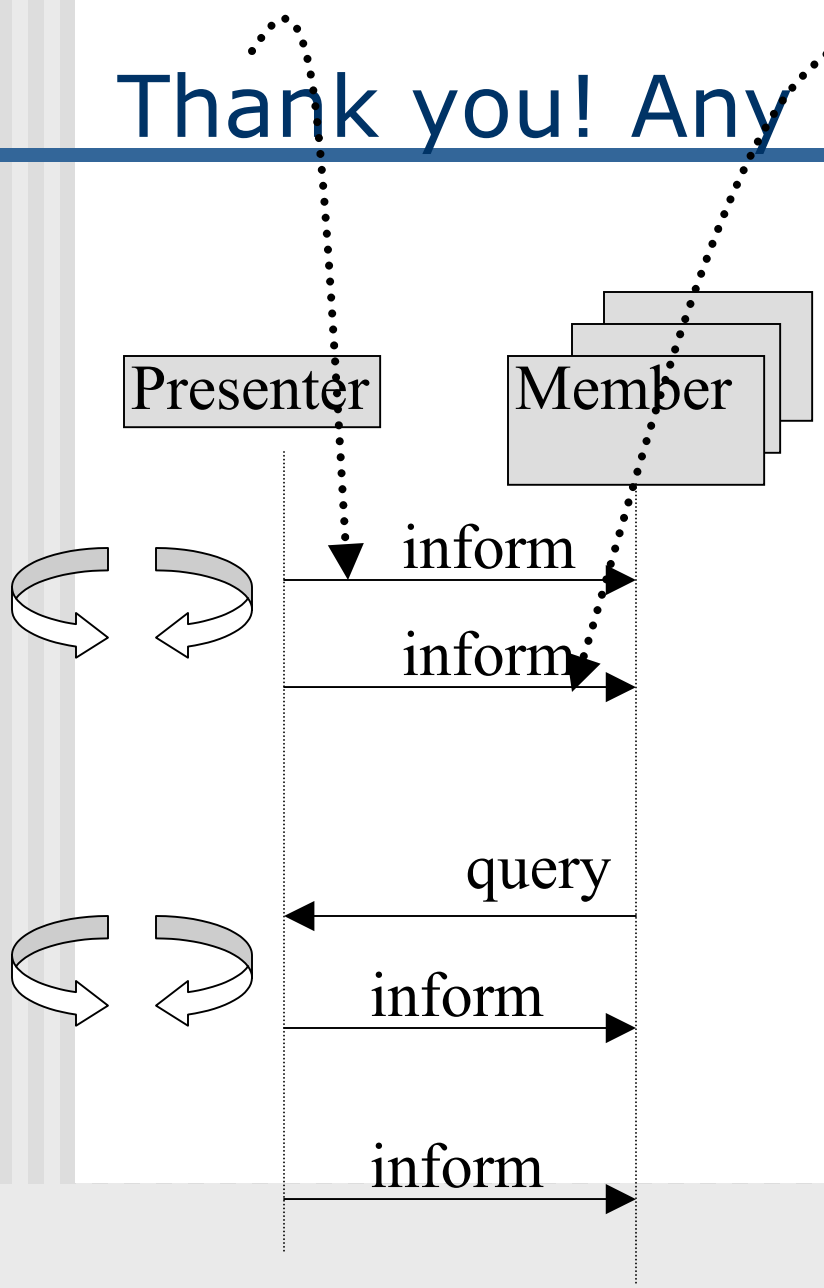
Much more about developing FIPA MAS services in the next presentation by Steve Willmot

Outline

- **Introduction to MASs based on speech-act communication √**
- **Specifying MAS communication: FIPA approach √**
- **Designing FIPA MAS applications √**
- **Implementing MAS applications √**

Thank you! Any Questions?



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Some useful URLS:

- http://www.fipa.org

Some FIPA agent projects

- http://www2.elec.qmul.ac.uk/~stefan
- At FIPA web-site

email: stefan.poslad@elec.qmul.ac.uk

Acknowledgements: the view expressed are those of the author, they do not necessarily reflect FIPA's official position