FOUNDATION FOR INTELLIGENT PHYSICAL AGENTS

FIPA 97 Specification
Part 3
Agent Software Integration

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Contents

Foreword

The Foundation for Intelligent Physical Agents (FIPA) is a non-profit association registered in Geneva, Switzerland. FIPA's purpose is to promote the success of emerging agent-based applications, services and equipment. This goal is pursued by making available in a timely manner, internationally agreed specifications that maximise interoperability across agent-based applications, services and equipment. This is realised through the open international collaboration of member organisations, which are companies and universities active in the agent field. FIPA intends to make the results of its activities available to all interested parties and to contribute the results of its activities to appropriate formal standards bodies.

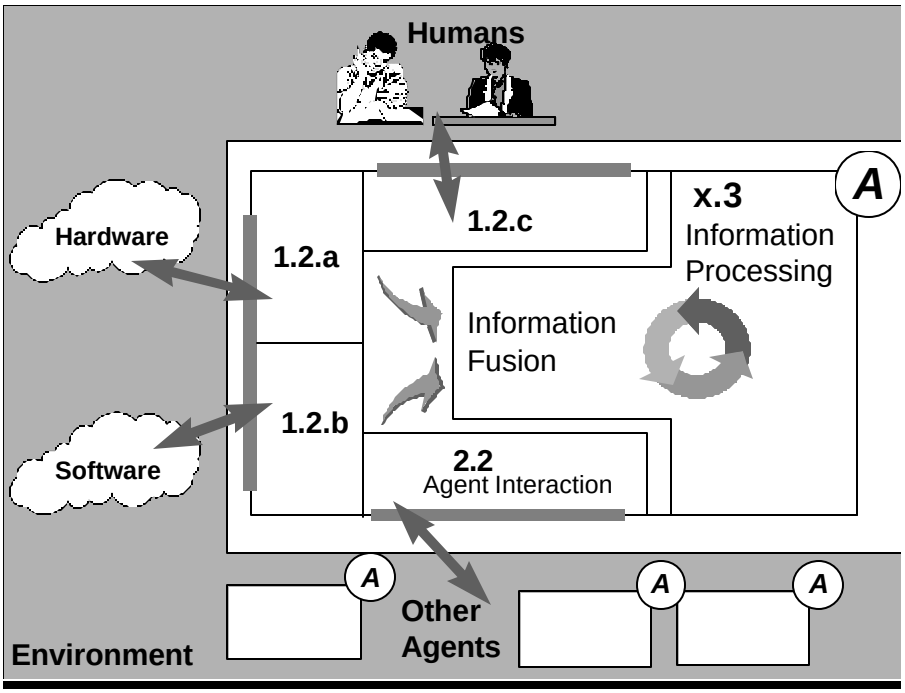
This specification has been developed through direct involvement of the FIPA membership. The 35 corporate members of FIPA (October 1997) represent 12 countries from all over the world Membership in FIPA is open to any corporation and individual firm, partnership, governmental body or international organisation without restriction. By joining FIPA each Member declares himself individually and collectively committed to open competition in the development of agent-based applications, services and equipment. Associate Member status is usually chosen by those entities who do want to be members of FIPA without using the right to influence the precise content of the specifications through voting.

The Members are not restricted in any way from designing, developing, marketing and/or procuring agent-based applications, services and equipment. Members are not bound to implement or use specific agent-based standards, recommendations and FIPA specifications by virtue of their participation in FIPA.

This specification is published as FIPA 97 ver. 1.0 after two previous versions have been subject to public comments following disclosure on the WWW. It has undergone intense review by members as well non-members. FIPA is now starting a validation phase by encouraging its members to carry out field trials that are based on this specification. During 1998 FIPA will publish FIPA 97 ver. 2.0 that will incorporate whatever adaptations will be deemed necessary to take into account the results of field trials.

Introduction

This FIPA 97 specification is the first output of the Foundation for Intelligent Physical Agents. It provides specification of basic agent technologies that can be integrated by agent systems developers to make complex systems with a high degree of interoperability.
FIPA specifies the interfaces of the different components in the environment with which an agent can interact, i.e. humans, other agents, non-agent software and the physical world. See figure below



FIPA produces two kinds of specification:
— **normative** specifications that mandate the external behaviour of an agent and ensure interoperability with other FIPA-specified subsystems;
— **informative** specifications of applications for guidance to industry on the use of FIPA technologies.
The first set of specifications – called FIPA 97 – has seven parts:
— three normative parts for basic agent technologies: agent management, agent communication language and agent/software integration
— four informative application descriptions that provide examples of how the normative items can be applied: personal travel assistance, personal assistant, audio-visual entertainment and broadcasting and network management and provisioning.
Overall, the three FIPA 97 technologies allow:
— the construction and management of an agent system composed of different agents, possibly built by different developers;
— agents to communicate and interact with each other to achieve individual or common goals;
— legacy software or new non-agent software systems to be used by agents.

A brief illustration of FIPA 97 specification is given below
Part 1 Agent Management

This part of FIPA 97 provides a normative framework within which FIPA compliant agents can exist, operate and be managed.
It defines an agent platform reference model containing such capabilities as white and yellow pages, message routing and life-cycle management. True to the FIPA approach, these capablities are themselves intelligent agents using formally sound communicative acts based on special message sets. An appropriate ontology and content language allows agents to discover each other's capabilities.

Part 2 Agent Communication Language

The FIPA Agent Communication Language (ACL) is based on speech act theory: messages are actions, or *communicative acts*, as they are intended to perform some action by virtue of being sent. The specification consists of a set of message types and the description of their pragmatics, that is the effects on the mental attitudes of the sender and receiver agents. Every communicative act is described with both a narrative form and a formal semantics based on modal logic.
The specifications include guidance to users who are already familiar with KQML in order to facilitate migration to the FIPA ACL.
The specification also provides the normative description of a set of high-level interaction protocols, including requesting an action, contract net and several kinds of auctions etc.

Part 3 Agent/Software Integration

This part applies to any other non-agentised software with which agents need to "connect". Such software includes legacy software, conventional database systems, middleware for all manners of interaction including hardware drivers. Because in most significant applications, non-agentised software may dominate software agents, part 3 provides important normative statements. It suggests ways by which Agents may connect to software via "wrappers" including specifications of the wrapper ontology and the software dynamic registration mechanism. For this purpose, an Agent Resource Broker (ARB) service is defined which allows advertisement of non-agent services in the agent domain and management of their use by other agents, such as negotiation of parameters (e.g. cost and priority), authentication and permission.

Part 4 - Personal Travel Assistance

The travel industry involves many components such as content providers, brokers, and personalization services, typically from many different companies. In applying agents to this industry, various implementations from various vendors must interoperate and dynamically discover each other as different services come and go. Agents operating on behalf of their users can provide assistance in the pre-trip planning phase, as well as during the on-trip execution phase. A system supporting these services is called a PTA (Personal Travel Agent).
In order to accomplish this assistance, the PTA interacts with the user and with other agents, representing the available travel services. The agent system is responsible for the configuration and delivery - at the right time, cost, Quality of Service, and appropriate security and privacy measures - of trip planning and guidance services. It provides examples of agent technologies for both the hard requirements of travel such as airline, hotel, and car arrangements as well as the soft added-value services according to personal profiles, e.g. interests in sports, theatre, or other attractions and events.

Part 5 - Personal Assistant

One central class of intelligent agents is that of a personal assistant (PA). It is a software agent that acts semi-autonomously for and on behalf of a user, modelling the interests of the user and providing services to the user or other people and PAs as and when required. These services include managing a user's diary, filtering and sorting e-mail, managing the user's activities, locating and delivering (multimedia) information, and planning entertainment and travel. It is like a secretary, it accomplishes routine support tasks to allow the user to concentrate on the real job, it is unobtrusive but ready when needed, rich in knowledge about user and work. Some of the services may be provided by other agents (e.g. the PTA) or systems, the Personal Assistant acts as an interface between the user and these systems.

In the FIPA 97 test application, a Personal Assistant offers the user a unified, intelligent interface to the management of his personal meeting schedule. The PA is capable of setting up meetings with several participants, possibly involving travel for some of them. In this way FIPA is opening up a road for adding interoperability and agent capabilities to the already established.

Part 6 - Audio/Video Entertainment & Broadcasting

An effective means of information filtering and retrieval, in particular for digital broadcasting networks, is of great importance because the selection and/or storage of one's favourite choice from plenty of programs on offer can be very impractical. The information should be provided in a customised manner, to better suit the user's personal preferences and the human interaction with the system should be as simple and intuitive as possible. Key functionalities such as profiling, filtering, retrieving, and interfacing can be made more effective and reliable by the use of agent technologies.

Overall, the application provides to the user an intelligent interface with new and improved functionalities for the negotiation, filtering, and retrieval of audio-visual information. This set of functionalities can be achieved by collaboration between a user agent and content/service provider agent.

Part 7 - Network management & provisioning

Across the world, numerous service providers emerge that combine service elements from different network providers in order to provide a single service to the end customer. The ultimate goal of all parties involved is to find the best deals available in terms of Quality of Service and cost. Intelligent Agent technology is promising in the sense that it will facilitate automatic negotiation of appropriate deals and configuration of services at different levels.

Part 7 of FIPA 1997 utilizes agent technology to provide dynamic Virtual Private Network (VPN) services where a user wants to set up a multi-media connection with several other users.

The service is delivered to the end customer using co-operating and negotiating specialized agents. Three types of agents are used that represent the interests of the different parties involved:

- The Personal Communications Agent (PCA) that represents the interests of the human users.
- The Service Provider Agent (SPA) that represents the interests of the Service Provider.
- The Network Provider Agent (NPA) that represents the interests of the Network Provider.

The service is established by the initiating user who requests the service from its PCA. The PCA negotiates in with available SPAs to obtain the best deal available. The SPA will in turn negotiate with the NPAs to obtain the optimal solution and to configure the service at network level. Both SPA and NPA communicate with underlying service- and network management systems to configure the underlying networks for the service.

FIPA Agent Software / Integration

1 Scope

This document provides a specification which deals with technologies enabling the integration of services provided by non-agent software into a multi-agent community. This part of the FIPA 97 International Standard defines in general the relationship between agents and software systems. The purpose of this standard is twofold: it allows agents to describe, broker and negotiate over software systems; and it allows new software services to be dynamically introduced into an agent community. The specification defines a reference model, identifying agent roles (e.g. broker, client, etc.) and the messages / actions which define each of these roles. It builds upon the [PART2] *Agent Communication* (structure and semantics of inter-agent communication) and [PART1] *Agent Management* specifications.
This standard operates at the agent-communication level and does not define any mappings to specific software architectures such as Java, CORBA or DCOM. Such mappings are considered outside the scope of FIPA 97.

This specification enables developers to build:

- wrappers for software services which are to be utilized and/or controlled by a community of agents (so called “public services”);
- agents which provide the Agent Resource Broker (ARB) service to allow for registration in a query repository and management of such software services;
- agents ready to access such public services.

It is also intended to be used in the future by third party developers wishing to implement new software systems ready to be used by FIPA-compliant agents.

To keep the applicability of this specification as unrestricted as possible, the approach used is platform independent.

2 Normative reference(s)

[PART1] FIPA 97, *Foundation for Intelligent Physical Agents - Part 1: Agent Management*
[PART2] FIPA 97, *Foundation for Intelligent Physical Agents - Part 2: Agent Communication Language*

3 Term(s) and definition(s)

For the purposes of this specification, the following terms and definitions apply:
Action
A basic construct which represents some activity which an agent may perform. A special class of actions is the *communicative acts*.
Agent Communication Language (ACL)
A language with precisely defined syntax, semantics and pragmatics that is the basis of communication between independently designed and developed software agents.

ARB Agent
An agent which provides the Agent Resource Broker (ARB) service. There must be at least one such an agent in each Agent Platform in order to allow the sharing of non-agent services.
Communicative Act (CA)
A special class of *actions* that correspond to the basic building blocks of dialogue between agents. A communicative act has a well-defined, declarative meaning independent of the content of any given act. CA's are modelled on *speech act theory*. Pragmatically, CA's are performed by an agent sending a *message* to another agent, using the message format described in this specification.
Content
That part of a communicative act which represents the domain dependent component of the communication. Note that "the content of a message" *does not* refer to "everything within the message, including the delimiters", as it does in some languages, but rather specifically to the domain specific component. In the ACL semantic model, a content expression may be composed from *propositions, actions* or *IRE's*.
Conversation
An ongoing sequence of communicative acts exchanged between two (or more) agents relating to some ongoing topic of discourse. A conversation may (perhaps implicitly) accumulate context which is used to determine the meaning of later messages in the conversation.
Knowledge Querying and Manipulation Language (KQML)
A *de facto* (but widely used) specification of a language for inter-agent communication. In practice, several implementations and variations exist.
Message
An individual unit of communication between two or more agents. A message corresponds to a communicative act, in the sense that a message encodes the communicative act for reliable transmission between agents. Note that communicative acts can be recursively composed, so while the outermost act is directly encoded by the message, taken as a whole a given message may represent multiple individual communicative acts.
Message content
See *content*.
Message transport service
The *message transport service* is an abstract service provided by the agent management platform to which the agent is (currently) attached. The message transport service provides for the reliable and timely delivery of messages to their destination agents, and also provides a mapping from agent logical names to physical transport addresses.
Ontology
An *ontology* gives meanings to symbols and expressions within a given domain language. In order for a message from one agent to be properly understood by another, the agents must ascribe the same meaning to the constants used in the message. The ontology performs the function of mapping a given constant to some well-understood meaning. For a given domain, the ontology may be an explicit construct or implicitly encoded with the implementation of the agent.
Ontology sharing problem
The problem of ensuring that two agents who wish to converse do, in fact, share a common ontology for the domain of discourse. Minimally, agents should be able to discover whether or not they share a mutual understanding of the domain constants. Some research work is addressing the problem of dynamically updating agents' ontologies as the need arises. This specification makes no provision for dynamically sharing or updating ontologies.
Proposition
A statement which can be either true or false. A *closed proposition* is one which contains no variables, other than those defined within the scope of a quantifier.
Protocol
A common pattern of *conversations* used to perform some generally useful task. The protocol is often used to facilitate a simplification of the computational machinery needed to support a given dialogue task between two agents. Throughout this document, we reserve *protocol* to refer to dialogue patterns between agents, and *networking* or *communication protocol* to refer to underlying transport mechanisms such as TCP/IP.
Software System
A software entity which is not conformant to the FIPA Agent Management specification.

Software Service
An instantiation of a connection to a software system.

Speech Act Theory
A theory of communications which is used as the basis for ACL. Speech act theory is derived from the linguistic analysis of human communication. It is based on the idea that with language the speaker not only makes statements, but also performs actions. A speech act can be put in a stylised form that begins "I hereby request …" or "I hereby declare …". In this form the verb is called the *performative*, since saying it makes it so. Verbs that cannot be put into this form are not speech acts, for example "I hereby solve this equation" does not actually solve the equation. [Austin 62, Searle 69].
In speech act theory, communicative acts are decomposed into *locutionary*, *illocutionary* and *perlocutionary* acts. Locutionary acts refers to the formulation of an utterance, illocutionary refers to a categorisation of the utterance from the speakers perspective (e.g. question, command, query, etc), and perlocutionary refers to the other intended effects on the hearer. In the case of the ACL, the perlocutionary effect refers to the updating of the agent's mental attitudes.

TCP/IP
A networking protocol used to establish connections and transmit data between hosts on the Internet.

Wrapper Agent
An agent which provides the FIPA-WRAPPER service to an agent domain.

4 Symbols (and abbreviated terms)

ACC: Agent Communication Channel

ACL: Agent Communication Language

API: Application Programming Interface

ARB: Agent Resource Broker

CA: Communicative Act

CORBA: Common Object Request Broker Architecture

DB: Database

DCOM: Distributed COM

DF: Directory Facilitator

FIPA: Foundation for Intelligent Physical Agents

HTTP: Hypertext Transfer Protocol

IDL: Interface Definition Language

IIOP: Internet Inter-ORB Protocol

OMG: Object Management Group

ORB: Object Request Broker

RMI: *Remote Method Invocation*, an inter-process communication method embodied in the Java programming language.

SL: Semantic Language

SMTP: Simple Mail Transfer Protocol

SQL: Structured Query Language

Sw: Software System

TCP / IP: Transmission Control Protocol / Internet Protocol

5 Overview of Agent Software Integration

In most significant applications, agents may have a need to obtain a service by other entities in the system. Sometimes, such services could be provided by other agents. However, there are and in the future there will continue to be a wealth of non-agent software systems which provide useful services. If agents are to be truly useful they must be able to interface with and control existing software system such as databases, web-browsers, set-top boxes, speech synthesis programs and so forth.

This specification defines how software resources can be described, shared and dynamically controlled in an agent community. Software systems are characterised by *software descriptions* which define the nature of the software system and how to connect to it. The rationale behind this specification is to allow agents to openly share and trade software resources with each other. Allowing agents to communicate about software resources, means agents can inform each other about the existence of new software resources and thereby facilitate the dynamic inclusion and management of new software systems. This provides agents with a method by which they can dynamically acquire new capabilities.

FIPA 97 concerns itself with how agents can connect to and control *external* software systems, that is systems which are external to and independent of an agents execution context. By way of contrast, internal attachment to software, where the software is included in an agents execution context is not considered in FIPA 97 as it would require assumptions to be made about the internal implementation of agents.

Software systems come in all shapes and sizes. Many different types of interfaces are possible each with their own particular networking protocol, strengths and weaknesses. Furthermore, there are a number of emerging distribution technologies such as CORBA, DCOM and Java / Java-RMI which are creating (competing) standards for the integration of software systems and resources. To simplify this situation and to provide the freedom to agent-programmers, this specification does not mandate the use of any particular API or distribution technology, rather it treats software integration at the agent-communication level. That is in terms of the types and contents of messages exchanged between agents. To support this, two new agent *roles* have been identified:

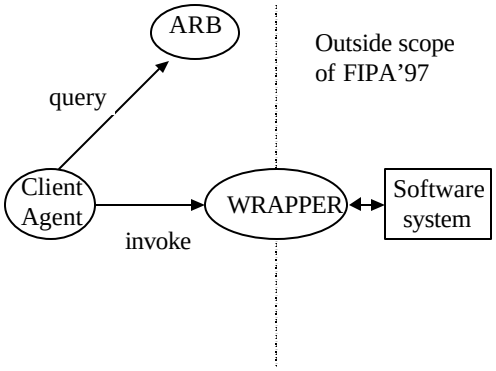


Figure 1 — General Agent Software Integration Scenario

a) Agent Resource Broker (ARB) - an ARB agent brokers a set of *software descriptions* to interested agents. Clients query it about what software services are available.
b) WRAPPER Agent - this agent allows an agent to connect to a software system uniquely identified by a *software description*. Client Agents can relay commands to the WRAPPER

agent and have them invoked on the underlying software system. The role provided by the WRAPPER agent provides a single generic way for agents to interact with software systems.

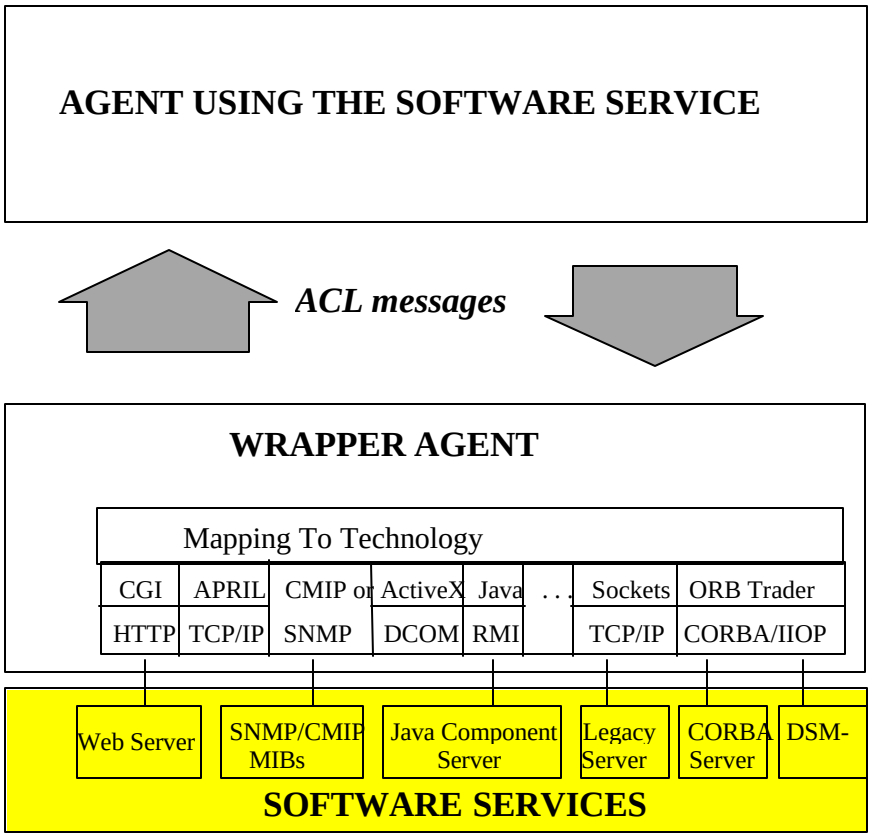


Figure 2 — Layered Model for a Wrapper

In this document we refer to ARB and WRAPPER agents. However, these are defined as agent capabilities rather than explicit agent types. Each capability is defined by an ontology (defining the syntax and semantics of a set of actions and predicates) which are supported by an agent fulfilling the corresponding ARB or WRAPPER role.

NOTE This specification is only concerned with the interactions between agents. How a WRAPPER agent actually connects to and invokes operations on a software system is the responsibility of individual WRAPPER agent developers. WRAPPER agents can be specific in that they only support specific types of software systems, or they may be able to support connections to a number of different software system types.

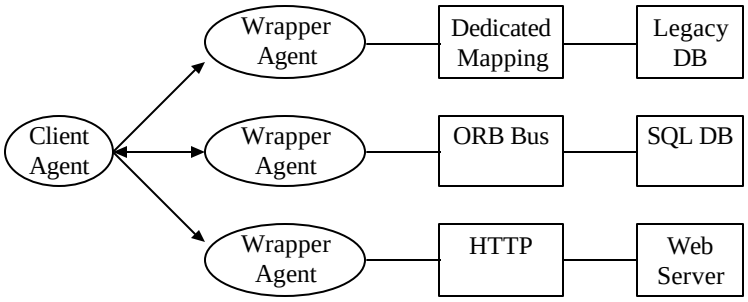


Figure 3 — Example Scenario WRAPPER Agents and Software Systems

Figure 3 shows three examples of possible WRAPPER Agents. The top WRAPPER agent provides a dedicated mapping to a legacy database over, for example say, the TCP/IP protocol. The top WRAPPER agent will set-up a connection to the legacy DB and will translate invocation requests from the client agent into operations on the legacy database. The bottom WRAPPER

agent provides a mapping to the application-level HTTP protocol, enabling the client agent to access internet resources from web-servers. Finally, the middle WRAPPER agent provides a mapping to a CORBA standard Object Request Broker (ORB) allowing the client agent to manipulate an SQL database over an ORB bus. This WRAPPER agent could be specialised to accessing just SQL databases using CORBA ORBs or it could be a more general WRAPPER agent which supports dynamic connection to any system which has been registered with the ORB's Implementation Repository.

This specification contains a normative part (section 6) which provides details about how to find and interface with software systems in a manner which is FIPA compliant.

6

Normative Specification

This section contains the detailed normative specification of how software systems should be integrated into an agent domain. A reference model is presented which identifies agent roles such as ARB and WRAPPER. For each role it defines the ACL messages and actions and predicates (service ontology) which are understood by agents who fulfill these roles in an agent domain.

6.1 Reference Model

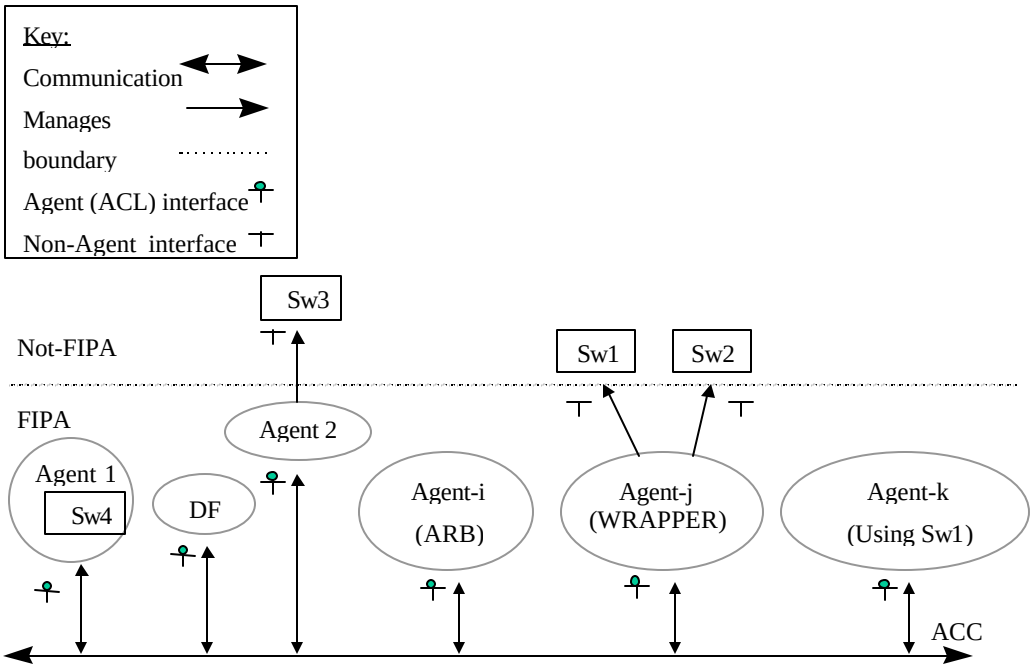


Figure 4 — Reference Model

Figure 4 extends the conceptual view of an agent domain, as defined in [*PART1 Agent Management*], to include two new agent roles (ARB and WRAPPER). The entities of this reference model are:

- Directory Facilitator (DF) - this is a specialized agent which provides a "yellow pages" directory service. Agents advertise their services to an agent domain by registering service-descriptions with the DF.
- Agent Communication Channel (ACC) this provides a message-routing function for inter-agent communication. Messages are defined according to the Agent Communication Language (ACL) as defined by [*PART2 Agent Communication*]. It can be accessed by non-agent entities in order to route messages to agents but non-agent entities cannot be the recipients of messages routed via the ACC.
- Software (Sw) - these are non-agent software entities which are controllable through some transport medium, encoding scheme, message format and interaction scheme (communication or networking protocol). Such interfaces are application dependent and are outside the scope of FIPA standardisation.
- ARB Agent (Agent-i in the figure) - this is an agent which supports the ARB capability as defined in this specification. An ARB agent brokers a set of *software descriptions* to interested client agents. An ARB advertises this service to the agent domain by registering with the DF. See section 0 for further details.

Software services are described by textual *software descriptions* which list the properties of the software service. Part of the software description will describe where the software is located and how to interface with it (e.g. networking protocols, encoding types supported). An agent providing the ARB interface supports the FIPA-ARB ontology with commands and predicates for registering and searching for software services.

— WRAPPER Agent (Agent-j in the figure) - this is an agent which can dynamically interface with a software system uniquely described by a *software description*. The WRAPPER agent will allow client agents to invoke commands on the underlying software system, translating the commands contained in ACL messages into operations on the underlying software system. WRAPPER agents may be able to support multiple connections to software systems simultaneously.
NOTE A WRAPPER agent which supports the full WRAPPER ontology is considered to provide more than a simple bridging function to an external software system. Such an agent implicitly provides a management functionality.

A WRAPPER agent supports the FIPA-WRAPPER ontology with commands and predicates for initialising and issuing requests to software systems.

How a WRAPPER agent is implemented and what interface exists between the WRAPPER agent and the underlying software system which provides the software service is a matter for WRAPPER developers and third-party tool support vendors. It is outside the scope of this specification.

A key point to remember is that WRAPPER agents have the ability to dynamically manage new software devices. This is the conceptual difference between a WRAPPER agent and an agent which upgrades a software service to being an agent-level service. This difference will of course be reflected in the Directory Facilitator (DF). To illustrate the point consider two agents: The first agent has the capability to send and receive email and accordingly it will advertise this service in its DF entry. The second agent has the capability of connecting to an email service, it is a WRAPPER agent and will accept a description of the software service required (in this case the location of the mailhost and the networking protocol to use e.g. POP-3). The first agent will allow a client to send and receive email; it has a static connection to a given email server. The second agent will allow an agent to dynamically connect to a remote email service identified by a software description. See section 0 for further details.

— Client Agents (Agent-k in the figure) - this is an agent which wishes to use the services provided by a software system, for example Sw1. It will query the DF in order to find out if an agent exists which provides an ARB service in the agent domain. Next it will query the ARB agent to see if there is a software system (identified by a software description) which meets its requirements (Sw1). If Agent-k cannot interface directly with the software system (Sw1) identified by the software description returned by the ARB, it must obtain the services of an agent who can (a WRAPPER agent). Agent-k queries the DF to find out if there is an agent which supports the WRAPPER capability for the specific software system which the software description identifies. In this example, the DF returns Agent-j in response to the query. Agent-k then contacts Agent-j (the WRAPPER agent) to initiate control of SW1. The WRAPPER agent (Agent-j) will invoke operations on the underlying software system in response to requests sent to it by Agent-k.
— Agents that can directly interface to software systems (Agent-2 in the figure) in the reference model. This Agent has the ability to directly interface to a software system (Sw3 in the figure) and thus does not need to avail of the services of a WRAPPER agent. Such capabilities are outside the scope of this specification. It should be noted, that Agent-2 could have obtained the address of Sw3 from the ARB agent.
— Agents that can embed private software within their execution context (Agent-1 in the figure). This is outside the scope of this specification.

Summary of steps necessary to support the reference model

a) Agent-i registers with the DF. It advertises the fact that it provides an ARB service by providing a service-description with FIPA-ARB listed in the service-type. See [PART1] and section 0 in this document for further information about registering services with the DF.
b) Agent-j registers with the DF. It advertises the fact that it provides a WRAPPER service by providing a service description with FIPA-WRAPPER listed in the service-type. See [PART1] and section 0 of this document for further information.
c) Agent-k queries the DF for an agent which provides an ARB service. The DF returns the name of Agent-i as satisfying the query.
d) Agent-k queries the Agent-i for a software system which matches some specific requirements, for example a Group3 fax-server. Agent-i returns a software description which uniquely identifies a specific software service.
e) Agent-k queries the DF for an agent which can provide a WRAPPER service to a Group3 fax-server. The DF returns the name of Agent-j as satsifying the query.
f) Agent-k requests that Agent-j initialise a connection to the Group3 fax server identified by the service description (from step 4).
g) Agent-k requests that Agent-j invoke operations on the Group3 fax server.
h) Agent-k requests that Agent-j close the connection to the Group3 fax server.

6.2

The Agent Resource Broker (ARB) is a special service that can be provided by an agent. Every agent in the domain is allowed to support this service, however **it is mandatory that every agent platform which wants to support FIPA-compliant software sharing must have at least one agent that provides this ARB service.** This service must be registered with the DF in order to be advertised in the agent domain; [PART1] specifies the registration procedure. Every ARB agent is able to understand the FIPA-ARB ontology as specified in this section. Therefore, in order to find an agent which provides ARB service, agents must query the Directory Facilitator (DF), whose address is by default known by all agents in the domain. [PART1] specifies a *search* action which is supported by the DF. For illustrative purposes an example query is shown below:

Example 1

```
(request
          :sender Agent-k
          :receiver DF
          :content
                 (action DF
                  (search
                   (:df-description
                    (:agent-services
                     (:service-description
                     (:service-type      FIPA-ARB)
                     (:service-ontology  FIPA-ARB))))
                    (:df-depth max 1)
                    ))
          :language SL0
          :ontology fipa-agent-management
          :protocol fipa-request
        ..... )
```

If the request is successful, the Directory Facilitator (DF) responds with an *inform* CA with the content set to the following form:

```
(result <Action> (<agent-description>*))
```

An agent which offers the ARB service wishes to broker a set of software services for direct use by other agents. However, an ARB may not wish to simply hand over a software description is response to a query from an interested agent. It may wish to negotiate over the terms and conditions of use of the software system; request authorisation; or even provide permanent or evaluatory keys for use with the software system. Such negotiation is application-dependent and is not specified here.

6.2.1 FIPA-ARB Ontology

The keyword FIPA-ARB is reserved in all FIPA compliant implementations of this specific ontology and agent service.

In the following the FIPA-ARB Ontology is described by using a frame-like formalism. The list of object types, actions and predicates to be used in this ontology is given. The use of the SL content language is mandatory. The use of this FIPA-ARB ontology is mandatory. The keyword FIPA-ARB is reserved in all the FIPA compliant implementations to denote this specific ontology and agent service.

6.2.1.1 Content type and parameters

These tables describe the list of object types that can be used in this ontology and the relative list of parameters. A description of each parameter is given. The label "(M)" identifies mandatory parameters while the label "(O)" optional parameters.

6.2.1.1.1 service-description

Table 1 — Service Description Attributes

Parameter	Description	Pre-defined constants
`:service-name`	Denotes the service name. It must be unique within the wrapper scope. (M)	
`:service-type`	Identifies the type of service described, (e.g. DataBase) (M)	`FIPA-ARB` `FIPA-WRAPPER`
`:service-ontology`	Denotes the ontology(ies) the service can support. Notice that more services can support the same ontology even if playing different roles (e.g. producer and consumer). The played role is then identified by the service-type. (M)	`FIPA-ARB` `FIPA-WRAPPER`
`:fixed-properties`	Denotes a list of fixed, i.e. static and non-negotiable, properties of the service. It is assumed that they are defined with regard to a commonly held view of the service, i.e. the service-ontology. The value of this parameter is a list of keyword-value pairs, e.g. `(:fixed-properties (:cost 1000) (:size 200))`. (O)	
`:negotiable-properties`	Denotes a list of properties whose value can be determined dynamically or the ARB agent may wish to negotiate over. It is assumed that they are defined with regard to a commonly held view of the service, i.e. the service-ontology. The value of this parameter is a list of keyword, e.g. `(:negotiable-properties (priority bit-rate waiting-time))`. (O)	
`:communication-properties`	Identifies the unique address of the software system described by this software descriptions as well as the networking protocol to be used when interfacing with the software system. (M)[1]	(see next table)

The domain-dependent description of the service can be further refined by two types of properties:

a) fixed-properties – these describe the fixed (non-negotiable, static) properties of the service. Continuing the movie-database example, fixed properties could be "size of database" or "number of output streams". It is assumed that fixed properties are defined with regard to the service ontology, a commonly held view of the service (for example, an industry standard).

[1] It should be noted that an ARB agent may withhold this piece of information in response to a query from a client agent subject to subsequent successful negotiation.

b) negotiable-properties - these describe those properties of the service which can be determined dynamically or those that the ARB agent may wish to negotiate over. For example, “cost of movie”, “bit-rate”, etc. Negotiable properties do not have associated values. It is assumed that negotiable properties are defined with regard to the service ontology, a commonly held view of the service (for example, an industry standard).

6.2.1.1.2 communication-properties

These are the generic service-independent properties which describe how to actually connect to the service.

NOTE It is not mandatory to return all the communication properties in response to a query. These could be withheld (for example, the address of the service) by the ARB pending a successful negotiation over the terms and conditions of the service.

Communication properties shall be independent of any given communication protocol. They are complete, and provide at least the minimum information required for an agent to successfully connect directly to a software system.

NOTE All parameters are mandatory in the registration of the service.

Table 2 — communication-property Attributes

Parameter	Description	Pre-defined constants
`:net-protocol`	Denotes the networking protocol. (M)	`IIOP SMTP HTTP`
`:address`	Denotes the address. (M)	Address format is associated to the types of communication protocol selected.
`:message-body-format`	Denotes the message body format. (M)	`FIPA-ACL HTML`
`:message-body-encoding`	Denotes the encoding type for the message body. (M)	`ISO-2022`

6.2.1.2 Actions

These tables describe the list of actions that can be requested in this ontology. A description of each action is given including the agent that supports the action itself, the content of the action (i.e. its parameters), the interaction protocol [PART2] and an example. The failure and refuse predicates listed in the tables must be mandatory supported by every Wrapper agent.

6.2.1.2.1 register-software

Supported by	ARB
Description	This action instructs the ARB to register the description of a software service and its associated properties
Parameter	`service-description`
FIPA Protocol	`fipa-request`

Example	`(request`
	`:sender Agent-k`
	`:receiver ARB_1`
	`:content`
	`(action ARB_1`
	`(register-software`
	`(:service-description`
	`(:service-name web-server-1075)`
	`(:service-type web-server)`

	(:service-ontology web-server) (:communication-properties (:net-protocol HTTP) (:address www.fipa.org) (:message-body-format HTML) (:message-body-encoding Latin-1))))) :language SL :protocol fipa-request .....) This example shows an agent requesting to register a software description of a web-server with an ARB
Failure / Refuse Predicates	(not-valid-description) (service-name-in-use) (unauthorised-request)

6.2.1.2.2 de-register-software

Supported by	ARB
Description	This action instructs the ARB to de-register the description of a software service.
Parameter	service-name
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver ARB_1 :content (action ARB_1 (de-register-software (:service-name web-server-1075))) :language SL :protocol fipa-request .....) This example shows an agent requesting to de-register a web-server identified by the name web-server-1075
Failure / Refuse Predicates	(not-valid-description) (not-valid-service-name) (unauthorised-request)

6.2.1.2.3 modify-description

Supported by	ARB
Description	This action instructs the ARB to modify the description of a software service.

Parameter	`service-name, service-description` (including a list of service parameters to change)
FIPA Protocol	`fipa-request`

Example	`(request`
	`:sender Agent-k`
	`:receiver an-ARB`
	`:content`
	`(action an-ARB`
	`(modify-wrapper`
	`(:service-name web-server-1075)`
	`(:service-description`
	`(:communication-properties`
	`(:address new-www.fipa.org)) )))`
	`:language SL`
	`:protocol fipa-request`
	`..... )`
	An-agent requests to change the address of the web-server

Failure / Refuse Predicates	`(not-valid-description)`
	`(not-valid-service-name)`
	`(unauthorised-request)`

6.2.1.3 Predicates

The ARB ontology also supports a number of predicates. Client agents can make use of this service using the *query-ref, query-if, subscribe, request-when and request-whenever* communicative acts. This specification mandates only that an agent who wishes to support the ARB ontology supports the *request, query-if* and *query-ref* communicative acts.

6.2.1.3.1 Registered Predicate

When an ARB agent performs a register-software action it asserts a predicate:

`(registered <service description>).`

This predicate can be subsequently be queried through the use of query-ref and query-if communicative acts.

Example 2

```
(query-ref
          :sender Agent-k
          :receiver ARB_1
          :content
             (iota ?NAME
               (registered
                 (:service-description
                    (:service-name ?NAME)
                    (:service-ontology EMAIL)) ))
          :language SL
          :ontology FIPA-ARB
          :protocol FIPA-QUERY
..... )
```

This example illustrates the use of the query-ref communicative act which Agent-k uses to find the name of an Email software service.

6.2.1.3.2 Member Predicate

This specification introduces the use of the member predicate. This predicate can be used to bind sets of expressions to iota supplied variables. The syntax of a member predicate is:

```
(member <element> <set>)
```

Which is true when <element> is a member of the set <set> (i.e. the member predicate is the $\in$ symbol from set theory). The following example illustrates its use. Here Agent-k is querying the ARB_1 agent to return the set of all Email software service names.

Example 3

```
(query-ref
          :sender Agent-k
          :receiver ARB_1
          :content
           (iota ?SET-OF-NAMES
             (forall ?NAME
               (equiv (member ?NAME ?SET-OF-NAMES)
                       (registered
                        (:service-description
                          (:service-name ?NAME)
                          (:service-ontology EMAIL))))))
          :language SL
          :ontology FIPA-ARB
..... )
```

6.2.2 Querying the ARB

Every ARB can be queried using the query-if and query-ref communicative acts for the FIPA-ARB ontology. For example, you can use the query-ref communicative act to query what are the available software systems which satisfy a specific service description.l

6.2.3 Registering the ARB service with the DF

To advertise its intention to provide an ARB service to the agent domain descriptions, an ARB agent must register with the DF. Specifically it must register a service-description with the service-type set to FIPA-ARB and the service-ontology also set to FIPA-ARB [PART1]. The following communicative act shows how service descriptions are registered:

Example 4

```
(request
          :sender ARB_1
          :receiver DF
          :content
                 (action DF
                    (register
                      (:df-description
                       (:agent-name ARB_1)
                      (:agent-services
                       (:service-description
                          (:service-type FIPA-ARB)
                          (:service-ontology FIPA-ARB)) ))))
          :language SL
          :protocol fipa-request
..... )
```

6.2.4 Conformance

A FIPA compliant ARB agent must at least:

- register the ARB service with the DF with the service-type and the service-ontology set to FIPA-ARB, as described in section 0;
- implement the actions described in the FIPA-ARB Ontology according to the behaviour and parameters speficied in section 0;
- implement and assert the predicates described in the FIPA-ARB Ontology according to the semantics specified in section 0;
- create and store registration predicates in response to a successful register operation as specified in section 0;

- understand the *request* communicative act to request the execution of one of these FIPA-ARB actions;
- understand the *query-if* and *query-ref* communicative acts to query its knowledge by using the FIPA-ARB predicate;
- implement the *fipa-request* and *fipa-query* interaction protocols speficied in [PART2];
- implement the *not-understood, agree, refuse, failure, inform* communicative acts in order to respond to requests and queries according to the *fipa-request* and *fipa-query* interaction protocols.

Even if these requirements guarantee FIPA compliance, of course they are not sufficient to guarantee the usefulness of the ARB agent to the agent domain.

6.3

Wrapper services are provided by agents. The Wrapper service allows an agent to (the corresponding actions for the WRAPPER ontology / communicative acts are indicated in *italics*):

- request a dynamic connection to a software system *(init <software* description>*)*;
- invoke operations on the software system *(invoke <operation>)*;
- to be informed of the results of operations (*inform <result*>);
- to query the properties of the software system (*query-ref and query-if);*
- set the parameters of a software system (*achieve*);
- subscribe to events of the software system (*software-subscribe, software-unsubscribe*);
- manage the state of the service *(store, restore, suspend and resume)*;
- terminate the service (*close*).

An agent can request of an agent which provides a wrapper service to dynamically connect to a software system uniquely identified by a *software service description*. This specification has defined the ARB service (see section 0) which supports the sharing and brokering of such software descriptions.

An agent providing a wrapper service (WRAPPER agent) can be specific to a type of software system (specifically it commits to a given software system ontology). In addition, a WRAPPER can be specific about the types of connection / communication protocols it can support when interfacing with a software system, for example HTTP, SMTP etc. This allows client agents who wish to avail of the services of a WRAPPER agent to discriminate between WRAPPER agents on the basis of both software systems supported and the types of connections supported. Section 6.3.2provides an example of how to query the DF to find an appropriate WRAPPER agent. Section 0 provides an example of how to WRAPPER agent might register itself. Both examples are based on [PART1] specifications.

WRAPPER agents may be able to support multiple software types and multiple service instances simultaneously. In order to allow a WRAPPER agents to distinguish between concurrent services, WRAPPER agents will return a *service-instance-id* to the client agent on the successful completion of an *init* action. Most of the actions supported by the FIPA-WRAPPER ontology require the inclusion of this service-instance-id.

6.3.1 FIPA-WRAPPER Ontology

The keyword FIPA-WRAPPER is reserved in all FIPA compliant implementations of this specific ontology and agent service.
A WRAPPER agent has freedom on how it chooses to “wrap” a software system. The most basic integration scenario would model a software system simply as a collection of operations which can be performed on the software system.
A more sophisticated WRAPPER agent can divide the operations into three general categories. Specific actions and predicates have been included in the WRAPPER ontology to reflect and support this distinction. That is to provide WRAPPER agents with the necessary vocabulary to support such distinctions should WRAPPER agent-designers wish to support them. The three categories are:

a) Event Notification: the software system asynchronously notifies every agent subscribed to an event when that specific event occurs. The actions *software-subscribe* and *software-unsubscribe* actions support this activity. The *subscribed* predicate supports the querying of what events an agent is subscribed to.

b) Sensing Functions: the agent can require to the wrapper to be informed of the result of a function call (e.g. number of e-mails in the Inbox) which does not change the state of the environment and of the software system itself. The *query-ref* and *query-if* communicative actions and the *parameter* predicate support this activity.
c) Effecting Actions: the agent can require the wrapper to perform an action (e.g. send this e-mail to Kim). The *invoke* action supports this function for domain-dependent operatons. The *achieve* action provides a generic way to set the parameters of a software service.

Such a categorisation allows the interfaces to different software systems to be treated in a generic component-based manner. There is a generic method for discovering what event types, parameters and operations are supported using the *query-ref* and *query-if* communicative acts in conjunction with the predicates supported by the FIPA-WRAPPER ontology. The actions of the FIPA-WRAPPER ontology provide a single generic way to (un)subscribe to events, modify parameters and invoke operations.

As mentioned already, a WRAPPER agent does not have to provide such a component-based interface to a software system.

6.3.1.1 Content type and parameters

These tables describe the list of object types that can be used in this ontology and the corresponding list of parameters. A description of each parameter is given. The label “(M)” identifies mandatory parameters while the label “(O)” optional parameters. The “Pre-defined constants“ are mandatory.

6.3.1.1.1 service-description

Table 3 — Service Description Attributes

Parameter	Description	Pre-defined constants
`:service-name`	Denotes the service name. It must be unique within the wrapper scope. (M)	
`:service-type`	Identifies the type of service described, (e.g. DataBase) (M)	`FIPA-ARB` `FIPA-WRAPPER`
`:service-ontology`	Denotes the ontologies the service can support. Notice that several services can support the same ontology even if playing different roles (e.g. producer and consumer). The role played is then identified by the service-type.(M)	`FIPA-ARB` `FIPA-WRAPPER`
`:fixed-properties`	Denotes a list of fixed, i.e. static and non-negotiable, properties of the service. It is assumed that they are defined with regard to a commonly held view of the service, i.e. the service-ontology. The value of this parameter is a list of keyword-value pairs, e.g. `(:fixed-properties (:cost 1000) (:size 200))`. (O)	
`:negotiable-properties`	Denotes a list of properties whose value can be determined dynamically or the ARB agent may wish to negotiate over. It is assumed that they are defined with regard to	

	a commonly held view of the service, i.e. the service-ontology. The value of this parameter is a list of keyword, e.g. `(:negotiable-properties (priority bit-rate waiting-time))`. (O)	
`:communication-properties`	Identifies the unique address of the software system described by this software descriptions as well as the communication protocol to be used when interfacing with the software system. (M)[2]	(see next table)

The domain-dependent description of the service can be further refined by two types of properties:

a) fixed-properties – these describe the fixed (non-negotiable, static) properties of the service. Continuing the movie-database example, fixed properties could be “size of database” or “number of output streams”. It is assumed that fixed properties are defined with regard to the service ontology, a commonly held view of the service (for example, an industry standard).
b) negotiable-properties - these describe those properties of the service which can be determined dynamically or those that the WRAPPER agent may wish to negotiate over. For example, “cost of movie”, “bit-rate”, etc. Negotiable properties do not have associated values. It is assumed that negotiable properties are defined with regard to the service ontology, a commonly held view of the service (for example, an industry standard).

6.3.1.1.2 communication-properties

These are the generic service-independent properties which describe how to actually connect to the service.

Communication properties shall be independent of any given communication protocol. They are complete, and provide at least the minimum information required for the WRAPPER agent to successfully connect directly to a software system. The “Pre-defined constants“ are mandatory.

NOTE All parameters are mandatory in the registration of the service.

Table 4 — communication-property Attributes

Parameter	**Description**	**Pre-defined constants**
`:net-protocol`	Denotes the networking protocol. (M)	`IIOP SMTP HTTP`
`:address`	Denotes the address. (M)	Address format is associated to the types of networking protocol selected.
`:message-body-format`	Denotes the message body format. (M)	`FIPA-ACL HTML`
`:message-body-encoding`	Denotes the encoding type for the message body. (M)	`ISO-2022`

6.3.1.2 Actions

In all the following action definitions, the message parameters `:language` and `:ontology` are assumed to be mandatory set to SL and FIPA-WRAPPER respectively. The failure and refuse predicates listed in the tables must be mandatory supported by every Wrapper agent.

6.3.1.2.1 init

Supported by	WRAPPER

[2] It should be noted that an ARB agent may withhold this piece of information in response to a query from a client agent subject to subsequent successful negotiation.

Description	This action allows an agent to properly initialize the underlying software. The parameter `service-description` allows the wrapper-agent to distinguish between several wrapped services. The parameter `content-expression` could be used to pass parameters to the software for the initialization. The result of the *init* operation is that a `service-instance-id` is returned to the agent via an inform CA. If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent will respond with an inform CA with the content set to : `(result <Action> (:service-instance-id <identifier>))`
Parameter	`service-description, <content-expression>` (optional)
FIPA Protocol	`fipa-request`

Example	`(request`
	`:sender Agent-k`
	`:receiver A-WRAPPER-agent`
	`:content`
	`(action A-WRAPPER-agent`
	`(init`
	`(:service-description`
	`(:service-name web-server-1075)`
	`(:service-type web-server)`
	`(:service-ontology web-server)`
	`(:communication-properties`
	`(:net-protocol HTTP)`
	`(:address www.fipa.org)`
	`(:message-body-format HTML)`
	`(:message-body-encoding Latin-1)) )`
	`(:encrypted-password X3432S$%) ))`
	`..... )`

Failure / Refuse Predicates	`(not-valid-service-description)`
	`(unauthorised)`
	`(maximum-number-of-instances-exceeded)`
	`(service-in-use)`
	`(service-unreachable)`

6.3.1.2.2 close

Supported by	WRAPPER
Description	This action is used to close the connection to a software instance. The `content- expression` could be used to pass some parameters to the software. The `service-instance-id` (returned by a successful *init*) must be included to identify the instance of the service to be closed.
Parameter	`service-instance-id, <content-expression>` (optional)
FIPA Protocol	`fipa-request`

Example	(request :sender Agent-k :receiver A-WRAPPER-agent :content (action A-WRAPPER-agent (close (:service-instance-id web-server-001) (:encrypted-password X3432S$%))) :protocol fipa-request .....)
Failure / Refuse Predicates	(not-valid-service-instance-id) (unauthorised)

6.3.1.2.3 store

Supported by	WRAPPER
Description	This action is a request from the agent to the wrapper to store the current state of the software instance. The result of the store operation is that a state-id is returned to the agent. The state-id allows a subsequent restore procedure to identify the state to go back. If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent will respond with an inform CA with the content set to: (result <Action> (:state-id <identifier>))
Parameter	service-instance-id
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver A-WRAPPER-agent :content (action A-WRAPPER-agent (store (:service-instance-id web-server-001))) :protocol fipa-request .....)
Failure / Refuse Predicates	(not-valid-service-instance-id) (unauthorised) (not-enough-resources) (exceeded <resource>) (not-storable)

6.3.1.2.4 restore

Supported by	WRAPPER
Description	This action allows an agent to restore a previously stored state of the software instance.

	instance. If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent will respond with an inform CA with the content : (done <Action>)
Parameter	service-instance-id, state-id
FIPA Protocol	fipa-request
Example	(request :sender An-agent :receiver A-WRAPPER-agent :content (action A-WRAPPER-agent (restore (:service-instance-id web-server-001) (:state-id web-server-stored-001))) :protocol fipa-request .....)
Failure / Refuse Predicates	(not-valid-service-instance-id) (not-valid-state-id) (unauthorised) (not-enough-resources) (service-suspended) (exceeded <resource>)

6.3.1.2.5 software-subscribe

Supported by	WRAPPER
Description	It must be used to subscribe to an event. The agent will be asynchronously notified by the wrapper every time this event occurs. If the request is successful, then it causes the equivalent of a predicate (subscribed <service-instance-id> <event-name>) to be asserted within the WRAPPER agent. This allows queries on the list of subscribed / unsubscribed events to be performed (using *query-ref* and *query-if*). If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent will respond with an inform CA with the content : (done <Action>)
Parameter	service-instance-id, event-name
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver A-WRAPPER-agent :envelope (service-instance-id web-server-001) :content (action A-WRAPPER-agent

	(software-subscribe (:service-instance-id web-server-001) (:event-name NEW-CONTENT-EVENT))) :protocol fipa-request .....) An-Agent requests of A-WRAPPER-agent that it subscribes to an NEW-CONTENT-EVENT.
Failure / Refuse Predicates	(not-valid-service-instance-id) (unauthorised) (exceeded <resource>) (service-suspended) (unknown-event-name)

6.3.1.2.6 software-unsubscribe

Supported by	WRAPPER
Description	This action must be used to unsubscribe to an event. If the request is successful then the predicate (subscribed <service-instance-id> <event-name>) is retracted within WRAPPER agents. If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent will respond with an inform CA with the content : (done <Action>)
Parameter	service-instance-id, event-name
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver A-WRAPPER-agent :content (action A-WRAPPER-agent (software-unsubscribe (:service-instance-id web-server-001) (:event-name NEW-CONTENT-EVENT))) :protocol fipa-request .....)
Failure / Refuse Predicates	(not-valid-service-instance-id) (unauthorised) (exceeded <resource>) (unknown-event-name) (service-suspended)

6.3.1.2.7 suspend

Supported by	WRAPPER
Description	This action instructs the WRAPPER agent to suspend the software service identified by the service-instance-id

	identified by the service-instance-id. If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent will respond with an inform CA with the content : (done <Action>)
Parameter	service-instance-id
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver A-WRAPPER-Agent :content (action A-WRAPPER-Agent (suspend (:service-instance-id web-server-001))) :protocol fipa-request .....)
Failure / Refuse Predicates	(not-valid-service-instance-id) (unauthorised) (not-enough-resources) (exceeded <resource>) (service-already-suspended) (not-suspendable)

6.3.1.2.8 resume

Supported by	WRAPPER
Description	The action instructs the WRAPPER agent to resume a previously stored service. If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent will respond with an inform CA with the content : (done <Action>)
Parameter	service-instance-id
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver A-WRAPPER-agent :content (action A-WRAPPER-agent (resume (:service-instance-id web-server-001))) :protocol fipa-request .....)
Failure / Refuse	(not-valid-service-instance-id)

Predicates	(unauthorised) (not-enough-resources) (exceeded <resource>) (service-not-suspended) (not-resumable)

6.3.1.2.9 achieve

Supported by	WRAPPER
Description	This action instructs the WRAPPER agent to attempt to make the associated predicate become true for the WRAPPER agent. If successful, according to the FIPA-Request Protocol [PART2], the WRAPPER agent responds with an inform CA with the content set to: (result <Action> <Domain Dependent Result>)
Parameter	<predicate>
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver A-WRAPPER-agent :content (action A-WRAPPER-agent (achieve (parameter web-server-001 EmptyTrashFolder True))) :protocol fipa-request .....)
Failure / Refuse Predicates	(not-valid-service-instance-id) (not-valid-predicate) (unauthorised) (service-suspended) (exceeded <resource>)

6.3.1.2.10 invoke

Supported by	WRAPPER
Description	This action instructs the WRAPPER agent to invoke an operation on a software system identified by service-instance-id
Parameter	service-instance-id, <functional-expression>
FIPA Protocol	fipa-request
Example	(request :sender Agent-k :receiver A-WRAPPER-agent :content

	(action A-WRAPPER-agent (invoke (:service-instance-id web-server-001) (get “welcome.html”))) :protocol fipa-request .....)
Failure / Refuse Predicates	(not-valid-service-instance-id) (not-valid-operation) (unauthorised) (service-suspended) (exceeded <resource>)

6.3.1.3 Predicates

The WRAPPER ontology also supports a number of predicates. Client agents can make use of this service using the *query-ref, query-if, subscribe, request-when and request-whenever* communicative acts. This specification mandates only that an agent who wishes to support the WRAPPER ontology supports the *request*, *query-if* and *query-ref* communicative acts.

6.3.1.3.1 Member Predicate

The member predicate of section 0 is defined also for this ontology.

6.3.1.3.2 Parameter Predicate

When an WRAPPER agent initialises the connection to a software service, following a request to init from a client agent, a parameter predicate for each of the set of available parameters of the software system is asserted in the WRAPPER agent. The syntax of a parameter predicate is:

```
(parameter <service-instance-id> <parameter name> <value>)
```

This means that it is true that the value of the parameter <parameter name> of the software system identified by the identifier <service-instance-id> is <value>. This parameter predicate can be used as the subject of a query-ref and query-if communicative act in order to determine the values of parameters or indeed what parameters are available (in conjunction with the member predicate). Furthermore, parameter values can be set using the achieve action (see section 0).

6.3.1.3.3 Subscribed Predicate

When a connection to a software system is initialized, for each event type supported by the software system, this predicate expression is asserted in the WRAPPER agent:

```
(not (subscribed <service-instance-id> <event-name>) )
```

That is the WRAPPER assumes that the client agent is not subscribed to any events.

The predicate

```
(subscribed <service-instance-id> <event-name>)
```

is true when the WRAPPER has (through whatever proprietary means the software system requires) subscribed to the event service called <event name> for the software system identified by the <service-instance-id>.

NOTE Some software systems will not support event services in which case no subscribed predicates are asserted by the WRAPPER agent.

6.3.1.3.4 Operation Predicate

When a WRAPPER initiates a service, for each operation supported by the software system it asserts an operation predicate. This predicate has the following syntax:

```
(operation <service-instance-id> <operation name> <argument type>*)
```

This predicate is true when the operation <operation name> with arguments of <argument type>* is invokable on the software system identified by the identifier <service-instance-id>. The types of arguments <argument type> are only guaranteed to have significance within the ontology of the software service.

NOTE A WRAPPER agent is free to retract these predicates if the operation subsequently becomes unavailable. It is not mandatory that all WRAPPER support this functionality.

6.3.2 Querying the WRAPPER

Every WRAPPER can be queried using the query-if and query-ref communicative acts for the FIPA-WRAPPER ontology. For example, you can use the query-ref communicative act to query what are the available events, operations and parameters of a instantiated software service.

6.3.3 Registering the WRAPPER service with the DF

In order for an agent to advertise its willingness to provide a wrapper service to an agent domain, it must register with a DF [PART1]. Again in order to allow interoperability, this section specifies a number of constants which universally identify the software wrapping service.

— the service-type must be declared to be “FIPA-WRAPPER”,
— the service-ontology must include “FIPA-WRAPPER”, which identifies the set of actions that can be requested to a wrapper agent.
— the fixed-properties list must include a property:

```
(:systems-supported <service-description>+)
```

This property indicates what types of software systems that the WRAPPER agent can support connections to. The service description must name at least:

a) the service-ontology of the software service and
b) the communication properties which describe that what sort of connections the WRAPPER can support.

Example 5

```
(request
     :sender   A-WRAPPER-agent
     :receiver DF
     :language SL0
     :protocol fipa-request
     :content
        (action DF
         (register
           (:df-description
            (:agent-name A-WRAPPER-agent)
            (:agent-services
             (:service-description
              (:service-name Web-Wrapper-service)
              (:service-type FIPA-WRAPPER)
              (:service-ontology FIPA-WRAPPER)
              (:fixed-properties
                     (:systems-supported
                        (:service-description
                           (:service-ontology  web-server)
                           (:communication-properties
                                     (:net-protocol          HTTP)
                                     (:message-body-format   HTML)
                                     (:message-body-encoding Latin-
1)) ))) ))))))
.... )
```

6.3.4 Conformance

A FIPA compliant WRAPPER agent must at least:

— register the WRAPPER service with the DF with the service-type and the service-ontology set to FIPA-WRAPPER, as described in section 0;
— implement the actions described in the FIPA-WRAPPER Ontology according to the behaviour and parameters speficied in section 0;

- implement and assert the predicates described in the FIPA-WRAPPER Ontology according to the semantics specified in section 0;
- understand the *request* communicative act to request the execution of one of these FIPA-WRAPPER actions;
- understand the *query-if* and *query-ref* communicative acts to query its asserted predicates by using the FIPA-WRAPPER predicates;
- implement the *fipa-request* and *fipa-query* interaction protocols speficied in [PART2];
- implement the *not-understood; agree, refuse, failure, inform* communicative acts in order to respond to requests and queries according to the *fipa-request* and *fipa-query* interaction protocols.

Annex A
(normative)

EBNF Grammar for FIPA-ARB Ontology

The following grammar, expressed in BNF, defines the FIPA-ARB as a valid subset of the SL language. This specification is not complete and the reader is directed to [PART2] Agent Communication specification for further information. When communicating with agents supporting the FIPA-ARB ontology the language parameter should be set to SL or SL2. This grammar merely defines what are the valid sentences in the FIPA-ARB ontology in the wider context of the SL language.

```
ARBFunctionalTerm =     SLFunctionalTerm
                    | “(“ “register-software” service-description
“)”
                    | “(“ “de-register-software” service-name “)”
                    | “(“ “modify-description” service-name service-
description “)“
                    | “(“ “registered” service-description “)”
                    | “(“ “member” SLxTerm SlxTerm “)”  .


ARBTerm =           SLTerm
                         | service-description
                    | service-description-item
                    | service-name
                    | communication-properties
                    | communication-properties-item .



service-description =  “(“ “:service-description” service-
description-item+ “)” .

service-description-item = service-name
                    | “(“ “:service-type” Word “)”
                    | “(“ “:service-ontology” SLTerm “)”
                    | “(“ “:fixed-properties” SLFunctionalTerm “)”
                    | “(“ “:negotiable-properties” SLFunctionalTerm
    “)”
                    | communication-properties .

service-name =      “(“ “:service-name” Word “)” .

communication-properties = “(“ “:communication-properties”
communication-properties-item+ “)” .

communication-properties-item = “(“ “:net-protocol” SLTerm “)”
                    | “(“ “:address” SLTerm “)”
                    | “(“ “:message-body-format” SLTerm “)”
                    | “(“ “:message-body-encoding” SLTerm “)” .
```

```
ARBPropositionSymbol =  SLPropositionSymbol
                      | “not-valid-description”
                      | “service-name-in-use”
                      | “unauthorised-request”
                      | “not-valid-service-name” .
```


Annex B
(normative)

EBNF Grammar for FIPA-WRAPPER Ontology

The following grammar, expressed in BNF, defines the FIPA-WRAPPER as a valid subset of the SL language. This specification is not complete and the reader is directed to [PART2] Agent Communication specification for further information. When communicating with agents supporting the FIPA-WRAPPER ontology the language parameter should be set to SL or SL2. This grammar merely defines what are the valid sentences in the FIPA-WRAPPER ontology in the wider context of the SL language.

```
WrapperFunctionalTerm = SLFunctionalTerm
                      | “(“ “init” service-description SLTerm “)”
                      | “(“ “close” service-instance-id SLTerm “)”
                      | “(“ “store” service-instance-id “)“
                      | “(“ “restore” service-instance-id state-id “)”
                      | “(“ “software-subscribe” service-instance-id
event-name “)”
                      | “(“ “software-unsubscribe” service-instance-id
event-name “)”
                      | “(“ “suspend” service-instance-id “)“
                      | “(“ “resume” service-instance-id “)“
                      | “(“ “achieve” SLTerm “)“
                      | “(“ “invoke” service-instance-id SLTerm“)“
                      | “(“ “member” SLxTerm SlxTerm “)”
                      | “(“ “parameter” service-instance-id Word
SLConstant “)”
                      | “(“ “subscribed” service-instance-id Word
SLConstant “)”
                      | “(“ “operation” service-instance-id Word Word+
“)”
                      | “(“ “exceeded” Word “)” .


WrapperTerm =       SLTerm
                         | service-description
                      | service-description-item
                      | service-name
                      | communication-properties
                      | communication-properties-item
                      | service-instance-id
                      | state-id .



service-description =  “(“ “:service-description” service-
description-item+ “)” .

service-description-item =   service-name
                      | “(“ “:service-type” Word “)”
```

```
                    | “(“ “:service-ontology” SLTerm “)”
                    | “(“ “:fixed-properties” SLFunctionalTerm “)”
                    | “(“ “:negotiable-properties” SLFunctionalTerm
     “)”
                    | communication-properties .

service-name =      “(“ “:service-name” Word “)” .

event-name =        “(“ “:event-name” Word “)” .

communication-properties = “(“ “:communication-properties”
communication-properties-item+ “)” .

communication-properties-item = “(“ “:net-protocol” SLTerm “)”
                    | “(“ “:address” SLTerm “)”
                    | “(“ “:message-body-format” SLTerm “)”
                    | “(“ “:message-body-encoding” SLTerm “)” .

service-instance-id =   “(“ “:service-instance-id” Word “)” .

state-id =              “(“ “:state-id” Word “)” .



WrapperPropositionSymbol = SLPropositionSymbol
                    | “not-valid-description”
                    | “unauthorized”
                    | “maximum-number-of-instances-exceeded”
                    | “service-in-use”
                    | “service-unreachable”
                    | “not-valid-service-instance-id”
                    | “not-enough-resources”
                    | “not-valid-state-id”
                    | “service-suspended”
                    | “unknown-event-name”
                    | “service-already-suspended”
                    | “service-not-suspended”
                    | “not-valid-predicate”
                    | “not-valid-operation”
                    | “not-storable”
                    | “not-suspendable”
                    | “not-resumable”.
```