On the application of multi-agent systems in health care

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Outline of the talk

- Introduction
- Health care areas where agents have been applied
- K4Care: agent-based provision of Home Care services
- Benefits of the application of agents in health care problems

Characteristics of Health Care problems

- Distributed knowledge
  - E.g. different units of a hospital
- Coordinated effort
  - E.g. receptionist, general and specialised doctors, nurses, tests personnel, ...
- Complex problems
  - E.g. patient scheduling
- Need to manage different types of knowledge
  - Medical, organisational, procedural

Why use MAS in Health Care?

- MAS are inherently distributed
- Agents can coordinate their activities, while keeping their autonomy and local data
- Dynamic and flexible distributed problem solving mechanisms
- Use of personalisation techniques
  - Knowledge-based behaviour of the system

Main application domains

1-Medical data management

National electronic Library for Health (NeLH)

Management of palliative patients (PalliaSys)

Virtual Electronic Patient Record (VEPR)

Context-aware Hospital Information System (CHIS)

3-Planning and resource allocation

Agent.Hospital (simulation)

CARREL (transplant management)

Medical Information Agents (MIA)

Medical Services Coordination (MeSSyCo)

5-Composite Systems

SHARE-IT (assistive technologies)

K4Care (Home Care)

Geriatric Ambient Intelligence (GerAmI)

2-Decision support systems

Singh's intelligent assistant

HealthAgents [Microart]

Health Care Services (HeCaSe)

4-Remote care, telemedicine

Aingeru (elder monitoring)

INCA (Community services)

Medical Contact Centres [Koutkias]

Monitor chronic patients [Cervantes]

1-Medical data management

- This area includes different kinds of systems:
  - Information agents that collect, filter and analyse medical information available in electronic resources
  - Agents that provide a transparent access to physically distributed information sources
    - Different medical organisations, or different units within a hospital
  - In general, intelligent management of the personal and medical information in the Electronic Health Record of a patient

2-Decision support systems

- These systems aim to assist the professionals in the decisions to be taken during the healthcare process.
  - E.g. help in the diagnosis phase, or in the definition and execution of the most appropriate personalised treatment.
- Agents can also perform routine actions, such as checking periodically the patient state, or waiting for the results of a medical test to be available
- They usually perform complex reasoning processes

3-Planning and resource allocation

- Systems in which professionals and/or medical resources are represented by autonomous agents
- The basic aspect is the coordination of their activities to take appropriate decentralised scheduling decisions in medical centres
  - E.g. patient scheduling

4-Remote care, Telemedicine

- In most cases, the basic aim of the system is to monitor continuously the state of the patients, allowing permanent care
- Main elements of the system:
  - Collection of sensors
  - Analysers of signals from sensors, problem detection
  - Generation of alarms and reports for medical staff

5-Composite systems

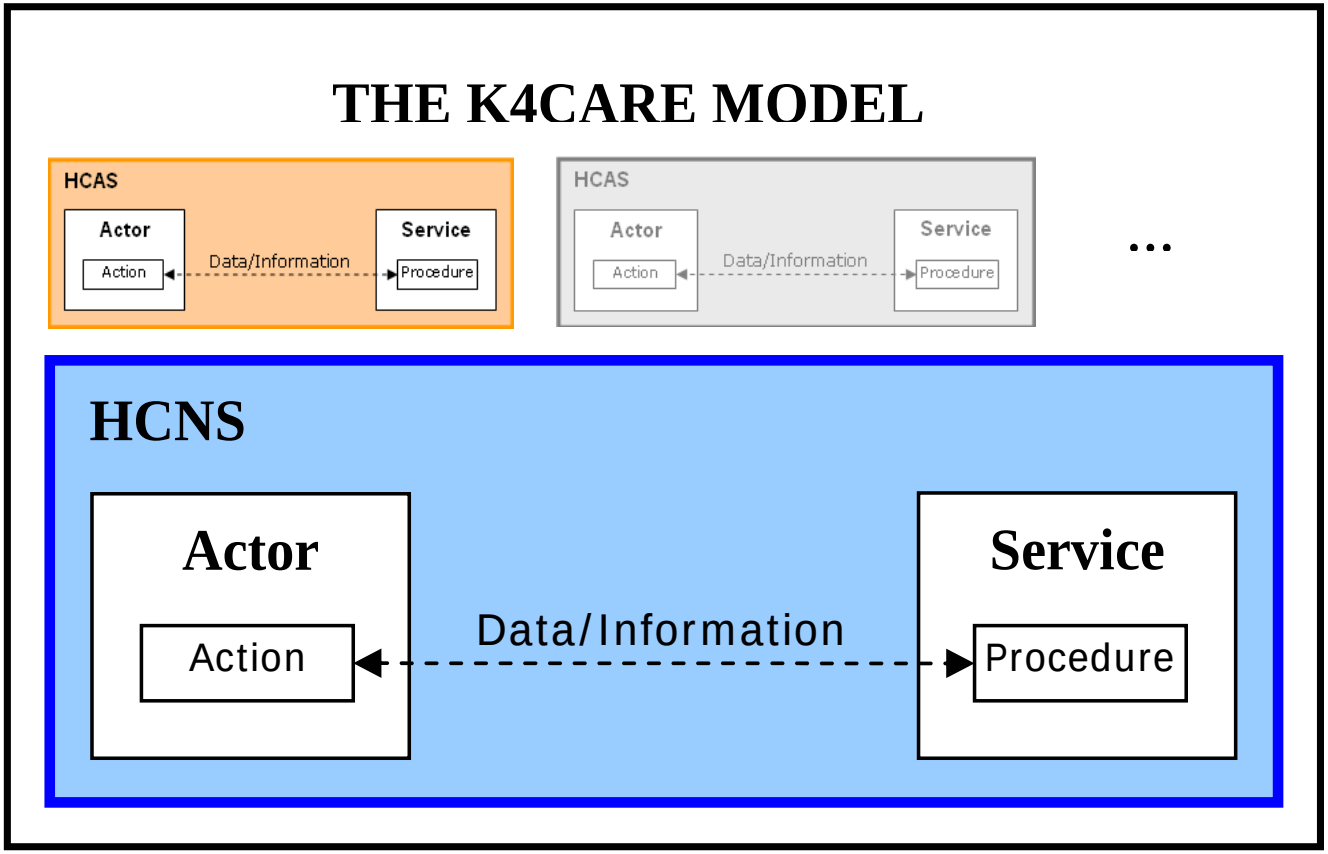
- Agent-based platforms that integrate different ICTs and Artificial Intelligence techniques in order to provide an efficient coordination of the activities to be performed to provide an efficient health care to a particular kind of patients

K4Care European project

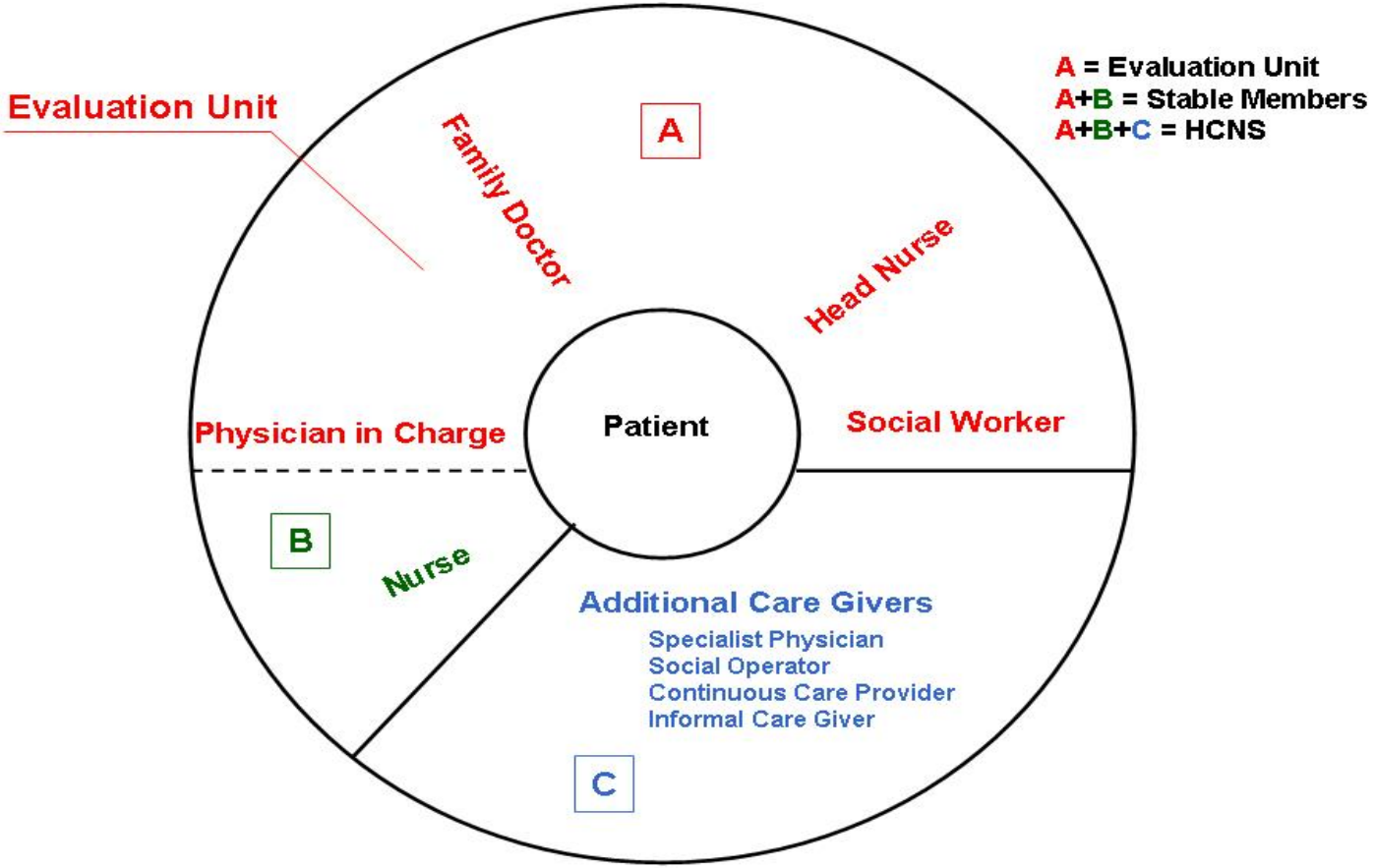
- 2006-2009, 13 partners, coordinated by URV
- The aim of the K4Care European project was to provide a *Home Care model*, as well as to develop a prototype system, based on Web technology and intelligent agents, that provided the services defined in the model

K4Care Model: Structure

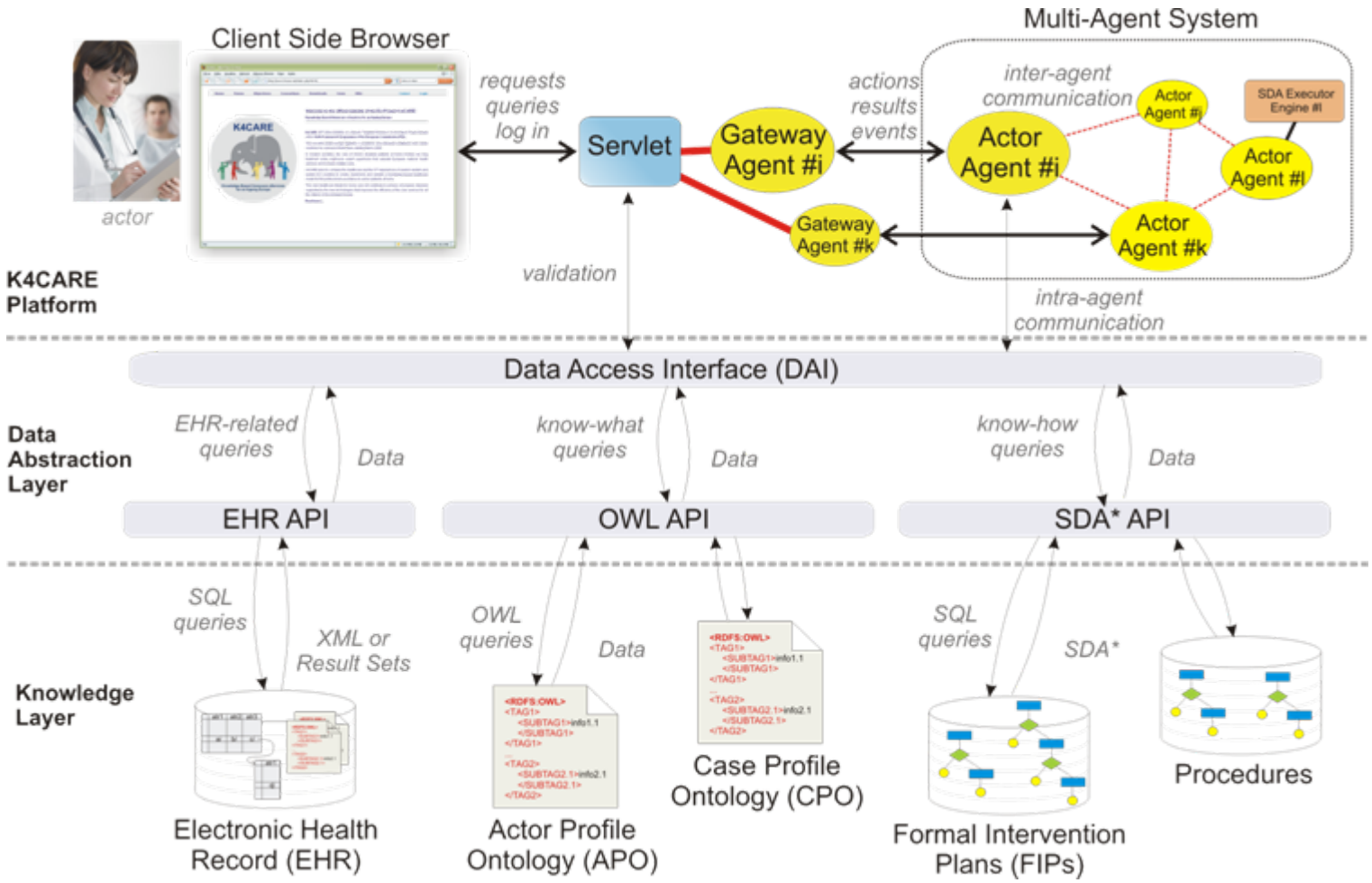
- **1 Nuclear Structure + *n* Accessory Services**



K4Care Model: Actors and Teams



K4Care architecture

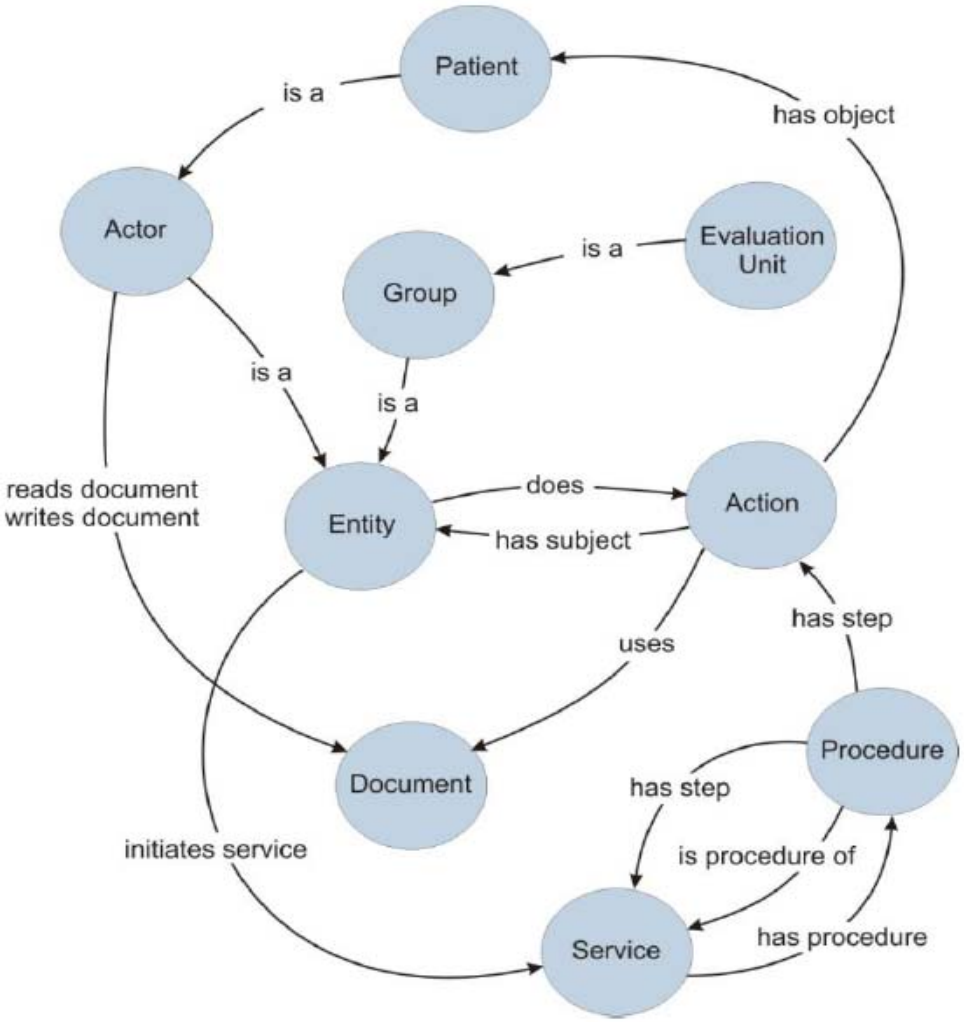


K4Care Knowledge structures

- EHCR: Electronic Health Care Record
- APO: Actor Profile Ontology
- CPO: Case Profile Ontology
- Procedures
- FIP: Formal Intervention Plan
- IIP: Individual Intervention Plan

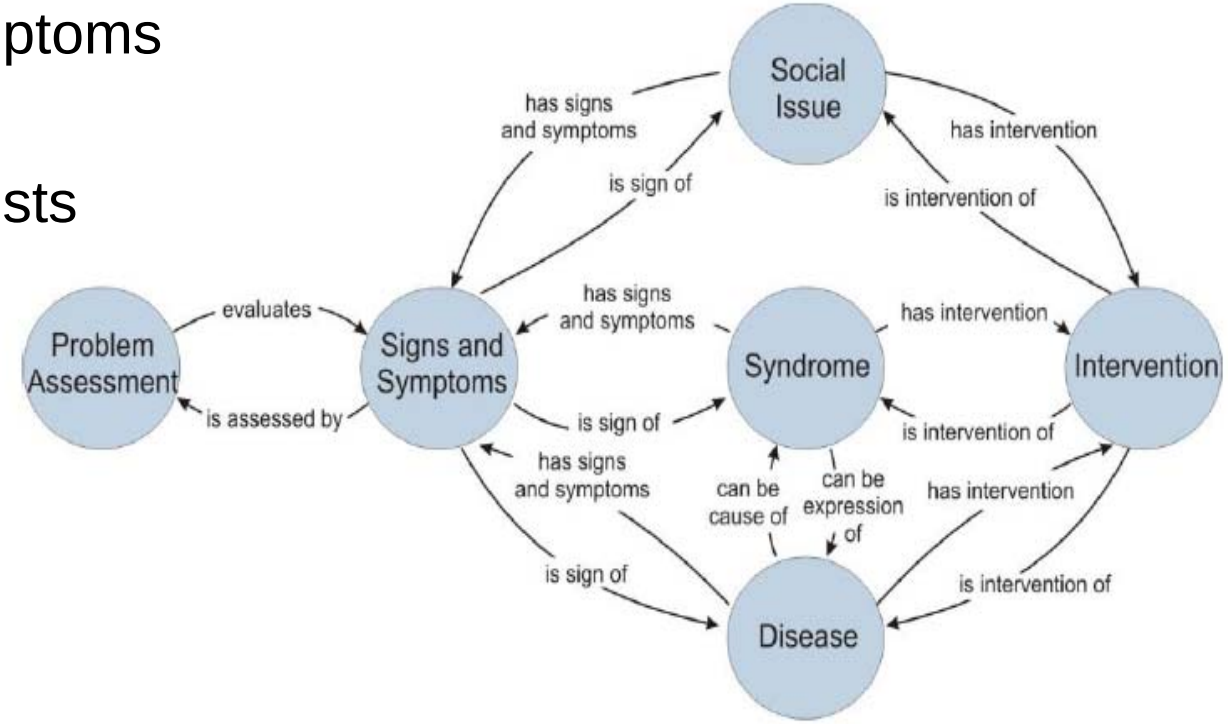
K4Care Ontologies (I)

- Actor Profile Ontology (APO)
  - Types of actors
  - Actions related to each role
  - Platform services
  - Procedures
  - Documents
  - ...



K4Care Ontologies (II)

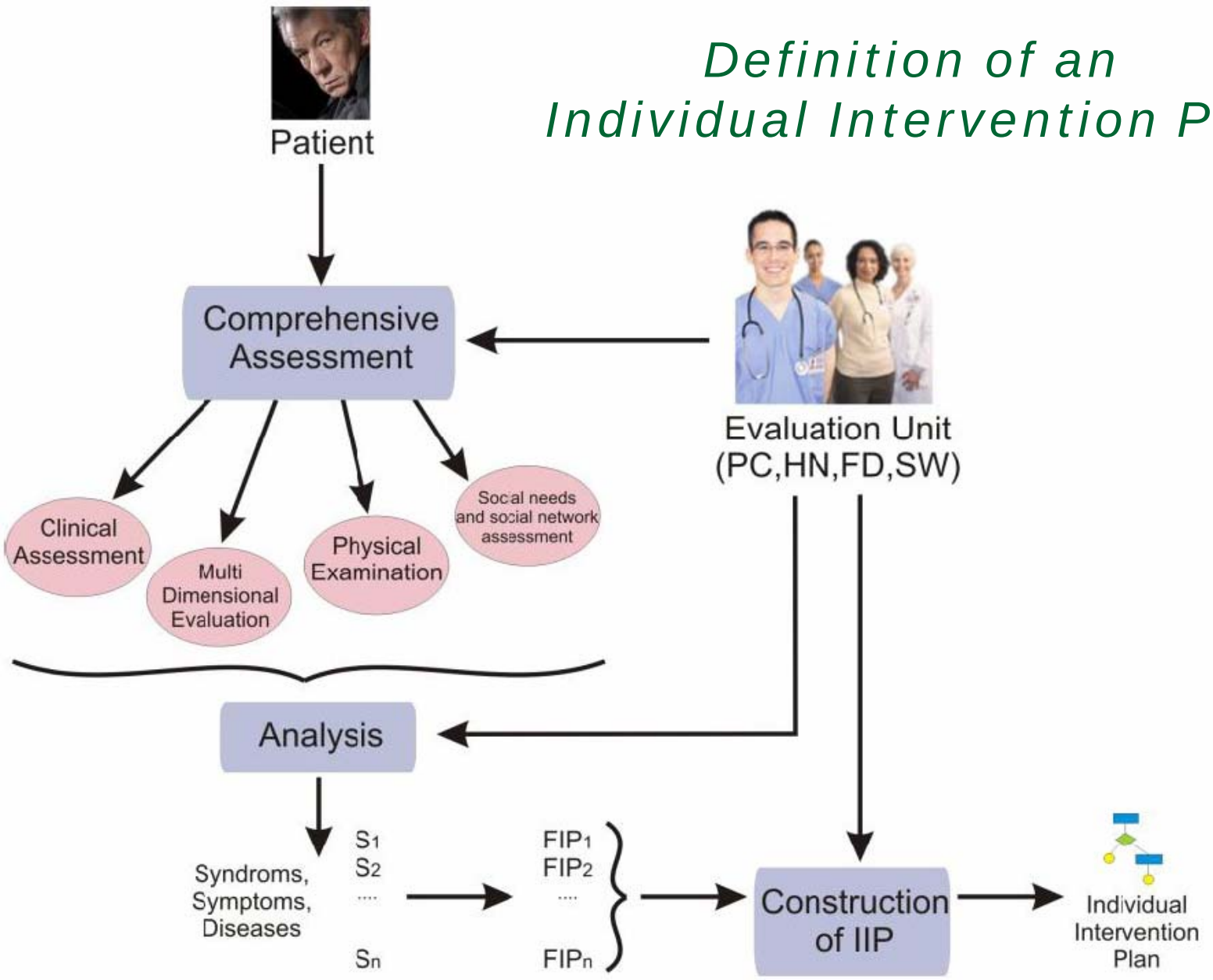
- Case Profile Ontology (CPO)
  - Diseases
  - Syndromes
  - Signs and symptoms
  - Social issues
  - Assessment tests
  - Interventions
  - ...



Procedures, FIPs and IIPs

- All the careflow procedural aspects are represented in SDA* (States, Decisions, Actions)
- Procedures are formal specifications of the way in which an administrative service (e.g. *admit a new patient to the Home Care service*) has to be implemented
- Formal Intervention Plans (FIPs) are formal structures representing the health care workflow to assist patients suffering form particular ailments or diseases
  - Problem: application of guidelines to co-morbid patients

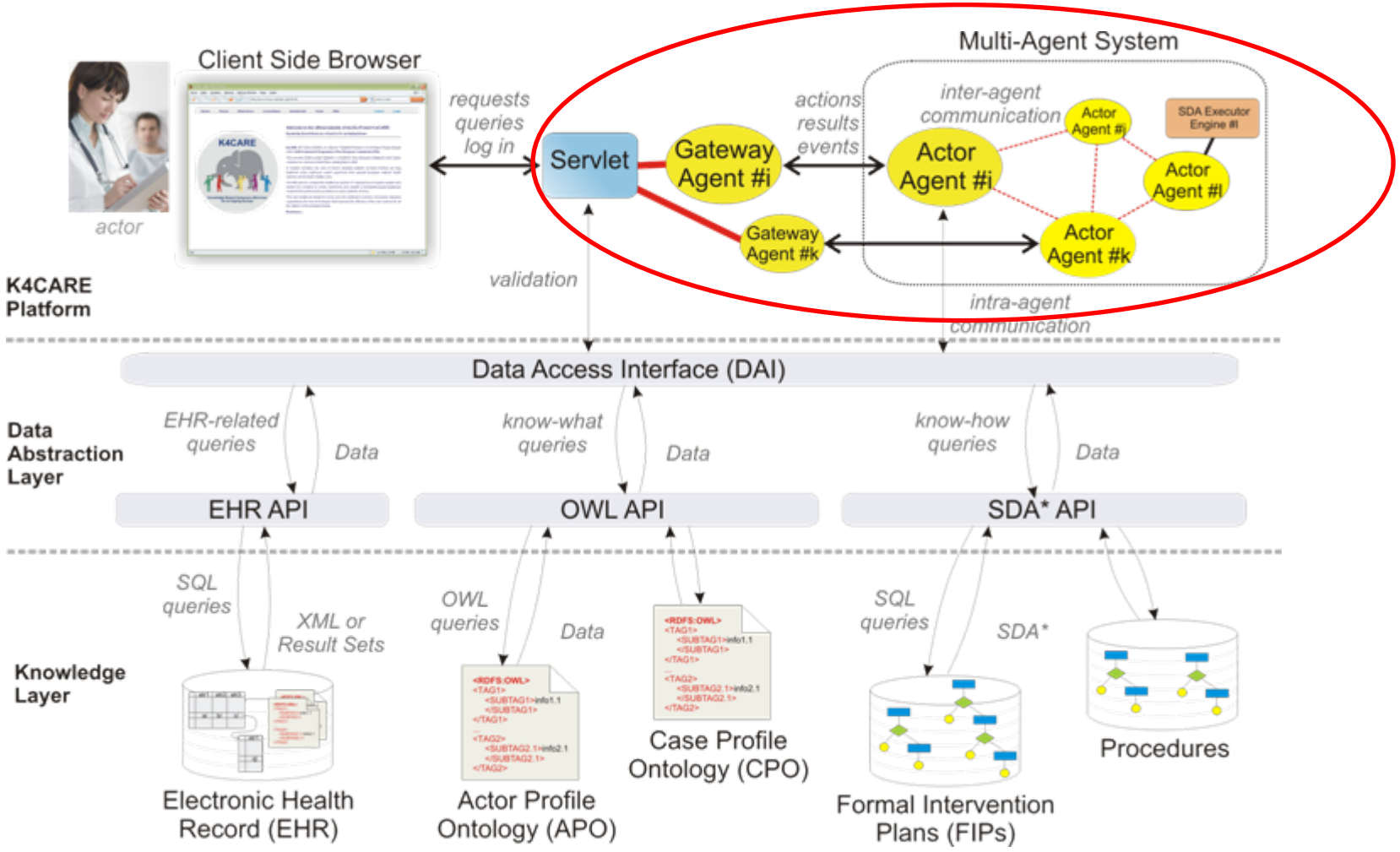
Definition of an Individual Intervention Plan



K4Care platform features

- Agent-based Web-accessible platform that provides a set of basic Home Care services
  - Admit a patient to the Home Care service
  - Create an Evaluation Unit
  - Assign an Evaluation Unit to a particular patient
  - Assess the initial state of a patient
  - Definition of an IIP for a patient
  - Apply IIP to the patient
  - ...

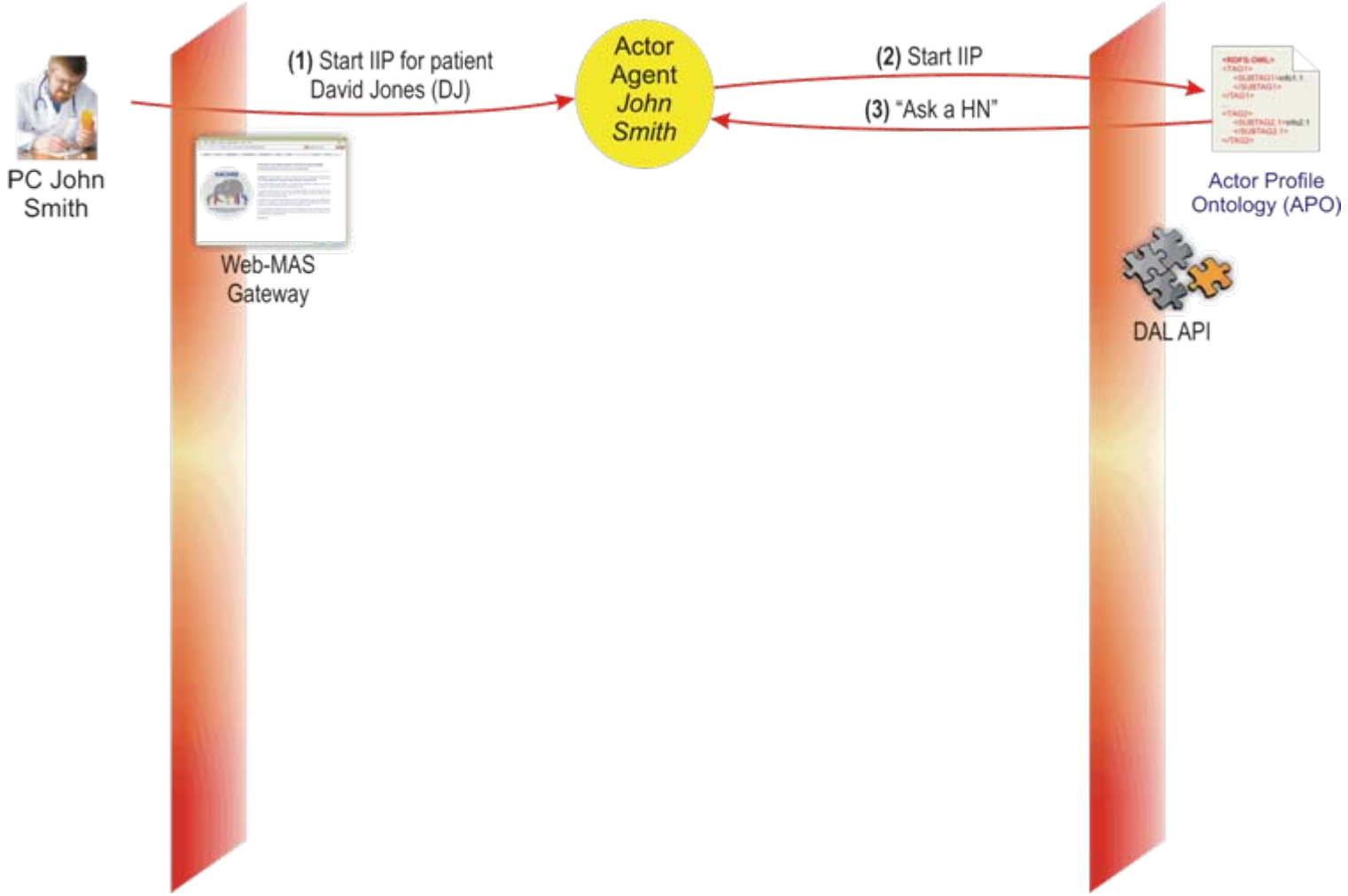
K4Care agent-based platform



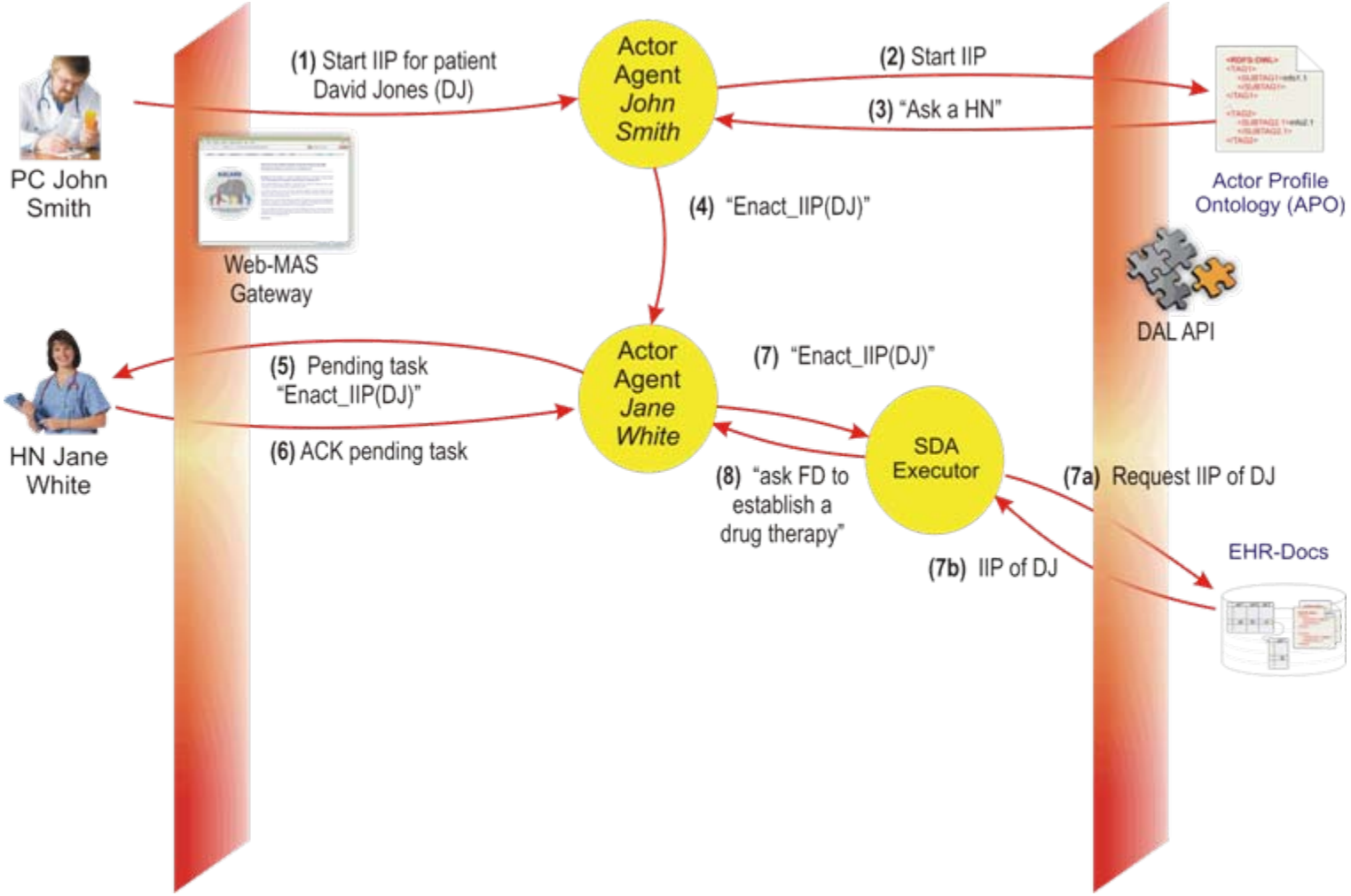
Multi-agent system

- 1 Actor Agent for each user, permanently running
- When the user logs in, a Gateway Agent is dynamically created
  - Two-way communication Web-servlet-GA-AA
- When an Actor Agent has to manage the execution of a procedure/IIP, it creates dynamically a SDA-executor Agent

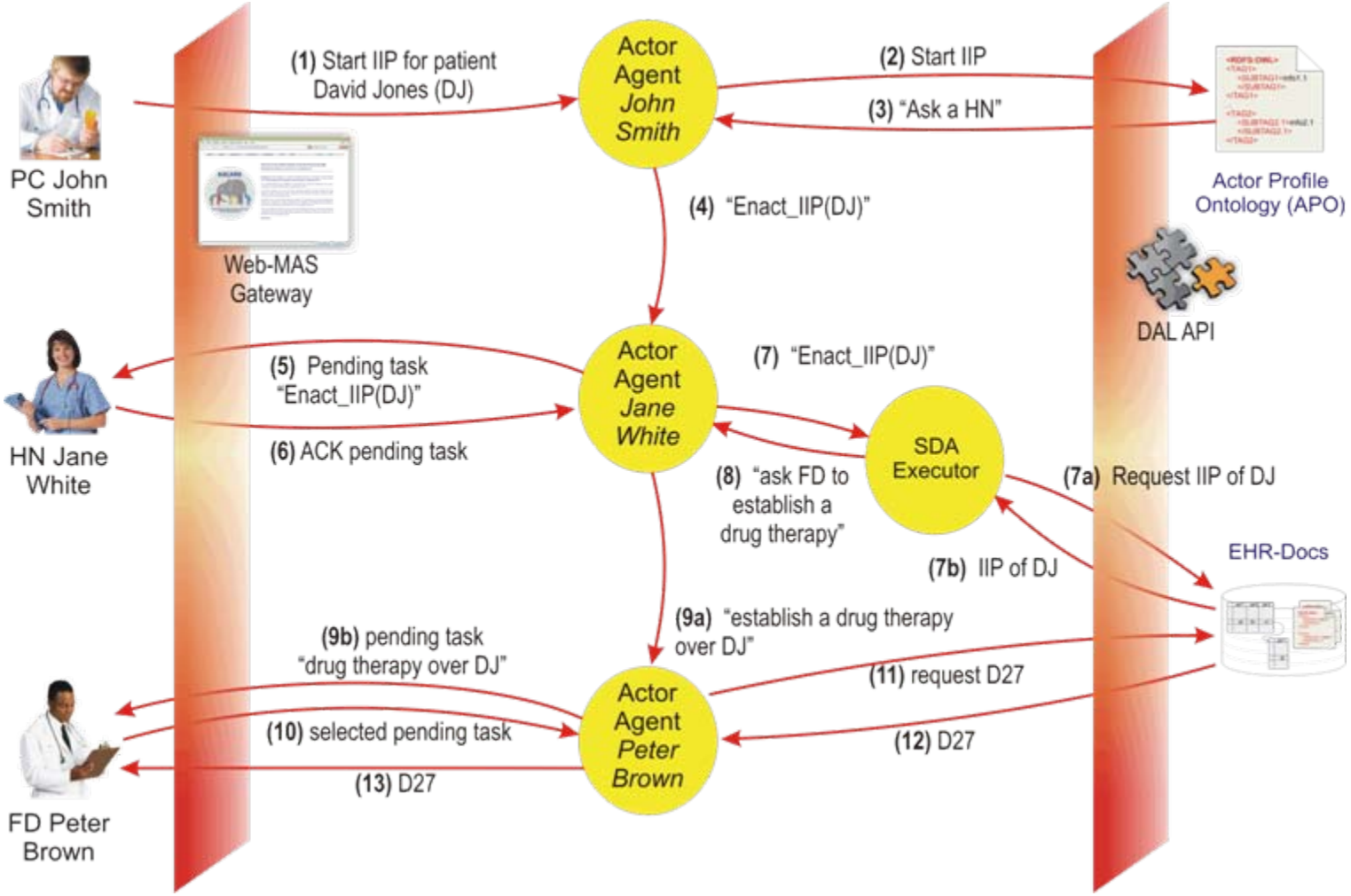
Agent-based execution of IIPs (I)



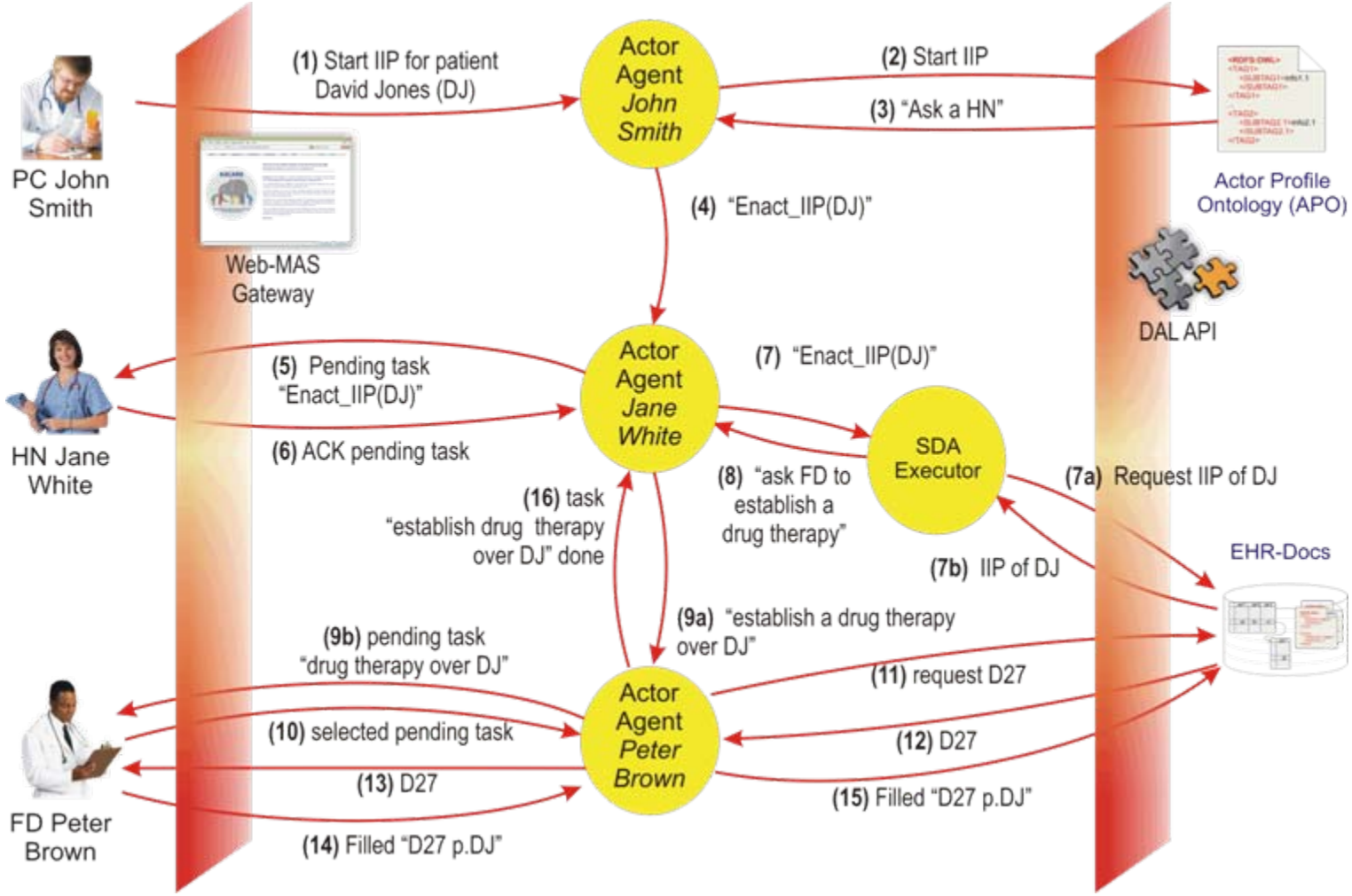
Agent-based execution of IIPs (II)



Agent-based execution of IIPs (III)



Agent-based execution of IIPs (IV)



Summary of K4Care main aspects

- Declarative (medical, organizational) and procedural knowledge
- Web-based interaction between agents and end-users
- Individual Intervention Plans allow practitioners to implement accurate and personalised sequences of actions for the treatment of a particular patient
- The architecture allows implementing agent-based coordination methods between the actors relevant in Home Care, which adapt their behaviour dynamically depending on the knowledge available in the platform

Positive aspects of MAS [in HC] (I)

- Modularity
  - A complex problem is divided in subproblems which may be solved by autonomous units, with the appropriate coordination among them
- Efficiency
  - Agents may be running in different computers, speeding up the resolution of the problem
- Decentralisation
  - Less single point-of-failure risk than centralised systems

Positive aspects of MAS [in HC] (II)

- Flexibility
  - The MAS components may change at run time, the tasks may be dynamically distributed
- Personalisation
  - Personal agents may have information on the user preferences and adapt the system's behaviour to them
- Distributed planning
  - Use of coordination techniques for distributed problem solving

Positive aspects of MAS [in HC] (III)

- Monitoring, alarm management
  - Continuous monitoring of personal and medical data, with immediate activation of emergencies when needed
- Proactivity
  - Agents may perform tasks without requiring a constant intervention or request from the user
- Security
  - Confidentiality of medical data

Recommended extra material

- Publications at http://deim.urv.cat/~itaka
- D.Isern, D.Sánchez, A.Moreno

  Agents applied in health care: a review

  International Journal of Medical Informatics, Vol. 70, pp. 145-166, 2010

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Review

Agents applied in health care: A review

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Agents – general definition

- Computational entities, capable of sensing the environment and acting proactively and autonomously upon it in order to satisfy their design objectives
- Can communicate with other agents to share information, coordinate their activities and cooperate to solve complex distributed problems

DBs, Electronic Health Care Record

- Data Base: with information about the K4Care actors as users of the K4Care Platform (e.g. contact information)
- EHCR: with the data about the Home-Care processes performed within the K4Care Platform
  - Medical documents stored in XML

FIP for the management of hypertension