A Semantic Web Service-based Architecture for the Interoperability of E-government Services

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Abstract

We propose a semantically-enhanced architecture to address the issues of interoperability and service integration in e-government web information systems. An architecture for a life event portal based on Semantic Web Services (SWS) is described. The architecture includes loosely-coupled modules organized in three distinct layers: User Interaction, Middleware and Web Services. The Middleware provides the semantic infrastructure for ontologies and SWS. In particular a conceptual model for integrating domain knowledge (Life Event Ontology), application knowledge (E-government Ontology) and service description (Service Ontology) is defined. The model has been applied to a use case scenario in e-government and the results of a system prototype have been reported to demonstrate some relevant features of the proposed approach.

1. Introduction

The current trend in e-government applications calls for joined-up services that are effective, simple to use, shaped around and responding to the needs of the citizen, and not merely arranged for the provider's convenience. In this way, the users need have no knowledge of – nor direct interaction with – the government entities involved. Thus, services need to be interoperable in order to allow for data and information to be exchanged and processed seamlessly across government.

Interoperability is a key issue in the development of current e-government services. A recent working paper by the Commission of European Communities [14] emphasized its role, not only as a technical issue concerned with linking up computer networks, but also as a fundamental requirement to share and re-use knowledge between networks, and reorganize administrative processes to better support the services themselves.

Still in ref.[14], three levels of interoperability were in-

dividuated: *technical*, *semantic* and *organizational*. The first one refers to the topics of connecting systems, defining standard protocols and data formats. The second one concerns the exchange of information in an understandable way, whether within and between administrations, either locally or across countries and with the enterprise sector. The third one refers to enabling processes to co-operate, by rewriting rules for how Public Administrations (PAs) work internally, interact with their customers, use Information and Communication Technologies (ICT).

On practical grounds, the *integration* of services is a basic requirement of PA portals, which aim at gathering and transforming processes – needed for a particular citizen's life event – into one single service and the corresponding back-office practices. A promising solution, which we extend in this paper, is offered by the *one-stop government portals* [23], [17], that are unified on-line access points, where various PAs collaborate for the provision of integrated services.

Another technological solution adopted for integration purposes are the Web Services (WS) [10] [3] and Semantic Web Services (SWS) [12], which enable the standardized description, retrieval, invocation and combined use of pre-existing applications.

The present paper addresses the issues of semantic interoperability and service integration, by adopting knowledge management techniques. In particular, ontologies are employed [2],[1] in support of the following activities: systematic and standard description of information resources (documents, processes and their relations); support to the automation of services, systems and infrastructures involving PAs; supply of added-value services, such as selected information retrieval and personalization of contents.

We describe the architecture of a one-stop government portal based on a SWS infrastructure, which we have implemented an experimental testbed. The portal provides common services from government organizations without affecting their autonomy, with flexible solutions to enhance and include additional functionalities. We use the IRS-III [15] framework that supports the creation and management of SWS according to the WSMO [25] ontology.

The project also involves the development of a domain ontology that represents the semantic structure of life events underlying the service supply.

Advantages of the proposed solution are: providing a single access point to government services via the web, providing citizen-oriented services by means of the life event metaphor, providing the tools for collecting information from autonomous Public Administrations (PAs), while keeping their internal processes and legacy systems intact.

The paper is organized as follows: in Section 3 we introduce the system architecture; in Sections 5 and 4 we describe the middleware layer; in the next we present typical system operations and a case study implemented using the architecture. The final section contains our conclusions.

2 Related Work

2.1 Web Information Systems in E-Government

Many e-government projects are being developed and various approaches have been proposed for the design and the development of an architecture to deliver e-government services to citizens.

The *eGOV* project [6] proposes an architecture to enable 'one-stop government'. In order to describe services a markup language (GovML) has been developed [11]. GovML defines a set of metadata to describe public administration services and life events.

The *FASME* project [9] focuses on supporting citizen mobility across European countries by the integration of administrative process. In order to satisfy this objective a smart card is provided to citizens for the storage of all personal information and documents. Services are delivered through dedicated kiosks.

The *EU-PUBLI.com* project [8] defines a Unitary European Network Architecture. It proposes a middleware solution to connect heterogeneous systems of different public administration and to enable a service-based cooperation between public administrations.

The *eGovSM* project [17] supports the automation of administrative process involving several administrations and allowing the reuse of data. The eGovSM is formalized using a set of XML Schema models in order to support the realization of an interoperable system.

Unlike our approach, no one of such projects takes into account the use of SWS technology as the base for developing a government portal nor the use of ontologies for describing life events, services and e-government knowledge.

2.2 Semantic Technologies in E-Government

The e-government scenario is an obvious and promising application field for ontologies, since legislative knowledge is by nature formal to a large extent and its definition is shared by many stakeholders. In fact there are other e-government projects where the semantic technologies are involved.

The *ONTOGOV* project [19] is developing a platform that will facilitate the consistent composition, reconfiguration and evolution of e-government services.

The *e-POWER* project [7] has employed knowledge modeling techniques for inferences like consistency check, harmonisation or consistency enforcement in legislation.

The *SmartGov* project [21] developed a knowledge based platform for assisting public sector employees to generate on-line transaction services.

The *ICTE-PAN* project [13] developed a methodology for modeling PA operations and tools to transform these models into design specification for government portals.

Such projects have demonstrated the feasibility of semantic technologies in e-government, but they did not explore the possibility of using a Semantic Web Services infrastructure for the interoperability and integration of different public administration services.

3 The proposed E-Government Portal Architecture

We define here the basic structure of a generic e-government one-stop portal based on a SWS infrastructure. This architecture extends the one defined in [16], wherein the concept and the architecture of an *active life event portal* were illustrated. The core component of such portal is a knowledge-based system. Which is a program based on inference mechanisms to solve a problem by employing the relevant knowledge. Its primary goals are identifying a life event applicable to the user's requirements, identifying the services needed to solve a given event and matching the user request, and identifying an instance of each service in the list. In our approach, the role of knowledge-based system is played by a semantically-enhanced architecture, which is composed of the loosely-coupled modules outlined in Figure 1.

The modules are organized in three layers.

User Interaction supports the user to identify a life event and collects information for service execution.

Middleware allows the semantic description, publishing and updating of life events in order to provide citizens with an up-to-date and personalized list of available services and allows the description, identification, instantiation and invocation of services.

Service Layer is responsible for the execution of services for a life event. Each PA supplies services through the WS technology. Each one is connected to the back-office and semantically described via the IRS-III module of the Middleware layer.

The core of the architecture is the Middleware, the semantically-enhanced layer responsible for the interoperability and service integration. The main issues addressed in the Middleware layer are follows[12].

Infrastructure for semantic interoperability: enables the automated interpretation and paves a common ground for services.

The ontologies: knowledge models for defining the concepts of the e-government domain and the semantic structure of the life events involved in the service supply.

Both issues will be detailed in the forthcoming sections.

4 The Infrastructure for Semantic Interoperability

We use a Semantic Web Services infrastructure for the semantic interoperability of e-government portal services. Our approach uses IRS-III [15], which is a framework allowing the publication, configuration and execution of multiple, heterogeneous web services, compliant with WSMO [25]. The architecture of IRS-III includes the following components: Server, Publisher and Client. The components communicate through a SOAP-based protocol. Publishing with IRS-III entails associating a specific web service to a WSMO description. IRS-III contains platforms to support the publishing of web services as well as standalone Java and Lisp code. Web applications accessible via HTTP GET methods are handled internally by the IRS-III server. The IRS-III Client supports a goal-centric invocation mechanism. The user simply asks for a goal to be solved; the IRS-III broker locates the appropriate semantic description, and then invokes the deployed service.

The *Web Service Modeling Ontology (WSMO)* [25] is a formal ontology for describing the various aspects of services in order to enable the automation of Web Service discovery, composition, mediation and invocation. Its main components are Ontologies, Goals, Web Services and Mediators. *Goals* represent the objectives that users would like to achieve via the WSs. The WSMO definition of goal describes the state of the desired information space and the desired state of the world after the execution of a given WS. A goal can import existing concepts and relations defined elsewhere, by either extending or simply re-using them as appropriate. *Web Service* descriptions describe the functional behavior of an actual WS. The description also outlines how Web Services communicate (choreography) and how they are composed (orchestration). *Mediators* define mappings between components: for instance, a goal can be related to one or more web services through mediators. They facilitate the clear-cut separation of different interoperability mechanisms. *Ontologies* provide the basic glue for semantic interoperability and are used by the three other components.

5 The Conceptual Model

Both PAs and citizens can benefit from a standard conceptual model for describing public services and life events. PAs will have a shared description structure, thus production and management of government information would be eased, while interoperability with other agencies would be fostered. Ontologies can also be used to represent the viewpoint of citizens in the application, making it easier for them to navigate through different services and administrations.

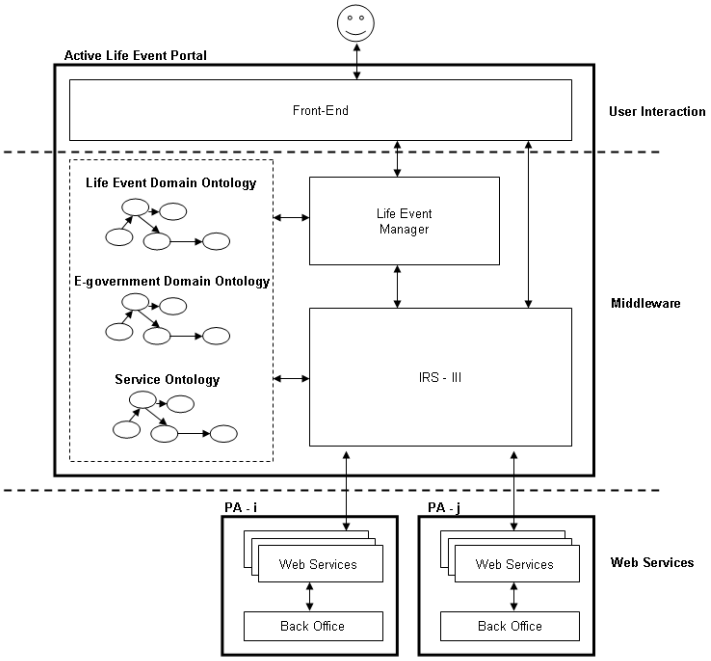

Figure 1. The semantically-enhanced infrastructure of a portal.

Ontologies enable the use of vocabulary about a certain domain in a coherent and consistent manner [20]. In particular, ontologies are the tools for formalizing knowledge and encoding higher-level data models, such as life events, procedures and services.

We use OCML (Operational Conceptual Modeling Language) [18] for describing a conceptual model for the e-government portal based on three ontologies: the E-Government Domain Ontology, the Life Event Domain Ontology, and the Service Ontology.

In the design of the ontologies above, we followed a deductive approach based on existing upper and specialized ontologies, with the assistance of domain experts. In particular we used the Description & Situations (D&S) [5] – a module of the DOLCE ontology [4]. D&S is a theory to describe context elements (non-physical situations, plans, beliefs,...) as entities. It features a philosophically concise axiomatization.

The *E-Government Domain Ontology* encodes concepts in the PA domain: organizational, legal, economic, business, information technology and end-user concepts. Starting from the D&S ontology we have built a domain ontology where all the PA concepts refer to (subclasses of) D&S main concepts. The formal descriptions of the PA-related concepts are the building blocks for the descriptions of the two other ontologies. Part of this ontology is shown in Figure 2.

The *Life Event Domain Ontology* defines a hierarchy of topics. Each life event can branch into sub-life events. It describes a life event in terms of norms that define it, information objects that describe it, parameters, involved agents (actor, applicant and provider), involved objects, involved procedures, and results (effects) of the life event. Moreover, for each Life Event, it is possible to associate one or more Goals, a concept of the WSMO ontology, and Entitlements, which include services and benefits. We show in Figure 3 the UML diagram of the Life Event model. All the classes describing life events – e.g. someone-move-in, getting-married, getting-divorced, moving-house, etc.– are subclasses of the life event class model.

The following ontology (OCML code) defines the *Someone-Move-In* life event and the related *Someone-Move-In-Description*:

```
(def-class Someone-Move-In
            (Manage-Family-Related-Life-Event) ?x
((defined-by :type Someone-Move-In-Description
            :min-cardinality 1)
 (has-associated-entitlement
            :value Child-benefit-someone-gets-for-you
            :value Guardian-Allowance)
 (has-associated-goal
            :value moving-in-person-change-of-domicile
            :value moving-in-person-change-of-residence
            :value family-change-of-circumstance)
 (moving-in-person-change-of-domicile
            :type notify-change-of-domicile)
 (moving-in-person-change-of-residence
            :type notify-change-of-residence)
 (family-change-of-circumstance
            :type notify-change-of-family))
 :constraint (and (defined-by ?x ?d)
```

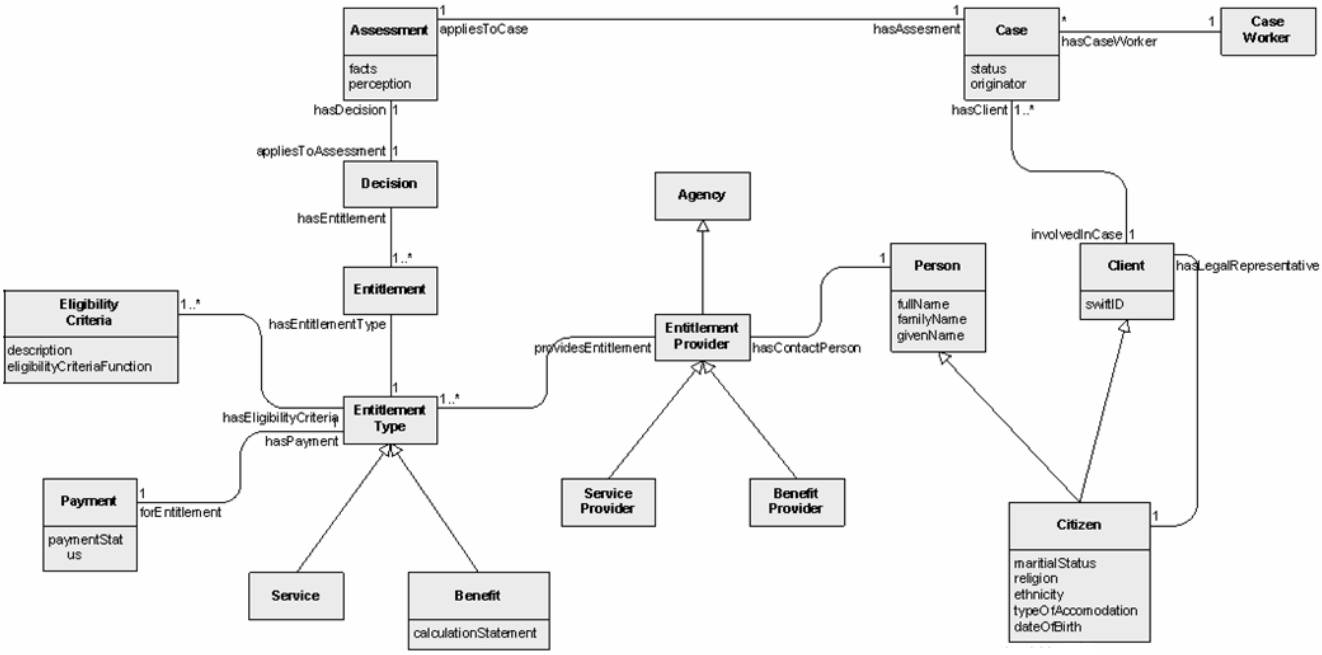

Figure 2. The UML diagram showing a small part of the whole E-Government Domain Ontology, which specifically models the 'Change of Circumstance' case study scenario (Section 6.1).

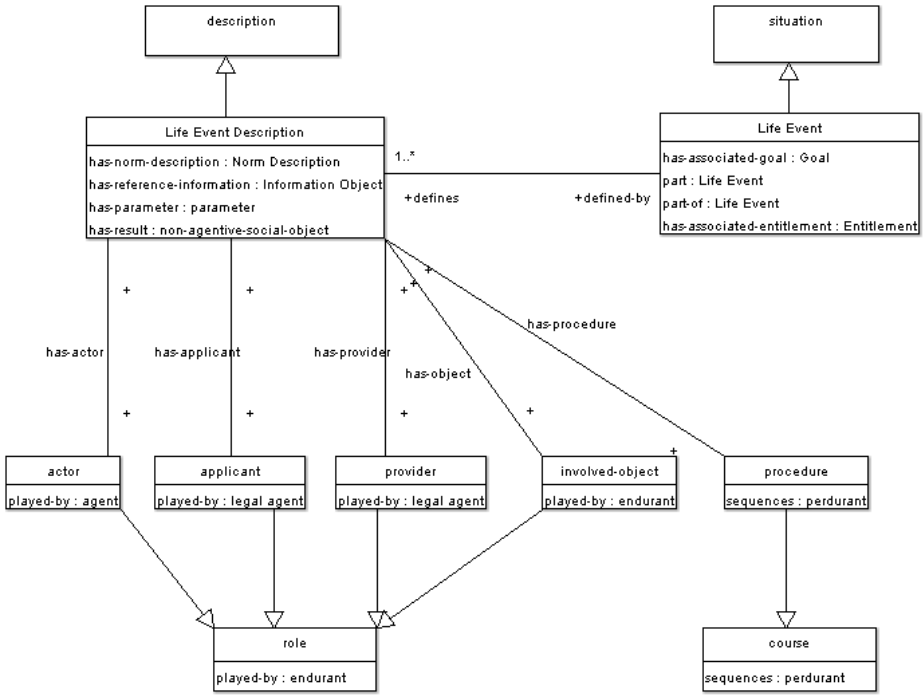

Figure 3. The UML diagram showing the generic description of a life event. A Life Event is a Situation (D&S concept) that satisfies one or more descriptions (different points of view: citizen, provider, PA, . . .). A Life Event Description is a Description (D&S concept). A description is composed by different role and courses (D&S concepts)

```
                (has-moving-in-person ?d ?p)
                (played-by ?p ?c)
                (or (exists ?g

                    (and (moving-in-person-
                          change-of-domicile ?x ?g)
                         (notify-
                          change-of-domicile ?g)
                         (has-citizen ?g ?c)))
                    (exists ?gr
                    (and (moving-in-person-
                          change-of-residence ?x ?gr)
                         (notify-
                          change-of-residence ?gr)
                         (has-citizen ?gr ?c))))))


(def-class Someone-Move-In-Description
           (Life-Event-Description) ?x
((defines :type Someone-Move-In
          :min-cardinality 1
          :max-cardinality 1)
 (has-parameter
          :value has-moving-date)
 (has-moving-date
          :type date-parameter)

 (has-applicant
          :value has-citizen-applicant)
 (has-citizen-applicant
          :type citizen-applicant)

 (has-provider
          :value has-government-provider)
 (has-government-provider
          :type government-provider)

 (has-actor :value has-moving-in-person
            :value has-destination-family-group
            :value has-origin-family-group)
 (has-moving-in-person
            :type moving-in-person)
 (has-destination-family-group
            :type destination-family-group)
 (has-origin-living-unit
            :type origin-living-unit)

 (has-result :value has-modified-living-unit)
 (has-modified-living-unit :type modified-living-unit))
 :constraint (and (exists (?md ?f ?lu)
                   (and (has-modified-living-unit ?x ?md)
                        (played-by ?md ?f)
                        (living-unit ?f)
                        (has-origin-living-unit ?x ?lu)
                        (played-by ?lu ?f)))
                  (exists (?md2 ?f2 ?d)
                   (and (has-modified-
                         living-unit ?x ?md2)
                        (played-by ?md2 ?f2)
                        (family-group ?f2)
                        (has-destination-
                         family-group ?x ?d)
                        (played-by ?d ?f2)))
                  (exists (?p ?c ?o)
                   (and (has-moving-in-person ?x ?p)
                        (played-by ?p ?c)
                        (has-origin-living-unit ?x ?o)
                        (member ?o ?c)))
                  (exists (?a ?c ?fg)
                   (and (has-citizen-applicant ?x ?a)
                        (played-by ?a ?c)
                        (has-destination-
                         family-group ?x ?fg)
                        (member ?fg ?c)))))
```

The *Service ontology* contains the SWS definitions. They correspond to instances of the Goal, Web Service and Mediator classes used in the IRS-III module (Section 4), following the WSMO definitions (Section 4). The following OCML code defines the *notify-change-of-address-goal* and the description of the *county-council-provider-notify-change-of-address* capability:

```
(def-class notify-change-of-address-goal (GOAL) ?goal
  ((has-input-role :value has-new-address
                   :value has-old-address
                   :value has-client-name
                   :value has-client-id
                   :value has-source-provider
                   :value has-target-provider)
   (has-output-role :value has-confirmation)
   (has-new-address :type string)
   (has-old-address :type string)
   (has-client-name :type string)
   (has-client-id :type integer)
   (has-source-provider :type service-provider)
   (has-target-provider :type service-provider)
   (has-confirmation :type string)))

(def-class county-council-provider-
           notify-change-of-address-ws-capability
  (capability) ?capability
  ((used-mediator
          :value notify-change-of-address-mediator
    has-assumption
          :value
    (kappa (?psm)
     (and (unit-of-organization
             (role-value ?psm 'has-target-provider)
             ?agency)
          (county-council-organization ?agency)))))
```

6 E-Government Portal Implementation

By using the infrastructure described previously, the application (portal) developer will use tools for describing, publishing and invoking services. Figure 4 shows some snapshots for the prototype scenario explained in next section.

Managing Services A developer creates a new WS for supplying a service through the portal. He provides a Goal description which represents the objectives that citizens would like to achieve via WS – and associates it to a Life Event. The developer might also refer to an already existing Goal instead of defining a new one. Then, the developer semantically describes its WS and associates it to the Goal. Dedicated interfaces and the IRS-III module are used for describing Goals and Web Services. Descriptions are maintained in the Service Ontology. Finally, through the publisher interface of the IRS-III module, the developer publishes the SWS, associating the semantic description to the developed WS.

Consistency between the Middleware layer and the Web Services is maintained by means of the Service Ontology. If changes are made to a web service or if a web service is removed/replaced, the developer updates only the correspondent SWS description. Goals, Mediators and other parts of the system (domain ontologies, infrastructure) are not affected.

Invoking a Goal A request presented by the user through the portal interface is satisfied by a goal achievement. The request is processed by the Life Event Manager module, which discovers all related life events, allowing the user to select the appropriate Life Event (e.g. Notify change of address). Information is described through the E-Government Domain Ontology, while the Goals are described via the Service Ontology. When the user invokes one of the goals, the Life Event Manager calls the IRS-III module, which retrieves the semantic description of the goal. Then, it creates an instance with specific data items, and identifies and invokes the web services addressing the user needs by means of their semantic description. Finally, the web service is executed by the PA information system and the result is presented to the user.

6.1 Prototype Scenario: Change of Circumstance

We illustrate the implementation of our e-government portal through an application scenario.

The prototype is a portal for the Essex County Council based on the infrastructure reported in Section 3. In this scenario the end users are the caseworkers of the Community Care department which are helping the citizen to report his/her change of circumstance to the different agencies involved in that process. In this way, the citizen only has to inform the county once about his/her change, and the government agency (Community Care unit) automatically notifies all the agencies involved. An example Community Care service scenario might be when a disabled Mother Moves In to her daughter's home. The change of circumstance provokes a change in which services and benefits – health, housing, etc. – the citizens are eligible to receive. Multiple service-providing agencies need to be informed and interact.

The main objective is that a citizen should only notify his/her change of circumstance to one single local authority. Then, all changes (Post Office, Treasury, National Health Service, etc.) will be automatically notified.

For instance, the mother notifies a case worker at Community Care department that she is moving. The case workers have a coordination role, which are frequently centred on tracking changes of the living address of the client.

We have developed the E-government Domain Ontology for describing the main concepts related to the change of circumstance scenario (Figure 2). The concepts describe the process of defining a *Case* for a particular *Client*. The *Case Worker* does an *Assessment* about the *Citizen* situation and takes a *Decision* about the *Benefits* and *Services* the Client is entitled to. Every Entitlement Type has specific Eligibility Criteria, described by a function.

The portal is associated with the Life Event Domain Ontology that can represent events related to the E-government Domain Ontology for Change of Circumstance. These include getting married, going into hospital, someone move in, going into residential/nursing home, inheriting money, winning a lottery, retiring, and death.

In addition, the Life Event Domain Ontology associates events with Semantic Web Services. In particular we refer to the *Someone move in* life event and its associated goal *Change of address*.

The prototype portal administers a network of agencies – service/benefit providers – that can register declaring which services/benefits they supply. Every registered agency publishes one or more SWS, which have to be based on the agreed E-Government Domain Ontology. There are a number of fixed SWS Goals (e.g. change of address) to which agencies could subscribe for publishing services.

Agencies can also define and make their own SWS Goals available through the portal. For instance, the change of address goal is defined by the Community Care department, but different agencies can create their own SWS for managing the change of address on their systems.

The case worker can register a new client, search or update the information of an existing one through the portal. He has to fill in several fields about the citizen's information. This information will be stored and related in the E-Government domain ontology, as a new instance of the class *Client*.

The same procedure is followed to register a new agency. This time it is not the case worker, but the agency, the one that registers itself. It also has to fill in the name of the service/benefit it provides (in the form of SWS), accompanied with the URL of the server where the SWS is published. This information will be stored and related in the E-Government domain ontology, as a new instance of the class *Agency*.

In Figure 5, we present the user interface for invoking the change of address goal. The case worker chooses the agency he wants to notify, he can also choose the option for automatically detecting the agency to notify. He then inserts the data of the client and activates the 'notify' button. With this simple form the case worker shares change of address details with relevant partner organizations (Housing, Pension Service, etc.) and providers of external commissioned services (e.g. meals on wheels and nursing support).

When doing this, the change of address goal is invoked and the IRS Server detects and calls the web services that match the data. A matching web service could be composed of different integrated web services that realize the change of address (updating different databases in different PAs). In our example, the Vulnerable Citizen Change of Address WS is detected (the web service published by the Community Care department). The client's address is updated in the Community Care legacy database and the user receives a confirmation on what happened. Figure 6 shows what happens in the IRS-module when the 'notify' button is pressed.

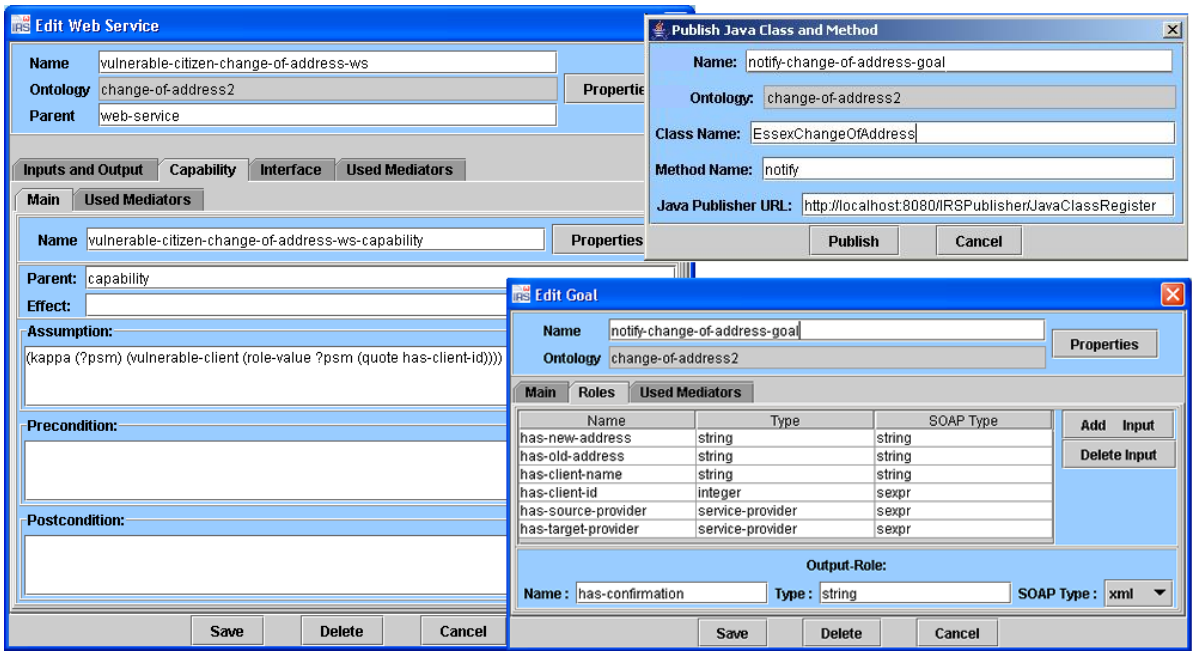

Figure 4. User interfaces for defining Goal and Web Service descriptions according to the WSMO ontology and the publisher interface for publishing SWS.

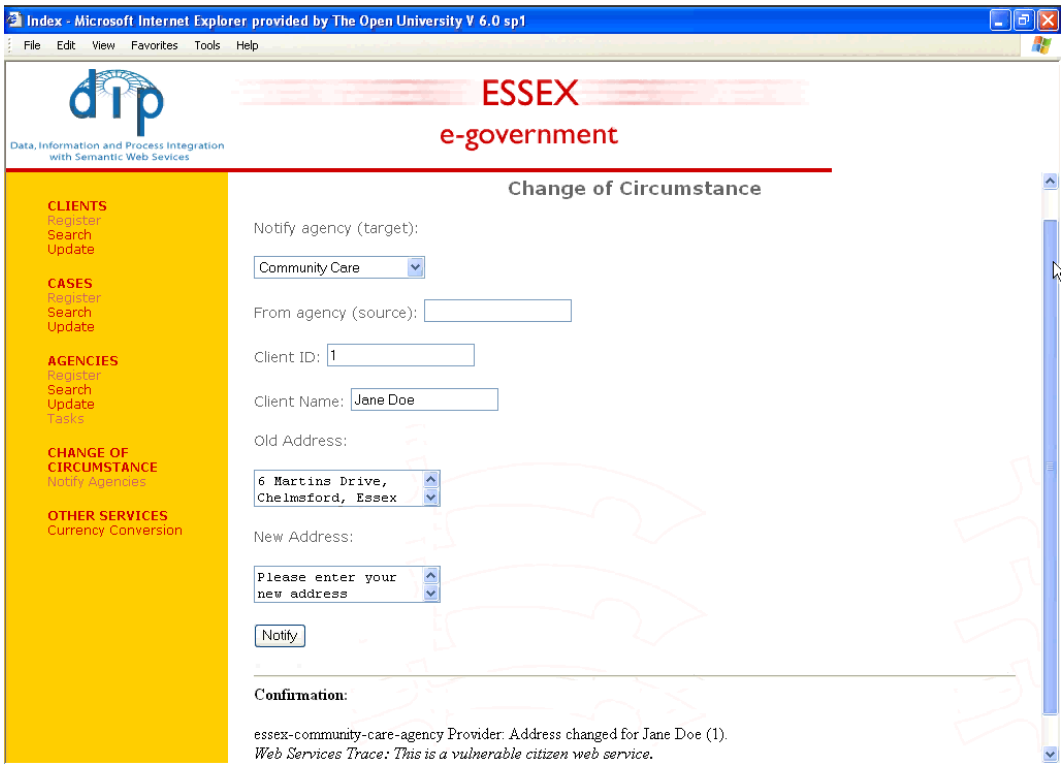

Figure 5. Web Page to invoke *the change of address* **goal**

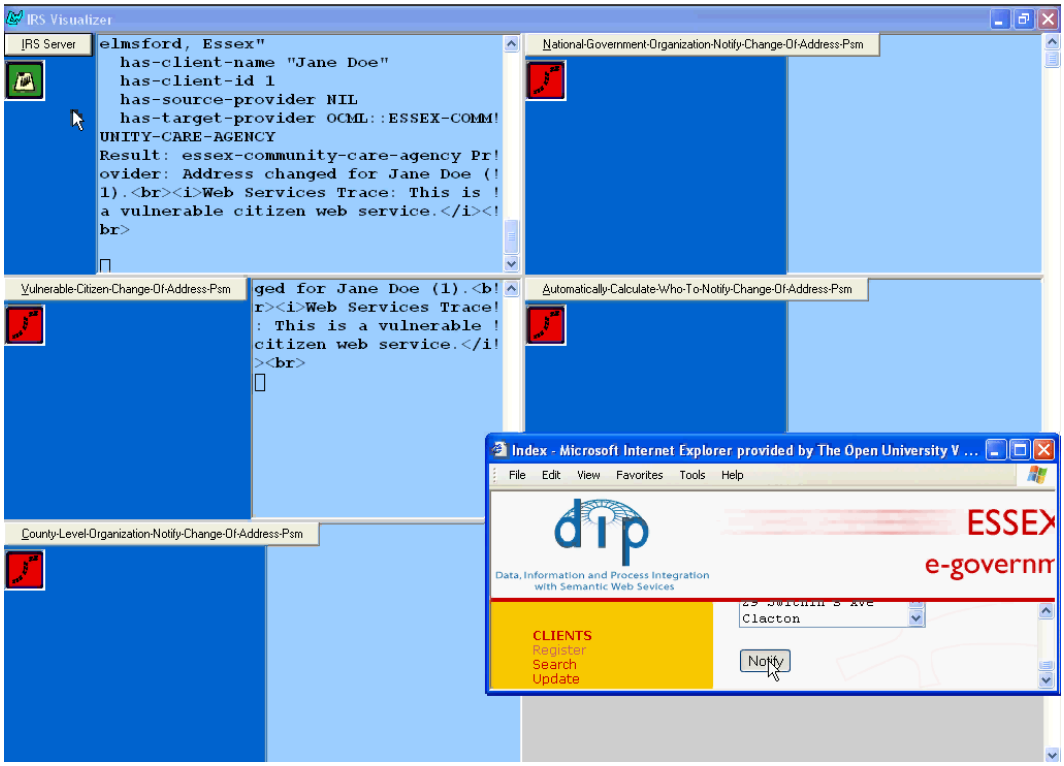

Figure 6. The IRS visualizer interface. It shows which web services are activated, among all published web services. Each box in the IRS visualizer represents a published web service. When a published web services is activated, its behavior (inputs, output, etc.) is traced in the respective box.

7 Conclusions and future work

The aim of our research effort is developing a semantic based architecture of a portal, that helps the user – citizen and business – to find the information and services that best fit his/her needs, and enables the interoperability between government agencies and service providers, as well as agencies to integrate existing service for creating new ones.

The proposed architecture is composed of a front-end, a middleware and a service layer; we focused on the second layer which defines an explicit conceptual model in terms of three domain ontologies: the E-Government, the Life Event and the Service Ontology, each of which is grounded on the upper ontology D&S, and an infrastructure for interoperability and integration in terms of Semantic Web Services, based on the IRS-III framework.

Our architecture applies semantic web technology at the data and service level.

A prototype of a portal realizing the proposed architecture has been implemented with a scenario about the 'Change of Circumstance' of citizens for illustrating the advantages of the proposed architecture. The difference between our prototype and the 'one stop portal' [23] is that end users are not citizens, but the main aim was to test the advantages of SWS in term of interoperability between different PAs and integration of services.

Future work includes the extension of the ontologies for capturing more concepts about the e-government domain and life events. Further life event and services descriptions will be integrated into the portal and a real one stop portal will be developed.

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