Grid-Based Decision Support System Used in Disaster Management

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Abstract: Natural disasters profoundly affect the development of human society, they are the most pervasive disasters in the world and they cause the greatest property and human loss. We consider that is absolutely necessary to develop a decision support system, which would prevent – as much as possible – natural disasters from occurring or would help mitigate their effects. All these objectives are unattainable without effectively applying information and communication technology in the field of natural disasters. The paper proposes a complex Grid-based architecture for assisting users in their decision making activities. With the help of actual semantic Web technologies, the designed system can be considered a viable solution for disaster management.

Keywords: decision support system, Grid, resource management.

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1. Introduction

Floods are natural phenomena that profoundly affect the development of human society as they are the most widespread disasters in the world and they cause the greatest property and human loss. The fact that the areas where flooding may occur are predictable and that warning is usually possible make flood risk management easier. Using mathematical simulations and models of flooding scenarios, we could able to prevent and to investigate the problems that arise during and after the occurrence of the disaster. Floods are modelled by (Donciulescu, et al, 1985), (Donciulescu, et al, 1986) in the context of decision support systems in water retention and alocation applications.

The paper describes a research project referring to the disaster prevention. Its main objectives are the following (Cioca *et al*, 2007):

1. Designing and building a calamity warning and prevention mechanism – an *early flood warning system* (EFWS);
2. Developing a *spatial information system* (SIS) by using geographical information systems (GIS), combined with mathematical models and other technologies, in order to evaluate the affected areas;
3. Developing flood scenarios processed by a *computational Grid-based system* and presented to the users via certain Web interfaces.

The main aim of the project is to accomplish the above mentioned objectives, as well as to pave the way for FP7 and the 2007-2013 National Research and Development Plan.

After the presentation of the concrete flood situation in Romania and the noticed difficulties in providing a coherent and global view of the calamity status, the paper will present most important characteristics of Grid architectures and tools. After this, we'll detail our proposal and we'll investigate the use of semantic Grid-based technologies in the domain of disaster management. The paper will end with conclusions and further directions of research.

2. Current Stage in Romania

Romania has lagged behind other European countries in terms of information centralization and access to information. The development of a spatial elements decision support system involves having access to diverse, updated information and making decisions based on accurate and promptly disseminated information. The resolution of this inconsistency is part of Romania's efforts toward Euro-Atlantic integration.

On the other hand, there are several sector domains which are actually deficient in information. For instance, for most of Romania's territory there is no thematic digital map designed at a reasonable scale (below 1:200,000), which will actually pose huge problems to our approach. However, there is a solution to this problem, although it entails a considerable amount of work: developing the GIS also involves creating a complex digital cartographic database.

Under disaster circumstances (rushes, floods, etc.) the flood warning systems that "fail" are, in this order: TV cable, electrical network, and possibly mobile phone networks. As shown below in figure 1, the system designed to inform the citizen on the imminence of a rush "short-circuits" – in general – between points 3 and 4 (5) and respectively 2-5.

Thus, we consider our solution feasible and realistic as it provides a practical alternative to existing warning systems. After discussing the issue with authorities responsible for informing the citizens of a certain locality (especially a rural one), we describe an actual situation that happened in the Sibiu area (Cioca *et al*, 2007). The head of a fire brigade who is a member of the emergency committee told us that "… during the flooding in commune X, I tried to contact the mayor in order to inform him. No one answered the phone in his office, so the secretary was not at work either, the mayor's mobile phone was turned off and I strived for about one and a half hour to reach him." (Cioca *et al*, 2007)

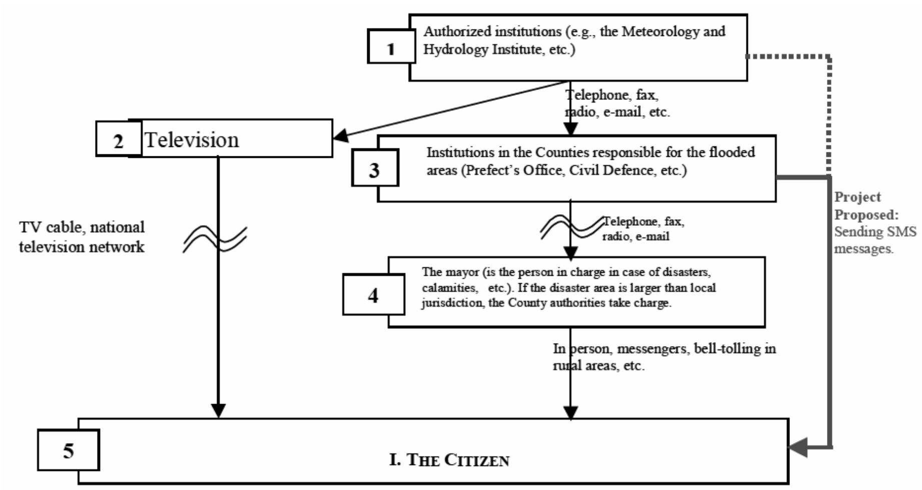

Figure 1. Classic Disaster Warning System Diagram

As the example tells us, one and a half hour was wasted in a situation when every second is crucial. If the person in charge with informing the citizens on the impending flooding had been able to use a communication system as that described below (and a database containing the phone numbers of all persons in the risk areas [data filed with the agreement of their owners and possibly for an immaterial fee of $0.5/month]), he/she would have gained 90 minutes.

We can remark that in the case of a rush (flooding, etc.), citizens may find themselves in one of the following situations:

- They are not informed on the matter.
- They are informed too late.
- They are informed at the right time (this has been rather uncommon in 2005 and 2006, especially in the rural areas).

3. Grid Technologies

In order to solve these difficulties and to build a concrete system, our proposal is focused on Grid technologies. This section will give a brief presentation of most important aspects regarding the actual Grid-based methodologies, approaches, and applications. Also, we draw several definitions and possible classifications of the Grid platforms, and we enumerate the challenges and different areas of research. At the end, we'll expose the use of semantic Web technologies in the context of Grid computing.

According to (Buyya, 2002), *Grid computing* – a new paradigm for next-generation computing – enables the sharing, selection, and aggregation of world-wide distributed heterogeneous resources for solving large-scale problems in certain areas of interest or for proving access to large data, information, or knowledge repositories.

Resource management and scheduling in existing environments – and in the special context of disaster management – is a complex under-taking. The geographic distribution of resources owned by diverse organization with different usage policies, cost models, and varying load and availability patterns is problematic. The producers (the owners of resources) and consumers (the users of resources) have different goals, objectives, strategies, and requirements.

To address these challenges, a systematic approach to model and retrieve certain resources has to be adopted. A system managing available knowledge must offer facilities for the creation, exchange, storage, and retrieval of knowledge in an ex-changeable, platform-neutral and usable format.

3.1 Preamble

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3.2 Grid Computing: a General Presentation

Definitions and Characterization

The actual Internet technologies' opportunities have led to the undreamt possibility of using distributed computers as a single, unified computer resource, leading to what is known as *Grid computing* (Buyya, 2002). Grids enable the sharing, selection, and aggregation of a wide variety of heterogeneous resources, such as supercomputers, storage systems, data sources, specialized devices (e.g., wireless terminals) and others, that are geographically distributed and owned by diverse organizations for solving large-scale computational and data intensive problems in science, engineering and commerce.

According to (Abbas, 2004) and (Laszewski and Wagstrom, 2004), different definitions of what Grid computing represent are available:

1. The flexible, secure, coordinated resource sharing among dynamic collections of individuals, institutions, and resources.

2. Transparent, secure, and coordinated resource sharing and collaboration across sites.

3. The ability to form virtual, collaborative organizations that share applications and data in an open heterogeneous server environment in order to work on common problems.

4. The capability to aggregate large amounts of computing resources which are geographically dispersed to tackle large problems and workloads as if all the servers and resources are located in a single site.

5. A hardware and software infrastructure that provides dependable, consistent, pervasive, and inexpensive access to computational resources.

6. A way of processing distributed information available on Web.

One of the most used definitions is provided by (http://www.globus.org): "Grid Computing enables virtual organizations to share geographically distributed resources as they pursue common goals, assuming the absence of central location, central control, omniscience, and an existing trust relationship".

Virtual organizations can span from small corporate departments that are in the same physical location to large groups of people from different organizations that are spread out across the globe. Virtual organizations can be large or small, static or dynamic.

A *resource* is a shared entity available in the Grid. It can be computational, such as a personal digital assistant (PDA), laptop, desktop, workstation, server, cluster, and supercomputer or a storage resource such as a hard drive in a desktop, RAID (Redundant Array of Independent Disks), and terabyte storage device. Other types of resources are the I/O ones: sensors, networks (e.g., bandwidth), printers, etc. Within a Grid, logical resources are also available: users, time counters and others.

Absence of a central location and central control implies that Grid resources do not involve a particular central location for their management. The final key point is that in a Grid environment the resources do not have prior information about each other nor do they have pre-defined security relationships (Abbas, 2004).

Related technologies to Grid computing are peer-to-peer network architectures, cluster computing and, of course, Internet/Web computing.

Architectural Model of the Grid

Grid applications are distinguished from traditional Internet applications – mostly based on client/server model – by their simultaneous use of large number of (hardware and software) resources. That implies dynamic resource requirements, multiple administrative domains, complex and reliable communication structures, stringent performance requirements, etc. (Buyya, 2002).

Some of the important issues regarding resource sharing across boundaries of organizations are (Abbas, 2004): identity and authentication, authorization and policy, resource discovery, resource characterization, resource allocation, resource management, accounting/billing/service level agreement, and security.

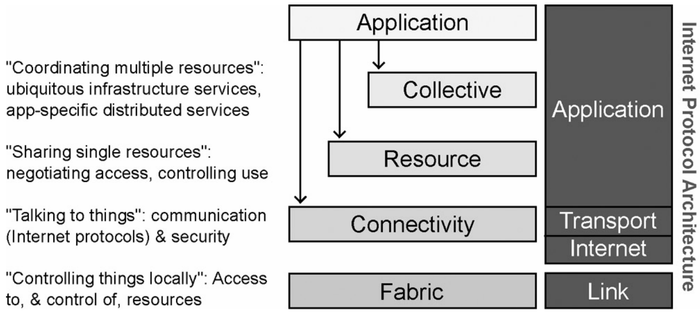

Figure 2. Grid model architecture (Abbas, 2004)

In order to address these problems, a set of protocols and mechanisms need to be defined and/or adopted.

The Grid architecture model is a layered one (see Figure 2).

Similar to Internet architecture, certain protocols, services, and APIs (Application Programming Interfaces) occur at each level of the Grid architecture model. The relationships between them are depicted in Figure 3.

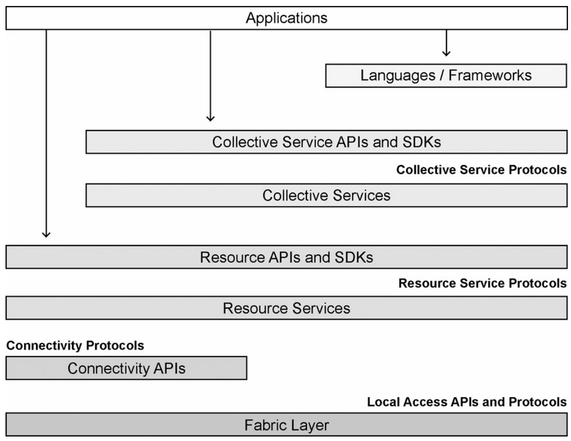

Figure 3. Relations between Grid protocols, services, and APIs – more details in (Abbas, 2004)

The *fabric layer* includes the protocols and interfaces that provide access to the resources that are being shared. This layer is a logical view rather than a physical view.

The *connectivity layer* defines core protocols required for Grid-specific network transactions. Normally, these utilize the existing Internet (TCP/IP) protocols via wired or wireless interconnection technologies. Another set of protocols defined by the connectivity layer include the core Grid security protocol – Grid Security Infrastructure (GSI) which provides uniform authentication, authorization, and message protection mechanisms.

The *resource layer* offers protocols required to initiate and control sharing of *local* resources. Several protocols, based on the existing Internet stack, are:

- Grid Resource Allocation Management (GRAM) is used for remote allocation, reservation, monitoring, and control of resources.
- GridFTP (File Transfer Protocol Extensions) provides high performance data access and transport.
- Grid Resource Information Service (GRIS) offers access to structure and state information within a Grid node.

The *collective layer* defines protocols that provide system oriented (versus local) capabilities for wide scale deployment of a Grid system. This includes index or meta-directory services in order to custom structure and access the resources available on the Grid. It also includes resource brokers that discover and then allocate resources based on application-level defined criteria.

The *application layer* defines protocols and services that are targeted toward a specific application or a class of applications (in our case, the decision support system). This layer is currently the least defined in the Grid architecture and depends on the specific suites of deployed applications.

Grid Initiatives

Globus is a reference implementation of the Grid architecture and Grid protocols providing software tools in order to build grids and Grid-based applications. These open source tools are collectively called the *Globus Toolkit* (the current version is Globus 4) (http://www.globus.org).

The main aspects addressed by Globus are the Grid security, resource management (GRAM support is available), data management (e.g., GridFTP), information services (for example, GIS – Geographical Information System).

Other related projects are *Apple XGrid*, *Condor*, *Legion*, and *Sun Grid Engine*.

Open Grid Services Architecture (OGSA) concerns the use of Web services technologies in the context of Grid computing (Berman *et al*, 2003). Grid services are in fact Web services (Erl, 2005) executed to give access to resources by using actual Web technologies and languages (e.g., WSDL – Web Service Description Language, SOAP protocol, XML – Extensible Markup Language). A standardized model of infrastructure is available: Open Grid Services Infrastructure (OGSI). In order to include different Web Services extensions (WS-Security, WS-Trust, BPEL4WS) and to define stateful Web services, an important proposal is the Web Services Resource Framework (WSRF).

The effort of standardization of Grid protocols, architectural models, and software tools is carried by the Global Grid Forum (http://www.globalgridforum. org).

Several Classifications of Grid

Regarding the type of resources, a three layer model (Jeffery and Kacsuk, 2004) for the Grid infrastructure was adopted by various world-wide research communities. This model views the Grid as an architecture made by:

1. the *Computational Grid* – the lower layer concerned with large-scale pooling of computational and data resources that requires significant shared infrastructure to enable the monitoring and control resources in the resulting ensemble. This kind of Grid can be further classified in *desktop grids*, *server grids*, and *high-performance/cluster grids* (Abbas, 2004). A computational Grid can offer access to data or to compute resources (services), in order to augment other resources.

2. the *Information Grid* – this middle layer allows uniform access – via metadata (data about data) descriptions – to heterogeneous information sources and providing commonly used services running on distributed computational resources; the computational resources can vary, from simple method invocations to complete sophisticated applications;

3. the *Knowledge Grid* – the top most layer provides specialized (meta-)services used for data discovery in existing data repositories and for managing information services; the meta-services aggregates many other types of services.

From the point of view of the structure of the organization (virtual or not) that uses a Grid platform, the following classification could be made (Abbas, 2004):

1. *Departmental Grid* – is deployed to solve problems for a particular group of people within an enterprise. The existing resources are not shared by other groups within the enterprise. This kind of

grids are named *cluster grids* (in the vision of Sun corporation, represents one or more systems working together to provide a single point of access to users) or *infra grids* (term used by IBM to define a Grid that optimizes resources within an enterprise and does not involve any other internal partner; physical localization could be a campus or interconnected campuses);

2. *Enterprise Grid* – consists of resources spread across an enterprise and provides certain services to all users within that enterprise (is also called *intra grid* or *campus grid*). Enterprise grids resources are protected by the corporate firewall;

3. *Extraprise Grid* – is established between companies, their partners, and their customers, at the level of the extranet. This Grid resources are generally made available through a virtual private network, in order to reach a common goal;

4. *Global Grid* – is established by several organizations to facilitate their business or purchased in part, or in whole, from service providers. It is based on the public Internet technologies (especially, via a Web portal). This type of Grid is also called *inter grid* by the IBM.

According to (Laszewski and Wagstrom, 2004), other classification concerns the specific of applications that can be deployed on the Grid architecture. From this point of view, Grid architectures are divided into following classes:

1. *N-tiered application architecture* – provides a model for Grid developers to create flexible and reusable Grid applications. In order to simplify the implementation and deployment, the Grid applications are decomposing into tiers.

2. *Role-based architecture* – can be adopted to identify fundamental system components, specify the purpose and function of these components, and indicate how these components interact with one another. Using this model, we can classify protocols, services, application programming interfaces, and software development kits according to their roles in enabling resource sharing. The Grid model architecture presented in Figure 2 respects this model.

Service-based architecture – using this approach, a Grid platform is composed by a collection of loose-coupling services. A service is a platform-independent software component, which is described with a description language and published within a directory or registry by a service provider. A service requester can locate a set of services with a query to the registry, a process known as *resource discovery*. A suitable service can then be selected and invoked, a process known as *binding*. These concepts are assimilated from the Web services and are used by the OGSA.

Grid Initiatives. Examples

In the following paragraphs, we'll give several examples of European Grid initiatives, mainly selected from (Jeffery and Kacsuk, 2004).

In order to build open, large-scale and inter-operable distributed applications in the context of Grid computing, one of the important requirements is the design of an environment in which collaborative distributed applications may be developed in a standardized way.

Actually, there are many existing network computing and Grid projects, each of them presenting various (incompatible) architectures and distinct characteristics. The main goal is to design a generic high-level Grid infrastructure able to give support for multiple existing and future protocols, programming languages, and standards. One of the most important infrastructures is the *GridPP* – A UK Computing Grid for Particle Physics, related with the Large Hadron Collider (LHG) Computing Grid – LCG project initiated by CERN – details in (Berman *et al*, 2003).

Another one is the *Fraunhofer Grid Alliance* that has been successfully applied to solving different engineering problems (e.g., casting process optimization, microstructure simulation, drug design).

There are also available special-purpose Grid infrastructures – for example, in the area of e-learning (the *ELeGI* project which uses different semantic Web approaches for creation of learning scenarios) or in the domain of digital libraries (the *DILIGENT* project).

A layered infrastructure for facilitating complex interactions between heterogeneous components is *tuBiG* (Alboaie and Buraga, 2003).

At the level of Grid architectures, we mention:

- JGrid – a Jini technology-based service Grid which extends the Jini low-level service discovery mechanism in order to efficiently find Grid services by using flexible search queries;

- GRASP – an architectural framework for Grid-based Application Service Provision that is built on the top of OGSA and offers support for service orchestration (composition and coordination of Grid Web-based services) via workflow specifications.

There are many Grid middleware proposals, concerning mobile computing, data access and integration, resource management, data routing, etc. Several examples are *Commodity Grid* (CoG) toolkits, *OGSA-DAI* and *UNICORE*, available for different programming languages (such as C#, Java, Python, Perl) and platforms (CORBA, JXTA, .NET) – more details in (Abbas, 2004), (Berman *et al*, 2003), (Laszewski and Wagstrom, 2004).

Other domains of interest are virtual surgery, molecular simulation, bioinformatics, photorealistic visualization, optimization problem solving, telecommunications, astrophysics and many others (Abbas, 2004), (Filip, 2002), (Shadbolt, 2006).

3.3 Semantic Web and Grid Services = Semantic Grid Services

To achieve significant knowledge acquisition and management, a Grid system must support user collaborative tools and, more important, must provide a means of adding metadata (data about data) about the concepts and relations established between the resources within a given Grid platform.

When advancing towards *Semantic Web* (Daconta, 2005), (Jeffery, 2004), the main obstacle is the effort that the creator of information must put into organizing the knowledge and metadata, into tagging entities and relations, using vocabularies he must be familiar with, in order to make it comprehensible not only for humans, but also for machines.

The solution for this problem is to offer software instruments which help *transparently* organizing data and metadata for machine-comprehensibility. The users of the Grid applications do not need to know semantic Web vocabularies, as the system automatically generates metadata based on the creator's actions and on the progress of the information manipulated within the platform, in order to classify and to further retrieve given resources. From our point of view, a Grid system can be enhanced to support semantic Web technologies, in order to create, manage and present knowledge for any categories of users.

Additionally, Grid services can be semantically enriched by metadata and ontological descriptions. We can mention *Semantic Web Services Framework* (SWSF) which includes several proposals like *OWL-S* (www.daml.org/services/owl-s/1.1/overview) and *Semantic Web Services Ontology*.

Using semantic Web-based descriptions for Grid services, the applications will automatically discover, invoke and compose the desired services. With the help of the ontologies, the inter-operability and execution monitoring are also possible.

The top-level process ontology proposed by OWL-S is illustrated by Figure 4.

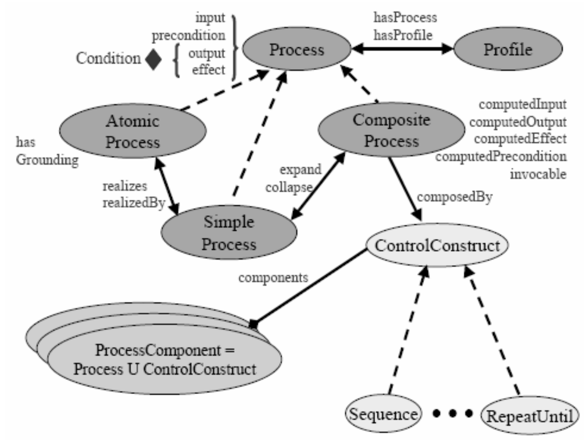

Figure 4. The process ontology defined by OWL-S specification (www.daml.org/services/owl-a/1.1)

A Grid resource accessed via a Web portal interface can embed the following metadata (for example, different DCMI constructs about an image created during a flood simulation on the Grid and supplementary annotated by the specialists):

```
<link rel="schema.DC" href="http://purl.org/dc/elements/1.1/" />
<meta name="DC.title" content="Flood affected area"/>
<meta name="DC.description" content="This is an image created during the flood simulation."/>
<meta name="DC.creator" content="Flood Software Simulator"/>
<meta name="DC.contributor" content="Sabin Buraga"/>
<meta name="DC.contributor" content="Marius Cioca"/>
<meta name="DC.created" content="2007-03-26"/>
<meta name="DC.modified" content="2007-03-27"/>
<meta name="DC.format" content="image/png"/>
<meta name="DC.language" content="en"/>
<meta name="DC.isPartOf" content="Disaster Simulation"/>
```

Using such of annotations, any Grid resource can be easily grouped for further processing.

A possible interesting aspects in resource modelling and structuring is denoted by the *Simple Knowledge Organization System* – SKOS, which provides a RDF-based model for expressing the basic structure and content of concept schemes (thesauri, classification schemes, taxonomies, terminologies, glossaries and other types of controlled vocabulary).

The following lines denote an OWL-S declaration which expresses the fact: “a collection of processes (services) are to be split for parallel execution”. At this level, no any information regarding the synchronization or waiting is made.

```
<owl:Class rdf:ID="Split">
  <!-- specialization of a control construct -->
  <rdfs:subClassOf rdf:resource="#ControlConstruct"/>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#components"/>
      <owl:toClass rdf:resource="#ProcessComponentBag"/>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
```

4. Proposed Architecture and Implementation

In the next sections, we shall describe our vision regarding the architecture of the decision support system to be used for disaster management. Our focus is to provide general solutions concerning the three aspects mentioned in the introduction of this paper.

4.1 Early Flood Warning System (EFWS)

To avoid poor of lack of communication in the case of urgency, a possible solution – which actually does not exist at the present moment – would have been a protocol between mobile operators and the Government, solution that mobile operators have probably never thought of, being to busy with sending to subscribers their unsolicited text messages with information on cultural events, bills, etc., which are undoubtedly important, but missing them never poses a threat to people's lives.

The proposal is viable also due to the fact that mobile telephony has gained more subscribers than fixed telephony; some families possess even 2-3 mobile phones, so there is a chance that at least one member of the family gets the warning in the case of certain calamity.

In Figure 1 (with a continuous line), the system develops at a regional (county) scale and may be easily expanded to a national one (with dotted line); if implemented at a national level, the system will radically reduce the number of situations when people is taken by surprise by raging waters, for example.

The minimum requirement is to send a text/picture message to responsible authorities (or directly to citizens) in the case of a disaster. The system must be as reliable as possible and platform independent. It must be user friendly and intuitive, addressing people with minimal/medium computer skills. These warning messages and announcements can be sent via regular SMS (Short Message System) facilities. An *intranet application* (under the control of an institution such as the Mayor's Office) must have access to an SMS server provided by a mobile operator.

The EFWS can function within a Grid system deployed by a civil authority (The Meteorology and Hydrology Institute, Mayor, Civil Defence, etc.) or – in extreme cases – by a military one.

4.2 Spatial Information System (SIS)

When we mention spatial information systems, we refer to a combination of GIS (Geographical Information System) technologies and computer numerical methods (models and algorithms) in order to build a spatial decision support system.

With the help of certain numerical techniques, machine learning algorithms, and optimization methods, the system can be very useful for modelling and simulating various possible scenarios.

One important aspect is to prepare non-spatial input data required by numerical models by operations executed on spatial data. Another one is starting a set of operations on spatial data in order to evaluate the impact the solutions obtained by numerical methods might have.

For example, when selecting a location for a point of observation regarding natural disasters, we can use a multi-attribute analysis approach (Cioca, M. and Cioca, L., 2005), in order to visualize the neighbourhoods and the access ways for making the right decision with the help of the proposed system (Filip, 2002), (Filip, 2004).

Various aspects regarding GIS technologies denote (Cioca *et al*, 2007):

- Basic digital maps (at a county scale) that contain infrastructure elements (e.g., road networks, hydrological network, and localities), administrative borders, building areas etc. as "support" information for control and decision management systems.
- Complementary digital maps that contain particular elements of every department or compartment and that will be made/integrated/acquired gradually within the system;
- GIS software solutions which can manage existing spatial information on various levels and enable the end-user to perform real-time updates and modifications of spatial information and central database.

Databases can be stored and deployed on classical actual database management systems (for example, *Oracle*, *Informix IDS*, *Microsoft SQL Server*). At the level of desktop, for mapping we can use an application like *MapInfo Professional*. A suitable solution for the intranet/internet is provided by *MapInfo Discovery* and *MapXtreme Deployment*.

Due to the fact that the acquirement of the input data (maps) – e.g., satellite maps – is the most time-consuming task, we can purchase maps of scales between 1:10,000 – 1:50,000 from *Geo Strategies* (http://www.geo-strategies.com).

The designed system must be simple and user friendly, in order to be accessed even by the end-users with no programming or Internet skills. The application must provide the quick access to the type and category of maps required and offer basic functions regarding map manipulation: pan, zoom, search, layer control, measure distance, select, etc. Also, the system needs to give flexible access to digital maps in different locations and made by different authors.

4.3 Grid-based Decision Support System

The decisional problems related to planning the water retention and allocation system have as main objective the maintaining water flows of rivers and water accumulations close to prescribed levels. Another aspect of interest is to meet, as much as possible, the necessities related to water consumption.

To have a global view about the situation of hydrological dynamics, certain mathematical models must be considered. Also, several simulations of risk situation (e.g., floods) and calamities (for example, overflows) must be easily performed, using geo-spatial acquired data. The system must warn the decision factors about the real problems that may arise, in order to communicate important information regarding these.

Data processing is a distributed one and concerns heterogeneous sources of information collected from above mentioned modules, from territorial points of observation, and from different external services.

A possible conceptual architecture for a semantic Grid platform that concerns services can be that proposed in (Fensel *et al*, 2002), but adapted to our context. To achieve an intelligent and automatic Grid service discovery, selection, mediation and composition into complex services, several aspects must be identified:

1. *Resource types* – modeled by an upper-level or several domain-related ontologies (in our case, for example: hydrological and spatial information, grade of flood severity);
2. *Syntax* – textual content of resources can be represented in different syntaxes available, but the best solution is provided by the XML family of languages, in order to provide platform independence, flexibility, reuse of data etc.;
3. *Semantics* – we must use vocabularies, metadata, ontologies, and rules (main layers of the semantic Web initiatives) (Daconta *et al*, 2003);
4. *Transport binding* – several transport mechanisms are provided by each Grid infrastructure (HTTP, HTTPS, FTP, SOAP etc.);
5. *Process definition/management* – this aspect is related with different Web services-related standards and initiatives (such as WSDL, WS-Addressing, WS-Coordination, WS-Policy, Business Process Execution Language and many others) (Erl, 2005) and process ontologies (see Section 3.3). This last aspect is very important for making decisions or for assisting users in the activity of decision making.

In the context of World-Wide Web space, a decisional system can function as a group of Web services in order to be invoked by other Web applications, within the proposed Grid system that can be viewed as a service oriented architecture (SOA) (Erl, 2005). An XML-based approach in storing decision trees could be more flexible and useful than classical representations (the XML format of decision trees can be viewed as a serialization mechanism of information or knowledge exchanged by decision-making components, e.g., Web agents or services) (Buraga and Rusu, 2006). A distributed native XML-based decisional system can play an important role, because it can offer semantic Web services for making decisions within complex Web applications – in this context, the Grid system. The decision rules incorporated by decision trees offer a superior layer of the actual semantic Web layers and can be easily expressed by XML constructs.

GIS data can be easily converted to XML documents, in order to be exchanged by the entities of the designed system modules, and to be mashed-up into other applications. For example, on the mobile terminals the users can detect in their proximity all risk areas to be avoided.

A possible general architecture is inspired by the *myGrid* (Jeffery and Kacsuk, 2004) project. With the help of semantic Web technologies, involved resources and decision making processes can be easily described, annotated, validated or/and controlled, among other activities – see Figure 5.

This architecture can be a suitable solution, regarding the management of the heterogeneous, complex and multiple inter-connected domain resources. Also, we considered that such of approach can be effectively used for monitoring and prevention of natural disasters. All involved Grid services can be semantically annotated in order to be easily composed and orchestrated.

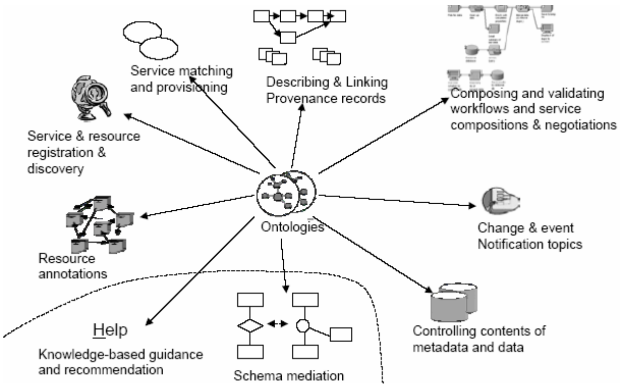

Figure 5. *myGrid project* (Jeffery and Kacsuk, 2004)

5. Conclusion and Further Work

Because of its complexity, the problem of disaster automatic management, in an intelligent manner can not be easily resolved. The paper drawn certain considerations regarding the actual situation of calamity warning and prevention activities and was focused on providing online support for making decisions regarding these aspects.

Several main components were identified, in order to simplify the design and implementation of a complex Grid-based system that can use semantic Web (Shadbolt *et al*, 2006) technologies for enhancing disaster management. The paper presented a general view of the proposed suite of applications and not imposed a particular, specific, solution of implementation.

Unquestionable, further studies must be directed. One important path will concern the aggregation and visualization of the data about the observed disasters. Other interesting directions regard the searching, reusing, merging distributed ontologies and discovering and classifying the relationships (Sheth et al., 2003) established between different Grid components.

Using different approaches for expressing decision rules and workflows, the system can implement a module that may act as an expert system.

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