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A Holistic ICT Solution to Improve Matching between Supply and Demand over the Water Supply Distribution Chain

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ABSTRACT

While many water management tools exist, these systems are not usually interconnected and therefore cannot communicate between one another, preventing Integrated Water Resources Management to be fully achieved. This paper presents the solution proposed by WatERP project[*] where a novel solution enables better matching between water supply and demand from holistic perspective. Subsystems that control the production, management and consumption of water will be interconnected through both information architecture and intelligent infrastructure. The main outcome will consist of, a web-based Open Management Platform integrating near real-time knowledge on water supplies and demand, from sources to users, across geographic and organizational scales and supported by a knowledge base where information will be structured in water management ontology to ensure interoperability and maximize usability. WatERP will thus provide a major contribution to: 1) Improve coordination among actors, 2) Foster behavioural change, 3) Reduce water and energy consumption, 4) Optimize water accountability.

KEYWORDS

SOA-MAS, Water management, Ontology, Agents, WaterML2.0, IWRM, Logical models.

INTRODUCTION

Water domain situation

In recent years, water shortage has become an increasing concern, with a growing imbalance between water demand and availability reaching critical levels. As cities grow and environmental problems escalate, managing human demand for fresh water presents an increasing challenge [1]. Increasing scarcity of supply, pollution, over-exploitation of resources and climate change are placing increasing stress on water supply systems. Meanwhile land use changes affect groundwater bodies and surface water ecosystems, putting more pressure on water reserves [2]. With ever-growing demand reaching ecological and economic limits, the need for innovative water management is acute. The worldwide gap between water demand and availability is projected to grow significantly in the next 20 years, reaching nearly 40% by 2030. In Europe, climate change is causing increased water shortages and more frequent, more severe droughts, especially in Mediterranean countries [2]. Under mid-range assumptions on temperature and

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precipitation changes, water availability is expected to decline in southern and south-eastern Europe by 10% or more in some river basins by 2030. The sectorial profile of water abstraction is also expected to change [3]. Meanwhile, water demand is increasing as a result of population growth, changing consumer patterns and growing industrial use [4]. In order to secure water supplies into the future, there is an urgent need to transition towards a more water-smart society and develop water-wise solutions to improve water and energy efficiency, reduce water consumption and preserve water resources [2].

Water resource management situation

Water resource management involves a wide array of actors, from water authorities to water regulators, water utilities and finally the end-users. While many optimization, planning and monitoring tools have been developed and are currently used, such as hydro meteorological forecasting and hydrologic and hydraulic models, decision support systems for reservoir and hydraulic infrastructure operations, and real-time monitoring and control systems for water treatment and distribution, these systems cannot communicate between one another and currently no framework is available for integrating all of these applications [5]. Yet water management is becoming increasingly more complex, with continual changes in human and natural systems affecting water availability, access, affordability and quality [4] and therefore, there is a need for more integrated and adaptive management approaches based on reliable monitoring systems and a solid knowledge base [2].

Although water and energy savings have been achieved in various sectors, these improvements are localized and uncoordinated. Each entity currently acts independently without much knowledge regarding the needs, constraints or operations of the others and information is not easily accessible. Yet net water savings and environmental improvements can only be realized if the water saved in one area is not used elsewhere by others or downstream [6]. In order to achieve wide scale improvements, there is a need for enhanced coordination, cooperation between water supply actors across different scales, in order to address both long-term water imbalances (water scarcity), and enhance resilience to drought [7].

In parallel, there is a need for increased information sharing. If information were shared among the various decision-makers and stakeholders, operations could be coordinated, better decisions could be made, water supplies could be prioritized according to needs and changing conditions, overall water use efficiency could be improved, and water shortages and energy waste could be reduced.

Why this is the right moment to go a step forward?

Over the past decades, Europe has made important progress in regards to infrastructure, technologies and water management. However, despite substantial efforts and improvements related to water resources management, the 2010 European Environment State and Outlook Report revealed that many of the water bodies will fail to meet the Water Framework Directive (WFD) objectives of achieving good status by 2015. Meanwhile, freshwater systems are still under pressure, demand often exceeds availability, and drought and water stress are expected to increase as a result of climate change. There is a need for a more sustainable approach for water resources management to improve water demand management more widely across Europe and to avoid mismanagement of water resources, especially in areas of water scarcity [8].

While the WFD river basin management plans will remain the primary framework for managing water resources in Europe, a new demand-side management approach is needed, including measures such as water pricing and efficiency in order to secure water for all essential uses. This new water paradigm is what the upcoming Blueprint is set out to accomplish. In parallel, the 2011 Flagship initiative on resource efficiency under the EU 2020 Strategy makes water saving measures and increasing water efficiency a priority.

One of the most innovative elements of the WFD is its integrative approach to water management, bringing together different water management issues within a unified framework. Recent ICT technological advances make sharing information and such integration all the more possible. Information systems are now being called upon to support knowledge management and not just to process data or information. Today, information can be exchanged in real-time, very large amounts of data can be processed in automated manners and web-based internet services enable information to be collected, processed and shared in ways that were not possible before. With the upcoming next generation of semantic applications, data can become more machine-interpretable by developing ontologies that can support the development of integrated software systems, and by aligning the ontologies of different applications, information can be shared, resulting in increased interoperability [9]. A framework providing interoperability between loosely coupled software applications and data sources, as is being proposed in WatERP project, will enable integrated water resources management to be achieved. Indeed with new applications and web-based services supplementing existing tools within a joint collective network, current water resource management capabilities can be greatly enhanced.

One of the first ICT water management resource planning concepts was adopted by Visseman ad Welty [10] in 1985 and the next year, the first water resource planning tool was implemented and integrated into a Decision Support System called StateMod [11], it is capable of making a comparative analysis for the assessment of various historic and future water management policies, simulating water flows, allowing reservoirs to be operated with multiple accounts serving multiple users, and estimating natural stream flows and reservoir data. During following years, the interest in the “systems” approach grew with the advent of much more user friendly PC-based software. The evolution of PC optimization and mathematical tools permitted the application of these technologies in the water resource management planning framework. However, the process of translating a water resources problem into a mathematical problem causes much of the reality of the problem to be lost. As a result, analysts turned their attention to more user-focused descriptive approaches. Expert systems and emerging artificial intelligence techniques offered the promise of a more user-centred approach. User-defined heuristic decision rules [12] were developed, the resulting advantage of this architecture being the inclusion of the clients in the problem definition to solve and adapt the water resource planning management according to their necessity. Early on, the experience with experts systems indicated that the most important need for decision support systems was a user-friendly database management system.

In the last decade, ICT management architectures for complex installations (water deposit, water treatment plants, waste water treatment plants, water distribution, etc.) have become widespread, focusing on concrete and specific applications. These infrastructures provide information about the status and performance of the installation, integration of sensors, media and databases [13-17]. Numerous efforts in artificial intelligence were made to solve problems of conventional processes by applying different knowledge-based systems. Related to the water supply distribution chain, knowledge techniques have been developed as isolated support systems for monitoring, diagnosis, design, process optimization, etc., [14, 18-20] among others. These systems are becoming more and more sophisticated, advanced and have enabled significant water management improvements. However, in today's complex installations, the information is treated as a local resource and is not shared between systems.

THE SOLUTION

Holistic view, basin scale approach

Water resources management is extremely complex, related not only to the environment but also to the numerous human activities that are carried out within this environment. Water availability and usage depend on the timing and manner of its arrival (rainfall intensity, rain or snow, duration, frequency), the physical setting of the region (climate and weather, topography, geology), the engineering structures in place, the environmental constraints (existing ecosystems), as well as the legal regulatory context and institutional policies.

Traditional approaches to water resources management have typically been based on black-box optimization models, handled by technical people and developed for very specific purposes. They do not include interactions with the end users or stakeholders involved and have not been able to include in their computations the full variety of important factors that must be considered by decision makers, or in ways that are transparent to the public.

The water industry lacks an adequate holistic understanding of water supply, its use, and how it flows. A common subject across the entire water chain is the need for improved data collection and the transformation of that data to generate actionable information and knowledge. Moreover, the Water industry is under pressure to take a more holistic perspective of water, considering its whole life cycle from abstraction to treatment, distribution, use and end treatment. This also means a stronger recognition of the role of green infrastructure.

The potential for service integration between water sectors is enabling companies operating in the water industry to examine mechanisms by which technology and its usage can bring holistic improvements to the water network and bring potential reductions to their operating costs.

Therefore, there is an urgent need for more holistic approaches that can address the complex coupled human and physical system interactions at the basin scale. Furthermore, new integrative approaches must include multi-resolution capacity so that findings and information can be transferred and used across models and users, based on an agreed-upon conceptual model of the system. Doing so will help stakeholders and decision-makers understand what are the main issues and challenges at the system level, but also for each stakeholder.

Scope

The WatERP solution focuses on the different actors involved in water supply distribution chain and on obtaining, from each one of these, the necessary parameters required for enabling demand to be matched with supply across the entire cycle. For this purpose, WatERP will provide standard interfaces to integrate the necessary information from each supply management step, either through direct interaction with control or management systems.

Ultimately, WatERP will result in a web-based Open Management Platform (OMP) tool that integrates near real-time knowledge on available water supplies and demand, from water sources to users, and across geographic and organizational scales, so the information from each step of the process can be exchanged and accessed and the entire water supply distribution network can be viewed, understood and improved in an integrated and collaborative manner. This platform will be integrated in an intelligent ICT architecture that interconnects different management tools (or building blocks) available in the supply distribution network and will be supported by an ontology driven knowledge base on water supplies and water usage providing a continuous flow of information including historical, current, and forecasted values.

Description

The OMP will provide water resource managers inferred information regarding water supplies, flows, water consumption patterns, water losses, distribution efficiency, and water supply and demand forecasts, within an intelligent unified framework based on open standards. This information will be stored using semantics and common language which will be defined in the water management ontology to ensure interoperability and maximize usability. External linkages to costs, energy factors, control systems, data acquisition systems, external models, forecasting systems and new data sources will be made possible for easy integration into the system. The main purpose of this information interaction and processing will be to improve the matching between supply and demand. To achieve this final goal, tools will be developed to support coordination of actions throughout the entire water supply distribution chain, prioritization of water uses, distribution efficiency improvements, and water, energy and cost savings. In addition to the openly extensible technology platform, WatERP will provide end-to-end consulting and systems integration services that include:

- Operational dashboards for continuous monitoring of time-sensitive key indicators and metrics;
- Advanced rules management, constraint-based optimization, and visualization tools to more effectively manage and automate the water management decision making processes;
- Integrated high-resolution local weather predictions that will enable optimizing weather sensitive water management operations to improve availability;
- Innovative capabilities for standards-based, secure data exchange;
- Analytical demand-management and decision-support tools as well as access to information from other sources;
- Ensuring appropriate information is available at the right time, place and scale.

To accomplish its function, WatERP will develop the following building blocks:

- Decision Support System (DSS);
- Demand Management System (DMS);
- Water Data Warehouse (WDW).

The information produced for these building blocks and others systems (external systems) will be interconnected through a specific ICT architecture, the knowledge structured and managed by the water management ontology and the interaction of the information and knowledge with the water resource manager performed in the OMP. The following sections of this paper are focused on the last three systems.

The ICT architecture

The communication architecture will focus on providing intelligent and near real-time linkage between the various water supply distribution chain management tools or building blocks (Data Management Systems, Decision Support systems, Demand Management Systems, Weather Forecast Systems, etc.) and the OMP that will support water management decisions, enabling knowledge-based water governance to be achieved throughout the water supply distribution chain.

A combined Service Oriented Architecture (SOA) with Multi-Agent System (MAS) is being designed to:

- Link each decisional/informational system to help the integration in a collaborative framework;
- Provide near real-time information flow;
- Distributed intelligence to generate actions and alerts related to management processes;
- Procedure to perform orchestration of existing and new management tools throughout the whole architecture.

Nowadays, SOA architecture is a booming technology with a high level of maturity and success. It is widely used to exchange information between systems that are located remotely and managed by third-parties (e.g., legacy systems, systems with unknown codification and exploitations, etc.). This architecture permits the orchestration and automation of critical processes using a distributed architecture that exchanges the information in a standardised way, XML being the format most typically used. Thanks to this concept, the internet provides millions of services and resources around the world. A good example in the water domain was developed by CUAHSI (http://www.cuahsi.org/), providing hydrological information via Web Services.

Nowadays, the problem is not the lack of information, but rather its integration with a common goal. With the aim of integrating and reusing knowledge provided by different services and resources, techniques such as BPEL engines [21] or matchmaking multi-agent systems [22] are used. The BPEL engine allows creating static business processes with the services to orchestrate those [22-24]. Alternatively, the MAS are used for their flexibility and dynamicity in matchmaking problems. The MAS can solve conflicts, adapt to changes and is highly scalable [25].

Water supply management involves a very large quantity of control and management systems (services) that must be interconnected and orchestrated, along with the emergence of new services. WatERP’s SOA-MAS architecture is based on a pool of services provided by the building blocks and ontological instantiation. These services should be orchestrated with the purpose of integrating all information and facilitating the decision making to improve water resource management and energy efficiency. Different alternatives exist for this purpose such as previously-mentioned BPEL and MAS. In spite of its extended application, BPEL presents a well-known disadvantage, its stiffness [26]. This disadvantage limits its application in the WatERP project, mainly because of its lack of flexibility and inconvenience for easy integration of new services or the modification of existing ones.

To overcome this challenge, one of the most applied solutions by the scientific community is, the implementation of a matchmaking process by using agents which auto-manages services in order to fit the needs [22-24]. The MAS orchestrator is flexible to integrate new services at any time which is essential in the water management. This flexibility is provided by the auto-organization of the agents which manages the needs of the platform and the knowledge of the provided services. Moreover, the use of MAS provides numerable intrinsic benefits such as fault tolerance, scalability and flexibility. Therefore, MAS is the piece of the puzzle which best fits the different services because it provides two important benefits to the orchestration which are not provided by the BPEL. These benefits are: flexibility and scalability.

In order to ensure interoperability all the ICT architecture is designed following standardization principles. The WatERP MAS is therefore being designed by following standardized languages to communicate among agents such as: FIPA-ACL and KQML.

Once the MAS orchestration identifies the service provided by a building block that satisfies the requirement, the involved agent need to interact with the deployed services to transfer the information/knowledge required. To do so, agents and building blocks must accomplish an open interface based on a standard layer to provide its functionalities. This standard layer facilitates the discovering of service functionalities and is based on Open Geospatial Consortium (OGC®, http://www.opengeospatial.org/) WPS/WFS specifications. Moreover, with the aim to standardize the exchange information between the MAS and services, OGC®'s WaterML 2.0 will be used as the common transport format.

Figure 1 depicts the ICT architecture design. The three main building blocks represented (DMS, DSS and External Systems) interchange information with the MAS through an open interface based on WPS (or WFS) standard schema. The integration of MAS with WPS/WFS conforms the SOA-MAS architecture that enables interoperability by connecting each of the building blocks according its requirements and needs (matchmaking process). Furthermore, the figure shows how the information from water operators (Authorities/Utilities) is gathered, transformed and published on an OGC-SOS server towards feeding the Water Data Warehouse (WDW). The WDW offer the data/information to the visualization and decisional systems such as DMS, DSS, External systems and the OMP by using the same architecture. Transversally to this architecture where the information flows continuously, the WatERP ontology permit to enhance semantically the water domain knowledge by adding metadata information related with water domain decisional, observation and measurement process. This semantically definition stored in the ontology is able to improve the interoperability by enhancing data provenance (by categorising it measurement process) and data fusing (by understanding the measurement nature).

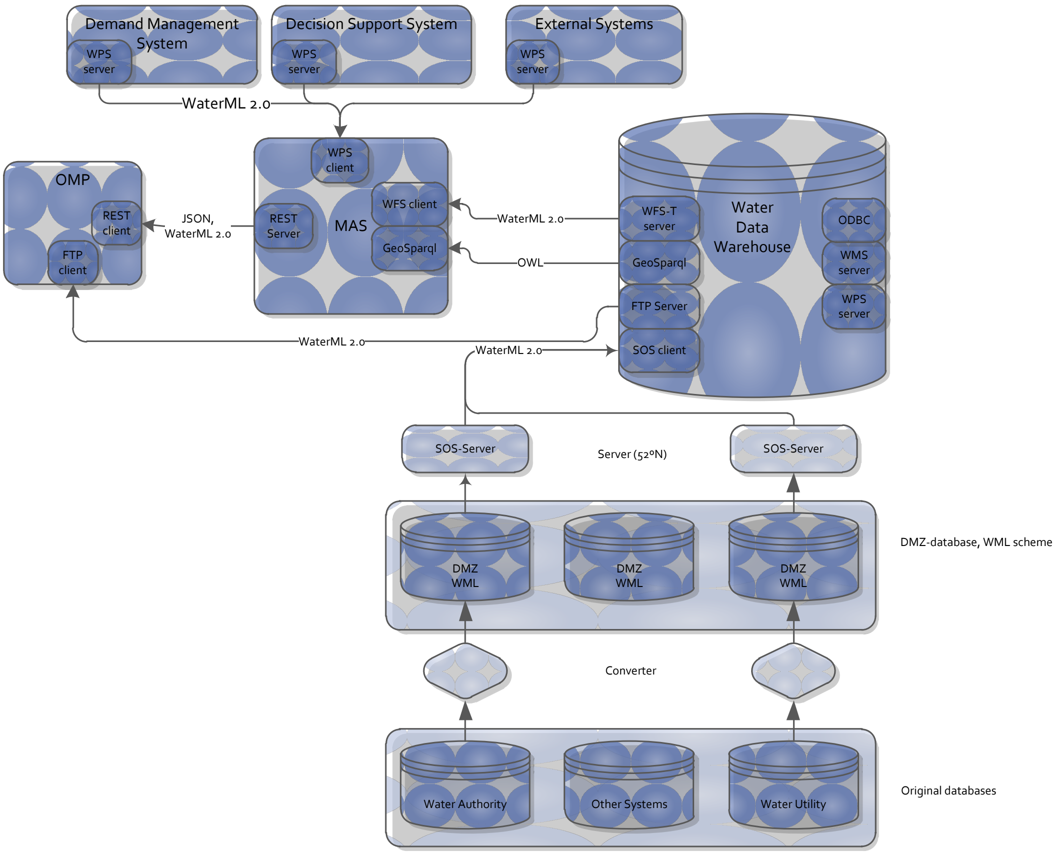

Figure 1. ICT architecture initial design

The water management ontology

The WatERP ontology (Figure 2) will provide easy access to information and will support decision-making and water resource planning. All of the decision making processes will be vertically integrated using universal standards in such a way that different multilevel inferences can be made:

- In each step of the water supply distribution chain;
- From the interactions among functions involved in each step of the water transport from the hydrometeorological data to the final user;
- From the interplay between currently separated control and optimization systems such as reservoir or hydroelectric plant decision support systems or water treatment and distribution management tools;
- From analysis of the impact of water savings on energy savings.

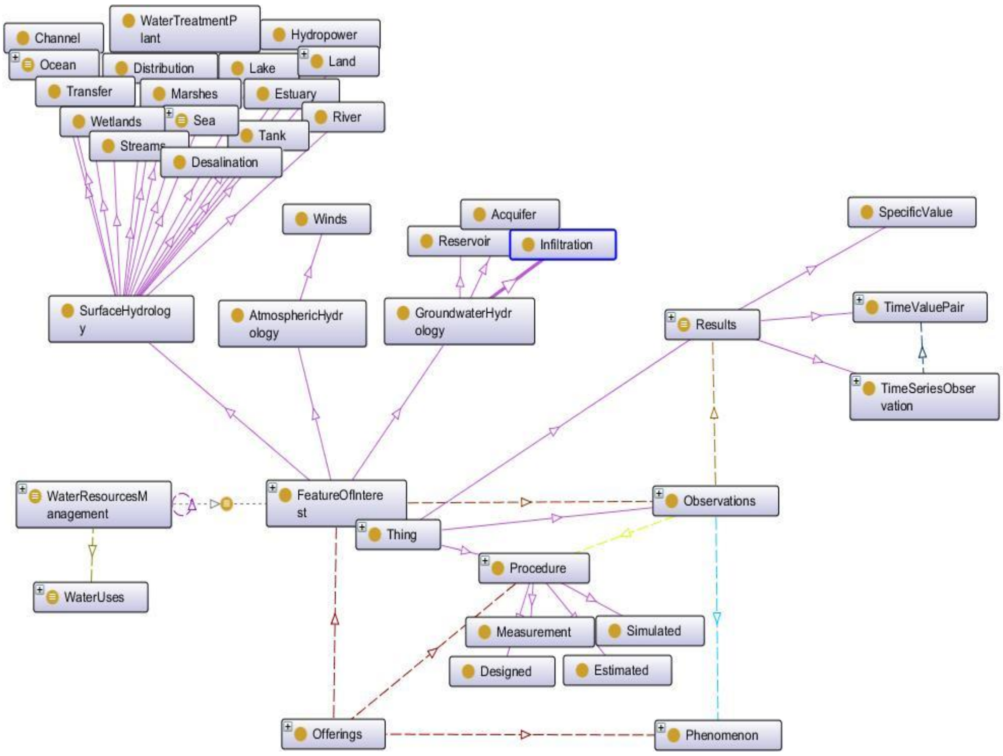

Figure 2. WatERP ontology general overview

The water management ontology contains corresponding ontologies, as well as multi-level data regarding:

- Water resource availability;
- Ecological, cultural and social functions of water resources and potential impacts of changes on hydrological regimes;
- Current water infrastructure/assets and the economic value of water;
- Administrative, policy or regulatory issues of relevance;
- Sectorial use and water hierarchy.

Existing ontologies such as those developed by CUAHSI and the OGC® have tried to model the hydrologic cycle from the hydrological and environmental perspective. Following a different approach, the National Aeronautics and Space Administration (NASA) tried to give a definition of the hydrological cycle with the perspective of the earth/environment science connection (NASA-SWEET ontology). On the one hand, the knowledge base such as the one developed by CUAHSI was done by merging the hydrological and environmental fields in a way as to provide sensor information of the water environment and correlate it with environmental data. However, CUAHSI's application does not show linked information semantically or link it with the web to create a certain meaning for each data. On the other hand, ontologies such as SWEET, OGC® (Onto Sensor and more) and W3C-Semantic Incubator Group (SSN ontology) provide mechanisms that support information retrieval from sensors (case of Onto Sensor and SSN ontology) and also provide an environment where multiple fields and sciences are linked semantically and are defined by a trustworthy organization (case of SWEET).

However, there is no ontology that encompasses the water cycle from its management perspective with the aim to establish recommendations and alerts regarding actions taken or decisions made concerning its various elements. Such harmonization could provide the water field the possibility of an enhanced understanding, and in an automatic way, of water resource management systems. The novelty of the WatERP ontology over previous developments lies in its inclusion of man-made infrastructure elements. Doing so enables them to be linked to the natural water flow processes such that the interactions among natural and human made entities can be better understood, along with their effects on water resources management. These human made modifications of the natural hydrological cycle flow paths have been defined in WatERP as human-altered paths. As a result, the WatERP ontology can semantically represent both the human-altered and natural paths to discover new interrelations (hidden knowledge) among water resource elements, ultimately enabling improvements and new strategies for water resource management (Figure 3).

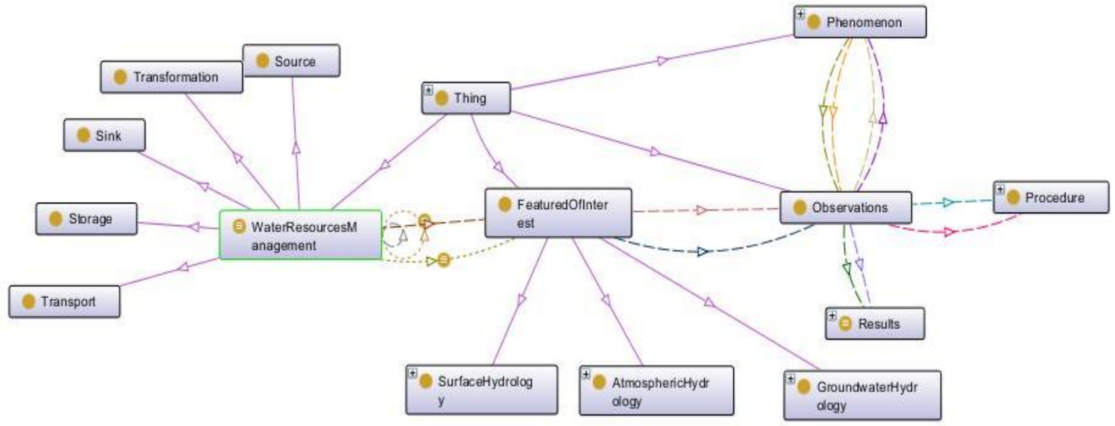

Figure 3. WatERP ontology decisional process representation (logical models) and the linkage with the observation and measurement process

This knowledge representation is supported by a data provenance mechanism in order to define a process towards observation understanding and standardization of the ontology including concepts and standard terms provided by other ones, such as the NASA, CUAHSI, OGC® and World Wide Web Consortium (W3C) ontologies. Moreover, the WatERP ontology has been constructed following the principles of Linked Open Data Cloud (LODC) contributing to the aim of achieving interconnectivity within the WatERP solution. LODC permits resources to be accessed by an URI and linked with other elements enabling automatic understanding (human-readable). From this, ontological information can be integrated and accessed, the terms of different vocabularies can be mapped, and data fusion supported. All of these features contribute to resolve data conflicts by integrating data from different sources into an entity.

The Open Management Platform (OMP)

The WatERP Open Management Platform will be a water supply distribution chain information hub, which will support decision making at different stages such as water supply and demand (and forecasting), determining water consumption patterns, water allocation decisions, etc., all of which will help improve overall water governance. The OMP will integrate the outcomes of the existing building blocks and modules in a graphical way which will empower local and global management. Along this line of improvement, a business intelligence tool will also be provided including predefined dashboards and reports according to the needs. These dashboards and reports will be defined in a way that they can be easily extended or modified according to specific needs.

It is important to remark that WatERP innovates with respect to the existing hydrological systems knowledge representations by defining an ontology that encompasses all of the elements and knowledge involved in water management. The Water Management Ontology is specified using logical models, which constitutes the basis for the analyses performed by the water resource manager. A logical model is the representation of the managed water supply system components and relations that acts as interface between the water manager and the water management ontology. As such, the user can obtain information from specific ontology as well as recommendations based on applying a rule-based analysis based on expert experience. This will allow two kinds of abstractions to be made: one regarding to the elements' interactions and other regarding to the specific information available in each of the physical elements involved. In the OMP, the abstraction of the geographical environment is achieved by the inclusion of the logical model.

In practice, the inclusion of logical models allows parts of the water supply distribution system to be grouped or detailed as needed in function of the quantity and quality of existing information and the decisions that must be made. Thus, it is possible to include in the platform all decision groups (one or various elements grouped) of the system with the same level of knowledge than the users, so that the system can grow over time as the user gains more knowledge about the physical environment. The introduction of logical models does not mean that the system removes any reference to geographic elements or temporal scope of decision, but rather, that each of them are defined according to the type of logic element to which they relate:

- Each element of the logical model corresponds to one or a set of physical elements;
- Each element of the logical model has its corresponding temporal scope. It should be noted that there may be other logical elements containing the same information but with a different temporal scale.

Logical models (Figure 4) define each use case which is managed by the resource manager. Therefore, it is essential that the OMP implements a Graphical User Interface (GUI) for handling, creation and editing of the logical models. In addition to allowing visualization of the water management chain where decisions are being made, the GUI has to permit access to the information contained in each entity of the model.

For interoperability of logical models in the field of hydrology, the only significant existing effort is HY_Features, However, at present there is not yet an OGC® standard (under Discussion Paper state) for this and its technology is not enough mature to use it at this moment. Because of this, logical models are actually instantiated entities of the WatERP management ontology; and the proposed encoding and exchange language of logical models is the same used for the actual design of the ontology (typed in an OWL format). It is important to mention that OGC® is currently working on the development of a future standard for semantic representation in the water domain (HY_Features). This initiative is in its early stages of development; nevertheless, it is being considered and will be tracked during the design of the WatERP management ontology.

Any logical model has a correspondence to a physical model. A physical model is a collection of real elements that match a structure consisting of a geographical positioning component and other associated information (geodata). These elements define how things work in real life. Therefore, they have to be also managed by the OMP facilitating interaction with their information. As the standard language for interoperability with geodata, the use of Geography Markup Language (GML) is used, both standard Open Geospatial Consortium and ISO 19136:2007.

Logical and physical models contain information to be provided through OMP to the water resource manager, such as observational data that will be used as input to decision-making processes. This information is based on time series, and these series are within the scope of hydrology. There have been several efforts to standardize the exchange of this kind of information, these efforts have concluded in the specification of WaterML2.0, which is an OGC® encoding standard for the representation of hydrological observations data with a specific focus on time series structures. WaterML2.0 is implemented as an application schema of the Geography Markup Language version 3.2.1 (GML), making use of the OGC® Observations and Measurements standards. WaterML2.0 transports can be made in any form: email, ftp, file-copy, arbitrary http or standardized http transfer (as OGC® Sensor Observation Service or Web Feature Service), this constitutes a very important characteristic for information exchange.

In summary, the GUI concerning the decision making process exploits ontological resources defined in the specific ontology (using logical models) to give the user information linked semantically and associated with its geographical location and temporal scale. This linkage between concepts (ontological resources), temporal scale and geographical information renders graphically understandable measured variables and facilitates decision making and permits to implement practically the holistic approach.

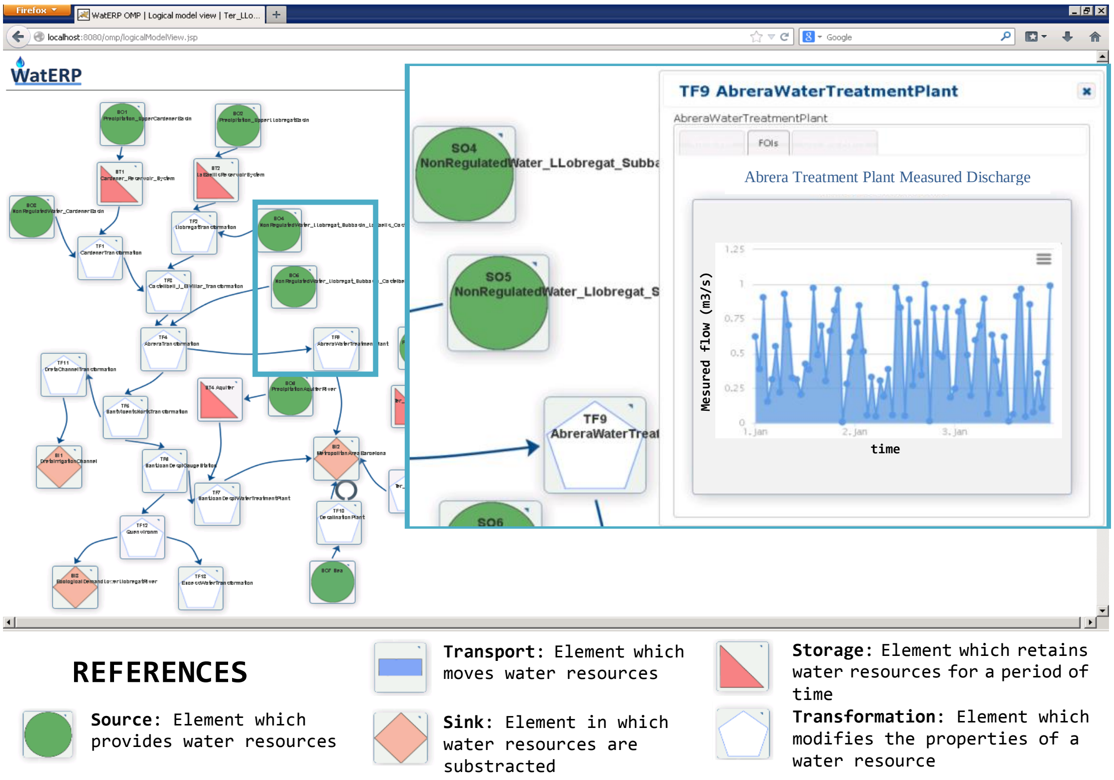

Figure 4. Logical model representation inside the OMP

CONCLUSIONS

The combination of SOA and MAS architectures and particularly the matchmaking use of agents, provides the whole architecture with:

- The capacity of selecting the most appropriate and required information for the water resource manager (via OMP) and the rest of modules interconnected;
- Conflict resolution between information providers;
- Orchestration of the architecture modules in order to manage the knowledge provisioning according to the desired business process goals (e.g., energy efficiency, matching supply with demand, etc.);
- Common and standardized language that permits the communication between agents (e.g., using FIPA language; KQML) and with the building blocks of WatERP's architecture that have a service behavior (e.g., WaterML2.0). Given the interoperable nature of the proposed system and the use of open standards, additional data sources, such as future smart metering expansions, can be easily discovered and added as they become available.

The ontology driven knowledge-management has been designed with the aim to support domain expert users in their decision making process and enhance the comprehension of the water supply systems upon which it is applied. The Water Management Ontology has been based on defining the necessary ontological resources that describe water managers' expertise related to managing water supply and demand. As previously pointed out, the WatERP project extends existing hydrological ontologies by including man-made infrastructure elements and enabling semantic representations of the human-altered water flow paths and therefore permitting new discoveries to be made for water resources management.

Until now, water supply and distribution management has been limited to isolated, uncoordinated solutions. The WatERP Open Management Platform will empower these existing solutions while at the same time offer a new water supply distribution management tool. This management tool, holistic in its approach, will enable global benefits (in terms of water optimization and reducing water and energy consumption) instead of only local ones. This is very much in line with the WFD objective of attaining integrated water resources management (IWRM). As the information will be treated from a higher point of view, it will facilitate the coordination between the different stakeholders, making them participants in the global situation, and recommending correct actions to be taken.

At the river basin level, the OMP will help improve water supply allocations among users and needs, by making information regarding available water supplies and demand more accessible. From this, water usage hierarchies could be established, available water supply sources could be prioritized, river basin scale water balances could be made, sectorial water usage could be better quantified, and illegal abstractions could be identified. In addition, the platform will enable greater cooperation among water regulators, operators and users which will lead to significant water savings.

At the distribution-network level, the information provided by the WatERP Open Management Platform will enable real-time tracking of water supplies, flows and distribution efficiency across the entire distribution network. This will enable daily operations to be better coordinated, water energy savings to be identified, ultimately resulting in water savings and increased overall efficiency. Regarding short-term benefits, a better demand prediction as well as demand and network monitoring in (near) real-time, combined with more accurate supply data and forecasts, will allow for a more energy-efficient distribution-network operation (helping determine which reservoirs or tanks should be filled and when, which pumps should be started and when, etc.).

Finally, the proposed WatERP Open Management Platform encourages open data policies and supports current standardization efforts to develop both European and international standards for water data sharing by fuelling further developments and by providing valuable feedback from the testing of existing standards in real-life scenarios, including how to address data security and data quality issues as well as how to properly track the treatment processes applied to the data, in particular, hydro-meteorological data.

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