Semantic and Rule Based Event-driven Services-Oriented Agricultural Recommendation System

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Abstract

Agricultural Information Systems (AIS) are rich sources of information being created, maintained and published for the benefit of farmers and agro-professionals. Ongoing research has generated knowledge regarding best practices in various aspects for farming practices to improve the yield. On the other hand, advancements in information technology and sensor technology have enabled new avenues of information for informed decisions and to utilize near real-time monitoring of data to provide effective recommendations. Even in this scenario, finding, extracting and integrating information from distributed heterogeneous sources of AIS and assimilating with real-time events like change in climatic conditions, change in market etc have raised interesting issues. We need a mechanism to collect and integrate information from scattered sources according to events and to notify the end-users with precise recommendations according to user context, location and requirements. In this paper, we propose a semantic and rule based event-driven Services-Oriented Architecture to facilitate the seamless and meaningful information integration and interoperation of distributed and heterogeneous web hosted AIS services to deliver personalized recommendation driven by real-time events and user preferences.

1. Introduction

Being an agrarian economy country, India is handling agricultural activities since ages. Agricultural system is cyclic in nature and affected by physical, biological and climatic conditions. Agricultural Information Systems (AIS) is gradually becoming available to farmers, covering nearly all aspects of the agriculture and farming related activities. AIS is typically accessed by kiosks, web browsers, or any other special interfaces. Jensen [1] demonstrated the system for web-based information system for selection of crop variety. Runquist et al. [2] developed a field-level information system for precision farming. Similarly implementations of AIS with specific requirements are developed and documented regularly. The AIS knowledge base contains best practices, rules, recommendations and other important information provided by various experts in the respective field. AIS also hosts vast amount of spatial and non-spatial databases with possible temporal versions. This data includes information like soil type, soil profiles, climatic conditions, crop production, distribution of natural resources, availability of water resources, and similar parameters that are vital for decision making. Jarvis et al. [3] demonstrated incorporation of weather related data as one of the inputs to agricultural decision support system for risk prediction. On the receiver's end, the targeted users have also accepted such systems for their agricultural practices. Nuthall [4] narrated various case studies linking the usage of computer based systems and the increased profitability. The large scale adoption of such systems is still challenged by certain unaddressed issues. Cox [19] identified reasons for poor uptake of the utilization of such systems, and focused on providing user specific decision-support as one of the important recommendations. This challenge is well addressed by the research community by providing means of Information and Communication Technology (ICT) based systems. Advancement in sensor technology has made it possible to deploy sensors for real-time monitoring of critical parameters and with the advancement of ICT, World Wide Web has become a huge pool for storing, publishing, searching and accessing various types of information. The main focus is shifting towards the convergence of the sensor technology, communication technology and Information technology to improve the user involvement and ultimately increase the usage of the AIS. Along with the countless benefits of these advancements there are also certain challenging problems associated with it. Finding, sharing and integration of information has raised many issues [3]. Information has become heterogeneous and distributed across the networks. Single point access of such information has created problems related to interoperability and integration of information. Hence a need to find useful information in an easy manner has become increasingly important. On the other hand, user requirements have increased and each user demands personalized, relevant information based on preferences, context, location as well as changes occurring among various events [22].

Web Services (WS) are emerging technology to publish, discover and invoke the software component as

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services. It also provides loosely coupled, integration of interoperable distributed heterogeneous web hosted services. WS and Service-oriented architecture (SOA) are emerging as promising distributed computing paradigms and are well suited to solve the above-mentioned problems. SOA is a software architecture to provide interoperable integration of scattered services by using services as components. WS are based on standard internet protocol like XML for data representation, WSDL for binding and to define interface, UDDI for discovery and SOAP for message exchange and are accessible with the help of wide range of computing devices [25][26]. Beside these advantages it also has shortcomings such as standards and specifications are syntax based, not matured enough, not machine processable, and not sufficient for certain kinds of applications where composition, security, state, transaction management and scalability are highly recommended [23][32].

Semantic [21] is the only solution of finding meaningful information and integrating with related information. Semantic approach helps in search, discovery, selection, composition and integration of WS and also in automation of invocation, composition and execution of services. Ontology [24] is the key technology behind Semantic web for making information more meaningful, by adding more knowledge. Rules are the next development area in semantic web to specify declarative knowledge, constraints and to enforce policy.

2. Our Contributions

As an extension to our previous work [31], in this paper we propose a semantic and rule based event-driven Service-Oriented Architecture for agricultural recommendation system. We have selected the problem of lower penetration of computer-based systems in a potentially large target user base of agro-professionals. Such systems are typically comprised of two categories of actors namely experts and users. Our approach considers experts and information sources as service providers, and agro-professionals as service consumers. From the perspective of the users, instead of considering users referring to AIS casually, we allow them to subscribe to 'events' that really meet their decision-making requirements. Thus, we tried to increase the involvement of AIS for every possible decision likely to be taken by the user. As AIS is considered to be a collection of 'services', SOA is considered as an implementation strategy. We have demonstrated the use of semantic to deliver common vocabulary and knowledge of agricultural domain, automated discovery of event sources for subscription and event correlation. The proposed architecture facilitates the seamless and meaningful information integration, interoperation of distributed and heterogeneous web hosted AIS services, delivery of personalized context and location based information. The contributions of this paper are thus twofold:

- The first is semantic and rule based event-driven SOA to demonstrate how semantic can be employed in SOA to deliver common vocabulary, knowledge and automation and how rules can be used to provide behavioral knowledge, constraints and reaction to events.
- The second is to evaluate different strategies for the SOA and to test the capabilities of WS-* specifications and use of semantic in solving large scale real life system.

3. Issues and Challenges

This section of the paper provides a brief account of problems and possible solution to achieve our goal.

3.1. Challenges in AIS

Research involved in AIS helped to identify the reasons for poor adoption amongst the users. Parker et al. [20] attributed end users' inability to provide required inputs to AIS as one of the main reasons for agricultural decision support systems. A study with similar objective by Cox [19] revealed various reasons for lower uptake of the AIS. The reasons include the complexity of models deployed by the experts, having no or limited computing capability and know-how required to use the complex decision support system were the evident factors. The output of the model and its proper interpretation is another challenge along with the extraordinary or unpredictable situations encountered on the ground. Another important challenge for improving the usage was identified as the failure to demonstrate the cost benefits of the system.

3.2. Challenges in sensor based monitoring

Sensors and sensor networks are generally deployed considering the information requirements of some specific application [5]. The same deployment may also be useful for other decision support that requires similar monitoring data as input parameters. The challenge here is when an information system like AIS is targeted for a large user base, it is evident that uniform deployment of sensors cannot be expected to exist throughout. Another issues include heterogeneity amongst sensors, discovery, data fusion, processing, analysis and easy utilization.

Sensor Web Enablement has proven [6], [18] to be a dependable solution to this problem. Even though sensors are "Web Enabled", one has to address challenges regarding seamless interoperable integration of sensor monitoring data with AIS knowledgebase to derive meaningful decisions. Chaudhary et al. [18] demonstrated the use of AIS data warehouse as an effective solution to this problem, yet designing of such a large scale system remains to be an open challenge.

3.3. Challenges in implementing event-based systems and WS specifications

WS and SOA have become important as they bridge the gap between IT services and business services. Business services are driven by events, hence people are arguing whether SOA is Event-driven architecture or not. Different specifications and mechanisms have been proposed to achieve eventing and notification in SOA. Major vendors like IBM and Microsoft disagree on specifications related to Eventing and Notification. Microsoft publishes WS-Eventing and IBM publishes WS-Notification as a collection of specifications and white papers [34] namely, Publish-Subscribe Notification for WS [9], WS Topics[10], WS Base Notification[11] and WS Brokered Notification[12]. Apart from these specifications, WS stack is now flooded with numerous specifications like routing, addressing, reliable messaging etc [8]. So challenges are in the form of careful selection to achieve compliance among the proposed specifications while developing a real life application. Among eventing and notifications, CORBA notification service is the strongest [14]. Even though CORBA is not suited for enterprise wide interoperable integration, for integration WS are coming up as effective and efficient solution over IDL due to its open standards [7] and drawing attention as an alternative to these technologies. [28][13] and [14] provide a critical review of the strengths and weaknesses of some of the discussed approaches. Due to the limitation of WS there is no clear winning solution that can meet the requirements. WS technology is also facing certain challenges, which are to be addressed to attain desired results. Some of the challenges identified by [32][23][7][16] include its inability to ensure scalability, robustness and QoS related issues that make it unfit for mission critical and certain business applications. At present, defining and tracking the events and integration of services as per the event and exception handling are quite challenging due to lack of maturity, and conflicts among specifications.

3.4. Challenges in Implementation of Rules

As specified in Semantic Web Stack, rules are sitting on the top of ontologies. Rules are next stage in the development of semantic web and its combination with ontologies is a major challenge. Even rules can be classified in the form of different types: rewrite rules, event-condition-action rules, derivation rules and quantified constraints rules [33]. Selection of rules, identification of rules to extend the knowledge base and integration with other components of system are challenging issues. RuleML (Rule Markup Language) is proposed by Rule Markup Initiative to standardize the rule language. Semantic Web Rule Language (SWRL) was proposed, which has combined the RuleML, OWL DL and OWL-lite. Various tools are developed like Protégé for editing OWL based ontology and SWRL rules. Jess, RACER and SweetRules provide support for reasoning.

4. Our Proposal

We propose the following semantic and rule based event-driven service-oriented architecture to meet the information needs of agro-professionals. The role of the targeted system is to be advisory in nature and to deliver user specific recommendations as per subscription preferences, context and location of the user. The proposal mainly depends upon WS-Notification (WSN) specifications, semantic web standards Resource Description Framework (RDF), OWL and SWRL to achieve the compliance. The architecture shown in figure-1 comprises of five components.

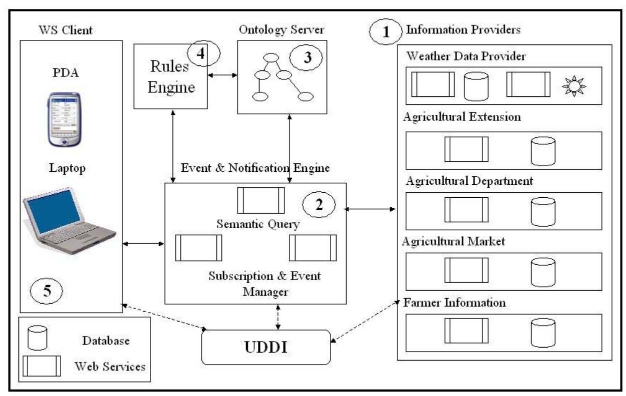

Figure 1: Proposed Architecture

Information providers: Various components of AIS are implemented as WS, maintained and published by respective organizations and acting as an information provider.

Event & Notification Engine: This component is responsible for handling and co-relating events, generating alerts, notifications and recommendations according to user preferences. It controls various events that are accessible to AIS users like: events related to climate, agriculture extension, government schemes, agro-industry and agro-market. It is evident that generation of a single event can be dependent upon continuously flowing information from data provider and various parameters stored in the user profile. The main contribution of this component is to link the information according to the event - based on context, location and user requirements with the help of rules and ontology. Advantage of this mechanism is user has to provide only minimum input to the system. System will integrate the heterogeneous services and furnish precise and user specific information. Recommendations and alerts are provided to specific user for three types of event scenarios. The event is generated (1) as soon as the update is available like sensor reading, (2) when it crosses the stipulated limit preferred by the user. (3) It generates the recommendation at particular interval of the time according to rules define in the system. For example, during registration farmer will provide information like location, cultivated crop etc. System will subscribe to the related events such as weather monitoring, agricultural market and extension based on requirements and preferences. Whenever any change occur in climatic conditions and if it is affecting the farmer’s crop this component will integrate with agricultural extension services, and generate the required recommendations for the user.

Ontology Server: Ontology supports at two levels, one to provide the common vocabularies of an agricultural domain and other provides knowledge of the various services implemented in AIS. The ontology developed for agriculture domain is based on a comprehensive reference [35] covering various aspects of the subject. It also gives properties, relationships and disjointness among the classes and object and meaning of event occur in AIS [29].

Rules Engine: This component is the main controlling component of the system. Rules engine contains set of rules, which enhance the functionality of Semantic web and gives behavioral knowledge, expressing constraints and reacting to events. It defines flow, provides constrain and controls the behavior of AIS. Example of rule is “ If temperature increases, then rice price goes down”. This rule will trigger according to corresponding event of climatic condition. It guides the event & notification server to integrate information of heterogeneous services and to generate the recommendation for AIS users according to events. For example rules are defined to generate AIS recommendation at particular intervals of time for suggesting appropriate cultivation practice for each user.

WS mobile client: We followed the asynchronous publish/subscribe architecture [31], which supports the loosely coupled integration and occasional connectivity. As depicted in the Architecture, the mobile client is developed that can access the proposed Web Services based AIS [28]. The client should be capable to register with the AIS, provide preferences, subscribe to events and display event notification results. We can also access the multidimensional information using a thin client. We recommend the use of PDA as mobile Web Services client, to interact with AIS.

5. Research Experiment

For the purpose of the experiment, we considered the information requirements of a farmer to be satisfied on a resource constraint client. Provision for receiving updates and critical alerts regarding the changing conditions and appropriate recommendations from AIS. We have followed existing standard, specification and tools for the development of various components as specified in our architecture. WS are implemented in compliance with WS* specifications. Implementation of the Event & Notification was carried out using Apache Pubscribe API [27], which follows the WS-notification family of specifications. WS-Notification consists of three specifications (WS-BaseNotification, WS-Topic, WS-BrokeredNotification) and built upon WS-ResourcesFramework family of specifications (contain five specifications: WS-Resource, WS-ResourcelProperties, WS-ResourceLifeTime, WS-BaseFault and WS-ServiceGroup). WS-BaseNotification defines interface of WSN consumer, producer and the required messages. WS-Topic defines the hierarchy of interested item “topic”, which can be subscribed by consumer and also provides methods to organize and categorize the topics. WS-BrokeredNotification defines interface of NotificationBroker that manages the message exchanges, aggregates the messages and works as a mediator. Using these APIs, we can expose notification as a resource. Code Snippet-1 displays the Climate NotificationProducer that publishes the climate specific topic so that user can subscribe to it.

```
<portType name="ClimatePortType"
wsrp:ResourceProperties="tns:
ClimateProperties"> ………………
<operation name="Subscribe"><input
message="wsntw:SubscribeRequest" /><output
message="wsntw:SubscribeResponse" /><fault
name="ResourceUnknownFault"
message="wsntw:ResourceUnknownFault" />
….………..
<operation name="GetCurrentMessage">
<input
message="wsntw:GetCurrentMessageRequest"
/><output
message="wsntw:GetCurrentMessageResponse"
/><fault name="ResourceUnknownFault"
message="wsntw:ResourceUnknownFault" />
……………..
```

Code Snippet 1: Climate.wsdl NotificationProducer portTupe

Notification can be received from producer by using portType of NotificationConsumer.

For the development of ontology we used Protégé tool, which supports RDF and OWL standards that allows processing of metadata, creation and sharing of ontology. We used Sesame server for hosting ontology and Sesame API and SeRQL (Sesame RDF query Language) for storing and querying the RDF and RDFS information [30]. Code Snippet 2 contains a part of AIS.owl that indicates Temperature as a one of the parameter of climatic condition.

```
<owl:Class rdf:ID="Temperature">
<rdfs:subClassOf>    <owl:Class
rdf:about="#Climate"/>
</rdfs:subClassOf>  </owl:Class>
```

Code Snippet 2: rdfs:subClassOf from AIS.owl

Code Snippet 3 displays the generation of query to retrieve all the concepts that has rdfs:subClassOf relationship with the term provided by the user. Besides supporting RQL, RDQL, N3 and N-Triples, N3 features SeRQL also include some more features [30].

```
 String ns = "<http://www.da-
iict.org/AIS.owl#";
String query = "select SUB from {SUB}
rdfs:subClassOf {"+ns+user_input+">}";
QueryResultsTable resultsTable =
myRepository.performTableQuery(QueryLanguag
e.SERQL, query);
```

Code Snippet 3: Code to query Sesame

Agriculture Rule-base development is carried out using SWRL. It is a standard rule language to express the rule in terms of OWL concepts. SWRL editor is available as a Protégé plug-in and can be integrated with jess rule engine for rule-based reasoning of the semantic web. For writing ECA rule we have used SweetRules tool that is based on above standards and Jess, and also support effective integration of semantic web rules and Ontologies. Code Snippet 4 display SWRL rule, which allows for identification of any event, given the climatic conditions of the farm and the crop being grown. The values of suitable temperature for specific crop are referred from the agriculture knowledge base. Upon detection of the event, suitable recommendation is provided as a part of the Notification Message.

```
hasCurrentTemp(?Farm, ?Temp_curr) ∧
hasCropGrown(?Farm, ?Crop) ∧
hasSuitableTemp(?Crop, ?Suitable_temp)∧
swrlb:graterThan(?Temp_curr,
?Suitable_temp)
⇒ isaffecting(?Temp_curr, ?Crop)
```

Code Snippet 4: SWRL rule

When the user will register, system will query the ontology server based on his/her preferences, context and location. Using that knowledge and rules the system will search the available event sources and suggest or subscribe the user to the related services. When any event occurs, system will again query the ontology server to correlate the event, and trigger rules in the rules engine. Rules engine execute the rule(s) and generate the recommendation and also provide guidance in accessing other services. Finally the result or any exception will transfer to Event & Notification Server and then it will provide to the user according to his/her subscriptions. We can notify the user using different mechanisms like, SMS, SMTP, HTTP, SOAP and .NET alert.

6. Conclusions and Future Work

In this paper we focused our attention towards integration of existing components in AIS and to increase the recommendation capability of the AIS. To achieve these objectives, we proposed semantic and rule based event-driven service-oriented architecture based on relevant specification and standards in this area. As an extension to our previous work, we also demonstrated the use of rules and semantic for interoperable integration of scattered information and use of real time information like sensor data to provide precise information and recommendation based on context, location and preferences of AIS users.

This work is done as a part of our ongoing research to achieve dynamic event driven Web Services composition for automation of web processes. The future work is diverted into several paths. Automation in the process of discovery, event-driven composition and integration of Web Services and Grid Services to harness the power of grid are also prospective areas for future work.

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