Utilizing a Policy Ontology to Facilitate Spectrum Changes in Cognitive Radio

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***Abstract*—Cognitive and next generation radio technology is instrumental in handling the dynamic nature of spectrum management. Efficient use of spectrum is essential due to increased competition for licensed and unlicensed spectrum as it is divided up to more stakeholders. There are two distinct changes in the area of spectrum management. The first is the availability of white space (broadcast) spectrum bands that was freed up by the conversion to digital TV. The second is the United States national broadband plan, which involves selling off some of its licensed spectrum for budgetary needs. This greatly affects the military, which now has a much smaller piece of the spectrum pie. How can Semantic Web technology improve this? We need an ontology that can define radio characteristics and define a policy ontology framework to manage the dynamics changes in a radio system. If there was a common ontology, all the devices involved in a radio system and between radio systems would be able to share information more efficiently.**

Dynamic spectrum access, white space spectrum, policy, IEEE DySPAN, cogitive radio.

I. Introduction

There are many stakeholders affected by national spectrum policy changes, such as 1) commercial wireless and networking product suppliers: they need to know how to search for available spectrum to use in their local devices; 2) military: need to efficiently use their diminishing spectrum band; 3) Federal Communications Commission: they need to be able to propagate spectrum changes easily to consumers and make sure that users and suppliers are following the rules; 4) public safety domain: they need an easier way to take over spectrum in emergencies; and lastly, 5) the general public: who wants all their wireless devices to work all the time.

Semantic web ontologies along with policy concepts defined in the IEEE DySPAN P1900.5 specification can facilitate an infrastructure for managing dynamic spectrum access (DSA).

II. Whitespace and the National Broadband Plan

Two significant national policy changes have occurred that affect the use of spectrum. First, the availability of new whitespace bands came after the federally mandated switch from analog to digital television. On November 4, 2008, the FCC unanimously agreed to open up unused broadcast TV spectrum for unlicensed use. The FCC has also been developing tools to allow access to the whitespace databases that hold the current spectrum allocation. These databases need to be accessible to policy management points so that only allowed spectrum is used by devices.

The second change is the National Broadband Plan proposed in March 2010. The goal of this plan is to provide American households with wireless broadband access. This requires an effort to re-allocate existing spectrum to increase the capacity of mobile broadband. Global mobile traffic has tripled each of the last three years. The FCC has been given authority to provide incentives to accelerate the freeing of spectrum. The re-allocation required to fulfill these goals will come at the expense of some government entities, specifically the military.

III. IEEE DySPAN P1900.5 DSA Policy Specification

Publication will soon complete on a standard that defines language requirements and architecture to support DSA policy. The IEEE DySPAN P1900.5 specification effort was started in 2008 and is in final publication editing. We expect that it will be available in early 2012. The IEEE DySPAN standards committee is responsible for fostering the creation of standards related to dynamic spectrum access, cognitive radio, interference management, coordination of wireless systems, advanced spectrum management, and policy languages for next generation radio systems.

P1900.5 architecture incorporates commonly known policy components from previous standards with cognitive radio components as shown in Figure 1. The Policy Management point is the policy interface from the cognitive radio system to the outside network and the spectrum authority (i.e. FCC). This is the component that would get available spectrum information and formulate it into a policy to be disseminated to components in the network. It will store policies in a repository and send to the policy conformance reasoner (PCR). If the spectrum policy changed, that change would have to be reflected in the PCR so that it can have the appropriate information to determine compliance of all transmission requests. If the cognitive radio system, through the system strategy reasoning capability (SSRC), that there are issues using a particular frequency band, it can use its information to reason and propose a solution. The SSRC gathers data to optimize radio operation, formulates communications strategies, and coordinates these strategies with the policy conformance reasoner to evaluate compliance with the active policy set. When a transmission change has been deemed compliant, it is interpreted and sent to the radio control through the policy enforcer.

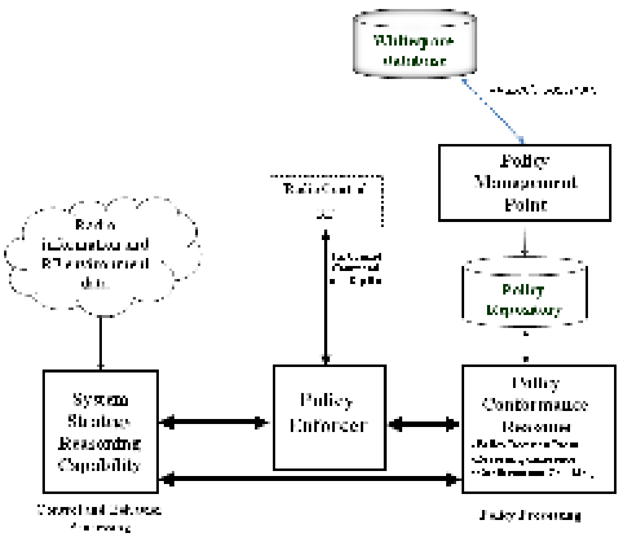

Figure 1

IV. Whitespace Database Access

The FCC is still in development of concise and equitable solutions for the management and regulation of unused spectrum. Currently, there are capabilities for the general public to search for unused spectrum and who owns licenses for spectrum in what is called the Spectrum Dashboard. The databases of licenses and spectrum usage are also available. Some developer application programming interfaces (API) have been created to allow automatic searching. There is an API set for getting the current spectrum distribution and an API set for searching spectrum licenses. I expect that more API resources will be forthcoming. Currently, there are database schemas defined for this information but no known ontology.

One such application of the whitespace database is implemented by Spectrum Bridge, Inc®. It takes as input the user's location and selection of device type and displays the table of available channels and a location map.

V. Semantic Web Technology

The semantic web provides the next revolution in defining distributed data in a more effective way for human and machine consumption. The eXtensible Markup Language (XML) gave us our first foray into the concept of data definition with meaning. With the onslaught of service oriented architectures (SOA) and web services, the semantic web is a key component in moving the technology forward. It not only defines the data but also adds the ability to define relationships between the data. These relationships are part of the data and not just interpreted by the user. The components of the semantic web are the ontology, a language, instance data, statements that define structure, a Uniform resource Locator (URI) to create a unique name for items and finally, the suite of tools for construction, interrogation and reasoning.

The data domain of DSA will involve overlapping information but these basic constructs can be shared by all areas. The policies will contain cognitive radio information as payload and the whitespace database will contain license information along with spectrum data that needs to be disseminated to the policy management point and the radio. There have been efforts to define some of this information independently.

The Mobility Language for Machines (MLM) subgroup of the Wireless innovation Forum™ (WINF) published a cognitive radio ontology which focuses on the signaling between advanced radio systems. This is the lower level definition to support radio transmission. This ontology was loaded into Protégé and a portion is displayed in Figure 2.

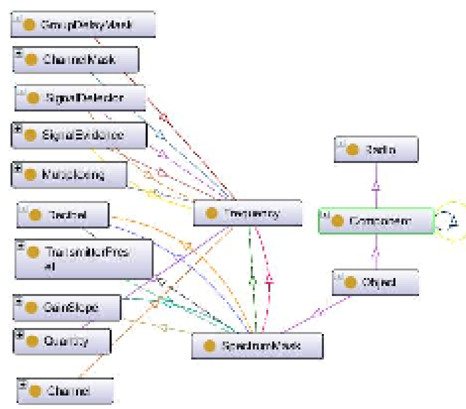

Figure 2

So we have a cognitive radio ontology that can be used to define radio information. Now we need a policy ontology. Defining a policy language and ontology will be part of a newly initiated IEEE DySPAN standard as an extension to the P1900.5 standard (which will be identified as P1900.5.1). The P1900.5 working group will be creating this standard in cooperation with the Mobility Language for Machines (MLM) subgroup of the Wireless innovation Forum™ (WINF). The group will be analyzing use cases and creating a policy language and ontology or possibly extending existing work to meet the requirements defined in the P1900.5 standard.

In the meantime, for the purpose of analysis, we will utilize the Kaos policy ontology. This ontology set was created by the Florida Institute for Human and Machine Cognition to enable defining and managing policy and semantically rich services in software agents and human-robotic environments. It has the basic capabilities needed for proof of concept for cognitive radio. Figure 3 depict some of the basic components of the Kaos policy ontology.

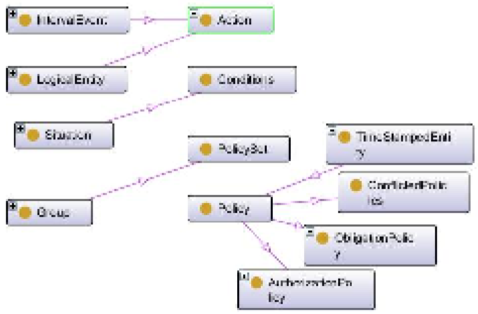

Figure 3

VI. Tools for Proof of Concept

There are many good tools to use when working with a semantic web ontology. Some of the popular for Java development are Jena for manipulating the ontology, SPARQL for doing queries. Protégé is very good for viewing, populating and saving the ontology. I also found an API that was helpful in some other ontology tasks such as merging ontologies from Java code. It is called OWL API and is primarily maintained by the University of Manchester. This tool allowed the merging of the CRontology and the Kaos ontology for ease of use.

I wrote a blog series about the creation of the proof of concept demonstration at pompanolynn.wordpress.com under the category *semantic web project*. This demonstration is intended to show how to manipulate the ontologies along with the creation of a policy that contains frequency information from the whitespace database and show how that is filtered to the cognitive radio via the policy manager. The blog contains information about the project.

VII. Conclusion

While cognitive radio and dynamic spectrum management are still on the bleeding edge, it is best to use semantic web technology to aide in moving into the future of policy based radio systems. Policy provides a vehicle for managing the "dynamic" nature of mobile devices. The cognitive radio ontology can help to define the capabilities in the radio as well as the spectrum payload from policy authorities. We urge interested parties to join the P1900.5 working group to participate in the standardization effort for creating a policy language and ontology for dynamic spectrum access in cognitive radio.

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