The Dynamic Spectrum Access Policy Framework in Action*†

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Abstract. Because radio spectrum is a finite resource, its usage and sharing is regulated by government agencies through policies that manage spectrum allocation. With more portions of the spectrum being licensed for commercial use, the importance of providing an increased level of automation when evaluating such policies becomes crucial for the efficiency and efficacy of spectrum management. This poster showcases the Dynamic Spectrum Access Policy Framework, which acts as a machine-readable policy repository providing policy management features and spectrum access request evaluation. It includes the use of the framework's policy management capabilities to create and modify policies in a novel policy representation using two recommended web standards (OWL and PROV-O), and the request evaluation engine to verify the assignment of permit/deny effects to spectrum requests.

1 Introduction

Usable radio spectrum is becoming crowded[7] as an increasing number of services, both commercial and governmental, rely on wireless communications to operate. Techniques known as Dynamic Spectrum Access (DSA) [7] have been extensively researched as a way of promoting more efficient methods for sharing the radio spectrum among distinct organizations, and their respective devices, while adhering to regulations. Government agencies, such as the National Telecommunications and Information Administration[8] (NTIA), publish author-

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[7] http://bit.ly/FCC_AWS

[8] http://ntia.doc.gov

itative documents[9] that contain spectrum policies to regulate the usage of the spectrum.

This poster presents the Dynamic Spectrum Access Policy Framework (DSA Policy Framework) for supporting the management of machine-readable, radio spectrum usage policies. This is accomplished via the utilization of a novel policy representation, based on two World Wide Web Consortium recommendations for encoding ontologies and provenance on the web (OWL and PROV-O), that encodes its rules in an ontology. This ontology, combined with background knowledge from a number of relevant sources, is stored in a Knowledge Graph that is used by a domain-specific reasoning implementation that mixes a standard for representation and querying geospatial linked data (GeoSPARQL [4]), OWL reasoning, and knowledge graph traversal to evaluate policies that are applicable to spectrum access requests. This poster complements our submission to the In-use track [5] by showcasing the usability of the system with an in-depth view of the framework's capabilities from the user perspective.

2 Dynamic Spectrum Access Policy Framework

Rensselaer Polytechnic Institute collaborated with spectrum domain experts from Capraro Technologies Inc. and LGS Labs of CACI International Inc. to select and analyze English, text-based policies from the NTIA Redbook and from various Federal Communications Commission (FCC) documents. The English text was converted into a different representation, and many of the terms used in the English text were incorporated into a DSA domain ontology. During this process, a number of requirements were elicited:

- To store machine-readable spectrum policies in a modeling that supports common constructs
- To allow users to interact with the machine-readable policies, creating, modifying, and specializing them as needed
- To provide a policy evaluation endpoint able to receive transmission requests in a common format and assign permit/deny effects, based on existing policies, while explaining the reasons for the policies' decisions

The DSA Policy Framework serves as a centralized, machine-readable, radio spectrum policy repository, providing policy management features (including creation and customization) for a wide range of radio spectrum domain users. It uses the machine-readable policies as a basis for automatically evaluating radio spectrum access requests.

Built on top of the Whyis Knowledge Graph Framework [3], the DSA Policy Framework provides two major functions: *Policy Management* and *Request Evaluation*. *Policy Management* enables spectrum managers to explore and manage policies. The framework provides a web interface to allow spectrum managers to have a comprehensive understanding of the DSA Knowledge Graph, which is

[9] http://bit.ly/NTIA_Redbook

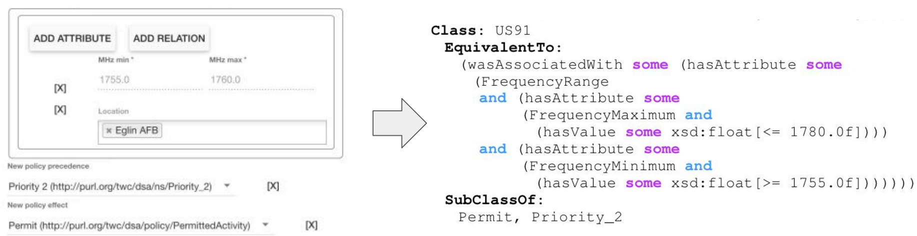

Fig. 1. Policy Builder: enables the visual creation of DSA policies in OWL

composed of policies, named locations, and entities in the DSA domain ontology. The structure and content of the interface are driven by the DSA Knowledge Graph, which ensures that it displays relevant and contextualized information and features.

The *Policy Builder* (Figure 1), a key component of the DSA Policy Framework, allows users to build policies from scratch or to create policies by reusing the rules of existing policies. The Policy Builder leverages the DSA Knowledge Graph to provide user support during policy creation. In the back end, the policy is converted to an OWL representation and stored as a new piece of knowledge in the DSA Knowledge Graph.

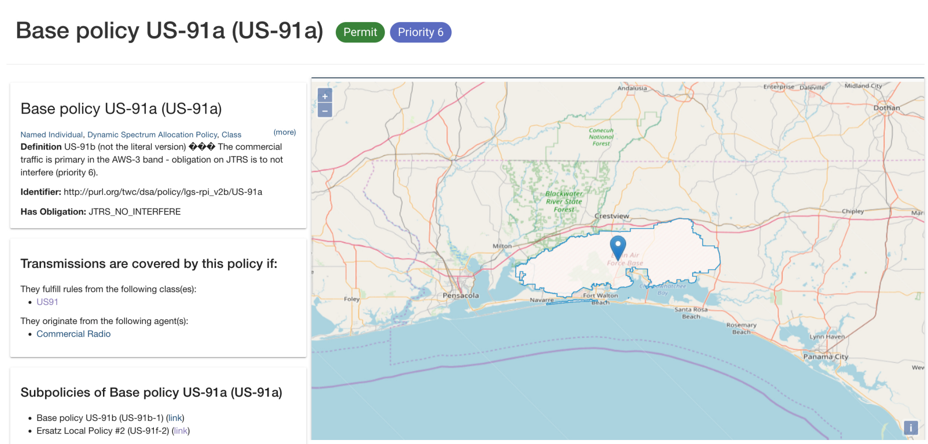

Fig. 2. Visualizing a policy's details

The *Policy Detail* view (Figure 2) provides a display of policy metadata, including name, original text and identifier, and a human-readable version of the policy encoded rules. If the policy specifies locations, those locations will be displayed on a map.

Request Evaluation utilizes policies to automatically process incoming spectrum requests originating from devices that want to use a part of the spectrum. The request evaluation engine (Figure 3) follows a four-phase pipeline, with a set of requests as input and the assigned effect, a list of obligations, and a list of reasons for each request as output. First, the engine elicits the geographical relationships among the requests' coordinates and named locations in the DSA KG using GeoSPARQL. Following this, the HermiT OWL reasoner [2] is used to classify the requests' instances in the applicable policies' classes. Next, policy precedence is decided by comparing precedence levels of applicable policies. Lastly, the engine traverses the KG to find rules that were not satisfied in order to explain the assignment of the deny effect to requests.

The results generated include references to any policy that was involved in the evaluation. As policies evolve, the underlying knowledge representation evolves, enabling the *request evaluation* engine to use the most current policy information to reason and assign effects (permit, deny, permit with obligation) to spectrum requests.

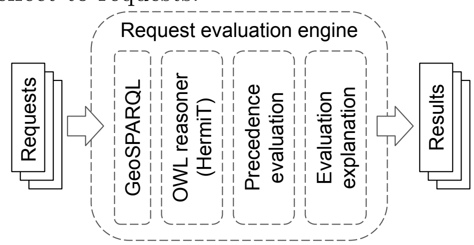

Fig. 3. Request evaluation pipeline

3 The DSA Policy Framework in Use

The DSA Policy Framework is being used in simulated scenarios, where it supports the research & development of other components of a dynamic spectrum management system. It currently contains approximately 165 high-level policies from the NTIA Redbook (including their sub-policies). The DSA Ontology contains 695 classes and is constantly evolving to address new domain constructs and support more precise request evaluation.

The framework is transitioning to support live, over-the-air field exercises that involve a diverse set of federal and commercial radios. During these exercises, the Framework supports (1) the creation, deletion, and revision of local policies, (2) the real-time processing of numerous spectrum requests, and (3) the generation of explanations that describe how the spectrum requests were processed. The publicly released assets developed during the course of the project can be accessed at `https://github.com/tetherless-world/dsa-open/`.

4 Conclusion

While the policy aspect of dynamic spectrum access has been extensively researched over the past years, there is a shortage of working implementations in the literature to operationalize it in a real environment. Ulversøy [6] describes the potential that policy-based spectrum management offers to combine comprehensive administrative control with the benefit of fast, local decision making. This paper provides an overview of research about policy-based spectrum management. The second part of their paper outlines a proposed OWL-based ontology for spectrum management and provides a few examples. It concludes by stating that the efficient evaluation of highly localized, fine-grained spectrum access policies is a "hard problem" requiring further research.

The DSA Policy Framework relies on a novel policy representation approach that builds on previous work by matching the cross-domain policy expression semantics of XACML [1]. It extends these semantics with the capacity to express rich spatio-temporal restrictions, enabling the implementation of a wide variety of attribute-based policies across domains. It leverages background knowledge from domain-specific knowledge graphs that are structured with a domain-derived ontology, enabling the inference of policy applicability based on attributes and constraints. It also uniquely conceptualizes policies as PROV activities and provides a set of user interfaces to enable the exploration, visualization, creation, and modification of such policies. One of the outstanding benefits of this policy representation is the ability to provide detailed explanations for denied requests. By identifying unsatisfied rules, the framework allows domain policy developers to understand the precise reasons for policy decisions.

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