Towards Computable and Explainable Policies Using Semantic Web Standards

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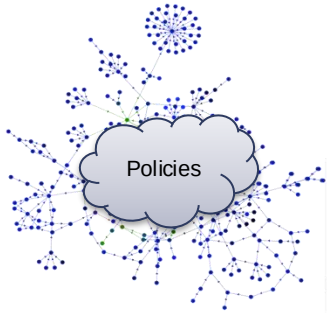
Why Computable Policies and Guidelines?

- Commonly defined as authoritative resources that serve as a reference when domain specialists need to check the alignment of their intended actions or decisions

- Natural language-based policies convey limited domain knowledge
  - This knowledge is often necessary for the correct evaluation of policy applicability
- Policy versioning and archiving of textual policies are burdensome
- Evaluation of textual policies is highly dependent on domain experts and field specialists
  - In some domains, policy evaluation is a critical path, requiring increased levels of automation

Moving from Text-based to Computable Policies

- Necessity to standardize policy authoring, including support to explainability of policy evaluations
- In some domains, the necessity to quickly adapt existing policies to accommodate special settings
  - E.g., Dynamic radio spectrum
- Domain knowledge is increasingly available as Knowledge Graphs (KGs)
  - Including in RDF
- Existing standards for computable policies, especially for access control (e.g. XACML)



The Premises of the OWL+PROV Ontology Design Pattern

- This pattern emerged from two initial use cases:
  - Dynamic Spectrum Allocation
  - Diabetes care guidelines

- Both scenarios have authoritative resources in natural language to document policies and guidelines
  - National Telecommunication and Information Administration's Manual of Regulations for Federal Radiofrequency Spectrum Management[1] (NTIA Redbook)
  - American Diabetes Association "Standards of Care in Diabetes"[2] (ADA Guidelines)

$$action \wedge subj \wedge attr0 \wedge attr1 \wedge \cdots \rightarrow effect(s)$$

1. Manual of Regulations and Procedures for Federal Radio Frequency Management (Redbook) | National Telecommunications and Information Administration, https://www.ntia.gov/publications/redbook-manual, last accessed 2024/11/10.
2. American Diabetes Association Professional Practice Committee: Summary of Revisions: Standards of Care in Diabetes—2024. Diabetes Care. 47, S5–S10 (2023). https://doi.org/10.2337/dc24-SREV.

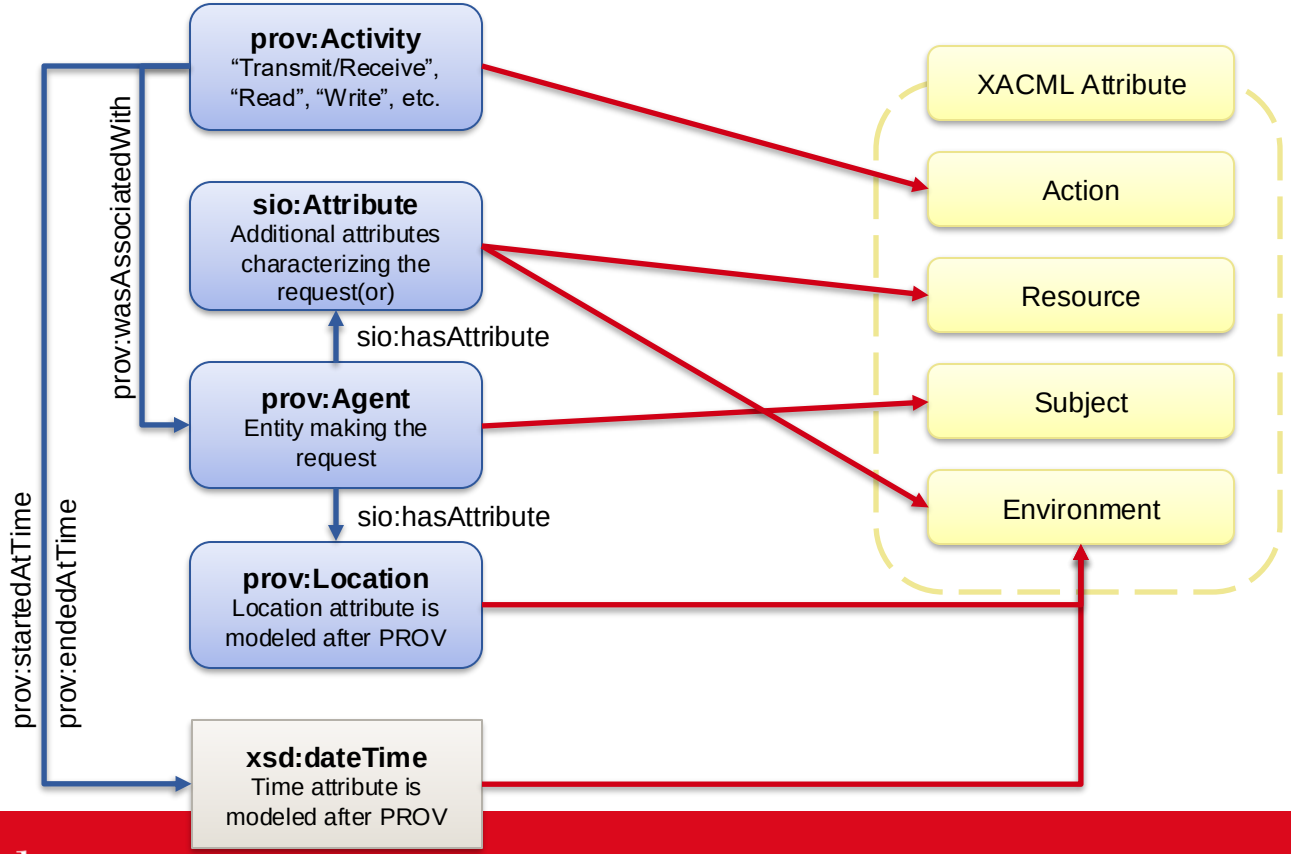
Example US91 Policy from the NTIA Redbook

US91 In the band 1755-1780 MHz, the following provisions shall apply:

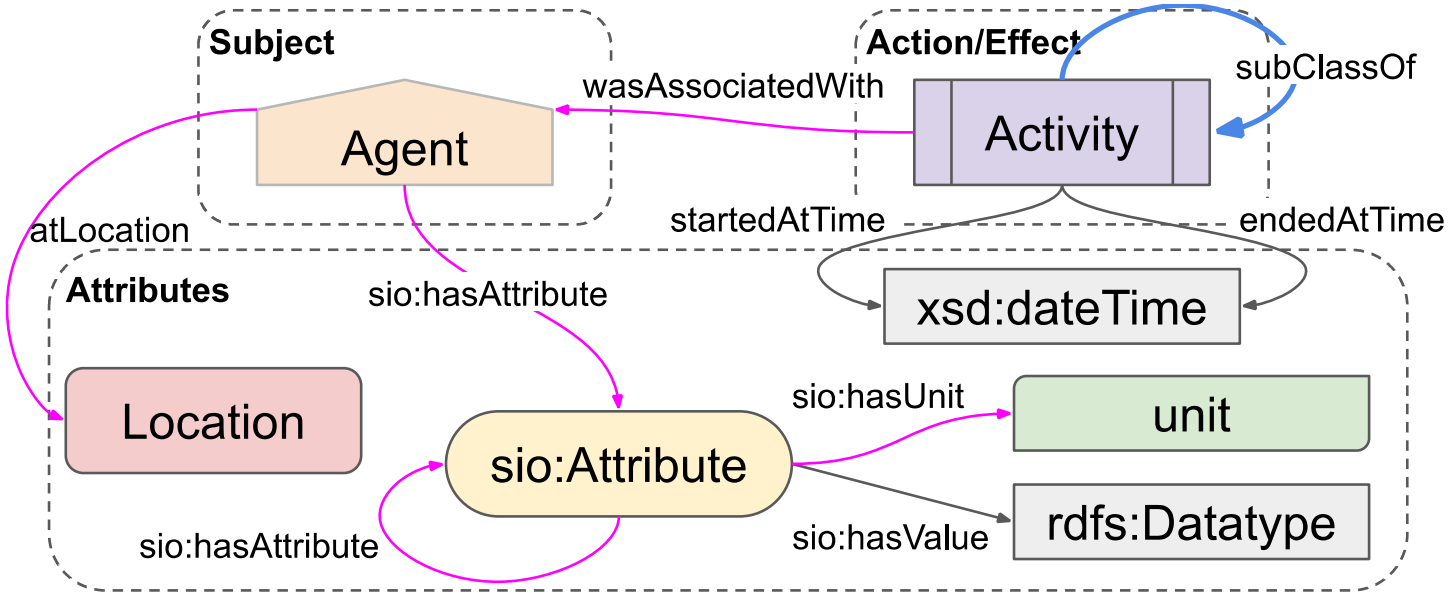
(a) Non-Federal use of the band 1755-1780 MHz by the fixed and mobile services is restricted to stations in the Advanced Wireless Service (AWS). Base stations that enable AWS mobile and portable stations to operate in the band 1755-1780 MHz must be successfully coordinated on a nationwide basis prior to operation, unless otherwise specified by Commission rule, order, or notice.

Santos, H., Mulvehill, A., Erickson, J.S., McCusker, J.P., Gordon, M., Xie, O., Stouffer, S., Capraro, G., Pidwerbetsky, A., Burgess, J., Berlinsky, A., Turck, K., Ashdown, J., McGuinness, D.L.: A Semantic Framework for Enabling Radio Spectrum Policy Management and Evaluation. In: The Semantic Web – ISWC 2020. pp. 482–498. Springer International Publishing, Cham (2020). https://doi.org/10.1007/978-3-030-62466-8_30.

From XACML to RDF

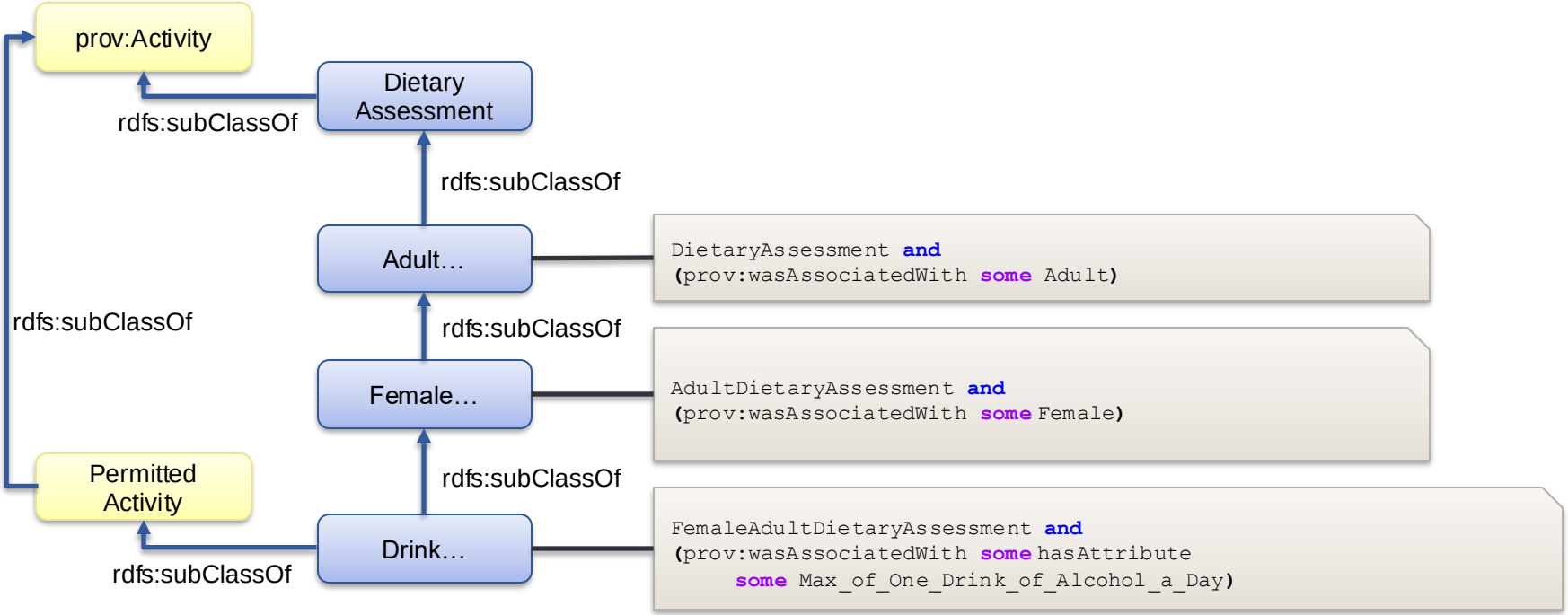


The OWL+PROV model

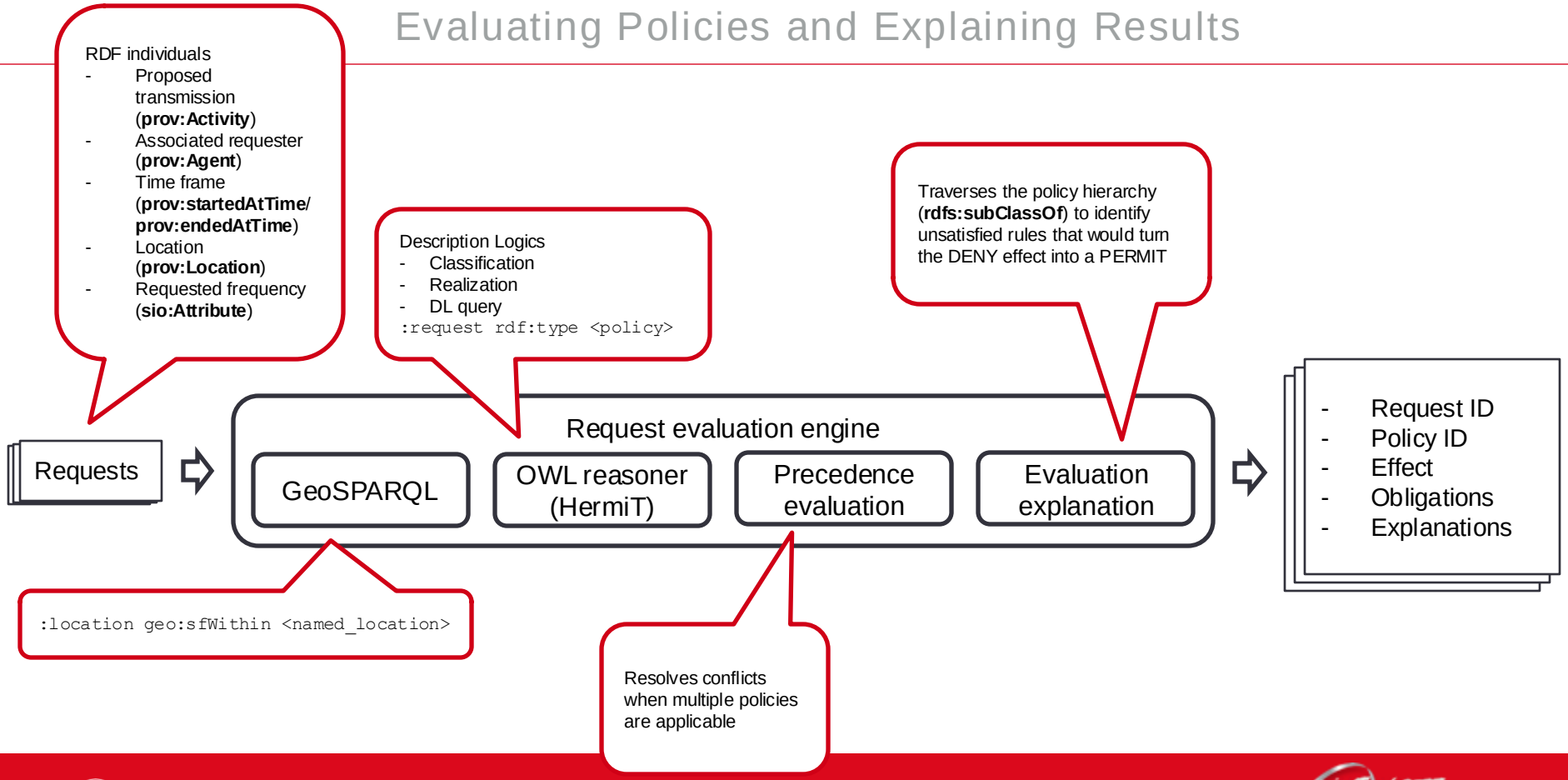


Encoding Rules in OWL+PROV

Example Instantiation for a Diabetes Care Guideline



Evaluating Policies and Explaining Results



OWL+PROV pattern evaluation

- Thörn's[1] criteria for model quality

Changeability	Reusability	Formalness	Mobility	Correctness	Usability
New attributes can be included in new classes, extending existing policies	Existing policies and rules can be reused by creating new classes that extend existing classes	Employment of standardized knowledge representation (OWL), enabling exiting OWL reasoners to be used	Common Logic[2] can be used to serialize policies between compatible systems	Domain coverage analysis	Tools such as Protégé and specialized policy editors[4]
Similarly, new rules can be encoded in new classes	-	The proposed model maps to existing standards (XACML)	Domain Specific Languages can be developed[3]		

1. C. Thörn, On the quality of feature models, Ph.D. thesis, Linköping University Electronic Press, 2010.
2. 14:00-17:00: ISO/IEC 24707:2018 Information technology — Common Logic (CL) — A framework for a family of logic-based languages, https://www.iso.org/standard/66249.html, last accessed 2020/09/01.
3. Xie, O.: A hybrid approach to developing ontology-driven applications : a case study in describing radio spectrum usage policies, https://hdl.handle.net/20.500.13015/2698, (2021).
4. Falkow, M., Santos, H., McGuinness, D.L.: Towards a Domain-Agnostic Computable Policy Tool. In: ESWC 2021 Posters & Demos Track (2021).

Advantages of this Semantic Web approach to policy representation

- Policies created through the ontology-driven policy graph editor embody all policy relationships and rules. Standard reasoning engines can be applied since it is fully expressed in OWL2.
- Policies can leverage multiple ontologies and knowledge graphs, incorporating domain knowledge during reasoning.
- Integrating policy source materials enables provenance traces from policy elements to control documentation.
- Policy evaluation results can be explained by identifying rules not fulfilled during reasoning.