

IEEE Standard for Policy Language for Dynamic Spectrum Access Systems

IEEE Communications Society

Developed by the
Dynamic Spectrum Access Networks Standards Committee

IEEE Std 1907.5.1™-2020

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IEEE Standard for Policy Language for Dynamic Spectrum Access Systems

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Dynamic Spectrum Access Networks Standards Committee
of the
IEEE Communications Society

Approved 3 December 2020

IEEE SA Standards Board

Abstract: A vendor-independent policy language for managing the functionality and behavior of dynamic spectrum access networks based on the language requirements defined in IEEE Std 1900.5™, IEEE Standard Policy Language Requirements and System Architectures for Dynamic Spectrum Access Systems, is defined in this standard.

Keywords: Description Logic, Dynamic Spectrum Access, First Order Logic, Horn-based rules, IEEE 1900.5.1™, IEEE 1900.5.2™, Policy Language, RIF Framework for Logic Dialect (RIF-FLD), rule interchange format (RIF), Spectrum Consumption Modeling, Web Ontology Language (OWL 2)

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Introduction

This introduction is not part of IEEE Std 1900.5.1-2020, IEEE Standard for Policy Language for Dynamic Spectrum Access Systems.

Acknowledgments

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OWL 2 Web Ontology Language Direct Semantics (Second Edition). W3C Recommendation, 11 December 2012. Available at <http://www.w3.org/TR/owl2-direct-semantics/>

OWL 2 Web Ontology Language Profiles (Second Edition). W3C Recommendation, 11 December 2012. Available at http://www.w3.org/TR/owl2-profiles/#Feature_Overview_3

RIF Framework for Logic Dialects (Second Edition). W3C Recommendation, 5 February 2013. Available at http://www.w3.org/TR/rif-fld/#Semantic_Framework

RIF Core Dialect (Second Edition). W3C Recommendation, 5 February 2013. Available at <http://www.w3.org/TR/rif-core/>

OWL Web Ontology Language Reference, M. Dean, G. Scherrie, Editors, W3C Recommendation, 10 February 2004. Available at <http://www.w3.org/TR/owl-re/>

Resource Description Framework (RDF): Concepts and Abstract Syntax], G. Klyne, J. Carroll, Editors, W3C Recommendation, 10 February 2004, <http://www.w3.org/TR/2004/REC-rdf-concepts-20040210/>. Available at <http://www.w3.org/TR/rdf-concepts/>

RIF Basic Logic Dialect (Second Edition) Harold Boley, Michael Kifer, eds. W3C Recommendation, 5 February 2013, <http://www.w3.org/TR/2013/REC-rif-bld-20130205/>. Available at <http://www.w3.org/TR/rif-bld/>

RIF Core Dialect (Second Edition) Harold Boley, Gary Hallmark, Michael Kifer, Adrian Paschke, Axel Polleres, Dave Reynolds, eds. W3C Recommendation, 5 February 2013, <http://www.w3.org/TR/rif-core/>

RIF Datatypes and Built-In 1.0 (Second Edition) Axel Polleres, Harold Boley, Michael Kifer, eds. W3C Recommendation, 5 February 2013, <http://www.w3.org/TR/2013/REC-rif-dtb-20130205/>. Available at <http://www.w3.org/TR/rif-dtb/>

RIF In RDF (Second Edition) Sandro Hawke, Axel Polleres, eds. W3C Working Group Note, 5 February 2013, <http://www.w3.org/TR/2013/NOTE-rif-in-rdf-20130205/>.

RIF Combination with XML data (Second Edition) Christian de Sainte Marie, editor. W3C Working Group Note, 5 February 2013, <http://www.w3.org/TR/2013/NOTE-rif-xml-data-20130205/>. Available at <http://www.w3.org/TR/rif-xml-data/>

RIF Overview, Kifer M. and Boley H. (Editors), W3C Rule Interchange Format Working Group Note. Available at <http://www.w3.org/TR/rif-overview/>

OWL 2 RL in RIF (Second Edition) Dave Reynolds, editor. W3C Working Group Note, 5 February 2013, <http://www.w3.org/TR/2013/NOTE-rif-owl-rl-20130205/>.

RIF Framework for Logic Dialects (Second Edition) Harold Boley, Michael Kifer, eds. W3C Recommendation, 5 February 2013, <http://www.w3.org/TR/2013/REC-rif-fld-20130205/>. Available at <http://www.w3.org/TR/rif-fld/>

RIF Production Rule Dialect (Second Edition) Christian de Sainte Marie, Gary Hallmark, Adrian Paschke, eds. W3C Recommendation, 5 February 2013, <http://www.w3.org/TR/2013/REC-rif-prd-20130205/>. Available at <http://www.w3.org/TR/rif-prd/>

RIF RDF and OWL Compatibility (Second Edition) Jos de Bruijn, Chris Welty, eds. W3C Recommendation, 5 February 2013, <http://www.w3.org/TR/2013/REC-rif-rdf-owl-20130205/>. Available at <http://www.w3.org/TR/rif-rdf-owl/>

RIF Test Cases (Second Edition) Stella Mitchell, Leora Morgenstern, Adrian Paschke, eds. W3C Working Group Note, 5 February 2013, <http://www.w3.org/TR/2013/NOTE-rif-test-20130205/>. Available at <http://www.w3.org/TR/rif-test/>

RIF Use Cases and Requirements (Second Edition) Adrian Paschke, Leora Morgenstern, David Hirtle, Allen Ginsberg, Paula-Lavinia Patranjan, Frank McCabe, eds. W3C Working Group Note, 5 February 2013, <http://www.w3.org/TR/2013/NOTE-rif-ucr-20130205/>.

RIF Approved Test Cases, Mitchell, S. (Editor), RIF Approved Test Cases. Available at <http://www.w3.org/2005/rules/wiki/Category:Approved>

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IEEE Standard for Policy Language for Dynamic Spectrum Access Systems

1. Overview

1.1 Introductory prevailing conditions

In the development of this standard, the following conditions were to be met:

- a) The development of this standard was required to follow the specifications of IEEE Std 1900.5TM-2011.¹
- b) According to IEEE Std 1900.5-2011, the language should be based both on the Web Ontology Language (OWL 2) and on a rules language compatible with OWL 2, that is, be compatible with a suitable rule interchange format (RIF) dialect.
- c) The development of the standard required some linguistic constructs that are not available in current RIF dialects as RIF Basic Logic Dialect (RIF-BLD), RIF Production Rule Dialect (RIF-PRD), and RIF-Core.
- d) Consequently, this new standard is introducing a new dialect of RIF [RIF Spectrum Consumption Modeling (SCM) Dialect based on RIF Framework for Logic Dialect (RIF-FLD) called “RIF-DSA”].
- e) Since this standard is addressed to the community of radio and networks community, to make the language usable to this community, introductory material on formal languages like RDF, OWL, and RIF, as well as logic and theory of computation, needed to be included.
- f) One requirement of IEEE Std 1900.5-2011 was that the language should be able to use ontologies to define policies. Toward this end, an example ontology was used. This ontology is not part of the standard.

1.2 Scope

This document defines a standard for a formal language to specify policies for radio devices that use cognitive patterns in their operating behavior.

¹ Information on references can be found in Clause 2.