Implementing Military Hierarchical Restrictions in Communication Applications

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***Abstract*—The need for a comprehensive representation of both operational and technical contexts is an open issue concerning the integration of cognitive radios (CR) and software-defined networks (SDN) within tactical communication networks. In light of this, we introduce an ontological model to confront and alleviate the ambiguities that hinder the decision-making process. Based on this model it is possible to generate a machine-readable ontology, which facilitates cognitive radio reasoning, thereby enhancing its capacity to communicate and furnish situational awareness. Furthermore, this approach is also useful for Command and Control (C2) applications that need to communicate with each other during military operations.**

***Index Terms*—ontology, semantic reasoning, wireless communications, command and control applications.**

I. Introduction

In recent years, wireless communication networks have experienced significant advancements, ushering in greater flexibility in network management and a plethora of novel services for users. Many wireless technologies now coexist seamlessly, catering to emerging requirements. Moreover, every component within these networks has become adaptable and capable of communicating using multiple protocols. On the one hand, we find a heterogeneous network amalgamating various wireless access technologies, while on the other, a network where nodes can alter their protocols without the need for hardware replacements. This scenario is characterized by the network element's flexibility to adjust itself and make decisions, the essence of Software Defined Networks (SDN) [1] and Cognitive Radios (CR) [2]. However, such flexibility and decision-making capability must be supported by data coming from several different sources. Authors in [3] describe data fusion process as combining data from multiple sources to provide more accurate and useful information than any individual source. In this sense, wireless communications networks, data fusion can significantly enhance its performance.

In most cases, the CR's decision problem focuses on observing the electromagnetic spectrum, primarily concerning technical aspects like spectrum management, service quality enhancement, and energy conservation. However, introducing a cognitive radio into tactical communication scenarios substantially elevates the complexity and relevance of this decision problem, which also challenges Command and Control (C2) applications. Behavior is no longer limited to resolving technical issues but it incorporates tactical considerations from military doctrine. For instance, there are situations where it is necessary to manage communication between two military personnel who are part of different groups, since they may not be allowed to talk to each other, according to the current doctrine. Hence, data fusion in such a scenario demands an improved conceptual data model able to present not only technical information but also tactical military doctrine.

In response to these challenges, an ontological model underpinned by a well-founded ontology was chosen to address the intricacies of the domain and mitigate potential ambiguities. This paper presents a simple example of how such model and its implementation using the Web Ontology Language (OWL) in association with the Semantic Web Rule Language (SWRL), can deal with doctrine-based restrictions and support communication decisions in a military scenario. The idea of using ontologies to support the reasoning in military operation scenarios is not new [4], but the challenge of representing communication restrictions has not yet been addressed.

II. MiScOn Ontology Fragment

In the context of a military operation, one of the important pieces of information for the organizations involved concerns their hierarchical position among the groups, i.e. who their superiors and subordinates are. This information must be available to each military person operating communications equipment. To represent such information that could be used for tactical decisions, we present a fragment of the ontological model named Military Scenario Ontology (MiScOn), shown in Figure 1. It covers elements from the military domain and some elements from the networking domain. Military organizations (`MilitaryOrganization`) are represented and can play different roles concerning other military organizations, such as subordination role (`Subordinate`) and commander role (`Commander`). The relationship `isSubordinateTo` represents the hierarchical relations among the roles within those organizations.

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A military person (`MilitaryPerson`) is related to a military organization through an employment relationship (`MilitaryEmployment`). When operating a communication user equipment (`Ue`), she/he plays the role of an operator (`UeOperator`). Depending on the military person who operates it and his corresponding organization, a certain `Ue` may assume the higher command role (`UeDown`) and talk down to its subordinate units or assume the lower command role when talking to their hierarchical superiors (`UeUp`).

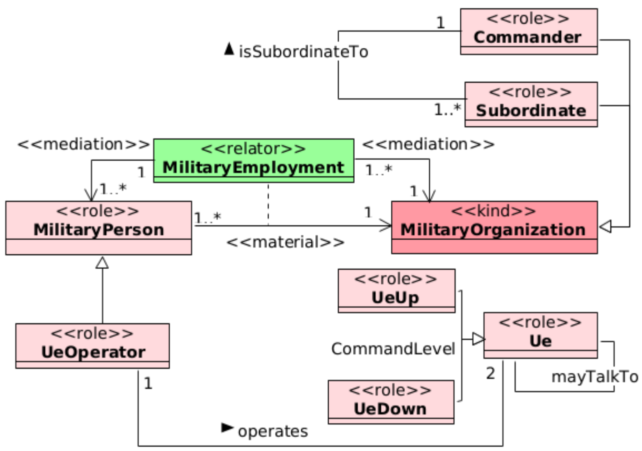

Fig. 1. Fragment of the conceptual modeling of the MiScOn ontology in OntoUML.

It is worth highlighting that this ontological model was conceived using a Foundation Ontology to allow important distinctions such as roles and relators (relationships). The explicit representation of such roles enabled the expression of the hierarchical restrictions that are usual in C2 scenarios. Listing 1 presents the operational ontology (in OWL/TTL syntax) generated based on the ontological model specified in Figure 1.

```
:MilitaryOrganization owl:Class, owl:NamedIndividual;
:MilitaryPerson owl:Class, owl:NamedIndividual;
:UeOperator owl:Class, owl:NamedIndividual;
:CommDevice owl:Class, owl:NamedIndividual;
:MilitaryEmployment owl:Class,owl:NamedIndividual;
:Subordinate owl:Class, owl:NamedIndividual;
:Commander owl:Class, owl:NamedIndividual;
:Interface owl:Class, owl:NamedIndividual;
:Ue owl:Class, owl:NamedIndividual;
:UeUp owl:Class, owl:NamedIndividual;
:UeDown owl:Class, owl:NamedIndividual;
:isSubordinateTo owl:ObjectProperty;
    rdfs:domain :Subordinate; rdfs:range :Commander;
:operates owl:ObjectProperty;
    rdfs:domain :UeOperator; rdfs:range :Ue;
:mayTalkTo owl:ObjectProperty;
    rdfs:domain :Ue; rdfs:range :Ue;
:militaryPersonHasMilitaryOrganization owl:ObjectProperty;
    rdfs:domain :MilitaryPerson;
    rdfs:range :MilitaryOrganization;
```

Listing 1. RDF Ontology Fragment

III. Hierarchic Communication Reasoning

The communication between members of two organizations is usually restricted according to their hierarchical roles, and this must be reflected in their communication equipment. For example, when one organization is directly subordinate to another, they are allowed to communicate. Otherwise, they are not allowed to. Thus, reasoning can be made to restrict communications between equipment, according to the military organization hierarchy levels of their operators. Listing 2 presents the rule expressed in SWRL that implements this communication restriction. In short, it states that given two military persons that operate two different communication user equipment, they may talk to each other if their corresponding military organizations have a subordination relationship.

```
MilitaryPerson(?m2) ^ MilitaryPerson(?m1) ^
UeDown(?i1) ^ UeUp(?i2) ^
operates(?m1, ?i1) ^ operates(?m2, ?i2) ^
MilitaryOrganization(?o1) ^ MilitaryOrganization(?o2) ^
isSubordinateTo(?o2, ?o1) ^
militaryPersonHasMilitaryOrganization(?m1, ?o1) ^
militaryPersonHasMilitaryOrganization(?m2, ?o2)
-> mayTalkTo(?i1, ?i2)
```

Listing 2. SWRL Rule

To illustrate the application of this rule, we take three military combatants: John, Paul and George. They operate three `Ue`s, respectively: `sta0-wlan0`, `sta1-wlan1`, `sta2-wlan1`. George and Paul belong to organizations that are subordinate to John's organization. Therefore, according to the rule at Listing 2, the reasoner will infer the properties assertions presented at Listing 3, i.e., that John may talk to Paul and to George.

```
<ObjectPropertyAssertion><ObjectProperty IRI="#mayTalkTo"/>
    <NamedIndividual IRI="#sta0-wlan0"/>
    <NamedIndividual IRI="#sta1-wlan1"/>
</ObjectPropertyAssertion>
<ObjectPropertyAssertion><ObjectProperty IRI="#mayTalkTo"/>
    <NamedIndividual IRI="#sta0-wlan0"/>
    <NamedIndividual IRI="#sta2-wlan1"/>
</ObjectPropertyAssertion>
```

Listing 3. Object Assertion Example Showing the Result of SWRL Inference.

IV. Conclusion

This paper presented the MiScOn ontology fragment and its potential to serve as a reasoning artifact for Cognitive Radios (CR). It can also be useful in C2 applications, which are used in military operational scenarios, to communicate and provide situational awareness. Typically, C2 applications operate as a constellation of interconnected systems running simultaneously. However, military hierarchy restrictions also apply in these scenarios and must be dealt with by each constellation member when communicating with each other. Currently, MiScOn is already in use in communication emulation software and is intended to be used in C2 applications.

References

[1] D. Kreutz, F. M. V. Ramos, P. E. Veríssimo, C. E. Rothenberg, S. Azodolmolky, and S. Uhlig, "Software-defined networking: A comprehensive survey," *Proceedings of the IEEE*, vol. 103, no. 1, pp. 14–76, 2015.

[2] J. Mitola and G. Maguire, "Cognitive radio: making software radios more personal," *IEEE Personal Communications*, vol. 6, no. 4, pp. 13–18, 1999.

[3] S. K. Balam, P. Siddaiah, and S. Nallagonda, "Performance analysis of decision/data fusion-aided cooperative cognitive radio network over generalized fading channel," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 55, no. 5, pp. 2269–2276, 2019.

[4] F.-P. Pai, L.-J. Yang, and Y.-C. Chung, "Multi-layer ontology based information fusion for situation awareness," *Applied Intelligence*, vol. 46, pp. 285–307, 2017.