StaRe: Statistical Reasoning Tool for 5G Network Management

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Abstract. In operations of increasingly complex telecommunication networks, characterization of a system state and choosing optimal operation in it are challenges. One possible approach is to utilize statistical and uncertain information in the network management. This paper gives an overview of our work in which a Markov Logic Network model (MLN) is used for mobile network analysis with an RDF-based faceted search interface to monitor and control the behavior of the MLN reasoner. Our experiments, based on a prototype implementation, gives promising results of utilizing an ontology and MLN model in network status characterization, optimization and visualization.

1 Introduction

The growing complexity of telecommunication networks requires more automation from the network management layer. Currently researched and standardized technology in the telecommunication field is Self-Organizing Networks (SON) [1] which solves automatically some management tasks in a limited context using a fixed rule base. However, advanced uncertainty management beyond simple static rule bases is required to combine high service quality with optimization of operational expenses [4]. For this goal, we present a prototype tool StaRe that provides the user with a possibility to understand the characterization of the autonomic network management system and its uncertainties. The novel idea is to apply MLN [7] for mobile network analysis and management under uncertainty. We have examined how an ontology-based MLN model can be utilized by a human operator using a SPARQL endpoint and a faceted browser GUI. It is crucial that the operator monitors and controls the system behavior even when the autonomic system solves the majority of management tasks [8].

2 Prototype Architecture and Data Sequence

StaRe is a runtime environment tool that integrates dynamically an MLN model, an ontology based on it, and a GUI for mobile network data analysis and management. A Long-Term Evolution (LTE) simulator is used for simulating an urban mobile network environment.

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Figure 1 depicts our architecture and its data sequence for managing a mobile network. The data sequence starts from the right where the simulator data is retrieved to the MLN model in every 15 min of simulation time. This data contains key performance indicators (KPI) for measurement cases, such as channel quality indicator (CQI) and radio link failures (RLF). In return, the MLN model reasons configuration management parameters for the mobile network (i.e., the LTE simulator) that contain needed changes in the transmission power (TXP) and angle (remote electrical tilt, RET) of a cell antenna. These parameters are critical for the quality of service of the network and operation optimization.

The simulator data is used as the evidence of the MLN model to infer posterior probabilities for action proposals. Network cells in the simulator are then configured based on the action proposal distributions. In order to make this process manageable to the operator, the ontology processor retrieves and parses the evidence, rules, action proposals, and configurations, and populates the ontology with network- and MLN-related instances. The ontology is then uploaded into a SPARQL server based on Fuseki[1]. The server dynamically generates facets from the ontology (with SPARQL update scripts) for the GUI and acts as a data storage both for the GUI and MLN model. The GUI interacts with the SPARQL endpoint to retrieve semantic data from the ontology and to update the semantic MLN rule base. Similarly, the MLN model queries the SPARQL endpoint in order to retrieve updated rule base.

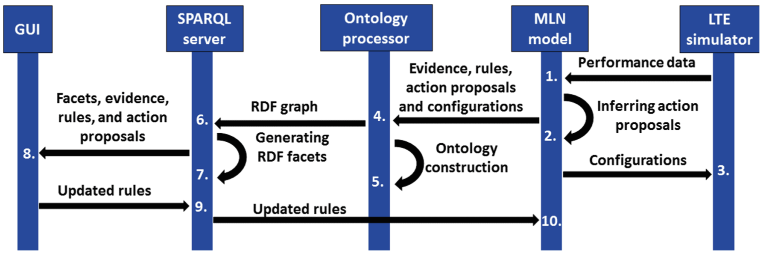

Fig. 1. Data sequence diagram for managing a mobile network (simulator)

3 Faceted Browser Interface

The GUI is an HTML5 application which is built by using faceted browsing and interactive visualization methods in order to (1) determine needed network management actions in a situation and to (2) manage the MLN rules. Figure 2 shows how facet selections can be used to search for recommended actions. Here cells with a high RLF value and low CQI value are selected on the facets on the left, and the tool suggests as an action proposal to increase the TXP of the cells on the right with a varying uncertainty.

[1] https://jena.apache.org/documentation/serving_data/.

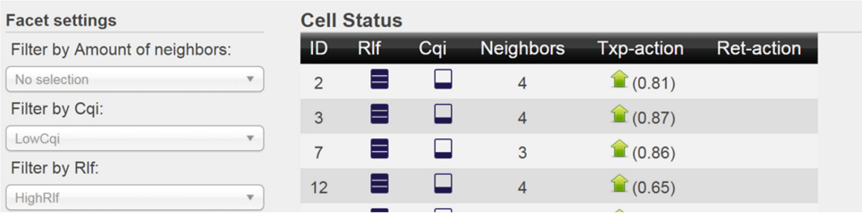

Fig. 2. Faceted browsing for the filtering reasoning outcome

Figure 3 shows a view for managing the uncertain MLN rules by dividing each rule into a rule weight and to semantically defined rule classes: context (current network status), objective (desired change in the network status) and action (configurations for the network). The operator uses this view to investigate contents of the rules and to manipulate the rule base in order to change the behaviour of the MLN reasoner.

The facets are generated as a combination of rule classes (context, objectives and actions) and their objects (CQI, RLF, TXP, and RET). Here the operator has filtered out rules containing low CQI in the context part and increase CQI in the objective part. The result indicates that every single rule can be removed or its weight can be updated. The possibility to remove a set of rules that satisfies current facet selections can be seen above the result table.

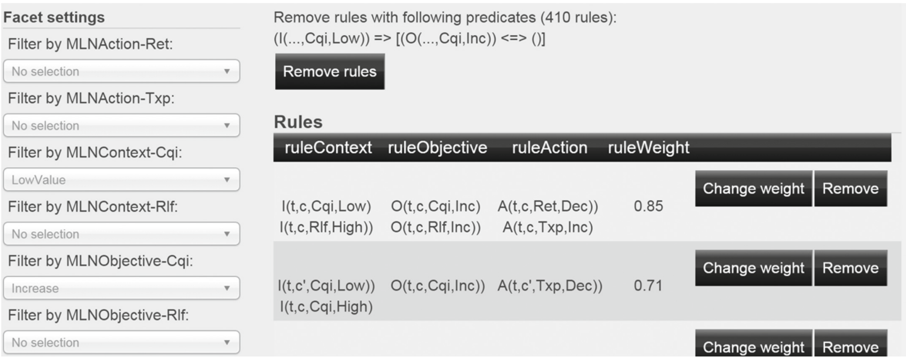

Fig. 3. Faceted search for uncertain rules

In StaRe, the operator can also create new rules with a rule creation form which enables a productive way to create MLN rules without writing the actual MLN syntax.

4 Related Work and Discussion

Various uncertain reasoning techniques have been applied to different network management tasks in the telecommunications field. For example, Bayesian networks (BN) are proposed for automatic network fault management [2,5] and MLN to diagnose anomalous cells [3]. Ontologies have also been used to model general concepts of the telecommunication field [6] as well as to model context in mobile network management [9,11]. The Linked Open Data (LOD)[2] paradigm has also been addressed in [10], which models cells and terminals, and combines them with other data sources, for example with event data. However, there exists no research of using ontologies and statistical reasoning together to analyze and configure the mobile network, as in this paper.

Altogether, StaRe has proven to be a useful tool in complex network management tasks as it contains a reasoner for processing uncertain information and a semantic faceted browser interface for information exploration. As this paper shows, the StaRe ontology can be used as a semantic data storage between the MLN reasoner and GUI.

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