Knowledge-Based Management of Softwarized Networks

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ABSTRACT

As societies gradually change their shape and become more digital, the expectations of end-users greatly influence the design, deployment, and management of computer networks. Moreover, flexibility and the ability to scale on demand have become important requirements for modern infrastructures. This leads to increased complexity in computer networks and the rise of paradigms such as network automation and programmability. Software-based technologies such as Network Function Virtualization (NFV) and Software-Defined Networking (SDN) can improve dynamicity but also introduce an additional level of abstraction. This evolution and the growth in networked systems, requires many cross-disciplinary stakeholders with different expectations and degrees of understanding. In such environments, common representation models and interoperability are crucial. In this work we propose using ontologies and logic programming to model and manage processes in softwarized networks. Ultimately, a knowledge-based approach might enable computer agents to assist human agents by verifying configurations, consistency and inferring new knowledge.

KEYWORDS

Softwarized networks, ontologies, knowledge-based management

1 Introduction

Due to the expansion of new applications and services running over computer networks, many businesses are heavily dependent on the Information and Communication Technology (ICT) infrastructure. Computer networks are getting increasingly complicated to satisfy the needs of various services. Network softwarization has been introduced, so that the network infrastructure becomes more flexible and scalable [1]. Two widely used examples of network softwarization technologies are Software-Defined Networking (SDN) and Network Function Virtualization (NFV).

SDN has been proposed as a solution to the problems of static network infrastructures and to ease network management [2]. NFV complements SDN as it separates the software network functions from vendor-specific hardware functions. Network services are running independently in a virtual environment which means that deployment of network functions is more efficient compared to legacy systems.

Another approach that brought dynamicity and adaptability to network architectures is the Network-as-a-Service (NaaS) paradigm. NaaS allows network managers to perform on-demand scaling and implement desired services faster than in traditional networks [3].

Besides adding programmability and dynamicity to the computer network domain, it is important to also recognize the tradeoff from using the software-based networks approach, since they become operationally more complex. In addition, SDN, NFV and NaaS introduce levels of abstraction that must be correctly handled.

DevOps principles are also widely integrated in computer networks. They foster collaboration among several teams working around the system, including engineers, business managers, and security specialists. Several tools are used to improve the processes and the cooperation between different actors [4]. However, not all actors are networking specialists, and not everyone will have the same understanding of a system, its components, and dependencies between them. Therefore, knowledge and expectation management become a problem.

Ontologies have been used to represent domains, providing a structure and common language that can be understood by both humans and machines. Ontological representations and semantics can help us to describe the defined knowledge and relations between concepts [5]. Furthermore, through inference, an ontological model may allow drawing new conclusions based on already described facts and concepts.

We propose using the ontology-based approach to define a formal model that will represent the processes of softwarized networks. The goal is to increase interoperability and reduce the complexity.

2 Related work

The ontological representation of specific domains of knowledge has been investigated in various research fields. Valderas, Torres, and Serral [6], have created an ontology of IoT devices, their characteristics, and other related data (e.g., location, product, and observations made by sensors). The authors use Semantic Web Rule Language (SWRL) and SPARQL Protocol and RDF Query Language (SPARQL) to make conclusions from the existing knowledge and used them as the input ("high-level events") for a Business Process Model and Notation (BPMN) model.

A method for representing the data model for electrical power systems as a semantic graph has been proposed by Schumilin, Stucky, Sinn, et al. [7]. The authors demonstrate that it is possible to construct an ontology with many objects, set up their relationships, and formulate queries to gather data and arrive at a specific solution.

Knowledge representation in a structured way has been recently studied in the computer networking domain. Martinez, Yannuzzi, Lopez De Vergara, et al. [8], propose using Web Ontology Language (OWL), to represent the semantics for configuring routers and switches. The authors show how semantics from the

Command-Line Interface (CLI) of network devices can be automatically deducted using an ontology-based information extraction system. Liang and Su [9], present the possibility of using knowledge graphs to detect the conflicts between flow rules in SDN. They use SPARQL to check if the correlation conflict appears between flow rules.

3 Knowledge-based Network Management

The key motivational factors for our approach are illustrated in Figure 1. As networks and services are increasingly more automated and software-based, the deployments and orchestration of such systems are convoluted. Furthermore, system monitoring, and data analytics are processes that require a deep understanding of the system, its entities, and their relationships. As these processes are highly interconnected, we want to investigate softwarized networks with the goal to improve the overall knowledge management. Through semantics, we can understand the meaning of different concepts represented in an ontology and draw valid conclusions with the incorporated logic. Thus, our aim is to represent specific processes of computer networks, such as the ones found in containerized services, and build a semantically valid and intelligible model. Eventually, we want to represent different elements of software-based networks through ontologies and exploit semantics and logic to infer new knowledge, enabling powerful human-in-the-loop automation.

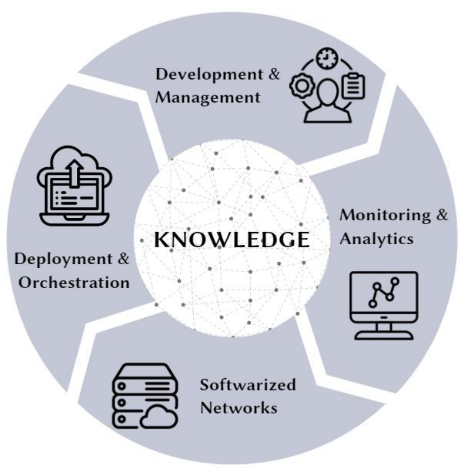

Figure 1: **Motivating factors for our approach**

The system may identify the relationship between the existing semantics and acquire new information by using ontology-based reasoning. When reasoning is incorporated into the loop, both machines and different intervening human actors should share a common understanding regardless of the complexity of the system. Therefore, we will develop a model that makes it accessible for network administrators or other system users to handle relevant data and make informed decisions.

To provide a structured way of organizing knowledge, we intend to use the Semantic Web technologies, Resource Description Framework (RDF), OWL and SPARQL. OWL is a logic-based language created to represent complex knowledge of a specific domain, its elements, characteristics, and their relationship [10]. RDF is a framework for modelling data in a structural way, in the triple form (subject-predicate-object) [11]. To access the data in RDF and extract "graph patterns" or one of the elements of triples, SPARQL can be used. We can investigate the relationship of RDF graph data through complex patterns that consist of several simple ones [12].

4 Conclusion and future work

As demand for various services and applications grows, computer networks are changing and becoming more software-based, resulting in complexity and barriers towards common understanding. We identified that an ontology-based approach could be used to model software-based network knowledge and performed an analysis of related work. Our next step is to explore ontology-based modeling applied to software-based networks. With this approach, different collaborators should benefit from the formal representation of domain knowledge and improve their comprehension of the system. Our future work will include involving users and their perspective towards human-centered network management.

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