Automated Refinement of Sustainability-Oriented Policies for a Sustainable Network Management

Ana Carolina Riekstin, Tereza C. M. B. Carvalho
Escola Politécnica, University of São Paulo
São Paulo, Brazil
{carolina.riekstin,terezacarvalho}@usp.br

***Abstract*—Sustainable networks management represents a significant opportunity for reducing energy consumption among Information and Communication Technologies. Policy Based Network Management (PBNM) is one of the key approaches to bring sustainability to networks. However, despite its potential, PBNM is not yet widely commercially used. The widespread use depends on an automated policies refinement process in order to translate high-level policies into machine-readable policies able to put the business strategies into practice. This work aims at proposing an automated sustainability-oriented policies refinement method, as well as an architecture and a prototype to a sustainable network management.**

I. Introduction

The Information and Communication Technologies (ICT) are responsible, in average, for 2% of the carbon emissions worldwide [1]. The communication networks are responsible for a great part of this amount [2]. The network service providers (NSPs) usually over-provision bandwidth in order to ensure service level agreements (SLA) [3]. Nonetheless, the links are usually underutilized. Therefore, there is an opportunity to reduce the energy consumption by managing networks in a more sustainable way. Policy Based Network Management (PBNM) is one of the key approaches to communication networks management [4], being also a way to achieve a more sustainable networks management. A policy is a set of rules used to manage and control access to a set of ICT resources and services [[5], being able to handle quality of service, security and sustainability issues [6]. Policy rules have four main components: the context in which the rule is applied, the condition under which it is applicable, the priority and the action that must be executed if the condition is achieved [5]. Despite being the subject of several previous works, PBNM is not yet widely commercially used [4]. This widespread use depends on the integration of a consistent and coherent approach to extend business level policies down to machine-readable policies, the so-called "policy refinement"İ. Policy refinement is the process of transforming a high-level policy statement into a low-level policy specification [7]. The main objectives of this process are (1) to meet the policy requirements, translating high-level policies into policies the system is able to perform, and (2) to verify if the low-level policies meet the high-level policies requirements [4]. Within this context, the objective of this work is to study sustainability-oriented policies refinement and propose an automated policy refinement method for them. Policies have been commonly used to specify Quality of Service (QoS) and access control rules. However, as the sustainability has become a prominent issue, the policies should also specify sustainability rules. A sustainability-oriented policy should consider QoS parameters relaxation to build a policy that accepts some QoS degradation in order to save energy in the network. The amount of accepted degradation will depend on the business goals. The expected main contributions of this work are the requirements that a policy refinement process should address in order to tackle energy efficiency, a refinement method and an architecture able to support sustainability-oriented policies refinement, as well as a prototype able to perform a proof-of-concept of the proposed method and architecture. This paper is structured as follows. Section 2 describes the current research regarding sustainable networks, policy-based network management and policy refinement methods. Section 3 specifies the methodology that has been used to develop this work. Section 4 summarizes the current problem and outlines the expected results.

II. Current Research

[2] classified the existing solutions to reduce energy consumption in communication networks into three categories: (1) re-engineering, that addresses the design and materials used in equipment; (2) dynamic adaptation, that deals with adapting the network according to traffic or service requirements; and (3) sleeping/standby. This refers to turning off parts of the network that are being underutilized, which demands the equipment to interpret specific commands to sleep, and that there be a centralized entity able to make decisions (by evaluating energy consumption, availability and load metrics). It is also essential to consider that networks are, mostly, composed by heterogeneous equipment. To handle this scenario and to allow the evaluation of the trade-offs (e.g., "how much is lost in performance given an energy consumption reduction"), the management system must capture the required data from its equipment and decide what to do based on policies as studied by [8] [9] [10]. According to IETF (Internet Engineering Task Force), policies can have different abstraction levels: business, system, network, device, and instance. A management policy must be specified in the business level (service level agreements, information security policies or, in the context of this project, sustainability goals). The policy must be translated to the system level by using performance indicators and workflow information ("how" the business policies will take effect). From the system

978-3-901882-56-2

to the network level, the policy must incorporate specific network metrics. In this level, the policy is defined using structured languages, like Ponder2 [11]. The device level provides the instructions that each network device can handle. The instance level has specific instructions to be applied in every part of the device. These levels comprise the Policy Continuum. The translation between these levels is not simple, and automated approaches are under development [12]. This problem is called "Policy Refinement Problem" [13]. According to [12], an automated approach is still an open issue. According to [4], we are still far away from a generic solution that covers the gaps between SLAs and high-level goals definition. According to [14], a complete policy framework must consider: (1) an extensible specification language (being formal makes the interpretation easier); (2) a way to distribute policies to the enforcement points (PEPs); (3) a policies analysis mechanism; and (4) a mechanism that allows actions identification and execution. Ideally, this framework should also be automated, and support the definition of policies in high-level languages, as well as conflicts detection and resolution. Table I summarizes some of the main existing proposals for policy refinement considering the aforementioned requirements, based on the work of [15], as well the availability of the method for download. KAoS [16] seems to be the most complete solution, starting the process with a constrained set of natural language, going down to actions to be performed in the devices. However, as the other studies, it is not fully available for download over the Internet.

TABLE I. Comparison among policy refinement methods

	[6]	[4]	[11]	[16]	[17]	[18]	[19]
Automated	χ	partial	partial	√	partial	√	partial
High-level language	√	√	√	√	χ	χ	χ
Extensible language	√	√	√	√	√	√	√
Conflict resolution	√	√	partial	√	χ	χ	χ
Policies analysis mechanisms	√	√	√	√	√	√	√
Actions identific. and execution	√	√	χ	√	χ	√	χ
Policies distribution	√	√	χ	√	χ	√	χ
Download available	partial	partial	χ	χ	χ	partial	χ

To the best of the author's knowledge, there is no automated policy refinement method applied to sustainability. [6] proposed a policy refinement from the business down to the instance level using Ponder2 considering sustainability issues as depicted in Fig. 2, but it is not an automated method.

III. Proposed Solution Methodology

Considering all the described issues and existing solutions, this work aims at proposing an automated policy refinement method applied to sustainability-oriented policies, translating policies and verifying if the low-level policies meet the high-level policies requirements. Methodologically, the sustainability policies refinement was already verified by [6] as illustrated in Fig. 1. To achieve the proposed results, the plan described in Table II has been followed.

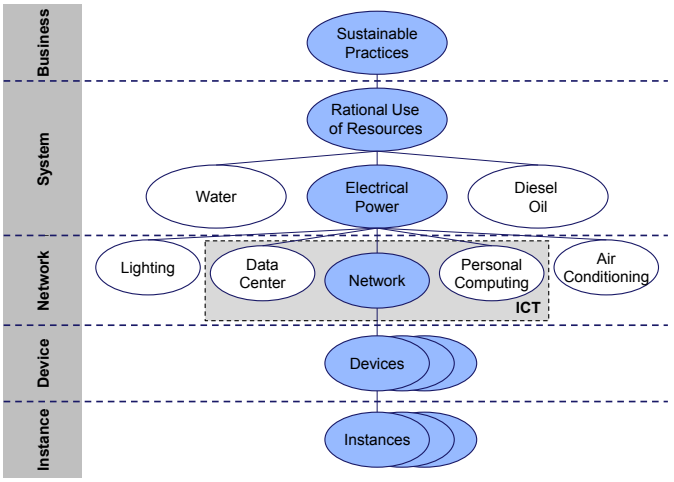

Fig. 1. Methodological sustainability policy refinement

The policies verification was studied considering an authorization policy (network level) using CPN Tools [20], a tool of Colored Petri Nets. Simulations using CPN Tools allow the verification of a policy by simulating the operation or, exhaustively, by using the state space tool. The last is a complete way to verify a policy given that the simulation is exhaustively executed. After the state space construction, it is possible to use queries to check if a prohibited state is reached. It is necessary to note that this state space verification, exhaustive, is possible for authorization policies. Obligation policies are tested using only simulations and, therefore, are probabilistic, as done by [21]. It is necessary to investigate other ways to verify policies

TABLE II. Methodology

Step	Planned activities
1	State-of-the-art research considering: (a) contextualization of the Policy Refinement Problem to sustainability-oriented policies; (b) Identification of strategies for automated policy refinement and verification
2	Architecture proposal considering: (c) specification of the functional requirements for sustainability-oriented policies refinement; (d) refinement method specification; (e) architecture specification
3	Prototype implementation, considering: (f) specification and development of a testbed environment; (g) specification and implementation of the prototype

Considering the requirements listed in Table I, we propose to map the business level using Business Process Modelling Notation (BPMN) related to the Service Level Agreements or sustainability goals. As presented by [21], the BPMN mapping for a more formal language has some limitations that will be considered while integrating the business level into the policy continuum. Using BPMN also addresses other two requirements, usage of high-level and extensible language. BPMN can be used in different levels of abstraction, what gives us the possibility to incorporate

the required metrics to address the system level and start to tell the system "how"İ the business requirements are going to be put in practice. BPMN can be mapped into Business Process Execution Language (BPEL). At this point, we need to understand how we could match this lower level language with the network level obligation and authorization policies. At this level, we will be able to identify the actions that must be placed in the system, as well as evaluate them and check for conflicts. The device level will provide information regarding the types of devices used to implement the network, as well as their capability. To conclude, the instance level, that comprises vendor and other device-specific characteristics, will apply the instructions to each device.

IV. Expected Results and Final Considerations

Policy refinement is an open issue. Many proposals have been presented, but there is neither fully automated method from the business level down to the instance level, nor an approach considering sustainability-oriented policies. The widespread adoption of policy based network management depends on this automation, as well as a sustainable operation for networks. As expected results, this work aims at an automated approach to sustainability-oriented policies refinement, considering the translation and verification of refined policies. The main contributions are the requirements for such a solution, the refinement method, the related architecture, and the prototype implementation.

Acknowledgment

This work was supported by the Innovation Center, Ericsson Telecomunicações S.A., Brazil. Additionally, we would like to thank Marcelo C. Amaral, Guilherme C. Januario, Enlai L. Cheng, Lucas B. Figueiredo, and Catalin Meirosu for also being part of this project.

References

[1] GeSI, "Smart 2020: Enabling the low carbon economy in the information age," The Climate Group on behalf of the Global eSustainability Initiative (GeSI), Tech. Rep., Jun. 2008.

[2] R. Bolla, R. Bruschi, F. Davoli, and F. Cucchietti, "Energy efficiency in the future internet: a survey of existing approaches and trends in energy-aware fixed network infrastructures," *Communications Surveys & Tutorials, IEEE*, vol. 13, no. 2, pp. 223–244, 2011.

[3] M. Zhang, C. Yi, B. Liu, and B. Zhang, "Greente: Power-aware traffic engineering," in *Network Protocols (ICNP), 2010 18th IEEE International Conference on*. IEEE, 2010, pp. 21–30.

[4] J. Rubio-Loyola, *Towards the Policy Refinement Problem in Policy-based Management Systems: A synthesis study*. VDM Publishing, 2008. [Online]. Available: http://books.google.com/books?id=hO0HNQAACAAJ

[5] J. Strassner, *Policy-Based Network Management: Solutions for the Next Generation*, 1st ed. Morgan Kaufmann, Sep. 2003.

[6] T. C. M. B. Carvalho, A. C. Riekstin, M. Amaral, C. H. A. Costa, G. C. Januario, C. K. Dominicini, and C. Meirosu, "Towards sustainable networks - energy efficiency policy from business to device instance levels." in *ICEIS (3)*, L. A. Maciaszek, A. Cuzzocrea, and J. Cordeiro, Eds. SciTePress, 2012, pp. 238–243.

[7] A. K. Bandara, E. C. Lupu, and A. Russo, "Using event calculus to formalise policy specification and analysis," in *Policies for Distributed Systems and Networks, 2003. Proceedings. POLICY 2003. IEEE 4th International Workshop on*. IEEE, 2003, pp. 26–39.

[8] M. C. Amaral, C. H. A. Costa, T. C. M. B. Carvalho, and C. Meirosu, "REASoN - REliability and/or availability evaluation for sustainable networking," in *4th Int. Work. on Reliable Networks Design and Modeling (RNDM'12)*, St. Petersburg, Russia, Oct. 2012.

[9] C. H. Costa, M. C. Amaral, G. C. Januario, T. C. Carvalho, and C. Meirosu, "Sustnms: Towards service oriented policy-based network management for energy-efficiency," in *Sustainable Internet and ICT for Sustainability (SustainIT), 2012*. IEEE, 2012, pp. 1–5.

[10] G. C. Januario, C. H. Costa, M. C. Amarai, A. C. Riekstin, T. C. Carvalho, and C. Meirosu, "Evaluation of a policy-based network management system for energy-efficiency," in *Integrated Network Management (IM 2013), 2013 IFIP/IEEE International Symposium on*. IEEE, 2013, pp. 596–602.

[11] Y. B. Udupi, A. Sahai, and S. Singhal, "A classification-based approach to policy refinement," in *Integrated Network Management, 2007. IM'07. 10th IFIP/IEEE International Symposium on*. IEEE, 2007, pp. 785–788.

[12] A. Uszok, J. M. Bradshaw, J. Lott, M. Breedy, L. Bunch, P. Feltovich, M. Johnson, and H. Jung, "New developments in ontology-based policy management: Increasing the practicality and comprehensiveness of kaos," in *Policies for Distributed Systems and Networks, 2008. POLICY 2008. IEEE Workshop on*. IEEE, 2008, pp. 145–152.

[13] K. Twidle, E. Lupu, N. Dulay, and M. Sloman, "Ponder2-a policy environment for autonomous pervasive systems," in *Policies for Distributed Systems and Networks, 2008. POLICY 2008. IEEE Workshop on*. IEEE, 2008, pp. 245–246.

[14] J. Rubio-Loyola, J. Serrat, M. Charalambides, P. Flegkas, and G. Pavlou, "A methodological approach toward the refinement problem in policy-based management systems," *Communications Magazine, IEEE*, vol. 44, no. 10, pp. 60–68, 2006.

[15] T. Phan, J. Han, J.-G. Schneider, T. Ebringer, and T. Rogers, "A survey of policy-based management approaches for service oriented systems," in *Software Engineering, 2008. ASWEC 2008. 19th Australian Conference on*. IEEE, 2008, pp. 392–401.

[16] F. I. for Human and M. Cognition. Kaos project. [Online]. Available: http://ontology.ihmc.us/kaos.html

[17] M. S. Beigi, S. Calo, and D. Verma, "Policy transformation techniques in policy-based systems management," in *Policies for Distributed Systems and Networks, 2004. POLICY 2004. Proceedings. Fifth IEEE International Workshop on*. IEEE, 2004, pp. 13–22.

[18] R. Craven, J. Lobo, E. Lupu, A. Russo, and M. Sloman, "Policy refinement: decomposition and operationalization for dynamic domains," in *Network and Service Management (CNSM), 2011 7th International Conference on*. IEEE, 2011, pp. 1–9.

[19] B.-S. Liao and J. Gao, "An automatic policy refinement mechanism for policy-driven grid service systems," in *Grid and Cooperative Computing-GCC 2005*. Springer, 2005, pp. 166–171.

[20] D. Zaitsev and T. Shmeleva, "Simulating of telecommunication systems with cpn tools," 2006.

[21] P. Wohed, W. M. van der Aalst, M. Dumas, A. H. ter Hofstede, and N. Russell, "On the suitability of bpmn for business process modelling," in *Business Process Management*. Springer, 2006, pp. 161–176.