Model-Driven Middleware to Support Dynamic Applications for different Domains in Smart Cities

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ABSTRACT

The concept of smart cities entails the use of information technologies to access the resources of the city in a more intelligent way providing specialized services to citizens. In this way, the city's IT infrastructure should facilitate the development, deployment and operation of smart city applications for several different domains. Building these applications becomes a great challenge since: they are used on a large scale, have dynamic behavior, must access heterogeneous resources and must deal with the semantics of these different domains. In this work, we propose an integrated environment to assists in the construction and execution of smart city applications. To achieve this goal, we propose the use of a model-driven approach to domain-specific middleware which provides support for the development of application on top of a domain-independent smart city platform.

CCS CONCEPTS

• **Software and its engineering** → **Middleware**; *Software system models*; • **Computer systems organization** → *Embedded and cyber-physical systems*;

KEYWORDS

model-driven middleware, smart city platform

1 INTRODUCTION

The concept of Smart Cities has been widely used in recent years and has attracted considerable attention in the context of urban development policies. A smart city can be defined as the integration of social, physical, and IT infrastructures to improve the quality of city services [1, 8]. Alternatively, it can be defined as a set of information and communication technology tools used to create an integrated environment [4, 7, 8]. In this way, the city's infrastructure should facilitate the development, deployment, and operations of smart city applications belonging to multiple domains, such as public lighting, public transport, health care, and safety [5].

A smart city platform is the technology responsible for this integration, exposing the capabilities of smart cities and solving problems such as heterogeneity and resource sharing and discovery [5]. Such access to the infrastructure enabled by the platform is independent of application domain. Although it is possible to build applications for specific domains directly on top of such platforms, the applications need to access the resources at a low level, having to add the domain-specific semantics of resources by themselves, which results in unnecessary complexity.

In order to overcome this problem, we propose the use of domain-specific middleware (DSM), in an approach that we call model-driven DSM (MD-DSM) [6]. The model-driven approach defines high-level building blocks, in the form of a metamodel, which are used to define the structure and operational semantics of DSM. The domain-specific nature of MD-DSM allows to shorten the semantic distance between the implementation platform and the applications, by relying on abstractions that are familiar to the application domain. This work propose an architecture that combine this approach and an existing smart city platform called InterSCity [2, 3].

2 OBJECTIVES

The main goal of this work is to design, implement and evaluate an integrated architecture that combines MD-DSM and a smart city platform in order to provide high level support for the creation and execution of dynamic applications for different smart city domains. While MD-DSM enables a high level application development model, the smart city platform promotes the unified use of city resources across different applications and application domains.

3 CONTRIBUTIONS

This work advances the state-of-the-art by proposing the symbiotic integration between an smart city platform and domain-specific middleware. By relying on a smart city platform, application developers have unified access to city resources and services. At the same time, by building applications on top of DSM systems that are tailored for each application domain, developers can access city resources using domain-specific semantics, which significantly raises the abstraction level.

Another important contribution of this work is the mechanism for accomplishing this integration that transforms a generic resource into a specific resource for an application domain.

4 MD-DSM FOR SMART CITIES PLATFORMS

With the proliferation of domain-specific application that use and deliver smart city resources, smart city platforms must not only facilitate and abstract the use of resources but also support the construction of the applications that user them. MD-DSM is an elegant solution to this problem as, for each application domain, it enables the instantiation of a specific middleware, as illustrated in Figure 1 and described in Section 4.2. This section outlines the design principles of the approach proposed in this work, followed by the description of an architecture to realize it.

Middleware Doctoral Symposium '18, December 10-14 2018, Rennes, France

ACM ISBN 978-x-xxxx-xxxx-x/YY/MM…$15.00
https://doi.org/10.1145/nnnnnnn.nnnnnnn

4.1 DESIGN PRINCIPLES

Smart cities emerge from advances in tools and techniques developed both in the industry and academia. However, integrating these tools and technologies to support the creation and execution of applications from different domains raises complex issues, such as ensuring reliability in the construction of middleware and applications, and in the access to resources.

To enable MD-DSM on top of a smart cities platform, we address six key design issues for the wide adoption of existing solutions in different smart city initiatives and application domains: scalability, model orientation, simplicity, consistency, compliance, dynamic adaptivity, and reliability.

Model orientation – the proposed approach must thoroughly follow the MDE principles, meaning that middleware instances are built using models and are meant to run applications that are themselves defined in the form of models.

Simplicity – middleware systems must have features that make it easier and simpler to build domain-specific applications.

Consistency – between the middleware and the smart city platform on top of which it runs, especially considering the shared use of the underlying city resources.

Compliance – between the language (DSML) used to create applications models and the middleware that executes those models.

Dynamic adaptivity – DSM must have the ability to dynamically interpret domain-specific application models.

Reliability and Assurance – (i) in the construction of the domain-specific middleware, maintaining its internal consistency, (ii) in the processing an application models, exerting the correct domain semantics, and (iii) in the access to resources, e.g., to prevent unintended side effects when sharing resources across domains.

4.2 OVERVIEW OF THE APPROACH

In this section we present the overview of the proposed approach to realize MD-DSM on top of a smart city platform, as illustrated in Figure 1. In a more traditional approach, applications interact directly with the platform and are in charge of handling all aspects of resource access, such as data transformation and interpretation of the specific characteristics of each resource type, including the mapping of generic resources to the specific semantics required for the domain.

As shown in Figure 1, each application domain comprises a DSM model that incorporates the domain knowledge (which contains the operational semantics needed to execute application models) and the structural elements that are needed to execute applications in the domain. Each application domain typically also comprises a Domain-Specific Modeling Language (DSML), which is used to model the applications that are executed by the respective DSM.

A DSM instance is built from a middleware model and allows the execution of applications within a specific domain. It promotes the access to city resources (via the smart city platform) by attributing domain-specific semantics to the interactions with them.

5 CONCLUSION

The main contribution of this work is the symbiotic integration of a Smart City platform with a Model-Driven Domain-Specific Middleware to support the construction and execution of specialized and dynamic applications. In this way, this approach involves a smart city platform that manages the domain-independent access

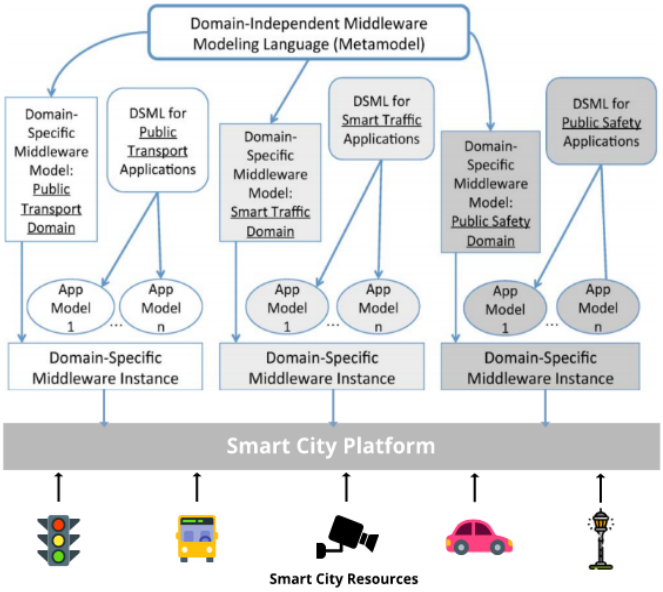

Figure 1: Overview of the Approach.

to the infrastructure resources of the city. The middleware in turn associates domain semantics to each resource as it executes high level application models.

As next steps we intent to develop a mechanism to transform generic resources into domain-specific resources, to test and evaluate the approach, as well as extend it to capture the dynamic behavior of smart city applications by adapting the operational semantics of DSM. We also intend to explore the use of verification and validation tools to assure the reliability, compliance, and consistency requirements of MD-DSM.

ACKNOWLEDGMENTS

This research is part of the INCT of the Future Internet for Smart Cities funded by CNPq, proc. 465446/2014-0, CAPES proc. 88887.136-422/2017-00, and FAPESP, procs. 2014/50937-1 and 2015/24485-9.

REFERENCES

[1] A. Caragliu, C. Del Bo, and P. Nijkamp, "Smart cities in Europe," Journal of Urban Technology, vol. 18, no. 2, pp. 65–82, 2011.
[2] A. M. Del Esposte, F. Kon, F. M. Costa, & N. Lago (2017). InterSCity: A Scalable Microservice-based Open Source Platform for Smart Cities. In SMARTGREENS (pp. 35-46).
[3] Batista, D. M., Goldman, A., Hirata, R., Kon, F., Costa, F. M., & Endler, M. (2016, November). Interscity: Addressing future internet research challenges for smart cities. In Network of the Future (NOF), 2016 7th International Conference on the (pp. 1-6). IEEE.
[4] D. Washburn, U. Sindhu, S. Balaouras, R. A. Dines, N. M. Hayes, and L. E. Nelson, "Helping CIOs understand 'smart city' initiatives," Growth, vol. 17, 2009.
[5] E. F. Z. Santana, A. P. Chaves, M. A. Gerosa, F. Kon, and D. S. Milojicic, "Software platforms for smart cities: Concepts, requirements, challenges, and a unified reference architecture," Submitted for publication (avail- able at http://arxiv.org/abs/1609.08089), 2016.
[6] F. M. Costa, K. A. Morris, F. Kon, & P. J. Clarke (2017, June). Model-Driven Domain-Specific Middleware. In Distributed Computing Systems (ICDCS), 2017 IEEE 37th International Conference on (pp. 1961-1971). IEEE.
[7] R. E. Hall, B. Bowerman, J. Braverman, J. Taylor, H. Todosow, and U. Von Wimmersperg, "The vision of a smart city," in 2nd International Life Extension Technology Workshop, Paris, 2000.
[8] R. G. Hollands, "Will the real smart city please stand up? intelligent, progressive or entrepreneurial?" City, vol. 12, no. 3, pp. 303–320, 2008.