

Chapter 31

Aspect-Oriented Self-Configuring P2P Networking in Mobile Environments: A Formal Specification and Verification

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ABSTRACT

In mobile environments (MEs) such as vehicular ad hoc networks (VANETs), mobile ad hoc networks (MANETs), wireless sensor networks (WSNs), and so on, formal specification of self-configuring P2P networking (SPN) emerges as a need for programming and verifying such mobile networks. Moreover, well-specified SPN in MEs becomes a requirement of developing middleware for the mobile networks. Meeting these challenges of mobile networks requires a fundamental approach to the facets of SPN in MEs not tackled before. To this end, taking advantage of the categorical structures we establish, in this chapter, a firm formal basis for specifying P2P, self-configuration, aspect-orientation, and aspect-oriented self-configuring P2P networking (ASPN) in MEs. All of these are to support a mechanism of verification for ASPN in MEs.

INTRODUCTION

In mobile environments (MEs) such as vehicular ad hoc networks (VANETs), mobile ad hoc networks (MANETs), wireless sensor networks (WSNs) and so on, *self-configuring P2P networking* (SPN), which is seen as a fundamental paradigm of mobile computing, is currently on the spot as one of the priority research areas and research activities are booming nowadays (Denko, Yang, & Zhang, 2009 ; Xhafa, 2009).

Although this networking paradigm is potentially very powerful using nature-inspired computational intelligence (Vinh, 2009a, 2009c), there are still many aspects of designing such mobile networks that are not yet well understood. Thus investigating SPN in MEs emerges as a need, on the one hand, for managing the mobile networks, but on the other hand, for modeling, specifying, programming, and verifying such mobile networks. Moreover, well-established SPN in MEs becomes a requirement of developing middleware for the mobile networks. Hence

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this chapter is intended to present a rigorous approach to SPN in MEs on how SPN in MEs can be specified and verified formally. In other words, our aim is to formalize SPN in MEs using categorical language for developing and verifying SPN in MEs. Especially, taking advantage of aspect-oriented approach, SPN in MEs is primarily investigated based on this aspect-orientation such that we firstly construct aspects of SPN in MEs. Secondly, categorical specification for *aspect-oriented self-configuring P2P networking* (ASPN) in MEs is developed. Thirdly, by the categorical specification, significant properties of ASPN in MEs are built as strong criteria for verification. Finally, a mechanism of verification for ASPN in MEs is illustrated.

Furthermore, this chapter breaks new ground in dealing with ASPN in MEs taking advantage of categorical approach – a firm formal method applicable to a wide variety of ASPN in MEs. While the dealing with this subject is normally very formal (Vinh, 2009c), the chapter goes across some categorical structures straightforwardly, leading the readers to an understanding of what it means to give a rigorous approach to ASPN in MEs.

OUTLINE

The chapter is a reference material for readers who already have a basic understanding of the MEs for their applications and are now ready to know how to specify and verify formally ASPN in MEs using categorical language, assured that their computing needs are handled correctly and efficiently.

ASPN in MEs is presented in a straightforward fashion by discussing in detail the necessary components and briefly touching on the more advanced components. Several explanatory notes and examples are represented throughout the chapter as a moderation of the formal descriptions. Significant properties of ASPN in MEs,

which emerge from the specification, create the firm criteria for verification.

We attempt to make the presentation as self-contained as possible, although familiarity with the notion of MEs is assumed. Acquaintance with categorical language and the associated notion of aspect-orientation is useful for recognizing the results, but is almost everywhere not strictly necessary.

The rest of this chapter is organized as follows: In section of Preliminaries, we recall some concepts from the category theory used in the chapter. Section of Related Work includes some major work related directly to the content of the chapter. Section of Formal Specification of ME Peers presents formal specification of ME peers including the formal structures of P2P, self-configuration, aspect-orientation and ASPN in MEs using categorical language. In section of Formal Verification of ME Peers, we present formal verification of ME peers including a mechanism of verification based on specification and an illustration in detail. In section of Discussions, we briefly discuss a direction of further developments in the future. Finally, a short summary and further investigations are given in section of Conclusions and Future Work.

PRELIMINARIES

In this section, we recall some concepts from the category theory (Asperti & Longo, 1991 ; Bergman, 1998 ; Adamek, Herrlich, & Strecker, 2009 ; Levine, 1998 ; Lawvere & Schanuel, 1997) used in this chapter.

What is a Category?

Category as a graph: A category C can be viewed as a graph $(Obj(C), Arc(C), s, t)$, where

- $Obj(C)$ is the set of nodes we call *objects*,

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