The Formal Specification Column

by

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Formal Modeling and Analysis of Flexible Processes in Mobile Ad-Hoc Networks

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Abstract

Our new project has started in October 2006 and concerns modeling and analysis of processes in mobile ad-hoc networks. In this contribution our work plan is discussed and first results are presented.

1 Introduction

Mobile Ad-hoc NETworks (MANETS) consist of mobile nodes which communicate with each other independently from a stable infrastructure, while the topology of the network constantly changes depending on the current position of the nodes and their availability. Unfortunately there are almost no approaches so far for the modeling and the analysis of those MANETS which are urgently needed for a correct course of the relevant processes.

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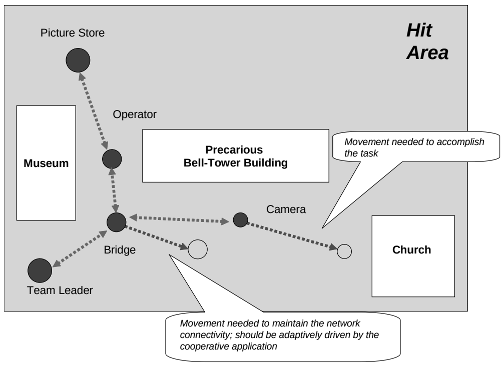
Here, we introduce our project *forMA$_f$NET*[1] where we aim at modeling flexible processes that are the changing workflows at the nodes of a MANET.

It is the goal of this project to develop a formal technique which on the one hand enables the modeling of flexible processes in MANETs and on the other hand supports changes of the network topology and the transformation of processes. This can be achieved by an appropriate integration of graph transformation, Petri nets and processes in high level net classes. In this project a successful application on MANETs requires a specific advancement concerning structuring, process modeling, analysis, methodology and tool support.

The achieved results will be validated by a case study in the area of emergency management that is developed in cooperation with some research projects [2]where an adaptive workflow management system for MANETs, specifically targeted to emergency scenarios, is partly realized resp. going to be implemented.

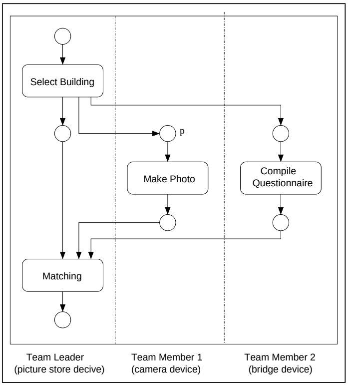


As a running example we use a scenario in archaeological disaster/recovery: after an earthquake, a team (led by a team leader) is equipped with mobile devices (laptops and PDAs) and sent to the affected area to evaluate the state of archaeological sites and the state of precarious buildings. The goal is to draw a situation map in order to schedule restructuring jobs. The team is considered as an overall MANET in which the team leader's device coordinates the other team member devices by providing suitable information (e.g. maps, sensible objects, etc.) and assigning activities.

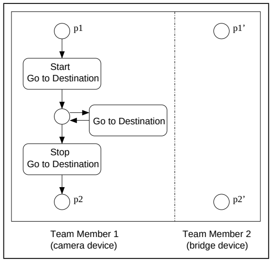
A typical cooperative process to be enacted by the team is shown in Fig. 1.a,

[1]Formal modeling and analysis of flexible processes in mobile ad-hoc networks, funded by the German Research Council (DFG) (2006 - 2008) `http://tfs.cs.tu-berlin.de/projekte/formalnet/`.

[2]MOBIDIS - `http://www.dis.uniroma1.it/pub/mecella/projects/MobiDIS`,
MAIS - `http://www.mais-project.it`,
IST FP6 WORKPAD - `http://www.workpad-project.eu/`



(a) Workflow



(b) Mobility net

Fig. 1. P/T-nets in workflow and mobility layer

where the team leader has to select a building based on previously stored details of the area while team member 1 could take some pictures of the precarious buildings and team member 2 (after a visual analysis of a building) could fill in some specific questionnaires. Finally, these results have to be analyzed by the team leader in order to schedule next activities.

In a particular scenario the movement of the device equipped with the camera could result in a disconnection from the others. To maintain the network connectivity and ensuring a path among devices a layered architecture should be able to alert the mobility layer to select a possible "bridge" device (e.g., the one owned by team member 2) to follow the "going-out-of-range" camera device. In general this may result in a change of the MANET topology. Specifically, the current mobility net and the P/T-net of team member 2 have to be transformed in order to adapt it to the evolving network topology.

In [2] we introduced the paradigm "nets and rules as tokens" using a high-level model with suitable data type part. This model called algebraic higher-order (AHO) system exploits some form of control not only on rule application but also on token firing. In general an AHO-system is defined by an algebraic high-level net with system places and rule places as for example shown in Fig. 2, where the marking is given by a suitable P/T-system respectively rule on these places. For a detailed description of the data type part, i.e. the AHO-SYSTEM-signature and corresponding algebra A we refer to [2].

2 Work Plan

The goal of this project is an adequate specification technique for multi-level modeling of workflows in MANETS.

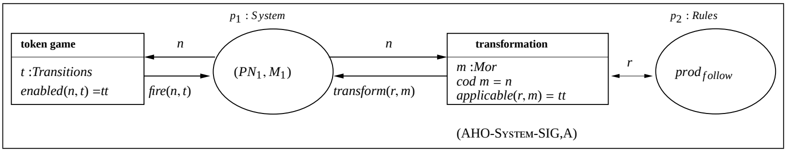


Figure 2: Algebraic higher-order system

The collective task of a team using the MANET is divided into individual workflows of team members. We develop a formal technique which on the one hand enables the modeling of flexible processes in MANETs and on the other hand supports changes of the network topology and the transformation of the processes. Changes of flexible processes are induced by the need to maintain the infrastructure, by changes of the collective workflow, and – most interesting – by changes induced by individual team members.

The main tasks in the project can be grouped into this areas:

Characterization of main properties: The requirements for formal modeling of MANETs and of flexible processes in MANETs need to be analyzed exhaustively to consolidate the choice of the formalisms and to consider possible extensions from the beginning. One of the recent developments is a suitable restriction of AHO nets and the choice of reconfigurable Petri net systems [2] for the description of the flexible processes in MANETs.

Structuring and transformation of AHO *nets* : Tokens of AHO nets are nets and rules forming reconfigurable nets that combine the usual firing behavior with dynamic changes of the net structure given in terms of graph transformations. This combination yields a high modeling power as well as intriguing theoretic questions concerning structuring, transformation, and their compatibility with each other and their semantics. Possible choices for the underlying net formalism are place/transition (as in [2]), algebraic high-level or open nets.

Process modeling and analysis in AHO *nets* : Reconfigurable nets need to be developed into a well-defined and well-equipped modeling technique. This comprises a suitable semantics that supports the process intention and adequate analysis techniques as known both from the area of Petri nets, e.g invariants, deadlocks, and the area of graph transformations, e.g. confluence, parallelism.

Methodology and (prototypes of) tool support: A methodology comprising tool environments and suitable modeling techniques is necessary for any practical application, we will provide the fundamental concepts and a prototype of tool support. We plan a development environment that provides an export to AGG[3], a

[3] http://tfs.cs.tu-berlin.de/agg/

graph transformation engine as well as a tool for the analysis of graph transformation properties like termination and rule independence. Furthermore, the token net properties could be analyzed using the Petri Net Kernel[4], a tool infrastructure for Petri nets different net classes.

3 First Results

Formal modeling of workflows in MANETS using algebraic higher order nets (AHO nets) was first introduced in [1] based on [2]. AHO nets are Petri nets with complex tokens, namely Petri net systems as well as rules and net transformations for changing these nets. On this basis we have present a layered architecture of the model that allows the separation of support activities concerning the network from activities concerning the intended workflow in [3]. This yields better and conciser models, since supporting the network connectivity has a much finer granularity than the more or less fixed workflow execution. The layered architecture of AHO net models of workflows in MANETS distinguishes three layers, the workflow layer, the mobility layer and the team layer. The workflow layer describes the overall workflow that is to be achieved by the whole team. The mobility layer describes the workflows in order to maintain the MANETS connectivity. The team layer describes the individual activities of the team members. Moreover, we provide a set of rules in each layer for the transformation of corresponding P/T-nets expressing different system states.

References

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[4] http://www2.informatik.hu-berlin.de/top/pnk/