MoNoTrac: A Mobile Node Trace Generator

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***Abstract*—Mobility is a core feature of future networks, e.g., wireless sensor, wireless mesh, and mobile ad-hoc networks. Thus the ability to generate accurate traces of mobile nodes is an important aspect for wireless network research. Many publications regarding wireless networks rely on simulations. The applied mobility models are often highly abstract and emulate human behavior poorly. Graph-based approaches try to restrict the area of movement to street-like structures yet they do not model real environments. MoNoTrac is a work-in-progress framework to create mobility traces based on real maps provided by *OpenStreetMaps*. Its plug-in architecture allows the usage of custom mobility models and provides simplified access for research in the domain of mobile networks.**

***Index Terms*—Mobile Ad-Hoc Network (MANET), Mobility Model, Trace, Generator**

I. Motivation

Wireless networks are in an emerging state since the last decade. Wireless mesh networks (WMN) and wireless sensor networks (WSN) are two of the most prominent examples. Although often only considered as static networks, mobile nodes can be part of these network architectures. In WMNs the clients are usually mobile and roam from one mesh router to another. Depending on the definition, the wireless mesh routers can also show at least some limited mobility. High mobility is introduced when clients extend the network by offering a routing service. WSNs used for animal tracking [1], [2], to monitor elderly [3], or for localization tasks [4] are only some of the many example applications that also possess this property. The disctinction into disjunct groups of WMNs, WSNs, and mobile ad-hoc networks (MANETs) is becoming blurred as novel applications are evolving traditional network architectures. The future Internet and the often named “Internet of Things” will likely possess mobile components. Thus the simulation of mobile networks is still an aspect of current and future scientific and industrial research. Many publications are based on simulations [5]. However, simulations make assumptions and have limitations that often result in conclusions that cannot be transfered to real networks as they abstract from the reality in many aspects [6]. Besides the used radio propagation model, mobility models play a significant role in experiments and their scientific soundness. To evaluate real world applications the simulated nodes have to move as close as possible like their real counterparts [7]. Yet many of the commonly used mobility models emulate human or vehicular behavior poorly. Additionally, often times an empty and rectangular movement area is considered or a simple grid-like graph. Although more sophisticated models for urban and suburban mobile networks exist, these approaches have limitations. In this paper we introduce the *Mobile Node Tracer* (MoNoTrac), a work-in-progress tool to generate mobility traces based on geographical data provided by the *OpenStreetMap* project. A plug-in interface allows the customization and adaptation to the requirements for specific experiments.

The remainder of the paper is organized as follows. In Section II the related work is discussed. Subsequently in Section III, MoNoTrac is introduced and its features elaborated. Section IV lists some features for future versions of MoNoTrac that are up for discussion. The paper closes with a conclusion in Section V.

II. Related Work

Several mobility models have been defined to generate traces as input to other applications or alternatively to directly control mobile nodes in a simulation environment. The most simple mobility model *random walk* resembles a Brownian motion but no human behaviour. This applies also to the *random waypoint* mobility [8] and *random direction* models that show sharp angles in the paths of the nodes. The *Gauss-Markov* model considers recent moves of a node for the next waypoint and generates a smoother human-like path. Animal movement can be modeled by the Levy Walk model although it also represents some human walk patterns [9].

None of these models often used in simulations restricts the area of movement to real world like structures. With the *Manhattan grid* model [10] the area of movement is limited to a grid-like graph resembling some central city areas. *Freeway* models try to simulate traffic flows on roads, whereas *city area* models combine densely populated city centers with suburban and rural areas. One tool making use of these models is the *Communication Scenario and Mobility Scenario Generator* (CosMos) [11] which allows to create zones where different mobility models are applied to mobile nodes. The nodes can move from one zone to another which is modeled as a Markov-Chain.

Besides the artificial generation of mobile node traces, real data is often preferred. Yet these data sets are hard to get and require large expenses to distribute, maintain, and operate tracking devices and the required infrastructure. Privacy concerns aside, GSM and UMTS data is glady used if available [12]. Only the date and time of a communication and cell location information are available but no detailed

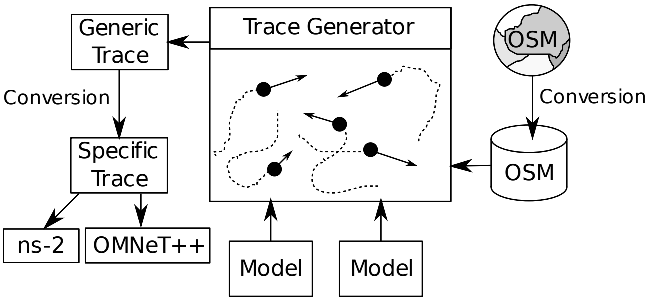

Figure 1: System model of MoNoTrac.

information about the traveled path. The mobility data is only coarse grained (macroscopic level of mobility). Simulations of mobile networks require more detailed position information. Further on, for the simulation of WSNs, WMNs, and MANETs a different user behaviour and mobility can be assumed than the one in cellular systems.

The CCC Sputnik project [13] published several traces gathered by RFIDs from conferences, e.g, the Chaos Communication Camp in 2007. The project wants to demonstrate the problems, threats, and benefits that have to be considered by tracking and data mining. Their movement data is limited to conference buildings.

One of the major problems with real traces is that they cover a limited time span that cannot be extended at will. For the sound simulation of mobile networks multiple traces of mobile nodes in the same environment are required.

Several applications try to provide the user with more realistic traces based on real maps. Street maps in the MapInfo MIF/MID-format are used by the *random waypoint city* model [14] to simulate vehicular movement. Saha and Johnson [15] used maps from the *Topologically Integrated GEographic Encoding and References* (TIGER) database provided by the *US Census Bureau* for their mobility model of vehicular traffic. The *Mobility model generator for VEhicular networks* (MOVE) [16] is a tool that uses user or randomly generated maps as well as maps from the TIGER database. It is built on top of SUMO a micro-traffic simulator [17]. Generated traces can be imported by ns-2 or Qualnet. The TIGER database seems to be a popular source of maps but it only comprises US street maps and provides limited information, e.g., no speed limits or no one-way roads.

III. MoNoTrac

MoNoTrac is a work-in-progress framework to generate mobility traces based on mobility models and real map data. Scenario descriptions, which consist of a movement area, mobile nodes, mobility models, and a simulation time are used as input for MoNoTrac to generate mobility traces. The application is based on Java 6 and published under the GPL.

Users create a scenario by selecting a region with streets, roads, and public transportation stations from a repository of geographic data that serves as movement area of mobile nodes. In a next step, the number and type of mobile nodes are added to the scenario description. A mobility model is applied to each participating node. The implemented mobility models are available as plug-ins. This software architecture allows the user to extend MoNoTrac with custom mobility models. Finally a runtime is specified for the scenario.

Based on the scenario description, MoNoTrac generates mobility traces in a meta format based on XML. This format is designed in a way, that a translation script can automatically convert the generated mobility traces to input formats of popular simulation environments such as ns-2 and OMNeT++. Thus, mobility traces based on real map data can be easily integrated into custom wireless network simulation scenarios. The system model and workflow of MoNoTrac is shown in Figure 1. With the focus on the usability and simplicity to define scenarios and generate mobility traces, a rapid trace generation is achieved, which we missed in other tools.

The maps of the OpenStreetMap project are used for the real world map data sets. The vector format based OpenStreetMap data are parsed and transformed to a graph representation and stored in a relational database[1]. The main window of MoNoTrac is shown in Figure 2. On top of the rendered OpenStreetMap map data the extracted graph is drawn. The user can draw any polygon to specify the movement area of the mobile nodes. The movement area can be bounded or boundless. Thus nodes can leave, enter, and reenter the simulation area if required.

The number, type, and distribution of mobile nodes can be specified. Currently, the types *pedestrian* and *car* are supported. These types of nodes are limited in their movement to the appropriate edges of the graph based on the values provided by the OpenStreetMap data. The nodes move according to the specified mobility model. At the time being, the *random walk*, *random waypoint*, and a variant of the *manhattan grid model* are implemented as plug-ins for MoNoTrac.

IV. Outlook and Topics of Discussion

A first release candidate of MoNoTrac will be soon available at http://des-testbed.net. The application is under heavy development. Currently the map of the Berlin area has been preprocessed and stored in a database.

In the next step an online processing is required to make all areas available for MoNoTrac. Also the possibility to visualize the generated mobility traces will be implemented. Several extensions are envisioned. First of all, different models shall be usable for particular zones with inter-zone mobility similar to CosMos. Temporal mobility characteristics, e.g., rush hours are considered. While they can be part of a loaded mobility model, the framework should provide support to dynamically modify the configuration. We also like to incorporate the public transportation system to provide further “roads” for pedestrians. While extracting the public transportation lines from the maps is feasible, there is no general and easy way to provide schedules for the public transportation vehicles. MOVE supports bus timetables but they have to be specified by the user which is a labour-intensive task. To increase the accuracy of simulations based on the generated traces additional information could be

[1]The graph presentation is kindly provided by the *Databases and Information Systems* research group at *Freie Universität Berlin*. Thanks to Joos-Hendrik Böse and Jürgen Bross.

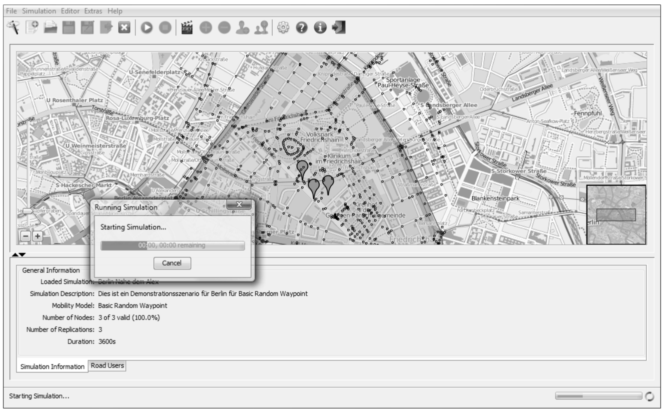

Figure 2: Mainwindow of MoNoTrac. Currently a trace is generated.

provided based on the OpenStreetMap data, such as the road type and according speed limits. To adapt the radio propagation to the environment several environmental parameters could be extracted, e.g., where living, industrial, and office areas are.

V. Conclusion

Simulation environments are one of the most important tools of scientific research of mobile networks. For life-like simulation of real world applications the most often used simple mobility models do not generate data resembling human movement patterns. As real traces of mobile nodes are of limited availability, their generation based on map data has been of interest in the last years. In this publication we introduced MoNoTrac a framework to create traces of mobile nodes. Data from the *OpenStreetMaps* project is used together with user supplied mobility models via a plugin infrastructure to create input for various simulation environments.

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