Technische Universität Hamburg-Harburg

Communication Networks

On the Required Degree of Detail in Mobility Modeling for Vehicular Multihop Access Networks

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City Mobility Models

The basis for the investigation of detail in mobility modeling are two street-based mobility models using data of real digital street maps. The first is the **Random Waypoint City mobility model (RaWaCi)**. It uses a Random Waypoint approach to restrict the movement of users to paths on streets of the map between two waypoints. The principle is shown in Figure 1.

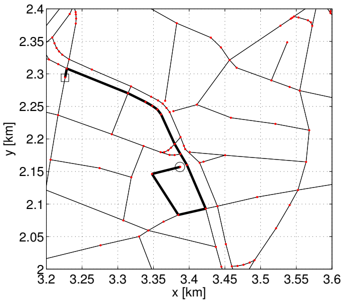

Figure 1: Random Waypoint City Model: Movement between waypoints on the fastest path on streets of different type.

The second, the **Random Direction City mobility model (RaDiCi),** uses a random choice of direction at every intersection to guide movement of users in a simulation area. The probability of turning in a specific direction can be set differently for every crossing and every incoming direction. This can be used to realize arbitrary, desired steady state user distributions on streets (**RaDiCi mod**).

Both models use random speeds on streets with v in [0.9;1.1]v_s and v_s depending on the type of street as defined in Table 1.

Additional Features

The two simple models are refined with additional features whose influence on the performance of wireless multihop access networks is analyzed in simulations.

Pausing is implemented in two different degrees of realism. The first approach is a **probabilistic pausing** at crossings. The pausing probability p_p depends on the type and number of intersecting streets as defined in Table 2.

Table 1: Street Types

Type m	Description	V_s(m)
1	Autobahn	35 m/s
2	Highway	22 m/s
3	Main street	15 m/s
4	Regional street	12 m/s
5	Local street	8 m/s
6	Small street	2 m/s

Table 2: Pausing Probability

m_{on}-m_x	p_p	
	d=3	d>3
>0	0.2	0.7
<0	0.05	0.3
=0	0.1	0.5

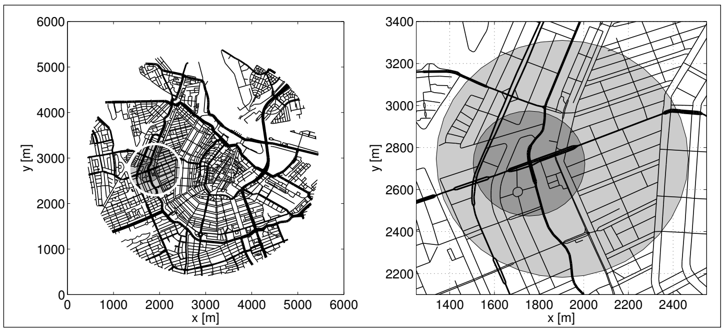

Figure 2: Simulation area, a section of Amsterdam's city center. Movement area: 20,4km², network simulation area (light grey) 1km², coverage area (dark grey) 0,2km².

Abstract

This work investigates mobility models for vehicular multihop access network simulations. The models are derived from simple graph-based mobility models. By adding more and more features to increase their realism, we show to which extent this approaching of reality is really necessary. To this end, we identify the properties of mobility models that really do influence the performance of several applications using a vehicular multihop access network.

The alternative is a simulation of **traffic lights**. An automatic calculation of phase plans is used to determine the sorting of streets to phases and the duration of green-light-times.

Another aspect of vehicular traffic is the **influence of users on each other**. In urban environments, the speed of users is not only limited by the street type m but also by the speed of preceding users. Beside the total **independence,** two approaches with increasing realism are implemented.

The first is a **basic dependence of speed on a preceding user** on the same street if the randomly chosen speed would lead to an overtaking. In that case, the speed is reduced so that the arrival occurs after that of the predecessor.

The second implementation is the **Intelligent Driver Model (IDM)** [1]. Speed depends on the predecessor on the chosen path as defined in

$$\frac{\mathrm{d}v_\alpha}{\mathrm{d}t} = \dot{v}_\alpha = a\left[1 - \left(\frac{v_\alpha}{v_d}\right)^\delta - \left(\frac{s^*}{s_\alpha}\right)^2\right]$$

$$s^*(v_\alpha, \Delta v_\alpha) = s_0 + \max\left(v_\alpha T + \frac{v_\alpha \Delta v_\alpha}{2\sqrt{ab}}, 0\right).$$

The current acceleration of every user is a function of his current speed, his desired speed, the current distance and difference of speed to the predecessor.

The final feature concerns the **border behavior**. Implemented were a **closed border** with reflecting borders and an **open border** with a small network simulation area embedded in a large movement simulation area. The open border leads to the number of networking peers being a random variable.

Therefore, simulations with constant mean number of users in the network simulation area were realized.

Movement- and network simulation areas as well as the coverage area of the wireless LAN access point are shown in Figure 2.

Simulations

19 different mobility models, shown in Table 3, were composed using combinations of the described features achieving different degrees of realism. The models were used in simulations of **three applications** of a vehicular multihop access network which are:

- **CBR broadcast** to all users
- **CBR unicast** to 10 users
- File download of 10 users with **TCP**

The selected routing protocol for unicast is AODV.

Results

Results are presented for CBR (Figure 3) and TCP unicast (Figure 4). Results for broadcast were very similar to CBR unicast. The results are grouped into four subplots reflecting the separation of Table 3.

Table 3: Mobility Models

ID	Base Model	Traffic control	Inter-action	Border behavior
1	RaDiCi	-	-	closed
2	RaDiCi mod	-	-	closed
3	RaWaCi	-	-	closed
4	RaWaCi	-	idm	closed
5	RaDiCi	random	-	closed
6	RaDiCi mod	random	-	closed
7	RaDiCi mod	tl	-	closed
8	RaDiCi mod	tl	basic	closed
9	RaWaCi	tl	basic	closed
10	RaWaCi	tl	idm	closed
11	RaDiCi	-	-	open
12	RaWaCi	-	-	open
13	RaWaCi	-	basic	open
14	RaWaCi	-	idm	open
15	RaDiCi	random	-	open
16	RaWaCi	random	-	open
17	RaWaCi	tl	-	open
18	RaWaCi	tl	basic	open
19	RaWaCi	tl	idm	open

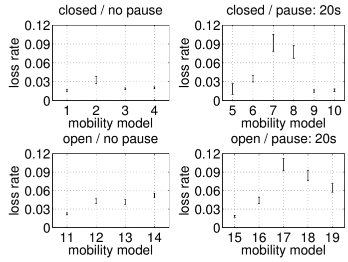

Figure 3: CBR unicast loss rate.

Counterintuitively, the introduction of pauses leads to a degradation of packet delivery rate, although mobility is decreased. This is caused by a concentration of users at crossings which are the only locations where pauses occur. Even more important is the implementation of pausing. Loss rates were more than doubled when changing from probabilistic to traffic-light controlled pausing. Again, this is due to a temporarily even higher concentration of users at crossings which can even lead to isolation of such a user cluster from the access point.

Increasing user dependence leads to slightly improved results in the models with pausing. This is a result of the spreading of users between crossings which prevents isolation of clusters in some scenarios.

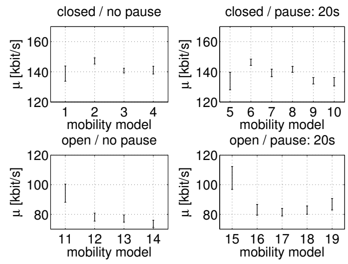

Figure 4: TCP throughput.

While the border behavior did not have a strong impact on CBR loss rate, TCP's throughput is massively reduced by introducing the open border behavior. The reason is the reduced session duration which is limited to the sojourn time inside the networking area. Whenever a new session starts, TCP has to use Slow Start and Congestion Avoidance to reach its maximum rate.

Pausing and user interaction, however, do not have a major impact on mean throughput. The reason is TCP's adaptability. Data rates can be adjusted so that connections suffering packet loss get less throughput, but others with better connectivity receive more at the same time.

Concluding, it can be said that required features are realistic pausing for CBR (Model 7) and realistic sessions for TCP (Model 12).

References

[1] D. Helbing, A. Hennecke, V. Shvetsov, and M. Treiber, "Micro- and Macrosimulation of Freeway Traffic," *Mathematical and Computer Modelling*, vol. 35, pp. 517–547, 2002.

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