Towards a Mobility Metric for Reproducible and Comparable Results in Ad Hoc Networks Research

[Poster Abstract]

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Keywords

Ad hoc networks, mobility model, topological change rate

1. INTRODUCTION

The performance of a mobile ad hoc network depends on its ability to adapt to changes in the network topology. It is therefore important to understand the relation between *node mobility* and *topology dynamics*. While the input parameters of a mobility model allow for generating different simulation scenarios (e.g., by selecting the speed, pause time, system area, and number of nodes), the relation to the actually generated degree of topology dynamics is usually not immediate. Thus, a translation of the mobility model to the resulting topology dynamics is required. A natural way to do this is to introduce the *topology change rate (TCR)*, defined as the number of link changes per time unit as observed by a single node. If we measure the network performance versus the TCR instead of versus 'incidental' input parameters of a mobility model, a higher level of abstraction of the results will be achieved, and the reproducability and comparability of the results will be enhanced.

This short paper derives in an analytical manner the TCR in a scenario where nodes move according to the *random waypoint (RWP) model* [5], being the most heavily used mobility model in reseach on ad hoc networks. Recent insights into RWP mobility have shown some unexpected behavior, e.g., with respect to the spatial node distribution [2] and the average velocity over time [8]. These results do not mean that RWP as a mobility model is 'invalid', but show the importance of proper use due to thorough understanding of the model. This contribution now provides the link between RWP mobility and the corresponding TCR. We

- derive in an analytical manner the TCR as observed by a static node located at the center of a circular area in which mobile nodes move according to RWP model.
- show via simulation that our expression takes over to the TCR as observed by a moving node and to other shapes of the system area.

We see this result as a step towards establishing TCR as a 'generic' mobility metric that can help to improve the reproducability and comparability of simulation results on ad hoc networking.

2. THE TCR OF THE RWP MODEL

With RWP mobility, a node selects a waypoint by sampling from a uniform distribution over the system area. The node moves with a speed v sampled from a uniform distribution on the interval $[v_{min}, v_{max}]$ to the waypoint and pauses for a predefined pause time t_p. After this pause, the procedures iterates. The movement from one waypoint to the next waypoint is denoted as a movement transition.

For the analytical derivation of the TCR, we first study the number of link changes observed by a static node located in the center of a circular system area. We assume an ideal transmission range r and a system area radius R, where we introduce the normalized range $\hat{r} = r/R$. Since different nodes are independent of each other, we simply look at a single node following the RWP mobility pattern. We proceed in four steps:

Step 1. The probability that a transition causes a *single* topological change can be determined with geometric reasoning to be $P_1 = 2\hat{r}^2 \left(1 - \hat{r}^2\right)$.

Step 2. The probability that a transition causes *two* topological changes is[1]

$$P_2 = \frac{1}{2\pi}\Big(\pi - 3\hat{r}^2\pi + 2\hat{r}^4\pi + 4\hat{r}\left(1-\hat{r}^2\right)^{3/2} + 2\left(1-\hat{r}^2\right)\left(\arcsin\hat{r} - \arccos\hat{r}\right)\Big).$$

Step 3. The expected number of topology changes in one transition is thus

$$E\{C\} = P_1 + 2P_2\,.$$

[1]This probability is proportional to the area 'behind' the circle given by the transmission range of the static node and seen from the perspective of the RWP node when it starts to move to a new waypoint. In case of acceptance of this paper, we will provide the full derivation with illustrations as a technical report posted to our web page.

Submission to Mobicom 2003, San Diego

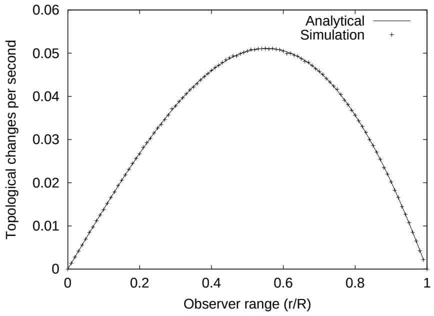

Figure 1: TCR for a static node at center of circular area and a RWP node moving at $v = 5\,\mathrm{m/s}$.

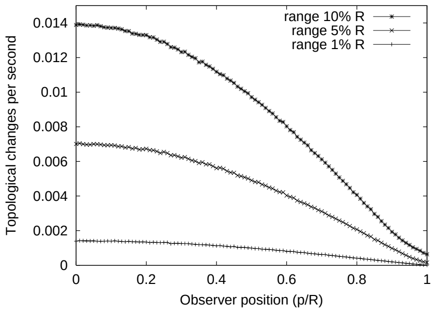

Figure 2: TCR over the observer's position.

Step 4. The final result, the number of topological changes per time unit, is given by

$$\overline{c} = \frac{E\{C\}}{E\{T\} + t_p}$$

where

$$E\{T\} = \frac{1}{v_{max} - v_{min}} \ln\left(\frac{v_{max}}{v_{min}}\right) E\{L\}$$

is the expected duration of a transition, and $E\{L\} = \frac{128}{45\pi} R$ is the expected length of a transition [3]. The corresponding curve of $\overline{c}$ for constant speed $v = v_{min} = v_{max} = 5\,\mathrm{m/s}$ and no pause time $t_p = 0$ is given in Figure 1. Under these assumptions, $\overline{c}$ is linear with respect to the number of moving nodes and their speed v.

More complicated scenarios, in which the observing node is not located in the center of the area or it is moving around, could be studied in the same way, however, due to less symmetric layout, the elaboration of these cases is more tedious. We thus cover these cases by accurate simulations.

Simulation results of a static node at a non-centric position are shown in Figure 2. The case of a static observer at the center of the system area is actually the 'worst case', i.e., it represents the exact upper bound on the TCR. Figure 3 compares the analytical TCR for the static observer on the center and the simulated TCR for a moving observer. As a result, we see that the difference between both curve is marginal for $\hat{r} \ll 1$. A similar result, shown on the poster, also holds for the comparison with a square system area.

3. CONCLUSIONS & OPEN ISSUES

Our closed–form expression of the TCR represents a good approximation to predict the generated TCR in a variety

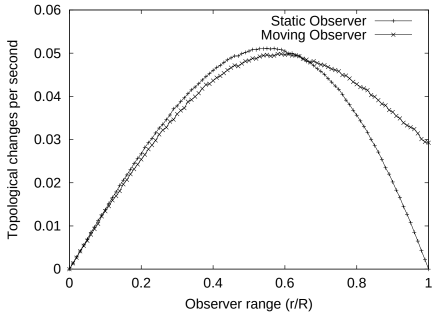

Figure 3: Comparison of TCR for static node at center and a moving RWP node.

of scenarios. The result allows us to select the parameter of the mobility model in a way that a specific TCR is obtained. This procedure allows for generating a sequence of mobility patterns with a prescribed network dynamics. We believe that performance evalutions measured against such a suite of scenarios will be more valuable than those comparing some performance metrics with some 'incidental' tuning parameters. The result put forward in this paper thus provides a building block towards a systematic understanding of the impact of mobility on ad hoc network performance [1].

While the behavior of RWP mobility is made more immediate with this paper, we see a number of open problems in the area of mobility models and metrics: it has to be proven that TCR really represents a measure that can be used independently of a mobility model and allows comparison across various models used (as suggested in, e.g., [7, 4]). Moreover, a similar analysis as presented here has to be done for other models, most prominently for the random direction model. Also, the relation between TCR and link and path stability [6] must be made explicit.

4. REFERENCES

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