Towards a Common Mobility Metric for Comparative Studies of Mobile Ad Hoc Networks: Results and Challenges

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The Need for Mobility Models and Metrics

- The performance of a mobile ad hoc network depends on its ability to adapt to changes in network topology due to the nodes' mobility.
- Mobility models: key element for mobile ad hoc network simulation since changes in network topology depend on them.
- Mobility metrics: needed to assess the degree of dynamicity of a scenario *independently* of the mobility model used.
  - A mobility metric should provide a quantitative measure of mobility that is *relevant* to assess performance of the network.
  - Today: tuning parameters of a specific mobility model are used that do not provide an accurate measure of mobility, e.g., 'speed' or 'pause time'.

Topological Change Rate (TCR) as a Mobility Metric

- TCR is the 'natural' mobility metric: reflects changes in network topology perfectly and is independent of specific tuning parameters of the mobility model.
- Potentially allows *comparability* of results obtained with different mobility models and/or scenarios.
- There is already some related work in this direction [1]
- However, for most models the TCR cannot be directly configured. Instead, analytical derivations or a simulative assessment of the TCR are needed.

Random Waypoint (RWP) Mobility: Basics and Recent Insights

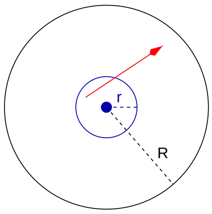
- Heavily used in ad hoc network simulations.
- A node selects the next waypoint by sampling from a uniform distribution over the system area; the node moves with constant or a speed sampled from a distribution to the waypoint; it might pause there and then iterates the scheme.
- But recent insights show some deficiencies:
  - RWP spatial node distribution non-uniform [2].
  - RWP speed distribution over time has intricacies [3].

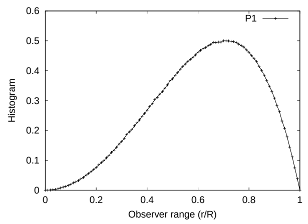
Topological change rate of RWP: Analytical results

- Consider one node following the RWP mobility model and one static observer in the center of a circular system area.
- Due to the *ergodicity* of the RWP process, each transition period – which is not independent of the next one other – can be treated as if they were independent (see [4]).
- We derived the TCR of the RWP model in 3 steps:

Step 1: Probability of *one* topological change in a transition:

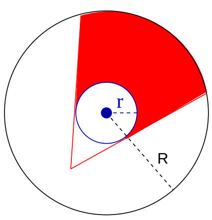
$P1 = 2 \cdot r_{00}^2 \cdot (1 - r_{00}^2)$ where $r_{00} = \frac{r}{R}$

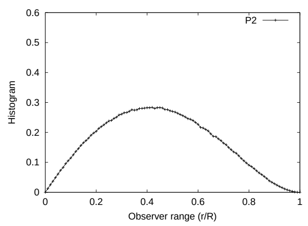




Step 2: Probability of *two* topological changes in a transition:

$P2 = \frac{1}{2\cdot\pi}(\pi - 3\cdot r_{00}^2 \cdot \pi + 2\cdot \arcsin(r_{00}) + 4 \cdot r_{00} \cdot \sqrt{1 - r_{00}^2} - 2 \cdot r_{00}^2 \cdot \arcsin(r_{00}) - 4 \cdot r_{00}^3 \cdot \sqrt{(1 - r_{00}^2)} - 2 \cdot \arccos(r_{00}) + 2 \cdot r_{00}^4 \cdot \pi + 2 \cdot r_{00}^2 \cdot \arccos(r_{00}))$

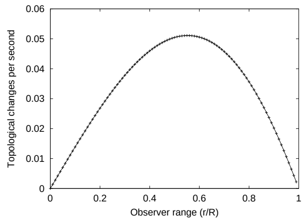




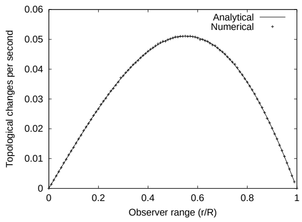
Step 3: Expected number of topological changes per time unit:

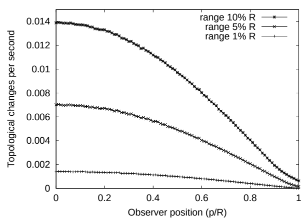
$E_{top\_ch/s} = (P1 + 2 \cdot P2 \cdot)\frac{E\{speed\}}{E\{mov\_length\}}$

- $E\{mov\_length\} = \frac{128}{45\pi} \cdot R$ [4]
- Maximum topological change rate/s: 0.051 at $r = 0.055 \cdot R$
- ...

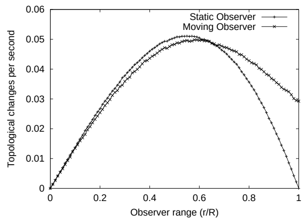


Topological Change Rate of RWP: Simulation Results





- The analytical expression for the static observer in the center case matches perfectly the simulation results
- The static observer in the center case yields the topological change rate *upper bound* compared to static observers located in different positions or moving observers



- The dependency of the topological change rate with respect to the speed of the mobile nodes or the number of mobile nodes is linear

Contribution and Future steps

- Proposal of a mobility metric independent of the mobility model used and the considered scenario that allows performance comparison of results that depend on the mobility generated
- Analytical derivation and simulative evaluation of the topological change rate mobility metric.
- Enhance understanding of the Random Waypoint Mobility model.
- Propose a research agenda of what should be done *i)* to design a better mobility model and *ii)* to ... mobility metric.
- The upper bound for other mobility models should be obtained to make a comparative study of the performance under the same TCR conditions to validate the hipothesis of the TCR independence of the mobility model.

References

[1] B. Kwak, N. Song, and L.E.Miller, "A Mobility Measure for Mobile Ad-Hoc Networks," to appear in IEEE Communication Letters, 2003.

[2] C.Bettstetter, "Smooth is Better than Sharp: A random mobility model for simulation of wireless networks," In Proceedings of ACM MSWIM, 2001.

[3] J.Yoon, M.Liu, and B.Noble, "Random Waypoint Considered Harmful," In Proceedings of IEEE Infocom, 2003.

[4] Chr.Bettstetter, H.Hartenstein, and X.Pérez-Costa, "Stochastic Properties of the Random Waypoint Mobility Model," to appear in ACM Kluwer Wireless Networks Special Issue on Modeling & Analysis of Mobile Networks, 2003.