# MobiCom Poster Abstract: Modeling Static and Dynamic Behavior of Routes in Mobile Ad hoc Networks

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*Ad hoc networking research needs meaningful models to describe the behavior of multihop routes. We survey existing static models to describe the distribution of link and path distances as well as dynamic models describing the lifetime of links, paths, and routes. Next, we enhance and combine selected models to form a combined model describing both, the static and dynamic aspects of multihop ad hoc routes. In particular, our model allows for prediction of lifetimes for single and multipath routes for a bounded and an unbounded modeling area. As a proof-of-concept, the model is applied to analyze the efficiency of different usage strategies of multipath routes: based on the lifetime predictions of our model we estimate the transport capacity of the routes.*

## I. Introduction

The promise of self-organizing operation of mobile and wireless nodes in multihop ad hoc networks gives rise to several interesting research challenges of which routing is a prominent one. Key problems such as the efficient, scalable, and dependable operation of ad hoc routing protocols are only partially solved, today. We believe that research in this area suffers especially from the lack of meaningful and realistic models. Based on existing work, we formulate a combined analytical model describing both, static and dynamic aspects of routes to capture the characteristics of the routing system in ad hoc networks. Our contributions are as follows:

- We survey and classify existing static and dynamic models, which describe link, path, or route characteristics.
- We formulate a combined model that extends existing static models, which describe the distribution of link- and path-distances, with dynamic aspects describing the lifetime of links, paths, and routes.
- We show the applicability of our model for the evaluation of efficient ad hoc communication by analyzing the transport capacity of multipath routes for various path-usage strategies.

The structure of this extended abstract mirrors the structure of the poster, which is available online [4].In Section II we give a survey and classification of existing models. These models are analyzed and extended to fit the requirements of our combined model in Section III. We describe the formulation of the combined model in Section IV and, as a proof-of-concept, apply our model to analyze the transport capacity of multipath routes. We summarize and conclude our work in Section V.

## II. Survey and Classification

There exists a large body of related work to describe the static properties of wireless multihop networks. Most of this work studies the performance and capacity of the network under ideal conditions. We can classify these models in static and dynamic models that describe either the properties of links, paths, or routes (See Fig. 1 for the classification of models).

- Primary targets for static models are the description of the connection distances between nodes; either for direct or multihop communication. They describe the direct (Euclidean) link distance between the communicating nodes or – in case of multihop routing – they approximate the distance of the individual path segments that form the route.
- Modeling objectives for dynamic models are the lifetime of links, paths and routes. The breakage of a multihop path is given by the minimum lifetime of the links that form this path. The lifetime of a single-path route equals the lifetime of a path. The lifetime of multipath routes is given by the maximum lifetime of all paths.

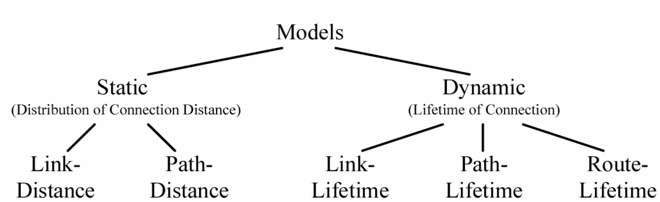


Fig. 1. Classification of models.

## III. Analysis and Model Extension

Based on Miller's work on the distribution of link distances in static ad hoc networks [5], Hollick in [3] formulates and instantiates a model describing the route acquisition process of the AODV protocol [7] and introduces the route-length distribution as a meaningful metric for the analysis of the performance and dependability of the routing system. Both models use a bounded modeling area, i.e., a rectangle/square, and, hence, strongly influence the possible communication distances between nodes because of the size and shape of the area. For our study we extend [3] to also describe an unbounded modeling area to obtain further insights for an increasing communication distance.

In contrast to static models, dynamic models capture the dynamics of the network induced by node mobility. We investigated the models of Samar et al. [8] and Turgut et al. [9] describing the expected link lifetime for various scenarios. Investigated models for the path lifetime are the models of Tseng et al. [10], Bai et al. [1], and Gruber et al. [2]. While [10] assumes discrete node movement between cells, [1] and [2] discuss scenarios for different mobility models that are related to ad hoc network.

We assume that a route may be composed of multiple paths. Hence, we studied the models of Nasipuri et al. [6] and Ye et al. [11] describing the route lifetime for the case of multipaths analytically and by means of simulation. Based on the assumption of independent link lifetimes, in [6] an exponential distribution of route lifetimes is obtained, which, for the single-path case corresponds to the result of [1].

## IV. Combined Model Formulation

We unify the two classes of models and present a combined model. As basis we use the static model of Hollick [3] that is augmented with the dynamic behavior described in the model of Nasipuri et al. [6]. The combination of these models is possible, because the model assumptions can be matched. In particular, the nodes are similarly distributed and the paradigm of a reactive routing protocol is equally employed in both models. Model assumptions include the independence of link breaks and that nodes are i.i.d. uniformly distributed in the modeled area.

A synergetic combination of the models is possible while retaining the flexibility of the underlying models. Our approach is to (1) use the static model to estimate the possible distribution/number of routes in the network and to (2) use the lifetime of the routes to estimate the breakage of routes over time. Combining both results we are able to predict the remaining routes in the network. Our poster [4] visualizes the basic assumptions underlying the models we selected for combination and present the most important model equations of these base models. We detail the modeling process and give the corresponding model equations of the combined model for the generalized multipath case. Moreover, we show representative model predictions for a selected set of parameters to visualize our results.

As a proof-of-concept we apply our combined model to analyze the lifetime of multipath routes for different numbers of multipaths (see [4] for details). Equipped with these results we calculate the transport capacity of the routes for various path-usage strategies. The insights obtained are of interest for the choice of multipath strategies in dynamic networks.

## V. Summary

We developed a unified model to describe both, static as well as dynamic aspects of routes in ad hoc networks. Static aspects are covered using the distribution of link- and path-distances. Dynamic aspects are covered using the lifetime of links, paths, and routes. As a proof-of-concept, we have shown the applicability of our model for the evaluation of efficient ad hoc communication.

## VI. Referenzes


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