Empirical Modeling of Campus-wide Pedestrian Mobility: Observations on the USC Campus

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Mobility is one of the main factors affecting the performance of mobile ad hoc networks (MANETs). Specifically, in the absence of fixed infrastructure as in MANETs, mobile computing devices (such as handheld devices) may be used to route packets. Mobility of such devices may cause established links to break and consequently established paths between a sender and a receiver to become invalid. Obtaining realistic mobility models is thus essential to the proper design and evaluation of ad hoc protocol performance. Thus far, work on mobility modeling for ad hoc networks considered synthetic models and wireless network usage pattern measurement. In this work, we present a novel approach to model student mobility on campus using "mobility traces". Unlike previous measurement-based techniques, we actually trace user mobility (vs. network access patterns for W-LANs). This provides a new perspective on mobility modeling. We develop a methodology to capture movements of pedestrians (mobility traces) on the USC campus. We further propose various statistical metrics to capture spatio-temporal correlation among people. We then propose a hybrid parameterized mobility model, using the group, smooth random and obstacle mobility models. Parameters for such a hybrid model are estimated based on the trace. Such a model will be also useful for future ad-hoc networks, where an "ad-hoc enabled" device will be ubiquitous; especially in campus-like settings.

APPROACH & RELATED WORK

A wide variety of mobility models [1][2] have been proposed from analytic and simulation-based studies (so called "synthetic" models) on mobile nodes forming an ad-hoc network These are not based on actual measurements of mobility. Other wireless network-usage studies conducted at MIT[4], Dartmouth[3] and UC San Diego[5] capture user usage over access points in the campus. This however, does not model true movement behavior of users, although it does give useful insight for current networks. We capture snapshots of actual movements of people i.e. mobility traces by concentrating on 7 major intersections on the USC campus and divide the students into groups to cover regular time-windows for all weekdays, systematically. Collected data included number of people in groups, number of those who spilt in subgroups and this was collected for each path around the intersection. Subsequently, based on these "real" traces of movements, we obtain statistical parameters of user movements leading to a probabilistic description of user direction and speed. These descriptions are used in conjunction with parameters and attributes of existing synthetic models to obtain closed form expressions or distributions of the mobility, forming a hybrid mobility model.

SCENARIO AND SAMPLE RESULTS

The traces were collected from Feb. 26 to April 25, 2004. During this period, we observed 6389 people, 1758 groups of which 2382 subgroups were formed. About 60 students participated in the observations, and about 220 man hours of traces were collected.

We did not observe stationarity in the distribution of people in campus over different time slots. However, the temporal and the spatio-temporal distributions closely followed human behavior for example movement out of campus was observed during lunch hours. It also followed schedules of the campus such as that for classes or library hours.

Directional probabilities were also calculated from the wireless network usage in the campus and these were found to be very different from those obtained from our traces. The reason is that movement of people in this case tends to cluster around access points and also is restricted to people possessing laptops. Our traces did not have these limitations and as such the sample population observed in the two cases was very different.

The probabilistic description of direction is modeled by a state machine very similar to the finite state machine **(FSM)** where the state is the user location in campus and the "transitional probability" is the probability of movement of a user in a particular direction (example: North). We implemented the FSM using a tool that operates on our traces to generate another trace file which is readable by the Network Simulator (NS). This trace file may be used for the purpose of simulating the mobility of nodes as if they are in the USC campus. This code was used by other teams and they obtained results very dissimilar to those obtained from the synthetic models. It was also established that the FSM or directional equation depends on a direction update factor which is a probability measure which in turn is a function of the user's current location and time. This is desirable in a mobility model.

CONCLUSION

We propose a new method for mobility modeling. The approach we adopted for the development of the proposed mobility model is very different from that used by previous synthetic models. Due to the use of real traces this model aligns closely to the actual movement of people on campus. Thus, it could be used to develop or better evaluate ad-hoc routing protocols, or in capacity planning. The model has been implemented by a FSM and our tool facilitates simulations studies for such protocol evaluations.

References

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