A 2-D Random-Walk Mobility Model for Location-Management Studies in Wireless Networks

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***Abstract*—In this work, a novel two-dimensional (2-D) random-walk mobility model is proposed, which can be used for studying and analyzing the location-area crossing rate and dwell time of mobile users in wireless networks. The development and application of the model under two cell structures, namely the square and hexagon cells, have been detailed. The analytical results obtained for location-update rates and dwell times have been validated using simulated and published results. The highlights of the model are its simplicity, minimal assumptions, and adaptability to conduct both "location-crossing rate" and "dwell-time" studies using the same model with slight modifications for either the square or hexagon cells. Using symmetry of mobile-user movement, a reduced number of computational states was achieved. A novel wrap-around feature of the model facilitates reduced assumptions on user mobility, which has also resulted in considerably reduced mathematical computation complexity. A regular Markov chain model was used for computing the average location-area crossing rate. A slightly modified model with absorbing states was used to derive the dwell time. This is the first model of its kind that can be used for studying area-crossing rates. To further emphasize the flexibility of the model, we have extended the model to study an overlapped location-area strategy. The study and analysis of overlapped locations areas has hitherto been difficult due to the complexity of the models.**

***Index Terms*—Land mobile radio cellular systems, Markov processes, modeling.**

I. Introduction

The MOBILITY of users is a major advantage of wireless over fixed telecommunications systems. The signaling traffic and database processing to support the mobility of users are always key concerns in the design and performance of wireless networks. Mobility models play a key role in studying different mobility-management features such as registration, paging, handoff, and database approaches. A mobility model with minimum assumptions and that is simple to analyze will be very useful under such circumstances. In most wireless network performance studies, the cell is assumed to be either hexagon or square shaped [1], although in real life cell shapes may be highly irregular. Some authors assume a circular cell shape, especially those using a fluid flow model. However, in our work, we have restricted our analysis to hexagon and square cells; the model we propose can easily accommodate these two types of cell shapes.

In this work, we highlight a novel two-dimensional (2-D) random-walk model that can be used for studying and analyzing the location-area crossing rate and dwell time of mobile with slight modifications to the basic proposed model. The development and application of the model under two cell structures, namely the square and hexagon cells, have been detailed. In both cases, the analytical results obtained for location-update rates and dwell times have been validated using simulated and published results. The analytically obtained results from the model show excellent concurrence with simulated and published results. The highlights of the model are its simplicity, minimal assumptions, and adaptability to conduct both location-crossing rate and dwell-time studies using the same model with slight modifications for both square and hexagon cells. We have used mobile-movement symmetry within and across "location areas" and applied the "lumped-process" property of Markov chains to obtain a model with reduced computational states. A novel wrap-around feature has been used in these models to reduce constraints on mobile movements, thereby providing a more realistic roaming scenario. The model uses a set of aggregate states to trace user movement within one location area and then uses a set of special (asterisk) states when crossing the boundary of the location area. Due to the wrap-around technique, the movement of the mobile is modeled to enter the original states again from the special states, once the mobile starts moving within the new location area. The average number of location-area crossing rates or updates made by the user is obtained by solving for the regular Markov chain. A slightly modified model with absorbing states was used to derive the dwell time. This is the first model of its kind that can be used for studying area-crossing rates and dwell times using a simple model. To further emphasize the flexibility of the model, we extended it to study an overlapped location-area strategy. We have provided comparative results between the overlapped and nonoverlapped strategies. Overlap location-area strategies are commonly used concepts in cellular networks. However, the study and analysis of such overlapped configurations has been difficult, due to the requirement of complex models. We show that it is possible to study such overlapped location-area schemes by using the proposed model.

Location areas can be dynamic or static. The proposed model can be adapted to study location-area crossing rates and dwell time in both dynamic as well as static location-area strategies.

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