Chapter 10

Conclusion and Perspective

OBJECTIVES OF THE CHAPTER

• To summarize the work done

• To suggest future directions

This chapter concludes the thesis and summarizes the major contributions while highlighting future research directions and perspectives. Through this research work, we have sought to characterize the temporal behaviour of a number of network parameters such as number of neighbour nodes, link load, path length and delay using time series models. Through our experiments, we found that most of these parameters can be modelled with autoregressive models of order \( p \), i.e. \( AR(p) \) for suitable values of \( p \). The experiments also confirmed that the values of \( p \) lie between 1 and 3 for a threshold value of transmission range, trying time and node velocities. Yet, above the threshold value, the autocorrelations of the node distribution are not very important. The thresholds of different parameters have been determined and tabulated. The threshold values obtained are suitable for any practical deployment of ad-hoc networks. The summary of the thesis contributions is presented below.

10.1 Thesis Contributions

A fresh insight into characterizing and modelling of different parameters of mobile ad hoc network using time series is attempted in this research study. The details of the various
parameters and their suitable models are discussed in the following subdivisions.

10.1.1 Modelling Neighbour Count

We have anticipated the number of neighbouring nodes in future times and establish that these predictions are statistically close to the assessed values. The forecast values of neighbouring nodes can be utilized for different network services such as multi-path routing, congestion control, topology construction and traffic prediction. The forecast values are found to be similar to the actual values with 95% confidence.

10.1.2 Modelling Link Duration

We have modelled the link load distribution of a liaison between two clients using an Auto-regressive $AR(p)$ model used in the stationary time series analysis. We found through our experiments that link load distribution between two nodes for different mobility models are well correlated and can be represented by $AR(p)$ model for a suitable choice of $p$. We have also predicted the link loads between two nodes in future time frames and found that the prediction is close enough to the actual values with 95% confidence. These predicted values of link loads may be utilized for routing with quality of service parameters.

10.1.3 Modelling Path Length

We compared the routing protocols with respect to their path lengths across different mobility models and did find that DSDV achieves the shortest path length across all mobility models considered here. We also tried to model the path length distribution between two nodes using an Auto-regressive $AR(p)$ model used in stationary time series analysis. We found through our experiments that path length distribution between two nodes across various mobility models are well correlated and can be represented by $AR(p)$ model for suitable value of $p$. We have also predicted the future path length between two nodes and took note that the prediction is near enough to the actual values with 95% confidence. These predicted values of path length may be used for routing with quality of service parameters.
10.1.4 Modelling Weight based Clusters

The other contribution of the research is exploring the impact of different mobility patterns on the weight based clustering algorithms. The effect of average speed of the nodes on clustering the network under different mobility patterns is also evaluated. The weights of mobile nodes are represented as a time series and modelled by Autoregressive model $AR(p)$ of order $p$. The order $p$ of the model is found to lie between 1 and 3. The fitted model is applied to make prognostications about the node weights which is found to be in conformity with the actual weight with 95% confidence.

10.1.5 Modelling End-to-End Delay

We compute the end-to-end delay experienced by data packets in an ad-hoc network. We evaluate the dependence of end-to-end packet delay on the routing protocols and mobility models followed by packets. We also verified the effect of total number of nodes in the network on packet end-to-end delay. In the end, we assessed the correlation of path length with the packet delay and found that they are highly correlated. This high correlation motivated us to obtain a linear equation for the delay as dependent variable and path length as an independent variable. Since, path length is known whenever a route to the destination is known, we can derive the approximate value of the packet delay based on the path length.

10.1.6 Delay Modelling using Artificial Neural Network

We have applied neural network to model the end-to-end delay experienced by data packets in mobile ad-hoc network environment. By using Back Propagation network (BPN), Generalized Regression Neural Network (GRNN) and Radial Basis Function Network (RBFN), we predicted the end-to-end packet delay based on their path length in ad hoc network. The forecast values of close-to-end delays are found to have a very good correlation with the actual values with a correlation coefficient of more than 0.8 in maximum cases. The index of agreement between the predicted values and the actual values are found to be in more than 0.999 in all cases. These statistical results show that the predicted values are indeed very close to the actual values. This calculated delay can be used to determine a delay guaranteed routing in ad-hoc network.
10.1.7 Delay Modelling Using Fuzzy Time Series

We established a regression equation for the delay as dependent variable and path length as an independent variable. The regression is linear in nature and fits well for the end-to-end delay datasets. Since, path length is known, whenever a route to the destination is recognized, we can infer the approximate value of the packet delay whenever a route has been grounded by a source destination pair. Further, we have represented end-to-end packet delay in the framework of fuzzy time series. Using trapezoidal fuzzy numbers, our fuzzy time series yields promising results, but inferior to path length based regression. Then we merged these two algorithms using suitable weights, to achieve better results compared to the both algorithms individually. The weighted techniques has increased the prediction accuracy as indicated by a very high correlation coefficient in the orbit of 0.9 to 0.99.

10.2 Perspectives

The research findings made out of this thesis has opened several auxiliary research directions, which can be further looked into. Some of the future research directions are summarized as follows:

1. Along with the number of neighbour nodes, one can find the exact nodes, which are neighbours of a particular node at specific intervals.

2. We have not taken into account the interference of other nodes while calculating the link duration between two nodes. The interference model can be introduced to further refine the link durations.

3. Some more parameters like interference, number of neighbours, channel contentions, packet queuing process, packet distribution etc. can be introduced to make delay modelling more refined and precise.

4. Some nonlinear regression model can also be sought for more precise characterization of end-to-end delay in MANET.

5. Some more soft computing tools may be used to obtain a better fit for end-to-end delay dataset.
In close, this thesis presents methods for building predictive models for different network parameters such as neighbour count, link, load, route length, cluster count and time lag in mobile ad hoc network.