An Interference-aware Algorithm for Topology Control in Ubiquitous Ad hoc Networks

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ABSTRACT

Ubiquitous ad hoc network introduces heterogeneous mobile devices (or nodes) of varying capabilities from laptops to micro-sensors. In this context, some devices are equipped with more powerful radios with higher transmission range and some with lesser power with smaller transmission range. It is a known fact that a higher transmission range causes more interference and a possible decrease in overall network capacity while the smaller one may cause a failure of full network connectivity. In this paper, we consider the problem of topology control in this type of ubiquitous systems and propose an optimal power assignment algorithm for each device, such that the potential interference across the network can be minimized while maintaining connectivity.

Keywords

Topology control, Ubiquitous ad hoc networks

INTRODUCTION

Ubiquitous system is a new paradigm for computing and communication, where devices in the surrounding environment autonomously co-ordinate with each other in a self-organizing fashion. In such a domain, ad hoc networks will proliferate as the number of different types of devices are manufactured and consumed. The special feature of relaying packets by these devices makes them applicable to situations where spontaneous networking without pre-existing infrastructure is required.

Although a mobile ad hoc network seems to be desirable for fulfilling the need of ubiquitous computing, it faces severe challenges due to its shared wireless medium, heterogeneity and dynamic topology. This paper considers the problem of topology control in heterogeneous ad hoc networking environments, where each device has different transmission ranges according to their embedded radio. A device with the larger transmission range causes more interference, while the one with smaller range may not be able to reach other devices. Interference is the known problem in ad hoc networks due to a variation in transmission ranges. Adjustment of transmission ranges of each device based on the geometry of network topology has been the most evident technique for topology control. However, most of the research efforts have focused on reducing energy consumption and claimed on implicit mitigation of radio interference [1]. Recent research [2] has proved that certain topologies exist where such implication is not true and that the sparseness or smaller degree does not necessarily lessen interference. In this paper, we propose topology control algorithm in two steps. First, we compute the minimum transmission power required to reach all the neighbors within one-hop. Next we assign the optimal minimum power, such that the closer neighbor relays the data from source to the destination in multiple hops. Since the network is mobile we assume the existence of GPS equipment that provides current position information from which future positions can be predicted. These predictions are used to minimize the transmission power of each device and hence conserve energy reduce interference and maintain connectivity. The following section provides the detail of the proposed scheme.

PROPOSED TOPOLOGY CONTROL SCHEME

The main motivation behind this work is from the observation that the assignment of transmission power based on predicted distance of one-hop neighbors produces a robust topology. First, HELLO packets are transmitted with maximum transmission power, P_{max}, at some time t_0. It contains the information about the node current position, speed, deviation, and predicted transmission power list of its one-hop neighbors. As HELLO packet is received, each node computes the position and the distance of its neighbors for the future time instant $t_{0+\alpha}$. A node then selects an appropriate transmission power level through optimal power assignment algorithm (OPAA). We utilize the two-ray ground reflection model [3] that is designed to predict the mean signal strength for an arbitrary transmitter-receiver separation distance. Initially, node computes the received signal strength of its neighbor and based on this information, a transmitter power for the predicted distance is given by:

$$P_{min}(d(t_{0+\alpha})) = Pr(d(t_{0+\alpha})) + 20*\log(d(t_{0+\alpha}))$$

where, P_{min} is the minimum transmitter power, d is the distance between the node and its neighbor and Pr is the receiver sensitivity.

After computing transmission power for its one-hop neighbors, it is embedded on the HELLO packet and transmitted. Through received one-hop neighbor information in the HELLO packet and its own list of computed power levels, a node can eventually decide the optimal power $P_{optimal}$ to get connected with all of its neighbors. If the neighbor's neighbor is also within its range and if the power required to reach the one is greater then from the existing neighbor, a transmission power is further reduced for the nearest neighbor. In this way, optimal power is calculated in every time interval for the snapshot of the predicted topology.

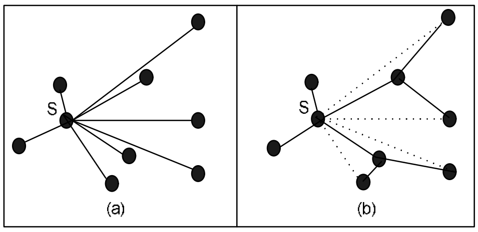

Fig 1: (a) Initial topology (b) Minimum optimal range assigned to node S

Fig 1 (a) shows the initially predicted topology and Fig 1(b) shows the reduced transmission power after minimum optimal power is assigned to node S. Dotted lines means that those nodes will be reached through multi-hops. Reduced transmission power reduces the potential interference across the network and also maintains the connectivity with its farthest one-hop neighbor through multi-hop links. In our ns-2 simulation, we have assumed that the potential ad hoc devices will have an ability to set its transmission power in multiple discrete levels. This choice is made according to the commercially available CISCO Aironet 350 series wireless LAN card [4], which has six power levels corresponding to the transmission range from maximum 250m to minimum 50m.

PERFORMANCE EVALUATION

To evaluate our scheme we have implemented it as a part of routing layer in ns-2 simulator. We have performed our simulation on semi-deterministic and deterministic mobility models, and compared it with a flooding scheme. The reason for applying this mobility models is because we can achieve more realistic scenario as compared to random models. From the preliminary results we see that our scheme has significantly lesser overhead, saves energy by reducing average transmit power and similar throughput as compared to flooding data packets in the network. In 300seconds simulation, HELLO packets are sent every 10s and are included in our overhead evaluation. We also calculate the delay for each data transmission and observe that the delay is somewhat higher in our proposed scheme, since the data has to be transmitted through multi-hop links.

From the simulation results we can infer that by reducing transmission power, we decrease interference and hence the significant energy saving of the nodes without losing connectivity. Reduction in transmission power also reduces possible collisions that are evident in multi-hop links.

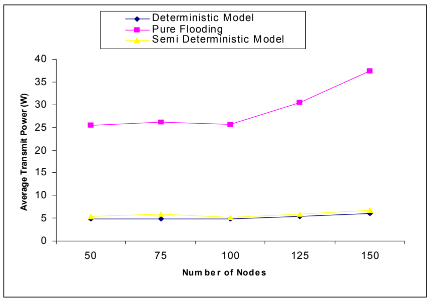

Fig 2: Average Transmit Power in Semi-deterministic and Deterministic model

CONCLUSION

In this paper, we presented a solution for the topology control problem in ad hoc networks. Our scheme exploits non-random node mobility information to predict future state of network topology. Each device locally runs our proposed algorithm and sets the optimum power level in order to achieve the robust topology.

Simulation results show that our approach advocates multi-hop communication among nodes for efficient utilization of scarce system resources. Most of all, it reduces transmission power and hence minimize radio interference, which is one of the major drawback of the shared medium. In future, we plan to extend our simulation in other mobility models including random mobility. We will also apply our proposed scheme under routing protocols in mobile ad hoc networks and evaluate its performance.

ACKNOWLEDGMENTS

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