PERFORMANCE MODELING OF IEEE 802.11 AD HOC NETWORKS UNDER TIME-VARYING CHANNEL

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ABSTRACT

Physical Carrier Sensing plays a crucial role in the effectiveness of CSMA-based MAC protocols, yet its properties and impact on the system performance under a slow fading channel have not been well understood. We demonstrate that carrier sensing can be highly unreliable even within the “carrier sensing range” and the channel is largely stable during a transmission between slowly moving mobile stations. Then we formulate the carrier sensing outage probability between competing mobile stations and propose a model to estimate the frame error rate and normalized throughput of a saturated IEEE 802.11 DCF single-hop ad-hoc network. Our model is validated via extensive simulations using Qualnet. The numerical and simulation results reveal substantial degradation in system performance with a small amount of carrier sensing outage.

In reality, the impact of slow fading on a CSMA-based wireless network is three-fold. The transmission reliability, physical capture capability, and carrier sensing reliability are all affected so as to exhibit different characteristics from a non-fading environment. Based on our numerical model of 802.11 DCF performance with carrier sensing outage, we formulate and incorporate the overall capture probability and transmission error in a homogeneous wireless ad-hoc network, and derive the system throughput and delay from an individual station’s point of view. This is the first effort to include all three issues of slow Rayleigh fading channel into one model. The computation results match closely with extensive simulations using Qualnet. The model has great potential to be extended to an arbitrary topology and to multi-hop networks. We also expect to study the power and carrier-sensing threshold control problems by utilizing this model.

As the prerequisite to extend our work to an arbitrary topology, we propose a model that predicts the saturated single-hop performance of an asymmetric IEEE 802.11 ad hoc network within a single and perfect carrier sensing range in the face of the physical capture effect under a block-fading Rayleigh channel. Based on an estimation of the frame delivery rate and a fixed point iteration algorithm, we devise

an efficient mechanism to expedite the rate of convergence and make a wise selection of the interferer sets that significantly affect the final results, so as to overcome the explosive time complexity of the iteration algorithm. These enhancements achieve up to two orders of magnitude speedup for large ad hoc networks with minimal and controllable prediction error, so that large scale experiments for various scenarios and real time processing are made possible.

We then enhance the fixed point iteration algorithm with consideration of carrier sensing outage, while maintaining quick convergence and minimal redundant computations. Specifically, we adopt the first-order approximation for overall capture probability developed in the symmetric network model to apply to individual links, and use a similar technique developed for the asymmetric networks to sum up all significant components of the overall carrier sensing outage probability. The prediction error of frame delivery rate is kept minimal even for the worst applicable cases, and the real-time processing capability of the previous model is retained.