DYNAMIC RESOURCE ALLOCATION AND STOCHASTIC SCHEDULING STRATEGIES IN WIRELESS NETWORKS

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ABSTRACT

Wireless networks ushered an age of ubiquitous and pervasive computing. However, they greatly complicate resource allocation and scheduling problems as compared to traditional wired networks. The main reason is that wireless signals not only span multiple dimensions (e.g., time, space, frequency and power) simultaneously, making various types of resources correlated, but also introduce uncertainty due to time-varying wireless channels. In this dissertation, we investigate *dynamic* resource allocation and *stochastic* scheduling strategies through different theoretical frameworks for several types of wireless networks with specific objectives and constraints.

We first design a joint node sleep and orientation scheduling policy for directional sensors (e.g., image, camera, radar sensors), in order to balance two paramount but conflicting objectives, i.e., energy-efficiency and quality of coverage, in surveillance wireless sensor networks. Specifically, given a set of random deployed directional sensors, we propose Maximum Coverage with Minimum Sensors (MCMS) problem of combinatorial nature, where coverage in terms of the number of targets to be covered is maximized whereas the number of sensors to be activated is minimized. We present its exact Integer Linear Programming (ILP) formulation and an approximate centralized greedy algorithm (CGA) solution. These centralized solutions are used as baselines for later comparison. Next, we provide a distributed greedy algorithm (DGA) solution. By incorporating a measure of the sensors' residual energy into DGA, we further develop a Sensing Neighborhood Cooperative Sleeping (SNCS) protocol, which performs adaptive scheduling at a larger time scale. We evaluate the properties of the proposed solutions and protocols through extensive simulations. Moreover, for the case of circular coverage, we compare against the best known existing coverage algorithm.

We then design an opportunistic packet forwarding scheme, in order to adapt to time-varying wireless channels, in wireless ad hoc networks. We are aware that various channel-adaptive schemes have been proposed to exploit inherent spatial diversity in wireless ad hoc networks, where there are usually alternate next-hop

relays available at a given forwarding node. However, current schemes are designed based on heuristics, implying room for performance enhancement. To seek a theoretical foundation for improving spatial diversity gain, we formulate the selection of the next-hop as a sequential decision problem and propose a general "Optimal Stopping Relaying (OSR)" framework for designing such next-hop diversity schemes. As a particular example, assuming Rayleigh fading channels, we implement an OSR strategy to optimize information efficiency (IE) in a protocol stack consisting of Greedy Perimeter Stateless Routing (GPSR) and IEEE 802.11 MAC protocols. We present mathematical analysis of the proposed OSR together with other schemes in literature for a single forwarding node. Moreover, we perform extensive simulations by QualNet to evaluate the end-to-end performance of these relaying strategies in a multi-hop network. Both mathematical and simulation results demonstrate the superiority of OSR over other existing schemes.

We finally design a low-complexity opportunistic spectrum access (OSA) scheme for secondary users with limited spectrum sensing capability to track and exploit instantaneous spectrum opportunities in presence of bursty traffic of primary users in cognitive radio networks. Generally, a sequential decision framework is used to design optimal policies to take advantage of the history of spectrum sensing and access decisions. However, many existing schemes based on a partially observed Markov decision process (POMDP) framework reveal that optimal policies are non-stationary in nature, rendering them difficult to calculate and implement. Therefore, we pursue stationary policies, which are efficient yet low-complexity and take account of many practical factors, such as spectrum sensing errors and a priori unknown statistical spectrum knowledge. First, with an approximation on channel evolution, we formulate OSA in a multi-armed bandit (MAB) framework. Thus, the optimal policy is specified by the well-known Gittins index rule, where the channel with the largest Gittins index is always selected. Then we derive closed-form formulae and design a reinforcement learning algorithm to calculate Gittins indices, depending on whether the Markovian channel parameters are available a priori or not. Finally, we demonstrate the superiority of our scheme over other existing schemes in terms of the trade-off between quality of policies and complexity via extensive simulations.