

Preface

Resource management has been a perpetual theme in wireless network design, deployment, and operations. In today's wireless systems, data demands continue to grow with a diverse range of applications from bandwidth-hungry multimedia streaming, delay-sensitive instant messaging, and online gaming to bulk data transfer. The ever-increasing needs for high-speed ubiquitous network access by mobile users are further aggravated by emerging machine-to-machine communication for home and industrial automation, wide-area sensing and monitoring, autonomous vehicles, etc. Delivery of these rich sets of applications is fundamentally limited by resource scarcity in wireless networks that manifests at various levels. For instance, spectrum scarcity has emerged as a primary problem when trying to launch new wireless services. Vendors and operators are increasingly looking into millimeter radio bands for 5G cellular standard though the spectrum was previously considered unsuitable for wider area applications. Interferences among wireless transceivers in close proximity continue to pose challenges to the delivery of reliable and timely services. Mobile devices are inherently power-constrained, demanding efficient communication schemes and protocols.

Many resource management solutions in wireless networks operate on the assumption that the decision makers have the complete knowledge of system states and parameters (e.g., channel states, network topology, and user density). When such information is unavailable or incomplete, probing or learning has to be conducted prior to the making of resource management decisions. As an example, in orthogonal frequency-division multiplexing (OFDM) systems, pilot signals are transmitted either along a dedicated set of subcarriers or a specific period across all subcarriers for channel estimation. This allows the adaption of subsequent transmissions to current channel conditions. Sequential learning, in contrast, is a paradigm where learning and decision-making are performed *concurrently*. The framework is applicable in a variety of scenarios where the utility of resource management resources follows single-parametrized independent and identically distributions, Markovian or unknown adversarial processes. It is a powerful tool in wireless resource management. Sequential learning and decision-making have been

successfully applied to for resource management in cognitive radio networks, wireless LANs, and mesh networks.

However, there are significant barriers in the wider adoption of the framework in addressing resource management problems in the wireless community. We believe that this can be attributed to two reasons: First, the sequential learning theory originates from complex stochastic concepts posing a significant learning curve. Effective algorithms often rely on underlying assumptions such as stationary and independent stochastic processes. Identifying a suitable solution to a specific problem can be a tall order for beginners. Second, there is a disconnect between theory and practical constraints in real-world settings. For example, in practice, the timeliness of decision-making often trumps optimality. In contrast, the primary concerns of sequential learning literature are the convergence rate in a long run and the optimality of the sequence of actions.

This book is the first attempt to bridge the aforementioned gaps. Though the literature on sequential learning is abundant, a comprehensive treatment of its applications in wireless networks is lacking. In this book, we aim to lay out the theoretical foundation of the so-called multi-armed bandit (MAB) problems and put it in the context of resource management in wireless networks. Part I of this book presents the formulations, algorithms, and performance of three forms of MAB problems, namely stochastic, Markov, and adversarial. To the best of our knowledge, this is the first work that covers all the three forms of MAB problems. Part II of this book provides detailed discussions of representative applications of the sequential learning framework in wireless resource management. They serve as case studies both to illustrate how the theoretical framework and tools in Part I can be applied and also to demonstrate how existing algorithms can be extended to address practical concerns in operational wireless networks. We believe both the industry and the wireless research community can benefit from a comprehensive and timely treatment of these topics.

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