

Preface

Game theoretic analysis of congestion, safety, and security is an interdisciplinary undertaking. Many researchers working on congestion have not extensively considered safety/security, and vice versa. However, significant interactions exist between the two research areas, which motivated this book. This book is intended to establish a new and enhanced current state of affairs within this topic, illustrate linkages between research approaches, and lay the foundation for subsequent research. Congestion (excessive crowding) is defined broadly to include all kinds of flows; e.g., road/sea/air traffic, people, data, information, water, electricity, and organisms. The book considers systems where congestion occurs, systems which may be in parallel, series, interlinked, or interdependent, with flows one way or both ways. Congestion models exist in abundance. The book makes ground by introducing game theory and safety/security. For the analysis to be game theoretic, at least two players must be present. For example, in Wang and Zhuang [1] one approver and a population of normal and adversary travelers are considered. Similarly, in Bier and Hausken [2], one defender and one attacker are considered, in addition to drivers who choose the more time-efficient of two arcs of different lengths. Multiple players can be adversaries with different concerns regarding system reliability; e.g., one or several terrorists, a government, various local or regional government agencies, companies, or others with stakes for or against system reliability. Governments, companies, and authorities may have tools to handle congestion, as well as ensure safety/security against various threats. The players may have a variety of individual concerns which may or may not be consistent with system safety or security. Much of the congestion literature is not game-theoretic, and does not extensively consider safety or security. Also, most game-theoretic analysis does not account for congestion. Volume 2 consists of nine chapters.

In “A Game Theory-Based Hybrid Medium Access Control Protocol for Congestion Control in Wireless Sensor Networks,” Raja Periyasamy and Dananjayan Perumal consider a game-theoretical hybrid medium access control (GH-MAC) protocol in the face of wireless sensor networks congestion scenarios. GH-MAC is integrated with a game-based energy efficient time division multiple

access (G-ETDMA) protocol for intra-cluster communication, as well as a game theory-based nanoMAC (G-nanoMAC) protocol for inter-cluster communication between the head nodes. The evaluation results show that GH-MAC would help reducing the energy consumption of the nodes in wireless sensor networks and increase the lifetime of the sensor networks.

In “[Cooperative Games Among Densely Deployed WLAN Access Points](#),” Josephina Antoniou, Vicky Papadopoulou-Lesta, Lavy Libman, and Andreas Pitsillides develop a method to mitigate the interference caused by individual wireless access points (AP) that share the same channels and cooperate by serving each other’s clients. A small-size graphical game is used, where the underlying graph is a clique with heterogeneous edge weights. The equilibrium conditions are provided for APs to jointly serve each other’s clients and achieve the maximum benefit for their clients.

In “[Simulating a Multi-Stage Screening Network: A Queuing Theory and Game Theory Application](#),” Xiaowen Wang, Cen Song and Jun Zhuang use simulations to study the game-theoretical screening strategies for the approver to balance congestion and security for a multi-stage security screening network facing strategic applicants. The Arena simulation software is used to build the screening system with three major components: arrival process, screening process, and departure process. A Matlab graphic user interface (GUI) is used to collect user inputs, then export data for Arena simulation through Excel, and finally export simulation from the results of the Arena to Matlab for analysis and visualization.

In “[A Leader-Follower Game on Congestion Management in Power Systems](#),” Mohammad Reza Salehizadeh, Ashkan Rahimi-Kian, and Kjell Hausken model a leader-follower game on congestion management. An operator first chooses multiple possible strategies which are announced to the generators (power generation companies). Each strategy consists of emission penalty factors for each power generation company, renewable power resources to reduce emission, and maximum prices generation companies can bid for selling electrical power. Second, each generator bids one price at which it is willing to sell its power, and a Nash-Supply Function equilibrium game is solved. Third, the operator performs congestion management and congestion-driven attributes and emission are obtained. Fourth, the operator’s preferred strategy is selected using TOPSIS, a technique for order preference.

In “[Network Throughput and Reliability: Preventing Hazards and Attacks Through Gaming—Part I: Modeling](#),” Yupo Chan studies network throughput and reliability for preventing hazards and attacks by modeling a stochastic network, characterized by arcs and nodes that can fail unexpectedly. The author identifies not only tactics to prevent disruptions caused by natural/technological hazards and hostile tampering, but also strategies for defense budget allocations to balance maintaining critical infrastructure and defending against adversarial attacks.

In “[Network Throughput and Reliability: Preventing Hazards and Attacks Through Gaming—Part II: A Research Agenda](#),” following up on the modeling world in “[Network Throughput and Reliability: Preventing Hazards and Attacks Through Gaming—Part I: Modeling](#),” Yupo Chan provides a research agenda for

pre-disaster mitigation/maintenance for critical civil infrastructure networks. Based on research to date, conditions under which a Pareto Nash equilibrium exists to prevent both hazards and attacks are provided. The author concludes with general principles of how to best defend networks of specific types against intelligent attacks, including both computational and behavioral considerations.

In “[The Price of Airline Frequency Competition](#),” Vikrant Vaze and Cynthia Barnhart present a game-theoretic model of airline frequency competition. Frequency competition affects congestion and each airline’s market share and profit. Congestion affects and is affected by runway, taxiway, and airborne safety considerations. Myopic learning dynamics are analyzed and equilibria are determined for the two-player game and the N-player symmetric game. The price of airline frequency competition in the form of increased congestion and decreased profits is analyzed.

In “[A Simulation Game Application for Improving the United States’ Next Generation Air Transportation System NextGen](#),” Ersin Ancel and Adrian Gheorghe develop a simulation game to evaluate the United States’ next generation air transportation system NextGen. Such systems are characterized by congestion, energy shortage, delays, etc., which depend on technology, politics, environmental concerns, and interaction between players such as the government, the Federal Aviation Administration, military stakeholders, airlines, airport operators, and the general public.

In “[A Congestion Game Framework for Emergency Department Overcrowding](#),” Elizabeth Verheggen analyzes emergency department overcrowding as an El Farol Bar Game, illustrating the Tragedy of the Commons. Ambulance diversion, extensive wait times, and patient elopements cause overutilization and inefficient load balancing. Agent-based simulations reveal no statistically significant difference between two games and empirical observations, suggesting that a bar may be a good metaphor to understand congestion.

References

1. Wang X, Zhuang J (2011) Balancing congestion and security in the presence of strategic applicants with private information. *Eur J Oper Res* 212(1):100–111
2. Bier V, Hausken K (2013) Defending and attacking networks subject to traffic congestion. *Reliab Eng Sys Saf* 112:214–224

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