Dynamic Power Allocation and Routing for Satellite and Wireless Networks with Time Varying Channels

by

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Submitted to the Department of Electrical Engineering and Computer Science
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

November 2003

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Abstract

Satellite and wireless networks operate over time varying channels that depend on attenuation conditions, power allocation decisions, and inter-channel interference. In order to reliably integrate these systems into a high speed data network and meet the increasing demand for high throughput and low delay, it is necessary to develop efficient network layer strategies that fully utilize the physical layer capabilities of each network element. In this thesis, we develop the notion of *network layer capacity* and describe capacity achieving power allocation and routing algorithms for general networks with wireless links and adaptive transmission rates. Fundamental issues of delay, throughput optimality, fairness, implementation complexity, and robustness to time varying channel conditions and changing user demands are discussed. Analysis is performed at the packet level and fully considers the queueing dynamics in systems with arbitrary, potentially bursty, arrival processes.

Applications of this research are examined for the specific cases of satellite networks and ad-hoc wireless networks. Indeed, in Chapter 3 we consider a multi-beam satellite downlink and develop a dynamic power allocation algorithm that allocates power to each link in reaction to queue backlog and current channel conditions. The algorithm operates without knowledge of the arriving traffic or channel statistics, and is shown to achieve maximum throughput while maintaining average delay guarantees. At the end of Chapter 4, a crosslinked collection of such satellites is considered and a *satellite separation principle* is developed, demonstrating that joint optimal control can be implemented with separate algorithms for the downlinks and crosslinks.

Ad-hoc wireless networks are given special attention in Chapter 6. A simple cell-partitioned model for a mobile ad-hoc network with N users is constructed, and exact expressions for capacity and delay are derived. End-to-end delay is shown to be $O(N)$, and hence grows large as the size of the network is increased. To reduce delay, a transmission protocol which sends redundant packet information over multiple paths is developed and shown to provide $O(\sqrt{N})$ delay at the cost of reducing throughput. A fundamental rate-delay tradeoff curve is established, and the given protocols for achieving $O(N)$ and $O(\sqrt{N})$ delay are shown to operate on distinct boundary points of this curve.

In Chapters 4 and 5 we consider optimal control for a general time-varying network. A cross-layer strategy is developed that stabilizes the network whenever possible, and makes fair decisions about which data to serve when inputs exceed capacity. The strategy is decoupled into separate algorithms for dynamic flow control, power allocation, and routing, and allows for each user to make greedy decisions independent of the actions of others. The combined strategy is shown to yield data rates that are arbitrarily close to the optimally fair operating point that is achieved when all network controllers are coordinated and have perfect knowledge of future events. The cost of approaching this fair operating point is an end-to-end delay increase for data that is served by the network.

Thesis Supervisor: Eytan Modiano
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Acknowledgments

I think that every scientist, engineer, and mathematician is, to some degree, a person of faith. It requires faith to believe that there exist simple and elegant solutions to difficult problems, as well as to believe that we are gifted with the capacity to discover them. I take faith a simple step further by believing that both the structured world we live in and the ability for us to understand it are gifts from God. Furthermore, I believe God has given us an even greater gift in Jesus Christ, that we might know him more deeply both now and throughout eternity.

Therefore, I thank God for providing me with all that I need, and for sustaining me throughout my graduate studies. I'm glad to have known his love and to have experienced his faithfulness even in times when my own faith is weak. I'd also like to thank all of my friends, both Christian and non-Christian, who have supported and encouraged me over the years.

I'd like to thank my advisor Eytan Modiano for his research example, guidance, and generous support. According to Eytan, a Ph.D. advisor is "an advisor for life," not just an advisor for the duration of graduate study. I greatly appreciate this openness, and would like to thank him in advance for all of his future advice. Thanks to Charlie Rohrs, who directed my masters thesis and who has continued to meet with me during the course of my Ph.D. The continued encouragements from Charlie have been very helpful. I'd like to thank Bob Gallager for his insightful comments and feedback as a thesis reader and committee member. I also want to thank him for his encouraging remarks about my masters thesis presentation several years ago (which happened to be when I first met Eytan). Thanks also to Vincent Chan, the final reader and committee member on my thesis. I still remember the time a few years ago when he said: "I think your research is pretty cool."

I'd like to thank my undergraduate research advisor at the University of Maryland, Professor Isaak Mayergoyz. He taught me the value in finding simple solutions to difficult problems, and throughout my time here at MIT I've tried to emulate his bold style of research.

Finally, I'd like to thank God for my darling wife Jean, whom I love. Thank you, Jean, for your support during my studies, and for your commitment to live and love along with me.

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