Wireless Optimisation Based on Economic Criteria

by

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B.E. (IT & T, Hons. 1)

Thesis submitted for the degree of

Doctor of Philosophy

in

School of Electrical and Electronic Engineering,

Faculty of Engineering, Computer and Mathematical Sciences

The University of Adelaide, Australia

2006

Typeset in $\LaTeX\,2_\varepsilon$
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Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Acknowledgements

I am highly indebted to my principal supervisor Professor Langford B. White for his guidance, support, motivation and encouragement throughout my candidature. Working with such an inspiring and excellent mentor has been an insightful journey for me. I still have a lot to learn from him, who never ceases to explore new knowledge.

I have profited immensely from various discussions with my two other excellent supervisors, Dr. Paul Chapman and Dr. Matthew Sorell. Particularly, my simulation work on Smart Pricing with them at the beginning of this research has sparked the idea for our work in Chapter 3. I am also grateful to them for patiently helping me to improve my writing skills.

This research would not have been possible without the generous financial help in the form of the Australian Postgraduate Award (APA) and the CRC for Smart Internet Technology top-up scholarships. I would also like to thank the CRC for Smart Internet, University of Adelaide, and ACORN for sponsoring my workshop and conference travels.

My sincere gratitude also goes to my wonderful colleagues at the Centre for Internet Research (CIR) who have given me a friendly second home for the past three years. Extra kudos to those (especially Ange) who gave me chocolates and lollies from time to time! I am also thankful to the friendly people working at the main office of the School of Electrical and Electronic Engineering for their help regarding various matters.

Last but not least, I would like to thank my partner and family. Without your encouragement, emotional support and understanding, I will never be able to complete this remarkable but often challenging journey.

Siew-Lee Hew

April 2006

Abstract

The rapid growth in demand due to the emergence of mobile communication services with variable rates, coupled with the resource scarcity of mobile air interface, has encouraged researchers to find technological solutions to increase spectral efficiency in order to support different levels of Quality of Service (QoS). Radio resource management (RRM) plays a major role in QoS provisioning and congestion control for wireless networks. The main problem with the congestion control mechanisms provided by current RRM schemes is that they are mostly reactive, triggered only when congestion occurs. The common, traditional solution to congestion has been for system planners to *over-engineer* a network by assigning more resources than are necessary. This approach is very costly because busy periods are usually brief, causing the network to be often under-utilised outside of these periods. Current static, usage-based pricing models also fail to assist in traffic shaping to even out loads.

Economic modelling offers a new perspective into current RRM schemes and enables efficient utilisation of scarce resources and congestion prevention based on concepts such as utility, price, Pareto optimality and game theory. Dynamic pricing has been proposed as a mechanism to encourage users to adapt their resource consumption level according to network conditions. A good pricing model can provide the necessary positive incentives to increase users' arrival rate when the network load is relatively low and negative incentives for users to defer their usage when the load is relatively high. In this dissertation, we propose an economic framework for pricing and RRM for 3G and beyond systems. Our aim is two-fold: to calculate an optimal integrated dynamic pricing and RRM policy; and to allocate scarce network resources in a fair and Pareto-optimal manner.

The optimal integrated dynamic pricing and RRM policy is computed based on the stochastic distribution of users' budget, arrivals, handoffs and departures. Our results show that the integrated policy is superior in terms of average reward improvement and congestion prevention to current schemes that use static pricing models. In interference-based networks such as WCDMA, we suggest users be charged according to their noise rise factor, i.e. an estimate of the amount of interference generated by the call. This interference-based pricing model improves on the conventional load-based model in by delivering higher revenue and lower call blocking and handoff probabilities.

Using the axiomatic bargaining concepts from cooperative game theory, we derive a class of fair and Pareto-optimal bargaining solutions that allocate wireless resources based on users' minimum and maximum rate requirements. We propose two models: symmetric and asymmetric. In the latter, resource is allocated according to the price paid by the users. An important significance of the asymmetric bargaining model is that this solution is still Pareto-optimal and fair according to the users' bargaining power. Our approach is also a departure from current works using noncooperative game theory that can only achieve an inefficient outcome, i.e. the Nash equilibrium; or cooperative game theory that focus on only one solution on the Pareto-optimal boundary. By analysing a range of bargaining solutions instead of specific ones, operators can proceed to select the best outcome out of these Pareto-optimal solutions based on criteria like revenue.

Publications

1. S-L. Hew and L. B. White, "Interference-based dynamic pricing and radio resource management for WCDMA networks", in *Proc. of 61st IEEE Vehicular Technology Conference (VTC2005-Spring)*, May 30 - June 1 2005, Stockholm, Sweden.

2. S-L. Hew and L. B. White, "Optimal integrated call admission control and dynamic pricing with handoffs and price-affected arrivals", in *Proc. of Asia-Pacific Conference on Communications (APCC'05)*, Oct. 3-5 2005, Perth, Australia.

3. S-L. Hew and L. B. White, "Fair resource bargaining solutions for cooperative multi-operator networks", in *Proc. of IEEE International Zurich Seminar on Communications (IZS'06)*, Feb. 22-24 2006, Zurich, Switzerland.

4. S-L. Hew and L. B. White, "A game theoretical approach for resource bargaining in shared WCDMA networks: symmetric and asymmetric models", in *Proc. of 1st IEEE International Conference on Wireless Broadband and Ultra Wideband Communications (AusWireless'06)*, Mar. 13-16 2006, Sydney, Australia.

5. S-L. Hew and L. B. White, "Integrated call admission control and dynamic pricing in multiservice networks with price-affected arrivals, retrials and substitutions", submitted for publication.

6. S-L. Hew and L. B. White, "Interference-based dynamic pricing for WCDMA networks using neuro-dynamic programming", accepted for publication in *IEEE Trans. on Automatic Control*.

7. S-L. Hew and L. B. White, "Cooperative resource allocation games in shared networks", submitted to *IEEE Trans. on Wireless Communications*, in Feb. 2006.

Dedication

This dissertation is dedicated to my parents, *Hew Peng Fah* and *Tan Hong Gaik*, for their sacrifice, valuable teachings and unconditional support all these years.

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