

CSC 579 Project Biweekly Update 1: An Intelligent Transportation System (ITS) Approach to Teletraffic Engineering

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First biweekly update for my teletraffic engineering project from CSC 579 at the University of Victoria. Discusses challenges encountered in the first two weeks, and briefly summarizes teletraffic engineering, game theory, and Wireless Ad-Hoc Networks (WANETs). Followed by a summary of a protocol I could potentially replicate.

Introduction

My project proposal asked the following: *How can teletraffic engineering approaches improve strategies for SDN or WANETs?*. My next steps were outlined as follows: (1) select either a WANET or a SDN protocol which could benefit from either Intelligent Traffic Systems (ITS) and/or teletraffic engineering approaches, (2) conduct a small-scale replication, (3) propose improvements, and (4) evaluate the impact of the proposed improvements.

In the past two weeks I have read through literature to determine possible candidates for protocols I might select. Along the way I also selected several of the most important considerations in my protocol selection:

1. How feasible is it to integrate ITS and/or teletraffic engineering approaches?
2. How difficult would a small-scale replication be to perform?
3. How relevant is the protocol to WANETs or SDNs?

On the first point, finding any previous work which applies the principles of ITS to general communications networks has proven difficult. This dearth of papers has led me to reconsider whether approaching conventional networking through an ITS-lens makes any sense at all. At a minimum, the lack of literature indicates that publishing an introduction to this problem is outside of the scope of a class research project (after all, one would expect many papers to exist if it were easy). In contrast, I have stumbled upon examples of the reverse (principles commonly used in communications networks which influence ITS).^{1,2,3,4} However, my primary interest is not in exploring ITS directly. Therefore, it seemed most prudent that I

¹ Nan Cheng, Ning Lu, Ning Zhang, Xiang Zhang, Xuemin Sherman Shen, and Jon W. Mark. Opportunistic WiFi Offloading in Vehicular Environment: A Game-Theory Approach. *IEEE Transactions on Intelligent Transportation Systems*, 17(7):1944–1955, July 2016. ISSN 1558-0016. DOI: 10.1109/TITS.2015.2513399

² Caixia Li, Sreenatha Gopal Rao Anavatti, and Tapabrata Ray. A game theory based traffic assignment using queueing networks. In *2013 13th International Conference on ITS Telecommunica-*

consider dropping the relation to ITS entirely in favour of focusing solely on teletraffic engineering.

Once I decided to move on from research involving ITS, I realized a common set of definitions would greatly benefit my research. Starting this project, I have little familiarity with teletraffic engineering, game theory, or ad-hoc networks. So here is a summary of what I have learned so far.

Background

Teletraffic Engineering

Teletraffic engineering is the discipline concerned with applying queueing theory to telecommunication network traffic engineering.⁵ As teletraffic engineering only broadly encompasses traffic theory itself, it is possible that even if I cannot apply concepts from ITS to this project, some aspects of regular traffic theory may apply.

Game Theory in Wireless Networking

Game theory is the study of how incentives can affect individual operators in the context of them competing or collaborating with each other.

Previous literature has reviewed game theory's applications to wireless networks in general^{6,7} and WANETs in particular.⁸

Wireless Ad-Hoc Networks

A Wireless Ad-Hoc Network (WANET) is a network which "consists of autonomous or mobile nodes which communicate with each other without a centralized control or assistance."⁹ Every node acts as both a router and a receiver.

Progress on protocol selection

Apple has several network protocols that are of interest: the first is Apple Wireless Direct Link (AWDL). It is an undocumented ad-hoc protocol based on IEEE 802.11, better known as the technology which enables AirPlay and AirDrop.¹⁰ Apple's Find My network, in particular the functionality which enables its Offline Finding feature, is also of interest to me because it is "the largest crowd-sourced location tracking system in existence."¹¹

Upon my initial inspection neither of these two protocols appear to fit my second and third points of my protocol selection criteria, but I am hoping that the ideas from either of the papers I found which

⁵ Franco Callegati, Walter Cerroni, and Carla Raffaelli. *Traffic Engineering: A Practical Approach*. Textbooks in Telecommunication Engineering. Springer International Publishing, Cham, 2023. ISBN 978-3-031-09588-7 978-3-031-09589-4. DOI: 10.1007/978-3-031-09589-4

⁶ Dimitris E. Charilas and Athanasios D. Panagopoulos. A survey on game theory applications in wireless networks. *Computer Networks*, 54(18):3421–3430, December 2010. ISSN 1389-1286. DOI: 10.1016/j.comnet.2010.06.020

⁷ Zhu Han, Dusit Niyato, Walid Saad, Tamer Başar, and Are Hjørungnes. *Game Theory in Wireless and Communication Networks: Theory, Models, and Applications*. Cambridge University Press, Cambridge, 2011. ISBN 978-0-521-19696-3. DOI: 10.1017/CBO9780511895043

⁸ V. Srivastava, J. Neel, A.B. Mackenzie, R. Menon, L.A. Dasilva, J.E. Hicks, J.H. Reed, and R.P. Gilles. Using game theory to analyze wireless ad hoc networks. *IEEE Communications surveys and tutorials*, 7(4):46–56, 2005. ISSN 1553-877X

⁹ Fei Tong. *Protocol Design and Performance Evaluation for Wireless Ad Hoc Networks*. PhD thesis, University of Victoria, 2016

¹⁰ Milan Stute, David Kreitschmann, and Matthias Hollick. One Billion Apples' Secret Sauce: Recipe for the Apple Wireless Direct Link Ad hoc Protocol. In *Proceedings of the 24th Annual International Conference on Mobile Computing and Networking, MobiCom '18*, pages 529–543, New York, NY, USA, October 2018. Association for Computing Machinery. ISBN 978-1-4503-5903-0. DOI: 10.1145/3241539.3241566

¹¹ Alexander Heinrich, Milan Stute, Tim Kornhuber, and Matthias Hollick.

explore the protocols will fit within the scope of this project. As I plan to select my protocol of study in the coming week, I should be able to definitively answer this in my next biweekly update, alongside any progress I have made in implementing the selected protocol.

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