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Agent-based Modeling for the Analysis of Technology Introduction and Competition in Telecommunication Markets

Case studies of Fiber Optic Broadband and Wireless Markets

Farhaanullah Baig Mirza

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Information Systems

The University of Auckland
2015
Abstract

Technical standards evolve and enhance compatibility in their respective areas of ICT, creating opportunity in the market for consumption, competition and overall growth. Technological competitions are becoming ever more complex, due to increased numbers of stakeholders, complexity of technology, and large market sizes. Theoretical concepts of network economics from industrial organization can be used to explain dynamics of competitions. Using this as a context the thesis focuses on analyzing dynamics of technology introduction and adoption using network economic theory in the telecommunication domain. This is done specifically by applying a multi-methodological approach to analyze two cases: firstly consumer and Mobile Service Providers (MSPs) making decisions in a Mobile Service Market (MSM), and secondly Fiber-To-The-Home (FTTH) service deployments. The multi-methodological approach was used for developing theoretical frameworks and system development of computational Agent Based Models (ABMs).

For the first case the MSM-ABM simulated market dynamics that include both consumers’ decisions and MSPs’ strategic actions revising their commercial offers. The results generated over a period of simulated-time reveal emergent patterns of MSP’s competitive strategies to revise their offers, and consumer market-behavior for preferring value based options while being influenced by their friends.

The second case dealt with FTTH service deployments, especially the Ultra-fast Broadband (UFB) project in New Zealand (NZ). The FTTH network is regarded as a two-sided platform that accommodates both end-users and Service Providers (SPs), creating the conditions for the two sides to exploit mutual network effects. Grounded theory was used to produce research frameworks for consumer adoption of UFB access (CAUA), and consumer adoption of UFB content (CAUC) to portray pertinent consumer drivers, barriers and deciding factors for the UFB initiative. The findings show consumer awareness and pricing are main factors that need to be addressed for a successful UFB rollout. Two ABMs were developed first to portray UFB-specific fiber-line subsidization effects on access uptake and the second ABM takes a generic FTTH approach with enhanced consumer decision making processes. Results show that the greater the number of users (end-users or providers) on one side, the more the number of users (provider or end-users) grows on the opposite side. Overall the complexity of the scenarios analyzed deserved an ABM to add value to the topical issues of this research.
Acknowledgements

I would like to praise and thank Allah (God) Almighty, for providing me with the intellectual ability, persistence and discipline to conduct this research. My research and thesis would have not materialized if I had not had love, support, and encouragement from a number of people.

Firstly I would like to thank my Coach, Dr. Fernando Beltrán. I refer to Fernando as a coach because the word supervisor or advisor would do injustice to his approach to helping me. Fernando provided me with specific direction towards literature, theoretical, and practical approaches that helped in producing the work in this thesis. I would like to acknowledge support of Jairo Guitierrez who was initially my PhD Supervisor, Tony Norris (Massey University) who recommended that I should pursue a PhD at University of Auckland (UoA), and all of the Department of Information Systems and Operations Management (ISOM) staff, fellow students, and friends. I would like to thank Rosalie and Vanessa from Chorus, and James from Snap Internet for providing me with secondary data and consultation. I also thank the Center of Digital Enterprise (CODE) for their support.

I wish to thank my family for their prayers and providing a loving environment for me: my mother Qamar Sultana, and my father, Dr. Mirza Shafiullah Baig, my young ones Zainab, Muhammad, Khadeeja, Aamina and Umar; my brothers, Asfahaa, Mohsin and Mansoor; my sisters Tazeen and Mariam; my uncles and aunties Abdul-Haleem, Ayesha and Kauser; my grandparents Muhammad Azam and Basheerunisa; my father-in-law Mirza Ibrahim Baig; and my mother-in-law Dr. Iffathunisa, were all particularly supportive.

Among the many people to whom I owe my deepest gratitude, respect and affection, my wife Shazia Farha, deserves the most special place. She coped with my excessively busy schedule for the past eight years – which helped me co-found a design and tech company - Mirza Bros Limited, achieve a Masters degree, and produce this thesis. To her I dedicate this thesis.
Foreword

The research was conducted during 2009 – 2014 and relied on active industry consultation and submitting articles to premium conferences for obtaining feedback.

This thesis provides an introductory conceptual framework, a methodology followed by seven articles, and an aggregated conclusion. Each article presents its own literature, and articles contain overlaps. To avoid repetition of content cross-references are used in the text outside articles.

The text is written using US English, and American Psychological Association (APA) Style 6th Edition. The text outside the articles is written using first-person pronoun, often relying on the word “we”. The syntax inside the articles varies based on guidelines suggested by the publishing outlet.

Note: Additional thesis resources can be found in the CD attached to the thesis.
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Article 2 - Using Agent Based Analysis for Technological Standardization. In Universitas 21, Doctoral Research Conference in Business (U21 DRCB). Hartford 2012

A previous version of this article was also submitted in 2nd annual New Zealand Information Systems Doctoral Conference (NZISDC), held at Victoria University of Wellington 2011

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Article 4 - Drivers and Barriers to the Uptake of a FTTH Ultra-Fast Broadband in New Zealand. In the 41st Research Conference on Communication, Information and Internet Policy. Arlington: 2013

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Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.


| Nature of contribution by PhD candidate | Farhaan Mirza coded the simulation model that was jointly designed with co-author Fernando Beltrán. Writing and editing was a joint effort. |
| Extent of contribution by PhD candidate (%) | 60 |

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Beltrán</td>
<td>Proposed the economic model that underlies the agent-based model; during article preparation provided editing and reviewing.</td>
</tr>
</tbody>
</table>

**Certification by Co-Authors**

The undersigned hereby certify that:
- the above statement correctly reflects the nature and extent of the PhD candidate’s contribution to this work, and the nature of the contribution of each of the co-authors; and
- in cases where the PhD candidate was the lead author of the work that the candidate wrote the text.

<table>
<thead>
<tr>
<th>Name</th>
<th>Signature</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>Fernando Beltrán</td>
<td>[Signature]</td>
<td>25/02/2014</td>
</tr>
</tbody>
</table>

Last updated: 25 March 2013
Co-Authorship Form

This form is to accompany the submission of any PhD that contains research reported in published or unpublished co-authored work. Please include one copy of this form for each co-authored work. Completed forms should be included in all copies of your thesis submitted for examination and library deposit (including digital deposit), following your thesis Acknowledgements.

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.


Note: This paper’s extended abstract was accepted and presented at the 20th International Congress on Modelling and Simulation (MODSIM2013), held in Adelaide 2013.

<table>
<thead>
<tr>
<th>Nature of contribution</th>
<th>Extent of contribution by PhD candidate (%)</th>
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<tbody>
<tr>
<td>Farhaan Mirza has taken the lead in writing this article with feedback, reviewing and editing from Fernando Beltrán</td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fernando Beltrán</td>
<td>Feedback, reviewing and editing.</td>
</tr>
</tbody>
</table>

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- in cases where the PhD candidate was the lead author of the work that the candidate wrote the text.

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<tbody>
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<td>Fernando Beltrán</td>
<td>[Signature]</td>
<td>25/02/2014</td>
</tr>
</tbody>
</table>

Last updated: 25 March 2013
Key Research Outputs

Below is a list of research outputs during the term of this research. Where authorship is concerned, all the outputs below are co-authored with Fernando Beltrán.

### Journal Submissions

<table>
<thead>
<tr>
<th>Date</th>
<th>Outlet</th>
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</table>

### Book Chapter

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<tr>
<th>Year</th>
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<tr>
<td>2014</td>
<td>Artificial Economics and Self Organization, Agent-Based Approaches to Economics and Social Systems, Lecture Notes in Economics and Mathematical Systems - Springer International Publishing</td>
<td>Using an Agent-Based Approach for the Analysis of Competition Dynamics in a Mobile Service Market</td>
</tr>
</tbody>
</table>

¹ The 2013 TPRC paper has been forwarded to this Journal using a slightly different title based on feedback received.
<table>
<thead>
<tr>
<th>Date</th>
<th>Outlet</th>
<th>Title</th>
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<tr>
<td>July 2011</td>
<td>15th Pacific Asia Conference on Information Systems (PACIS), Brisbane.</td>
<td>Technology Standardization Battles: An Agent Based Analysis</td>
</tr>
<tr>
<td>August 2011</td>
<td>2nd NZISDC, Wellington.</td>
<td>Using Agent Based Analysis for Technological Standardization</td>
</tr>
<tr>
<td>April 2012</td>
<td>Universitas 21, Doctoral Research Conference in Business (U21 DRCB), Hartford.</td>
<td>Using Agent Based Analysis for Technological Standardization</td>
</tr>
<tr>
<td>August 2013</td>
<td>Dynamics of Social and Economic Networks, Proceedings of Artificial Economics, Klagenfurt.</td>
<td>An agent-based model of access uptake on a high-speed broadband platform²</td>
</tr>
<tr>
<td>August 2013</td>
<td>The 41st Research Conference on Communication, Information and Internet Policy (TPRC), Arlington.</td>
<td>Drivers and Barriers to the Uptake of a FTTH Ultra-Fast Broadband in New Zealand</td>
</tr>
<tr>
<td>December 2013</td>
<td>20th International Congress on Modelling and Simulation (MODSIM). Modelling and Simulation Society of Australia and New Zealand (MSSANZ), Adelaide.</td>
<td>Agent Based Model of Service Providers and Consumers within a Dynamic Mobile Communications Market</td>
</tr>
<tr>
<td>January 2014</td>
<td>36th Annual Pacific Telecommunications Conference (PTC), Honolulu.</td>
<td>Using an Agent-Based Approach for the Analysis of Competition Dynamics in a Mobile Service Market</td>
</tr>
</tbody>
</table>

All conferences were peer reviewed except the two NZISDC conferences.

² Presented by Fernando Beltrán in Klagenfurt
## Posters

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<tr>
<td>October 2009</td>
<td>University of Auckland Business School (UoABS) PhD Conference, Auckland.</td>
<td>Supremacy of 4G Technology: WiMAX or LTE at the University of Auckland Business School PhD Conference¹</td>
</tr>
<tr>
<td>January 2014</td>
<td>36th Annual Pacific Telecommunications Conference, Honolulu.</td>
<td>Using an Agent-Based Approach for the Analysis of Competition Dynamics in a Mobile Service Market⁴</td>
</tr>
</tbody>
</table>

## Seminars

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<th>Date</th>
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<tbody>
<tr>
<td>2010 – 2013</td>
<td>Department of ISOM PhD Annual Progress Seminars, Auckland.</td>
<td>Yearly progress seminars on PhD Research</td>
</tr>
<tr>
<td>2011–2013</td>
<td>Casual guest lecturer for the Post Graduate course of Data Communications (INFOSYS 730) at UoABS, Auckland.</td>
<td>Theoretical and Topical issues in Telecommunications Industry</td>
</tr>
<tr>
<td>August 2011</td>
<td>Three-Minute Thesis Competition, Auckland.</td>
<td>Standardization Battles</td>
</tr>
<tr>
<td>December 2012</td>
<td>Industry Seminar held by CODE at UoABS, Auckland.</td>
<td>Using agent-based simulation to understand competition drivers in next-generation broadband and wireless markets</td>
</tr>
<tr>
<td>October 2013</td>
<td>Departmental Seminar held by Department of ISOM, UoABS, Auckland.</td>
<td>Agent-based Modeling as a Methodology for the Analysis of Technology Introduction and Competition in Telecommunication Markets</td>
</tr>
</tbody>
</table>

¹ See Appendix C
² See Appendix D
### Awards, Nominations and Funding

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Funding for establishing Pricing in Next Generation Networks (PING) research group’s web presence.</td>
</tr>
<tr>
<td>2010</td>
<td>Nominated to submit paper to International Conference on Information Systems (ICIS) doctoral consortium.</td>
</tr>
<tr>
<td>2011</td>
<td>Nominated to submit paper to PACIS, travel expenses funded by Head of Department of ISOM.</td>
</tr>
<tr>
<td>2012</td>
<td>Nominated from UoABS to participate in submit paper to U21-DRCB, travel expenses funded by the Dean of UoABS.</td>
</tr>
<tr>
<td>2013</td>
<td>Achieved PhD Conference funding awards twice, total value of $5000.</td>
</tr>
<tr>
<td>2014</td>
<td>Awarded the Pacific Young Scholar award by Pacific Telecommunications Council, travel expenses funding by PTC.</td>
</tr>
</tbody>
</table>

### Relevant Professional Memberships

<table>
<thead>
<tr>
<th>Year</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009 – 2011</td>
<td>Accelerating Aotearoa</td>
</tr>
<tr>
<td>2010 – 2014</td>
<td>PING Research Group</td>
</tr>
<tr>
<td>2011 – 2013</td>
<td>Association of Information Systems (AIS)</td>
</tr>
<tr>
<td>2011 – 2014</td>
<td>Netlogo Users Group</td>
</tr>
<tr>
<td>2013 – 2014</td>
<td>Simulation Computer Society</td>
</tr>
<tr>
<td>2013 – 2014</td>
<td>Modelling and Simulation Society of Australia and New Zealand</td>
</tr>
</tbody>
</table>
List of Abbreviations

The acronyms found below are used throughout this thesis. They are presented by their full name when they are first used but will later on be referred to by their acronym. In the list below the acronyms are presented in alphabetical order. The list is provided to help the reader if a need for refreshing the full name of an acronym is required after its first introduction should occur.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3G</td>
<td>Third Generation</td>
</tr>
<tr>
<td>3GPP</td>
<td>The 3rd Generation Partnership Project</td>
</tr>
<tr>
<td>4G</td>
<td>Fourth Generation</td>
</tr>
<tr>
<td>ABM</td>
<td>Agent Based Models or Agent Based Modeling</td>
</tr>
<tr>
<td>ADSL</td>
<td>Asymmetric Digital Subscriber Line</td>
</tr>
<tr>
<td>AE</td>
<td>Artificial Economics</td>
</tr>
<tr>
<td>AFTS</td>
<td>Analytical Framework of Technology Standardization</td>
</tr>
<tr>
<td>APA</td>
<td>American Psychological Association</td>
</tr>
<tr>
<td>AUT</td>
<td>Auckland University of Technology</td>
</tr>
<tr>
<td>B</td>
<td>Business</td>
</tr>
<tr>
<td>BO</td>
<td>Behavioral Options</td>
</tr>
<tr>
<td>BWA</td>
<td>Broadband Wireless Access</td>
</tr>
<tr>
<td>C</td>
<td>Cost</td>
</tr>
<tr>
<td>CAS</td>
<td>Complex Adaptive System</td>
</tr>
<tr>
<td>CAUA</td>
<td>Consumer Adoption of UFB Access</td>
</tr>
<tr>
<td>CAUC</td>
<td>Consumer Adoption of UFB Content</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
<tr>
<td>CFH</td>
<td>Crown Fibre Holdings</td>
</tr>
<tr>
<td>CODE</td>
<td>Center of Digital Enterprise</td>
</tr>
<tr>
<td>CRM</td>
<td>Customer Relationship Management</td>
</tr>
<tr>
<td>DF</td>
<td>Deciding Factors</td>
</tr>
<tr>
<td>DIY</td>
<td>Do It Yourself</td>
</tr>
<tr>
<td>DVI</td>
<td>Digital Visual Interface</td>
</tr>
<tr>
<td>FCC</td>
<td>Friend Circle Creator</td>
</tr>
<tr>
<td>FDRF</td>
<td>Faculty Development Research Fund</td>
</tr>
<tr>
<td>FTTH</td>
<td>Fiber-To-The-Home</td>
</tr>
<tr>
<td>GB</td>
<td>Gigabyte</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System for Mobile Communications</td>
</tr>
<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
</tr>
<tr>
<td>HDMI</td>
<td>High-Definition Multimedia Interface</td>
</tr>
<tr>
<td>ICIS</td>
<td>International Conference on Information Systems</td>
</tr>
<tr>
<td>ICT</td>
<td>Information Communications Technology</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>IPTV</td>
<td>Internet Protocol Television</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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<tr>
<td>ISOM</td>
<td>Information Systems and Operations Management</td>
</tr>
<tr>
<td>ISR</td>
<td>Information Systems Research</td>
</tr>
<tr>
<td>JIP</td>
<td>Journal of Information Policy</td>
</tr>
<tr>
<td>LARA</td>
<td>Lightweight Architecture for boundedly Rational Agents</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid-Crystal Display</td>
</tr>
<tr>
<td>LED</td>
<td>Light-Emitting Diode</td>
</tr>
<tr>
<td>LFC</td>
<td>Local Fiber Company</td>
</tr>
<tr>
<td>MAN</td>
<td>Metropolitan Area Network</td>
</tr>
<tr>
<td>Mbps</td>
<td>Megabits per second</td>
</tr>
<tr>
<td>MODSIM</td>
<td>Modelling and Simulation</td>
</tr>
<tr>
<td>MSM</td>
<td>Mobile Service Market</td>
</tr>
<tr>
<td>MSM-ABM</td>
<td>Mobile Service Market Agent Based Model</td>
</tr>
<tr>
<td>MSP</td>
<td>Mobile Service Providers</td>
</tr>
<tr>
<td>MSSANZ</td>
<td>Modelling and Simulation Society of Australia and New Zealand Inc.</td>
</tr>
<tr>
<td>NBN</td>
<td>National Broadband Network</td>
</tr>
<tr>
<td>NGN</td>
<td>Next Generation Networks</td>
</tr>
<tr>
<td>NZ</td>
<td>New Zealand</td>
</tr>
<tr>
<td>NZISDC</td>
<td>New Zealand Information Systems Doctoral Conference</td>
</tr>
<tr>
<td>OS</td>
<td>Operating Systems</td>
</tr>
<tr>
<td>PACIS</td>
<td>Pacific Asia Conference on Information Systems</td>
</tr>
<tr>
<td>POC</td>
<td>Proof of Concept</td>
</tr>
<tr>
<td>PReSS</td>
<td>Postgraduate Research Student Support Accounts</td>
</tr>
<tr>
<td>PTC</td>
<td>Pacific Telecommunications Conference</td>
</tr>
<tr>
<td>QUT</td>
<td>Queensland University of Technology</td>
</tr>
<tr>
<td>R</td>
<td>Residential</td>
</tr>
<tr>
<td>RBI</td>
<td>Rural Broadband Initiative</td>
</tr>
<tr>
<td>RFC</td>
<td>Reason for Change</td>
</tr>
<tr>
<td>RP</td>
<td>Research Phase</td>
</tr>
<tr>
<td>RSP</td>
<td>Retail Service Provider</td>
</tr>
<tr>
<td>S</td>
<td>Sponsorship</td>
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<tr>
<td>SD</td>
<td>Secure Digital</td>
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<td>SP</td>
<td>Service Provider</td>
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<td>SPA</td>
<td>Service Provider Agent</td>
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<td>TPJ</td>
<td>Telecommunications Policy Journal</td>
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<td>TPRC</td>
<td>Conference on Communication, Information and Internet Policy</td>
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<tr>
<td>U21 DRCB</td>
<td>Universitas 21 Doctoral Research Conference in Business</td>
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<tr>
<td>UAHPEC</td>
<td>University of Auckland Human Participants Ethics Committee</td>
</tr>
<tr>
<td>UConn</td>
<td>The University of Connecticut</td>
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<tr>
<td>UFB</td>
<td>Ultra-fast Broadband</td>
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<tr>
<td>UoA</td>
<td>University of Auckland</td>
</tr>
<tr>
<td>UoABS</td>
<td>University of Auckland Business School</td>
</tr>
<tr>
<td>USB</td>
<td>Universal Serial Bus</td>
</tr>
<tr>
<td>V</td>
<td>Value</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<td>--------------</td>
<td>--------------------------------------</td>
</tr>
<tr>
<td>VCR</td>
<td>Video Cassette Recorder</td>
</tr>
<tr>
<td>VHS</td>
<td>Video Home System</td>
</tr>
<tr>
<td>VOIP</td>
<td>Voice over Internet Protocol</td>
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</tbody>
</table>
List of Articles

This thesis consists of an introduction and conclusion, and seven articles. The articles are listed below along with an abstract, keywords, outlet information, author contribution, awards, previous versions, and related funding information.

---

Article I


**Abstract:** A competition between two or more technologies for becoming the dominant technological standard is a regular occurrence and some popular examples include media formats, Internet browsers, operating systems, game consoles etc. This study introduces an Analytical Framework for Technological Standardization (AFTS) that helps analyze competitors involved in a technical standard competition. This paper presents case studies of technological standardization, which include success of QWERTY keyboard standard, mobile operating systems like iPhone and Android, and the Fourth Generation (4G) Broadband Wireless Access (BWA) standard. Network economic concepts are useful to explain the market factors and tactics that contenders use to compete. Researchers conducting similar sorts of analysis have also relied on using economic concepts.

The study extends the AFTS to set up ABM simulations in order to mimic market conditions. The main focus of the simulation models is on keyboard standard battle (historic) and the 4G BWA competition (unsettled) while employing multi methodological techniques. The ABM is set up to simulate a market with consumers and technology providers. By simulating several scenarios we can learn and explain what constitutes key drivers for these competitions. The ability to simulate an unsettled competition will be of value to the stakeholders involved.

**Keywords:** 4G, Agent Based Modeling, BWA, LTE, Simulation and WiMAX

---

5 LTE, an acronym for Long Term Evolution, also known as 4G LTE, is a standard for high-speed wireless data communication for mobile phones and data terminals.

6 WiMAX (Worldwide Interoperability for Microwave Access) is a wireless communications standard, once a contender for 4G wireless.
Outlet Information: PACIS, sponsored by the AIS, is a premier information systems conference in the Pacific-Asia region; PACIS serves to provide a platform to researchers and practitioners in the field of information technology to share their research findings and practices.

Author contribution: Farhaan Mirza has taken the lead in writing this article with feedback, reviewing and editing from Fernando Beltrán.

Awards: This paper’s initial version was developed for 2010 ICIS doctoral consortium. In a departmental student competition, Farhaan succeeded in becoming the sole nominated candidate from UoA Department of ISOM to submit to the ICIS doctoral consortium. However ICIS reviewers in this highly competitive doctoral consortium didn’t accept the paper.

In 2011 Farhaan was successful at being nominated from the UoA ISOM department to submit to PACIS. The article was accepted at the PACIS DC, and included in conference proceedings.

Funding: Farhaan was awarded funding from the ISOM department for conference registration, accommodation, and flights. Farhaan participated in the 2011 PACIS held in Queensland University of Technology (QUT) Brisbane.

Article II


Abstract: A competition between technologies for becoming the dominant technological standard is a regular occurrence and some examples include media formats, Internet browsers, operating systems, game consoles etc. This paper introduces an AFTS that helps analyze competitors involved in a standard competition. A review of case studies in this paper includes iPhone and Android, and the 4G BWA standard. Network economic concepts are useful to explain the market factors and tactics that contenders use to compete. Researchers conducting similar sorts of analysis have also relied on a variety of methods including economic concepts, ecological models and game theory. The agent based simulation experiments are for the keyboard standard battle (historic) and the 4G BWA
competition (unsettled) while employing multi methodological techniques. The ability to simulate an unsettled competition will be of value to the stakeholders involved.

**Keywords:** 4G, Agent Based Modeling, BWA, LTE, Simulation and WiMAX

**Outlet information:** The University of Connecticut (UConn) School of Business hosted the U21 DRCB April 10-13, 2012. PhD students from twelve U21 schools, including UConn, presented research and received feedback regarding their dissertations from their counterparts, faculty from the participating universities, and the UConn faculty. The vision of U21 DRCB is to create a global learning and research platform to prepare the next generation of intellectual leaders in the fields of business, commerce and economics.

**Author contribution:** Farhaan Mirza has taken the lead in writing this article with feedback, reviewing and editing from Fernando Beltrán.

**Awards:** Farhaan succeeded in a Business School competition, which comprised three steps: firstly achieving a *sole candidate* departmental nomination, secondly submitting the written paper to a panel, and finally presenting the paper to the panel.

**Funding:** The Dean of the Business School approved funding for conference registration, accommodation, and flights to Hartford.

**Previous Versions:** An earlier version of this paper was also accepted and presented at the NZISDC 2011 in Victoria University of Wellington.

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**Article III**


**Abstract:** Network industry products and services rely on designing competitive business models including aspects of consumers influencing other consumers. Consumer decision-making is a complex process involving rich attributes that include value consideration and network effects. Using compatible products within an organization or home, or between friends results in greater utility and satisfaction, emphasizing the consumer decisions are not just based on value but also on what their peers recommend and use. This paper presents a
generic Friend Circle Creator (FCC) ABM, which leverages network formation theory to create and evolve friend circles within the consumer agent population. These friend circles can be used to simulate consumer decision-making scenarios for cases consisting network externalities. We apply the FCC model to a mobile phone plan case study. The results of this case study demonstrate how the presence of network effects is able to retain a large population of consumers in an inefficient deal. FCC can be used as a module to complement larger ABMs to enhance analysis in studying drivers of consumer decision-making.

**Keywords:** Network effects, consumer decision making, network industries

**Outlet information:** Society for Computer Simulation, established in 1952, is the premier technical Society dedicated to: advancing the use of modeling and simulation to solve real-world problems; the advancement of simulation and allied computer arts in all fields, and facilitating communication among professionals in the field of simulation.

**Author contribution:** Farhaan Mirza has taken the lead in developing the simulation model and writing this article with feedback, reviewing and editing from Fernando Beltrán.

**Funding:** Farhaan Mirza was awarded PhD Conference Funding of $2500; this funding combined with Postgraduate Research Student Support Accounts (PReSS) enabled payment for conference registration, accommodation and flights.

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**Article IV**


**Abstract:** NZ is currently implementing a high-speed FTTH broadband project known as the UFB initiative. In this article we explore drivers and barriers of consumer adoption of UFB. We use a mixed methods approach for conducting empirical research, which includes interviewing broadband consumers, and analyzing secondary research insights from industry. Using grounded theory we postulate research frameworks for CAUA, and CAUC to portray pertinent consumer drivers, barriers, and deciding factors for the UFB initiative. We find that consumer awareness and pricing are main factors that need to be addressed for a successful UFB rollout. This case study presents us with a timely unique opportunity to analyze the
issues involved as the market evolves and stabilizes. This research has the advantage of gathering consumer resistance insights from an early phase of technological introduction.

**Keywords:** Ultra-Fast Broadband Initiative, UFB, fiber-optic implementation, FTTH, consumer broadband adoption.

**Outlet information:** TPRC is an annual conference on communication, information and Internet policy that convenes international and interdisciplinary researchers and policymakers from academia, industry, government, and nonprofit organizations. Its purpose is to present original research relevant to policy making, share information about areas where research is needed, and engages in discussion on current policy issues.

**Other publications from this work:**

This paper is accepted into the Journal of Information Policy, which is a peer-reviewed professional journal dedicated to timely policy research that addresses contemporary challenges and connects researchers to policymakers. The title of the article is changed based on the feedback.


**Author contribution:** Farhaan Mirza has taken the lead in writing this article with feedback, reviewing and editing from Fernando Beltrán. Industry contacts James Koers, from Snap Internet, Rosalie Nelson and Vanessa Kennedy-Casas from Chorus provided data and feedback for research related to this paper.

**Funding:** Fernando Beltrán was successful at achieving UoA Faculty Development Research Funding (FDRF); this helped the data collection component of this study. Farhaan Mirza used PReSS account to pay for conference registration, accommodation, and flights.

**Article V**

Abstract: Local Fiber Companies (LFCs) and the government of NZ are jointly implementing a nation-wide fiber-optics network, a project known as the UFB initiative, expected to cover 75% of households by 2019. New opportunities are expected to open up because the UFB network by regulation forbids LFCs to directly provide retail services. Consumers will need to purchase fiber services from Retail Service Providers (RSPs). The UFB represents a scenario of a two-sided platform, with consumers and RSPs on each side. Using two-sided platform theory and normative economics this paper presents the results of an ABM of platform access dynamics. The UFB platform currently subsidizes fiber lines for consumers. As the industry debates whether subsidization should continue, the results indicate that subsidy can be reduced when a large number of users on either side appear in the market. This case study presents us with a timely unique opportunity to analyze the issues involved as the market evolves and stabilizes.

Keywords: Fiber deployment in New Zealand, Cross Network Effects, Two Sided Platforms

Author contribution: Farhaan Mirza has taken the lead in developing the simulation model and writing this article with feedback, reviewing and editing from Fernando Beltrán.

Outlet information and funding: Same as Article III

Article VI


Abstract: We model the access uptake on a newly built high-speed FTTH broadband network using a computational ABM. Two cases illustrate the model analyzed in this paper: the UFB Network in NZ and the National Broadband Network (NBN) in Australia. Common aspects of both projects are used in our model to describe and analyze the uptake of fiber connections to households and businesses. By design network operation is decoupled from service provision and the platform is open-access, meaning any provider can operate end-user services. In our model a high-speed broadband network is regarded as a two-sided platform that accommodates both end-users and service providers, creating the conditions for the two sides to exploit mutual network effects. Results show that the greater the number of users
(end-users or providers) on one side, the more the number of users (provider or end-users) on the opposite side grows. Providing free connections and raising consumer awareness is a means for driving consumer uptake. Scenario based analysis allows us to investigate the magnitude of network effects’ on the fiber connection uptake.

**Keywords:** Fiber deployment, Cross Network Effects, Two Sided Platforms

**Outlet information:** This paper was accepted and presented at the Artificial Economics (AE) 2013 conference held in Klagenfurt. It is also published as a book chapter in Springer Link’s 2014 series of Lecture Notes in Economics and Mathematical Systems.

The main aim of the AE Symposium is to facilitate the meeting of people working on different topics in different fields (mainly Economics, Finance and Computer Science) in order to encourage a structured multi-disciplinary approach to social sciences. Presentations and keynote sessions center around multi-agent modeling, from the viewpoint of both applications and computer-based tools.

Lecture Notes in Economics and Mathematical Systems reports on new developments in mathematical economics, economic theory, econometrics, operations research and mathematical systems.

**Author contribution:** Farhaan Mirza has taken the lead in developing the simulation model and writing this article with feedback, reviewing and editing from Fernando Beltrán. The paper was presented in Klagenfurt (Austria) in August 2013 by Fernando. Industry contacts James Koers, from Snap Internet, Rosalie Nelson and Vanessa Kennedy-Casas from Chorus provided data and feedback for research related to this paper.

**Article VII**


**Abstract:** MSMs are continually evolving due to the introduction of new technology and greater consumption needs of the consumer. This paper justifies why an ABM approach can help understand the main elements of competition in a market where MSPs need to frequently adapt their offers to increasingly savvier consumers. Artificial consumer and service provider
agents are setup with heterogeneous preferences and behaviors. The computational model is run multiple times to test a collection of hypothetical scenarios and produce results that explain emergent market outcomes of the competition dynamics. The results depict the effects of first mover advantages and the network effects within the consumer population. Additionally the findings show how sponsorship in mobile plans can counter lock-ins.

**Keywords:** Mobile market competition, Consumer decision making, Agent based modeling methodology, service provider tactics.

**Outlet information:** PTC's annual conference is the Asia-Pacific's premier telecommunications event. Now in its 36th year, the annual conference is a strategic springboard for the global telecommunications industry.

**Other publications from this work:**

This paper’s extended abstract was accepted and presented at the 20th International Congress on MODSIM, held at the Adelaide Convention Centre in Adelaide, South Australia in December 2013.


The MSSANZ aims to promote, develop and assist in the study of all areas of modeling and simulation.

**Author contribution:** Farhaan Mirza has taken the lead in developing the simulation model and writing this article with feedback, reviewing and editing from Fernando Beltrán.

**Awards:** Farhaan Mirza was awarded a Pacific Telecommunication Young Scholar Award for this paper.

**Funding:** PTC award included complete funding for conference attendance. Farhaan was awarded PhD Conference Funding of $2500, this funding combined with PReSS account enabled payment for MODSIM conference registration, accommodation, and flights.
1 Introduction

The world total of mobile subscriptions exceeds 6.2 billion (World Bank, 2013). Broadband connections have managed to penetrate a large percentage of homes. Enhanced communication is benefiting consumers and businesses in all facets of life. Access to computing, smartphones, and faster download speeds open up immense consumer demand. For instance, the Apple Appstore downloads exceeded forty billion downloads in Apple App Store (Bergvall-Kåreborn & Howcroft, 2013).

This rapidly changing domain of Information Communications Technology (ICT) has unique characteristics; it’s a networked industry - which means the overall utility for each user is increased when the number of users in that market increase. For example we all enjoy compatibility and versatility of PDF documents, USB cables and SIM cards – mainly because of the technology user uptake. These networked-industries industry consists of economic drivers that are absent from other industries – some drivers include first mover advantages, lockins, path dependence, switching costs etc. Imagine using alternatives to PDF documents and proprietary connectors for flash storage drives.

For a technology to successfully compete in these standard oriented networked markets will require it to employ multiple strategies based on its strengths and propositions. Strategies could include controlling installed base of users, intellectual property rights, ability to innovate, first-mover advantages, manufacturing capabilities, strength in complements, brand name and reputation (Shapiro & Varian, 1999).

This study appreciates the above-mentioned issues and frequent competitions amongst technology standards in a world we live in today. Thereby this thesis produces analytical frameworks and computational simulators using a multi-methodological approach including ABM for the networked ICT market and competitive aspects of it, especially within the telecommunications domain. The thesis specifically focuses on (1) consumer decision-making in a MSM and (2) takes advantage of timely analysis of FTTH service deployments.

The research audience is not limited to but includes telecom operators, application providers, mobile device manufacturers, vendors, investors, and researchers in the telecommunications
area. ABM researchers may find our approach to using an ABM tool useful and apply it to other contexts. Additionally this topic may interest economists interested in exploring the analysis of competing technologies.

1.1 Motivation

The motivation for exploring this research area is four-fold. Firstly, due to continuous innovation in telecommunications, which is increasing consumer satisfaction and demand, telecommunication services are effective and add value to one’s lifestyle or business. Better communication leads to cost savings and greater efficiencies. These innovations have influenced information storage to become more integrated using server based cloud architecture. Businesses instead of being fixed and local are now offering their services globally using web-based e-commerce. People that were office-bound are now able to work mobiles using wireless Internet.

Increasing speeds on mobile processors, smarter screens and keyboards, better network connectivity, increase of mobile applications, mature mobile development platforms, and mass adoptions globally have now established a rich market for SPs and consumers. Mobile devices are becoming more capable and the devices usually include built-in multimedia functionalities, Internet connectivity, and modular software design (enabling user-installed applications) and are penetrating developed markets (Verkasalo, 2009). Despite these significant improvements, the price of technology is also getting cheaper. For example you could buy one transistor for a dollar in 1968 versus 10 million transistors for a dollar today (Kurzweil, 2004).

Mobile and fixed environments for applications discussed above rely on leverage from Internet connectivity. Businesses and consumers require an Internet connection that is fast, wireless, cheap, always connected, and ubiquitous. These desired features are being enabled by the 4G mobile Internet, and Fiber-based broadband. As the industry is in transition regarding enabling of these networks, it presents us with a unique opportunity to analyze how these markets develop.

The second motivation is due to the prevalence of technology standards in ICTs. Each mechanism in an ICT is delivered by one or more technology standard. For example media
delivery is provided through cable, satellite and IPTV\(^7\), and the client hardware can include tablets, phones and smart TVs, or come via consoles such as Apple TV, Google Play, and Microsoft Xbox. Televisions are available as plasma, LCD\(^8\), LED\(^9\), and more recently providing three-dimensional capabilities. Computers can also consume or produce media content, and standards, for instance cable ports, USB\(^10\) connections, SD\(^11\) Cards, DVI\(^12\), and HDMI\(^13\) are used for connecting multimedia devices.

An added dimension of technology standards is their competing *frequently and constantly*. Some examples include competitions between web standards HTML 5 Vs. Flash; Mobile operating systems (OS) iPhone OS, Android, and Windows Phone, and among desktop operating systems Linux, Windows, and Mac OS. This thesis explores aspects of standard introduction and competition. Articles I and II provide further insights into competing technology standards.

Thirdly *researchers extensively report on the outcomes of competition*; the following are a few references. The economics of QWERTY were reported by David (1985). The standards in wireless telephone networks by Gandal, Salant, & Waverman (2003). The battle of Video Home System (VHS) and BETA\(^14\) by Cusumano, Mylonadis, & Rosenbloom (1992). Innovation and competition in US Home video game market was presented by Gallagher (2002). Therefore it is worthwhile leveraging the research data available for the research objectives.

A fourth motivation is *the knowledge of the drivers in an unsettled technology market or a technology competition* will be of value to the users and stakeholders. While the standard development within ICT markets is of interest, this thesis specifically focuses on Next Generation Networks (NGNs) because these are presently transforming the present day standards and markets. 4G wireless and Fiber-based broadband are being implemented in many countries worldwide (2009 - 2014); this is stimulating change in market structures. This research views this situation as an opportunity for us to analyze such issues as they occur.

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\(^7\) Internet Protocol television (IPTV) is a standard that is used to deliver television using the Internet protocol.

\(^8\) A liquid-crystal display (LCD) is a flat panel display

\(^9\) A Light-emitting diode (LED) is a flat panel display, which uses an array of light-emitting diodes as a video display.

\(^10\) Universal Serial Bus (USB) is an industry standard to standardize the connection of computer peripherals

\(^11\) Secure Digital (SD) is a non-volatile memory card format for use in portable devices

\(^12\) Digital Visual Interface (DVI) is a video display interface to connect a video source to a display device

\(^13\) HDMI (High-Definition Multimedia Interface) is a compact audio/video interface for transferring video and audio data

\(^14\) Betamax also referred to as BETA is a videocassette magnetic tape standard developed by Sony.
NGNs increase end-user value and satisfaction due to high speeds and stable connections. New applications, services, devices, and business models are being based on the availability and performance of networks; for example VOIP\textsuperscript{15} calling, video streaming, cloud storage, and remote work. NGNs involve multiple stakeholder groups such as infrastructure owners, implementers, retailers, virtual operators, businesses, and general consumers. Additionally, access to NGNs involve varying initial cost to these stakeholders and these costs along with the benefits received determine how stakeholders participate in these markets.

This motivation leads us to define the study’s context, focus area and application.

**Research context:** Provide an analytical methodology based on ABM, network economics and aspects from historical ICT competition cases to enrich understanding of multiple stakeholder involvement in competing technology standards or developing markets.

**Research focus:** Propose and apply ABM to analyze dynamics of technology introduction and technology adoption using network economic theory in the telecommunication domain.

**Specific examples:** Apply theory and methods to two cases: 1) consumer and MSP decision making MSM and 2) FTTH service deployments.

### 1.2 The Conceptual Framework

The purpose of this section is to present the conceptual framework, and subsequent research questions. According to Miles & Huberman (1994) conceptual frameworks serve the purpose of outlining what is studied. The conceptual framework in this thesis serves the purpose of placing the articles presented into a ‘bigger picture’ to explain how this study is shaped. It also explains the research questions applied to the study, and the theoretical basis used for each stage of the research. The conceptual framework for this study is illustrated in Figure 1.

\textsuperscript{15} Voice over Internet Protocol (VoIP) is a method used for the delivering voice communications over Internet Protocol (IP)
The conceptual framework for this thesis consists of three main stages: context, focus area, and response to specific case studies. It also illustrates the data collection and theoretical approach for each stage. Each of these stages is a subset of the preceding stage. Technology standardization and competition, the top-most stage, allows for the exploration of the technological ecosystem of competitions, and introduces the idea of utilizing ABM to further investigate the drivers of such competitions. The next stage deals with exploring dynamics of technology introduction and technology adoption in networked markets, this is a subset of the framework produced in the first stage. Finally, the specific example stage addresses examples of 1) competition and consumption in MSMs and 2) introduction of FTTH access. In the proceeding sections, the framework will be deconstructed to explain each of its components.
1.3 Stage 1: Research Context

The initial step of this research activity was to explore the ecosystem of technology introduction, competition, and standardization to establish context of the research area. To understand this phenomenon and its commonalities several historical cases of technology standardization were reviewed. Therefore our first research question is:

*Research Question 1: What are the common aspects of a technology standards battle?*

The research began with the premise of understanding how technologies compete for standards. The review of historical technological battles helped the study appreciate network economic factors involved in competitions. A commonality in these competitive markets is its multiple stakeholders; we classified them into four groups as follows. First group involves technology sponsors or owners – who are the initiators, founders, or developers of the technical standard. Second group consists distributors, sellers or retailers, their job to sell services or products based on the standard. Third group are the technology enhancers, these are third party companies that build plugins, accessories, or extensions to the standard that enhances a technology standard’s ability to become more attractive. Lastly, technology adopters are the end users of the standard. For example Google Android being the technology sponsor has device manufacturers (Samsung, HTC etc.) who sell mobile devices, where Google software developers release apps to leverage Android’s footprint and access a large consumer-base.

Researchers (Besen & Farrell, 1994; Fransman, 2002, 2007; Michael L Katz & Shapiro, 1986; Shapiro & Varian, 1999; Shy, 1996, 2001) reported on historical competitions and present models, frameworks, and techniques to analyze these case studies systematically. For instance Shapiro & Varian (1999) classify types of standard wars and provide a list of seven assets to become successful in a technological battle which include – control over installed base of users, intellectual property rights, ability to innovate, first-mover advantages, manufacturing capabilities, strength in complements, and brand name and reputation.

In ICTs in present time, there is frequent occurrence of new technology introduction, which is either an evolved version of an existing technology or a new revolutionary concept. Shapiro & Varian (1999) classify these standard wars into four quadrants – where a competition can be between evolutionary or revolutionary technologies with a compatibility factor see Figure 2. An example of evolution in technology is desktop operating systems – every couple of
years an updated version of Windows, Mac OSX or Ubuntu becomes available. Whereas a \textit{revolution} is when an entirely new technology breaks through – for example social networking sites, or smartphones (iPhone and Android). The competitive behavior in an evolutionary technology versus revolutionary technology is vastly different. The adoption of a revolutionary technology over the existing technology depends on whether consumers value the network effect over quality of the technology and how compatible it is with the old technology.

![Figure 2: Types of standard wars – adapted from Shapiro & Varian (1999)](image)

Fransman (2002, 2007) provides a model for the \textit{New ICT Ecosystem} as shown in Figure 3. This model refers to the interactions between four groups of players: network element providers (those who provide the individual elements of networks); network operators (those who create and operate networks); platform, content and applications providers (those who use elements and networks to provide content and applications); and final consumers (divided into various subgroups).

We leveraged Fransman’s thinking especially in the later sections of the thesis when we presented the FTTH network as a two-sided platform. However for the initial portion of the research we have taken a very simple heuristic overview of the landscape, by means of listing the stakeholder groups that are usually present in tech battles. As a result we derived the AFTS (see Figure 15), this provided the thesis a consistent method to compare contenders and measure strengths and weaknesses; in addition pinpoint economic factors that reflect tactics employed by stakeholder groups (see examples in Figure 16 and Figure 17).
Figure 3: Simplified model of the new ICT ecosystem adapted from Fransman (2007)

The study’s longer-term intention was to develop computational agent-based simulation models to depict competition drivers present in these markets. For the purpose of an agent-based design we found stakeholder groups in standard battles (as organized in the AFTS) – a convenient consideration. In the ABMs – the stakeholders would be converted into agents. The choices in the market would become products and services for the consumers to choose from.

The articles (I and II) produced in this stage of summaries cases of historical competitions including keyboard layout, video recording standard, digital wireless communications, mobile operating systems, Internet standards, and DVD standards.

In response to research question 1, the thesis produced its first research artifact: AFTS. Furthermore the characteristics and benefits of an ABM approach were explored in order to analyze technology standardization. The research questions at this stage (2010 – 2011) were as follows:

Research Question 2: Use an agent based simulation model to analyze technologies competing to become an industry standard.
Research Question 3: Conceptualize using ABM for simulating the battle of 4G to investigate possible outcomes of this battle and how each outcome may occur?

We particularly interested in the analysis of competition between WiMAX and LTE, and ambitious to use ABM to explore dynamics of a wireless market.

WiMAX forum and 3GPP (LTE developers) are industry-led consortia consisting each of 500+ members working towards standard specifications. WiMAX is a BWA technology that can create metropolitan area network and provide last mile broadband, as each WiMAX tower can cover up to a 50km radius. LTE can provide peak data rates exceeding 300Mbit/s in download and more than 75 Mbit/s in upload (Mogensen et al., 2009). When a LTE mobile subscriber leaves a LTE environment, they can still be connected to the network, because LTE supports handover and roaming to existing mobile 3G networks. This is a significant advantage of LTE over the first mover WiMAX. At the time of research (2010) – this battle between WiMAX and LTE was unsettled, however now (2015) LTE is clearly the favorite, being adopted by mobile carriers for delivering 4G BWA. The main reason for LTE’s success is because of its backward compatibility features and because the 3GPP consortium has a larger network of mobile carrier stakeholders.

ABM is a method for studying systems that are composed of interacting agents and emergent properties (Axelrod & Tesfatsion, 2006). Emergent properties are an aggregate of the properties of interacting agents. For example – in wireless network service, providers may serve many users. These users could be joining the service, leaving the service, using the service or influencing others to use the service. ABM is well suited for this objective as it is a method for studying systems exhibiting the following two properties (Flake, 1999): 1. The system is composed of interacting agents and, 2. The system exhibits emergent properties, that is, properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents.

The research questions (2 and 3) are addressed in Article II. As a proof of concept (POC) we simulated the historical keyboard layout battle between Dvorak Simplified Keyboard (DSK) and QWERTY. Furthermore the competition between LTE and WiMAX for providing 4G BWA was analyzed. Thereafter the AFTS framework was applied to articulate the battle of 4G. Finally an initial version simulation model was developed for this battle.
The main findings from the research context stage are as follows. Competitions between technologies for standardization are a regular occurrence. Competitions are becoming more complex over time, due to increased numbers of stakeholders, complexity of technology, and large market size. This makes it difficult to set assumptions and develop scenarios. Theoretical concepts of network economics from *industrial organization* can be used to explain the dynamics of competitions. Secondary data can help establish assumptions in an ABM.

The wireless market battle’s simulation results (from Article II) demonstrated four main contexts of a market situation, including better features, cheaper costs, network effects and path dependence. The better features and cheaper costs were obvious results, where consumers prefer better plans, cost wise and feature wise. The network effects can potentially fail an attractive offering or even completely *disable* a MSP’s entry into the market. Simulation tools can provide a means of analyzing dynamics present in a competition.

### 1.4 Stage 2: Focus Area

We evaluated the previous stage’s progress together with feedback from conferences and departmental seminars, and we realized it was inappropriate to set an expectation of developing a simulation model of *tech-battle* using ABM. In Articles I and II we did mention the simulation is catering only for the *market level* factors, however the initial introductions of Article I and II set expectations of developing a tech-battle model using ABM. The simulation is worthwhile only when addressing *market level* factors, which is one aspect of an overall standard competition. The market competition dynamics usually involve consumers, retailers, suppliers, and distributors. The boxes B, C, D, and E show these stakeholders in Figure 15.

So the research questions 2 and 4 in section 1.3 needed to be revised, and the research plan was adjusted to become more focused on market level factors. The focus for stage 2 of this study was on applying ABM using network economic theory for a MSM setting rather than simulating an entire battle of 4G. In this stage, we extended our literature to look at consumer decision-making processes because these processes ultimately effect how a product becomes successful.
Consumers decision making process can be complicated, as consumers are often faced with a large number of options, due to new technologies and competitive pressures (Bettman, Johnson, & Payne, 1991). A well recognized model of consumer purchase decision-making presented by Engel, Blackwell, and Miniard (1993) divides the consumer purchase decision process into five stages: 1) problem recognition, 2) information search, 3) alternative evaluation, 4) purchase decision, and 5) post-purchase behavior. A range of factors including long term memory, rationality, evaluations, personal characteristics, social context, cost/benefit factors, contingencies, advertising and word of mouth contribute to the decision to consume a product or service. An aspect that is important in consumer decision-making is motivation; this is of particular interest to this paper. The idea that social factors guide individual decision-making was a cornerstone of early social influence research (Asch, 1951). Motivation of friends, family and co-workers is an attribute that is very important to models that depict consumer decision-making in network industries.

The research steered toward developing consumer agents who can make independent and interdependent decisions in a market with network externalities. Our aim was to model this consumer behavior in a MSM; the research questions at this stage of research are as follows:

*Research Question 4: Leverage network economics to explore competition dynamics in a MSM?*

*Research Question 5: Utilize network formation theory to create a network of friends, in order to introduce endogenous network effects within consumer agent population.*

For the consumer agents to make decisions based on motivation or influence from other agents we require a “friend network” inside the ABM. Using network formation theory we can create networks and partition them as required in order to achieve a representation of friend circles (Jackson, 2005; Newman, 2010). In a *consumer friend circle network* the nodes are the consumer agents and the edges are undirected friendship links. As a result of this effort we devised the FCC module that can be used inside Netlogo application to create friend circles of agents.

Article III responds to research questions 4 and 5 by presenting a generic FCC-ABM, which leverages network formation theory to create and evolve friend circles within the consumer agent population. These friend circles can be used to simulate consumer decision-making scenarios for cases consisting of network externalities. The MSM mobile phone plan case
study is used as an example to demonstrate the FCC-ABM. The results of this case study demonstrate how the presence of network effects is able to retain a large population of consumers in an inefficient deal. The potential of FCC can be exploited by it complementing larger ABMs to enhance analysis in studying drivers of consumer decision-making.

1.5 Stage 3: Specific Examples

The theoretical frameworks and FCC from stages 1 and 2 provided potential to explore specific telecommunication examples. Stage 3 involved addressing two case studies:

1. Analysis of Competition Dynamics in a MSM - consumer choice and MSP competition (see section 1.5.1)

2. Access uptake of high-speed fiber based broadband (see section 1.5.2)

1.5.1 Analysis of Competition Dynamics in a MSM - Consumer choice and MSP competition

In Article III we simulated consumer decision making, however the tactical behavior of MSPs is lacking. For instance if a MSP is losing market share, they would react by revising their business model. This defined the next research goal.

Research question 6: Simulate independent decisions of consumers and MSPs in a MSM where MSPs revise their offerings to compete in the market and consumers subscribe based on their preferences including influence of friends.

MSM is a dynamic market that frequently changes in multiple aspects of its delivery and consumption. In response to dealing with this changing landscape of MSM, the MSPs design subscription-based products often known as plans. The plans offered by an MSP include a monthly subscription to a limited amount of data, minutes of voice calls, and text messages. MSPs often revise these plans frequently in order to stay competitive in the market. On the other hand when consumers subscribe to mobile plans their selection is based on a range of factors such as pricing, features, switching costs, and influence of friends.

Article VII addressed this requirement. This article used ABM as a methodology without relying on any secondary data. Most articles in this thesis provide justification of ABM,
however Article VII is the most through version of justifying ABM as a methodology for analysis conducted in this thesis.

1.5.2 Access uptake of high-speed fiber based broadband

The present day implementation of fiber networks: NBN in Australia and UFB in NZ, and the work presented by Beltrán (2012) inspired this study to apply ABM, two-sided platform theory, and network economics to this research. This case study produced three articles IV, V, and VI. An overview of this case study outputs is shown in Figure 4.

![Figure 4: Overview of Case Study 2](image)

The Australian and New Zealand governments are committed to the construction of high-speed, fiber-optics next-generation access networks. The NBN in Australia is the largest publicly funded infrastructure project in Australia costing AU$37.4 billion. NBN will serve 93% of Australian households and businesses. In NZ the UFB initiative is also a high-speed FTTH broadband network costing NZ$1.35 billion and covering 75% of households and businesses. Australian government decided to fully fund the NBN whereas in New Zealand it is a public and private investment. From a market structure and stakeholder role point of view the FTTH operators and retailers are independent entities. Our first research question in this case study was to provide an overview of this market structure.
Research Question 7: Produce an overview of NZ broadband market and develop a model that generates cross network effects on both sides of the platform.

In New Zealand prior to introduction of UFB, majority of RSPs who sell retail broadband needed to purchase wholesale broadband from Telecom NZ (who was also a RSP). This structure was discriminatory in provisioning retail services, because Telecom had the upper hand and didn’t allow for fair competition. The above-mentioned market structure changed for UFB market. For instance in New Zealand the LFCs provide the network at wholesale prices to RSPs when they sign up fiber customers. LFCs are not allowed to sell directly to consumers. We highlighted these market and regulatory changes in provisioning broadband in Article V. In addition to this Article V outlines differences Asymmetric Digital Subscriber Line (ADSL\(^{16}\)) broadband market structure versus UFB Market Structure.

1.5.2.1 Two-sided platforms

We modeled the high-speed FTTH networks as two-sided platforms because it involves two or more user groups, who provide each other with beneficial network effects. The model is built on a two-sided market approach where users’ and RSPs’ decisions to participate in the market are mutually influenced, mainly by the number of the “agents” on the other side.

The definition and context of a platform can have many variations. Gawer (2009) defines a platform as a building block, which can be a product, a technology, or a service, that acts as a foundation upon which other firms can develop complementary products, technologies, or services. Platforms are systems that support complementary economic activity varying greatly in terms of complexity and the level of the ecosystem at which they exist (Fransman, 2002).

Founding work on the economics of two-sided platforms was presented by Rochet and Tirole (2002, 2003) who introduced the term two-sided market. Two-sided platforms guise in many forms. For example a shopping mall, which has shoppers on one side and stores on the other side. Another example is a credit card platform (MasterCard or Visa) with cardholders, vendors, and banks – all different sides to the platform.

Pricing in a two-sided platform has the ability to affect the total welfare through changes in the price level and the price structure; in other words, a two-sided platform can affect the

\(^{16}\) ADSL is a communications standard that enables data transmission over copper telephone lines. This is a superior standard of dialup but is inferior to the fiber-based broadband.
volume of transactions by charging one side and reducing the price charged to the other side (Rochet & Tirole, 2003). In large two-sided platforms (especially in the ICT domain) it is typical for one of the sides to be subsidized. For instance on eBay or Trademe web sites, access to the website listings is free of charge to the general public whereas the advertisers and sellers pay for listings.

In this case study for FTTH we leverage the concepts of two-sided platforms to study the cross network effects of both sides. When dealing with an expensive large-scale platform, in our case the FTTH. These initiatives follow a platform leadership strategy, in the sense that a central system component is established to structure an entire industry around it (Ballon, 2009). For example the UFB initiative has CFH, the company tasked to manage Crown's investments in the UFB. The LFCs are the fiber companies that wholesale to RSPs who sell to consumers.

### 1.5.2.2 Consumer adoption of UFB

While these technology implementations and market changes of FTTH occur, there are consumer resistance issues for transitioning from ADSL to a fiber line. This became an area of interest; therefore our next research question was to:

*Research Question 8: Explore drivers and barriers of consumer adoption of UFB.*

Consumers will need to purchase fiber-based broadband services from RSPs. The UFB initiative embodies two market components - an *access market* and a *content market*. The access market involves consumers achieving fiber connectivity from their LFC; while the content market involves subscription or purchase of connectivity of actual retail products such as phone line, broadband, IPTV, etc.

The consumer can have one of four statuses with regard to UFB service: (1) not being eligible (never fiber), (2) being eligible but without fiber (no fiber yet), (3) getting fiber connectivity at the curb (passing fiber), and (4) purchasing services (with fiber). If a consumer lives in an allocated UFB zone, they will be approached by their allocated LFC informing them regarding cabling work closer to the date their street is due for fiber cabling. When the consumer’s street has fiber connectivity – the consumer (with passing fiber) can purchase fiber services from RSPs. This process will require installing a fiber connection from curb to door, which is currently free of cost due to the government subsidy till 2015 (Adams, 2012).
Without subsidy the installation can vary per household and can cost up to NZ$500. The UFB initiative is expected to end by 2019, which means many residents might need to pay for obtaining curb to home fiber access during the 2016 and 2019 term.

After obtaining UFB access the consumer will need to buy products from RSPs to take advantage of their fiber line. The products can include home phone, broadband, on demand video subscriptions, and IPTV. However the product range in the UFB content market is expected to grow and diversify after the UFB access market is established.

To understand issues of consumer adoption – the research needed to collect consumer data. We were successful at obtaining secondary survey data from the industry – Chorus and Snap Internet. In addition to consumer interviews were conducted to acquire detailed information about the consumer perceptions of participating in the access and content market of a high-speed FTTH platform. The results would complement the secondary data from the industry.

The outputs of this empirical work produced Article IV, which presents theoretical frameworks of consumer adoption. Finally our objective was to:

Research Question 9: Design an abstract ABM to portray broadband access uptake on a high-speed platform.

This requirement was delivered in article VI. The model produced a consumer uptake ABM for FTTH broadband. The consumer decision-making process for considering subscribing to a fiber retailer was articulated – with or without subsidy for connection costs. The results showed high consumer utility assures the access market’s performance, regardless of service providers having a high or a low utility. Additionally the results show that having a large number of first mover service providers allows the platform to keep generating revenue, even though the consumer utility may remain low.
In the preceding section we presented the conceptual framework applied to this study. Figure 5 shows how each of the original articles presented in this thesis fit with the conceptual framework. The article-based approach helped the study obtain active feedback from the industry and academics. The feedback at each stage – helped define next steps of the research. Figure 6 illustrates the articles at each stage of this research and their contributions. The articles follow the methodology section of this thesis.
Figure 6: Stages, articles, and their contribution

1.7 Thesis Structure

The thesis is a paper-based thesis. It adapts a simple structure. In Chapter 2 we present the methodology, followed by Articles I – VII, and an aggregated conclusion at the end.

Chapter 1: Introduction. This chapter introduces the main purpose of this thesis, and presents the motivation for the analysis of technology introduction and competition in telecommunication markets. It also presented conceptual framework which summarizes theoretical literature, connects the original articles, and the research questions together.
Chapter 2: Methodology. This chapter presents the multi-methodological approach we adapted to create and validate various artifacts. This multi-methodological approach was used to designing and implementing computational ABMs. It consisted of four research strategies/phases - observation, theory building, systems development and experimentation.

Chapter 3: Article I. This article introduces the AFTS that helps analyze competitors involved in a technical standard competition. It also includes case studies of technological standardization from the past and present.

Chapter 4: Article II. Advancing the work in Article I, this chapter reviewed other research techniques including economic concepts, ecological models and game theory that were used for the analysis of competing technologies. Agent based simulations are created for the keyboard standard battle and the 4G BWA competition.

Chapter 5: Article III. This chapter focuses on an ABM to leverage network formation theory to create and evolve friend circles within the consumer agent population. These friend circles can prove useful in simulating consumer decision-making scenarios for cases consisting network externalities. All simulation models variants to follow in the study inherited the FCC module.

Chapter 6: Article IV. This chapter deals with empirical research related to consumer adoption of UFB services. This included interviewing broadband consumers, and analyzing secondary research insights from industry. The article presents CAUA, and CAUC frameworks to portray pertinent consumer drivers, barriers, and deciding factors for the UFB initiative.

Chapter 7: Article V. The UFB represents a scenario of a two-sided platform, with consumers and RSPs on each side. The ABM analyzes the RSPs and consumers activating on the UFB network.

Chapter 8: Article VI. This chapter further enhances the ABM (from previous chapters) for the two-sided high-speed broadband that accommodates both end-users and service providers, creating the conditions for the two sides to exploit mutual network effects. Scenario based analysis is used investigate the magnitude of network effects’ on the fiber connection uptake.
**Chapter 9: Article VII.** This chapter provides a thorough justification for use of ABM approach in competitive telecommunication markets. In this chapter we incorporated MSPs agents who to frequently adapt their offers to compete in the market. The computational model is run multiple times to test a collection of hypothetical scenarios and produce results that explain emergent market outcomes of the competition dynamics.

**Chapter 10: Conclusion.** Following on from the original articles, this chapter concludes the thesis. It presents the contributions of this thesis to theory and practice. It summarizes the contributions of each of the articles, and presents the limitations of this thesis and some opportunities for future research.
2 Methodology

This research applied a multi-methodological approach to produce articles enclosed in this thesis. Each article presents its own methodology. However, in this section we present the research approach as an aggregate. The underlying principle in this research was to follow an iterative approach of submitting to relevant publication outlets including academic conferences, doctoral colloquia, and journals.

In recent years, it has become increasingly common to adopt a multi-methodological approach that integrates both qualitative and quantitative research in a single study (Bryman, 2006). The multi-methodological approach is defined as a procedure of collecting, analyzing, and “mixing” or integrating both quantitative and qualitative data at some stage of the research process within a study, for the purpose of gaining a better understanding of the research problem (Creswell, Plano-Clark, & Clark, 2007; Creswell, 2009; Tashakkori & Teddlie, 1998).

As mentioned previously in section 1.2 the aim of this research is to propose and apply ABM to analyze the dynamics of technology introduction and technology adoption using network economic theory in the telecommunication domain. Specifically this involves applying a mixed methods approach to analysis of two cases: 1) consumer and MSP decision making MSM and 2) FTTH service deployments.

2.1 Multi-methodological Approach

For this study we apply the multi-methodological approach for information systems research (ISR) depicted in Figure 8 adapted from Nunamaker Jr, Chen, & Purdin (1990). It will be adapted to create and validate various artifacts. This multi-methodological approach is a practical way of designing and implementing a system (in our case computational ABMs). It consists of four research strategies/phases - observation, theory building, systems development and experimentation. The phases are not in any particular order but they are all mutually connected to support creation and validation of a system with multiple iterations. Nunamaker Jr et al. (1990) believe that having an integrated approach will enable ISR to keep pace with technological advancements and organization acceptance. Below is a summary of four research phases from Nunamaker Jr et al. (1990).
1) **Theory Building** - development of new ideas and concepts, creation of conceptual frameworks, processes, or models. Theories are generally addressing a generic system of behavior and are subjected to rigorous analysis. The theoretical artifacts can be used to suggest research hypotheses, design of experiments, and conduct of observations.

![Multi-methodological approach to IS Research](image)

Figure 8: Multi-methodological approach to IS Research, adapted from Nunamaker Jr, Chen, & Purdin (1990)

2) **Experimentation** – focuses on conducting laboratory or field experiments, computer simulations, surveys or interviews. The design of experiment is influenced by theories and facilitated by systems development. This phase allows the researcher to validate or refine the theories and enhance the system.

3) **Observation** – includes research methodologies such as case studies, field studies, and sample surveys. The observations will help bring clarity to the research domain – to know what is currently taking place. The outcomes may assist in formulating specific hypotheses to be tested through experiments.
4) **System Development** – involves five stages: concept design, constructing the system architecture, prototype, product development, and technology transfer. Concept design is incorporation of technological and theoretical concepts into potential practical applications. Development of prototype (proof-of-concept) is used to demonstrate feasibility of the system. If feasibility tests are passed, the fully functional system can be developed. A successful outcome of theories, concepts and systems will result in transfer of technology (system) to an organization or community. System Development is the core of design science research and interacts with other research phases.

### 2.2 Mixed Methods Structure

According to J Creswell & Plano-Clark (Creswell et al., 2007): Mixed methods studies may involve collecting and analyzing qualitative and quantitative data within a single study or within multiple studies in a program of inquiry. When multiple studies are involved each project is reported separately as a distinct study, but, overall, the program of inquiry can be called mixed methods research. We adapt this approach to structuring the multi-study mixed methods research conducted for this thesis as shown in Figure 9. This structure is synchronized with the conceptual framework of this research as presented in section 1.2.

![Figure 9: Multiple studies conducted for this research using mixed methods approach](image)

Each study involves multiple research phases that include activities of theory building, experimentation, systems development, and observation as described in section 2.1. The following sections present the adapted multi-methodological approach for each of the studies conducted for this research.
2.3 Study 1: Context – Technology Standardization and Competition

This study involved establishing the context of the research area. The research questions are presented in section 1.3. The multi-methodological Research Phases (RPs) conducted for this study are shown in Figure 10. The RP numbers are used in the following text to link with the RP numbers shown in Figure 10 and Table 1. The outputs of this study include Articles I and II.

RP1 involved conducting a literature review on technological standard competitions (see section 3.2). This activity involved conducting an initial review of historical technological standard battles. Case studies included - keyboard layout, digital wireless communications, mobile operating systems, 4G wireless standard. These cases provide a background to network economic theory. The common aspects of technical standard competitions and the
common stakeholder groups within each case helped (RP2) postulate the AFTS as shown in Figure 15 and presented in Section 3.2. AFTS provides a consistent method for this research to contenders in a competition, measuring the strengths and weaknesses of each side, enabling them to pinpoint economic factors that reflect tactics employed. In RP3, the ABM literature was reviewed, see section 3.3. ABM’s usefulness for predicting outcomes of the 4G technical battles is explored.

Table 1: Research phases of Study 1, and references to related content in thesis

<table>
<thead>
<tr>
<th>RP</th>
<th>Type of RP</th>
<th>Description</th>
<th>Thesis section</th>
<th>RP in Article</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Observation</td>
<td>Literature review on technological standard competitions</td>
<td>3.2</td>
<td>I</td>
</tr>
<tr>
<td>2</td>
<td>Theory Building</td>
<td>AFTS Framework</td>
<td>3.2</td>
<td>I</td>
</tr>
<tr>
<td>3</td>
<td>Observation</td>
<td>Initial literature review on ABM</td>
<td>3.3</td>
<td>I</td>
</tr>
<tr>
<td>4</td>
<td>Experimentation</td>
<td>Trial ABM simulation software packages</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>Systems Development</td>
<td>Proof of concept simulation model of keyboard layout battle</td>
<td>4.4.1</td>
<td>II</td>
</tr>
<tr>
<td>6</td>
<td>Experimentation</td>
<td>Simulation results for keyboard layout battle</td>
<td>4.1.1</td>
<td>II</td>
</tr>
<tr>
<td>7</td>
<td>Observation</td>
<td>Literature review on WiMAX and LTE</td>
<td>3.2.2 and Appendix C</td>
<td>I and II</td>
</tr>
<tr>
<td>8</td>
<td>Theory Building</td>
<td>Initial specification of Battle of 4G</td>
<td>3.4</td>
<td>I</td>
</tr>
<tr>
<td>9</td>
<td>Theory Building</td>
<td>Article I</td>
<td>3</td>
<td>I</td>
</tr>
<tr>
<td>10</td>
<td>Observation</td>
<td>Feedback from Article I</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>Observation</td>
<td>Literature review on analytical methods for standardization battles</td>
<td>4.3</td>
<td>II</td>
</tr>
<tr>
<td>12</td>
<td>Observation</td>
<td>Literature review on network economics in relation to 4G MSM.</td>
<td>4.4.2</td>
<td>II</td>
</tr>
<tr>
<td>13</td>
<td>Systems Development</td>
<td>Computational model for 4G, POC</td>
<td>4.4.2</td>
<td>II</td>
</tr>
<tr>
<td>14</td>
<td>Experimentation</td>
<td>Compile results for the computational model in #12</td>
<td>4.4.2</td>
<td>II</td>
</tr>
<tr>
<td>15</td>
<td>Observation</td>
<td>Document results and scenarios</td>
<td>4.4.2</td>
<td>II</td>
</tr>
<tr>
<td>16</td>
<td>Theory Building</td>
<td>Article II</td>
<td>4</td>
<td>II</td>
</tr>
</tbody>
</table>

RP4 involved evaluating simulation software packages. Repast provided benefits of a popular programming language Java, and useful system libraries. We preferred Netlogo as it offers a simple native logo programming language, and a superior graphical user interface (GUI). The
GUI allowed easier experimentation and observation capabilities. Overall we felt Netlogo was able to fulfill research requirements. We benefited from its online documentation, models library\textsuperscript{17}, and support forum\textsuperscript{18} that was useful in seeking help for challenging programming tasks.

In RP5, the model of the keyboard layout battle was setup as a POC ABM. The ABM consisted of keyboard adopters and manufacturers’ agents, see section 4.4.1. The model was based on known events and assumptions: introduction of the QWERTY standard in the year 1870 and the DSK standard in 1960. Results were collected in RP6 to portray a similar outcome to the literature. This activity allowed us to familiarize ourselves with the computational side of Netlogo and ABM.

As previously stated the 4G wireless access can be provided by LTE and WiMAX. RP7 involved reviewing prominent features of LTE and WiMAX, further the AFTS model is used to portray the similarities and differences between the two standards, see section 3.2.2 and 4.2.2. This literature review also produced a poster that was presented at the University of Auckland Business School Conference, see Appendix C. Based on this review RP8 produced an initial specification for simulating the battle of 4G.

The notion of simulating the battle of 4G was presented at the PhD ISOM departmental proposal defense in 2010. A proposal was submitted to the ISOM department competition to achieve a sole nomination for submitting in ICIS 2010 conference. Although the paper became the sole nomination from UoA, the ICIS reviewers in its highly competitive doctoral consortium did not accept it. The abstract titled “The Battle for the Supremacy of Wireless Broadband Access (4G)” was presented at 2010 NZISDC conference held in Massey University, Auckland campus. The revised article was accepted in 2011 PACIS (RP9).

RP10 involved reflecting on feedback received from the above conferences, which was certainly to pursue development of a simulation model. At this stage of research there were two elements missing from a literature point of view, firstly analyzing how other standard competitions were analyzed by other researchers (RP11), secondly enriching the concepts of

\textsuperscript{17} Available online and inside of the software: http://ccl.northwestern.edu/netlogo/models/index.cgi

\textsuperscript{18} Netlogo users can browse archives of discussions or ask questions to the Netlogo community. Netlogo Yahoo group – https://groups.yahoo.com/neo/groups/netlogo-users/info
network economics in order to integrate into the simulation model (RP12). RP11 and RP12 involved achieving these shortcomings, see section 4.3 and 4.4.2.

RP13 involved initial POC system development for the battle of a 4G-simulation model. The objective of this simulation model was to demonstrate effects of network economic factors. Consumers would prefer a mobile service offering based on its features, cheaper costs, network effects and path dependence, see section 4.4.2. The results were compiled in RP14 and 15.

Article II was produced to compete in a UoABS competition (RP16), to be nominated for attendance at a prestigious U21 conference in 2012 held at UConn in Hartford USA. The panel of business school and academics at U21 provided valuable feedback – which helped the work conducted in following studies.

Figure 11: Adapted multi-methodological approach displaying research phases for study 2
2.4 Study 2: Focus Area – Dynamics of technology introduction and adoption in networked markets

This study involved establishing focus of the research area. The research questions are presented in section 1.4. The multi-methodological RPs conducted for this study are shown in Figure 11. The RP numbers are used in the following text to link with the RP numbers shown in Figure 11 and Table 2. The research of this study produced Article III.

<table>
<thead>
<tr>
<th>RP</th>
<th>Type of RP</th>
<th>Description</th>
<th>Thesis section</th>
<th>RP in Article</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Observation</td>
<td>Feedback and reflection from study 1</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Observation</td>
<td>Literature review on consumer decision making and network formation theory</td>
<td>5.2</td>
<td>III</td>
</tr>
<tr>
<td>3</td>
<td>Theory Building</td>
<td>FCC algorithm</td>
<td>5.3.2</td>
<td>III</td>
</tr>
<tr>
<td>4</td>
<td>Systems Development</td>
<td>Standalone FCC module ABM</td>
<td>5.3</td>
<td>III</td>
</tr>
<tr>
<td>5</td>
<td>Experimentation</td>
<td>Simulation results and testing FCC module</td>
<td>5.3</td>
<td>III</td>
</tr>
<tr>
<td>6</td>
<td>Observation</td>
<td>Review FCC results and evaluate embedding FCC into the MSM model</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>Theory Building</td>
<td>MSM consumer decision making process leveraging FCC</td>
<td>5.4</td>
<td>III</td>
</tr>
<tr>
<td>8</td>
<td>Systems Development</td>
<td>FCC module integrated into MSM ABM</td>
<td>5.4</td>
<td>III</td>
</tr>
<tr>
<td>9</td>
<td>Experimentation</td>
<td>Generate simulation results for MSM-ABM</td>
<td>5.4.2</td>
<td>III</td>
</tr>
<tr>
<td>10</td>
<td>Observation</td>
<td>Summarize and group results into scenarios</td>
<td>5.4.2</td>
<td>III</td>
</tr>
<tr>
<td>11</td>
<td>Theory Building</td>
<td>Article III</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

RP1 involved reflecting on feedback received from earlier research outputs. The main realization was the need to change the orientation of research objectives to focus on market-level factors instead of claiming to simulate a standard battle, see 1.4. We extended our literature (RP2) to look at consumer decision-making processes and network formation.
theory. This led to developing a standalone FCC model\(^\text{19}\) (RP3, RP4 and RP5) that would consist of evolving friend circles, these friend circles would exhibit the network effects required in a market for consumer decision-making based on friend influence, see 5.3 and Appendix E. In RP7 the FCC module was integrated into MSM, and results were produced (RP9 and RP10) and the study produced Article III (RP11).

### 2.5 Study 3: Case Study 1 - Consumer choice & MSP competition in a MSM

![Figure 12: Adapted multi-methodological approach displaying research phases for Study 3](image)

This study was conducted in parallel to Study 4. This study involved specifically dealing with the MSM-ABM. The study aimed to simulate independent decisions of consumers and MSPs in a MSM where MSPs revise their offerings to compete in the market and consumers

\(^{19}\) Netlogo file is available in the CD attached to the thesis.
subscribe based on their preferences including influence of friends. The research questions are presented in Section 1.5.1. The multi-methodological RPs conducted for this study are shown in Figure 12. The RP numbers are used in the following text to link with the RP numbers shown in Figure 12 and Table 3. The research in this study produced Article III.

As mentioned earlier in section 1.5.1 (page 12), Study 2 lacked the dynamics of MSPs making decisions and competing in the MSM by altering their plans. Article VII is developed as a journal article, and it doesn’t use any secondary or empirical data, therefore it strengthened the justification on usage of ABM in this context (RP2), see 9.2. The logical decision-making processes of MSPs and Consumers are conceptualized (RP3); these processes support the requirements of competition and consumption in a MSM that is being simulated.

The decision-making processes were implemented into an ABM in RP4. Thereafter sets of scenarios were set up (RP5) in order to vary the conditions of each run and identify the dynamics present in the simulation. This followed an iterative activity (RP6, RP7 and RP4) of system development, experimentation, and observation to arrive at Article VII.

Table 3: Research phases of Study 3, and references to related content in thesis

<table>
<thead>
<tr>
<th>RP</th>
<th>Type of RP</th>
<th>Description</th>
<th>Thesis section</th>
<th>RP in Article</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Observation</td>
<td>Feedback and reflection from Study 2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Theory Building</td>
<td>Justify ABM as a suitable methodology for analysis of telecommunication markets</td>
<td>9.2</td>
<td>VII</td>
</tr>
<tr>
<td>3</td>
<td>Theory Building</td>
<td>Specify MSP and consumer agents and their tactical behavior</td>
<td>9.3</td>
<td>VII</td>
</tr>
<tr>
<td>4</td>
<td>Systems Development</td>
<td>Enhanced MSM-ABM with FCC integrated and includes MSP competition tactics</td>
<td>9.3</td>
<td>VII</td>
</tr>
<tr>
<td>5</td>
<td>Theory Building</td>
<td>Define simulation scenarios</td>
<td>9.4</td>
<td>VII</td>
</tr>
<tr>
<td>6</td>
<td>Experimentation</td>
<td>Generate simulation results</td>
<td>9.4</td>
<td>VII</td>
</tr>
<tr>
<td>7</td>
<td>Observation</td>
<td>Summarize results and highlight findings</td>
<td>9.4</td>
<td>VII</td>
</tr>
<tr>
<td>8</td>
<td>Theory Building</td>
<td>Article VII</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
2.6 Study 4: Case Study 2 - Access uptake of high-speed fiber based broadband

This study was conducted in parallel to Study 3. This study involved specifically dealing with the issues related to implementation of FTTH broadband network. The core of this study aimed to analyze consumer access uptake. The research questions are presented in section 1.5.2. The multi-methodological RPs conducted for this study are shown in Figure 13. The RP numbers are used in the following text to link with the RP numbers shown in Figure 13 and Table 4. The research of this study produced Article IV, V, and VI.

Table 4: Research phases of Study 4, and references to related content in thesis
<table>
<thead>
<tr>
<th>RP</th>
<th>Type of RP</th>
<th>Description</th>
<th>Thesis section</th>
<th>RP in Article</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Observation</td>
<td>Inspiration from Beltrán (2012) article</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Observation</td>
<td>Literature review of FTTH cases, NZ broadband market structure specifically dealing with UFB project, and two-sided platform economics</td>
<td>6.1, 7.2 and 7.3</td>
<td>IV and V</td>
</tr>
<tr>
<td>3</td>
<td>Theory Building</td>
<td>UFB market structure and access uptake model</td>
<td>7.4</td>
<td>V</td>
</tr>
<tr>
<td>4</td>
<td>Systems Development</td>
<td>UFB access uptake computational model</td>
<td>7.5</td>
<td>V</td>
</tr>
<tr>
<td>5</td>
<td>Experimentation</td>
<td>Generate simulation results</td>
<td>7.6</td>
<td>V</td>
</tr>
<tr>
<td>6</td>
<td>Observation</td>
<td>Summarize results and highlight findings</td>
<td>7.6 and 7.7</td>
<td>V</td>
</tr>
<tr>
<td>7</td>
<td>Theory Building</td>
<td>Article V</td>
<td>7</td>
<td>V</td>
</tr>
<tr>
<td>8</td>
<td>Observation</td>
<td>Analyze secondary data from Industry</td>
<td>6.2 and 6.3</td>
<td>IV</td>
</tr>
<tr>
<td>9</td>
<td>Observation</td>
<td>Interview potential UFB consumers</td>
<td>6.2 and 6.3</td>
<td>IV</td>
</tr>
<tr>
<td>10</td>
<td>Theory Building</td>
<td>CAUA and CAUC frameworks</td>
<td>6.3.2 and 6.3.3</td>
<td>IV</td>
</tr>
<tr>
<td>11</td>
<td>Theory Building</td>
<td>Article IV</td>
<td>6</td>
<td>IV</td>
</tr>
<tr>
<td>12</td>
<td>Observation</td>
<td>Feedback from academics and industry for Article IV and VI</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13</td>
<td>Theory Building</td>
<td>FTTH market structure and FTTH as a two sided platform</td>
<td>8.2</td>
<td>VI</td>
</tr>
<tr>
<td>14</td>
<td>Theory Building</td>
<td>Access market model for FTTH platform</td>
<td>8.3</td>
<td>VI</td>
</tr>
<tr>
<td>15</td>
<td>Theory Building</td>
<td>ABM justification from a telecommunication perspective</td>
<td>8.2.2 and 9.2</td>
<td>VI &amp; VII</td>
</tr>
<tr>
<td>16</td>
<td>Theory Building</td>
<td>Integrate consumer decision making processes into ABM</td>
<td>8.3.3</td>
<td>VI</td>
</tr>
<tr>
<td>17</td>
<td>Systems Development</td>
<td>FTTH High speed broadband ABM</td>
<td>8.3.4</td>
<td>VI</td>
</tr>
<tr>
<td>18</td>
<td>Experimentation</td>
<td>Generate simulation results</td>
<td>8.4</td>
<td>VI</td>
</tr>
<tr>
<td>19</td>
<td>Observation</td>
<td>Summarize results and highlight findings</td>
<td>8.4</td>
<td>VI</td>
</tr>
<tr>
<td>20</td>
<td>Theory Building</td>
<td>Article VI</td>
<td>8</td>
<td>VI</td>
</tr>
</tbody>
</table>

This study was inspired by Beltrán’s (2012) paper (RP1), which uses economics of platforms for understanding the broadband-based market formation in NZ’s UFB network. In Study 3 we strived to arrive at an abstract contribution to show dynamics of MSM competition and
consumption. The UFB project was a perfect opportunity to apply the ABM to a specific real case in order to analyze how the fiber optic standard and its market develop. Therefore a literature review was conducted (RP2) to learn from current FTTH implementation cases, specifically dealing with the UFB project. The notion of two-sided platforms was part of Beltrán’s (2012) paper; this study uses this as a theoretical leverage. The literature review (RP3) helped specify unique aspects of UFB market structure, and an access uptake model.

One topical issue was related to the UFB uptake in and government subsidization for household connection costs, the ABM developed (RP4, RP5 and RP6) showed the effects of subsidization on the UFB access uptake. The experimentation produced Article V (RP7).

2.6.1 Empirical work

In this study we conducted empirical work (RP8 – RP11), which in itself used a multi-methodological approach. The empirical work led to producing Article IV (RP11). This work was granted an Ethics approval by University of Auckland Human Participants Ethics Committee (UAHPEC), see 0. The empirical research design uses a dominant (imperialist) multi-methodological design – one method or methodology as the main approach with contribution(s) from other(s) (Mingers, 2001), presented in section 6.2. In our case the dominant method is qualitative data from 15 consumer interviews (RP9). The contributions include (1) research data from Chorus\(^2\); (2) randomly selected data of 100 customers from Snap\(^21\)’s Customer Relationship Management (CRM) system (RP8).

The following text describes the methodological process for the empirical component of this study, which includes secondary data (section 2.6.1.1) and consumer interview analysis (section 2.6.1.2).

2.6.1.1 Contacting the industry and analyzing secondary data

This involved sending out letters, in-person meetings, and posting on social media, up to eight companies were contacted. Two companies: Chorus and Snap, offered their help by providing access to their data. Other companies showed interest but eventually stopped communicating. The nature of data provided by Snap and Chorus is documented in section

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\(^2\) Chorus is the largest LFC in the UFB project.

\(^21\) Snap is a small sized RSP – provides ADSL and Fiber broadband packages.
6.2. The data from the industry provided knowledge that explains the UFB consumer’s profile and opportunities for UFB in the content market.

2.6.1.2 Consumer interviews

The interviews we conducted diverged from industry data, because we asked the consumer how they intend to participate in the UFB market. Additionally we explored what factors would sway the consumer’s preferences towards or away from the UFB market. This activity was conducted as a team and involved three main steps, shown in Figure 14. A company called Academic Consulting based in Auckland conducted the phone interviews. Fernando Beltran was able to engage Academic Consulting as he achieved FDRF funding for this research. Farhaan Mirza specified the research design, coding framework, and theory building, with consultation and advice from Fernando Beltrán.

![Figure 14: Main steps conducted for UFB project related consumer interviews](image)

The first step involved identifying 15 potential participants via a range of methods. Notices advertising the research were displayed in public places (e.g. library notice-boards), and messages were posted on social media and other websites. Information about the study was also distributed via the research team’s personal networks. Individuals interested in taking part were required to contact a member of the research team, who ascertained their eligibility for the study via a short questionnaire. Farhaan Mirza provided the short questionnaire (Appendix H) and the recruitment criteria (Appendix G) to Academic consulting. All those eligible were provided with participant information (0) as per the UAHPEC protocols and invited to take part in a 30-40 minute long semi-structured telephone interview.

The second step involved conducting the telephone interview. Brief objectives and an agenda for the interview are described in section 6.2. The specific interview outline that was provided to Academic Consulting is in Appendix J.

Finally we applied grounded theory to deal with the qualitative data because it allows emergence of original and rich findings that are firmly grounded in the empirical data.
(Urquhart, Lehmann, & Myers, 2010). After transcribing the data we conducted open coding, developing a preliminary set of codes. Eventually we performed selective coding as analysis became more certain. Interview transcripts were coded into a framework developed by Farhaan Mirza, see Appendix K. Coding was undertaken with the assistance of NVivo (a qualitative data analysis software package). The final coding framework including parent and child nodes is in Appendix K.

An outcome of this was formulating a theory of consumer participation in UFB access and content markets using theoretical coding. As we documented the theoretical findings, we validated and enhanced the claims by using Chorus’s research outputs and Snap’s customer data. This resulted in postulating CAUA and CAUC frameworks presented in section 6.3.2 and 6.3.3 (RP10) and publishing Article V (RP11).

*The CD attached to the thesis includes raw interview transcripts, audio files for two interviews, coded interview data organized into nodes, and the NVivo project file.*

### 2.6.2 FTTH Access Uptake Model

The FTTH access uptake model involved leveraging the work conducted from RP1-RP11 to produce an abstract ABM to portray broadband access uptake on a high-speed platform with consumer agents participating in the market.

The theoretical activities included developing the market structure of the FTTH platform (RP13) and relating it to the theory of two-sided platforms (RP14, see section 8.2.1), followed by highlighting key features of ABM (RP15, presented in 8.2.2). The key features of ABM and its justification are developed further in Study 3’s RP2, (see section 9.2). This computational model integrated the consumer decision-making process for considering subscribing to a fiber retailer (RP16 see section 8.3.3).

This followed an iterative activity (RP17, RP18 and RP19) of system development, experimentation, and observation to arrive at Article VII.
Article I
3 Article I: Technology Standardization Battles: An Agent Based Analysis

Abstract: A competition between two or more technologies for becoming the dominant technological standard is a regular occurrence and some popular examples include media formats, Internet browsers, operating systems, game consoles etc. This study introduces an AFTS that helps analyze competitors involved in a technical standard competition. This paper presents case studies of technological standardization, which include success of QWERTY keyboard standard, mobile operating systems like iPhone and Android, and the 4G BWA standard. Network economic concepts are useful to explain the market factors and tactics that contenders use to compete. Researchers conducting similar sorts of analysis have also relied on using economic concepts.

The study extends the AFTS to set up ABM simulations in order to mimic market conditions. The main focus of simulation models is on keyboard standard battle (historic) and the 4G BWA competition (unsettled) while employing multi methodological techniques. The ABM is set up to simulate a market with consumers and technology providers. By simulating several scenarios we can learn and explain what constitutes key drivers for these competitions. The ability to simulate an unsettled competition will be of value to the stakeholders involved.

Keywords: 4G, Agent Based Modeling, BWA, LTE, Simulation and WiMAX

3.1 Introduction

Competitions for technical standards may have multiple potential outcomes. Lessons can be learnt from historical technological standardization cases such as Video Cassette Recorder (VCR), keyboard layout, operating systems, Internet browsers, video game consoles etc. When technologies compete, the outcomes can be unpredictable, the superior or the cheapest technology may well have a reasonable chance to become the most popular or dominant but history shows that sometimes inferior technologies can bypass the superior. This is due to factors mentioned in network economics literature such as path dependence, network effects; lock ins’, first mover advantages and bandwagon effects.
The macro objective of this research is to develop an agent based simulation model of technologies competing to become an industry standard. The simulation results will assist us in understanding the dynamics of technological competitions in past or occurring at present. While the aim is to contribute a generic model or approach for simulating any given technological competition, the focus is set on the battle of 4G BWA standard as our core case study, which I refer to as “Battle of 4G”.

The first part of the study conducts a brief review of historical technological battles to appreciate network economic factors involved in competitions. Additionally to understand the theoretical foundations used by researchers for explaining the effects and consequences of competitions. The second part of the study involves applying concepts ABM to extend our pre-simulation analysis in order to create a simulation model that provides us with abilities to mimic conditions of a given competition. The simulation model’s purpose is to assist explaining the factors that led to a given outcome, for example a technologies victory over the other. Additionally the simulation model provides with the ability to change historical events, introduce future events, or configure changing variables to see how the outcomes differ. I wish to extend the usage of this simulation model to analyze technological battles that are occurring in real-time that haven’t yet reached an outcome. The simulation would allow for running multiple scenarios in order to report the outcomes of competitions based on the presence or absence of applied network economic effects. This may provide a useful insight for stakeholders involved in that competition.

Our main focus is to investigate the battle of 4G for providing BWA. The two main contenders that provide 4G BWA are WiMAX and LTE. WiMAX has the capacity to deliver high-speed Internet connectivity on wide areas such as campuses, last mile coverage, and cities. LTE is the next leap from third generation (3G) networks, offering high-speed Internet and cellular connectivity. For this case study I outlay the technical aspects and prominent features of these competing technologies (WiMAX and LTE) and contrast their areas of competition, and, finally suggest and attempt to develop an ABM simulation of competition between WiMAX and LTE contending for achieving technical standard supremacy of 4G. The relevancy of this research lies on its timeliness, the involved technologies, and the complexity of the competitive landscape. Thus the research outcomes have the potential to provide market watchers with valuable information about the evolution of 4G-based wireless communications markets.
3.2 Technical Standardization

Usually a competition transpires when multiple technologies provide the same features and the outcomes of it can lead to one of three scenarios: Firstly *winner takes it all*; this is when a single dominating technology is able to eliminate competitors from the market. Secondly technologies can *co-exist*, when there is a vast market, or the market may be too diverse for a single option and technologies could be providing differentiation to cater for the variance in needs. Thirdly *convergence* can occur when collaboration occurs for mutual benefit or public demand. Our analysis is selective of competitions that involve some level of technical standardization.

A. Technology Sponsors or Owners can be the initiators, founders, or developers of the technical standard.

B. Technology Distributors or Sellers are entities that sell the standard and create services or products based on the standard. These entities are responsible for creating choices in the market, for the technology adopters.

C. Technology Enhancers are 3rd party developers building plugins, accessories, or extensions to the standard that enhances its ability to become more attractive.

D. Choices in the Market are the options available in the market that technology adopters can subscribe to, purchase or use.

E. Technology Adopters are the end users of the standard.

Figure 15: Analytical Framework for Technological Standardization (AFTS)

Several cases of technical standard competitions occurred in the past, examples of which are the VCR standard, keyboard layout, game consoles etc. Researchers that analyze case studies of technological competitions have often relied on network economic theory and more specifically the branch of *Industrial Organization*. I came up with the AFTS, in Figure 15, which is a result of reviewing several competing technologies case studies (see also section 1.3 for more information). AFTS provides a consistent method to compare one competition from the other, measure strengths and weaknesses of contenders, and to be able to pinpoint economic factors that reflect tactics employed by contenders.
The following text summarizes case studies of technological competitions while highlighting the related economic concepts that aid in explaining the factors involved.

3.2.1 Case Studies – Competing for Technological Standards

In 1870s the QWERTY keyboard design was architected mainly to slow down typists, so that the hammers on the typewriter wouldn’t jam frequently. DSK, which is superior keyboard arrangement according to some researchers, introduced in the 1930s when the tangling of typing arms was no longer an issue. DSK didn’t excel because QWERTY was well established as the standard, with all the advantages of network externalities (Choi, 2008). Network externalities are the effects on a user of a product or service of others using the same or compatible products or services. A U.S. Navy study showed the efficiency gain from switching to DSK was such that the cost of retraining typists could be recovered within 10 days; also, Apple Computer claimed that DSK could increase typing speed by 20–40% (David, 1985). The world is now stuck with QWERTY layout due to path dependence and first mover advantages. Path dependence is the set of decisions one faces for any given circumstance is limited by the decisions one has made in the past. AFTS model can help us understand the important factors involved in this competition, see Figure 16.

For the video recording standard competition between Sony’s Betamax and JVC’s VHS, Sony’s first mover role and strategic initiatives did not result in a sustainable advantage, which led Sony and its partners to cease producing Beta models. The reasons that made VHS successful included better features, JVC’s collaboration with companies, better market exploitation in Japan and USA by utilizing Matsushita’s huge engineering and manufacturing resources to offer a variety of products with more combinations, features and prices, i.e. pricing of products. The opposite of QWERTY occurred in the case of video recording, Betamax was superior and a first mover, but didn’t manage to gain dominance over VHS. The VHS success factor was the bandwagon effect at level B in AFTS. Cusumano, Mylonadis, & Rosenbloom (1992) explain the bandwagon effect referring to situations where early sales or licensing of a particular product lead (either accidentally or deliberately) to rising interest in that product. Bandwagon effects create a momentum that encourages other potential licensees, distributors, and customers to support the product that seems most likely to become the industry standard, regardless of whether it is technically superior, cheaper, or "better" in other ways than alternatives.
Digital wireless communications provide a more recent example of competing standards. Due to the barriers in analogue mobile services, a low cost digital technology Global System for Mobile Communications (GSM) was introduced, which became a fast growing technology. The battle between GSM and Code Division Multiple Access (CDMA) started when CDMA offered a competing standard to GSM, but gained little traction outside USA due to intellectual property ownership issues with Qualcomm and other firms (Snyder, 2010). Here CDMA failed to experience bandwagon effects or a positive network externality at level B in AFTS. This battle was more complex than keyboard or video standards one of reasons is because the technology sponsors (Level A) in AFTS were not a small group or single companies but rather consortia of many members.

In mobile operating systems Apple iPhone OS gained bandwagon popularity via platforms like Appstore that catered iPhone developers to sell iPhone applications. The application downloads reached 10 billion app sales by January 2011. Apple introduced iAd Network creating rivalry with AdMob, iBooks creating rivalry with Amazon’s kindle. Apple managed to create success for itself due to the following key reasons; firstly the iPhone was a very appealing device, as it was unique, extremely usable and eliminated the need for having keypad, or stylus (West & Mace, 2010). Secondly Apple enjoyed bandwagon effects (at

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22 iAd is a platform for developers to advertise inside iPhone apps. Developers can make money by embedding the iAds into their apps when publishing free or low cost versions of their applications.
23 AdMob an advertising platform in exclusive to iPhone existed prior to Apple’s iAd.
24 A platform to sell books to read on Apple mobile devices including iPhone, iPad, and Apple desktop and laptops.
25 Amazon Kindle is a portable e-book reader, developed by Amazon.com, a device can be bought to download eBooks alternatively Kindle software can be installed to read books on personal mobile devices and or Windows based computers or Macintosh computers.
level C of AFTS) as book publishers, advertisers, and software developers opted to use these frameworks. Thirdly Apple enjoyed positive network externalities from their phone buyers.

Same reasons apply for Google’s open source mobile operating system called ‘Android’. However Android exceeded past Apple mainly because multiple hardware manufacturers such as HTC, Motorola, and Samsung etc. are developing android phones. Google achieved a bandwagon effect by device manufacturers (at level B of AFTS) and enjoys being most popular mobile OS.

Apple being a solo entity in level A and B of AFTS, we can assume that the Apple will enjoy high profits and increasing returns, as it has ultimate control on hardware and software of the iOS platform.

The success of Google and Apple has endangered legacy mobile operating systems like Symbian, and pose a steep challenge for newer entrants like Windows mobile.

![Figure 17: Drivers of competition between Google Android and Apple iOS platforms portrayed on the AFTS](image)

### 3.2.2 Battle of 4G

WiMAX and LTE are 4G technologies that will provide fast BWA for lesser prices and operators are busy extending their 4G coverage or preparing to offer 4G in the near future. I am planning to simulate this occurrence by running several scenarios to explain what constitutes key drivers for this competition. The ability to simulate a competition that is
unsettled will be of value to the stakeholders involved. Let us look at the prominent features of both contenders.

WiMAX Forum\textsuperscript{26} maintains WiMAX standard and 3GPP\textsuperscript{27} maintains LTE standard. WiMAX forum and 3GPP are consortia that are industry-led consisting each of 500+ members working towards specifications, development, meeting customer and government requirements. This ensures production of robust standards. WiMAX is an emerging BWA technology that is already in market providing transmission of data using a variety of transmission modes, from point-to-multipoint links to portable and fully mobile Internet access. WiMAX has the capability to create Metropolitan Area Network (MAN) or provide last mile broadband, as each WiMAX tower can cover up to a 50km radius. WiMAX deployments currently exceed 582 deployments in 150 countries\textsuperscript{28}. WiMAX 2, to be released in 2011 is posed to add new capabilities while maintaining backward compatibility, delivering peak rates of 300 megabits per second (Mbps), lower latency and increased VoIP capacity.

LTE is designed to increase the capacity and speed of mobile telephone networks significantly. LTE will provide peak data rates exceeding 300Mbit/s in download and more than 75 Mbit/s in upload (Mogensen et al., 2009). When a LTE mobile subscriber leaves a LTE environment, they can still be connected to the network, because LTE supports handover and roaming to existing mobile networks and today most areas are covered by 2G or 3G networks. This is a significant advantage of LTE over the first mover WiMAX. LTE is a step behind in market deployments worldwide compared to WiMAX. Many operators are trailing and testing LTE. Recently Verizon launched LTE, reaching major US cities (Verizon, 2010). Clearwire and Sprint who deployed WiMAX in 2009 for major US cities already met this milestone.

Technically WiMAX & LTE both offer fast connection speeds wirelessly, they are both easy to deploy, both use the OFDM\textsuperscript{29} technology, and both are based on the Internet Protocol (IP) architecture. At present LTE is superior in terms of speed around 100+Mbps (WiMAX is 70Mbps). WiMAX on the other hand has the first mover advantage. Both technologies are

\textsuperscript{26} WiMAX Forum formed in June 2001 to promote conformity and interoperability of the WiMAX standard.
\textsuperscript{27} The 3rd Generation Partnership Project (3GPP), formed in 1998 maintains the LTE standard.
\textsuperscript{28} Stats obtained from WiMAX Forum, see \url{http://www.wimaxforum.org}
\textsuperscript{29} Orthogonal frequency-division multiplexing (OFDM) is a modulation technique for digital communication.
being enhanced into: LTE Advanced and WiMAX 2. The following text hypothesizes and discusses the possible outcomes:

Let us first analyze the advantages WiMAX has over LTE. Foremost advantage of WiMAX is its early start; a technology that by chance gains an early lead in adoption may eventually corner the market (Arthur, 1989). We know from the QWERTY case how first mover advantage can help, in case of WiMAX it doesn’t compare to the inefficiencies QWERTY had, in fact WiMAX and LTE are very well engineered and standardized by hundreds of stakeholders in the wireless industry. WiMAX does suffer a speed deficiency; however the development of 802.16m (a more advanced version) already begun and this standard is targeted to deliver similar speeds as LTE. Intel is heavily promoting WiMAX and being a dominant player that makes processors for mobile devices including both Windows and Mac platforms, and many new notebooks already ship inbuilt WiMAX.

Now to the benefits of LTE, primary strength of LTE is the backing of the GSM vendors and many carriers who plan to upgrade to LTE, this makes existing mobile subscribers an easy target market. LTE is backward compatible with 3G and 2G technologies, which makes it easy for carriers to introduce the service, they can upgrade eventually. LTE has the opportunity to benefit from existing customer base, as the mobile phone customers naturally remain with their service provider. If the business model set by the carriers is competitive with WiMAX and the deployment occurs relatively quickly, there could be good news for LTE.

Regulators or governmental preference toward either technology influences the success or failure in a particular region. In many countries (or remote areas) the government (or mayor or regulator or planners) may prefer one of the technologies. This will lock in the consumers of the region into a single choice. For example in a small town, the mayor decides to deploy a single choice of technology and this choice will may limit the competing technologies entry into that market altogether.

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30 Lock in makes a customer dependent on a specific vendor for products and services, unable to use another vendor.
The way technology was pushed to the market in past is quite different to today, now we have consortiums, collaborations and technology ecosystems. There isn’t a single innovator like QWERTY or DSK. The standards are now usually developed by a large number of members; as a result the standard has much more credibility and acceptance. This is illustrative in AFTS level A in Figure 18. Thus co-existing is likely to happen, as regulators or governmental preference could vary region to region. Secondly mobile customers are usually a significant portion of the population of the region (millions of people per country), so there is no reason why there could be two types of technologies offered. Today CDMA and GSM providers co-exist; WiMAX and LTE could coexist in similar fashion. Technically WiMAX & LTE both use the OFDM technology, and both are based on the IP architecture. The consortia may think about convergence or improve interoperability among the two technologies. Or alternatively the technologies could evolve to a single standard in 5th Generation.

In summary we can expect that one of the three scenarios to occur. Firstly winner takes it all: like VHS or QWERTY, either LTE or WiMAX could create a lock in, this is possible if the planners choose one network over the other then the consumers end up using that network. Secondly co-existence: there may be a market for both technologies to co-exist and it may be easy for manufacturers to cater for both and given the demand in the market. Thirdly convergence: After all both are IP technologies with very similar architecture, the consortia may think about convergence or improve interoperability between the two technologies. Or alternatively evolve to a single standard in 5th Generation. Besen and Farrell (1994) identify these tactics for inter technology competitions: building an early lead, attract
suppliers, pre-announcing the product offerings and disclosing attractive price commitments. LTE and WiMAX can benefit from these tactics.

3.3 Research Approach

This study employs a multi methodological approach using qualitative, quantitative and ABM methods. ABMs are compatible with quantitative and qualitative research methods and provide a new way of doing science that has developed form the concepts and techniques of complexity theory (Achorn, 2004). The qualitative side will deal mainly with content analysis. The 4G technologies are rapidly being developed and deployed around the world. This information needs to be captured into our analysis. The information updates are studied as they become available via telecommunication news outlets; this informs the simulation model about maturity and superiority of each contender. The quantitative component informs the ABM regarding preferences of consumers via surveys and statistical data analysis. For example Horrigan (2009) survey shows statistics such as, 19% of adults access the Internet on the typical day with a cell or smartphone and 31% of laptop users access the Internet wirelessly at least once a day. This can be used as an assumption for the consumer agent preferences.

ABMs are especially used to study complex systems – systems that use simple micro-level rules that generate macro level phenomenon. ABMs consist of purposeful agents who interact in space and time whose micro level interactions create emergent patterns (Page, 2006). Examples of possible agents include individuals (e.g., consumers, workers), social groupings (e.g., families, firms, government agencies), institutions (e.g., markets, regulatory systems), biological entities (e.g., crops, livestock, forests), and physical entities (e.g., infrastructure, weather, and geographical regions) (Tesfatsion, 2006). For the purpose of competing standards an agent could be a technology adopter, distributer, seller etc. For example in the case of modeling the 4G BWA competition an agent could be an individual consumer planning to use the network or it could be a service provider planning to deploy services. A consumer generally is known to gather data about the network, select their preferred network, use the network, influence other people about their choice and change the network provider. These are some of the decisions a customer can execute, mostly because of their previous knowledge or current learning. On the other hand an agent could be a service provider who can choose to deploy certain network-based services, compete with other networks, maintain
users etc. These interactions happen and from these interactions a macro level outcome is generated.

ABM is a method for studying systems that are composed of interacting agents and emergent properties (Axelrod & Tesfatsion, 2006). Emergent properties are an aggregate of the properties of interacting agents. For example in our case a system could be a deployed network service with many users. These users could be joining the service, leaving the service, using the service or influencing others to use the service. ABM is well suited for this objective as it is a method for studying systems exhibiting the following two properties (Flake, 1999): 1. The system is composed of interacting agents and, 2. The system exhibits emergent properties, that is, properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents. The battle of 4G simulation meets these criteria as it involves interacting agents, and the simulation would help aggregate properties about our agents. Additionally this study is aimed at predicting outcomes of the 4G technical standard battles. Wolfers and Zitzewitz (2004) explain that a prediction market concerns a particular future event whose outcome is currently unknown, for example: which team will win a particular sport event or an election. Conitzer (2010), who touches on many areas where ABM is useful includes prediction markets. Conitzer (2010) explains that the agents trading in the prediction market generally cannot (significantly) influence the outcome of the event; the goal of the market is merely to predict the outcome of the event, based on the collective information and reasoning of the participating agents.

3.4 Simulation Model

This study already managed to test the simulation model which is an extension of AFTS for QWERTY keyboard standard, and results show as it occurred that users become more and acquainted with QWERTY basing their future decisions on choices made in the past, thus majority of the keyboard user agents pick QWERTY as their choice of keyboard. The remembering choices from the past to create choices of the future is one form of endogenous behavior, and endogeneity is a ubiquitous feature of the reality of social interactions (Vriend, 2006), which can be implemented using ABMs. The QWERTY simulation catered for technology adopter agents to remember up to five previous choices of keyboards, when DSK was introduced into the market, even though it was assumed to have richer features, the QWERTY familiarity made it a more favorite choice to pick for consumer agents. The
manufacturers agents gave up on introducing DSK keyboards which would attract lesser returns in comparison to QWERTY. This may not be an interesting result, because the outcome is already known. Below is how the battle for 4G simulation is being designed.

<table>
<thead>
<tr>
<th>Technology Distributors</th>
<th>Private Data:</th>
<th>Private Methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level B in AFTS</td>
<td>Network types</td>
<td>Introduce new networks</td>
</tr>
<tr>
<td>Agent: Wireless Service Provider</td>
<td>BWA features</td>
<td>Retire old networks</td>
</tr>
<tr>
<td></td>
<td>Plans in market</td>
<td>Review market position</td>
</tr>
<tr>
<td></td>
<td>Hardware requirements</td>
<td>Create new plans</td>
</tr>
<tr>
<td></td>
<td>Geographical regions</td>
<td>Change existing plans</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Choices in the Market</th>
<th>Public Data:</th>
<th>Public Methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level D in AFTS</td>
<td>Plan information</td>
<td>Increase population</td>
</tr>
<tr>
<td>Environment</td>
<td>Coverage information</td>
<td>Keep count of network users</td>
</tr>
<tr>
<td></td>
<td>Network information</td>
<td>Remove obsolete technology</td>
</tr>
<tr>
<td></td>
<td>Service provider information</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology Adopters</th>
<th>Private Data:</th>
<th>Private Methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level E in AFTS</td>
<td>Call consumption</td>
<td>Subscribe to plan</td>
</tr>
<tr>
<td>Agent: Consumer</td>
<td>Data consumption</td>
<td>Change plan</td>
</tr>
<tr>
<td></td>
<td>Plan status</td>
<td>Buy HW devices</td>
</tr>
<tr>
<td></td>
<td>Hardware ownership</td>
<td>Use network</td>
</tr>
</tbody>
</table>

Figure 19: Partial ABM simulation model specification for the battle of 4G.

For the Battle of 4G, we can create agents as shown in Figure 19. The agents will be initialized with some assumptions to support the simulation scenarios that observe market changes based on a range of economic factors that have presented in this paper. The quantitative data and qualitative content analysis will assist in defining the preferences and processes of how agent behaves. Agents will perform micro tasks to create emergent patterns. In the ABM I aim to maintain a high level of endogenity and cater for agents to apply learnt behavior based on past experiences.

### 3.5 Conclusion

Competitions between technologies for standardization are a regular occurrence, this study aims to develop methods that will aid the analysis of such cases using ABM and computing power. It’s noteworthy that competitions are becoming more complex by time, the amount of stakeholders, the complexity of technology, the market size making it difficult to set assumptions and develop scenarios. Network economic concepts from industrial organization are used explain the dynamics of competitions. Qualitative content analysis and quantitative surveys inform the ABM simulations. The study is widening up the use of multiple
methodological techniques, including ABM, and economic theory. The ability to simulate competitions that are unsettled will be of value to the stakeholders involved and provide opportunity for interesting insights. At present a work in progress paper has been started to report the comparative analysis for the variety of competitions. The simulation model has been implemented for QWERTY, and a partial simulation model exists for battle of 4G. I am trying to continually enhance the simulation models through surveys and content analysis, and develop a variety of scenarios to report on. Additional goal of the study is to create an abstract simulation model that can be used as a template or starting point for analyzing and simulating a given competition.

3.6 References


Article II
4 Article II - Using Agent Based Analysis for Technological Standardization

Abstract: A competition between technologies for becoming the dominant technological standard is a regular occurrence and some examples include media formats, Internet browsers, operating systems, game consoles etc. This paper introduces an AFTS that helps analyze competitors involved in a standard competition. A review of case studies in this paper includes iPhone and Android, and the 4G BWA standard. Network economic concepts are useful to explain the market factors and tactics that contenders use to compete. Researchers conducting similar sorts of analysis have also relied on a variety of methods including economic concepts, ecological models and game theory. The agent based simulation experiments are for the keyboard standard battle (historic) and the 4G BWA competition (unsettled) while employing multi methodological techniques. The ability to simulate an unsettled competition will be of value to the stakeholders involved.

Keywords: 4G, Agent Based Modeling, BWA, LTE, Simulation and WiMAX

4.1 Introduction

Competitions for technical standards may have multiple potential outcomes. Lessons can be learnt from historical technological standardization cases such as VCR, keyboard layout, etc. When technologies compete, the outcomes can be unpredictable, the superior or the cheapest technology may well have a reasonable chance to become the most popular or dominant but history shows that sometimes inferior technologies can bypass the superior. This is often explained by factors mentioned in network economics literature such as path dependence, network effects, lock-ins’, first mover advantages and bandwagon effects. We propose usage of ABM, to enhance the analysis of standardization.

Our main goal of this paper is to demonstrate analytical techniques that can explain how technologies compete to achieve standard supremacy in their domains. Firstly we present an AFTS, which identifies common stakeholders groups that exist across most competitions. We review a variety of standardization cases, using AFTS. Secondly we highlight social ecology and game theory analytical methods. Thirdly the paper presents two ABM simulation experiments for the battle of keyboard layout and presently occurring 4G BWA standard
battle. The paper uses a case-by-case presentation style, to present theory, previous research and practical simulation experiments.

Our analysis deals with cases that belong to technology and network markets. The difference between traditional markets (grain and dairy products) and network markets is explained by Shy (2001). Shy explains that the characteristics that the network markets are complementarity, compatibility, consumption externalities, switching costs, lock-ins’ and significant economies of scale in production. To explain these characteristics, we can use an example of the phone. We buy a compatible phone, one that can connect (complements) to the telephone line in order to make phone calls. Complementarity is when goods must be consumed together, for example a phone without a network is of no use. The phone connections have consumption externalities; increase in phone users increases the overall good for the consumer population. In this market to upgrade or change phone lines, there could be switching costs. An individual might be locked-in to a phone plan, or a geographical region is locked-in to the type of phone infrastructure it has, based on historical choices by regional telecommunication bodies. We refer to these characteristics as network economic factors.

4.1.1 Value of this research area

The analysis and ideas presented in this paper are important firstly because of frequently occurring technological competitions. Multiple technologies are providing multiple options for similar functions, for example many smartphone mobile operating systems now exist including Android, iPhone OS, Symbian, and Windows 7 Mobile. Competitions like these are occurring frequently, each contender trying to achieve a supreme standard in their domain. Secondly we are surrounded by an abundance of standards; whether it is cable ports like (DVI, VGA or 3.5mm headphones) or file types (mp3, zip, or PDF). Each of these standards experienced a unique journey for being established, some of these standards fought hard to achieve supremacy and others just enjoyed first mover advantages. Thirdly because researchers extensively report on outcomes of competitions, the literature if bundled together and analyzed, can provide emergent themes for explaining the process of standardization, several authors contributed to explain theory behind standardization (Besen & Farrell, 1994; Choi, 2008; M L Katz & Shapiro, 1985; Michael L Katz & Shapiro, 1986; Kerin, Varadarajan, & Peterson, 1992; Tassey, 2000).
Fourthly this paper tries to fulfill the demand of the IS discipline. Lyytinen and King (2006) mention in the MIS Quarterly: “Despite the importance of standardization, the IS field has not pursued research on it vigorously. Scholarly discussions are rare, and strong contributions are lacking. Our rough analysis showed in 2002 that roughly 2 percent of published journal papers in the field have dealt with ICT standards during the last decade.” In the 2006 MIS Quarterly issue, there are a total of seven papers that addressed issues of standardization, each paper looking at different aspects of standardization, using a variety of theoretical bases. The theory on economics of standards was the most popular choice used by authors (Chen & Forman, 2006; Weitzel, Beimborn, & Konig, 2006; Zhu, Kraemer, Gurbaxani, & Xu, 2006), actor network theory used by (Hanseth, Jacucci, Grisot, & Aanestad, 2006), Clegg’s circuit of power theory used by (Backhouse, Hsu, & Silva, 2006), collective action theory used by (Markus, Steinfield, Wigand, & Minton, 2006), and social ecology analysis used by (Nickerson & Muehlen, 2006). These papers are only a partial list of many other methodologies that have been applied by researchers to study standardization. Neither it is feasible to review all the approaches nor it is our objective to do so, but in this paper we do present some case studies on the usage of social ecology, game theory, and economics.

Lastly, this paper is proposing the usage of ABM for standardization analysis, especially for battles that are unsettled. We present results for the battle of keyboard layout and present a proof of concept simulation model for the BWA 4G standard. Using simulation models might produce valuable insights for investors and decision makers to evaluate their tactics. This paper doesn’t provide a means to predict what the outcome of a battle is; rather it provides a means to understand what might happen. The strength of the simulations will depend on accuracy of market conditions and assumptions.

4.1.2 Standardization

Standard is a set of specifications adhered to by a producer, either tactically or as a result of a formal agreement (David & Greenstein, 1990). As a result of standardized goods, the manufacturers provide more interchangeability than necessary (Farrell & Saloner, 1985), as a result standardization becomes advantageous. Standardization creates social benefits for the consumers, as the value of a consumer’s good increases when other consumers have goods adhering to the same standard (compatible), this is also known as a positive network effect or externality. A disadvantage though are coordination difficulties (of innovating a new
standard) and being bound to compatibility, this makes the industry extremely reluctant to innovating a new or better standard (Farrell & Saloner, 1985). A typical example of this occurrence is the QWERTY standard for the keyboard layout; we elaborate this in later sections of this paper.

The birth of a standard can potentially be of two types – a revolution or an evolution as explained by Shapiro and Varian (Shapiro & Varian, 1999). One aspect of evolution is when the technology is backward compatible to the former, LTE is a 4G BWA technology and it is backwards compatible with 3G. Revolution is when a brand-new standard is introduced. For example WiMAX is also a 4G BWA technology, without any predecessors. So the 4G battle (LTE versus WiMAX) would be an evolution versus revolution battle. An example of a rival evolution is the Internet browsers, each one (Internet Explorer, Firefox and Chrome) has frequent new version releases, matching rivals features or innovating new capabilities. Besen and Farrell (1994) identify these tactics for inter technology competitions: building an early lead, attract suppliers, pre-announcing the product offerings and disclosing attractive price commitments. The outcomes of battle’s can lead to multiple outcomes such as monopoly, duopoly, truce and fight to death.

4.2 Analytical Framework for Technological Standardization (AFTS)

One common aspect of standard battles is the stakeholder groups. We derived the AFTS (see Figure 15) as a result of reviewing several standardization battles. AFTS provides a consistent method to compare contenders and measure strengths and weaknesses (see also section 1.3 for more information). Additionally pinpoint economic factors that reflect tactics employed by stakeholder groups. Rather than a ground up explanation of how we arrived at AFTS, we use the AFTS, in our presentation of historical standard battles, and that will justify its versatility for aiding cross comparisons of contenders within and across different battles.

4.2.1 Standard battle case studies

In 1870s the QWERTY keyboard design was architected mainly to slow down typists, so that the hammers on the typewriter wouldn’t jam frequently. DSK which is superior keyboard arrangement according to some researchers, introduced in the 1930s when the tangling of typing arms was no longer an issue. DSK didn’t excel because QWERTY was well
established as the standard, with all the advantages of network externalities (Choi, 2008). A U.S. Navy study showed the efficiency gain from switching to DSK was such that the cost of retraining typists could be recovered within 10 days; also, Apple Computer claimed that DSK could increase typing speed by 20–40% (David, 1985). The world is now stuck with QWERTY layout due to path dependence and first mover advantages. Path dependence is the set of decisions one faces for any given circumstance is limited by the decisions one has made in the past. AFTS model can help us understand the important factors involved in this competition, see Figure 16

**Digital wireless communications** provide a more recent example of competing standards. Due to the barriers in analogue mobile services, a low cost digital technology GSM was introduced, which became a fast growing technology. The battle between GSM and CDMA started when CDMA offered a competing standard to GSM, but gained little traction outside USA due to intellectual property ownership issues with Qualcomm and other firms (Snyder, 2010). Here CDMA failed to experience bandwagon effects or a positive network externality at (level B in AFTS). This battle was more complex than keyboard or video standards one of reasons is because the technology sponsors (level A in AFTS) were not a small group or single companies but rather consortia of many members.

**In mobile operating systems** Apple iPhone OS gained bandwagon popularity via platforms like AppStore that catered iPhone developers to sell iPhone applications. The application downloads reached 10 billion app sales by January 2011. Apple introduced iAd Network\(^{31}\) creating rivalry with AdMob\(^{32}\), iBooks\(^{33}\) creating rivalry with Amazon’s kindle. Apple managed to create success due to three key reasons; firstly the iPhone was a very appealing device, as it was unique, extremely usable and eliminated the need for having keypad, or stylus (West & Mace, 2010). Secondly Apple enjoyed bandwagon effects (at level C of AFTS) as book publishers, advertisers, and software developers opted to use their frameworks. Thirdly Apple enjoyed positive network externalities from their phone buyers. Being a solo entity in level A and B of AFTS, we can assume that the Apple will enjoy high profits and increasing returns. Google released a smartphone open source operating system called ‘Android’. Major hardware manufacturers such as HTC, Motorola, and Samsung etc. are developing android phones. Google achieved a bandwagon effect by device

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31 iAd is a platform for developers to advertise inside iPhone apps. Developers can make money by embedding the iAds into their apps when publishing free or low cost versions of their applications.

32 AdMob an advertising platform in exclusive to iPhone existed prior to Apple’s iAd.

33 A platform to sell books to read on Apple mobile devices including iPhone, iPad, and Apple desktop and laptops.
manufacturers (at level B and C of AFTS) and enjoys being second most popular mobile OS after Symbian.

4.2.2 Battle of 4G Broadband Wireless Access

WiMAX and LTE are 4G technologies that will provide fast BWA at cheap rates and presently (2011) operators are busy provisioning 4G coverage in the near future. One of our ABM experiments simulates a portion of this battle. The ability to simulate a competition that is unsettled will be of value to the stakeholders involved. WiMAX forum and 3GPP (LTE developers) are industry-led consortia consisting each of 500+ members working towards standard specifications. WiMAX is an emerging BWA technology that is already in market. WiMAX can create metropolitan area network and provide last mile broadband, as each WiMAX tower can cover up to a 50km radius. LTE will provide peak data rates exceeding 300Mbit/s in download and more than 75 Mbit/s in upload (Mogensen et al., 2009). When a LTE mobile subscriber leaves a LTE environment, they can still be connected to the network, because LTE supports handover and roaming to existing mobile networks and today most areas are covered by 2G or 3G networks. This is a significant advantage of LTE over the first mover WiMAX. LTE is a step behind in market deployments worldwide compared to WiMAX. Many operators are trailing and testing LTE. Recently Verizon launched LTE, reaching major US cities (Verizon Wireless, 2010). Clearwire and Sprint who deployed WiMAX in 2009 for major US cities already met this milestone. See Figure 18, for comparison of LTE and WiMAX.

4.3 Analytical Methods For Standardization Battles

Researchers that analyze case studies of technological competitions have often used theoretical frameworks of Industrial Organization, a branch of economics, examples include (Cusumano et al., 1992; David, 1985; Liebowitz & Margolis, 1990). The economic theoretical base is the most popular. We have also used it in previous section to present historical battle cases. The following text presents two case studies: the development of Internet standards analyzed using a social ecological model and the battle of Digital Versatile Disc (DVD) analyzed using game theory.
4.3.1 Ecological model toward understanding development of Internet standards

The Internet is built upon multiple underlying standards such as TCP/IP, DNS, HTTP and HTML. A single company did not create standards for the Internet; rather it was a collaborative effort by several institutions including Internet Engineering Task Force (IETF), W3C, Object Management Group (OMG), and the Organization for the Advancement of Structured Information Standards (OASIS). In the paper (Nickerson & Muehlen, 2006) the authors examine events between 1993 and 2005 tracing 505 participants engaged in standard-making activities across nine institutions. The participants were the standard designers, level A of AFTS. In their investigation, they use an ecological model. The authors relate the variety of institutions in ecological terms as distinct niches in the overall habitat.

The authors presented at several episodes in the development of Internet standards (referred as Web services choreography). The standards’ development was conducted by formation of new working groups, death of working groups, participant movements, etc. These are found in ecologies too. The most important event occurred in 2001 when an Internet W3C working group proposed changing the licensing terms for the intellectual property created by W3C, and it was greeted by public pressure (level E in AFTS) and criticism. Thus W3C offered their corporate sponsors an economic argument that was the royalty-free processes of the past that allowed companies to profit from applications that run on top of the Internet. This episode indicated the influence of public pressure on the decisions of Internet standards makers. The authors state that the public can mobilize an institution’s own legitimacy against the short-term interests of its members. In ecological terms, a habitat that appeared to be dominated by a population of large corporations proved instead to be dominated by a population of vocal technical standard makers, who control the levers of acceptance.

Nickerson and Muehlen (2006) did a brilliant job of reviewing plethora of documents, meetings and tracing the activities of several work groups over a decade of standard development. The authors relate standard bodies to be an ecological environment, with subtle differences, like an individual (organism in a natural sense) can belong to multiple habitats, which isn’t true for natural ecology. Alcatel Lucent in one of their reports (Kuhn, 2009) refers to standard making bodies as ecosystems. One of the strengths of ecosystems is they have the potential to create new value propositions and business models that cannot be delivered by an individual company. And this was the case with the Internet standards, and continues to be the case for cellular standards, networking, etc.
We can learn from this paper that role of standard makers in specifying standards. However the enforcement of standard depends of distributors’ and adopters. Similar methodology can be of value, if we are dealing with large standard making bodies and data is in public domain.

4.3.2 Game theory applied to the DVD standard

After the VHS, the mainstream video format for movies is the DVD. In 1994 Philips and Sony announced their Multimedia Compact Disc (MMCD) format, an enhancement to the CD-ROM, which could hold 135 minutes of digital video. Other players including Toshiba and Matsushita, JVC, and Time Warner were developing the Super Density (SD) disc. A technical working group consisting of computer experts like Microsoft, Apple, Dell and others voted to boycott both formats and eventually managed to get the two camps agreed on a single converged standards (favorable to Phillips), in an attempt to establish compatibility. This battle was analyzed by Lint and Pennings (2003) using game theory. A framework is presented with four key steps of analysis: 1) identification of key players which involves analysis of their competitive position and market opportunities 2) assessment of the money at stake including average cost of capital and pay offs that represent Net Present Value (NPV) 3) determining optimal strategy this could be cooperating or competing choices, and 4) getting the most out of the game, involves execution of optimal actions, by means of having feedback procedures.

The game was set up and in one of the game scenarios; it was shown that the initial delays in standardization allowed Matsushita to keep earning their massive NPV as the market (level D in AFTS) was using VHS (pro Matsushita) standard. Eventually when the standard (Pro-Phillips) was established, the NPV earned during postponement phase compromised the losses of Matsushita. The paper also generated results combining both games (VCR and DVD), and if both battles combined as a bigger game, then Matsushita made greater profits than Phillips.

In this battle the technology sponsors and distributors (level A and B in AFTS) were companies, not consortia. The enhancers (level C in AFTS) like Microsoft, Dell, Apple and others had an interest in this battle, because they were producers of hardware and content (like software) and relied on compatibility to create a positive network effect. The level B AFTS distributors realized this and for the overall benefit they agreed to converge on the standard. The game by (Lint & Pennings, 2003) was set up largely on the basis of financial
assumptions and the understanding of product standardization process. This would be a good method to use if the financial details are known and if the analysis is to deal with individual product battles between companies rather than large consortia.

4.4 Agent Based Modeling Simulation experiments

We will use the keyboard layout battle and the 4G BWA battle cases as examples to set up ABM simulation experiments. ABMs are compatible with quantitative and qualitative research methods and provide a new way of doing science that has developed form the concepts and techniques of complexity theory (Achorn, 2004). The qualitative side will deal mainly with content analysis. The 4G technologies are rapidly being developed and deployed around the world. The quantitative component informs the ABM regarding preferences of consumers via surveys and statistical data analysis. For example Horrigan (2009) survey shows statistics such as, 19% of adults access the Internet on the typical day with a cell or smartphone and 31% of laptop users access the Internet wirelessly at least once a day. These data can be used as consumer agent preferences.

ABMs are especially used to study complex systems – systems that use simple micro-level rules that generate macro level phenomenon. ABMs consist of purposeful agents who interact in space and time whose micro level interactions create emergent patterns (Page, 2006). For the purpose of competing standards an agent could represent individuals or groups in the AFTS. ABM is a method for studying systems that are composed of interacting agents and emergent properties (Axelrod & Tesfatsion, 2006). Emergent properties are an aggregate of the properties of interacting agents.

4.4.1 Keyboard Layout Battle

The keyboard layout simulation was created using Netlogo, multi-agent modeling environment. In summary this simulation experiment depicts what has occurred in this battle. The objective was to portray the utility of ABM in terms of an analytical tool. The agents in the simulation are: keyboard manufacturers (level B of AFTS) and keyboard adopters (level E of AFTS).

DSK, provided a superior alternative layout to QWERTY (level D in AFTS), however due to existing strong network effects by keyboard manufacturers of keyboards and the users being
path dependent to the QWERTY layout, DSK failed its struggle to replace or co-exist with QWERTY. Additionally it wasn’t possible for keyboard manufacturers in favor of DSK to coordinate decisions all over the world among the developers of the keyboards, as each manufacturer was rationally bounded to their own user base and regions. For example it would have been difficult for Japanese keyboard manufacturers to communicate with the US keyboard manufacturers regarding adhering to a newer standard. In the ABM we situate keyboard manufactures randomly at a distance (in Netlogo space) to each other so that they cannot fully coordinate with each other mimicking the historical coordination issue.

![Keyboard manufactures depicted as green square boxes in the Netlogo space.](image)

**Figure 20: Keyboard manufactures depicted as green square boxes in the Netlogo space.**

The scenario: the manufacturers produce keyboards (limit of 5 keyboard-models at a given time) while the adopters, buy keyboards. This is an approximate configuration, which implies a keyboard accessory company (like Logitech of present day) would maintain 5 keyboard-models in their catalogue.

Every 5 years, the manufacturers review the uptake of their keyboards. They judge the success of uptake based on comparing uptake within their own inventory and with other keyboard manufacturers known to them. This is emphasizing the manufacturer doesn’t have full knowledge about product performance through the Netlogo space.

The concept of finding out information with limited access is known as bounded rationality. According to (H. A. Simon, 1997), bounded rationality is a pair of scissors whose blades are "the structure of task environments and the computational capacities of the actor." So for the keyboard manufacturers they are rationally bounded to a limited environment.
If a keyboard-model’s uptake is poor comparatively then the manufacturer makes it obsolete and introduces new keyboard-models.

On the other hand - the keyboard adopters pick keyboards they wish to use every 5 years, based on their preferences such as: known format, only option with hardware, or superior features.

![Code snippet from the keyboard simulation ABM](image)

**Figure 21:** Code snippet from the keyboard simulation ABM

We specified *known events* (see Figure 21) of introduction of QWERTY in the year 1870 and the introduction of DSK standard in the 1960. We purposefully give DSK the benefit that in year 1960, up to 40% of the manufacturers produces DSK keyboard-models.

The results of the simulation show minimal uptake by technology adopters of DSK, eventually DSK standard becomes obsolete. In the graphs (Figure 22), the red line is of DSK standard and the green line is for QWERTY, the graph shows the number of keyboard-models of a standard is available. A count of keyboards each year is plotted. The line drops every 5 years, because that is when some keyboard-models are made redundant by
manufactures (due to fewer uptakes). The red line spikes up at year 1960, and falls by early 70s, because of not being able to capture market share, and the manufactures stopped developing DSK keyboards.

![Graph](image)

**Figure 22:** Simulation results of keyboard layout battle, X axis represents time and the Y axis represents the count of keyboard choices in the model.

### 4.4.2 4th Generation Standard

Network providers are rolling out LTE and WiMAX networks at present (2011). The experiment below doesn’t represent the *complete battle*. If the entire breadth of this battle, including all stakeholders were to be set up, it would make the model too complex, and the model would have to rely on too many assumptions. So we respectfully acknowledge the need for multi methodological approach to explain the battle in its entirety. The deeper analyzers of this battle can potentially take an ecological approach for studying the technology sponsors (level A in AFTS) WiMAX Forum and 3GPP, learning from (Nickerson & Muehlen, 2006). We can also use game theory for analyzing service providers (level B in AFTS) as shown by (Lint & Pennings, 2003). However this experiment is limited to: 1) *technology adopters*, these are general consumers who actually use 4G services, represented in level E of the AFTS 2) *technology distributors*, these are MSPs, who are responsible for creating choices in the market represented in level B of the AFTS 3) *choices in the market*, these are plans, represented in level D of AFTS. The objective of the experiment is to conduct what-if scenarios, relying on economic factors discussed in the previous sections.

The agents will be initialized with some preferences to support the simulation scenarios that observe market changes based on a range of economic factors. The quantitative data and qualitative content analysis will assist in defining the preferences and processes of how agent behaves. Agents will perform micro tasks to create emergent patterns. The aim of the ABM is to achieve high level of endogenity, i.e. let the agents behave with minimal external input. That is ensuring agents remember choices from the past to create choices of the future, this is
one form of endogenous behavior, and endogeneity is a ubiquitous feature of the reality of
social interactions (Vriend, 2006), which can be implemented using ABMs.

In this experiment the consumers are expected to be joining the service, leaving the service,
using the service or influencing others to use the service. ABM is well suited for this
objective as it is a method for studying systems exhibiting the following two properties
(Flake, 1999): 1. The system is composed of interacting agents and, 2. The system exhibits
emergent properties, that is, properties arising from the interactions of the agents that cannot
be deduced simply by aggregating the properties of the agents. Additionally this approach is
aimed at contributing ideas to predicting outcomes of given scenarios in the 4G technical
standard battle. Wolfers and Zitzewitz (2004) explain that a prediction market concerns a
particular future event whose outcome is currently unknown, for example: which team will
win a particular sport event or an election. Conitzer (2010) mentions many areas where ABM
is useful and this includes prediction markets. Conitzer (2010) explains that the agents
trading in the prediction market generally cannot (significantly) influence the outcome of the
event; the goal of the market is merely to predict the outcome of the event, based on the
collective information and reasoning of the participating agents.

Predictions can depend on the quality of the exogenous inputs and initial assumptions. While
ABM has been found useful for this activity, unsettled standardization simulations can
benefit using a what-if approach. The usage of what-if approach is found in microeconomics
for elasticity and marginal concepts, math programming and decision theory for sensitivity
and parametric analysis, simulation models, and expert systems (Philippakis, 1988a). In order
to be able to evaluate beforehand the impact of a strategic or tactical move, decision makers
need reliable provisional systems, and what-if analysis satisfies this need by enabling users to
simulate and inspect the behavior of a complex system under some given hypothesis, called
scenarios (Golfarelli, Rizzi, & Proli, 2006).

The basic flow of the model starts by two exogenous inputs, firstly the plan configuration.
Several plans can are created into the model’s plan matrix. Secondly consumer Reason for
Change (RFC) is specified. For example 2degrees mobile company conducted a survey on
their website, and found the following factors to be most influential in switching MSPs: call
charges 41.0%, text message charges 33.0%, the dislike of another MSP 9.0%, customer
service 8.0%, using the same network as your friends 6.0%, and handset upgrade offers 4.0%.
Total voters were 2308. This sort of input can be incorporated into the model as RFC.
The consumers using 4G services and changing plans based on RFC preferences. For example a smart phone user might use 10Mb of data and 15Mins of talk time each day. Each consumer agent remembers their usage. If they are on a term plan, the lock-in variable decrements on each run cycle. The usage of each day is based on a normal distribution curve, which has the mean and standard deviation of the region of the consumer. There is also a separate countdown, which decrements to the day when the consumer agent is going to review the plan. These inputs can be changed based on market information known via the qualitative or quantitative studies.

The review process involves shortlisting plans by checking: the network coverage, plan availability, compatibility, switching costs are checked and finally the consumer agent – may or may not decide to switch based on historical familiarity with other plans, and network effects the consumer is bounded to. The market environment contains the following public data: plan information, coverage information, network information, and service provider information. The market contains public methods: increase population, keep count of network users, and remove obsolete technology. The MSPs have the following private data: network types, features, plans in market, hardware requirements, and geographical regions. The private methods of MSPs are: introduce new plans, remove old plans, review market position, advertise, and change existing plans.

The main economic factors that we want to demonstrate part of these results are better features, cheaper costs, network effects and path dependence. The reason for demonstrating these scenarios is because they are the most common. All charts represent time on X axis and consumers on the Y axis. The simulation scenarios presented in this section only contained a single user type that is mobile Internet users, using USB mobile broadband plans.

**Better features scenario (graph 1)** is purposefully simple and obvious. In this scenario we assume that the consumer agents will prefer faster speeds (upload and download) and wider coverage’s. The consumer agents RFC were exogenously\(^34\) forced to select plans giving 50% importance to speed and 50% importance to coverage. Red plans are faster and have better coverage’s. Obviously most of the consumer agents pick Red.

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\(^34\) ABM model is set up with external inputs, in order to create a scenario
Cheaper plans scenario (graph 2) gets slightly complex. In this scenario we assume that the consumer agents will have to choose between cheaper prices less featured plans or give preference to expensive but high spec plans. Several Blue and Red plans are created, we set the Red plans on average are set with approximate speeds of 5Mbps, 90% coverage and $50 cost. The Blue plans are set with average speeds of 1Mbps, 40% coverage, but cost is $30. The consumers RFC was set at 30% on speed, 30% on coverage and 40% on cost, this produced a co-existence scenario.

For cheaper and better plans combined scenario (graph 3) we set up the market which only has Red plans, all the consumer agents are on one of the Red plans (a monopoly situation). Eventually the Blue plans become available to the market, naturally the consumers are divided on which plan to use and a duopoly is created. Lastly a Green plan is introduced which is cheaper. Consumers are attracted to cheaper costs and Green plans become the most popular. The RFC in this scenario was the same as the previous scenarios, but several factors are combined. The consumers give cheaper plan precedence, and then they opt for the best featured plan. This is quiet natural in real life.

Network effect scenario (graph 4) is set up with the same plan configuration, if we change the RFC to 90% network effects and 10% is the cost, we achieve the result shown in graph 4 in Figure 23. What happened is that the consumers are on the Red plans, and because 90% of the consumers are looking at following other consumers, they are content on the Red plan, when the Blue plans are introduced, no agents picks those (doesn’t get shown in graph 4) reason being they are expensive and network effect is very strong on the Red plans. Later Green plans are introduced which are cheaper, so they are able to capture some of the market share from Red and eventually become the dominant plan. Having said that, the practicality of this happening is limited, as the service providers of Blue plans would have reacted to their failure and the service providers of the Red plans would have tried tactics that would prevent Green plans overtaking their consumers by so much.
**Path dependence scenario (graph 5):** From a mobile service point of view, the key reasons for consumers to become dependent on their prior choices or stay locked-in to their current plan could be due to: the consumer being sponsored into a long term contract with high early termination fees. Or it could be due to having ownership of hardware that is incompatible with the alternative plans. We tried several scenarios of superior Blue plans in terms of cost and features, while maintaining high termination fees for Red plans. We found that due to the high switching cost, it cost delays for blue plans to make progress in achieving higher market share.

### 4.4.3 Summary of Results

The 4G battle results demonstrated four main contexts of a market situation which included better features, cheaper costs, network effects and path dependence. The better features and cheaper costs were obvious results, where consumers picked better plans cost wise and feature wise. The network effect simulation showed how a network effect could potentially completely *disable* a MSPs entry into market. It was also interesting to note that despite a strong network effect, it wasn’t unbeatable. Having differentiated plans will attract consumers, and as a niche group of consumers are attracted to the new plan, it might create its own network effect and can pose an immense threat to the initial monopolist. One of the main messages of the path dependence result is to show how switching costs can cause a great delay in consumers leaving a plan. Sometimes these delays will allow losing MSPs to rectify their pricing and adjust their features, in order to preserve their market share. Just because a plan is superior in features and price, it won’t immediately become successful. First mover advantages, network effects can create significant delays.

This is one of the reasons behind constant toggling of pricing and features by the MSPs. If they fell asleep, the competitors will affect their position in the market. Simulation tools can provide a means to experiment introducing different configurations of plans to learn about possible outcomes and better realizations of markets. As a result come up with smarter tactics to compete.

The experiments described above are not meant to be ready solutions for next times use. The experiment’s purpose was only to highlight how AFTS can be used to make sense of the battle, and then single out the portion and stakeholders that can be simulated in order to create what-if analysis for presently occurring battles. To do this effectively will require
support of other methods, surveys, data, content etc. Using the power of ABM, we can combine many aspects of competition, which would be hard to achieve using single mathematical formula. Also using the power of agents, multiple social groups within a type of agent can be created, e.g. for the battle of 4G, we could have groups of agents, like business users or home users.

4.5 Conclusion

Competitions between technologies for standardization are a regular occurrence. It’s noteworthy that competitions are becoming more complex by time, the amount of stakeholders, and the complexity of technology, the market size making it difficult to set assumptions and develop scenarios. This paper demonstrated several methods including ABM that will aid the analysis of standard battles. Economic concepts from industrial organization are used explain the dynamics of competitions. In this paper we switch case-by-case presenting aspects of standardization and battles. We present the AFTS, which serves as a good topology to describe competitors and its drivers, in a consistent way. ABMs can add value for the analysis of standardization battles, especially when a complex system exists. Qualitative content analysis and quantitative surveys can inform the ABM simulations. This approach is widening up the use of multiple methodological techniques, including ABM, and economic theory.

Further work can be conducted to review standardization articles with a variety of methodological approaches and construct a full comparison of methods including strengths and limitation analysis. Secondly apply the ABM to real market contexts, with actual qualitative and quantitative data.

Every standards battle is unique. The ability to simulate competitions that are unsettled will be of value to the stakeholders involved and provide opportunity for interesting insights.

4.6 References


Article III
5 Article III - Using an Agent-Based Friend Circle Creator Model to Analyze Drivers of Consumer Choice: Network Effects Vs. Value Proposition

Abstract: Network industry products and services rely on designing competitive business models including aspects of consumers influencing other consumers. Consumer decision-making is a complex process involving rich attributes that include value consideration and network effects. Using compatible products within an organization or home, or between friends results in greater utility and satisfaction, emphasizing the consumer decisions are not just based on value but also on what their peers recommend and use. This paper presents a generic FCC ABM, which leverages network formation theory to create and evolve friend circles within the consumer agent population. These friend circles can be used to simulate consumer decision-making scenarios for cases consisting network externalities. We apply the FCC model to a mobile phone plan case study. The results of this case study demonstrate how the presence of network effects is able to retain a large population of consumers in an inefficient deal. FCC can be used as a module to complement larger ABMs to enhance analysis in studying drivers of consumer decision-making.

Keywords: Network effects, consumer decision making, network industries

5.1 Introduction

Network industries contain economic drivers that are absent in other industries. In network industries utility of a product or service has an effect on its overall network (Shy, 2001); this effect is known as network externality or network effect. A typical example of network industry is the telephone – the utility of our telephone increases when all our friends have a phone also, as it enables us to call one another. The information communication technology services include mobile services, Internet access, smart-phones, tablets, and computers etc. The Internet and other mechanisms increase consumer awareness by allowing users to find, compare and identify the features and prices of their choices. Therefore these new technologies not only rely on their value proposition to succeed but also rely on establishing networked platforms to grow their consumer base.
An example of this is Nokia Corporation. Before the release of iPhone in 2007, Nokia like other phone manufacturers focused on innovative features, pricing, and distribution etc. A consumer who owned a Nokia phone would achieve little compatibility advantage whether or not his friend circle has a Nokia device, as the standard communication protocols were based on voice calls and text messages. On the other hand iPhone and Android phones introduced platforms such as the Apple App Store and Google Play, making these smartphones a networked industry product. An operating system used by Nokia called Symbian had numerous applications, which were downloadable through decentralized independent websites. However, the early entrant Nokia was unable to create a network effect comparable to Android and iOS. Presently Nokia partners with Microsoft and leverages from the Windows phone application community.

This paper presents the FCC model, which can potentially enhance consumer decision-making analysis for network industry products and services. The paper also presents an example of a FCC model integrated into a mobile service market.

5.2 Consumer decision making

Consumers are often faced with a large number of options, due to new technologies and competitive pressures (Bettman et al., 1991); which renders the consumer decision-making task complicated. Marketing scientists have contributed a vast literature to this area. A well recognized model of consumer purchase decision-making presented by Engel, Blackwell, and Miniard (1993) divides the consumer purchase decision process into five stages: 1) problem recognition, 2) information search, 3) alternative evaluation, 4) purchase decision, and 5) post-purchase behavior. A range of factors including long term memory, rationality, evaluations, personal characteristics, social context, cost/benefit factors, contingencies, advertising and word of mouth contribute to the decision to consume a product or service. The decision-making process includes elements of intelligence, control and rationality (Kahneman, 2011).

An aspect that is important in consumer decision-making is *motivation*; this is of particular interest to this paper. The idea that social factors guide individual decision-making was a cornerstone of early social influence research (Asch, 1951). Motivation of friends, family and
co-workers is an attribute that is very important to models that depict consumer decision-making in network industries. Kahneman (2011) presents two types of thinking: system one and system two. System one thinking leads to an individual’s response that is quick and automatic but lacking control; an example could be driving on an empty road. In the case of selecting a mobile phone plan, a system one response is when an individual remains with his existing mobile carrier, or blindly follow his friends recommendation, or if he is a traveler - visiting the first physical retail store in the airport mall. On the other hand system two allocates attention and produces much more rational outputs; an example could be filling out a tax form. FCC supports models with consumer decisions are rational system two behaviors. However within an ABM – there can be many decisions that are system one oriented – in which agents make decisions without extensive rational considerations. In summary FCC will allow creating friend circles, having this embedding in an ABM, agents will be able to make decisions based on considerations of value and network effect of their friend circle.

To create friend circles in ABMs an option is to use a geographical boundary of an agent situated in the ABM space (known as world). So the nearest individuals to an agent are assumed friends of that agent. This approach was used by Zhang and Zhang (2007). A purchase decision ABM was created in which the network of friends or influence was based on geographical radius of the agent. A generic decoy effect was implemented with three elements: price, quality, and motivation. The price and quality aspects were dealt with using a decoy effect and the motivation (network effect) was based on the radius of the agent.

The FCC differentiates from Zhang and Zhang’s (2007) approach in three aspects. Firstly FCC establishes actual friend links (a feature in Netlogo Modeling software) regardless of geographical location of agents in the ABM based on specified configuration. Secondly FCC appreciates evolution of friends, i.e. friend links changing over time. Lastly FCC is able to grow agent population while the model is running – and deal with establishing friend links for newly introduced agents in the model. The following section presents how the FCC model can be configured to create agent-based friend circles.

5.3 Friend circle creator model

Network formation theory can be used to create networks and partition them as required in order to achieve a representation of friend circles (Jackson, 2005; Newman, 2010). Networks formation in the most simplistic form can be seen as connecting points using lines to form a
network. The points are referred to as vertices or nodes. The lines are referred as the edges, which can be either directed or undirected. In a consumer friend circle network the nodes are the consumer agents and the edges are undirected friendship links. Degree is a simple and useful measure of a network. The degree of a node in a network is the number of edges that node has. In a network of friendships between individuals, the degree of an individual is the number of friends. A technique known as graph partitioning is used to split the entire network into separate groups.

5.3.1 Configuration

The aim of the FCC model is to provide a foundation for creating friend circles. The user interface of the FCC model is shown in Figure 24. The FCC model on its own doesn’t solve any complex system problem; rather the FCC model can be adapted in other models that require it. Therefore one of the design goals of the FCC is its configurability. The following text presents the configuration of FCC; the variables are shown inside the brackets.

![Figure 24: User interface of the FCC Model.](image)

The configuration is divided into three parts; see Figure 24. All values in the configuration of FCC can be adjusted in according to the context it is being applied.
The first part of the configuration defines consumer population (initial-consumer-population) and growth of consumers per year (population-growth-percent). Population growth is a useful driver in network market models. For example service or product availability extends into new areas, increasing the number of applicable users — therefore having population growth functionality is useful to manage such scenarios.

Secondly friend circle sizes are calculated from the values specified for average size of friend circle (size-of-friend-circle) and its standard deviation (size-of-friend-circle-sd). The size of a friend circle for any node is modeled as a probability distribution (size-fc-distribution-type). The average value, standard deviation and distribution choices will allow creating a variety of friend circles as per the requirement. The rationale for providing a friend circle size configuration is based its usefulness for appreciating diversity in types of friend circles. For example an online social network of an individual can comprise hundreds of friend links on the other hand the number would reduce based on segmentation of family, school, or office friends.

Finally consumer preferences in FCC allow for specifying how often a consumer’s friend circle will change, and how much it will evolve. For instance — neighbors and family change every few years, whereas office or school or social friends would change more frequently. The variables review-friend-circle and its standard deviation allow for creating a range of review cycles. The ratio specified for maintaining old friends (p-maintain-old-friends) determines how many friend links change per review cycle.

### 5.3.2 FCC Model Flow

A single friend circle needs to be represented as an individual group of nodes with links amongst them. Additionally, links will exist amongst friend circles also, as an individual may belong to more than one friend circle. The overall FCC algorithm is shown in Figure 25. The setup button creates the population of consumers as per the configuration. Then consumers are grouped into X number of friend circles. X is derived from FCC configuration. The sizes of each friend circle may vary depending on the distribution and standard deviation. It is possible to create equal sized friend circles if the standard deviation is set to zero.
The FCC model runs periodic checks. Each tick in FCC is a day. Every 90 days the FCC checks if there are any consumers that are not part of a friend circle. A consumer may end up having zero friends. This may happen due to newly introduced consumer agents in the model because of population growth. Alternatively it might be due to agents who have completely severed their friend links.

Every year (365 days) the model manages the population of consumer agents by creating new consumers as required. Lastly, every consumer agent reviews its own friend circle – this is to imitate the natural cycle of friendship evolution, which involves making new friends and sometimes losing contact with people. The frequency of periodic checks can be altered easily by changing the values as required. The algorithm above repeats itself indefinitely until required.

As the FCC algorithm iterates multiple times and consumers change their friend circles the model develops a small-world setting. The small-world effect was first studied in the context of friendship networks and is becoming more popular in other network contexts. The claim is that a person can get to anyone else in the network via a small sequence of six steps. This is referred to as “six degrees of separation”. Small-world effect is often observed in situations
such as spread of gossip and how machines are connected over the Internet. A popular small world problem was experimented with in the USA, by (Milgram, 1967) and (Travers & Milgram, 1969). The small world that emerges in FCC and the degree of separation is dependent on the input parameters.

5.4 FCC model in a mobile service market

The MSM model involves a market of wireless plans with wireless consumers. In this model, the consumers are expected to make rational decisions in a wireless market. The consumer agent’s behaviors include joining, using, leaving mobile services, additionally influencing others to use the service. ABM is well suited for this objective as it is a method for studying systems exhibiting the following two properties (Flake, 1999): 1) The system is composed of interacting agents and, 2) The system exhibits emergent properties, that is, properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents. Additionally, this approach is aimed at contributing ideas to predicting outcomes of given scenarios. Conitzer (2010) explains that the agents trading in the prediction market generally cannot significantly influence the outcome of the event; the goal of the market is merely to predict the outcome of the event, based on the collective information and reasoning of the participating agents.

Predictions can depend on the quality of the exogenous inputs and initial assumptions. While ABM has been found useful for this activity, unsettled market simulations can benefit from using a what-if approach. The what-if approach is found in microeconomics for elasticity and marginal concepts, math programming and decision theory for sensitivity and parametric analysis, simulation models and expert systems (Philippakis, 1988b). In order to be able to evaluate the impact of a strategic or tactical move, decision makers need reliable provisional systems, and what-if analysis satisfies this need by enabling users to simulate and inspect the behavior of a complex system under some given hypothesis, called scenarios (Golfarelli et al., 2006).

5.4.1 Mobile Services Market Model Flow

The basic flow of the model starts with two types of exogenous inputs. Firstly, the plan configuration contains information about the wireless plan and its features. Several plans are integrated into the model’s plan matrix. Secondly, consumer RFC is specified. Consumers
will change mobile services based on multiple factors including costs, included calls, texts, mobile data, customer service, and reputation of the MSP. This kind of input can be incorporated into the model as RFC. However to illustrate the use of FCC for this paper we are simply testing value proposition versus network effects.

For the MSM model the consumers will use wireless services and change plans based on RFC preferences. This leads to two main consumer behaviors: use services and review services. The usage is recorded on a day-by-day basis. For example a smart phone user might use 10Mb of data and 15Mins of talk time each day. The consumer agent remembers their usage. If they are on a term plan, the lock-in variable decrements on each run cycle. The usage of each day is based on a probability distribution. There is a separate countdown, which decrements to the day when the consumer agent is going to review the plan. These inputs can be derived from market information or complementary research results. The main parts of review process are shown in Figure 26, which is similar to the purchase decision-making model presented by Engel, Blackwell, and Miniard (1993), (see section 5.2). The
review process involves estimation analysis, information search, checking alternatives, decision-making and then keeping track of usage information that contributes to future intelligence and rationality.

The review process starts with estimation analysis, which involves calculating the usage and estimating the future usage. In this MSM model the future usage is regarded more than the present usage, as consumers often buy more than they need, and also the usage of technology is increasing as the way we communicate is more often over the Internet and mobile devices.

The RFC process is the most important element for the consumer agent because the agent will adjust its preference toward their network of friends or value proposition. Based on these preferences mobile plans will be shortlisted, after which a single plan is picked and revived. A new review schedule is set, and the review process ends.

5.4.2 Results

The main economic factors that we want to demonstrate are value proposition versus network effects. The network or friend circles are created using the FCC model described previously. All the following scenarios deal with two mobile plans: Plan 1 (solid line) is cheaper and plan 2 (dotted line) is expensive. The features (which can include call time or included data) in each of the plans are kept constant except for price – which may be high or low. From an RFC perspective, we vary value proposition and network effects using the what-if approach to create respective scenarios.

In the first scenario both plans are available in the market at the start of the simulation. RFC for consumer agents is purely based on value, i.e. 100% based on value and 0% based on network effects. Scenario 1 in Table 5 shows plan 1 becoming the popular choice in the market.

For the second, third and fourth scenario the expensive plan is available in the market at the start of simulation. The cheaper plan is introduced after a delay.

The second scenario RFC for consumer agents is based on 75% value and 25% network effects. The cheaper plan eventually manages to overtake the expensive plan. As it overtakes, the network effects work for its advantage, and a significant lead is achieved. In the third scenario RFC for consumer agents is based on 50% value and 50% network effects. The cheaper plan does not manage to overtake the expensive plan. In the fourth scenario, the RFC
is based on 25% value and 75% network effect, which results in a very low market position for the cheaper plan. A short screen recorded video* shows the model running.

<table>
<thead>
<tr>
<th>Table 5: MSM Model Plots - Value versus Network Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1, RFC based on 100% Value.</td>
</tr>
<tr>
<td>Scenario 3, RFC is based on 50% value and 50% network effect.</td>
</tr>
</tbody>
</table>

Solid line: cheaper plan and dotted line: expensive plan

5.5 Summary

In this paper we presented the FCC Model and applied it to a MSM case study. FCC adds value to network formation models, because it is adaptable, modular, and configurable. FCC creates fixed or varying size networks that evolve over time. In the MSM Model we were able to apply FCC and demonstrate network effects can retain a large population of users even within an inefficient deal. First mover advantages and network effects can create significant delays for a new competing business model against established products and services.

This paper demonstrated an approach using ABM that will complement the analysis of competing products and services in network industries. The ability to simulate such unsettled

* http://screencast.com/t/qwmZ84eO
markets will be of value to the stakeholders involved by providing interesting insights on pertaining drivers within network markets.

5.6 References

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Article IV
6 Article IV - Drivers and Barriers to the Uptake of a FTTH Ultra-Fast Broadband in New Zealand

Abstract: NZ is currently implementing a high-speed FTTH broadband project known as the UFB initiative. In this article we explore drivers and barriers of consumer adoption of UFB. We use a mixed methods approach for conducting empirical research, which includes interviewing broadband consumers, and analyzing secondary research insights from industry. Using grounded theory we postulate research frameworks for CAUA, and CAUC to portray pertinent consumer drivers, barriers, and deciding factors for the UFB initiative. We find that consumer awareness and pricing are main factors that need to be addressed for a successful UFB rollout. This case study presents us with a timely unique opportunity to analyze the issues involved as the market evolves and stabilizes. This research has the advantage of gathering consumer resistance insights from an early phase of technological introduction.

Keywords: Ultra Fast Broadband Initiative, UFB, fiber-optic implementation, FTTH, consumer broadband adoption.

6.1 Introduction

Broadband technologies enhance the consumption of rich multimedia content and allow development of enterprise level integrated business applications over the Internet. The consumers are now using the Internet in numerous ways that include running online business functions, buying and selling, gaming, learning, and for entertainment. Such requirements demand faster and robust broadband connections. NZ ranks 44th in the world in terms of average measured connection speed (Akamai Technologies Inc, 2012). The report states NZ has 3.9 Mbps average speed, and only 2.3% of the population is able to achieve speeds over 10 Mbps. At present household consumers in NZ access the Internet mostly via ADSL services. Download speeds range between 2Mbps to 15Mbps and the data allowance is between 20-500 Gigabytes (GBs). Features and pricing vary based on broadband packages and geo-location of the consumer.

To improve the broadband network in NZ, the government established Crown Fibre Holdings Limited (CFH) - an agency to manage the NZ Government’s $1.2 billion investment in UFB infrastructure. CFH and private LFCs are jointly implementing a nation-wide fiber-optics
network, a project known as the UFB initiative, expected to cover 75% of households by 2019 (CFH, 2010). CFH has established allocated regions of NZ that are eligible for fiber connections. CFH has agreements with four LFCs who will implement the fiber infrastructure; the geographic region for each LFC’s scope is defined\(^{35}\) (CFH, 2013). The UFB initiative involves connecting each household with a fiber-optic connection that will be able to deliver a stable connection with impressive speeds of 100 Mbps downlink and 50 Mbps uplink. This is sufficient speed to facilitate rich application requirements of health, gaming, entertainment and cloud computing.

New opportunities are expected to open up because the UFB network by regulation forbids LFCs from directly providing retail services. Consumers will need to purchase fiber-based broadband services from RSPs. The UFB initiative embodies two market components - an access market and a content market. The access market involves consumers achieving fiber connectivity from their LFC; while the content market involves subscription or purchase of connectivity of actual retail products such as phone line, broadband, IPTV, etc.

The consumer can have one of four statuses with regard to UFB service: (1) not being eligible (never fiber), (2) being eligible but without fiber (no fiber yet), (3) getting fiber connectivity at the curb (passing fiber), and (4) purchasing services (with fiber). If a consumer lives in an allocated UFB zone, they will be approached by their allocated LFC informing them regarding cabling work closer to the date their street is due for fiber cabling. When the consumer’s street has fiber connectivity – the consumer (with passing fiber) can purchase fiber services from RSPs. This process will require installing a fiber connection from curb to door, which is currently free of cost due to the government subsidy till 2015 (Adams, 2012). Without subsidy the installation can vary per household and can cost up to NZ$500. The UFB initiative is expected to end by 2019, which means many residents might need to pay for obtaining curb to home fiber access during the 2016 and 2019 term.

After obtaining UFB access the consumer will need to buy products from RSPs to take advantage of their fiber line. The products can include home phone, broadband, on demand video subscriptions, and IPTV. However the product range in the UFB content market is expected to grow and diversify after the UFB access market is established.

\(^{35}\) Chorus will implement 69.4% of the UFB followed by Enable Services 15.3%, Waikato Networks 13.7%, and Northpower 1.6%. 
Related literature to the UFB initiative is actively available through whitepapers and reports published by CFH, LFCs, and RSPs. Academic publications related to this area are as follows. Milner (2009) provides an overview of NZ telecommunication landscape, including mentioning the UFB project to be conducted by CFH. Given (2010) discusses industry structures, regulation, and public investment in Australia’s National Broadband Network and the public-private partnership in NZ’s UFB. MacMahon & Milner (2013) provide a review on usage of UFB to enhance the outcomes for business, education and healthcare, including an update of the UFB implementation nationwide. Articles especially co-authored by Howell critiques the productivity gains by fiber initiatives in comparison to their substantial investments; these articles also question and discuss the efficiency of public-private partnerships and regulations (Howell & Grimes, 2010; Howell, 2012; Sadowski & Howell, 2012). Beltrán (2012) applies economics of platforms to present theory on UFB market formation. Mirza & Beltrán (2014) use a computational ABM to show UFB platform access dynamics. In (Beltrán & Mirza, 2014) the ABM was further enhanced by appreciating empirical findings of this paper.

This paper focuses on the consumer segment as the returns for the investment in the UFB initiative can only be recovered when consumers actively acquire fiber connectivity and eventually purchase fiber-based broadband products. Our research serves the following objectives: (1) to empirically explore the drivers and barriers to consumer adoption of UFB, and, based on the findings (2) to formulate propositions and postulate research frameworks portraying pertinent consumer drivers, barriers and deciding factors involved in the UFB initiative.

The paper unfolds as follows: section 6.2 outlines the empirical research methodology; section 6.3 presents the findings of the research that led to postulating research frameworks including CAUA and CAUC; and section 6.4 provides the overall conclusion.

### 6.2 Methodology

The empirical research design uses a *dominant (imperialist)* multi-methodological design – one method or methodology as the main approach with contribution(s) from other(s) (Mingers, 2001). In our case the dominant method is qualitative data from 15 consumer interviews. The contributions include (1) research study data from Chorus; (2) randomly selected data of 100 customers from Snap’s CRM system. The Chorus study was a sequential
mixed methods study involving 132 qualitative interviews followed by an online quantitative survey that totaled 1009 respondents. The Chorus study’s fieldwork was completed in October 2012. The study involved a rich analysis of three main aspects: firstly understanding how consumers use broadband, secondly understanding the potential use for fiber and finally consumer segmentation in relation to broadband use. The Chorus research outputs include a wealth of knowledge that explains UFB consumer’s profile and explores the opportunities for UFB in the content market. The interviews we conducted differentiated from Chorus’s agenda by actually teasing the consumer with propositions, offers and costs in order to develop an understanding of how the consumer plans to participate and what factors will swing the consumer’s preferences towards or away from the UFB market. Snap provided us with quantitative data of 100 customers from their CRM – which included information such as the type of broadband product consumers are using, costs, location, and why the consumer decided to use Snap.

The qualitative interview is a dominant instrument of this research because the topic is very new and academic research covering this subject is limited. We designed the interview with industry consultation, in order to make it serve our research objectives effectively. Additionally open-ended interactions with the consumers would lead to gathering rich insights. The contributions from Chorus and Snap are used as supplements to our dominant method, and provide analytical value in terms of reaffirmation and validation of data. The aim of the interviews was to acquire detailed information about the consumer perceptions of participating in the access and content market of UFB. Potential participants eligibility for the study was ascertained via a short questionnaire. The eligibility involved (1) living in Auckland city, (2) having a broadband connection, and (3) being the responsible or jointly responsible person for deciding which broadband products are used in the household. Further, we ensured 10 participants had some advanced knowledge regarding their broadband connection. All those eligible to participate were invited to take part in a 30-40 minute-long semi-structured telephone interview.

The interview involved three main parts. The first part kindled a brief discussion about present broadband usage and current RSP, trying to find why the consumer decided to use these services. Secondly we switched topic to understand consumer awareness and

36 Consumers were segmented in the following groups: pragmatists, digital natives, affluent families and connected matriarchs.
37 Consumer understands how much capacity (gigabytes) their broadband product has; is well informed about the usage at home and costs.
expectations from the UFB initiative. After assessing consumers’ initial understanding, we played a short audio clip produced by Telecom NZ (2013) which provided a simple overview of the UFB initiative and what it might mean for the consumer. Finally we presented potential options of broadband products, and incited discussion on what factors are affecting the consumer’s decision. The interview was semi-structured and every interview resulted to be unique in terms of additional content discussed.

We applied grounded theory because it allows emergence of original and rich findings from empirical data (Urquhart et al., 2010). After transcribing the data we conducted open coding, developing a preliminary set of codes. Eventually we performed selective coding as analysis became more certain; finally we formulated a theory of consumer participation in UFB access and content markets using theoretical coding. As we documented the theoretical findings, we validated and enhanced the claims by using Chorus’s research outputs and Snap’s customer data.

6.3 Findings and Discussion

Consumers accept that technology will keep changing and they are constantly learning and adapting to new technological products and services. This is an advantage for the UFB introduction as it is not overwhelming consumers. However some consumers also pointed out that not all technology that is being introduced in the market is robust. They also added that this might be a process manufacturers would follow to test products. Based on this assumption consumers confess waiting for early adopters to use new products and also wait till the market matures prior to deciding to use it. Consumers are aware that using a newly introduced technology can be costly; this is another reason why those consumers who classify themselves as late adopters wait till prices drop.

6.3.1 Consumer awareness and general perceptions regarding UFB implementation

Some consumers were reasonably aware of the UFB rollout and the majority favored it. Consumers considered the UFB connection would be faster, smoother, impressive, like the USA, quick, stable, and instantaneous. Many consumers appreciated the reliability of UFB providing the ability of multiple users using a single connection – this is a shortcoming of ADSL broadband. Consumers spoke of enjoying and using data-intensive applications such

38 Audio clip extracted from Telecom NZ UFB video available at the following link: http://youtu.be/20Ql3u0mYls
as: streaming movies, downloading movies, Quickflix, YouTube, Skype, upload and download of large files, Dropbox, and Smart TVs. Discussing the possibilities of UFB aroused practical ideas. A consumer mentioned how their charities organization will benefit by replacing some of the physical meetings with online video conferencing. The money consumed in travelling could be allocated to charity. The consumers also hoped that the reliability would enable them to use VOIP and Skype in order to lessen their international toll calls. When we enquired regarding the perceived target audience the following were stated: Internet junkies, heavy Internet users, gaming nerds, kids for education, media consumers, business consumers, everybody, and rich people.

Some consumers lacked the excitement or faith in the UFB offering, saying it was only hype. One contributor believed the government should focus on other issues such as social services, education, and healthcare. A consumer simply said the UFB initiative only sounds good in theory, while another didn’t see any value in utility. A consumer said she has established home and business systems with parental controls and she is resistant to change or restructuring her workflow. Some consumers regarded fiber technology as not so advanced because other countries have already used it for a long time. Other consumers confessed they are simply not early adopters and would make a decision when the market matures or their existing ADSL connection becomes obsolete; in fact this consumer said:

“One thing that I haven’t mentioned is that we’re not early adopters so we might wait for new technology to bed in before we consider it. We’re very happy with the level of service that we get and until they either turn it off or we can transition to the ultra-fast broadband with minimal kind of cost, I expect us to stay on it until, well we’re happy with it and we’ll stick with it.”

6.3.2 Consumer adoption of UFB access (CAUA)

The UFB access market involves obtaining a UFB connection at premises. During the theoretical coding phase we extracted the factors that mattered most for consumer adoption, postulating a CAUA research framework as shown in Figure 27. We aggregated barriers (B), drivers (D), and deciding factors (DF). The barriers are reasons for consumers to refrain from UFB access adoption whereas the drivers are motivators. The DFs can become either a barrier or a driver depending on the consumer preference or market condition of a particular DF. The following text elaborates each of the points in the CAUA framework.
The strongest drivers in CAUA include: performance (reliability and consistency), support for home phone and being equipped with the latest technology. Main findings reflect that the performance (D1) of an ADSL connection is limited and a reliable consistently fast connection is going to add value to the consumer experience, Chorus’s study also echoes this; and fiber-optic technology delivers this promise. The UFB access will maintain compatibility with existing home telephony. New Zealanders value their home phones (D2). The consumer recognizes mobile phones provide personalization and ubiquity but these benefits aren’t sufficient at present to compromise a home phone because the home phone is very embedded in NZ culture. Even at the time of 2001 Census of Population and Dwellings, 96 percent of NZ households had access to a telephone (Statistics New Zealand, 2001). The home phone number itself is invaluable – causing a historical identity lock in. Making a landline-to-landline call is often a cheaper alternative because of the high mobile call tariffs in NZ. Fiber infrastructure in NZ provides compatibility to maintain the popular home phone, which is a driver of UFB access. Finally many consumers appreciated the advantage of superior broadband technology at their home (D3).

In the interview a topical issue was consumer sensitivity to paying for the curb to home fiber connection. A minority of consumers stated they would pay to get a fiber connection as one of them felt it was normal; relating it to how they have paid Sky TV\textsuperscript{39} for initial connection followed by recurring monthly subscription charges. Another consumer didn’t mind paying because they appreciated the value of having a fiber connection; but s/he’d be “grumpy” about it. Lastly a consumer felt the existing wiring in his old house was no good, therefore

\textsuperscript{39} Paid television-broadcasting service in NZ.
s/he was willing to pay for the fiber line to improve his voice and broadband connectivity. A group of consumers were indifferent; they said they were happy with their existing ADSL broadband. An example of such perception is below:

“I would probably struggle in the short term to justify it, like I say there’s nothing particularly wrong with our Internet at the moment. I mean if it meant we had to pay that sum to get Internet then we’d probably pay it. But if it was, if there was an alternative of keeping what we’ve got or paying that to receive the better service we’d probably be reluctant initially to justify that then. But our circumstances may change.”

A majority of consumers were very negative about paying for a fiber connection. The consumers argued that the government or the telecommunication companies should pay for the fiber connections to home because they will eventually obtain revenue from monthly broadband subscription. A consumer justified this matter by posing questions below:

“We don’t pay for the wires for our phone line, why should we pay for the wires of the broadband? Isn’t that part of the monthly bill?”

Some consumers raised practical issues related to wiring. One consumer who was flatting said paying for such costs would require consultation with his flat mates, who may or may not endorse spending for the upgrade. A consumer in a rental home wondered if s/he should pay for a fiber-line connection.

From the above findings we can claim (DF1) that a free or low-cost connection to the premises will enhance the adoption. The DF1 in Figure 27, is currently a driver as the curb to home fiber connection is free of charge. In 2015, DF1 may work backwards when consumers will need to pay. Consumers lack awareness of UFB technology and its benefits (DF2). According to Canstar Blue a survey of 1800 broadband account holders showed that two in five respondents do not understand the difference between UFB and the connection they use at home (DF2); consumers struggled to understand the differences between their current connection and the fiber technology used by the UFB (Wade, 2013). This emphasizes the importance of DF2. Chorus also found that the specific UFB related understanding is low, but people feel positive about the potential of UFB promise.

CANSTAR Pty Limited is Australia and NZ’s consumer ratings research company.
Consumers acknowledge that broadband performance needs to improve. However in terms of evaluating existing performance the degree of dissatisfaction is minimal (B1). Chorus’s study scored a mean of 7.1 out of 10 for Internet performance satisfaction at home. Smith, et al. (2011) found only one in five users (19%) is dissatisfied with the speed of their Internet connection at home, and even fewer (13%) are dissatisfied with the reliability of their connection. The reason for their contentment could be that they have never experienced higher quality connections. This awareness barrier could be overcome if obtaining the connection were free or low cost (DF1). General consumer awareness (DF2) regarding benefits of fiber technology would also motivate consumers to participate in the UFB access market.

6.3.3 Consumer adoption of UFB content (CAUC)

The UFB content market involves distribution of UFB products and services from RSPs. The consumer participation will help recover cost of investment, maintain fiber cables, provide customer service, and eventually decommission ADSL technology. Using grounded theory we derived a research framework with a structure similar to CAUA, by deducing factors valid for CAUC as shown in Figure 28. The most cogent drivers are described in the following text.

Having a fiber connection at premises satisfies the prerequisites for eventual CAUC (D1). Broadband and home phone is a necessity for New Zealanders (D2). It has been reported by (Smith et al., 2011) that 86% of New Zealanders use the Internet of which 91% use broadband. Consumers value market rumors, press, market reviews, and comments on forums (D3). If the UFB is often hyped as a stable and robust technology then the consumers will eventually embrace it. Consumers also welcome technological change (D4); we learnt from the interviews that consumers appreciate old technology is not permanent. This means the consumer is familiar with learning and adapting to use new technological products and services.
Many consumers mentioned using data demanding applications like cloud, VoIP, and video – these experiences would be ideal on UFB (D5). The Chorus quantitative study found 72% watched video clips, 66% upload photos, 60% engaged in video conferencing, and 58% accessed TV on demand. Chorus found there is an average number of 2.9 connected devices per household and the consumers pointed out that connection worsened when multiple users are online. So the ability of multiple users to simultaneously use the same Internet connection (D6) is attractive. Consumers narrated their occasional frustrations on how the connection is satisfactory but not reliable enough to support practical needs. A consumer mentioned how their charities organization will benefit with UFB by replacing some of the physical meetings with online video conferencing. The money consumed in travelling can be allocated to charity instead. Chorus’s quantitative study identified reliability related problems such as slow Internet speed, poor video streaming, dropouts and freezes, and unreliable connection. The consumers are seeking a consistently fast reliable connection (D7).

As Given (2010) states “Forced migration from the copper access network is attractive to governments anxious about returns on their investment, but might be less popular with service providers and retail customers for whom the copper, and the equipment connected to it, continues to provide adequate, affordable services”. Forced migration can be an efficient and useful driver (D8) to eventually move 100% consumers to UFB. Consumers recalled RSPs offering upgrades, and special offers, which were positively received; this could be an effective (D9) avenue for promoting UFB services.

Deciding factors can either turn to a driver or barrier depending on the condition. Consumers hope the UFB technology will not only become faster and more reliable like overseas but also...
cheaper (DF1). The Chorus study also confirms this. Chorus found that 73% of consumers considered it important criteria while deciding on Internet package at home. The general expectation is that the cost of Internet as a commodity will decrease overtime because its utility is increasing. Snap’s data shows 56% of consumers received either free or discounted routers – this accounts for a cheaper startup cost. Those consumers who are exposed to markets overseas felt the prices in NZ are very expensive; regarding this a consumer said:

"The relatives overseas find it absolutely hilarious that kiwis pay so much for the speed and capacity they receive."

RSPs send out consumer premise equipment (routers or modems) along with a configuration manual to establish the Internet connection at home. Consumers appreciated the easy (DF2) installation and aren’t scared to try new solutions, a driver in comparison to a difficult product installation experience. Expensive calling rates (DF3) are motivating consumers to subscribe to a home phone, and expensive cellular data rates are stimulating the need for home broadband. Word of mouth advertising via friends, family, or work colleagues is popular. The consumers are learning information about broadband services and sharing their experiences. This knowledge eventually becomes an important factor when deciding (DF4). Some consumers stated consulting friends that are technologically savvy or early adopters to help while deciding. Chorus’s study can echo this – it found 56% of consumers consulted friends and family to seek information on broadband services and 28% admitted this information is the most useful while deciding. Snap’s data on how a consumer found out about them is as follows: 1% Facebook, 11% forum, 49% friends, 10% mail, 5% other, 6% print advertisement, 1% TV and 17% web search. Most popular influential sources are friends, and forum.

This (DF5) has already been discussed in DF2 of the CAUA framework. UFB has the ability to deliver 100 Mbps, which is an attractive (DF6) proposition for heavy Internet users, gamers, or variations of early adopters.) The market structure of telecommunications is going to change due to the public-private investment in UFB and regulatory reformations; which is expected to introduce many more RSPs in the market (DF7). We briefly informed consumers regarding these changes. Most consumers received this very well, hoping the competition would benefit them by achieving UFB content at low prices. Some consumers said they were braced for advertising to become bewildering due to an increase in RSPs, implying increases in UFB products and services.
The barriers for the CAUC are elaborated in the following text. Consumers subscribe to plans that are efficient and economical to their usage needs (B1). The cohort of consumers with minimal needs—who have a very low usage and never reach their data cap, mentioned using the lowest rate plan because they never watch movies or download music. The lowest rate plans usually offer 5 – 10 gigabytes of data allowance. These individuals also mentioned never being bothered about checking their usage as they are never above the data cap. They claimed paying too much for checking emails a couple of times a week. The monetary savings achieved in a lower capacity plan compared to those in a higher capacity are slim.

Consumers confess to waiting for early adopters (B2) to use new products and also waiting till the market matures prior to deciding to use it. Consumers are aware that using a newly introduced technology can be costly; this is another reason why the consumers (those who classify themselves as late adopters) wait till prices drop. Consumers are sensitive to hidden costs (B3), leading them to form negative impressions about their RSPs. A consumer related a sour experience regarding an antivirus protection offered as a free add-on to their broadband connection, which eventually started costing money. After this incident the consumer felt the goal of RSPs is to make as much money as possible.

Technical details that describe broadband plans of a RSP were overwhelming to a few (B4). Consumers often use RSP websites to learn about offers. Chorus also found RSP websites are used by 54% of consumers in their survey and these websites proved most influential source of information for 25% of the consumers. Consumers felt they get very confused; hence they either enquire for recommendations from their savvy friends or trust their long established relationship with their RSP. This (B5) barrier has already been discussed in B1 of CAUA framework.

Some consumers lacked confidence in the way NZ is implementing fiber (B6); they were hoping that the project was well managed and designed for the future. Some had fears of infrastructure malfunctioning while NZ starts depending on it. One consumer hopes UFB implementers are thinking long-term and not using a haphazard approach. The UFB initiative is a multi stakeholder project and the consumers didn’t seem to be aware of CFH who are managing this project. Consumers also would appreciate defined service level guarantees on connection reliability, including speed. There seems to be ambiguity regarding the specific dates and addresses of fiber implementation; accurate information will allow consumers to achieve the right mindset and make preparations for it. Finally consumers needed to know
what prerequisites they will need to use UFB, one of the consumers asked whether their existing ADSL modem will work for the UFB.

6.4 Conclusion

This paper focused on the consumer adoption issues as UFB is implemented in NZ. Consumer adoption is a critical success factor for the UFB initiative, which involves both an access and content component, using a dominant imperialist mixed methods approach, with consumer interviews being the dominant dataset. The contribution of this research is its theoretical frameworks CAUA and CAUC respectively. These frameworks depict the overall drivers, barriers, and deciding factors for consumer adoption. We provided an elaborate discussion for each of the factors using our theoretical findings and supplementary secondary data from the industry. If the market is able to convert deciding factors of CAUA and CAUC to drivers; then a faster establishment of UFB market seems likely. The two most critical factors are subsidization of curb to premises fiber line, and uplifting consumer awareness of UFB benefits. When the access market is established we can assume the RSPs will actively market their products, which will create awareness, word of mouth, and eventually catalyze consumer adoption. The limitation of this research is the small qualitative sample size, however we tried to minimize this shortcoming by using a mixed method approach that provided us with reassurance and validation of facts.

6.5 Acknowledgements

The authors would like to thank Rosalie Nelson and Vanessa Kennedy-Casas from Chorus, James Koers from Snap, and the CODE at The University of Auckland for their assistance. The authors would like to acknowledge receiving Faculty Development Research Fund for conducting this study.

6.6 References


Article V
7 Article V - Modeling the Access Market of the Two-Sided Ultra Fast Broadband Platform in New Zealand

Abstract: LFCs and the government of NZ are jointly implementing a nation-wide fiber-optics network, a project known as the UFB initiative, expected to cover 75% of households by 2019. New opportunities are expected to open up because the UFB network by regulation forbids LFCs to directly provide retail services. Consumers will need to purchase fiber services from RSPs. The UFB represents a scenario of a two-sided platform, with consumers and RSPs on each side. Using two-sided platform theory and normative economics this paper presents the results of an ABM of platform access dynamics. The UFB platform currently subsidizes fiber lines for consumers. As the industry debates whether subsidization should continue, the results indicate that subsidy can be reduced when a large number of users on either side appear in the market. This case study presents us with a timely unique opportunity to analyze the issues involved as the market evolves and stabilizes.

Keywords: Fibre deployment in New Zealand, Cross Network Effects, Two Sided Platforms

7.1 Introduction

The target of UFB initiative is to serve 75 percent of NZ homes by 2019 (CFH, 2010). The UFB initiative involves connecting each household with a fiber connection, which will be able to deliver impressive speeds of 100 Mbps downlink and 50 Mbps uplink. Once the household has a fiber connection, the household can purchase retail fiber services from a RSP of their choice.

The UFB market comprises of two market components - an access market and a content market. The access market involves consumers achieving fiber connectivity from their LFC and subscribing to a RSP. The content market includes actual retail services and products such as phone line, IPTV, broadband etc. This paper excludes issues of content market and focuses on the access market as the UFB network is still under construction. Due to the UFB initiative, significant changes are expected to occur within the telecommunication markets in NZ.
This paper uses ABM as a means to represent the most important aspects of the access market and deal with the complexity of the issues involved. ABMs consist of purposeful agents who interact in space and time whose micro level interactions create emergent patterns (Page, 2006). Examples of possible agents include individuals (e.g., consumers, workers), social groupings (e.g., families, firms, government agencies), institutions (e.g., markets, regulatory systems), biological entities (e.g., crops, livestock, forests), and physical entities (e.g., infrastructure, weather, and geographical regions) (Tesfatsion, 2006). ABMs are especially useful to study complex systems – systems that use simple micro-level rules that generate macro level phenomenon. ABM is a method for studying systems that are composed of interacting agents and emergent properties (Axelrod & Tesfatsion, 2006). Emergent properties are an aggregate of the properties of interacting agents. In our case the complex system is a developing fiber network service with RSPs appearing in the market and consumers subscribing to UFB services. The simulation model is developed using Net Logo, which is a multi-agent modeling environment.

The UFB case presents us with a timely unique opportunity to analyze the issues and drivers involved as the market forms, evolves and stabilizes.

7.2 NZ Broadband Market Structure

At present household consumers access the Internet mostly via ADSL services. Download speeds range between 2Mbps to 15Mbps and the data allowance is between 20-500GB, features vary based on broadband packages and geo-location of the consumer. Most broadband plans include a home line connection. The recent broadband market structure before 2011 is shown in Table 6. Most of the physical infrastructure (layer 1) for wholesale services (layer 2), was owned by Telecom NZ. Majority of retailers who sell retail broadband (layer 3) needed to purchase wholesale broadband from Telecom NZ. This structure was discriminatory in provisioning layer 1 and 2 services and didn’t allow for fair competition. The above-mentioned market structure changed for UFB market.

Meeting the steep cost of implementing the nationwide UFB network would be a huge challenge for private companies. Consumers wouldn’t pay much more than their current broadband expenses and the return on investment for a private company would be extremely difficult to achieve within low populated country like NZ. The NZ government's conception
of the broadband ecosystem recognizes that it is paramount to have a robust UFB infrastructure as it aids toward development of other industries like health, education, and entertainment. In 2011 the largest telecommunications company in the country, Telecom NZ, was split into a wholesaler, Chorus, and a retailer, Telecom, which has also kept the mobile business.

Table 6: ADSL broadband market structure

<table>
<thead>
<tr>
<th>Layer 3</th>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telecom NZ</td>
<td>Retailer</td>
</tr>
<tr>
<td>Layer 2</td>
<td>Retailer</td>
</tr>
<tr>
<td>Layer 1</td>
<td>Retailer - with infrastructure</td>
</tr>
</tbody>
</table>

The government set up CFH, an agency that will invest NZ $1.2 billion to develop the UFB network jointly with four private LFCs, who are expected to make a similar investment. This forms a public-private partnership between CFH and respective LFCs to develop the UFB network. A total of four LFCs will implement the fiber network, each having their own assigned geographical implementation region. Chorus is the dominant LFC implementing 70% of the UFB network region. New business opportunities are expected to open up for existing and new operators because the UFB network by regulation forbids LFCs to directly provide retail services. CFH is expected to provide governance for the UFB network, by ensuring a level of quality is maintained and timely progress is made by the LFCs in accordance with the initial agreements. UFB is complemented with the Rural Broadband Initiative (RBI), aimed for the rural sector with, about NZ $300 million of government investment and two private partners.

Table 7: UFB Market Structure

<table>
<thead>
<tr>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>TelecomNZ</td>
</tr>
<tr>
<td>Slingshot</td>
</tr>
<tr>
<td>Chorus Ltd</td>
</tr>
<tr>
<td>Layer 2</td>
</tr>
<tr>
<td>Layer 3</td>
</tr>
</tbody>
</table>

The main task of each LFC is to install fiber connections to households in their regions and maintain fiber lines. LFCs own and operate the UFB platform and higher benefit will be achieved if they manage to implement network rapidly, as it would satisfy the prerequisite for
RSPs to start retail services to receive returns on their investments. Initially CFH reached agreement with LFC partners to provide free residential connections for distances of up to 200 meters per house from the road, until at least the end of 2015 (Bell, 2012a). Industry claims this subsidy isn't sufficient as consumers might opt for not having a fiber connection, failing to pay up to NZ $500, due to a number of reasons. Firstly, because the consumers that live in a rental property may not invest in a line upgrade, as they are uncertain about how long they will be renting. Secondly, the consumers may lack financial ability. Thirdly, the present ADSL broadband may satisfy all their needs, and the consumer is unable to perceive the additional value of a fiber connection. It is estimated that another NZ $30 million will be required to subsidies free connection for the estimated 60 percent of connections that will come in after 2015 (Bell, 2012b). The industry continues to discuss the subsidy issues, as it is a critical factor for consumer consumption. For developing the models in this paper, we will assume the fiber deployment is either free of cost to the consumer or only subsidized till 2015 as mentioned above.

The retail services can only be sold by the RSPs to consumers (see Table 7). LFCs sell layer-2 wholesale services at a regulated fixed price per consumer with a slight increase each year until 2019 (see Table 8). The RSPs are expected to develop business models that include high-speed broadband, phone line, IPTV and video services over the UFB network. The new market structure, depicted in Table 7 has introduced a vertical separation and from an industry perspective, giving birth to an LFC-operated two-sided platform.

7.3 Access Market as a Two-Sided Platform

Founding work on the economics of two-sided platforms by Rochet and Tirole (2002, 2003) introduced the term two-sided market. On a two-sided platform the price level is the sum of the prices charged to the two sides and the price structure is the allocation of the price level between consumers on both sides of the market (OECD, 2009). The most commonly accepted feature of a two-sided platform is its ability to affect the total welfare through changes in the price level and the price structure; in other words, a two-sided platform can affect the volume of transactions by charging one side and reducing the price charged to the other side (Rochet & Tirole, 2003).

Typical examples of two-sided platforms include financial exchanges, software platforms, and advertising supported media (Evans, Schmalensee, Noel, Chang, & Garcia-Swartz,
More inclusive approaches are found in Weyl (2010) who states that a two-sided market is characterized by the importance (intensity) of the interdependencies between the two sides, or Evans (2003) who refers to the existence of “two customer groups who benefit from interacting and for whom a platform can provide efficient intermediation services between the two groups”. In a traditional value chain, value moves from left to right: to the left of the company is cost; to the right is revenue; meanwhile in a two-sided market, cost and revenue are both to the left and the right, because the platform has a distinct group of users on each side (Eisenmann, Parker, & Van Alstyne, 2006). The platform will incur costs in serving both groups and can collect revenue from each group, although one side is often subsidized.

Table 8: Wholesale Pricing for RSPs - from (Beltrán, 2012)

<table>
<thead>
<tr>
<th>Product</th>
<th>Downstream/Upstream data rates</th>
<th>2011 CCPM* (NZD)</th>
<th>2019 CCPM* (NZD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Voice Channel</td>
<td>Greenfields or LFC-discretionary</td>
<td>25.00</td>
<td>25.00</td>
</tr>
<tr>
<td>GPON Residential Entry</td>
<td>30 Mbps/10 Mbps</td>
<td>37.50</td>
<td>42.50</td>
</tr>
<tr>
<td>GPON Residential Triple-Play</td>
<td>30 Mbps/10 Mbps</td>
<td>41.25</td>
<td>46.25</td>
</tr>
<tr>
<td>GPON Business Entry</td>
<td>30 Mbps/10 Mbps</td>
<td>49.95</td>
<td>49.95</td>
</tr>
<tr>
<td>GPON Triple-Play</td>
<td>100 Mbps/50 Mbps</td>
<td>55.00</td>
<td>49.90</td>
</tr>
<tr>
<td>GPON 100/100</td>
<td>100 Mbps/100 Mbps</td>
<td>175.00</td>
<td>175.00</td>
</tr>
<tr>
<td>HD Video Channel</td>
<td>10 Mbps for multicast video</td>
<td>5.00</td>
<td>5.00</td>
</tr>
</tbody>
</table>

* CCPM: Customer charges per month.

The UFB represents a scenario of a two-sided platform. LFCs will implement the UFB network, which is the platform. On one side the platform sells wholesale services to RSPs, whereas on the other it offers fiber connections to consumers. It is common in two-sided markets for one of the user groups to be subsidized. For example, Yellow Pages is free of cost to consumers, but advertisers pay to get a featured advertisement. Usually job seekers access job portals for free and employers need to pay to advertise. If these platforms reversed their approach, their network probably wouldn’t exist. In the case of UFB, the consumers are subsidized so that a large user group can be established and the platform is used by RSPs to market broadband-based services such as VoIP, IPTV and other multimedia applications.

The other side of the platform involves LFCs selling wholesale fiber to RSPs. The government and CFH are ensuring that LFCs will not sell directly to consumers, and wholesale rates are consistent to all the RSPs to allow for fair competition, as shown in Table 8. RSPs are expected to create broadband packages, with varying prices and features leveraging rich capabilities of UFB infrastructure to create offerings that did not exist previously. This could include collaborating with businesses that offer IPTV entertainment, gaming, security solutions, health, and education applications. The consumers will use the broadband services to discover new ways to utilize their high-speed connection.
This paper argues that studying the impact of network effects among RSPs and consumers on the UFB platform can benefit from modeling the network as an access two-sided platform. As the fiber consumer base gets larger, it is expected that large number of RSPs will enter the market.

### 7.4 Access Market Model

We leverage Beltrán’s (2012) model to describe the effects of cross network effects on optimal retail pricing in the UFB access platform. The model is built on a two-sided market approach where users’ and RSPs’ decisions to participate in the market are mutually influenced, mainly by the number of the “agents” on the other side. One the first side of the platform, the RSP purchases wholesale services from the platform operator, i.e. the LFC. If \( C_{\text{RSP}} \) represents the cost to a RSP to get services from the platform then:

\[
C_{\text{RSP}} = n_{\text{AR}}P_R + n_{\text{AB}}P_B \tag{1}
\]

where \( n_{\text{AR}} \) and \( n_{\text{AB}} \) are the number of residential and business consumers who activated their fiber connection with a RSP; \( P_R \) and \( P_B \) are the wholesale layer 2 rates payable to the platform per individual residential or business consumer. Regulated wholesale prices are charged based on individual connections. This means the platform obtains revenue \( C_{\text{RSP}} \) from the RSP side based on the number of consumers it will manage to subscribe.

The second side of the platform, the end-user side, is split in two groups: residential (R) customers and business (B) customers. The RSP’s utility function at time \( t \) would consider the positive effect of the presence of residential and business consumers less the cost of purchasing wholesale services from the platform:

\[
U_{\text{RSP}}(t) = [n_{\text{FR}}(t) - \alpha_{\text{RSP}}(n_{\text{FR}} + n_{\text{FB}})] \cdot P_{\text{RSP}} \tag{2}
\]

where \( n_{\text{FR}} \) and \( n_{\text{FB}} \) are the number of residential and business consumers who achieved a fiber connection from the LFC and \( \alpha_{\text{RSP}} \) measures the effect of each consumer’s platform presence perceived by the RSP. In other words eligible to activate UFB services. \( n_{\text{AR}} \) is a
subset of \( n_{FR} \) and \( n_{AB} \) is a subset of \( n_{FB} \). On a first approach business consumers are excluded mainly because their associated connection costs are not clearly defined at this early stage of implementation (at least in the international cases inspiring the present model). The expenses that need to be paid to the platform by a RSP are represented by \( P_{RSP} \), which is equal to \( C_{RSP} \). We can condense \( U_{RSP}(t) \) as below:

\[
U_{RSP}(t) = n_{FR}(t) - \alpha_{RSP} n_{FR} \quad \text{Equation (3)}
\]

where \( \alpha_{RSP} \) measures the effect of each consumer’s platform presence perceived by the RSP. \( n_{FR}(t) \) is the number of consumers with a fiber connection at time \( t \). The \( U_{RSP}(t) \geq 0 \) when \( n_{FR} \) in the market exceed the perceived consumer platform presence of the RSP. This means the RSPs will find the market increasingly attractive as the \( n_{FR} \) increases over time. When \( U_{RSP}(t) \geq 0 \), the market becomes sufficiently convincing for the RSP to start offering UFB services.

A residential consumer’s utility function can be expressed as shown in equation 4 where \( \alpha_{R} \) measures the effect of each RSP’s platform presence perceived by the consumer. \( n_{RSP} \) is the number of RSPs active in the UFB market.

\[
U_{R}(t) = n_{RSP}(t) - \alpha_{R} n_{RSP} \quad \text{Equation (4)}
\]

7.5 Computational Model

The main objective of this simulation is to represent the market dynamics with cross-network effects in this two-sided UFB platform access market. The agents of this model are: a single LFC, varying number of RSPs and UFB consumers. For simplification purposes, we exclude UFB business consumers. The simulation model will run for a period of approximately 6 years and 10 months, which is similar to the actual time-span of UFB rollout in NZ.

We varied subsidy settings for generating simulation results: full subsidy (scenarios 1-4) and partial subsidy till 2015 (scenarios 5-8) as shown in Table 9. For the full subsidy scenarios all of the consumers will have fiber installed at their premises by the end of each simulation run. The approximated speed is set to 10 houses per day, for the simulation results. For the partial
subsidy scenarios, the assumption is that some consumers may refuse to pay connection costs; therefore the implementation speed is lowered to 7 houses per day.

RSP and consumer agents will be assigned a unique $\alpha_{\text{RSP}}$ and $\alpha_{R}$ by the simulation model and this will influence how they participate in this two-sided platform. The following scenarios with varying utilities: $U_{\text{RSP}}$ and $U_R$ are setup.

**Table 9: Simulation Scenarios**

<table>
<thead>
<tr>
<th>Full subsidy scenarios</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partial subsidy scenarios</strong></td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td><strong>Utility</strong></td>
<td>High RSP</td>
<td>Low Cons</td>
<td>High RSP</td>
<td>High Cons</td>
</tr>
</tbody>
</table>

Consumer agents maintain two attributes: *connection-status* and *when-to-subscribe*. The connection status is either - *no-fiber*, *with-fiber* or *subscribed*. The model creates all consumer agents with a *no-fiber* status. The fiber reaches consumers based on the speed at which the LFC agent is implementing fiber. When the consumer agent is equipped with a fiber connection, the consumer will eventually subscribe to UFB services. How fast this occurs is defined by the consumers attribute *when-to-subscribe*, which equals $\alpha_{R} n_{\text{RSP}}$.

The value of $\alpha_{R} n_{\text{RSP}}$ is derived based on a gamma distribution with $\alpha$ and $\lambda = 1$. Random number $X$ is drawn from $X \sim \Gamma (\alpha, \lambda) = \Gamma (\alpha, \lambda)$. Using a scaling variable $S$, the model multiplies $X$ in order to relate to the number of RSPs in the market. Therefore the consumer attribute when-to-subscribe = $X*S$. For example: if $X = 0.5$ and $S = 4$ then when-to-subscribe = 2, this means that this specific consumer will subscribe to a fiber service with a RSP only when there are 2 or more RSPs in the UFB market.

The S variable can vary based on the scenarios, if we want the consumer agents to quickly take up RSP subscription (scenarios 2, 4, 6 and 8), then S is set to lower values. Whereas, when the scenarios require consumers to delay (scenarios 1, 3, 5, and 7), then S is set to higher values. The scaling configuration (S values) appreciates current (2013) market information from the LFC websites; see Chorus* and North Power Fibre**. The LFCs list the number of potential RSPs expected to enter the market and which of these are operational. Based on the NZ UFB market, it is estimated that up to 10-16 RSPs might be providing UFB service plans.

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* http://www.chorus.co.nz/where-can-i-get-ufb-based-services-from
** http://northpowerfibre.co.nz/index.php/partners
Gamma distribution is used because its cumulative distribution function is similar to the conditions of this platform. RSPs are slowly getting introduced into the market and will eventually reach saturation. Consumers on the other-hand subscribing to UFB services until most of the consumers are UFB platform users. For the RSPs when $n_{FR}$ is maximum it would encourage most of the potential RSPs to enter the market.

RSP agents maintain a *when-to-market* attribute which equals $\alpha_{RSP} \ n_{FR}$, this specifies when a RSP actively starts selling UFB services, for example if *when-to-market* is 40 - this means that the RSP will enter market only when 40% of consumers have fiber connections, i.e. $n_{FR}$ = 40. To establish a numeric value for RSP’s *when-to-market* we follow the similar approach of the consumer agent’s *when-to-subscribe* attribute using a gamma distribution.

The model initiates by setting up the agents based on specified scenario configuration. The LFC agent implements fiber connections, ten houses per day for scenarios 1 to 4 and seven houses per day for scenarios 5 to 8. Secondly the RSPs become active in the market when $U_{RSP}(t) \geq 0$. Thirdly the consumers activate their fiber connection with a RSP when $U_{R}(t) \geq 0$. This process continues for the entire term. Cumulative results and plots are collected, to appreciate cross-network effects with varying utilities.

### 7.6 Results

The simulation results presented in Table 10 and Table 11 show cumulative plots for each scenario from a consumer perspective. The X-axis shows number of days and Y-axis represents the number of consumers. The dotted line represents the consumers who achieved a fiber connection ($n_{FR}$). The solid line is for the consumers who already activated the fiber connection with a RSP ($n_{AR}$).

The results are organized according to the scenarios specified in Table 9. The type of subsidy enforced in the model groups scenarios; scenarios 1-4 show fully subsidized implementation and scenarios 5-8 show a partially subsidy implementation. Each scenario has a varying utility setting, so the best-case scenario is high utility for consumers and RSPs, scenario 2 and 6. The worst case is scenario 3 and 7.
Table 10: Fully Subsidized Scenarios (1-4)

<table>
<thead>
<tr>
<th>Strength of Cross Network Effects (Consumer)</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>n\textsubscript{FR}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n\textsubscript{AR}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n\textsubscript{FR}: dotted line and n\textsubscript{AR}: solid line

Table 11: Partially Subsidized Scenarios (5-8)

<table>
<thead>
<tr>
<th>Strength of Cross Network Effects (Consumer)</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>n\textsubscript{FR}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n\textsubscript{AR}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n\textsubscript{FR}: dotted line and n\textsubscript{AR}: solid line

In the best case (scenario 2 and 6) we can see that the gap between n\textsubscript{AR} and n\textsubscript{FR} is narrow emphasizing that the consumers immediately started subscribing to UFB services when they achieved fiber access, as their utility had a higher strength of cross network effects. In the worst case (scenario 3 and 7) we can see that the gap between n\textsubscript{AR} and n\textsubscript{FR} is greater implying the unwilling consumers are expecting a greater presence of active RSPs on the UFB platform.

Scenario 4 and 8 are close to best-case scenario and scenario 1 and 5 is close to the worst-case scenario, emphasizing effects of high U\textsubscript{R} having a greater effect on the platform than U\textsubscript{RSP}. 
When we analyzed aggregate-averages of simulation runs we found that there were 50% $n_{AR}$ in scenario 3 and only 46% $n_{AR}$ in scenario 1, when $n_{FR}$ was 100%. This difference could be explained by the *rate of subscriptions*. We found that the $n_{AR}$ in scenario 1 were constantly close to 50% from the start, which is much more beneficial as the platform would be generating revenue from early days. Finally we can see that the partial subsidy scenarios can never perform as well as the fully subsidized setting as $n_{FR}$ cannot reach its potential maximum.

### 7.7 Discussion

As NZ upgrades its broadband infrastructure through the UFB initiative, a two-sided platform is born. This presents us with an interesting triangular set of relationships, between the platform, RSPs and the consumers. The platform embodies an architecture that has a set of rules, by which the platform operators (LFCs) are prohibited from selling to consumers, additionally adhering to fixed wholesale rates for selling to RSPs. This platform exhibits cross network effects. The results show that increasing number of users on one side makes the platform more valuable to the users on the other-side. From the consumer perspective, they are basically being pampered with a free fiber connection. It is hoped that they will eventually find their favorite RSP offering fiber services suitable to their needs and transition to the fiber network.

From the RSP perspective, they need to pay attention to increasing number of fiber-connected homes and develop competitive packages. At present in NZ, the smaller RSPs (Orcon, Snap, Slingshot) are trying to publicize their business models, where as the larger RSPs like Telecom and Vodafone, have not yet disclosed their fiber packages. Perhaps this could be because they don't wish to in-stabilize existing sales and revenue from the ADSL connections. RSPs are likely to provide three key service over fiber: phone, broadband and IPTV. Consumers will have a choice to consume either or all of these products over fiber.

The focus of this paper is on access market issues to the extent of RSPs and consumers activating in the UFB initiative. However over time the number of RSPs will increase, as a result the competition will spread into the *content market* of the UFB platform. The article in section 9 – provides an agent-based approach for the competition analysis of retail providers in a mobile service market.
From the LFC perspective, their revenue is somewhat assured, sooner or later a large majority of the consumers will use fiber services. How soon that will happen is at the mercy of RSPs - to promote and push fiber services. On the other hand though, LFCs are running awareness campaigns demonstrating UFB capabilities in efforts to increase consumer awareness regarding benefits of using UFB platform. At present the access market issues are important because it is prerequisite to the existence of a content market; end-users must be given a drop of the fiber network so that they can get connected.

The telecommunications industry in NZ recognizes the importance of subsidizing consumer fiber connections; the strategic question is for how long do you subsidize. Current subsidy is allowing creating that cross-side network effect, but on the other hand it is not proving to be cheap. Perhaps the free connections will occur until the market players are convinced they have been able to create sufficient momentum, enough to make consumers happily pay for connection costs, as it is the case with mobile consumers buying new smartphone every couple of years.

The simulation model was able to leverage two-sided platform theory and create a platform comprising cross network effects. The results reassure that subsidy is useful. When the utility of consumers was high, the market performed regardless of RSPs having a high or low utility. Secondly the results show that having large number of first mover RSPs allows the platform to keep generating revenue, even though the consumer utility may remain low. This could mean that when the platform achieves to have a large number of RSPs in the market, then the platform can risk reducing subsidy for the consumers. Perhaps the future format of the utility functions would be much more reliant on the content market, as the access market issues will fade away when most of the homes will achieve fiber connections.

7.8 Conclusion

This paper presented an overview of the NZ broadband market and the UFB network as a two-sided platform. The UFB joint venture between the NZ government and four LFCs includes regulatory changes whereby the LFC is prohibited to sell retail fiber services to consumers. Using theory from economics of two-sided platforms and ABM a simulation model was setup to highlight how varying utilities of consumers and RSPs generate cross network effects on the opposite side of the platform.
7.9 References


Article VI
8 Article VI - An Agent-based Model of Access Uptake on a High-speed Broadband Platform

Abstract: We model the access uptake on a newly built high-speed FTTH broadband network using a computational ABM. Two cases illustrate the model analyzed in this paper: the UFB Network in NZ and the NBN in Australia. Common learning of both projects is used in our model to describe and analyze the uptake of fiber connections to households and businesses. By design network operation is decoupled from service provision and the platform is open-access, meaning any provider can operate end-user services. In our model a high-speed broadband network is regarded as a two-sided platform that accommodates both end-users and service providers, creating the conditions for the two sides to exploit mutual network effects. Results show that the greater the number of users (end-users or providers) on one side, the more the number of users (provider or end-users) on the opposite side grows. Providing free connections and raising consumer awareness is a means for driving consumer uptake. Scenario based analysis allows us to investigate the magnitude of network effects’ on the fiber connection uptake.

8.1 Introduction

Recent national broadband initiatives have led to the construction of countrywide, fiber-based broadband networks. Countries such as Australia, NZ and Singapore have adopted a high-speed, FTTH network model where public funds are invested (with or without participation of private partners) and an open access operation is adopted. This paper models a high-speed, open access broadband network as a two-sided platform. On one side of the platform is the FTTH network operator, and on the other side it is the FTTH retailers (RSPs.). This two-sided platform comprises two markets: an access market and a content market. The scope of the access market involves consumers achieving fiber connectivity from their network provider known as LFC. The content market involves consumers subscribing to a RSP for actual retail services and products such as Internet access, voice service, and video (broadcast TV or on-demand). In this paper we focus on the access market and exclude issues of content market because the platform is still under construction. Focusing on consumer uptake helps understand salient aspects of FTTH growth when both, attractiveness of the platform to end-users and incentives for RSP participation are considered through the network effect
approach. New high-speed broadband network build-up presents us with a timely unique opportunity to analyze the issues and drivers for uptake and growth as the markets take shape and evolve. Our approach builds upon (Beltrán, 2012) where both access market and content market are modeled as a developing two-sided market platform. We use an ABM to simulate a range of scenarios that illustrate how the broadband uptake rate is affected by varying factors.

The rest of the paper develops as follows. In section 8.2 we present the market structure of the FTTH platform and relate it with the theory of two-sided platforms, followed by highlighting key features of agent-based modeling. In section 8.3 we present the access market model and provide details on configuration of simulation scenarios. We describe how the agents will interact in the model including consumer decision-making process. Section 8.4 presents the key findings followed by conclusions in section 8.5.

<table>
<thead>
<tr>
<th>Layer 3</th>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSP1</td>
<td>RSP2</td>
</tr>
<tr>
<td>Layer 2 &amp; Layer 1</td>
<td>LFC1</td>
</tr>
<tr>
<td>Local Fiber Companies</td>
<td></td>
</tr>
</tbody>
</table>

### 8.2 A high-speed broadband market as a two-sided platform

The new high-speed broadband structure will see a vertical separation of ownership and operation with LFCs being owners and RSPs being providers of services. LFCs will own and operate the lower layers of the network which will be geographically exclusive providing them a monopoly on the franchised area. This structure (Table 12) has introduced a vertical separation (lower layers structurally separated from upper layers), giving birth to an open-access platform. The main task of each LFC is to install fiber connections to their consumers in their regions and maintain fiber lines. Higher benefit will be achieved if LFCs manage to quickly implement the network, as it would satisfy the prerequisite for RSPs to start retail services. The retail services can only be sold by the RSPs to consumers. RSPs will purchase layer 2 services at regulated wholesale prices from the LFCs. The RSPs are expected to
develop business models that include high-speed broadband, phone line, IPTV and video services over the platform.

### 8.2.1 The broadband platform as a two-sided market

Founding work on the economics of two-sided platforms is found in Rochet & Tirole (2002, 2003) who introduced the term two-sided market. In a traditional value chain diagram, value moves from left to right: to the left of the company is cost; to the right is revenue whereas in two-sided networks, cost and revenue are both to the left and the right, because the platform has a distinct group of users on each side (Eisenmann et al., 2006).

An open-access, high-speed broadband network represents a scenario of a two-sided platform (Beltrán, 2012). A network provider implements a fiber-based network which can be regarded as a platform. On one hand the platform sells wholesale services to RSPs, whereas on the other it offers fiber connections to consumers. It is common in two-sided markets for one of the user groups to be subsidized. For example the Yellow Pages is usually free of cost to consumers, but advertisers pay to get a featured advertisement. Usually job seekers access job portals for free and employers need to pay to advertise. If these platforms reversed their approach, their network probably would not exist. In the case of FTTH network consumer access is being partially subsidized to encourage consumer participation.

### 8.2.2 Agent-based approach

The high-speed broadband market comprises multiple stakeholder groups, each with their own self-serving objectives. The stakeholder groups of LFCs, RSPs and consumers can be represented as heterogeneous agents in an ABM, each behaving according to their own preferences. Our ABM demonstrates how some market activities can be generated by the endogenously evolving interactions among such boundedly-rational stakeholders over time (Windrum, Fagiolo, & Moneta, 2007).

The use of ABM is not peculiar to the analysis of telecommunication markets. It is an effective methodology to tackle dynamics of telecommunication markets that involve: changing technologies, products, and regulatory reforms. Among the work conducted on telecommunication markets using ABM following is a sample of relevant references.
Beltrán and Roggendorf (2005) used ABM to create an auction-based pricing scheme to facilitate network resource distribution negotiations for the analysis of bidding behaviors and in (Beltrán & Roggendorf, 2006) they enhanced the simulation model by introducing richer strategies. Baryshnikov, Borger, Lee, and Saleh (2008) created consumer and service provider agents assigned with utility based preference scores. The model included two types of RSP agents, RSPs providing bundled services vs. undiversified services. The simulation model showed RSPs providing bundled services outperformed the other type of RSP. Douglas, Lee, and Lee (2011) presented a model in which the iPhone was introduced into the market, the model showed satisfactory reproduction of historical data but failed to predict exact market share in the future. Zheng, Jin, and Zhang (2011) explored the effects of regulation with a duopoly mobile market and found that the duopoly market operated more efficiently with regulatory interventions. Diedrich and Beltrán (2012) leveraged ABM to compare traffic discrimination policies. The model varied policy and competition scenarios. The results found that the content providers performed best when network neutrality is imposed; while network providers and consumers may benefit from traffic discrimination under certain circumstances. In the following text we present the ABM for the high-speed broadband platform access market.

8.3 Participation of RSPs and consumers in the access market

Beltrán (2012) used two-sided market theory to explain the presence of cross-network effects on an open access broadband platform. Cross-network effects embody the interdependencies between the two sides. One side, the RSP side, purchases whole-sale services from the platform operator. The other side, the end-user side, is split in two groups: residential (R) customers and business (B) customers.

8.3.1 Access market model

$C_{RSP}$ represents the wholesale cost to a RSP to get services from the platform. The number of residential and business consumers with active subscriptions from the RSP are given by: $n_{AR}$ and $n_{AB}$. $P_R$ and $P_B$ are the wholesale rates payable to the platform per individual residential or business consumer Therefore we can define the $C_{RSP}$ as below:
Regulated wholesale prices are charged based on individual connections (each of \(n_{AR}\) and \(n_{AB}\)). This means the LFC owned platform obtains revenue \(C_{RSP}\) from the RSP side based on the number of consumers it will manage to subscribe.

An RSP’s utility function would consider the positive effect of the presence of residential \((n_{FR})\) and business consumers \((n_{FB})\) with potential fiber connectivity (passing fiber line on the street) less the cost of purchasing wholesale services from the platform. In other words, the market becomes increasingly attractive to the RSP as passing fiber becomes available to homes and businesses. On a first approach business fiber consumers \((n_{FB})\) are excluded mainly because their associated connection costs are not clearly defined at this early stage of implementation (at least in the international cases inspiring the present model). The expenses that need to be paid to the platform by a RSP are represented by \(P_{RSP}\), which is equal to \(C_{RSP}\). Thus, if \(n_{FR}\) is the number of residential passing fiber consumers - who may potentially activate a fiber connection with a RSP, the utility of a RSP, \(U_{RSP}\) can be written as, equation (2). \(U_{RSP}\) increases as \(n_{FR}\) increases over time \((t)\) and \(\alpha_{RSP}\) measures the effect of each consumers platform presence perceived by the RSP.

\[
U_{RSP}(t) = n_{FR}(t) - \alpha_{RSP} n_{FR}
\]  

Equation (6)

The other side of the access market involves consumers. A residential consumers utility function is expressed as:

\[
U_{R}(t) = n_{RSP}(t) \alpha_{R}
\]  

Equation (7)

where \(\alpha_{R}\) measures the effect of each of the \(n_{RSP}\) RSPs presence connected to the platform, which is perceived by a representative consumer. An additional assumption is that residential users may or may not pay for their fiber connection to home; this will depend on the subsidy terms defined by LFCs and the government.
The cross network issues described above were setup as an ABM (Mirza & Beltrán, 2013a) for the NZ case in order to highlight the impact of these cross network effects between RSPs and consumer groups. In this article we introduce further improvements to the ABM of (Mirza & Beltrán, 2013a).

We conducted an empirical study in NZ by engaging with leading platform operator (Chorus), RSP (Snap Internet) and consumers using a dominant imperialist multi-methodological design - one method or methodology as the main approach with contribution(s) from other(s) (Mingers, 2001). In our case the dominant method is qualitative data from 15 consumer interviews. The contributions include: firstly research study data from Chorus that included a large sample of 132 qualitative interviews followed by an online quantitative survey that totaled 1009 respondents. Secondly broadband customers sample data from Snap’s CRM system which included information including the type of broadband products consumers are using, costs, location, and why the consumer decided to use Snap. The aim of the interviews was to acquire detailed information about the consumer perceptions of participating in the access and content market of a high-speed FTTH platform. The results would complement the secondary data from Chorus and Snap.

In this article we are leveraging the results obtained from this empirical study, therefore only describing a brief summary of relevant details for the ABM. We found the main driver for consumers to participate in the FTTH access market was perceived platform’s reliability and consistently fast connection. The barrier for participation was consumer contentment with the inferior ADSL or similar alternatives, however in the Australian NBN initiative the plan is to eventually make the old technologies obsolete. The deciding factors which promotes or withdraws consumer participation in the access market were firstly, start up costs which include cost of connection. Secondly, awareness regarding the benefits of fiber technology and its products. We incorporate these deciding factors in our ABM.

The price of the connection to the street is often met by the government or the platform operators. However the connection into the house may or may not be subsidized. In NZ the connection from curb to home is free until 2015, however not a very small number of potential consumers have taken benefit of such an offer. Chorus revealed only a 1.7 per cent uptake of 80,299 end users able to connect (Morton, 2013). This report echoes our findings related to awareness being an important driver for consumer participation.
8.3.2 Setting up simulation scenarios

The model simulates consumer uptake of a newly developed open-access, high-speed broadband platform. End-users find it attractive to connect to the network when they find that a large number of RSPs operate on the platform, a fact that enhances consumers' expectations of service.

RSP and consumer agents will be assigned a unique utility score by the simulation model and this will influence how they participate in this two-sided platform, based on equations (2) and (3). The values for the $\alpha_{\text{RSP}}$ and $\alpha_{\text{R}}$ are randomly generated from probability distributions. RSPs will slowly appear into the market and will eventually reach saturation. New consumers, on the other-hand, keep subscribing to platform services as the connection becomes available. For the RSPs the larger number of consumers adopting fiber, the more encouraged they will be to enter the market. RSP agents maintain a when-to-market attribute, this specifies when a RSP should enter the market. This is when the $U_{\text{RSP}}$ is positive. The consumer on the other hand maintains a when-to-subscribe attribute. These attributes vary based on the scenario settings and the probability distribution of the network effect parameter. We set up the following scenario groups:

1. Strength of cross network effects are high for consumers and RSPs.
2. Strength of cross network effects are high for consumers and low for RSPs.
3. Strength of cross network effects are low for consumers and high for RSPs.
4. Strength of cross network effects are low for consumers and RSPs.

8.3.3 Consumer Awareness

The consumer can become aware by multiple means. For this model we setup the following three drivers. Firstly, the platform operating LFC may run marketing campaigns causing an increase in awareness in a given percentage subset of the population. For this model we configured these awareness campaigns to occur every six months reaching 5% of consumers. Secondly the consumer becomes more aware when the number of RSPs in the market increases beyond the consumer’s own perceived utility. Lastly we found from the interviews and industry data that family, friends, and word of mouth advertising is a trusted way for consumers to become aware. Therefore we integrated a friend circle creator model (Mirza &
Beltrán, 2013b) into this ABM. This allows the consumer agents to become informed via their friend circle; in the case of this ABM the awareness goes up for the consumer when a majority of his friends subscribe to RSPs. Awareness score is maintained for each consumer and a score of five is considered to be high awareness, and anything lower is low awareness.

The scenario groups above are further explored by varying connection subsidization within the market and consumer awareness settings. As a result each of the scenario groups 1-4 specified are further explored by the scenarios A-D below, producing a total of 16 scenarios.

A. Partial subsidy and low awareness

B. Partial subsidy and high awareness

C. Full subsidy and low awareness

D. Full subsidy and high awareness

The agents are: a single broadband platform operator, a number of RSPs and a large number of residential consumers. The following text will describe each agent’s behavior in the model.

The platform operator is tasked to implement fiber, which involves adjusting the consumer’s status from no fiber to passing fiber. The speed of implementation is scaled relatively to the actual implementation - which is around 5-7 years in the international FTTH cases. In the reported results (Table 14) we configured the simulation for 250 ticks for the platform operator achieving 2500 homes with passing fiber status. In this term all of the consumers will have fiber installed at their premises (i.e. \( n_{fr} = 2500 \)), making the implementation speed approximately 10 houses per day. The RSPs behavior is simple - which is to become active in the market when \( U_{RSP} \) becomes positive, as explained above.

### 8.3.4 Consumer agent decision making process

Consumer agents maintain a connection status attribute. The connection status is either - no fiber, passing fiber or subscribed to RSP. The model creates all consumer agents with a no fiber status. The fiber eventually reaches consumer’s curb based on the speed at which the platform agent is laying fiber, this changes the consumer status to passing fiber. This is when the consumer becomes eligible to subscribe to a RSP in order to benefit from the fiber based services. The decision making process for a consumer transitioning eventually to activating high-speed services is shown in Figure 29.
When the consumer’s street receives passing fiber, the LFC usually informs the consumer regarding their construction schedule and identify which RSPs are operating on their platform. This is when the process presented in Figure 29 starts, whereby the consumer will check if $U_R(t)$ is positive. If $U_R(t)$ is positive, the consumer agent will activate their fiber connection with a RSP. Incases when the $U_R(t)$ isn’t positive then the consumer agent defers its reconsideration till its awareness score increases over a configured threshold. This action is triggered endogenously at the time when each consumer’s awareness becomes high, in this ABM its set to a score of 5. Consumers are also rationally bounded as they may or may not become aware based either via their friends or through LFC’s marketing impact on the environment of the model.

![Diagram](image)

**Figure 29: Consumer decision-making process for considering subscribing to a fiber retailer**

While reconsidering, the consumer agent obtains a score from the matrix shown in Table 13, this value is based on a combination of present awareness and dissatisfaction with existing
connection. The consumer agent upon creation is profiled to have a certain type of satisfaction score with the alternative broadband technology to fiber. The consumer with high awareness of fiber services and with an unsatisfactory alternative connection will be most likely to transition to fiber. This score is further scaled - either higher or lower depending on the present subsidy conditions in the market. As a result, the consumer either activates fiber or decides to remain on the inferior alternative, such as ADSL.

The access market model described above is a simplification of the many complex issues (political as well as economic) surrounding the build-up of a government-funded FTTH network. Fiber access uptake in this kind of subsidized environment presents itself with issues not found in full private network expansion.

8.4 Simulation Results

Cumulative results are collected to appreciate how uptake rate is affected by the combination of cross-network effects, consumer awareness and connection pricing as shown in Table 14. Each plot displays the number of consumers connecting to the platform and subscribing to a RSP as a function of time. The inclining straight dashed line shows the number of households the fiber is passing. The solid black line with varying values shows the number of consumers who subscribed to a RSP. Underneath each plot the percentage of consumers that subscribed to a RSP is given along with number of active RSPs in the market at the end of each simulation run. The plots shown in Table 14 are averages of running the simulation a number of times.

The platform best outcome from the cross network effects perspective is found in scenario group 1 (high utilities) and the worst outcome in scenario group 4 (low utilities). Scenario 1D is the best platform outcome as expected because the consumer awareness is high, connection costs are subsidized, and the strength of cross network effects is high for RSPs and consumer sides of the platform. The opposite applies for scenario 4A. The conditions in scenario 1D manage to subscribe 46% of consumers to a RSP and 11 RSPs become active in the market. The worst conditions of 4A could only subscribe 9% of consumers to a RSP and 4 RSPs became active in the market. The results of the best and worse outcomes are as expected.

Scenario group 2 is closest to the best outcome scenario group 1 and scenario 3 is closer to the worst outcome scenario group 4, emphasizing effects of high $U_k$ having a greater effect on
the platform than $U_{RSP}$. For example if we compare the percentages of consumers that subscribed to a RSP between scenario 2D (41%) and scenario 3D (30%), we can see that the subscribers 2D score significantly higher despite the active number of RSPs were 4. This shows that the consumers took advantage of free connections because they were aware of the benefits of the high-speed broadband platform.

**Table 13: Matrix for determining a score for consumer reconsidering fiber**

<table>
<thead>
<tr>
<th>Awareness</th>
<th>Dissatisfaction with existing connection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>High</td>
<td>2</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
</tr>
</tbody>
</table>

In scenario group C and D - the connections were fully subsidized whereas the scenario groups A and B provided partial subsidy, which expired in mid-implementation term. The curvature in the plots shows how removing the subsidy limits the consumer uptake in the platform. It is common in two-sided markets for one of the user groups to be subsidized. The simulation shows the negative effects of not providing the subsidy.

If we compare the end of run values for percentage of subscribed consumers in scenario group 3 and 4, we can see that there is a little difference. For example scenario 3B (15.32%) versus scenario 4B (14.92%). The advantage of scenario group 3 is such that the rate of consumer subscriptions were higher than scenario group 4 from the start, which is much more beneficial as the platform would be generating revenue from an early phase of implementation. This is because more RSPs became active in the early stages of implementation.

The friend recommendations helped uplifting the uptake percentages especially when cross network effects were low and subsidization was partial. Friend recommendations increased the uptake ranging between 2 - 4%.
Table 14: Simulation results of varying scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>(A) Partial Subsidy Low Awareness</th>
<th>(B) Partial Subsidy High Awareness</th>
<th>(C) Full Subsidy Low Awareness</th>
<th>(D) Full Subsidy High Awareness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
<tr>
<td>1B</td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
</tr>
<tr>
<td>1C</td>
<td><img src="image9" alt="Graph" /></td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
</tr>
<tr>
<td>1D</td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
<td><img src="image15" alt="Graph" /></td>
<td><img src="image16" alt="Graph" /></td>
</tr>
</tbody>
</table>

- Percentage of subscribed consumers at end of run:
  - 1A: 15.60%
  - 1B: 24.68%
  - 1C: 35.60%
  - 1D: 46.76%

- Number of RSPs active in market at end of run:
  - 1A: 7
  - 1B: 9
  - 1C: 9
  - 1D: 11

<table>
<thead>
<tr>
<th>Scenario</th>
<th>(2) Strength of cross network effects are high for consumers and low for RSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2A</td>
<td><img src="image17" alt="Graph" /></td>
</tr>
<tr>
<td>2B</td>
<td><img src="image18" alt="Graph" /></td>
</tr>
<tr>
<td>2C</td>
<td><img src="image19" alt="Graph" /></td>
</tr>
<tr>
<td>2D</td>
<td><img src="image20" alt="Graph" /></td>
</tr>
</tbody>
</table>

- Percentage of subscribed consumers at end of run:
  - 2A: 15.16%
  - 2B: 23.08%
  - 2C: 29.84%
  - 2D: 40.64%

- Number of RSPs active in market at end of run:
  - 2A: 6
  - 2B: 6
  - 2C: 7
  - 2D: 4

<table>
<thead>
<tr>
<th>Scenario</th>
<th>(3) Strength of cross network effects are low for consumers and high for RSPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3A</td>
<td><img src="image21" alt="Graph" /></td>
</tr>
<tr>
<td>3B</td>
<td><img src="image22" alt="Graph" /></td>
</tr>
<tr>
<td>3C</td>
<td><img src="image23" alt="Graph" /></td>
</tr>
<tr>
<td>3D</td>
<td><img src="image24" alt="Graph" /></td>
</tr>
</tbody>
</table>

- Percentage of subscribed consumers at end of run:
  - 3A: 9.60%
  - 3B: 15.32%
  - 3C: 15.96%
  - 3D: 30.08%

- Number of RSPs active in market at end of run:
  - 3A: 10
  - 3B: 7
  - 3C: 9
  - 3D: 9

<table>
<thead>
<tr>
<th>Scenario</th>
<th>(4) Strength of cross network effects are low for consumers and low for RSPs</th>
</tr>
</thead>
<tbody>
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<td>4A</td>
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</tr>
<tr>
<td>4B</td>
<td><img src="image26" alt="Graph" /></td>
</tr>
<tr>
<td>4C</td>
<td><img src="image27" alt="Graph" /></td>
</tr>
<tr>
<td>4D</td>
<td><img src="image28" alt="Graph" /></td>
</tr>
</tbody>
</table>

- Percentage of subscribed consumers at end of run:
  - 4A: 8.84%
  - 4B: 14.92%
  - 4C: 12.16%
  - 4D: 27.72%

- Number of RSPs active in market at end of run:
  - 4A: 4
  - 4B: 5
  - 4C: 2
  - 4D: 7

---

Number of consumers with passing fibre
Number of consumers subscribed to a RSP
8.5 Conclusion

The platform embodies an architecture that separates network services provision from end-user (retail) service provision. It operates under a set of rules which are in place by design (and regulatory intervention) whereby the LFC is prohibited from selling services directly to consumers. RSPs deal with the platform to acquire wholesale services which are used as inputs to their end-user services. We postulate the existence of cross network effects on the platform whereby end-users represented by consumer agents and RSPs represented by provider agents find themselves mutually attracted with an agent types attraction level increasing, the larger the number of agents of the other agent type in the platform.

A high consumer utility assures the access markets performance, regardless of RSPs having a high or a low utility. Additionally the results show that having large number of first mover RSPs allows the platform to keep generating revenue, even though the consumer utility may remain low. The deciding factors for consumers in transitioning to the high-speed platform include awareness, subsidized connection to home, dissatisfaction with their existing broadband connection, and friends’ influence. The simulation scenarios display a wide variation of these factors to demonstrate how they affect consumer uptake. Critical success factors for a successful FTTH market establishment include evaluating subsidy considerations along with upliftment of consumer awareness. This will prevent delays in consumer uptake which will benefit the overall market by attracting revenue from early stages.

Our work contributes to the increasing literature on ABM of market performance whose main features include: modeling the FTTH access market structure, understanding the access market as a two-sided platform, and the computational ABM for a scenario-based analysis.

Future work can analyze post FTTH connectivity issues, i.e. what would when most RSPs and consumers activate inside the FTTH market. When this happens the content market competition in FTTH platform would be an interesting case to analyze via ABM techniques. The following article in section 9 – provides an agent-based approach for the competition analysis of retail providers in a mobile service market.
8.6 Acknowledgements

The authors want to acknowledge the support that CODE at UoA - Faculty of Business and Economics has provided to this work.

8.7 References


Article VII
9 Article VII - Using an Agent-based Approach for the Analysis of Competition Dynamics in a Mobile Service Market

Abstract: MSMs are continually evolving due to the introduction of new technology and greater consumption needs of the consumer. This paper justifies why an ABM approach can help understand the main elements of competition in a market where MSPs need to frequently adapt their offers to increasingly savvier consumers. Artificial consumer and service provider agents are setup with heterogeneous preferences and behaviors. The computational model is run multiple times to test a collection of hypothetical scenarios and produce results that explain emergent market outcomes of the competition dynamics. The results depict the effects of first mover advantages and the network effects within the consumer population. Additionally the findings show how sponsorship in mobile plans can counter lock-ins.

Keywords: agent based modeling, mobile services, competition, simulation model

9.1 Introduction

MSM is a dynamic market that frequently changes in many aspects of its delivery and consumption. Telecommunication infrastructure standards such as 3G, 4G, or WiMAX are continually enhanced to deliver richer offerings. New devices and mobile applications with their potential to impact users’ experience increase consumer utility. In response to dealing with this changing landscape of MSM, the MSPs design subscription-based products often known as plans consisting of services such as voice and data for the consumers. The plans offered by an MSP usually include a monthly subscription to a limited amount of data, minutes of voice calls, and SMS. MSPs revise these plans frequently in order to stay competitive in the market. To revise the plans MSPs apply business model strategies such as reducing costs, increasing allocation (calling time, SMS, data), and providing initial sponsorship (free credit or gadgets) in order attract consumers.

On the other hand consumers subscribe to mobile plans, their selection based on a range of factors such as pricing, features, switching costs, and influence of friends. This paper classifies the MSM as a networked industry. Shy (2001) explains that the characteristics of network markets are complementarity, compatibility, consumption externalities, switching costs, lock-ins, and significant economies of scale in production. To appreciate these
characteristics within a MSM, one can relate to an example of the mobile phone. A consumer buys a compatible mobile phone, one that can connect with (complements) the MSP network in order to make phone calls. Complementarity is when goods must be consumed together, for example a phone without a network is of no use. The mobile phone connections involve consumption externalities; increase in mobile phone users increases the overall good for the consumer population. In this market, switching cost may be incurred by her (the consumer) if she needs to upgrade her device or change her MSP. She might be locked in to a long-term subscription, or a geographical region is locked in to the type of telecommunication infrastructure previously bought and deployed by regional telecommunication bodies. Achieving success for the MSPs in MSMSs is dependent on characteristics of network effects, meaning the best product in terms of features and value doesn’t always necessarily dominate. This paper refers to these characteristics as network economic factors.

The main objective of this paper is to firstly present a justification of why ABM can aid the analysis of such a market. Secondly, using network economic concepts and ABM, a computational simulator for MSM is built.

The MSM-ABM would simulate market dynamics which include consumers’ decisions, and MSPs’ strategic actions regarding their commercial offers (referred to in this paper as mobile plans or plans); the results generated over a period of simulated time will reveal emergent patterns of market behavior. Results are presented as a structured scenario-based analysis.

The rest of the paper develops as follows. Section 9.2 highlights key features of ABM; Section 9.3 presents the computational model and provides details on consumer and MSP agent preferences. Section 9.4 presents the key findings followed by conclusions.

9.2 Agent Based Modeling

A market can be modeled as a collection of autonomous, interacting entities called agents (Janssen & Ostrom, 2006). Each agent individually assesses its situation, makes decisions on the basis of a set of rules and executes various behaviors following the rules and interactions with other agents and the environment. By comparison with pure mathematical methods, using a simulation tool to study repetitive independent interactions between agents can further advance exploration of the dynamics involved. Even a simple ABM can exhibit complex behavior patterns and provide valuable information about the dynamics of the real-
world system that it emulates. In addition, agents may be capable of evolving, allowing unanticipated behaviors to emerge (Bonabeau, 2002).

A MSM evolves based on how MSPs and consumers participate in the market. The behavior of each agent (MSP or consumer) is independent of any other agent’s, and not always perfectly rational. These micro level decisions lead to a macro level outcome in the MSM. ABM is a suitable methodology for analyzing competitive features of a MSM; this can be justified in four main ways.

Firstly the stakeholder groups of MSPs and consumers can be represented as autonomous heterogeneous agents in an ABM, with each agent behaving independently according to its own attributes (often also referred to as preferences). The ontological correspondence between computational agents and real-world actors makes it easier to design the model and interpret its outcome than would be the case with, for example an equation based model (Gilbert, 2008). Wooldridge & Jennings (1995) describe autonomy in agents, which is to perform the behavior required in a given situation independently without any global controller. Agents can have social abilities to interact with other agents and react to stimuli in the environment while being proactive in pursuing their goal. Heterogeneous agents are created based on varying combinations of their attributes. For example consumer demand for voice calls can be drawn from a probability distribution, making each consumer’s call consumption needs slightly different. Likewise the heterogeneity is appreciated in other preferences related to consumers and MSPs. An agent-based approach provides the MSM-ABM with abilities to create a sufficiently large population of consumer agents in order to mimic a real market where a large number of independent decision-making agents purchase or subscribe to MSP plans.

Agent behavior is subject to their bounded rationality as agents are not perfect optimizers due to their limited cognitive abilities (H. Simon, 1955). Decisions are made based on a set of rules based on known information and previous experience, to the degree to which an agent can optimize utility (Kahneman, 2003). Agents are confined in their own explicit space – which allows the creation of agent-specific boundaries in the model. Agent interactions are micro level and localized to their system boundary within the model.

Heterogeneity can extend beyond preferences to agent behavior as well. Agents can be interconnected but have heterogeneous disaggregated behavior, for example the agents in a friend circle may influence other agents in a friend circle; however, each consumer agent
behaves independently. The aggregation in ABM is not additive; rather it is a non-linear accumulation of several conditional interactions.

Secondly the MSM comprises properties of a Complex Adaptive System (CAS), and ABM is suited for the analysis of CAS, comprising multiple stakeholder groups, each with their own self-serving objectives (Tesfatsion, 2003). The MSM can be seen as a CAS that comprises MSPs and consumers; both stakeholder groups have their own self-serving objectives. The MSPs and consumers in this approach are being set up as interacting agents. This MSM-ABM system exhibits emergent properties, that is, properties arising from the interactions of the agents that cannot be deduced simply by aggregating the properties of the agents (Flake, 1999). The MSM-ABM allows deriving macro-level projected evolution of the market, by aggregating micro interactions of agents. The market evolution influences perception of agents and their micro level decisions. The micro-macro relationships are at the core of ABMs as they allow representation and exploration of such micro-macro complexes.

Thirdly, the MSM has characteristics of a networked market. Network industries often represent a CAS. In network industries, a large consumer base is usually involved and empowered not only to make choices, but to influence and follow. Brenner (2006) introduces a variety of learning models used in ABMs. In the MSM-ABM consumers can learn from the evolving environment. The MSM-ABM comprises of a dynamic network of interactions that can include a MSP’s consumer base, and the consumer’s own friend circles. Within these dynamic networks the agents can interact and make independent or interdependent decisions as required. Consumer agents use historical relationships with MSP, consumer awareness, and feedback from their friend circle as learning inputs in order enhance their decision-making.

Finally, the use of ABM is not peculiar to the analysis of telecommunication markets, it is an effective methodology to tackle the dynamics of telecommunication markets that involve: changing technologies, products, and regulatory reforms. Among the work conducted on telecommunication markets using ABM the following is a sample of relevant references.

Beltrán and Roggendorf (2005) used ABM to create an auction-based pricing scheme to facilitate network resource distribution negotiations for the analysis of bidding behaviors’ and in (2006) they enhanced the simulation model by introducing richer strategies. Baryshnikov, Borger, Lee, and Saleh (2008) created consumer and service provider agents assigned with utility-based preference scores. The model included two types of service provider (SP)
agents: SPs providing bundled services vs. undiversified services. The simulation model showed SPs providing bundled services outperformed the other type of SP.

Douglas, Lee, and Lee (2011) presented a model in which the iPhone was introduced into the market, the model showed satisfactory reproduction of historical data but failed to predict exact market share in the future. Zheng, Jin, and Zhang (2011) explored the effects of regulation with a duopoly mobile market and found that the duopoly market operated more efficiently with regulatory interventions.

Diedrich and Beltrán (2012) leveraged ABM to compare traffic discrimination policies. The model varied policy and competition scenarios. The results found that the content providers performed best when network neutrality is imposed; while network providers and consumers may benefit from traffic discrimination under certain circumstances.

The FTTH access uptake was modeled in (Beltrán & Mirza, 2014), a NZ specific example is shown in (Mirza & Beltrán, 2013a). These models use two-sided platform economics to portray the FTTH network as a two-sided platform that accommodates both end-users and service providers, creating the conditions for the two sides to exploit mutual network effects. Results show that the greater the number of users (end-users or providers) on one side, the more the number of users (provider or end-users) grows on the opposite side. A FCC ABM by Mirza and Beltran (2013b), allows creating friend networks, the networks help agents receive feedback from peers. This is incorporated into section 9.3 of this paper.

The Lightweight Architecture for boundedly Rational Agents (LARA) framework provides prefabricated components of an agent’s decision process like perception, memory, and different modes of decision making (Briegel, Ernst, Holzhauer, & Klemm, 2012). This paper leverages the LARA framework to structure the overall logical architecture for the MSM-ABM as it is helpful to systemize decision-making processes of MSPs and consumers. The following section presents the computational model and discusses how the LARA framework was integrated for decision processes.

9.3 Computational Model

The MSM-ABM is a conceptual model for easy analysis based on varying configurations. The simulator can propose, create scenarios, and run the simulation using a tool for an analytical what-if investigation. The simulation results of each run are not predictions or
factors; rather they are *hypotheses to be tested*. Conitzer (2010) explains that the agents trading in the prediction market generally cannot significantly influence the outcome of the event; the goal of the market is merely to predict the outcome, based on the collective information and reasoning of the participating agents.

MSM-ABM provides configurability to create a large set of scenarios. A simple intervention in configuration can cause a lasting directed effect. ABM and simulation techniques allow describing precise details on how and why the macro details are produced. Other analytical techniques investigate agents and behaviors separately; the strength of ABM allows simultaneous study of both. The MSM-ABM makes use of Netlogo application, which is multi-agent simulation software equipped with a GUI. Using the GUI makes it convenient to input conditions (exogenous attributes) required for the analysis, see Table 15. By altering the exogenous conditions several scenarios are set up as shown in: Table 17.

The MSM-ABM aids analysis of competition and consumption drivers within the MSM. The MSM involves multiple aspects of complexity such as pricing, regulation, technology features, and infrastructure, etc. This paper’s focus is simplified to only deal with how MSPs compete in the market and how consumers subscribe to the plans available. The MSM-ABM needs to demonstrate market activities over time. These can be generated by the endogenously evolving interactions among such bounded rational stakeholders over time (Windrum et al., 2007).

![Figure 30: Main Function of MSM-ABM](image-url)
Every *tick* or time-step is considered as a day, and the main function (see Figure 30) runs once on each tick. Four main processes (P) constitute the main function, depicted as P1-P4 in Figure 30. P1 involves the MSP agents performing a set of defined activities as shown in Figure 33. The consumer daily activities (P2) are elaborated in Figure 36. Actions of P1 and P2 resemble micro agent behavior, contributing to a larger emergent macro level outcome. The consumer and MSP behaviors are rules and boundaries these agents must follow, allowing the analysis of multiple scenarios, which should be assumed as hypotheses to be tested rather than facts. Results are collected and visualized using plots (see Figure 31 and Figure 32).

MSM-ABM can grow the population by specifying the exogenous attributes initial consumer-population and percentage-growth. Evolutionary friend circle networks can be formed to represent networks of consumer friend circles. Every month, P3 involves creating new consumers to grow consumer agent population. The model forms friend networks of consumers using a FCC module of Mirza & Beltrán (2013b). P4 activates the FCC to setup new friend circles for the newly created consumers. Consumers may refer to their friends while deciding which mobile plans to use; this is one way for the model to exhibit network effects.

There are three MSPs in the market, MSP1, MSP2, and MSP3. As the model runs, cumulative MSP market share information (actual values and plots) is collected; the plot in Figure 31 shows market share information for each MSP’s plan over time. MSP1 manages p1, which is available in the market before p2 and p3, managed by MSP2 and MSP3. Overtime p1 loses market share to p2 and p3 in the result shown in Figure 31. The MSM-ABM collects and tracks information on what strategies MSPs apply over time to compete in
the market, see Figure 32 which shows the adjustments MSPs apply to their plan in order to compete in the market. These data reflect the competition dynamics in that single run. Further elaboration on MSP competitive strategies appears in section 9.3.1 and consumer decision-making processes in section 9.3.2.

![MSP strategies](image1)

**Figure 32: MSP strategies**

![MSP activities per tick](image2)

**Figure 33: MSP activities per tick**
9.3.1 MSP Agents

The MSP agents maintain market and plan related attributes. For the results presented in this paper, a total of 3 MSPs are initialized. An attribute MSP-when-to-market specifies what day a MSP will become active in the market. The first mover MSP, MSP1 is activated on the first day, second mover (MSP2) after three months, and the third mover (MSP3) after a year; this remains consistent for all scenarios presented in this paper. We refer to these individual MSPs according to their activation into the market, e.g. MSP1, MSP2, and MSP3. The delay in activation for the MSPs allows us analyze varying initial strategies for each MSP.

The MSM-ABM model excludes mobile plans involving mobile gadgets or devices, and each MSP agent manages a single plan. This is unrealistic, but allowing creation of multiple plans would inhibit identifying specific reasons of MSPs applying certain strategies. Multiple plans of a MSP usually cater for multiple consumer segments, whereas this model only deals with a single type of MSM consumer.

MSPs provide a range of products and services with a rich set of features, often referred to as plans. For this MSM-ABM the following aspects are considered: calling allocation, joining subsidies, pricing, and contractual lock-ins as the primary attributes. The MSP agent manages its own plan related information such as plan-cost-per-month, plan-included-calls, plan-overgage-calls-per-min, plan-prerequisites, plan-sponsorship, plan-lock-in, and plan-early-termination-fees. The monthly cost and included calls in a plan vary as the model runs, these changes happen endogenously as the MSPs implement strategies to compete in the market. Plan-sponsorship refers to the incentives provided by the MSP for its consumers. Plan-prerequisites are the joining costs to be paid by the consumers to start using the plan. Therefore plan-prerequisites minus plan-sponsorship are switching costs, which is what the consumer pays to subscribe to a given MSP’s plan. However if a consumer were locked-in to a contract, then they would pay additional early termination fees.

Each day the MSP agents process activities outlined in Figure 33. To introduce a plan (P5) – the process outlined in Figure 34 is executed, in which the MSP uses a first mover, second mover, or third mover strategy. Table 17 in column 2, 3 and 4 shows the initial strategy variation of each MSP, this variation can be configured in the exogenous MSP attributes shown in Table 15.
9.3.1.1 Initial MSP Strategies

The first mover strategy involves taking advantage of being a monopoly in the market (P13). This involves setting the highest possible prices, offering the lowest amount of features, setting a long-term lock-in, and providing no joining incentives (sponsorships). Basically taking full advantage of the market being a first mover because there are no competing plans or services, the switching costs are high to create a barrier for the consumers to switch to an alternative offering when it becomes available. Table 17 in MSP1 column shows how the strategy of MSP1 remains consistent.

![Figure 34: MSP activating a plan in the MSM](image)

The second mover MSP applies a second mover strategy (P14) when introducing a plan, which involves cloning the first mover plan – and revising it by applying two of the following three strategies: reduce cost (C), increase value (V) or increase sponsorship (S). The decision of picking two strategies may either involve an exogenous preset strategy defined based on scenarios (see Table 17 column 3), or it may be completely endogenous, which means the MSP decides for itself based on a set of rules which are similar to reviewing a plan (see Figure 35).

MSP3’s strategy to introduce a plan (P15) is similar to the MSP2. However MSP3 may use the plan of MSP1 or MSP2 as a starting point prior to applying its own strategies. The variation in starting points defines the scenario sets 1 to 4 as shown in: Table 17. The
variation in initial strategy selection defines the scenario series A to I. Resulting in a total of 36 scenarios from 1A to 4I.

![Diagram of MSP reviewing plan]

**Figure 35: MSP reviewing plan**

### 9.3.1.2 Revising mobile plans

The primary goal of MSPs is to dominate in the market by attracting consumers to their plan. To do this MSPs review the plans regularly in order to stay competitive (Figure 35). The *review plan* process is scheduled (P6) using a probability distribution. The results presented in this paper use a mean of 60 days with a standard deviation of 30 days. A countdown is maintained: *MSP-countdown-review-plans* (P7); this attribute is decremented to zero when the MSP is due for a review.

The strategies applied to revise a *plan* are selected based on known consumer preferences (P16), and competing MSP plan information (P17). MSPs compile a list (*MSP-strategy-list*) based on competitor plans and consumer preferences related to changing plans (P18). For example if competing MSPs provide lower pricing, then “reduce cost” could be added as a potential strategy. Similarly all the features of the plan are compared against the other MSPs. Further consumer preferences related to switching plans are traversed.
The MSP plan revision can involve two strategies from [C, V and S]. Marginal profit of calling plan is set to $20; therefore it’s the lowest price a MSP will sell for. Therefore the MSPs will reduce cost per month by $5 (P19) until cost is $20 each time this C strategy is committed. Likewise the plan sponsorship will increase (P20) by $50 till $300 maximum, each time the sponsorship strategy S is applied. For implementing value strategy V– the MSP can increase call allocation by 25 minutes up to a maximum of 350 calls per month. The initial strategies of MSP’s [C, V and S] are specified exogenously as shown in Table 17. However when and what strategies MSPs apply to their plans is endogenous. A log is maintained recording all the strategies committed by a MSP for further analysis.

<table>
<thead>
<tr>
<th>MSP Related Attributes</th>
<th>Consumer Related Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>msp-review-plan* and msp-review-plan-sd</td>
<td>initial-consumer-population</td>
</tr>
<tr>
<td>msp2-initial-primary-tactic</td>
<td>population-growth</td>
</tr>
<tr>
<td>msp2-initial-secondary-tactic</td>
<td>review plan*, review-plan-sd</td>
</tr>
<tr>
<td>msp3-initial-primary-tactic</td>
<td>call-usage*, call-usage-sd</td>
</tr>
<tr>
<td>msp3-initial-secondary-tactic</td>
<td>ratio-of-estimate-max</td>
</tr>
<tr>
<td></td>
<td>rfc-factors-consideration-ratios</td>
</tr>
<tr>
<td></td>
<td>ratio-most-eco-consideration</td>
</tr>
<tr>
<td></td>
<td>ratio-of-switchingcost-consideration</td>
</tr>
</tbody>
</table>

* Probability distribution

9.3.2 Consumer Agents

Heterogeneous consumer agents are initialized by exogenously specifying consumer related attributes (Table 15), which remain constant for all scenarios. Consumer agents perform daily activities and periodical review of plans. Each tick of the simulation run represents a day. Consumer agents perform activities outlined in Figure 36 each day. Consumer agents maintain data of their usage; their consumption per day (P9) is based on a value drawn from a normal distribution. The consumer usage is recorded on a day-by-day basis. If consumers are on a term plan, the lock-in variable decrements on each run cycle. A countdown variable is maintained to decrement to the day when the consumer agent is going to review the plan. These inputs can be changed based on informed assumptions or test cases.

If the consumer is newly introduced into the model then a plan is assigned (P10) to the consumer randomly. If the plan is to be reviewed then a review plan process (P11) is initiated, see Figure 37.
Consumers are often faced with large number of options, due to new technologies and competitive pressures (Bettman et al., 1991). This complicates the consumer decision-making task. Marketing scientists have contributed vast literature for this area. A well recognized model of consumer purchase decision-making presented by (Engel, Blackwell, & Miniard, 1995) divides the consumer purchase decision process into 5 stages: 1) problem recognition, 2) information search, 3) alternative evaluation, 4) purchase decision, and 5) post-purchase behavior. A range of factors including - long term memory, rationality, evaluations, personal characteristics, social context, cost/benefit factors, contingencies, advertising and word of mouth contribute to the decision of consuming a product or service. Decision-making process includes elements of intelligence, control and rationality (Kahneman, 2011).

An aspect that is important in consumer decision-making is motivation; this is of particular interest to this paper. Motivation of friends, family and co-workers is very important to models that depict consumer decision-making in network industries. The MSM-ABM model leverages the FCC model from Mirza & Beltrán (2013b) to set up evolving friend circles within the consumer agent population.
The main parts of review process are shown in Figure 37. This decision making process including consumer behavior before and after the decision making, resembles purchase decision making model presented by Engel et al. (1995). The review process involves needs analysis, information search, checking alternatives, making decisions and then keeping track of usage information that contributes to future intelligence and rationality.

The review process starts with estimation analysis (P22), which involves calculating the usage and estimating the future usage. In this MSM Model the future usage is regarded more than the present usage, as consumers are prone to often buy more than they need, and also the usage of technology is increasing as the way we communicate is more often over the Internet and mobile devices.

<table>
<thead>
<tr>
<th>Table 16: Consumer RFC Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Set I and II</strong></td>
</tr>
<tr>
<td>RFC based on 75% value and 25% Consumer Network Effect</td>
</tr>
<tr>
<td>RFC Variable setting</td>
</tr>
<tr>
<td>rfc-factor-calls 37.5</td>
</tr>
<tr>
<td>rfc-factor-network-effects 25</td>
</tr>
<tr>
<td>rfc-factor-sponsorship 37.5</td>
</tr>
</tbody>
</table>

The consumers based on initially specified exogenous RFC factors (P23) prefer plan based on consideration towards their network of friends or the value proposition. RFC specifies ratios
on consumer inclination toward considerations for choosing a plan; this could be based on value (cost and features) or network effects (what friends use). In scenario set II, and I the RFC is based on 75% value and 25% Consumer Network Effect whereas in scenario sets III and IV it is the opposite, as shown in Table 16 and Table 17. Based on these preferences mobile plans will be shortlisted (P24). After which a single plan is picked and revived (P25). A new review schedule is set, and the review process ends.

9.3.3 LARA Framework

The agent characteristics defined by LARA for decision making are: 1) perception, 2) memory, 3) pre-processor, 4) action selection, 5) post processor and 6) action. The decision making process of MSPs (Figure 35) and consumers (Figure 37) adopt the LARA framework.

Perception, defined in LARA, is the basic process of translating physical information external to the individual into a format that lends itself to further internal processing. In the MSM-ABM the perception is developed by initial heterogeneous usage configuration of the agents, the friend-circle an agent belongs to, and the plans that are available in the market.

The memory can be the percept itself, the current context, the time an entry was captured or the retention time of the entry. This form of memory (that is changing and context oriented) is able to mimic the bounded rationality. The consumer agents store their consumption attributes and friend links. However these attributes change over time, and at the time of decision making the timely memory helps inform the consumer agents. Also, for the MSPs they maintain a watch on competitor plans, and based on the competitors’ context the relative strategies are applied in order to stay competitive.

The pre-processor retains behavioral options (BOs) that are updated by BO updater. In this paper’s case this could relate to service consumption by the consumer, such as making daily phone calls or being inconsiderate of switching plans when in a fresh lock-in. A repetitive outcome of such daily activities results in an agent’s preference update (in the memory). Another example of this is a MSP waiting to activate in the market, as it is exogenously configured to enter the market at a certain time.

Action specified in LARA deals with deliberate decision-making in which the agent’s actual selection of a BO will then be based on the situational utility matrix, which is obtained by multiplying each element of the basic utility matrix with the situational weight of the
corresponding goal. In the LARA framework this process comprises three steps: decision makers goal preferences, response appropriate to situation and knowledge about the utility. The MSM-ABM uses such an approach, for example the consumer agent establishes an estimate of consumption (P22), reasons for change (P23), and then shortlists available options (P24).

The LARA framework’s post processor component is triggered after deciding and before performing the action in order to evaluate the decision and store selected BOs in the agent’s memory. This is lacking in the MSM-ABM, mainly because the consumer consumption preferences remain fixed.

Table 17: Scenario tree of simulation results

<table>
<thead>
<tr>
<th>Series</th>
<th>Initial plan introduction in the MSM</th>
<th>RFC based on 75% value and 25% Consumer Network Effect</th>
<th>RFC based on 25% value and 75% Consumer Network Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MSP1</td>
<td>MSP2 initial plan similar to MSP1</td>
<td>MSP3 initial plan similar to MSP1</td>
</tr>
<tr>
<td></td>
<td>MSP3</td>
<td>MSP2</td>
<td>MSP1</td>
</tr>
<tr>
<td></td>
<td>Set: 1</td>
<td>1A</td>
<td>2A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12, 70, 17</td>
<td>19, 45, 39</td>
</tr>
<tr>
<td>A</td>
<td>Initial Plan</td>
<td>1B</td>
<td>2B</td>
</tr>
<tr>
<td>B</td>
<td>Initial Plan</td>
<td>37, 47, 15</td>
<td>34, 50, 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3A</td>
<td>4A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43, 26, 30</td>
<td>34, 29, 36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3B</td>
<td>4B</td>
</tr>
<tr>
<td></td>
<td></td>
<td>37, 54, 9</td>
<td>56, 30, 14</td>
</tr>
<tr>
<td>C</td>
<td>Initial Plan</td>
<td>1C</td>
<td>2C</td>
</tr>
<tr>
<td>D</td>
<td>Initial Plan</td>
<td>28, 50, 21</td>
<td>19, 36, 44</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1D</td>
<td>2D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18, 64, 18</td>
<td>36, 54, 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1E</td>
<td>3C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12, 67, 20</td>
<td>65, 10, 24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1F</td>
<td>4C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11, 52, 36</td>
<td>58, 18, 23</td>
</tr>
<tr>
<td>E</td>
<td>Initial Plan</td>
<td>1G</td>
<td>2G</td>
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<tr>
<td>F</td>
<td>Initial Plan</td>
<td>14, 70, 16</td>
<td>9, 69, 22</td>
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<td>G</td>
<td>Initial Plan</td>
<td>1H</td>
<td>2H</td>
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<td></td>
<td>21, 68, 10</td>
<td>23, 54, 23</td>
</tr>
<tr>
<td>H</td>
<td>Initial Plan</td>
<td>1I</td>
<td>2I</td>
</tr>
<tr>
<td>I</td>
<td>Initial Plan</td>
<td>25, 66, 9</td>
<td>3I</td>
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<tr>
<td></td>
<td></td>
<td>4I</td>
<td>16, 59, 25</td>
</tr>
</tbody>
</table>

Note: The comma separated values for scenarios 1A – 4I represents average market share for each MSP. The average is obtained from 5 runs of a scenario. The values do not necessarily add up to 100, because some consumers may be new to the market and still have no assigned plan.

9.4 Findings and Discussion

The scenarios and results are captured in Table 17. Each series A – I is run multiple times, as each run of a computational ABM produces varying results. The initial plan strategies are
defined for MSP2 and MSP3, whereas MSP1 always uses a first mover strategy as explained above. Sets 1-4 differ based on which *plan* MSP3 uses as a starting point before introducing its own.

It is important to note that this ABM is only a conceptual implementation of a competitive mobile market. The aim is to vary market factors (constructing scenarios) in order to produce a range of outcomes allowing us to draw conclusions for the drivers present. A total of 36 scenarios are run 5 times each. Each scenario time-length was set up for 4 years. We initially ran the simulation scenarios 1000s of times to produce an accurate average, however we found the value of results inclines more toward the *reasons* of achieving the final outcomes rather than the *value* of averages. For example, see Figure 38 which presents the simulation outcomes of scenario runs in Set III in Series A (this is a subset of all the plots presented in Appendix B). In this set of results – we can see by means of an average that MSP1 – is outperforming the other two MSPs. However the visual plots in the bottom rows show how MSP2 or MSP3 is able to overtake MSP1, the simulation model results allow analysis of *why* such an outcome occurred – what were the decisions / strategies employed by the MSPs to become a favorite MSP.
Figure 38: Simulation outcomes of scenarios in Set III in Series A
In general the results portray early mover advantages for MSPs. The later entrants will need to catch up and the earlier entrant is trying to retain its lead. Results show MSP3 performed better in sets 2 and 4 than set 1 and 3; this is because the MSP2 plan was already revised more than the MSP1’s plan. The network effects help MSP1, (see Figure 39 left side plot); the results show MSP1 preformed better in set 3 and 4 compared to set 1 and 2. In sets 3 and 4 consumers prefer plans similar to their friends, therefore the MSP1 is able to gain advantages from being the first mover. Scenarios 3A and 4A show how MSP1 maintains a significant portion of the market share due to the presence of consumer network effects.

In scenarios 1A and 2A in which consumers preferred value based plans, the results show how such preferences suited MSP2 to take significant lead when it applies CV strategies; MSP2 obtained an average market share of 70% in 1A. In series D – MSP2 performs well again because it offers sponsorship to counter the lock-in of MSP1. This resembles MSP2 and MSP3 in series E, where both MSPs apply sponsorship strategies (see Figure 39 right side plot).

CS as an initial strategy for MSP2 returns the highest benefits in set 1, especially when MSP3’s initial plan is derived from MSP1. MSP2 maintains a high market share, in all scenarios in set 1. MSP3 when initializing by cloning MSP2 (set 2) further applied CV strategies and achieved 39% market share, one of the better outcomes for MSP3 among the 36 scenarios.

All MSPs apply distinct initial plan strategies in series B. In 1B the MSP2 applies a CV strategy that delivers a favorable option to the value-preferring consumers and MSP2 manages to gather 47% market share. The MSP3 causes little impact with a CS strategy in
series B. Similar consequences emerge in series C, however the initial VS tactic provides better outcomes for MSP3 in 1C and 2C in comparison to 1B and 2B.

Scenarios 3C and 4C favor MSP1 in comparison to 3B and 4B in which the strategies of MSP1 and MSP2 were similar. This shows the possible variation of results in an ABM.

When comparing the results of 3E and 4E with 3I and 4I; in which MSP2 and MSP3 apply CS initial strategy in 3E and 4E, VS initial strategy in 3I and 4I. The results show that the value-alteration in the plans proved more effective. The results show this in series F where MSP3 benefits from a VS strategy.

9.5 Conclusions

The agent behaviors comprise of rules and boundaries agents must follow, rules are also based on partially known information, therefore they should be assumed as hypotheses to be tested rather than facts. This paper demonstrated setting up a competitive MSM-ABM as a CAS, with heterogeneous agents including MSPs and consumers, constituting network effects. This paper’s focus is to look at how MSPs and consumer agents behave endogenously within a model. The ABM allowed an analytical implementation of a conceptual market, in which factors can vary to produce a range of outcomes allowing us to draw conclusions regarding the drivers present.

The limitations include simplification of ABM to produce results that can explain the dynamics involved. The MSM market however involves multiple issues such as regulation, which may affect the development of the market. However the analysis for uncovering regulatory issues would suit employing other methodologies.

The primary contribution is justification of ABM computing techniques to analyze competition in telecommunication markets such as MSM. Secondly this paper demonstrates a methodology to develop an ABM, which involves creation of artificial agents equipped with the ability to learn, interact, and make decisions. By using this approach the paper widens the use of an agent-based computational and economic theory as a methodology to bridge the gap between economics literature and ABM. Most importantly the analysis of a dynamic market will be of value to the stakeholders involved.
9.6 References


10 Conclusion

The goal of this research was to provide an analytical methodology based on ABM, network economics and aspects from historical ICT competition cases to enrich understanding of multiple stakeholder involvement in competing technology standards or developing markets. To achieve this we proposed and applied ABM in order to analyze dynamics of technology introduction and technology adoption using network economic theory in the telecommunication domain. We used multi-methodological approach to analyze two cases: 1) consumer and MSP decision making MSM and 2) FTTH service deployments.

The research is rendered via multiple Studies (1-4, see Figure 40), which answered eight research questions, framed within the conceptual framework (Figure 41). The research produced several artifacts including theoretical frameworks, empirical data and computational simulation models. The work was validated continuously by submitting articles to relevant outlets and liaising with the industry to obtain feedback. The articles were recognized at highly regarded outlets in the disciplines of information systems, telecommunications, business and economics and simulation societies.

Each Article (1-7) presents its own conclusion. This chapter will present a generalized conclusion for each study including contributions, limitations and directions for future research.

Figure 40: Multiple studies conducted for this research using mixed methods approach
10.1 Study 1: Context – Technology Standardization and Competition

The study is motivated by frequently occurring competitions between technologies for standardization; therefore a literature review on historical ICT competitions was conducted. The core aim of this study was to propose analytical methods for enriching analysis of such cases using ABM.

Standards are either revolutionary (without a traceable predecessor, e.g. the Internet) or evolutionary (preceding an existing standard, e.g. LTE). Standards evolve and enhance compatibility in their respective areas of ICT and this creates opportunity in the market for consumption, competition and overall growth. Standard making bodies usually operate as a consortia; this empowers them with potential to create new value propositions and business
models that cannot be delivered by an individual company. Competitions are becoming more complex over time, due to increased numbers of stakeholders, complexity of technology, and large market sizes. Theoretical concepts of network economics from industrial organization can be used to explain the dynamics of competitions. Learnings from the literature review produced AFTS. The AFTS was applied to compare and present a variety of tech-standard competitions including presently occurring competitions.

Among the many standard battles - WiMAX and LTE standards were compared, and the outcome as we know now (2015) is that LTE is the preferred method for delivering BWA. The main reasons for this are, first the preferences of cellular operators and their involvement in 3GPP, and secondly because LTE is backward compatible to 3G, which makes LTE coexist with 3G and cater for a large population which may not have a LTE capable device.

The idea of simulating a battle of 4G wireless standard was presented. The idea was to use ABM combined with assumptions from known literature or secondary data. Article II presented a POC ABM for a 4G wireless MSM. Eventually we realized the contribution of the model was significant only within the market-level factors rather than standard development. Therefore the research questions were adjusted and a more focused approach was applied in following studies.

The theoretical contributions of this study include: literature review of technology standard battles, alternate methodologies used by researchers for the analysis of standards, introduction of ABM, and presentation and application of AFTS. Practical contributions of this study include computational POC ABMs for keyboard battle and 4G wireless Internet.

10.2 Study 2: Focus Area – Dynamics of technology introduction and adoption in networked markets

Based on the evaluation of the previous study’s progress including feedback from conferences and departmental seminars, the notion of developing an ABM of tech-battle was revised, and now the focus was to use ABM for analyzing market level factors, which is one aspect of an overall standard competition. The market competition dynamics usually involve consumers, retailers, suppliers, and distributors. These dynamics contribute to the outcomes of products, services and standards in ICT.
Study 2 extended the literature to look at consumer decision-making processes because this process is crucial in defining how a product or service is consumed. The consumers not only decide based on value of the product, but also consider what their friends use. A generic FCC ABM was created to create and evolve friend circles within the consumer agent population. The MSM mobile phone plan case study is used as an example to demonstrate the FCC-ABM. The results of this case study demonstrate how the presence of network effects is able to retain a large population of consumers in an inefficient deal. FCC can be used as a module to complement larger ABMs to enhance analysis in studying drivers of consumer decision-making.

FCC adds value to network formation models, because it is adaptable, modular, and configurable. FCC can create fixed or varying size networks that evolve over time. In the MSM Model we were able to apply FCC and demonstrate that network effects can retain a large population of users even within an inefficient deal. First mover advantages and network effects can create significant delays for competing business models against established products and services.

The practical contribution of this study included demonstrating an approach using ABM that will complement the analysis of competing products and services in network industries. Additionally two simulation models are developed: a standalone FCC module and an initial version of MSM ABM integrated with FCC.

10.3 Study 3: Case Study 1 - Consumer choice & MSP competition in a MSM

Article III lacked demonstration of tactical behavior of MSPs. This study involved simulating independent decisions of consumers and MSPs in a MSM where MSPs revise their offerings to compete in the market and consumers subscribe based on their preferences including influence of friends. This was achieved in Article VII.

MSM-ABM simulated market dynamics, which include consumers’ decisions and MSPs’ strategic actions regarding their commercial offers; the results generated over a period of simulated time reveal emergent patterns of market behavior. Results are presented as a structured scenario-based analysis. This study relied on ABM as a methodology without support of any secondary data.
The theoretical contribution of this study was its justification of ABM as a methodology to analyze competition in telecommunication markets such as MSM. The practical contribution is the computational ABM and its results for a wide range of scenarios that portrayed analytical insights of a dynamic MSM.

10.4 Study 4: Case Study 2 - Access uptake of high-speed fiber based broadband

The present implementation of fiber networks worldwide, specially the UFB project of NZ, and the work presented in Beltrán (2012) inspired this research to apply ABM, two-sided platform theory, and network economics to this case study. This case study produced Articles IV, V, and VI.

Article IV involved exploring consumer resistance issues for the adoption of UFB in NZ. A mixed methods empirical research was conducted. Secondary data from the industry and interviews with broadband consumers unearthed themes that were incorporated into research frameworks CAUA and CAUC. These frameworks portrayed pertinent consumer drivers, barriers, and deciding factors for the UFB initiative. Article IV provided an elaborate discussion for each of the factors using theoretical findings and supplementary secondary data. The two most critical factors are subsidization of fiber connection (curb to home), and uplifting consumer awareness of UFB benefits. So far (2015) the uptake of UFB access is low among the households that are eligible. This case study presented us with a timely unique opportunity to analyze the issues involved as the market evolves and stabilizes. This research had the advantage of gathering consumer resistance insights from an early phase of technological introduction.

Article V presents the NZ broadband market structure with respect to the UFB network. The UFB project is a joint venture between the NZ government and four LFCs; this has introduced regulatory changes whereby the LFC is prohibited from selling retail fiber services to consumers. Using theory from the economics of two-sided platforms, the ABM highlights how varying utilities of consumers and RSPs generate cross network effects on the opposite side of the platform. The ABM focuses on FTTH line subsidization issues and provides a discussion on how long to provide consumer subsidy. Presently in 2014, despite the subsidization, the uptake of UFB access has been low. We argue based on our results that
this is because of low consumer awareness and lack of UFB products and services appearing in the market.

In Article VI we present a generic FTTH network model in which public funds are invested (with or without participation of private partners) and an open access operation is adopted, this resembles deployments in Australia, NZ and Singapore. Two sides of the platform, end-users and service providers, exploit mutual network effects in an ABM. Scenario based analysis was employed to investigate the magnitude of network effects on the fiber connection uptake. The consumer decision-making process for considering subscribing to a fiber retailer was achieved based on the empirical research results.

The article shows how a high consumer utility assures the access market’s performance, regardless of RSPs having a high or a low utility. Additionally the results show that having large number of first mover RSPs allows the platform to keep generating revenue, even though the consumer utility may remain low. The deciding factors for consumers in transitioning to the high-speed platform include awareness, subsidized connection to home, dissatisfaction with their existing broadband connection, and friends’ influence.

The theoretical contribution of this research is its theoretical frameworks CAUA and CAUC. The practical contributions include the UFB access simulation model and the FTTH access model. The UFB access ABM focuses on fiber line subsidization issues, whereas the FTTH access ABM analyzes consumer awareness coupled with fiber subsidy.

10.5 Practical Impacts

This research produced many artifacts and contributions, which led to publication of peer-reviewed articles. The articles provided opportunities to learn, reflect, leverage, and improve as an ongoing process. The three key practical impacts of this study are as follows:

Firstly, the timely analysis of WiMAX and LTE technologies, at the time of their introduction into the market was conducted by this research. The competition drivers for serving 4G wireless broadband was presented. Technically both technologies offered fast connection speeds wirelessly, they are both easy to deploy, and both are based on the Internet Protocol (IP) architecture. Despite WiMAX’s early start – LTE now is leading, and has become the favorable 4G standard. One of the reasons is due to its backward compatibility with 3G networks. The positive network effects of consumers (with existing 3G phones), and existing
3G infrastructures might have been reasons to motivate the uptake of LTE. In present time (2015) – devices like the iPad and most smartphones equip LTE chips for offering high speed Internet access. This analysis was being conducted at the time this issue was topical in the wireless telecommunication space. We were able to present the competition drivers and relate or refer to past tech battles towards this discussion at academic and industry forums.

Secondly, this research had a practical impact on the usage ABM with network economics theory. This research has produced ABM models that allow agents to coordinate and make decisions on product purchases. A module for creating friend circles (FCC) was presented – which allows creation of evolving friend networks. Consumer agents in the ABMs could make independent and influenced decisions for product purchases in telecommunication markets. Going further than this – service providers agents were developed in order to compete in the market by altering their product’s features and pricing. The techniques, approaches, and logic presented in the articles can help aid analytical studies of consumer purchase behavior and provider competition.

Finally, this research contributes to the increasing literature on ABM of telecommunication market performance whose main features include: modeling the FTTH access market structure, understanding the access market as a two-sided platform, and the computational ABM for a scenario-based analysis.

The present (2011 - 2015) deployments of FTTH in New Zealand, Australia, and Singapore inspired this work. This area of work was carried out using multiple methods. The empirical research component highlighted what is motivating and preventing consumers and service providers to activate of their fiber services. The empirical research involved interviewing consumers and analyzing related industry data. This was an exhaustive effort involving multiple sources of data – quantitative, qualitative, interviews with consumers, and discussions with RSPs and LFCs. We were constantly engaged with the Industry to validate, verify and seek input in developing the artifacts presented in Study 4. The results show how a high consumer utility assures the access markets performance, regardless of RSPs having a high or a low utility. Additionally the results show that having large number of first mover RSPs allows the platform to keep generating revenue, even though the consumer utility may remain low. The deciding factors for consumers in transitioning to the high-speed platform include awareness, subsidized connection to home, dissatisfaction with their existing broadband connection, and friends’ influence. Using ABM simulation scenarios the research
argued critical success factors for a successful FTTH market establishment includes evaluating subsidy considerations along with upliftment of consumer awareness.

The research articles were published in multiple academic outlets including disciplines of business, telecommunication, simulation, and information systems. In addition the research was continually shared with Industry. We felt the alignment of innovative modeling techniques combined with topical telecommunication case studies made the research outputs relevant to practical issues of today.

10.6 Limitations and Future Avenues

The limitations and future directions for each study are presented below:

Study 1: Context – Technology Standardization and Competition

In this study the research was limited to a theoretical explanation of technology standardization and competition. This founding study provided the context for research to develop into the consecutive studies. The AFTS framework was used to discuss competitions from past and present. However the analysis of tech battles can be extended even further. Technologies competing are a recurring pattern in today’s ICT landscape. AFTS can be applied for observation and theory building for numerous other battles, for example: social networking platforms (Facebook, Twitter and Google Plus), software application stores (Apple App Store, Google Play and Windows Store), and cloud services (Dropbox, Google Drive, iCloud and One Drive).

Article II presented the usage of social ecology and game theory by other researchers for technology standard analysis. The research departs from this study towards ABM, and relies on it as the dominant approach for further work. The research is limited in terms of evaluation of other researcher’s approaches to deal with technology standard competition studies. Further work can be conducted to review standardization articles especially to identify the types of methodological approaches used by researchers. Thereafter construct a comparison of methods including each methodologies strengths and limitation analysis. This analysis can be contrasted with the choice of ABM and other approaches used in this thesis.
Study 2: Focus Area – Dynamics of technology introduction and adoption in networked markets

The FCC is created as a standalone simulation model for Netlogo, a limiting factor of this model is its validation or testing in comparison to other ABMs. We do report that similar work to the FCC is presented by Zhang and Zhang (2007) where a purchase decision ABM was created in which the network of friends or influence was based on geographical radius of the agent. FCC differentiates from Zhang and Zhang (2007) by establishing actual evolving friend links that are configurable. However this research does not compare FCC model with alternative approaches, this is a potential future avenue for FCC.

Additionally, the FCC model is built as a standalone model (included in the CD of this thesis). A future avenue of this could be to release it to an open-source society of simulation models. This will require technical documentation to be developed, along with installation instructions and videos. This will benefit the ABM community with similar requirements.

The FCC model was integrated within a MSM – in this market the consumers make decisions, based on value of the product or the network externalities within the market. The article was written for a simulation society audience, and this was its primary purpose, i.e. to demonstrate a simulation technique. The process defined for consumer decision-making is limited; this can be enriched in future – which may enhance the algorithms for purchase behavior of consumers.

Lastly in Article III we simulated consumer decision making in a MSM, however the tactical behavior of MSPs is lacking. For instance if a MSP is losing market share, they would react by revising their business model. This limitation was addressed in article VII of Study 3 – where the MSP agents reacted to changes in the MSM.

Study 3: Case Study 1 - Consumer choice & MSP competition in a MSM

This study provides a thorough justification for the usage of ABM to analyze consumer choice and MSP competition in a MSM. This work can be extended to compare ABM with other methods such as game theory.

Future work can be conducted to extend the simulation model to produce a generalized (DIY) framework, which could potentially provide configurability for defining product features, and customer preferences. As a result the model could produce emergent market
results. This model can be developed and deployed as a web or mobile application – which would increase its utility to wider audience.

Often audiences at conferences and seminars questioned how this methodology could be utilized for predictions or forecasting. In order for this to happen the simulation setup would require accurate assumptions based on real data and rigorous analysis of defining agent-behavior. Therefore a future project could look at constructing simulation scenarios, in collaboration with a RSP or LFC that would share data required to establish assumptions and setup the simulation model. Using a focus group or Industry collaboration approach can assist in producing actual claims, predictions and forecasts. This will also help in defining regulatory drivers within the simulation model, which was omitted in Study 3.

**Study 4: Case Study 2 - Access uptake of high-speed fiber based broadband**

This case study produced three articles IV, V, and VI. It started with an exploration of the FTTH initiatives. In this Study – we explored and presented features of the UFB initiative of NZ and FTTH cases in general. Empirical research comprising interviews and secondary data was conducted. Finally simulation models were developed, to highlight critical success factors for the uptake and growth of the FTTH access market.

The work from this study encourages many future avenues. Firstly the empirical portion of this study was limited to New Zealand. Future work can be conducted to study issues of each country – i.e. either by interviewing consumers in another region or accessing secondary data or relevant literature. This will help validate the CAUA and CAUC models in foreign markets. Additionally the FTTH deployments country to country can be compared amongst each other to find similarities and differences and how they effect market development.

Secondly the empirical work can extend to RSPs, LFCs or other telecommunication bodies. This will highlight barriers and opportunities of FTTH market from a different perspective. These findings can be incorporated into the simulation models – in order to analyze the market drivers more thoroughly.

Thirdly the empirical work was conducted during a time when the Fiber was being implemented by LFCs. This means the data was collected at an early stage of technology introduction. A future opportunity could be to revisit and critique the adoption models CAUA, CAUC and findings from the simulation models after five years in year 2020. This
will be an interesting evaluation, as it would provide a post-implementation perspective – looking back at the research.

Finally the fiber-based content market is developing; further work can be conducted to analyze these issues. The fiber-based products and services are introducing changes in the way we access television, healthcare, education, and cloud storage. These cases can be analyzed using the theoretical frameworks presented in this thesis to add value to the FTTH research domain.

### 10.7 Final Remarks

This thesis was able to evolve by means of submitting articles and collaborating with the Industry. This approach overcame the issue of having access to data, and allowed producing generic theoretical artifacts and computational models.

Our advice and reflection toward the ABM approach for other researchers in this field is that the ABM approach can become more modular overtime to increase its reuse in research projects. Further development of ABM can look at leveraging mobile and web technologies to make it more ubiquitous. We also felt ABM oriented methodology offers complementarity to existing research methods. ABM methods can potentially simulate knowledge from empirical research or secondary to explain the drivers in an intuitive way. This was evident in Study 4 of this thesis, where we leveraged the empirical research and produced ABM models to analyze FTTH access markets.

For the policy makers and strategists, especially for the FTTH case studies – the research presented how subsidy on connection costs and uplifment of consumer awareness can have a positive effect on the market growth. On the other hand the LFCs or managers of the project (CFH) could incentivize RSP participation because the lack of fiber services and availability has a negative impact on the market growth. Policy makers and telecommunication planners can evaluate ceasing support for old technology where possible; this will set an expectation for operators, retailers, and consumers to migrate to fiber access.

The ability to simulate unsettled market dynamics will be of value to the stakeholders involved by providing interesting insights on pertaining drivers within network markets. Theory building was the key component of this research; as shown in the methodology
chapter. Overall the complexity of the scenarios analyzed deserved an ABM and added value to the topical issues presented.

As the ICT products and services transform the way we work and enjoy our digital lifestyle, we can notice how *features* of products or services are as important as its network externalities. ABM is gaining interest in the research community and it is envisaged that ABM will continue to complement and enhance analysis in fields of ICT development and telecommunications.
11 Appendices

Appendix A.  Wireless Simulation Model GUI for MSM-ABM

Appendix B.  Elaborated Computational MSM-ABM’s Results

The results below is an elaboration to the article VII, see Chapter 9. The results are organized in Table 17. The following is a presentation of each scenario’s findings.
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Appendix C.

Supremacy of 4G Technology: WiMAX or LTE

Supremacy of 4G Technology: WiMAX or LTE

Introduction

Mobile Communication

Mobile communication is a rapidly developing area of technology. From the first mobile phone call in 1973 [1] to today—significantly advanced—technology in mobile communication is continually being developed to suit the needs of consumers. The success of mobile communication has exploded and requires mobile users to be an expert in technology that includes technological platforms, value added service systems, advanced service plans, and customer protection agencies.

4G Technologies

Upcoming technologies Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution (LTE) are known as 4G technologies which are equipped with extensive capability to produce and deliver new services.

Competitions between technologies may have multiple potential outcomes [2] however, they can be learnt from historical cases with an understanding of the decision-making principles of scientific motion studies, this was when typewriter arms ceased production in 1974 and QWERTY dominated till today (2009) dominated by QWERTY and DSK.

Who:

fied Keyboard (DSK) between 1970.

What:

change” [5].

Findings of the US Navy showed efficiency gain from switching to DSK is a superior keyboard layout introduced in 1930 based on principles of scientific motion studies, this was when typewriter arms ceased production in 1974 and QWERTY dominated till today (2009) dominated by QWERTY and DSK.

ds fixated QWERTY always change” [5].

DSK was designed not only to slow down typists so the hammers had a “safeness” in investment element.

QWERTYs keyboard pur-

up training schools.

QWERTY manufacturers set up training schools.

QWERTY keyboard pur-

DSK was engineered to slow down the first prototype of QWERTY was introduced in 1868 and was later on a QWERTY based on principles of scientific motion studies, this was when typewriter arms were in operation in 1874.

Who:

The first company was QWERTY and DSK.

Standard: QWERTY always dominated in the market.

Battle of the keyboards

DQWERTY was engineered to slow down the first prototype of QWERTY was introduced in 1868 and was later on a QWERTY based on principles of scientific motion studies, this was when typewriter arms were in operation in 1874.

Main Issues

Who:

The key company was QWERTY and DSK.

Standard: DQWERTY always dominated in the market.

Why DQWERTY Won

- DSQWERTY had a bigger chance of success at least until the 17th century since it was more easily available.
- Sony marketed its technology, for DSK recording.
- Sony developed a better version of electronic support from other patents and日本の製品開発コンサルタントとの連携.
- Matsushita’s huge engineering and manufacturing commitment.

Why DQWERTY Won

- DQWERTY was the main purchasing of typewriters and hence was one of the earliest etc.
- QWERTY manufacturers set up training schools.
- Easy to find trained personnel for DQWERTY layouts.

QWERTY took it all. Like VHS to DQWERTY, although VHS was a superior technology, DQWERTY was easier to install, maintenance, and repair. Hence the market complexity and the reduction in work load dependent on QWERTY keyboard layout.

WiMAX & LTE Possibilities

Winners take it all. Like VHS to DQWERTY, although VHS was a superior technology, DQWERTY was easier to install, maintenance, and repair. Hence the market complexity and the reduction in work load dependent on QWERTY keyboard layout.

Analysis

Overview

What:

LTE explained

WiMAX has the capability to deliver high-speed Internet connectivity on a global scale, fast roaming, and seamless handovers.

Who:

LTE is the new leap from 3G offering high-speed Internet and cellular connectivity.

Who:

WiMAX and LTE are poised to compete with one another in providing high-speed Internet and cellular connectivity.

Why VHS Won

- New customer base needed to be established.
- Need specific WiMAX compatible equipment.
- Need LTE compatible equipment.
- WiMAX & LTE Possibilities

- WiMAX, LTE, WiMAX & LTE Possibilities

In this Poster

This poster describes the process of WiMAX and LTE in the coming future and current competition in the area of communication.

This poster is part of a literature review of a PhD research being conducted by students at the University of Auckland. The PhD research is looking at developing viable business models for WiMAX and LTE in the coming future and current competition in the area of communication.

References


Appendix D. **PTC Poster Board**

**PTC14 New World, New Strategies**

**Using an Agent-based Approach for the Analysis of Competition Dynamics in a Mobile Service Market**

**RESEARCH SCOPE**

An agent-based modeling approach can help understand the main elements of competition in a market where service providers need to frequently adapt their offers to increasingly savvier consumers.

- Artificial consumer and service provider agents are setup with heterogeneous preferences and behaviors.
- The computational model is run multiple times to test a collection of hypothetical scenarios and produce results that explain emergent market outcomes of the competition dynamics.

Farhaan Mirza

farhaan@mirzabros.com

PhD candidate at University of Auckland | Solutions Architect at Bros Ltd

**RESULTS**

Simulation outcomes for consumer plan uptake in the market

The network effects help MSP1 for the scenario on the left. Value based plans of late competitors take lead on the right. Wireless Market

**NETLOGO - USER INTERFACE**

**WHY AGENT BASED MODELING**

Stakeholder groups of service providers and consumers can be represented as agents.

- Agent behavior is subject to bounded rationality as agents are not perfect optimizers due to their limited cognitive abilities.
- Mobile service markets comprise properties of a complex adaptive system, for which ABM is a suitable methodology.
- Mobile markets have characteristics of a networked market. In network industries, a large consumer base is usually involved and empowered not only to make choices, but to influence and follow.
- The use of ABM is not peculiar to the analysis of telecommunications markets; it is an effective methodology to tackle the dynamics of telecommunications markets that involve changing technologies, products, and regulatory reforms.

**CONCLUSIONS**

This paper justifies use of ABM in the mobile service market context.

- Consumer and MSP decision making is simulated, to portray a developing competitive mobile service market.
- Widening up the usage of ABM leveraging network economics literature.
- Results portray early mover advantages for service providers and network effects within consumer population.

The analysis of a dynamic market will be of value to stakeholders involved.

Commercial Value: Create a business modeling tool for testing product performance in a market consisting network externality.

**RESEARCH ARTICLES**

Appendix E.  FCC Network Effects Main Steps

Step 1: Create friendship Networks

Step 2: Establishing How the friend circles mixup

At the moment each circle is independent

Step 2: Linking up friendcircles by making new friends

Step 2: Establishing How the friend circles mixup
Video demo: http://screencast.com/t/aFdmMPG7

Video demo: http://screencast.com/t/sItali9yXa
Appendix F.  Ethics Approval for Ultrafast Broadband Study

Office of the Vice-Chancellor
Research Integrity Unit

UNIVERSITY OF AUCKLAND HUMAN PARTICIPANTS ETHICS COMMITTEE

19–Oct-2012

MEMORANDUM TO:
Hector Beltran
Info Systems & Operations Mgmt

Re: Application for Ethics Approval (Our Ref. 8528)
The Committee considered your application for ethics approval for your project entitled Ultrafast Broadband Study.

Ethics approval was given for a period of three years.
The expiry date for this approval is 19-Oct-2015.
If the project changes significantly, you are required to submit a new application to UAHPEC for further consideration.

In order that an up-to-date record can be maintained, you are requested to notify UAHPEC once your project is completed.
The Chair and the members of UAHPEC would be happy to discuss general matters relating to ethics approvals if you wish to do so. Contact should be made through the UAHPEC Ethics Administrators at humanethics@auckland.ac.nz in the first instance.

All communication with the UAHPEC regarding this application should include this reference number: 8528.

(This is a computer generated letter. No signature required.)

UAHPEC Administrators
University of Auckland Human Participants Ethics Committee

c.c. Head of Department / School, Info Systems & Operations Mgmt

Additional information:
1. Do not forget to fill in the ‘approval wording’ on the Participant Information Sheets and Consent Forms, giving the dates of approval and the reference number, before you send them out to your participants.
2. Should you need to make any changes to the project, write to the UAHPEC Administrators by email (humanethics@auckland.ac.nz) giving full details of the proposed changes including revised documentation.
3. At the end of three years, or if the project is completed before the expiry, please advise UAHPEC of its completion.
4. Should you require an extension, write to UAHPEC by email before the expiry date, giving full details along with revised documentation. An extension can be granted for up to three years, after which a new application must be submitted.
5. If you have obtained funding other than from UniServices, send a copy of this approval letter to the Manager - Funding Processes, UoA Research Office. For UniServices contracts, send a copy of the approval letter to the Contract Manager, UniServices.
6. Please note that UAHPEC may from time to time conduct audits of approved projects to ensure that the research has been carried out according to the approval that was given.
Appendix G.  UFB Study Participant Recruitment Criteria

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<td>1. Participant must be living in Auckland (Q1 = Yes).</td>
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<td>2. Participant must have a broadband connection at home (Q2 = Yes).</td>
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<td>3. Participant must be responsible or jointly responsible for deciding on what broadband products and services are used in their household (Q3 = Yes).</td>
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<td>4. Participant must have some technical knowledge* about their broadband connection. Technical knowledge in this case means that the participant:</td>
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<td>a. Understands how much capacity (gigabytes) their plan has</td>
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<td>b. What their typical usage is like</td>
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<td>c. How much their broadband plan costs</td>
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*At least 10 out of 15 people should have this level of knowledge (maximum of 5 in the sample who don’t).

Appendix H.  UFB - Recruitment Questions

Record Participant Name:

*1. Do you live in Auckland?

☐ Yes

☐ No > do not recruit

*2. Do you currently have broadband Internet access at home?

☐ Yes

☐ No > do not recruit

*3. Are you the person responsible or jointly responsible for deciding which broadband products and services are used in your household?

☐ Yes

☐ No > do not recruit
*4. How familiar are you with the details of your home phone line and broadband package? (e.g. how many Gigabytes per month, how much data you typically use in a month?) Note: Familiarity in this case means that the participant: Understands how much capacity (gigabytes) their plan has, what their usage is like, and how much their broadband plan costs

☐ Don’t know anything
☐ Know a little
☐ Fairly informed
☐ Fully aware
☐ Other (please specify)

Check sample quotas and continue if appropriate.

5. Do you have a home telephone line? (Recruiter to assess if question is appropriate – i.e. may be calling them on home line)

☐ Yes
☐ No

6. Who is your broadband service provider?

CallPlus □
InspireNet □
Kiwilink □
Now □
Orcon □
Slingshot □
Snap □
Telecom □
TelstraClear □
Vodafone □
WorldNet □
Xnet □
Other (please specify)
7. Who is your telephone service provider?

- CallPlus
- InspireNet
- Kiwilink
- Now
- Orcon
- Slingshot
- Snap
- Telecom
- TelstraClear
- Vodafone
- WorldNet
- Xnet
- Other (please specify)

8. What is your current home telephone and broadband plan?

Cost of phone line: ______________________________
Cost of phone line + BB: _________________________
Included data: __________________________________
Other details: _________________________________

9. Does your house have Wi-Fi or a wireless network?

☐ Yes        ☐ No

10. How many people are using the Internet in your household? (Write in the box below).
11. This research is exploring people's perceptions and expectations of the new UFB services that are being implemented in New Zealand (2011-2019). Thinking about your knowledge of this, which of the following describes you?

- Don’t know anything  □
- Know a little  □
- Fairly Informed  □
- Very knowledgeable  □
- Other (please specify)  □

[Check quotas and ensure a mix of the above]

To ensure we include a range of people in this research, we need to collect a few details about you.

12. Gender

- Male  □
- Female  □

13. Age

- Under 16 > do not recruit  □
- 16-17  □
- 18-20  □
- 21-29  □
- 30-39  □
- 40-49  □
- 50-59  □
- 60-69  □
- 70-79  □
- 80+  □
14. Ethnicity

15. Which suburb do you live in?

16. Are you currently employed? If yes, what is your current job?

17. Double-check how participant found out about research > check spread of respondents (i.e. include a mix of different recruitment sources) and recruit if appropriate.

18. Checklist for finalizing the recruitment process

   - Provided further background information on what it will involve
   - If appropriate, invite participant to the study
   - Arranged date and time for interview
   - Arranged for PIS to be sent at least 24 hours before interview
   - Record Participant Contact Information
Appendix I. UFB Study Participant Information

Project description and invitation

The research proposed here is a part of a larger study, which involves the development of a computational environment to simulate the consumer side of the telecommunications markets to arise from the Ultra-Fast Broadband (UFB) network currently under construction in New Zealand.

We would like to invite you to participate in this study.

As part of this, qualitative research is required to gain an understanding of consumer knowledge, needs, and expectations with regard to services provided over the UFB network.

The results of this survey will be used in a computational model which will simulate the future telecommunications service markets; more specifically the data will be used as inputs to a computational simulation model called “agents” which will behave just like consumers in our simulated environment.

You have been invited to participate in this study. For the purpose of contacting you our partner Academic Consulting has learned your name and phone number.

Your answers will be treated as anonymous. No personal data will be collected and the information provided will be used to build profiles of several classes of consumers.

Project Procedures

You will be interviewed for about 30 to 40 minutes via a telephone call. Your participation is voluntary. Before proceeding with the survey questions you will be formally asked whether you consent to participate in this survey. The consent question and your answer will be recorded.

The interview will also be recorded so that it can be transcribed. The transcription will be used to collect the data this project needs.

Upon completion of the interview you will be asked to provide a postal address so that Academic Consulting will be able to send you a $20 grocery or petrol voucher as a thank you for your contribution to the research.
Data storage/retention/destruction/future use

Academic Consulting will transcribe the recorded interview. Academic Consulting will keep the data for as long as their report is delivered to the main researcher. A Confidentiality Agreement between Academic Consulting and the main researcher ensures that data will be handled in a secured and confidential manner.

Once the data has been handed out to the main researcher it will be kept for about two years in a secured computer located in the main researcher’s office and will not be available in any public repository. The computer files containing the data will be deleted using the "delete" option provided by the Microsoft Windows 7 delete facility, which places files on the Recycle Bin. In a second step each file will be manually deleted from the Recycle Bin to ensure final destruction. The paper files with data will be shredded and put in a recycling bin.

The first stage of this project will end in December this year. More funding is sought for stage 2 of the project in which further analysis of UFB markets will be done. The latter is the main reason why data collected for our project and the following stages need to be kept and available for a longer time.

Right to Withdraw from Participation

As a participant you have the right to withdraw from participation at any time. If you choose to do so you can ask Academic Consulting to withdraw the data from the research. You will have up to one week after the date of the interview to ask us to withdraw the data.

You can contact Rachael Butler at Academic Consulting as shown below:

By phone: 09 522 0676

By email: rachael@academic-consulting.co.nz

Anonymity and Confidentiality

The information collected by this project is protected by a confidentiality agreement between Academic Consulting and the main researcher. As already explained, the data will be used to build consumer profiles to be used in a market simulator.

After the interview and up to one week later Academic Consulting will keep the participant’s identity available. The latter will allow discarding of the information should a participant
decide to withdraw from the study as explained above. After one week the data collected from the interview Academic Consulting will not be able to associate the data with a particular participant, ensuring that the data becomes anonymous.

For any queries regarding ethical concerns you may contact the Chair, The University of Auckland Human Participants Ethics Committee, The University of Auckland, Research Office, Private Bag 92019, Auckland 1142.

Telephone 09 373-7599 extn. 87830/83761.

Email: humanethics@auckland.ac.nz.

Appendix J. UFB - Interview Schedule

Consent

Read out the following prior to the interview commencing: (needs to be recorded as part of interview):

Have you received the information sheet from Academic Consulting that describes the research study exploring people’s use of broadband services?

Have you read the information contained in the information sheet and do you have any questions?

Please confirm the following with the participant: It is entirely up to you whether you wish to participate - you may withdraw at any time and you may skip questions you would prefer not to answer. You must be aware we are asking for your consent to participate and your answer is tape-recorded. Can I confirm that you have been fully informed about the research, and that you provide your consent to participate?

If yes – begin asking questions.

If no – Thank you for your time, we will not be able to proceed further but we appreciate your willingness to be contacted.
Broadband Usage

1. Please tell me about your typical broadband usage at home.

   Probe:
   
   How often do you access the Internet?
   
   What is your typical data usage per month?
   
   How do you feel about your broadband speed?
   
   How do you estimate your broadband requirements? (i.e. is it based on data usage or speed – or other factors?)
   
1a. How would you describe yourself in terms of your level of technical expertise when it comes to your broadband package?

Current Provider

2. For what reasons did you choose your current broadband plan and provider?

   Probe: What other considerations are important when you are selecting a broadband plan/provider?
   
   Friends or word of mouth
   
   Perceived value of the plan
   
   Free credit / hardware / startup cost
   
   Hard to terminate contract
   
   Well-known company with good reputation
   
   An existing connection with the provider
   
   Ability to set up short-term contracts

3. How did you find out about your current provider/plan?

   Check – is friends/word of mouth mentioned spontaneously?
   
   If not, probe as per question. 4 below

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41 Optional question – check interview recruitment responses
4. What level of influence do your friends and family have on the technological choices/services you use?

   *Probe: In what way? (e.g. they may have recommended a broadband plan OR talked positively or negatively about a provider)*

5. Overall, how satisfied are you with your current broadband provider?

   *Probe: What are the reasons for your answer? (i.e. why are you satisfied/not satisfied?)*

**Awareness and Expectations of UFB**

6. As you are aware this research is looking at people’s perceptions of the new Ultrafast Broadband service that is being rolled out across New Zealand. What do you currently know about this new service?

   *Probe: What do you think it will mean for you and the services you receive?*

7. I would now like to play you an audio recording, which provides an overview regarding the Ultrafast Broadband Service. This will take about one minute (I’ll play you a little excerpt first to check the sound, and then the whole recording). Audio recording is available in CD included with thesis and at the following link: http://goo.gl/W78gI

   What are your impressions now regarding this service?

   *Probe:*

   - *What difference do you think it will make for you?*
   - *What would you use it for (if nothing, why not?)*
   - *What sort of people do you think it will appeal to?*

8. What else would you want to know about UFB?
9. Discuss the following aspects of UFB:

- From a speed point of view it might be 30Mbps - 100Mbps
  
  *What’s your impressions of this?*
  
  *What difference do you think this will make for your telecommunication/broadband needs?*
  
- From a delivery point of view you will have more options in terms of packages available, and there will be more broadband retailers
  
  *What’s your impression of this?*
  
  *What difference do you think this will make for your telecommunication/broadband needs?*
  
  *Any negative aspects/downsides to this?*
  
- What would you use such a connection for?
  
  *Probe: Telephone, Internet, TV, Streaming, Gaming, Other needs*
  
  *Why would you use it for these things?*
  
  *If interviewee can’t imagine using UFB, why not?*

10. I am going to read out 3 possible UFB packages that may be offered to consumers, and am interested in your opinions on these, including how appealing they are to you.\(^\text{42}\)

| Option 1: Broadband only $60 25GB @ 50Mbps download | Option 2: Broadband and Phone: $75 25GB @ 50Mbps download | Option 3 Broadband, Phone and IPTV: $150 250GB @ 100Mbps download |

*Probe:*

*Initial reactions?*

*How appealing is each? Why/why not?*

*What are the main factors that would influence your decision?*

*How do you feel about the suggested pricing?*

*Any other comments*

11. In some cases re-wiring (or additional wiring) may be required to fully utilize the benefits of the fiber connection. There will be some cost for this.

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\(^{42}\) Most important aspect here is to tease out what’s important to interviewees, and how they assess the packages.
• How would you feel about paying for access to UFB at your property?

  *Probe: Why / Why not?*

• What is the maximum you would be prepared to pay? [Note: Costs can vary, but this may be between $250 - $500]

  *Probe: What do you think of these costs?*

12. Is there anything else you would like to add regarding UFB?

13. Thank the participant and close.

**Appendix K. UFB Interview Coding – Node Framework**

Bold text in the table below shows parent nodes. Underneath each parent node are its child nodes.

<table>
<thead>
<tr>
<th>Node Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical Usage</td>
<td>All comments relating to participants' typical broadband usage at home.</td>
</tr>
<tr>
<td>Purpose of Use</td>
<td>All comments relating to what they are accessing the Internet for - e.g. emails, TV on Demand, gaming, etc.</td>
</tr>
<tr>
<td>Data Usage</td>
<td>All comments relating to how much data they typically use (usually by month). Includes comments re: not knowing how much they use.</td>
</tr>
<tr>
<td>Speed</td>
<td>All comments relating to the speed of their connection - includes both positive and negative comments, and descriptions of how fast it is.</td>
</tr>
<tr>
<td>Frequency of Use</td>
<td>All comments relating to how frequently they access the Internet.</td>
</tr>
<tr>
<td>Other</td>
<td>All comments that do not fit into the pre-defined categories above.</td>
</tr>
<tr>
<td>Level of Technical Expertise</td>
<td>All comments relating to how technically 'savvy' they considered themselves to be (re: Broadband/Internet/Telecommunication issues).</td>
</tr>
<tr>
<td>Key Considerations Re Provider</td>
<td>All comments relating to the key factors influencing their choice of provider.</td>
</tr>
<tr>
<td>Cost</td>
<td>All comments relating to cost/price of the package. Also includes perceptions of value for money.</td>
</tr>
<tr>
<td>Structure</td>
<td>All comments relating to the structure of the package/telecommunications set-up being an important consideration (e.g.an all-in-one package).</td>
</tr>
<tr>
<td>Node Name</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Convenience</td>
<td>All comments relating to wanting the process to be easy and convenient when selecting a provider. Also includes not wanting too many options.</td>
</tr>
<tr>
<td>Reliability</td>
<td>All comments relating to the reliability and dependability of the service (e.g. no problems with the Internet connection).</td>
</tr>
<tr>
<td>Customer Service</td>
<td>All comments relating to customer service issues (e.g. the company's ability to address technical problems, respond in a timely manner, etc.).</td>
</tr>
<tr>
<td>Existing Relationship</td>
<td>All comments relating to having a pre-existing relationship with a company being important.</td>
</tr>
<tr>
<td>Company Reputation</td>
<td>All comments relating to the reputation of the company being a consideration. Includes both positive and negative aspects (e.g. also those who wouldn't go with a company they consider to have a 'bad' reputation).</td>
</tr>
<tr>
<td>Contract</td>
<td>All comments relating to contract issues (e.g. ability to terminate early, not being 'locked in' to a provider, etc.)</td>
</tr>
<tr>
<td>Data</td>
<td>All comments relating to the level of data provided as part of the package.</td>
</tr>
<tr>
<td>Recommendations from Others</td>
<td>All comments relating to taking the advice of others re: which provider to go with. Includes basing decisions on other people's experiences.</td>
</tr>
<tr>
<td>Other</td>
<td>All comments that do not fit into the pre-defined categories above.</td>
</tr>
<tr>
<td>Accessing Information</td>
<td>All comments relating to how participants accessed information when deciding on their broadband provider (e.g. looking up company websites). Includes asking the advice of friends and family members.</td>
</tr>
<tr>
<td>Current Levels of Satisfaction</td>
<td>All comments relating to how satisfied participants were with their current broadband provider.</td>
</tr>
<tr>
<td>Overall level of satisfaction</td>
<td>All general/overview comments relating to how satisfied (or not) participants were with their provider(s)</td>
</tr>
<tr>
<td>Negative Issues</td>
<td>All comments relating to feeling negative about their provider - and the reasons why.</td>
</tr>
<tr>
<td>Positive issues</td>
<td>All comments relating to feeling positive about their provider - and the reasons why.</td>
</tr>
<tr>
<td>Other</td>
<td>All comments that do not fit into the pre-defined categories above.</td>
</tr>
<tr>
<td>UFB</td>
<td>All comments relating to the new UFB service in New Zealand.</td>
</tr>
<tr>
<td>Impressions of UFB (pre-clip)</td>
<td>All comments re: awareness of UFB prior to listening to the audio file. Includes what they know about it, expectations, etc.</td>
</tr>
<tr>
<td>Impressions of UFB (post-clip)</td>
<td>All comments re: impressions of UFB after listening to the audio file. Includes expectations of the service.</td>
</tr>
<tr>
<td>Anticipated Usage</td>
<td>All comments relating to whether or not participants anticipated connecting to the UFB service. Includes the reasons why.</td>
</tr>
<tr>
<td>Node Name</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>---------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Perceived Target Audience</strong></td>
<td>All comments relating to who they predicted it would appeal to (e.g. in terms of age, level of technological expertise, etc.).</td>
</tr>
<tr>
<td><strong>Information Requirements</strong></td>
<td>All comments relating to what else they would want to know about UFB (after listening to the audio file).</td>
</tr>
<tr>
<td><strong>Views on Specific Elements</strong></td>
<td></td>
</tr>
<tr>
<td>a) Increased Options</td>
<td>All comments relating to views on the potential increased options available (e.g. in terms of retailers and packages).</td>
</tr>
<tr>
<td>b) Speed</td>
<td>All comments relating to the proposed speed of the UFB service (i.e. 30-100Mbps).</td>
</tr>
<tr>
<td>Other</td>
<td>All comments that do not fit into the pre-defined categories above.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reactions to Proposed UFB Packages</th>
<th>All comments relating to the 3 options presented to the research participants.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>All comments relating to views and impressions of Options 1.</td>
</tr>
<tr>
<td>Option 2</td>
<td>All comments relating to views and impressions of Options 2.</td>
</tr>
<tr>
<td>Option 3</td>
<td>All comments relating to views and impressions of Options 3.</td>
</tr>
<tr>
<td>Key Factors Influencing Preferences</td>
<td>All comments relating to the key factors influencing preferences (with regard to the 3 packages presented).</td>
</tr>
<tr>
<td>Other</td>
<td>All comments that do not fit into the pre-defined categories above.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Re-Wiring</th>
<th>All comments relating to participant views on re-wiring or additional wiring in order to access UFB.</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Views on Re-wiring</td>
<td>All comments relating to how participants felt about the need for re-wiring or additional wiring in order to access UFB.</td>
</tr>
<tr>
<td>Cost of Re-wiring</td>
<td>All comments relating to how much people were prepared to pay for re-wiring. Includes reactions to the proposed costs presented in the research.</td>
</tr>
</tbody>
</table>

| Bigger Picture Issues              | Catch-all for all 'bigger picture' issues relating to telecommunication/broadband services in New Zealand - and UFB generally (e.g. new technologies, political issues, broadband speed relative to other countries, etc.). |
| Other                              | Catchall for all other comments which do not fit into any of the pre-defined categories.          |
References


