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Technology Standardization Battles: An Agent Based Analysis

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TECHNOLOGY STANDARDIZATION BATTLES: AN AGENT BASED ANALYSIS

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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 Agent Based Model (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 a unsettled competition will be of value to the stakeholders involved.

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

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 Fourth Generation (4G) Broadband Wireless Access (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 of Agent Based Modelling (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 analyse 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.

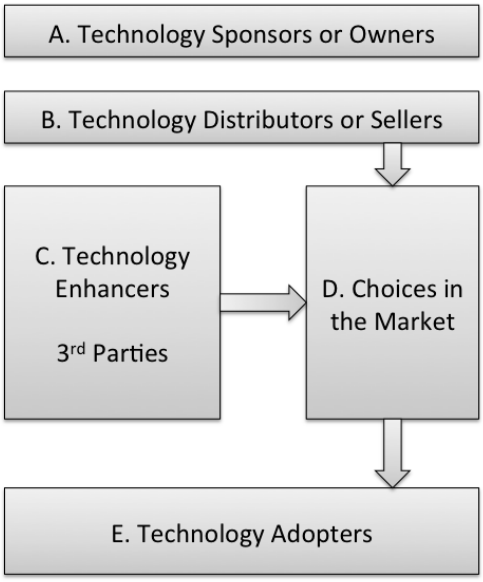
Our main focus is to investigate the battle of 4G for providing BWA. The two main contenders that provide 4G BWA are Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution (LTE). WiMAX has the capacity to deliver high-speed Internet connectivity on wide areas such as campuses, 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.

2 TECHNICAL STANDARDISATION

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.

Several cases of technical standard competitions occurred in the past, examples of which are the VCR standard, keyboard layout, game consoles etc. Researchers that analyse case studies of technological

competitions have often relied on network economic theory and more specifically the branch of *Industrial Organisation*. I came up with the Analytical Framework for Technological Standardization (AFTS), in Figure 1, which is a result of reviewing several competing technologies case studies. 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.



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 1. Analytical Framework for Technological Standardization (AFTS)

The following text summarises case studies of technological competitions while highlighting the related economic concepts that aid in explaining the factors involved.

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. Dvorak Simplified Keyboard (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 2.

For the **video recording standard** competition between Sony's Betamax and JVC's Video Home System (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.

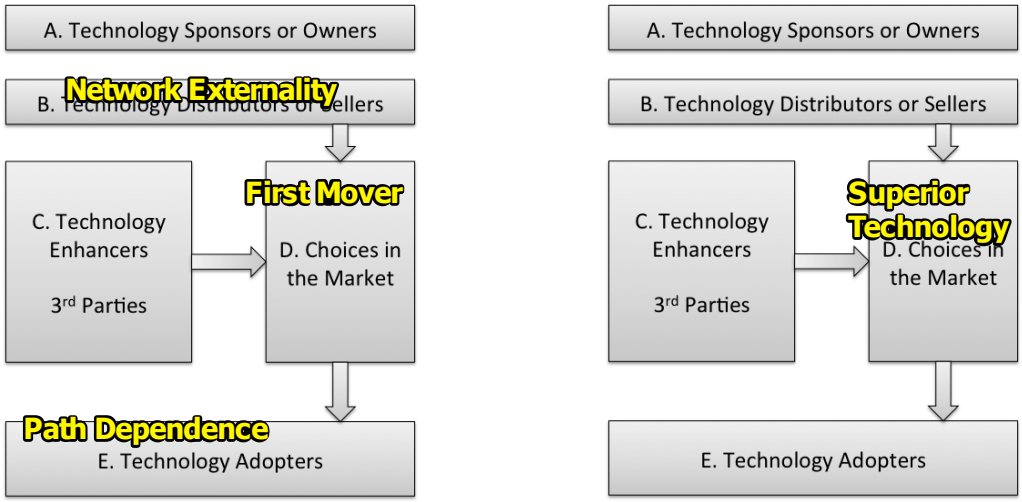


Figure 2. Factors that effected the keyboard layout standard competition. Effects of QWERTY standard are on left AFTS and DSK effects are on the right.

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[1] creating rivalry with AdMob[2], iBooks[3] creating rivalry with Amazon's kindle[4]. Apple managed to create success for itself I want to point out 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 these 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 manufacturers (at level B and C of AFTS) and enjoys being second most popular mobile OS after Symbian.

[1] 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.
[2] AdMob an advertising platform in exclusive to iPhone existed prior to Apple's iAd.
[3] A platform to sell books to read on Apple mobile devices including iPhone, iPad, and Apple desktop and laptops.
[4] 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.

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[5] maintains WiMAX standard and 3GPP[6] 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[7]. WiMAX 2, to be released in 2011 is posed to add new capabilities while maintaining backward compatibility, delivering peak rates of 300 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 Wireless 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[8] 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 being enhanced into: LTE Advanced and WiMAX 2. The following text **hypothesizes** and discusses the possible outcomes:

Let us first analyse 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

[5] WiMAX Forum formed in June 2001 to promote conformity and interoperability of the WiMAX standard.
[6] The 3rd Generation Partnership Project (3GPP), formed in 1998 maintains the LTE standard.
[7] Stats obtained from WiMAX Forum, see http://www.wimaxforum.org
[8] Orthogonal frequency-division multiplexing (OFDM) is a modulation technique for digital communication.

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[9] 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.

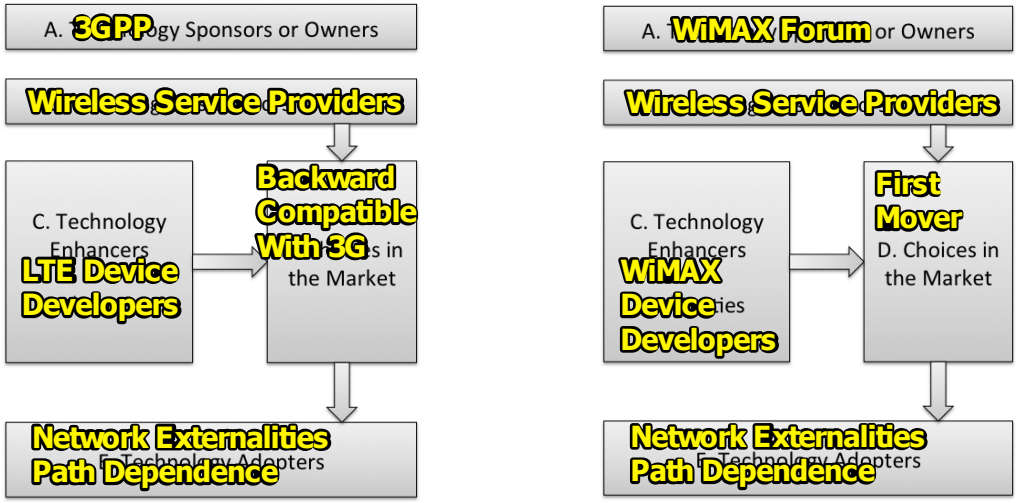


Figure 3. Factors that effect the 4G standard competition. Effects of LTE standard are on left AFTS framework and WiMAX effects are on the right.

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 3. 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 consortiums may think about convergence or improve interoperability among 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.

[9] Lock in makes a customer dependent on a specific vendor for products and services, unable to use another vendor.

3 RESEARCH APPROACH

This study employs a multi methodological approach using qualitative, quantitative and agent based modelling 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. Agent-based models 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 modelling 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 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), 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.

3.1 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 behaviour, 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 favourite 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.

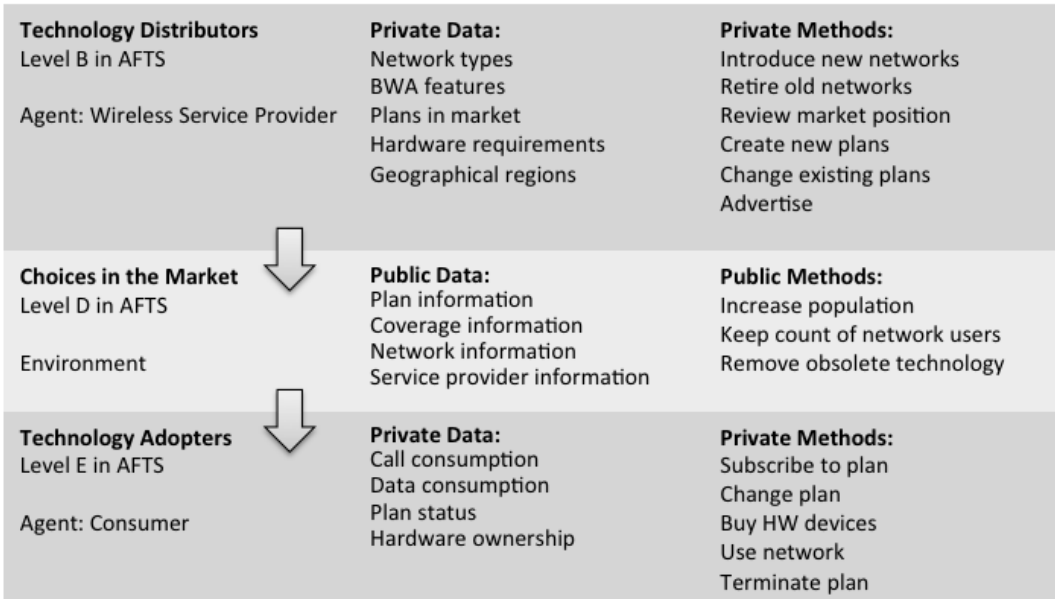


Figure 4. Partial ABM simulation model specification for the battle of 4G.

For the Battle of 4G, we can create agents as shown in Figure 4. The agents will be initialised 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 behaviour based on past experiences.

4 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 organisation 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. I am also writing a paper on comparing LTE and WiMAX technologies and their applications. 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 analysing and simulating a given competition.

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