USING AN AGENT-BASED APPROACH FOR THE ANALYSIS OF COMPETITION DYNAMICS IN A MOBILE SERVICE MARKET

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ABSTRACT
Mobile Service Markets (MSMs) are continually evolving due to introduction of new technology and greater consumption needs of the consumer. This paper justifies why agent based modeling approach can benefit analysis for competition elements in such a market where Mobile Service Providers (MSPs) frequently revise their plans. Artificial consumer and service provider agents are setup with heterogeneity in their preferences and behaviors. The conceptual model runs several scenarios to test a collection of hypothetical scenarios and produce results that explain emergent market outcome of the competition dynamics. The results depict first mover advantages and the effects of the network-effects within the consumer population. Additionally the findings show how sponsorship in mobile plans can counter lock-ins. Limitations include omission of regulatory issues and usage of real data.

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

1. INTRODUCTION
MSM is a dynamic market that frequently changes in multiple 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 include a monthly subscription to limited amount of data, minutes of voice calls, and SMS. MSPs often revise these plans frequently in order to stay competitive in the market.

On the other hand consumers subscribe to mobile plans, their selection is based on a range of factors such as pricing, features, switching costs, and influence of friends. This paper classifies this MSM as a networked industry. Using network economic concepts and agent-based modeling we can setup a computational ABM for MSM. This model simulates independent decisions of consumers and MSPs; these decisions generate an emergent market outcome. The main objective of this paper is to firstly present a justification of why agent-based modeling can aid the analysis of such a market. Secondly present the computational MSM-ABM model and its findings.

2. AGENT BASED MODELING
Using an agent-based approach a system can model a market that is a collection of autonomous decision-making entities called agents. Janssen & Ostrom [1] describe agent-based modeling as the computational study of agents as evolving systems of autonomous interacting agents. Each agent
individually assesses its situation and makes decisions on the basis of a set of rules. Agents may execute various behaviors appropriate for the system they represent. Repetitive independent interactions between agents using a simulation tool can lead to exploring dynamics further than pure mathematical methods. Even a simple agent-based model 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 [2].

The MSM evolves based on how MSPs and consumers participate in the market. The behavior of each MSP and consumer is independent, and not necessarily always rational. These micro level decisions lead to a macro level outcome in the MSM. Agent-based modeling is a suitable methodology for simulating such a market; we can justify this based on five main reasons.

Firstly the stakeholder groups of MSPs and consumers can be represented as autonomous heterogeneous agents in an ABM, each agent behaving independently according it’s own attributes (often also referred as preferences). Heterogeneous agents can be created based on varying combinations in their attributes, for example each consumer agent is assigned how many minutes of phone calls they will make, based on a probability distribution. Agent-based approach also provides the MSM-ABM with abilities to create sufficiently large population of consumer agents, in order to mimic the actual market to generate large number of independent decision-making processes.

Heterogeneity can be extended beyond preferences to agent-behavior as well. Agents can be interconnected but have heterogeneous disaggregated behavior, for example the agents are in a friend circle that may influence the entire friend circle however each consumer agent behaves independently. Autonomy in agents allows behavior of agents dependent on their state. Agent behavior is subject to their bounded rationality as agents are not perfect optimizers. Decisions are made based on a set of rules based on known information to them and previous experience. Agents are confined in their own explicit space – which allows creating agent-specific boundaries in the model. The interactions of agents are micro level and localized to their system boundary within the model. The aggregation in ABM doesn’t represent an additive; rather it is a non-linear accumulation of several conditional interactions.

Secondly the MSM constitutes properties of a complex adaptive system (CAS), and agent-based modeling is suited for the analysis of CAS, comprising of multiple stakeholder groups, each with their own self-serving objectives [3]. 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 our approach are being setup 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 [4]. The ABM of the MSM can allow deriving macro level projected evolution of the market, by aggregating the micro interactions of agents. Simultaneous findings of a norm influences perception to produce macro level analytical findings for a complex with upwards emergence and downward immergence. The micro-macro relationships are at the core of ABMs as it allows representation and exploration of such micro-macro complexes.

Thirdly, the MSM has characteristics of a networked market. The difference between traditional markets (grain and dairy products) and network markets is explained by Shy [5]. Shy explains that the characteristics in network markets are complementarity, compatibility, consumption externalities, switching costs, lock-ins, and significant economies of scale in production. Network industries often represent a CAS. To match these characteristics with MSM, we can apply an example of the mobile phone. We buy a compatible mobile phone, one that can connect (complements) to 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 have consumption externalities; increase in mobile phone users increases the overall good for the consumer population. In this market,
for a consumer to upgrade or change phone lines, there could be switching costs. A consumer 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. The MSMs have characteristics of economies of scale because it constitutes network effects by which the best product doesn't necessarily dominate. The dominant products in the market are a result of what the consumers adopt. This paper refers to these characteristics as network economic factors.

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 such as “routine based learning”, which we can apply in the MSM model to introduce learning behavior for consumers agents, in which the consumers can learn from the evolving environment.

The MSM model comprises of dynamic network of interactions that can include a MSP’s consumer base, and 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.

Fourthly agent-based modeling allows developing a conceptual model for conducting analysis based on varying configurations easily. We can propose, create scenarios and run the simulation using a tool for analytical what if investigation. Netlogo, a popular multi-agent programmable modeling environment software was used to setup this model. Netlogo provides us with a user interface, which simplifies altering market conditions in order to run varying simulation scenarios.

The simulation results of each run are not predictions or facts; rather it is hypothesis to be tested. Conitzer [6] 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. MSM-ABM is very configurable, 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 study agents and behaviors separately; the strength of ABM allows studying both at same time.

Finally, the use of ABM is not peculiar to the analysis of telecommunication markets, as these markets involve changing technologies, products, and regulatory reforms. Following is a sample of articles that apply an ABM in a telecommunication market context [7]–[14].

3. COMPUTATIONAL MODEL

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. Our 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. Market activities can be generated by the endogenously evolving interactions among such bounded rational stakeholders over time [15].
The configurable MSM-ABM, allows altering conditions for the agents and the market to produce results. The MSM-ABM makes use of Netlogo’s graphical user interface (GUI) as shown in Figure 1. Using the GUI, it is easy to alter input conditions (exogenous attributes) required for the analysis. The GUI is organized into categories of settings. Starting from top-left we can input consumer population information in the model. The model can grow the population by specifying a percentage per year. Evolutionary friend circle networks can be formed to represent networks of consumer friend circles. Consumer and MSP preferences can be altered for each run as required. The consumer and MSP behaviors comprise of rules and boundaries these agents must follow, allowing the analysis of multiple scenarios, which should be assumed as hypothesis to be tested rather than facts. Results are collected and visualized using plots.

The simulation run starts upon clicking the GO button. Every tick is considered as a day, and the main function shown in Figure 2 runs once each day. The main function constitutes of four main processes (P), depicted as P1-P4 in Figure 2. P1 involves the MSP agents to perform a set of defined activities shown in Figure 3. The consumer daily activities are processes into the simulation (P2), as shown in Figure 6. Actions of P1 and P2 are known as micro agent behavior, which are contributing to a larger emergent macro level outcome. Every month, P3 involves creating new consumers to grow consumer agent population. The model forms network of consumers using a Friend Circle Creator (FCC) module of Mirza & Beltrán [16]. 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.

As the model runs cumulative MSP market share information (actual values and plots) is collected, the large plot in Figure 1 shows market share information for each MSP. The MSM-ABM also collects and
tracks information on what strategies MSPs apply over time (shown in the smaller plots of Figure 1) to compete in the market. These data reflect the competition dynamics in that single run.

**Figure 2: Main Function of MSM-ABM**

### 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 is activated on the first day, second mover after three months, and the third mover after a year; this is consistent for all scenarios presented in this paper. The delay in activation for the MSPs allows us analyze varying initial strategies for each MSP. Table 1 in column 2, 3 and 4 shows the initial strategy variation of each MSP.

Each MSP agent manages a single plan. Though this is unrealistic, but allowing creation of multiple plans would inhibit identifying specific reasons of MSPs applying certain strategies. Multiple plans of a MSP are usually to 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 have a rich set of features, often referred to as plans. For this MSM-ABM following aspects are considered: calling allocation, joining subsidies, pricing, and contractual lock-ins as the primary attributes. The MSP agent manages it’s own plan related information such as plan-cost-per-month, plan-included-calls, plan-average-calls-per-min, plan-pre-requisites, plan-sponsorship, plan-lock-in, and plan-ETF. The costs and included calls vary as the model runs, these changes happen endogenously as the MSP implements strategies to compete in the market. Plan-sponsorship refers to the incentives provided by the MSP for its consumers. Plan-pre-requisites are the joining costs to be paid by the consumers to start using the plan. Therefore plan-pre-requisites minus plan-sponsorship is what the consumer pays to subscribe to a given MSP’s plan. The MSM-ABM model excludes the plans involving mobile gadgets or devices.
Each day the MSP agents process activities outlined in Figure 3, this is an elaboration of P1 in Figure 2. To introduce a plan (P5) – the process outlined in Figure 4 is executed, in which the MSP uses a first mover, second mover, or third mover strategy. 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 so that the consumers are less likely to switch to another offering when they become available. Table 1 in MSP1 column shows how the strategy of MSP1 is always consistent.
When the second MSP is introducing a plan (P14), the MSP copies the first mover plan – but revises the plan using two of the following strategies out of the following: reduce cost, increase value or increase sponsorship. The decision of picking two strategies may either involve an exogenous preset strategy defined based on scenarios (see Table 1 MSP2 column), 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 5).

The third MSP’s strategy to introduce a plan (P15) is similar to the second MSP. However the third may use the plan of first MSP or second MSP as a starting point prior to applying its own strategies. The variation in starting points define the scenario sets I, II, III, IV as shown in Table 1.

The review plan process is scheduled (P6) using a normal probability distribution, this can be altered, for 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 primary goal of MSPs is to try to dominate in the market by gaining market share, to do this the MSPs review the plans regularly in order to stay competitive (Figure 6). The tactics can be strategically selected based on known consumer preferences (P16), and competing MSP plan information (P17). A list variable MSP-strategy-list is populated by checking competition and consumer preferences related to changing plans (P18). For example if competing MSPs have a lesser pricing, then “reduce cost” would be added as a strategy. Similarly all the features of the plan will be checked against the other MSPs. Further consumer preferences related to switching plans are traversed. A scale of 0-100 is setup, with range of values assigned to the reasons for change (RFC) specified in consumer preferences. For example if 50% of RFC is related to call allocation, and the random number draw is a number between 1-50, then “network effects” would be added to the MSP-strategy-list. Thereafter two strategies out of the MSP-strategy-list will be applied to revise the plan. A log is maintained recording all the strategies committed by a MSP for further analysis.
The review-strategies of MSPs can either involve 1) reducing cost 2) increasing value 3) increasing sponsorship. Marginal profit of calling plan is set to $20; no MSP will sell less than this price. Therefore the MSPs will reduce cost per month by $5 (P19) until cost is $20 each time this strategy is committed. Likewise the plan sponsorship will increase (P20) by $50 till $300 maximum, each time the sponsorship strategy is applied. For implementing value strategy – the MSP can increase call allocation by 25 minutes up to a maximum of 350 calls per month. These boundaries are approximations from the New Zealand MSM.

The initial strategies of MSP’s are specified exogenously as shown in Table 1. However when and what strategies MSPs apply to their plans is endogenous.

### 3.2 CONSUMER AGENTS

Consumer agents can be initialized using consumer agent building blocks (attributes), varying attributes of each agent allows appreciating the heterogeneity. The consumer agents also perform daily activities and periodical review of plans they are currently subscribed with. Each tick in the simulation run represents a day. Consumer agents perform the activities outlined in Figure 6 each day. Consumer agents maintain data of their usage; their consumption per day (P9) is based on a value drawn from a normal distribution. 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 7.
Consumers are often faced with large number of options, changing due to new technologies and competitive pressures [16]. This makes the consumer decision-making task complicated. Marketing scientists have contributed vast literature for this area. A well recognized model of consumer purchase decision-making presented by [17] 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 [18].

An aspect that is important in consumer decision-making is motivation; this is of particular interest to this paper. Motivation of friends, family, co-workers is an attribute that is very important to models that depict consumer decision-making in network industries. We can leverage the FCC model from Mirza & Beltrán [13] to setup evolving friend circles within the consumer agent population.

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. The usage of each day is based on value drawn from a normal distribution. 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 informed assumptions or test cases.

The main parts of review process are shown in Figure 7. This decision making process including consumer behavior before and after the decision making, is similar to the purchase decision making model presented by authors in [10]. The review process involves needs analysis, information search, checking alternatives, making decision 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 buy more than they need often, and also the usage of technology is increasing as the way we communicate is more often over the Internet and mobile devices.

The consumers based on RFC factors setup in the GUI exogenously (P23) will prefer plan preference toward their network of friends or value proposition. In scenario set II, and I the RFC based on 75% value and 25% Consumer Network Effect where as in scenario sets III and IV is the opposite, as shown in Table 1. 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.

4. FINDINGS AND DISCUSSION

The scenarios shown in Table 1 are setup to obtain findings. Each series A – I is run multiple times, as each run in ABM. The initial plan strategies are defined for MSP2 and MSP3, where as MSP1 always uses a first mover strategy as explained above. Sets differ based on what plan MSP3 uses as a starting point before introducing it’s own. Each scenario was run for 4 years. A total of 36 scenarios were run.
In general the results show that the MSP activating earlier into the market is better than the later. As the later entrants are trying to catch up and the earlier entrant is only trying to retain. Results show MSP3 performed better in sets II and IV than set I and III, the reason was that the MSP2 plan was already revised more than the MSP1’s plan. The network effects helped MSP1, (see Figure 8 left side plot); we found that MSP1 performed better in set III and IV in comparison to set I and II.

Table 1 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>MSP1</td>
<td>MSP2</td>
<td>MSP3 similar to MSP1</td>
<td>MSP3 similar to MSP2</td>
</tr>
<tr>
<td></td>
<td>MSP3 similar to MSP1</td>
<td>MSP3 similar to MSP2</td>
<td>MSP3 similar to MSP1</td>
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<td></td>
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<td>Set: I II III IV</td>
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</tr>
<tr>
<td>A</td>
<td>Initial Plan</td>
<td>Cost Value</td>
<td>Cost Value</td>
</tr>
<tr>
<td>B</td>
<td>Initial Plan</td>
<td>Cost Value</td>
<td>Cost Value</td>
</tr>
<tr>
<td>C</td>
<td>Initial Plan</td>
<td>Cost Value</td>
<td>Value Sponsorship</td>
</tr>
<tr>
<td>D</td>
<td>Initial Plan</td>
<td>Cost Sponsorship</td>
<td>Cost Value</td>
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<tr>
<td>E</td>
<td>Initial Plan</td>
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<td>F</td>
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<td>Initial Plan</td>
<td>Value Sponsorship</td>
<td>Cost Value</td>
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<td>I</td>
<td>Initial Plan</td>
<td>Value Sponsorship</td>
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</table>

We found that applying a *sponsorship* strategy helps a MSP in the initial stages. We found in series A, set I and II, scenarios 1 and 2 – MSP2 performs well. Because the consumers are after cost and value. And MSP2 alters just that. In series D – MSP2 performs well again because it offered sponsorship to counter lock-in of MSP1. Similar is the case for MSP2 and MSP3 in series E both apply sponsorship strategies (see Figure 8 right side plot).
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 hypothesis 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. Our focus is to look at how MSPs and consumer agents endogenously behave 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. MSM market however involves multiple issues such as regulation, which may have effects on the development of the market. However the analysis for uncovering regulatory issues would suit employing other methodologies.

The primary contribution is justification of agent based modeling 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 we are widening up the use of an agent-based computational and economic theory as a methodology to breach the gap between economics literature and ABM. Most importantly the analysis of a dynamic market will be of value to the stakeholders involved.

6. REFERENCES


